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Radiological Survey of the Shpack Landfill, Norton, Massachusetts

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HEALTH AND SAFETY RESEARCH DIVISION
OAK RIDGE NATIONAL LABORATORY

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Health and Safety Research Division

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Work performed
as part of the
Remedial Action Survey and
Certification Activities

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ABSTRACT

The results of a radiological survey of the Shpack Landfill, Norton, Massachusetts, are given in this report. The survey was conducted over approximately eight acres which had received radioactive wastes from 1946 to 1965. The survey included measurement of the following: external gamma radiation at the surface and at 1 m (3 ft) above the surface throughout the site; beta-gamma exposure rates at 1 cm (0.4 in.) from the surface throughout the site; concentrations of ^{226}Ra, ^{238}U, and ^{235}U in surface and subsurface soil on the site; and concentrations of ^{226}Ra, ^{238}U, ^{235}U, ^{230}Th, and ^{210}Pb in groundwater on the site and in surface water on and near the site. Results indicate that the radioactive contamination is confined to the site and to the swamp immediately adjacent to the site.

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted at the Shpack Landfill, located approximately three miles southwest of Norton, Massachusetts (Fig. 1). This site is a private landfill and is suspected of containing uranium materials which were derived from previous operations performed under contract to the Atomic Energy Commission (AEC).

The landfill comprises approximately eight acres and lies in the townships of Norton and Attleboro, Massachusetts. Five and one-half acres, owned by Mrs. Isadore Shpack, are located in the Town of Norton,

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*Eberline, Oak Ridge, Tennessee 37830.

and approximately 2.5 contiguous acres lie within the Attleboro corporate boundary and are owned by Attleboro Landfill, Inc. The landfill was developed on what was originally a swamp, by the progressive filling of a portion of the swamp with wastes, starting along Union Road and Peckham Street and proceeding southeast to the landfill's present terminus with Chartley Swamp. This dump site began receiving wastes in late 1946 and continued to receive both domestic and industrial wastes until it was closed by court order in 1965.[1]

Population in the immediate vicinity of the site is sparse. The only public thoroughfare near the site is a hard surface road, Union Road - Peckham Street, which passes along the site's northwest boundary. The nearest dwelling is approximately 150 feet from the site and receives its potable water supply from a shallow hand-dug well (approximately 12 feet deep). Very little development of the landfill occurred during the period 1946 to October 1951 (Fig. 2). After 1951, development was rather rapid, and by 1965, it had essentially assumed its present-day boundaries. Aerial photos of the landfill and surrounding area taken in 1970, 1971, and 1979, are shown in Figs. 3, 4, and 1, respectively.

The geology of the region is dominated by glacial deposits overlying bedrock. These unconsolidated deposits are 15 to 25 feet thick and are in turn overlain by organic deposits (peat) varying in thickness from 5 to 30 ft depending on the age and depth of the swamp. Groundwater in this area is produced from both bedrock and surficial aquifers. Wells drilled into bedrock aquifers often flow with their own pressure and are referred to as artesian. Wells producing from surficial deposits tend to stand at the level where encountered during drilling and are considered to be under water table conditions. (A geologic summary is given in Appendix I.)

Radiological survey measurements were made on the site during October and November 1978, by the Nuclear Regulatory Commission (NRC) and the Commonwealth of Massachusetts, Department of Public Health. During these surveys, elevated radiation levels were detected, and subsequent analyses of on-site samples confirmed the presence of radioactive materials in excess of background concentrations.[2]

The present survey was performed to characterize the existing radiological status of the site. It was conducted during the period August through October 1980, by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL). The survey included the following:

1. Beta-gamma dose rates at 1 cm (0.4 in.) from the ground surface, and external gamma radiation levels at the surface and at 1 m (3 ft) from the surface throughout the site.
2. Concentrations of ^{226}Ra, ^{238}U, and ^{235}U in surface and subsurface soil on the site.
3. Concentrations of ^{226}Ra, ^{238}U, ^{235}U, ^{230}Th, and ^{210}Pb in surface and subsurface water on the site.
4. Concentrations of ^{226}Ra, ^{238}U, ^{235}U, ^{230}Th, and ^{210}Pb in surface waters adjacent to the site and in ponds and streams that receive drainage from the site.
5. Gamma radiation levels at various depths in auger holes drilled on-site.
6. Radionuclide and elemental analysis of debris samples collected from the site.

SURVEY METHODS AND PROCEDURES

Measurement of Beta-Gamma Dose Rates and External Gamma Radiation Levels

The site was divided into 50 ft x 50 ft "survey blocks" by the rectangular grid system shown in Fig. 5.

