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Oak Ridge Associated Universities
Post Office Box 117
Oak Ridge, Tennessee 37830
Telephone (615) 576-3305

Manpower Education, Research, and Training Division

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January 31, 1983

Mr. William Crow
Div. Fuel Cycle & Mat. Safety
Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20912

Dear Mr. Crow:

Enclosed are the remaining 40 copies of the final report on the W.R. Grace property in Wayne, New Jersey. We hope you received the first 20 in satisfactory condition.

If you have any questions, please give me a call.

Sincerely,

Jim

James D. Berger
Program Manager
Radiological Site Assessment Program

JDB/jm

Enclosures:

Reports (40 copies) in 2 packages

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Prepared for
Division of Fuel Cycle and Material Safety

U.S. Nuclear Regulatory Commission

RADIOLOGICAL SURVEY

OF THE

W. R. GRACE PROPERTY

WAYNE, NEW JERSEY

P. W. FRAME

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

FINAL REPORT

January 1983

RADIOLOGICAL SURVEY
OF THE
W.R. GRACE PROPERTY
WAYNE, NEW JERSEY

Prepared for

Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission

P. W. Frame

Project Staff

J. D. Berger
R. D. Condra
G. R. Foltz
J. R. Frazier
R. C. Gentry
A. J. Liu
A. M. Pitt
T. J. Sowell
C. F. Weaver
T. S. Yoo

Prepared by

Radiological Site Assessment Program
Manpower Education, Research, and Training Division
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

FINAL REPORT

January 1983

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WAYNE, NEW JERSEY

INTRODUCTION

In 1948, Rare Earths, Inc., of Wayne, New Jersey, began processing monazite sand to extract thorium and rare earths. The facility was acquired by the Davison Chemical Division of W.R. Grace and Co. in 1957. Processing activities continued until July 1971 when the plant was permanently closed. In 1974 Applied Health Physics, Inc., decontaminated the buildings and the property was released by the Nuclear Regulatory Commission (NRC) for unrestricted use in January 1975. The buildings are currently under lease to, and occupied by, Electro-Nucleonics, Inc.

In January 1981, as part of a review of formerly licensed facilities, the Nuclear Regulatory Commission measured direct radiation levels and radionuclide concentrations in soil on the W.R. Grace property. The results of the survey indicated radiation levels ranging from 10-1000 μR/h and Th-232 concentrations as high as 1200 pCi/g of soil.[1] The State of New Jersey was represented at this survey and requested, through the U.S. Environmental Protection Agency, an aerial radiological survey. In May 1981, the aerial survey was conducted by EG&G. This survey identified elevated radiation levels at 1 m above the surface with average exposure rates greater than 120 μR/h.[2]

In the summer of 1982, the Pequannock Township Health Department performed a radiological survey of the Erie Lackawanna Railroad tracks in response to information that ore destined for W.R. Grace had been unloaded from trains near the Pompton Plains railroad station. This survey and subsequent investigations by the NRC and State of New Jersey identified elevated radiation levels near the intersection of Peck Road and a spur of the Erie Lackawanna Railroad line approximately 200 m north of the railroad station.

At the request of the NRC Division of Fuel Cycle and Material Safety, radiological surveys of the W.R. Grace site, adjacent properties, and the Erie Lackawanna Railroad tracks near Peck Avenue were conducted during July and August 1982, by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), Oak Ridge, Tennessee. This report represents the findings of those surveys.

A glossary of technical and nuclear terms and schematic representations of the naturally-occurring thorium and uranium radioactive decay series have been presented as Appendices A and B, respectively, to aid in the interpretation of this report.

SITE DESCRIPTION

General

W.R. Grace Property

The W.R. Grace property is located at 868 Black Oak Ridge Road about 2 km east of Pompton Plains and 3 km north of Wayne, in the northeast corner of New Jersey (Figures 1 and 2). The site, shown in Figure 3, occupies approximately 2.6 hectares, most of which is surrounded by a chain link security fence. Two office buildings and a warehouse are the main structures on the site. The eastern and northern sections of the site are wooded and heavy brush and weeds grow along a small drainage stream. This stream enters the property near the southeast corner, flows north, then west. Prior to leaving the fenced-in portion of the site, the stream enters an underground conduit. This conduit carries the water into a tank, where it is mixed with the occasional overflow from an inactive on-site artesian well and the storm sewer system. The water is then discharged to an off-site storm sewer.

The site is bounded by private residences to the north and east, to the south by a property currently used for storage and maintenance of

school buses, and by several commercial firms on the west side of Black Oak Ridge Road, across from the W.R. Grace property (see Figure 2).

Erie Lackawanna Railroad

The Erie Lackawanna Railroad runs in a north-south orientation through Pompton Plains in Morris County (see Figure 4). Just north of the point where the railroad crosses Jackson Avenue is the Pompton Plains Railroad Station. Another 200 m further north of the railroad station is the point where Peck Avenue runs into an unused spur of the railroad. The area is a mixture of commercial and residential properties; the nearest residence being approximately 10 m north of Peck Avenue and 20 m west of the spur.

Operations

Between 1948 and 1956 Rare Earths, Inc., processed thorium-containing monazite ore to recover various rare earths and to separate the thorium for use by the Atomic Energy Commission (AEC). Wastes and residues from the processing operations contained less than 5% of the original thorium concentration and were disposed of by burial on the site. Liquid effluents from these processes were neutralized in an on-site treatment plant and combined with the occasional outflow of an on-site artesian well and the small surface drainage stream. The combined effluents were carried, via conduit under the company's north parking lot, to the intersection of Black Oak Ridge Road and Pompton Plains Cross Road where they were released into the storm sewer system (see Figure 5). This storm sewer system flows westerly where it discharges into Sheffield Brook and, eventually, into the Pompton River.

The Davison Chemical Division of W.R. Grace and Co. acquired the plant in 1956 because of the potential uses for purified rare earths and thorium. Between 1957 and 1967, residues and wastes containing most of the thorium from the monazite ores were disposed of by on-site burial. From 1967 to 1971, when processing operations at the site were discontinued, residues were shipped to the W.R. Grace plant in Chattanooga, Tennessee. The Pompton Plains plant was permanently closed in April 1971.

In 1974 Applied Health Physics, Inc., performed a radiological survey of the site and conducted decontamination operations designed to bring the site into compliance with existing regulations permitting release for unrestricted use.[3] In the course of the decontamination operations, contaminated materials and equipment were buried on-site. Portions of the property were then filled or covered with soil and the site was leveled and landscaped.

A fire in May 1977 heavily damaged the main building and destroyed most of the early records, including those containing details concerning the quantities and locations of on-site waste burials. Based on information available in the Applied Health Physics report and conversations with several former employees, suspected burial locations have been identified and are shown on Figure 6.

Several other properties in the Wayne-Pompton Plains area were involved directly or indirectly with the Rare Earths and/or W.R. Grace operations. The property immediately to the south of the W.R. Grace site was formerly leased by W.R. Grace for occasional storage of monazite ore; rail shipments of the ore were unloaded near the Pompton Plains station of the Erie Lackawanna Railroad. Surveys of these two areas were conducted and the findings are included in this report. The drainage stream system (including Sheffield Brook) between the W.R. Grace site and the Pompton River received the treated liquid wastes from facility operations and surface run-off. A survey of this area was conducted earlier and the results have been reported in a separate document.[4]

SURVEY PROCEDURES

Objectives

The survey objectives were as follows:

I. W.R. Grace Site and Adjacent Properties

a. to measure direct radiation levels,
b. to determine the concentrations of radionuclides in surface and subsurface soil,
c. to define locations of burials, and
d. to determine if radionuclides are migrating and/or have migrated from the burial sites.

II. Erie Lackawanna Railroad

a. to measure direct radiation levels, and
b. to determine the concentrations of radionuclides in surface and subsurface soil.

Plan

The survey plans adopted to achieve these objectives included the following activities:

I. W.R. Grace Site and Adjacent Properties

a. Clearance of brush and weeds over the suspected burial areas and the establishment of a 20 m grid system for survey reference.
b. A ground penetrating radar survey to identify the location of the subsurface disturbances and buried objects.
c. Measurement of exposure levels (μR/h) at the surface and at 1 m above the surface at 5 m intervals throughout the W.R. Grace site.

d. Measurement of surface dose rates (μrad/h) at 5 m intervals throughout the W.R. Grace site.

e. Walkover surface scans to identify locations of elevated radiation levels on the W.R. Grace site and adjacent properties.

f. Collection of surface soil samples at grid line intersections and at locations indicated by the walkover scan to have elevated exposure rates.

g. Drilling boreholes and collection of subsurface soil and water samples.

h. Collection of sediment samples from the on-site drainage stream and from the storm drainage sewers.

i. Collection of on-site water samples from the drainage stream and storm sewers.

j. Collection of vegetation samples from various points on the W.R. Grace property.

II. Erie Lackawanna Railroad

a. Measurement of exposure levels (μR/h) 1 m above the ground at 0 m, 5 m, and 10 m distances from either edge of the railroad spur.

b. Walkover surface scans to identify locations of elevated radiation levels.

c. Collection of surface and subsurface soil samples.

d. Collection of vegetation samples.

Procedures

Ground Penetrating Radar Survey

A ground penetrating radar survey of the W.R. Grace property was performed under subcontract by Geo-Centers, Inc. of Newton Upper Falls, MA. The survey technique involves traversing the surface with a transmitter/receiver which emits electromagnetic signal pulses. The reflected signals are recorded and analyzed to identify the locations and

depths of buried objects and other subsurface disturbances. The procedure is described in greater detail in the radar survey report included as Appendix C.

Measurement of Direct Radiation Levels

The 20 m grid system established on the W.R. Grace site (see Figure 7) was subdivided into 5 m intervals. At each of these points, exposure rates were measured at the surface and at 1 m above the surface. Measurements were performed with portable NaI(Tl) gamma scintillation ratemeters field calibrated using a pressurized ionization chamber. Beta-gamma dose rates were measured at 1 cm above the surface at each of the locations where exposure rates were measured. These measurements were performed using thin window ($7mg/cm^2$) "pancake" GM detectors with scaler/ratemeters. To evaluate contributions from non-pentrating radiations, measurements were also made with the detectors shielded with approximately 2 mm of steel. Walkover surface scans of the gridded areas were performed at 1-2 m intervals, using NaI(Tl) gamma scintillation ratemeters. Locations of significantly elevated radiation levels were noted. At locations where the exposure rates were above the range of the NaI(Tl) scintillation ratemeters, measurements were made with an energy compensated GM detector and scaler.

Walkover surface scans were performed at 2-5 m intervals on adjacent properties to the north and south of the W.R. Grace site. Radiation levels were mapped relative to surface features and landmarks.

The Pequannock Township and State of New Jersey surveys identified elevated radiation levels primarily along a 50 m section of a railroad siding just north of Peck Avenue. Several isolated spots were also noted approximately 50 m south of Peck Avenue. The ORAU survey, extending approximately 100 m north and south of Peck Avenue, consisted of walkover surface scans of the railroad tracks. North of Peck Avenue, the siding area was divided into 2 m intervals. At each of these intervals, exposure rates were measured 1 m above the surface, at the edge of the tracks and at 5 and 10 m on either side of the tracks.

Surface Soil Sampling

Surface (0-5 cm) soil samples of approximately 1 kg each were collected at the intersections of 20 m grid lines on the W.R. Grace property. Samples were also collected at selected locations of elevated gamma radiation levels. Efforts were made to include the source of the elevated levels in these samples. Sampling was performed using garden trowels, from which residual soil was cleaned between samples. Locations of on-site surface soil sampling are shown on Figure 8.

Surface soil samples were collected at locations of elevated radiation levels identified on the property south of the W.R. Grace site. Additional surface samples were also obtained at random locations on the adjacent properties. These sampling locations are indicated on Figure 9.

Subsurface Measurements and Sampling

Forty-three boreholes were drilled on the W.R. Grace property. Twenty-three of these were deep holes drilled to ground water depth. Site Engineers of Voorhees, New Jersey, performed the drilling, using 15 cm and 20 cm diameter hollow stem augers. The other twenty boreholes were shallow (approximately 1 m deep) and were drilled by the survey team, using a portable motorized auger.

The ground radar survey results were used to guide the selection of deeper borehole locations to ensure that subsurface utilities were not damaged. Drilling directly into burial trenches was also avoided to prevent damaging trench linings, thus creating potential migration pathways. Shallower boreholes were often located in areas where elevated exposure rates had identified near-surface thorium contamination. Locations of these boreholes are indicated on Figure 10. Shallow boreholes were drilled at two locations on the property south of the site and at eight locations along the railroad. Locations of boreholes on these off-site properties are shown on Figures 9 and 11, respectively.

In boreholes drilled on the W.R. Grace site a collimated NaI(Tl) scintillation probe was lowered into the hole and gamma radiation levels determined at 30 cm intervals. Gamma logging was not performed in the shallow boreholes drilled on the adjacent properties or along the Erie Lackawanna Railroad.

Soil samples were collected at the surface and at several depths in each borehole. The subsurface samples were at depths where gamma logging identified increased direct radiation levels and at additional points to provide a representative profile of subsurface thorium concentrations. Sampling was accomplished by scraping soil from the edges of the borehole using a specially constructed sampling tool or, at greater depths, by use of a split spoon sampler driven through the center of the hollow stem auger.

Because of heavy precipitation which occurred prior to and during the borehole drilling, the water table was unusually high. The pressure caused by the high water table resulted in the water rapidly filling most of the boreholes to within one to two meters of the ground surface. This water was not considered to be representative of the normal ground water conditions on the W.R. Grace site. Permanent monitoring wells have been installed on the property by W.R. Grace. Samples from these wells will be analyzed by ORAU and the results presented in an addendum to this report.

Sediment Sampling

Sediment samples of 1 kg each were collected on the W.R. Grace property from four locations in the drainage stream, from three drainage tiles, and from eight locations in the storm sewer system (see Figure 12). To provide more representative samples, several closely spaced points were sampled at each location and these samples composited.

Vegetation Sampling

Approximately 1 kg of surface vegetation, i.e. grass, weeds, and other ground cover, was collected from five locations on the W.R. Grace site.

These locations are indicated on Figure 12. No vegetation was collected from the adjacent properties. Three vegetation samples were collected from the area along the railroad (see Figure 11).

Water Sampling

Water samples were collected from three locations along the on-site drainage stream and from five locations in the storm sewer system as indicated on Figure 12. Water samples were not obtained from the railroad property or the adjacent properties since no appropriate sources were available for sampling.

Baseline and Background Measurements

Five soil samples, two water samples, and two vegetation samples were collected at locations 0.3 to 10 km from the W.R. Grace site. Direct radiation levels were measured at the locations of the soil samples. Figure 13 indicates the locations of the baseline samples and background measurements which were used for comparison with the other results of this survey.

Equipment and Analytical Procedures

Appendix D contains a list of the major equipment and instrumentation used for this survey. Analytical procedures are described in Appendix E.

RESULTS

Background Radiation Levels and Baseline Concentrations

Background exposure rates measured in the Wayne-Pompton Plains, NJ, area ranged from 6-12 μR/h; surface beta-gamma dose rates ranged from 10-24 μrad/h.

Baseline radionuclide concentrations in soil, vegetation, and water are presented in Tables 1-A and 1-B. The concentrations in these samples are typical of those normally encountered.

W.R. Grace Site

Ground-Penetrating Radar Survey

The report of the ground-penetrating radar survey provided by Geo-Centers, Inc., is presented as Appendix C. This report concluded that the soil on the W.R. Grace property had been subjected to extensive disturbances. Although there were some similarities between the areas of these disturbances and the burial locations as identified by W.R. Grace records, specific numbers and locations of these burial sites did not agree. In addition to the regions of disturbed subsurface soil, numerous individual reflecting targets were observed by the radar scans. These targets were located between the surface and a depth of approximately 2 m, and were randomly distributed, rather than being associated with the subsurface soil disturbances.

Direct Radiation Levels

Exposure rates measured systematically at predetermined grid locations on the W.R. Grace property ranged from 13 to 540 μR/h at 1 m above the surface. The highest levels generally occurred on the portions of the property where burials reportedly are located. However, only a limited correlation was noted between the exposure levels and the burial locations, as identified by site personnel or by the ground-penetrating radar survey. Exposure rates at 1 m decreased to near background levels at the north, east, and west property boundaries. These exposure levels are presented graphically in Figure 14.

The general pattern and levels of the systematically measured surface exposure rates were very similar to those measured at 1 m above the surface. The levels ranged from 9 to 610 μR/h. Many small areas, having significantly elevated contact radiation levels (up to 7710 μR/h), were

identified by the walkover surface scan. The locations and exposure rates of some of these areas, which were selected for further surface and subsurface investigations, are shown on Figure 15.

Individual dose rate data are not presented in this report; however, the pattern of these dose rates is in good agreement with the pattern of exposure rates described above. Dose rates (μrad/h) were generally between 1.25 and 2.0 times the surface exposure rates (μR/h). The unshielded probe measurements ranged from 25 to 40 percent higher than the measurements performed with the probe face shielded, indicating a significant dose contribution from beta and low-energy photon radiations. This is consistent with the presence of thorium contamination.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in the surface soils collected on the W.R. Grace property are presented in Table 2. The total thorium concentrations (Th-232 + Th-228) ranged from 2.14 pCi/g (sample location S5) to 721 pCi/g (S9) in the samples systematically collected at grid line intersections. The total thorium concentrations in soil collected at locations identified by the walkover survey to have elevated exposure rates (see Figure 8) ranged from 51.2 pCi/g (S58) to 7540 pCi/g (S30). In general, there was a positive correlation between the thorium concentration in the soil and the direct radiation level at the point of sampling. Thorium concentrations in soil samples collected east and north of the drainage stream ranged from 2.14 pCi/g (S5) to 20.0 pCi/g (S4). Surface soil systematically collected on the western portion of the property along Black Oak Ridge Road contained total thorium concentrations ranging from 3.49 pCi/g (S49) to 49.6 pCi/g (S56). However, several isolated spots with elevated exposure rates were identified in this area, and soil samples taken from these locations had thorium concentrations between 51.2 pCi/g (S58) and 832 pCi/g (S54).

Radionuclide concentrations in soil from boreholes on the W.R. Grace site are presented in Table 3. In general, the lowest thorium concentrations were measured in soil from the boreholes drilled east and

north of the drainage stream (B1-B9), through the paved areas (B38-B41), and in the lawn near Black Oak Ridge Road (B35, B42, and B43). In the boreholes east and north of the drainage stream, the total thorium concentrations ranged from 2.66 pCi/g (B7) to 11.5 pCi/g (B3) for surface soil and from 1.75 pCi/g (B7) to 9.90 pCi/g (B9) for soil collected from the bottom of the boreholes. Thorium concentrations in soil from boreholes B1-B8 decreased with depth; however, in borehole B9 the concentration increased from 3.50 pCi/g at the surface to 9.90 pCi/g at 1 m. Samples from boreholes B38-B41, drilled in the paved areas, contained thorium concentrations ranging between 3.83 pCi/g (B38) and 5.28 pCi/g (B40) just below the pavement. Concentrations in these boreholes decreased or remained constant down to approximately 2 m. In the boreholes drilled near Black Oak Ridge Road (B35, B42, and B43), the thorium concentrations ranged from 3.06 pCi/g (B35) to 30.4 pCi/g (B43) at the surface and from 2.25 pCi/g at 2 m in B35 to 15.5 pCi/g at 3.6 m in B43.

The maximum thorium concentration measured in the subsurface samples was 30,500 pCi/g. This sample was from the 3.9 m depth in borehole B29. Other boreholes where high subsurface thorium levels were measured were B26 (15,900 pCi/g), B22 (15,400 pCi/g), B15 (9,800 pCi/g), B27 (6,350 pCi/g), and B30 (5,460 pCi/g). Four of these (B22, B15, B27, and B30) were shallow boreholes drilled at locations with notably elevated exposure rates. In each of these boreholes, the thorium concentrations in the soil increased with depth, suggesting that these holes were drilled over areas of buried residues.

The ratios of Ra-226 and U-238 concentrations to total thorium concentrations varied widely in soil samples from the site. Radium-226 concentrations ranged from approximately 0.3% to 32% of the thorium levels; U-238 concentrations ranged from about 0.3% to 35% of the thorium levels. Ratios of U-238 to Ra-226 were also inconsistent. No pattern was noted in these variations. These differences suggest that the materials encountered represent residues from different processes and stages in operations conducted at this site.

Although the Th-232 and Th-228 concentrations generally agreed, several samples exhibited significant differences. For example sample S13 contained 2710 pCi/g of Th-232 but only 1540 pCi/g of Th-228; sample S36, on the other hand, contained 1850 pCi/g of Th-232 and 2300 pCi/g of Th-228. These differences indicate that some of the residues on this site have not yet reached an equilibrium state with the entire thorium decay series.

Radionuclide Concentrations in Sediment Samples

The radionuclide concentrations in sediment samples are presented in Table 4. In the four samples collected from the drainage stream the thorium concentrations ranged from 3.76 pCi/g (sample location D4) to 10.3 pCi/g (D1). No clear pattern was observed in these samples, the highest levels being found in sediment from the stream near its entrance to the W.R. Grace property. Sediment samples D8-D15 collected from the storm sewer system contained thorium levels ranging from 34.3 pCi/g (D8) to 1820 pCi/g (D14). Although the path of this sewer system is not precisely known, a general pattern of increasing concentrations was observed as the system neared the outfall from the W.R. Grace property.

Radionuclide Concentrations in Water Samples

Radionuclide concentrations measured in the water samples from the drainage stream and from the storm sewer system are presented in Tables 5 and 6. Water collected from the drainage stream contained gross alpha concentrations ranging from <3.19 pCi/ℓ* (W3) to 7.21 pCi/ℓ (W1). Gross beta levels in these samples were <5.00 pCi/ℓ. Radium-228 concentrations were <0.18 pCi/ℓ. Radium-226 concentrations ranged from <0.03 pCi/ℓ (W2) to 0.11 pCi/ℓ (W3).

Elevated radionuclide concentrations were present in water from the storm sewer system. Levels ranged from 5.33 pCi/ℓ (D13) to 28.6 pCi/ℓ (D11), gross alpha; 13.4 pCi/ℓ (D13) to 60.8 pCi/ℓ (D11), gross beta;

** The "less than" symbol (<) indicates that the concentration is below the detection limits of the analytical technique. Refer to Appendix E for further discussion.*

6.59 pCi/ℓ (D11) to 14.2 pCi/ℓ (D12), Ra-228; and 0.10 pCi/ℓ (D10) to 0.86 pCi/ℓ (D12), Ra-226. The pattern of concentrations in these water samples was consistent with the concentrations in the sediments from the same locations.

Radionuclide Concentrations in Vegetation Samples

Radionuclide concentrations in the five on-site vegetation samples are presented in Table 7. In these samples the Ra-228 concentrations ranged from 1.00 pCi/g (V1) to 3.41 pCi/g (V4) and the Th-228 concentrations from 0.26 pCi/g (V1) to 0.59 pCi/g (V5). All these values are slightly elevated above the baseline sample concentrations. No other radionuclides were present in levels significantly above the baseline concentrations.

Properties Adjacent to the W.R. Grace Site

Surface Radiation Exposure Levels

Elevated radiation levels were noted extending onto the school bus maintenance yard south of the W.R. Grace property. The exposure rates measured at contact with the surface are indicated on Figure 16. Areas with the highest levels were in the vicinity of the concrete loading platform at the northwest corner of the building and near a door on the building's northeast side. Maximum exposure rates at these locations were 250 and 890 μR/h, respectively. Inside the building, elevated direct radiation levels were limited to the northern half of the building and were primarily associated with cracks in the concrete floor.

Exposure rates on the properties to the north, east, and west of the site were in the range of area background levels.

Radionuclide Concentrations in Soil Samples

The radionuclide concentrations in surface soil from the adjacent properties are indicated in Table 8. The three randomly collected soil samples from the private residence north of the W.R. Grace property

(S68-S70) had total thorium concentrations between 1.24 pCi/g (S69) and 2.08 pCi/g (S68). These values are within the range of the baseline samples. Total thorium in the three soil samples (S71-S73) collected in the commercial area immediately west of the W.R. Grace property, ranged between 1.85 pCi/g (S71) and 7.21 pCi/g (S72). The highest concentration was found in sample S72 which was collected from the location (in this area) determined in the walkover survey to have a slightly elevated contact exposure rate of 18 μR/h. The other two samples had concentrations within the range of the baseline samples. South of the W.R. Grace property, in the school bus maintenance yard, the thorium concentrations in the surface soil ranged between 2.32 pCi/g (S81) and 2720 pCi/g (S77). Two samples scraped from the floor inside the north building (S78 and S79) had thorium concentrations of 647 pCi/g and 17.8 pCi/g, respectively.

Two shallow boreholes were drilled in the school bus maintenance yard near the southern boundary of the W.R. Grace site. The radionuclide concentrations in soil from these boreholes are presented in Table 9. The borehole drilled at a location with an elevated surface exposure rate (B44) had a thorium concentation of 3,760 pCi/g in the surface soil. The concentration decreased with depth to baseline levels, i.e. 2.08 pCi/g, at 1 m. The thorium concentration in surface soil from the other borehole, B45, was slightly elevated, 9.30 pCi/g, but the concentrations in subsurface samples were near the baseline range.

Erie Lackawanna Railroad

Direct Radiation Levels

Exposure rates along the Erie Lackawanna Railroad in the vicinity of Peck Avenue measured systematically at 1 m above the ground ranged from 9 to 135 μR/h (see Figure 17). Contact exposure rates are presented in Figure 18. These levels ranged from 7 μR/h to 970 μR/h. (At 1 m above the location with the highest surface exposure rate, i.e. 970 μR/h, the exposure rate was 190 μR/h.) Elevated radiation levels are primarily associated with the west embankment of an unused railroad siding between the spur and a footpath for a distance of 40-50 m north of Peck Avenue.

Three isolated spots with exposure rates of 200 μR/h were also identified adjacent to the railroad spur 70-100 m south of Peck Avenue.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in soil samples collected along the Erie Lackawanna Railroad are presented in Table 10. Total thorium concentrations in the surface soil samples ranged from 1.56 pCi/g (B54) to 1280 pCi/g (B46). The lowest levels are in the range of the baseline concentrations; these were in samples (B52-B54), collected from the east side of the railroad tracks. The highest concentrations were in samples from boreholes B46, B47, and B51, drilled at locations having elevated direct radiation levels. The thorium concentrations in these samples were 1280 pCi/g, 813 pCi/g, and 403 pCi/g respectively. In each case the thorium concentrations decreased with depth. Boreholes B48-B50 were drilled in a small mound located between the end of Peck Avenue and the railroad spur. In each of these boreholes, the thorium concentrations increased with depth from near baseline concentrations at the surface to a maximum at a depth of about 0.5 m. The maximum thorium concentrations in boreholes B48, B49, and B50 were 50.4 pCi/g, 42.9 pCi/g, and 9.83 pCi/g respectively. Ratios of Ra-226 to thorium activities in these samples were nearly constant, ranging from about 5% to 8%. Concentrations of Ra-226 to U-238 were approximately equal, suggesting that the contamination in this area is due to unprocessed monazite sand.

Radionuclide Concentrations in Vegetation Samples

The radionuclide concentrations in vegetation samples (V6-V8) collected from the vicinity of the Erie Lackawanna Railroad are presented in Table 11. In all cases, the radionuclide concentrations were within the range of the baseline samples.

DISCUSSION

This survey identified thorium contamination in soil on the W.R. Grace site, the adjacent property south of that site, and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains. Elevated direct radiation levels are associated with this contamination. The contamination on the W.R. Grace property appears to be process residues, consistent with previous uses of monazite sands and on-site burials of wastes. Contamination on the adjacent property south of the W.R. Grace site and the Erie Lackawanna Railroad appears to be unprocessed monazite sand, originating from handling or storage of the sands on those properties.

W.R. Grace Site

Contamination on the W.R. Grace and Co. site apparently originated from on-site storage and shallow land burial of ores, wastes, residues, and contaminated equipment from previous operations. The relatively high thorium surface contamination levels in some locations and the findings of the ground-penetrating radar survey suggest that the burials were not necessarily at well defined locations and that buried wastes may have been disturbed and eventually spread over the eastern portion of the property.

Borehole sampling and measurements at suspected burial locations indicated higher concentrations in the subsurface soil than in the surface soil. Thorium concentrations in soil samples collected east and north of the drainage stream (well away from the burial areas) and along the western property boundary were slightly elevated. Thorium concentrations in surface and subsurface soil, collected near the south property boundary also were elevated.

Due to the extensive disturbance of soil on the property, lack of agreement between site personnel and ground-penetrating radar results concerning the burial locations, and because of intentional avoidance of drilling into suspected burial trenches, it was not possible to estimate with reasonable accuracy the total volume and activity of the on-site wastes.

Direct radiation levels on almost the entire portion of the site where burials are suspected exceeded 60 μR/h. Access to areas of highest radiation levels is restricted and the site is posted with radiation warning signs.

Buildings on the site were surveyed prior to termination of the W.R. Grace license and levels were verified recently by the NRC Region 1 office. These buildings were found to meet the NRC criteria for release for unrestricted use and therefore were not included in the ORAU survey.

Radionuclide levels in the sediment and water from the drainage stream are elevated but do not indicate that this is a significant migration pathway. The general slope of the property is away from the stream. Surface run-off from areas of contaminated soil into this stream is, therefore, very limited.

All of the sediment samples from the on-site storm sewer contained elevated thorium concentrations; all of the water samples collected from the storm sewer had gross alpha levels above those in baseline samples. The high thorium levels in some of these sediment samples indicate a concentration by placer action. These findings and the elevated radiation levels and surface soil concentrations along other surface drainage pathways on the W.R. Grace site suggest transport by water run-off has been and continues to be a significant mode of migration.

Ground water sampling was complicated by heavy rains. Permanent monitoring wells have been installed and the results of sampling from these wells will be provided as an addendum to this report.

Adjacent Properties

Only one soil sample from the adjacent properties north and west of the site had a thorium level exceeding the range of the baseline samples. Thorium concentrations in surface soil from the adjacent property, south of the W.R. Grace site, exceeded baseline levels. Thorium contamination is

also present on the floor of one of the buildings. This contamination probably resulted from occasional use of the property for monazite sand storage.

Surface run-off from the W.R. Grace site may also have contributed to this contamination. Thorium concentrations in the subsurface soil samples, collected on this property, were only slightly higher than those in baseline samples.

Surface exposure rates on the northern portion of this property also exceed area background levels. Highest levels are located along the boundary nearest the W.R. Grace property and in several small isolated areas adjacent to and inside the building once used for monazite sand storage.

Erie Lackawanna Railroad

Elevated surface soil concentrations of thorium are present along the section of the Erie Lackawanna Railroad included in this survey. Subsurface soil samples, collected at locations of higher direct radiation levels, also contain thorium concentrations exceeding the baseline soil levels. The contamination is believed to be in the form of unprocessed monazite sand, which was reportedly unloaded at this location. Elevated direct radiation levels, associated with the thorium contamination, are present along the track north of Peck Avenue, and there are several small isolated areas of elevated surface radiation 50-75 m south of Peck Avenue.

Radiation Guidelines

Guidelines for levels of radiation and radioactive materials in the environment are established by federal regulatory agencies such as the Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA). These guidelines are usually based on conservative factors of land use and occupancy, potential intake by inhalation and ingestion, biological retention times, relative hazard of the radionuclide, and potentially exposed population group. Such guidelines are, therefore, for highly

restrictive situations that may not be representative of the actual conditions at a specific site. For this reason, these federal guidelines are often used as target criteria with site-specific limits established on case-by-case basis. Guidelines for concentrations of radionuclides in soil have not been specifically developed for the W.R. Grace site or other properties included in this survey.

The Nuclear Regulatory Commission's Standards for Protection Against Radiation (10CFR20) establishes limits of radiation dose for occupational radiation workers and for the general public. An individual in the general public may receive an annual radiation dose of 500 millirem.[5] Assuming continual exposure, i.e. 168 h/wk, this allowable annual dose is equivalent to an average exposure rate of approximately 60 μR/h.

SUMMARY

At the request of the Nuclear Regulatory Commission, the ORAU Radiological Site Assessment Program conducted a radiological survey of the W.R. Grace site in Wayne, New Jersey. Surveys of properties adjacent to the W.R. Grace site and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains were also performed.

The findings indicate extensive thorium contamination in soil on portions of the W.R. Grace site. Radionuclide concentrations in the sediment and water collected from the on-site storm sewer indicate this system is a possible pathway for off-site migration of contamination. Migration appears to be by placer movement, rather than by leaching of radionuclides from the residues.

A portion of the property (including one of the buildings) bordering the W.R. Grace site on the south and a section of the Erie Lackawanna Railroad also have elevated thorium concentrations in soil and radiation levels. The contamination on these two properties appears to be primarily unprocessed ore. Other properties adjacent to the W.R. Grace site do not have thorium concentrations or direct radiation differing significantly from the range of area baseline and background levels.

Permanent monitoring wells are being installed to measure radionuclide concentrations in ground water on the W.R. Grace site. Results of these measurements are not completed and will be provided as an addendum to this report.

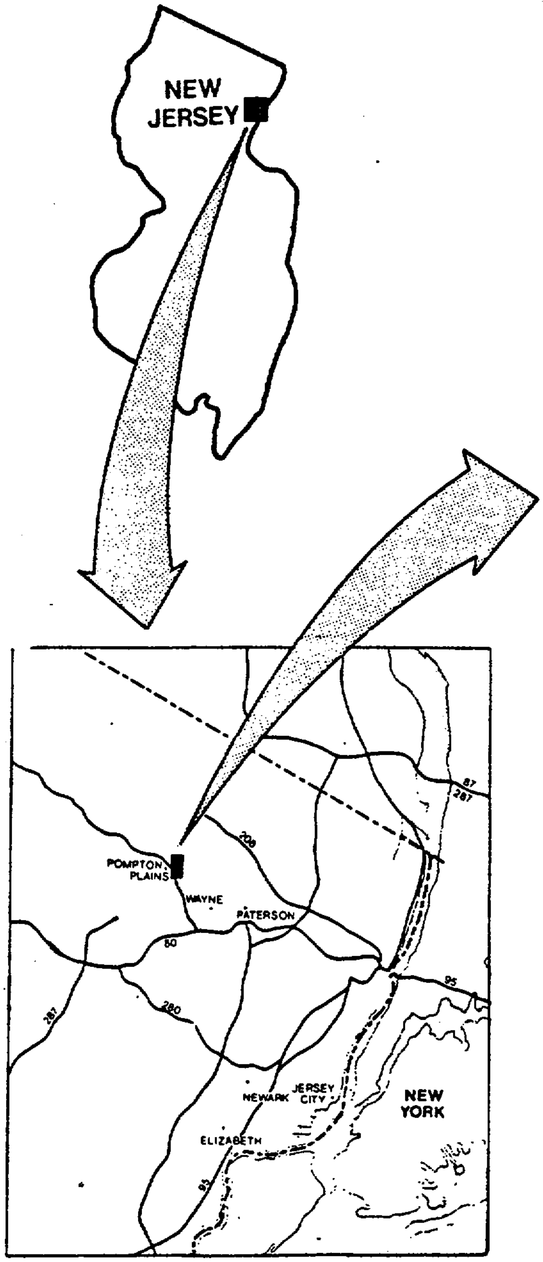


FIGURE 1. Map of Northeastern New Jersey Indicating the Location of the W.R. Grace Property.

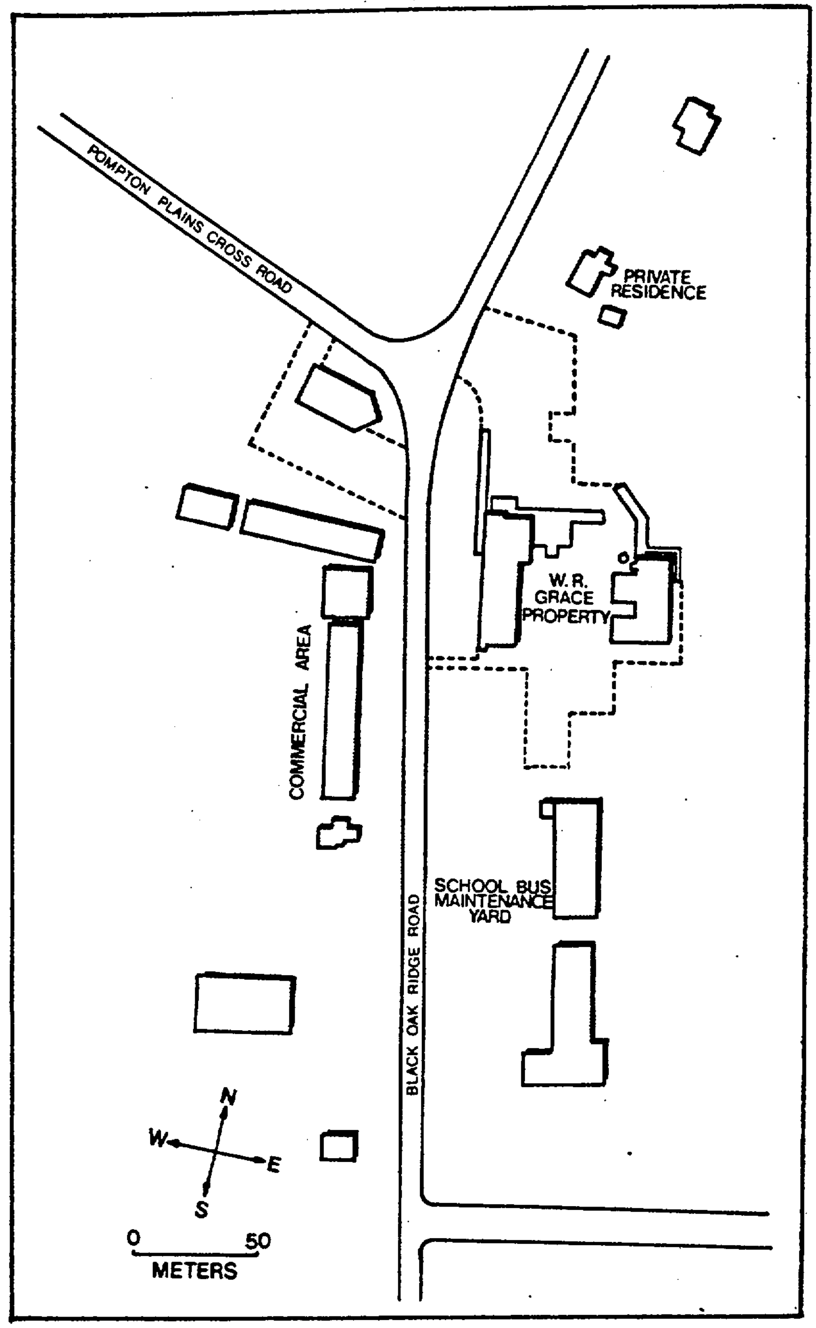


FIGURE 2. Portion of Wayne, New Jersey, Indicating the Locations of the W.R. Grace Property and Adjacent Properties. (Dotted lines indicate paved areas.)

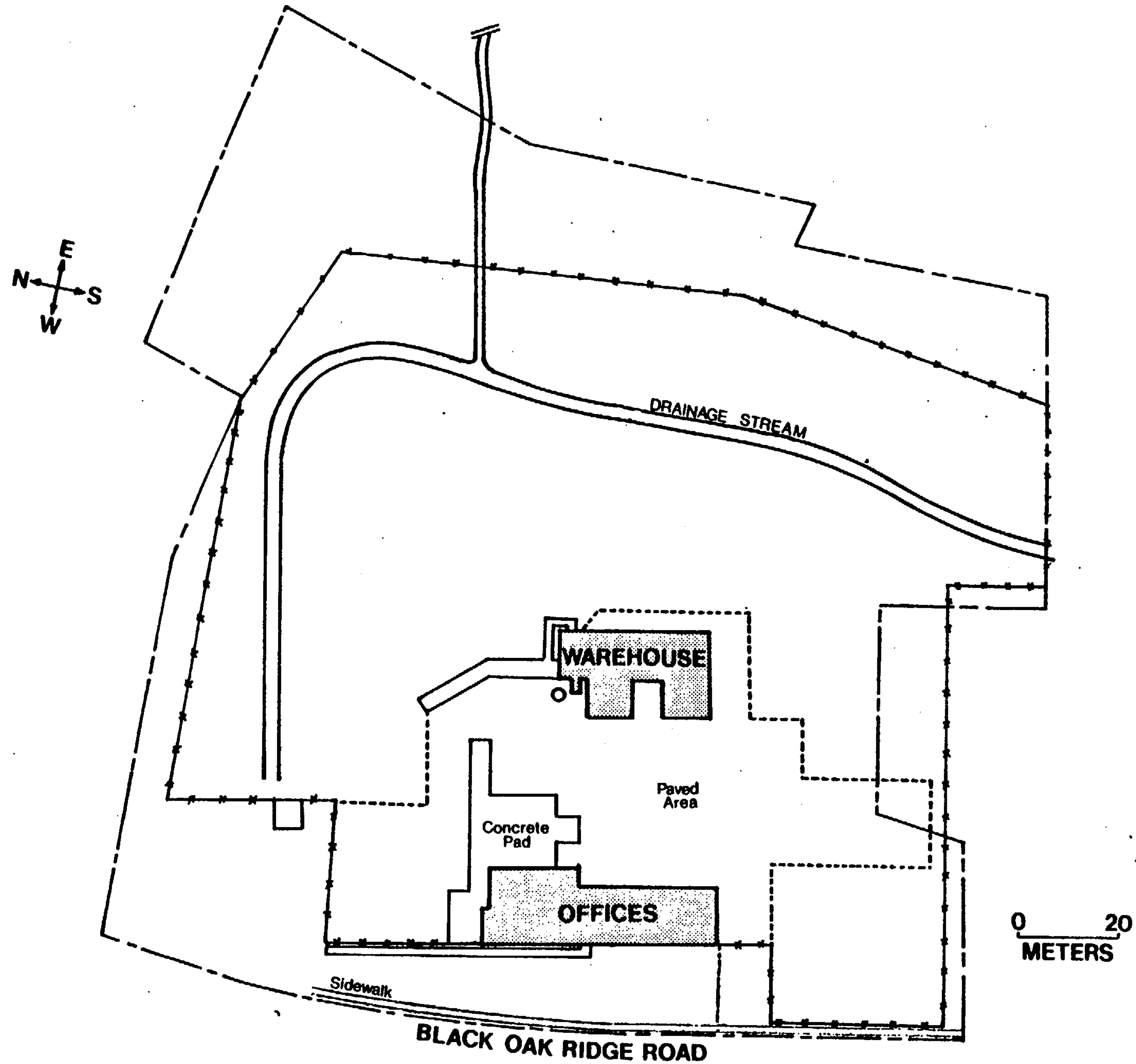


FIGURE 3. Plan View of the W.R. Grace Property.

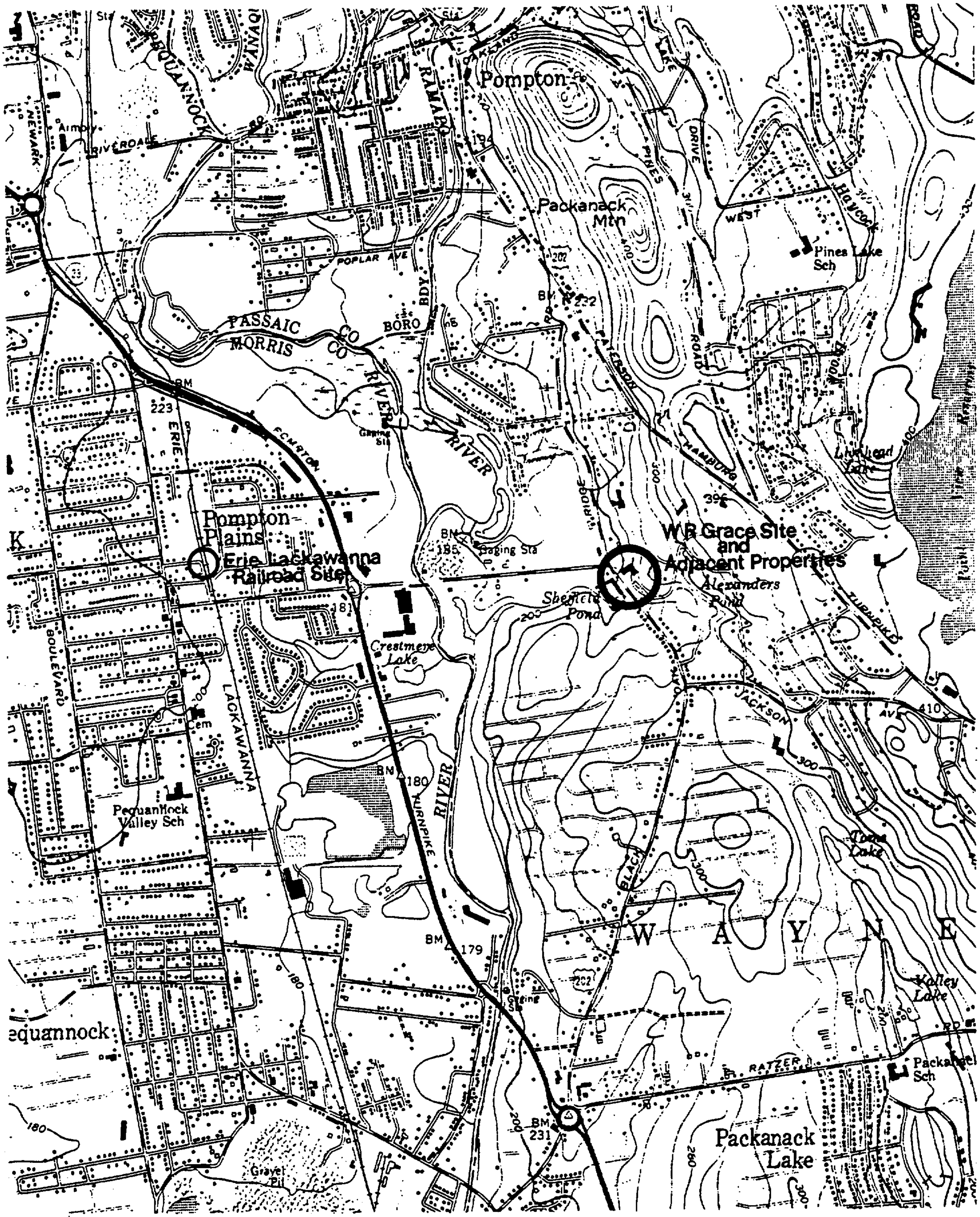


FIGURE 4. Map of the Wayne-Pompton Plains, New Jersey, Area Indicating the Location of the W.R. Grace Site and the Erie Lackawanna Railroad Site.

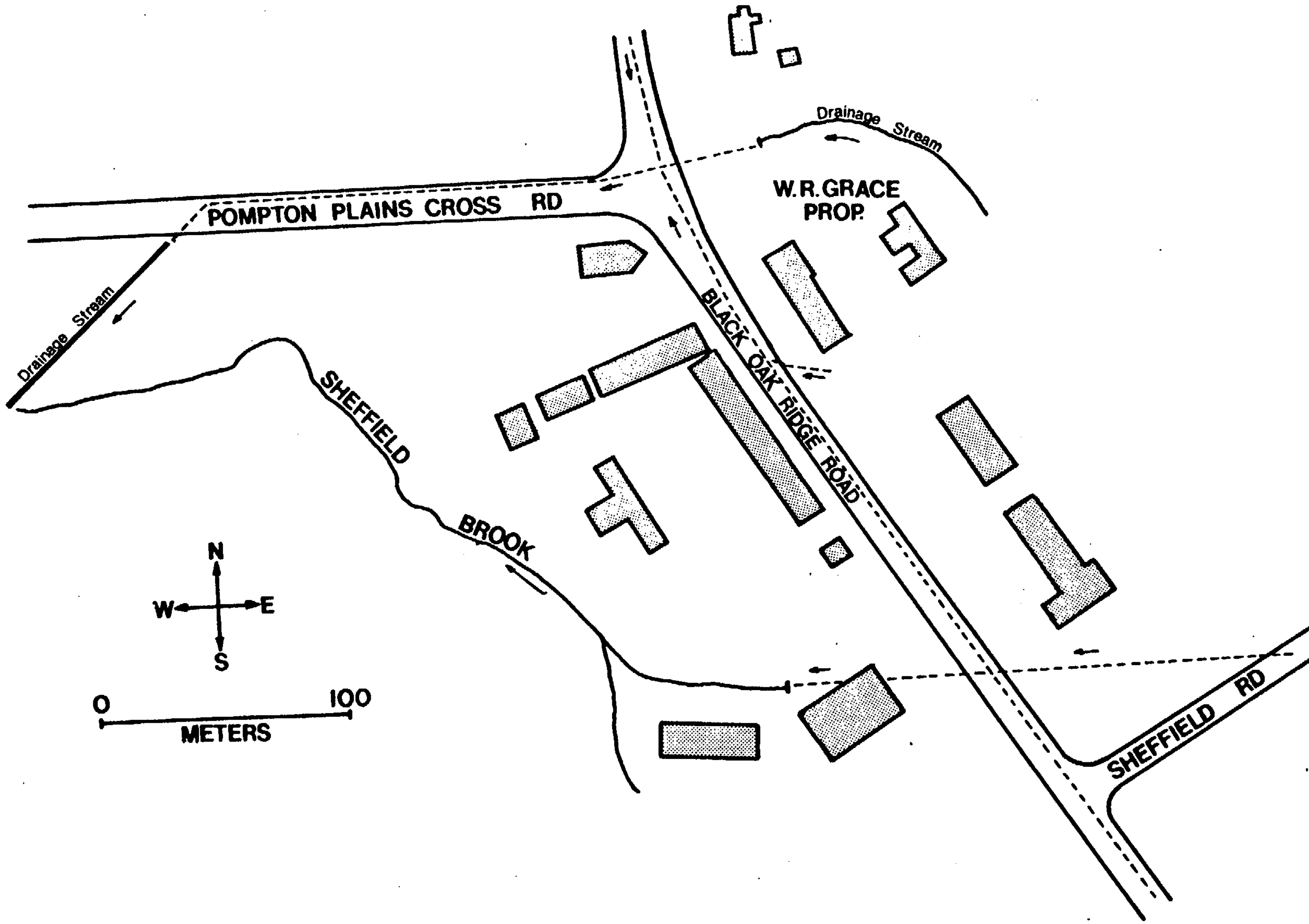
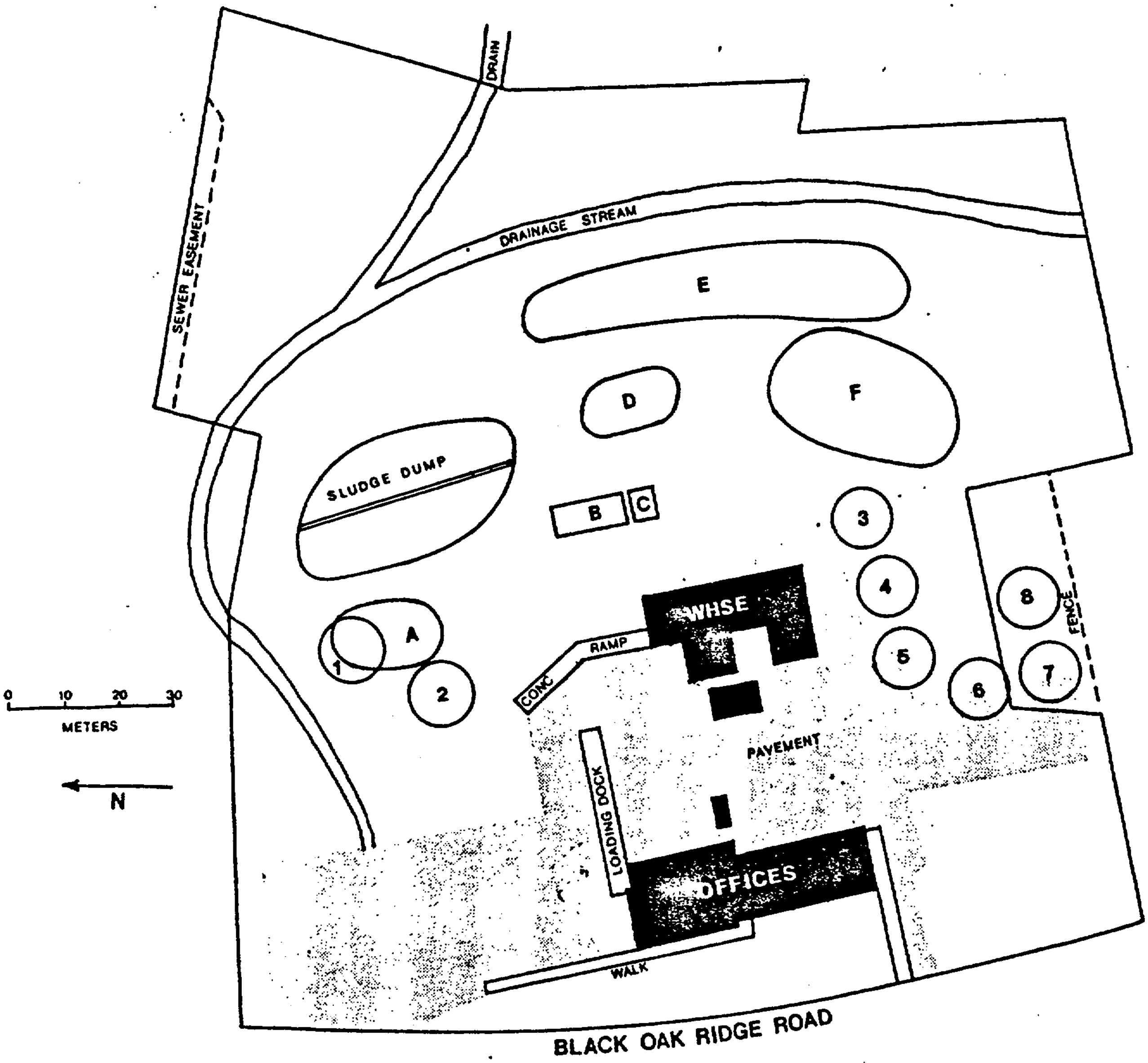


FIGURE 5. Plan View of the Storm Drainage System Servicing the W.R. Grace Site.



A=Reworked Sludges
B=Yttrium Concentrate
C=Thorium Hydroxide

D=Waste Treatment Disposal
E=Ore Tailings and Gangue
F=Yttrium and Silica Sludges

1-8 = Circular Holes Filled April-June 1974 with debris and contaminated equipment resulting from decontamination of buildings.

FIGURE 6. Suspected Burial Locations on the W. R. Grace Property.

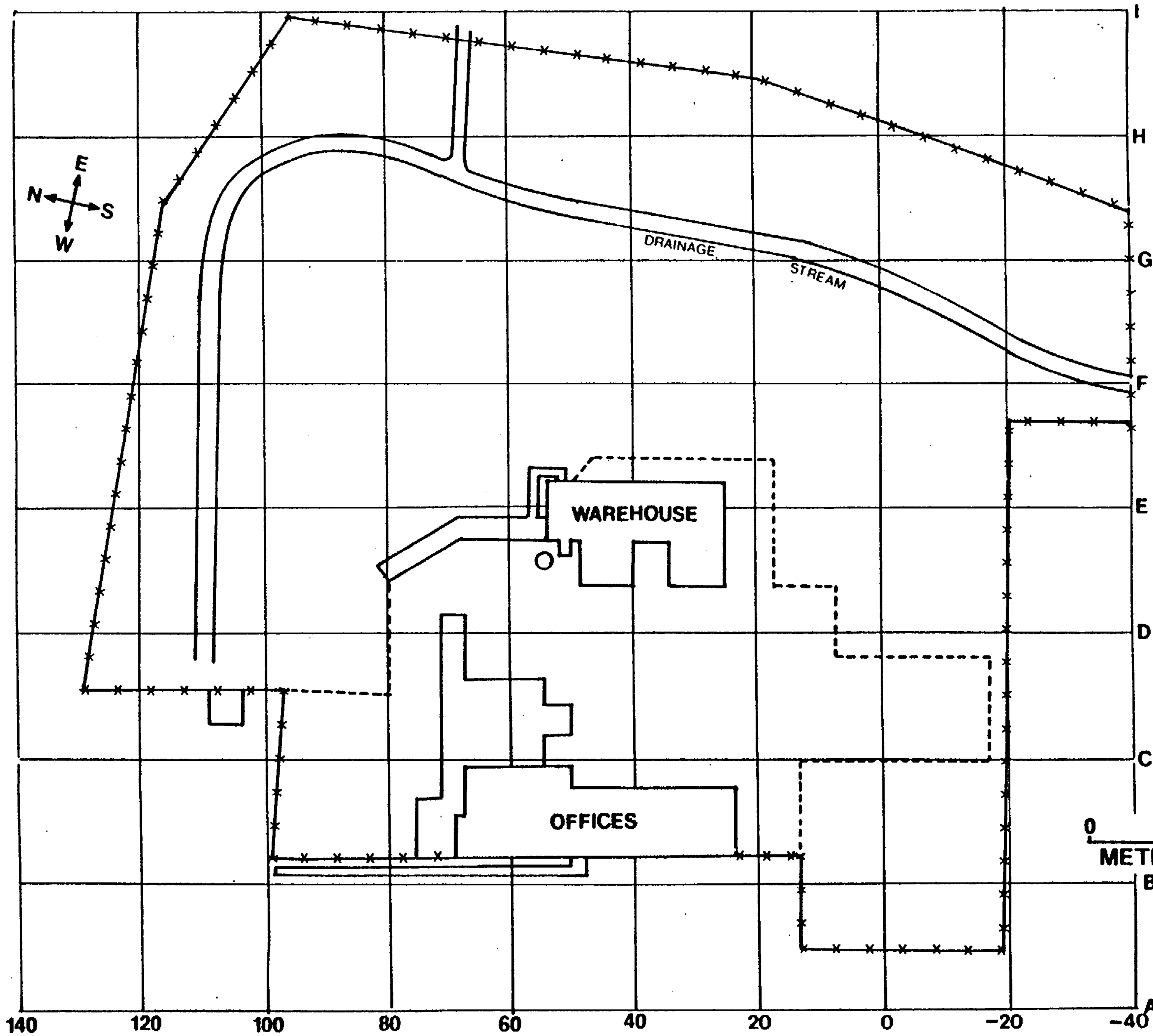


FIGURE 7. Grid System Established for Survey Reference.

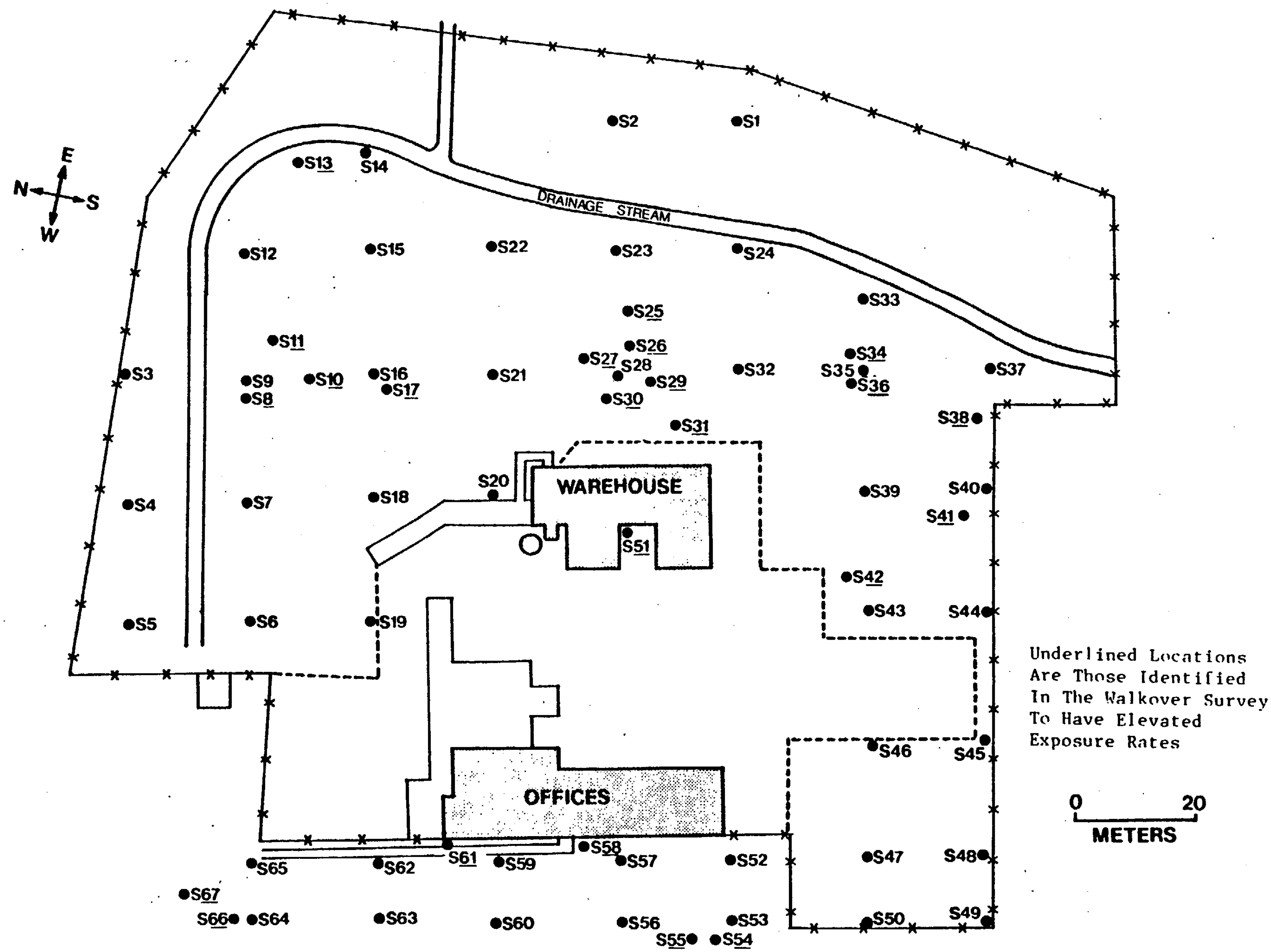


FIGURE 8. Surface Soil Sampling Locations on the W.R. Grace Property.

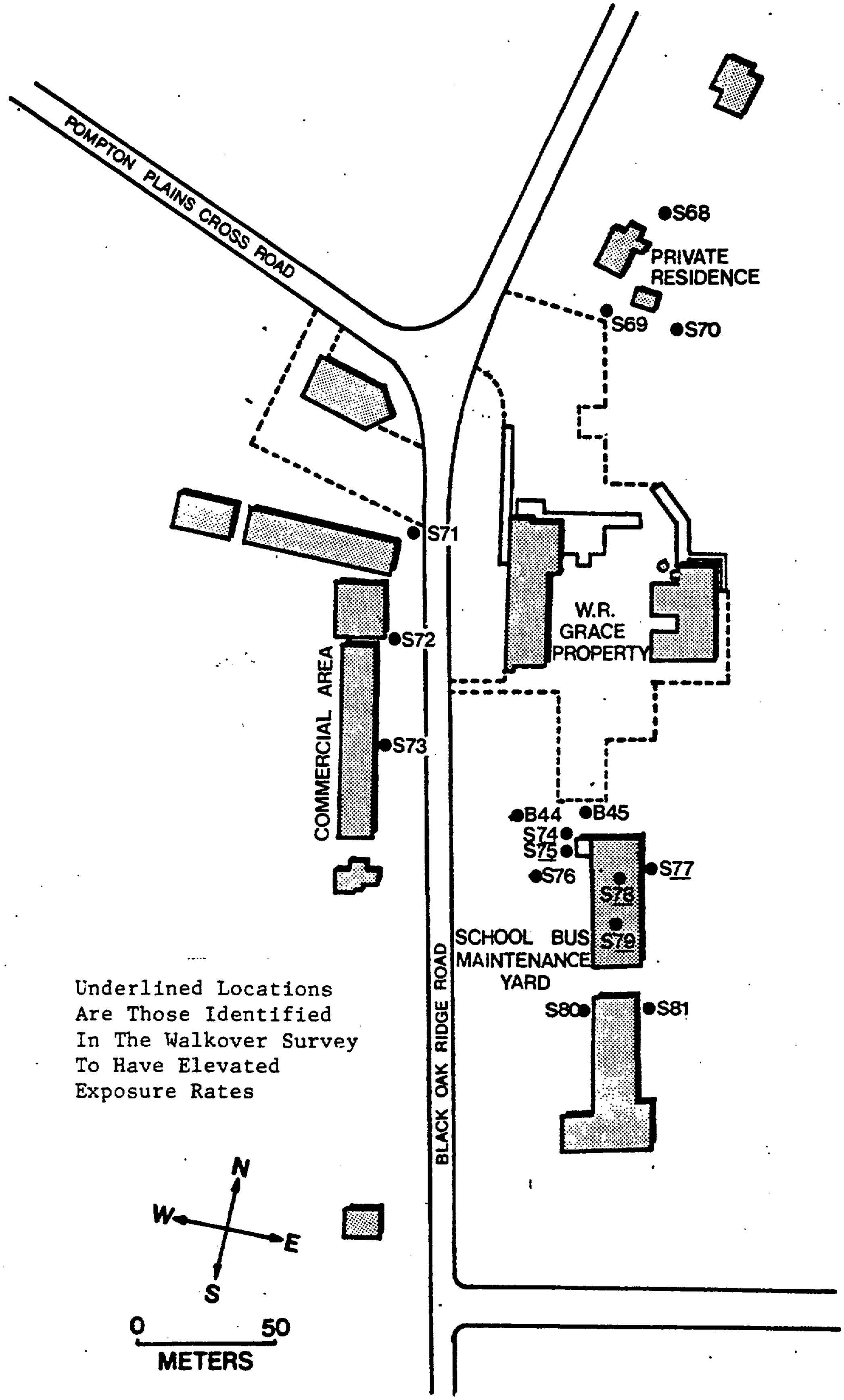


FIGURE 9. Surface Soil Sampling and Borehole Locations Adjacent to the W.R. Grace Property.

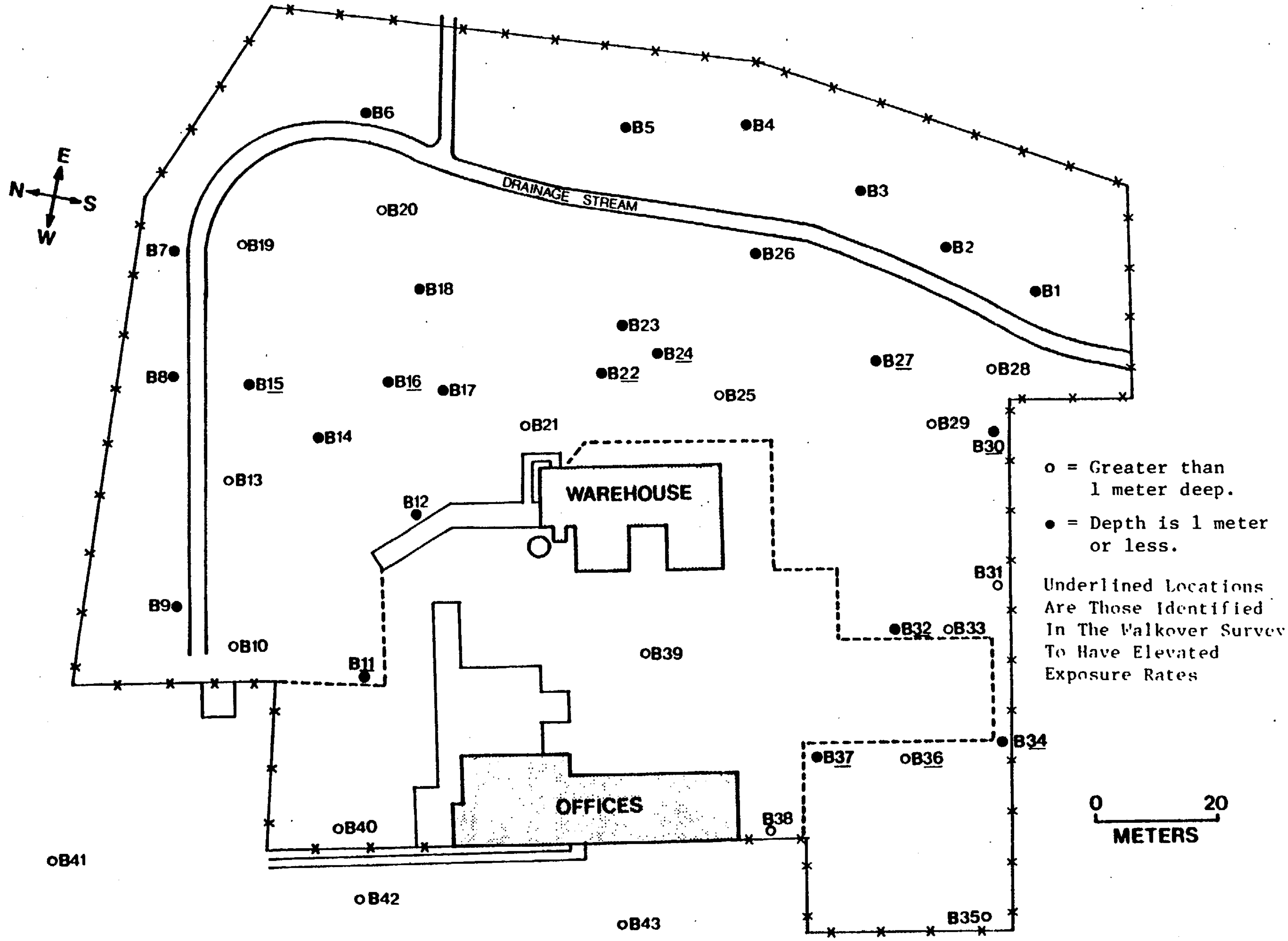


FIGURE 10. Borehole Locations on the W.R. Grace Property.

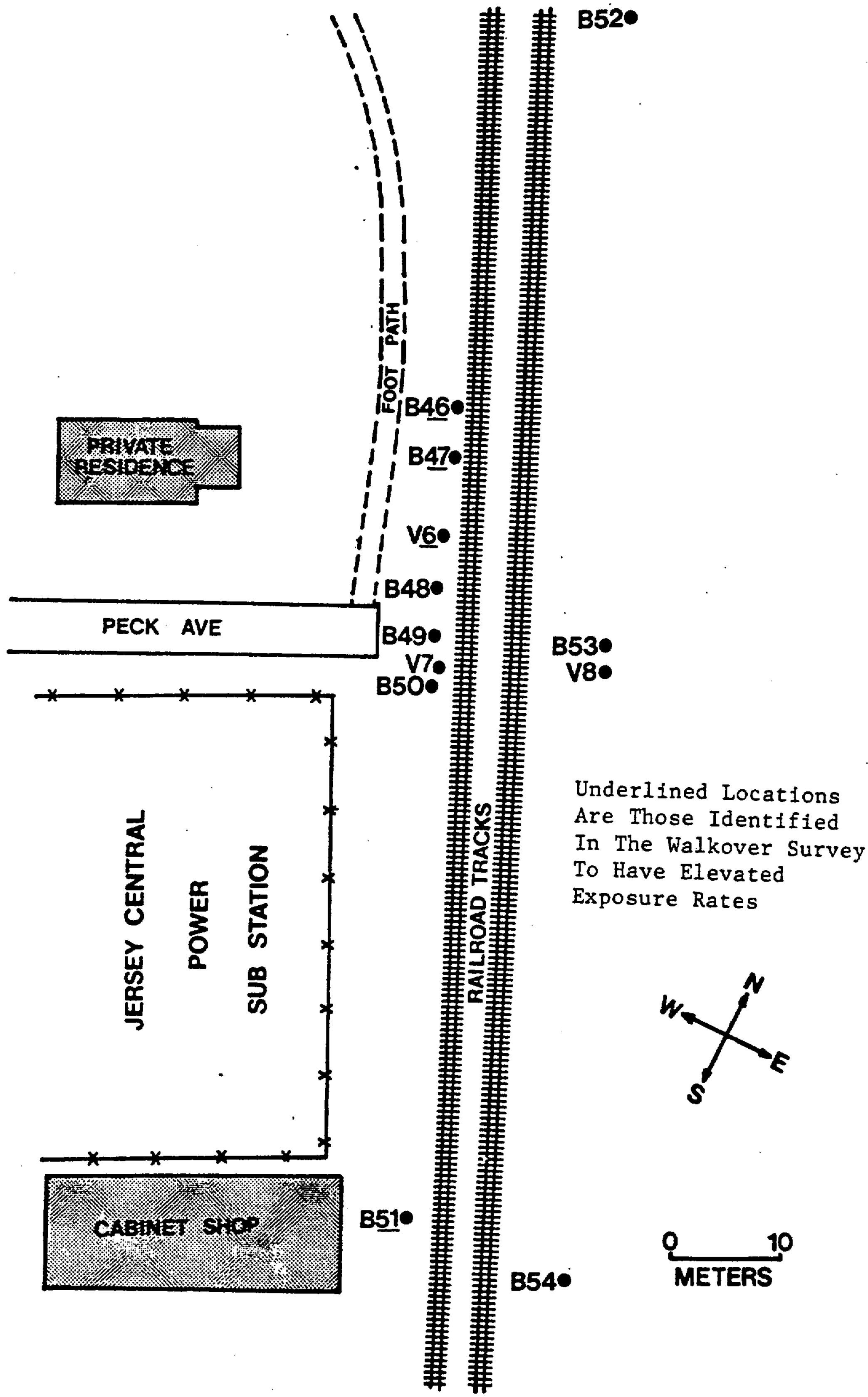


FIGURE 11. Borehole and Vegetation Sampling Locations Along the Erie Lackawanna Railroad in Pompton Plains, NJ.

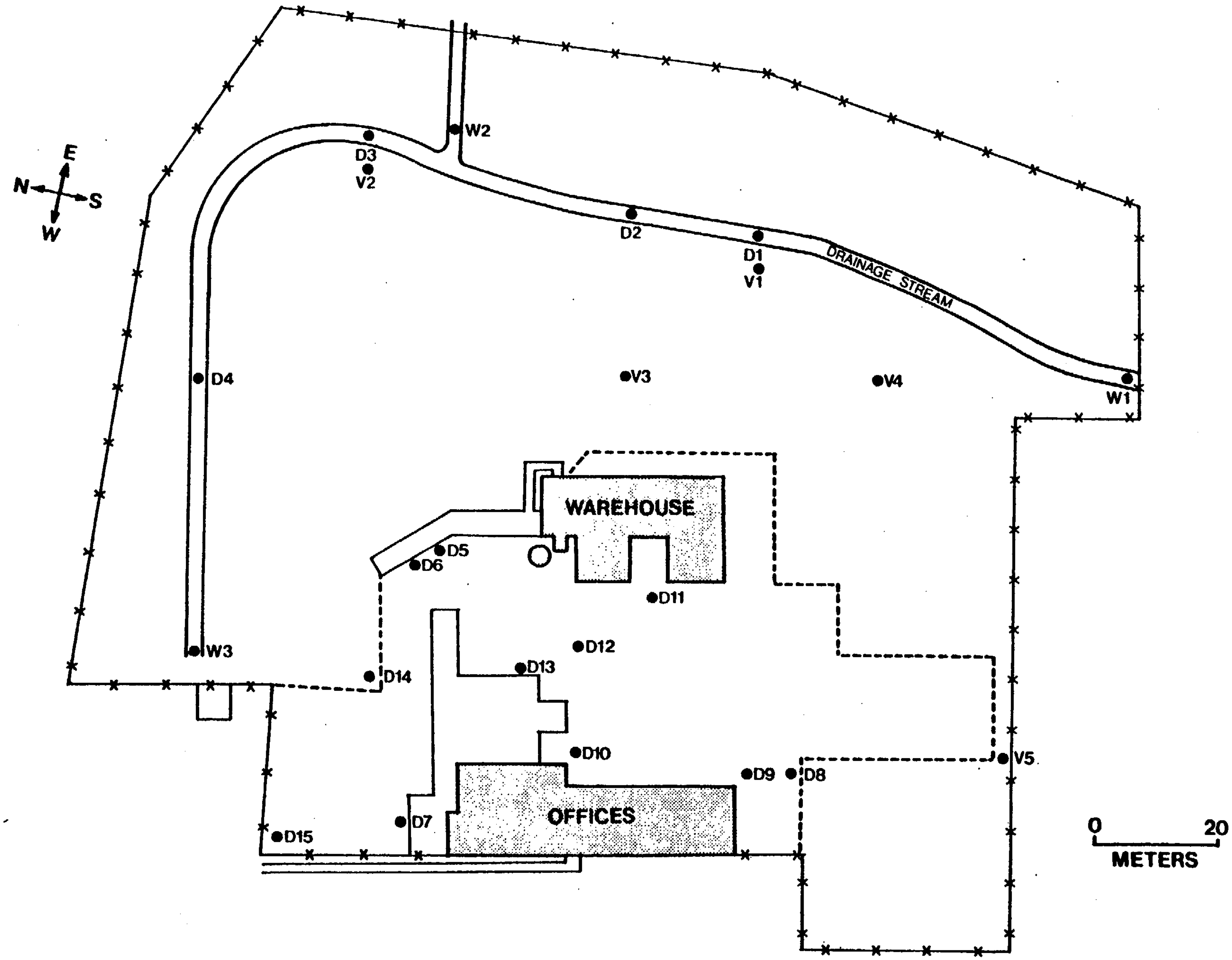


FIGURE 12. Sediment, Water, and Vegetation Sampling Locations on the W.R. Grace Property.

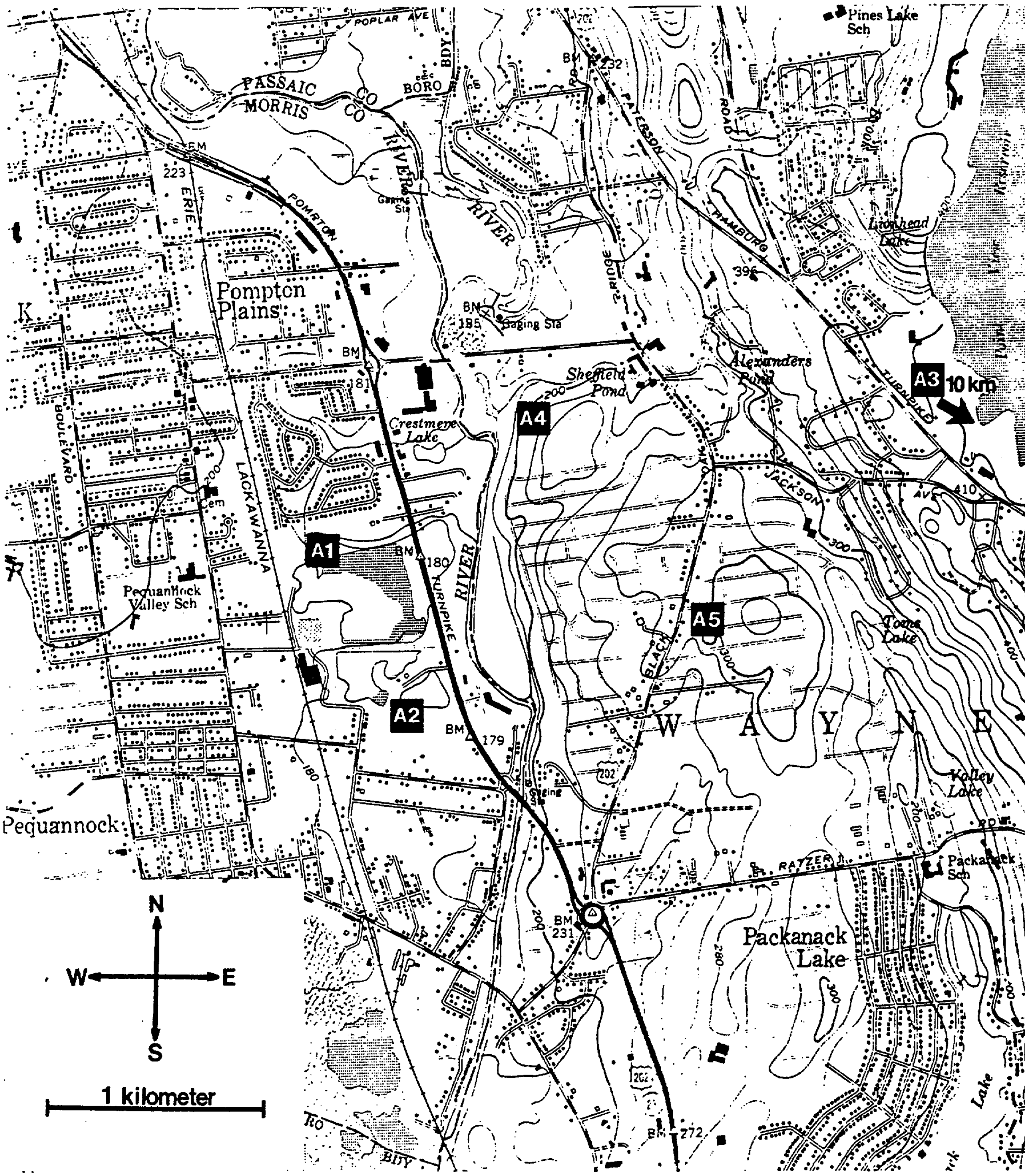


FIGURE 13. Locations of Background Measurements and Baseline Samples in the Wayne-Pompton Plains Area.

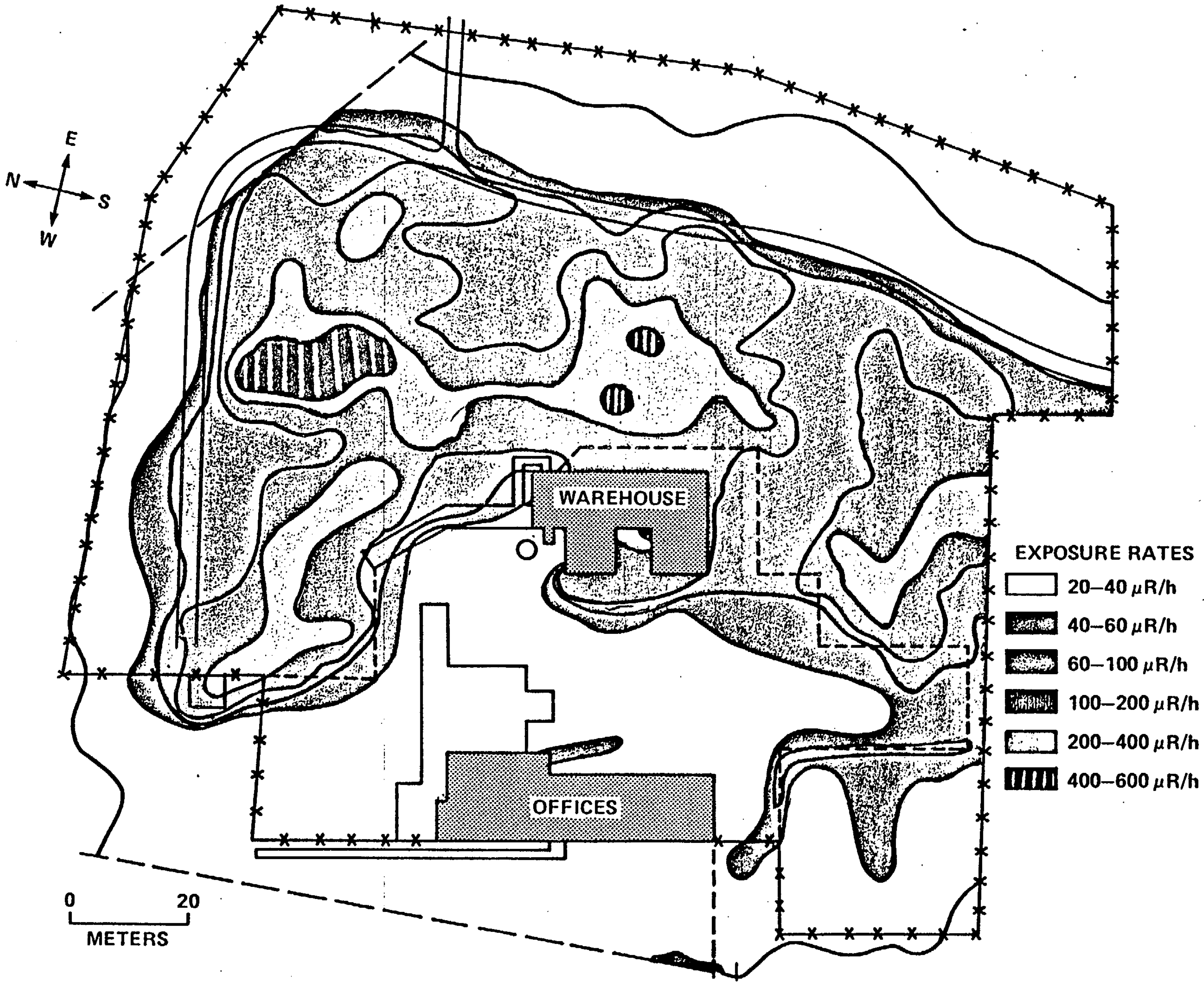


FIGURE 14. Exposure Rates (μR/h) at 1 m Above the Surface on the W.R. Grace Property.

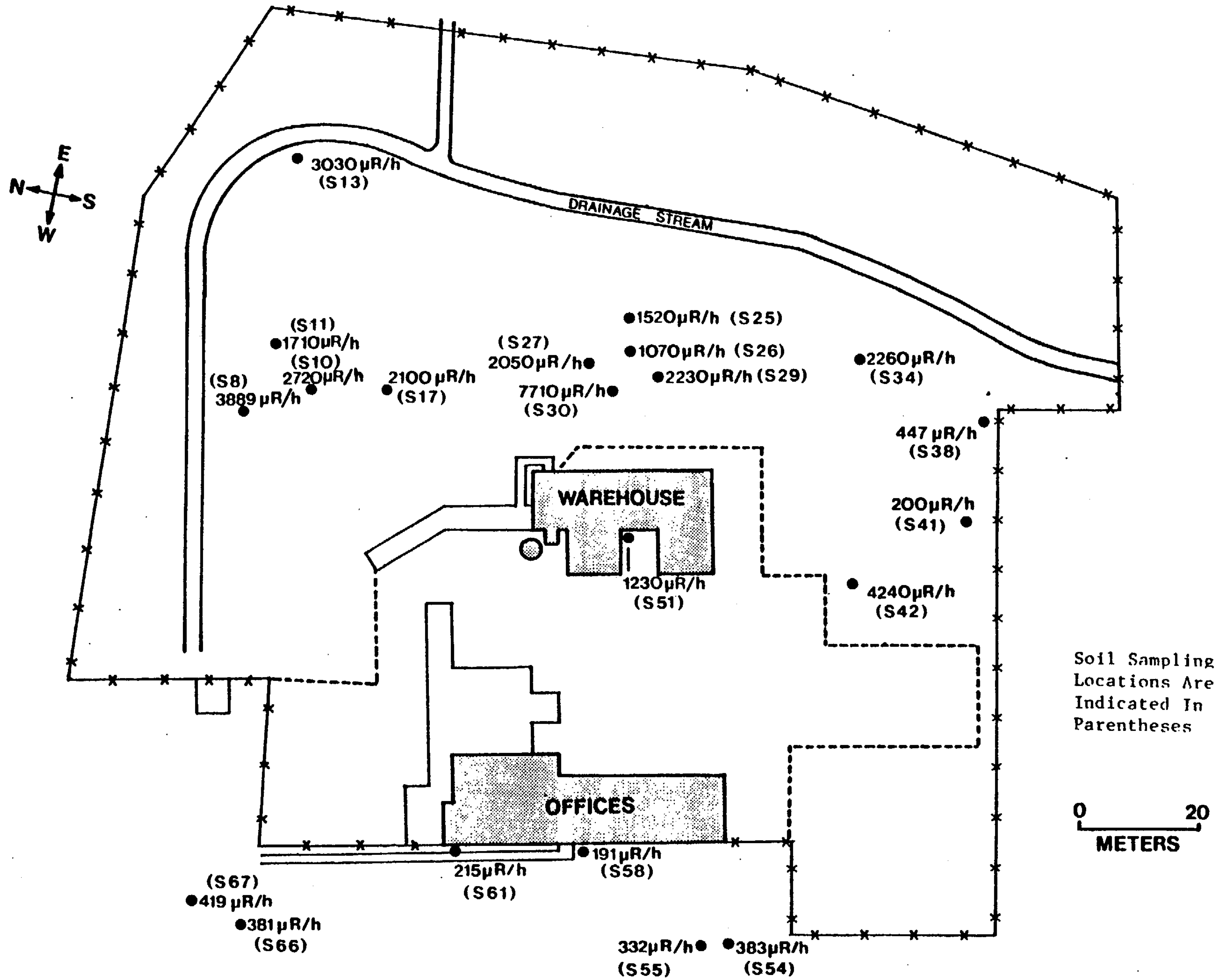


FIGURE 15. Surface Exposure Rates at Sampling Locations of Biased Surface Soil Samples.

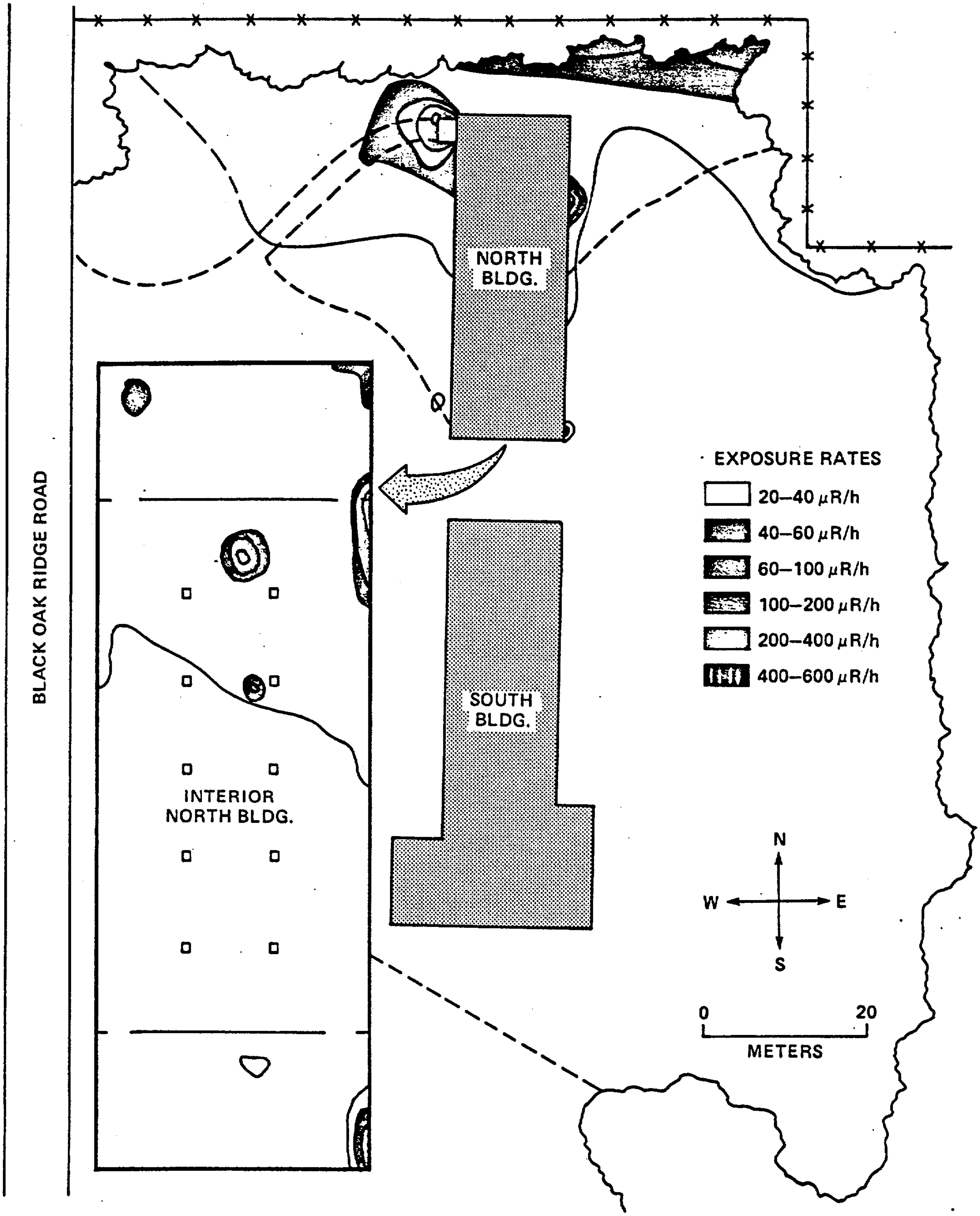


FIGURE 16: Surface Exposure Rates (μR/h) on the School Bus Maintenance Yard.

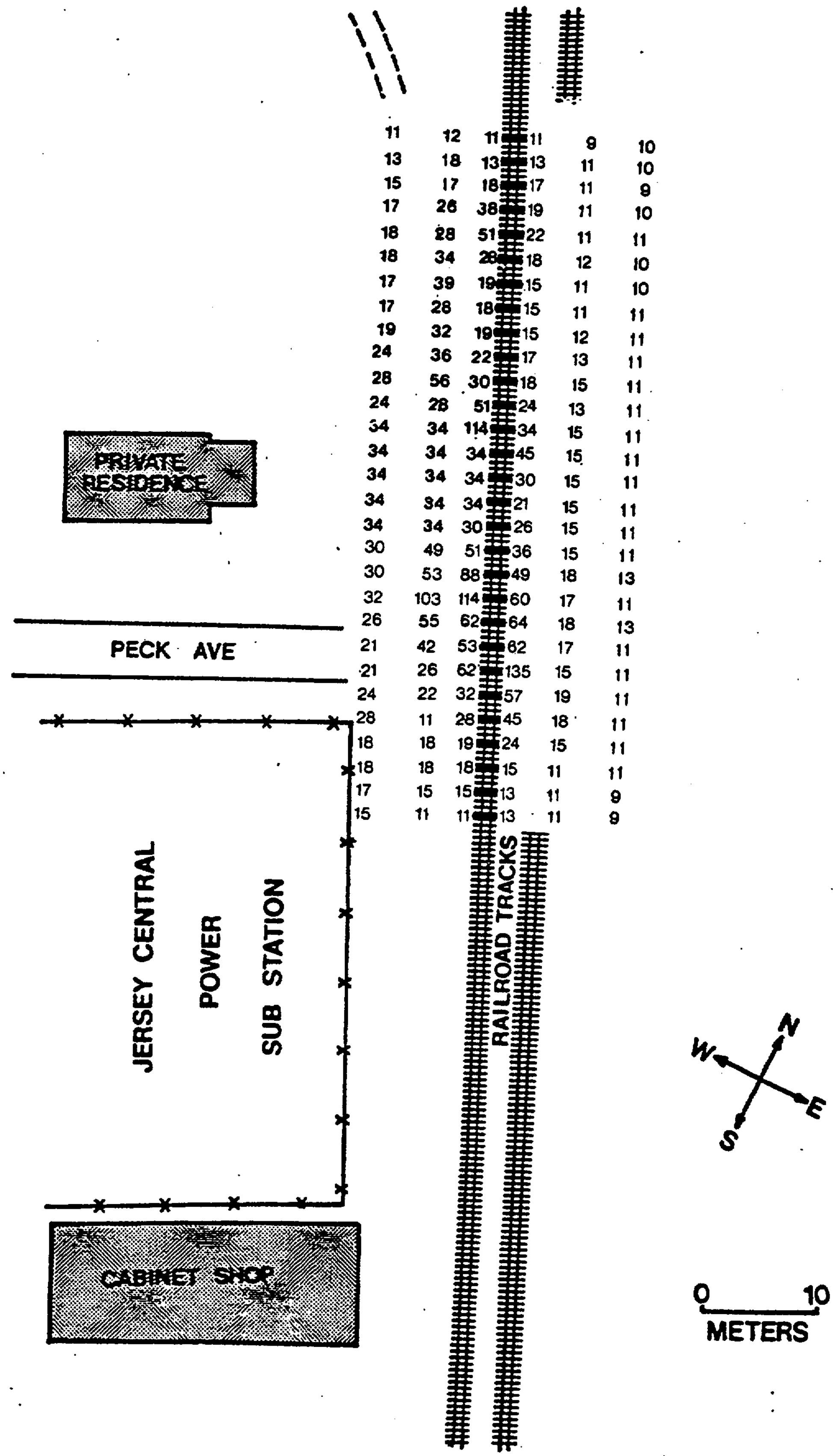


FIGURE 17. Exposure Rates (μR/h) at 1 m Above the Surface Along the Erie Lackawanna Railroad in Pompton Plains.

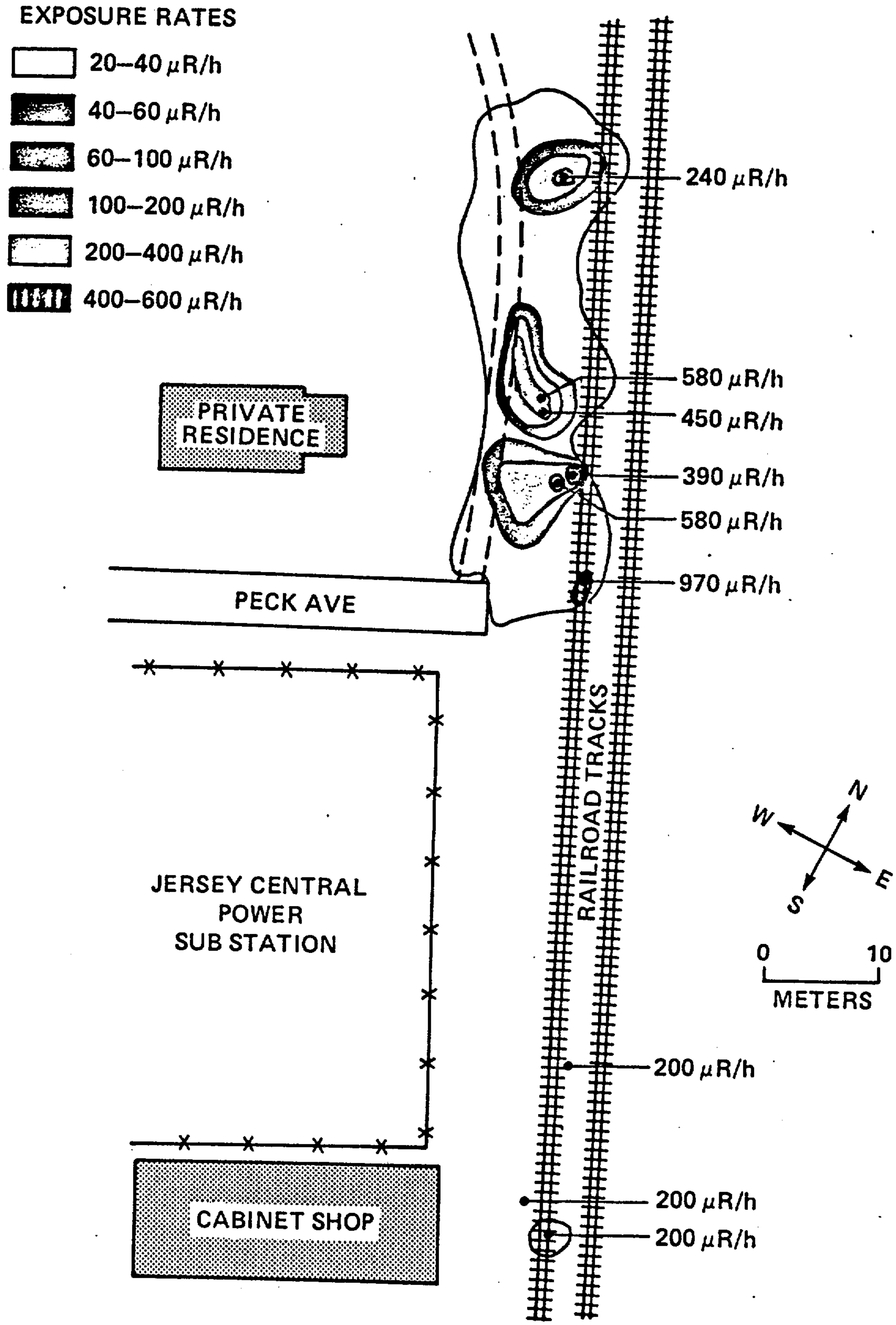


FIGURE 18. Surface Exposure Rates (μR/h) Along the Erie Lackawanna Railroad in Pompton Plains.

TABLE 1-A

RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL
AND VEGETATION SAMPLES

Sample Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
Soil:					
A1 - P.V. Park	surface	0.51 + 0.23[b]	0.58 ± 0.27	0.47 ± 0.15	<MDA[c]
	30	0.72 ± 0.22	0.80 ± 0.21	0.47 ± 0.22	"
	60	0.69 ± 0.21	0.69 ± 0.21	0.49 ± 0.13	"
	90	0.45 ± 0.33	0.54 ± 0.17	0.50 ± 0.16	"
A2 - McDonald Park	surface	0.69 ± 0.25	0.56 ± 0.23	0.45 ± 0.17	"
	30	1.00 ± 0.25	0.71 ± 0.30	0.58 ± 0.20	"
	60	0.56 ± 0.23	0.59 ± 0.18	0.37 ± 0.12	"
	90	0.72 ± 0.24	0.66 ± 0.21	0.40 ± 0.19	"
A3 - Orth Ave.	surface	1.36 ± 0.33	1.60 ± 0.31	1.13 ± 0.26	"
	30	1.17 ± 0.23	1.39 ± 0.19	1.34 ± 0.17	"
	60	1.18 ± 0.24	1.31 ± 0.19	1.11 ± 0.17	"
A4 - Farmingdale Rd.	surface	0.92 ± 0.32	1.00 ± 0.26	1.12 ± 0.25	"
	30	1.00 ± 0.29	1.21 ± 0.28	1.05 ± 0.21	"
A5 - Black Oak Ridge Road	surface	0.85 ± 0.30	0.70 ± 0.21	0.85 ± 0.20	"
	30	0.91 ± 0.29	0.73 ± 0.22	0.65 ± 0.18	"
Vegetation:					
A1 - P.V. Park		<0.10	0.29 ± 0.13	<0.06	"
A2 - McDonald Park		0.39 ± 0.18	0.31 ± 0.14	0.21 ± 0.15	"

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics.
[c] MDA levels for U-238 ranged between 2 and 5 pCi/g.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations in Water (pCi/l or x 10^{-9} μCi/ml)									
	Gross Alpha	Gross Beta	Th-228	Th-230	Th-232	Ra-226	Ra-228	U-234	U-235	U-238
A1 P.V. Park	0.95 ± 1.20[b]	<1.3	0.10 ± 0.07	0.07 ± 0.03	<0.05	0.09 ± 0.08	<0.63	0.19 ± 0.03	<0.05	0.13 ± 0.03
A2 McDonald Park	<2.28	<3.6	<0.05	<0.05	<0.05	—[c]	—	0.12 ± 0.03	<0.05	0.09 ± 0.02
A6 City Water	<1.56	<3.7	<1	<1	<1	<0.07	1.12 ± 0.65	<1	<1	<1

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics only.
[c] Dash indicates analysis not performed.

TABLE 2

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S1	2.17 ± 0.42[b]	2.06 ± 0.36	0.68 ± 0.25	<3.81
S2	3.00 ± 0.55	3.35 ± 0.46	1.09 ± 0.28	<3.08
S3	1.95 ± 0.39	1.88 ± 0.31	0.91 ± 0.24	<3.46
S4	10.4 ± 0.8	9.59 ± 0.65	1.29 ± 0.35	<5.52
S5	1.18 ± 0.42	0.96 ± 0.26	0.60 ± 0.18	<3.22
S6	69.5 ± 2.4	69.1 ± 2.1	4.01 ± 0.90	33.4 ± 0.9
S7	41.4 ± 1.6	36.7 ± 1.3	4.82 ± 0.67	28.3 ± 0.8
S8[c]	2250 ± 20	1670 ± 10	13.2 ± 5.1	423 ± 2
S9	368 ± 5	353 ± 5	10.9 ± 1.8	114 ± 1
S10	2240 ± 20	1830 ± 20	39.0 ± 6.1	173 ± 2
S11	1920 ± 20	1450 ± 10	48.5 ± 7.0	401 ± 2
S12	73.8 ± 2.0	69.0 ± 1.7	3.05 ± 0.75	<9.42
S13	2710 ± 20	1540 ± 10	13.6 ± 6.5	109 ± 1
S14	23.5 ± 1.1	19.7 ± 0.9	0.85 ± 0.42	<5.40
S15	21.6 ± 1.0	18.7 ± 0.9	1.31 ± 0.39	<5.56
S16	66.3 ± 2.1	54.5 ± 1.8	5.10 ± 0.93	34.5 ± 0.8
S17	1010 ± 10	729 ± 8	18.2 ± 4.1	172 ± 1
S18	269 ± 4	214 ± 3	10.2 ± 1.4	<17.7
S19	77.2 ± 2.1	69.0 ± 1.7	4.99 ± 0.79	10.7 ± 0.7
S20	24.8 ± 1.4	24.7 ± 1.0	1.03 ± 0.41	3.13 ± 0.50
S21	74.0 ± 2.1	70.8 ± 1.7	7.46 ± 0.42	16.2 ± 0.7
S22	33.1 ± 1.5	29.1 ± 1.0	1.16 ± 0.44	<6.41
S23	16.6 ± 1.1	17.5 ± 1.0	2.62 ± 0.52	<6.06
S24	9.69 ± 0.89	8.74 ± 0.77	3.94 ± 0.48	<6.57
S25	1190 ± 10	931 ± 8	360 ± 7	<70.5
S26	1330 ± 10	1440 ± 10	710 ± 6	61.0 ± 1.0
S27	1200 ± 10	899 ± 13	87.2 ± 5.9	90.7 ± 1.1
S28	206 ± 3	171 ± 3	15.0 ± 1.3	33.4 ± 0.8
S29	1630 ± 30	1760 ± 20	586 ± 15	116 ± 1
S30	4500 ± 30	3040 ± 20	159 ± 11	144 ± 1
S31	1000 ± 10	869 ± 5	114 ± 4	61.1 ± 0.8
S32	63.5 ± 1.9	58.0 ± 1.6	5.02 ± 0.77	<0.97
S33	9.83 ± 0.89	9.51 ± 0.70	1.56 ± 0.03	<5.29
S34	2740 ± 30	2700 ± 30	646 ± 12.	35.7 ± 0.9
S35	109 ± 3	115 ± 2	13.2 ± 1.1	<12.0
S36	1850 ± 20	2300 ± 20	591 ± 12	47.7 ± 0.9
S37	18.5 ± 1.6	18.9 ± 0.65	1.29 ± 0.35	<5.52
S38	558 ± 5	479 ± 5	56.0 ± 2.6	<28.7
S39	101 ± 2	98.8 ± 2.0	9.85 ± 1.00	16.0 ± 0.8
S40	32.6 ± 1.6	31.6 ± 1.2	3.62 ± 0.62	<7.98
S41	216 ± 4	253 ± 3	32.1 ± 1.6	<17.7
S42	2220 ± 30	2090 ± 30	705 ± 16	75.4 ± 1.2
S43	82.7 ± 2.3	84.8 ± 2.0	11.6 ± 1.0	<11.4

TABLE 2, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S44	94.8 ± 2.7	88.5 ± 2.1	4.21 ± 0.89	14.6 ± 0.7
S45	41.4 ± 1.7	41.7 ± 1.5	6.30 ± 0.80	<9.22
S46	172 ± 3	170 ± 2	21.0 ± 1.3	<15.4
S47	3.65 ± 0.61	3.42 ± 0.56	0.92 ± 0.31	<3.76
S48	2.79 ± 0.48	3.10 ± 0.42	0.99 ± 0.24	<3.15
S49	1.63 ± 0.42	1.86 ± 0.38	0.86 ± 0.22	<3.63
S50	1.81 ± 0.42	1.89 ± 0.36	0.81 ± 0.24	<3.30
S51	212 ± 3	211 ± 3	20.5 ± 1.4	14.5 ± 0.6
S52	5.57 ± 0.59	5.89 ± 0.51	0.84 ± 0.28	<3.61
S53	3.81 ± 0.51	4.35 ± 0.45	0.96 ± 0.29	<4.07
S54	438 ± 7	394 ± 6	14.7 ± 2.5	37.4 ± 0.8
S55	547 ± 5	431 ± 4	15.5 ± 2.2	39.2 ± 0.9
S56	26.2 ± 1.2	23.4 ± 1.0	4.86 ± 0.56	<6.76
S57	6.60 ± 0.70	7.56 ± 0.61	0.71 ± 0.30	<4.17
S58	26.5 ± 1.2	24.7 ± 1.0	1.33 ± 0.42	<5.61
S59	4.95 ± 0.58	4.88 ± 0.53	0.77 ± 0.31	<4.29
S60	10.6 ± 0.8	8.19 ± 0.62	1.10 ± 0.34	<4.28
S61	101 ± 2	104 ± 2	15.3 ± 1.1	<11.9
S62	6.63 ± 0.71	6.59 ± 0.50	0.97 ± 0.33	<3.97
S63	7.41 ± 0.64	6.86 ± 0.55	0.88 ± 0.29	<3.65
S64	7.57 ± 0.82	7.87 ± 0.62	1.16 ± 0.34	<4.41
S65	9.78 ± 0.79	8.88 ± 0.66	1.31 ± 0.37	<5.34
S66	207 ± 3	192 ± 3	8.31 ± 1.32	42.0 ± 0.9
S67	321 ± 4	269 ± 4	8.63 ± 1.52	52.8 ± 44.5

[a] Refer to Figure 7.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location[a]	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B1	Surface	4.36 ± 0.59[b]	4.22 ± 0.48	1.20 ± 0.25	<4.67
	0.5	1.12 ± 0.34	1.18 ± 0.24	0.62 ± 0.19	<2.62
	0.75	0.96 ± 0.25	1.09 ± 0.23	0.88 ± 0.18	<2.53
B2	Surface	5.41 ± 0.65	5.34 ± 0.51	1.34 ± 0.31	<4.51
	0.5	1.14 ± 0.36	0.96 ± 0.25	0.74 ± 0.16	<2.59
	1.0	0.96 ± 0.26	0.93 ± 0.26	0.70 ± 0.17	<1.86
B3	Surface	5.31 ± 0.73	6.17 ± 0.65	2.29 ± 0.48	<5.45
	0.5	1.44 ± 0.31	1.35 ± 0.29	1.01 ± 0.20	1.49 ± 0.52
	0.75	1.05 ± 0.29	1.05 ± 0.23	0.64 ± 0.17	<2.69
B4	Surface	3.45 ± 0.67	3.76 ± 0.57	1.30 ± 0.34	<4.73
	0.5	0.99 ± 0.24	1.10 ± 0.21	0.72 ± 0.17	<2.62
B5	Surface	4.19 ± 0.66	4.40 ± 0.53	1.39 ± 0.36	1.54 ± 0.57
	0.5	1.54 ± 0.42	2.07 ± 0.32	1.14 ± 0.24	<2.76
B6	Surface	1.67 ± 0.30	1.73 ± 0.26	0.88 ± 0.20	<2.81
	0.5	1.43 ± 0.37	1.45 ± 0.27	1.35 ± 0.22	<2.34
	1.0	1.32 ± 0.32	1.38 ± 0.31	1.03 ± 0.20	<3.56
B7	Surface	1.46 ± 0.49	1.20 ± 0.33	0.79 ± 0.23	<1.93
	0.5	0.89 ± 0.25	0.87 ± 0.27	0.69 ± 0.18	<2.93
	0.75	0.84 ± 0.27	0.91 ± 0.21	0.59 ± 0.16	<2.61
B8	Surface	1.47 ± 0.38	1.41 ± 0.29	1.12 ± 0.24	<3.17
	0.5	1.62 ± 0.43	1.68 ± 0.35	1.63 ± 0.28	<2.95
	1.0	1.53 ± 0.37	1.45 ± 0.35	1.12 ± 0.24	<3.38
B9	Surface	1.91 ± 0.33	1.59 ± 0.31	0.65 ± 0.21	<3.22
	0.5	2.38 ± 0.44	2.43 ± 0.35	0.93 ± 0.23	<3.33
	1.0	4.98 ± 0.51	4.92 ± 0.48	0.89 ± 0.26	5.54 ± 0.52
B10	Surface	39.7 ± 1.3	30.0 ± 1.0	2.17 ± 0.54	<6.95
	0.5	31.9 ± 1.2	25.3 ± 0.9	1.15 ± 0.38	16.6 ± 0.5
	2.4	1.90 ± 0.34	1.54 ± 0.30	0.79 ± 0.20	18.4 ± 0.6
B11[c]	Surface	258 ± 3	227 ± 3	14.4 ± 1.4	29.5 ± 0.7
	0.5	196 ± 3	181 ± 3	8.35 ± 1.26	35.0 ± 0.9
	0.75	191 ± 3	182 ± 3	7.08 ± 1.19	53.0 ± 0.9

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B12	Surface	56.8 ± 1.6	45.5 ± 1.3	3.60 ± 0.61	11.1 ± 0.6
	0.5	10.6 ± 0.9	8.64 ± 0.60	2.29 ± 0.35	15.4 ± 0.6
B13	Surface	13.8 ± 0.9	12.8 ± 0.8	2.57 ± 0.49	8.8 ± 0.6
	0.5	4.41 ± 0.53	4.78 ± 0.44	1.24 ± 0.27	<4.16
	1.0	5.08 ± 0.55	4.84 ± 0.52	0.91 ± 0.24	<3.93
	2.0	1.20 ± 0.28	1.43 ± 0.27	0.80 ± 0.21	<2.62
B14	Surface	10.9 ± 1.0	11.2 ± 0.6	2.79 ± 0.41	9.19 ± 0.55
	0.5	6.45 ± 0.58	5.73 ± 0.48	2.32 ± 0.34	4.77 ± 0.51
	1.0	6.80 ± 0.58	5.86 ± 0.48	2.59 ± 0.34	<4.84
B15	Surface	3970 ± 30	4000 ± 30	296 ± 16	910 ± 4
	0.5	702 ± 22	785 ± 15	477 ± 11	559 ± 3
	1.0	4650 ± 30	5150 ± 30	782 ± 19	653 ± 3
B16	Surface	1750 ± 10	1860 ± 10	930 ± 9	205 ± 1
	0.5	565 ± 8	637 ± 9	370 ± 6	185 ± 1
	1.0	366 ± 7	392 ± 5	171 ± 4	123 ± 1
B17	Surface	6.21 ± 0.60	6.02 ± 0.57	1.41 ± 0.32	41.0 ± 0.8
	0.5	33.4 ± 1.6	30.5 ± 1.1	11.8 ± 0.7	30.2 ± 0.6
	1.0	88.6 ± 2.1	55.7 ± 1.5	5.02 ± 0.79	40.1 ± 0.8
B18	Surface	23.5 ± 1.1	18.0 ± 0.9	4.41 ± 0.55	40.4 ± 0.7
	0.5	17.8 ± 1.0	15.3 ± 0.8	4.32 ± 0.45	26.2 ± 0.6
	1.0	36.0 ± 1.3	23.8 ± 1.0	4.32 ± 0.56	16.4 ± 0.6
B19	Surface	13.1 ± 0.80	10.4 ± 0.6	1.53 ± 0.32	<4.71
	0.5	<2.59	<0.75	<1.17	<42.9
	1.0	9.37 ± 0.82	10.0 ± 0.7	1.69 ± 0.39	10.5 ± 0.5
	1.5	3.45 ± 0.41	3.21 ± 0.35	1.02 ± 0.22	3.46 ± 0.50
	2.0	1.23 ± 0.29	1.23 ± 0.23	0.83 ± 0.19	<2.60
	2.5	1.09 ± 0.28	1.06 ± 0.22	0.81 ± 0.21	<2.39
	4.8	17.9 ± 1.0	17.1 ± 0.9	1.51 ± 0.41	4.62 ± 0.50
B20	Surface	195 ± 3	135 ± 2	5.83 ± 0.97	<12.3
	0.5	990 ± 11	933 ± 9	27.4 ± 4.6	<68.7
	1.7	842 ± 8	617 ± 8	16.2 ± 3.1	248 ± 85
B21	Surface	206 ± 3	212 ± 4	14.0 ± 1.5	39.6 ± 0.8
	0.3	406 ± 7	376 ± 6	14.6 ± 2.5	<34.0
	1.7	616 ± 9	355 ± 5	<1.26	<39.3

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B22	Surface	595 ± 8	568 ± 9	59.4 ± 4.1	<51.9
	0.5	7570 ± 50	7840 ± 40	1760 ± 20	180 ± 1
B23	Surface	106 ± 4	118 ± 3	48.2 ± 2.0	<18.7
	0.5	69.6 ± 3.1	75.5 ± 2.2	38.9 ± 1.4	<15.2
	1.0	169 ± 5	189 ± 4	115 ± 3	<24.4
B24	Surface	643 ± 9	589 ± 6	253 ± 5	<49.7
	0.5	430 ± 4	458 ± 4	200 ± 3	18.9 ± 0.7
	1.0	293 ± 4	436 ± 4	79.8 ± 2.1	45.7 ± 0.8
B25	Surface	47.2 ± 1.6	41.6 ± 1.3	8.16 ± 0.73	<8.08
	0.5	31.8 ± 1.5	27.8 ± 1.0	5.99 ± 0.63	<6.56
	1.0	2.95 ± 0.42	3.04 ± 0.32	1.11 ± 0.22	<2.89
	2.0	1.32 ± 0.33	1.38 ± 0.26	0.89 ± 0.20	<3.13
B26	Surface	14.6 ± 0.8	15.0 ± 0.7	7.27 ± 0.53	0.74 ± 0.53
	0.5	18.2 ± 1.0	17.1 ± 0.8	9.74 ± 0.61	<5.84
	1.0	8200 ± 500	7660 ± 500	101 ± 146	106 ± 2
B27	Surface	34.2 ± 1.8	31.9 ± 1.7	3.49 ± 0.80	<9.73
	0.6	3190 ± 20	3160 ± 20	555 ± 14	44.4 ± 1.1
B28	Surface	21.4 ± 1.2	21.7 ± 1.0	4.13 ± 0.56	<6.52
	0.5	9.24 ± 0.72	10.3 ± 0.6	6.51 ± 0.45	2.68 ± 0.48
	1.0	0.91 ± 0.22	0.96 ± 0.19	0.59 ± 0.14	<2.24
	1.5	0.85 ± 0.25	0.96 ± 0.25	0.61 ± 0.18	<2.27
	3.2	4.34 ± 0.56	4.14 ± 0.50	1.23 ± 0.36	<4.18
B29	Surface	184 ± 3	150 ± 3	20.5 ± 1.3	<14.9
	0.5	390 ± 5	347 ± 4	41.6 ± 2.0	46.2 ± 0.8
	1.0	1150 ± 10	808 ± 7	84.5 ± 4.6	79.8 ± 1.0
	3.9	14800 ± 700	15700 ± 600	1450 ± 300	110 ± 1
B30	Surface	46.9 ± 1.5	44.4 ± 1.3	5.33 ± 0.67	<7.02
	1.0	3080 ± 30	2380 ± 20	343 ± 12	53.1 ± 1.0
B31	Surface	26.8 ± 1.1	30.0 ± 1.0	3.43 ± 0.53	<5.88
	0.5	10.7 ± 0.9	13.5 ± 0.6	1.67 ± 0.32	<4.33
	1.0	4.82 ± 0.49	5.95 ± 0.53	0.90 ± 0.28	<3.42
	4.8	35.2 ± 1.4	35.0 ± 1.2	3.76 ± 0.49	<6.67

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B32	Surface	23.1 ± 1.0	26.4 ± 0.9	3.89 ± 0.48	<5.83
	0.5	309 ± 3	254 ± 3	23.9 ± 1.5	26.3 ± 0.7
B33	Surface	47.6 ± 1.6	49.3 ± 1.4	8.42 ± 0.76	<9.02
	0.5	26.7 ± 1.1	24.3 ± 0.9	3.02 ± 0.51	<5.83
	5.4	3.91 ± 0.45	3.60 ± 0.37	1.19 ± 0.27	<3.32
B34	Surface	171 ± 3	178 ± 3	26.5 ± 1.6	<17.9
	0.3	55.1 ± 2.0	57.1 ± 1.5	7.47 ± 0.79	<9.19
	0.5	62.0 ± 1.8	67.3 ± 1.6	11.2 ± 0.8	<9.57
B35	Surface	1.58 ± 0.34	1.48 ± 0.30	0.89 ± 0.22	<3.33
	0.5	2.02 ± 0.38	1.77 ± 0.31	0.81 ± 0.21	<3.32
	1.0	2.01 ± 0.41	2.13 ± 0.29	0.83 ± 0.22	<2.64
	2.0	1.04 ± 0.39	1.21 ± 0.23	0.70 ± 0.17	<2.86
	3.0	1.50 ± 0.30	1.30 ± 0.24	0.81 ± 0.18	<2.59
	6.3	1.27 ± 0.36	1.20 ± 0.28	0.96 ± 0.22	<3.55
B36	Surface	28.0 ± 1.5	29.5 ± 1.1	3.35 ± 0.53	<6.43
	0.5	1.04 ± 0.35	1.21 ± 0.31	0.70 ± 0.22	<2.79
	1.0	1.10 ± 0.29	1.15 ± 0.25	0.62 ± 0.17	<2.78
	2.0	1.35 ± 0.28	1.26 ± 0.24	0.60 ± 0.16	<3.10
	2.5	1.51 ± 0.31	1.21 ± 0.25	0.74 ± 0.18	<2.76
B37	Surface	114 ± 1	112 ± 2	17.3 ± 0.7	18.7 ± 0.6
	0.5	60.4 ± 1.3	61.6 ± 1.1	28.5 ± 0.7	15.9 ± 0.7
B38	Surface	1.98 ± 0.35	1.85 ± 0.34	1.14 ± 0.19	<2.60
	2.0	1.35 ± 0.29	1.41 ± 0.24	0.84 ± 0.19	<0.10
B39	Surface	2.05 ± 0.32	1.91 ± 0.27	0.81 ± 0.18	<2.76
	2.0	2.50 ± 0.38	2.22 ± 0.30	0.92 ± 0.21	<2.90
B40	Surface	2.75 ± 0.42	2.53 ± 0.32	0.79 ± 0.23	<2.60
	0.5	0.88 ± 0.36	1.01 ± 0.29	0.61 ± 0.20	<3.66
	1.8	0.40 ± 0.35	0.55 ± 0.24	0.53 ± 0.15	<2.57
B41	Surface	2.23 ± 0.40	2.24 ± 0.12	0.59 ± 0.20	<3.45
	0.5	1.03 ± 0.35	1.18 ± 0.25	0.61 ± 0.17	<3.09
	1.8	0.67 ± 0.22	0.71 ± 0.23	0.52 ± 0.18	<2.85

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B42	Surface	2.34 ± 0.42	4.22 ± 0.37	0.66 ± 0.20	<3.07
	0.5	2.29 ± 0.35	3.91 ± 0.36	0.78 ± 0.20	<3.19
	1.0	0.66 ± 0.23	2.51 ± 0.30	0.58 ± 0.14	<2.93
	1.5	0.76 ± 0.25	2.37 ± 0.27	0.40 ± 0.14	<2.09
	3.3	2.26 ± 0.35	5.66 ± 0.40	0.60 ± 0.22	<2.63
B43	Surface	12.9 ± 0.8	17.5 ± 0.8	1.64 ± 0.36	<5.23
	0.5	0.82 ± 0.25	3.22 ± 0.32	0.58 ± 0.18	<2.42
	1.0	1.07 ± 0.30	2.55 ± 0.29	0.58 ± 0.20	<2.60
	3.6	7.04 ± 0.58	8.43 ± 0.55	0.79 ± 0.27	1.38 ± 0.47

[a] Refer to Figure 10.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES

Sample Location[a]	Description	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
D1	Drainage Stream	5.28 ± 0.72[b]	5.04 ± 0.56	1.70 ± 0.35	<4.46
D2	Drainage Stream	2.29 ± 0.55	1.77 ± 0.43	0.51 ± 0.31	<4.05
D3	Drainage Stream	4.72 ± 0.64	2.75 ± 0.43	0.76 ± 0.39	<3.84
D4	Drainage Stream	2.03 ± 0.32	1.73 ± 0.31	0.63 ± 0.20	<2.61
D5	Drainage Tile	5.12 ± 0.46	4.70 ± 0.39	1.31 ± 0.24	<3.22
D6	Drainage Tile	9.17 ± 0.78	9.78 ± 0.59	1.77 ± 0.32	<4.14
D7	Drainage Tile	18.0 ± 1.0	19.1 ± 0.9	3.04 ± 0.47	<6.34
D8	Storm Sewer	16.8 ± 1.0	17.5 ± 0.8	3.65 ± 0.48	6.03 ± 0.51
D9	Storm Sewer	23.4 ± 1.0	25.2 ± 0.9	3.89 ± 0.47	13.6 ± 0.6
D10	Storm Sewer	43.2 ± 1.5	38.7 ± 1.2	4.12 ± 0.61	19.9 ± 0.7
D11	Storm Sewer	24.7 ± 1.3	24.4 ± 1.0	3.67 ± 0.51	<6.36
D12	Storm Sewer	383 ± 4	327 ± 3	30.2 ± 1.8	24.5 ± 0.8
D13	Storm Sewer	78.2 ± 1.9	70.0 ± 1.6	5.37 ± 0.77	12.7 ± 0.6
D14	Storm Sewer	951 ± 6	866 ± 5	101 ± 3	46.9 ± 1.0
D15	Storm Sewer	10.9 ± 0.8	9.57 ± 0.63	1.49 ± 0.33	<4.26

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μC/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
W1	7.21 ± 5.69[b]	4.83 ± 7.38	<0.18	0.03 ± 0.03
W2	3.29 ± 4.97	<4.95	c	<0.03
W3	<3.19	<5.00	<0.18	0.11 ± 0.03

a Refer to Figure 12.
b Error is 2σ based on counting statistics only.
c Analysis not performed.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN STORM SEWER WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μCi/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
D10	12.8 ± 5.4[b]	36.1 ± 6.2	1.68 ± 0.20	0.10 ± 0.04
D11	28.6 ± 29.8	60.8 ± 40.3	6.59 ± 0.57	0.19 ± 0.04
D12	17.9 ± 15.7	47.8 ± 18.2	14.2 ± 0.4	0.86 ± 0.08
D13	5.33 ± 7.45	13.4 ± 8.5	8.55 ± 0.42	0.40 ± 0.06
D15	17.5 ± 5.1	26.0 ± 5.3	10.0 ± 0.6	0.15 ± 0.04

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN ON-SITE VEGETATION SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V1	1.00 ± 0.22[b]	0.26 ± 0.17	0.35 ± 0.12	<2.63
V2	1.04 ± 0.15	0.32 ± 0.09	0.07 ± 0.06	<1.22
V3	2.19 ± 0.25	0.48 ± 0.15	0.11 ± 0.10	<2.07
V4	2.15 ± 0.26	0.53 ± 0.14	0.40 ± 0.12	<2.04
V5	3.41 ± 0.36	0.59 ± 0.23	0.30 ± 0.16	<2.51

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN
SURFACE SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S68	1.16 ± 0.31[b]	0.92 ± 0.23	0.69 ± 0.23	1.45 ± 0.52
S69	0.60 ± 0.20	0.64 ± 0.16	0.45 ± 0.17	<1.95
S70	0.78 ± 0.30	0.71 ± 0.22	0.40 ± 0.18	<3.06
S71	0.97 ± 0.27	0.88 ± 0.23	0.49 ± 0.15	<1.93
S72	3.59 ± 0.45	3.62 ± 0.39	0.74 ± 0.25	<3.46
S73	1.22 ± 0.35	1.27 ± 0.29	0.85 ± 0.2	<3.60
S74[c]	227 ± 3	375 ± 4	36.8 ± 1.7	21.2 ± 0.7
S75	75.4 ± 2.2	60.4 ± 1.7	4.85 ± 0.81	19.8 ± 0.7
S76	3.90 ± 0.67	4.17 ± 0.61	1.18 ± 0.38	<4.97
S77	1580 ± 20	1140 ± 10	83.4 ± 6.2	<79.3
S78	319 ± 5	328 ± 6	67.9 ± 2.9	45.4 ± 0.8
S79	8.81 ± 0.80	8.94 ± 0.60	1.63 ± 0.38	<4.70
S80	2.41 ± 0.53	2.41 ± 0.46	1.19 ± 0.36	<5.18
S81	0.97 ± 0.32	1.35 ± 0.25	0.73 ± 0.19	<3.24

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Depth (meter)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B44[c]	Surface	2400 ± 20[b]	1360 ± 10	315 ± 9	2.11 ± 0.46
	0.5	2.38 ± 0.39	2.45 ± 0.37	1.06 ± 0.24	<3.23
	1.0	1.05 ± 0.32	1.03 ± 0.24	0.27 ± 0.21	<3.66
B45	Surface	4.59 ± 0.54	4.71 ± 0.49	1.21 ± 0.27	<3.86
	0.5	1.70 ± 0.34	1.61 ± 0.28	0.89 ± 0.21	<2.80
	0.75	1.28 ± 0.29	1.45 ± 0.28	0.85 ± 0.20	<3.36

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to elevated exposure rates.

TABLE 10

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE
SOIL SAMPLES FROM THE
ERIE LACKAWANNA RAILROAD PROPERTY

Sample Location[a]	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B46[b]	Surface	640 ± 5[c]	639 ± 4	59.4 ± 2.6	45.4 ± 0.8
	0.5	61.6 ± 2.2	67.3 ± 2.0	7.95 ± 0.93	<11.1
	1.0	20.1 ± 1.2	21.7 ± 0.9	2.94 ± 0.46	<5.59
B47	Surface	412 ± 4	401 ± 5	53.0 ± 2.2	49.2 ± 0.9
	0.5	31.1 ± 1.8	31.0 ± 1.2	4.63 ± 0.66	5.55 ± 0.52
B48	Surface	0.85 ± 0.26	0.89 ± 0.23	0.46 ± 0.16	<2.71
	0.5	25.4 ± 1.3	25.0 ± 1.1	4.00 ± 0.56	<7.26
	0.75	12.3 ± 0.9	12.3 ± 0.8	2.75 ± 0.44	<5.06
B49	Surface	1.39 ± 0.3	1.36 ± 0.28	0.59 ± 0.19	<3.09
	0.5	21.3 ± 1.2	21.6 ± 1.0	3.83 ± 0.53	<6.56
	0.75	5.81 ± 0.8	6.97 ± 0.57	2.05 ± 0.37	<4.57
B50	Surface	1.36 ± 0.37	1.09 ± 0.29	0.58 ± 0.22	<2.68
	0.5	4.40 ± 0.54	5.10 ± 0.47	1.48 ± 0.28	<3.66
	0.75	4.53 ± 0.54	5.30 ± 0.48	1.64 ± 0.3	<3.72
B51	Surface	195 ± 4	208 ± 4	28.7 ± 2.00	29.0 ± 0.90
	0.5	3.60 ± 0.45	4.35 ± 0.41	0.91 ± 0.23	<3.48
	1.0	2.80 ± 0.38	2.81 ± 0.36	0.95 ± 0.20	<3.21
B52	Surface	0.76 ± 0.30	0.94 ± 0.24	0.67 ± 0.18	<2.53
	0.5	0.96 ± 0.36	0.90 ± 0.23	0.74 ± 0.21	<2.47
	1.0	0.80 ± 0.27	1.03 ± 0.24	0.76 ± 0.17	<3.59
B53	Surface	0.89 ± 0.26	0.76 ± 0.24	0.49 ± 0.16	<2.53
	0.5	0.94 ± 0.26	1.22 ± 0.26	0.67 ± 0.26	<2.65
	1.0	0.91 ± 0.32	0.92 ± 0.21	0.69 ± 0.16	<2.77
B54	Surface	0.73 ± 0.30	0.83 ± 0.24	0.61 ± 0.21	<2.81
	0.5	0.92 ± 0.36	1.06 ± 0.28	0.65 ± 0.18	<2.83
	1.0	3.51 ± 0.42	4.10 ± 0.37	1.27 ± 0.23	<2.88

[a] Refer to Figure 11.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 11

RADIONUCLIDE CONCENTRATIONS IN VEGETATION SAMPLES FROM VICINITY OF THE ERIE LACKAWANNA RAILROAD IN POMPTON PLAINS, NEW JERSEY

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V6[c]	0.28 ± 0.10[b]	0.18 ± 0.08	0.16 ± 0.04	<1.38
V7	0.12 ± 0.07	0.04 ± 0.06	0.05 ± 0.03	<0.88
V8	<0.06	0.24 ± 0.12	<0.03	<1.67

[a] Refer to Figure 11.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

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APPENDIX A

GLOSSARY OF TERMS

Glossary

Activation:	The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles.
Activity:	Radioactivity, the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an unstable nuclide. As a result of this emission, the radioactive material is converted (or decays) into a different nuclide (daughter), which may or may not be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) nuclide is formed.
Aerial survey:	A search for sources of radiation by means of sensitive instruments mounted in a helicopter or airplane. Generally, the instrumentation records the intensity, location, and spectral analysis of the radiation.
Alpha particle:	A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, and hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, and can be stopped by a sheet of paper.
Background radiation:	The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements. It is also called natural radiation. The term may also mean radiation that is unrelated to a specific experiment. Levels vary, depending on location.
Baseline concentration:	The concentration of a given substance typically encountered in the area under consideration, i.e. the normal or naturally occurring level.
Beta particle:	An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.
Contamination:	Undesired radioactive materials that have been deposited on surfaces, are internally ingrained into structures or equipment, or that have been mixed with another material.

Curie: A special unit of activity. One curie equals 3.7×10^{10} nuclear disintegrations per second. Several fractions of the curie are in common usage:

— Millicurie - one thousandth of a curie. Abbreviated as mCi.

— Microcurie - one millionth of a curie. Abbreviated as μCi.

— Nanocurie - one billionth of a curie. Abbreviated as nCi.

— Picocurie - one trillionth of a curie. Abbreviated as pCi.

Daughter: The product of radioactive decay of a nuclide. (also see Parent).

Decay, radioactive: The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in a decrease, with time, of the number of original radioactive nuclides in a sample. It involves the emission from the nucleus of alpha particles, beta particles, or gamma rays; or the nuclear capture or ejection of orbital electrons; or fission. Also called radioactive disintegration.

Decontamination: Those activities employed to reduce the levels of contamination.

Dose: A measure of the quantity of radiation absorbed in a unit mass of a medium. The unit of dose is the rad.

Dose rate: The radiation dose delivered per unit time and measured, for example, in rads per hours.

Exposure: A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.

Exposure rate: The radiation exposure per unit time. Measured, for example, in roentgens per hour.

Gamma radiation: High-energy, short-wave length electromagnetic radiation of nuclear origin (radioactive decay). Gamma rays are

the most penetrating of the three common types of radiation.

Half-life: The time in which half the atoms of a particular radioactive sustance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Microrad (μrad): A submultiple of the rad, equal to one-millionth of a rad. (see rad).

Microroentgen (μR): A submultiple of the roentgen, equal to one-millionth of a roentgen. (see roentgen).

Millirem (mrem): A submultiple of the rem, equal to one-thousandth of a rem. (see rem).

Natural uranium: Uranium as found in nature, containing 0.7 percent of uranium-235, 99.3 percent of uranium-238. It is also called normal uranium.

Natural thorium: Thorium as found in nature. Natural thorium contains equal activity level of thorium-232 and thorium-228.

Parent: A radionuclide which disintegrates or decays to produce another nuclide which is also radioactive. This second radionuclide is known as the daughter product.

Picocurie (pCi): One-trillionth (10^{-12}) of a curie.

Rad: The unit of absorbed dose. The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. One rad equals 0.01 joules/kilogram of absorbing material.

Radiation: Energetic nuclear particles including neutrons, alpha particles, beta particles, x-rays, and gamma rays (nuclear physics). Also includes electromagnetic waves (radiation) of any origin.

Radioactivity: The property of certain nuclides of spontaneously emitting particles, or gamma radiation. Often shortened to "activity."

Radionuclide: A general term applicable to any radioactive form of the elements, a radioactive nuclide.

Radium (Ra): A radioactive metallic element with atomic number 88. As found in nature, the most common isotope has an atomic weight of 226. It occurs in minute quantities associated with uranium in pitchblende, carnotite, and other minerals; the uranium decays to radium in a series

of alpha and beta emissions. By virtue of being an alpha- and gamma-emitter, radium is used as a source of illuminescence and as a radiation source in medicine and radiography. The isotope of radium with an atomic weight of 228 is found in the thorium decay series.

Radon (Rn): The heaviest element of the noble gases, produced as a gaseous emanation from the radioactive decay of radium. Its atomic number is 86. All isotopes are radioactive. Rn-222 is an isotope with a half-life of 3.82 days.

Rare earths: A group of 15 chemically similar metallic elements, including elements 57 through 71 on the Periodic Table of the Elements, also known as the Lanthanide Series.

Rem: The unit of ionizing radiation that produces the same biological damage to man as a unit of absorbed dose (1 roentgen) of high voltage x-rays.

Roentgen (R): A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge (either positive or negative) in one cubic centimeter of dry air under standard conditions.

Secular Equilibrium: The state which prevails when the rate of formation of a radioactive material equals the material's rate of decay. Although, by theory, this condition is never completely achieved, it is essentially established in the thorium decay series as it occurs in nature.

Survey: An evaluation of the radiation hazards incidental to the production, use, or existence of radioactive materials or other sources of radiation under a specific set of conditions.

Thorium (Th): A naturally occurring radioactive element with atomic number 90 and, as found in nature, an atomic weight of approximately 232.

Thorium series: The series (sequence) of nuclides resulting from the radioactive decay of thorium-232. Many man-made nuclides decay into this sequence. The end product of the sequence in nature is lead-208.

Uranium (U): A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natual uranium) and uranium-238 (99.3 percent of natural uranium). Natural uranium also includes a minute amount of uranium-234.

Uranium series: The series (sequence) of nuclides resulting from the radioactive decay of uranium-238. The end product of the series is lead-206.

EXPLANATION OF SYMBOLS AND UNITS

Symbols	Unit	English Equivalents
cm	centimeter (x 10^{-2} meters)	0.394 inches
g	gram	0.032 ounces
h	hour	-----
kg	kilogram (x 10^{3} grams)	2.2 pounds
km	kilometer (x 10^{3} meters)	0.622 miles
l	liter	0.264 gallons
m	meter	3.28 feet
ml	milliliter (x 10^{-3} liters)	0.061 cubic in.
mrem	millirem (x 10^{-3} rem)	-----
pCi	picocurie (x 10^{-12} curies)	-----
Ra	Radium	-----
U	Uranium	-----
Th	Thorium	-----
μCi	microcurie (x 10^{-6} curies)	-----
μrad	microrad (x 10^{-6} rads)	-----
μR	microroentgen (x 10^{-6} roentgens)	-----

APPENDIX B

THORIUM AND URANIUM DECAY SERIES

Appendix B

Thorium Decay Series

Parent	Half-Life	Major Decay Products	Daughter
Thorium-232	14 billion years	alpha	Radium-228
Radium-228	5.8 years	beta	Actinium-228
Actinium-228	6.13 hours	beta, gamma	Thorium-228
Thorium-228	1.91 years	alpha	Radium-224
Radium-224	3.64 days	alpha	Radon-220
Radon-220	55 seconds	alpha	Polonium-216
Polonium-216	0.15 seconds	alpha	Lead-212
Lead-212	10.6 hour	beta, gamma	Bismuth-212
Bismuth-212	60.6 minutes	alpha (1/3)* beta (2/3)*	Thallium-208 Polonium-212
Thallium-208	3.1 minutes	beta, gamma	Lead-208
Polonium-212	0.0000003 seconds	alpha	Lead-208
Lead-208	stable	none	none

* Two decay modes are possible for Bismuth-212.

Uranium Decay Series

Parent	Half-Life	Major Decay Products	Daughter
Uranium-238	4.5 billion years	alpha	Thorium-234
Thorium-234	24 days	beta, gamma	Protactinium-234
Protactinium-234	1.2 minutes	beta, gamma	Uranium-234
Uranium-234	250,000 years	alpha	Thorium-230
Thorium-230	80,000 years	alpha	Radium-226
Radium-226	1,600 years	alpha	Radon-222
Radon-222	3.8 days	alpha	Polonium-218
Polonium-218	3 minutes	alpha	Lead-214
Lead-214	27 minutes	beta, gamma	Bismuth-214
Bismuth-214	20 minutes	beta, gamma	Polonium-214
Polonium-214	2/10,000 second	alpha	Lead-210
Lead-210	22 years	beta	Bismuth-210
Bismuth-210	5 days	beta	Polonium-210
Polonium-210	140 days	alpha	Lead-206
Lead-206	stable	none	none

APPENDIX C

GROUND-PENETRATING RADAR SURVEY
OF THE
W.R. GRACE SITE
WAYNE, NEW JERSEY

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1. INTRODUCTION

A ground penetrating radar (GPR) survey was conducted during the week of July 12, 1982 at the W.R. Grace site, Pompton Plains, New Jersey. The survey was performed under contract to the Oak Ridge Associated Universities (ORAU) in support of their assessment of the radiological conditions at the site. The objectives of the GPR Survey were:

1. to define the exact location of burial trenches, and
2. to identify the locations and depths of subsurface objects.

The results of this survey will allow further radiological site assessment to proceed in an efficient manner. These results are discussed in section 5 of this report.

In addition to radar soundings, bulk soil resistivity measurements were made. These measurements aided in the selection of the optimum GPR system parameters, and were used to estimate system capability, particularly depth of penetration, in the site geology.

2. W.R. GRACE SITE DESCRIPTION

Monazite sands were processed at the site in the period from 1948 to 1967 to extract thorium and rare earths. The resulting waste products were buried in shallow excavations as permitted by regulations (10CFR20.304) governing licenses of the Atomic Energy Commission.

The site, which occupies approximately 2.6 hectares, is located on Black Oak Ridge Road 1.5 miles north of Wayne, New Jersey, in a residential and light commercial district. Three main buildings are located on the west side of the property, which is mostly paved for parking and loading facilities. The burial area on the eastern part is open land covered with weeds and a few small trees, having a gradual downward slope from east to west. A small stream courses north along the eastern boundary and loops west to exit the property at the north west corner. A few isolated piles of debris are the only visible evidence of disposal activity. A tall chain link fence encompasses the site.

A grid system, shown in Figure 1, was established on the site based on 20 meter centers identified by lettered and numbered markers. In the burial area these were wooden stakes driven into the ground. In the paved areas, bench nails were used. The lettered rows, A+10m through G+18m, ran north-south with row A+10m at the western edge. Subsequent rows progressed alphabetically toward the east. Numbered rows, -1 through 7, ran east-west with numbers increasing towards the north. This grid gave comprehensive coverage of the property.

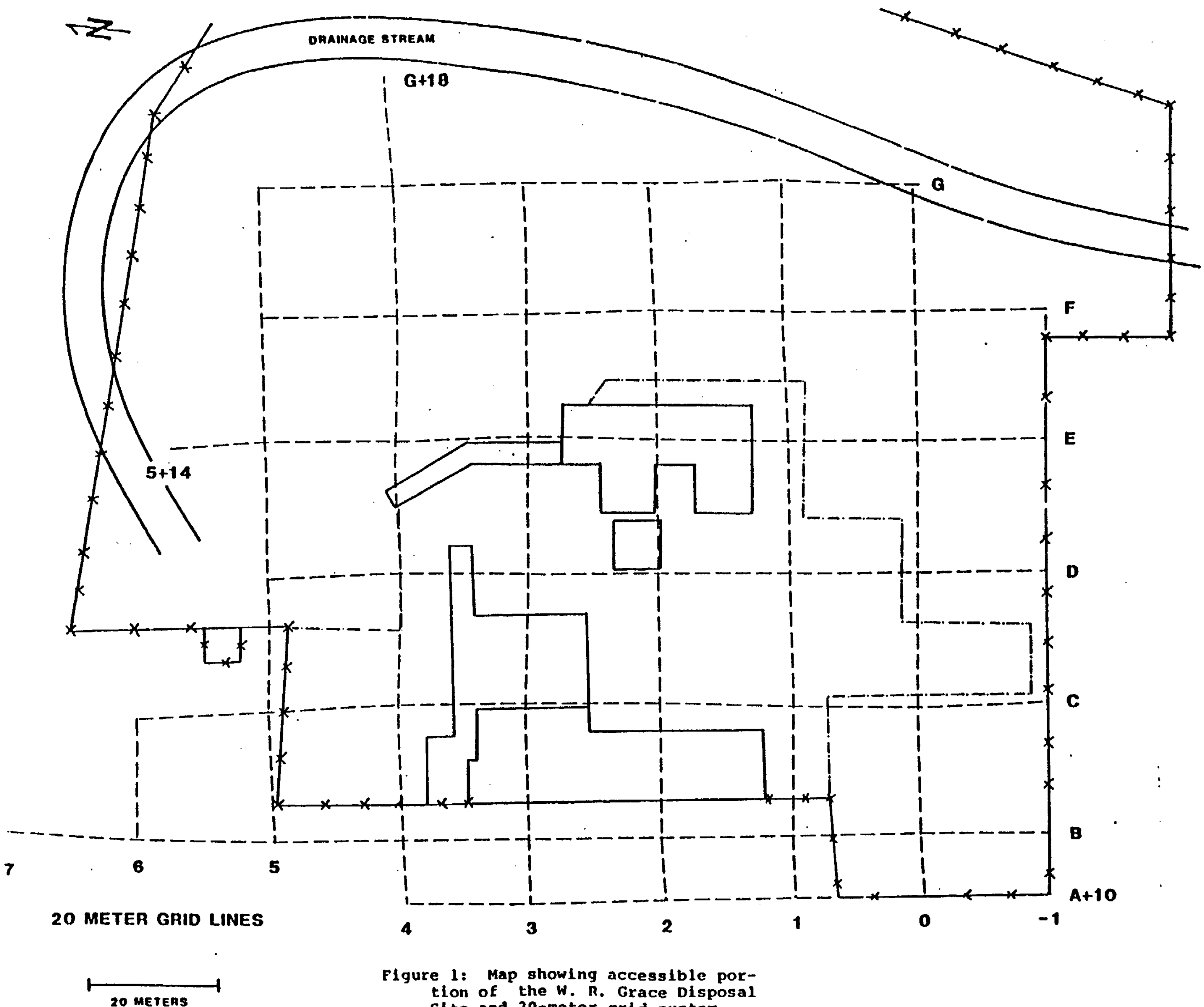


Figure 1: Map showing accessible portion of the W. R. Grace Disposal Site and 20-meter grid system.

3. FIELD MEASUREMENT TECHNIQUES

This section describes the geophysical measurement techniques of ground penetrating radar (GPR) and electrical resistivity (ER) that were used in this survey. Section 3.1 reviews the theory of GPR, while Section 3.2 describes the GPR instrumentation used to make the measurements. Section 3.3 reviews the electrical resistivity techniques and instrumentation.

3.1 Ground Penetrating Radar Theory

Subsurface radar detection systems have been the object of study for over a decade by both military and environmental agencies. In both applications, the objectives are to locate and identify buried or submerged objects, otherwise not detectable, and to spatially determine the structural makeup of the subsurface.

The principle of operation involves the generation of a pulse train of electromagnetic radiation in the frequency range of 10-1000 MHz. In accordance with the laws of classical electromagnetism, the wave propagates, with material dependent attenuation, through a given medium - the earth. When the wavetrain encounters a material or boundary of different electromagnetic properties, the wave is partially reflected. This reflected wave is then detected and the time interval between transmission and detection is recorded.

With knowledge of the velocity of propagation, the time interval can be converted to a range or depth.

As part of the calibration process the velocity of propagation of the electromagnetic wave in the particular medium is determined. For earth materials with a relative effective dielectric constant, ε_{er}, the velocity of propagation, v_m, of the electromagnetic signals, is usually approximated by:

$$v_m = \frac{c}{\varepsilon_{er}^{1/2}} \quad (1)$$

where: $c = 3 \times 10^8$ m/sec, the propagation velocity in free space. However, equation (1) is actually derived from

$$v_m = \frac{\omega}{\beta} \quad (2)$$

where: $\omega = 2\pi f$ = angular frequency

f = frequency in Hertz

β = phase constant, imaginary part of propagation constant.

The phase constant, β, is obtained from γ, the complex propagation constant of the medium which is derived from Maxwell's equations describing the behavior of electromagnetic fields. The propagation constant, γ, is defined as:

$$\gamma = \alpha + j\beta = (-\omega^2 \mu' \varepsilon_e + j\omega\mu' \sigma_e)^{1/2} \quad (3)$$

where: α = attenuation constant

μ' = magnetic permeability of the medium

σ_e = effective conductivity

The probing depth is determined by the frequency of operation and the electromagnetic properties of the soil, principally the conductivity and the dielectric constant. Signal attenuation, A, usually given in terms of dB/meter (Morey, 1974), is approximated by:

$$A = (12.863 \times 10^{8})\ f\ (\varepsilon_{er})^{\frac{1}{2}}\ ((p + 1)^{\frac{1}{2}} - 1)^{\frac{1}{2}} \qquad (4)$$

where: $p = \text{loss tangent} = \dfrac{\sigma_e}{2\pi f \varepsilon_o \varepsilon_{er}} = \dfrac{1.8\sigma_e}{f\ \varepsilon_{er}} \times 10^{10}$

ε_o = dielectric constant of free space

$= 8.85 \times 10^{-12}$ farads/meter

Equation (4) is derived from:

$$A = 20 \log e^{\alpha} = 8.686\ \alpha \qquad (5)$$

Nominal GPR systems transmit approximately 100 volts and can readily detect 1 millivolt, giving 100 dB of usuable signal. However, the attenuation increases with increasing frequency. Thus, by changing the radar frequency through the use of different antennas, a range of probing depth of resolution is made available.

In common earth materials there is a trade-off between probing depth and resolution. Quantitatively, the spatial resolution, r, is approximated by one-half the radar wavelength in the medium:

$$r = \lambda/2 = v_m/(2f) = c/(2f\ \varepsilon_{er}^{\frac{1}{2}}) \qquad (6)$$

using equation (1) in the derivation, or

$$r = \lambda/2 = v_m/(2f) = (\omega/\beta)/({}^{2}b) = \pi/\beta \qquad (7)$$

using equation (2)

A summary of the physical properties of common media which affect the propagation and attenuation of electromagnetic signals is shown in Table 1. Careful analysis of the reflected pulse, combined with a knowledge of the electromagnetic properties of the soil, can reveal information such as percentage of water content, density variation, and the location and depth of buried objects.

Table 1: Approximate VHF electromagnetic parameters of typical earth materials.

Material	Approximate Conductivity σ (mho/m)	Approximate Dielectric Constant	Depth of Penetration
Air	0	1	Max (km)
Limestone (dry)	10^{-9}	7	↓
Granite (dry)	10^{-8}	5	
Sand (dry)	10^{-7} to 10^{-3}	4 to 6	
Bedded Salt	10^{-5} to 10^{-4}	3 to 6	
Freshwater Ice	10^{-5} to 10^{-4}	4	
Permafrost	10^{-4} to 10^{-2}	4 to 8	
Sand, Saturated	10^{-4} to 10^{-2}	30	
Freshwater	10^{-4} to 3×10^{-2}	81	
Silt, Saturated	10^{-3} to 10^{-2}	10	
Rich Agricultural Land	10^{-2}	15	
Clay, Saturated	10^{-2} to 1	8 to 12	
Seawater	4	81	Min (cm)

Inference as to the composition of the reflecting and intervening material is possible, depending on the intensity and phase of the return signal. For example, metallic objects

have different dielectric properties than soils and will, therefore, give rise to strong reflections and a phase shift. Geological interfaces, on the other hand, give relatively weak reflections and no significant phase shift. The complex reflection coefficient, ρ, in the case of reflection involving a two-layer earth is given by:

$$\rho = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \tag{8}$$

where: η_1 = complex impedance of upper layer

η_2 = complex impedance of lower layer

The complex impedance is derived from:

$$\eta = \frac{j\omega\mu'}{\gamma} \tag{9}$$

where γ is given by equation (3). Table 2 compares typical electromagnetic properties at 100 MHz of some of the materials listed in Table 1.

A more quantitative picture of the penetration performance of the GPR is shown in Figure 2. Here, the range or depth (for different electromagnetic frequencies) is plotted directly as a function of attenuation in various media. The plots result from calculations assuming the return signal is from a rough plane reflector with a reflection coefficient equal to 1.0.

Table 2

Typical Electromagnetic Properties of Materials at 100 MHz

Material	A dB/m	V_m cm/ns	η Ohms
Air	0	30	377
Fresh Water	0.18	3.33	42+j0.046
Sea Water	326	1.50	10+j9.33
Sandy Soil, Dry	0.44	16.0	202+j2.6
Loamy Soil, Wet	1.93	7.07	88.8+j2.6
Clayey Soil, Wet	12.5	7.63	93+j16.2
Iron	1.7×10^{7}	3.2×10^{-5}	2.0+j2.0
Basalt	8.2×10^{-3}	15.0	188+j0.04
Sandstone	0.73	13.4	168+j3.0

Where η = Characteristic Impedance of Material

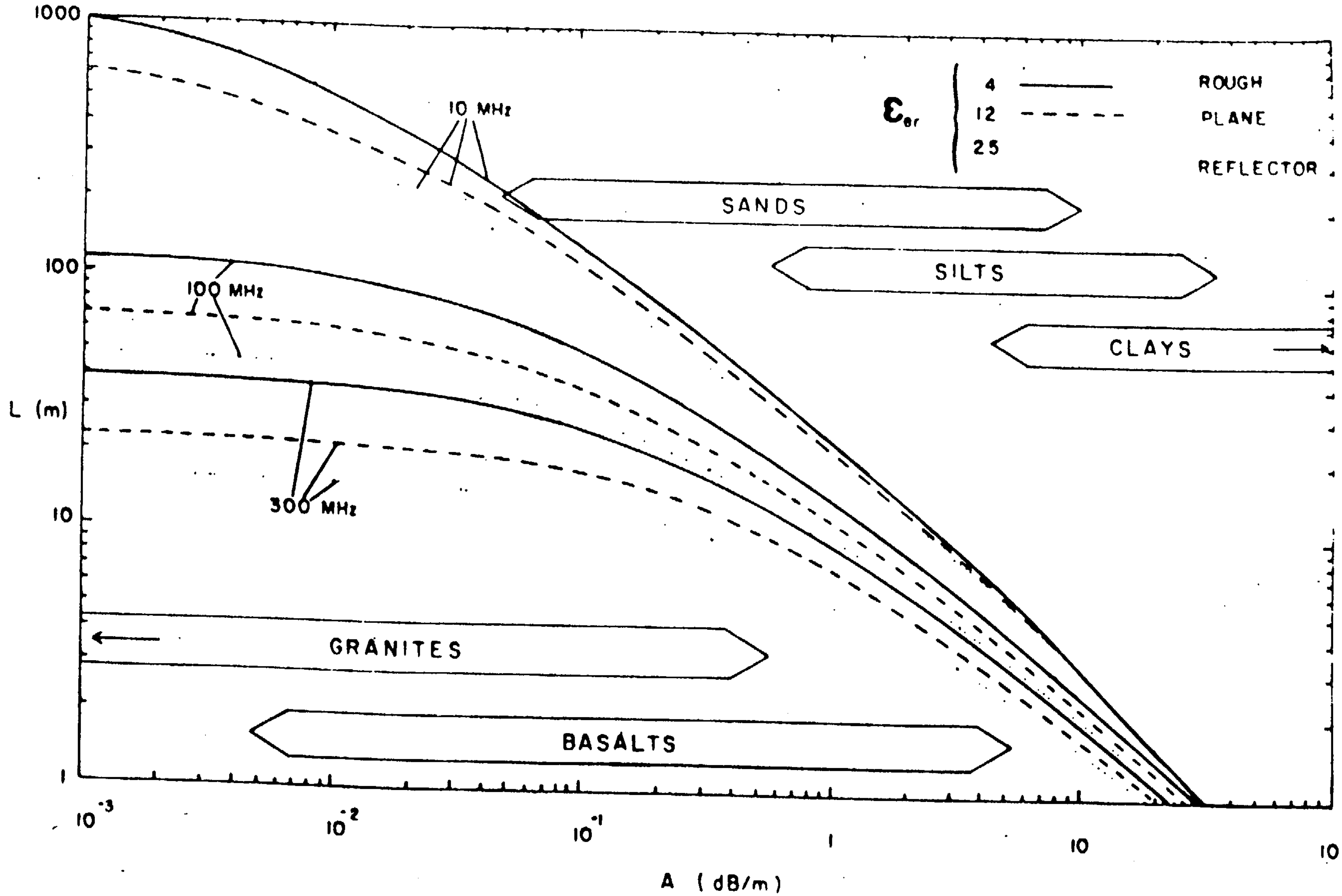


Figure 2: Variation of maximum depth of penetration (L) as a function of attenuation (A) for different frequencies and dielectric constants. Typical ranges of attenuation for different earth materials are also shown (after Horton et al, 1981).

Table 3. Selected Radar Parameters for Calculating Maximum Range

RADAR SYSTEM PARAMETERS

System	Geo-Centers Proprietary Design	Standard GSSI Systems	
Center frequency	10 MHz	80/120 MHz	300 MHz
Parameter			
P_s(Peak) (Watts)	2.5×10^3	50	12
P_{min}(Watts)	2.5×10^{-8}	5×10^{-10}	1.2×10^{-10}
Q	-110 dB	-110 dB	-110 dB
$E_t = E_r$	5%(-13 dB)	5%(-13 dB)	5%(-13 dB)
$G_t = G_r$	1.585(2 dB)	1.585(2 dB)	1.585(2 dB)

3.2 Ground Penetrating Radar Instrumentation

A Geophysical Survey Systems, Inc., (GSSI) System 7 was used to conduct the survey. Figure 3 is a block diagram of a typical GPR system. The equipment consists of a portable, gasoline powered electrical generator, a power supply, a control unit, a graphic recorder, and a tape recorder all mounted in a vehicle. A number of antennas were available for use on this program. Frequencies ranged from 10 MHz (Geo-Centers' proprietary deep penetrating antenna) to 300 MHz. Table 3 summarizes the characteristics of several of the available antennas. Data were recorded on magnetic tape and on a hard-copy graphic recorder; the latter information was compressed because of the high input data rate. After the field survey, the magnetic tape was played at a slower speed to generate full-resolution hard copy for analysis.

3.3 Electrical Resistivity Techniques and Instrumentation

Earth resistivity surveys have been used for many years in exploration for ground water and mineral deposits, and in the study of engineering properties of earth materials. Equipment to measure resistivity consists of a controlled source of electric current, a device for measuring the potential differences generated by the current passing through the earth and a number of electrodes for coupling the current into the earth. The volume of subsurface material influencing the resistivity measurement is controlled by the spacing and geometry of the electrodes. While any array of four or more electrode contracts can be used in studying earth resistivity, relatively few electrode configurations have been accepted as standard arrays in practice. Figure 4 shows the three most common electrode arrays used in the resistivity method. Many

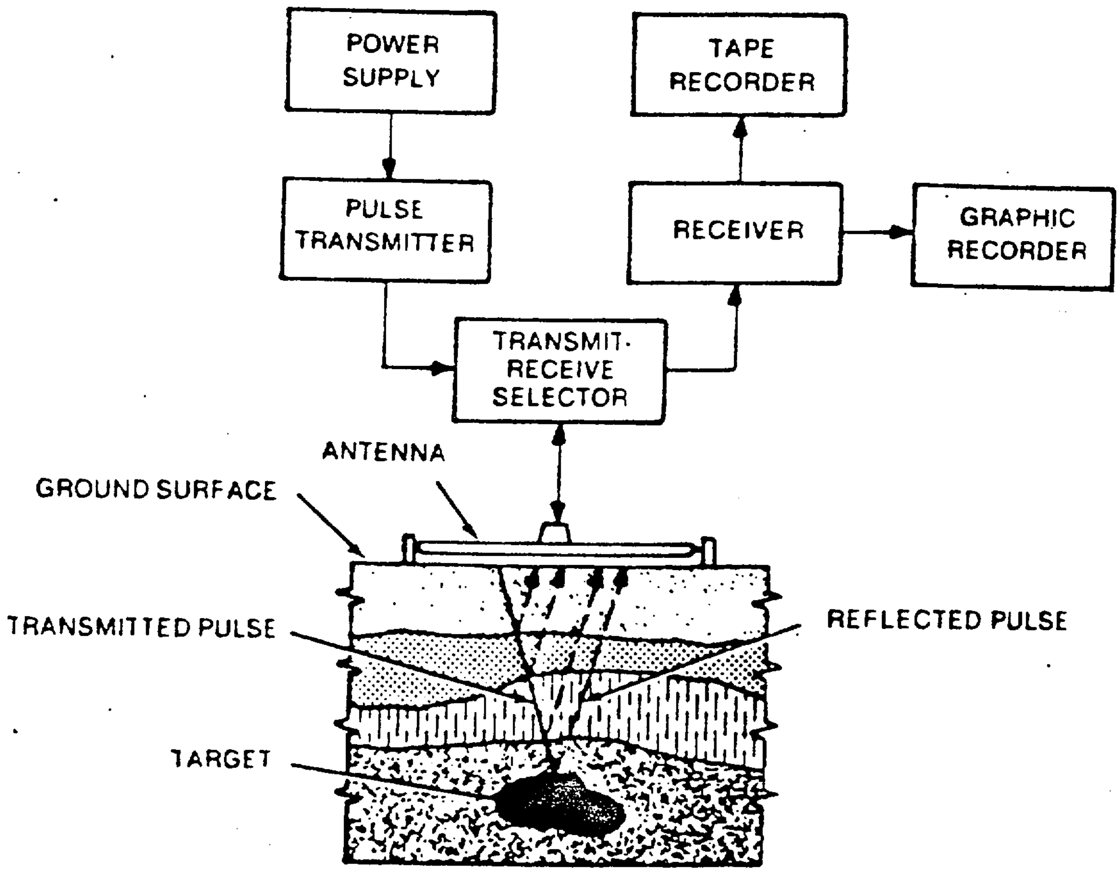
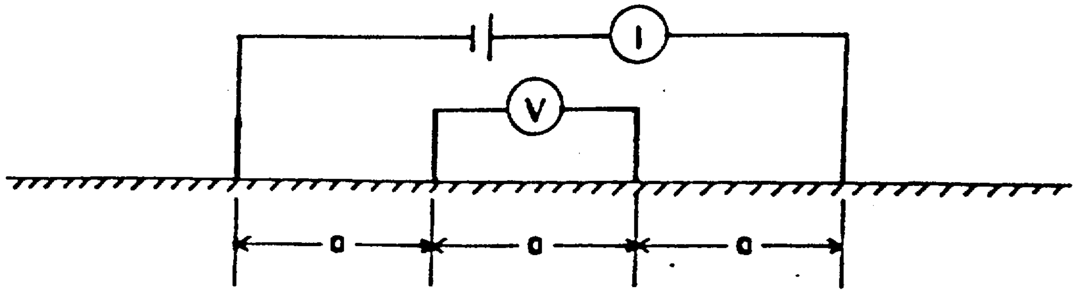
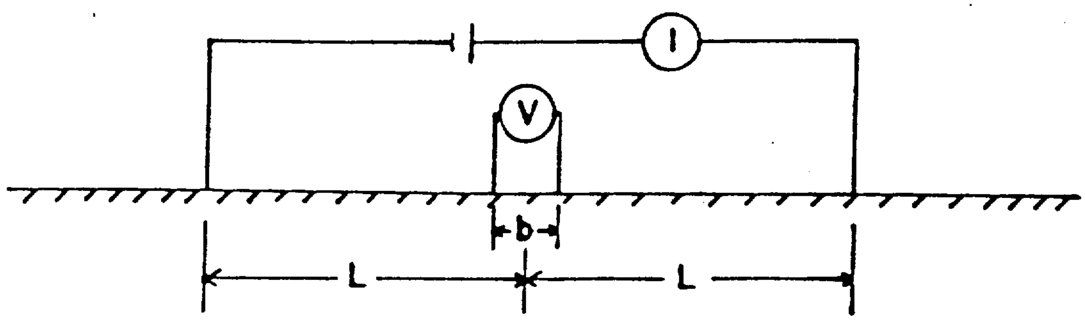


Figure 3 Ground-Penetrating Radar (GPR) System, block diagram.

(a) Wenner Spread



(b) Schlumberger Spread



(c) Double-dipole Spread

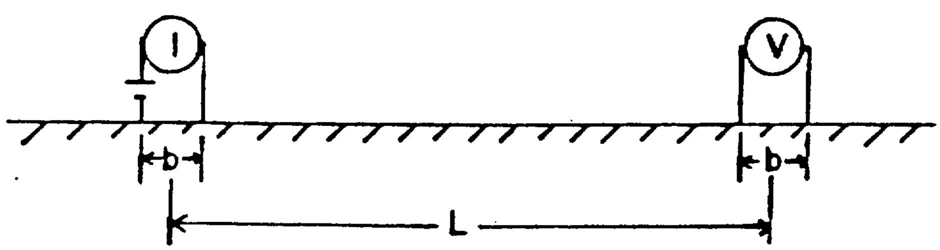


Figure 4: Common electrode configurations for resistivity arrays.

factors are considered in the choice of array configurations for a given problem. Susceptibility to geological noise, ease of array movement, and the nature of the assumed structure are a few of these factors.

For each of the three (3) electrode configurations in Figure 4, the apparent resistivity, ρ_a, can be calculated from:

$$\rho_a = 2\pi \frac{V}{I} a, \text{ Wenner Array} \quad (10a)$$

Where: V = potential difference
I = induced electric current
a = spacing between electrodes

$$\rho_a = \pi \frac{V}{I} (b) \left[\left(\frac{L}{b}\right)^2 - \tfrac{1}{4} \right], \text{ Schlumberger Array} \quad (10b)$$

Where: b = distance between potential electrodes
L = half the distance between current electrodes

$$\rho_a = \pi \frac{V}{I} (L) \left[\left(\frac{L}{b}\right)^2 - 1 \right], \text{ Double-dipole array} \quad (10c)$$

Where: b = distance between current electrodes and between potential electrodes.
L = distance between mid-points of current electrodes and potential electrodes.

As discussed in section 3.1, a knowledge of soil properties allows prediction of radar performance at a specific site. Measurements of bulk soil resistivity can be used to estimate expected penetration depth of the GPR. Figure 5 shows maximum radar range as a function of electrical resistivity (DC conductivity). From a few measurements of resistivity on the site of interest, the expected depth of penetration can be estimated for a range of frequencies. The best antenna for the application can then be selected, providing the optimum trade-off between penetration and resolution.

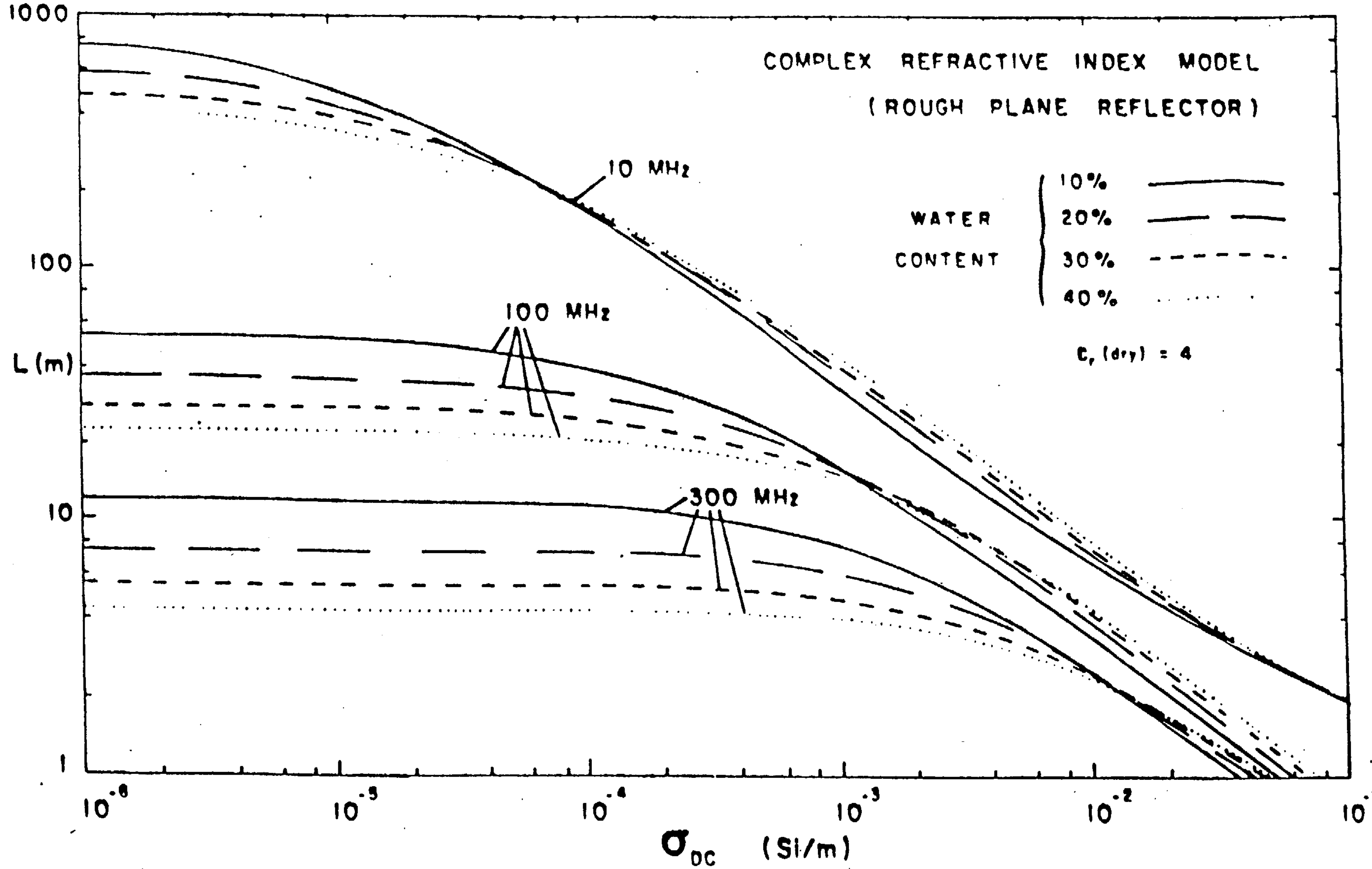


Figure 5: Radar range (L) as a function of DC conductivity (σ_{DC}) at different frequencies. Plots are based on a Complex Refractive Index Soil Model and reflection from a rough plane reflector. (after Horton et al, 1981).

In addition to supporting radar operations, mapping the site with resistivity measurements aids in the interpretation of radar data. Changes in bulk resistivity can indicate the presence of materials foreign to the particular site. For example, a cluster of metallic objects would lower the resistivity values measured for the area surrounding these materials. Correlations between resistivity measurements and GPR measurements are strong indications of disturbed areas.

4. OPERATIONS

The grid system with 20 meter centers was used as the coordinate system for the GPR scan lines and the resistivity measurements. For estimating GPR depth of penetration, bulk resistivity data were collected along the east-west, numbered grid lines using the Wenner spread (Figure 4) with the spacing, a, equal to 10 feet. The measurements ranged from 2 to 72 ohm-meters, or in terms of conductivity, from 0.5 to 1.39 X 10^{-2} Si/meter. The average for the site, taken over 86 readings, was 20.14 ohm-meters (4.97 X 10^{-2} Si/meter). From Figure 5, this resulted in a predicted range of penetration depths for the 80 MHz antenna of 1 to 5 meters (3 to 16 feet).

A depth value was derived from the time interval measurements between the transmit and receive pulses by using Equation 2 to calculate the velocity of propagation of the pulse in the earth medium. The value of the relative dielectric constant, ε_{er}, was estimated to be 25 by comparing the soil at the W.R. Grace site with similar materials. This yielded a velocity of propagation of approximately 5.86 cm/nsec. Using this value in Equation 7 gives a calculated resolution for the 80 MHz antenna of 1.5 meters (4.92 feet).

The antenna was towed along a series of survey lines to cover the site in a thorough manner. The survey lines are shown in Figure 6 superimposed on a diagram of the site. The antenna was towed manually for scans less than 20 meters in

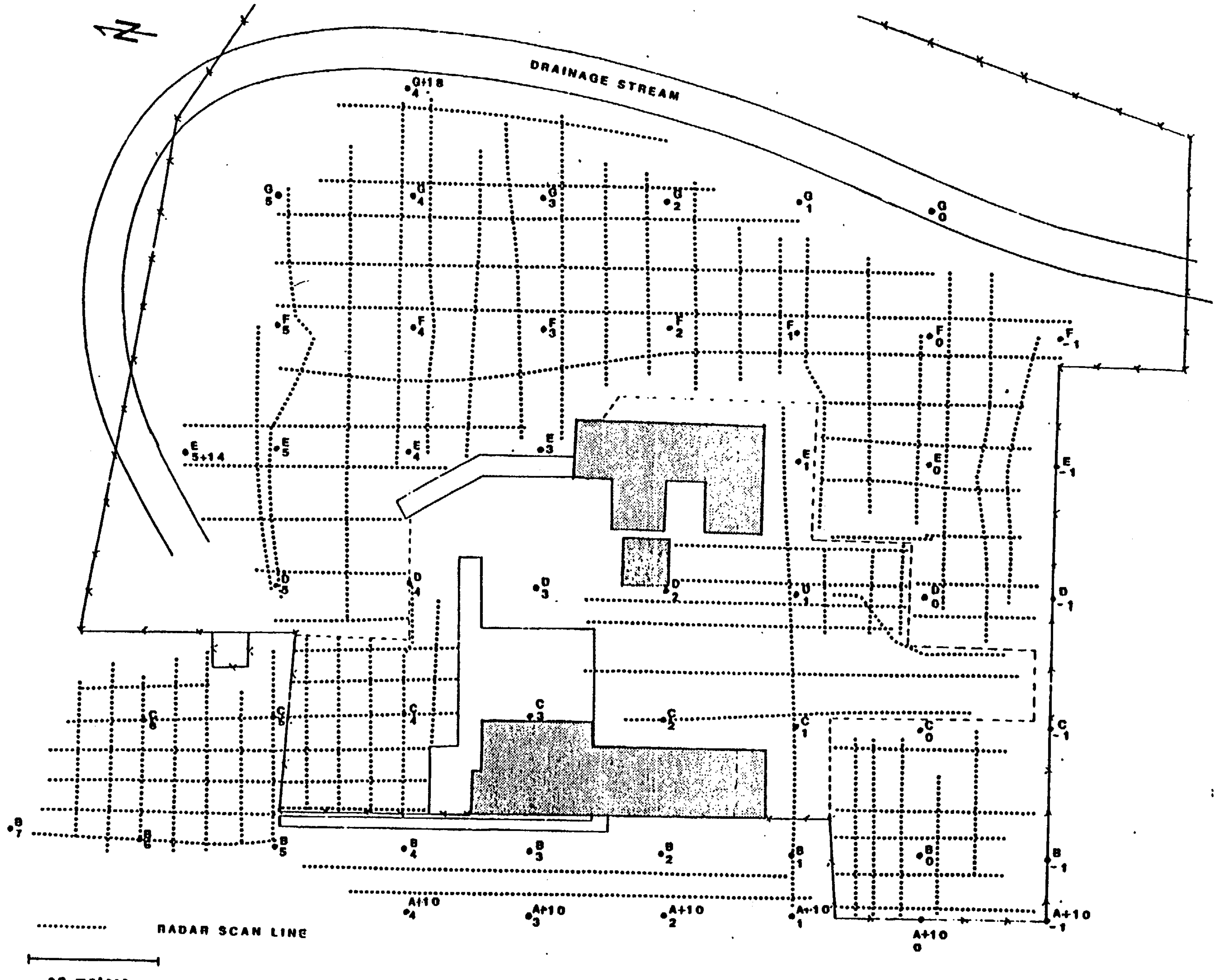


Figure 6: Radar survey lines.

length and for scans in level, paved areas. Otherwise, the antenna was secured to the back of the vehicle carrying the electronic equipment. Scan lines deviated from the straight grid system when it was necessary to avoid obstacles such as trees and piles of debris. Towing speeds were kept as constant as possible, averaging 2 to 3 mph. As the antenna passed each grid marker, the data tape was indexed, thus adding distance markers to the graphic display copy.

5. DISCUSSION OF RESULTS

The 300 MHz and the 80 MHz antenna systems were evaluated and calibration measurements were made to tailor the radar system for the specific conditions at the W.R. Grace site. Data collected with the 300 MHz antenna indicated a depth of penetration of approximately 1 to 8 feet, which precluded its use. The results in this report were derived from data obtained with the 80 MHz antenna.

Typical examples of radar profiles taken at the site are displayed in Figures 7 and 8. Figure 7 shows a scan along the F+3m, line from -1+00m to 5+00m. Figure 8 shows a scan along the 5-2m line from G+2m to D-2m

In Figure 7, several distinct, well defined regions are readily apparent. At the beginning of the scan near -1+2m, a sharply delineated area of strong reflectivity about 3m wide stands out. A gradual transition from a strong reflective zone to a moderate reflective zone occurs near 0-4m. The area from 0+00m to 1+00m is nearly uniform, with numerous small reflections evident at depth. A sharp transition is visible close to 1+00m leading into a region of irregular, individual scatterers. This region ends at 1+9m where an absorptive zone containing a number of diffuse scatters is encountered. The strong vertical signature at 2+3m is probably due to a near surface metallic object. Beginning with 2+5m the shallow return signal becomes increasingly disturbed,

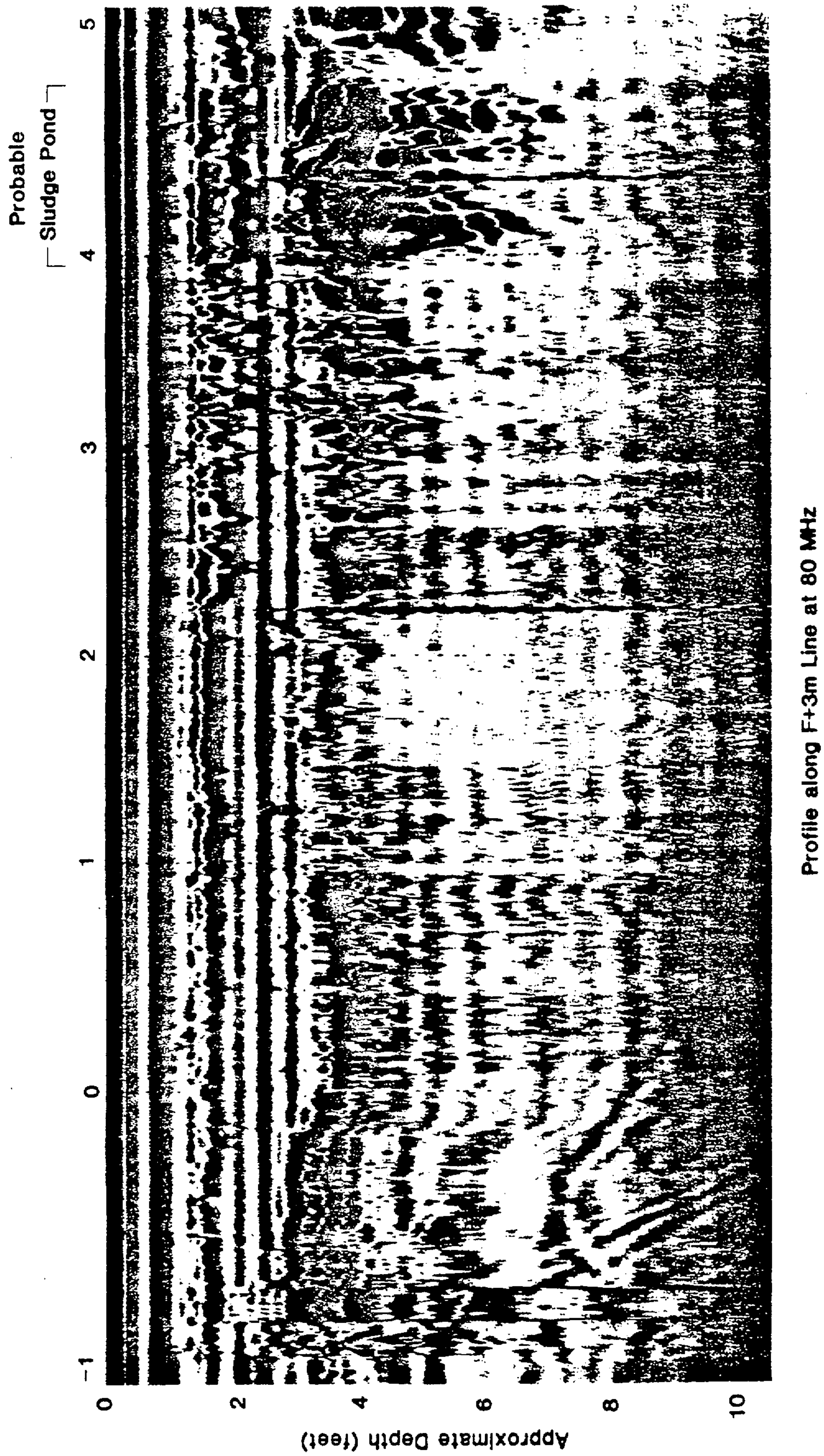


Figure 7: Radar profile along F+3 meters line.

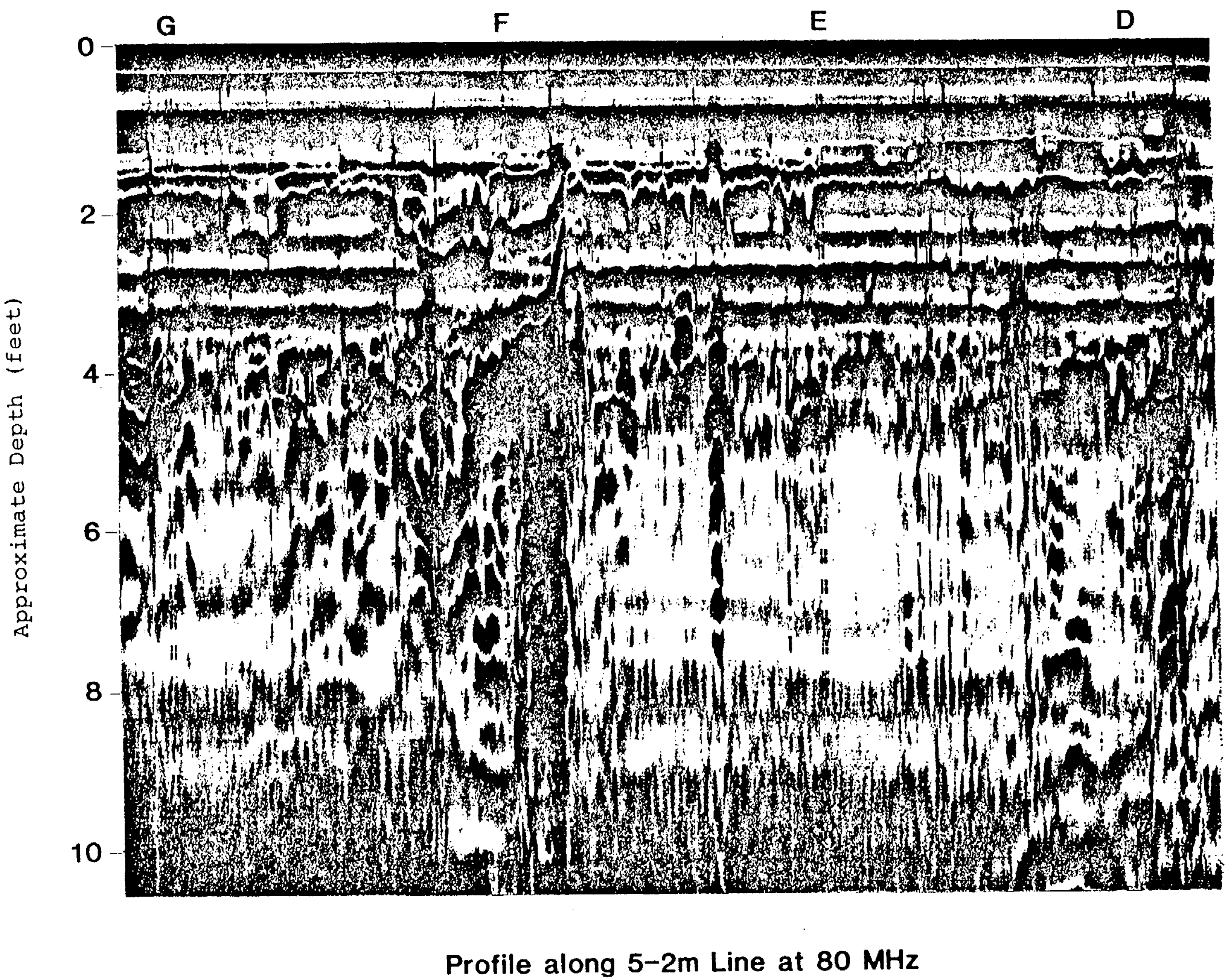


Figure 8: Radar profile along 5-2 meters line.

indicating burial activity. The region from 2+17m to 3+16m is a highly disturbed melange of numerous shallow reflectors. The scan reveals an abrupt discontinuity at about 4+00m leading into an extensive region of high reflectivity, in the midst of which a very shallow object is detectable. This zone, which continues to the end of the scan, includes an amomalous band of reduced reflectivity from 4+15m to 4+18m.

Figure 8 is a radar profile along the 5-2m line from G+2m to D-2m. A strong, continuous reflector at depth with an associated shallow disturbance extends from F+6m to F-4m, where the border is shaply defined. Portions of this zone are highly reflective. Three objects appear in the scan at E+12m, E+8m, and E+6m. The estimated depths are 3 feet 2.5 feet, and ground surface, respectively. The perturbations in the shallow ground signal just before E+00m were caused as the antenna moved over a pile of rocks.

An anomalous zone of high signal attenuation stretches from E+00m to E-5m. From D+11m to D+5m a tight cluster of scatters at depth is evident, associated with a disturbance in the shallow ground return. This suggests burial activity has occured at this location.

Figure 9 presents the zonal GPR interpretation for the W.R. Grace property. The spatial accuracy of the survey data is estimated at ± 1 meter along a scan line. Zones of anomalous radar signals are indicated.

In the burial area, the most prominant feature is located between the F, G, 4m, and 5m grid lines. This zone exhibits a very strong reflection transected by a band of diminish reflectivity. This feature may be the sludge pond indicated

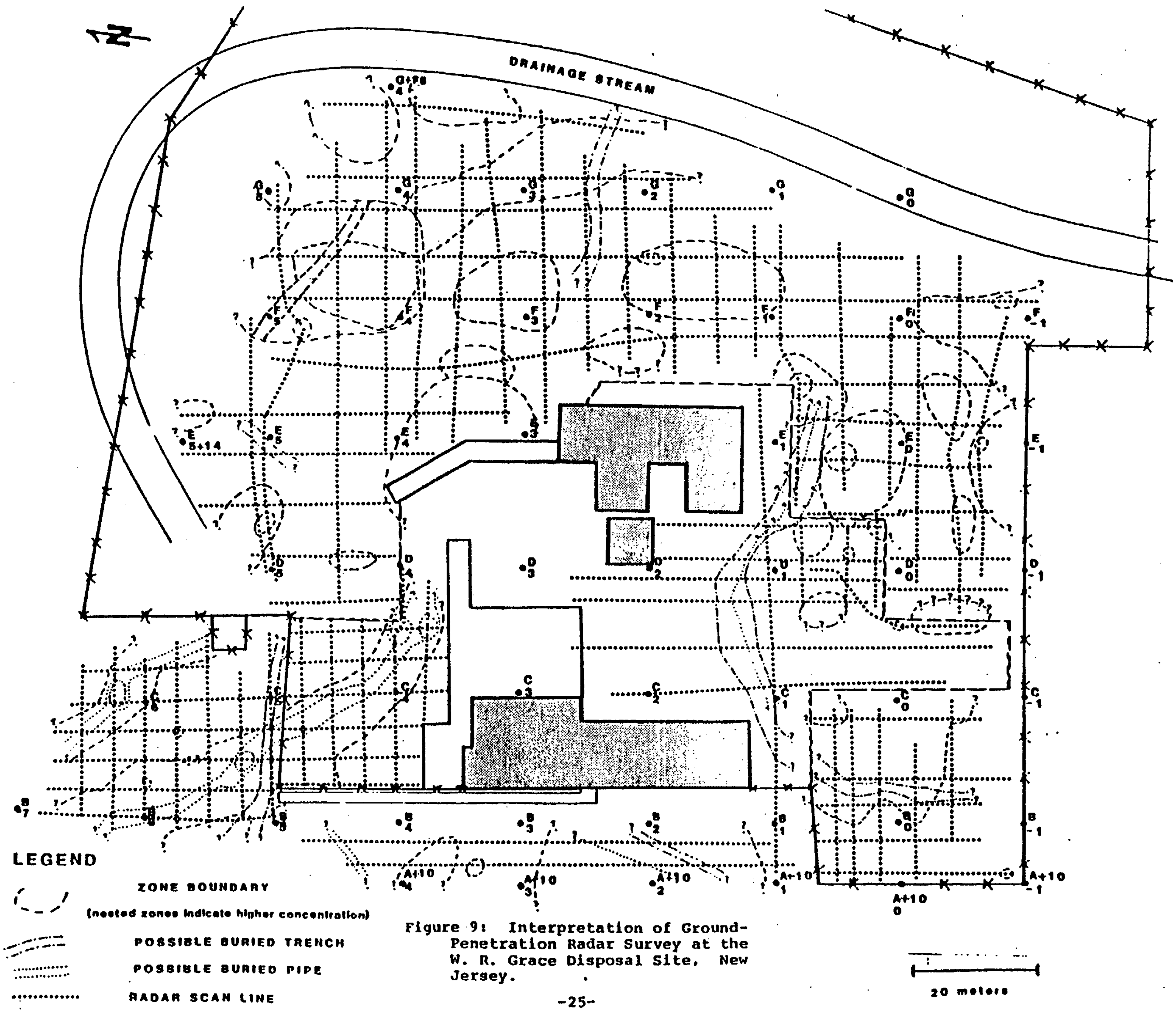


Figure 9: Interpretation of Ground-Penetration Radar Survey at the W. R. Grace Disposal Site, New Jersey.

on early maps of the site. In the parking lot areas, the main features revealed were buried pipes and catch basins with associated trenching. Particularly interestng is one which crosses the south lawn and parking area and enters the burial ground from the west.

The locations and approximate depths of detected objects are shown in Figure 10. While most appear to be randomly scattered, several zones correlate well with a high concentration of objects. The extensive zone including the coordinate G-3 and the small zone between coordinate F-2 and the building are two such examples.

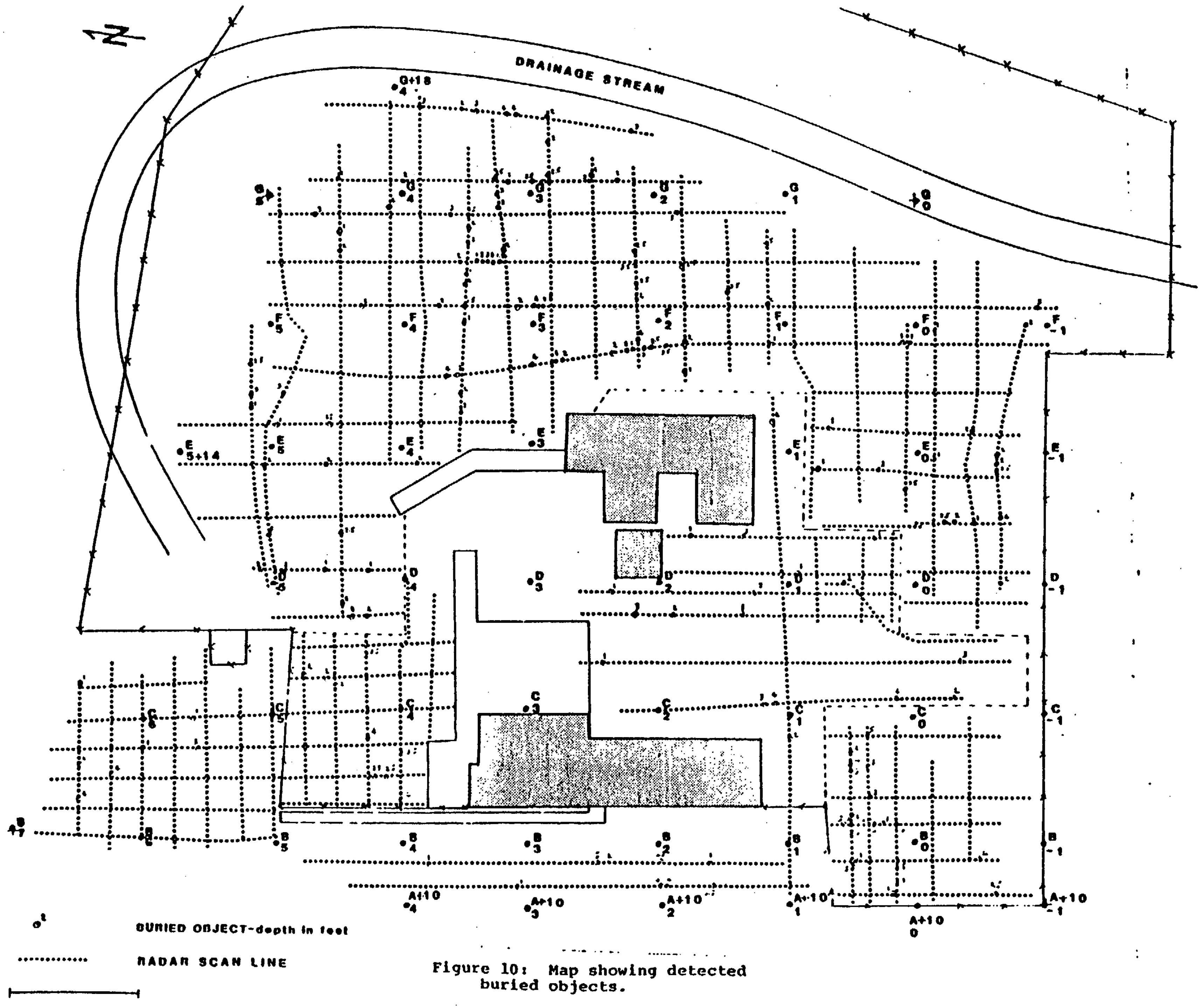


Figure 10: Map showing detected buried objects.

6. CONCLUSIONS

The interpretation of the GPR data, presented in Figures 9 and 10 has shown the W.R. Grace site to be extremely complex. The long history of burial activities, evident in the highly disturbed character of many of the GPR profiles and the profusion of buried objects detected, has produced many different anomalous zones in a small area, some of which overlap. Several of the larger zones correspond to those indicated in early reconstructed maps of the burial area.

Low values of resistivity and anomalous radar signals may be due to any or several of the following possible causes:

- Presence of metallic objects, especially pipes and conduits.
- Increased porosity and moisture content caused by disturbance of the natural soils through burial activities.
- Migration zones of electrically conductive fluids resident on site.
- Greater infiltration of runoff due to topography, etc.

With few exceptions, most of the subsurface objects were detected at an apparent depth of less than 4 feet. Their extensive, scattered distribution suggest that these materials may not have been disposed of in typical organized trenches.

In areas surveyed outside the burial ground, the only detected features were pipes and surrounding trenches. Anomalous zones in the lawn areas are probably caused by old pavement underlying the turf.

7. LITERATURE CITED

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APPENDIX D

MAJOR ANALYTICAL EQUIPMENT

APPENDIX D

Major Analytical Equipment

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

A. Direct Radiation Measurements

Eberline "RASCAL"
Portable Ratemeter-Scaler
Model PRS-1
Beta-Gamma "Pancake" Probe, Model HP-260
Energy Compensated G-M Probe Model HP-270
(Eberline Instrument, Santa Fe, NM)

Eberline PRM-6
Portable Ratemeter-Scaler
Scintillation Probe, Model 489-55
(Victoreen, Inc., Cleveland, OH)

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

Ludlum Ratemeter-Scaler
Model 2200
(Ludlum Measurements Inc., Sweetwater, TX)

B. Laboratory Analysis

Ge(Li) Detector
Model LGCC2220SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, SPG-16
(Applied Physical Technology, Smyrna, GA)

Pulse Height Analyzer, ND680
Model 88-0629
(Nuclear Data, Inc., Schaumburg, IL)

Alpha Spectroscopy System
Tracor Northern 1705
Pulcir PA-1 Alpha Module
(Pulcir, Inc., Oak Ridge, TN)

Low Background Alpha-Beta Counter
Model LB5100-2080
(Tennelec, Inc., Oak Ridge, TN)

25 mg Californium-252 Source with Flexo-Rabbit
Pneumatic Transfer System
(Reactor Experiments, Inc., San Carlos, CA)

Multichannel Analyzer
Model TN-7200
(Tracor Northern, Middleton, WI)

APPENDIX E

ANALYTICAL PROCEDURES

APPENDIX E

Analytical Procedures

Gamma Scintillation Measurments

Walkover surface scans and measurements of gamma exposure rates were performed using an Eberline PRM-6 portable ratemeter with a Victoreen Model 489-55 gamma scintillation probe containing a 3.2 cm x 3.8 cm NaI(Tl) scintillation crystal. A graph of count rate (cpm) vs. exposure rate (μR/h) was developed by comparing the response of the scintillation detector with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at several locations on and off the W.R. Grace property. This plot was used to convert the meter readings to exposure rates.

Additional Exposure Rate Measurements

Exposure rates at several locations on the property exceeded the measuring range of the gamma scintillation equipment. At those locations, exposure rates were measured using Eberline energy compensated Model HP-270 G-M probes with Eberline "Rascal" Model PRS-1 portable ratemeters. Calibration of this instrumentation was by cross reference to a Reuter-Stokes Model RSS-111 pressurized ionization chamber.

Beta-Gamma Dose Rate Measurements

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

Borehole Logging

Borehole gamma radiation measurements were made using a Victoreen Model 489-55 gamma scintillation probe connected to a Ludlum Model 2200

portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the shield in 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 in all holes.

Because of varying ratios of thorium, uranium, and radium noted on the site no attempt was made to use the borehole logging data to directly estimate subsurface thorium soil concentrations. The borehole logging data was used to identify regions of elevated residues and thus guided the selection of subsurface soil sampling locations.

Soil and Sediment Sample Analysis

Soil and sediment samples were sifted to remove rocks (the fraction removed constituted <5% of the total), dried at 120° C, finely ground, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and typically ranged from 500 to 800 g of soil. Net weights were determined and the samples counted using a 23% Ge(Li) detector (Princeton Gamma Tech) coupled to a Nuclear Data model ND 680 pulse height analyzer. The following energy peaks were used for determination of the radionuclides of concern:

Th-232	- 0.911 MeV from Ac-228	(secular equilibrium assumed)
Th-228	- 0.583 MeV from Tl-208	" " "
Ra-226	- 0.609 MeV from Bi-214	" " "
U-238	- 1.001 MeV from Pa-234m	" " "

Peak identification and concentration calculations were provided by computer analyses.

Samples for which gamma spectrometry indicated detectable levels of uranium were subsequently analyzed for U-238 by neutron activation. Approximately 15-20 g of soil were irradiated for 15 minutes in a neutron flux of 10^8 n/cm^2/sec. After a one minute wait time, the U-239 peak (74.6 keV) was counted for 10 minutes and the U-238 concentration calculated.

Water Samples

Water samples were rough filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by filtration through 0.45 μm pore size membrane filters. The filters, together with attached solids, were discarded, and the filtrate was acidified by the addition of 20 ml of concentrated nitric acid.

Gross Alpha and Gross Beta Analysis

Fifty milliliters of each sample was evaporated to dryness and counted on a Tennelec Model LB5100 low background proportional counter.

Radium-226/228 Analysis

Samples were analyzed for Ra-226 and 228 using the standard technique EPA 600/4-75-008 (Rev.)

Vegetation Analysis

Gamma Spectrometry

After being washed vegetation samples were air dried, chopped, and mixed. Aliquots were placed in 3.5 ℓ Marinelli beakers and analyzed for identifiable photopeaks in the same manner described above for soil sample analysis. Due to possible preferential uptake and assimilation of various radionuclides by vegetation, it could not be assumed that Th-232 and Ra-228 were in equilibrium. Therefore, Ra-228, rather than Th-232, concentrations are reported for vegetation samples.

Errors and Detection Limits

The errors, associated with the analytical data presented in the tables of this report, represent the 95% (2σ) confidence levels for that data. These errors were calculated, based on both the gross sample count

levels and the associated background count levels. When the net sample count was less than the 2σ statistical deviation of the background count, the sample concentration was reported as less than the minimum detectable activity (<MDA). This means that the radionuclide was not present, to the best of our ability to measure it, utilizing the analytical techniques described in this appendix. Because of variations in background levels, caused by other constituants in the samples, the MDAs for specific radionuclides differ from sample to sample.

Calibration and Quality Assurance

Laboratory analytical instruments are calibrated using NBS-traceable standards. Portable survey instruments for exposure rate and dose rate measurements are calibrated by comparison of their responses to those of other instruments having NBS-traceable calibration. Field comparisons or comparisons using samples typical of the area are used to develop these calibrations.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU Laboratory participates in the EPA Quality Assurance Program.

Contract No. W-7405-eng-26

Health and Safety Research Division

RESULTS OF THE MOBILE GAMMA SCANNING ACTIVITIES AT WAYNE, NEW JERSEY, AND SURROUNDING COMMUNITIES*

January 1983

Work performed
as part of the
REMEDIAL ACTION SURVEY AND
CERTIFICATION ACTIVITIES PROGRAM

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
Operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

B1286

ITEM # 287

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Contract No. W-7405-eng-26

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LIST OF FIGURES AND TABLES

RESULTS OF THE MOBILE GAMMA SCANNING ACTIVITIES AT WAYNE, NEW JERSEY, AND SURROUNDING COMMUNITIES*

INTRODUCTION

The former W. R. Grace property, located at 868 Black Oak Ridge Road in Wayne, New Jersey, has been the focus of several investigations over the past several years.[1,2] The site, presently occupied by Electro-Nucleonics, Inc., is known to have thorium residues and contaminated debris buried onsite. Samples of soil and stream sediment from along Sheffield Brook between the site and its confluence with the Pompton River have also been found to contain elevated thorium concentrations.[1]

At the request of the Department of Energy's (DOE) Office of Operational Safety (OOS), the Energy Measurements Group of EG&G conducted an aerial radiological survey over all of Wayne Township and surrounding areas in October 1982.[3] Results of this survey indicated elevated exposure rates associated with excess thorium over the W. R. Grace site, Sheffield Brook west of the site, and over quarries located approximately three miles northwest of the W. R. Grace site. Several other areas were recognized by the aerial survey which showed excess thorium concentrations with no associated elevated radiation exposure rates and appear to be due to slight perturbations in the relative amount of thorium within these areas compared to the rest of the survey area.

In order to further define the excess thorium anomalies found on the EG&G aerial survey, a mobile gamma scanning survey was conducted by personnel from Oak Ridge National Laboratory (ORNL) during the period of November 11-13, 1982. This report summarizes the results of the mobile survey.

SURVEY METHODS

The following is a brief description of the scanning methods utilized for the mobile scanning of the Wayne, New Jersey, area. Details of the system description and operation have been provided in Reference 4.

Instrumentation

The gamma radiation detection system employed in the ORNL scanning van consists of three 4 x 4 x 16-in. NaI(Tl) log crystals housed in a lead-shielded steel frame to provide a 12 x 16-in. detector surface area for acceptance of gamma radiation through one side of the survey van. The detector and shield height can be varied with a hydraulic lift mechanism to optimize the detector field-of-view. The detector output

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* The survey was performed by members of the Remedial Action Survey and Certification Activities Group of the Health and Safety Research Division at Oak Ridge National Laboratory under DOE contract W-7405-eng-26.

is transferred to a computer-controlled, eight-channel discriminator and interface, which provides for continuous analysis of data inputs for correlation of system location with count rate information. Six separate energy regions-of-interest are analyzed and a ^{226}Ra-specific algorithm is employed to identify locations containing residual radium-bearing materials. Changes in the multichannel analysis capabilities of the system were made for additional qualitative thorium identification prior to conducting the survey in the Wayne area.

Mobile Scanning Methods

The data analysis method employed on the ORNL van is based on computations involving background count rates in specific energy regions. These background levels are normally obtained within small (10 square block) survey areas, based on coverage of at least 75% of the accessible streets in that area. Scanning of these areas are conducted at a slow speed (<5 mph), which maximizes response of the detectors at anomalous subject properties. Anomaly locations are highlighted by the computer system when the preset hit criteria are exceeded during the scan.

SURVEY RESULTS

Scope of Activities

The purpose of this survey was primarily to verify the excess thorium anomalies found on the EG&G aerial survey. Areas with indicated anomalous thorium and several background areas to further characterize the survey area were scanned.

Scan Results

As the basis for analysis of the mobile scan data, background radiation levels were measured in eight areas in the Wayne Township and surrounding communities. Count rates in the regions of interest were found to vary between these areas. To illustrate this variability, the values for three background radiation levels are given as follows:

	Background 1	Background 2	Background 3
Average total Ra Count rate (cps)	217 ± 15	245 ± 16	565 ± 24
Average Th count rate (cps)	16 ± 4	29 ± 5	78 ± 9
Average K count rate (cps)	82 ± 9	116 ± 11	224 ± 15
Average Ra/Th ratio	13 ± 3	8 ± 1	7 ± 1

This range indicates that the background levels in the Wayne area show considerable variation. The observed variations are a direct result of the geologic setting found in the Wayne area. Three major bedrock types are represented within the survey area (Fig. 1).

Background 1 represents areas underlain by Triassic Age [approximately 200 million years before present (mybp)] basalts.[5] Basalt is an extrusive (volcanic) rock composed primarily of calcic plagioclase feldspar, pyroxene, and olivine.[5] The relatively large atomic radii of the naturally-occurring radionuclides U(Ra), Th, and K tends to exclude them from the composition of the minerals present in basalt.[7] Packanack Mountain and Second Watchung Mountain are two roughly north-south trending ridges composed of basalt within the survey area.

Background 2 represents the typical radiation levels found in areas underlain by Triassic Age (~200 mybp) sedimentary rocks. These rocks are shales and sandstones which underlie the lowlands between the basalt ridges in the survey area.[5] Considering the more hetrogeneous composition of the sedimentary rocks when compared to basalt, the observed increase in the background radiation levels is to be expected.[7]

Both the Triassic basalts and sedimentary rocks are within the Triassic Lowlands of the Piedmont Physiographic Province. Northwest of Pompton Lakes, rocks of the New Jersey Highlands section of the New England Physiographic Province are present.[5] The Highlands are underlain by granites and granitic gneisses of Precambrian (>800 mybp) age. Granitic magmas are enriched in potassium, silicon, and aluminum, and cool very slowly. During the late stages of the cooling process, potassium feldspar crystallizes out of the magma, leaving the leftovers, the trace element suite, to form minor minerals which often contain thorium and uranium.[7]

Background 3 was taken at a granite quarry and reflects the higher concentrations of naturally-occurring radionuclides in the granitic rocks of the New Jersey Highlands.

SIGNIFICANCE OF FINDINGS

Based on the results of the ORNL scanning activities, 20 properties or areas in the Wayne Township and surrounding area were found to contain excess thorium anomalies above the background levels for their respective areas. Three properties are recommended for future comprehensive onsite surveys because of their proximity to previously-surveyed (Reference 1) areas related to the former W. R. Grace property, or because no natural cause for the observed anomaly was observed (Table 1). Four properties with observed excess thorium anomalies have already been surveyed (Table 2).

The remaining 13 locations are the New Jersey Highlands' "granite" quarries, or areas where there was probable use of the "granite" as roadbase or in asphalt (Table 3). Since these properties are probably unrelated to the W. R. Grace property, they are not recommended for comprehensive onsite surveys by DOE contractors.

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1. Frame, P. W., Radiological Site Assessment Program, Oak Ridge Associated Universities, Radiological Survey of Sheffield Brook, Wayne, New Jersey, October 1982.

2. Dahlstrom, T. S., An Aerial Radiological Survey of the W. R. Grace Property, Wayne Township, New Jersey, EG&G Survey Report, NRC-8113, November 1981.

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4. Oak Ridge National Laboratory, Mobile Gamma-Ray Scanning System for Detecting Radiation Anomalies Associated with ^{226}Ra-Bearing Materials, ORNL/TM-8475, November 1982.

5. Harper, D. P., Geology of Passic County in Brief, Bureau of Geology and Topography, State of New Jersey, 1977.

6. U.S. Bureau of Mines, A Dictionary of Mining, Mineral, and Related Terms, U.S. Department of the Interior, 1968.

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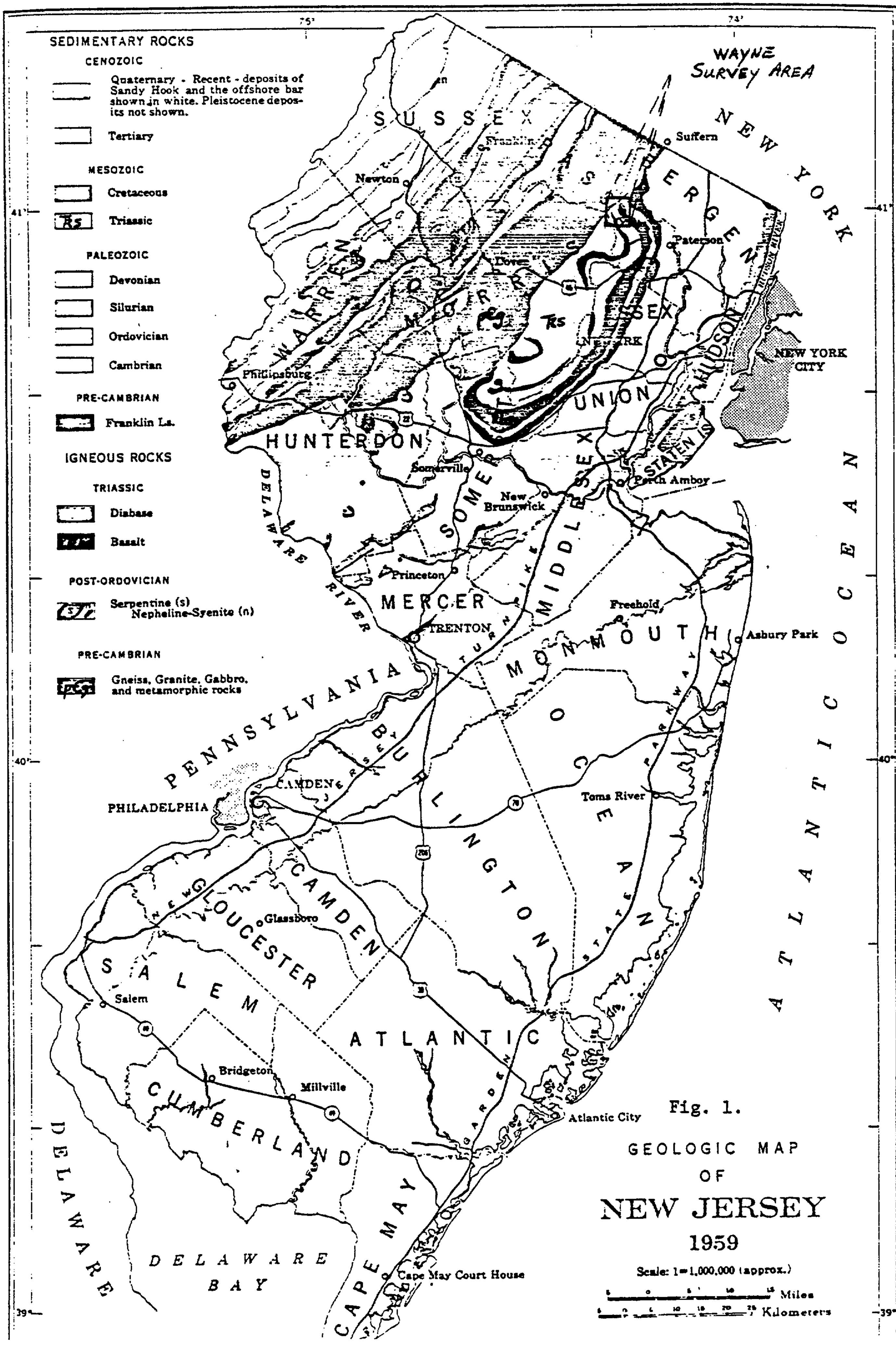

Fig. 1.

GEOLOGIC MAP OF NEW JERSEY 1959

Fig. 1. Continued

Explanation for Geologic Map of New Jersey with unit codes for rocks found in the Wayne, New Jersey, survey area.

Map Codes

SEDIMENTARY ROCKS

Cenozoic

Quaternary—Recent deposits of the last 10,000 years are chiefly beach sands forming Sandy Hook and the offshore bars. Pleistocene or ice age starting 1,000,000 years ago. Widespread thin deposits of till and outwash covering older formations are not shown on this map. Mineral production—peat moss, sand, and gravel.

Tertiary—Starting 70,000,000 years ago. Unconsolidated sands, gravels, and clays. Forms the outer Coastal Plain. Marked by three different periods of invasion by sea, separated by erosional periods of dry land. Mineral production—brick and terracotta clays; glass sands; ilmenite (titanium ore).

Mesozoic

Cretaceous—Starting 125,000,000 years ago. Unconsolidated sands, clays, and greensand marls Forms the inner Coastal Plain. Appalachian Province uplifted and coast depressed; fast moving rivers deposited sediments in marine environment. Mineral production—fireclay, brick clay, greensand marls.

Ꞧs

Triassic—Starting 200,000,000 years ago. Shales, argillites, sandstone, and some conglomerates. Forms Piedmont Plain. Appalachian Mts. uplifted and long thin depressed basins formed between ridges; fast moving rivers deposited sediments in these basins. Mineral production—Stockton sandstone (brownstone) for building stone; negligible amounts of copper found in some shales.

Paleozoic

Devonian—Starting 330,000,000 years ago. Sediments occur in two areas, 1) fossiliferous, calcareous shales and limestones in Appalachian Plateau, 2) sandy shales, sandstones, and conglomerates in valley south of Greenwood Lake in Highlands. No significant mineral production.

Silurian—Starting 360,000,000 years ago. Coarse conglomerates, sandstone, shale and, limestone. Occur to the southeast of Devonian sediments. From early Devonian, when sea receded to early Upper Silurian, N.J. was dry land.In late Silurian, the sea receded for a very short period and then re-invaded land. No significant mineral production.

Ordovician—Starting 420,000,000 years ago. Limestone, shales, and slates. Found in the Highlands and Appalachian Plateau. Three different invasions of land by sea, with erosional periods of dry land in between. Mineral production—cement rock and slate.

Cambrian—Starting 500,000,000 years ago. Quartzite followed by limestone. Found in the Highlands and Appalachian Plateau. During first and last parts of Cambrian time N.J. was covered by seas, while in Middle Cambrian time it was dry land

Precambrian—Franklin limestone -more than 500,000,000 years old. Typically a white crystalline limestone. Found in a narrow belt and a few isolated masses in the Highlands. Mineral production—zinc deposits at Franklin and Ogdensburg; limestone for flux and cement rock.

IGNEOUS ROCKS

Ꞧbs

Triassic—Diabase and Basalt—The same basic rock formed from cooling molten material. Differ in texture. Diabase is coarse grained due to slow cooling beneath the surface while basalt is fine grained due to quick cooling of lava at the surface. Diabase forms the Palisades and its extensions to the south in the Princeton area. Basalt forms the Watchung Mts. and the two small masses at New Germantown and Sand Brook. Diabase and basalt are extensively quarried for concrete, road metal, and railroad ballast.

p€g

Precambrian—Gneiss and Granite. Granite is a coarse grained igneous rock characterized by predominant alkali feldspar and quartz. Gneiss is a crystalline rock with a secondary rough foliation developed as a result of pressure on the solidified rock; bands or lenses in gneisses are commonly unlike. Metamorphic rocks are included in this zone, some of them having been derived from sediments. These rocks form "The Highlands of New Jersey". Mineral production—magnetite (iron ore), crushed stone and prospects for uranium, monazite, and rare earths.

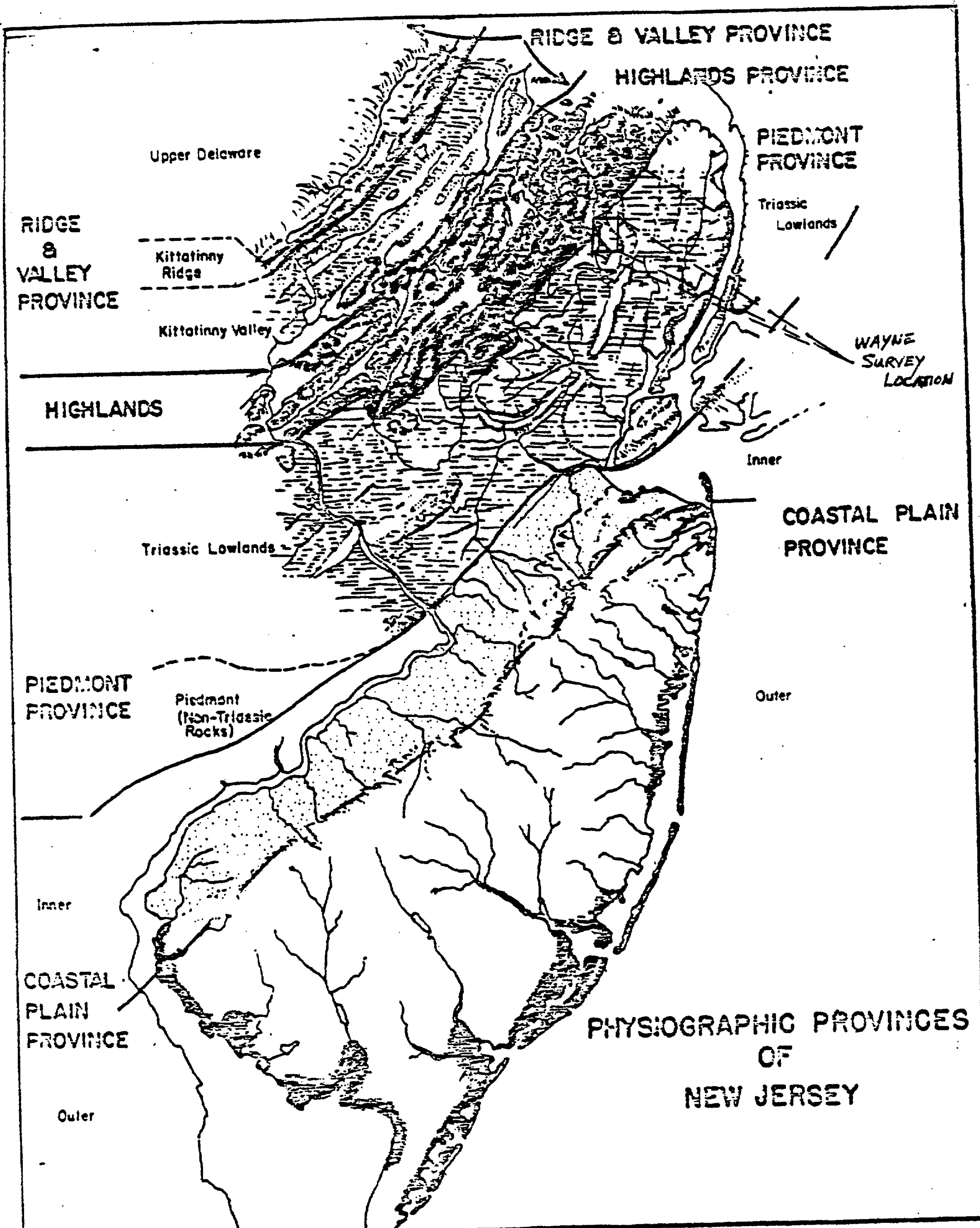

Fig. 2. Physiographic province map of New Jersey with location of Wayne

Table 1. Listing of Wayne, New Jersey, vicinity properties recommended for comprehensive onsite surveys

Property Location	Property Description
Last house at the east end of Peck Avenue, north side of street (across from railroad tracks), Pompton Plains, New Jersey.	Residential property.
15 Peck Avenue, Pompton Plains, New Jersey, last house on East end of Peck Avenue, south side of street.	Residential property.
Reinhardt Road, Wayne, New Jersey.	Southwest lawn of Passaic Technical and Vocational School property. Approximately 200-m^2 area of landscaped lawn at new building construction site (soil sample WNJ6).

Table 2. Listing of Wayne, New Jersey, vicinity properties which have been part of a previous radiological survey (Reference 1)

Property Location	Property Description
868 Black Oak Ridge Road.	Electro-Nucleonics, Inc. (Former W. R. Grace property).
East end of Peck Avenue, Pompton Plains, New Jersey.	Railroad tracks and abandoned earthen loading dock.[a]
South side of Pompton Plains Crossroad, Wayne, New Jersey.	Vacant land along Sheffield Brook.
21 Pompton Plains Crossroad, Wayne, New Jersey, southwest of W. R. Grace property across from Black Oak Ridge Road.	American Carving School (asphalt parking lot) and within ORAU survey area.

[a]Onsite survey of this area has been completed and a report of results is presently in preparation by Oak Ridge Associated Universities (ORAU).

Table 3. Listing of Wayne, New Jersey, vicinity properties where excess thorium anomalies were found related to New Jersey Highlands granite or use of granites in asphalt or road base material

Property Location	Property Description
125 Hamburg Turnpike, Riverdale, New Jersey.	Riverdale Quarry Company, large "granite" quarry and asphalt paving contractor, northwest most EG&G "quarry anomaly" (samples WNJ1 and WNJ2).
West end of Broad Street, Pompton Lakes, New Jersey.	Passaic Crushed Stone Co., Inc., large "granite" quarry and paving contractor (EG&G "quarry anomaly").
Pierson Miller Lane, Pompton Lakes, New Jersey.	"Granite" outcrops along street (northeastern most EG&G anomaly area).
Southeast corner of Pompton Plains cross road and New Jersey Rt. 23, Pompton Plains, New Jersey.	Plains Plaza Shopping Mall, new asphalt at main entrance to mall off Rt. 23 (soil sample from planter at mall entrance WNJ5).
Longport Road from Haddon Road to Black Oak Ridge Road.	New asphalt on street.
827 Black Oak Ridge Road.	SFE Printed Circuit Compay (new asphalt parking lot).
West end of West Parkway, Pequannock, New Jersey.	Mountainside Park asphalt parking lot (sample WNJ4) also a background soil sample (WNJ3) was taken from the area south of the asphalt parking lot.
West Parkway, Pequannock, New Jersey.	General Foods Distribution Center, large new asphalt parking lot on south side of building.
Riverdale Road, Riverdale, New Jersey.	A&A Concrete Products Co., large asphalt parking lot and crushed rock "granite" yard area.

Table 3. Continued

Property Location	Property Description
11 Lucas Lane, Wayne, New Jersey.	Residential property with new asphalt driveway.
7 Lucas Lane.	Residential property with new asphalt driveway.
Northeast corner lot at Kurland Street and Ferrara Avenue, Mountain View area of Wayne (EG&G area west of Rt. 23).	Residential property with new asphalt driveway on crushed "granite" base fill material. Area also showed slightly depressed Ra/Th ratio, i.e., excess thorium, but not over statistical "hit" criteria.
New Jersey Rt. 23 at U.S. Hwy. 202, Mountain View, New Jersey.	New asphalt used for highway resurfacing presently under construction.

Table 4. Results of sample analyses from Wayne, New Jersey, and surrounding communities

Sample Number	Location	Sample Description	Radionuclide Concentrations (pCi/g)			
			^{226}Ra	^{238}U	^{232}Th	^{40}K
WNJ1	Upper level of Riverdale Quarry, Riverdale, New Jersey.	Granitic rock fragments insitu.	2.9	3.4	8.6	38
WNJ2	Lower level of Riverdale Quarry, Riverdale, New Jersey.	Crushed granitic rock from aggregate stockpile.	2.6	3.5	8.1	34
WNJ3	Mountainside Park, Pequannock, New Jersey.	Sandy glacial soil from area south of parking lot.	0.46	0.5	0.8	16
WNJ4	Mountainside Park, Pequannock, New Jersey.	Asphalt from parking lot.	0.48	0.53	3.7	30
WNJ5	Plains Plaza, Pompton Plains, New Jersey.	Soil from flower planter at Rt. 23 entrance to shopping mall.	0.53	0.67	0.39	6.8
WNJ6	Passaic County Technical and Vocational School, Reinhardt Road, Wayne, New Jersey.	Soil from landscaped lawn area on southeast side of Reinhardt Road at the southwesternmost building on the school property.	4.7	3.5	40	10

FEB 1 1983

Docket No. 40-00086 License No. STA-422

W. R. Grace and Company
Davison Chemical Division
ATTN: Mr. Burton Mobley
Manager, Environmental Control
P.O. Box 2117
Baltimore, Maryland 21203

Gentlemen:

Subject: Radiological Survey of W. R. Grace and Company Property, Wayne, New Jersey

Enclosed for your information are three (3) copies of the subject report.

In accordance with Section 2.790 of the NRC's "Rules of Practice," Part 2, Title 10, Code of Federal Regulations, a copy of this letter and the enclosure will be placed in the Public Document Room.

No reply to this letter is required; however, should you have any questions, we will be pleased to discuss them with you.

Sincerely,

Original Signed By:
John D. Kinneman
for Thomas T. Martin, Director
Division of Engineering and
Technical Programs

Enclosure:
Radiological Surveys of W. R. Grace and Company Property,
Wayne, New Jersey (3 copies)

cc w/encl:
Public Document Room (PDR)
Nuclear Safety Information Center (NSIC)
State of New Jersey

bcc w/encl:
Region I Docket Room (with concurrences)

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Prepared by
Oak Ridge Associated
Universities

Prepared for
Division of Fuel
Cycle and
Material Safety

U.S. Nuclear
Regulatory
Commission

RADIOLOGICAL SURVEY

OF THE

W. R. GRACE PROPERTY

WAYNE, NEW JERSEY

P. W. FRAME

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

FINAL REPORT

January 1983

RADIOLOGICAL SURVEY
OF THE
W.R. GRACE PROPERTY
WAYNE, NEW JERSEY

Prepared for

Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission

P. W. Frame

Project Staff

J. D. Berger	A. J. Liu
R. D. Condra	A. M. Pitt
G. R. Foltz	T. J. Sowell
J. R. Frazier	C. F. Weaver
R. C. Gentry	T. S. Yoo

Prepared by

Radiological Site Assessment Program
Manpower Education, Research, and Training Division
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

FINAL REPORT

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RADIOLOGICAL SURVEY
OF THE
W.R. GRACE PROPERTY
WAYNE, NEW JERSEY

INTRODUCTION

In 1948, Rare Earths, Inc., of Wayne, New Jersey, began processing monazite sand to extract thorium and rare earths. The facility was acquired by the Davison Chemical Division of W.R. Grace and Co. in 1957. Processing activities continued until July 1971 when the plant was permanently closed. In 1974 Applied Health Physics, Inc., decontaminated the buildings and the property was released by the Nuclear Regulatory Commission (NRC) for unrestricted use in January 1975. The buildings are currently under lease to, and occupied by, Electro-Nucleonics, Inc.

In January 1981, as part of a review of formerly licensed facilities, the Nuclear Regulatory Commission measured direct radiation levels and radionuclide concentrations in soil on the W.R. Grace property. The results of the survey indicated radiation levels ranging from 10-1000 μR/h and Th-232 concentrations as high as 1200 pCi/g of soil.[1] The State of New Jersey was represented at this survey and requested, through the U.S. Environmental Protection Agency, an aerial radiological survey. In May 1981, the aerial survey was conducted by EG&G. This survey identified elevated radiation levels at 1 m above the surface with average exposure rates greater than 120 μR/h.[2]

In the summer of 1982, the Pequannock Township Health Department performed a radiological survey of the Erie Lackawanna Railroad tracks in response to information that ore destined for W.R. Grace had been unloaded from trains near the Pompton Plains railroad station. This survey and subsequent investigations by the NRC and State of New Jersey identified elevated radiation levels near the intersection of Peck Road and a spur of the Erie Lackawanna Railroad line approximately 200 m north of the railroad station.

At the request of the NRC Division of Fuel Cycle and Material Safety, radiological surveys of the W.R. Grace site, adjacent properties, and the Erie Lackawanna Railroad tracks near Peck Avenue were conducted during July and August 1982, by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), Oak Ridge, Tennessee. This report represents the findings of those surveys.

A glossary of technical and nuclear terms and schematic representations of the naturally-occurring thorium and uranium radioactive decay series have been presented as Appendices A and B, respectively, to aid in the interpretation of this report.

SITE DESCRIPTION

General

W.R. Grace Property

The W.R. Grace property is located at 868 Black Oak Ridge Road about 2 km east of Pompton Plains and 3 km north of Wayne, in the northeast corner of New Jersey (Figures 1 and 2). The site, shown in Figure 3, occupies approximately 2.6 hectares, most of which is surrounded by a chain link security fence. Two office buildings and a warehouse are the main structures on the site. The eastern and northern sections of the site are wooded and heavy brush and weeds grow along a small drainage stream. This stream enters the property near the southeast corner, flows north, then west. Prior to leaving the fenced-in portion of the site, the stream enters an underground conduit. This conduit carries the water into a tank, where it is mixed with the occasional overflow from an inactive on-site artesian well and the storm sewer system. The water is then discharged to an off-site storm sewer.

The site is bounded by private residences to the north and east, to the south by a property currently used for storage and maintenance of

school buses, and by several commercial firms on the west side of Black Oak Ridge Road, across from the W.R. Grace property (see Figure 2).

Erie Lackawanna Railroad

The Erie Lackawanna Railroad runs in a north-south orientation through Pompton Plains in Morris County (see Figure 4). Just north of the point where the railroad crosses Jackson Avenue is the Pompton Plains Railroad Station. Another 200 m further north of the railroad station is the point where Peck Avenue runs into an unused spur of the railroad. The area is a mixture of commercial and residential properties; the nearest residence being approximately 10 m north of Peck Avenue and 20 m west of the spur.

Operations

Between 1948 and 1956 Rare Earths, Inc., processed thorium-containing monazite ore to recover various rare earths and to separate the thorium for use by the Atomic Energy Commission (AEC). Wastes and residues from the processing operations contained less than 5% of the original thorium concentration and were disposed of by burial on the site. Liquid effluents from these processes were neutralized in an on-site treatment plant and combined with the occasional outflow of an on-site artesian well and the small surface drainage stream. The combined effluents were carried, via conduit under the company's north parking lot, to the intersection of Black Oak Ridge Road and Pompton Plains Cross Road where they were released into the storm sewer system (see Figure 5). This storm sewer system flows westerly where it discharges into Sheffield Brook and, eventually, into the Pompton River.

The Davison Chemical Division of W.R. Grace and Co. acquired the plant in 1956 because of the potential uses for purified rare earths and thorium. Between 1957 and 1967, residues and wastes containing most of the thorium from the monazite ores were disposed of by on-site burial. From 1967 to 1971, when processing operations at the site were discontinued, residues were shipped to the W.R. Grace plant in Chattanooga, Tennessee. The Pompton Plains plant was permanently closed in April 1971.

In 1974 Applied Health Physics, Inc., performed a radiological survey of the site and conducted decontamination operations designed to bring the site into compliance with existing regulations permitting release for unrestricted use.[3] In the course of the decontamination operations, contaminated materials and equipment were buried on-site. Portions of the property were then filled or covered with soil and the site was leveled and landscaped.

A fire in May 1977 heavily damaged the main building and destroyed most of the early records, including those containing details concerning the quantities and locations of on-site waste burials. Based on information available in the Applied Health Physics report and conversations with several former employees, suspected burial locations have been identified and are shown on Figure 6.

Several other properties in the Wayne-Pompton Plains area were involved directly or indirectly with the Rare Earths and/or W.R. Grace operations. The property immediately to the south of the W.R. Grace site was formerly leased by W.R. Grace for occasional storage of monazite ore; rail shipments of the ore were unloaded near the Pompton Plains station of the Erie Lackawanna Railroad. Surveys of these two areas were conducted and the findings are included in this report. The drainage stream system (including Sheffield Brook) between the W.R. Grace site and the Pompton River received the treated liquid wastes from facility operations and surface run-off. A survey of this area was conducted earlier and the results have been reported in a separate document.[4]

SURVEY PROCEDURES

Objectives

The survey objectives were as follows:

I. W.R. Grace Site and Adjacent Properties

a. to measure direct radiation levels,
b. to determine the concentrations of radionuclides in surface and subsurface soil,
c. to define locations of burials, and
d. to determine if radionuclides are migrating and/or have migrated from the burial sites.

II. Erie Lackawanna Railroad

a. to measure direct radiation levels, and
b. to determine the concentrations of radionuclides in surface and subsurface soil.

Plan

The survey plans adopted to achieve these objectives included the following activities:

I. W.R. Grace Site and Adjacent Properties

a. Clearance of brush and weeds over the suspected burial areas and the establishment of a 20 m grid system for survey reference.
b. A ground penetrating radar survey to identify the location of the subsurface disturbances and buried objects.
c. Measurement of exposure levels (μR/h) at the surface and at 1 m above the surface at 5 m intervals throughout the W.R. Grace site.

d. Measurement of surface dose rates (μrad/h) at 5 m intervals throughout the W.R. Grace site.

e. Walkover surface scans to identify locations of elevated radiation levels on the W.R. Grace site and adjacent properties.

f. Collection of surface soil samples at grid line intersections and at locations indicated by the walkover scan to have elevated exposure rates.

g. Drilling boreholes and collection of subsurface soil and water samples.

h. Collection of sediment samples from the on-site drainage stream and from the storm drainage sewers.

i. Collection of on-site water samples from the drainage stream and storm sewers.

j. Collection of vegetation samples from various points on the W.R. Grace property.

II. Erie Lackawanna Railroad

a. Measurement of exposure levels (μR/h) 1 m above the ground at 0 m, 5 m, and 10 m distances from either edge of the railroad spur.

b. Walkover surface scans to identify locations of elevated radiation levels.

c. Collection of surface and subsurface soil samples.

d. Collection of vegetation samples.

<u>Procedures</u>

Ground Penetrating Radar Survey

A ground penetrating radar survey of the W.R. Grace property was performed under subcontract by Geo-Centers, Inc. of Newton Upper Falls, MA. The survey technique involves traversing the surface with a transmitter/receiver which emits electromagnetic signal pulses. The reflected signals are recorded and analyzed to identify the locations and

depths of buried objects and other subsurface disturbances. The procedure is described in greater detail in the radar survey report included as Appendix C.

Measurement of Direct Radiation Levels

The 20 m grid system established on the W.R. Grace site (see Figure 7) was subdivided into 5 m intervals. At each of these points, exposure rates were measured at the surface and at 1 m above the surface. Measurements were performed with portable NaI(Tl) gamma scintillation ratemeters field calibrated using a pressurized ionization chamber. Beta-gamma dose rates were measured at 1 cm above the surface at each of the locations where exposure rates were measured. These measurements were performed using thin window ($7 mg/cm^2$) "pancake" GM detectors with scaler/ratemeters. To evaluate contributions from non-pentrating radiations, measurements were also made with the detectors shielded with approximately 2 mm of steel. Walkover surface scans of the gridded areas were performed at 1-2 m intervals, using NaI(Tl) gamma scintillation ratemeters. Locations of significantly elevated radiation levels were noted. At locations where the exposure rates were above the range of the NaI(Tl) scintillation ratemeters, measurements were made with an energy compensated GM detector and scaler.

Walkover surface scans were performed at 2-5 m intervals on adjacent properties to the north and south of the W.R. Grace site. Radiation levels were mapped relative to surface features and landmarks.

The Pequannock Township and State of New Jersey surveys identified elevated radiation levels primarily along a 50 m section of a railroad siding just north of Peck Avenue. Several isolated spots were also noted approximately 50 m south of Peck Avenue. The ORAU survey, extending approximately 100 m north and south of Peck Avenue, consisted of walkover surface scans of the railroad tracks. North of Peck Avenue, the siding area was divided into 2 m intervals. At each of these intervals, exposure rates were measured 1 m above the surface, at the edge of the tracks and at 5 and 10 m on either side of the tracks.

Surface Soil Sampling

Surface (0-5 cm) soil samples of approximately 1 kg each were collected at the intersections of 20 m grid lines on the W.R. Grace property. Samples were also collected at selected locations of elevated gamma radiation levels. Efforts were made to include the source of the elevated levels in these samples. Sampling was performed using garden trowels, from which residual soil was cleaned between samples. Locations of on-site surface soil sampling are shown on Figure 8.

Surface soil samples were collected at locations of elevated radiation levels identified on the property south of the W.R. Grace site. Additional surface samples were also obtained at random locations on the adjacent properties. These sampling locations are indicated on Figure 9.

Subsurface Measurements and Sampling

Forty-three boreholes were drilled on the W.R. Grace property. Twenty-three of these were deep holes drilled to ground water depth. Site Engineers of Voorhees, New Jersey, performed the drilling, using 15 cm and 20 cm diameter hollow stem augers. The other twenty boreholes were shallow (approximately 1 m deep) and were drilled by the survey team, using a portable motorized auger.

The ground radar survey results were used to guide the selection of deeper borehole locations to ensure that subsurface utilities were not damaged. Drilling directly into burial trenches was also avoided to prevent damaging trench linings, thus creating potential migration pathways. Shallower boreholes were often located in areas where elevated exposure rates had identified near-surface thorium contamination. Locations of these boreholes are indicated on Figure 10. Shallow boreholes were drilled at two locations on the property south of the site and at eight locations along the railroad. Locations of boreholes on these off-site properties are shown on Figures 9 and 11, respectively.

In boreholes drilled on the W.R. Grace site a collimated NaI(Tl) scintillation probe was lowered into the hole and gamma radiation levels determined at 30 cm intervals. Gamma logging was not performed in the shallow boreholes drilled on the adjacent properties or along the Erie Lackawanna Railroad.

Soil samples were collected at the surface and at several depths in each borehole. The subsurface samples were at depths where gamma logging identified increased direct radiation levels and at additional points to provide a representative profile of subsurface thorium concentrations. Sampling was accomplished by scraping soil from the edges of the borehole using a specially constructed sampling tool or, at greater depths, by use of a split spoon sampler driven through the center of the hollow stem auger.

Because of heavy precipitation which occurred prior to and during the borehole drilling, the water table was unusually high. The pressure caused by the high water table resulted in the water rapidly filling most of the boreholes to within one to two meters of the ground surface. This water was not considered to be representative of the normal ground water conditions on the W.R. Grace site. Permanent monitoring wells have been installed on the property by W.R. Grace. Samples from these wells will be analyzed by ORAU and the results presented in an addendum to this report.

Sediment Sampling

Sediment samples of 1 kg each were collected on the W.R. Grace property from four locations in the drainage stream, from three drainage tiles, and from eight locations in the storm sewer system (see Figure 12). To provide more representative samples, several closely spaced points were sampled at each location and these samples composited.

Vegetation Sampling

Approximately 1 kg of surface vegetation, i.e. grass, weeds, and other ground cover, was collected from five locations on the W.R. Grace site.

These locations are indicated on Figure 12. No vegetation was collected from the adjacent properties. Three vegetation samples were collected from the area along the railroad (see Figure 11).

Water Sampling

Water samples were collected from three locations along the on-site drainage stream and from five locations in the storm sewer system as indicated on Figure 12. Water samples were not obtained from the railroad property or the adjacent properties since no appropriate sources were available for sampling.

Baseline and Background Measurements

Five soil samples, two water samples, and two vegetation samples were collected at locations 0.3 to 10 km from the W.R. Grace site. Direct radiation levels were measured at the locations of the soil samples. Figure 13 indicates the locations of the baseline samples and background measurements which were used for comparison with the other results of this survey.

Equipment and Analytical Procedures

Appendix D contains a list of the major equipment and instrumentation used for this survey. Analytical procedures are described in Appendix E.

RESULTS

Background Radiation Levels and Baseline Concentrations

Background exposure rates measured in the Wayne-Pompton Plains, NJ, area ranged from 6-12 μR/h; surface beta-gamma dose rates ranged from 10-24 μrad/h.

Baseline radionuclide concentrations in soil, vegetation, and water are presented in Tables 1-A and 1-B. The concentrations in these samples are typical of those normally encountered.

W.R. Grace Site

Ground-Penetrating Radar Survey

The report of the ground-penetrating radar survey provided by Geo-Centers, Inc., is presented as Appendix C. This report concluded that the soil on the W.R. Grace property had been subjected to extensive disturbances. Although there were some similarities between the areas of these disturbances and the burial locations as identified by W.R. Grace records, specific numbers and locations of these burial sites did not agree. In addition to the regions of disturbed subsurface soil, numerous individual reflecting targets were observed by the radar scans. These targets were located between the surface and a depth of approximately 2 m, and were randomly distributed, rather than being associated with the subsurface soil disturbances.

Direct Radiation Levels

Exposure rates measured systematically at predetermined grid locations on the W.R. Grace property ranged from 13 to 540 μR/h at 1 m above the surface. The highest levels generally occurred on the portions of the property where burials reportedly are located. However, only a limited correlation was noted between the exposure levels and the burial locations, as identified by site personnel or by the ground-penetrating radar survey. Exposure rates at 1 m decreased to near background levels at the north, east, and west property boundaries. These exposure levels are presented graphically in Figure 14.

The general pattern and levels of the systematically measured surface exposure rates were very similar to those measured at 1 m above the surface. The levels ranged from 9 to 610 μR/h. Many small areas, having significantly elevated contact radiation levels (up to 7710 μR/h), were

identified by the walkover surface scan. The locations and exposure rates of some of these areas, which were selected for further surface and subsurface investigations, are shown on Figure 15.

Individual dose rate data are not presented in this report; however, the pattern of these dose rates is in good agreement with the pattern of exposure rates described above. Dose rates (μrad/h) were generally between 1.25 and 2.0 times the surface exposure rates (μR/h). The unshielded probe measurements ranged from 25 to 40 percent higher than the measurements performed with the probe face shielded, indicating a significant dose contribution from beta and low-energy photon radiations. This is consistent with the presence of thorium contamination.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in the surface soils collected on the W.R. Grace property are presented in Table 2. The total thorium concentrations (Th-232 + Th-228) ranged from 2.14 pCi/g (sample location S5) to 721 pCi/g (S9) in the samples systematically collected at grid line intersections. The total thorium concentrations in soil collected at locations identified by the walkover survey to have elevated exposure rates (see Figure 8) ranged from 51.2 pCi/g (S58) to 7540 pCi/g (S30). In general, there was a positive correlation between the thorium concentration in the soil and the direct radiation level at the point of sampling. Thorium concentrations in soil samples collected east and north of the drainage stream ranged from 2.14 pCi/g (S5) to 20.0 pCi/g (S4). Surface soil systematically collected on the western portion of the property along Black Oak Ridge Road contained total thorium concentrations ranging from 3.49 pCi/g (S49) to 49.6 pCi/g (S56). However, several isolated spots with elevated exposure rates were identified in this area, and soil samples taken from these locations had thorium concentrations between 51.2 pCi/g (S58) and 832 pCi/g (S54).

Radionuclide concentrations in soil from boreholes on the W.R. Grace site are presented in Table 3. In general, the lowest thorium concentrations were measured in soil from the boreholes drilled east and

north of the drainage stream (B1-B9), through the paved areas (B38-B41), and in the lawn near Black Oak Ridge Road (B35, B42, and B43). In the boreholes east and north of the drainage stream, the total thorium concentrations ranged from 2.66 pCi/g (B7) to 11.5 pCi/g (B3) for surface soil and from 1.75 pCi/g (B7) to 9.90 pCi/g (B9) for soil collected from the bottom of the boreholes. Thorium concentrations in soil from boreholes B1-B8 decreased with depth; however, in borehole B9 the concentration increased from 3.50 pCi/g at the surface to 9.90 pCi/g at 1 m. Samples from boreholes B38-B41, drilled in the paved areas, contained thorium concentrations ranging between 3.83 pCi/g (B38) and 5.28 pCi/g (B40) just below the pavement. Concentrations in these boreholes decreased or remained constant down to approximately 2 m. In the boreholes drilled near Black Oak Ridge Road (B35, B42, and B43), the thorium concentrations ranged from 3.06 pCi/g (B35) to 30.4 pCi/g (B43) at the surface and from 2.25 pCi/g at 2 m in B35 to 15.5 pCi/g at 3.6 m in B43.

The maximum thorium concentration measured in the subsurface samples was 30,500 pCi/g. This sample was from the 3.9 m depth in borehole B29. Other boreholes where high subsurface thorium levels were measured were B26 (15,900 pCi/g), B22 (15,400 pCi/g), B15 (9,800 pCi/g), B27 (6,350 pCi/g), and B30 (5,460 pCi/g). Four of these (B22, B15, B27, and B30) were shallow boreholes drilled at locations with notably elevated exposure rates. In each of these boreholes, the thorium concentrations in the soil increased with depth, suggesting that these holes were drilled over areas of buried residues.

The ratios of Ra-226 and U-238 concentrations to total thorium concentrations varied widely in soil samples from the site. Radium-226 concentrations ranged from approximately 0.3% to 32% of the thorium levels; U-238 concentrations ranged from about 0.3% to 35% of the thorium levels. Ratios of U-238 to Ra-226 were also inconsistent. No pattern was noted in these variations. These differences suggest that the materials encountered represent residues from different processes and stages in operations conducted at this site.

Although the Th-232 and Th-228 concentrations generally agreed, several samples exhibited significant differences. For example sample S13 contained 2710 pCi/g of Th-232 but only 1540 pCi/g of Th-228; sample S36, on the other hand, contained 1850 pCi/g of Th-232 and 2300 pCi/g of Th-228. These differences indicate that some of the residues on this site have not yet reached an equilibrium state with the entire thorium decay series.

Radionuclide Concentrations in Sediment Samples

The radionuclide concentrations in sediment samples are presented in Table 4. In the four samples collected from the drainage stream the thorium concentrations ranged from 3.76 pCi/g (sample location D4) to 10.3 pCi/g (D1). No clear pattern was observed in these samples, the highest levels being found in sediment from the stream near its entrance to the W.R. Grace property. Sediment samples D8-D15 collected from the storm sewer system contained thorium levels ranging from 34.3 pCi/g (D8) to 1820 pCi/g (D14). Although the path of this sewer system is not precisely known, a general pattern of increasing concentrations was observed as the system neared the outfall from the W.R. Grace property.

Radionuclide Concentrations in Water Samples

Radionuclide concentrations measured in the water samples from the drainage stream and from the storm sewer system are presented in Tables 5 and 6. Water collected from the drainage stream contained gross alpha concentrations ranging from <3.19 pCi/ℓ* (W3) to 7.21 pCi/ℓ (W1). Gross beta levels in these samples were <5.00 pCi/ℓ. Radium-228 concentrations were <0.18 pCi/ℓ. Radium-226 concentrations ranged from <0.03 pCi/ℓ (W2) to 0.11 pCi/ℓ (W3).

Elevated radionuclide concentrations were present in water from the storm sewer system. Levels ranged from 5.33 pCi/ℓ (D13) to 28.6 pCi/ℓ (D11), gross alpha; 13.4 pCi/ℓ (D13) to 60.8 pCi/ℓ (D11), gross beta;

* *The "less than" symbol (<) indicates that the concentration is below the detection limits of the analytical technique. Refer to Appendix E for further discussion.*

6.59 pCi/ℓ (D11) to 14.2 pCi/ℓ (D12), Ra-228; and 0.10 pCi/ℓ (D10) to 0.86 pCi/ℓ (D12), Ra-226. The pattern of concentrations in these water samples was consistent with the concentrations in the sediments from the same locations.

Radionuclide Concentrations in Vegetation Samples

Radionuclide concentrations in the five on-site vegetation samples are presented in Table 7. In these samples the Ra-228 concentrations ranged from 1.00 pCi/g (V1) to 3.41 pCi/g (V4) and the Th-228 concentrations from 0.26 pCi/g (V1) to 0.59 pCi/g (V5). All these values are slightly elevated above the baseline sample concentrations. No other radionuclides were present in levels significantly above the baseline concentrations.

Properties Adjacent to the W.R. Grace Site

Surface Radiation Exposure Levels

Elevated radiation levels were noted extending onto the school bus maintenance yard south of the W.R. Grace property. The exposure rates measured at contact with the surface are indicated on Figure 16. Areas with the highest levels were in the vicinity of the concrete loading platform at the northwest corner of the building and near a door on the building's northeast side. Maximum exposure rates at these locations were 250 and 890 μR/h, respectively. Inside the building, elevated direct radiation levels were limited to the northern half of the building and were primarily associated with cracks in the concrete floor.

Exposure rates on the properties to the north, east, and west of the site were in the range of area background levels.

Radionuclide Concentrations in Soil Samples

The radionuclide concentrations in surface soil from the adjacent properties are indicated in Table 8. The three randomly collected soil samples from the private residence north of the W.R. Grace property

(S68-S70) had total thorium concentrations between 1.24 pCi/g (S69) and 2.08 pCi/g (S68). These values are within the range of the baseline samples. Total thorium in the three soil samples (S71-S73) collected in the commercial area immediately west of the W.R. Grace property, ranged between 1.85 pCi/g (S71) and 7.21 pCi/g (S72). The highest concentration was found in sample S72 which was collected from the location (in this area) determined in the walkover survey to have a slightly elevated contact exposure rate of 18 μR/h. The other two samples had concentrations within the range of the baseline samples. South of the W.R. Grace property, in the school bus maintenance yard, the thorium concentrations in the surface soil ranged between 2.32 pCi/g (S81) and 2720 pCi/g (S77). Two samples scraped from the floor inside the north building (S78 and S79) had thorium concentrations of 647 pCi/g and 17.8 pCi/g, respectively.

Two shallow boreholes were drilled in the school bus maintenance yard near the southern boundary of the W.R. Grace site. The radionuclide concentrations in soil from these boreholes are presented in Table 9. The borehole drilled at a location with an elevated surface exposure rate (B44) had a thorium concentation of 3,760 pCi/g in the surface soil. The concentration decreased with depth to baseline levels, i.e. 2.08 pCi/g, at 1 m. The thorium concentration in surface soil from the other borehole, B45, was slightly elevated, 9.30 pCi/g, but the concentrations in subsurface samples were near the baseline range.

Erie Lackawanna Railroad

Direct Radiation Levels

Exposure rates along the Erie Lackawanna Railroad in the vicinity of Peck Avenue measured systematically at 1 m above the ground ranged from 9 to 135 μR/h (see Figure 17). Contact exposure rates are presented in Figure 18. These levels ranged from 7 μR/h to 970 μR/h. (At 1 m above the location with the highest surface exposure rate, i.e. 970 μR/h, the exposure rate was 190 μR/h.) Elevated radiation levels are primarily associated with the west embankment of an unused railroad siding between the spur and a footpath for a distance of 40-50 m north of Peck Avenue.

Three isolated spots with exposure rates of 200 μR/h were also identified adjacent to the railroad spur 70-100 m south of Peck Avenue.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in soil samples collected along the Erie Lackawanna Railroad are presented in Table 10. Total thorium concentrations in the surface soil samples ranged from 1.56 pCi/g (B54) to 1280 pCi/g (B46). The lowest levels are in the range of the baseline concentrations; these were in samples (B52-B54), collected from the east side of the railroad tracks. The highest concentrations were in samples from boreholes B46, B47, and B51, drilled at locations having elevated direct radiation levels. The thorium concentrations in these samples were 1280 pCi/g, 813 pCi/g, and 403 pCi/g respectively. In each case the thorium concentrations decreased with depth. Boreholes B48-B50 were drilled in a small mound located between the end of Peck Avenue and the railroad spur. In each of these boreholes, the thorium concentrations increased with depth from near baseline concentrations at the surface to a maximum at a depth of about 0.5 m. The maximum thorium concentrations in boreholes B48, B49, and B50 were 50.4 pCi/g, 42.9 pCi/g, and 9.83 pCi/g respectively. Ratics of Ra-226 to thorium activities in these samples were nearly constant, ranging from about 5% to 8%. Concentrations of Ra-226 to U-238 were approximately equal, suggesting that the contamination in this area is due to unprocessed monazite sand.

Radionuclide Concentrations in Vegetation Samples

The radionuclide concentrations in vegetation samples (V6-V8) collected from the vicinity of the Erie Lackawanna Railroad are presented in Table 11. In all cases, the radionuclide concentrations were within the range of the baseline samples.

DISCUSSION

This survey identified thorium contamination in soil on the W.R. Grace site, the adjacent property south of that site, and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains. Elevated direct radiation levels are associated with this contamination. The contamination on the W.R. Grace property appears to be process residues, consistent with previous uses of monazite sands and on-site burials of wastes. Contamination on the adjacent property south of the W.R. Grace site and the Erie Lackawanna Railroad appears to be unprocessed monazite sand, originating from handling or storage of the sands on those properties.

W.R. Grace Site

Contamination on the W.R. Grace and Co. site apparently originated from on-site storage and shallow land burial of ores, wastes, residues, and contaminated equipment from previous operations. The relatively high thorium surface contamination levels in some locations and the findings of the ground-penetrating radar survey suggest that the burials were not necessarily at well defined locations and that buried wastes may have been disturbed and eventually spread over the eastern portion of the property.

Borehole sampling and measurements at suspected burial locations indicated higher concentrations in the subsurface soil than in the surface soil. Thorium concentrations in soil samples collected east and north of the drainage stream (well away from the burial areas) and along the western property boundary were slightly elevated. Thorium concentrations in surface and subsurface soil, collected near the south property boundary also were elevated.

Due to the extensive disturbance of soil on the property, lack of agreement between site personnel and ground-penetrating radar results concerning the burial locations, and because of intentional avoidance of drilling into suspected burial trenches, it was not possible to estimate with reasonable accuracy the total volume and activity of the on-site wastes.

Direct radiation levels on almost the entire portion of the site where burials are suspected exceeded 60 μR/h. Access to areas of highest radiation levels is restricted and the site is posted with radiation warning signs.

Buildings on the site were surveyed prior to termination of the W.R. Grace license and levels were verified recently by the NRC Region 1 office. These buildings were found to meet the NRC criteria for release for unrestricted use and therefore were not included in the ORAU survey.

Radionuclide levels in the sediment and water from the drainage stream are elevated but do not indicate that this is a significant migration pathway. The general slope of the property is away from the stream. Surface run-off from areas of contaminated soil into this stream is, therefore, very limited.

All of the sediment samples from the on-site storm sewer contained elevated thorium concentrations; all of the water samples collected from the storm sewer had gross alpha levels above those in baseline samples. The high thorium levels in some of these sediment samples indicate a concentration by placer action. These findings and the elevated radiation levels and surface soil concentrations along other surface drainage pathways on the W.R. Grace site suggest transport by water run-off has been and continues to be a significant mode of migration.

Ground water sampling was complicated by heavy rains. Permanent monitoring wells have been installed and the results of sampling from these wells will be provided as an addendum to this report.

Adjacent Properties

Only one soil sample from the adjacent properties north and west of the site had a thorium level exceeding the range of the baseline samples. Thorium concentrations in surface soil from the adjacent property, south of the W.R. Grace site, exceeded baseline levels. Thorium contamination is

also present on the floor of one of the buildings. This contamination probably resulted from occasional use of the property for monazite sand storage.

Surface run-off from the W.R. Grace site may also have contributed to this contamination. Thorium concentrations in the subsurface soil samples, collected on this property, were only slightly higher than those in baseline samples.

Surface exposure rates on the northern portion of this property also exceed area background levels. Highest levels are located along the boundary nearest the W.R. Grace property and in several small isolated areas adjacent to and inside the building once used for monazite sand storage.

Erie Lackawanna Railroad

Elevated surface soil concentrations of thorium are present along the section of the Erie Lackawanna Railroad included in this survey. Subsurface soil samples, collected at locations of higher direct radiation levels, also contain thorium concentrations exceeding the baseline soil levels. The contamination is believed to be in the form of unprocessed monazite sand, which was reportedly unloaded at this location. Elevated direct radiation levels, associated with the thorium contamination, are present along the track north of Peck Avenue, and there are several small isolated areas of elevated surface radiation 50-75 m south of Peck Avenue.

Radiation Guidelines

Guidelines for levels of radiation and radioactive materials in the environment are established by federal regulatory agencies such as the Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA). These guidelines are usually based on conservative factors of land use and occupancy, potential intake by inhalation and ingestion, biological retention times, relative hazard of the radionuclide, and potentially exposed population group. Such guidelines are, therefore, for highly

restrictive situations that may not be representative of the actual conditions at a specific site. For this reason, these federal guidelines are often used as target criteria with site-specific limits established on case-by-case basis. Guidelines for concentrations of radionuclides in soil have not been specifically developed for the W.R. Grace site or other properties included in this survey.

The Nuclear Regulatory Commission's Standards for Protection Against Radiation (10CFR20) establishes limits of radiation dose for occupational radiation workers and for the general public. An individual in the general public may receive an annual radiation dose of 500 millirem.[5] Assuming continual exposure, i.e. 168 h/wk, this allowable annual dose is equivalent to an average exposure rate of approximately 60 μR/h.

SUMMARY

At the request of the Nuclear Regulatory Commission, the ORAU Radiological Site Assessment Program conducted a radiological survey of the W.R. Grace site in Wayne, New Jersey. Surveys of properties adjacent to the W.R. Grace site and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains were also performed.

The findings indicate extensive thorium contamination in soil on portions of the W.R. Grace site. Radionuclide concentrations in the sediment and water collected from the on-site storm sewer indicate this system is a possible pathway for off-site migration of contamination. Migration appears to be by placer movement, rather than by leaching of radionuclides from the residues.

A portion of the property (including one of the buildings) bordering the W.R. Grace site on the south and a section of the Erie Lackawanna Railroad also have elevated thorium concentrations in soil and radiation levels. The contamination on these two properties appears to be primarily unprocessed ore. Other properties adjacent to the W.R. Grace site do not have thorium concentrations or direct radiation differing significantly from the range of area baseline and background levels.

Permanent monitoring wells are being installed to measure radionuclide concentrations in ground water on the W.R. Grace site. Results of these measurements are not completed and will be provided as an addendum to this report.

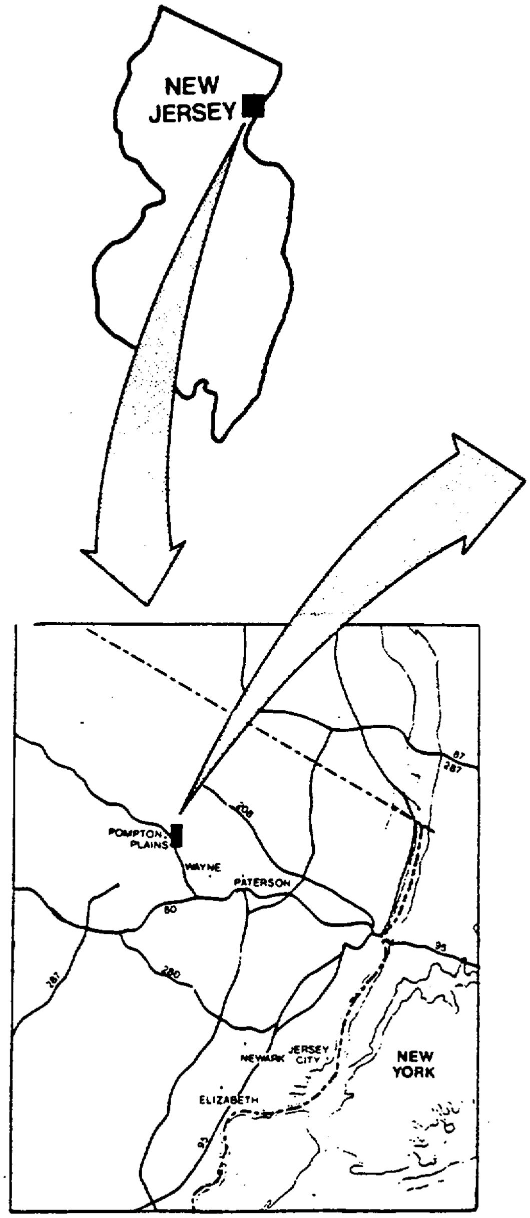


FIGURE 1. Map of Northeastern New Jersey Indicating the Location of the W.R. Grace Property.

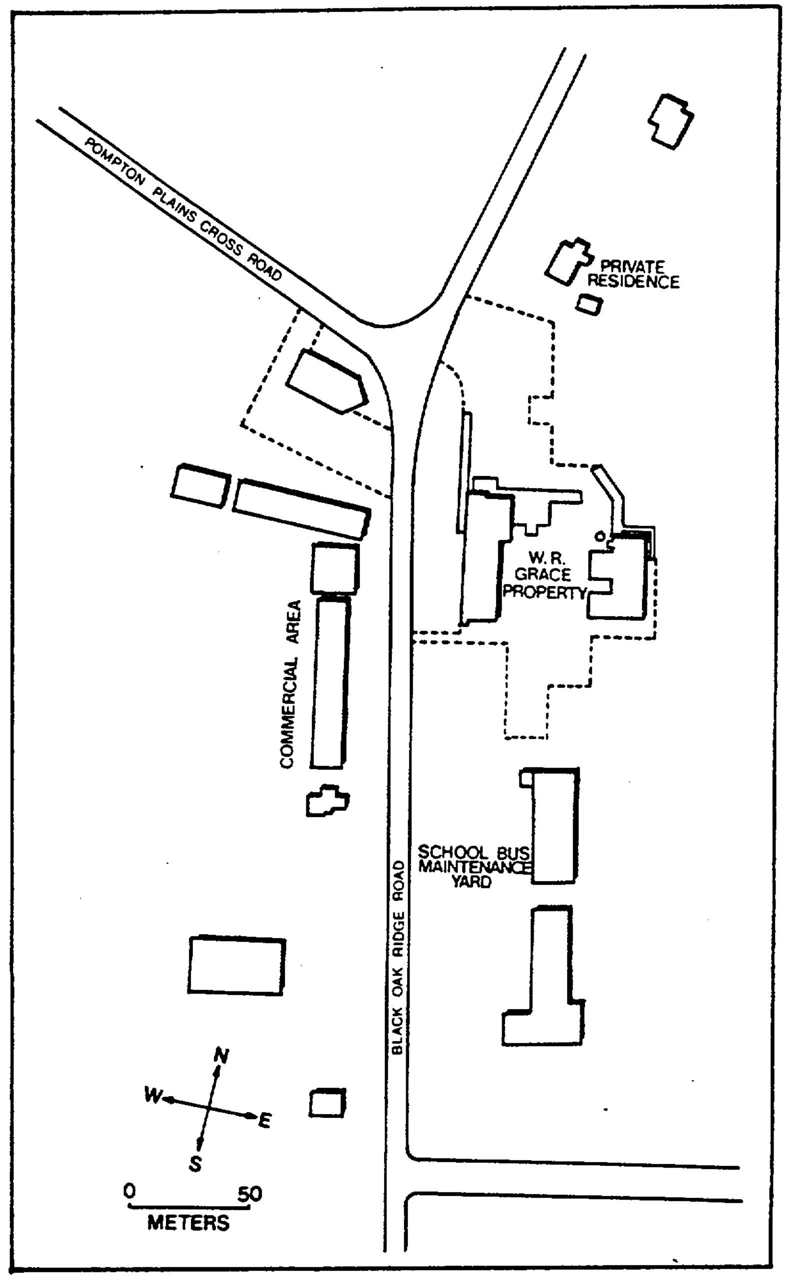


FIGURE 2. Portion of Wayne, New Jersey, Indicating the Locations of the W.R. Grace Property and Adjacent Properties. (Dotted lines indicate paved areas.)

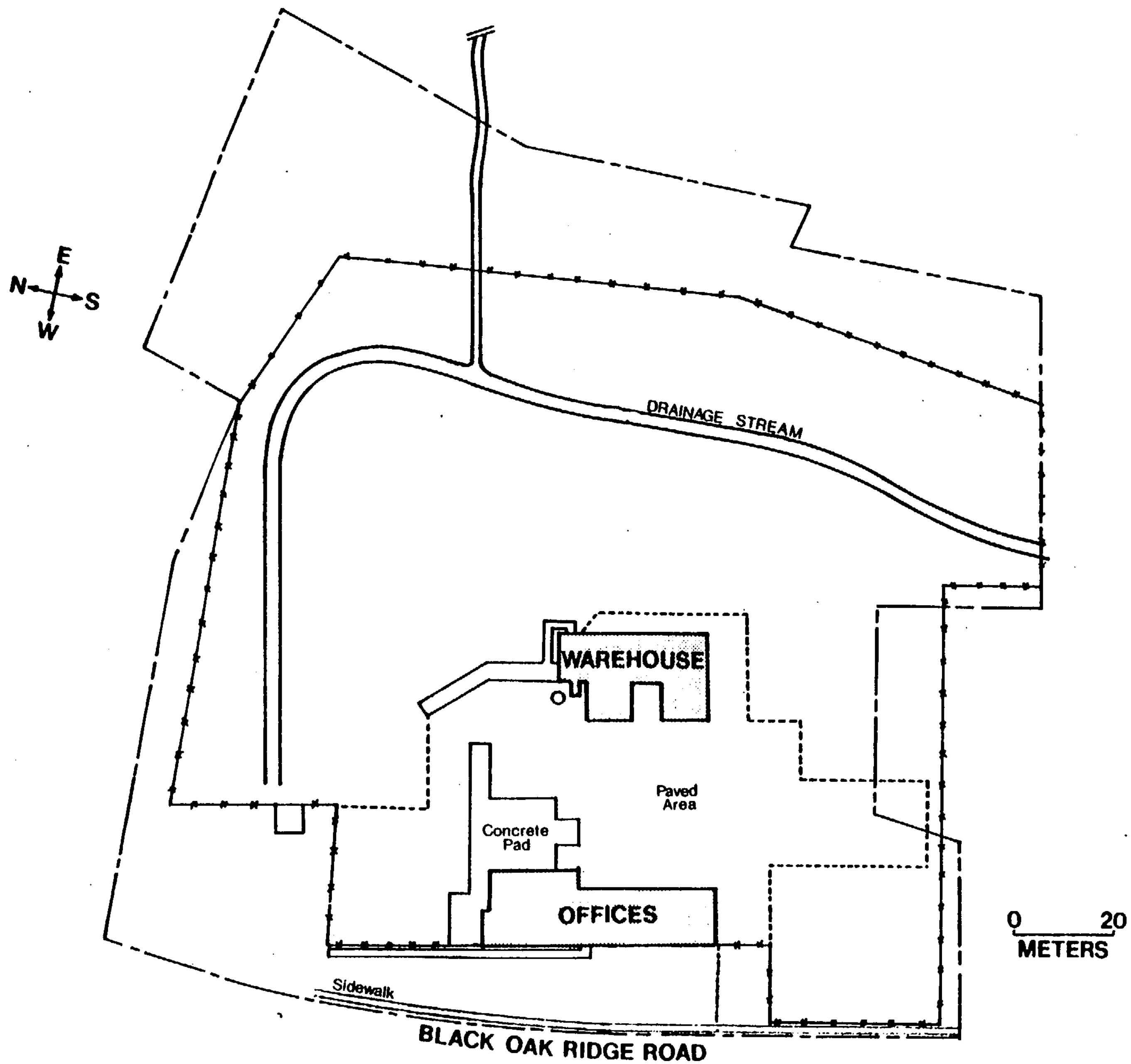


FIGURE 3. Plan View of the W.R. Grace Property.

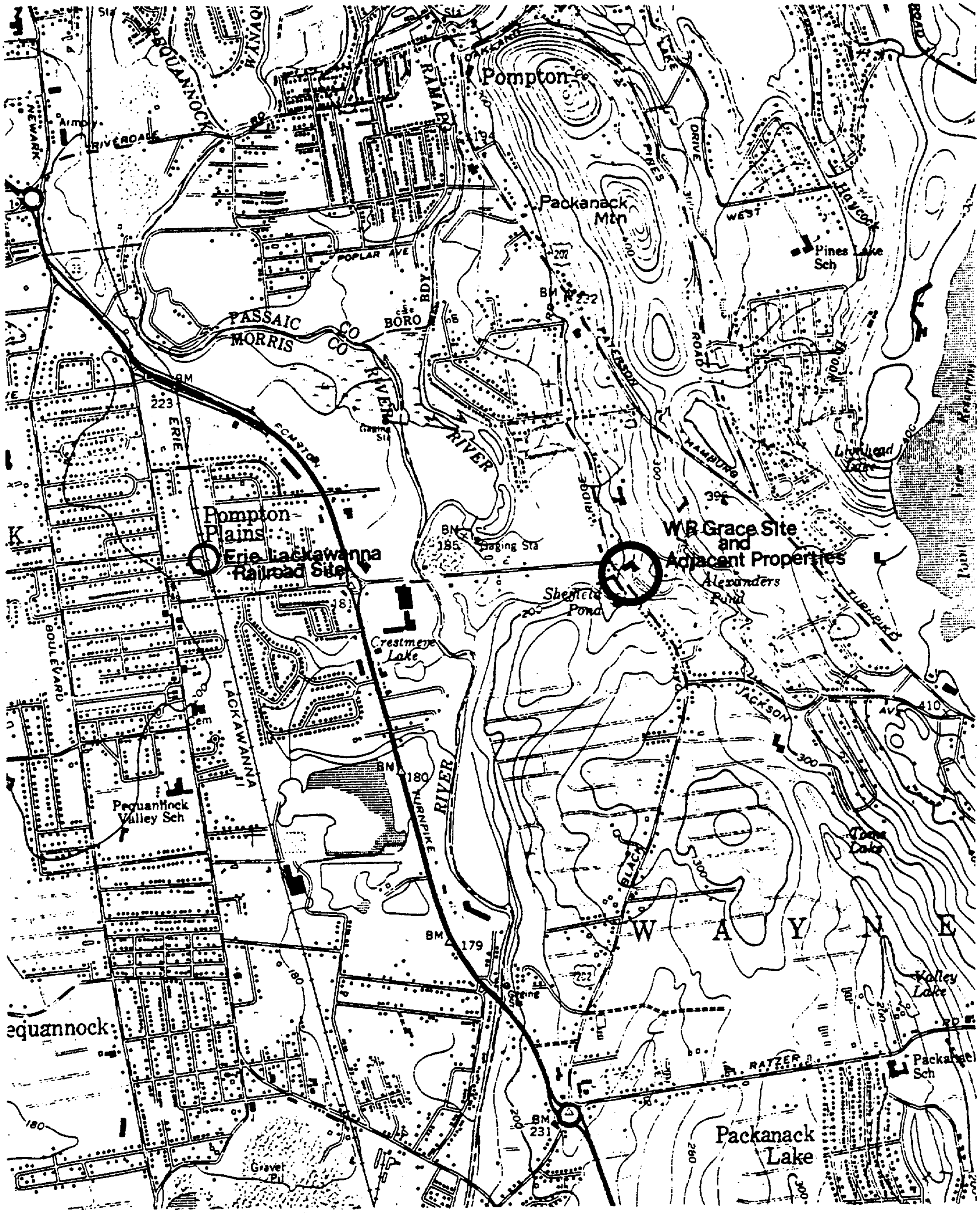


FIGURE 4. Map of the Wayne-Pompton Plains, New Jersey, Area Indicating the Location of the W.R. Grace Site and the Erie Lackawanna Railroad Site.

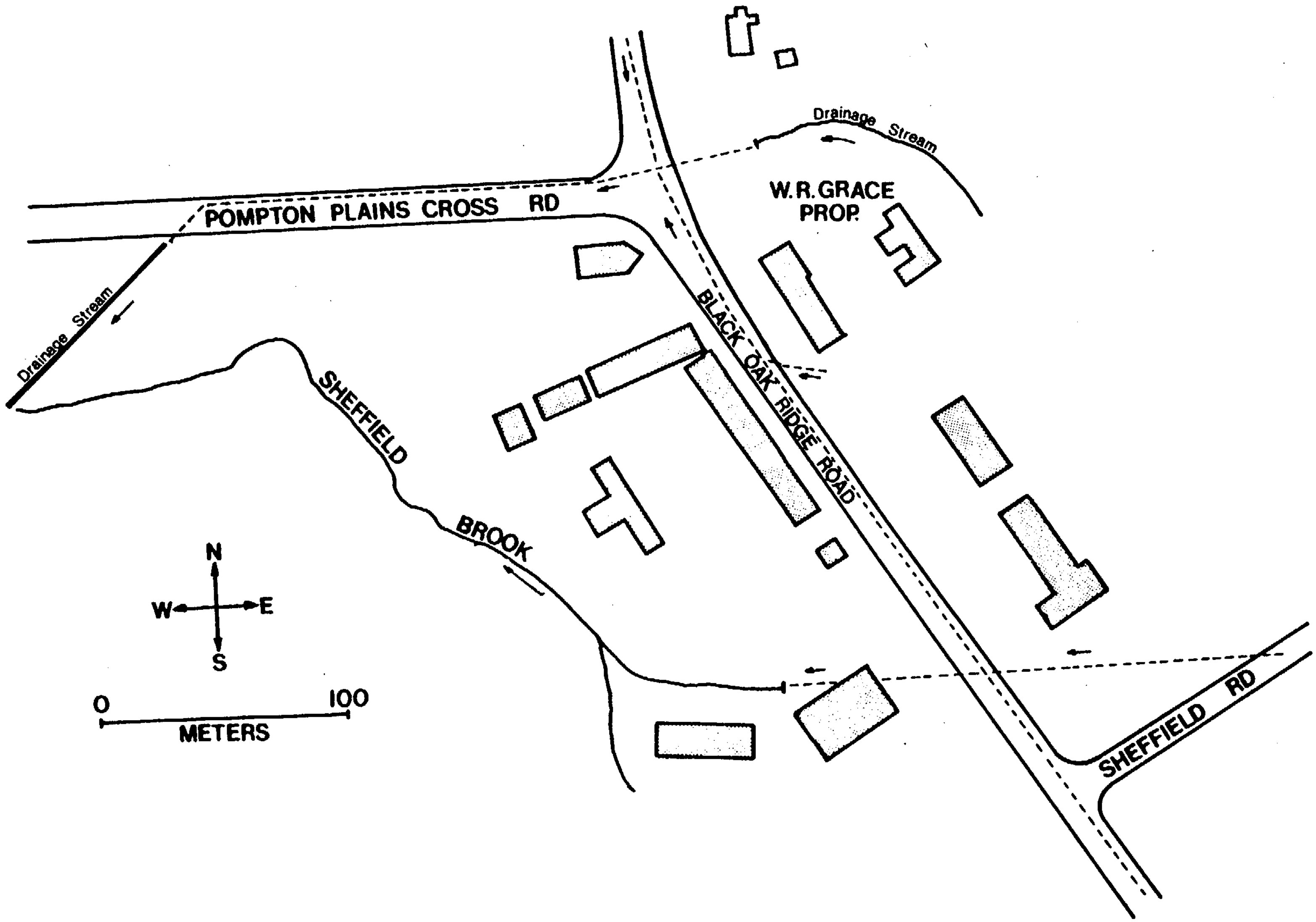
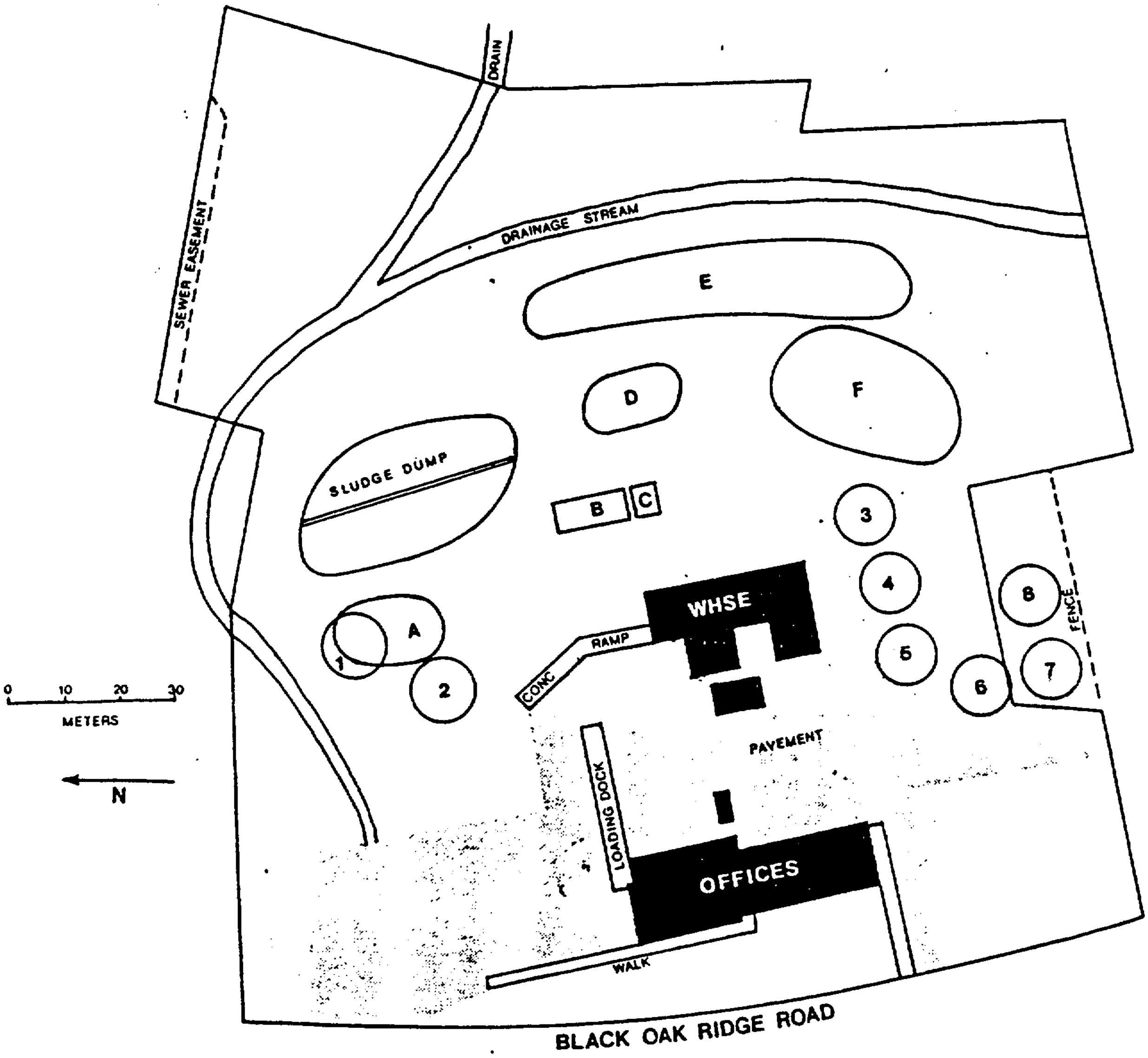


FIGURE 5. Plan View of the Storm Drainage System Servicing the W.R. Grace Site.



A=Reworked Sludges
B=Yttrium Concentrate
C=Thorium Hydroxide

D=Waste Treatment Disposal
E=Ore Tailings and Gangue
F=Yttrium and Silica Sludges

1-8 = Circular Holes Filled April-June 1974 with debris and contaminated equipment resulting from decontamination of buildings.

FIGURE 6. Suspected Burial Locations on the W. R. Grace Property.

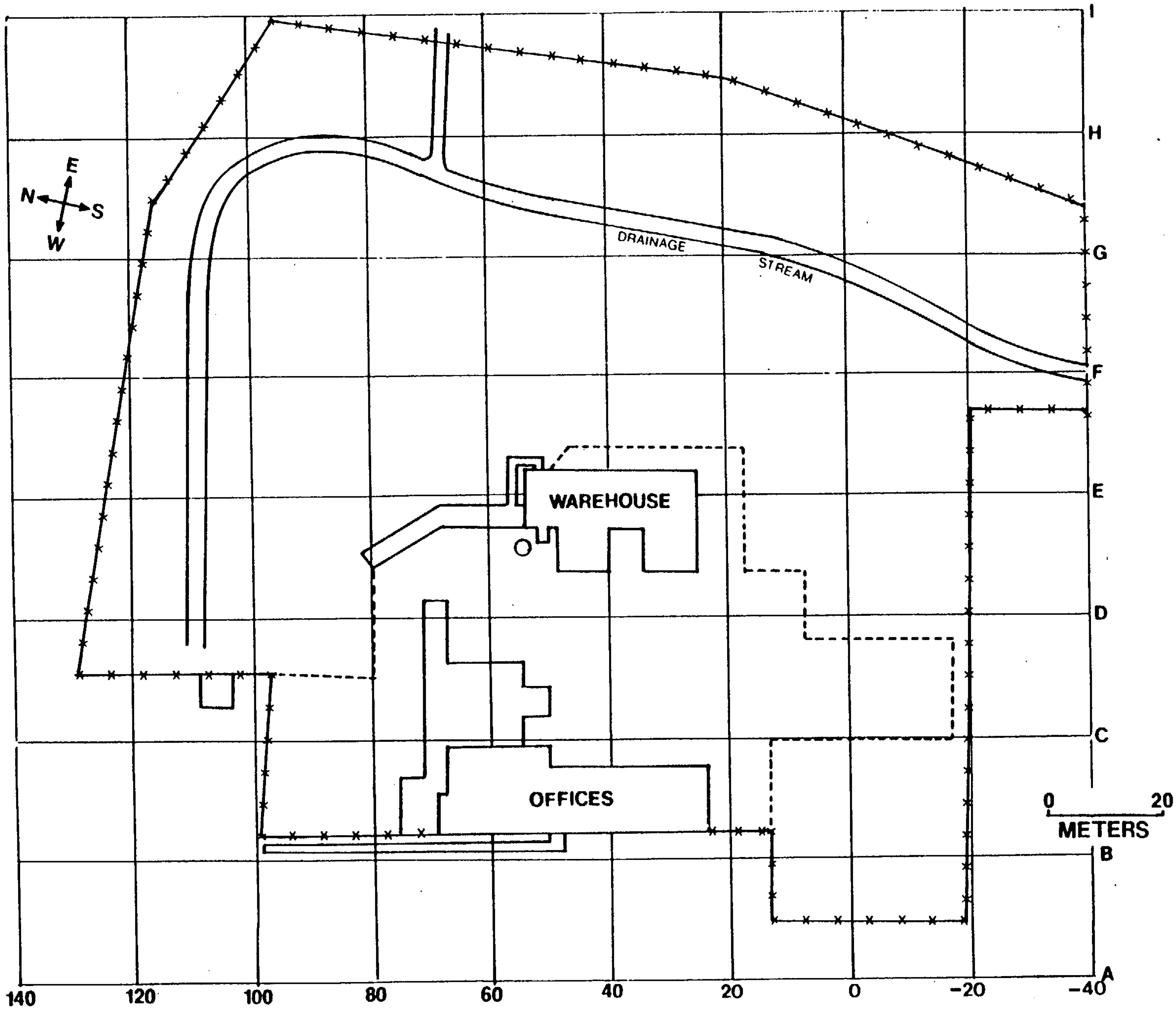


FIGURE 7. Grid System Established for Survey Reference.

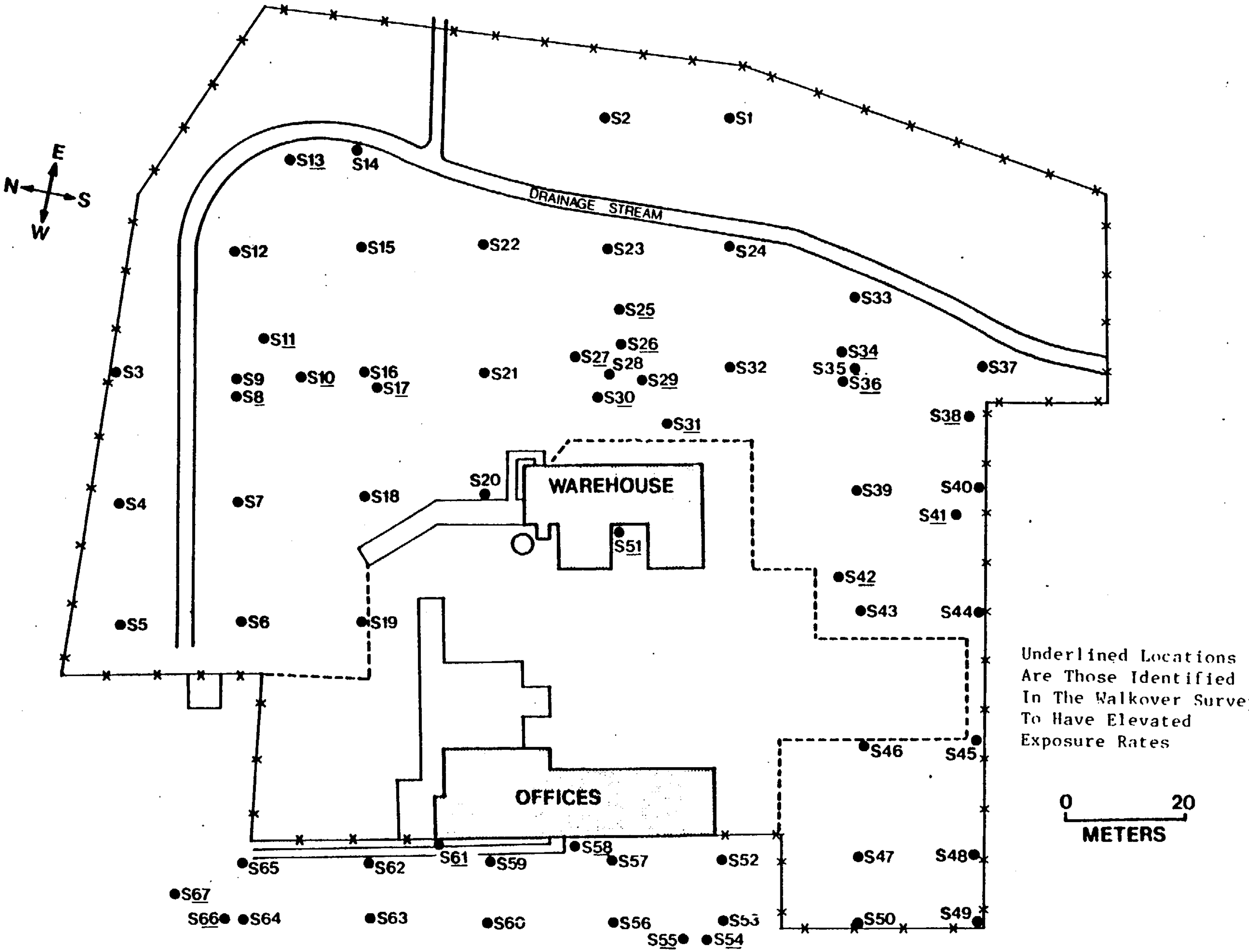


FIGURE 8. Surface Soil Sampling Locations on the W.R. Grace Property.

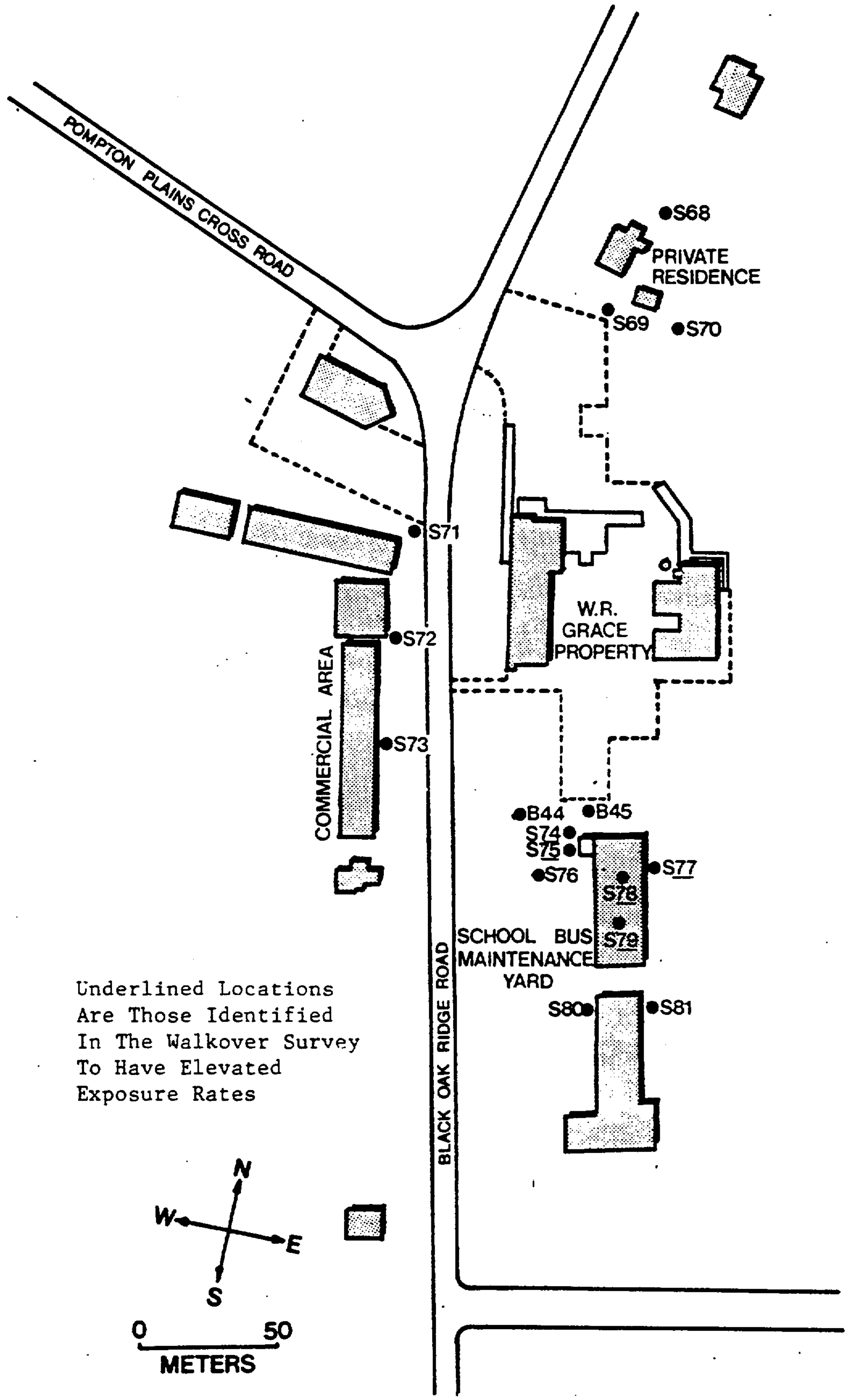


FIGURE 9. Surface Soil Sampling and Borehole Locations Adjacent to the W.R. Grace Property.

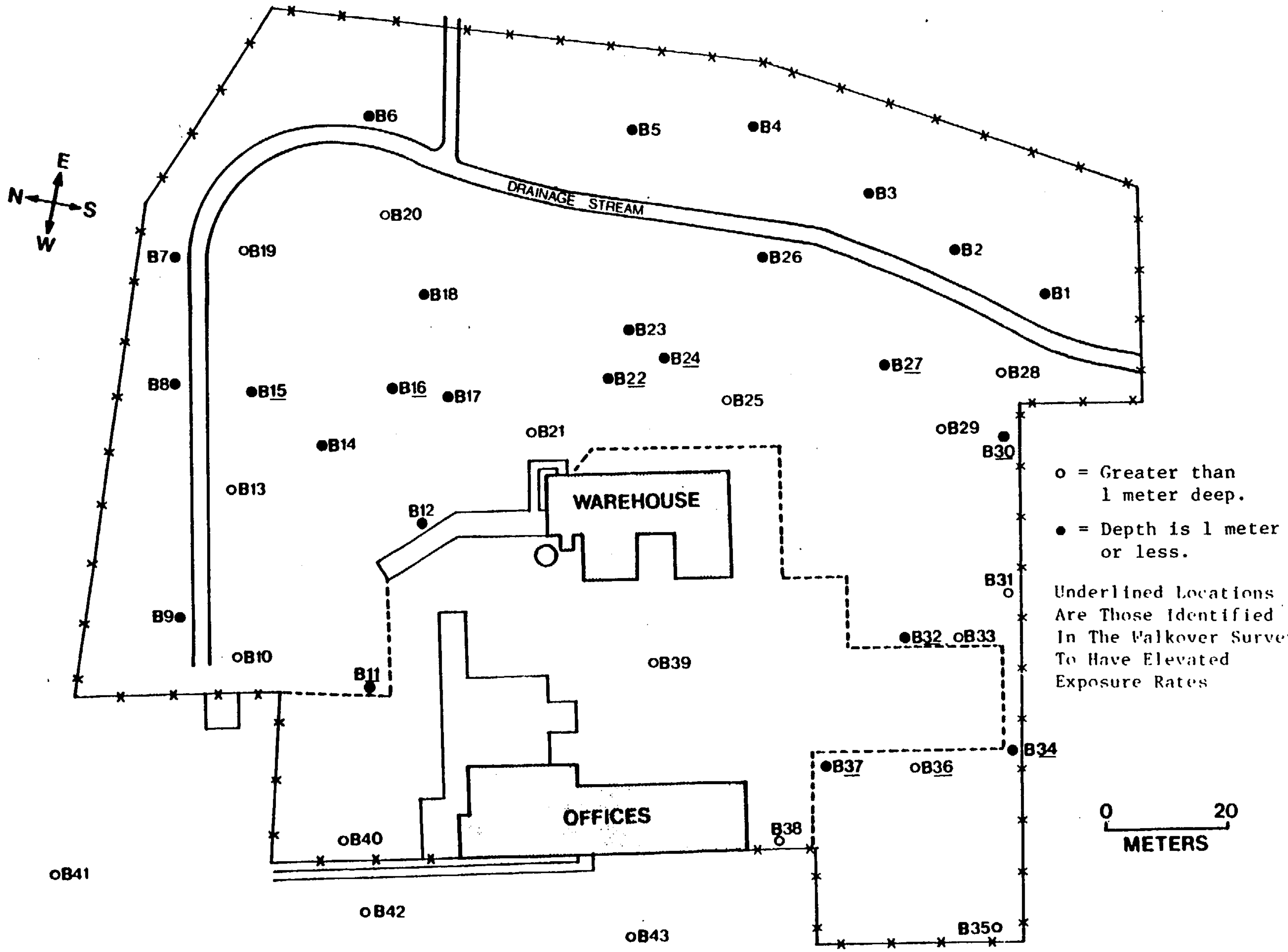


FIGURE 10. Borehole Locations on the W.R. Grace Property.

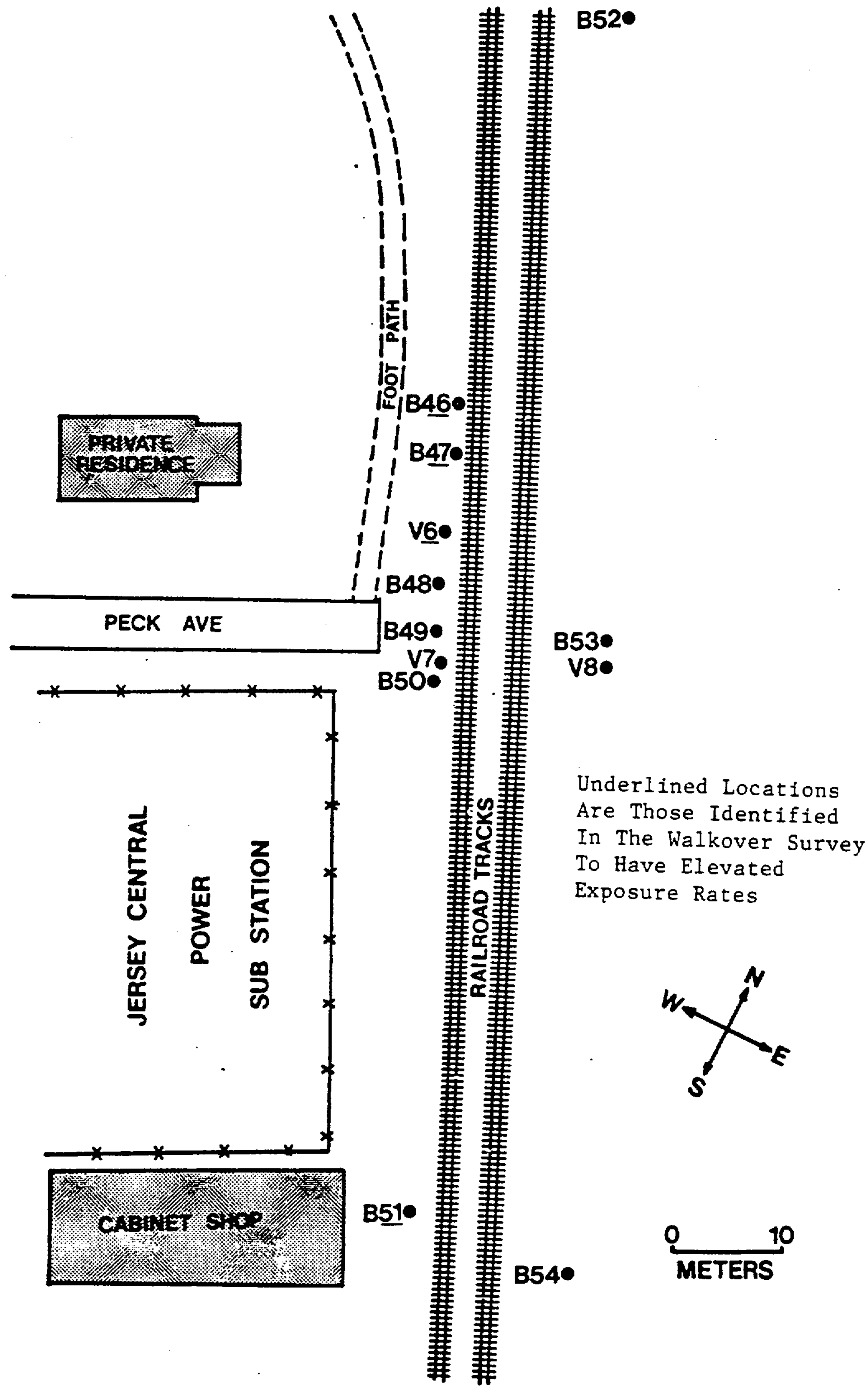


FIGURE 11. Borehole and Vegetation Sampling Locations Along the Erie Lackawanna Railroad in Pompton Plains, NJ.

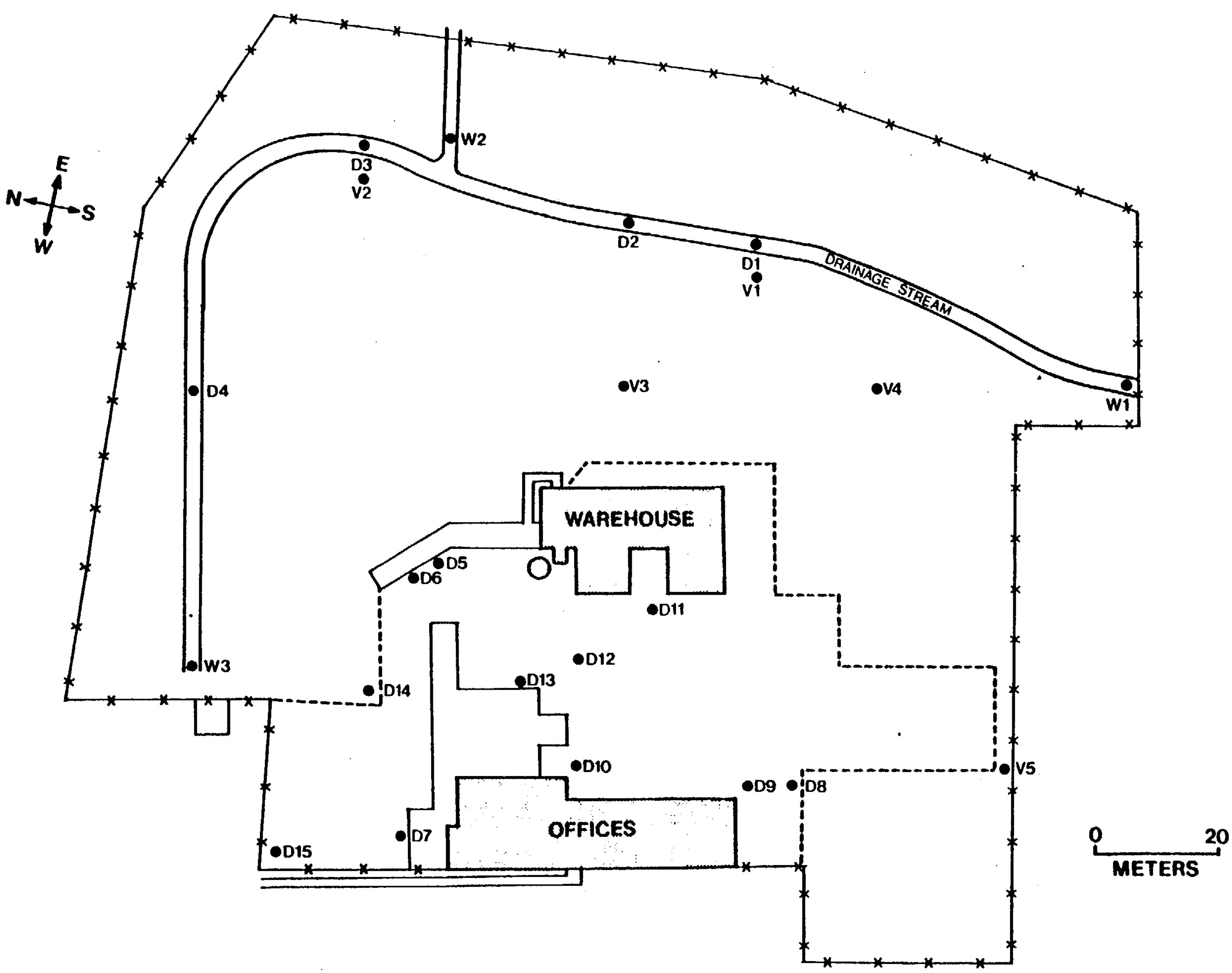


FIGURE 12. Sediment, Water, and Vegetation Sampling Locations on the W.R. Grace Property.

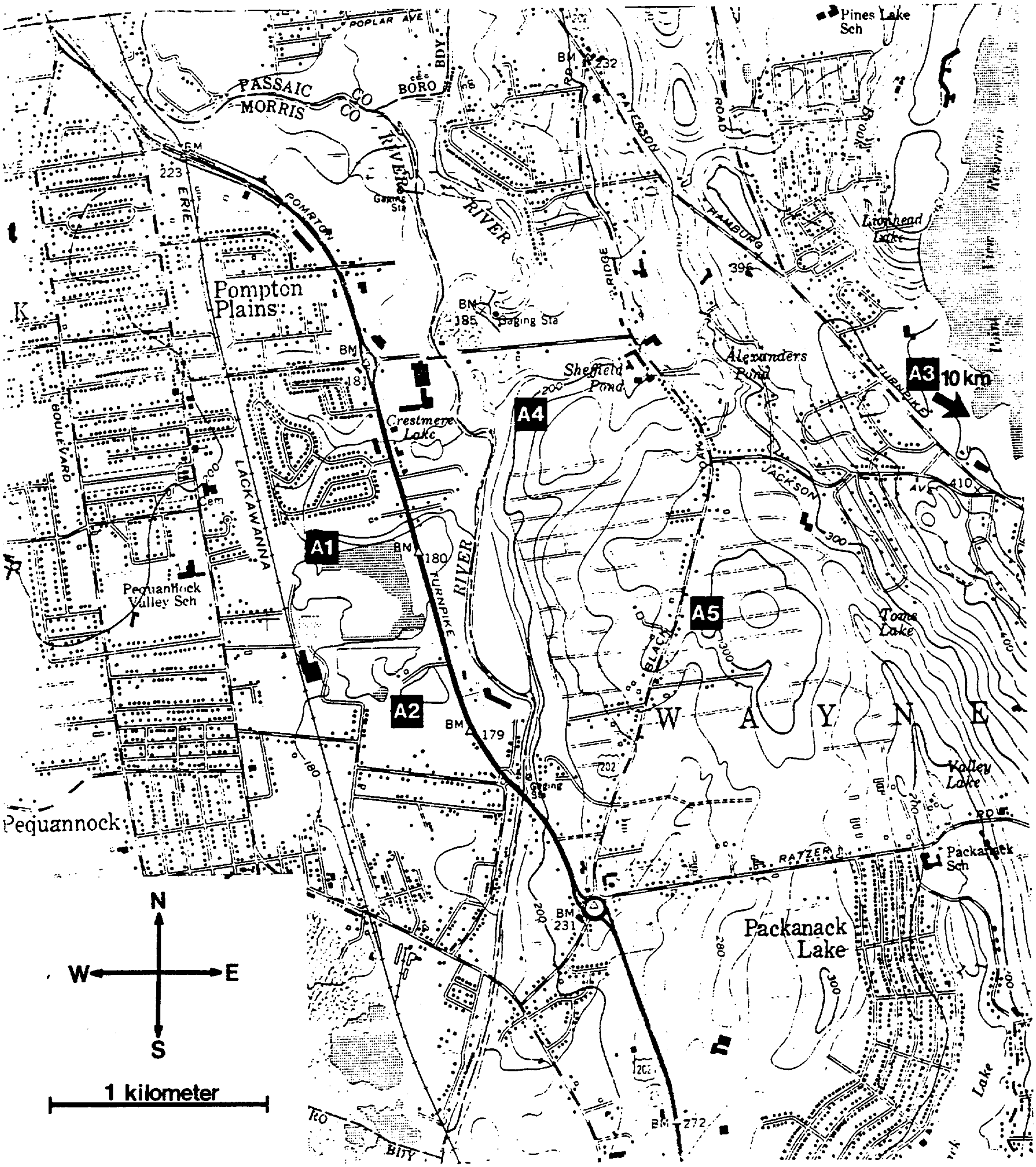


FIGURE 13. Locations of Background Measurements and Baseline Samples in the Wayne-Pompton Plains Area.

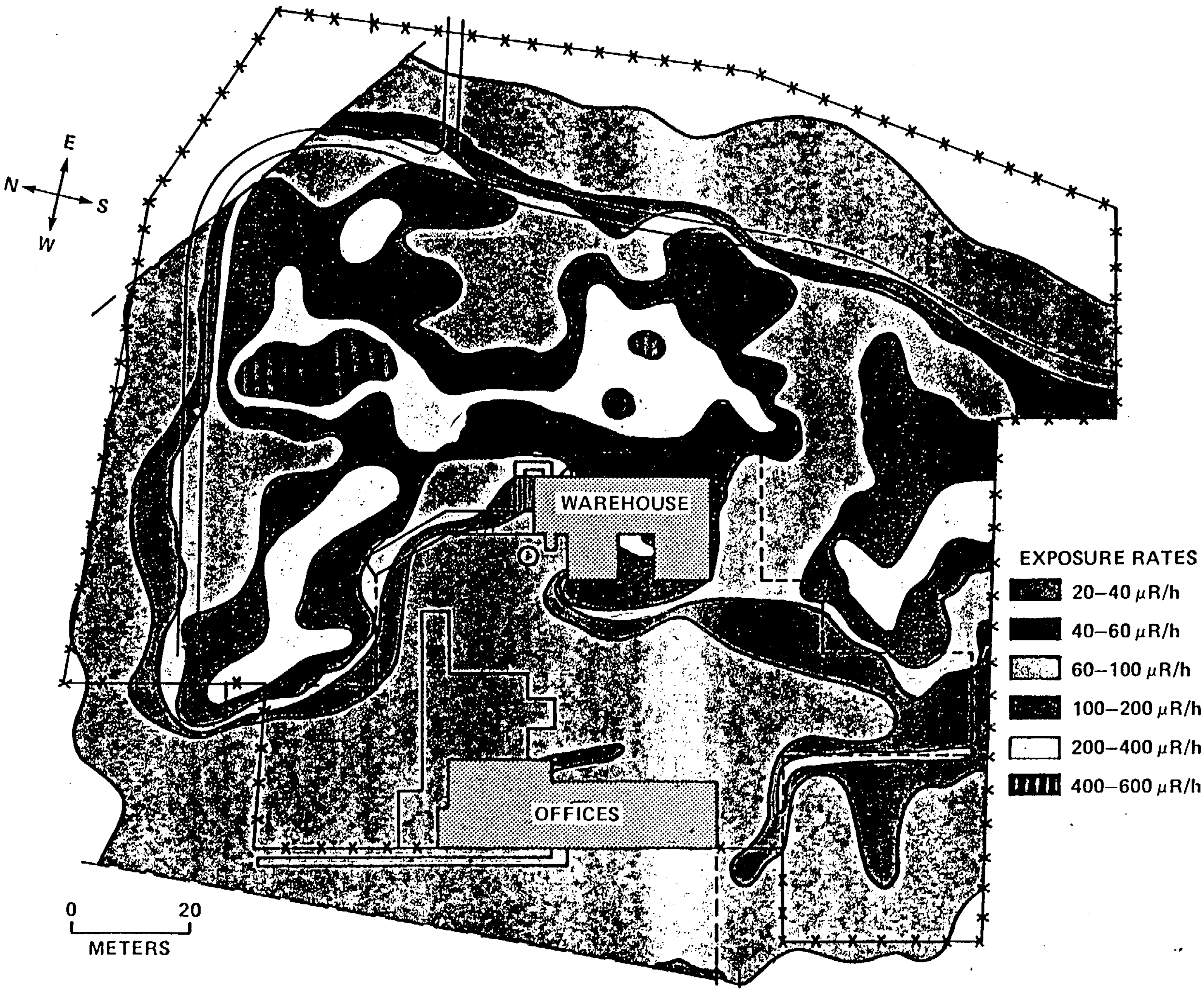


FIGURE 14. Exposure Rates (μR/h) at 1 m Above the Surface on the W.R. Grace Property.

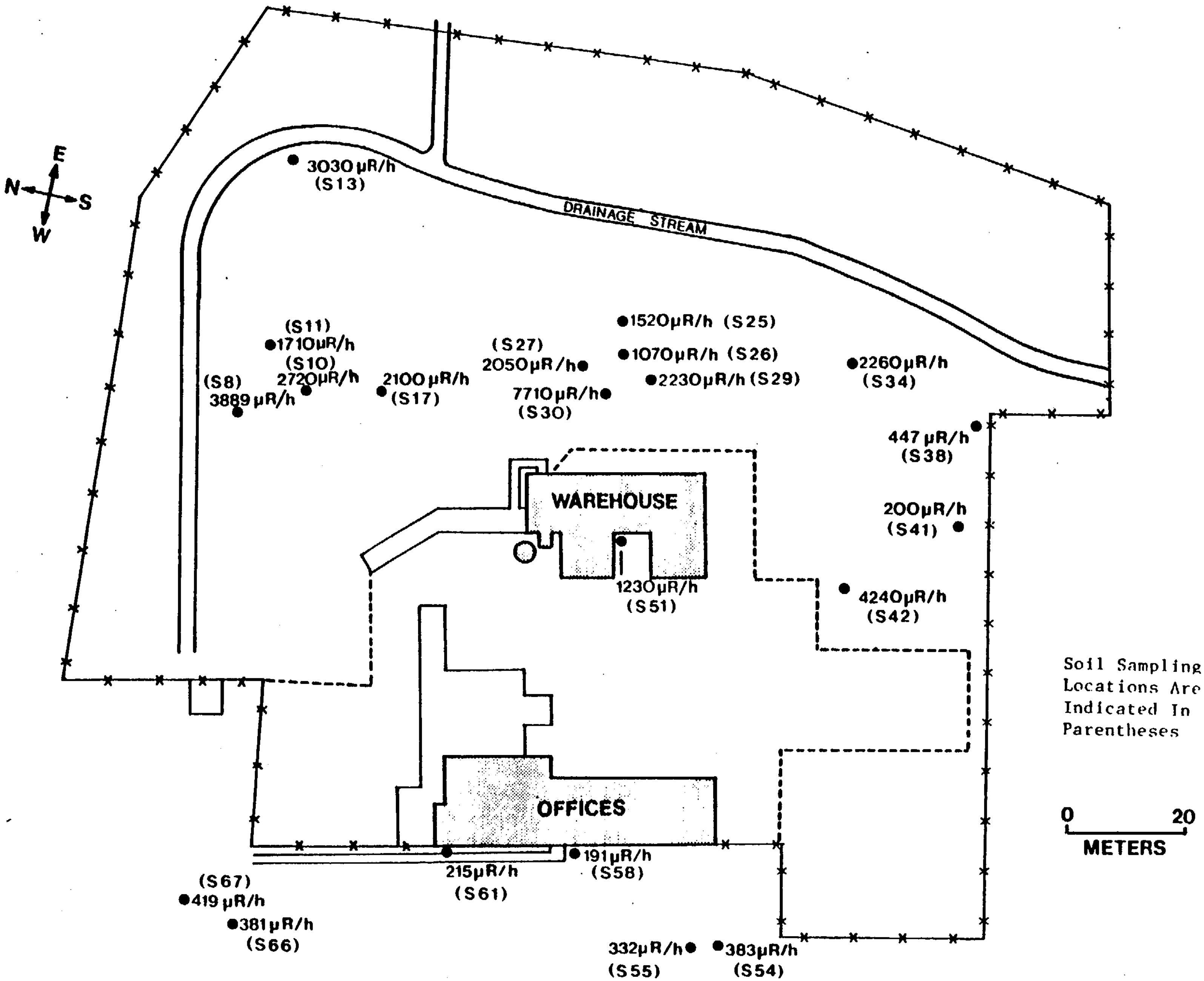


FIGURE 15. Surface Exposure Rates at Sampling Locations of Biased Surface Soil Samples.

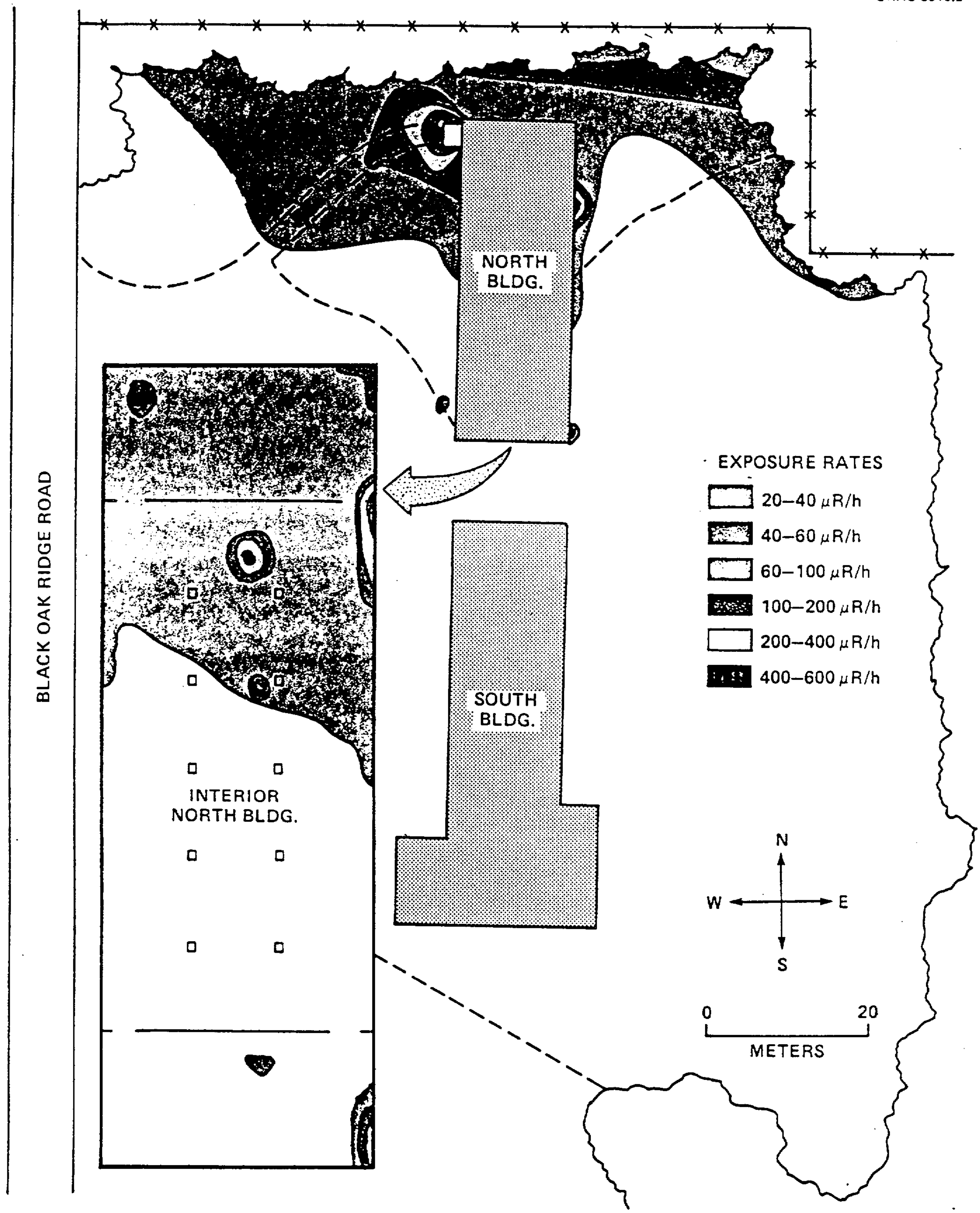


FIGURE 16: Surface Exposure Rates (μR/h) on the School Bus Maintenance Yard.

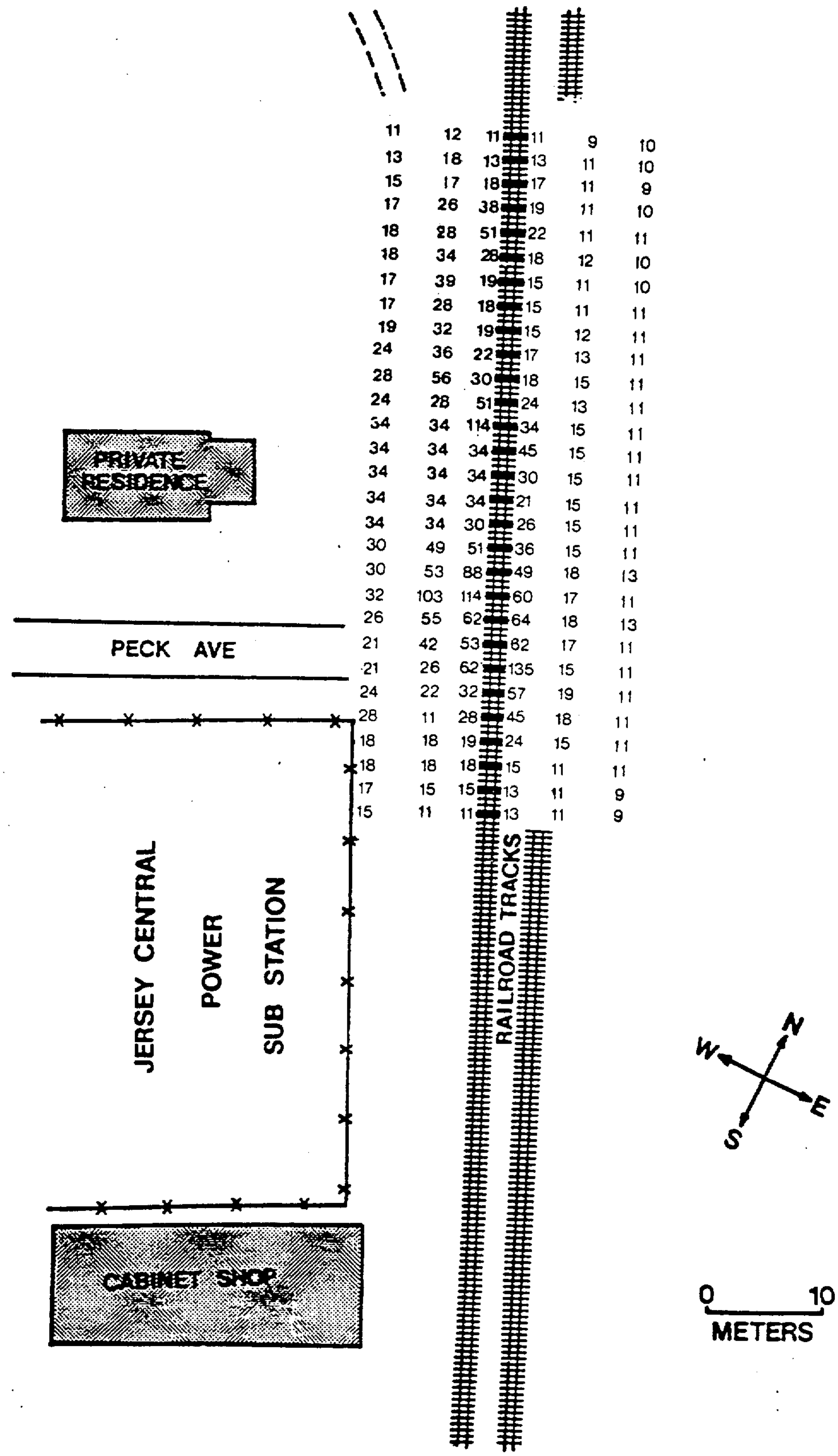


FIGURE 17. Exposure Rates (μR/h) at 1 m Above the Surface Along the Erie Lackawanna Railroad in Pompton Plains.

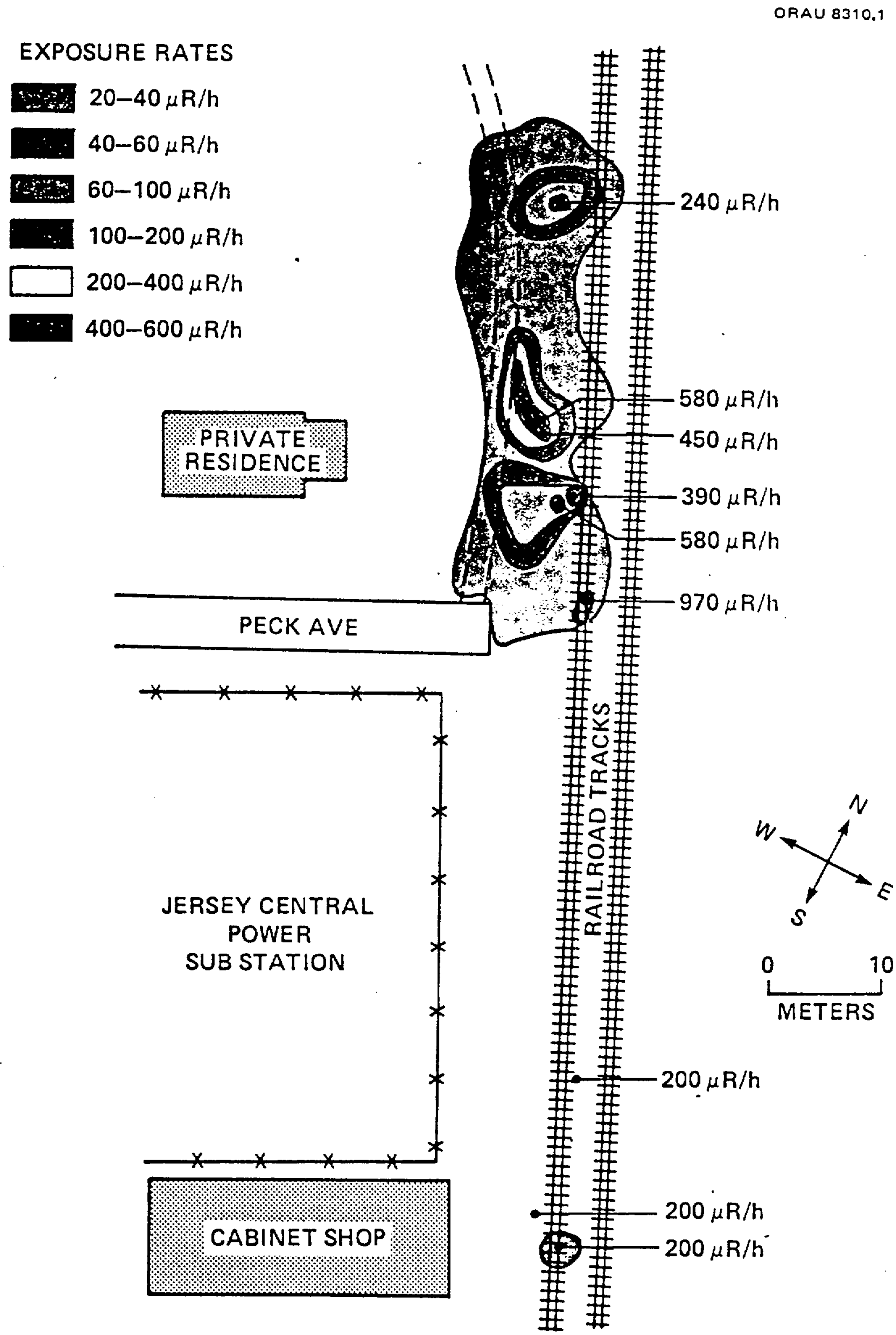


FIGURE 18. Surface Exposure Rates (μR/h) Along the Erie Lackawanna Railroad in Pompton Plains.

TABLE 1-A

RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL AND VEGETATION SAMPLES

Sample Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
Soil:					
A1 - P.V. Park	surface	0.51 + 0.23[b]	0.58 ± 0.27	0.47 ± 0.15	<MDA[c]
	30	0.72 ± 0.22	0.80 ± 0.21	0.47 ± 0.22	"
	60	0.69 ± 0.21	0.69 ± 0.21	0.49 ± 0.13	"
	90	0.45 ± 0.33	0.54 ± 0.17	0.50 ± 0.16	"
A2 - McDonald Park	surface	0.69 ± 0.25	0.56 ± 0.23	0.45 ± 0.17	"
	30	1.00 ± 0.25	0.71 ± 0.30	0.58 ± 0.20	"
	60	0.56 ± 0.23	0.59 ± 0.18	0.37 ± 0.12	"
	90	0.72 ± 0.24	0.66 ± 0.21	0.40 ± 0.19	"
A3 - Orth Ave.	surface	1.36 ± 0.33	1.60 ± 0.31	1.13 ± 0.26	"
	30	1.17 ± 0.23	1.39 ± 0.19	1.34 ± 0.17	"
	60	1.18 ± 0.24	1.31 ± 0.19	1.11 ± 0.17	"
A4 - Farmingdale Rd.	surface	0.92 ± 0.32	1.00 ± 0.26	1.12 ± 0.25	"
	30	1.00 ± 0.29	1.21 ± 0.28	1.05 ± 0.21	"
A5 - Black Oak Ridge Road	surface	0.85 ± 0.30	0.70 ± 0.21	0.85 ± 0.20	"
	30	0.91 ± 0.29	0.73 ± 0.22	0.65 ± 0.18	"
Vegetation:					
A1 - P.V. Park		<0.10	0.29 ± 0.13	<0.06	"
A2 - McDonald Park		0.39 ± 0.18	0.31 ± 0.14	0.21 ± 0.15	"

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics.
[c] MDA levels for U-238 ranged between 2 and 5 pCi/g.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations in Water (pCi/l or x 10^{-9} μCi/ml)									
	Gross Alpha	Gross Beta	Th-228	Th-230	Th-232	Ra-226	Ra-228	U-234	U-235	U-238
A1 P.V. Park	0.95 ± 1.20[b]	<1.3	0.10 ± 0.07	0.07 ± 0.03	<0.05	0.09 ± 0.08	<0.63	0.19 ± 0.03	<0.05	0.13 ± 0.03
A2 McDonald Park	<2.28	<3.6	<0.05	<0.05	<0.05	---[c]	---	0.12 ± 0.03	<0.05	0.09 ± 0.02
A6 City Water	<1.56	<3.7	<1	<1	<1	<0.07	1.12 ± 0.65	<1	<1	<1

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics only.
[c] Dash indicates analysis not performed.

TABLE 2

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S1	2.17 ± 0.42[b]	2.06 ± 0.36	0.68 ± 0.25	<3.81
S2	3.00 ± 0.55	3.35 ± 0.46	1.09 ± 0.28	<3.08
S3	1.95 ± 0.39	1.88 ± 0.31	0.91 ± 0.24	<3.46
S4	10.4 ± 0.8	9.59 ± 0.65	1.29 ± 0.35	<5.52
S5	1.18 ± 0.42	0.96 ± 0.26	0.60 ± 0.18	<3.22
S6	69.5 ± 2.4	69.1 ± 2.1	4.01 ± 0.90	33.4 ± 0.9
S7	41.4 ± 1.6	36.7 ± 1.3	4.82 ± 0.67	28.3 ± 0.8
S8[c]	2250 ± 20	1670 ± 10	13.2 ± 5.1	423 ± 2
S9	368 ± 5	353 ± 5	10.9 ± 1.8	114 ± 1
S10	2240 ± 20	1830 ± 20	39.0 ± 6.1	173 ± 2
S11	1920 ± 20	1450 ± 10	48.5 ± 7.0	401 ± 2
S12	73.8 ± 2.0	69.0 ± 1.7	3.05 ± 0.75	<9.42
S13	2710 ± 20	1540 ± 10	13.6 ± 6.5	109 ± 1
S14	23.5 ± 1.1	19.7 ± 0.9	0.85 ± 0.42	<5.40
S15	21.6 ± 1.0	18.7 ± 0.9	1.31 ± 0.39	<5.56
S16	66.3 ± 2.1	54.5 ± 1.8	5.10 ± 0.93	34.5 ± 0.8
S17	1010 ± 10	729 ± 8	18.2 ± 4.1	172 ± 1
S18	269 ± 4	214 ± 3	10.2 ± 1.4	<17.7
S19	77.2 ± 2.1	69.0 ± 1.7	4.99 ± 0.79	10.7 ± 0.7
S20	24.8 ± 1.4	24.7 ± 1.0	1.03 ± 0.41	3.13 ± 0.50
S21	74.0 ± 2.1	70.8 ± 1.7	7.46 ± 0.42	16.2 ± 0.7
S22	33.1 ± 1.5	29.1 ± 1.0	1.16 ± 0.44	<6.41
S23	16.6 ± 1.1	17.5 ± 1.0	2.62 ± 0.52	<6.06
S24	9.69 ± 0.89	8.74 ± 0.77	3.94 ± 0.48	<6.57
S25	1190 ± 10	931 ± 8	360 ± 7	<70.5
S26	1330 ± 10	1440 ± 10	710 ± 6	61.0 ± 1.0
S27	1200 ± 10	899 ± 13	87.2 ± 5.9	90.7 ± 1.1
S28	206 ± 3	171 ± 3	15.0 ± 1.3	33.4 ± 0.8
S29	1630 ± 30	1760 ± 20	586 ± 15	116 ± 1
S30	4500 ± 30	3040 ± 20	159 ± 11	144 ± 1
S31	1000 ± 10	869 ± 5	114 ± 4	61.1 ± 0.8
S32	63.5 ± 1.9	58.0 ± 1.6	5.02 ± 0.77	<0.97
S33	9.83 ± 0.89	9.51 ± 0.70	1.56 ± 0.03	<5.29
S34	2740 ± 30	2700 ± 30	646 ± 12.	35.7 ± 0.9
S35	109 ± 3	115 ± 2	13.2 ± 1.1	<12.0
S36	1850 ± 20	2300 ± 20	591 ± 12	47.7 ± 0.9
S37	18.5 ± 1.6	18.9 ± 0.65	1.29 ± 0.35	<5.52
S38	558 ± 5	479 ± 5	56.0 ± 2.6	<28.7
S39	101 ± 2	98.8 ± 2.0	9.85 ± 1.00	16.0 ± 0.8
S40	32.6 ± 1.6	31.6 ± 1.2	3.62 ± 0.62	<7.98
S41	216 ± 4	253 ± 3	32.1 ± 1.6	<17.7
S42	2220 ± 30	2090 ± 30	705 ± 16	75.4 ± 1.2
S43	82.7 ± 2.3	84.8 ± 2.0	11.6 ± 1.0	<11.4

TABLE 2, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S44	94.8 ± 2.7	88.5 ± 2.1	4.21 ± 0.89	14.6 ± 0.7
S45	41.4 ± 1.7	41.7 ± 1.5	6.30 ± 0.80	<9.22
S46	172 ± 3	170 ± 2	21.0 ± 1.3	<15.4
S47	3.65 ± 0.61	3.42 ± 0.56	0.92 ± 0.31	<3.76
S48	2.79 ± 0.48	3.10 ± 0.42	0.99 ± 0.24	<3.15
S49	1.63 ± 0.42	1.86 ± 0.38	0.86 ± 0.22	<3.63
S50	1.81 ± 0.42	1.89 ± 0.36	0.81 ± 0.24	<3.30
S51	212 ± 3	211 ± 3	20.5 ± 1.4	14.5 ± 0.6
S52	5.57 ± 0.59	5.89 ± 0.51	0.84 ± 0.28	<3.61
S53	3.81 ± 0.51	4.35 ± 0.45	0.96 ± 0.29	<4.07
S54	438 ± 7	394 ± 6	14.7 ± 2.5	37.4 ± 0.8
S55	547 ± 5	431 ± 4	15.5 ± 2.2	39.2 ± 0.9
S56	26.2 ± 1.2	23.4 ± 1.0	4.86 ± 0.56	<6.76
S57	6.60 ± 0.70	7.56 ± 0.61	0.71 ± 0.30	<4.17
S58	26.5 ± 1.2	24.7 ± 1.0	1.33 ± 0.42	<5.61
S59	4.95 ± 0.58	4.88 ± 0.53	0.77 ± 0.31	<4.29
S60	10.6 ± 0.8	8.19 ± 0.62	1.10 ± 0.34	<4.28
S61	101 ± 2	104 ± 2	15.3 ± 1.1	<11.9
S62	6.63 ± 0.71	6.59 ± 0.50	0.97 ± 0.33	<3.97
S63	7.41 ± 0.64	6.86 ± 0.55	0.88 ± 0.29	<3.65
S64	7.57 ± 0.82	7.87 ± 0.62	1.16 ± 0.34	<4.41
S65	9.78 ± 0.79	8.88 ± 0.66	1.31 ± 0.37	<5.34
S66	207 ± 3	192 ± 3	8.31 ± 1.32	42.0 ± 0.9
S67	321 ± 4	269 ± 4	8.63 ± 1.52	52.8 ± 44.5

[a] Refer to Figure 7.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location[a]	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B1	Surface	4.36 ± 0.59[b]	4.22 ± 0.48	1.20 ± 0.25	<4.67
	0.5	1.12 ± 0.34	1.18 ± 0.24	0.62 ± 0.19	<2.62
	0.75	0.96 ± 0.25	1.09 ± 0.23	0.88 ± 0.18	<2.53
B2	Surface	5.41 ± 0.65	5.34 ± 0.51	1.34 ± 0.31	<4.51
	0.5	1.14 ± 0.36	0.96 ± 0.25	0.74 ± 0.16	<2.59
	1.0	0.96 ± 0.26	0.93 ± 0.26	0.70 ± 0.17	<1.86
B3	Surface	5.31 ± 0.73	6.17 ± 0.65	2.29 ± 0.48	<5.45
	0.5	1.44 ± 0.31	1.35 ± 0.29	1.01 ± 0.20	1.49 ± 0.52
	0.75	1.05 ± 0.29	1.05 ± 0.23	0.64 ± 0.17	<2.69
B4	Surface	3.45 ± 0.67	3.76 ± 0.57	1.30 ± 0.34	<4.73
	0.5	0.99 ± 0.24	1.10 ± 0.21	0.72 ± 0.17	<2.62
B5	Surface	4.19 ± 0.66	4.40 ± 0.53	1.39 ± 0.36	1.54 ± 0.57
	0.5	1.54 ± 0.42	2.07 ± 0.32	1.14 ± 0.24	<2.76
B6	Surface	1.67 ± 0.30	1.73 ± 0.26	0.88 ± 0.20	<2.81
	0.5	1.43 ± 0.37	1.45 ± 0.27	1.35 ± 0.22	<2.34
	1.0	1.32 ± 0.32	1.38 ± 0.31	1.03 ± 0.20	<3.56
B7	Surface	1.46 ± 0.49	1.20 ± 0.33	0.79 ± 0.23	<1.93
	0.5	0.89 ± 0.25	0.87 ± 0.27	0.69 ± 0.18	<2.93
	0.75	0.84 ± 0.27	0.91 ± 0.21	0.59 ± 0.16	<2.61
B8	Surface	1.47 ± 0.38	1.41 ± 0.29	1.12 ± 0.24	<3.17
	0.5	1.62 ± 0.43	1.68 ± 0.35	1.63 ± 0.28	<2.95
	1.0	1.53 ± 0.37	1.45 ± 0.35	1.12 ± 0.24	<3.38
B9	Surface	1.91 ± 0.33	1.59 ± 0.31	0.65 ± 0.21	<3.22
	0.5	2.38 ± 0.44	2.43 ± 0.35	0.93 ± 0.23	<3.33
	1.0	4.98 ± 0.51	4.92 ± 0.48	0.89 ± 0.26	5.54 ± 0.52
B10	Surface	39.7 ± 1.3	30.0 ± 1.0	2.17 ± 0.54	<6.95
	0.5	31.9 ± 1.2	25.3 ± 0.9	1.15 ± 0.38	16.6 ± 0.5
	2.4	1.90 ± 0.34	1.54 ± 0.30	0.79 ± 0.20	18.4 ± 0.6
B11[c]	Surface	258 ± 3	227 ± 3	14.4 ± 1.4	29.5 ± 0.7
	0.5	196 ± 3	181 ± 3	8.35 ± 1.26	35.0 ± 0.9
	0.75	191 ± 3	182 ± 3	7.08 ± 1.19	53.0 ± 0.9

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B12	Surface	56.8 ± 1.6	45.5 ± 1.3	3.60 ± 0.61	11.1 ± 0.6
	0.5	10.6 ± 0.9	8.64 ± 0.60	2.29 ± 0.35	15.4 ± 0.6
B13	Surface	13.8 ± 0.9	12.8 ± 0.8	2.57 ± 0.49	8.8 ± 0.6
	0.5	4.41 ± 0.53	4.78 ± 0.44	1.24 ± 0.27	<4.16
	1.0	5.08 ± 0.55	4.84 ± 0.52	0.91 ± 0.24	<3.93
	2.0	1.20 ± 0.28	1.43 ± 0.27	0.80 ± 0.21	<2.62
B14	Surface	10.9 ± 1.0	11.2 ± 0.6	2.79 ± 0.41	9.19 ± 0.55
	0.5	6.45 ± 0.58	5.73 ± 0.48	2.32 ± 0.34	4.77 ± 0.51
	1.0	6.80 ± 0.58	5.86 ± 0.48	2.59 ± 0.34	<4.84
B15	Surface	3970 ± 30	4000 ± 30	296 ± 16	910 ± 4
	0.5	702 ± 22	785 ± 15	477 ± 11	559 ± 3
	1.0	4650 ± 30	5150 ± 30	782 ± 19	653 ± 3
B16	Surface	1750 ± 10	1860 ± 10	930 ± 9	205 ± 1
	0.5	565 ± 8	637 ± 9	370 ± 6	185 ± 1
	1.0	366 ± 7	392 ± 5	171 ± 4	123 ± 1
B17	Surface	6.21 ± 0.60	6.02 ± 0.57	1.41 ± 0.32	41.0 ± 0.8
	0.5	33.4 ± 1.6	30.5 ± 1.1	11.8 ± 0.7	30.2 ± 0.6
	1.0	88.6 ± 2.1	55.7 ± 1.5	5.02 ± 0.79	40.1 ± 0.8
B18	Surface	23.5 ± 1.1	18.0 ± 0.9	4.41 ± 0.55	40.4 ± 0.7
	0.5	17.8 ± 1.0	15.3 ± 0.8	4.32 ± 0.45	26.2 ± 0.6
	1.0	36.0 ± 1.3	23.8 ± 1.0	4.32 ± 0.56	16.4 ± 0.6
B19	Surface	13.1 ± 0.80	10.4 ± 0.6	1.53 ± 0.32	<4.71
	0.5	<2.59	<0.75	<1.17	<42.9
	1.0	9.37 ± 0.82	10.0 ± 0.7	1.69 ± 0.39	10.5 ± 0.5
	1.5	3.45 ± 0.41	3.21 ± 0.35	1.02 ± 0.22	3.46 ± 0.50
	2.0	1.23 ± 0.29	1.23 ± 0.23	0.83 ± 0.19	<2.60
	2.5	1.09 ± 0.28	1.06 ± 0.22	0.81 ± 0.21	<2.39
	4.8	17.9 ± 1.0	17.1 ± 0.9	1.51 ± 0.41	4.62 ± 0.50
B20	Surface	195 ± 3	135 ± 2	5.83 ± 0.97	<12.3
	0.5	990 ± 11	933 ± 9	27.4 ± 4.6	<68.7
	1.7	842 ± 8	617 ± 8	16.2 ± 3.1	248 ± 85
B21	Surface	206 ± 3	212 ± 4	14.0 ± 1.5	39.6 ± 0.8
	0.3	406 ± 7	376 ± 6	14.6 ± 2.5	<34.0
	1.7	616 ± 9	355 ± 5	<1.26	<39.3

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B22	Surface	595 ± 8	568 ± 9	59.4 ± 4.1	<51.9
	0.5	7570 ± 50	7840 ± 40	1760 ± 20	180 ± 1
B23	Surface	106 ± 4	118 ± 3	48.2 ± 2.0	<18.7
	0.5	69.6 ± 3.1	75.5 ± 2.2	38.9 ± 1.4	<15.2
	1.0	169 ± 5	189 ± 4	115 ± 3	<24.4
B24	Surface	643 ± 9	589 ± 6	253 ± 5	<49.7
	0.5	430 ± 4	458 ± 4	200 ± 3	18.9 ± 0.7
	1.0	293 ± 4	436 ± 4	79.8 ± 2.1	45.7 ± 0.8
B25	Surface	47.2 ± 1.6	41.6 ± 1.3	8.16 ± 0.73	<8.08
	0.5	31.8 ± 1.5	27.8 ± 1.0	5.99 ± 0.63	<6.56
	1.0	2.95 ± 0.42	3.04 ± 0.32	1.11 ± 0.22	<2.89
	2.0	1.32 ± 0.33	1.38 ± 0.26	0.89 ± 0.20	<3.13
B26	Surface	14.6 ± 0.8	15.0 ± 0.7	7.27 ± 0.53	0.74 ± 0.53
	0.5	18.2 ± 1.0	17.1 ± 0.8	9.74 ± 0.61	<5.84
	1.0	8200 ± 500	7660 ± 500	101 ± 146	106 ± 2
B27	Surface	34.2 ± 1.8	31.9 ± 1.7	3.49 ± 0.80	<9.73
	0.6	3190 ± 20	3160 ± 20	555 ± 14	44.4 ± 1.1
B28	Surface	21.4 ± 1.2	21.7 ± 1.0	4.13 ± 0.56	<6.52
	0.5	9.24 ± 0.72	10.3 ± 0.6	6.51 ± 0.45	2.68 ± 0.48
	1.0	0.91 ± 0.22	0.96 ± 0.19	0.59 ± 0.14	<2.24
	1.5	0.85 ± 0.25	0.96 ± 0.25	0.61 ± 0.18	<2.27
	3.2	4.34 ± 0.56	4.14 ± 0.50	1.23 ± 0.36	<4.18
B29	Surface	184 ± 3	150 ± 3	20.5 ± 1.3	<14.9
	0.5	390 ± 5	347 ± 4	41.6 ± 2.0	46.2 ± 0.8
	1.0	1150 ± 10	808 ± 7	84.5 ± 4.6	79.8 ± 1.0
	3.9	14800 ± 700	15700 ± 600	1450 ± 300	110 ± 1
B30	Surface	46.9 ± 1.5	44.4 ± 1.3	5.33 ± 0.67	<7.02
	1.0	3080 ± 30	2380 ± 20	343 ± 12	53.1 ± 1.0
B31	Surface	26.8 ± 1.1	30.0 ± 1.0	3.43 ± 0.53	<5.88
	0.5	10.7 ± 0.9	13.5 ± 0.6	1.67 ± 0.32	<4.33
	1.0	4.82 ± 0.49	5.95 ± 0.53	0.90 ± 0.28	<3.42
	4.8	35.2 ± 1.4	35.0 ± 1.2	3.76 ± 0.49	<6.67

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B32	Surface	23.1 ± 1.0	26.4 ± 0.9	3.89 ± 0.48	<5.83
	0.5	309 ± 3	254 ± 3	23.9 ± 1.5	26.3 ± 0.7
B33	Surface	47.6 ± 1.6	49.3 ± 1.4	8.42 ± 0.76	<9.02
	0.5	26.7 ± 1.1	24.3 ± 0.9	3.02 ± 0.51	<5.83
	5.4	3.91 ± 0.45	3.60 ± 0.37	1.19 ± 0.27	<3.32
B34	Surface	171 ± 3	178 ± 3	26.5 ± 1.6	<17.9
	0.3	55.1 ± 2.0	57.1 ± 1.5	7.47 ± 0.79	<9.19
	0.5	62.0 ± 1.8	67.3 ± 1.6	11.2 ± 0.8	<9.57
B35	Surface	1.58 ± 0.34	1.48 ± 0.30	0.89 ± 0.22	<3.33
	0.5	2.02 ± 0.38	1.77 ± 0.31	0.81 ± 0.21	<3.32
	1.0	2.01 ± 0.41	2.13 ± 0.29	0.83 ± 0.22	<2.64
	2.0	1.04 ± 0.39	1.21 ± 0.23	0.70 ± 0.17	<2.86
	3.0	1.50 ± 0.30	1.30 ± 0.24	0.81 ± 0.18	<2.59
	6.3	1.27 ± 0.36	1.20 ± 0.28	0.96 ± 0.22	<3.55
B36	Surface	28.0 ± 1.5	29.5 ± 1.1	3.35 ± 0.53	<6.43
	0.5	1.04 ± 0.35	1.21 ± 0.31	0.70 ± 0.22	<2.79
	1.0	1.10 ± 0.29	1.15 ± 0.25	0.62 ± 0.17	<2.78
	2.0	1.35 ± 0.28	1.26 ± 0.24	0.60 ± 0.16	<3.10
	2.5	1.51 ± 0.31	1.21 ± 0.25	0.74 ± 0.18	<2.76
B37	Surface	114 ± 1	112 ± 2	17.3 ± 0.7	18.7 ± 0.6
	0.5	60.4 ± 1.3	61.6 ± 1.1	28.5 ± 0.7	15.9 ± 0.7
B38	Surface	1.98 ± 0.35	1.85 ± 0.34	1.14 ± 0.19	<2.60
	2.0	1.35 ± 0.29	1.41 ± 0.24	0.84 ± 0.19	<0.10
B39	Surface	2.05 ± 0.32	1.91 ± 0.27	0.81 ± 0.18	<2.76
	2.0	2.50 ± 0.38	2.22 ± 0.30	0.92 ± 0.21	<2.90
B40	Surface	2.75 ± 0.42	2.53 ± 0.32	0.79 ± 0.23	<2.60
	0.5	0.88 ± 0.36	1.01 ± 0.29	0.61 ± 0.20	<3.66
	1.8	0.40 ± 0.35	0.55 ± 0.24	0.53 ± 0.15	<2.57
B41	Surface	2.23 ± 0.40	2.24 ± 0.12	0.59 ± 0.20	<3.45
	0.5	1.03 ± 0.35	1.18 ± 0.25	0.61 ± 0.17	<3.09
	1.8	0.67 ± 0.22	0.71 ± 0.23	0.52 ± 0.18	<2.85

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B42	Surface	2.34 ± 0.42	4.22 ± 0.37	0.66 ± 0.20	<3.07
	0.5	2.29 ± 0.35	3.91 ± 0.36	0.78 ± 0.20	<3.19
	1.0	0.66 ± 0.23	2.51 ± 0.30	0.58 ± 0.14	<2.93
	1.5	0.76 ± 0.25	2.37 ± 0.27	0.40 ± 0.14	<2.09
	3.3	2.26 ± 0.35	5.66 ± 0.40	0.60 ± 0.22	<2.63
B43	Surface	12.9 ± 0.8	17.5 ± 0.8	1.64 ± 0.36	<5.23
	0.5	0.82 ± 0.25	3.22 ± 0.32	0.58 ± 0.18	<2.42
	1.0	1.07 ± 0.30	2.55 ± 0.29	0.58 ± 0.20	<2.60
	3.6	7.04 ± 0.58	8.43 ± 0.55	0.79 ± 0.27	1.38 ± 0.47

[a] Refer to Figure 10.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES

Sample Location[a]	Description	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
D1	Drainage Stream	5.28 ± 0.72[b]	5.04 ± 0.56	1.70 ± 0.35	<4.46
D2	Drainage Stream	2.29 ± 0.55	1.77 ± 0.43	0.51 ± 0.31	<4.05
D3	Drainage Stream	4.72 ± 0.64	2.75 ± 0.43	0.76 ± 0.39	<3.84
D4	Drainage Stream	2.03 ± 0.32	1.73 ± 0.31	0.63 ± 0.20	<2.61
D5	Drainage Tile	5.12 ± 0.46	4.70 ± 0.39	1.31 ± 0.24	<3.22
D6	Drainage Tile	9.17 ± 0.78	9.78 ± 0.59	1.77 ± 0.32	<4.14
D7	Drainage Tile	18.0 ± 1.0	19.1 ± 0.9	3.04 ± 0.47	<6.34
D8	Storm Sewer	16.8 ± 1.0	17.5 ± 0.8	3.65 ± 0.48	6.03 ± 0.51
D9	Storm Sewer	23.4 ± 1.0	25.2 ± 0.9	3.89 ± 0.47	13.6 ± 0.6
D10	Storm Sewer	43.2 ± 1.5	38.7 ± 1.2	4.12 ± 0.61	19.9 ± 0.7
D11	Storm Sewer	24.7 ± 1.3	24.4 ± 1.0	3.67 ± 0.51	<6.36
D12	Storm Sewer	383 ± 4	327 ± 3	30.2 ± 1.8	24.5 ± 0.8
D13	Storm Sewer	78.2 ± 1.9	70.0 ± 1.6	5.37 ± 0.77	12.7 ± 0.6
D14	Storm Sewer	951 ± 6	866 ± 5	101 ± 3	46.9 ± 1.0
D15	Storm Sewer	10.9 ± 0.8	9.57 ± 0.63	1.49 ± 0.33	<4.26

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μC/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
W1	7.21 ± 5.69[b]	4.83 ± 7.38	<0.18	0.03 ± 0.03
W2	3.29 ± 4.97	<4.95	c	<0.03
W3	<3.19	<5.00	<0.18	0.11 ± 0.03

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.
[c] Analysis not performed.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN STORM SEWER WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μCi/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
D10	12.8 ± 5.4[b]	36.1 ± 6.2	1.68 ± 0.20	0.10 ± 0.04
D11	28.6 ± 29.8	60.8 ± 40.3	6.59 ± 0.57	0.19 ± 0.04
D12	17.9 ± 15.7	47.8 ± 18.2	14.2 ± 0.4	0.86 ± 0.08
D13	5.33 ± 7.45	13.4 ± 8.5	8.55 ± 0.42	0.40 ± 0.06
D15	17.5 ± 5.1	26.0 ± 5.3	10.0 ± 0.6	0.15 ± 0.04

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN ON-SITE VEGETATION SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V1	1.00 ± 0.22[b]	0.26 ± 0.17	0.35 ± 0.12	<2.63
V2	1.04 ± 0.15	0.32 ± 0.09	0.07 ± 0.06	<1.22
V3	2.19 ± 0.25	0.48 ± 0.15	0.11 ± 0.10	<2.07
V4	2.15 ± 0.26	0.53 ± 0.14	0.40 ± 0.12	<2.04
V5	3.41 ± 0.36	0.59 ± 0.23	0.30 ± 0.16	<2.51

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN
SURFACE SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
S68	1.16 ± 0.31[b]	0.92 ± 0.23	0.69 ± 0.23	1.45 ± 0.52
S69	0.60 ± 0.20	0.64 ± 0.16	0.45 ± 0.17	<1.95
S70	0.78 ± 0.30	0.71 ± 0.22	0.40 ± 0.18	<3.06
S71	0.97 ± 0.27	0.88 ± 0.23	0.49 ± 0.15	<1.93
S72	3.59 ± 0.45	3.62 ± 0.39	0.74 ± 0.25	<3.46
S73	1.22 ± 0.35	1.27 ± 0.29	0.85 ± 0.2	<3.60
S74[c]	227 ± 3	375 ± 4	36.8 ± 1.7	21.2 ± 0.7
S75	75.4 ± 2.2	60.4 ± 1.7	4.85 ± 0.81	19.8 ± 0.7
S76	3.90 ± 0.67	4.17 ± 0.61	1.18 ± 0.38	<4.97
S77	1580 ± 20	1140 ± 10	83.4 ± 6.2	<79.3
S78	319 ± 5	328 ± 6	67.9 ± 2.9	45.4 ± 0.8
S79	8.81 ± 0.80	8.94 ± 0.60	1.63 ± 0.38	<4.70
S80	2.41 ± 0.53	2.41 ± 0.46	1.19 ± 0.36	<5.18
S81	0.97 ± 0.32	1.35 ± 0.25	0.73 ± 0.19	<3.24

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Depth (meter)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B44[c]	Surface	2400 ± 20[b]	1360 ± 10	315 ± 9	2.11 ± 0.46
	0.5	2.38 ± 0.39	2.45 ± 0.37	1.06 ± 0.24	<3.23
	1.0	1.05 ± 0.32	1.03 ± 0.24	0.27 ± 0.21	<3.66
B45	Surface	4.59 ± 0.54	4.71 ± 0.49	1.21 ± 0.27	<3.86
	0.5	1.70 ± 0.34	1.61 ± 0.28	0.89 ± 0.21	<2.80
	0.75	1.28 ± 0.29	1.45 ± 0.28	0.85 ± 0.20	<3.36

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to elevated exposure rates.

TABLE 10

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES FROM THE ERIE LACKAWANNA RAILROAD PROPERTY

Sample Location[a]	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B46[b]	Surface	640 ± 5[c]	639 ± 4	59.4 ± 2.6	45.4 ± 0.8
	0.5	61.6 ± 2.2	67.3 ± 2.0	7.95 ± 0.93	<11.1
	1.0	20.1 ± 1.2	21.7 ± 0.9	2.94 ± 0.46	<5.59
B47	Surface	412 ± 4	401 ± 5	53.0 ± 2.2	49.2 ± 0.9
	0.5	31.1 ± 1.8	31.0 ± 1.2	4.63 ± 0.66	5.55 ± 0.52
B48	Surface	0.85 ± 0.26	0.89 ± 0.23	0.46 ± 0.16	<2.71
	0.5	25.4 ± 1.3	25.0 ± 1.1	4.00 ± 0.56	<7.26
	0.75	12.3 ± 0.9	12.3 ± 0.8	2.75 ± 0.44	<5.06
B49	Surface	1.39 ± 0.3	1.36 ± 0.28	0.59 ± 0.19	<3.09
	0.5	21.3 ± 1.2	21.6 ± 1.0	3.83 ± 0.53	<6.56
	0.75	5.81 ± 0.8	6.97 ± 0.57	2.05 ± 0.37	<4.57
B50	Surface	1.36 ± 0.37	1.09 ± 0.29	0.58 ± 0.22	<2.68
	0.5	4.40 ± 0.54	5.10 ± 0.47	1.48 ± 0.28	<3.66
	0.75	4.53 ± 0.54	5.30 ± 0.48	1.64 ± 0.3	<3.72
B51	Surface	195 ± 4	208 ± 4	28.7 ± 2.00	29.0 ± 0.90
	0.5	3.60 ± 0.45	4.35 ± 0.41	0.91 ± 0.23	<3.48
	1.0	2.80 ± 0.38	2.81 ± 0.36	0.95 ± 0.20	<3.21
B52	Surface	0.76 ± 0.30	0.94 ± 0.24	0.67 ± 0.18	<2.53
	0.5	0.96 ± 0.36	0.90 ± 0.23	0.74 ± 0.21	<2.47
	1.0	0.80 ± 0.27	1.03 ± 0.24	0.76 ± 0.17	<3.59
B53	Surface	0.89 ± 0.26	0.76 ± 0.24	0.49 ± 0.16	<2.53
	0.5	0.94 ± 0.26	1.22 ± 0.26	0.67 ± 0.26	<2.65
	1.0	0.91 ± 0.32	0.92 ± 0.21	0.69 ± 0.16	<2.77
B54	Surface	0.73 ± 0.30	0.83 ± 0.24	0.61 ± 0.21	<2.81
	0.5	0.92 ± 0.36	1.06 ± 0.28	0.65 ± 0.18	<2.83
	1.0	3.51 ± 0.42	4.10 ± 0.37	1.27 ± 0.23	<2.88

[a] Refer to Figure 11.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 11

RADIONUCLIDE CONCENTRATIONS IN VEGETATION SAMPLES
FROM VICINITY OF THE ERIE LACKAWANNA RAILROAD
IN POMPTON PLAINS, NEW JERSEY

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V6[c]	0.28 ± 0.10[b]	0.18 ± 0.08	0.16 ± 0.04	<1.38
V7	0.12 ± 0.07	0.04 ± 0.06	0.05 ± 0.03	<0.88
V8	<0.06	0.24 ± 0.12	<0.03	<1.67

[a] Refer to Figure 11.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

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APPENDIX A

GLOSSARY OF TERMS

Glossary

Activation:	The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles.
Activity:	Radioactivity, the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an unstable nuclide. As a result of this emission, the radioactive material is converted (or decays) into a different nuclide (daughter), which may or may not be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) nuclide is formed.
Aerial survey:	A search for sources of radiation by means of sensitive instruments mounted in a helicopter or airplane. Generally, the instrumentation records the intensity, location, and spectral analysis of the radiation.
Alpha particle:	A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, and hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, and can be stopped by a sheet of paper.
Background radiation:	The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements. It is also called natural radiation. The term may also mean radiation that is unrelated to a specific experiment. Levels vary, depending on location.
Baseline concentration:	The concentration of a given substance typically encountered in the area under consideration, i.e. the normal or naturally occurring level.
Beta particle:	An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.
Contamination:	Undesired radioactive materials that have been deposited on surfaces, are internally ingrained into structures or equipment, or that have been mixed with another material.

Curie: A special unit of activity. One curie equals 3.7×10^{10} nuclear disintegrations per second. Several fractions of the curie are in common usage:

- -- Millicurie - one thousandth of a curie. Abbreviated as mCi.
- -- Microcurie - one millionth of a curie. Abbreviated as μCi.
- -- Nanocurie - one billionth of a curie. Abbreviated as nCi.
- -- Picocurie - one trillionth of a curie. Abbreviated as pCi.

Daughter: The product of radioactive decay of a nuclide. (also see Parent).

Decay, radioactive: The spontaneous transformation of one nuclide into a different nuclide or into a different energy state of the same nuclide. The process results in a decrease, with time, of the number of original radioactive nuclides in a sample. It involves the emission from the nucleus of alpha particles, beta particles, or gamma rays; or the nuclear capture or ejection of orbital electrons; or fission. Also called radioactive disintegration.

Decontamination: Those activities employed to reduce the levels of contamination.

Dose: A measure of the quantity of radiation absorbed in a unit mass of a medium. The unit of dose is the rad.

Dose rate: The radiation dose delivered per unit time and measured, for example, in rads per hours.

Exposure: A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.

Exposure rate: The radiation exposure per unit time. Measured, for example, in roentgens per hour.

Gamma radiation: High-energy, short-wave length electromagnetic radiation of nuclear origin (radioactive decay). Gamma rays are

the most penetrating of the three common types of radiation.

Half-life: The time in which half the atoms of a particular radioactive sustance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Microrad (µrad): A submultiple of the rad, equal to one-millionth of a rad. (see rad).

Microroentgen (µR): A submultiple of the roentgen, equal to one-millionth of a roentgen. (see roentgen).

Millirem (mrem): A submultiple of the rem, equal to one-thousandth of a rem. (see rem).

Natural uranium: Uranium as found in nature, containing 0.7 percent of uranium-235, 99.3 percent of uranium-238. It is also called normal uranium.

Natural thorium: Thorium as found in nature. Natural thorium contains equal activity level of thorium-232 and thorium-228.

Parent: A radionuclide which disintegrates or decays to produce another nuclide which is also radioactive. This second radionuclide is known as the daughter product.

Picocurie (pCi): One-trillionth (10^{-12}) of a curie.

Rad: The unit of absorbed dose. The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. One rad equals 0.01 joules/kilogram of absorbing material.

Radiation: Energetic nuclear particles including neutrons, alpha particles, beta particles, x-rays, and gamma rays (nuclear physics). Also includes electromagnetic waves (radiation) of any origin.

Radioactivity: The property of certain nuclides of spontaneously emitting particles, or gamma radiation. Often shortened to "activity."

Radionuclide: A general term applicable to any radioactive form of the elements, a radioactive nuclide.

Radium (Ra): A radioactive metallic element with atomic number 88. As found in nature, the most common isotope has an atomic weight of 226. It occurs in minute quantities associated with uranium in pitchblende, carnotite, and other minerals; the uranium decays to radium in a series

of alpha and beta emissions. By virtue of being an alpha- and gamma-emitter, radium is used as a source of illuminescence and as a radiation source in medicine and radiography. The isotope of radium with an atomic weight of 228 is found in the thorium decay series.

Radon (Rn): The heaviest element of the noble gases, produced as a gaseous emanation from the radioactive decay of radium. Its atomic number is 86. All isotopes are radioactive. Rn-222 is an isotope with a half-life of 3.82 days.

Rare earths: A group of 15 chemically similar metallic elements, including elements 57 through 71 on the Periodic Table of the Elements, also known as the Lanthanide Series.

Rem: The unit of ionizing radiation that produces the same biological damage to man as a unit of absorbed dose (1 roentgen) of high voltage x-rays.

Roentgen (R): A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying one electrostatic unit of electrical charge (either positive or negative) in one cubic centimeter of dry air under standard conditions.

Secular Equilibrium: The state which prevails when the rate of formation of a radioactive material equals the material's rate of decay. Although, by theory, this condition is never completely achieved, it is essentially established in the thorium decay series as it occurs in nature.

Survey: An evaluation of the radiation hazards incidental to the production, use, or existence of radioactive materials or other sources of radiatiou under a specific set of conditions.

Thorium (Th): A naturally occurring radioactive element with atomic number 90 and, as found in nature, an atomic weight of approximately 232.

Thorium series: The series (sequence) of nuclides resulting from the radioactive decay of thorium-232. Many man-made nuclides decay into this sequence. The end product of the sequence in nature is lead-208.

Uranium (U): A radioactive element with the atomic number 92 and, as found in natural ores, an average atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natual uranium) and uranium-238 (99.3 percent of natural uranium). Natural uranium also includes a minute amount of uranium-234.

Uranium series: The series (sequence) of nuclides resulting from the radioactive decay of uranium-238. The end product of the series is lead-206.

EXPLANATION OF SYMBOLS AND UNITS

Symbols	Unit	English Equivalents
cm	centimeter (x 10^{-2} meters)	0.394 inches
g	gram	0.032 ounces
h	hour	-----
kg	kilogram (x 10^{3} grams)	2.2 pounds
km	kilometer (x 10^{3} meters)	0.622 miles
l	liter	0.264 gallons
m	meter	3.28 feet
ml	milliliter (x 10^{-3} liters)	0.061 cubic in.
mrem	millirem (x 10^{-3} rem)	-----
pCi	picocurie (x 10^{-12} curies)	-----
Ra	Radium	-----
U	Uranium	-----
Th	Thorium	-----
μCi	microcurie (x 10^{-6} curies)	-----
μrad	microrad (x 10^{-6} rads)	-----
μR	microroentgen (x 10^{-6} roentgens)	-----

APPENDIX B

THORIUM AND URANIUM DECAY SERIES

Appendix B

Thorium Decay Series

Parent	Half-Life	Major Decay Products	Daughter
Thorium-232	14 billion years	alpha	Radium-228
Radium-228	5.8 years	beta	Actinium-228
Actinium-228	6.13 hours	beta, gamma	Thorium-228
Thorium-228	1.91 years	alpha	Radium-224
Radium-224	3.64 days	alpha	Radon-220
Radon-220	55 seconds	alpha	Polonium-216
Polonium-216	0.15 seconds	alpha	Lead-212
Lead-212	10.6 hour	beta, gamma	Bismuth-212
Bismuth-212	60.6 minutes	alpha (1/3)* beta (2/3)*	Thallium-208 Polonium-212
Thallium-208	3.1 minutes	beta, gamma	Lead-208
Polonium-212	0.0000003 seconds	alpha	Lead-208
Lead-208	stable	none	none

* Two decay modes are possible for Bismuth-212.

Uranium Decay Series

Parent	Half-Life	Major Decay Products	Daughter
Uranium-238	4.5 billion years	alpha	Thorium-234
Thorium-234	24 days	beta, gamma	Protactinium-234
Protactinium-234	1.2 minutes	beta, gamma	Uranium-234
Uranium-234	250,000 years	alpha	Thorium-230
Thorium-230	80,000 years	alpha	Radium-226
Radium-226	1,600 years	alpha	Radon-222
Radon-222	3.8 days	alpha	Polonium-218
Polonium-218	3 minutes	alpha	Lead-214
Lead-214	27 minutes	beta, gamma	Bismuth-214
Bismuth-214	20 minutes	beta, gamma	Polonium-214
Polonium-214	2/10,000 second	alpha	Lead-210
Lead-210	22 years	beta	Bismuth-210
Bismuth-210	5 days	beta	Polonium-210
Polonium-210	140 days	alpha	Lead-206
Lead-206	stable	none	none

APPENDIX C

GROUND-PENETRATING RADAR SURVEY
OF THE
W.R. GRACE SITE
WAYNE, NEW JERSEY

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1. INTRODUCTION

A ground penetrating radar (GPR) survey was conducted during the week of July 12, 1982 at the W.R. Grace site, Pompton Plains, New Jersey. The survey was performed under contract to the Oak Ridge Associated Universities (ORAU) in support of their assessment of the radiological conditions at the site. The objectives of the GPR Survey were:

1. to define the exact location of burial trenches, and
2. to identify the locations and depths of subsurface objects.

The results of this survey will allow further radiological site assessment to proceed in an efficient manner. These results are discussed in section 5 of this report.

In addition to radar soundings, bulk soil resistivity measurements were made. These measurements aided in the selection of the optimum GPR system parameters, and were used to estimate system capability, particularly depth of penetration, in the site geology.

2. W.R. GRACE SITE DESCRIPTION

Monazite sands were processed at the site in the period from 1948 to 1967 to extract thorium and rare earths. The resulting waste products were buried in shallow excavations as permitted by regulations (10CFR20.304) governing licenses of the Atomic Energy Commission.

The site, which occupies approximately 2.6 hectares, is located on Black Oak Ridge Road 1.5 miles north of Wayne, New Jersey, in a residential and light commercial district. Three main buildings are located on the west side of the property, which is mostly paved for parking and loading facilities. The burial area on the eastern part is open land covered with weeds and a few small trees, having a gradual downward slope from east to west. A small stream courses north along the eastern boundary and loops west to exit the property at the north west corner. A few isolated piles of debris are the only visible evidence of disposal activity. A tall chain link fence encompasses the site.

A grid system, shown in Figure 1, was established on the site based on 20 meter centers identified by lettered and numbered markers. In the burial area these were wooden stakes driven into the ground. In the paved areas, bench nails were used. The lettered rows, A+10m through G+18m, ran north-south with row A+10m at the western edge. Subsequent rows progressed alphabetically toward the east. Numbered rows, -1 through 7, ran east-west with numbers increasing towards the north. This grid gave comprehensive coverage of the property.

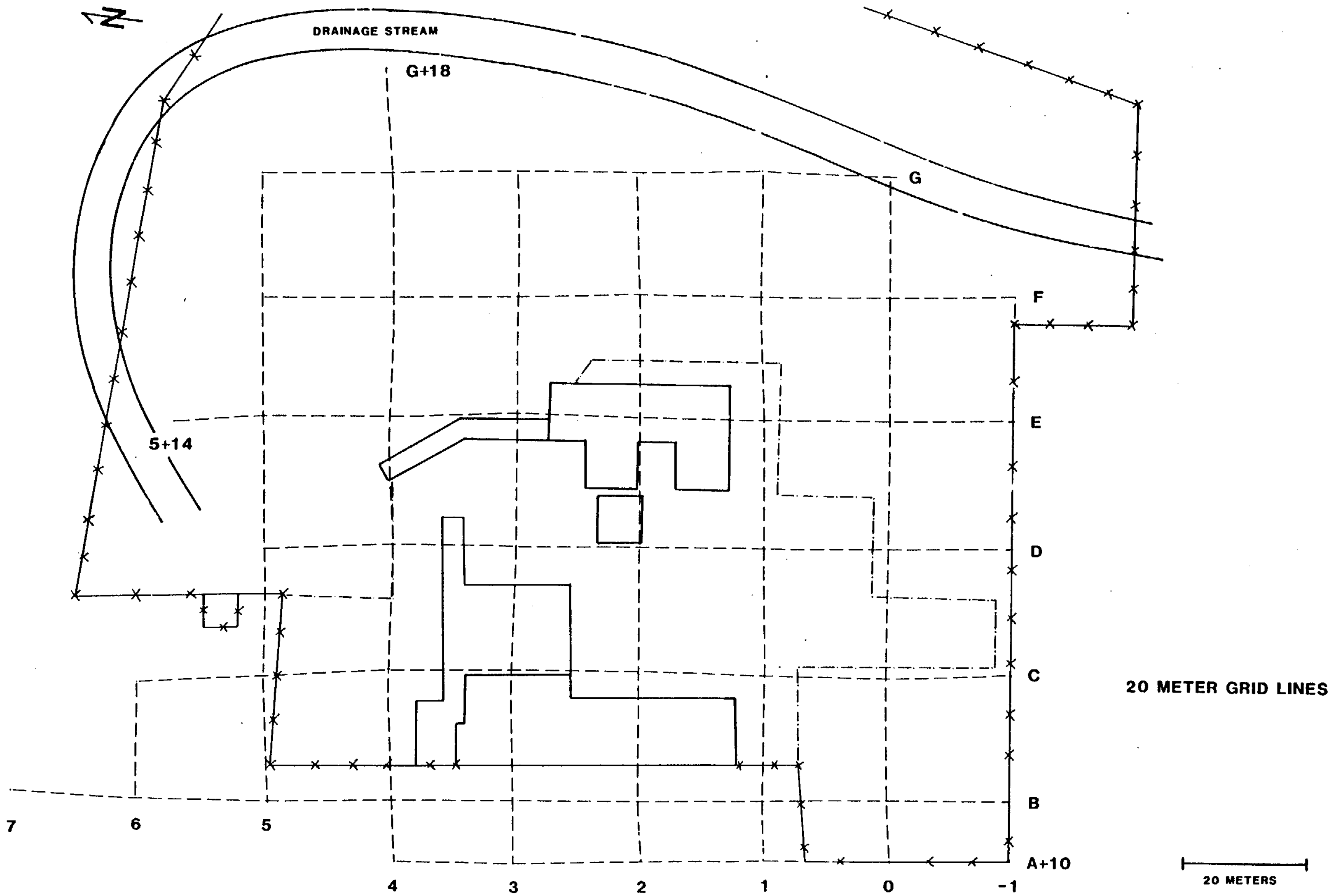

Figure 1: Map showing accessible portion of the W. R. Grace Disposal Site and 20-meter grid system.

3. FIELD MEASUREMENT TECHNIQUES

This section describes the geophysical measurement techniques of ground penetrating radar (GPR) and electrical resistivity (ER) that were used in this survey. Section 3.1 reviews the theory of GPR, while Section 3.2 describes the GPR instrumentation used to make the measurements. Section 3.3 reviews the electrical resistivity techniques and instrumentation.

3.1 Ground Penetrating Radar Theory

Subsurface radar detection systems have been the object of study for over a decade by both military and environmental agencies. In both applications, the objectives are to locate and identify buried or submerged objects, otherwise not detectable, and to spatially determine the structural make-up of the subsurface.

The principle of operation involves the generation of a pulse train of electromagnetic radiation in the frequency range of 10-1000 MHz. In accordance with the laws of classical electromagnetism, the wave propagates, with material dependent attenuation, through a given medium - the earth. When the wavetrain encounters a material or boundary of different electromagnetic properties, the wave is partially reflected. This reflected wave is then detected and the time interval between transmission and detection is recorded.

With knowledge of the velocity of propagation, the time interval can be converted to a range or depth.

As part of the calibration process the velocity of propagation of the electromagnetic wave in the particular medium is determined. For earth materials with a relative effective dielectric constant, ε_{er}, the velocity of propagation, v_m, of the electromagnetic signals, is usually approximated by:

$$v_m = \frac{c}{\varepsilon_{er}^{1/2}} \tag{1}$$

where: $c = 3 \times 10^8$ m/sec, the propagation velocity in free space. However, equation (1) is actually derived from

$$v_m = \frac{\omega}{\beta} \tag{2}$$

where: $\omega = 2\pi f$ = angular frequency

f = frequency in Hertz

β = phase constant, imaginary part of propagation constant.

The phase constant, β, is obtained from γ, the complex propagation constant of the medium which is derived from Maxwell's equations describing the behavior of electromagnetic fields. The propagation constant, γ, is defined as:

$$\gamma = \alpha + j\beta = (-\omega^2 \mu' \varepsilon_e + j\omega\mu' \sigma_e)^{1/2} \tag{3}$$

where: α = attenuation constant

μ' = magnetic permeability of the medium

σ_e = effective conductivity

The probing depth is determined by the frequency of operation and the electromagnetic properties of the soil, principally the conductivity and the dielectric constant. Signal attenuation, A, usually given in terms of dB/meter (Morey, 1974), is approximated by:

$$A = (12.863 \times 10^{8})\ f\ (\varepsilon_{er})^{\frac{1}{2}}\ ((p + 1)^{\frac{1}{2}} - 1)^{\frac{1}{2}} \qquad (4)$$

where: $p = \text{loss tangent} = \dfrac{\sigma_e}{2\pi f \varepsilon_o \varepsilon_{er}} = \dfrac{1.8\sigma_e}{f\ \varepsilon_{er}} \times 10^{10}$

ε_o = dielectric constant of free space

$= 8.85 \times 10^{-12}$ farads/meter

Equation (4) is derived from:

$$A = 20 \log e^{\alpha} = 8.686\ \alpha \qquad (5)$$

Nominal GPR systems transmit approximately 100 volts and can readily detect 1 millivolt, giving 100 dB of usuable signal. However, the attenuation increases with increasing frequency. Thus, by changing the radar frequency through the use of different antennas, a range of probing depth of resolution is made available.

In common earth materials there is a trade-off between probing depth and resolution. Quantitatively, the spatial resolution, r, is approximated by one-half the radar wavelength in the medium:

$$r = \lambda/2 = v_m/(2f) = c/(2f\ \varepsilon_{er}^{\frac{1}{2}}) \qquad (6)$$

using equation (1) in the derivation, or

$$r = \lambda/2 = v_m/(2f) = (\omega/\beta)/(^2b) = \pi/\beta \qquad (7)$$

using equation (2)

A summary of the physical properties of common media which affect the propagation and attenuation of electromagnetic signals is shown in Table 1. Careful analysis of the reflected pulse, combined with a knowledge of the electromagnetic properties of the soil, can reveal information such as percentage of water content, density variation, and the location and depth of buried objects.

Table 1: Approximate VHF electromagnetic parameters of typical earth materials.

Material	Approximate Conductivity σ (mho/m)	Approximate Dielectric Constant	Depth of Penetration
Air	0	1	Max (km)
Limestone (dry)	10^{-9}	7	↓
Granite (dry)	10^{-8}	5	
Sand (dry)	10^{-7} to 10^{-3}	4 to 6	
Bedded Salt	10^{-5} to 10^{-4}	3 to 6	
Freshwater Ice	10^{-5} to 10^{-4}	4	
Permafrost	10^{-4} to 10^{-2}	4 to 8	
Sand, Saturated	10^{-4} to 10^{-2}	30	
Freshwater	10^{-4} to 3×10^{-2}	81	
Silt, Saturated	10^{-3} to 10^{-2}	10	
Rich Agricultural Land	10^{-2}	15	
Clay, Saturated	10^{-2} to 1	8 to 12	↓
Seawater	4	81	Min (cm)

Inference as to the composition of the reflecting and intervening material is possible, depending on the intensity and phase of the return signal. For example, metallic objects

have different dielectric properties than soils and will, therefore, give rise to strong reflections and a phase shift. Geological interfaces, on the other hand, give relatively weak reflections and no significant phase shift. The complex reflection coefficient, ρ, in the case of reflection involving a two-layer earth is given by:

$$\rho = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \tag{8}$$

where: η_1 = complex impedance of upper layer

η_2 = complex impedance of lower layer

The complex impedance is derived from:

$$\eta = \frac{j\omega\mu'}{\gamma} \tag{9}$$

where γ is given by equation (3). Table 2 compares typical electromagnetic properties at 100 MHz of some of the materials listed in Table 1.

A more quantitative picture of the penetration performance of the GPR is shown in Figure 2. Here, the range or depth (for different electromagnetic frequencies) is plotted directly as a function of attenuation in various media. The plots result from calculations assuming the return signal is from a rough plane reflector with a reflection coefficient equal to 1.0.

Table 2

Typical Electromagnetic Properties of Materials at 100 MHz

Material	A dB/m	V_m cm/ns	η Ohms
Air	0	30	377
Fresh Water	0.18	3.33	42+j0.046
Sea Water	326	1.50	10+j9.33
Sandy Soil, Dry	0.44	16.0	202+j2.6
Loamy Soil, Wet	1.93	7.07	88.8+j2.6
Clayey Soil, Wet	12.5	7.63	93+j16.2
Iron	1.7×10^7	3.2×10^{-5}	2.0+j2.0
Basalt	8.2×10^{-3}	15.0	188+j0.04
Sandstone	0.73	13.4	168+j3.0

Where η = Characteristic Impedance of Material

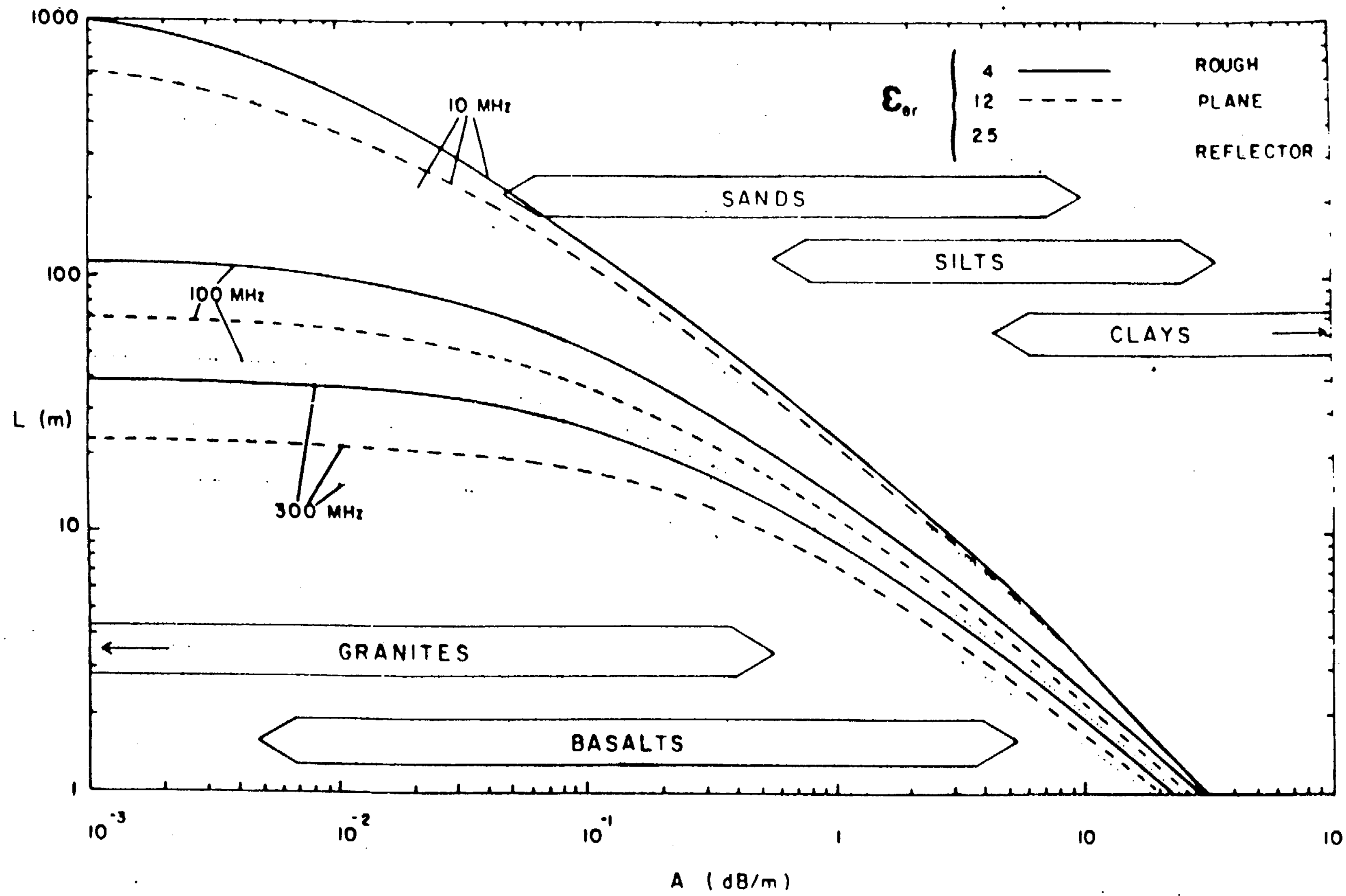

Figure 2: Variation of maximum depth of penetration (L) as a function of attenuation (A) for different frequencies and dielectric constants. Typical ranges of attenuation for different earth materials are also shown (after Horton et al, 1981).

Table 3. Selected Radar Parameters for Calculating Maximum Range

RADAR SYSTEM PARAMETERS

System	Geo-Centers Proprietary Design	Standard GSSI Systems	
Center frequency	10 MHz	80/120 MHz	300 MHz
Parameter			
P_s(Peak) (Watts)	2.5×10^3	50	12
P_{min}(Watts)	2.5×10^{-8}	5×10^{-10}	1.2×10^{-10}
Q	-110 dB	-110 dB	-110 dB
$E_t = E_r$	5%(-13 dB)	5%(-13 dB)	5%(-13 dB)
$G_t = G_r$	1.585(2 dB)	1.585(2 dB)	1.585(2 dB)

3.2 Ground Penetrating Radar Instrumentation

A Geophysical Survey Systems, Inc., (GSSI) System 7 was used to conduct the survey. Figure 3 is a block diagram of a typical GPR system. The equipment consists of a portable, gasoline powered electrical generator, a power supply, a control unit, a graphic recorder, and a tape recorder all mounted in a vehicle. A number of antennas were available for use on this program. Frequencies ranged from 10 MHz (Geo-Centers' proprietary deep penetrating antenna) to 300 MHz. Table 3 summarizes the characteristics of several of the available antennas. Data were recorded on magnetic tape and on a hard-copy graphic recorder; the latter information was compressed because of the high input data rate. After the field survey, the magnetic tape was played at a slower speed to generate full-resolution hard copy for analysis.

3.3 Electrical Resistivity Techniques and Instrumentation

Earth resistivity surveys have been used for many years in exploration for ground water and mineral deposits, and in the study of engineering properties of earth materials. Equipment to measure resistivity consists of a controlled source of electric current, a device for measuring the potential differences generated by the current passing through the earth and a number of electrodes for coupling the current into the earth. The volume of subsurface material influencing the resistivity measurement is controlled by the spacing and geometry of the electrodes. While any array of four or more electrode contracts can be used in studying earth resistivity, relatively few electrode configurations have been accepted as standard arrays in practice. Figure 4 shows the three most common electrode arrays used in the resistivity method. Many

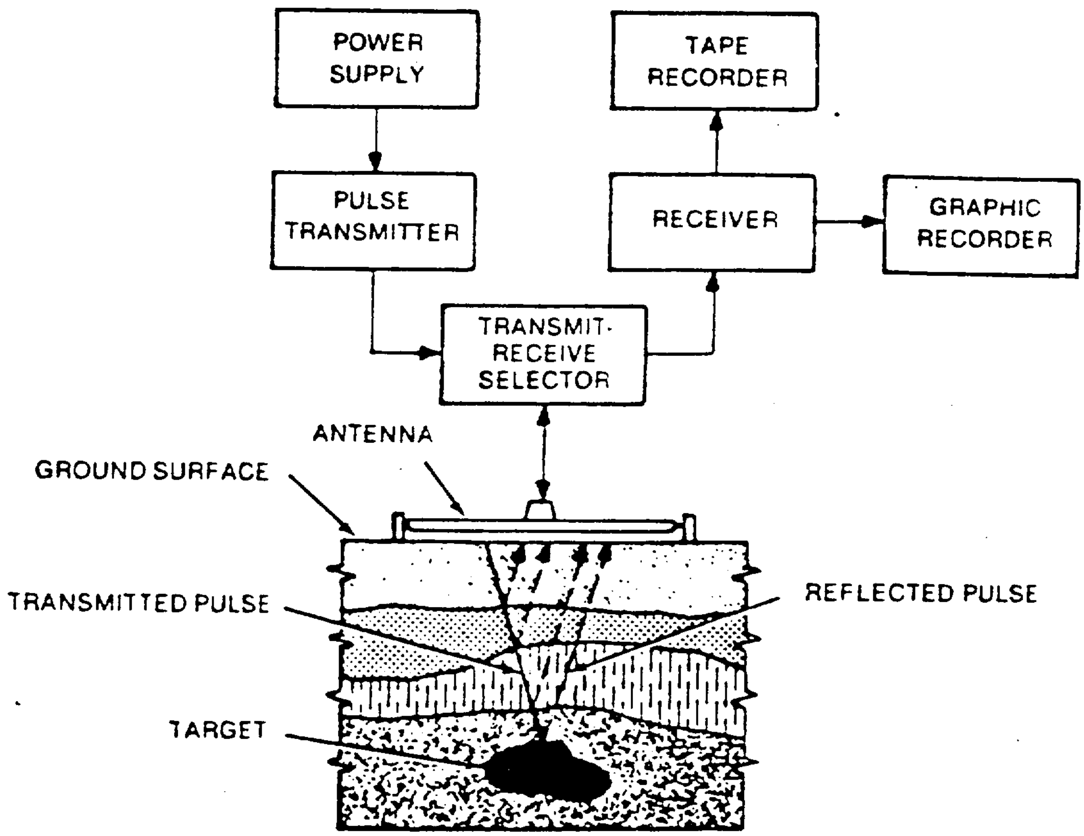

Figure 3 Ground-Penetrating Radar (GPR) System, block diagram.

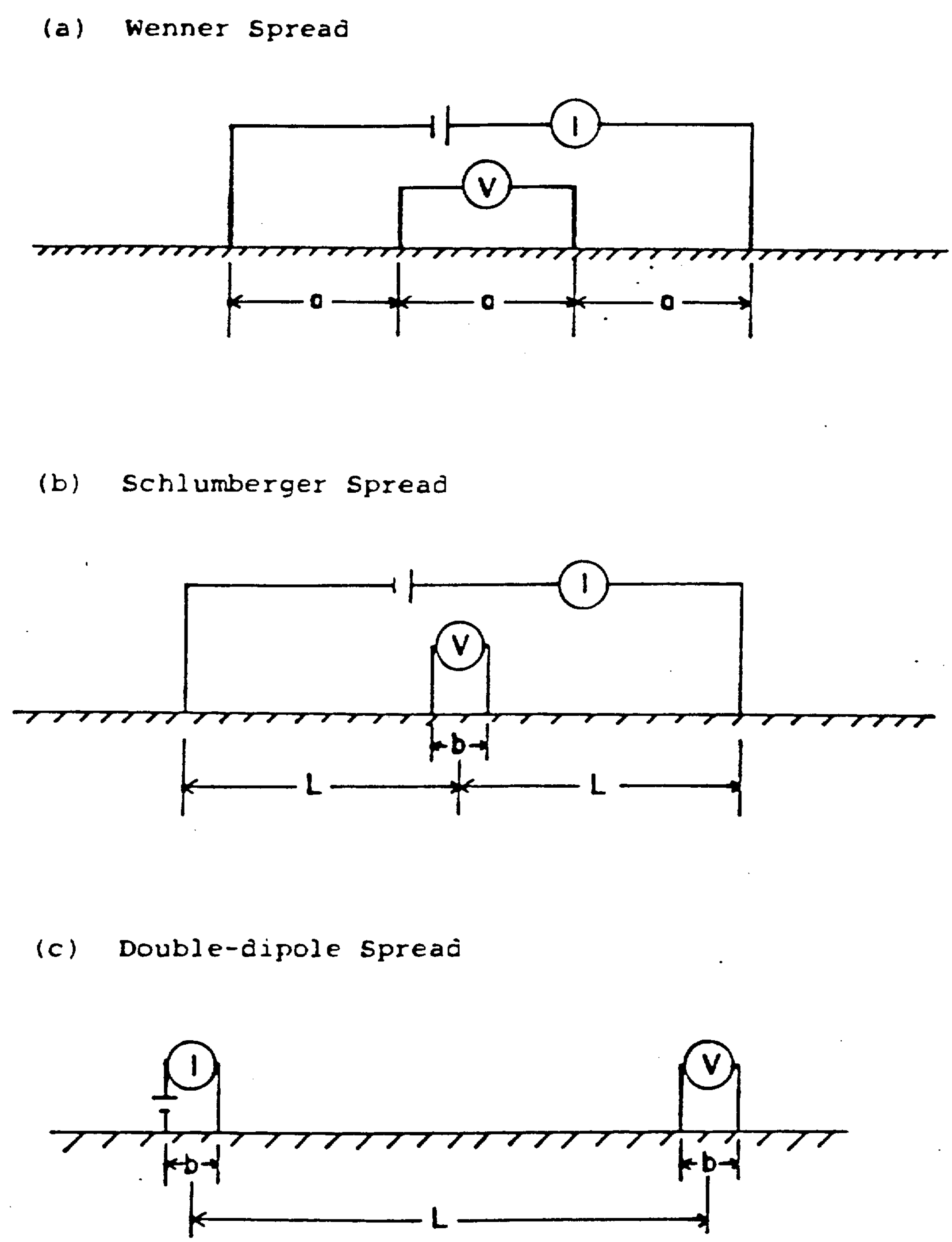

Figure 4: **Common electrode configurations for resistivity arrays.**

factors are considered in the choice of array configurations for a given problem. Susceptibility to geological noise, ease of array movement, and the nature of the assumed structure are a few of these factors.

For each of the three (3) electrode configurations in Figure 4, the apparent resistivity, ρ_a, can be calculated from:

$$\rho_a = 2\pi \frac{V}{I} a, \text{ Wenner Array} \tag{10a}$$

Where: V = potential difference

I = induced electric current

a = spacing between electrodes

$$\rho_a = \pi \frac{V}{I} (b) \left[\left(\frac{L}{b}\right)^2 - \tfrac{1}{4} \right], \text{ Schlumberger Array} \tag{10b}$$

Where: b = distance between potential electrodes

L = half the distance between current electrodes

$$\rho_a = \pi \frac{V}{I} (L) \left[\left(\frac{L}{b}\right)^2 - 1 \right], \text{ Double-dipole array} \tag{10c}$$

Where: b = distance between current electrodes and between potential electrodes.

L = distance between mid-points of current electrodes and potential electrodes.

As discussed in section 3.1, a knowledge of soil properties allows prediction of radar performance at a specific site. Measurements of bulk soil resistivity can be used to estimate expected penetration depth of the GPR. Figure 5 shows maximum radar range as a function of electrical resistivity (DC conductivity). From a few measurements of resistivity on the site of interest, the expected depth of penetration can be estimated for a range of frequencies. The best antenna for the application can then be selected, providing the optimum trade-off between penetration and resolution.

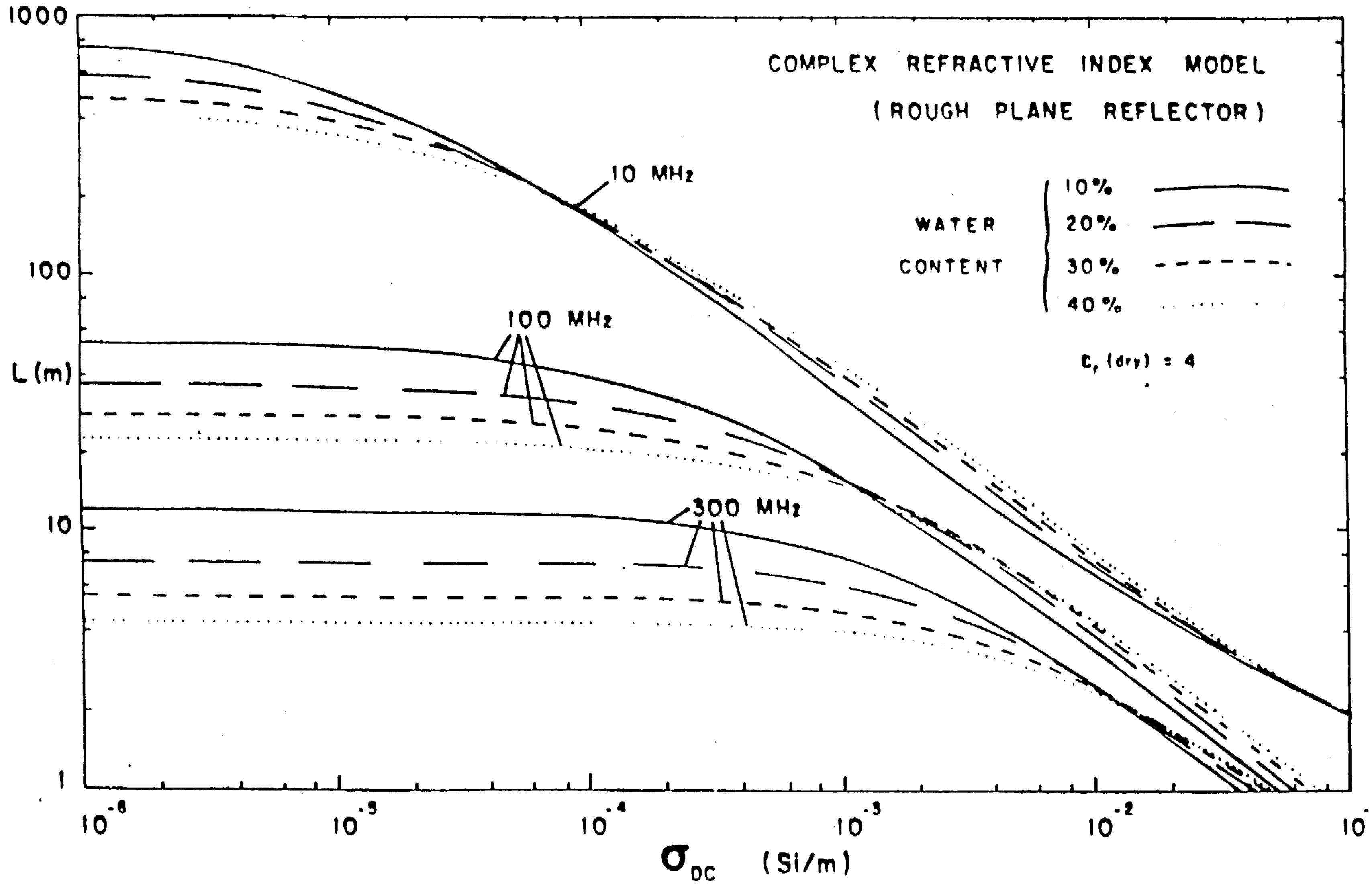

Figure 5: Radar range (L) as a function of DC conductivity (σ_{DC}) at different frequencies. Plots are based on a Complex Refractive Index Soil Model and reflection from a rough plane reflector. (after Horton et al, 1981).

In addition to supporting radar operations, mapping the site with resistivity measurements aids in the interpretation of radar data. Changes in bulk resistivity can indicate the presence of materials foreign to the particular site. For example, a cluster of metallic objects would lower the resistivity values measured for the area surrounding these materials. Correlations between resistivity measurements and GPR measurements are strong indications of disturbed areas.

4. OPERATIONS

The grid system with 20 meter centers was used as the coordinate system for the GPR scan lines and the resistivity measurements. For estimating GPR depth of penetration, bulk resistivity data were collected along the east-west, numbered grid lines using the Wenner spread (Figure 4) with the spacing, a, equal to 10 feet. The measurements ranged from 2 to 72 ohm-meters, or in terms of conductivity, from 0.5 to 1.39 X 10^{-2} Si/meter. The average for the site, taken over 86 readings, was 20.14 ohm-meters (4.97 X 10^{-2} Si/meter). From Figure 5, this resulted in a predicted range of penetration depths for the 80 MHz antenna of 1 to 5 meters (3 to 16 feet).

A depth value was derived from the time interval measurements between the transmit and receive pulses by using Equation 2 to calculate the velocity of propagation of the pulse in the earth medium. The value of the relative dielectric constant, ε_{er}, was estimated to be 25 by comparing the soil at the W.R. Grace site with similar materials. This yielded a velocity of propagation of approximately 5.86 cm/nsec. Using this value in Equation 7 gives a calculated resolution for the 80 MHz antenna of 1.5 meters (4.92 feet).

The antenna was towed along a series of survey lines to cover the site in a thorough manner. The survey lines are shown in Figure 6 superimposed on a diagram of the site. The antenna was towed manually for scans less than 20 meters in

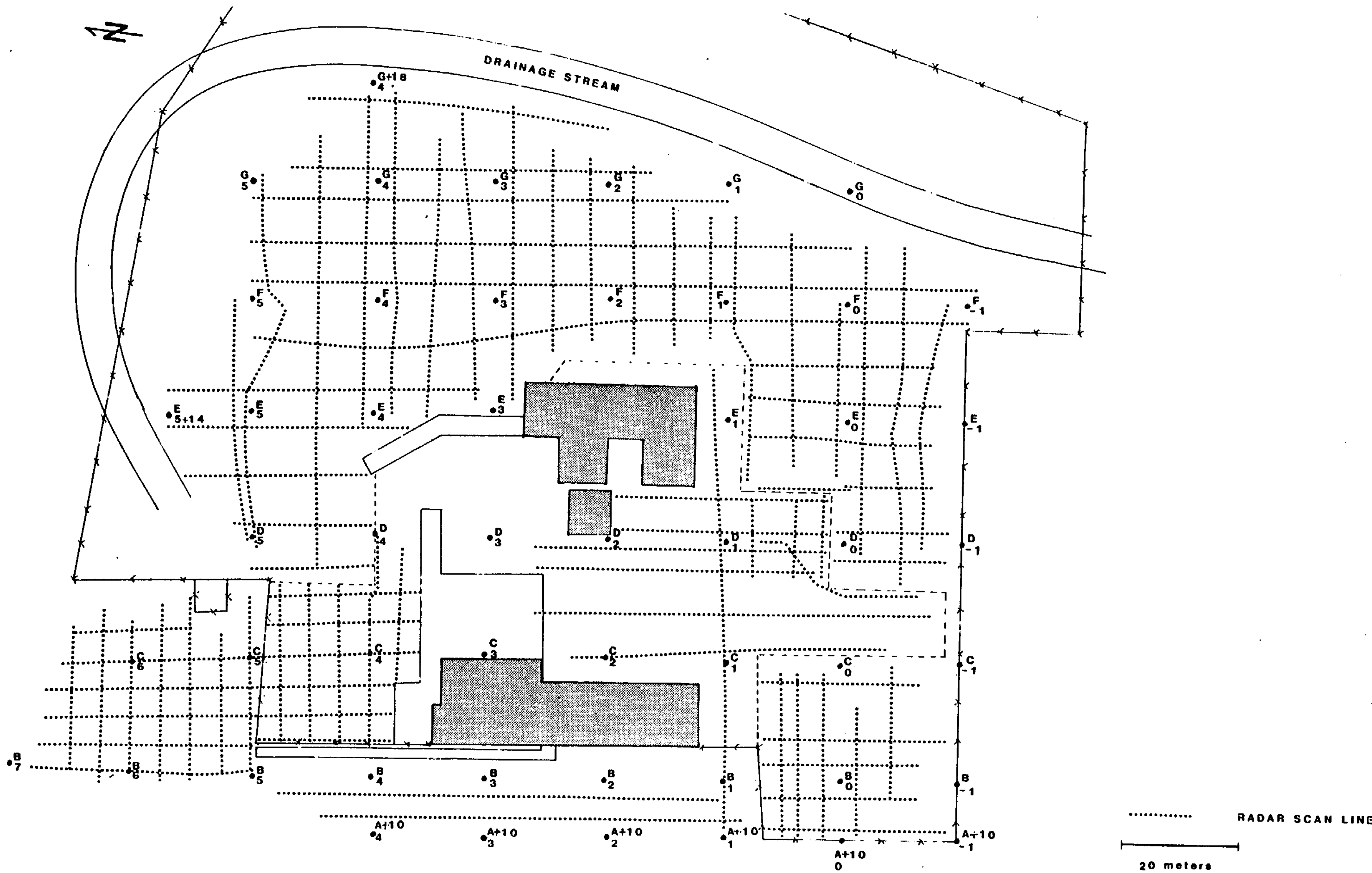

Figure 6: Radar survey lines.

length and for scans in level, paved areas. Otherwise, the antenna was secured to the back of the vehicle carrying the electronic equipment. Scan lines deviated from the straight grid system when it was necessary to avoid obstacles such as trees and piles of debris. Towing speeds were kept as constant as possible, averaging 2 to 3 mph. As the antenna passed each grid marker, the data tape was indexed, thus adding distance markers to the graphic display copy.

5. DISCUSSION OF RESULTS

The 300 MHz and the 80 MHz antenna systems were evaluated and calibration measurements were made to tailor the radar system for the specific conditions at the W.R. Grace site. Data collected with the 300 MHz antenna indicated a depth of penetration of approximately 1 to 8 feet, which precluded its use. The results in this report were derived from data obtained with the 80 MHz antenna.

Typical examples of radar profiles taken at the site are displayed in Figures 7 and 8. Figure 7 shows a scan along the F+3m, line from -1+00m to 5+00m. Figure 8 shows a scan along the 5-2m line from G+2m to D-2m

In Figure 7, several distinct, well defined regions are readily apparent. At the beginning of the scan near -1+2m, a sharply delineated area of strong reflectivity about 3m wide stands out. A gradual transition from a strong reflective zone to a moderate reflective zone occurs near 0-4m. The area from 0+00m to 1+00m is nearly uniform, with numerous small reflections evident at depth. A sharp transition is visible close to 1+00m leading into a region of irregular, individual scatterers. This region ends at 1+9m where an absorptive zone containing a number of diffuse scatters is encountered. The strong vertical signature at 2+3m is probably due to a near surface metallic object. Beginning with 2+5m the shallow return signal becomes increasingly disturbed,

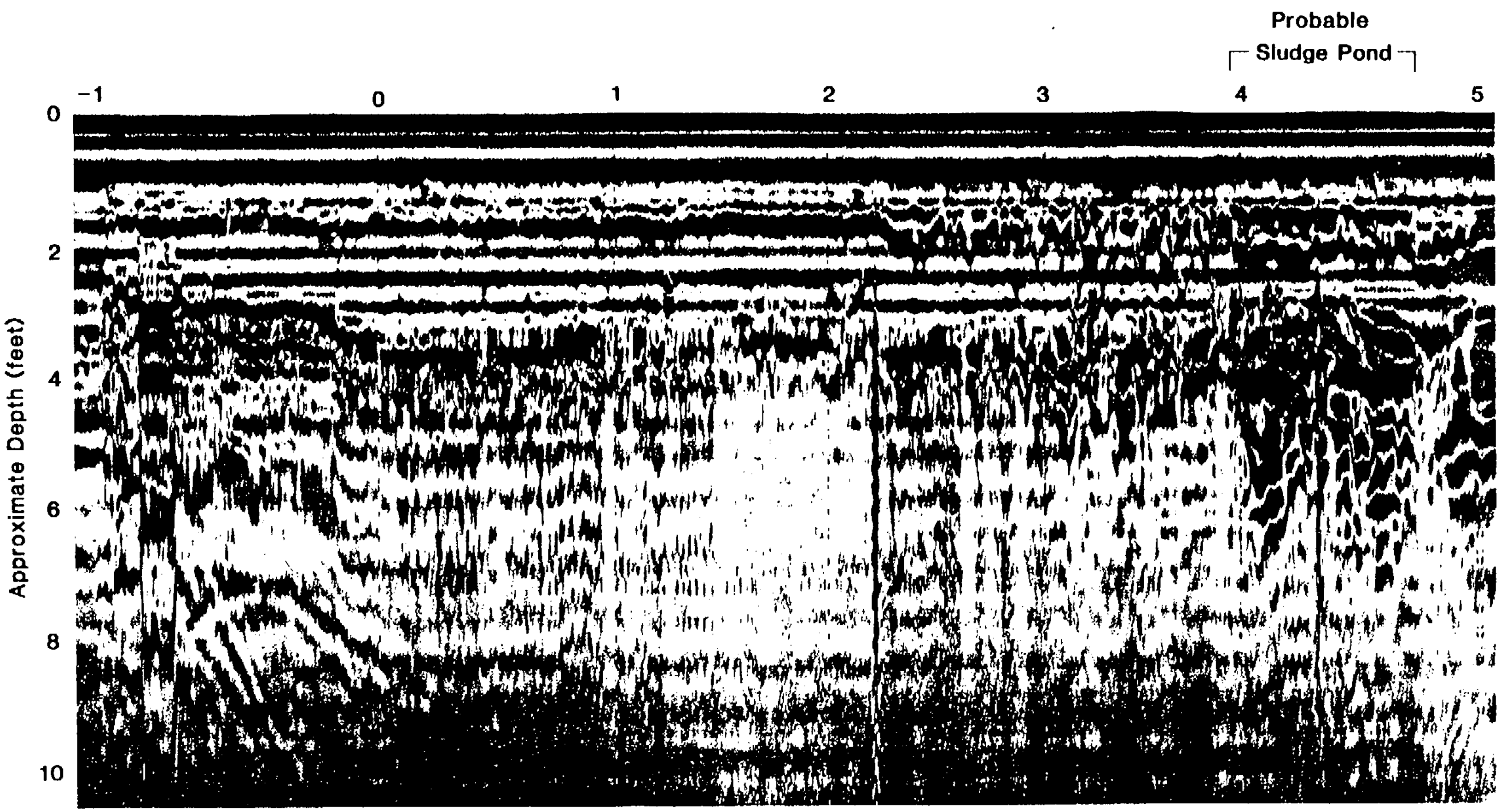

Figure 7: Radar profile along F+3 meters line.

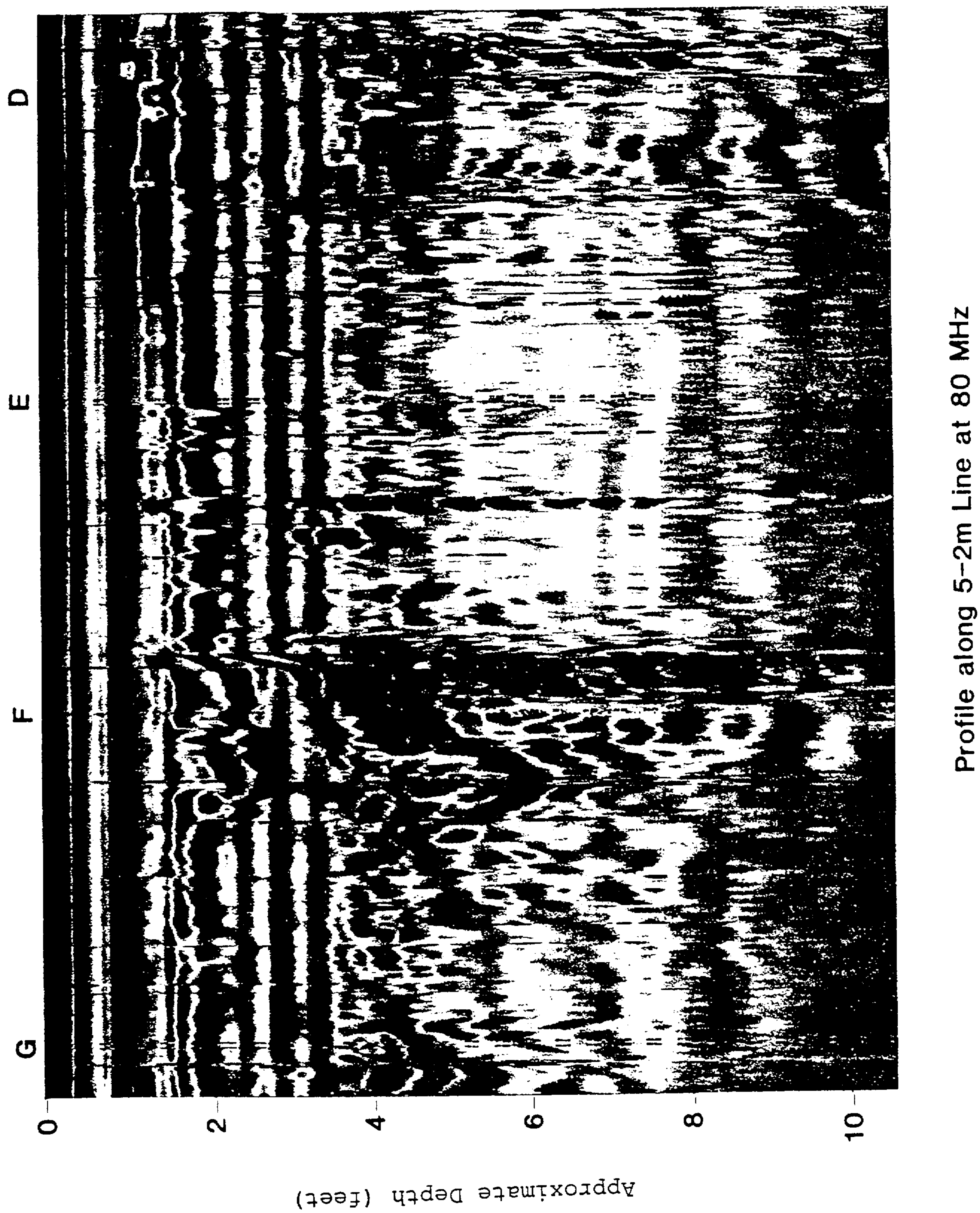

Figure 8: Radar profile along 5-2 meters line.

indicating burial activity. The region from 2+17m to 3+16m is a highly disturbed melange of numerous shallow reflectors. The scan reveals an abrupt discontinuity at about 4+00m leading into an extensive region of high reflectivity, in the midst of which a very shallow object is detectable. This zone, which continues to the end of the scan, includes an amomalous band of reduced reflectivity from 4+15m to 4+18m.

Figure 8 is a radar profile along the 5-2m line from G+2m to D-2m. A strong, continuous reflector at depth with an associated shallow disturbance extends from F+6m to F-4m, where the border is shaply defined. Portions of this zone are highly reflective. Three objects appear in the scan at E+12m, E+8m, and E+6m. The estimated depths are 3 feet 2.5 feet, and ground surface, respectively. The perturbations in the shallow ground signal just before E+00m were caused as the antenna moved over a pile of rocks.

An anomalous zone of high signal attenuation stretches from E+00m to E-5m. From D+11m to D+5m a tight cluster of scatters at depth is evident, associated with a disturbance in the shallow ground return. This suggests burial activity has occured at this location.

Figure 9 presents the zonal GPR interpretation for the W.R. Grace property. The spatial accuracy of the survey data is estimated at ± 1 meter along a scan line. Zones of anomalous radar signals are indicated.

In the burial area, the most prominant feature is located between the F, G, 4m, and 5m grid lines. This zone exhibits a very strong reflection transected by a band of diminish reflectivity. This feature may be the sludge pond indicated

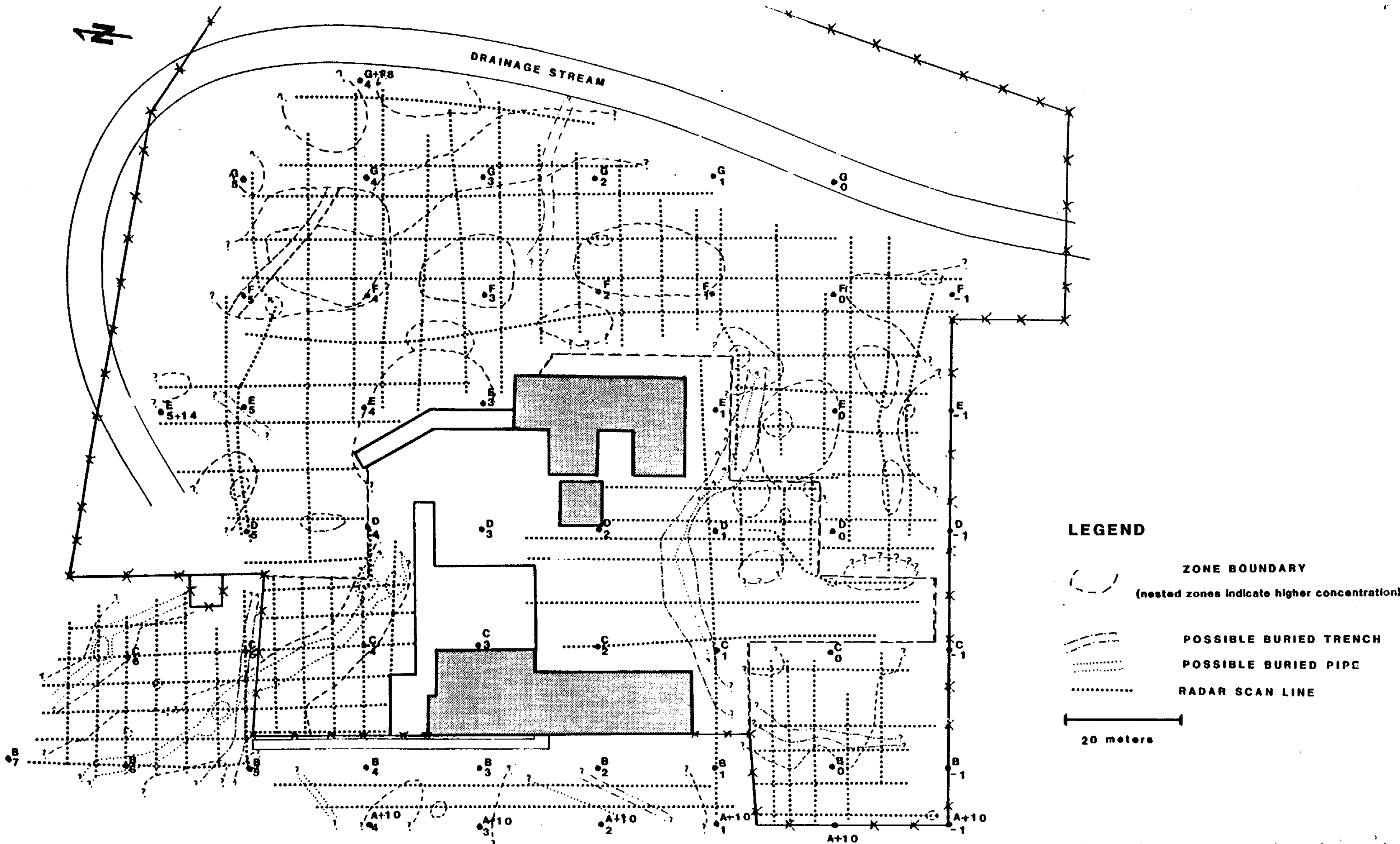

Figure 9: Interpretation of Ground-Penetration Radar Survey at the W. R. Grace Disposal Site, New Jersey.

on early maps of the site. In the parking lot areas, the main features revealed were buried pipes and catch basins with associated trenching. Particularly interestng is one which crosses the south lawn and parking area and enters the burial ground from the west.

The locations and approximate depths of detected objects are shown in Figure 10. While most appear to be randomly scattered, several zones correlate well with a high concentration of objects. The extensive zone including the coordinate G-3 and the small zone between coordinate F-2 and the building are two such examples.

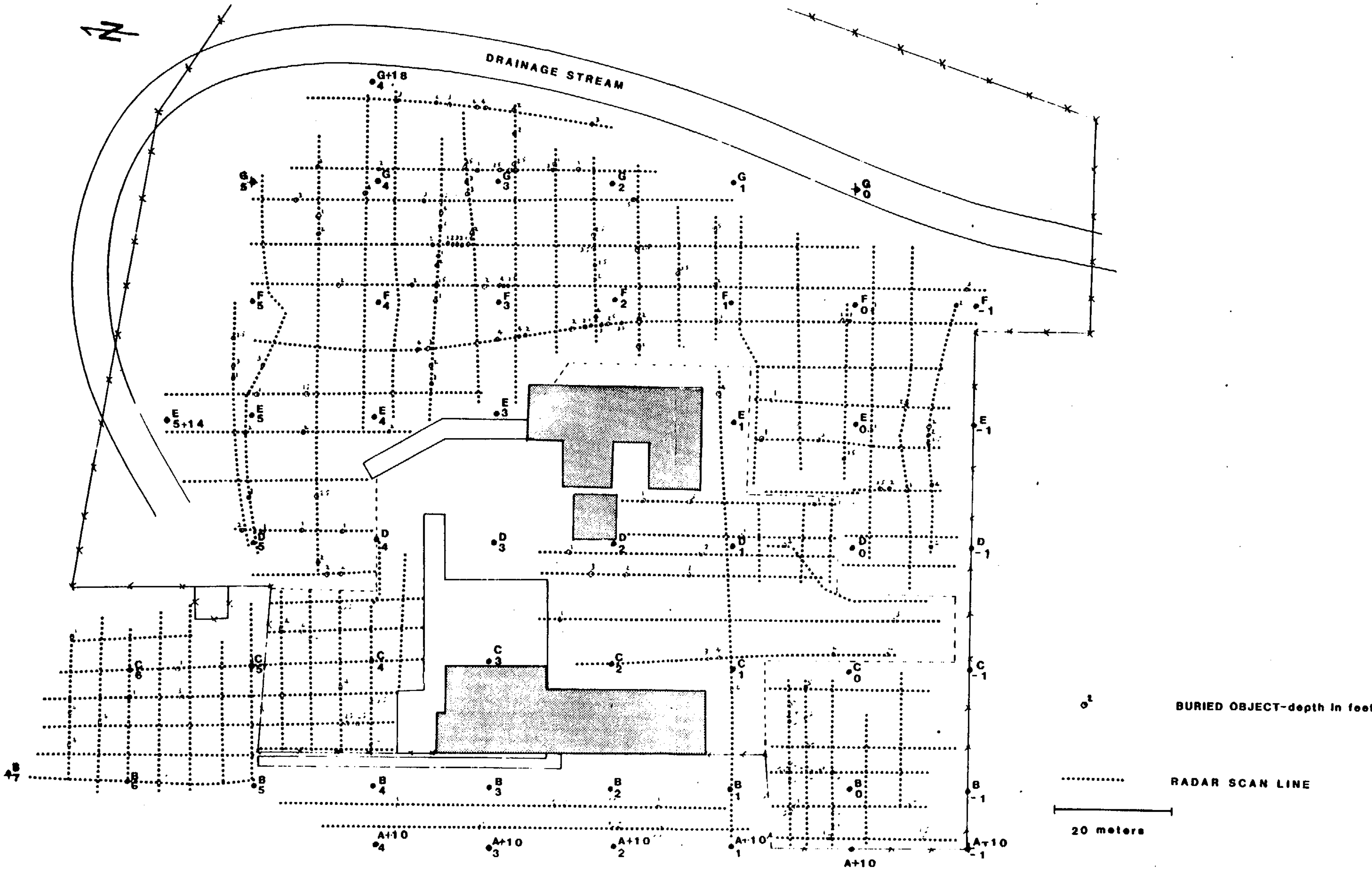

Figure 10: Map showing detected buried objects.

6. CONCLUSIONS

The interpretation of the GPR data, presented in Figures 9 and 10 has shown the W.R. Grace site to be extremely complex. The long history of burial activities, evident in the highly disturbed character of many of the GPR profiles and the profusion of buried objects detected, has produced many different anomalous zones in a small area, some of which overlap. Several of the larger zones correspond to those indicated in early reconstructed maps of the burial area.

Low values of resistivity and anomalous radar signals may be due to any or several of the following possible causes:

- Presence of metallic objects, especially pipes and conduits.
- Increased porosity and moisture content caused by disturbance of the natural soils through burial activities.
- Migration zones of electrically conductive fluids resident on site.
- Greater infiltration of runoff due to topography, etc.

With few exceptions, most of the subsurface objects were detected at an apparent depth of less than 4 feet. Their extensive, scattered distribution suggest that these materials may not have been disposed of in typical organized trenches.

In areas surveyed outside the burial ground, the only detected features were pipes and surrounding trenches. Anomalous zones in the lawn areas are probably caused by old pavement underlying the turf.

7. LITERATURE CITED

Horton, K.A., R.M. Morey, R.H. Beers, V. Jordan, S.S. Sandler, L. Isaacson, U.S. Nuclear Regulatory Commission, "Evaluation of Ground Penetrating Radar at Low-Level Nuclear Waste Disposal Sites," NUREG CR-2212, 1981.

Morey, R.M., "Continuous Subsurface Profiling by Impulse Radar," Proc. of Engineering Foundation Conference on Subsurface Exploration for Underground Excavation and Heavy Construction, American Society of Civil Engineers, 1974, pp. 213-232.

APPENDIX D

MAJOR ANALYTICAL EQUIPMENT

APPENDIX D

Major Analytical Equipment

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

A. Direct Radiation Measurements

Eberline "RASCAL"
Portable Ratemeter-Scaler
Model PRS-1
Beta-Gamma "Pancake" Probe, Model HP-260
Energy Compensated G-M Probe Model HP-270
(Eberline Instrument, Santa Fe, NM)

Eberline PRM-6
Portable Ratemeter-Scaler
Scintillation Probe, Model 489-55
(Victoreen, Inc., Cleveland, OH)

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

Ludlum Ratemeter-Scaler
Model 2200
(Ludlum Measurements Inc., Sweetwater, TX)

B. Laboratory Analysis

Ge(Li) Detector
Model LGCC2220SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, SPG-16
(Applied Physical Technology, Smyrna, GA)

Pulse Height Analyzer, ND680
Model 88-0629
(Nuclear Data, Inc., Schaumburg, IL)

Alpha Spectroscopy System
Tracor Northern 1705
Pulcir PA-1 Alpha Module
(Pulcir, Inc., Oak Ridge, TN)

Low Background Alpha-Beta Counter
Model LB5100-2080
(Tennelec, Inc., Oak Ridge, TN)

25 mg Californium-252 Source with Flexo-Rabbit
Pneumatic Transfer System
(Reactor Experiments, Inc., San Carlos, CA)

Multichannel Analyzer
Model TN-7200
(Tracor Northern, Middleton, WI)

APPENDIX E

ANALYTICAL PROCEDURES

APPENDIX E

Analytical Procedures

Gamma Scintillation Measurments

Walkover surface scans and measurements of gamma exposure rates were performed using an Eberline PRM-6 portable ratemeter with a Victoreen Model 489-55 gamma scintillation probe containing a 3.2 cm x 3.8 cm NaI(Tl) scintillation crystal. A graph of count rate (cpm) vs. exposure rate (μR/h) was developed by comparing the response of the scintillation detector with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at several locations on and off the W.R. Grace property. This plot was used to convert the meter readings to exposure rates.

Additional Exposure Rate Measurements

Exposure rates at several locations on the property exceeded the measuring range of the gamma scintillation equipment. At those locations, exposure rates were measured using Eberline energy compensated Model HP-270 G-M probes with Eberline "Rascal" Model PRS-1 portable ratemeters. Calibration of this instrumentation was by cross reference to a Reuter-Stokes Model RSS-111 pressurized ionization chamber.

Beta-Gamma Dose Rate Measurements

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

Borehole Logging

Borehole gamma radiation measurements were made using a Victoreen Model 489-55 gamma scintillation probe connected to a Ludlum Model 2200

portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the shield in 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 in all holes.

Because of varying ratios of thorium, uranium, and radium noted on the site no attempt was made to use the borehole logging data to directly estimate subsurface thorium soil concentrations. The borehole logging data was used to identify regions of elevated residues and thus guided the selection of subsurface soil sampling locations.

Soil and Sediment Sample Analysis

Soil and sediment samples were sifted to remove rocks (the fraction removed constituted <5% of the total), dried at 120° C, finely ground, mixed, and a portion placed in a 0.5 liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and typically ranged from 500 to 800 g of soil. Net weights were determined and the samples counted using a 23% Ge(Li) detector (Princeton Gamma Tech) coupled to a Nuclear Data model ND 680 pulse height analyzer. The following energy peaks were used for determination of the radionuclides of concern:

Th-232	- 0.911 MeV from Ac-228	(secular equilibrium assumed)
Th-228	- 0.583 MeV from Tl-208	" " "
Ra-226	- 0.609 MeV from Bi-214	" " "
U-238	- 1.001 MeV from Pa-234m	" " "

Peak identification and concentration calculations were provided by computer analyses.

Samples for which gamma spectrometry indicated detectable levels of uranium were subsequently analyzed for U-238 by neutron activation. Approximately 15-20 g of soil were irradiated for 15 minutes in a neutron flux of 10^8 n/cm^2/sec. After a one minute wait time, the U-239 peak (74.6 keV) was counted for 10 minutes and the U-238 concentration calculated.

Water Samples

Water samples were rough filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by filtration through 0.45 μm pore size membrane filters. The filters, together with attached solids, were discarded, and the filtrate was acidified by the addition of 20 ml of concentrated nitric acid.

Gross Alpha and Gross Beta Analysis

Fifty milliliters of each sample was evaporated to dryness and counted on a Tennelec Model LB5100 low background proportional counter.

Radium-226/228 Analysis

Samples were analyzed for Ra-226 and 228 using the standard technique EPA 600/4-75-008 (Rev.)

Vegetation Analysis

Gamma Spectrometry

After being washed vegetation samples were air dried, chopped, and mixed. Aliquots were placed in 3.5 ℓ Marinelli beakers and analyzed for identifiable photopeaks in the same manner described above for soil sample analysis. Due to possible preferential uptake and assimilation of various radionuclides by vegetation, it could not be assumed that Th-232 and Ra-228 were in equilibrium. Therefore, Ra-228, rather than Th-232, concentrations are reported for vegetation samples.

Errors and Detection Limits

The errors, associated with the analytical data presented in the tables of this report, represent the 95% (2σ) confidence levels for that data. These errors were calculated, based on both the gross sample count

levels and the associated background count levels. When the net sample count was less than the 2σ statistical deviation of the background count, the sample concentration was reported as less than the minimum detectable activity (<MDA). This means that the radionuclide was not present, to the best of our ability to measure it, utilizing the analytical techniques described in this appendix. Because of variations in background levels, caused by other constituants in the samples, the MDAs for specific radionuclides differ from sample to sample.

Calibration and Quality Assurance

Laboratory analytical instruments are calibrated using NBS-traceable standards. Portable survey instruments for exposure rate and dose rate measurements are calibrated by comparison of their responses to those of other instruments having NBS-traceable calibration. Field comparisons or comparisons using samples typical of the area are used to develop these calibrations.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU Laboratory participates in the EPA Quality Assurance Program.

FEB 7 1983

Docket No. 40-00086

License No. STA-422

Township of Wayne
ATTN: Arthur R. Bartolozzi
Health Officer
475 Valley Road
Wayne, New Jersey 07470

Gentlemen:

This refers to your letters of September 30, 1982, November 15, 1982 and your note dated December 6, 1982. In your September 30 letter you requested that the Nuclear Regulatory Commission investigate the Sheffield Brook thorium problem more thoroughly by investigating the potential contamination of the aquifer, performing additional tests in the actual burial pits on the W. R. Grace site, and immediately advising of the results of core samples. These same issues were addressed in Resolution 235 of the Wayne Township Council and were discussed in our letter to Congressman Roe dated September 29, 1982. A copy of this letter is enclosed for your information.

In this letter you also requested that we supply you with our findings regarding the additional flyovers as soon as possible. The aerial survey which was conducted over Wayne Township during September, 1982 was contracted for and paid for by the United States Department of Energy (DOE). Therefore, I suggest that you contact the U. S. Department of Energy in Germantown, Maryland regarding the results of this aerial radiological survey.

In your letter dated November 15, 1982, you requested that we address the question of removal of the radioactive material from the W. R. Grace and Company property and the Sheffield Brook area. To date, no information or survey results have changed our initial determination that there is no immediate threat to the health and safety of the residents of Wayne from the presence of this material. Decisions concerning specific actions to be taken will be made by the agency with responsibility for final disposition of the site. The Department of Energy will not make a final decision concerning their involvement in the site until they have reviewed the final report of the Oak Ridge Associated Universities surveys on the W. R. Grace property. We do not expect any recommendations until after that time. Due to the press of other work, the large number of samples to be analyzed, and the need for careful review of the data, this report has been delayed until now. However, a copy is enclosed.

I understand the desire for a prompt solution to this problem; however, we believe it is important to take sufficient time to develop good data on which to base sound decisions.

Thank you for the material you provided with your note dated December 6, 1982.

B/288

OFFICIAL RECORD COPY

ITEM # 289 IE:07 (104)

FEB 7 1983

If I can be of any additional assistance, please do not hesitate to contact me.

Sincerely,

Original Signed By:
John D. Kinneman, Chief
Nuclear Materials Section A
Nuclear Materials and Safeguards
Branch

Enclosures: As Stated

cc w/encl:
Public Document Room (PDR)
Nuclear Safety Information Center (NSIC)
State of New Jersey

bcc w/encl:
Region I Docket Room (with concurrences)
J. Suermann, OCA
W. Crow, NMSS

RI:DETP
Kinneman/wb
1/31/83

RI:DETP
Joyner
2/3/83

RI:DETP
Martin

OFFICIAL RECORD COPY

township of wayne

475 Valley Road
Wayne, New Jersey 07470
(201) 694-1800
Police Department
(201) 694-0600

ARTHUR R. BARTOLOZZI, R.S., M.A.
HEALTH OFFICER
DIRECTOR OF HEALTH & WELFARE

November 15, 1982

John D. Kinneman, Chief
Nuclear Materials Section A
U.S. Nuclear Regulatory Commission
Region 1
631 Park Avenue
King of Prussia, Pennsylvania 19406

Subject: Radiological Surveys of Sheffield Brook, Final Report

Dear Mr. Kinneman,

This is to acknowledge receipt of your report with reference to the above subject matter.

The report is comprehensive. However, it does not specify what, if any, recommendations you are making regarding the disposition of this material.

The Wayne Township administration would like you to address the question of removal of the radioactive material from the W. R. Grace site and the Sheffield Brook area.

I would appreciate your early response to these questions.

Sincerely,

Arthur R. Bartolozzi
Health Officer

ARB:kms

cc: Congressman Robert Roe
8th District, New Jersey

Dr. Marvin Resnikoff, Consultant
P.O. Box 92, Blairstown, N.J.

John Leidy, Business Administrator
Township of Wayne

November 30, 1982

MEMO

TO: Mayor W. Jasinski, Town Council, A. Bartolozzi

FROM: M. Resnikoff, consultant on thorium contamination

RE: Radiological Surveys of Sheffield Brook by the Nuclear Regulatory Commission and the New Jersey Department of Environmental Protection

In this memo, the Nuclear Regulatory Commission (NRC) and New Jersey Department of Environmental Protection (DEP) reports on radiological surveys of Sheffield Brook are critically reviewed and recommendations offerred to the Town Council for its consideration.

On October, 1982, both the NRC and DEP released reports of radiological surveys of Sheffield Brook taken Spring, 1982. This followed aerial surveys taken May, 1981 by EG & G, and preliminary ground measurements taken by the NRC November, 1981. One report is due December, 1982, an NRC radiological survey of the Grace & Co. property.

The final NRC report, virtually identical to the preliminary report released July, 1982 and confirmed by the DEP report, shows that Sheffield Brook is contaminated with radioactive materials, thorium and its decay products. This contamination extends the length of Sheffield Brook, about 700 meters (from the Grace property at Black Oak Ridge Road, to the Pompton River), up to 70 meters in width and one meter in depth. The levels of contamination are above the EPA interim cleanup standards and also above NRC guidelines. According to the NRC, approximately 13,000 cubic meters of contaminated earth would have to be removed to reduce radiation levels to NRC guidelines.. Despite the request of the Town of Wayne, neither the NRC nor DEP offer recommendations on what to do with this contamination which presently exceeds legal limits. Neither the federal agencies (NRC and DOE) nor Grace & Co. have assumed responsibility for the cleanup, nor proferred a plan with fixed goals and timelines. If the federal agencies perform the cleanup, Congress would have to appropriate the money, presumably according to an NRC or DOE recommended plan. The Mayor, Committee of the Town Council, or Town Attorney, should enter into informal negotiations with the federal agencies and the office of Representative Roe on a cleanup plan.

Water Contamination Levels

People are primarily affected by radioactivity from Sheffield Brook/Grace property in two ways: by direct exposure near the site and through ingestion of contaminated water. While the reports show that radioactive concentrations in water are below drinking water standards (the most restrictive standard), the levels downstream of the Grace property are much higher than up stream levels indicating that radioactivity is leaching from the site and the soil by Sheffield Brook.

DEP sampling shows gross alpha radioactivity upstream of the Grace property (W1) as 0.68 pCi/l, and leaving the Grace property (entering the sewer lines, W13) as 5.67 pCi/l. See Figure 1 for the location of sampling locat-

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DESIGNATED ORIGINAL

SEP 2 9 1982 Certified By [signature]

The Honorable Robert A. Roe
United States House of Representatives
Washington, D.C. 20515

Dear Congressman Roe:

I am pleased to address the issues identified in the letter dated August 25, 1982, from Marvin Resnikoff and in Resolution No. 235 of the Wayne Township Council, which were enclosed with your letter of September 14, 1982. The letter and the Resolution concerned the W. R. Grace and Company property and surrounding area in Wayne, New Jersey.

From previous discussions between you and members of the NRC staff and from our previous correspondence, including my letters to you dated May 21 and September 1, 1982, you are familiar with the background of the Wayne situation. In addition, our Office of Congressional Affairs provided you with a copy of a Preliminary Report, Radiological Survey of Sheffield Brook, Wayne, New Jersey, dated July 1982, which was prepared by our contractor, Oak Ridge Associated Universities (ORAU).

Detailed responses to the specific issues in Dr. Resnikoff's letter and in the Resolution are contained, respectively, in Enclosures 1 and 2 to this letter.

We realize that these issues are of significant concern to you and your constituents, and are working to resolve them. We will keep you informed of our progress.

Sincerely,

William J. Dircks
Executive Director
for Operations

Enclosures:
1. Response to Dr. Resnikoff's letter
2. Response to Resolution No. 235

ions. It therefore appears that the radioactivity concentrations increase due to surface drainage from the Grace site.

The surface drainage then enters an underground sewer line upon leaving the Grace property. Two sewer lines feed into the Grace property drainage and dilute the radioactivity levels. In moving further downstream, the radioactivity levels in Sheffield Brook again increase. This information is summarized in Table 1 below, the DEP measuring points being shown in Figure 1.

The NRC measurements are, in general, higher than those of DEP. For example, the radioactivity concentrations of the drainage ditch leaving the Grace & Co. property are 5.67 pCi/l (W13, DEP) versus 29 pCi/l (#8,NRC). The reason for this discrepancy is not clear since the methods are virtually identical. The NRC report did not list radioactivity measurements upstream of the Grace & Co property. Perhaps the December NRC report will have this information.

In sum, while the radiation levels in water are below EPA standards, measurements by DEP show unmistakable leaching of radioactivity, primarily radium-228 which is more soluble. This leaching is from both the Grace property and from property downstream. The NRC measurements show radioactivity concentrations at the drainage ditch leaving the Grace property above the EPA drinking water standards.

Direct Radiation Exposure Levels

The radioactivity released from the Grace property via Sheffield Brook over the years has washed over an extended area, and has been dredged onto the stream banks. This radioactivity emanates from thorium-232 and its decay products, some of which emit gamma radioactivity, causing whole body radiation exposures. The levels near Pompton Plains Cross Road range from 6 to 10 μR/h (background levels) up to 420 μR/h near Sheffield Brook, or about 40 times background. The band of land about Sheffield Brook with these higher than background levels is about 50 meters in width.

West of Farmingdale Road the radiation levels are lower and the band of land with greater than background radioactivity has a width 10 to 20 meters.

Do these levels exceed radiation standards? A range of standards, along with different methods of interpretation, exist. According to the NRC, no individual member of the general public is to receive more than 500 millirems per year (mr/y) (57 μR/h, assuming continual occupation). For an operating nuclear fuel cycle facility, the fencepost dose limit is 25 millirems per year. The guideline for a nuclear reactor is 5 mr/y. For inactive uranium mill tailings sites, a situation most closely resembling Wayne, the external exposure rate limit is equivalent to 10 μR/h. According to DEP, this latter value is exceeded in an area greater than 18,000 m^2 surface area along Sheffield Brook, from the Grace property to the Pompton River.

Soil Measurements

The levels of radioactivity in soil (in units of picocuries per gram, pCi/g) vary from background up to 722 pCi/g. Baseline soil measurements in the Wayne area vary from 0.58 pCi/g to 1.6 pCi/g. Clearly, the levels near Sheffield Brook exceed this natural radioactivity by a wide margin. The general surface area of higher than natural background thorium-228 closely parallels the area where higher radiation exposures occur.

The EPA standards for remedial action are 5 pCi/g for radium-226. The NRC criteria, set in 1981, is 5 pCi/g for thorium-232 for unrestricted use, which corresponds to a direct exposure rate of 10 μR/h above background. The levels along Sheffield Brook greatly exceed these levels. DEP estimates that a surface area of 18,000 m^2 would not meet these criteria. The NRC estimates that about 13,000 cubic meters of soil would have to be removed to reach a concentration limit of 10 pCi/g.

NRC Hazard Evaluation Faulty

While the NRC has declined to state whether or not Sheffield Brook should be decontaminated, its views on the hazard level and its understanding, are clearly stated in Appendix E. To determine the hazard, the NRC estimates the length of time a person would be exposed to radiation at Sheffield Brook, the exposure per year received, and the increased cancer risk incurred. One could disagree over details such as the amount of radiation exposure and the risk of low level ionizing radiation, but before entering into such a discussion, it is important to recognize that the NRC has changed the rules of the game at Wayne. At reactors or fuel cycle facilities, one customarily calculates a fence post dose to a hypothetical individual who spends 24 hours per day in residence. This dose must be less than 5 mr/y for a reactor and 25 mr/y for a fuel cycle facility. At Wayne such calculations would yield a dose up to 3700 mr/y from direct exposure alone, much higher than the limit of 500 mr/y. The NRC therefore takes a 10% occupancy factor, reducing the highest level to 370 mr/y, below the 500 mr/y limit. Second, the definition of the term "unrestricted release" has also been altered to fit the circumstances at Wayne. Customarily, when the NRC releases a site for "unrestricted" use, this implies that neither the former licensee nor the NRC would need to monitor and inspect the site. The Grace property and Sheffield Brook are in this category - no licenses are being held. While the NRC assumes an "occupancy factor" of 10%, they have no way of ensuring compliance. Property can be sold and uses will change over the long time periods that this radioactive material will remain toxic. Any future landowner or child can use the site as he or she wishes.

The NRC also compares the Wayne site to Florida (phosphate rock, 80 pCi/g) and Tennesee (bituminous rock, 30-50 pCi/g). These are natural rock formations that are not the result of human activities. However, in Wayne, monazite sands were imported from overseas and other outside areas, and processed at Wayne. The residues left at Wayne are the result of human activities in transporting and processing these sands.

It is important to recognize that a radioactive dump was created at Wayne without proper findings being made by the AEC. No analysis was performed by AEC Staff to evaluate the suitability of the Grace property for final disposal of thorium residues. No effective control was exercised by the AEC in preventing the Sheffield Brook area from becoming contaminated. The NRC has a conflict of interest in judging, in retrospect, whether proper findings were originally made and whether the site is hazardous.

Table 1. Radioactivity Concentrations in Water Samples

Sample No.	Location Description	Gross Alpha (pCi/l)	Comments
W_1	Sheffield Brook upstream of Grace property	0.68	
W_{13}	Sheffield Brook leaving Grace Property	5.67	radioactivity concentrations increase in passing over Grace property
W_2	Sheffield Brook at Pompton Plains Cross Road	1.69	radioactivity concentrations diluted by two additional sewer lines
W_3	Sheffield Brook, 50 meters north of Farmingdale Road	2.10	
W_4	Confluence of Sheffield Brook and Pompton River	9.22	radioactivity concentrations continue to increase in pass ing over contaminated soil

Data from DEP radiological survey

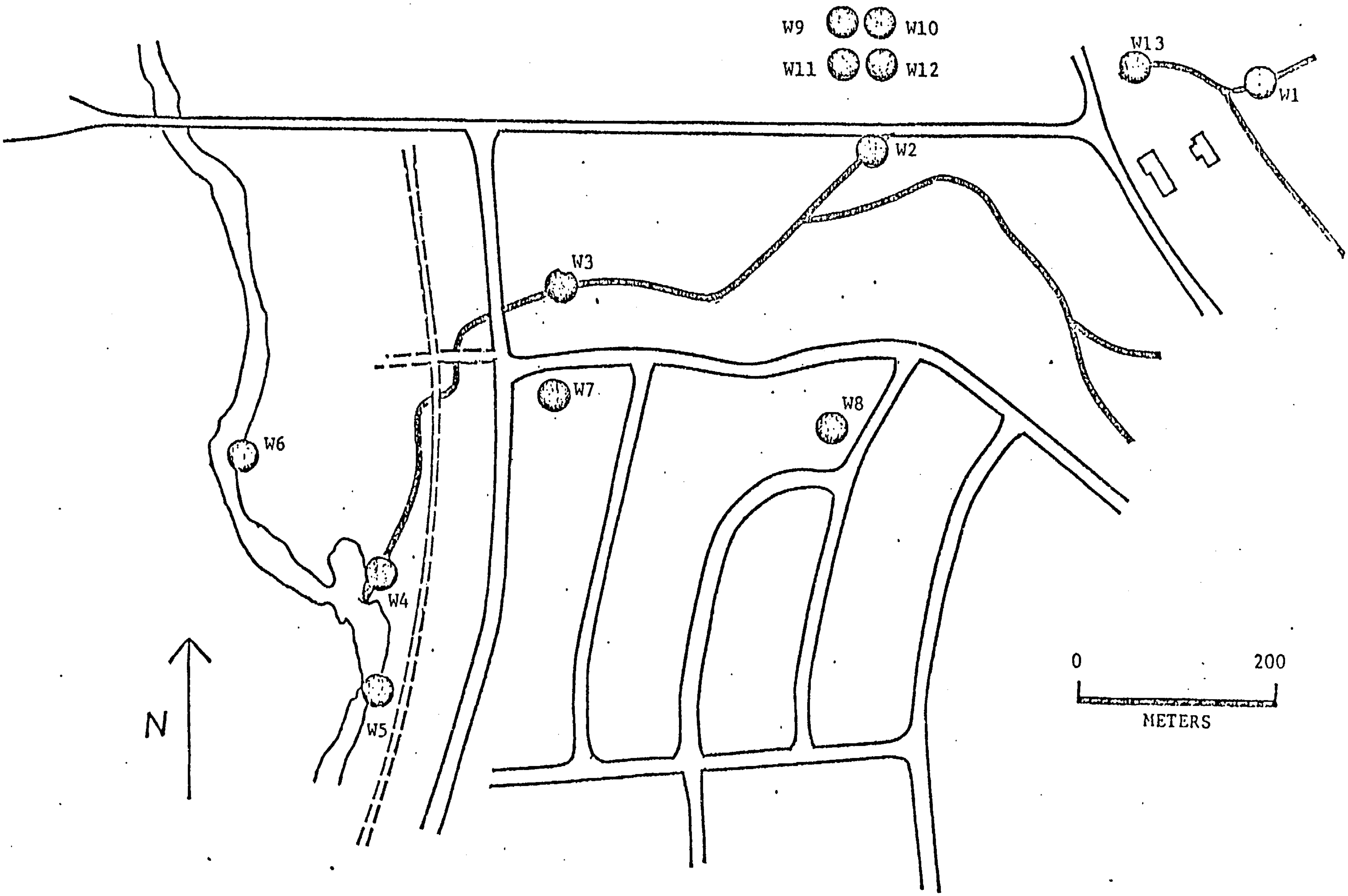

FIGURE 1: WATER SAMPLING LOCATIONS

From DEP radiological survey

DESIGNATED ORIGINAL

Certified By [signature]

December 6, 1982

John D. Kinneman, Chief
Materials Program Section No. 1
U.S. Nuclear Regulatory Commission
Region 1
631 Park Avenue
King of Prussia, PA 19406

Dear Mr. Kinneman,

For your information, enclosed please find report submitted by Dr. M. Resnikoff, Consultant, regarding the surveys of Sheffield Brook by the NRC and the DEP.

Sincerely,

[signature]

Arthur R. Bartolozzi
Health Officer

ENCLOSURE 1

Response to Dr. Resnikoff's letter

Items are numbered as in Dr. Resnikoff's letter dated August 25, 1982.

Item 1: "According to NRC's 'Proposed Radiological Survey Plan,' March 15, 1982, the final report on the stream survey was due in August. The preliminary report was completed on schedule in July. What is the holdup in the final report? Additional core drilling near Sheffield Brook was done in August. What was the purpose of these additional drillings?"

Response: The issuance of the final report has been delayed by the need of Oak Ridge Associated Universities to respond to NRC staff comments on the preliminary report and consider additional data which was not available at the time the preliminary report was published. The final report is scheduled to be available in October. The additional core drillings were conducted to provide additional and more complete information on conditions near the Brook. The results of these drillings will be incorporated in the final report.

Item 2: "The preliminary report has no recommendations. Though the Town Council and I will come to conclusions, and make recommendations, I think it would be useful to have the NRC do likewise, both for off- and on-site."

Response: The reports of the NRC contractor (Oak Ridge Associated Universities), who performed the radiological surveys around the Sheffield Brook and on the W. R. Grace site, are intended only to provide results of the survey measurements and observations of the survey group. Recommendations are the responsibility of the agency or party responsible for disposition of the site. Since the Department of Energy (DOE) has agreed to consider this site for the Formerly Utilized Site Remedial Action Program, this is likely to be the DOE staff. The NRC has previously concluded that there is no immediate hazard to the residents of Wayne from the presence of this thorium contamination. No data obtained from the contractor to date has changed this conclusion.

Item 3: "Finally, the site has an aquifer which may be passing through the burial pits. The on-site core drilling should include an investigation of the underground soil structure by a geologist, particularly a hydrogeologist. The NRC will be taking water samples from the drill-holes, where available."

Response: Drinking water samples taken from homes in this area have all been well within U.S. EPA standards for radioactivity. The results of the surveys on the W. R. Grace property will provide data to determine whether the site is affecting any water supplies. Such investigations will be the responsibility of the agency or party with ultimate responsibility for the site.

Item 4: "One of the Concerned Citizens asked how it would be possible to know the full extent of the buried materials on-site without core drilling into the burial pits. Grace & Company has objected to such drillings for fear the clay liner under the burial pits should be pierced. The NRC has instead carried out radar measurements of the pits and core drilling around the pits. Much of this awaits the NRC report, but unless the pits contain drums, it is also unclear to me how the full extent of buried materials will be known."

Response: Until the ORAU report is complete, it will not be known whether the core drilling and radar survey will provide sufficient information concerning the buried waste. They will certainly provide an important basis for planning additional work, should such work be necessary.

ENCLOSURE 2

Response to Resolution No. 235 of The Wayne Township Council

Items are lettered as in Resolution No. 235

Item a: "The hiring by the Nuclear Regulatory Commission of a Hydro geologist."

Response: The Nuclear Regulatory Commission has access to qualified hydro geologists both on staff and as consultants. We assume that the Resolution intends to suggest that a hydrogeologist review the situation in Wayne. Such a review will be the responsibility of the agency or party with responsibility for disposition of this site.

Item b: "That the contemplated flyover be performed over the entire Township."

Response: EG&G, under contract to the Department of Energy, began an additional aerial radiological survey over Wayne Township on September 16, 1982. EG&G has informed us that this survey will include essentially all of Wayne Township.

Item c: "That the material being dredged from the Pompton and Passaic River systems, as well as soil systems, be properly tested for radioactive material."

Response: The NRC Region I office has made arrangements to test samples of the dredged material for thorium.

Item d: "That the Nuclear Regulatory Commission perform additional tests on the W. R. Grace site in the actual burial pits."

Response: The recent surveys by ORAU include a large number of onsite measurements, including sampling from a number of boreholes near the burial pits. Additional testing is not planned until the analysis of these samples is complete and the results of all measurements are reported. A determination regarding additional testing will be made at that time.

Item e: "That the Nuclear Regulatory Commission immediately advise the Township and the affected residents of the results of the core samples taken from said residents' backyards."

Response: The NRC has made available to Township officials the preliminary report of the radiological survey of Sheffield Brook, Wayne, New Jersey dated July 1982. This report contains the preliminary results of the core samples. The final report of the survey at Sheffield Brook is expected to be available during October 1982 and a copy will be furnished to the Township officials and to the residents.

Item f: "That the Nuclear Regulatory Commission furnish the Township with final reports and recommendations for all the tested sites without further delay."

Response: The surveys and sample analysis being conducted by ORAU under contract to the Nuclear Regulatory Commission are both time consuming and complex. Due to the concerns of the people in Wayne, the NRC has expended considerable effort to produce the final reports as quickly as possible. A final report of the surveys of Sheffield Brook is scheduled to be available in October 1982. A preliminary copy of the final report of the surveys on the W. R. Grace property is expected to be available during December 1982.

Prepared by
Oak Ridge Associated
Universities

Prepared for
Division of Fuel
Cycle and
Material Safety

U.S. Nuclear
Regulatory
Commission

RADIOLOGICAL SURVEY OF THE W. R. GRACE PROPERTY WAYNE, NEW JERSEY

P. W. FRAME

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

FINAL REPORT

January 1983

8302070306

RADIOLOGICAL SURVEY
OF THE
W.R. GRACE PROPERTY
WAYNE, NEW JERSEY

Prepared for

Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission

P. W. Frame

Project Staff

J. D. Berger	A. J. Liu
R. D. Condra	A. M. Pitt
G. R. Foltz	T. J. Sowell
J. R. Frazier	C. F. Weaver
R. C. Gentry	T. S. Yoo

Prepared by

Radiological Site Assessment Program
Manpower Education, Research, and Training Division
Oak Ridge Associated Universities
Oak Ridge, Tennessee 37830

FINAL REPORT

January 1983

This report is based on work performed under Interagency Agreement DOE No. 40-770-80, NRC Fin. No. A-9093 between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Associated Universities performs complementary work under contract number DE-AC05-76OR00033 with the U.S. Department of Energy.

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LIST OF FIGURES

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RADIOLOGICAL SURVEY OF THE W.R. GRACE PROPERTY WAYNE, NEW JERSEY

INTRODUCTION

In 1948, Rare Earths, Inc., of Wayne, New Jersey, began processing monazite sand to extract thorium and rare earths. The facility was acquired by the Davison Chemical Division of W.R. Grace and Co. in 1957. Processing activities continued until July 1971 when the plant was permanently closed. In 1974 Applied Health Physics, Inc., decontaminated the buildings and the property was released by the Nuclear Regulatory Commission (NRC) for unrestricted use in January 1975. The buildings are currently under lease to, and occupied by, Electro-Nucleonics, Inc.

In January 1981, as part of a review of formerly licensed facilities, the Nuclear Regulatory Commission measured direct radiation levels and radionuclide concentrations in soil on the W.R. Grace property. The results of the survey indicated radiation levels ranging from 10-1000 μR/h and Th-232 concentrations as high as 1200 pCi/g of soil.[1] The State of New Jersey was represented at this survey and requested, through the U.S. Environmental Protection Agency, an aerial radiological survey. In May 1981, the aerial survey was conducted by EG&G. This survey identified elevated radiation levels at 1 m above the surface with average exposure rates greater than 120 μR/h.[2]

In the summer of 1982, the Pequannock Township Health Department performed a radiological survey of the Erie Lackawanna Railroad tracks in response to information that ore destined for W.R. Grace had been unloaded from trains near the Pompton Plains railroad station. This survey and subsequent investigations by the NRC and State of New Jersey identified elevated radiation levels near the intersection of Peck Road and a spur of the Erie Lackawanna Railroad line approximately 200 m north of the railroad station.

At the request of the NRC Division of Fuel Cycle and Material Safety, radiological surveys of the W.R. Grace site, adjacent properties, and the Erie Lackawanna Railroad tracks near Peck Avenue were conducted during July and August 1982, by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), Oak Ridge, Tennessee. This report represents the findings of those surveys.

A glossary of technical and nuclear terms and schematic representations of the naturally-occurring thorium and uranium radioactive decay series have been presented as Appendices A and B, respectively, to aid in the interpretation of this report.

SITE DESCRIPTION

General

W.R. Grace Property

The W.R. Grace property is located at 868 Black Oak Ridge Road about 2 km east of Pompton Plains and 3 km north of Wayne, in the northeast corner of New Jersey (Figures 1 and 2). The site, shown in Figure 3, occupies approximately 2.6 hectares, most of which is surrounded by a chain link security fence. Two office buildings and a warehouse are the main structures on the site. The eastern and northern sections of the site are wooded and heavy brush and weeds grow along a small drainage stream. This stream enters the property near the southeast corner, flows north, then west. Prior to leaving the fenced-in portion of the site, the stream enters an underground conduit. This conduit carries the water into a tank, where it is mixed with the occasional overflow from an inactive on-site artesian well and the storm sewer system. The water is then discharged to an off-site storm sewer.

The site is bounded by private residences to the north and east, to the south by a property currently used for storage and maintenance of

school buses, and by several commercial firms on the west side of Black Oak Ridge Road, across from the W.R. Grace property (see Figure 2).

Erie Lackawanna Railroad

The Erie Lackawanna Railroad runs in a north-south orientation through Pompton Plains in Morris County (see Figure 4). Just north of the point where the railroad crosses Jackson Avenue is the Pompton Plains Railroad Station. Another 200 m further north of the railroad station is the point where Peck Avenue runs into an unused spur of the railroad. The area is a mixture of commercial and residential properties; the nearest residence being approximately 10 m north of Peck Avenue and 20 m west of the spur.

Operations

Between 1948 and 1956 Rare Earths, Inc., processed thorium-containing monazite ore to recover various rare earths and to separate the thorium for use by the Atomic Energy Commission (AEC). Wastes and residues from the processing operations contained less than 5% of the original thorium concentration and were disposed of by burial on the site. Liquid effluents from these processes were neutralized in an on-site treatment plant and combined with the occasional outflow of an on-site artesian well and the small surface drainage stream. The combined effluents were carried, via conduit under the company's north parking lot, to the intersection of Black Oak Ridge Road and Pompton Plains Cross Road where they were released into the storm sewer system (see Figure 5). This storm sewer system flows westerly where it discharges into Sheffield Brook and, eventually, into the Pompton River.

The Davison Chemical Division of W.R. Grace and Co. acquired the plant in 1956 because of the potential uses for purified rare earths and thorium. Between 1957 and 1967, residues and wastes containing most of the thorium from the monazite ores were disposed of by on-site burial. From 1967 to 1971, when processing operations at the site were discontinued, residues were shipped to the W.R. Grace plant in Chattanooga, Tennessee. The Pompton Plains plant was permanently closed in April 1971.

In 1974 Applied Health Physics, Inc., performed a radiological survey of the site and conducted decontamination operations designed to bring the site into compliance with existing regulations permitting release for unrestricted use.[3] In the course of the decontamination operations, contaminated materials and equipment were buried on-site. Portions of the property were then filled or covered with soil and the site was leveled and landscaped.

A fire in May 1977 heavily damaged the main building and destroyed most of the early records, including those containing details concerning the quantities and locations of on-site waste burials. Based on information available in the Applied Health Physics report and conversations with several former employees, suspected burial locations have been identified and are shown on Figure 6.

Several other properties in the Wayne-Pompton Plains area were involved directly or indirectly with the Rare Earths and/or W.R. Grace operations. The property immediately to the south of the W.R. Grace site was formerly leased by W.R. Grace for occasional storage of monazite ore; rail shipments of the ore were unloaded near the Pompton Plains station of the Erie Lackawanna Railroad. Surveys of these two areas were conducted and the findings are included in this report. The drainage stream system (including Sheffield Brook) between the W.R. Grace site and the Pompton River received the treated liquid wastes from facility operations and surface run-off. A survey of this area was conducted earlier and the results have been reported in a separate document.[4]

SURVEY PROCEDURES

Objectives

The survey objectives were as follows:

I. W.R. Grace Site and Adjacent Properties

a. to measure direct radiation levels,
b. to determine the concentrations of radionuclides in surface and subsurface soil,
c. to define locations of burials, and
d. to determine if radionuclides are migrating and/or have migrated from the burial sites.

II. Erie Lackawanna Railroad

a. to measure direct radiation levels, and
b. to determine the concentrations of radionuclides in surface and subsurface soil.

Plan

The survey plans adopted to achieve these objectives included the following activities:

I. W.R. Grace Site and Adjacent Properties

a. Clearance of brush and weeds over the suspected burial areas and the establishment of a 20 m grid system for survey reference.
b. A ground penetrating radar survey to identify the location of the subsurface disturbances and buried objects.
c. Measurement of exposure levels (μR/h) at the surface and at 1 m above the surface at 5 m intervals throughout the W.R. Grace site.

d. Measurement of surface dose rates (μrad/h) at 5 m intervals throughout the W.R. Grace site.

e. Walkover surface scans to identify locations of elevated radiation levels on the W.R. Grace site and adjacent properties.

f. Collection of surface soil samples at grid line intersections and at locations indicated by the walkover scan to have elevated exposure rates.

g. Drilling boreholes and collection of subsurface soil and water samples.

h. Collection of sediment samples from the on-site drainage stream and from the storm drainage sewers.

i. Collection of on-site water samples from the drainage stream and storm sewers.

j. Collection of vegetation samples from various points on the W.R. Grace property.

II. Erie Lackawanna Railroad

a. Measurement of exposure levels (μR/h) 1 m above the ground at 0 m, 5 m, and 10 m distances from either edge of the railroad spur.

b. Walkover surface scans to identify locations of elevated radiation levels.

c. Collection of surface and subsurface soil samples.

d. Collection of vegetation samples.

<u>Procedures</u>

Ground Penetrating Radar Survey

A ground penetrating radar survey of the W.R. Grace property was performed under subcontract by Geo-Centers, Inc. of Newton Upper Falls, MA. The survey technique involves traversing the surface with a transmitter/receiver which emits electromagnetic signal pulses. The reflected signals are recorded and analyzed to identify the locations and

depths of buried objects and other subsurface disturbances. The procedure is described in greater detail in the radar survey report included as Appendix C.

Measurement of Direct Radiation Levels

The 20 m grid system established on the W.R. Grace site (see Figure 7) was subdivided into 5 m intervals. At each of these points, exposure rates were measured at the surface and at 1 m above the surface. Measurements were performed with portable NaI(Tl) gamma scintillation ratemeters field calibrated using a pressurized ionization chamber. Beta-gamma dose rates were measured at 1 cm above the surface at each of the locations where exposure rates were measured. These measurements were performed using thin window ($7 mg/cm^2$) "pancake" GM detectors with scaler/ratemeters. To evaluate contributions from non-pentrating radiations, measurements were also made with the detectors shielded with approximately 2 mm of steel. Walkover surface scans of the gridded areas were performed at 1-2 m intervals, using NaI(Tl) gamma scintillation ratemeters. Locations of significantly elevated radiation levels were noted. At locations where the exposure rates were above the range of the NaI(Tl) scintillation ratemeters, measurements were made with an energy compensated GM detector and scaler.

Walkover surface scans were performed at 2-5 m intervals on adjacent properties to the north and south of the W.R. Grace site. Radiation levels were mapped relative to surface features and landmarks.

The Pequannock Township and State of New Jersey surveys identified elevated radiation levels primarily along a 50 m section of a railroad siding just north of Peck Avenue. Several isolated spots were also noted approximately 50 m south of Peck Avenue. The ORAU survey, extending approximately 100 m north and south of Peck Avenue, consisted of walkover surface scans of the railroad tracks. North of Peck Avenue, the siding area was divided into 2 m intervals. At each of these intervals, exposure rates were measured 1 m above the surface, at the edge of the tracks and at 5 and 10 m on either side of the tracks.

Surface Soil Sampling

Surface (0-5 cm) soil samples of approximately 1 kg each were collected at the intersections of 20 m grid lines on the W.R. Grace property. Samples were also collected at selected locations of elevated gamma radiation levels. Efforts were made to include the source of the elevated levels in these samples. Sampling was performed using garden trowels, from which residual soil was cleaned between samples. Locations of on-site surface soil sampling are shown on Figure 8.

Surface soil samples were collected at locations of elevated radiation levels identified on the property south of the W.R. Grace site. Additional surface samples were also obtained at random locations on the adjacent properties. These sampling locations are indicated on Figure 9.

Subsurface Measurements and Sampling

Forty-three boreholes were drilled on the W.R. Grace property. Twenty-three of these were deep holes drilled to ground water depth. Site Engineers of Voorhees, New Jersey, performed the drilling, using 15 cm and 20 cm diameter hollow stem augers. The other twenty boreholes were shallow (approximately 1 m deep) and were drilled by the survey team, using a portable motorized auger.

The ground radar survey results were used to guide the selection of deeper borehole locations to ensure that subsurface utilities were not damaged. Drilling directly into burial trenches was also avoided to prevent damaging trench linings, thus creating potential migration pathways. Shallower boreholes were often located in areas where elevated exposure rates had identified near-surface thorium contamination. Locations of these boreholes are indicated on Figure 10. Shallow boreholes were drilled at two locations on the property south of the site and at eight locations along the railroad. Locations of boreholes on these off-site properties are shown on Figures 9 and 11, respectively.

In boreholes drilled on the W.R. Grace site a collimated NaI(Tl) scintillation probe was lowered into the hole and gamma radiation levels determined at 30 cm intervals. Gamma logging was not performed in the shallow boreholes drilled on the adjacent properties or along the Erie Lackawanna Railroad.

Soil samples were collected at the surface and at several depths in each borehole. The subsurface samples were at depths where gamma logging identified increased direct radiation levels and at additional points to provide a representative profile of subsurface thorium concentrations. Sampling was accomplished by scraping soil from the edges of the borehole using a specially constructed sampling tool or, at greater depths, by use of a split spoon sampler driven through the center of the hollow stem auger.

Because of heavy precipitation which occurred prior to and during the borehole drilling, the water table was unusually high. The pressure caused by the high water table resulted in the water rapidly filling most of the boreholes to within one to two meters of the ground surface. This water was not considered to be representative of the normal ground water conditions on the W.R. Grace site. Permanent monitoring wells have been installed on the property by W.R. Grace. Samples from these wells will be analyzed by ORAU and the results presented in an addendum to this report.

Sediment Sampling

Sediment samples of 1 kg each were collected on the W.R. Grace property from four locations in the drainage stream, from three drainage tiles, and from eight locations in the storm sewer system (see Figure 12). To provide more representative samples, several closely spaced points were sampled at each location and these samples composited.

Vegetation Sampling

Approximately 1 kg of surface vegetation, i.e. grass, weeds, and other ground cover, was collected from five locations on the W.R. Grace site.

These locations are indicated on Figure 12. No vegetation was collected from the adjacent properties. Three vegetation samples were collected from the area along the railroad (see Figure 11).

Water Sampling

Water samples were collected from three locations along the on-site drainage stream and from five locations in the storm sewer system as indicated on Figure 12. Water samples were not obtained from the railroad property or the adjacent properties since no appropriate sources were available for sampling.

Baseline and Background Measurements

Five soil samples, two water samples, and two vegetation samples were collected at locations 0.3 to 10 km from the W.R. Grace site. Direct radiation levels were measured at the locations of the soil samples. Figure 13 indicates the locations of the baseline samples and background measurements which were used for comparison with the other results of this survey.

Equipment and Analytical Procedures

Appendix D contains a list of the major equipment and instrumentation used for this survey. Analytical procedures are described in Appendix E.

RESULTS

Background Radiation Levels and Baseline Concentrations

Background exposure rates measured in the Wayne-Pompton Plains, NJ, area ranged from 6-12 μR/h; surface beta-gamma dose rates ranged from 10-24 μrad/h.

Baseline radionuclide concentrations in soil, vegetation, and water are presented in Tables 1-A and 1-B. The concentrations in these samples are typical of those normally encountered.

W.R. Grace Site

Ground-Penetrating Radar Survey

The report of the ground-penetrating radar survey provided by Geo-Centers, Inc., is presented as Appendix C. This report concluded that the soil on the W.R. Grace property had been subjected to extensive disturbances. Although there were some similarities between the areas of these disturbances and the burial locations as identified by W.R. Grace records, specific numbers and locations of these burial sites did not agree. In addition to the regions of disturbed subsurface soil, numerous individual reflecting targets were observed by the radar scans. These targets were located between the surface and a depth of approximately 2 m, and were randomly distributed, rather than being associated with the subsurface soil disturbances.

Direct Radiation Levels

Exposure rates measured systematically at predetermined grid locations on the W.R. Grace property ranged from 13 to 540 μR/h at 1 m above the surface. The highest levels generally occurred on the portions of the property where burials reportedly are located. However, only a limited correlation was noted between the exposure levels and the burial locations, as identified by site personnel or by the ground-penetrating radar survey. Exposure rates at 1 m decreased to near background levels at the north, east, and west property boundaries. These exposure levels are presented graphically in Figure 14.

The general pattern and levels of the systematically measured surface exposure rates were very similar to those measured at 1 m above the surface. The levels ranged from 9 to 610 μR/h. Many small areas, having significantly elevated contact radiation levels (up to 7710 μR/h), were

identified by the walkover surface scan. The locations and exposure rates of some of these areas, which were selected for further surface and subsurface investigations, are shown on Figure 15.

Individual dose rate data are not presented in this report; however, the pattern of these dose rates is in good agreement with the pattern of exposure rates described above. Dose rates (μrad/h) were generally between 1.25 and 2.0 times the surface exposure rates (μR/h). The unshielded probe measurements ranged from 25 to 40 percent higher than the measurements performed with the probe face shielded, indicating a significant dose contribution from beta and low-energy photon radiations. This is consistent with the presence of thorium contamination.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in the surface soils collected on the W.R. Grace property are presented in Table 2. The total thorium concentrations (Th-232 + Th-228) ranged from 2.14 pCi/g (sample location S5) to 721 pCi/g (S9) in the samples systematically collected at grid line intersections. The total thorium concentrations in soil collected at locations identified by the walkover survey to have elevated exposure rates (see Figure 8) ranged from 51.2 pCi/g (S58) to 7540 pCi/g (S30). In general, there was a positive correlation between the thorium concentration in the soil and the direct radiation level at the point of sampling. Thorium concentrations in soil samples collected east and north of the drainage stream ranged from 2.14 pCi/g (S5) to 20.0 pCi/g (S4). Surface soil systematically collected on the western portion of the property along Black Oak Ridge Road contained total thorium concentrations ranging from 3.49 pCi/g (S49) to 49.6 pCi/g (S56). However, several isolated spots with elevated exposure rates were identified in this area, and soil samples taken from these locations had thorium concentrations between 51.2 pCi/g (S58) and 832 pCi/g (S54).

Radionuclide concentrations in soil from boreholes on the W.R. Grace site are presented in Table 3. In general, the lowest thorium concentrations were measured in soil from the boreholes drilled east and

north of the drainage stream (B1-B9), through the paved areas (B38-B41), and in the lawn near Black Oak Ridge Road (B35, B42, and B43). In the boreholes east and north of the drainage stream, the total thorium concentrations ranged from 2.66 pCi/g (B7) to 11.5 pCi/g (B3) for surface soil and from 1.75 pCi/g (B7) to 9.90 pCi/g (B9) for soil collected from the bottom of the boreholes. Thorium concentrations in soil from boreholes B1-B8 decreased with depth; however, in borehole B9 the concentration increased from 3.50 pCi/g at the surface to 9.90 pCi/g at 1 m. Samples from boreholes B38-B41, drilled in the paved areas, contained thorium concentrations ranging between 3.83 pCi/g (B38) and 5.28 pCi/g (B40) just below the pavement. Concentrations in these boreholes decreased or remained constant down to approximately 2 m. In the boreholes drilled near Black Oak Ridge Road (B35, B42, and B43), the thorium concentrations ranged from 3.06 pCi/g (B35) to 30.4 pCi/g (B43) at the surface and from 2.25 pCi/g at 2 m in B35 to 15.5 pCi/g at 3.6 m in B43.

The maximum thorium concentration measured in the subsurface samples was 30,500 pCi/g. This sample was from the 3.9 m depth in borehole B29. Other boreholes where high subsurface thorium levels were measured were B26 (15,900 pCi/g), B22 (15,400 pCi/g), B15 (9,800 pCi/g), B27 (6,350 pCi/g), and B30 (5,460 pCi/g). Four of these (B22, B15, B27, and B30) were shallow boreholes drilled at locations with notably elevated exposure rates. In each of these boreholes, the thorium concentrations in the soil increased with depth, suggesting that these holes were drilled over areas of buried residues.

The ratios of Ra-226 and U-238 concentrations to total thorium concentrations varied widely in soil samples from the site. Radium-226 concentrations ranged from approximately 0.3% to 32% of the thorium levels; U-238 concentrations ranged from about 0.3% to 35% of the thorium levels. Ratios of U-238 to Ra-226 were also inconsistent. No pattern was noted in these variations. These differences suggest that the materials encountered represent residues from different processes and stages in operations conducted at this site.

Although the Th-232 and Th-228 concentrations generally agreed, several samples exhibited significant differences. For example sample S13 contained 2710 pCi/g of Th-232 but only 1540 pCi/g of Th-228; sample S36, on the other hand, contained 1850 pCi/g of Th-232 and 2300 pCi/g of Th-228. These differences indicate that some of the residues on this site have not yet reached an equilibrium state with the entire thorium decay series.

Radionuclide Concentrations in Sediment Samples

The radionuclide concentrations in sediment samples are presented in Table 4. In the four samples collected from the drainage stream the thorium concentrations ranged from 3.76 pCi/g (sample location D4) to 10.3 pCi/g (D1). No clear pattern was observed in these samples, the highest levels being found in sediment from the stream near its entrance to the W.R. Grace property. Sediment samples D8-D15 collected from the storm sewer system contained thorium levels ranging from 34.3 pCi/g (D8) to 1820 pCi/g (D14). Although the path of this sewer system is not precisely known, a general pattern of increasing concentrations was observed as the system neared the outfall from the W.R. Grace property.

Radionuclide Concentrations in Water Samples

Radionuclide concentrations measured in the water samples from the drainage stream and from the storm sewer system are presented in Tables 5 and 6. Water collected from the drainage stream contained gross alpha concentrations ranging from <3.19 pCi/ℓ* (W3) to 7.21 pCi/ℓ (W1). Gross beta levels in these samples were <5.00 pCi/ℓ. Radium-228 concentrations were <0.18 pCi/ℓ. Radium-226 concentrations ranged from <0.03 pCi/ℓ (W2) to 0.11 pCi/ℓ (W3).

Elevated radionuclide concentrations were present in water from the storm sewer system. Levels ranged from 5.33 pCi/ℓ (D13) to 28.6 pCi/ℓ (D11), gross alpha; 13.4 pCi/ℓ (D13) to 60.8 pCi/ℓ (D11), gross beta;

** The "less than" symbol (<) indicates that the concentration is below the detection limits of the analytical technique. Refer to Appendix E for further discussion.*

6.59 pCi/ℓ (D11) to 14.2 pCi/ℓ (D12), Ra-228; and 0.10 pCi/ℓ (D10) to 0.86 pCi/ℓ (D12), Ra-226. The pattern of concentrations in these water samples was consistent with the concentrations in the sediments from the same locations.

Radionuclide Concentrations in Vegetation Samples

Radionuclide concentrations in the five on-site vegetation samples are presented in Table 7. In these samples the Ra-228 concentrations ranged from 1.00 pCi/g (V1) to 3.41 pCi/g (V4) and the Th-228 concentrations from 0.26 pCi/g (V1) to 0.59 pCi/g (V5). All these values are slightly elevated above the baseline sample concentrations. No other radionuclides were present in levels significantly above the baseline concentrations.

Properties Adjacent to the W.R. Grace Site

Surface Radiation Exposure Levels

Elevated radiation levels were noted extending onto the school bus maintenance yard south of the W.R. Grace property. The exposure rates measured at contact with the surface are indicated on Figure 16. Areas with the highest levels were in the vicinity of the concrete loading platform at the northwest corner of the building and near a door on the building's northeast side. Maximum exposure rates at these locations were 250 and 890 μR/h, respectively. Inside the building, elevated direct radiation levels were limited to the northern half of the building and were primarily associated with cracks in the concrete floor.

Exposure rates on the properties to the north, east, and west of the site were in the range of area background levels.

Radionuclide Concentrations in Soil Samples

The radionuclide concentrations in surface soil from the adjacent properties are indicated in Table 8. The three randomly collected soil samples from the private residence north of the W.R. Grace property

(S68-S70) had total thorium concentrations between 1.24 pCi/g (S69) and 2.08 pCi/g (S68). These values are within the range of the baseline samples. Total thorium in the three soil samples (S71-S73) collected in the commercial area immediately west of the W.R. Grace property, ranged between 1.85 pCi/g (S71) and 7.21 pCi/g (S72). The highest concentration was found in sample S72 which was collected from the location (in this area) determined in the walkover survey to have a slightly elevated contact exposure rate of 18 μR/h. The other two samples had concentrations within the range of the baseline samples. South of the W.R. Grace property, in the school bus maintenance yard, the thorium concentrations in the surface soil ranged between 2.32 pCi/g (S81) and 2720 pCi/g (S77). Two samples scraped from the floor inside the north building (S78 and S79) had thorium concentrations of 647 pCi/g and 17.8 pCi/g, respectively.

Two shallow boreholes were drilled in the school bus maintenance yard near the southern boundary of the W.R. Grace site. The radionuclide concentrations in soil from these boreholes are presented in Table 9. The borehole drilled at a location with an elevated surface exposure rate (B44) had a thorium concentation of 3,760 pCi/g in the surface soil. The concentration decreased with depth to baseline levels, i.e. 2.08 pCi/g, at 1 m. The thorium concentration in surface soil from the other borehole, B45, was slightly elevated, 9.30 pCi/g, but the concentrations in subsurface samples were near the baseline range.

Erie Lackawanna Railroad

Direct Radiation Levels

Exposure rates along the Erie Lackawanna Railroad in the vicinity of Peck Avenue measured systematically at 1 m above the ground ranged from 9 to 135 μR/h (see Figure 17). Contact exposure rates are presented in Figure 18. These levels ranged from 7 μR/h to 970 μR/h. (At 1 m above the location with the highest surface exposure rate, i.e. 970 μR/h, the exposure rate was 190 μR/h.) Elevated radiation levels are primarily associated with the west embankment of an unused railroad siding between the spur and a footpath for a distance of 40-50 m north of Peck Avenue.

Three isolated spots with exposure rates of 200 μR/h were also identified adjacent to the railroad spur 70-100 m south of Peck Avenue.

Radionuclide Concentrations in Soil Samples

Radionuclide concentrations in soil samples collected along the Erie Lackawanna Railroad are presented in Table 10. Total thorium concentrations in the surface soil samples ranged from 1.56 pCi/g (B54) to 1280 pCi/g (B46). The lowest levels are in the range of the baseline concentrations; these were in samples (B52-B54), collected from the east side of the railroad tracks. The highest concentrations were in samples from boreholes B46, B47, and B51, drilled at locations having elevated direct radiation levels. The thorium concentrations in these samples were 1280 pCi/g, 813 pCi/g, and 403 pCi/g respectively. In each case the thorium concentrations decreased with depth. Boreholes B48-B50 were drilled in a small mound located between the end of Peck Avenue and the railroad spur. In each of these boreholes, the thorium concentrations increased with depth from near baseline concentrations at the surface to a maximum at a depth of about 0.5 m. The maximum thorium concentrations in boreholes B48, B49, and B50 were 50.4 pCi/g, 42.9 pCi/g, and 9.83 pCi/g respectively. Ratios of Ra-226 to thorium activities in these samples were nearly constant, ranging from about 5% to 8%. Concentrations of Ra-226 to U-238 were approximately equal, suggesting that the contamination in this area is due to unprocessed monazite sand.

Radionuclide Concentrations in Vegetation Samples

The radionuclide concentrations in vegetation samples (V6-V8) collected from the vicinity of the Erie Lackawanna Railroad are presented in Table 11. In all cases, the radionuclide concentrations were within the range of the baseline samples.

DISCUSSION

This survey identified thorium contamination in soil on the W.R. Grace site, the adjacent property south of that site, and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains. Elevated direct radiation levels are associated with this contamination. The contamination on the W.R. Grace property appears to be process residues, consistent with previous uses of monazite sands and on-site burials of wastes. Contamination on the adjacent property south of the W.R. Grace site and the Erie Lackawanna Railroad appears to be unprocessed monazite sand, originating from handling or storage of the sands on those properties.

W.R. Grace Site

Contamination on the W.R. Grace and Co. site apparently originated from on-site storage and shallow land burial of ores, wastes, residues, and contaminated equipment from previous operations. The relatively high thorium surface contamination levels in some locations and the findings of the ground-penetrating radar survey suggest that the burials were not necessarily at well defined locations and that buried wastes may have been disturbed and eventually spread over the eastern portion of the property.

Borehole sampling and measurements at suspected burial locations indicated higher concentrations in the subsurface soil than in the surface soil. Thorium concentrations in soil samples collected east and north of the drainage stream (well away from the burial areas) and along the western property boundary were slightly elevated. Thorium concentrations in surface and subsurface soil, collected near the south property boundary also were elevated.

Due to the extensive disturbance of soil on the property, lack of agreement between site personnel and ground-penetrating radar results concerning the burial locations, and because of intentional avoidance of drilling into suspected burial trenches, it was not possible to estimate with reasonable accuracy the total volume and activity of the on-site wastes.

Direct radiation levels on almost the entire portion of the site where burials are suspected exceeded 60 μR/h. Access to areas of highest radiation levels is restricted and the site is posted with radiation warning signs.

Buildings on the site were surveyed prior to termination of the W.R. Grace license and levels were verified recently by the NRC Region 1 office. These buildings were found to meet the NRC criteria for release for unrestricted use and therefore were not included in the ORAU survey.

Radionuclide levels in the sediment and water from the drainage stream are elevated but do not indicate that this is a significant migration pathway. The general slope of the property is away from the stream. Surface run-off from areas of contaminated soil into this stream is, therefore, very limited.

All of the sediment samples from the on-site storm sewer contained elevated thorium concentrations; all of the water samples collected from the storm sewer had gross alpha levels above those in baseline samples. The high thorium levels in some of these sediment samples indicate a concentration by placer action. These findings and the elevated radiation levels and surface soil concentrations along other surface drainage pathways on the W.R. Grace site suggest transport by water run-off has been and continues to be a significant mode of migration.

Ground water sampling was complicated by heavy rains. Permanent monitoring wells have been installed and the results of sampling from these wells will be provided as an addendum to this report.

Adjacent Properties

Only one soil sample from the adjacent properties north and west of the site had a thorium level exceeding the range of the baseline samples. Thorium concentrations in surface soil from the adjacent property, south of the W.R. Grace site, exceeded baseline levels. Thorium contamination is

also present on the floor of one of the buildings. This contamination probably resulted from occasional use of the property for monazite sand storage.

Surface run-off from the W.R. Grace site may also have contributed to this contamination. Thorium concentrations in the subsurface soil samples, collected on this property, were only slightly higher than those in baseline samples.

Surface exposure rates on the northern portion of this property also exceed area background levels. Highest levels are located along the boundary nearest the W.R. Grace property and in several small isolated areas adjacent to and inside the building once used for monazite sand storage.

Erie Lackawanna Railroad

Elevated surface soil concentrations of thorium are present along the section of the Erie Lackawanna Railroad included in this survey. Subsurface soil samples, collected at locations of higher direct radiation levels, also contain thorium concentrations exceeding the baseline soil levels. The contamination is believed to be in the form of unprocessed monazite sand, which was reportedly unloaded at this location. Elevated direct radiation levels, associated with the thorium contamination, are present along the track north of Peck Avenue, and there are several small isolated areas of elevated surface radiation 50-75 m south of Peck Avenue.

Radiation Guidelines

Guidelines for levels of radiation and radioactive materials in the environment are established by federal regulatory agencies such as the Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA). These guidelines are usually based on conservative factors of land use and occupancy, potential intake by inhalation and ingestion, biological retention times, relative hazard of the radionuclide, and potentially exposed population group. Such guidelines are, therefore, for highly

restrictive situations that may not be representative of the actual conditions at a specific site. For this reason, these federal guidelines are often used as target criteria with site-specific limits established on case-by-case basis. Guidelines for concentrations of radionuclides in soil have not been specifically developed for the W.R. Grace site or other properties included in this survey.

The Nuclear Regulatory Commission's Standards for Protection Against Radiation (10CFR20) establishes limits of radiation dose for occupational radiation workers and for the general public. An individual in the general public may receive an annual radiation dose of 500 millirem.[5] Assuming continual exposure, i.e. 168 h/wk, this allowable annual dose is equivalent to an average exposure rate of approximately 60 μR/h.

SUMMARY

At the request of the Nuclear Regulatory Commission, the ORAU Radiological Site Assessment Program conducted a radiological survey of the W.R. Grace site in Wayne, New Jersey. Surveys of properties adjacent to the W.R. Grace site and a section of the Erie Lackawanna Railroad in neighboring Pompton Plains were also performed.

The findings indicate extensive thorium contamination in soil on portions of the W.R. Grace site. Radionuclide concentrations in the sediment and water collected from the on-site storm sewer indicate this system is a possible pathway for off-site migration of contamination. Migration appears to be by placer movement, rather than by leaching of radionuclides from the residues.

A portion of the property (including one of the buildings) bordering the W.R. Grace site on the south and a section of the Erie Lackawanna Railroad also have elevated thorium concentrations in soil and radiation levels. The contamination on these two properties appears to be primarily unprocessed ore. Other properties adjacent to the W.R. Grace site do not have thorium concentrations or direct radiation differing significantly from the range of area baseline and background levels.

Permanent monitoring wells are being installed to measure radionuclide concentrations in ground water on the W.R. Grace site. Results of these measurements are not completed and will be provided as an addendum to this report.

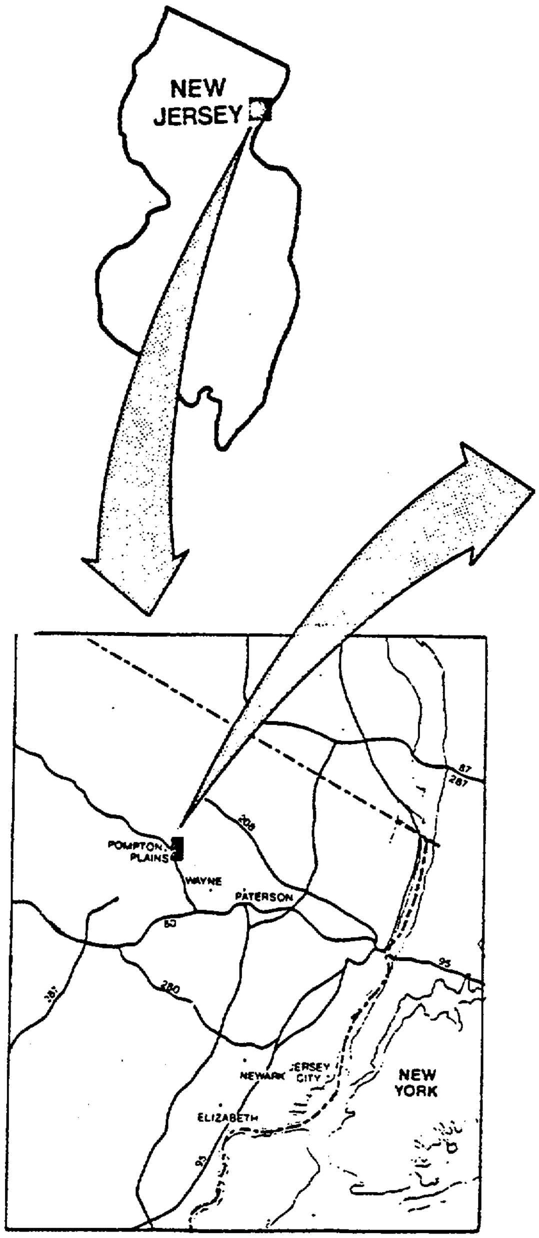


FIGURE 1. Map of Northeastern New Jersey Indicating the Location of the W.R. Grace Property.

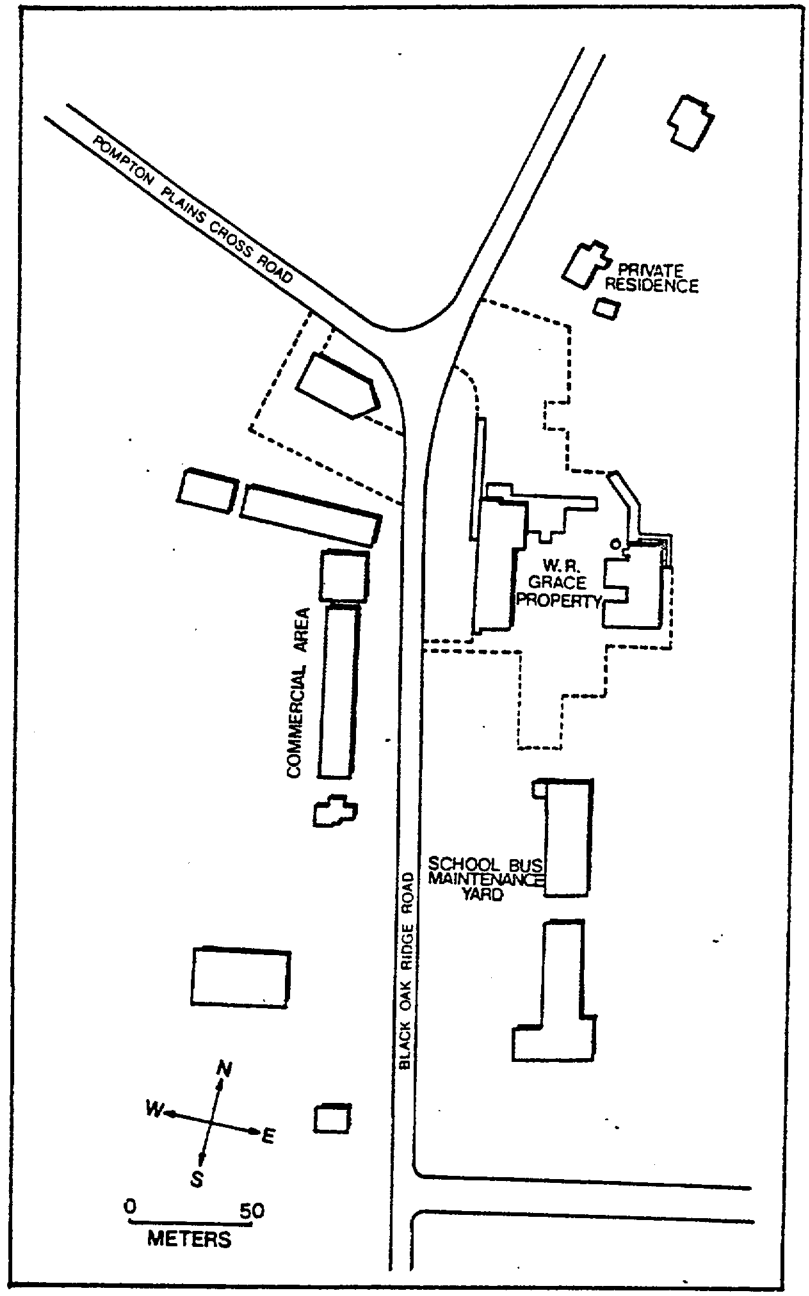


FIGURE 2. Portion of Wayne, New Jersey, Indicating the Locations of the W.R. Grace Property and Adjacent Properties. (Dotted lines indicate paved areas.)

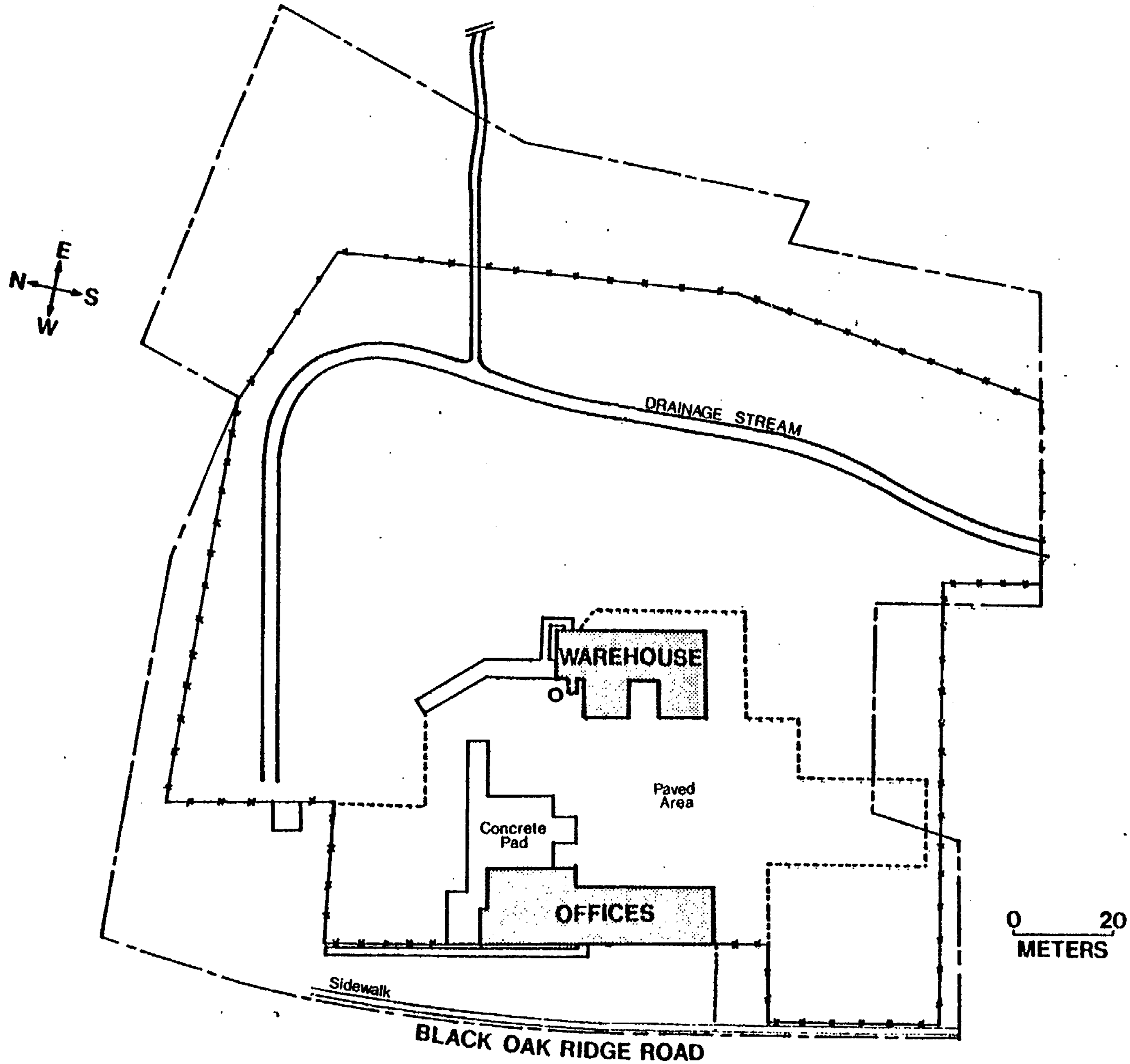


FIGURE 3. Plan View of the W.R. Grace Property.

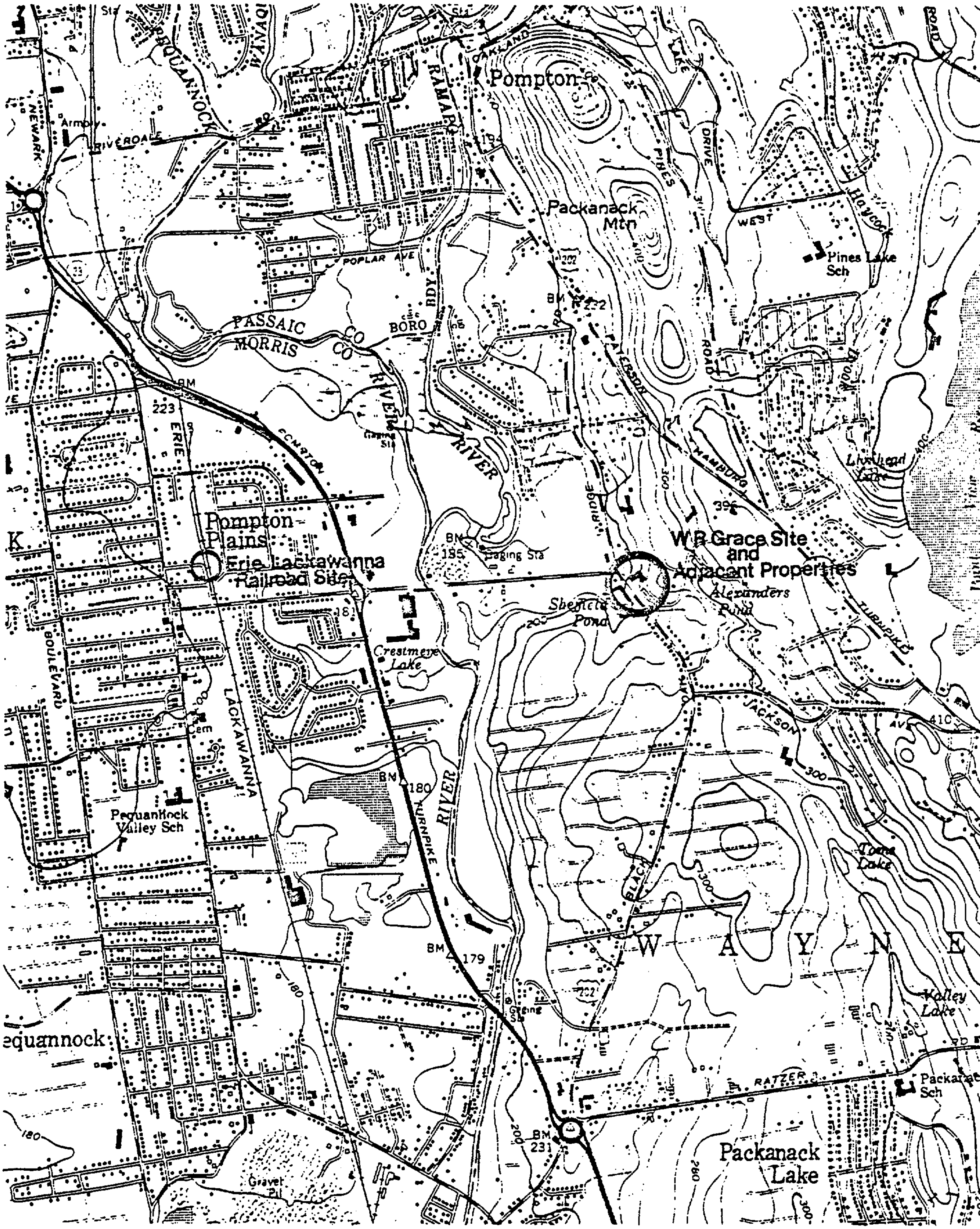


FIGURE 4. Map of the Wayne-Pompton Plains, New Jersey, Area Indicating the Location of the W.R. Grace Site and the Erie Lackawanna Railroad Site.

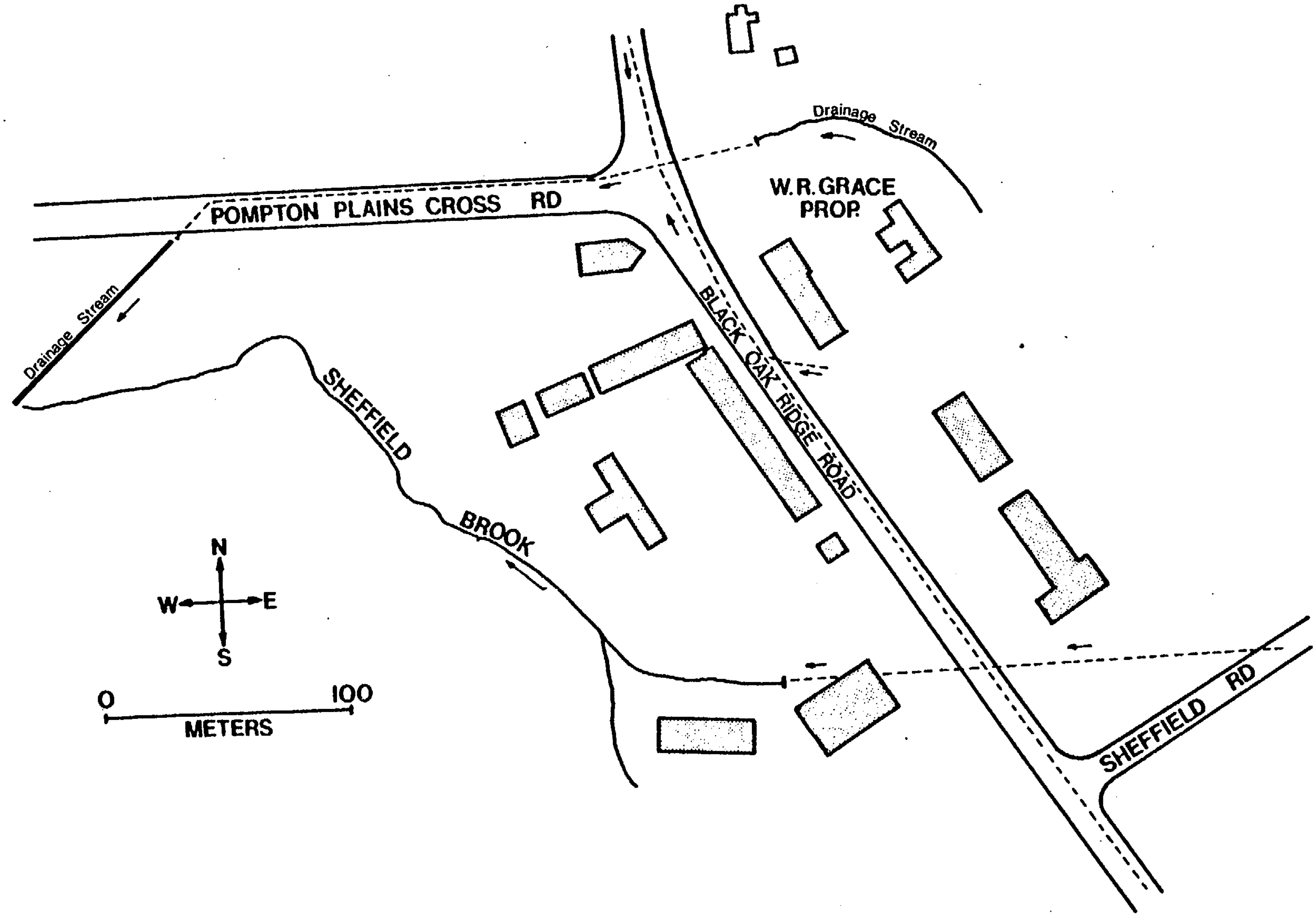
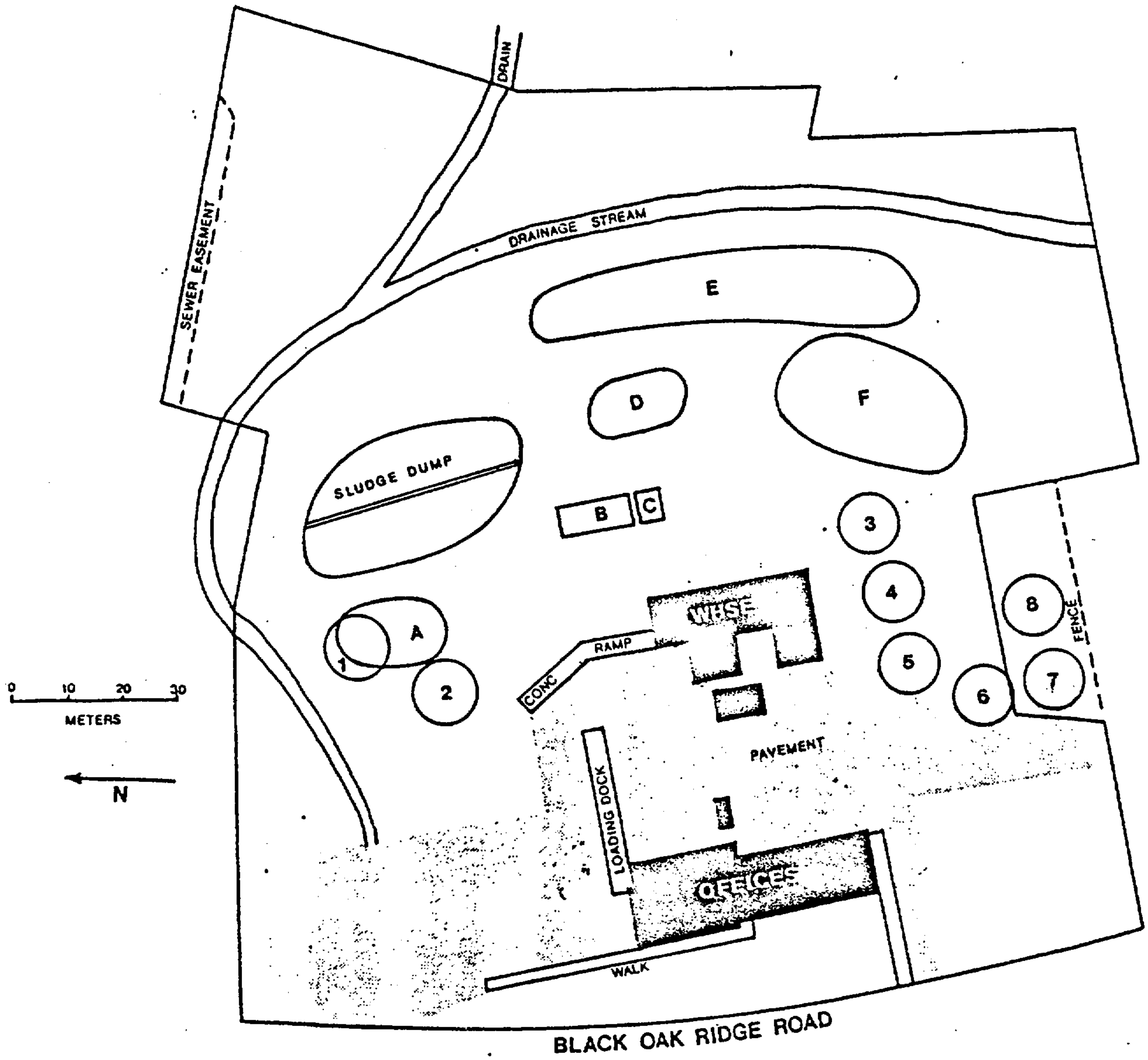


FIGURE 5. Plan View of the Storm Drainage System Servicing the W.R. Grace Site.



A=Reworked Sludges
B=Yttrium Concentrate
C=Thorium Hydroxide
D=Waste Treatment Disposal
E=Ore Tailings and Gangue
F=Yttrium and Silica Sludges

1-8 = Circular Holes Filled April-June 1974 with debris and contaminated equipment resulting from decontamination of buildings.

FIGURE 6. Suspected Burial Locations on the W. R. Grace Property.

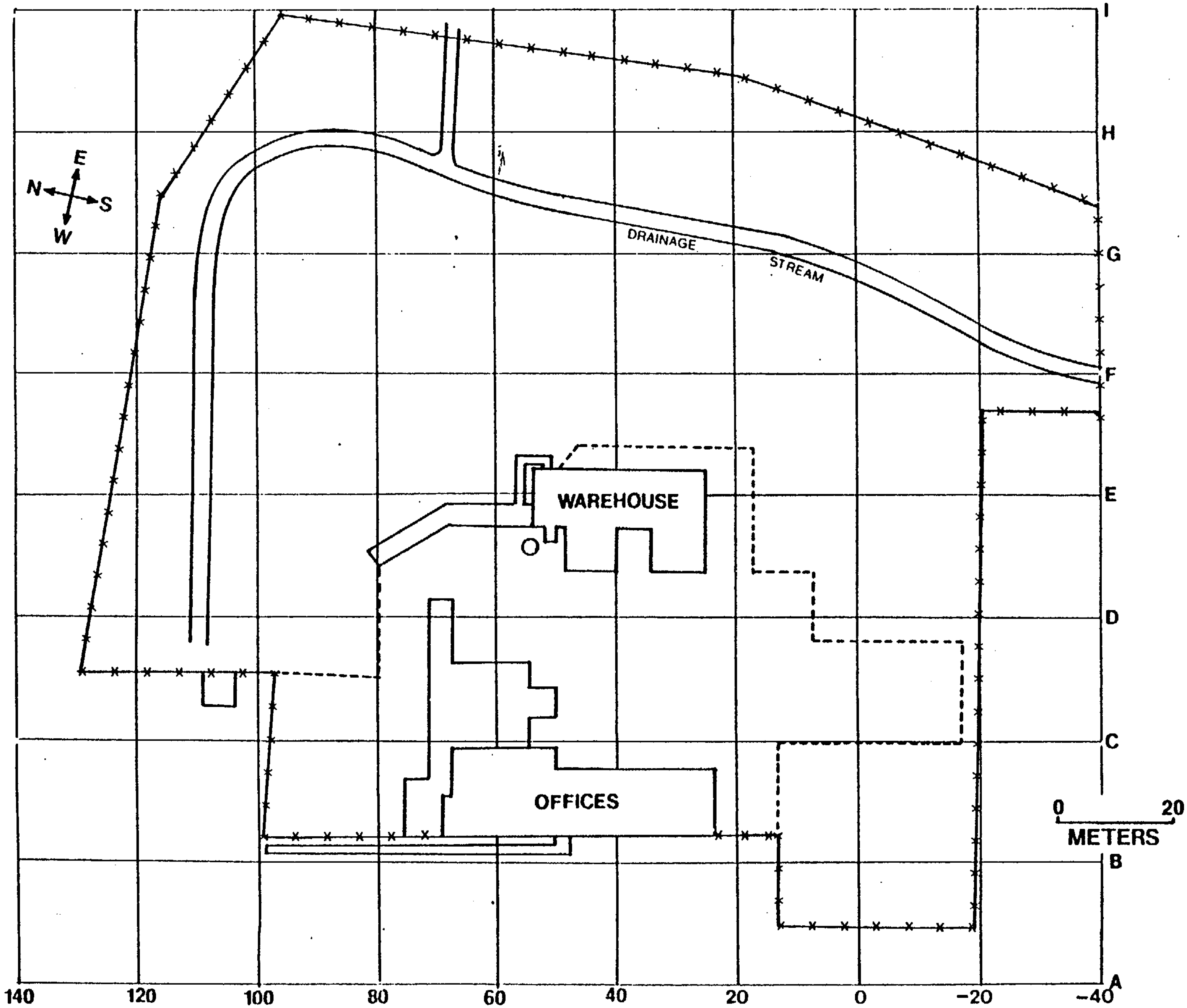


FIGURE 7. Grid System Established for Survey Reference.

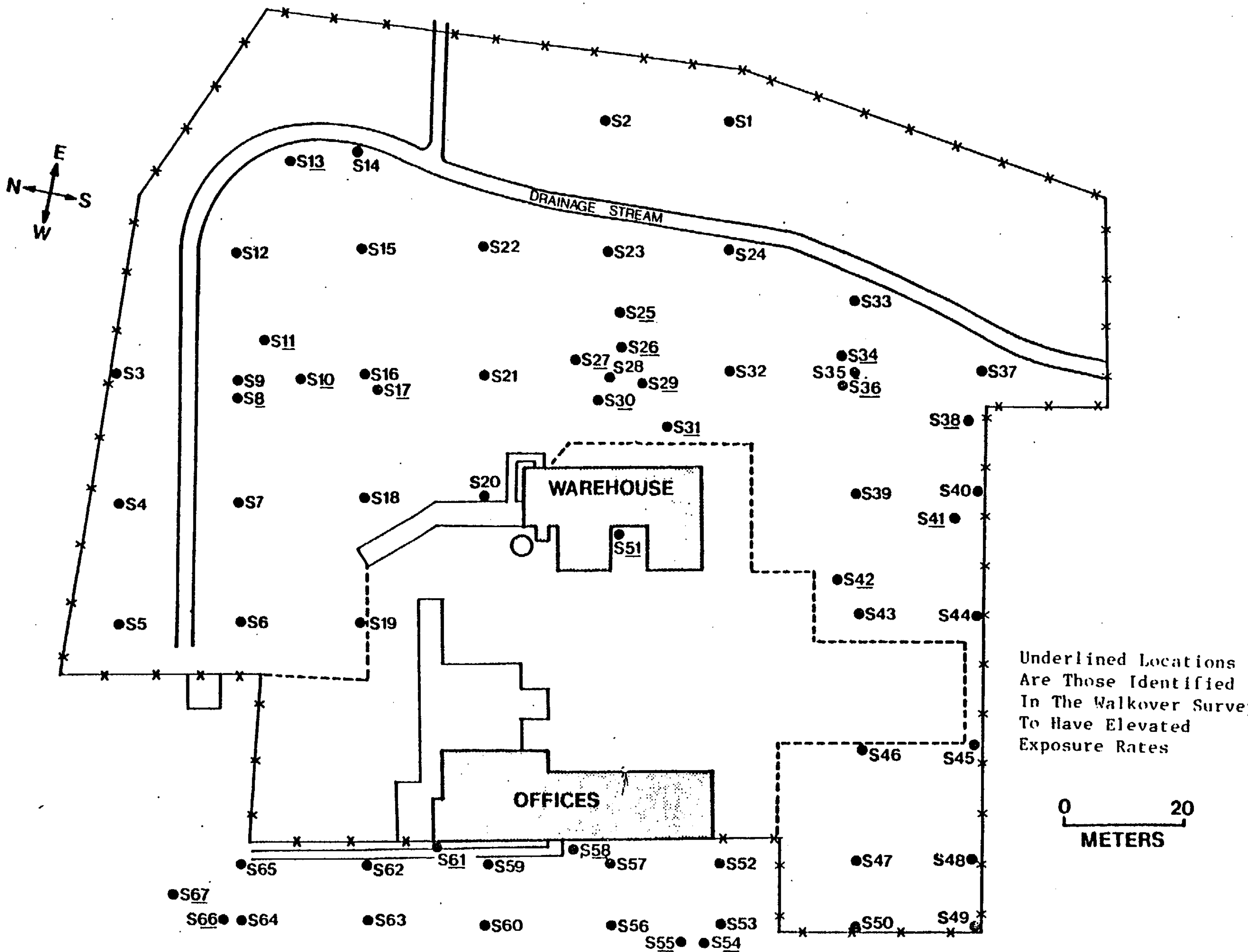


FIGURE 8. Surface Soil Sampling Locations on the W.R. Grace Property.

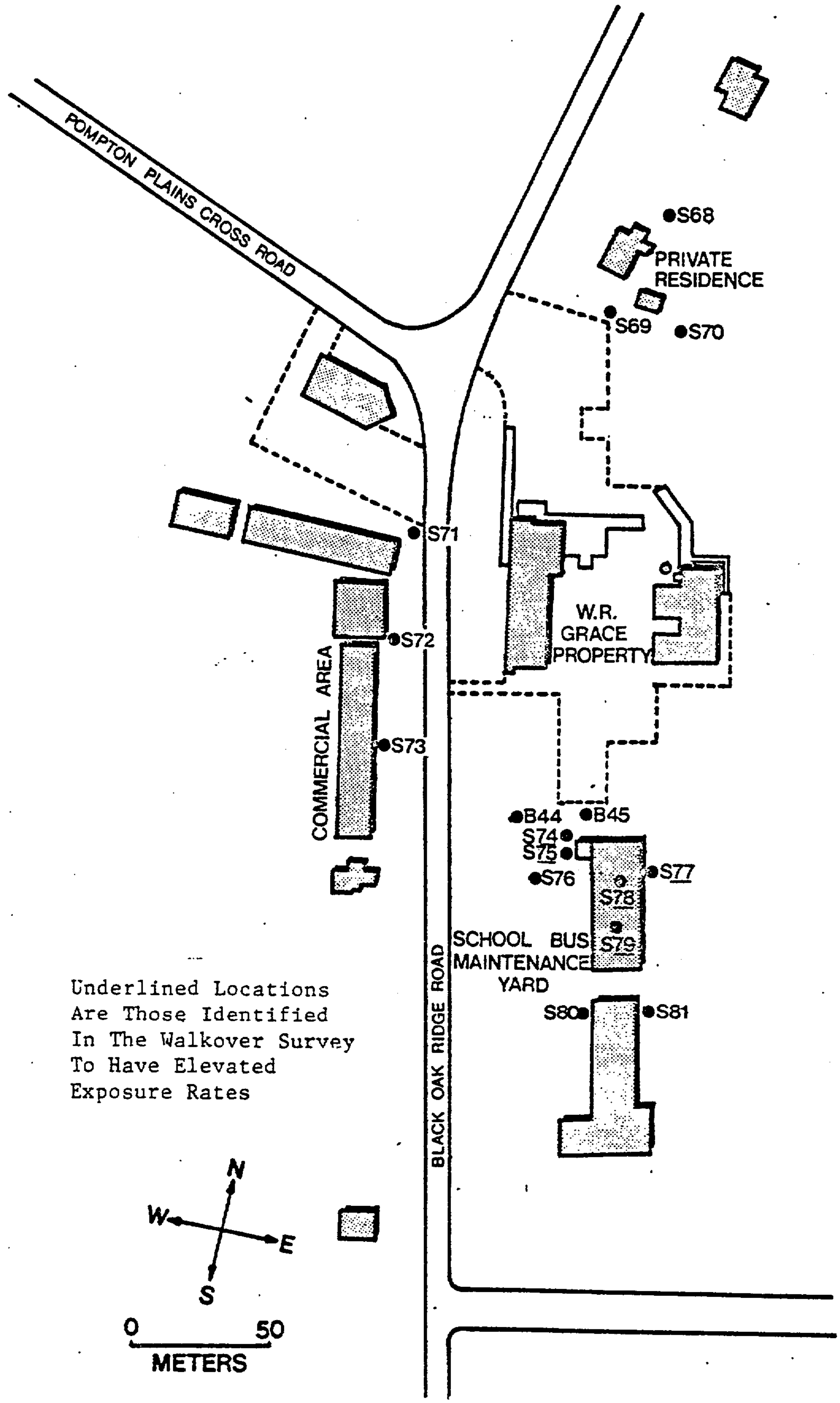


FIGURE 9. Surface Soil Sampling and Borehole Locations Adjacent to the W.R. Grace Property.

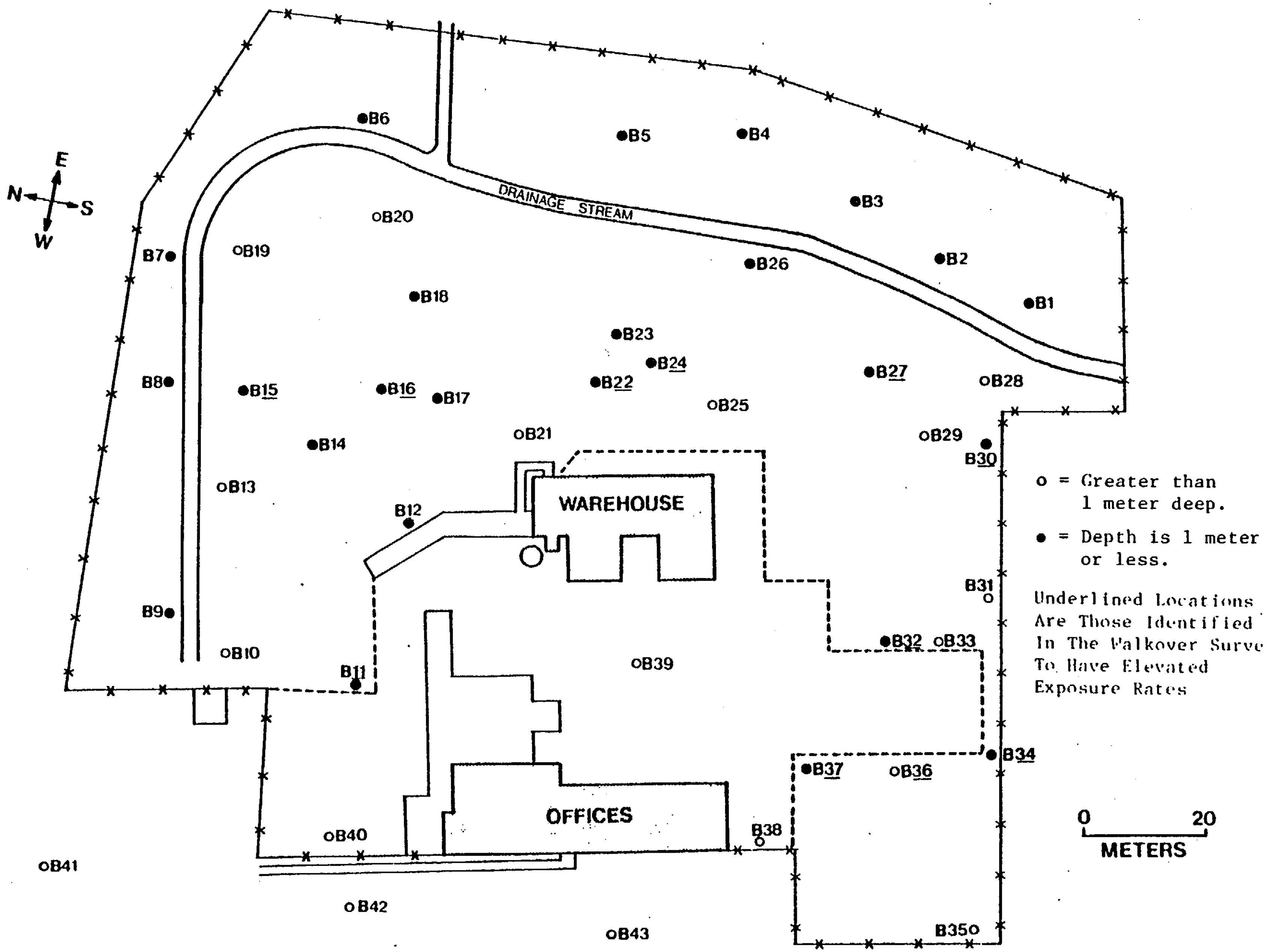


FIGURE 10. Borehole Locations on the W.R. Grace Property.

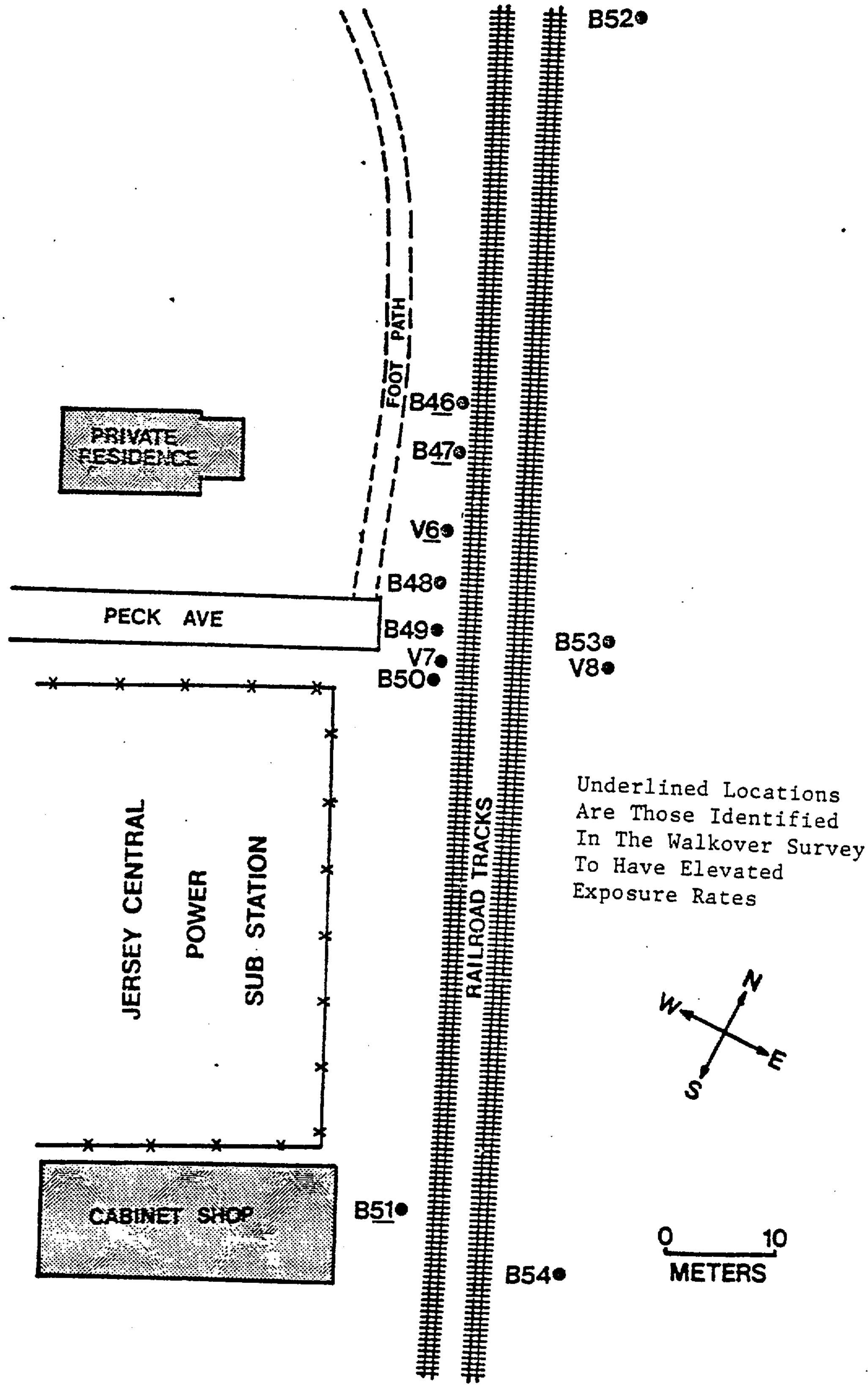


FIGURE 11. Borehole and Vegetation Sampling Locations Along the Erie Lackawanna Railroad in Pompton Plains, NJ.

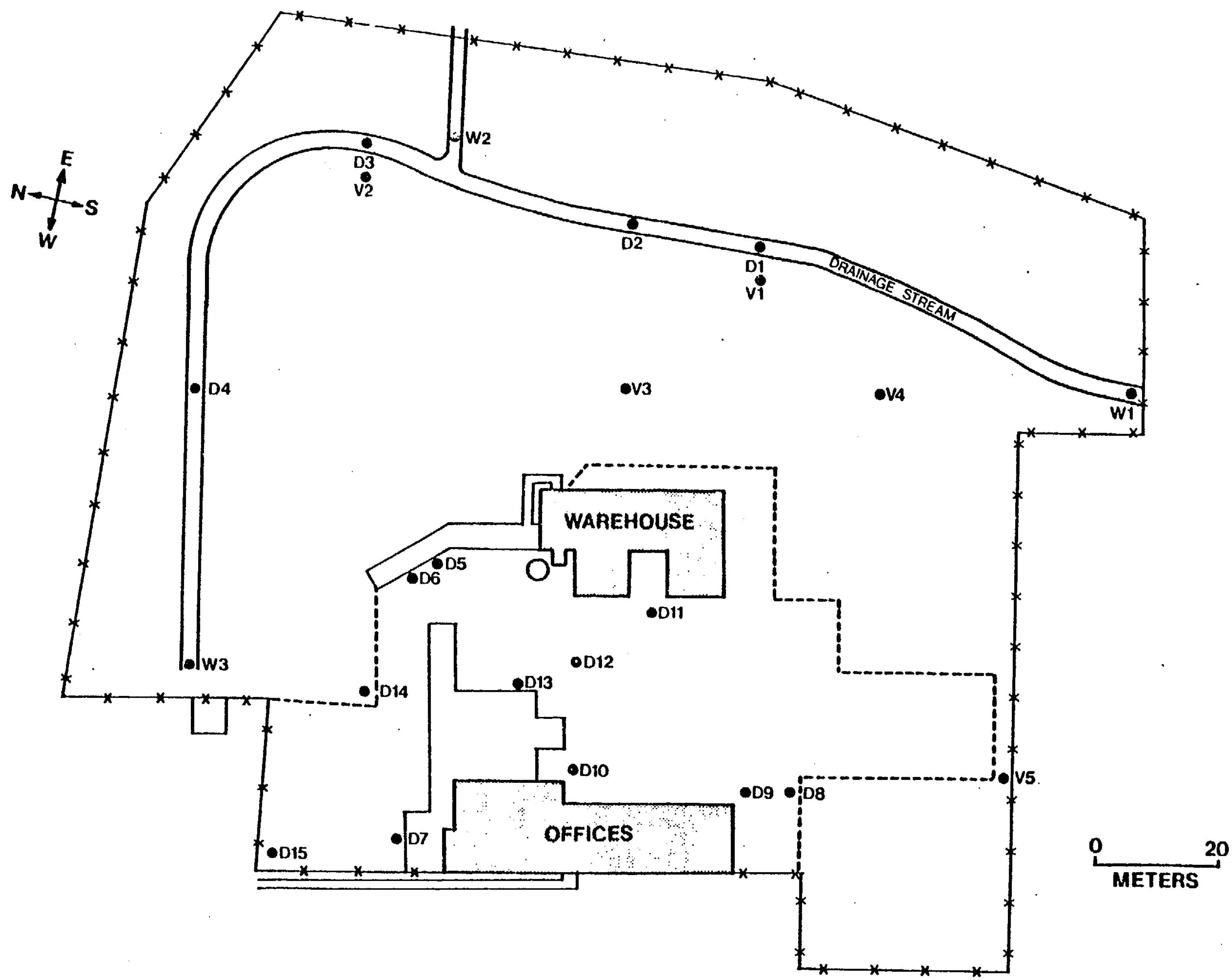


FIGURE 12. Sediment, Water, and Vegetation Sampling Locations on the W.R. Grace Property.

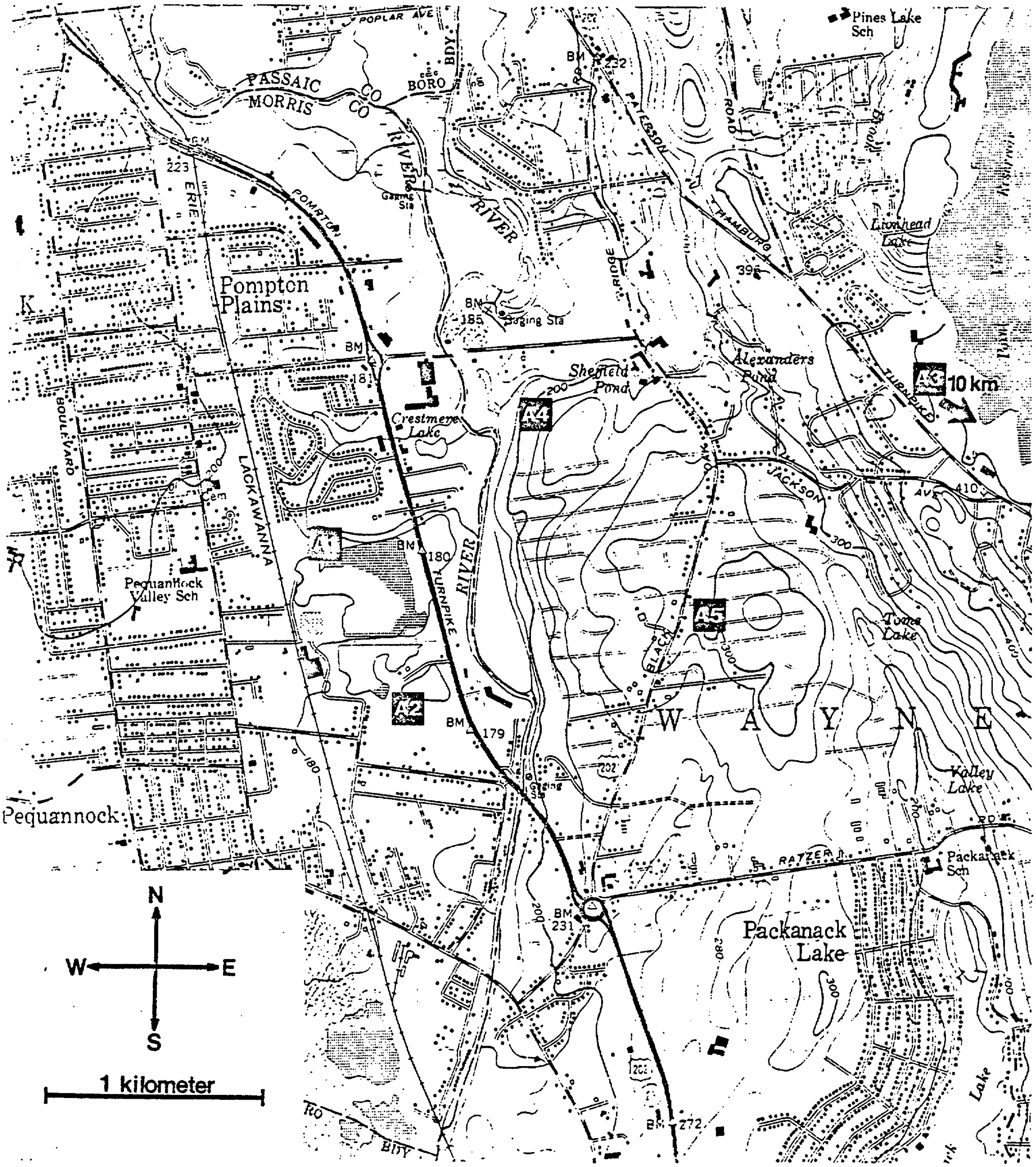


FIGURE 13. Locations of Background Measurements and Baseline Samples in the Wayne-Pompton Plains Area.

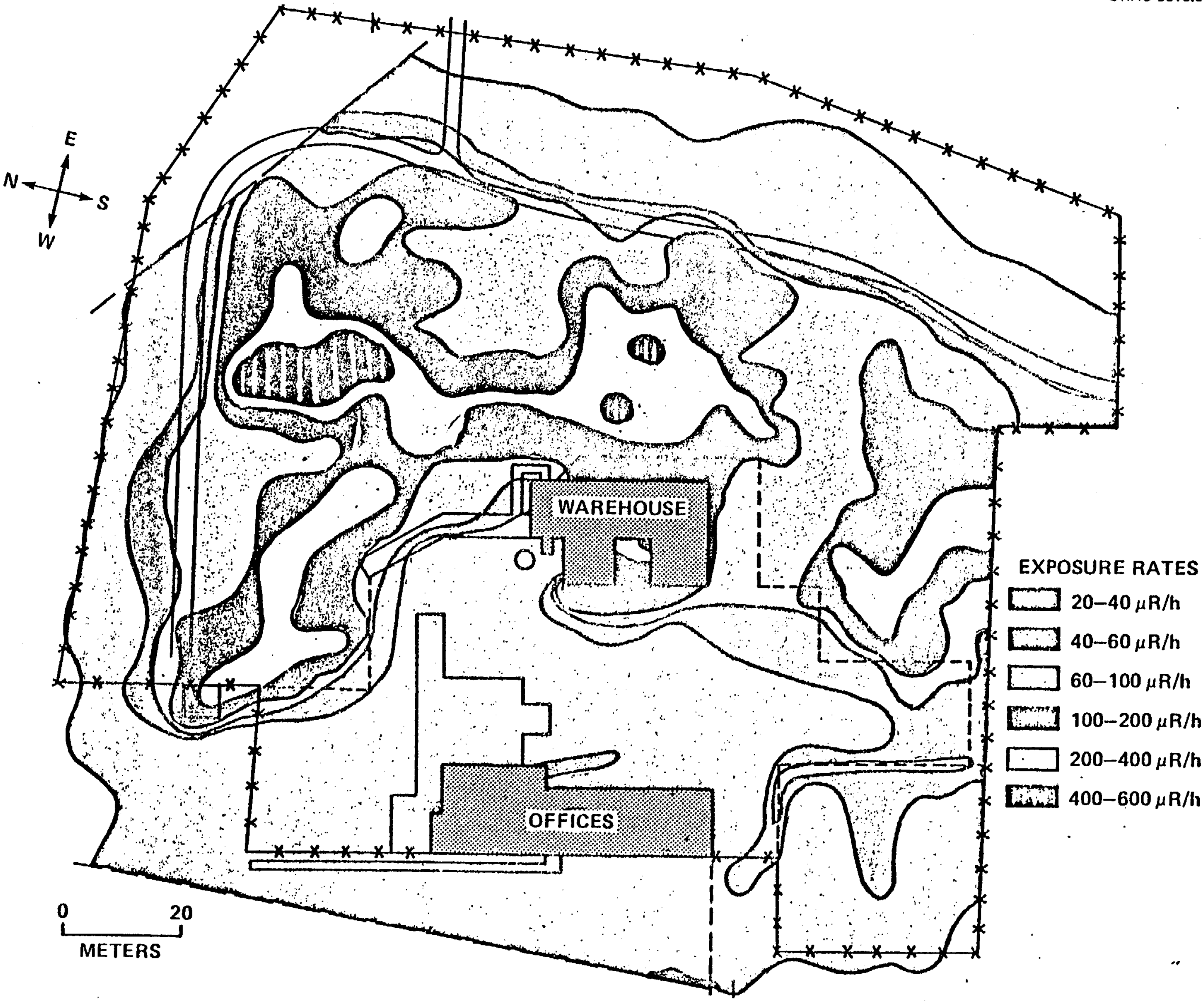


FIGURE 14. Exposure Rates (μR/h) at 1 m Above the Surface on the

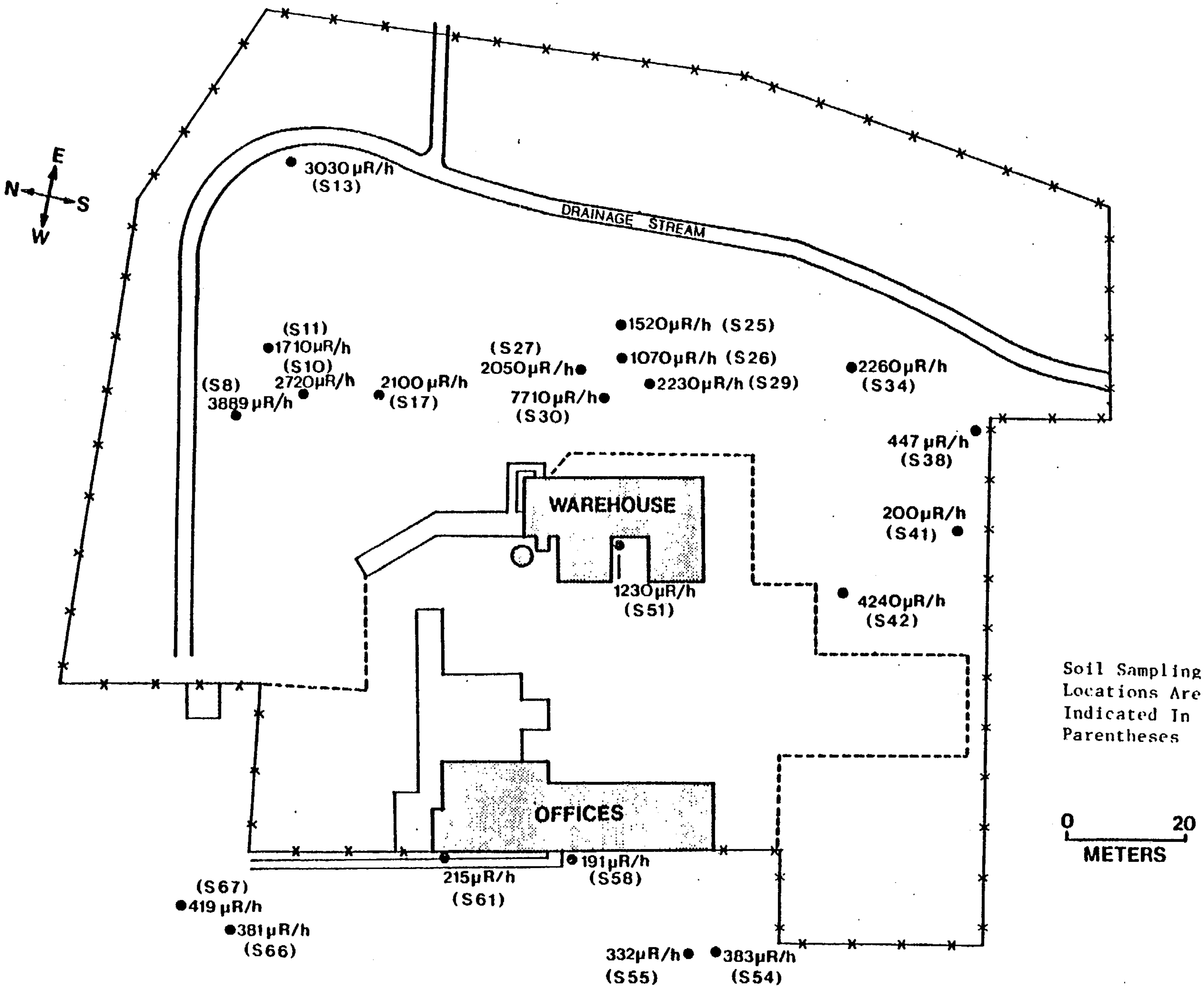


FIGURE 15. Surface Exposure Rates at Sampling Locations of Biased Surface Soil Samples.

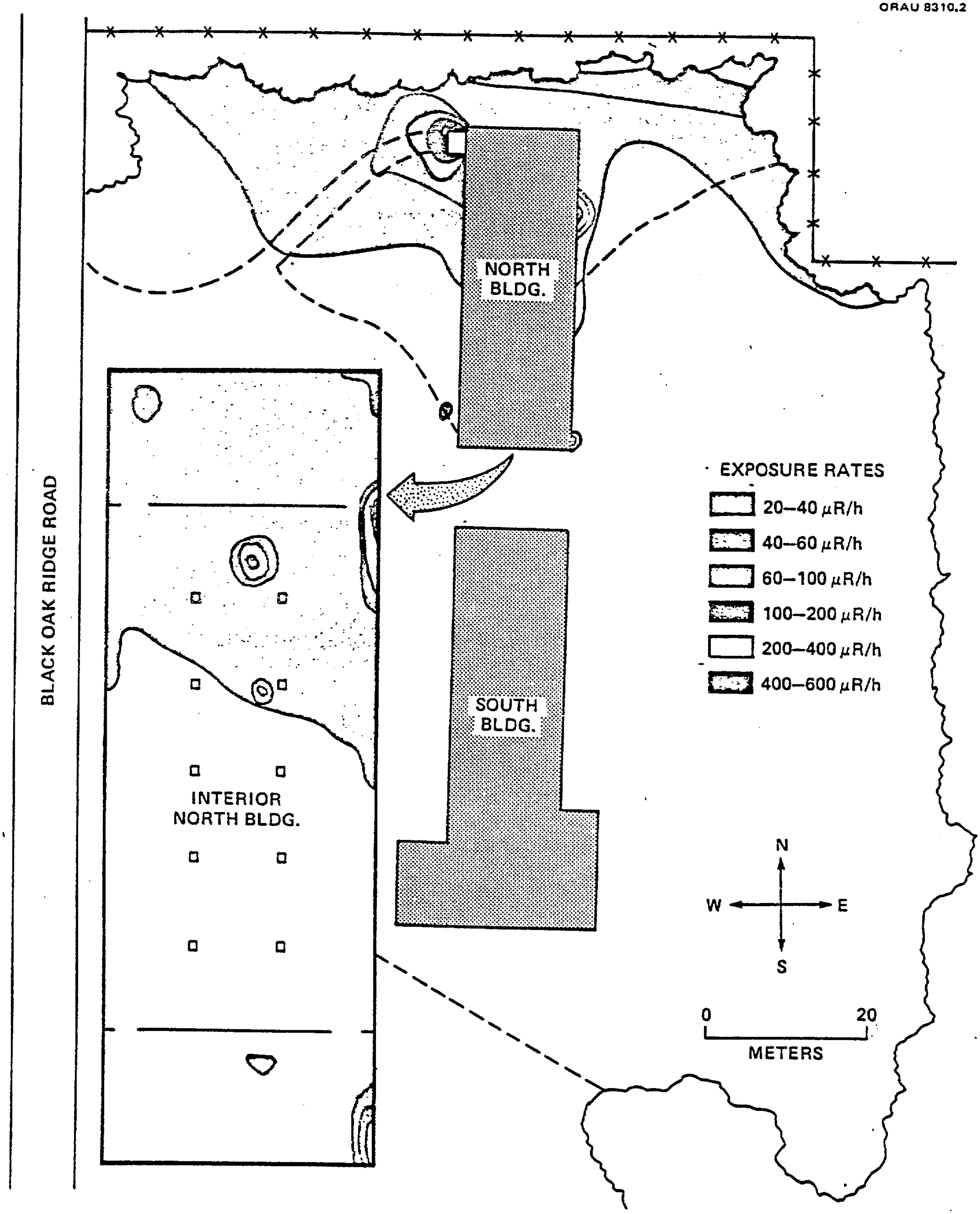


FIGURE 16: Surface Exposure Rates (μR/h) on the School Bus Maintenance Yard.

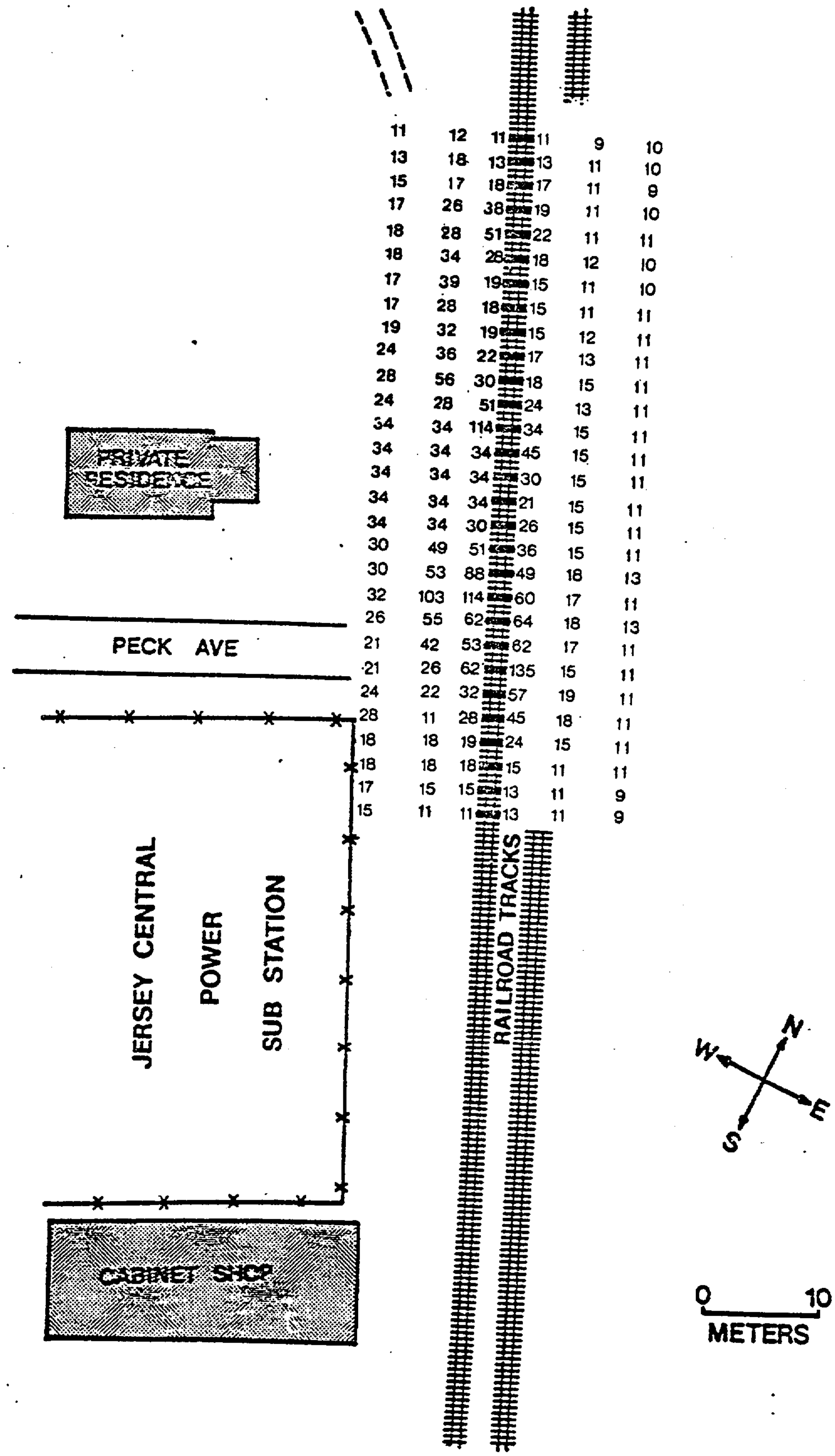


FIGURE 17. Exposure Rates (μR/h) at 1 m Above the Surface Along the Erie Lackawanna Railroad in Pompton Plains.

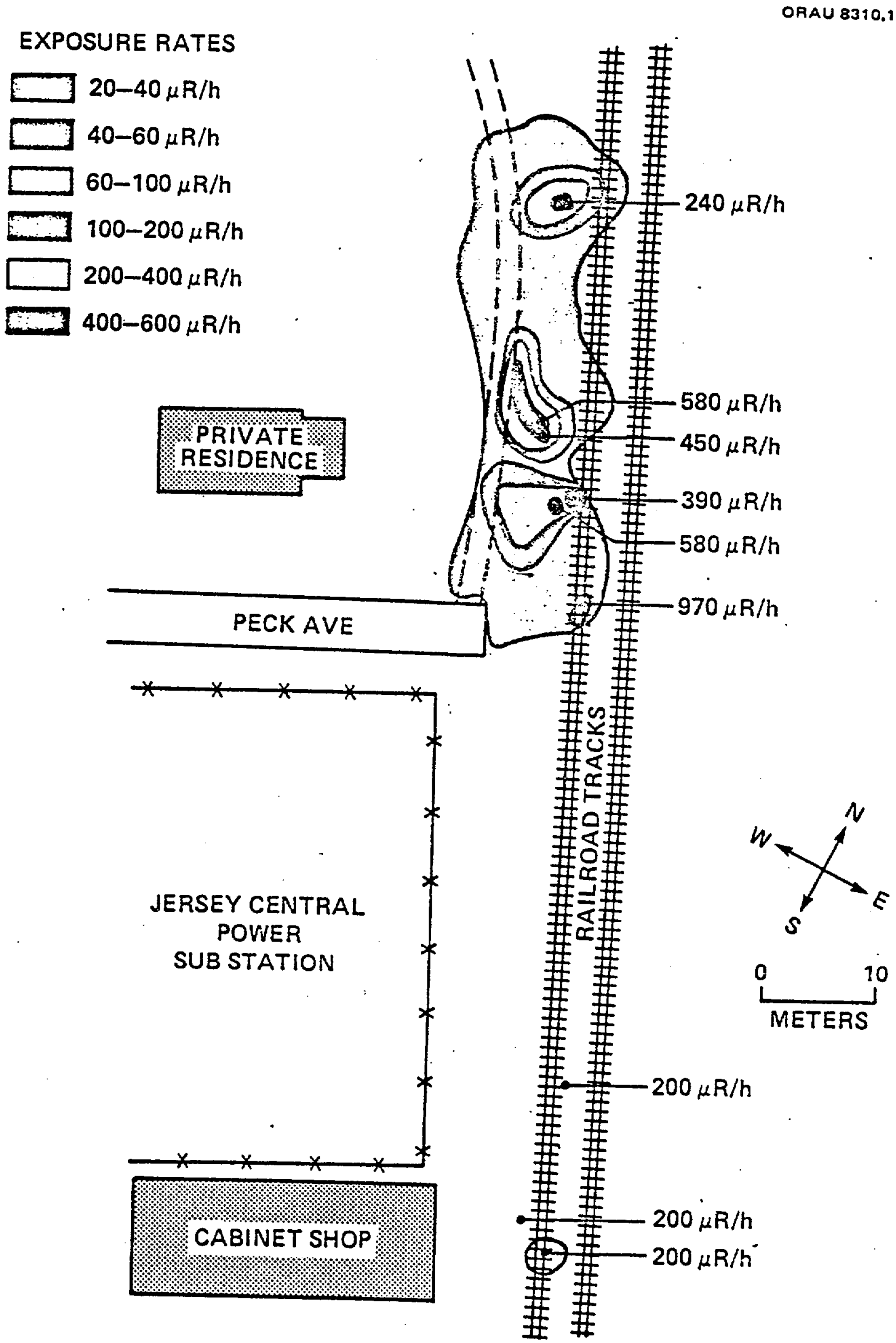


FIGURE 18. Surface Exposure Rates (μR/h) Along the Erie Lackawanna Railroad in Pompton Plains.

TABLE 1-A

RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL AND VEGETATION SAMPLES

Sample Location[a]	Depth (cm)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
Soil:					
A1 - P.V. Park	surface	0.51 + 0.23[b]	0.58 ± 0.27	0.47 ± 0.15	<MDA[c]
	30	0.72 ± 0.22	0.80 ± 0.21	0.47 ± 0.22	"
	60	0.69 ± 0.21	0.69 ± 0.21	0.49 ± 0.13	"
	90	0.45 ± 0.33	0.54 ± 0.17	0.50 ± 0.16	"
A2 - McDonald Park	surface	0.69 ± 0.25	0.56 ± 0.23	0.45 ± 0.17	"
	30	1.00 ± 0.25	0.71 ± 0.30	0.58 ± 0.20	"
	60	0.56 ± 0.23	0.59 ± 0.18	0.37 ± 0.12	"
	90	0.72 ± 0.24	0.66 ± 0.21	0.40 ± 0.19	"
A3 - Orth Ave.	surface	1.36 ± 0.33	1.60 ± 0.31	1.13 ± 0.26	"
	30	1.17 ± 0.23	1.39 ± 0.19	1.34 ± 0.17	"
	60	1.18 ± 0.24	1.31 ± 0.19	1.11 ± 0.17	"
A4 - Farmingdale Rd.	surface	0.92 ± 0.32	1.00 ± 0.26	1.12 ± 0.25	"
	30	1.00 ± 0.29	1.21 ± 0.28	1.05 ± 0.21	"
A5 - Black Oak Ridge Road	surface	0.85 ± 0.30	0.70 ± 0.21	0.85 ± 0.20	"
	30	0.91 ± 0.29	0.73 ± 0.22	0.65 ± 0.18	"
Vegetation:					
A1 - P.V. Park		<0.10	0.29 ± 0.13	<0.06	"
A2 - McDonald Park		0.39 ± 0.18	0.31 ± 0.14	0.21 ± 0.15	"

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics.
[c] MDA levels for U-238 ranged between 2 and 5 pCi/g.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations in Water (pCi/l or x 10^{-9} µCi/ml)									
	Gross Alpha	Gross Beta	Th-228	Th-230	Th-232	Ra-226	Ra-228	U-234	U-235	U-238
A1 P.V. Park	0.95 ± 1.20[b]	<1.3	0.10 ± 0.07	0.07 ± 0.03	<0.05	0.09 ± 0.08	<0.63	0.19 ± 0.03	<0.05	0.13 ± 0.03
A2 McDonald Park	<2.28	<3.6	<0.05	<0.05	<0.05	---[c]	---	0.12 ± 0.03	<0.05	0.09 ± 0.02
A6 City Water	<1.56	<3.7	<1	<1	<1	<0.07	1.12 ± 0.65	<1	<1	<1

[a] Refer to Figure 13.
[b] Error is 2σ based on counting statistics only.
[c] Dash indicates analysis not performed.

TABLE 2

RADIONUCLIDE CONCENTRATIONS IN ON-SITE SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S1	2.17 ± 0.42[b]	2.06 ± 0.36	0.68 ± 0.25	<3.81
S2	3.00 ± 0.55	3.35 ± 0.46	1.09 ± 0.28	<3.08
S3	1.95 ± 0.39	1.88 ± 0.31	0.91 ± 0.24	<3.46
S4	10.4 ± 0.8	9.59 ± 0.65	1.29 ± 0.35	<5.52
S5	1.18 ± 0.42	0.96 ± 0.26	0.60 ± 0.18	<3.22
S6	69.5 ± 2.4	69.1 ± 2.1	4.01 ± 0.90	33.4 ± 0.9
S7	41.4 ± 1.6	36.7 ± 1.3	4.82 ± 0.67	28.3 ± 0.8
S8[c]	2250 ± 20	1670 ± 10	13.2 ± 5.1	423 ± 2
S9	368 ± 5	353 ± 5	10.9 ± 1.8	114 ± 1
S10	2240 ± 20	1830 ± 20	39.0 ± 6.1	173 ± 2
S11	1920 ± 20	1450 ± 10	48.5 ± 7.0	401 ± 2
S12	73.8 ± 2.0	69.0 ± 1.7	3.05 ± 0.75	<9.42
S13	2710 ± 20	1540 ± 10	13.6 ± 6.5	109 ± 1
S14	23.5 ± 1.1	19.7 ± 0.9	0.85 ± 0.42	<5.40
S15	21.6 ± 1.0	18.7 ± 0.9	1.31 ± 0.39	<5.56
S16	66.3 ± 2.1	54.5 ± 1.8	5.10 ± 0.93	34.5 ± 0.8
S17	1010 ± 10	729 ± 8	18.2 ± 4.1	172 ± 1
S18	269 ± 4	214 ± 3	10.2 ± 1.4	<17.7
S19	77.2 ± 2.1	69.0 ± 1.7	4.99 ± 0.79	10.7 ± 0.7
S20	24.8 ± 1.4	24.7 ± 1.0	1.03 ± 0.41	3.13 ± 0.50
S21	74.0 ± 2.1	70.8 ± 1.7	7.46 ± 0.42	16.2 ± 0.7
S22	33.1 ± 1.5	29.1 ± 1.0	1.16 ± 0.44	<6.41
S23	16.6 ± 1.1	17.5 ± 1.0	2.62 ± 0.52	<6.06
S24	9.69 ± 0.89	8.74 ± 0.77	3.94 ± 0.48	<6.57
S25	1190 ± 10	931 ± 8	360 ± 7	<70.5
S26	1330 ± 10	1440 ± 10	710 ± 6	61.0 ± 1.0
S27	1200 ± 10	899 ± 13	87.2 ± 5.9	90.7 ± 1.1
S28	206 ± 3	171 ± 3	15.0 ± 1.3	33.4 ± 0.8
S29	1630 ± 30	1760 ± 20	586 ± 15	116 ± 1
S30	4500 ± 30	3040 ± 20	159 ± 11	144 ± 1
S31	1000 ± 10	869 ± 5	114 ± 4	61.1 ± 0.8
S32	63.5 ± 1.9	58.0 ± 1.6	5.02 ± 0.77	<0.97
S33	9.83 ± 0.89	9.51 ± 0.70	1.56 ± 0.03	<5.29
S34	2740 ± 30	2700 ± 30	646 ± 12.	35.7 ± 0.9
S35	109 ± 3	115 ± 2	13.2 ± 1.1	<12.0
S36	1850 ± 20	2300 ± 20	591 ± 12	47.7 ± 0.9
S37	18.5 ± 1.6	18.9 ± 0.65	1.29 ± 0.35	<5.52
S38	558 ± 5	479 ± 5	56.0 ± 2.6	<28.7
S39	101 ± 2	98.8 ± 2.0	9.85 ± 1.00	16.0 ± 0.8
S40	32.6 ± 1.6	31.6 ± 1.2	3.62 ± 0.62	<7.98
S41	216 ± 4	253 ± 3	32.1 ± 1.6	<17.7
S42	2220 ± 30	2090 ± 30	705 ± 16	75.4 ± 1.2
S43	82.7 ± 2.3	84.8 ± 2.0	11.6 ± 1.0	<11.4

TABLE 2, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
SURFACE SOIL SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S44	94.8 ± 2.7	88.5 ± 2.1	4.21 ± 0.89	14.6 ± 0.7
S45	41.4 ± 1.7	41.7 ± 1.5	6.30 ± 0.80	<9.22
S46	172 ± 3	170 ± 2	21.0 ± 1.3	<15.4
S47	3.65 ± 0.61	3.42 ± 0.56	0.92 ± 0.31	<3.76
S48	2.79 ± 0.48	3.10 ± 0.42	0.99 ± 0.24	<3.15
S49	1.63 ± 0.42	1.86 ± 0.38	0.86 ± 0.22	<3.63
S50	1.81 ± 0.42	1.89 ± 0.36	0.81 ± 0.24	<3.30
S51	212 ± 3	211 ± 3	20.5 ± 1.4	14.5 ± 0.6
S52	5.57 ± 0.59	5.89 ± 0.51	0.84 ± 0.28	<3.61
S53	3.81 ± 0.51	4.35 ± 0.45	0.96 ± 0.29	<4.07
S54	438 ± 7	394 ± 6	14.7 ± 2.5	37.4 ± 0.8
S55	547 ± 5	431 ± 4	15.5 ± 2.2	39.2 ± 0.9
S56	26.2 ± 1.2	23.4 ± 1.0	4.86 ± 0.56	<6.76
S57	6.60 ± 0.70	7.56 ± 0.61	0.71 ± 0.30	<4.17
S58	26.5 ± 1.2	24.7 ± 1.0	1.33 ± 0.42	<5.61
S59	4.95 ± 0.58	4.88 ± 0.53	0.77 ± 0.31	<4.29
S60	10.6 ± 0.8	8.19 ± 0.62	1.10 ± 0.34	<4.28
S61	101 ± 2	104 ± 2	15.3 ± 1.1	<11.9
S62	6.63 ± 0.71	6.59 ± 0.50	0.97 ± 0.33	<3.97
S63	7.41 ± 0.64	6.86 ± 0.55	0.88 ± 0.29	<3.65
S64	7.57 ± 0.82	7.87 ± 0.62	1.16 ± 0.34	<4.41
S65	9.78 ± 0.79	8.88 ± 0.66	1.31 ± 0.37	<5.34
S66	207 ± 3	192 ± 3	8.31 ± 1.32	42.0 ± 0.9
S67	321 ± 4	269 ± 4	8.63 ± 1.52	52.8 ± 44.5

[a] Refer to Figure 7.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
BOREHOLE SOIL SAMPLES

Sample Location[a]	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B1	Surface	4.36 ± 0.59[b]	4.22 ± 0.48	1.20 ± 0.25	<4.67
	0.5	1.12 ± 0.34	1.18 ± 0.24	0.62 ± 0.19	<2.62
	0.75	0.96 ± 0.25	1.09 ± 0.23	0.88 ± 0.18	<2.53
B2	Surface	5.41 ± 0.65	5.34 ± 0.51	1.34 ± 0.31	<4.51
	0.5	1.14 ± 0.36	0.96 ± 0.25	0.74 ± 0.16	<2.59
	1.0	0.96 ± 0.26	0.93 ± 0.26	0.70 ± 0.17	<1.86
B3	Surface	5.31 ± 0.73	6.17 ± 0.65	2.29 ± 0.48	<5.45
	0.5	1.44 ± 0.31	1.35 ± 0.29	1.01 ± 0.20	1.49 ± 0.52
	0.75	1.05 ± 0.29	1.05 ± 0.23	0.64 ± 0.17	<2.69
B4	Surface	3.45 ± 0.67	3.76 ± 0.57	1.30 ± 0.34	<4.73
	0.5	0.99 ± 0.24	1.10 ± 0.21	0.72 ± 0.17	<2.62
B5	Surface	4.19 ± 0.66	4.40 ± 0.53	1.39 ± 0.36	1.54 ± 0.57
	0.5	1.54 ± 0.42	2.07 ± 0.32	1.14 ± 0.24	<2.76
B6	Surface	1.67 ± 0.30	1.73 ± 0.26	0.88 ± 0.20	<2.81
	0.5	1.43 ± 0.37	1.45 ± 0.27	1.35 ± 0.22	<2.34
	1.0	1.32 ± 0.32	1.38 ± 0.31	1.03 ± 0.20	<3.56
B7	Surface	1.46 ± 0.49	1.20 ± 0.33	0.79 ± 0.23	<1.93
	0.5	0.89 ± 0.25	0.87 ± 0.27	0.69 ± 0.18	<2.93
	0.75	0.84 ± 0.27	0.91 ± 0.21	0.59 ± 0.16	<2.61
B8	Surface	1.47 ± 0.38	1.41 ± 0.29	1.12 ± 0.24	<3.17
	0.5	1.62 ± 0.43	1.68 ± 0.35	1.63 ± 0.28	<2.95
	1.0	1.53 ± 0.37	1.45 ± 0.35	1.12 ± 0.24	<3.38
B9	Surface	1.91 ± 0.33	1.59 ± 0.31	0.65 ± 0.21	<3.22
	0.5	2.38 ± 0.44	2.43 ± 0.35	0.93 ± 0.23	<3.33
	1.0	4.98 ± 0.51	4.92 ± 0.48	0.89 ± 0.26	5.54 ± 0.52
B10	Surface	39.7 ± 1.3	30.0 ± 1.0	2.17 ± 0.54	<6.95
	0.5	31.9 ± 1.2	25.3 ± 0.9	1.15 ± 0.38	16.6 ± 0.5
	2.4	1.90 ± 0.34	1.54 ± 0.30	0.79 ± 0.20	18.4 ± 0.6
B11[c]	Surface	258 ± 3	227 ± 3	14.4 ± 1.4	29.5 ± 0.7
	0.5	196 ± 3	181 ± 3	8.35 ± 1.26	35.0 ± 0.9
	0.75	191 ± 3	182 ± 3	7.08 ± 1.19	53.0 ± 0.9

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B12	Surface	56.8 ± 1.6	45.5 ± 1.3	3.60 ± 0.61	11.1 ± 0.6
	0.5	10.6 ± 0.9	8.64 ± 0.60	2.29 ± 0.35	15.4 ± 0.6
B13	Surface	13.8 ± 0.9	12.8 ± 0.8	2.57 ± 0.49	8.8 ± 0.6
	0.5	4.41 ± 0.53	4.78 ± 0.44	1.24 ± 0.27	<4.16
	1.0	5.08 ± 0.55	4.84 ± 0.52	0.91 ± 0.24	<3.93
	2.0	1.20 ± 0.28	1.43 ± 0.27	0.80 ± 0.21	<2.62
B14	Surface	10.9 ± 1.0	11.2 ± 0.6	2.79 ± 0.41	9.19 ± 0.55
	0.5	6.45 ± 0.58	5.73 ± 0.48	2.32 ± 0.34	4.77 ± 0.51
	1.0	6.80 ± 0.58	5.86 ± 0.48	2.59 ± 0.34	<4.84
B15	Surface	3970 ± 30	4000 ± 30	296 ± 16	910 ± 4
	0.5	702 ± 22	785 ± 15	477 ± 11	559 ± 3
	1.0	4650 ± 30	5150 ± 30	782 ± 19	653 ± 3
B16	Surface	1750 ± 10	1660 ± 10	930 ± 9	205 ± 1
	0.5	565 ± 8	637 ± 9	370 ± 6	185 ± 1
	1.0	366 ± 7	392 ± 5	171 ± 4	123 ± 1
B17	Surface	6.21 ± 0.60	6.02 ± 0.57	1.41 ± 0.32	41.0 ± 0.8
	0.5	33.4 ± 1.6	30.5 ± 1.1	11.8 ± 0.7	30.2 ± 0.6
	1.0	88.6 ± 2.1	55.7 ± 1.5	5.02 ± 0.79	40.1 ± 0.8
B18	Surface	23.5 ± 1.1	18.0 ± 0.9	4.41 ± 0.55	40.4 ± 0.7
	0.5	17.8 ± 1.0	15.3 ± 0.8	4.32 ± 0.45	26.2 ± 0.6
	1.0	36.0 ± 1.3	23.8 ± 1.0	4.32 ± 0.56	16.4 ± 0.6
B19	Surface	13.1 ± 0.80	10.4 ± 0.6	1.53 ± 0.32	<4.71
	0.5	<2.59	<0.75	<1.17	<42.9
	1.0	9.37 ± 0.82	10.0 ± 0.7	1.69 ± 0.39	10.5 ± 0.5
	1.5	3.45 ± 0.41	3.21 ± 0.35	1.02 ± 0.22	3.46 ± 0.50
	2.0	1.23 ± 0.29	1.23 ± 0.23	0.83 ± 0.19	<2.60
	2.5	1.09 ± 0.28	1.06 ± 0.22	0.81 ± 0.21	<2.39
	4.8	17.9 ± 1.0	17.1 ± 0.9	1.51 ± 0.41	4.62 ± 0.50
B20	Surface	195 ± 3	135 ± 2	5.83 ± 0.97	<12.3
	0.5	990 ± 11	933 ± 9	27.4 ± 4.6	<68.7
	1.7	842 ± 8	617 ± 8	16.2 ± 3.1	248 ± 85
B21	Surface	206 ± 3	212 ± 4	14.0 ± 1.5	39.6 ± 0.8
	0.3	406 ± 7	376 ± 6	14.6 ± 2.5	<34.0
	1.7	616 ± 9	355 ± 5	<1.26	<39.3

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B22	Surface	595 ± 8	568 ± 9	59.4 ± 4.1	<51.9
	0.5	7570 ± 50	7840 ± 40	1760 ± 20	180 ± 1
B23	Surface	106 ± 4	118 ± 3	48.2 ± 2.0	<18.7
	0.5	69.6 ± 3.1	75.5 ± 2.2	38.9 ± 1.4	<15.2
	1.0	169 ± 5	189 ± 4	115 ± 3	<24.4
B24	Surface	643 ± 9	589 ± 6	253 ± 5	<49.7
	0.5	430 ± 4	458 ± 4	200 ± 3	18.9 ± 0.7
	1.0	293 ± 4	436 ± 4	79.8 ± 2.1	45.7 ± 0.8
B25	Surface	47.2 ± 1.6	41.6 ± 1.3	8.16 ± 0.73	<8.08
	0.5	31.8 ± 1.5	27.8 ± 1.0	5.99 ± 0.63	<6.56
	1.0	2.95 ± 0.42	3.04 ± 0.32	1.11 ± 0.22	<2.89
	2.0	1.32 ± 0.33	1.38 ± 0.26	0.89 ± 0.20	<3.13
B26	Surface	14.6 ± 0.8	15.0 ± 0.7	7.27 ± 0.53	0.74 ± 0.53
	0.5	18.2 ± 1.0	17.1 ± 0.8	9.74 ± 0.61	<5.84
	1.0	8200 ± 500	7660 ± 500	101 ± 146	106 ± 2
B27	Surface	34.2 ± 1.8	31.9 ± 1.7	3.49 ± 0.80	<9.73
	0.6	3190 ± 20	3160 ± 20	555 ± 14	44.4 ± 1.1
B28	Surface	21.4 ± 1.2	21.7 ± 1.0	4.13 ± 0.56	<6.52
	0.5	9.24 ± 0.72	10.3 ± 0.6	6.51 ± 0.45	2.68 ± 0.48
	1.0	0.91 ± 0.22	0.96 ± 0.19	0.59 ± 0.14	<2.24
	1.5	0.85 ± 0.25	0.96 ± 0.25	0.61 ± 0.18	<2.27
	3.2	4.34 ± 0.56	4.14 ± 0.50	1.23 ± 0.36	<4.18
B29	Surface	184 ± 3	150 ± 3	20.5 ± 1.3	<14.9
	0.5	390 ± 5	347 ± 4	41.6 ± 2.0	46.2 ± 0.8
	1.0	1150 ± 10	808 ± 7	84.5 ± 4.6	79.8 ± 1.0
	3.9	14800 ± 700	15700 ± 600	1450 ± 300	110 ± 1
B30	Surface	46.9 ± 1.5	44.4 ± 1.3	5.33 ± 0.67	<7.02
	1.0	3080 ± 30	2380 ± 20	343 ± 12	53.1 ± 1.0
B31	Surface	26.8 ± 1.1	30.0 ± 1.0	3.43 ± 0.53	<5.88
	0.5	10.7 ± 0.9	13.5 ± 0.6	1.67 ± 0.32	<4.33
	1.0	4.82 ± 0.49	5.95 ± 0.53	0.90 ± 0.28	<3.42
	4.8	35.2 ± 1.4	35.0 ± 1.2	3.76 ± 0.49	<6.67

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g) Th-232 (Ra-228)	Th-228	Ra-226	U-238
B32	Surface	23.1 ± 1.0	26.4 ± 0.9	3.89 ± 0.48	<5.83
	0.5	309 ± 3	254 ± 3	23.9 ± 1.5	26.3 ± 0.7
B33	Surface	47.6 ± 1.6	49.3 ± 1.4	8.42 ± 0.76	<9.02
	0.5	26.7 ± 1.1	24.3 ± 0.9	3.02 ± 0.51	<5.83
	5.4	3.91 ± 0.45	3.60 ± 0.37	1.19 ± 0.27	<3.32
B34	Surface	171 ± 3	178 ± 3	26.5 ± 1.6	<17.9
	0.3	55.1 ± 2.0	57.1 ± 1.5	7.47 ± 0.79	<9.19
	0.5	62.0 ± 1.8	67.3 ± 1.6	11.2 ± 0.8	<9.57
B35	Surface	1.58 ± 0.34	1.48 ± 0.30	0.89 ± 0.22	<3.33
	0.5	2.02 ± 0.38	1.77 ± 0.31	0.81 ± 0.21	<3.32
	1.0	2.01 ± 0.41	2.13 ± 0.29	0.83 ± 0.22	<2.64
	2.0	1.04 ± 0.39	1.21 ± 0.23	0.70 ± 0.17	<2.86
	3.0	1.50 ± 0.30	1.30 ± 0.24	0.81 ± 0.18	<2.59
	6.3	1.27 ± 0.36	1.20 ± 0.28	0.96 ± 0.22	<3.55
B36	Surface	28.0 ± 1.5	29.5 ± 1.1	3.35 ± 0.53	<6.43
	0.5	1.04 ± 0.35	1.21 ± 0.31	0.70 ± 0.22	<2.79
	1.0	1.10 ± 0.29	1.15 ± 0.25	0.62 ± 0.17	<2.78
	2.0	1.35 ± 0.28	1.26 ± 0.24	0.60 ± 0.16	<3.10
	2.5	1.51 ± 0.31	1.21 ± 0.25	0.74 ± 0.18	<2.76
B37	Surface	114 ± 1	112 ± 2	17.3 ± 0.7	18.7 ± 0.6
	0.5	60.4 ± 1.3	61.6 ± 1.1	28.5 ± 0.7	15.9 ± 0.7
B38	Surface	1.98 ± 0.35	1.85 ± 0.34	1.14 ± 0.19	<2.60
	2.0	1.35 ± 0.29	1.41 ± 0.24	0.84 ± 0.19	<0.10
B39	Surface	2.05 ± 0.32	1.91 ± 0.27	0.81 ± 0.18	<2.76
	2.0	2.50 ± 0.38	2.22 ± 0.30	0.92 ± 0.21	<2.90
B40	Surface	2.75 ± 0.42	2.53 ± 0.32	0.79 ± 0.23	<2.60
	0.5	0.88 ± 0.36	1.01 ± 0.29	0.61 ± 0.20	<3.66
	1.8	0.40 ± 0.35	0.55 ± 0.24	0.53 ± 0.15	<2.57
B41	Surface	2.23 ± 0.40	2.24 ± 0.12	0.59 ± 0.20	<3.45
	0.5	1.03 ± 0.35	1.18 ± 0.25	0.61 ± 0.17	<3.09
	1.8	0.67 ± 0.22	0.71 ± 0.23	0.52 ± 0.18	<2.85

TABLE 3, cont.

RADIONUCLIDE CONCENTRATIONS IN ON-SITE
BOREHOLE SOIL SAMPLES

Sample Location	Depth (meters)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B42	Surface	2.34 ± 0.42	4.22 ± 0.37	0.66 ± 0.20	<3.07
	0.5	2.29 ± 0.35	3.91 ± 0.36	0.78 ± 0.20	<3.19
	1.0	0.66 ± 0.23	2.51 ± 0.30	0.58 ± 0.14	<2.93
	1.5	0.76 ± 0.25	2.37 ± 0.27	0.40 ± 0.14	<2.09
	3.3	2.26 ± 0.35	5.66 ± 0.40	0.60 ± 0.22	<2.63
B43	Surface	12.9 ± 0.8	17.5 ± 0.8	1.64 ± 0.36	<5.23
	0.5	0.82 ± 0.25	3.22 ± 0.32	0.58 ± 0.18	<2.42
	1.0	1.07 ± 0.30	2.55 ± 0.29	0.58 ± 0.20	<2.60
	3.6	7.04 ± 0.58	8.43 ± 0.55	0.79 ± 0.27	1.38 ± 0.47

[a] Refer to Figure 10.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES

Sample Location[a]	Description	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
D1	Drainage Stream	5.28 ± 0.72[b]	5.04 ± 0.56	1.70 ± 0.35	<4.46
D2	Drainage Stream	2.29 ± 0.55	1.77 ± 0.43	0.51 ± 0.31	<4.05
D3	Drainage Stream	4.72 ± 0.64	2.75 ± 0.43	0.76 ± 0.39	<3.84
D4	Drainage Stream	2.03 ± 0.32	1.73 ± 0.31	0.63 ± 0.20	<2.61
D5	Drainage Tile	5.12 ± 0.46	4.70 ± 0.39	1.31 ± 0.24	<3.22
D6	Drainage Tile	9.17 ± 0.78	9.78 ± 0.59	1.77 ± 0.32	<4.14
D7	Drainage Tile	18.0 ± 1.0	19.1 ± 0.9	3.04 ± 0.47	<6.34
D8	Storm Sewer	16.8 ± 1.0	17.5 ± 0.8	3.65 ± 0.48	6.03 ± 0.51
D9	Storm Sewer	23.4 ± 1.0	25.2 ± 0.9	3.89 ± 0.47	13.6 ± 0.6
D10	Storm Sewer	43.2 ± 1.5	38.7 ± 1.2	4.12 ± 0.61	19.9 ± 0.7
D11	Storm Sewer	24.7 ± 1.3	24.4 ± 1.0	3.67 ± 0.51	<6.36
D12	Storm Sewer	383 ± 4	327 ± 3	30.2 ± 1.8	24.5 ± 0.8
D13	Storm Sewer	78.2 ± 1.9	70.0 ± 1.6	5.37 ± 0.77	12.7 ± 0.6
D14	Storm Sewer	951 ± 6	866 ± 5	101 ± 3	46.9 ± 1.0
D15	Storm Sewer	10.9 ± 0.8	9.57 ± 0.63	1.49 ± 0.33	<4.26

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μC/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
W1	7.21 ± 5.69[b]	4.83 ± 7.38	<0.18	0.03 ± 0.03
W2	3.29 ± 4.97	<4.95	c	<0.03
W3	<3.19	<5.00	<0.18	0.11 ± 0.03

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.
[c] Analysis not performed.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN STORM SEWER WATER SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/ℓ or x 10^{-9} μCi/ml)			
	Gross Alpha	Gross Beta	Ra-228	Ra-226
D10	12.8 ± 5.4[b]	36.1 ± 6.2	1.68 ± 0.20	0.10 ± 0.04
D11	28.6 ± 29.8	60.8 ± 40.3	6.59 ± 0.57	0.19 ± 0.04
D12	17.9 ± 15.7	47.8 ± 18.2	14.2 ± 0.4	0.86 ± 0.08
D13	5.33 ± 7.45	13.4 ± 8.5	8.55 ± 0.42	0.40 ± 0.06
D15	17.5 ± 5.1	26.0 ± 5.3	10.0 ± 0.6	0.15 ± 0.04

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN ON-SITE VEGETATION SAMPLES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V1	1.00 ± 0.22[b]	0.26 ± 0.17	0.35 ± 0.12	<2.63
V2	1.04 ± 0.15	0.32 ± 0.09	0.07 ± 0.06	<1.22
V3	2.19 ± 0.25	0.48 ± 0.15	0.11 ± 0.10	<2.07
V4	2.15 ± 0.26	0.53 ± 0.14	0.40 ± 0.12	<2.04
V5	3.41 ± 0.36	0.59 ± 0.23	0.30 ± 0.16	<2.51

[a] Refer to Figure 12.
[b] Error is 2σ based on counting statistics only.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN
SURFACE SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Th-232 (Ra-228)	Th-228	Ra-226	U-238
S68	1.16 ± 0.31[b]	0.92 ± 0.23	0.69 ± 0.23	1.45 ± 0.52
S69	0.60 ± 0.20	0.64 ± 0.16	0.45 ± 0.17	<1.95
S70	0.78 ± 0.30	0.71 ± 0.22	0.40 ± 0.18	<3.06
S71	0.97 ± 0.27	0.88 ± 0.23	0.49 ± 0.15	<1.93
S72	3.59 ± 0.45	3.62 ± 0.39	0.74 ± 0.25	<3.46
S73	1.22 ± 0.35	1.27 ± 0.29	0.85 ± 0.2	<3.60
S74[c]	227 ± 3	375 ± 4	36.8 ± 1.7	21.2 ± 0.7
S75	75.4 ± 2.2	60.4 ± 1.7	4.85 ± 0.81	19.8 ± 0.7
S76	3.90 ± 0.67	4.17 ± 0.61	1.18 ± 0.38	<4.97
S77	1580 ± 20	1140 ± 10	83.4 ± 6.2	<79.3
S78	319 ± 5	328 ± 6	67.9 ± 2.9	45.4 ± 0.8
S79	8.81 ± 0.80	8.94 ± 0.60	1.63 ± 0.38	<4.70
S80	2.41 ± 0.53	2.41 ± 0.46	1.19 ± 0.36	<5.18
S81	0.97 ± 0.32	1.35 ± 0.25	0.73 ± 0.19	<3.24

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE
SOIL SAMPLES FROM ADJACENT PROPERTIES

Sample Location[a]	Depth (meter)	Radionuclide Concentrations (pCi/g)			
		Th-232 (Ra-228)	Th-228	Ra-226	U-238
B<u>44</u>[c]	Surface	2400 ± 20[b]	1360 ± 10	315 ± 9	2.11 ± 0.46
	0.5	2.38 ± 0.39	2.45 ± 0.37	1.06 ± 0.24	<3.23
	1.0	1.05 ± 0.32	1.03 ± 0.24	0.27 ± 0.21	<3.66
B45	Surface	4.59 ± 0.54	4.71 ± 0.49	1.21 ± 0.27	<3.86
	0.5	1.70 ± 0.34	1.61 ± 0.28	0.89 ± 0.21	<2.80
	0.75	1.28 ± 0.29	1.45 ± 0.28	0.85 ± 0.20	<3.36

[a] Refer to Figure 9.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to elevated exposure rates.

TABLE 11

RADIONUCLIDE CONCENTRATIONS IN VEGETATION SAMPLES FROM VICINITY OF THE ERIE LACKAWANNA RAILROAD IN POMPTON PLAINS, NEW JERSEY

Sample Location[a]	Radionuclide Concentrations (pCi/g)			
	Ra-228	Th-228	Ra-226	U-238
V6[c]	0.28 ± 0.10[b]	0.18 ± 0.08	0.16 ± 0.04	<1.38
V7	0.12 ± 0.07	0.04 ± 0.06	0.05 ± 0.03	<0.88
V8	<0.06	0.24 ± 0.12	<0.03	<1.67

[a] Refer to Figure 11.
[b] Error is 2σ based on counting statistics only.
[c] Underlined sample locations are those identified during the walkover survey to have elevated exposure rates.

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APPENDIX A

GLOSSARY OF TERMS

Glossary

Activation: The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear particles.

Activity: Radioactivity, the spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an unstable nuclide. As a result of this emission, the radioactive material is converted (or decays) into a different nuclide (daughter), which may or may not be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) nuclide is formed.

Aerial survey: A search for sources of radiation by means of sensitive instruments mounted in a helicopter or airplane. Generally, the instrumentation records the intensity, location, and spectral analysis of the radiation.

Alpha particle: A positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, and hence is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive materials and can be stopped by a sheet of paper.

Background radiation: The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements. It is also called natural radiation. The term may also mean radiation that is unrelated to a specific experiment. Levels vary, depending on location.

Baseline concentration: The concentration of a given substance typically encountered in the area under consideration, i.e. the normal or naturally occurring level.

Beta particle: An elementary particle emitted from a nucleus during radioactive decay, with a single electrical charge and a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Contamination: Undesired radioactive materials that have been deposited on surfaces, are internally ingrained into structures or equipment, or that have been mixed with another material.

the most penetrating of the three common types of radiation.

Half-life: The time in which half the atoms of a particular radioactive sustance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Microrad (μrad): A submultiple of the rad, equal to one-millionth of a rad. (see rad).

Microroentgen (μR): A submultiple of the roentgen, equal to one-millionth of a roentgen. (see roentgen).

Millirem (mrem): A submultiple of the rem, equal to one-thousandth of a rem. (see rem).

Natural uranium: Uranium as found in nature, containing 0.7 percent of uranium-235, 99.3 percent of uranium-238. It is also called normal uranium.

Natural thorium: Thorium as found in nature. Natural thorium contains equal activity level of thorium-232 and thorium-228.

Parent: A radionuclide which disintegrates or decays to produce another nuclide which is also radioactive. This second radionuclide is known as the daughter product.

Picocurie (pCi): One-trillionth (10^{-12}) of a curie.

Rad: The unit of absorbed dose. The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. One rad equals 0.01 joules/kilogram of absorbing material.

Radiation: Energetic nuclear particles including neutrons, alpha particles, beta particles, x-rays, and gamma rays (nuclear physics). Also includes electromagnetic waves (radiation) of any origin.

Radioactivity: The property of certain nuclides of spontaneously emitting particles, or gamma radiation. Often shortened to "activity."

Radionuclide: A general term applicable to any radioactive form of the elements, a radioactive nuclide.

Radium (Ra): A radioactive metallic element with atomic number 88. As found in nature, the most common isotope has an atomic weight of 226. It occurs in minute quantities associated with uranium in pitchblende, carnotite, and other minerals; the uranium decays to radium in a series

Uranium series: The series (sequence) of nuclides resulting from the radioactive decay of uranium-238. The end product of the series is lead-206.

APPENDIX B

THORIUM AND URANIUM DECAY SERIES

Appendix B

Thorium Decay Series

Parent	Half-Life	Major Decay Products	Daughter
Thorium-232	14 billion years	alpha	Radium-228
Radium-228	5.8 years	beta	Actinium-228
Actinium-228	6.13 hours	beta, gamma	Thorium-228
Thorium-228	1.91 years	alpha	Radium-224
Radium-224	3.64 days	alpha	Radon-220
Radon-220	55 seconds	alpha	Polonium-216
Polonium-216	0.15 seconds	alpha	Lead-212
Lead-212	10.6 hour	beta, gamma	Bismuth-212
Bismuth-212	60.6 minutes	alpha (1/3)* beta (2/3)*	Thallium-208 Polonium-212
Thallium-208	3.1 minutes	beta, gamma	Lead-208
Polonium-212	0.0000003 seconds	alpha	Lead-208
Lead-208	stable	none	none

* Two decay modes are possible for Bismuth-212.

APPENDIX C

GROUND-PENETRATING RADAR SURVEY
OF THE
W.R. GRACE SITE
WAYNE, NEW JERSEY

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

A ground penetrating radar (GPR) survey was conducted during the week of July 12, 1982 at the W.R. Grace site, Pompton Plains, New Jersey. The survey was performed under contract to the Oak Ridge Associated Universities (ORAU) in support of their assessment of the radiological conditions at the site. The objectives of the GPR Survey were:

1. to define the exact location of burial trenches, and
2. to identify the locations and depths of subsurface objects.

The results of this survey will allow further radiological site assessment to proceed in an efficient manner. These results are discussed in section 5 of this report.

In addition to radar soundings, bulk soil resistivity measurements were made. These measurements aided in the selection of the optimum GPR system parameters, and were used to estimate system capability, particularly depth of penetration, in the site geology.

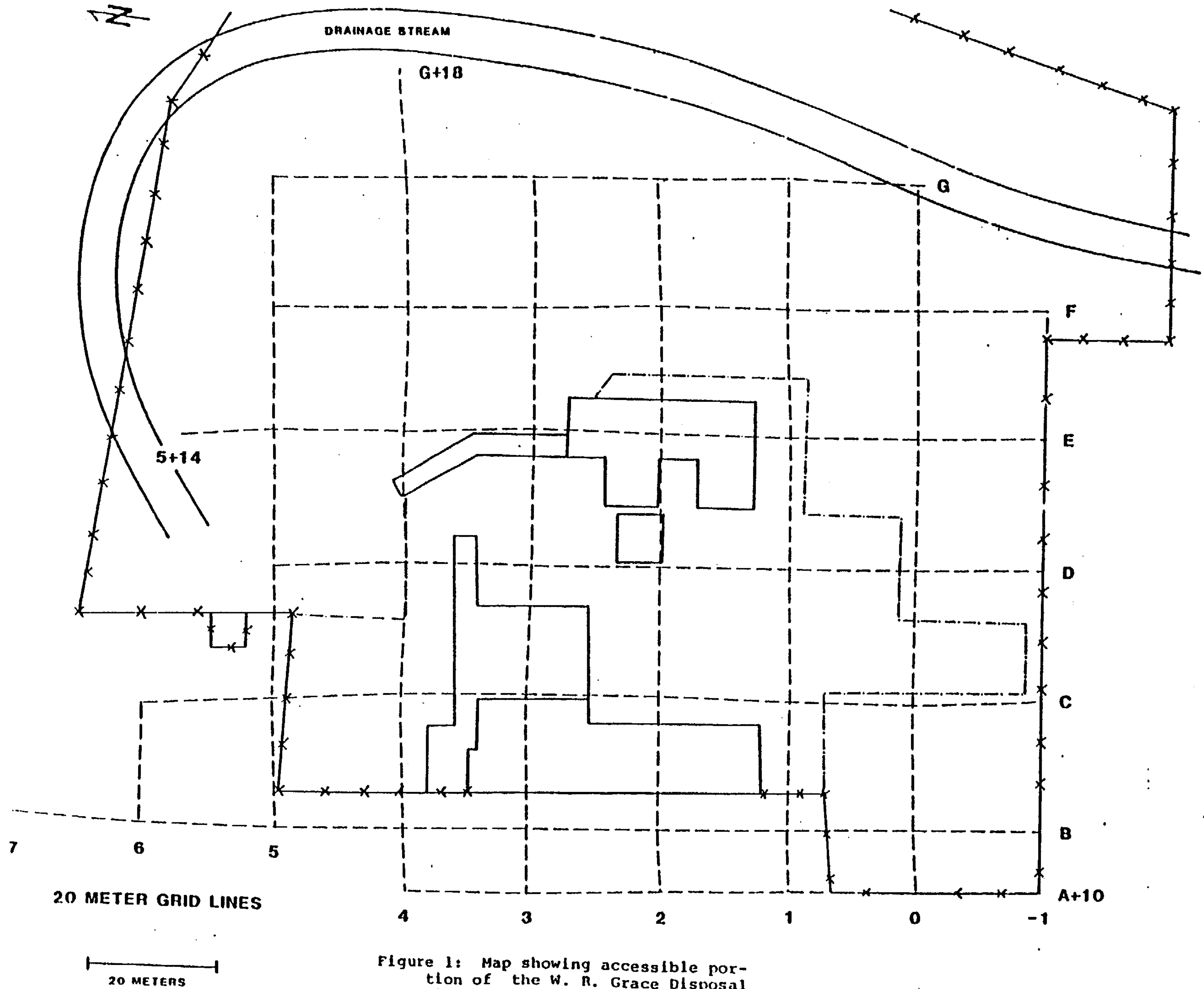


Figure 1: Map showing accessible portion of the W. R. Grace Disposal Site and 20-meter grid system.

With knowledge of the velocity of propagation, the time interval can be converted to a range or depth.

As part of the calibration process the velocity of propagation of the electromagnetic wave in the particular medium is determined. For earth materials with a relative effective dielectric constant, ε_{er}, the velocity of propagation, v_m, of the electromagnetic signals, is usually approximated by:

$$v_m = \frac{c}{\varepsilon_{er}^{1/2}} \tag{1}$$

where: $c = 3 \times 10^8$ m/sec, the propagation velocity in free space. However, equation (1) is actually derived from

$$v_m = \frac{\omega}{\beta} \tag{2}$$

where: $\omega = 2\pi f$ = angular frequency

f = frequency in Hertz

β = phase constant, imaginary part of propagation constant.

The phase constant, β, is obtained from γ, the complex propagation constant of the medium which is derived from Maxwell's equations describing the behavior of electromagnetic fields. The propagation constant, γ, is defined as:

$$\gamma = \alpha + j\beta = (-\omega^2 \mu' \varepsilon_e + j\omega\mu' \sigma_e)^{1/2} \tag{3}$$

where: α = attenuation constant

μ' = magnetic permeability of the medium

σ_e = effective conductivity

A summary of the physical properties of common media which affect the propagation and attenuation of electromagnetic signals is shown in Table 1. Careful analysis of the reflected pulse, combined with a knowledge of the electromagnetic properties of the soil, can reveal information such as percentage of water content, density variation, and the location and depth of buried objects.

Table 1: Approximate VHF electromagnetic parameters of typical earth materials.

Material	Approximate Conductivity σ (mho/m)	Approximate Dielectric Constant	Depth of Penetration
Air	0	1	Max (km)
Limestone (dry)	10^{-9}	7	↓
Granite (dry)	10^{-8}	5	
Sand (dry)	10^{-7} to 10^{-3}	4 to 6	
Bedded Salt	10^{-5} to 10^{-4}	3 to 6	
Freshwater Ice	10^{-5} to 10^{-4}	4	
Permafrost	10^{-4} to 10^{-2}	4 to 8	
Sand, Saturated	10^{-4} to 10^{-2}	30	
Freshwater	10^{-4} to 3×10^{-2}	81	
Silt, Saturated	10^{-3} to 10^{-2}	10	
Rich Agricultural Land	10^{-2}	15	
Clay, Saturated	10^{-2} to 1	8 to 12	↓
Seawater	4	81	Min (cm)

Inference as to the composition of the reflecting and intervening material is possible, depending on the intensity and phase of the return signal. For example, metallic objects

Table 2

Typical Electromagnetic Properties of Materials at 100 MHz

Material	A dB/m	V_m cm/ns	η Ohms
Air	0	30	377
Fresh Water	0.18	3.33	42+j0.046
Sea Water	326	1.50	10+j9.33
Sandy Soil, Dry	0.44	16.0	202+j2.6
Loamy Soil, Wet	1.93	7.07	88.8+j2.6
Clayey Soil, Wet	12.5	7.63	93+j16.2
Iron	1.7×10^{7}	3.2×10^{-5}	2.0+j2.0
Basalt	8.2×10^{-3}	15.0	188+j0.04
Sandstone	0.73	13.4	168+j3.0

Where η = Characteristic Impedance of Material

Table 3. Selected Radar Parameters for Calculating Maximum Range

RADAR SYSTEM PARAMETERS

System	Geo-Centers Proprietary Design	Standard GSSI Systems	
Center frequency	10 MHz	80/120 MHz	300 MHz
Parameter			
P_s (Peak) (Watts)	2.5×10^3	50	12
P_{min} (Watts)	2.5×10^{-8}	5×10^{-10}	1.2×10^{-10}
Q	-110 dB	-110 dB	-110 dB
$E_t = E_r$	5%(-13 dB)	5%(-13 dB)	5%(-13 dB)
$G_t = G_r$	1.585(2 dB)	1.585(2 dB)	1.585(2 dB)

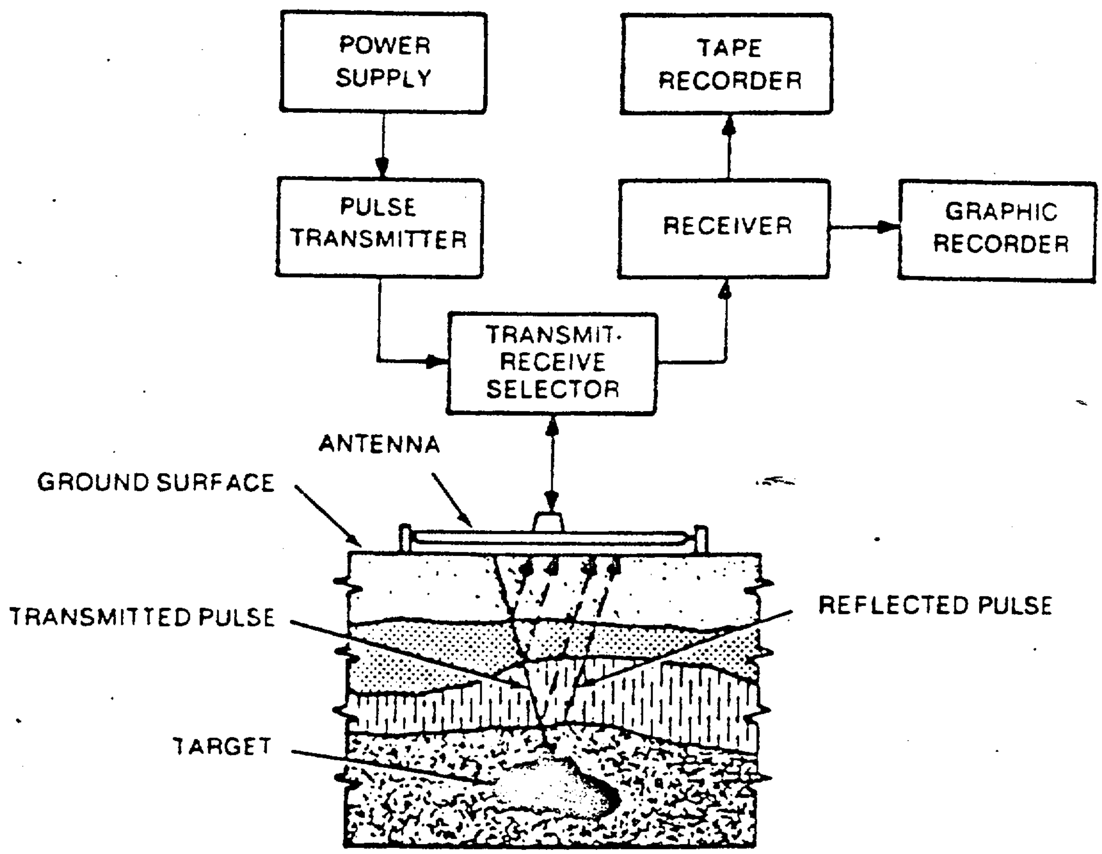


Figure 3 Ground-Penetrating Radar (GPR) System, block diagram.

factors are considered in the choice of array configurations for a given problem. Susceptibility to geological noise, ease of array movement, and the nature of the assumed structure are a few of these factors.

For each of the three (3) electrode configurations in Figure 4, the apparent resistivity, ρ_a, can be calculated from:

$$\rho_a = 2\pi \frac{V}{I} a, \text{ Wenner Array} \quad (10a)$$

Where: V = potential difference

I = induced electric current

a = spacing between electrodes

$$\rho_a = \pi \frac{V}{I} (b) \left[\left(\frac{L}{b}\right)^2 - \tfrac{1}{4} \right], \text{ Schlumberger Array} \quad (10b)$$

Where: b = distance between potential electrodes

L = half the distance between current electrodes

$$\rho_a = \pi \frac{V}{I} (L) \left[\left(\frac{L}{b}\right)^2 - 1 \right], \text{ Double-dipole array} \quad (10c)$$

Where: b = distance between current electrodes and between potential electrodes.

L = distance between mid-points of current electrodes and potential electrodes.

As discussed in section 3.1, a knowledge of soil properties allows prediction of radar performance at a specific site. Measurements of bulk soil resistivity can be used to estimate expected penetration depth of the GPR. Figure 5 shows maximum radar range as a function of electrical resistivity (DC conductivity). From a few measurements of resistivity on the site of interest, the expected depth of penetration can be estimated for a range of frequencies. The best antenna for the application can then be selected, providing the optimum trade-off between penetration and resolution.

In addition to supporting radar operations, mapping the site with resistivity measurements aids in the interpretation of radar data. Changes in bulk resistivity can indicate the presence of materials foreign to the particular site. For example, a cluster of metallic objects would lower the resistivity values measured for the area surrounding these materials. Correlations between resistivity measurements and GPR measurements are strong indications of disturbed areas.

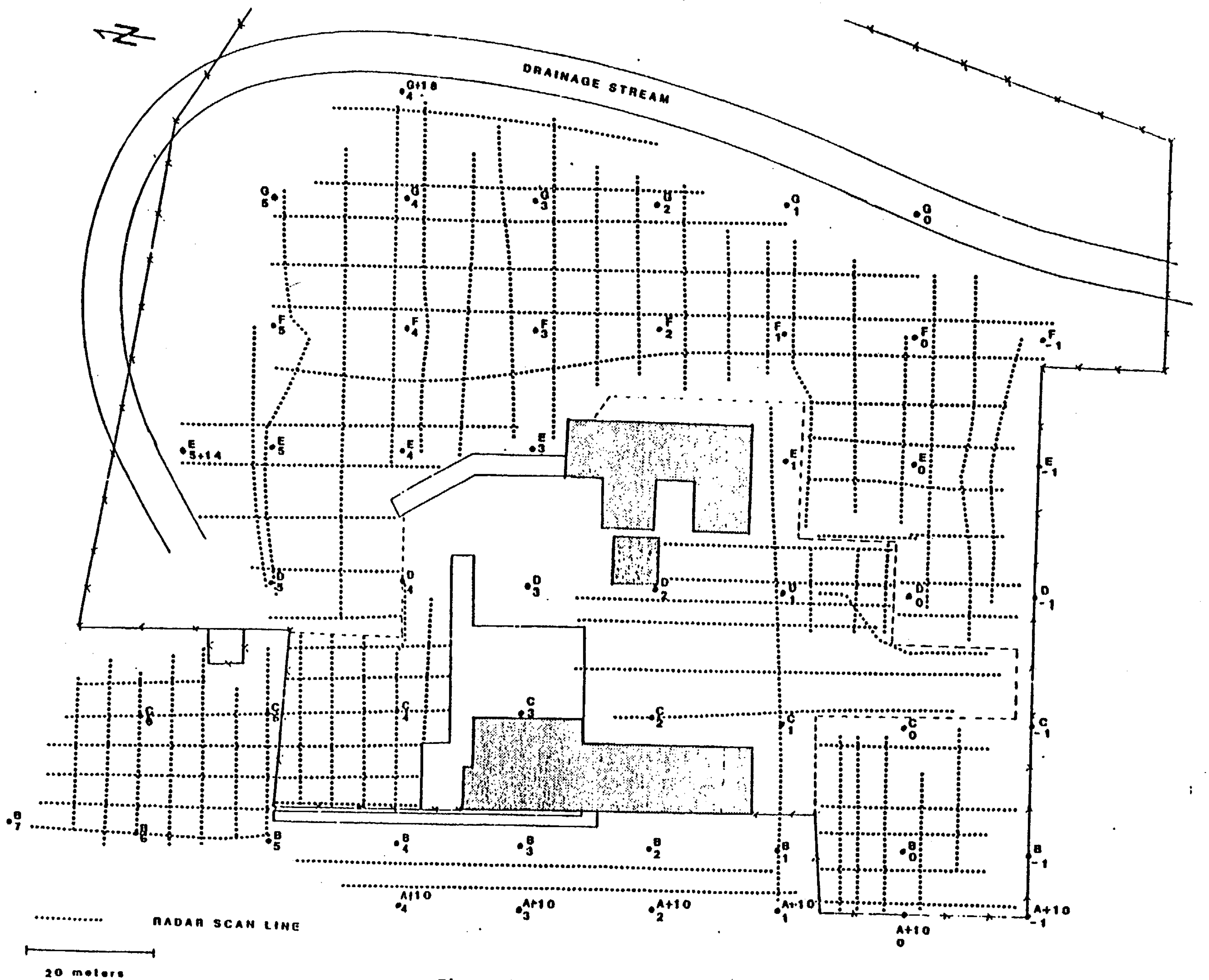


Figure 6: Radar survey lines.

5. DISCUSSION OF RESULTS

The 300 MHz and the 80 MHz antenna systems were evaluated and calibration measurements were made to tailor the radar system for the specific conditions at the W.R. Grace site. Data collected with the 300 MHz antenna indicated a depth of penetration of approximately 1 to 8 feet, which precluded its use. The results in this report were derived from data obtained with the 80 MHz antenna.

Typical examples of radar profiles taken at the site are displayed in Figures 7 and 8. Figure 7 shows a scan along the F+3m, line from -1+00m to 5+00m. Figure 8 shows a scan along the 5-2m line from G+2m to D-2m

In Figure 7, several distinct, well defined regions are readily apparent. At the beginning of the scan near -1+2m, a sharply delineated area of strong reflectivity about 3m wide stands out. A gradual transition from a strong reflective zone to a moderate reflective zone occurs near 0-4m. The area from 0+00m to 1+00m is nearly uniform, with numerous small reflections evident at depth. A sharp transition is visible close to 1+00m leading into a region of irregular, individual scatterers. This region ends at 1+9m where an absorptive zone containing a number of diffuse scatters is encountered. The strong vertical signature at 2+3m is probably due to a near surface metallic object. Beginning with 2+5m the shallow return signal becomes increasingly disturbed,

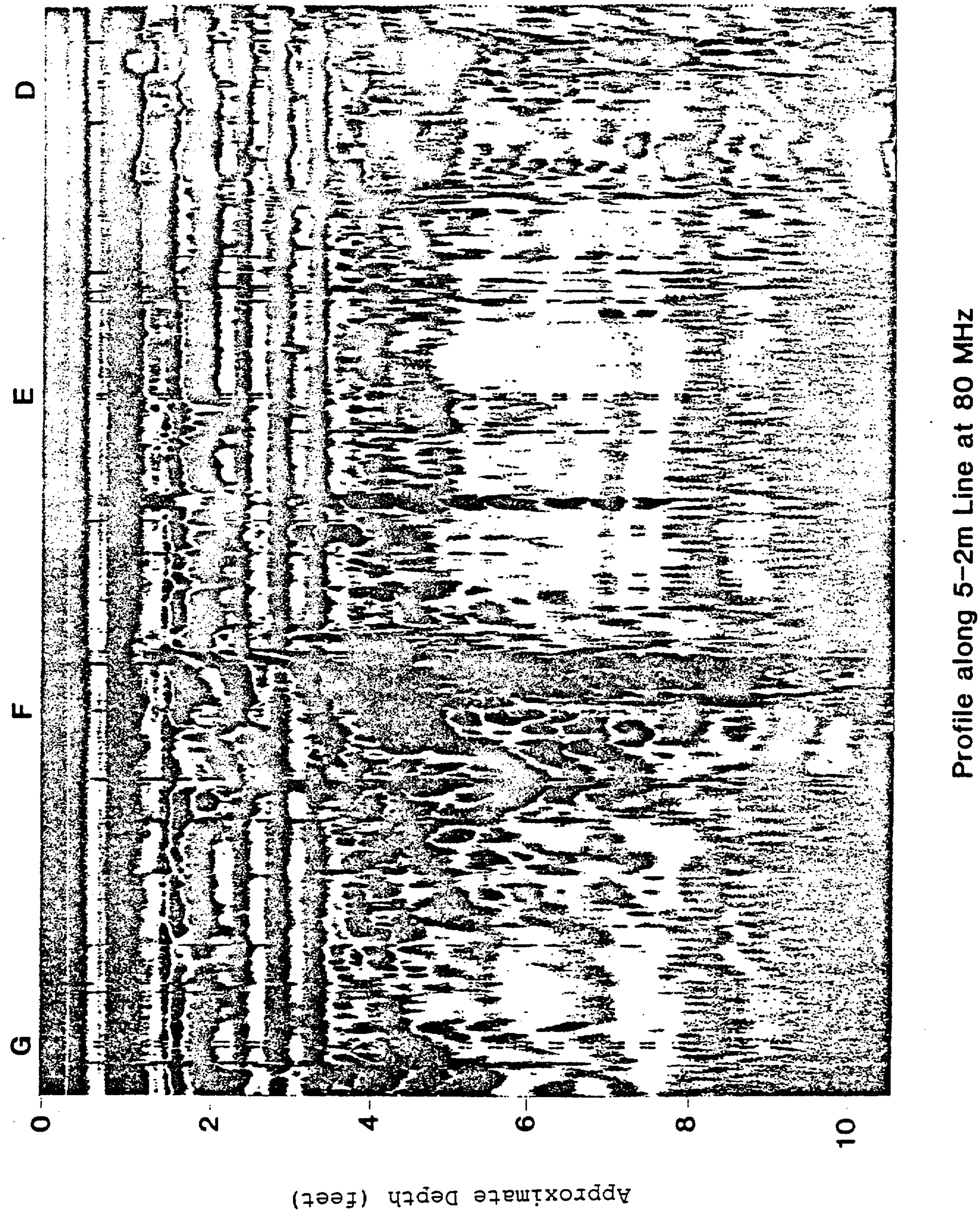
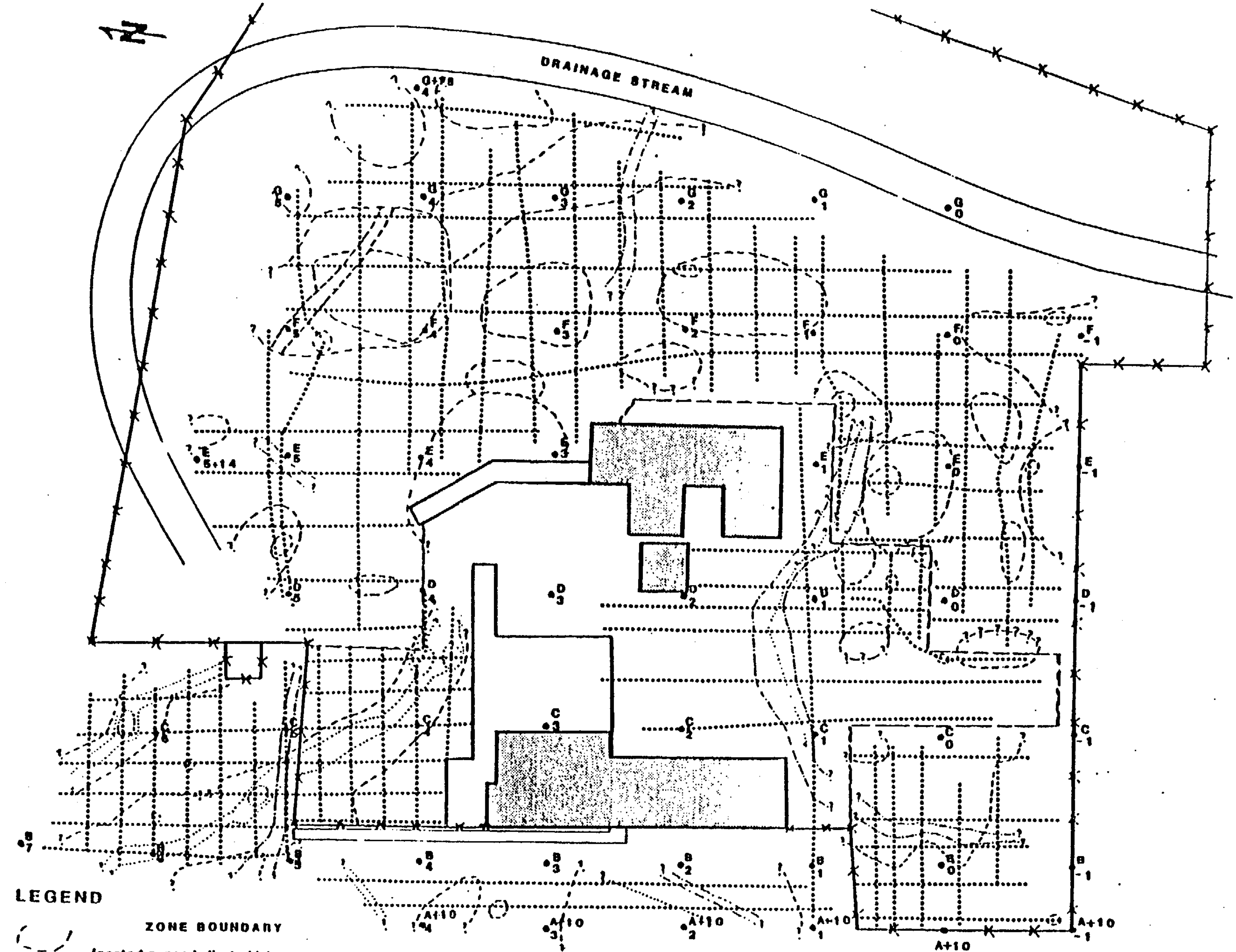


Figure 8: Radar profile along 5-2 meters line.



LEGEND

ZONE BOUNDARY (nested zones indicate higher concentration)

POSSIBLE BURIED TRENCH

POSSIBLE BURIED PIPE

RADAR SCAN LINE

20 meters

Figure 9: Interpretation of Ground-Penetration Radar Survey at the W. R. Grace Disposal Site, New Jersey.

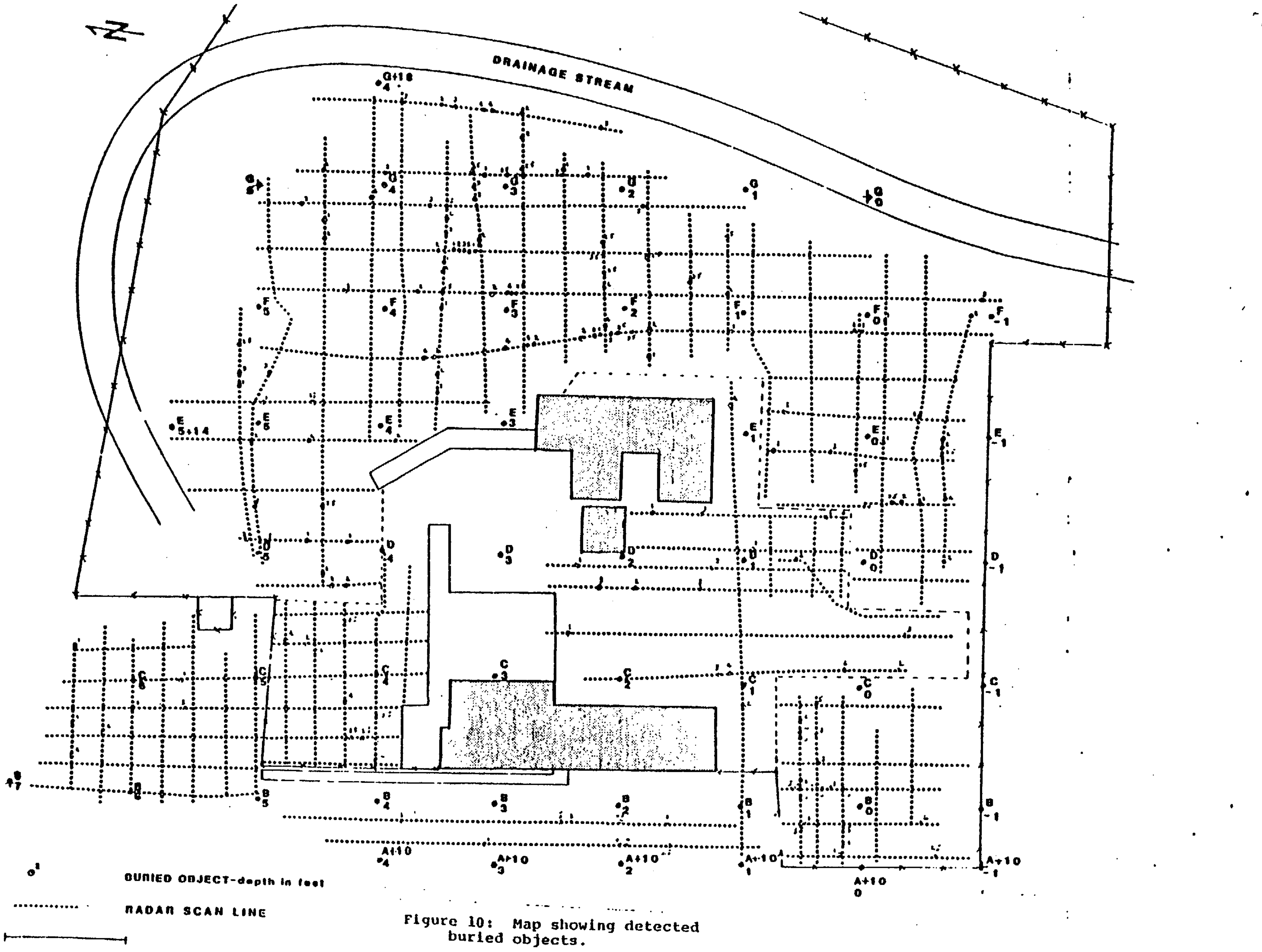


Figure 10: Map showing detected buried objects.

In areas surveyed outside the burial ground, the only detected features were pipes and surrounding trenches. Anomalous zones in the lawn areas are probably caused by old pavement underlying the turf.

APPENDIX D

MAJOR ANALYTICAL EQUIPMENT

APPENDIX D

Major Analytical Equipment

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

A. Direct Radiation Measurements

Eberline "RASCAL"
Portable Ratemeter-Scaler
Model PRS-1
Beta-Gamma "Pancake" Probe, Model HP-260
Energy Compensated G-M Probe Model HP-270
(Eberline Instrument, Santa Fe, NM)

Eberline PRM-6
Portable Ratemeter-Scaler
Scintillation Probe, Model 489-55
(Victoreen, Inc., Cleveland, OH)

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

Ludlum Ratemeter-Scaler
Model 2200
(Ludlum Measurements Inc., Sweetwater, TX)

B. Laboratory Analysis

Ge(Li) Detector
Model LGCC2220SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, SPG-16
(Applied Physical Technology, Smyrna, GA)

Pulse Height Analyzer, ND680
Model 88-0629
(Nuclear Data, Inc., Schaumburg, IL)

Alpha Spectroscopy System
Tracor Northern 1705
Pulcir PA-1 Alpha Module
(Pulcir, Inc., Oak Ridge, TN)

APPENDIX E

ANALYTICAL PROCEDURES

APPENDIX E

Analytical Procedures

Gamma Scintillation Measurments

Walkover surface scans and measurements of gamma exposure rates were performed using an Eberline PRM-6 portable ratemeter with a Victoreen Model 489-55 gamma scintillation probe containing a 3.2 cm x 3.8 cm NaI(Tl) scintillation crystal. A graph of count rate (cpm) vs. exposure rate (μR/h) was developed by comparing the response of the scintillation detector with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at several locations on and off the W.R. Grace property. This plot was used to convert the meter readings to exposure rates.

Additional Exposure Rate Measurements

Exposure rates at several locations on the property exceeded the measuring range of the gamma scintillation equipment. At those locations, exposure rates were measured using Eberline energy compensated Model HP-270 G-M probes with Eberline "Rascal" Model PRS-1 portable ratemeters. Calibration of this instrumentation was by cross reference to a Reuter-Stokes Model RSS-111 pressurized ionization chamber.

Beta-Gamma Dose Rate Measurements

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

Borehole Logging

Borehole gamma radiation measurements were made using a Victoreen Model 489-55 gamma scintillation probe connected to a Ludlum Model 2200

Water Samples

Water samples were rough filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by filtration through 0.45 μm pore size membrane filters. The filters, together with attached solids, were discarded, and the filtrate was acidified by the addition of 20 ml of concentrated nitric acid.

Gross Alpha and Gross Beta Analysis

Fifty milliliters of each sample was evaporated to dryness and counted on a Tennelec Model LB5100 low background proportional counter.

Radium-226/228 Analysis

Samples were analyzed for Ra-226 and 228 using the standard technique EPA 600/4-75-008 (Rev.)

Vegetation Analysis

Gamma Spectrometry

After being washed vegetation samples were air dried, chopped, and mixed. Aliquots were placed in 3.5 ℓ Marinelli beakers and analyzed for identifiable photopeaks in the same manner described above for soil sample analysis. Due to possible preferential uptake and assimilation of various radionuclides by vegetation, it could not be assumed that Th-232 and Ra-228 were in equilibrium. Therefore, Ra-228, rather than Th-232, concentrations are reported for vegetation samples.

Errors and Detection Limits

The errors, associated with the analytical data presented in the tables of this report, represent the 95% (2σ) confidence levels for that data. These errors were calculated, based on both the gross sample count

State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
JOHN FITCH PLAZA, CN027, TRENTON, N.J. 08625

STEVEN G. KUHRTZ
DIRECTOR

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Former Thorium/Rare Earths Processing Facility (W. R. Grace Property, Wayne, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the W. R. Grace property and vicinity. This survey is part of a DEP ongoing program to reevaluate former radiation sites to assess their radiological condition.

A comparison of the area's radiological conditions and current property use to the radiological standards for the general public, show that it is unlikely that an individual would be exposed to radiation levels that exceed existing federal and state radiation standards. However, current property use can change which could result in individuals receiving radiation doses above these standards, therefore an evaluation of the surveyed area should be based on more stringent environmental standards.

A comparison of the area's radiological condition to the most conservative environmental standards indicates that future remedial actions are necessary for approximately 15,000 square meters of the W. R. Grace property and 2,000 square meters of the contiguous property to the south. Further, as a result of the extensive soil contamination, the DEP is concerned that the overburden covering the waste disposal areas on the Grace property is insufficient to prevent future movement of contaminated soil by surface run-off.

Although the results of water samples taken in the surface drainage system meet federal and state drinking water standards, they show evidence of contamination. Air samples show radon-222 concentration outdoors and in the office building on the Grace property to be within the background levels for New Jersey, but higher levels were found in the warehouse building.

The DEP will pursue remedial actions for this site with all appropriate parties.

Sincerely,

Steven G. Kuhrtz

Steven G. Kuhrtz
Director

ITEM # 290

3/8/89

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RADIOLOGICAL SURVEY

OF A

FORMER THORIUM/RARE EARTHS

PROCESSING FACILITY

(W.R. GRACE PROPERTY
WAYNE, NEW JERSEY)

NEW JERSEY STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
BUREAU OF RADIATION PROTECTION

RADIOLOGICAL SURVEY

OF A

FORMER THORIUM/RARE EARTH PROCESSING FACILITY
(W. R. GRACE PROPERTY, WAYNE, NEW JERSEY)

MARCH 1983

Site Decontamination Assessment Section
Bureau of Radiation Protection
New Jersey Department of Environmental Protection

Members of the Bureau of Radiation Protection
who participated in this study:

Jeanette Eng
Joseph Morris
Frederick Rauch
Kent Tosch
Duncan White

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A. INTRODUCTION

History

In 1948, Rare Earths Inc. began its operation at the Wayne, New Jersey, site to extract thorium and rare earth from monazite ore. With the passage of the federal Atomic Energy Act in 1954, Rare Earths Inc. received an AEC (Atomic Energy Commission) license in 1954 to process monazite ore. In 1956, Rare Earths Inc. became affiliated with the Davidson Chemical Company, a division of W. R. Grace and Company. Monazite processing activities continued under W. R. Grace through 1971. The processing activities were to be in compliance with the licensing requirements of the AEC. Chemical discharges were to be in compliance with the permitting requirements of the N.J. Department of Health.

The monazite handled by Rare Earths/W. R. Grace were from domestic and foreign sources (Idaho, Brazil, India, Australia, etc.). Alluvial monazite sands containing typically 60% rare earth oxides and 3-10% thorium oxide were processed at this site. The process to extract the rare earths and thorium from the monazite was done by carefully controlling the pH, selectively precipitating and separating desired products (US55). Various waste residues were produced during the processing. A number of these residues were buried, including ore tailings, yttrium sludges and sulfate precipitates. Liquid effluent streams were treated in the waste treatment plant where the residues were solidified and disposed in an onsite sludge dump. After treatment, liquid effluents were neutralized and discharged into Sheffield Brook, a tributary of the Pompton River.

W. R. Grace ceased processing monazite ore in 1971 and amended its AEC license for storage only. The decontamination was performed in 1974 by the company and its consultant, Applied Health Physics, Inc. Some buildings and processing equipment were demolished and buried on the property. Remaining buildings were decontaminated by washing, vacuuming and chiselling to remove surficial contamination. According to the consultant's report (Mc74), the disposal areas were covered with clean fill to reduce exposure rate to below 0.2 mR/hr (200 μR/hr). Locations of disposal areas for wastes from processing (1948-1971) and decontamination (1974) are shown in Figure 1.

In 1975, after decommissioning at the site, the U.S. Nuclear Regulatory Commission (the NRC assumed AEC's role in 1974) terminated the storage license and released the site for unrestricted use, provided the land deed indicated that radioactive material is buried on the property.

In 1980, the New Jersey Department of Environmental Protection (NJ DEP) requested than an aerial survey be performed over the W. R. Grace facility in Wayne, New Jersey. The request was initiated by DEP to determine the radiological condition at former radiation facilities. The November 1981 report (An81) on the aerial survey performed in May 1981 by EG & G indicated elevated radiation levels at the plant site and an area west of the plant (a second aerial survey covering a larger area was performed in September 1982 reached the same conclusions (An82)). It was determined that a more detailed radiological survey of the plant site was needed to provide information on the extent and degree of the contamination. Radiological survey at the processing facility was performed in July and August 1982, by Oak Ridge Associated Universities (ORAU) for the NRC and by the Bureau of Radiation Protection for NJ DEP.

NJJ DEP Radiological Survey

The radiological survey by DEP covered:

a. Measurement of gamma radiation with field instruments.

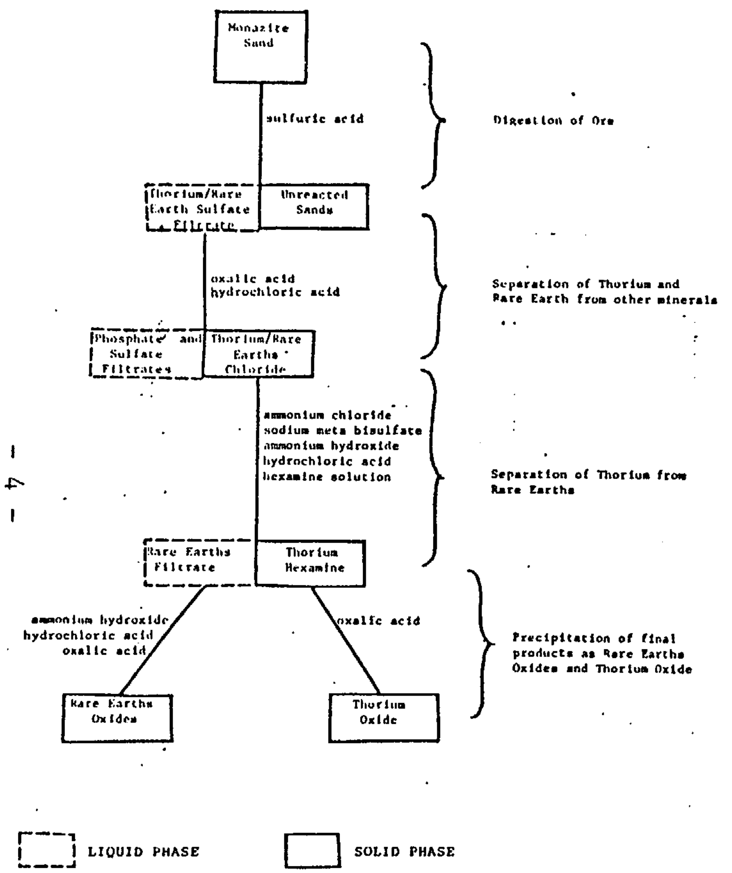
b. Measurement of radionuclide concentrations in soil and sediment samples.

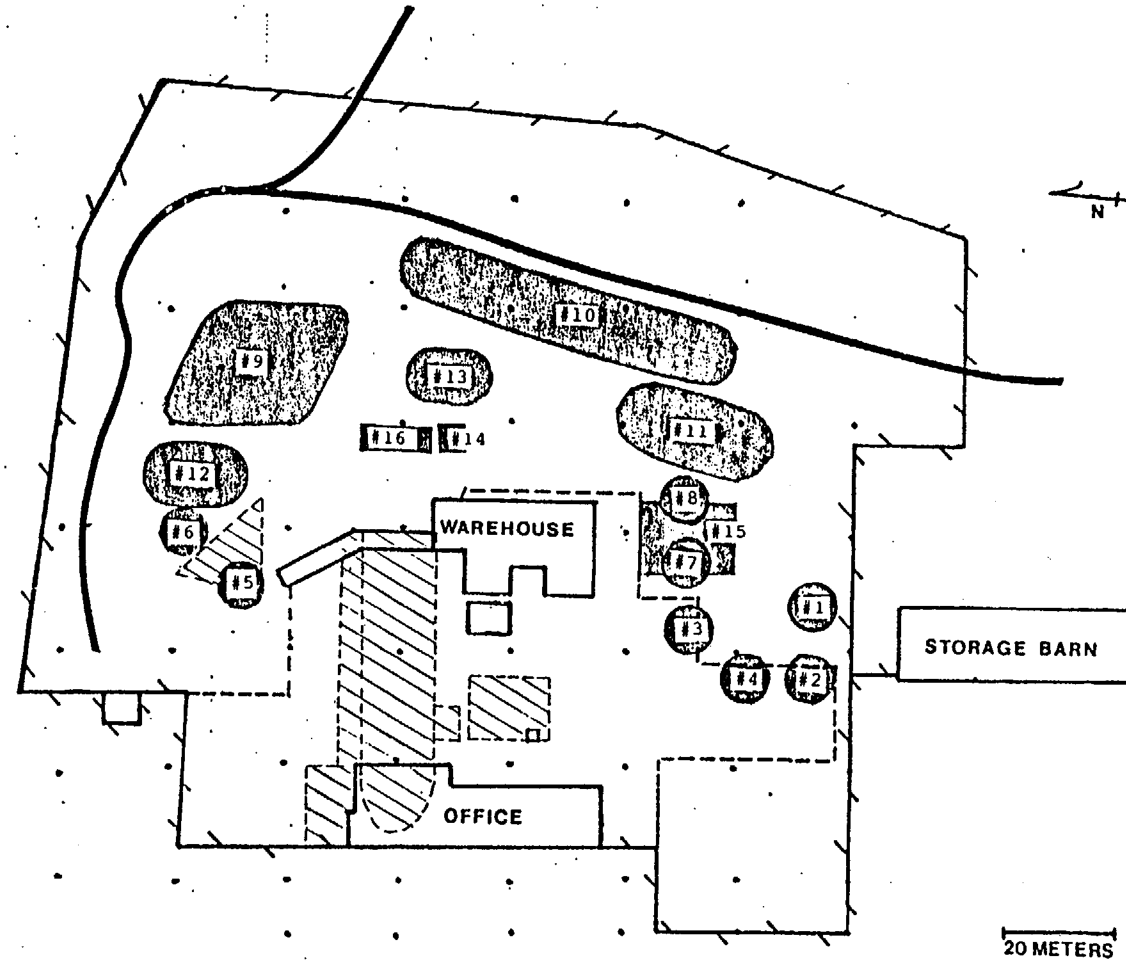
c. Measurements of radioactivity in water samples from the drainage ditch, Sheffield Brook and an artesian well.

d. Measurement of radon gas (Rn-222) concentration in ambient air and inside buildings as a result of radium in soil.

The report is arranged such that each section on gamma radiation, soil samples, water samples and air samples includes sampling procedure, analytical technique and data obtained. The final section of the report will compare the radiological data with radiological standards.

OVERVIEW OF THORIUM/RARE EARTHS EXTRACTION PROCESS





FORMER STRUCTURES

DISPOSAL AREAS
1974 Decontamination
#1 - #8: 1700 pounds of material
1948-1971 Processing Burial Areas
#9: sludge dump from treatment plant
#10: ore tailings and gangue
#11: yttrium and silica sludges
#12: reworked sludges
#13: waste treatment disposal
#14: thorium hydroxide
#15: carbonate cake
#16: yttrium concentrate

FIGURE 1: EXTRACTION PROCESS AND LOCATION OF DISPOSAL AREAS

B. SITE DESCRIPTION

Geographical Description

The study area shown in Figures 2 and 3 is located in the western portion of Wayne Township, Passaic County, at the intersection of Pompton Plains Cross Road and Black Oak Ridge Road (U.S. Highway #202). The former processing facility is situated on approximately seven acres of land. Adjacent to the northern and eastern boundaries of the site are residential homes, while to the southern boundary is a school bus maintenance yard. Black Oak Ridge Road forms the western side of the W. R. Grace property. This site has two major structures: an office building and a warehouse with an adjacent shed. An eight-foot high chainlinked fence encircles the W. R. Grace property with access available through two gates near the office building.

The first building, used as offices, is located approximately 50 feet east of Black Oak Ridge Road and faces the road. This two-story masonary structure's orientation is in a north to south direction. North of the building is an unfenced parking lot (northern parking lot). On the south end of this building is the employee access driveway which leads to a parking lot to the south and east, behind the building (southern parking lot). Due south of the access driveway is a 100 feet by 100 feet fenced front lawn area. West of the building and north of the access driveway is a 250 feet by 50 feet open front lawn area facing the road. Thirty feet east of and behind the office building is a 212 foot deep artesian well. General topography of the above described area reveals a higher elevation for the southern parking lot and southern fenced lawn area while lower elevations exist north and west of the building for the northern parkling lot and open front lawn area.

The second building, a bi-level masonary strucure used as a warehouse and production facility is located 200 feet east of Black Oak Ridge Road behind the office building.

The area surrounding the warehouse is covered with asphalt, except the northwestern end where a loading dock is attached. Several cartons and old equipment are found near the building's wall. A small shed is centrally located on the western side of the building. Beyond the paved portion to the south, east and north of the warehouse is a large open field.

The open field contains the burial locations for the various wastes from processing. This area slopes westerly but more steeply on the northern than the southern portion. Approximately 120 feet to the east, behind the warehouse runs a drainage ditch which encircles the eastern and northern perimeter of the open field. The drainage ditch joins the Sheffield Brook at the northeastern corner of the field. There is a steep drop along the northern portion down to the Sheffield Brook. Wooded or heavily brushed areas constitute the sloping sides of the banks.

Sheffield Brook, a tributary to the Pompton empties from a storm drain to the east of the study area and flows westerly across the northern end of the study area. The brook near the northern parking lot enters into an underground conduit and contines west under Pompton Plains Cross Road. The Sheffield Brook re-emerges 600 feet to the west across a field and finally drains into the Pompton River. The radioactivity in this portion of the Sheffield Brook was discussed in the October 1981 DEP report "Radiological Survey of Sheffield Brook, Wayne, New Jersey" (Ra82).

An adjacent property to the south of the Grace facility was also studied. The property is used as a maintenance and repair facility for school buses. The east half of the property is a dirt/gravel area used for school bus parking. A drainage ditch and woods to the east of the parking lot form the eastern boundary of this property. The storage barn nearest to the W. R. Grace property is used for tire storage, and the area is overgrown with heavy brush. A second barn used for maintenance and repairs is located to the south of the storage barn, and the area is covered with dirt/gravel, similar to the eastern half of the property.

Hydrogeolic Description

Lack of site specific hydrogeologic data on the W. R. Grace property precludes any detailed description of the underlying geology or groundwater properties. Two reports (Se75, Ca75) discuss the county of Passaic with regards to the soil, geology and groundwater characteristics, provide a general picture of the study area.

Wayne Township is geologically located in the Piedmont Lowlands, a region formed during the Triassac Age (200 million years ago). The underlying bedrock is sedimentary rock classified as the Brunswick Formation (e.g. Brunswick shale). Based on a survey of wells within a mile of W. R. Grace, the depth to bedrock is probably close to 70 feet (Ca75). The Brunswick Formation is an important source of groundwater in the area. Characteristic of the groundwater in the Brunswick formation is discrete zones of water bearing openings and the poor hydraulic connection between these zones. Consequently, no regional groundwater flow system underlies the area.

Soil in this portion of New Jersey was influenced by glacial activities during the Wisconsin Ice Age, ending about 15,000 years ago. Ridges and lowlands were scraped clean and later filled with a variety of unconsolidated deposits by glacial outwash as the glaciers retreated northward. The resulting soil is well drained and mostly sandy loams. In recent times, human activity has altered up to 80% of the natural soil profile. Consequently, the current soil characteristics reflect both urban land use and the original substrate.

Two types of soils are indicated by Soil Conservation Service (SCS) maps for the W. R. Grace property. In the flatter portions, the "Urban Land-Riverhead Complex" soil group dominates, whereas the hilly portions to the east are predominantly the "Urban Land - Rockaway Soil Complex". Urban Land - Rockaway Soil Complex has well drained soil and relatively high seasonal water table (1.5 - 2.5 feet). The Urban Land - Riverhead Complex is characterized by excessively to well-drained soils with a deep water table (greater than six feet).

The movement of groundwater in the burial areas cannot be precisely determined unless test wells are dug, but the four following features found on the W. R. Grace and nearby properties indicate that groundwater moves towards the surface. Hills (composed of Rockaway Soil) to the east of the study area and the presence of nearby surface water (Sheffield Brook and Pompton River) indicates that groundwater is close to the surface or intersects surface water. Further evidence of upward movement is the presence of an artesian well on the Grace property and a spring located about a half mile away on a farm north of Pompton Plains Cross Road.

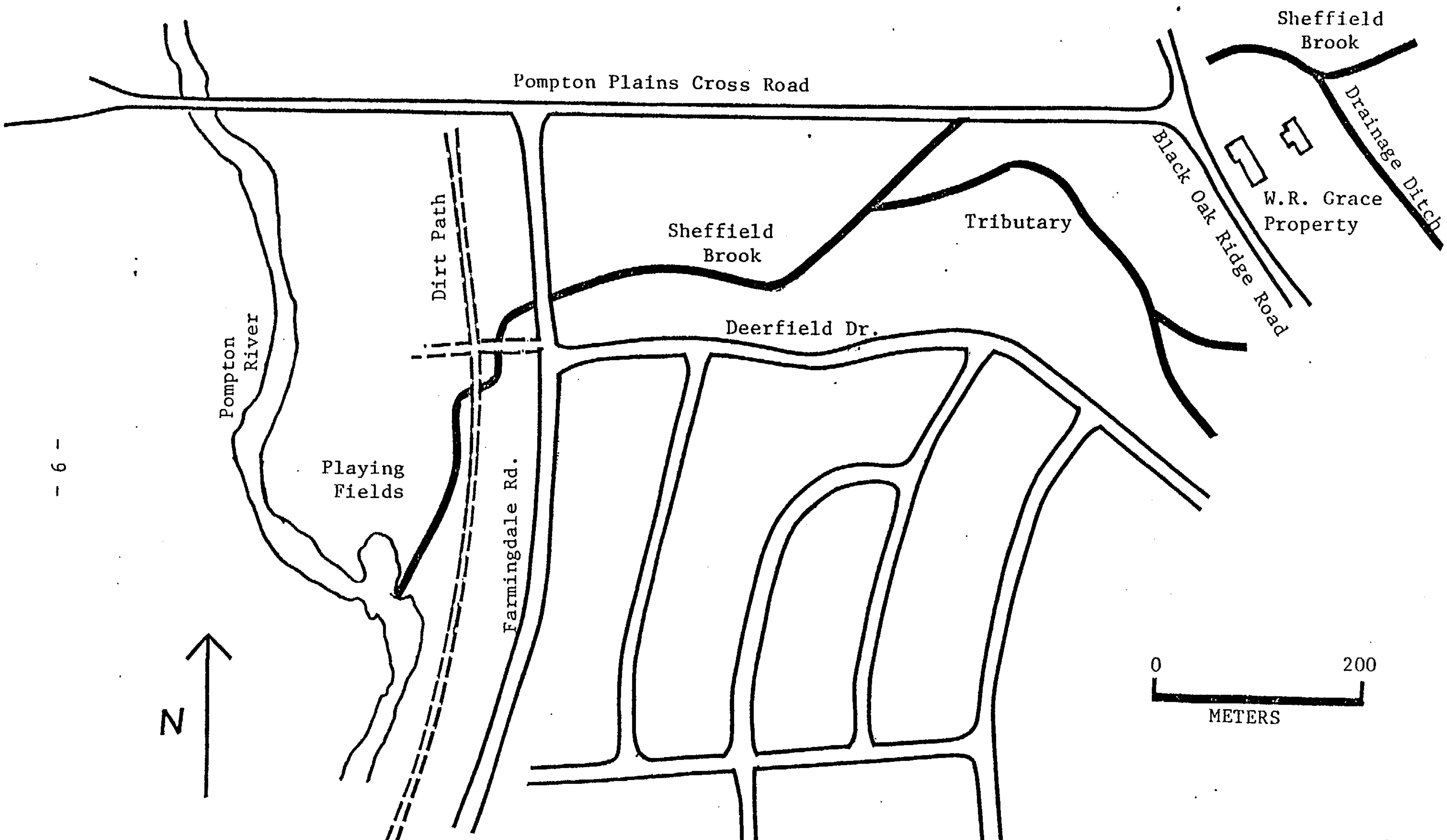


FIGURE 2: MAP OF W. R. GRACE PROPERTY AND VICINITY

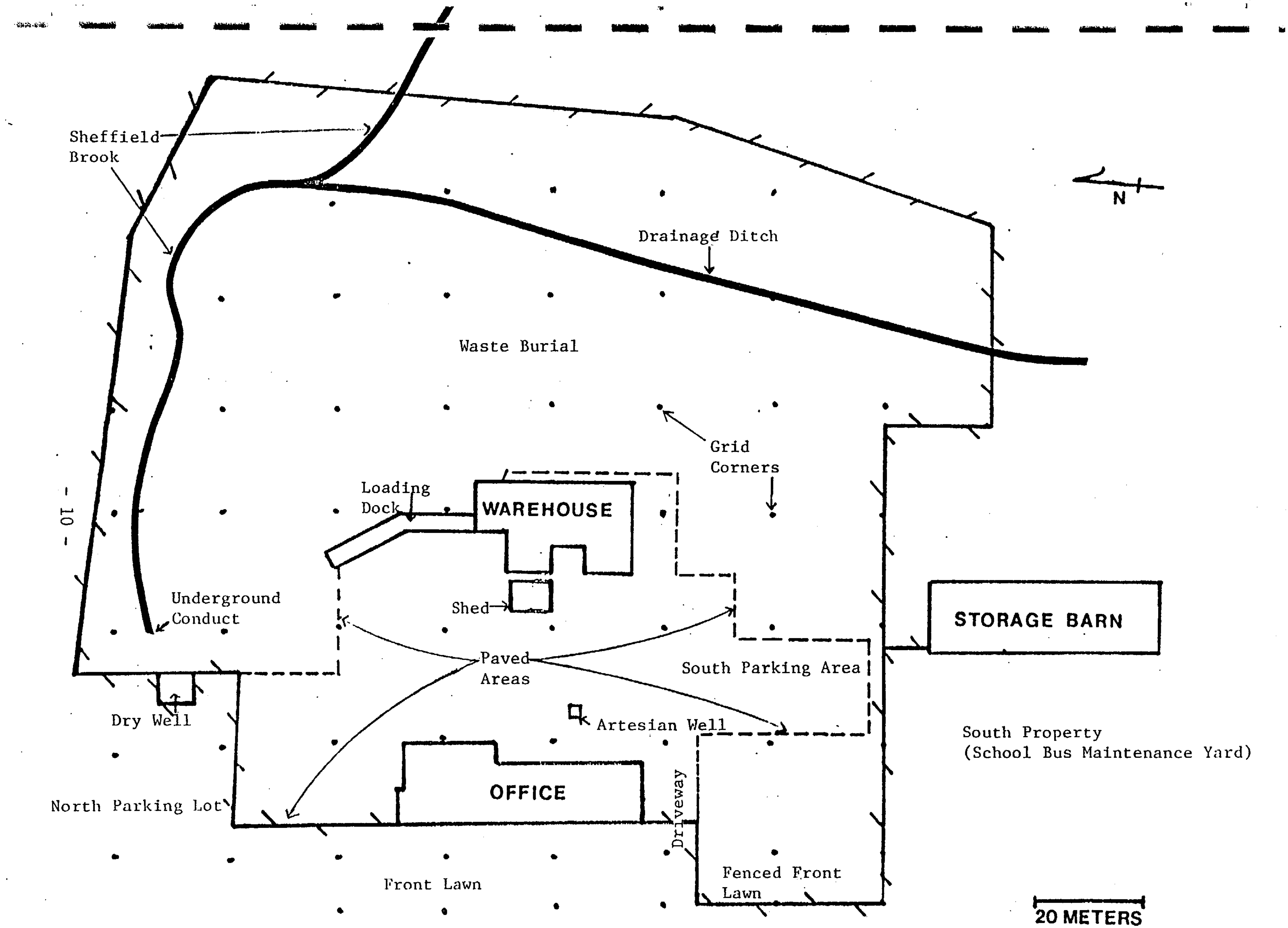


FIGURE 3: STUDY AREA (W.R. GRACE PROPERTY)

C. FIELD MEASUREMENTS OF GAMMA RADIATION LEVELS

Field Survey

Surface gamma radiation surveys were performed over the W. R. Grace property and related areas in order to determine the extent of elevated gamma radiation readings. Approximately seven acres of land were surveyed with sodium iodide (Na(Tl)) scintillometers.

The study area was divided into 20 by 20 meter grids using wooden stakes to identify the corners of the grids. Within each 20 by 20 meter grid, ground level gamma radiation readings were taken every two meters using a 20 meter rope marked in two meter intervals. Readings at one meter above ground level were taken every other interval, i.e., four meters apart, within the 20 by 20 meter grid. Exceptions to this survey procedure occurred when buildings, large crates, heavy shrubbery and vegetation prevented continuation of the two meter readings. Where no grids were established, radiological measurements along the brook, building foundations and fences were made and the readings incorporated into the grid system. The south property and structures were also surveyed.

Both ground and one meter measurements taken with the scintillometers were recorded in counts per minute (cpm). About 4,000 field measurements were taken for developing a map of the ground level gamma radiation and 1,600 field measurements for developing the map of one meter above ground gamma radiation. The scintillometers were field calibrated to a pressurized ionization chamber over a range of radiation levels. Consequently, the scintillometer count rates can be converted to exposure rates in microroentgens per hour (μR/hr).

In the discussion of the results for the gamma radiation field survey, the study area is subdivided into nine regions as shown in Figure 4. Figure 5 and Figure 6 are maps of ground level and one meter exposure rates for the entire study area, respectively.

Regions A, B and E constitute the open field in the eastern half of the Grace property where the processing residues were buried. Region C is both banks along 60 meters of the drainage ditch beginning at the south fence. Region D defines all areas between the drainage ditch or Sheffield Brook and the east or north fences on the Grace property. Paved areas between the two buildings, extending the entire north-south distance of the property, the parking areas and driveways are designated as Region F. Region G is the front lawn between the office building and Black Oak Ridge Road. Region H is south of the office building defined by a fence. Region I is the property on the southern boundary of the Grace property.

Ground Level Results

Figure 5 is a map of ground level exposure rates including background for the entire study area. Measurements in Region A ranged from 40 to 1491 μR/hr. The highest readings were in the northern sector, an elongated area oriented along a north-south line, with exposure rates exceeding 500 μR/hr. Areas between 200 and 500 μR/hr continued from north to south and easterly to the rear of the warehouse. A large portion of Region A has exposure rates between 100 and 200 μR/hr with an equally large portion reading 50 to 100 μR/hr. The northeast corner of this region is characterized by scattered groups of varying ranges of measurements, possibly indicative of shallow overburden. The lowest measurements (20 to 50 μR/hr) in Region A were found along the western and southern banks of the drainage ditch and Sheffield Brook. Based on past records, the northern portion of Region A was the site of the waste treatment plant and the burial areas for the reworked sludges, dewatering pond, thorium hydroxides, yttrium concentrates, waste treatment disposal pits, and, to the rear near the drainage ditch, ore tailings. Since the records are not of sufficient detail to show exact locations of the burial areas, the lower measurements in the center of Region A could indicate either a thicker cover or an area not used for burial.

Region B had a similar range of exposure rates as Region A, but there were fewer areas with readings above 200 μR/hr. Four small areas had ground level exposure rates between 500 and 1,000 μR/hr, with most of Region B having radiation levels between 50 and 200 μR/hr. Records indicate this region was used to bury yttrium and silica sludges, carbonate cakes, and contaminated materials from decommissioning activities in the early 1970's.

To the west of Region B is Region C, the area along the drainage ditch. On the eastside of the ditch, the highest reading was found on top of a small rise (166 μR/hr on contact). This was also the only area with elevated measurements found on the east bank. On the west bank, exposure rates were higher (up to 689 μR/hr), than other areas along either bank, possibly indicating slumping had occurred at this point on the west bank. Again, past records indicated that ore tailings and possibly the yttrium and silica sludges were disposed close to the west bank.

Region D encompasses those areas, beyond the waterways, along the east and north sides of the Grace property. No above background radiation levels were noted in these areas except for the previously discussed area designated as Region C and along the northwestern end of the property where the Sheffield Brook enters the underground conduit. The maximum ground level exposure rate was 29 μR/hr for the latter case. At no point did above background exposure rates extend beyond the north and east fences.

Region E, located between the drainage ditch and the warehouse loading dock, had ground level exposure rates up to 850 μR/hr. The higher exposure rates of more than 200 μR/hr were found near the loading dock and around the dry well which is a fenced area in the northern parking lot. Closer to Sheffield Brook the exposure rates were lower, between 50 and 100 μR/hr. Records indicate this region may be the former location of a waste treatment plant and the burial area for waste from the early 1970's decontamination and decommissioning activities.

Region F is defined as the paved areas of the site and constitutes most of the western half of the property. Generally the exposure rates were less than 50 μR/hr. The highest measurements in Region F were found within an alcove of the warehouse. An opening in the asphalt had a maximum exposure rate of 854 μR/hr but the remainder of the alcove measured between 200 and 600 μR/hr. Due to attenuation of gamma radiation by the asphalted surfaces, the generally lower radiation readings of Region F may not be indicative of lower radioactivity in the soil below the paved surface. This is supported by the observation of higher radiation measurements found in the warehouse alcove and the southern driveway where portions of the paved areas were cracked, exposing the underlying soil.

Most of Region G was between 20 and 30 μR/hr, with most of the sidewalk at background levels. The only significant ground level exposure rates were two areas with measurements of up to 259 and 301 μR/hr found in the grassy area between the sidewalk and the road curb. These areas were most likely due to direct deposition through human activities.

Elevated ground level exposure rates up to 238 μR/hr were found in Region H along the fence lines to the east and north. Since the portion of Region F between Regions B and H is paved, it is not certain whether the contamination in Region H is a continuation of Region B or separate. Records indicate that debris from the early 1970's decontamination and decommissioning may have been buried in this area.

The storage barn is located on the south property (Region I) adjacent to the Grace property. It is unclear from the records whether monazite ore was stored in this structure prior to beneficiation on the Grace property. The higher ground level exposure rates were associated with the storage barn loading dock and the barn entrance on the east side. Exposure rates up to 854 μR/hr were measured near this entrance, and rates up to 227 μR/hr were found next to the loading dock. Scattered small areas of elevated radiation were found inside the structure where the concrete floor was cracked. Measurements up to 233 μR/hr were found in areas near the southern fence between this property and the Grace property.

One Meter Above Ground Level Results

Figure 6 illustrates the exposure rates including background taken at one meter above ground. The radiological profile follows the pattern of exposure rates shown in Figure 5, but lacks the details that are seen by the ground level survey. The wide range of exposure rates measured at ground level results in the exposure rates measured at one meter level to effectively average the gamma radiation field in that area.

The highest one meter level exposure rates, up to 854 μR/hr, were from an elongated area, along a north to south line, in Region A. This area was surrounded by one of the two tracts with one meter level measurements greater than 200 μR/hr. The second tract was to the south and rear of the warehouse, with measurements up to 471 μR/hr. A large area with measurements between

100 and 200 μR/hr enclosed these two tracts. An equally large area, near the perimeters of Region A, had exposure rates less than 100 μR/hr.

In Region B, three isolated locations had one meter level exposure rates between 200 and 471 μR/hr. Measurements of less than 100 μR/hr were found in areas near the south wall of the warehouse, west of the drainage ditch, and along the south fence.

In Regions C and D, the one meter level exposure rates dropped off rapidly on the east and north banks of the drainage ditch and Sheffield Brook. In Region C the elevated readings on the west bank of the drainage ditch was associated with the higher ground level measurements previously discussed. The occassional above background measurements found in Region D of up to 30 μR/hr resulted from the gamma radiant field (shine) from radioactive materials buried in Region A.

In Region E, three isolated tracts had one meter level exposure rates greater than 200 μR/hr (up to 272 μR/hr). These tracts were associated with elevated ground level measurements.

In Region F, the elevated measurements in the north parking lot adjacent to Region E were the result of gamma radiation from the material in Region E. Exposure rates in the remainder of Region F followed closely those for the ground level measurements because of the large area of uniform radiation field. The readings were less than 50 μR/hr with several areas, particularly north of the office building, at background levels. The highest measurement found along the east wall of the office building was 106 μR/hr. One area in the driveway south of the office building had a reading of 157 μR/hr, where the asphalt was cracked.

Most of Region G had one meter exposure rates between 20 and 30 μR/hr. There were two tracts with readings at one meter elevations greater than

50 μR/hr, both associated with the grassy areas between the sidewalk and road curb. A maximum rate of 114 μR/hr was found in the area near the southern driveway. The second location was near the north parking lot with a maximum rate of 72 μR/hr.

Measurement of Region H, at one meter, reflected the L-shaped area identified in the ground level survey. Two locations had one meter level exposure rates of greater than 100 μR/hr, with a maximum of 123 μR/hr.

The property south of the W. R. Grace property (Region I) had one meter level measurements above 50 μR/hr limited to three locations: the loading dock (up to 89 μR/hr), the southeast corner of the storage barn (up to 54 μR/hr), and the east entrance way. The east entrance read up to 212 μR/hr over the 854 μR/hr ground level measurement.

Indoor Results

Ground level exposure rates (including background) measured inside the warehouse ranges from 12 to 89 μR/hr. The highest exposure rates were measured at the base of the north wall in the "CPG" wet room. All other ground level exposure rates in this room ranged from 21 to 40 μR/hr. Exposure rates in the furnace room ranged from 29 μR/hr in the open area to 55 μR/hr near the southwest corner of the room. A small room adjacent to the furnace room ranged from 29 to 55 μR/hr. The lunch room located on the upper level of the warehouse measured 29 μR/hr. A metal shop accessible from the lunch room had ground level exposure rates of 16 μR/hr. An entrance to the upper level of the warehouse near the metal shop had a maximum exposure rate of 39 μR/hr.

The interior of the storage barn located on the property south of W. R. Grace was also surveyed. Ground level exposure rates (including background) ranged from 11 to 318 μR/hr. High exposure rates were usually associated with broken areas in the concrete floor. Elevated exposure rates in the south room were confined to the southeastern corner where measurements ranged from 21 to 174 μR/hr. Measurements in the north end of the central room ranged from 20 to 318 μR/hr and the southern half of the central room ranged from 11 to 23 μR/hr. Ground level exposure rates in the north room were 20 to 74 μR/hr.

The interior and exterior of the office and bus maintenance building on the southern property were surveyed. The measurements were at background levels.

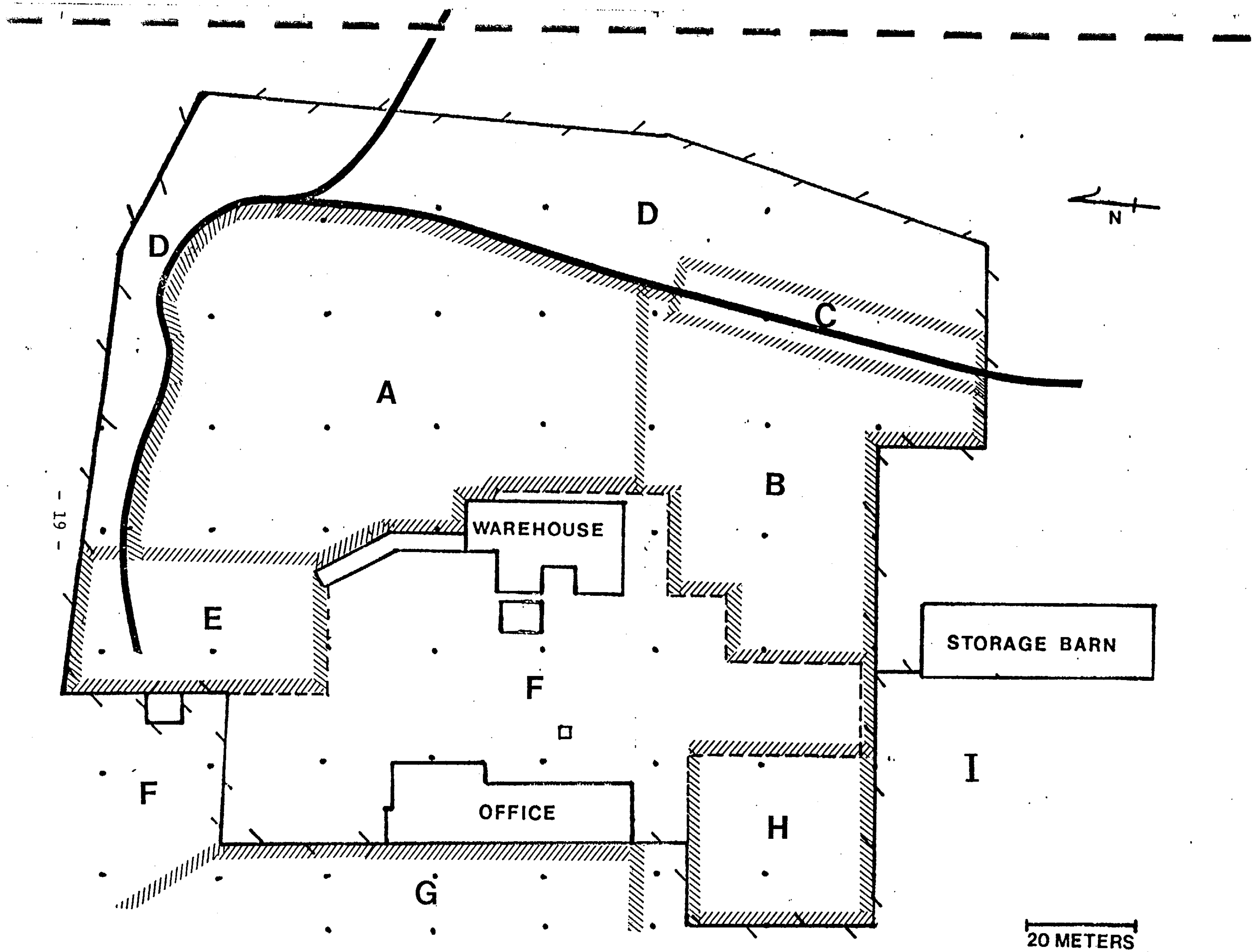


FIGURE 4: LOCATION OF DESCRIPTIVE REGIONS

D. SOIL SAMPLES

Sample Collection and Analyses

Surface soil samples were collected at the corners of the 20 x 20 meter grids. Bias samples were taken in areas not systematically sampled when field investigation indicated the need. Figure 7 identifies the soil sample locations.

Soil samples were collected with a garden trowel to a depth of 15 centimeters. Approximately 1000 grams of soil was taken per samples. Samples were bagged, sealed with tape and marked with location, date and instrument reading. At the laboratory, samples were dried for 24 hours at 105^{o} C and mechanically crushed in order to pass through a 10 mesh sieve. A 372 cc volume of sample was sealed in a cottage cheese container. A minimum of three weeks elapsed before counting to allow radionuclides to reach secular equilibrium.

Radium and thorium concentration were determined by gamma spectroscopy. Samples were counted for a minimum of 5000 seconds on a coaxial intrinsic germanium detector coupled to a multi-channel analyzer. Low activity samples were counted longer to obtain a confidence level of 95% in the results. Peaks were identified and quantified by computer analysis. The following radium and thorium related energy peaks were identified and concentration calculated for:

Ra-226	Th-232
352 keV (Pb-214 peak)	239 keV (Pb-212 peak)
609 keV (Bi-214 peak)	583 keV (Tl-208 peak)
	911 keV (Ac-228 peak)

Uranium concentration in soil samples were determined by delayed neutron counting, performed by Uranium-West Inc., for the NJ DEP. The technique involved neutron absorption by uranium-235 and analysis of the subsequent delayed neutron emitted. Uranium-238 concentrations were determined by calculation from the 0.7% abundance of uranium-235 in natural uranium.

Soil Sampling Results

Results of radionuclide concentration in soil samples are tabulated in Table 1. In the text, thorium refers to thorium-232 (Th-232), radium refers to radium-226 (Ra-226), and uranium refers to uranium-238 (U-238).

Analytical results of gamma spectroscopy of thorium-232 decay products (Tl-208, Pb-212 and Ac-228) showed no quantitative difference between individual daughters, indicating that the thorium decay products are in equilibrium. Hence, the Th-232 concentration is based on the Ac-228 (911 keV) peak. The same conclusion was reached for radium-226 and its decay products (Bi-214 and Pb-214). Unless otherwise noted, Ra-226 concentration is based on the Bi-214 (609 keV) peak. Soil results will be discussed according to the different regions indicated in Figure 4. A description of each region is found on page 12.

Thorium concentration in soil samples taken in Region A ranged from 10.9 $\pm$ 0.7 to 2008 $\pm$ 10 pCi/g, the highest concentration found in the soil study. Of the systematic samples, eight soil samples had concentrations under 100 pCi/g, two samples between 100 and 200 pCi/g, and three over 200 pCi/g. The highest thorium concentration was found in S-48, a bias surface soil sample. Samples from a core drilling (S-56 through S-58) ranged from 108 $\pm$ 2 to 77.0 $\pm$ 7.5 pCi/g in increasing depth. The concentration of radium was usually a magnitude lower than thorium concentration. The concentration of uranium was lower than thorium but was two to ten times higher than the radium. Two samples did not follow this trend; the radium concentration was only one-half of the thorium concentration and the uranium concentration was less than the radium. The two samples (S-22 and S-31) were within 20 meters of each other. These samples may indicate a disposal area for the more radium bearing portion of the processing waste streams.

In Region B, the concentration of thorium in soil ranged from 8.7 ± 0.8 to 389 ± 6 pCi/g. Systematic soil samples show concentration of thorium to be about 100 pCi/g in the center of Region B with perimeter samples taken along the ditches and fence less than 31.1 ± 1.2 pCi/g. Radium concentrations for these samples were a magnitude less than thorium concentration except for S-26, with nearly equivalent thorium and radium concentrations. The radium/uranium ratio varied but was within a factor of one-half to two.

Both sediment and soil samples taken in Region C fall into two distinct groups. Sediment samples (S-49, S-50, S-51, and S-34) taken in the drainage ditch had thorium concentrations less than 7.0 pCi/g with radium and uranium concentrations less than 1.8 pCi/g. Soil samples (S-52, S-53, S-54) taken on the banks of the drainage ditch had concentrations greater than sediment samples from the ditch which had equal ratio of radium to thorium concentrations and uranium to thorium concentrations at least an order of magnitude less. Concentration along the banks of the ditch ranged up to 395 ± 6 pCi/g thorium, 337 ± 3 pCi/g radium and 10.8 ± 0.10 pCi/g uranium. The difference in the thorium/radium/uranium ratios probably indicate a different composition of the process waste streams disposed in this particular area compared to other areas. Past records indicate ore tailings and yttrium and silica sludges were disposed in Region C (see Figure 1). Both silica sludges and ore tailings from the thorium/rare earth benefecation are waste residues in higher concentration of radium due to its removal in favor of thorium.

Both thorium and radium radionuclides measured in Region D had levels typical of background concentrations, less than 3.8 ± 0.1 and 2.0 ± 0.1 pCi/g respectively with the exception of S-25, with concentration of 18.5 ± 0.9 pCi/g thorium and 3.5 ± 0.4 pCi/g radium.

Region E had soil concentrations ranging from 1.5 ± 0.4 to 92.3 ± to 1.9 pCi/g for thorium, 0.7 ± 0.2 to 5.1 ± 0.5 pCi/g for radium and 0.18 to 21.1 pCi/g for uranium. The lower concentrations of thorium and radium were measured near the fences and higher in the central portion of this tract. The central portion of the tract (S-15 and S-16) had thorium/radium ratios similar to Region A.

No soil samples were taken in Region F due to the asphalt cover.

Thorium concentration in soil samples from Region G ranged from 6.1 ± 0.6 to 589 ± 5 pCi/g with the two highest concentrations (S-45 and S-46) found in bias soil samples from the strip between the curb and sidewalk. Radium concentration ranged from 1.0 ± 0.3 to 27.2 ± 1.5 pCi/g with the two highest concentrations corresponding to the samples with highest thorium concentrations. Exclusive of these two samples, the systematic soil samples had concentrations less than 23.4 pCi/g, 4.6 pCi/g, and 3.28 pCi/g for thorium, radium, and uranium, respectively.

The soil samples taken in Region H ranged from 2.9 ± 0.3 to 58.6 ± 1.5 pCi/g for thorium concentrations. The highest concentrations, 58.6 ± 1.5 pCi/g thorium, 6.1 ± 0.5 pCi/g radium, and 7.84 ± 0.19 pCi/g uranium were measured in sample S-12.

Soil samples were taken in Region I and inside the storage barn. The sample taken in the storage barn (S-59) had thorium concentration of 985 ± 11 pCi/g, radium of 108 ± 3 pCi/g and uranium of 107 ± 0.8 pCi/g. For a soil sample from the eastside of the storage barn entrance (S-60), 1721 ± 17 pCi/g of thorium, 51.2 ± 2.6 pCi/g of radium, and 93.6 ± 0.77 pCi/g of uranium were measured. A third sample (S-61) taken along the southeast corner of the barn measured 6.7 ± 0.6 pCi/g, 1.2 ± 0.2 pCi/g, and 1.13 ± 0.03 pCi/g for thorium, radium and uranium, respectively.

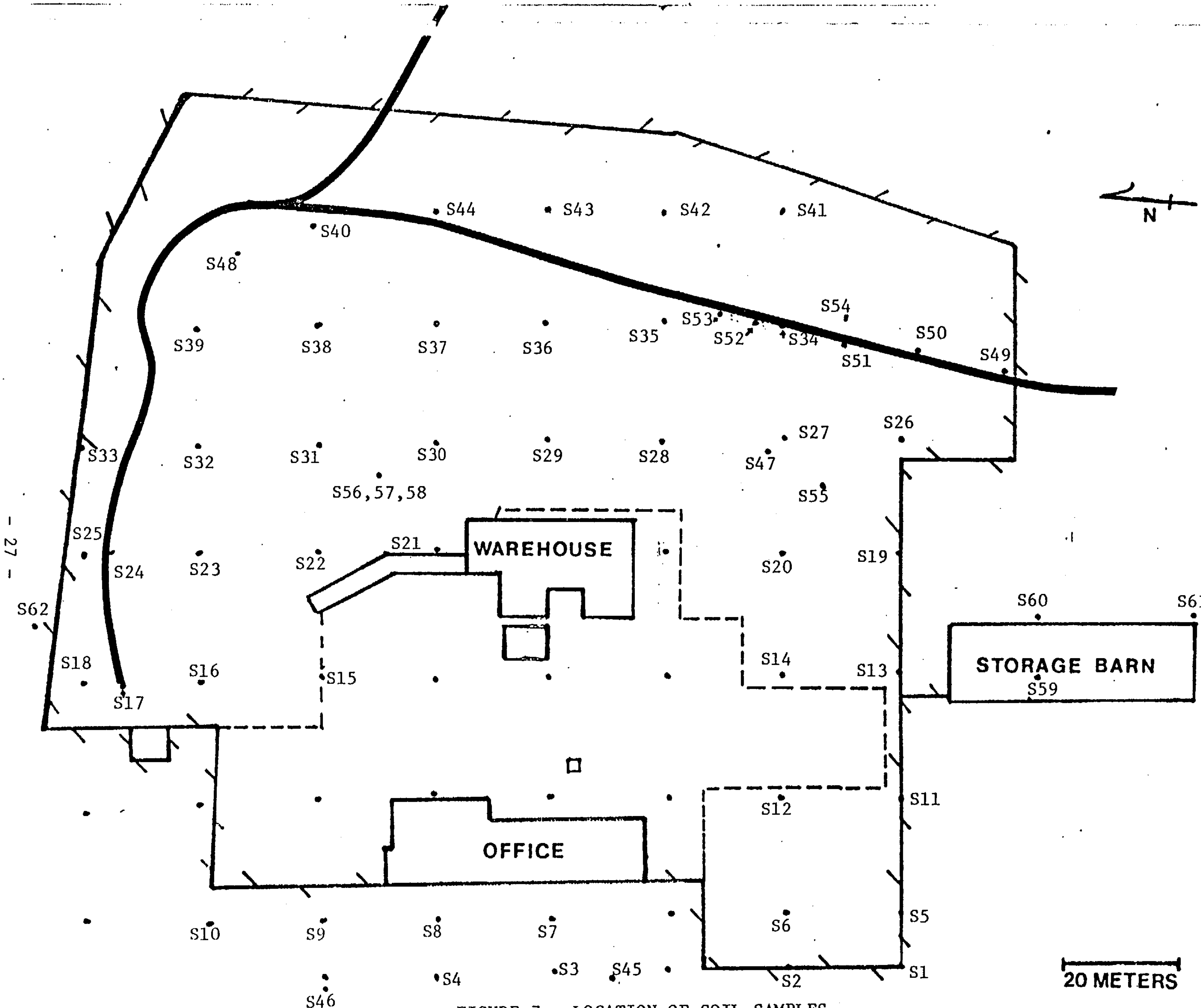


FIGURE 7: LOCATION OF SOIL SAMPLES

TABLE 1

RADIONUCLIDE CONCENTRATION IN SOIL SAMPLES
(Concentrations in pCi/g)

Sample No	Region	Th-232	Ra-226	U-238 (2)
S1	H	5.8 ± 0.6	1.9 ± 0.3	NA
S2	H	2.9 ± 0.3	1.1 ± 0.1	1.02 ± 0.03
S3	G	23.4 ± 1.0	4.6 ± 0.4	3.28 ± 0.12
S4	G	11.0 ± 1.0	1.5 ± 0.2	0.90 ± 0.08
S5	H	3.9 ± 0.6	1.8 ± 0.3	NA
S6	H	3.6 ± 0.5	0.9 ± 0.2	0.94 ± 0.08
S7	G	8.1 ± 0.7	1.0 ± 0.3	1.63 ± 0.10
S8	G	10.2 ± 0.2	1.5 ± 0.1	1.93 ± 0.10
S9	G	6.1 ± 0.6	1.0 ± 0.2	1.18 ± 0.03
S10	G	12.5 ± 0.8	1.4 ± 0.3	1.88 ± 0.03
S11	H	39.7 ± 1.3	6.6 ± 0.5	NA
S12	H	58.6 ± 1.5	6.1 ± 0.5	7.84 ± 0.19
S13	B	23.5 ± 1.1	2.5 ± 0.4	NA
S14	B	97.5 ± 2.2	9.8 ± 0.6	14.4 ± 0.25
S15	E	92.3 ± 1.9	5.1 ± 0.5	16.7 ± 0.30
S16	E	53.0 ± 1.3	1.9 ± 0.4	21.1 ± 0.32
S17	E	6.0 ± 0.5	1.1 ± 0.2	0.18 ± 0.01
S18	E	1.5 ± 0.4	0.7 ± 0.2 (1)	0.68 ± 0.06
S19	B	31.1 ± 1.2	4.9 ± 0.4	NA
S20	B	146 ± 3	11.9 ± 0.8	12.6 ± 0.25
S21	A	27.8 ± 0.9	1.6 ± 0.3 (1)	8.45 ± 0.20
S22	A	180 ± 3	66.5 ± 7.5	30.8 ± 0.39
S23	A	41.2 ± 1.3	3.9 ± 0.4	30.0 ± 0.62
S24	A	10.9 ± 0.7	1.9 ± 0.2	5.52 ± 0.05
S25	D	18.5 ± 0.9	3.5 ± 0.4	NA
S26	B	18.0 ± 1.0	15.7 ± 0.5	2.70 ± 0.05
S27	B	96.5 ± 2.5	8.4 ± 0.6	6.49 ± 0.06
S28	B	95.5 ± 2.3	7.4 ± 0.6	10.4 ± 0.07
S29	A	254 ± 3	23.7 ± 1.0	10.6 ± 0.22
S30	A	122 ± 2	12.0 ± 0.6	25.2 ± 0.35
S31	A	70.0 ± 2.2	31.6 ± 4.3	22.5 ± 0.36
S32	A	341 ± 5	15.5 ± 1.1	90.6 ± 0.25
S33	D	1.9 ± 0.4	0.8 ± 0.2	0.94 ± 0.08

TABLE 1 (continued)

Sample No.	Region	Th-232	Ra-226	U-238 (2)
S34	C	4.6 ± 0.5	1.4 ± 0.2	0.93 ± 0.07
S35	B	8.7 ± 0.8	5.8 ± 0.8	NA
S36	A	15.7 ± 0.3	2.4 ± 0.1	3.38 ± 0.12
S37	A	71.7 ± 0.3	2.4 ± 0.1	9.46 ± 0.07
S38	A	48.4 ± 1.3	1.9 ± 0.3	6.52 ± 0.06
S39	A	93.9 ± 2.2	2.8 ± 0.5	15.6 ± 0.28
S40	A	48.1 ± 1.4	2.3 ± 0.5	NA
S41	D	3.8 ± 0.5	1.6 ± 0.3	NA
S42	D	3.8 ± 0.1	1.8 ± 0.06	NA
S43	D	3.4 ± 0.2	2.0 ± 0.1	NA
S44	D	3.7 ± 0.3	1.6 ± 0.1	NA
S45	G	589 ± 5	27.2 ± 1.5	45.0 ± 0.45
S46	G	66.1 ± 1.5	4.8 ± 0.4	8.76 ± 0.23
S47	B	298 ± 4	39.8 ± 1.9	17.7 ± 0.27
S48	A	2008 ± 10	20.4 ± 2.6	166 ± 0.9
S49	C	1.7 ± 0.25	0.9 ± 0.2 (1)	0.69 ± 0.06
S50	C	3.7 ± 0.5	1.1 ± 0.2	1.42 ± 0.09
S51	C	5.8 ± 0.6	1.8 ± 0.4 (1)	1.75 ± 0.12
S52	C	395 ± 6	337 ± 3	10.8 ± 0.10
S53	C	124 ± 2	89.9 ± 1.2	5.78 ± 0.07
S54	C	58.8 ± 1.8	45.1 ± 0.9	4.66 ± 0.15
S55	B	389 ± 6	30.9 ± 1.3	54.3 ± 0.51
S56	A	108 ± 2	10.5 ± 0.7	57.9 ± 0.54
S57	A	80.7 ± 2.7	15.8 ± 0.7	50.0 ± 0.46
S58	A	77.0 ± 1.9	6.2 ± 0.5	25.8 ± 0.35
S59	I	985 ± 11	108 ± 3	107 ± 0.8
S60	I	1721 ± 17	51.2 ± 2.6	93.6 ± 0.77
S61	I	6.7 ± 0.6	1.2 ± 0.2	1.13 ± 0.03
S62	D	2.6 ± 0.2	1.6 ± 0.08	NA

Explanations

(1) Concentration based on Pb-214 peak (352 keV)
(2) Concentration determined by delayed neutron counting, assume natural ratio of uranium isotopes.

S1 thru S44: Surface samples at wood stakes
S45 thru S54: Surface samples taken at bias locations
S55 thru S58: Depth profile samples
S59 thru S62: Surface samples taken outside W.R. Grace property
NA - Not analyzed

TABLE 2

BACKGROUND SOIL SAMPLES
(Concentrations in pCi/g)

	Location	Th-232	Ra-226	U-238
1.	Pequannock, along Erie Lackawanna R.R. Tracks	2.2 ∓ 0.2	0.85 ± 0.06	
2.	Wayne - Soccer Field	1.2 ± 0.1	0.6 ± 0.05	
3.	Wayne - Pompton River Spillway	1.8 ± 0.1	0.7 ± 0.04	
4.	Literature(1)	0.31 to 1.5	0.24 to 1.4	0.13 to 1.4
5.	Literature(2)			
	Soil	0.2 to 1.3	0.3 to 1.4	0.3 to 1.4
	Rock (Shale)	1.2	1.2	1.2
6.	Literature(3) Chester, N.J.	2.50 ± 0.03	1.36 ± 0.02	1.36 ± 0.02

Explanations

(1) Source: My81

(2) Source: Un77

(3) Source: En78

E. WATER SAMPLES

Sample Collection and Analyses

Surface water grab samples were taken in the drainage ditch and Sheffield Brook. Samples were collected in one-gallon plastic containers, acidified, filtered and analyzed according to EPA procedures for drinking water. These samples were analyzed for gross alpha, gross beta, radium-226 and gamma emitting radionuclides.

Sample locations (Figure 8) included: the Sheffield Brook upstream of W. R. Grace, Sheffield Brook at the underground conduit, the drainage ditch, and the artesian well.

For gamma spectroscopy, 500-ml of acidified sample was placed in a marinelli container and analyzed on a coaxial intrinsic germanium detector coupled to a multi-channel analyzer.

Analyses for gross alpha, beta and radium-226 were performed on a low background proportional counter, after 500-ml aliquots of samples were filtered, evaporated, and dried.

A separate group of water samples were taken by the N.J. DEP's Division of Water Resources' Technical Support Branch at the request of the Bureau of Radiation Protection for analysis of 129 metals and priority pollutants. These samples were analyzed by the US EPA's Environmental Services Division in Edison, N.J.

Water Results

Radiological results for the surface water and artesian well water samples are contained in Table 3. All water samples indicate no gamma activity above background levels (minimum detectable activity = 50 pCi/l).

The highest gross alpha, gross beta, and radium-226 concentrations (6.82, ± 2.71, 17.34 ± 1.26 and 2.51 ± 0.17 pCi/l, respectively), were found in the drainage ditch (W4). The samples from Sheffield Brook upstream (W1) of the study area and the artesian well (W5) had concentrations less than samples from the drainage ditch (W4) and Sheffield Brook at the underground conduit (W2). The radiological concentrations of all samples meet the United States Environmental Protection Agency's (US EPA) and New Jersey Department of Environmental Protection's (NJ DEP) safe drinking water standards listed in Table 4.

Non-radiological results from the US EPA are contained in Table 5. Samples analyzed for metals and priority pollutants did not show any contaminants associated with thorium or rare earths processing activities. The trace quantities of metals present in the samples are probably from electronic component manufacturing as found in solder, solder flux or copper wiring. The mercury found in the sample W9A probably reflects its association with herbicides or pesticides used in agriculture. The presence of the two organics and the phthalates are widely associated with plastics (as piping, wire coating or sealed circuit boards).

Except for mercury found in W9A, all values for the metals and the organic compounds meet established drinking water standards or are within background environmental levels listed in table 6.

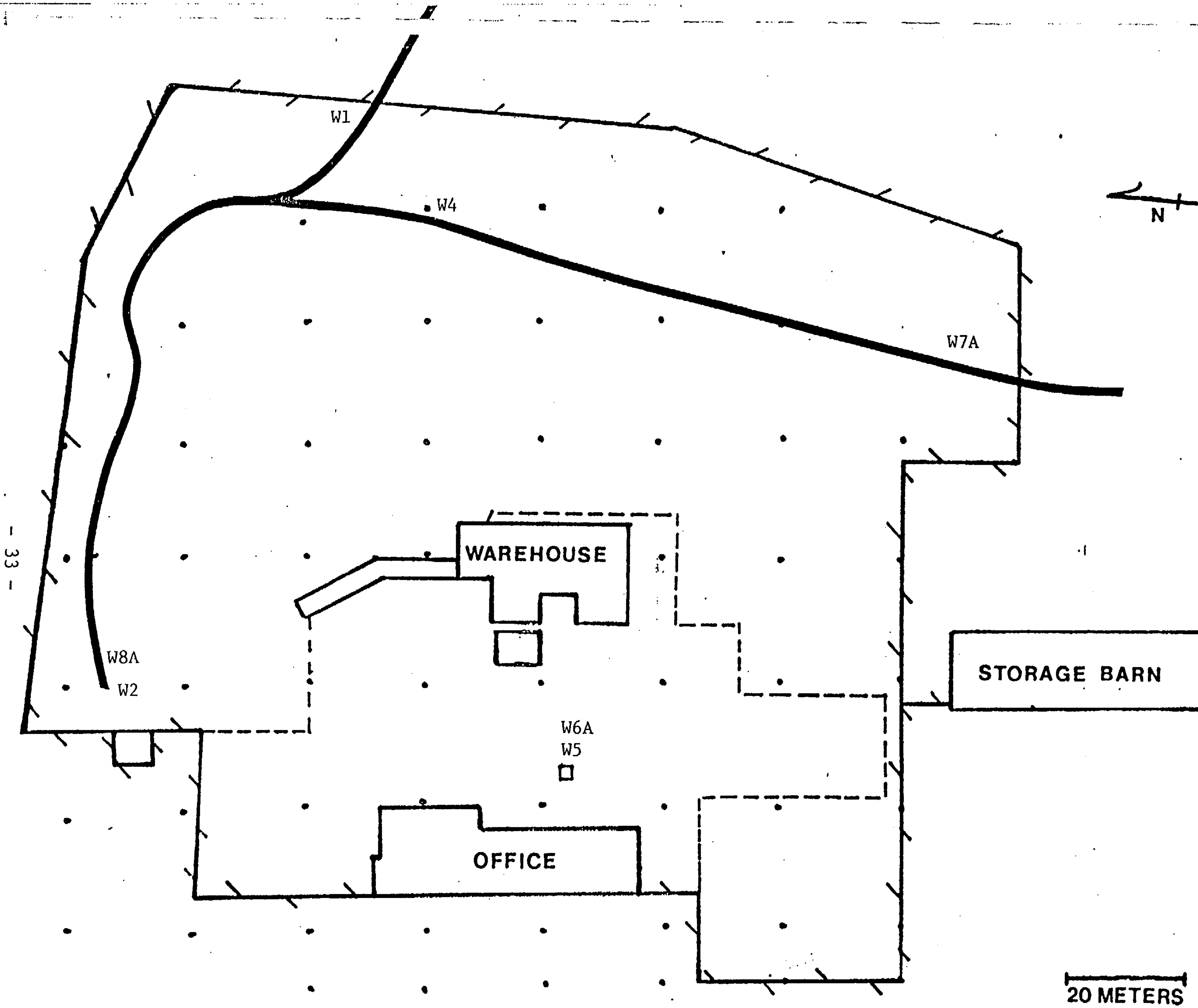


FIGURE 8: LOCATION OF WATER SAMPLES

W3 West 150 meters

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

(Concentration in pCi/l)

Sample No.		Gross Alpha	Gross Beta	Ra-226
W1	Sheffield Brook, East of W.R. Grace	0.68 ± 1.62	1.39 ± 0.67	NA
W2	Sheffield Brook at Underground Entrance	5.67 ± 2.61	4.01 ± 0.91	0.43 ± 0.10
W3	Sheffield Brook at Pompton Plains Cross Road	1.69 ± 1.86	6.84 ± 0.89	0.22 ± 0.10
W4	Drainage Ditch	6.82 ± 2.71	17.34 ± 1.26	2.51 ± 0.17
W5	Artesian Well	1.98 ± 1.55	2.86 ± 0.68	NA

Explanation

NA: Not Analyzed

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN DRINKING WATER

(Concentrations in pCi/l)

Potable Water Sources[2]	Gross Alpha	Gross Beta
Passaic Valley Water Commission	0.09 ± 0.30	2.48 ± 0.26
Pequannock Twp. Water Department	0.24 ± 0.52	(1)
Pompton Lakes MUA	0.85 ± 0.35	(1)
Riverdale Water Department	0.64 ± 0.40	(1)
Wayne Twp. Water Department	0.58 ± 0.43	(1)
Lincoln Park Water Utility	0.47 ± 0.36	(1)

USEPA/NJDEP Safe Drinking Water Standards (NJAC; 7:10-5.1 et seq.)

Gross Alpha	15 pCi/l
Gross Beta	50 pCi/l
Ra-226 and Ra-228	5 pCi/l

Explanation

(1) According to procedures for Safe Drinking Water, gross beta analysis is not required for water supplies serving less than 100,000 users.

(2) Source: Ra79

TABLE 5

METAL AND PRIORITY POLLUTANT CONCENTRATION IN WATER SAMPLES

(Concentrations in ug/l)

Substance	Artesian Well (W6A)	Drainage Ditch (W7A)	Conduit (W8A)	Pompton Plains Cross Road (W9A)
A. Metals				
Silver	<6.0	<6.0	<6.0	<6.0
Arsenic	<0.8	∿2.0	<0.8	<0.8
Beryllium	∿0.7	∿0.2	∿0.4	∿0.2
Cadmium	<3.0	<3.0	<3.0	<3.0
Chromium	<8.0	<6.0	<6.0	<6.0
Copper	<4.0	<2.0	<2.0	<2.0
Mercury	<0.2	<0.2	<0.2	3.91
Lead	<20.0	<20.0	<20.0	<20.0
Nickel	63.0	<10.0	<10.0	<10.0
Antimony	<30.0	<30.0	<30.0	<30.0
Selenium	<0.7	<0.7	<0.7	∿1.0
Thallium	<0.6	<0.6	<0.6	<0.6
Zinc	68.0	81.0	120.0	150.0
B. Priority Pollutants				
Di-N-Butylphthalate	<2.0	<2.0	<2.0	<2.0
Di-N-Ocytlphthalate	ND	ND	<2.0	ND
Methylene Chloride	ND	22.0	ND	ND
Chloroform	<2.0	ND	ND	ND

Explanation

ND - Not Detected

< - Actual value known to be less than value given

∿ - Estimated value

TABLE 6

BACKGROUND LEVELS AND STANDARDS FOR METAL AND PRIORITY POLLUTANTS

Substance	Background Environmental Levels (1) (in ug/l)	Safe Drinking Water Standards (in ug/l)
A. Metals		
Arsenic	<10	50 (2)
Beryllium	0.01-0.7	(5)
Cadmium	0.4-60	10 (2)
Chromium	3-40	50 (2)
Copper		1000 (3)
Mercury		2 (2)
Lead	<20	50 (2)
Nickel		(5)
Antimony		(5)
Selenium	<10	10 (2)
Silver	<2	50 (2)
Thallium		(5)
Zinc	60-7000	5000 (3)
B. Priority Pollutants		
Di-N-Butylphthalate		(5)
Di-N-Ocytlphthalate		(5)
Methylene Chloride		(5)
Chloroform		0.10 (4)

Explanations

(1) Source: St75

(2) Source: USEPA National Interim Primary Drinking Water Regulations (40CFR141.11)

(3) Source: NJDEP Safe Drinking Water Act Regulations (NJAC 7:10-7.26)

(4) Source: USEPA National Interim Primary Drinking Water Regulations (40CFR141.12c) Limit is for total trihalomethanes.

(5) No drinking water limits established.

F. RADON SAMPLES

Radon Sampling

Two sets of radon samples were taken in December 1982 in the study area at locations indicated in Figure 9. One set of measurements consisted of five grab samples, of which four were taken in locations where radium-226 was found in soil samples. Three of the samples were taken on the W. R. Grace property and the fourth inside the storage barn on the property south of the Grace property. The fifth grab sample was a background measurement taken on a residential property north of the study area not believed to be influenced by activities at W. R. Grace.

The grab samples were taken at one meter above ground on a cloudy day with no wind. Background for the individual cells were counted the previous day. Samples were allowed to reach secular equilibrium with radon before counting.

The second set of radon samples consisted of six activated carbon canisters placed in various locations inside the office building and the warehouse. Unlike the grab samples, this system provides longer term radon monitoring of 48 hours, hence averaging the diurnal variation in radon gas concentrations. The radon canisters were exposed for 48 hours, sealed, and shipped to the U.S. Department of Energy's Environmental Measurements Laboratory in New York, N.Y., for analysis. The samples were counted on a NaI(Tl) detector coupled with a multi-channel analyzer.

Radon Results

The radon results are summarized on Table 7. Concentration of radon gas, as indicated by grab sampling (R1, R2, R3, R4, R5), did not indicate any levels greater than background.

The radon concentrations, as indicated by 48-hour sampling, inside the two building on the W. R. Grace property were significantly different. Concentrations inside the office building were less than 1.0 pCi/l, with concentrations in the warehouse greater than 1.0 pCi/l. The highest concentration in the warehouse was measured in the lunchroom (R6) of 5.2 ± 0.8 pCi/l. Samples taken in the CPG wet room (R7) and the furnace room (R8) in the warehouse had lower radon concentrations of 2.0 ± 0.2 and 1.2 ± 0.2 pCi/l, respectively.

Radon concentration in air depends on diurnal and seasonal variations. Higher radon levels can be measured during the daylight hours and the summer season. Lower levels are found in evening hours and the winter season. Levels inside structures are usually higher than ambient air due to limited dispersion and exchange with outdoor air. Typical annual mean levels for outdoor and indoor air are 0.2 and 0.8 pCi/l, respectively, although the indoor means varies quite widely (Ge80). For comparison, Table 8 contains standards and background levels for Rn-222.

The concentrations of the three outdoor samples (R2, R3, R4) and the storage barn (R1) indicate background levels of radon in outdoor air. The samples taken inside the office building (R9, R10, R11) were consistent with background values for indoor air. Both groups of measurements met State and NRC guidelines for radon concentration in air. Although the radon concentration in the CPG wet room (R7) and the furnace room (R8) exceeded State guidelines, they met NRC guidelines and were within the range of literature values.

The sample taken in the lunchroom (R6) exceeded normal background levels, and Federal and State standards. The lunchroom is located in the middle of a work area and used by approximately a dozen people. This area is occupied only during business hours (40 hours/week).

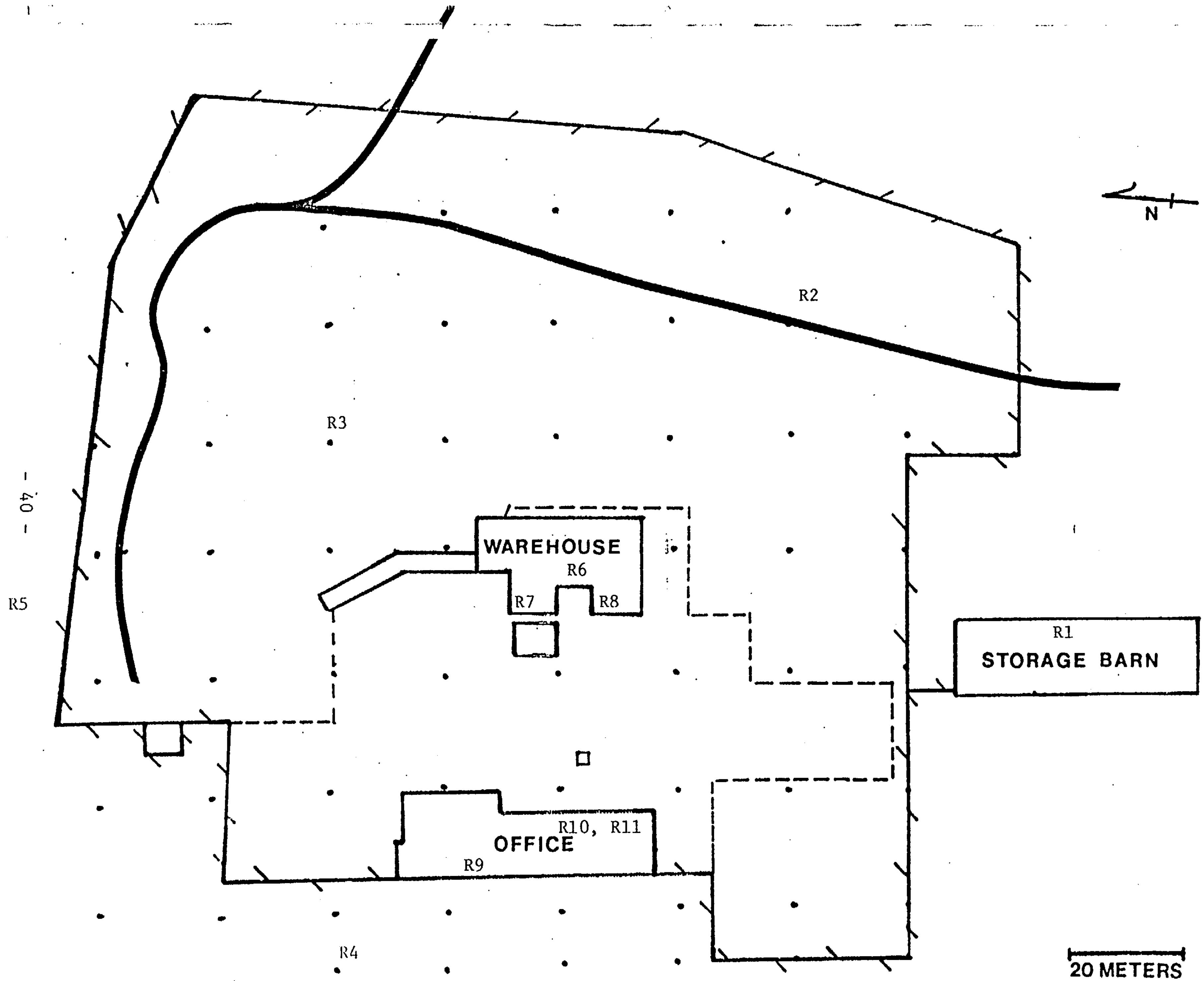


FIGURE 9: LOCATION OF RADON SAMPLES

TABLE 7

RADON RESULTS

Sample Number	Location	pCi/l ± 2σ
R1	Storage Barn	<0.5
R2	Region C (Drainage Ditch)	<0.5
R3	Region A (open field)	<0.5
R4	Region G (sidewalk)	<0.5
R5	Residential Property (background)	<0.5
R6	Warehouse, Lunch Room	5.2 ± 0.8
R7	Warehouse, CPG Wet Room	2.0 ± 0.3
R8	Warehouse, Furnace Room	1.2 ± 0.2
R9	Office, Downstairs	0.8 ± 0.1
R10	Office, Reception Room	0.8 ± 0.1
R11	Office, Reception Room	0.6 ± 0.1

Notes:

(1) R1 thru R5 were grab samples.

R6 thru R11 were activated carbon canisters measured over a 48-hour period.

TABLE 8

BACKGROUND RADON CONCENTRATIONS AND STANDARDS

Values Cited in Literature

1. UNSCEAR, outdoor	0.1 pCi/l
2. Environmental Measurement Laboratory Regional Baseline Station, Chester, New Jersey, outdoor	
Range of Hourly Measurements	0.01 pCi/l to 2.6 pCi/l
Range of Yearly Averages (Arithmetic Mean)	0.19 pCi/l to 0.24 pCi/l
3. Radon Distribution in New Jersey and New York, indoor (1)	
Annual (geometric mean)	0.83 pCi/l
Range of Annual Mean	0.20 pCi/l to 3.1 pCi/l
4. Radon Measurements in New Jersey, New York, Pa., indoor (2)	
Annual (geometric mean)	0.72 pCi/l
Range of Annual Mean	0.32 pCi/l to 4.5 pCi/l

Standards

NRC	10 CFR 20.106	3.0 pCi/l
NJ	NJAC;7:28-6.5	1.0 pCi/l

Explanation

(1) Ge80

(2) Ge83

G. SUMMARY

The purpose of the radiological survey of the W. R. Grace property was to define the extent of radiological contamination identified in the aerial survey of Wayne, New Jersey. The survey involved taking field measurements of direct radiation, and samples of soil, water and air for radiological analysis.

Generally, the topography of the study area is an urban environment consisting of woods, field, asphalt, concrete, and landscaped lawns. Only one section of the lawn and the north parking lot are not included in the fenced portion of the facility.

Measurements of direct gamma radiation show that above background exposure rates are highest in the open field east of the warehouse (Regions A, B, and E). The ground level exposure rates ranged from 10 to 1692 μR/hr and one meter rates ranged from 10 to 854 μR/hr. In areas outside the fence, (portion of Regions F, G, and I), ground level exposure rates ranged from 10 to 854 μR/hr and one meter exposure rates varied from 10 to 216 μR/hr. Field observations and the high variability in measurements indicate there is shallow to near non-existent overburden in some areas of Regions A and B.

Exposure rates inside the office building were background levels. Average exposure rates inside the warehouse were up to three times background. Near walls and corners, exposure rates were higher, up to 89 μR/hr including background. These structures are used in an occupational manner (2000 hrs/yr), hence a dose of up to 40 mrem/year above background can be calculated.

Exposure rates inside the storage barn ranged from 11 to 318 μR/hr including background. The barn is locked and used to store spare school bus tires.

Gamma spectroscopic analyses show that the significant radionuclides present in soil samples were related to thorium and uranium decay chains. The results showed thorium-232 and radium-226 in soil samples taken in the fenced area ranged from 1.7 to 2008 pCi/g for thorium and from 0.8 to 337 pCi/g for radium. Unfenced areas had a thorium range from 2.6 to 1721 pCi/g and radium from 1.2 to 108 pCi/g. Uranium analyses by delayed neutron counting technique showed uranium-238 concentration ranged from 0.18 to 166 pCi/g in the fenced areas and 0.90 to 107 pCi/g in the unfenced area.

Results of surface water samples indicated the presence of alpha and gross beta activity, but no gamma activity. Analysis for metals and priority pollutants did not show any contamination from activities associated with thorium/rare earth processing. Groundwater samples from wells on and off-site showed no radioactive contamination.

The results of radon analysis showed concentrations taken outdoors, inside the office building and storage barn to be within the range of background levels for New Jersey. Concentations inside the warehouse ranged from 1.2 to 5.2 pCi/l. An estimate of lifetime risk from environmental exposure to radon-222 and its progeny of 1 Working Level Month per year (1WLM/yr) to the lung corresponds to the risk about 500 mrem/yr whole body (Ev81). Assuming 50% equilibrium for progeny to parent, an annual exposure rate to 1 WLM is equivalent to exposure to 4 pCi/l for 8760 hrs/yr (continuous) or 17.5 pCi/l for 2000 hrs/yr (occupational). For the highest measured radon concentration of 5.2 pCi/l, the whole body dose equivalent of about 150 mrem/yr can be calculated.

Federal and State Radiation Standards

Federal regulations to control the use of radioactive materials licensed by the U. S. Nuclear Regulatory Commission are contained in 10 CFR 20. State regulations on the use of radioactive materials licensed by the N.J.

Department of Environmental Protection are contained in NJAC 7:28. Both federal and state regulations contain provisions for release of radioactive materials to air and water, disposal on the licensee's property and disposal at a disposal site. Concerning permissible releases of radioactivity in unrestricted areas, concentrations in air and water for radium-226 and thorium-232 are identical in federal and state regulations. Concentrations for radon-222 are 3.0 pCi/l and 1.0 pCi/l for federal and state regulations, respectively. Concerning onsite disposal, state regulations require prior written approval from N.J. DEP. Prior to January 28, 1981, federal regulations permitted onsite disposal of small quantities of licensed material provided burial is at a minimum depth of four feet, successive burials are separated by at least six feet and not more than 12 burials in any year, and each burial not exceed specified quantities. Current federal regulations (45 FR71761) do not permit onsite burial without prior approval by the NRC.

Both federal and state radiation regulations limit radiation dose for an individual member of the general public to 500 mrem/yr. Federal guidance provides an additional restriction of 170 mrem/yr for a defined segment of the population. There has been additional work done to establish standards for unrestricted use where there is no or little directly attributable benefit as in the case of terminated facilities, residual contamination, or remedial actions. The objective of these standards is to limit whole body equivalent dose to 10 mrem/yr or less.

Under the Uranium Mill Tailing Radiation Control Act (UMTRCA), the U.S. Environmental Protection Agency established standards for remedial action at inactive uranium mill sites. The final UMTRCA standards are 5 pCi/g above background for radium-226 for the first 15 centimeters of surface, 20 μR/hr above background for indoor gamma radiation exposure and a goal of 0.02 WL, but not to exceed 0.03 WL including background for radon progeny in structures (48FR590, January 5, 1983). The limit of 5 pCi/g radium in soil concentration would limit external exposure rate to 10 μR/hr.

Prior to the issuance of the UMTRCA standards by EPA, the U.S. Department of Energy with the New Jersey Department of Environmental Protection developed criteria for use at DOE remedial action projects in New Jersey. These criteria are 5 pCi/g above background for radium-226 and 40 pCi/g above background for uranium-238 not in equilibrium with its progeny.

In 1981, the U.S. Nuclear Regulatory Commission developed a technical position paper for residual thorium or uranium wastes from past processing facilities (46FR52061, October 23, 1981). The criteria presented varied according to associated land use restriction. The disposal criteria ranged from 5 pCi/g for thorium-232 in equilibrium with all its progeny for unrestricted use to 250 pCi/g for restricted use. Concentrations exceeding 250 pCi/g should be stored under license pending disposal in a facility licensed for disposal.

Under the Safe Drinking Water Act, the U.S. Environmental Protection gency established radiological standards for potable water. These standards, subsequently adopted by the State of New Jersey, provided a limit of 4 mrem/yr for water at the consumer tap. These drinking water standards were not established for untreated potable or nonpotable water sources, but they are the most stringent water standards promulgated to date. For comparison, the U.S. EPA/N.J. DEP drinking water limits are 15 pCi/l for gross alpha, 50 pCi/l for gross beta, and 5 pCi/l for radium-226 and radium-228.

Comparison of Surveyed Area to Radiological Standards

With respect to human exposure, a comparison of the study area's radiological condition and current property use to the radiological standards show that it is unlikely that an individual would receive a whole body dose that exceeds the radiological standard of 500 mrem/year. Workers in the warehouse could receive doses up to 200 mrem/yr (including radon-222 and external gamma exposures). Property use can change in the future (the site was released for unrestricted use by the NRC in 1975) which may cause individuals to receive doses greater than 500 mrem/yr.

A comparison of the area's radiological condition to the more conservative environmental standards of 10 µR/hr above background for external exposure rate and 5 pCi/g above background for thorium-232 shows that 15,000 m^2 of area on the W. R. Grace property (60% of the property) and 2,000 m^2 on the south property (Area I) along the fence would not meet these standards. In fact, most soil samples from Areas A, B, C, G and I exceed proposed NRC technical position for continued licensing (greater than 250 pCi/g thorium-232).

The results of all water samples taken during the survey meet standards for gross alpha, gross beta and radium-226. Analysis of water samples for metals and priority pollutants did not reveal any contaminants associated with thorium/rare earth processing.

Air sampling show radon-222 concentration outdoors and in the office building to be within the background levels for New Jersey. Radon measured inside the warehouse had concentrations greater than New Jersey's standard of 1.0 pCi/l. One sample from the warehouse lunchroom exceeded NRC's criteria of 3.0 pCi/l. The elevated radon levels are due to infiltration of radon gas from radium contaminated material surrounding the warehouse.

With respect to the radiological condition of the site, the presence of elevated radioactivity in the drainage ditch (sample W4) and the numerous surface soil samples in areas A, B, C and E with high radionuclide concentrations indicate shallow overburden covering the waste disposal areas. The current surveys are inconsistent with the 1974 decommissiong efforts to reduce exposure rates to below 200 μR/hr. The short period of time between the decommissioning at the facility and the current surveys (1975-1982) tends to place the cause of the shallow overburden not on weathering but on original soil cover for the waste pits. The clean overburden covering the waste pits does not meet the requirement that burial be at a minimum depth of four feet as stated in AEC regulations (10 CFR 20.304, June 1, 1974) at the time of decommissioning.

Although grass and a few small trees are growing on the burial areas, the sloped topography and the proximity of running surface water to the buried wastes would tend to increase erosion processes. Once the overburden erodes away, further weathering could permit the movement of radionuclides.

With respect to the potential for subsurface migration, because the movement of ground water near the burial areas is towards the surface, contamination of deep ground water strata is unlikely. Measurements for radioactivity in several water samples from either surface or groundwater sources on and offsite (Ra82) indicate that the groundwater around the burial pits is presently not contaminated. Samples taken by ORAU from the storm sewer under Black Oak Ridge Road had elevated gross alpha concentrations (Fr82), but the source of contamination is probably due to the extension of the drainage ditch into the storm sewer system and not groundwater infiltration. The results for well water samples indicate there is currently no groundwater contamination around the burial areas, but conditions do exist where problems could develop in the future. The rapid permability of water in both soil groups in the study area creates a potential for groundwater contamination. More information on site specific subsoil profile and groundwater movement in the burial area can be obtained by establishing an onsite groundwater monitoring system. This would enable a clearer evaluation of the subsurface hydrogeology.

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I. APPENDIX

EQUIPMENT USED

1. Eberline NaI(Tl) scintillation probe (SPA-3 Model) or Victoreen (Model 489-55) NaI(Tl) scintillation probe with Victoreen Thyac III (Model 490) Portable Survey Meter

2. Reuter Stokes Pressurized Ionization Chamber (Model RSS-111)

3. EDA Portable Radon Detector (RD-200) Zn(Ag) Scintillator coupled to high gain photomultiplier and scaler (33% efficiency)

4. Canberra Series 85 multichannel analyzer with coaxial instrinsic germainium detector (relative efficiency 14%)

5. Low background proportion counter (Gross Alpha, Gross Beta, Ra-226)
   a. Tennelec LB-5110
   b. Beckman Low Beta I & II

6. Activated carbon canister, passive radon collectors from U.S. DOE's Environmental Measurement Laboratory

CALIBRATION OF SURVEY EQUIPMENT

1. Gamma Scintillation -

   The NaI(Tl) scintillimeter was calibrated by the manufacturer in December 1981. In field calibration of NaI(Tl) scintillation probes at ground level and one meter with a pressurized ionization chamber (PIC) by comparing the instantaneous count rate (counts per minute) to the exposure rate (microroengtens per hour) at several locations in the study area. PIC was calibrated at the DOE's Environmental Measurements Laboratory.

2. Soil and Sediment Samples -

   The Canberra Series 85 MCA (multi-channel analyzer) with a coaxial instrinsic germanium detector was calibrated using an eleven point standard purchased from Amersham. Standards were counted in the same geometry as the soil and sediment samples. Amersham standards are traceable to the U.S. National Bureau of Standards (NBS).

3. Water Samples -

   a. gamma spectroscopy - An eleven point NBS traceable standard was used in a 500 ml Marinelli beaker and calibrated on the Canberra Series 85 MCA.

   b. gross alpha/beta and radium-226 - Counters were calibrated with NBS traceable standards. The New Jersey Radiation Laboratory uses procedures approved by EPA and participates in EPA's quality assurance program.

4. Radon-222 -

   The EDA Instruments' portable radon detector (RD-200) was calibrated at DOE's Environmental Measutrements Laboratory. Periodic checks with the manufacturer's check source are performed.

RADIOACTIVE DECAY PROPERTIES OF THE ^{40}K AND THE ^{232}Th SERIES (Un77)

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities: α	β	γ
^{40}K		1.26 10^9 y	–	1.32 (89%)	1.46 (11%)
10.7% → ^{40}Ar; 89.3% → ^{40}Ca					
^{40}Ar, ^{40}Ca		Stable	–		
$^{232}_{90}$Th	Thorium	1.41 10^{10} y	3.95 (24%) 4.01 (76%)	–	–
$^{228}_{88}$Ra	Mesothorium I	5.8 y	–	0.055 (100%)	–
$^{228}_{89}$Ac	Mesothorium II	6.13 h	–	1.18 (35%) 1.75 (12%) 2.09 (12%)	0.34 (15%) 0.908 (25%) 0.96 (20%)
$^{228}_{90}$Th	Radiothorium	1.910 y	5.34 (28%) 5.43 (71%)	–	0.084 (1.6%) 0.214 (0.3%)
$^{224}_{88}$Ra	Thorium X	3.64 d	5.45 (6%) 5.68 (94%)	–	0.241 (3.7%)
$^{220}_{86}$Rn	Emanation Thoron (Tn)	55 s	6.29 (100%)	–	0.55 (0.07%)
$^{216}_{84}$Po	Thorium A	0.15 s	6.78 (100%)	–	–
$^{212}_{82}$Pb	Thorium B	10.64 h	–	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
$^{212}_{83}$Bi	Thorium C	60.6 min	6.05 (25%) 6.09 (10%)	1.55 (5%) 2.26 (55%)	0.040 (2%) 0.727 (7%) 1.620 (1.8%)
64.0% → $^{212}_{84}$Po; 36.0% → $^{208}_{81}$Tl					
$^{212}_{84}$Po	Thorium C′	304 ns	8.78 (100%)	–	–
$^{208}_{81}$Tl	Thorium C″	3.10 min	–	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)
$^{208}_{82}$Pb	Thorium D	Stable	–	–	–

RADIOACTIVE DECAY PROPERTIES OF THE ^{238}U SERIES (Un77)

Nuclide	*Historical name*	*Half-life*	*Major radiation energies (MeV) and intensities* α	β	γ
$^{238}_{92}$U	Uranium I	4.51 10^9 y	4.15 (25%) 4.20 (75%)	–	–
$^{234}_{90}$Th	Uranium X$_1$	24.1 d	–	0.103 (21%) 0.193 (79%)	0.063 (3.5%) 0.093 (4%)
$^{234m}_{91}$Pa 99.87% | 0.13%	Uranium X$_2$	1.17 min	–	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
$^{234}_{91}$Pa	Uranium Z	6.75 h	–	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}$U	Uranium II	2.47 10^5 y	4.72 (28%) 4.77 (72%)	–	0.053 (0.2%)
$^{230}_{90}$Th	Ionium	8.0 10^4 y	4.62 (24%) 4.68 (76%)	–	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}$Ra	Radium	1602 y	4.60 (6%) 4.78 (95%)	–	0.186 (4%)
$^{222}_{86}$Rn	Emanation Radon (Rn)	3.823 d	5.49 (100%)	–	0.510 (0.07%)
$^{218}_{84}$Po 99.98% | 0.02%	Radium A	3.05 min	6.00 (~100%)	0.33 (~0.019%)	–
$^{214}_{82}$Pb	Radium B	26.8 min	–	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}$At	Astatine	~2 s	6.65 (6%) 6.70 (94%)	? (~0.1%)	–
$^{214}_{83}$Bi 99.98% | 0.02%	Radium C	19.7 min	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
$^{214}_{84}$Po	Radium C′	164 μs	7.69 (100%)	–	0.799 (0.014%)
$^{210}_{81}$Tl	Radium C″	1.3 min	–	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{210}_{82}$Pb	Radium D	21 y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{210}_{83}$Bi ~100% | .00013%	Radium E	5.01 d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	–
$^{210}_{84}$Po	Radium F	138.4 d	5.305 (100%)	–	0.803 (0.0011%)
$^{206}_{81}$Tl	Radium E″	4.19 min	–	1.571 (100%)	–
$^{206}_{82}$Pb	Radium G	Stable	–	–	–

State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
JOHN FITCH PLAZA. CN 027. TRENTON. N. J. 08625

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Monazite Unloading Area, Pompton Plains, Railroad Spur (Pompton Plains, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the Pompton Plains railroad spur. The ground contamination is the result of unloading monazite ore which was destined for the processing plant in Wayne, New Jersey.

A comparison of the area's radiological condition and current property use to the radiological standards for the general public, show that it is unlikely that an individual would be exposed to radiation levels that exceed existing federal and state radiation standards. However, current property use can change which could result in individuals receiving radiation doses above these standards, therefore, an evaluation of the surveyed area should be based on more stringent environmental standards.

A comparison of the area's radiological condition to the most conservative environmental standards indicates that future remedial actions should be performed for approximately 2,000 square feet of the railroad spur.

Sincerely,

Steven G. Kuhrtz
Director

ITEM # 292

B/290

89

RADIOLOGICAL SURVEY

OF A

MONAZITE UNLOADING AREA

POMPTON PLAINS RAILROAD SPUR
(POMPTON PLAINS, N.J)

NEW JERSEY STATE DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
BUREAU OF RADIATION PROTECTION

RADIOLOGICAL SURVEY
OF A
MONAZITE UNLOADING AREA

POMPTON PLAINS RAILROAD SPUR
(POMPTON PLAINS, N.J.)

APRIL 1983

Site Decontamination Assessment Section
Bureau of Radiation Protection
New Jersey Department of Environmental Protection

Members of the Bureau of Radiation Protection who participated in this study:

Jeanette Eng
Joseph Morris
Frederick Rauch
Kent Tosch
Duncan White

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A. INTRODUCTION

History

In 1948, Rare Earths Inc. began its operation at the Wayne, New Jersey site to extract thorium and rare earth from monazite ore. With the passage of the federal Atomic Energy Act in 1954, Rare Earths Inc. received an AEC (Atomic Energy Commission) license in 1954 to possess monazite ore.

Most of the monazite handled by Rare Earths/W. R. Grace were from domestic and foreign sources. Alluvial monazite sands containing typically 60% rare earth oxides and 3-10% thorium oxide were processed at this site. Monazite sand, used in processing at W. R. Grace in Wayne, N.J., was transported and unloaded from rail cars along the Erie Lackawana Railroad north of the Pompton Plains train station, Figure 1.

In 1971, W. R. Grace ceased processing monazite ore and amended its AEC license for storage only. When processing ended, transportation of the monazite ore terminated.

In 1980, the New Jersey Department of Environmental Protection requested that an aerial survey be performed over the W. R. Grace facility in Wayne, N.J. The request was initiated by DEP to determine the radiological condition for former radiation facilities. Two aerial surveys, completed in November 1981 and September 1982, conducted by EG&G indicated elevated radiation levels at the plant site and adjacent areas west of the plant. Neither aerial survey indicated elevated radiation levels near the Pompton Plains train station. However, a radiological survey by the Pequannock Health Department, in response to public information, identified some elevated radiation levels near the defunct rail road spur where monazite sand was unloaded. The U.S. Nuclear Regulatory

Commission's preliminary field survey verified that elevated radiation levels did exist along the railroad spur in Pompton Plains. Radiological surveys of this area was performed in August 1982, by the Oak Ridge Associated University (ORAU) for the U.S. Nuclear Regulatory Commission and by the Bureau of Radiation Protection for the New Jersey Department of Environmental Protection (N.J. DEP).

N.J. DEP Radiological Survey

The radiological survey by DEP covered:

a. Measurement of gamma radiation with field instruments along the railroad tracks to the north of the Pompton Plains train station

b. Measurement of radionuclide concentrations in soil samples. (Bias and background samples only)

This report represents the findings of the Pompton Plains railroad spur survey. The final section of the report will compare the radiological data with radiological standards.

AERIAL MAP

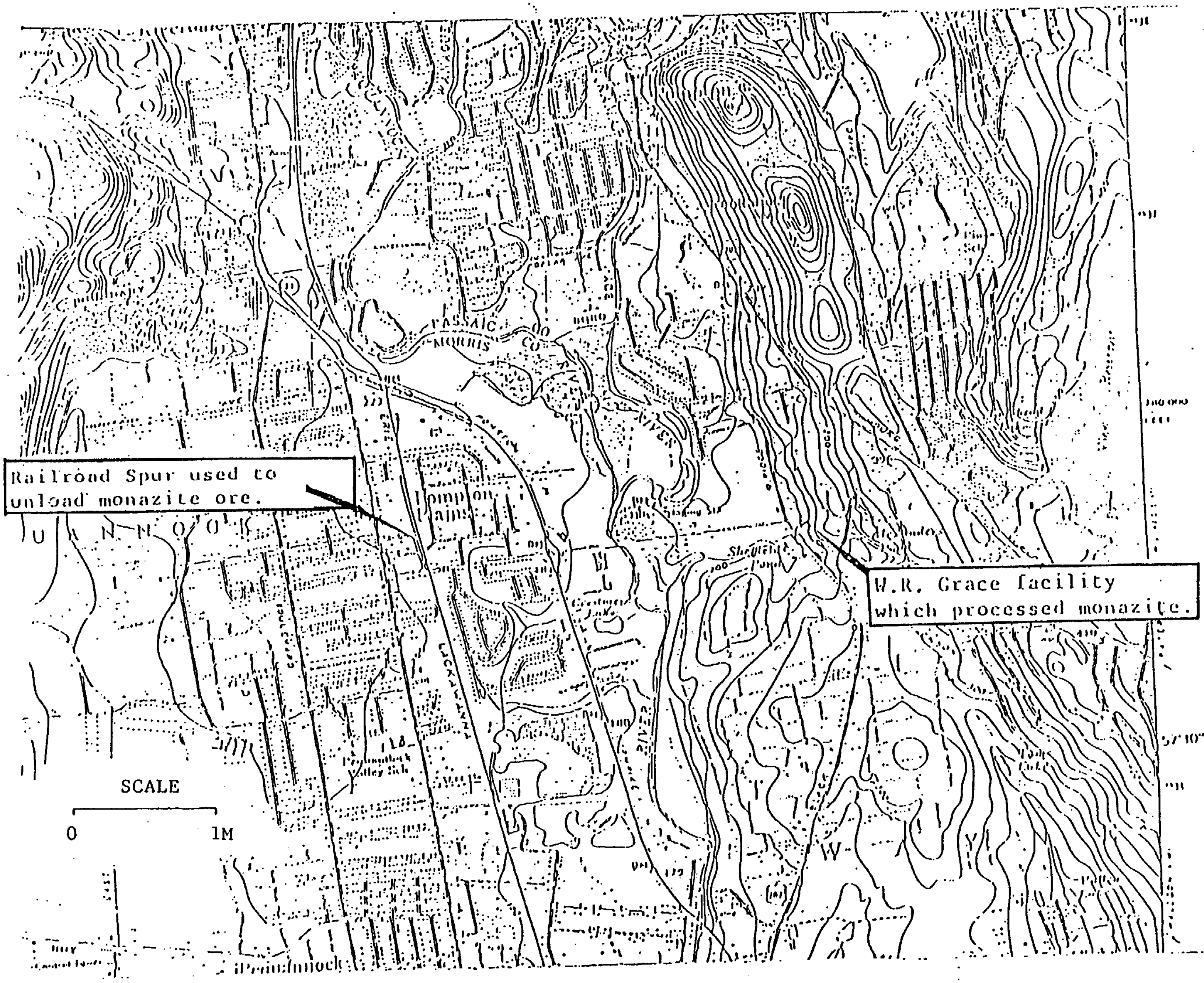

Figure 1: Relative Location Of Monazite Processing Facility In Wayne Township ... Ore in Pompton Plains.

B. SITE DESCRIPTION

The Pompton Plains train station in Morris County is located approximately 1.2 miles west of the W. R. Grace site in Wayne. The area is zoned for commercial and residential use, with the Erie Lackawanna Railroad running in a north-south orientation. The location of the contamination is two hundred feet north of the railroad station, where Peck Avenue runs into the unused portion of the railroad spur. Much of the spur is overgrown with small shrubs and a foot path runs along the spur's western enbankment. To the north of Peck Ave. and more than 600 feet west of the railroad spur is the nearest residence. While the closest commercial property to the contaminated area is an electrical substation to the south of Peck Avenue (refer to Figure 2).

C. FIELD MEASUREMENTS OF GAMMA RADIATION LEVELS

Field Survey

A surface gamma radiation survey was performed along the Pompton Plains railroad spur and Erie Lackawanna mainline to determine the extent of the radiation contamination identified by the Pequannock Health Department. Over 33,000 square feet of area north of the Pompton Plains train station was surveyed with a sodium iodide (NaI(Tl)) scintillometer.

The initial survey isolated pockets of contamination to a 2000 $feet^2$ area near Peck Ave. To further define the contaminated area, a radiological field survey based on a grid system (Figure 2) was performed. The zero reference point, location (0,0), was set at the northwestern fence post of the electrical substation. Positive distances ran in a northerly direction, while negative distances ran in an easterly direction. All distances were set in feet. Note: An isolated 1 $foot^2$ area of contaminated material was discovered 100 feet south of the grid area.

Ground and three-foot gamma level measurements taken with a scintillometer were recorded in counts per minute (cpm). The scintillometer was field calibrated over a range of gamma radiation fields against a pressurized ionization chamber (PIC).

Field Survey Results

All ground level and three-foot readings are illustrated in Figures 3 and 4, and tabulated in Tables 1 and 2, respectively.

Ground level exposure rates ranged from 10 to 404 μR/hr. Three-foot level exposure rates ranged from 10 to 174 μR/hr. The hightest radiation levels, greater than 100 μR/hr were found along the western edge of the unused railroad spur for a distance of 50 feet north of Peck Avenue. Those contaminated areas were generally confined to a three-foot band. Gamma radiation levels within 20 feet of the isolated spots decreased rapidly to 50 to 100 μR/hr at ground level and 30 to 60 μR/hr at three-foot level.

Traces of the radioactive material was evident near shrubbery which borders the residential property. These levels ranged from 20 to 50 μR/hr at ground level and 15 to 30 μR/hr at three-foot. Background levels were found to the west, beyond the shrubbery.

An isolated 1 m^2 hot spot located 100 feet south of the grid system read 182 μR/hr at ground level and 92 μR/hr at three-foot.

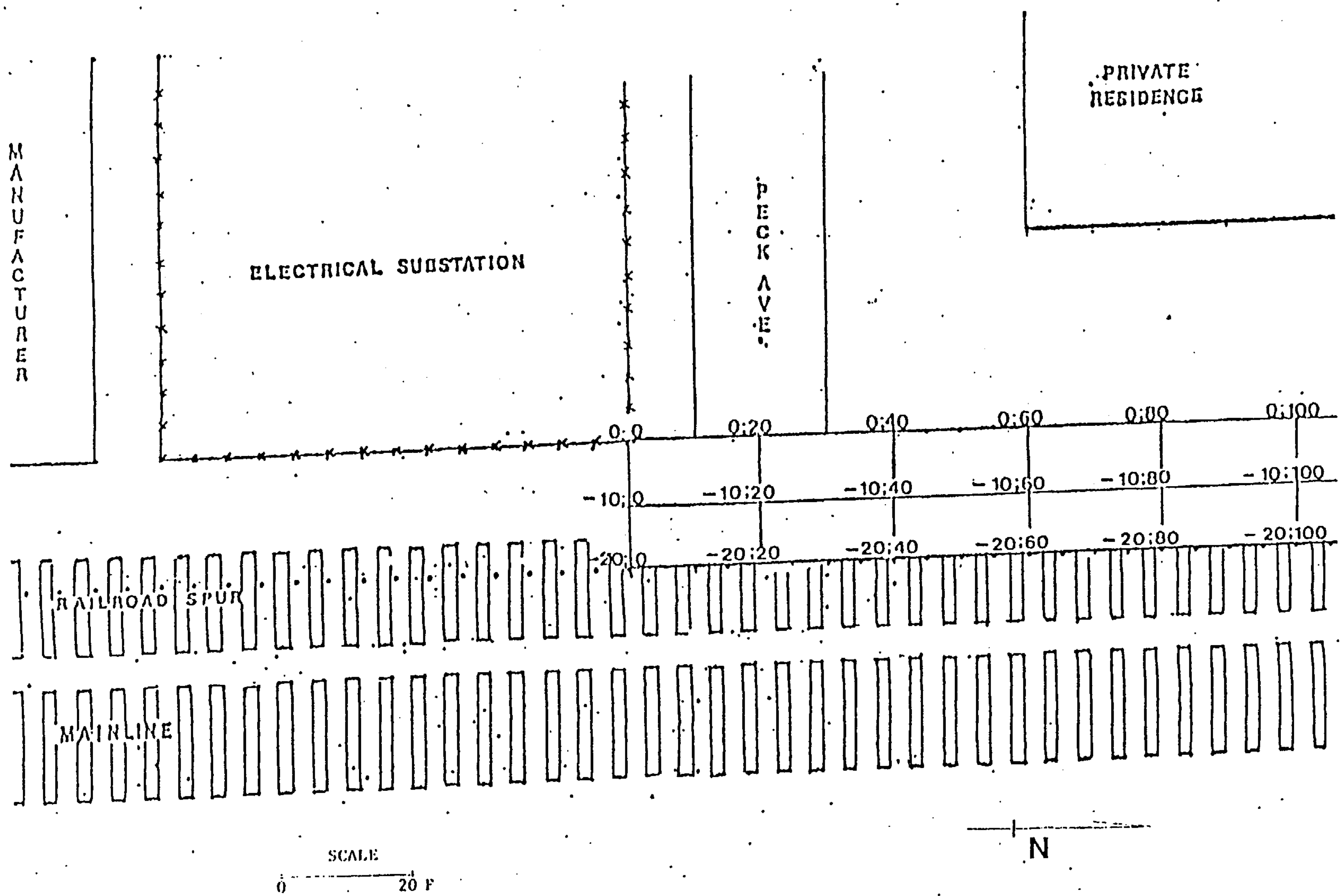

Figure 2: Site Description And Grid System
For Gamma Radiological Survey

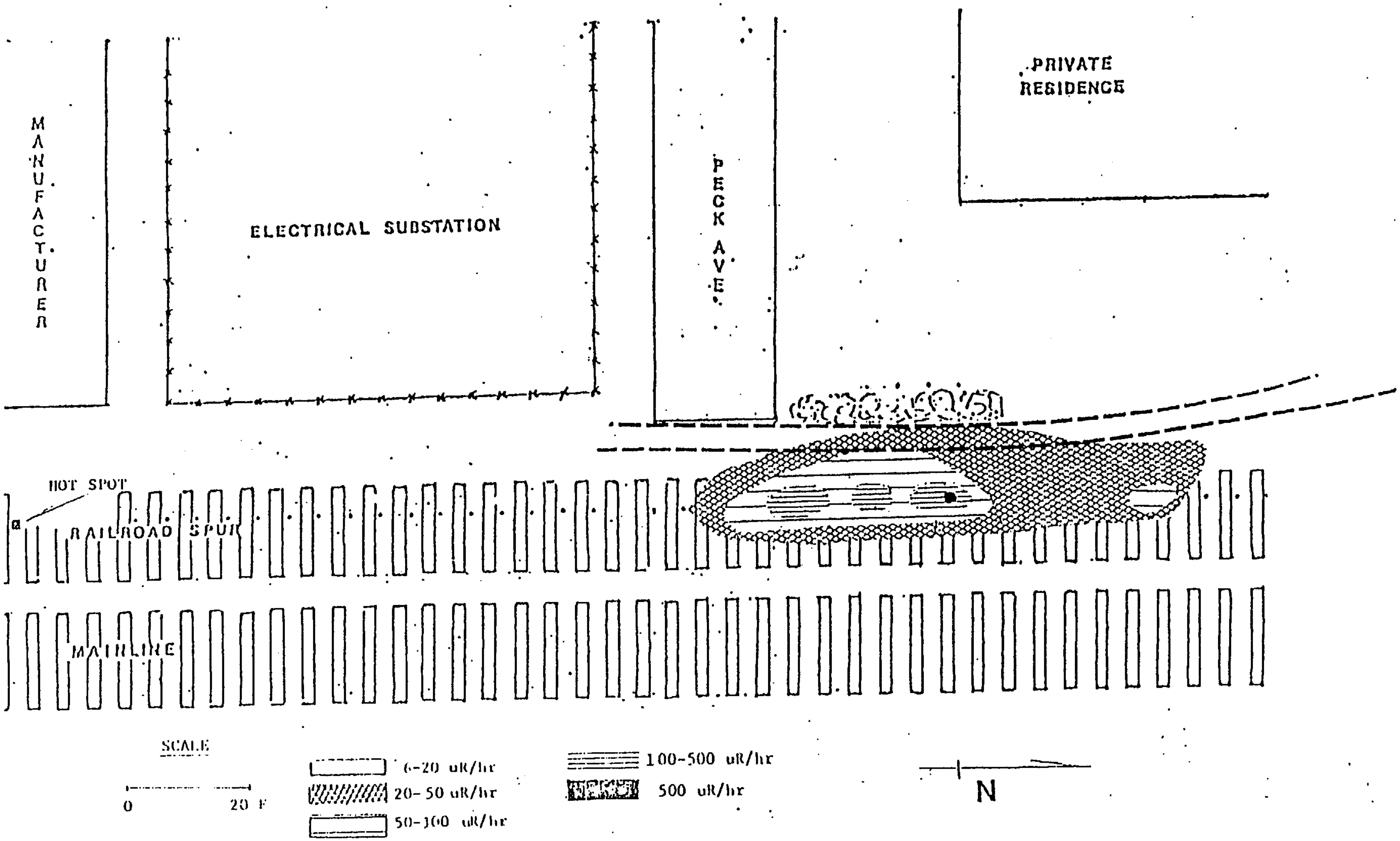

Figure 3: Field Survey Of Gamma Radiation Ground Level Exposure Rates in uR/hr, including bkg.

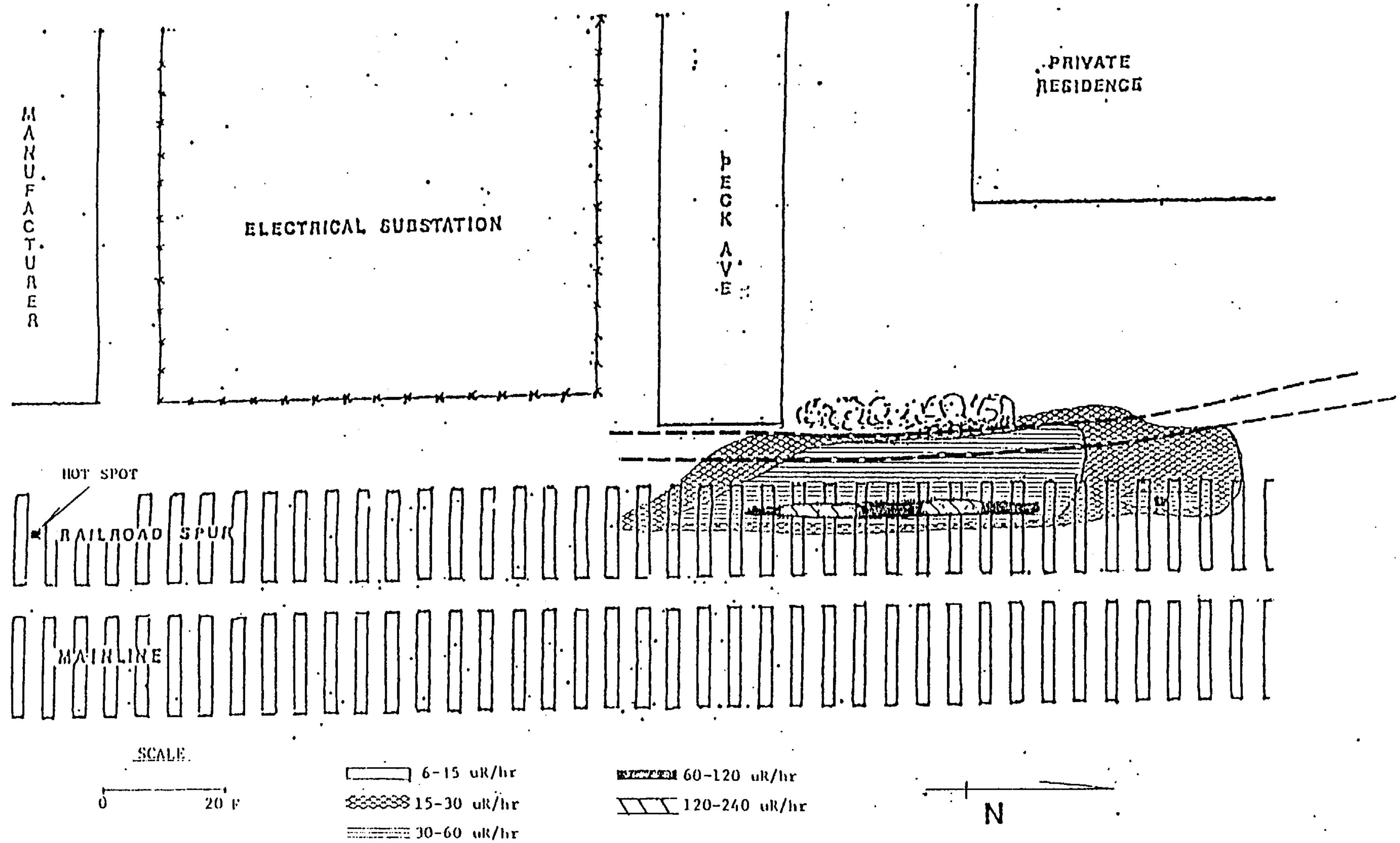

Figure 4: Field Survey Of Gamma Radiation, Three Foot Level Exposure Rate in uR/hr, including Bkg.

TABLE 1

GROUND LEVEL GAMMA SURVEY (μR/HR)

Grid Location	μR/hr	Grid Location	μR/hr	Grid Location	μR/hr
0, 0	-	-10, 0	-	-20, 0	12
0, +5	-	-10, +5	-	-20, +5	12
0, +10	-	-10, +10	12	-20, +10	12
0, +15	-	-10, +15	12	-20, +15	17
0, +20	-	-10, +20	17	-20, +20	47
0, +25	-	-10, +25	12	-20, +25	72
0, +30	12	-10, +30	21	-20, +30	174
0, +35	12	-10, +35	38	-20, +35	404
0, +40	12	-10, +40	47	-20, +40	55
0, +45	12	-10, +45	55	-20, +45	174
0, +50	12	-10, +50	59	-20, +50	89
0, +55	12	-10, +55	42	-20, +55	289
0, +60	12	-10, +60	32	-20, +60	514
0, +65	12	-10, +65	32	-20, +65	63
0, +70	17	-10, +70	29	-20, +70	38
0, +75	17	-10, +75	29	-20, +75	25
0, +80	12	-10, +80	21	-20, +80	29
0, +85	12	-10, +85	21	-20, +85	32
		-10, +90	29	-20, +90	131
		-10, +95	21	-20, +95	50
		-10, +100	21	-20, +100	17
		-10, +105	17	-20, +105	10
		-10, +110	12	-20, +110	10

TABLE 2

THREE-FOOT LEVEL GAMMA SURVEY (μR/HR)

Grid Location	μR/hr	Grid Location	μR/hr	Grid Location	μR/hr
0, 0	-	-10, 0	-	-20, 0	12
0, +5	-	-10, +5	-	-20, +5	17
0, +10	-	-10, +10	12	-20, +10	25
0, +15	-	-10, +15	12	-20, +15	38
0, +20	-	-10, +20	17	-20, +20	55
0, +25	-	-10, +25	21	-20, +25	68
0, +30	12	-10, +30	21	-20, +30	182
0, +35	12	-10, +35	38	-20, +35	132
0, +40	12	-10, +40	32	-20, +40	55
0, +45	12	-10, +45	38	-20, +45	55
0, +50	12	-10, +50	38	-20, +50	47
0, +55	12	-10, +55	38	-20, +55	101
0, +60	12	-10, +60	42	-20, +60	174
0, +65	12	-10, +65	47	-20, +65	55
0, +70	12	-10, +70	47	-20, +70	37
0, +75	10	-10, +75	42	-20, +75	25
0, +80	12	-10, +80	25	-20, +80	23
0, +85	-	-10, +85	21	-20, +85	34
		-10, +90	21	-20, +90	81
		-10, +95	21	-20, +95	47
		-10, +100	17	-20, +100	17
		-10, +105	-	-20, +105	10
		-10, +110	-	-20, +110	-

D. SOIL SAMPLES

Sample Collection, Preparation and Analysis

As shown in Figure 5, surface soil samples were collected at bias areas along the survey grid system. A background sample was collected outside the contaminated area to the east of the main railroad track.

Surface samples were collected with a garden trowel to a depth of 15 centimeters. About 1000 grams of soil were taken per sample. Samples were bagged, sealed with tape and marked with location, date and instrument reading. At the laboratory, samples were dried for 24 hours at 105°C and mechanically crushed in order to pass through a 10 mesh sieve. A 372cc sample was put into a cottage cheese container and sealed. A minimum of three weeks elapsed before counting to allow radionuclides to reach secular equilibrium.

Samples were counted for a minimum of 5000 seconds on a coaxial intrinsic germanium detector coupled to a multi-channel analyzer. Low activity samples were counted longer (from 10,000 to 30,000 seconds) to obtain a 95% confidence level in results.

Nuclides identified and quantified were:

Parent	Decay Products
Ra-226	352 keV (Pb-214)
	609 keV (Bi-214
	1764 keV (Bi-214)
Th-232	239 keV (Pb-212)
	583 keV (Tl-208)
	911 keV (Ac-228)

Soil Results

Results of radionuclide concentrations in soil are tabulated on Table 3. For comparison, Table 4 lists concentrations of thorium and radium in background soils.

Analytical results of gamma spectroscopy for thorium-232 decay products (Tl-208, Pb-212 and Ac-228) showed slight quantitative differences among them, however, when the effects of self-shielding by the soil samples were taken into account, no statistical differences were found. Therefore, thorium and its decay products were in secular equilibrium for soil samples obtained at the railroad spur. The same equilibrium state was found for radium-226 and its decay products (Bi-214 and Pb-214).

Secular equilibrium and the thorium to radium ratio of a factor of ten are characteristic of unprocessed monazite ore.

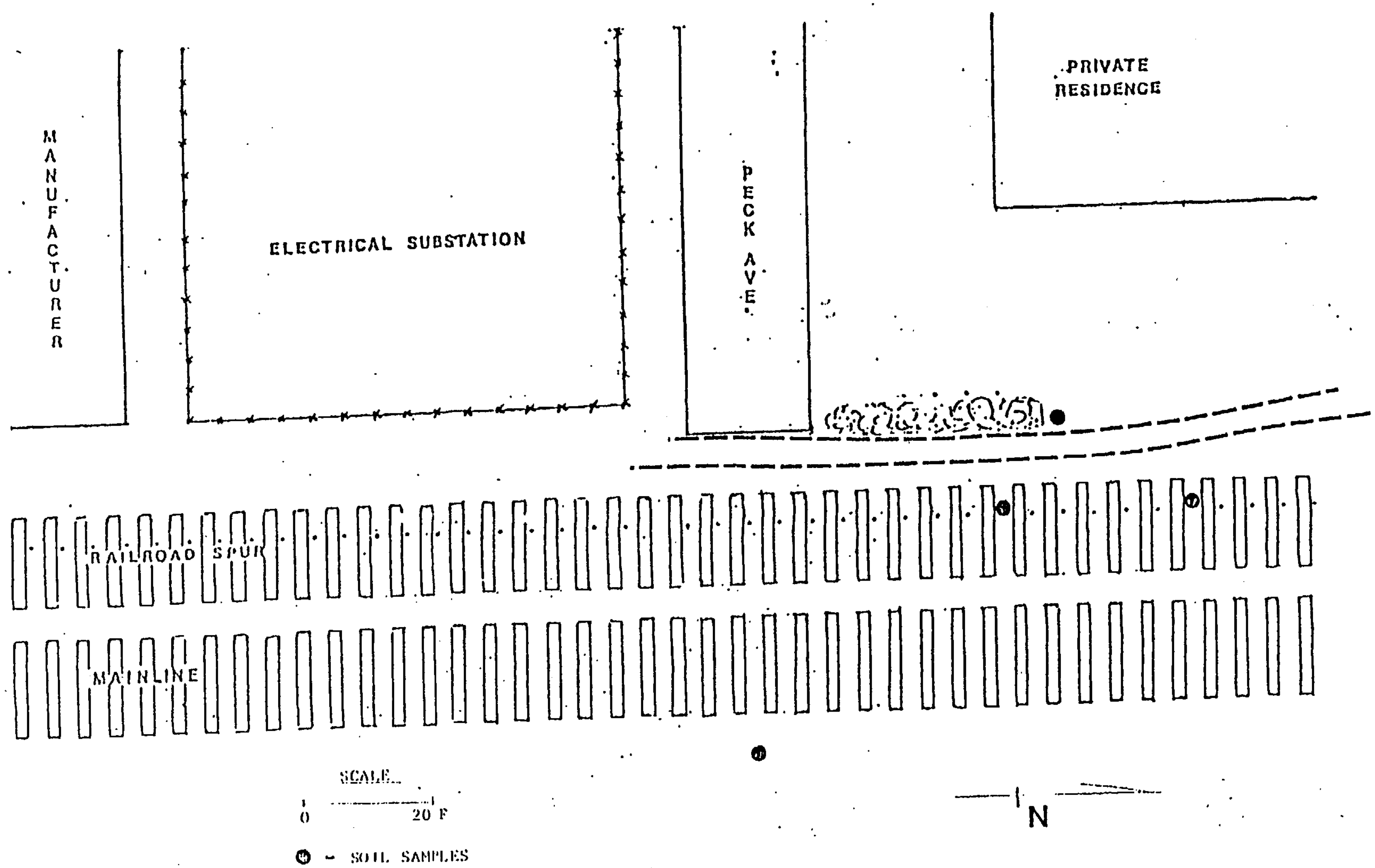

Figure 5: Location Of Bias Soil Samples

TABLE 3

RADIONUCLIDE CONCENTRATION IN SOIL SAMPLES
(Concentration in pCi/g)

Sample No.	Location	Th-232	Ra-226
S1	-20, +60	529 ± 7	41.7 ± 1.7
S2	-20, +90	102 ± 3	9.8 ± 0.7
S3	0, +70	7.5 ± 0.7	1.6 ± 0.2
S4	East of Main R/R Spur	2.1 ± 0.2	0.9 ± 0.08

TABLE 4

BACKGROUND SOIL SAMPLES
(Concentrations in pCi/g)

LOCATION	Th-232	Ra-226
Wayne - Soccer Field	1.2 ± 0.1	0.6 ± 0.05
Wayne - Pompton River Spillway	1.8 ± 0.1	0.7 ± 0.04
Literature(1)	0.31 to 1.5	0.24 to 1.4
Literature(2)		
Soil	0.2 to 1.3	0.3 to 1.4
Rock	2.2	2.6
Literature(3) Chester, N.J.	2.50 ± 0.03	1.36 ± 0.02

Explanations

(1) Source: My81 Myrick, T.D., B.A. Berven and F.F. Haywood, "State Background Radiation Levels - Results of Measurements Taken During 1975 - 1979", Oak Ridge National Laboratory Report ORNL/TM 7374, November, 1981.

(2) Source: Un77 "Sources and Effects of Ionizing Radiation", United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1977 Report to the General Assembly, 1977.

(3) Source: En78 "Environmental Measurements Laboratory, Regional Baseline Station, Chester, New Jersey", EML-347, Environmental Measurements Laboratory, U.S. Department of Energy, November 1981.

E. SUMMARY

The purpose of the radiological ground survey along the Pompton Plains railroad line was to define the extent of offsite radiological contamination initially identified by the Pequannock Health Department and to establish its origin by gamma spectroscopy. The ground survey involved taking field measurement of direct radiation and collecting soil samples for gamma spectrographic analysis.

The contaminated area in the survey grid was confined to 2000 $feet^2$, located 660 feet north of the Pompton Plains railroad station near Peck Avenue. In addition, a small 1 $foot^2$ area located 100 feet south of Peck Avenue was identified as an elevated hot spot with readings of 182 μR/hr at ground level to 92 μR/hr at three feet. This hot spot area was under low lying shrubs and inaccessible.

Ground and three-foot gamma level measurements on the survey grid near Peck Avenue had the maximum gamma radiation readings of 404 μR/hr and 174 μR/hr, respectively. Soil collected in this region had a maximum concentration of 529 $\pm$ 7 pCi/g for thorium-232 (Th-232) and 41.7 $\pm$ 1.7 pCi/g for radium-226 (Ra-226), respectively. A soil sample collected near the shrubbery on the residential property had nuclide concentrations of 7.5 $\pm$ 0.7 pCi/g of Th-232 and 1.6 $\pm$ 0.2 pCi/g of Ra-226.

Federal and State Radiation Standards

Both federal and state radiation regulations limit radiation dose for an individual member of the general public to 500 mrem/yr. Federal guidance provides an additional restriction of 170 mrem/yr for a defined segment of the population. There has been additional work done to establish standards for unrestricted use where there is little or no directly attributable benefit as in the case of terminated facilities, residual contamination, or remedial actions. The objective of these standards is to limit whole body equivalent dose to 10 mrem/yr or less.

Under the Uranium Mill Tailing Radiation Control Act (UMTRCA), the U.S. Environmental Protection Agency established standards for remedial action at inactive uranium mill sites. The limit of 5 pCi/g for radium-226 in soil concentration would limit external exposure rate to 10 μR/hr above background.

In 1981, the U.S. Nuclear Regulatory Commission developed a technical position paper for residual thorium or uranium wastes from past processing facilities (46FR52061, October 23, 1981). The criteria presented varied according to associated land use restriction. The criteria ranged from 5 pCi/g for thorium-232 in equilibrium with all its progeny from unrestricted use to 250 pCi/g for restricted use. Concentrations exceeding 250 pCi/g should be disposed in a facility licensed for disposal.

Comparison of Surveyed Area to Radiological Standards

A comparison of the area's radiological condition and current property use to the radiological standard for the general public shows that it is unlikely an individual would receive a whole body dose that exceeds the radiological standard of 500 mrem/yr. A comparison of the area's radiological condition to the most conservative environmental standard of 10 μR/hr above background for external exposure rate and 5 pCi/g above background for Th-232 in soil, shows that 2000 $feet^2$ along the Pompton Plains railroad spur would not meet these standards. The highest observed concentration of Th-232 is slightly more than twice the criteria for restricted use and about 100 times the criteria for unrestricted use. The highest observed concentration for Ra-226 is about 8 times the criteria for unrestricted use.

F. APPENDIX

EQUIPMENT USED

1. Eberline NaI(Tl) scintillation probe (SPA-3 Model) or Victoreen (Model 489-55) NaI(Tl) scintillation probe with Victoreen Thyac III (Model 490) Portable Survey Meter

2. Reuter Stokes Pressurized Ionization Chamber (Model RSS-111)

3. Canberra Series 85 multichannel analyzer with coaxial instrinsic germanium detector (relative efficiency 14%)

CALIBRATION OF SURVEY EQUIPMENT

1. Gamma Scintillation -
   The NaI(Tl) scintillimeter was calibrated by the manufacturer in December 1981. In field calibration of NaI(Tl) scintillation probes at ground level and one meter with a pressurized ionization chamber (PIC) by comparing the instantaneous count rate (counts per minute) to the exposure rate (microroengtens per hour) at several locations in the study area. PIC was calibrated at the DOE's Environmental Measurements Laboratory.

2. Soil and Sediment Samples -
   The Canberra Series 85 MCA (multi-channel analyzer) with a coaxial instrinsic germanium detector was calibrated using an eleven point standard purchased from Amersham. Standards were counted in the same geometry as the soil and sediment samples. Amersham standards are traceable to the U.S. National Bureau of Standards (NBS).

RADIOACTIVE DECAY PROPERTIES OF THE ^{40}K AND THE ^{232}Th SERIES (Un77)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities: α	β	γ
^{40}K (10.7% → ^{40}Ar; 89.3% → ^{40}Ca)		1.26 10^9 y	-	1.32 (89%)	1.46 (11%)
^{40}Ar, ^{40}Ca		Stable	-		
$^{232}_{90}Th$	Thorium	1.41 10^{10} y	3.95 (24%) 4.01 (76%)	-	-
$^{228}_{88}Ra$	Mesothorium I	5.8 y	-	0.055 (100%)	-
$^{228}_{89}Ac$	Mesothorium II	6.13 h	-	1.18 (35%) 1.75 (12%) 2.09 (12%)	0.34 (15%) 0.908 (25%) 0.96 (20%)
$^{228}_{90}Th$	Radiothorium	1.910 y	5.34 (28%) 5.43 (71%)	-	0.084 (1.6%) 0.214 (0.3%)
$^{224}_{88}Ra$	Thorium X	3.64 d	5.45 (6%) 5.68 (94%)	-	0.241 (3.7%)
$^{220}_{86}Rn$	Emanation Thoron (Tn)	55 s	6.29 (100%)	-	0.55 (0.07%)
$^{216}_{84}Po$	Thorium A	0.15 s	6.78 (100%)	-	-
$^{212}_{82}Pb$	Thorium B	10.64 h	-	0.346 (81%) 0.586 (14%)	0.239 (47%) 0.300 (3.2%)
$^{212}_{83}Bi$ (64.0% → ^{212}Po; 36.0% → ^{208}Tl)	Thorium C	60.6 min	6.05 (25%) 6.09 (10%)	1.55 (5%) 2.26 (55%)	0.040 (2%) 0.727 (7%) 1.620 (1.8%)
$^{212}_{84}Po$	Thorium C′	304 ns	8.78 (100%)	-	-
$^{208}_{81}Tl$	Thorium C″	3.10 min	-	1.28 (25%) 1.52 (21%) 1.80 (50%)	0.511 (23%) 0.583 (86%) 0.860 (12%) 2.614 (100%)
$^{208}_{82}Pb$	Thorium D	Stable	-	-	-

*Un77 "Sources and Effects of Ionizing Radiation", United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1977 Report to the General Assembly, 1977.

RADIOACTIVE DECAY PROPERTIES OF THE ^{238}U SERIES (Un77)*

Nuclide	Historical name	Half-life	Major radiation energies (MeV) and intensities: α	β	γ
$^{238}_{92}U$	Uranium I	4.51 10^9 y	4.15 (25%) 4.20 (75%)	–	–
$^{234}_{90}Th$	Uranium X_1	24.1 d	–	0.103 (21%) 0.193 (79%)	0.063 (3.5%) 0.093 (4%)
$^{234m}_{91}Pa$ 99.87% ↓ 0.13%	Uranium X_2	1.17 min	–	2.29 (98%)	0.765 (0.30%) 1.001 (0.60%)
$^{234}_{91}Pa$	Uranium Z	6.75 h	–	0.53 (66%) 1.13 (13%)	0.100 (50%) 0.70 (24%) 0.90 (70%)
$^{234}_{92}U$	Uranium II	2.47 10^5 y	4.72 (28%) 4.77 (72%)	–	0.053 (0.2%)
$^{230}_{90}Th$	Ionium	8.0 10^4 y	4.62 (24%) 4.68 (76%)	–	0.068 (0.6%) 0.142 (0.07%)
$^{226}_{88}Ra$	Radium	1602 y	4.60 (6%) 4.78 (95%)	–	0.186 (4%)
$^{222}_{86}Rn$	Emanation Radon (Rn)	3.823 d	5.49 (100%)	–	0.510 (0.07%)
$^{218}_{84}Po$ 99.98% ↓ 0.02%	Radium A	3.05 min	6.00 (~100%)	0.33 (~0.019%)	–
$^{214}_{82}Pb$	Radium B	26.8 min	–	0.65 (50%) 0.71 (40%) 0.98 (6%)	0.295 (19%) 0.352 (36%)
$^{218}_{85}At$	Astatine	~2 s	6.65 (6%) 6.70 (94%)	? (~0.1%)	–
$^{214}_{83}Bi$ 99.98% ↓ 0.02%	Radium C	19.7 min	5.45 (0.012%) 5.51 (0.008%)	1.0 (23%) 1.51 (40%) 3.26 (19%)	0.609 (47%) 1.120 (17%) 1.764 (17%)
$^{214}_{84}Po$	Radium C′	164 µs	7.69 (100%)	–	0.799 (0.014%)
$^{210}_{81}Tl$	Radium C″	1.3 min	–	1.3 (25%) 1.9 (56%) 2.3 (19%)	0.296 (80%) 0.795 (100%) 1.31 (21%)
$^{210}_{82}Pb$	Radium D	21 y	3.72 (.000002%)	0.016 (85%) 0.061 (15%)	0.047 (4%)
$^{210}_{83}Bi$ ~100% ↓ .00013%	Radium E	5.01 d	4.65 (.00007%) 4.69 (.00005%)	1.161 (~100%)	–
$^{210}_{84}Po$	Radium F	138.4 d	5.305 (100%)	–	0.803 (0.0011%)
$^{206}_{81}Tl$	Radium E″	4.19 min	–	1.571 (100%)	–
$^{206}_{82}Pb$	Radium G	Stable	–	–	–

*Un 77 "Sources and Effects of Ionizing Radiation", United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1977 Report to the General Assembly, 1977.

State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
JOHN FITCH PLAZA, CN 027, TRENTON, N. J. 08625

April 8, 1983

Office of the Regional Administrator
U.S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pennsylvania 19406

Dear Sir:

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Former Thorium/Rare Earths Processing Facility (W. R. Grace Property, Wayne, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the W. R. Grace property and vicinity.

A comparison of the area's radiological conditions and current property use to the radiological standards for the general public, show that it is unlikely that an individual would be exposed to radiation levels that exceed existing federal and state radiation standards. However, current property use can change which could result in individuals receiving radiation doses above these standards, therefore, an evaluation of the surveyed area should be based on more stringent environmental standards.

A comparison of the area's radiological condition to the most conservative environmental standards indicates that future remedial actions are necessary for approximately 15,000 square meters of the W. R. Grace property and 2,000 square meters of the contiguous property to the south. Further, as a result of the extensive soil contamination, the DEP is concerned that the overburden covering the waste disposal areas on the Grace property is insufficient to prevent future movement of contaminated soil by surface run-off.

ITEM # 293

3/29/91

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Based on the DEP radiological survey, it appears that disposal by on-site burial was not carried out in accordance to 10 CFR 20 provisions in effect during the operation and decommissioning periods of the facility. In particular, the large number of surface soil samples with high concentrations of thorium indicates that burial was not performed at a minimum depth of four feet. Also our radiological survey shows site condition to be inconsistent with the decommissioning survey performed in 1974 to support termination of W. R. Grace's NRC license.

Sincerely,

Steven G. Kuhrtz
Director

SGK:JE:cab
Enclosure: (1)

State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
JOHN FITCH PLAZA. CN 027. TRENTON. N. J. 08625

April 8, 1983

Mr. Ronald Mace
W. R. Grace and Company
P. O. Box 2117
Baltimore, Maryland 21203

Dear Mr. Mace:

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Former Thorium/Rare Earths Processing Facility (W. R. Grace Property, Wayne, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the W. R. Grace property and vicinity.

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A comparison of the area's radiological condition to the most conservative environmental standards indicates that future remedial actions are necessary for approximately 15,000 square meters of the W. R. Grace property and 2,000 square meters of the contiguous property to the south. Further, as a result of the extensive soil contamination, the DEP is concerned that the overburden covering the waste disposal areas on the Grace property is insufficient to prevent future movement of contaminated soil by surface run-off.

A comparison of the DEP radiological survey with the 1974 decommissioning survey show differences in the radiological condition of the site. In particular, DEP finds there are areas in the rear field which exceed the 1974 decommissioning survey results of 200 μR/hr. Our survey indicates areas where exposure rates ranged up to 1692 μR/hr at ground level and 854 μR/hr at one meter.

Also there exists elevated radon levels in the warehouse building towards the rear of the property. Since the elevated levels are because of the infiltration of radon from radium contaminated material, permanent elimination of this exposure can only be accomplished by removal of the radon source. As an interim short-term measure, elevated radon levels in structures can be reduced by increasing the air exchange rate. DEP can provide additional radon monitoring to document the effectiveness of any remedial measures you may undertake.

We are aware that on-site monitoring wells have been installed on the property. We request information on their locations, depths and analytical data be provided to us for evaluation.

Sincerely,

Steven G. Kuhrtz
Director

SGK:JE:cab
Enclosure: (1)

State of New Jersey
DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF ENVIRONMENTAL QUALITY
JOHN FITCH PLAZA, CN 027, TRENTON, N. J. 08625

April 8, 1983

Mr. Richard Mandall
Electronucleonics, Inc.
368 Passaic Avenue
Fairfield, New Jersey 07006

Dear Mr. Mandall:

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Former Thorium/Rare Earths Processing Facility (W. R. Grace Property, Wayne, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the W. R. Grace property and vicinity.

A comparison of the area's radiological conditions and current property use to the radiological standards for the general public, show that it is unlikely that an individual would be exposed to radiation levels that exceed existing federal and state radiation standards. However, current property use can change which could result in individuals receiving radiation doses above these standards, therefore, an evaluation of the surveyed area should be based on more stringent environmental standards.

A comparison of the area's radiological conditions to the most conservative environmental standards indicates that future remedial actions are necessary for approximately 15,000 square meters of the W. R. Grace property and 2,000 square meters of the contingous property to the south. Further, as a result of extensive soil contamination, the DEP is concerned that the overburden covering the waste disposal areas on the Grace property is insufficient to prevent future movement of contaminated soil by surface run-off.

Based on the DEP radiological survey there exists elevated radon levels in the warehouse building towards the rear of the property. Since increased air exchange can reduce radon concentrations, we suggest you consider short term interim remedial measures to elminate this exposure. The permanent elimination of this exposure can only be accomplished by removal of the radon source. DEP can provide additional radon monitoring to document the effectiveness of any remedial measures you may undertake.

Sincerely,

Steven G. Kuhrtz
Director

SGK:JE:cab
Enclosure: (1)

State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION

DIVISION OF ENVIRONMENTAL QUALITY

JOHN FITCH PLAZA, CN027, TRENTON, N.J. 08625

STEVEN G. KUHRTZ
DIRECTOR

Enclosed is the New Jersey Department of Environmental Protection's report, Radiological Survey of a Former Thorium/ Rare Earths Processing Facility (W. R. Grace Property, Wayne, New Jersey). The report contains the DEP's technical findings from the August 1982 survey of the W. R. Grace property and vicinity. This survey is part of a DEP ongoing program to reevaluate former radiation sites to assess their radiological condition.

A comparison of the area's radiological conditions and current property use to the radiological standards for the general public, show that it is unlikely that an individual would be exposed to radiation levels that exceed existing federal and state radiation standards. However, current property use can change which could result in individuals receiving radiation doses above these standards, therefore an evaluation of the surveyed area should be based on more stringent environmental standards.

A comparison of the area's radiological condition to the most conservative environmental standards indicates that future remedial actions are necessary for approximately 15,000 square meters of the W. R. Grace property and 2,000 square meters of the contiguous property to the south. Further, as a result of the extensive soil contamination, the DEP is concerned that the overburden covering the waste disposal areas on the Grace property is insufficient to prevent future movement of contaminated soil by surface run-off.

Although the results of water samples taken in the surface drainage system meet federal and state drinking water standards, they show evidence of contamination. Air samples show radon-222 concentration outdoors and in the office building on the Grace property to be within the background levels for New Jersey, but higher levels were found in the warehouse building.

The DEP will pursue remedial actions for this site with all appropriate parties.

Sincerely,

Steven G. Kuhrtz

Steven G. Kuhrtz
Director

NORTHEAST LOW-LEVEL RADIOACTIVE WASTE COMPACT

SUMMARY
FINAL DRAFT

OVERVIEW

Policy representatives of the northeastern states have met over the past year to develop a draft compact for the management of low-level radioactive wastes generated within the region. The draft compact provides a legal framework for a cooperative regional approach to meeting state responsibilities under the Low-Level Radioactive Waste Policy Act (P.L. 96-573), and to ensure the proper, safe and efficient management and disposal of these wastes. The Northeast draft compact is modeled after similar compacts in other regions, modified to reflect unique northeastern needs and concerns. It has been forwarded to each of the eleven northeastern states for their review and consideration.

The PWG has endeavored to draft a document that can remain viable throughout decades and diverse state administrative and legal systems. In its deliberations, the PWG was aware that a compact becomes both a law of each member state and a supra-state contract which creates a legally binding relationship among the party states. A LLW compact must be consistent with the primary federal responsibility for radioactive materials established by the Atomic Energy Act of 1954, as amended.

The PWG consciously chose not to anticipate and resolve every problem which might emerge, nor to specify in detail how each responsibility must be performed under the compact. As a single document which balances the interests of the sovereign states, the federal government, and the region in LLW management, the draft compact is designed as a basic charter of interstate and state-federal relations. It sets forth the principal rights and responsibilities of the signatory parties and provides guidance for future decisions by the states individually and collectively.

The compact has four major provisions.

- It sets forth the major roles, responsibilities and obligations of the party states, the host states (where facilities are located), and the regional commission. Major responsibilities include timely development of a regional facility by a host state, and the commitment of party states and the Commission to a coordinated regional approach to LLW management. An underlying responsibility is the good faith of each state to meet its obligations under the compact.

- The compact establishes the Northeast Interstate Low-Level Radioactive Waste Commission as an advisory and coordinative body to administer the compact. The Commission's role is to ensure that the states' collective interests are considered in the siting, development and management of a regional facility. It has no operational or regulatory authority over a facility. Its regulatory authority is limited to ensuring that member states comply with the compact.

- The compact establishes a process for selecting a state to host a facility. It does not specify how a state would site, develop, and oversee management of a regional facility, thus leaving these tasks to state and federal law.

- The compact sets forth the terms and conditions under which a state joins or withdraws from the compact. Reflecting the contractual basis of such a charter, it provides for penalties and sanctions, including revocation of membership, for states which fail to meet their agreed upon obligations.

SUMMARY OF MAJOR PROVISIONS

Article I. Policy and Purpose

This article recognizes that under federal law, each state is responsible for the disposal of low-level radioactive waste generated within its borders, and declares that in order to promote public health and safety, it is the policy of the party states to enter into a regional compact which will: provide a framework for cooperative efforts; assure proper transportation of low-level wastes; minimize the number of facilities required to manage such wastes; distribute the costs, benefits and obligations of proper waste management equitably among the party states; and ensure the environmental and economic management of low-level waste generated in the region.

Article II. Definitions

Key terms used in the compact are defined in this article.

Article III. Rights and Obligations

This article establishes certain rights and obligations of party states and host states, which are additional to the rights enjoyed by sovereign states. Items addressed under party state rights and obligations include: the right of access to regional facilities; ensuring proper packaging and transportation of waste consistent with applicable federal and state laws and regulations; information and reporting requirements; good faith performance by each state to ensure regional facilities are available; and the capability of each party state to host a regional facility and ensure its proper management.

The rights and responsibilities of each host state include: ensuring timely development, operation and management of a regional facility; providing for reasonable fees and surcharges; ensuring sound packaging, transportation and disposal of waste consistent with applicable federal and state laws and regulations; and regular reporting to the regional Commission.

This article also contains an exclusionary ban on management at a regional facility of wastes generated outside the party states after January 1, 1986. Waste generated in the region cannot be exported to facilities outside the region without approval of the Commission and the affected host states.

Article IV. The Commission

A Northeast Interstate Low-Level Radioactive Waste Commission is created, comprised of one member from each party state and two members from a host state, to be appointed by the Governor according to state procedures. The Commission is empowered to perform a variety of oversight, information-gathering, planning and management functions pertaining to low-level waste disposal within the region, and to designate (by two-thirds vote) a host state for a regional facility if no state volunteers. The Commission rules on applications of eligible and non-party states to become party states and may invoke penalties and sanctions, including revocation of membership, on states which fail to fulfill their obligations. It and the host states determine whether waste can be imported into or exported from the region.

The Commission may mediate disputes among party states, negotiate agreements with other compacts and act as an intervenor on behalf of party states. It must adopt procedural regulations to ensure efficient operation and protection of due process. Meetings of the Commission are to be open to the public. It is separate from the party states and not liable for actions of the party states nor a facility operator. The Commission would be financed initially by a $70,000 payment from each party state, and subsequently through a special surcharge on users of the regional facility (or facilities).

Article V. Host State Selection and Development and Operation of Regional Facilities

This article establishes basic procedures for selection of a host state and for development of a regional facility. The Commission must develop a regional management plan for determining the type and number of regional facilities. Following a review, the Commission may designate a state volunteering to host a facility.

If no state volunteers, the Commission adopts procedures and criteria for designating a host state, based on statutory selection criteria. These are limited to health, safety, and welfare; environmental economic, and social effects of a regional facility, benefits and costs; waste volumes and types generated in each party state; minimization of waste transportation; and existence of regional facilities in a party state.

A host state is responsible for timely identification of a site and timely development and operation of a facility. It oversees management of the facility, but must solicit comments from party states and the Commission on its management of the facility. A host state must provide notice of any emergency, temporary or scheduled closure of a facility. Fees and surcharges (for host state regulatory programs, post-closure and institutional control funds, compensation and incentives) must be reasonable, equitable and approved by the host state with comment by the Commission.

Article VI. Other Laws and Regulations

The legal parameters of the compact and its relationship to state laws and regulations are defined by this article. Party states are prohibited from passing any law which is inconsistent with the provisions of the compact without jeopardizing their membership status. All existing state laws and regulations of the state or its subdivisions which are inconsistent with the compact are declared null and void, and any provisions which prohibit, suspend or unreasonably delay or restrict the designation, siting or licensing of a regional facility are prohibited and repealed by ratification of the compact. The compact does not abrograte or limit the regulatory authority of the U.S. Nuclear Regulatory Commission or an agreement state under Section 247 of the Atomic Energy Act of 1954, as amended.

Article VII. Eligible Parties, Withdrawal, Revocation, Entry into Force, Termination

States initially eligible to join the compact include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The initial eligibility status expires June 30, 1984. Procedures and requirements for an "eligible state" to become a "party state" are set forth in this article, as are procedures for withdrawal and revocation of "party state" status. The compact will take initial effect upon enactment into law by at least three states, but will not take full effect until ratified by Congress. Congress may withdraw its consent every five years.

Article VIII. Penalties

Each state shall prescribe and enforce penalties for violations of the compact in accordance with its own laws. Importation or exportation of waste without Commission approval is prohibited. The states are responsible for enforcing violations of the law, but the Commission may seek enforcement or remedies as provided in the compact.

Article IX. Compensation Provisions

The host state must ensure that funds and procedures are available during the operating and post-closure periods to compensate injured parties and property damage (excluding property diminution) and to provide for clean-up and restoration. The obligation may be imposed on the facility operator, assumed by the state, or both.

The Commission is to provide a means of compensation to persons injured or property damaged during the institutional control period, due to the radioactive and waste management nature of the regional facility. The fund, based upon a users' surcharge, is also available for third party relief during operational and post-closure periods but only to the extent other resources and means are not available from the host state or other entities. Liability is limited to no more than the amount contained in the fund.

Article X. Severability and Construction

This article contains legal "boiler plate" to assure that if any provision of the compact is invalidated by the courts, the remaining provisions shall remain in full force and effect. Guidance is also given for liberal construction of specific compact provisions.

THE NEW YORK TIMES, SUNDAY, FEBRUARY 20, 1983

Northeast Waste Dump Panel Approves Plan

BOSTON, Feb. 19 (AP) — An 11-state regional group has approved a preliminary compact that is the first step toward establishing a low-level nuclear waste dump somewhere in the Northeast.

The plan, approved by the Coalition of Northeastern Governors' Low-Level Radioactive Waste Policy Working Group, now goes to the 11 governors for their approval.

The working group is made up of representatives of the governors and legislatures of New York, New Jersey, Maryland, Delaware, Pennsylvania, Massachusetts, Rhode Island, Connecticut, Maine, New Hampshire and Vermont.

The compact also requires the approval of states' legislatures and Congress before a dump site can be selected and before any work can be started.

The group is operating against a deadline of Jan. 1, 1986, the date under Federal law when the nation's three existing low-level radiation dump sites can refuse to accept waste from outside their areas. Those sites are in South Carolina, Nevada and Washington.

Environmentalists Critical

Low-level waste comes from nuclear power plants, from industries and from hospitals and research facilites. It does not include spent nuclear fuel.

The approval of the compact came Friday night after a daylong session of extensive debate over technical legal points in the agreement.

The proposal, which calls for establishing a regional commission that eventually will choose the state where the dump is to be situated, met with sharp criticism from environmentalists in the audience.

"I am very shocked this is the last meeting of this group here, given the amount of mass confusion that existed here today," said Mark Ernst, a lawyer for the Massachusetts Public Interest Research Group. "Perhaps as a public interest attorney, I should thank you for a lifetime of opportunity to litigate this document."

"We think it is an inappropriate response to the problem," said Hank E. Warren, a member of the working group.

Mr. Warren, who is the Maine Env ronmental Protection Commissione lost a battle Thursday night to get t group to propose excluding states th generate little low-level waste fro being chosen as dump sites. The states would have included Maine, Ve mont, Rhode Island, New Hampshi and Maryland.

The group rejected Mr. Warre plan, adopting instead a proposal th would take environmental, econon and social effects into account in dec ing where the dump would be located

The plan also requires states to r peal any law that would make it dif cult for it to be chosen as a dump site.

CHRONOLOGICAL REVIEW OF W. R. GRACE & CO. PLANT

IN WAYNE TOWNSHIP, NEW JERSEY

This document presents a brief chronological review of the W. R. Grace & Co. plant at Wayne Township, New Jersey.

1947 - Rare Earths, Inc. was incorporated in November, 1947 and purchased the 6.4 acre site with buildings from the Farms Hotel, Inc. Permission was granted from the Wayne Township zoning board to process monazite ore at the site and to carry out research activities related to rare earths and thorium materials. (Appendix 1, Pages 1-2).

1948 - April 1, 1948 the Atomic Energy Commission (AEC) issued Source Material License R-132 to Rare Earths, Inc. giving authority to process monazite ore at the site and stipulating record keeping requirements. (Appendix 1, Pages 3-6).

1949 - Equipment was installed and regular processing of monazite ore began,with periodic inspections of plant operations by AEC and New Jersey Department of Environmental Protection (DEP).

1950 - November 2, 1950 contract AT(30-1)1037 between AEC and Rare Earths, Inc. became effective in which the government agreed to purchase thorium fluoride materials. (Appendix 2, Pages 1-19).

1950-1954 - At the request of the Manhattan Engineering District (MED) and the Atomic Energy Commission (AEC) research was carried out by Rare Earths, Inc. to improve the quality of thorium salts that could be obtained from monazite ore and government-owned thorium sludges. The government was interested in thorium for nuclear activities and considered it to be a strategic material. This work was done to establish possible sources of thorium as well as its characteristics when and if needed by the Federal Government.

1955 - July, 1955 Rare Earths, Inc. entered into federal contract AT(49-6)-993 to process monazite ore from government stockpiles. (Appendix 2, Pages 20-77).

Mid-1955 W. R. Grace & Co. purchased Rare Earths, Inc. for the express purpose of supplying the government with thorium under contract AT (49-6)-993 and possible future contracts.

1956 - November, 1956 Rare Earths, Inc. was dissolved and W. R. Grace & Co. agreed to perform AEC contract AT(49-6)-993. (Appendix 3, Pages 1-2).

1958 - January, 1958 contract AT(49-6)-993 was terminated by mutual agreement. The plant continued to process monazite ore for commercial products. (Appendix 3, Pages 3-4).

With the promulgation of 10CFR 20.304 in 1957 all subsequent thorium burials were in strict compliance with this regulation.

1959 - November, 1959 joint inspection of plant carried out by the AEC and the New Jersey Department of Health. A report was issued January 25, 1960 citing several deficiencies, which were corrected. (Appendix 4, Pages 1-15).

1961 - June, 1961 a followup inspection of the site was carried out by the AEC. No items of non-compliance were found.

1964 - July, 1964 the plant was inspected by the AEC. Two items of non-compliance were cited; these were corrected. (Appendix 4, Pages 16-33).

1966 - November, 1966 the plant was inspected by the AEC. No items of non-compliance were found. (Appendix 4, Pages 34-46

1967 - March, 1967 burial of thorium-bearing sludges on the plant site was terminated. Sludges from continuing operation of the plant were transferred to W. R. Grace's facility in Chattanooga, Tennesee.

July, 1967 certain buildings on the property were leased to Electro-Nucleonics, Inc. (ENI).

1970 - April 3, 1970 all processing of monazite ore was terminated.

May 1, 1970 AEC issued storage license STA-422 under which the Grace plant assumed the status of a storage facility for source materials. This license remained in force until the property was decontaminated and released for unrestricted use in 1975.

1973 - December, 1973 Applied Health Physics, Inc. of Bethel Park, Pennsylvania conducted a radiological survey of the site. Results indicated radioactive contamination of land, buildings and equipment.

Following this survey, Applied Health Physics, Inc. was engaged to decontaminate the buildings and equipment. This included burial of radioactively contaminated demolition materials on-site. Grace assumed responsibility for decontamination of the plant grounds. Mr. Paul B. Klevin, certified health physicist and formerly an inspector in the AEC's Division of Compliance, was employed by Grace to direct the fieldwork.

The purpose of the decontamination work was to achieve radioactivity limits specified by NRC guidelines and the New Jersey state Department of Health in order to obtain a release from the conditions of the AEC license, and approval for unrestricted use of the property. Decontamination was based on achieving an average radioactivity level of 0.2mR/hr (200 micro R/hr) both inside the buildings and on the surface of the site.

Grace received permission from the State of New Jersey to bury mechanical equipment, wooden tanks, etc. that showed unacceptable levels of radioactivity on-site.

1974 - Decontamination was completed in late 1974. Inspections were made while work was in progress by Mr. Eugene Epstein of the NRC Compliance Section. Mr. Epstein's final inspection was completed September 20, 1974.

A complete report by Applied Health Physics, Inc., dated September 9, 1974, covered the preliminary survey, the decontamination work carried out, and a final survey of the site. This report was submitted to the Materials Licensing Section of the AEC in Washington, D.C. A copy of this report is available for review.

1975 - January 23, 1975 a letter from the NRC to Grace released the property for unrestricted use. (Appendix 5, Pages 1-8).

1976 - Grace commenced annual radiological survey of the property consisting of radioactivity measurements above the surface of the property as well as water samples leaving the property. No off-site measurements were made; at this time no off-site contamination was suspected.

Results showed that the average radiation levels were within the 0.2mR/hr NRC guidelines. Grace considered the survey results acceptable in that they met the guidelines used by the NRC as a basis for releasing the property for unrestricted use. Water samples were also found to be acceptable on the basis of the then-current drinking water standards. (Appendix 6, Pages 1-24).

1977 - May 14, 1977 a fire severely damaged the main building. Grace restored the front one-third of the structure for office space. Many files relating to Rare Earths, Inc. and W. R. Grace operations were destroyed in this fire.

1979 - October, 1979 all land and improvements were leased to ENI for a four-year term with renewal options. A copy of the lease was filed in the land records of Wayne County.

1981 - On May 25, 1981 an aerial radiological survey of the plant site and Sheffield Brook was conducted by EG & G, Inc. The aerial survey identified the known burial site on the Grace property and an off-site area west of the plant which exhibited higher than normal background radiation levels.

January through November, 1981 NRC conducted ground surveys of the plant site and Sheffield Brook. Results: "Buildings on the site meet current criteria for release for unrestricted use. Some areas around the buildings and off-site may not meet current criteria for release for unrestricted use." A more exhaustive survey was recommended. (Appendix 7, Pages 1-11).

1982 - September, 1982 a second aerial radiological survey was carried out that included a much larger area than the first. The survey confirmed higher than background radiation levels at the plant site, along Sheffield Brook, along the railroad siding in Pompton Plains and in a small area adjacent to the southern boundary of the property.

October, 1982 reports of radiological surveys of Sheffield Brook by the Oak Ridge Associated Universities (ORAU) and the New Jersey Department of Environmental Protection (DEP) were issued. Results of the ORAU survey indicated that "The levels of direct radiation and radionuclide concentrations in soil and sediment at many locations along Sheffield Brook and the associated drainage streams exceed target criteria proposed by the NRC for uncontrolled use by the general public." DEP survey confirmed ORAU findings in general. (Appendix 8, Pages 1-2 & 3-5)

1983 - January, 1983 a report of the on-site radiological survey of the W. R. Grace property by ORAU was issued. Results indicated contamination in the soil and on the surface of the site. Contamination was also found on the property bordering the site on the south and on the railroad siding in Pompton Plains. (Appendix 8, Pages 6-7).

January 28, 1983 Grace meeting with Department of Energy. DOE personnel present included:

Steven R. Miller	- Attorney, Office of General Counsel
John E. Baublitz	- Director, Division of Remedial Action Projects, Office of Nuclear Energy
Art Whitman & Ed Dulany	- Division of Remedial Action Projects, Office of Nuclear Energy

February 9, 1983 Grace meeting with Nuclear Regulatory Commission. NRC personnel present included:

R. G. Page	-	Chief, Uranium Fuel Licensing Branch Nuclear Material Safety and Safeguards
W. R. Crow	-	Fuel Cycle Licensing, Asst. to Mr. Page
R. L. Fonner	-	Counsel

February 17, 1983 Grace letter to Department of Energy requesting site be included in FUSRAP. (Appendix 9, Pages 1-4).

March 7, 1983 letter issued from Environmental Resources Management (ERM) presenting their evaluation of the ORAU off-site and on-site reports. (Appendix 9, Pages 5-12).

March 15, 1983 Grace meeting with Representative Robert A. Roe in Washington, D.C.

(212) STILLWELL 4-2121 (212) 784-4410

EXPERT CONCRETE PUMPING CO.
DIVISION OF
EXPERT CONCRETE BREAKERS, INC.
21-21 43RD AVENUE • LONG ISLAND CITY, N.Y. 11101

June 10, 1983

Mr.John D. Kinneman, Chief
Materials Radiological Protection Section
Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pa.

Dear Mr. Kinneman,

It has come to our attention that you are involved in the W. R. Grace dumpsite study near Black Oak Ridge Road in Wayne, New Jersey. As we understand the situation, further investigation is hampered by fears that drilling into the ground will release waste that may leach into ground water.

I believe that a new process our firm is using may be able to assist you in this matter. New York Grout (TACSS) is a one component chemical grout that when injected into the ground at low pressure reacts with water or moisture to form a solid, inert barrier to water and chemical penetration.

Naturally, no material of this type is impervious to radiation, however, it will confine leachate. The grout reacts with water in the soil to expand and fill voids in the soil structure, yielding a solid curtain.

The grout is inert, non-toxic and does not deteriorate when coming in contact with chemical pollution.

The grout has been used successfully for many years in Japan and Europe and now is making it's debut in the United States.

Enclosed is some information which I hope will be helpful. If there is further interest on your part, perhaps we can meet

(continued page two)

ITEM # 294

B/292

GROUTING • MUD JACKING • SHOT CRETE • SOLAR CRETE

(12)

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EXPERT CONCRETE PUMPING CO.
DIVISION OF
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Mr. John D. Kinneman

June 10, 1983

with you and demonstrate the system in your office. Please feel free to call my office for an appointment or for any questions that you may have.

We look forward to hearing from you.

Very truly yours,

NEW YORK GROUT, INC.

Randy Apfelbaum
Sales Representative

RA/ll
encl.
file/chrono

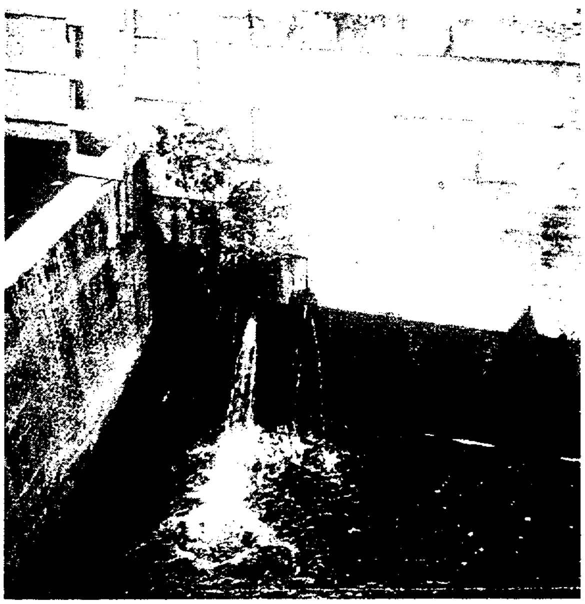
TACSS

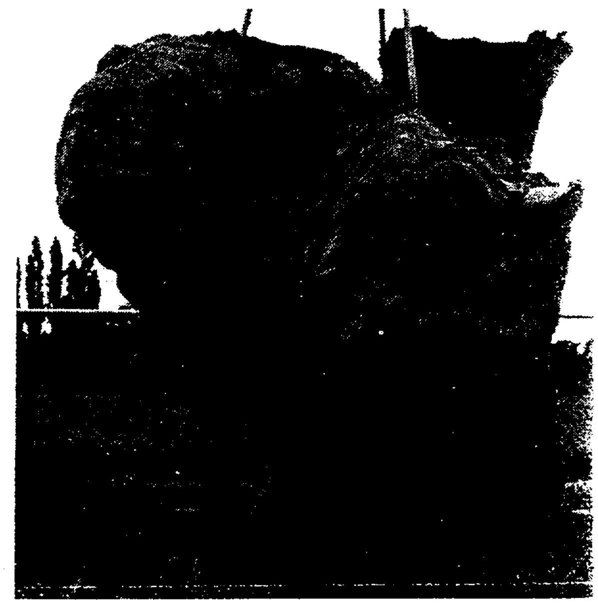
One Component Chemical Grout

The high fluctuating ground water levels cause enormous problems in the construction industry. From deep excavation until finished construction, a fast and effective sealing of the leakage is required. Also, the low stability of the soil becomes a problem now that the load on the soil increases.

TACSS grout brings the solution for leakages and soil-stabilization even with very difficult conditions such as: high water pressures; gushing leakages; high ground water flow; variations in ground water level; low permeability of the soil; etc.

The working principle of TACSS is totally different from the conventional chemical grouts like waterglas (silicates) and acrylamide etc. TACSS is an additional grout for these grouting materials.





A UNIQUE CHEMICAL GROUT USED FOR SEALING LEAKAGES OR SOIL STABILIZATION

Industriepark 8
3100 Heist o/d Berg
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Telephone (015) 247231
Telex (846) 62926

122 North Mill Street
St. Louis, Michigan 48880-0034
U.S.A.
Telephone (517) 681-5791
Telex 227441

[illegible]

In certain cases it is impossible to make a deep excavation with the conventional methods. For example:

- — where cables or pipes cross the excavation area.
- — where the lowering of the groundwater is impossible. This could result in settlements in the neighbors building, thus causing the necessity to make a water cut-off wall following the curtain grouting method.

Insertion of TACSS through injection pipes at regular distances and different depths will make a solidified TACSS watertight screen. Such a TACSS screen can also be used as a bottom slab of a deep excavation to create a dry pit.

[illegible]

Immediate sealing of leakages in deep excavations can be very important. Small leakages between sheetpiles, slurrywalls and retaining walls, as well as larger ones (for example where sheet piles don't fit together), can be sealed with TACSS.

Each leakage has its own approach; from inserting rags dipped in TACSS to injecting TACSS through injection pipes behind the wall. Each time TACSS will be the ideal product.

Sealing of voids in concrete construction

Canalize the leakage with hydraulic cement or another temporary shuttering and bring it into a few openings wherein you insert injection nipples with a valve. Via these nipples inject TACSS with the maximum geltime. TACSS reacts almost immediately with the water. Due to the expansion of TACSS it forms a "fluid wedge" and blocks the leakage. Because TACSS is a mechanical sealant, the usual bond obstructing conditions like dust, moisture, etc. . . . have no influence.

Even gushing leakages can be sealed without it being necessary to block the hydraulic pressure.

In little cracks (pouring seams, etc. . . .) the reaction mechanism of TACSS takes care of the marginal filling of the cracks.

Due to the very quick chemical reaction the results are immediately visable.

Its uses include:

MINES:

- Stoppage of water infiltration (even with high hydraulic pressure).
- Pregrouting of aquifers prior to shaft sinking.
- Ground consolidation.
- Preventing ice build-up during winter by stopping of water seepage.

TUNNELS, SUBWAYS:

- Stoppage of water seepage into tunnel or subway.
- Ground stabilization at heading to prevent crown collapse.
- Joint sealing of tunnel segments.

EARTH AND ROCK - FILLED DAMS

- Cutting off water leakage through dam foundation by formation of grout curtain in fractured bedrock and alluvium deposits.

CONCRETE AND MASONRY DAMS

- Sealing leakages in fractured rock abutments and in concrete or masonry structure.

SEWERS:

- Cure water leaks into sewer lines and into manholes through cracks and joints by treatment of ground adjacent to pipes.

CHEMICAL WASTE CONTAINMENT:

- Placing curtain of chemical grout to insulate and contain chemical spillage in porous ground.

STEEL TANKS:

- Underpinning and increasing the bearing capacity of soils under the steel tanks.

Characteristics of soil stabilized with TACSS

Mechanical characteristics

The mechanical characteristics of soils stabilized with TACSS depend on the type of TACSS used and the conditions of the soil. A few typical characteristics of the different types of TACSS will be found in the enclosed table.

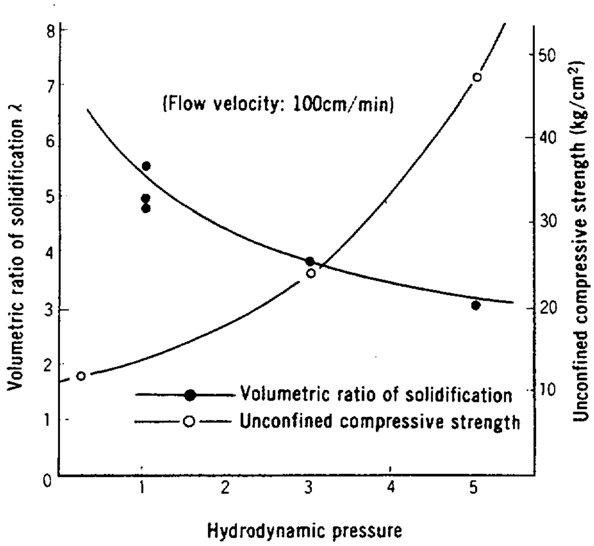
Typical is the high grade of stabilization which does not depend on the groundwater level. TACSS gives a higher compressive strength and an increase in internal angle of friction strength, due to the increase of the cohesion (3-18 kg/cm²), than conventional gelforming injection methods.

Impermeability

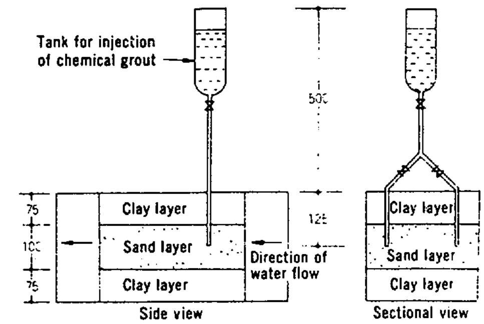
There exists a relationship between the increase in impermeability of the soil and the volumetric ratio of solidification (λ). The lower λ (for example: high waterpressure results in less expansion of the TACSS grout) the higher the density of the solidified soil.

The coefficient of permeability of alluvial sandy soil will be improved to around 10^{-7} cm/sec after solidification. In ground where there is water pressure of 5 kg/cm² or more, the coefficient of permeability will be even lower.

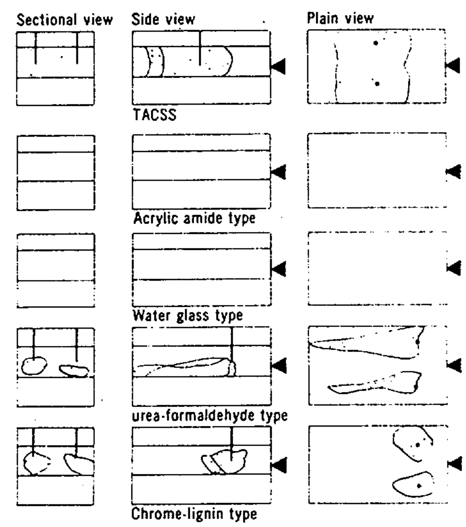
Relation between hydrodynamic pressure and volumetric ratio of solidification and unconfined compressive strength.



Model ground for water cut-off experiment.



Solidification of various chemical grouts in water cut-off experiment.



◀ Indicates the direction of water flow. A complete water cut-off wall was formed by TACSS only. Two kinds of other chemical grouts were entirely washed away.

Results of experiment on water cut-off in model ground with water flow.

Chemical Grout	Volume of Solidified Soil (cm³)	Volumetric Ratio of Solidification (λ)	Effective Rate (%)	Water Reducing Rate* (%)
TACSS	4750	7.92	300.8	100.0
Acrylic amide type	Washed away	0.00	0.0	0.0
Water glass type	Washed away	0.00	0.0	0.0
Urea-formaldehyde type	760	1.27	48.7	7.2
Chrom-lignin type	555	0.93	35.2	14.7

*Water deducing rate $= \frac{a-b}{a} \times 100$, where a: Flow of water per unit time before injection; b: Flow of water per unit time after injection

Conditions of water cut-off experiment in model ground with water flow.

Conditions of ground	Ground model	Sand layer with grain size of 0.6~1.2mm Sandwiched between clay layers
	Porosity of sand	38%
	Hydraulic head	120cm
	Hydraulic gradient	3.0
	Apparent flow velocity	1.39mm sec
	Real flow velocity	3.66mm sec
	Coefficient of permeability	4.98×10²cm sec
	Section of sand layer perpendicular to water flow	10cm×25cm
Conditions of injection	Mode of injection	Two injection pipes in one shot
	Volume of chemical grout injected	600ml
	Injection pressure	0.5kg cm²
	Injection time	15~30 sec
	Gel time	45 sec

TACSS APPLICATIONS IN NORTH AMERICA

A. Water Control

1) Dams

a. Brunswick/Topsham Hydroelectric

Owner: Central Main Power Company-Augusta, Maine
General Contractor: Cianbro Corporation-Pittsfield, Maine

P.V.C. waterstop vertically encased was leaking. It was determined that the leak originated approximately five (5) feet below the current placement elevation and that water was entering through a field splice, and under pressure, rising through the center bulb to the surface.

TACSS 020 NF was injected into center bulb and reacted against the water pressure sealing the void at its source.

b. James River Corporation Hydro

Owner: James River Corporation-Berlin, New Hampshire
Applicator: Jamieson Incorporated-Montpelier, Vermont

Sealing leakages through concrete dam and around penstock.

c. Smith Mountain Dam

Owner: Appalachian Power-Richmond, Virginia
Applicator: Concrete Repair Specialists-Lynchburg, Virginia

Seal leakage far below water level in dam.

2) Treatment Plants

a. Nutbush Creek Waste Water Plant-Henderson, North Carolina

Contractor: Paul H. Howard Company-Greensboro, North Carolina

Sealing water leaks in reservoir.

b. Shockoe Rentention Basin-Richmond, Virginia

Applicator: Concrete Repair Specialists-Lynchburg, Virginia

Stop severe leakage through waterstops in the new basin.

122 NORTH MILL STREET • ST. LOUIS, MICHIGAN

c. Waterproofing of Concrete Septic Tank

Owner: Huber Wafer Board-Easton, Maine
General Contractor: Merves Construction-Easton, Maine
Applicator: Jay-Kay Sales-Lewiston, Maine

The grouted joint between two connected sections of a large septic tank unit was leaking severly. The water table surrounding the tank was at an elevation approximately one (1) foot from the top of the tank. Through drilled holes in the bottom of the tank TACSS 020 NF was injected under pressure sealing the voids beneath the tank and the cracks, through the grouting materials.

3) Tunnels

a. Tunnel in Power Plant

Owner: Detroit Edison-Detroit, Michigan
General Contractor: Morrison-Knudsen Company-St. Clair, Michigan
Applicator: Structural Bonding Company-Flint, Michigan

Sealing leakage through expansion joints in cool water inlet tunnel of St. Clair Power Plant.

b. Subway-New York, New York

Owner: New York Transit Authority
Applicator: Expert Concrete Pumping Company-Long Island City, New York

Sealing leakages in side walls of subway tunnels.

4) Sewage Systems

a. Manhole Repairs-Montepelier, Vermont

Applicator: Jamieson Incorporated-Montpelier, Vermont

b. Concrete Manhole Repair-Flint, Michigan

Applicator: Structural Bonding Company-Flint, Michigan

5) Deep Excavations

a. Swimming Pool

Contractor: Blinderman Construction Company-Northbrook, Illinois
Westinghouse High School Project

Sealing hairline cracks in swimming pool.

b. Machine Pit

Owner: Taylor Forge Division-Memphis, Tennessee
Contractor: F. J. Jones Company-Southfield, Michigan

Sealing leakage through cold joints in concrete machine pit.

6) Mines

a. Sinking of Shaft

Owner: Falconbridge Nickel Mines Ltd.-Ontario, Canada
Location: Fraser Vent Shaft
Contractor: MacIsaac

During the sinking of the vent shaft, they inserted a fault zone at approximately six hundred (600) feet area that proved to be water bearing. Attempts to halt the inflow of water using cement grout techniques proved unsuccessful. The use of TACSS stopped all water leakage where it was injected.

b. Airshaft

Owner: Consolidation Coal Company-Morgantown, West Virginia
Location: Rudolf Shaft-Blacksville Number 1 Mine
Applicator: Graciano Corporation-Pittsburgh, Pennsylvania

Sealing leakage through cold joints in concrete shaft.

7) Artesian Waterflow Cut-Off

Contractor: CBA Engineering-B. C., Canada

Sealing water infiltration around casson through gravel zones between fifty (50) foot and fifteen (15) foot levels.

B. Soil Stabilization

1) Underpin Petroleum Tanks

Owner: Gulf Refineries-West Montreal, Quebec
Applicator: Canadian Grouting & Supplies Ltd.-Richmond, B.C.

Inject TACSS 025 NF under tanks to prevent settlement.

2) Underpin Foundation

Contractor: Expert Concrete Pumping Compnay-Long Island City, New York

Inject TACSS 025 NF under piles to increase bearing capacity prior to excavation, next to the footing.

BUILDING FOUNDATIONS

Owner: Peter Sharp & Co., 450 Park Ave. N.Y., NY
Contractor: New York Grout, Long Island City, NY

Injected TACSS 020NF into foundation wall to plug groundwater leaks.

Owner: Williams Real Estate
Contractor: New York Grout, Long Island City, NY

Injected TACSS 020NF into foundation wall and slab in several places to plug groundwater leaks.

1/26/82	33,337,140	8.?27	24
(as of 7/25/82)	106,966,366	111.595	284

*** A curie is a measure of radioactivity the way mph is a measure of speed. One curie equals 37 billion emissions of particles or waves per second. Government standards designated "permissible" levels of radioactivity in one/millionths and one/trillionths of one curie.*

the fissioning process inside a reactor core. This complicates the radioactivity and half-life decay characteristics.

The purpose of this article is to show that by making certain simplifying assumptions and using tables that account for the major radioactivity a rela-

Continued on page 4

From: The Waste Paper Vol. 5 (1)
Sierra Club RA Waste Campaign

Waste Graces Wayne

Wayne, New Jersey, twenty-five miles west of New York City, is an unlikely place for a nuclear waste dump. With its well-kept lawns, clean neighborhoods and shopping centers, the town is a look-alike to suburban America. But there is one difference – Wayne is a dump for thorium wastes.

In 1948, Rare Earths, Inc., under contract with the Atomic Energy Commission (AEC), began extracting thorium from a special type of sand called monazite. Thorium is a long-lived radioactive substance, needed to create uranium-233 for atomic bombs. Uranium-233 has now been replaced by plutonium. Rare Earths was purchased by Grace & Co. in 1956. Grace & Co. is also the former owner of Nuclear Fuel Services, the shut-down reprocessing plant at West Valley, N.Y.

The radioactive residue from the chemical extraction process was piled in uncovered mounds on the Wayne property. During heavy rains, water ran off an adjacent hill, carrying the thorium residue into a local stream, Sheffield Brook. Residents say the brook turned white during some rainstorms. Former Grace workers claim thorium waste was purposefully dumped into Sheffield Brook during periods of heavy run-off. In 1959, the AEC expressed alarm at the growing piles of thorium waste and asked Grace to come up with a solution.

Unlined Pits The mounds were eventually buried illegally in unlined pits on the Grace site, sometime between 1960 and 1964. A recent radiation survey by helicopter of the entire Town of Wayne has located another large *unlicensed* dump in the northwest corner of the town, known as the Riverdale section. Former Grace workers identified the dump. A local group, Concerned Citizens of Wayne, pressured federal officials to do the air survey which revealed the exact location of the Riverdale dump.

Analysis of spotty AEC records (most Grace & Co. records were destroyed in a fire of mysterious origin in 1977) shows that 76 tons of thorium, in 1,300 tons of residue, were buried at the Grace & Co. dump, and an unknown amount at the Riverdale dump. Recent Nuclear Regulatory Commission (NRC) testing shows that additional off-site areas have become contaminated. Piles of thorium waste have been found along Sheffield Brook and nearby Sheffield Park where children play. The radioactivity is at 40 times background levels and exceed the standards set by the Environmental Protection Agency for cleanup by a wide margin. The EPA standards are 5 pCi/g, whereas off-site locations have readings up to 562 pCi/g. Attempts by the mayor to re-open Sheffield Park were quickly withdrawn when Concerned Citizens collected 3,500 signatures on petitions in the period of one week, a tremendous response considering the Town of Wayne has only 55,000 residents.

The Grace & Co. site itself is expected to have radiation levels greatly exceeding off-site readings. An NRC survey report is due in December. A Department of Energy (DOE) report on the Riverdale dump is also in the pipeline. The full extent of radioactive contamination in Wayne will then be known. DOE intends to include the site in its program for remedial action at all Manhattan Project sites.

Questionable Circumstances Concerned Citizens want the illegal dumps cleaned up and have pressured the local Congressman Bob Roe for action. Other than performing measurements, no federal or state agency has come up with a clean-up plan. If Wayne follows the path of Canonsburg, Pa., Middlesex, N.J., and other Manhattan Project sites, tons of radioactive material which has moved off-site will be dug up and returned to the Grace & Co. site to be placed in a large, unstable, pile, all at federal expense. Though the Grace & Co. license was terminated in 1974, under questionable circumstances, (a former AEC inspector became consultant to the company), it is still owner of the Wayne site. The company may have some financial responsibility. Grace & Co., whose company motto reads, "one step ahead of the times," has maintained a low profile in the controversy.

The larger question of what to do with Manhattan Project waste dumps scattered about the country, has not been addressed by federal and state agencies. If no further action is taken, Manhattan Project sites such as Wayne, will join closed low-level waste dumps, such as West Valley, and mothballed nuclear reactors, as permanent reminders of this generation's nuclear folly. The brief period of operation of all these companies will bring thousands of years of monitoring and maintenance for future generations.

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