Beta-gamma dose rates were measured 1 cm (0.4 in.) above ground surface at the center of each grid block using a Geiger-Mueller (G-M) survey meter (Appendix II). External gamma radiation levels were measured at the surface and at 1 m (3 ft) above ground surface using portable gamma-ray scintillation (NaI crystal) survey meters (Appendix II). Each survey block was then scanned using a gamma-ray scintillation survey meter held approximately 5 cm (2 in) above the ground surface. The maximum observed gamma radiation level in each block was recorded;

and at the location showing the maximum gamma, beta-gamma dose rate measurements were made 1 cm (0.4 in.) from the surface and gamma radiation level measurements were made at the surface and at 1 m (3 ft) above the surface.

Surface Soil Sampling

Surface soil samples taken from a depth of 0 to 5 cm (2 in.) were collected at the center of alternate grid blocks (Fig. 6). These locations were chosen to provide systematic and representative sampling. However, a number of "biased" samples were collected from locations showing elevated radiation levels. Biased samples of soil, metal, and debris from a number of these locations were analyzed to determine radioactive content and the probable origin of the radioactive materials.

Samples of soil were returned to ORNL, dried at 110°C for 24 hours, and pulverized to a particle size <500 μ (-35 mesh). Aliquots of the samples were counted on a Ge(Li) detector and the spectra analyzed by computer techniques (Appendix III). Concentrations of ^{238}U and ^{235}U were determined by neutron activation methods[3] and the isotopic abundance of uranium was determined by mass spectrometry.

Metal and debris samples were examined by X-ray emission spectroscopy, radiochemical procedures, and mass spectrometry. The results of the characterization and analyses of the miscellaneous metal and debris samples will be the subject of a separate report.

Subsurface Soil Sampling

This site is known to have received chemical wastes from local chemical industries during its period of operation. Numerous metal drums are scattered over the surface of the dump (Fig. 7). Most of these drums are empty and in various stages of decay; however, a few of them still contain unidentified liquids and solids. In order to preclude drilling into buried drums that might contain toxic materials, the area was mapped using a ground penetrating radar system (Appendix IV) and these data[4] were given consideration in the selection of drilling locations for subsurface investigation.

Holes were drilled with a motorized rig, equipped with a 6-inch diameter auger, at locations shown in Fig. 8. Because of the concern that drilling below the water table could result in contamination entering a potable aquifer below the floor of the swamp, holes were drilled only until water was encountered, usually at depths of 1 to 6 feet. A plastic pipe (PVC Schedule 40) with a 4-inch inside diameter was placed in the hole and a NaI scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a horizontal row of collimating slits on the side. This allowed measurement of gamma radiation intensities resulting from contamination within small fractions of hole depth. Measurements were usually made at 6-inch or 1-foot intervals. Logging of the core holes was done to determine the extent of subsurface contamination at each location. A soil sample was collected from each auger hole, usually at the point of maximum contamination as indicated by the "logging" data.

The gamma-ray logs were used to select locations where continuous cores of subsurface material were collected. A split-spoon sampler was used to collect cores; however, considerable difficulty was encountered in driving the sampler through rubble and debris and, consequently, the recovery rate of cored material was extremely low.

Subsurface soil samples were analyzed using the same methods and procedures as were used for surface soil.

Groundwater Sampling

Water samples were taken from each hole where water was found. In addition, water samples were collected from adjacent swamps, sloughs, and drainageways leading from the site (Figs. 6 and 10). A water sample was collected from the shallow (hand-dug) well that furnishes the water supply for the Shpack residence, approximately 150 feet from the landfill (Figs. 8 and 9). In addition, samples were collected from three monitoring wells located along the northwest perimeter of the site (Fig. 8). All water samples were analyzed using radiochemical techniques to determine ^{226}Ra, ^{230}Th, and ^{210}Pb concentrations. Isotope dilution-mass spectrometry,[5,6] fluorometry, and neutron activation methods were used for total U and ^{235}U determinations.

SURVEY RESULTS

Units of Measurement

Throughout this report, results of measurements are presented in terms of units of measure which are traditionally English. For purposes of comparison to the newly adopted SI Metric Units of Measure, a conversion table is presented in Appendix V.

Background Measurements

Background external gamma radiation levels at 1 m (3 ft) above the ground were measured at distances between 100 feet and 1 mile from the site at points southwest, northeast, northwest, and southeast of the site (see Fig. 10 for locations). These measurements ranged from 4 to 9 μR/h with an average of 7 μR/h. Soil samples, taken at the same locations, showed an average of 0.64 pCi of ^{226}Ra and 0.66 pCi of ^{238}U per gram of soil. These data are listed in Table 1.

Background beta-gamma dose rates, as measured with the G-M survey meters used in this survey, typically averaged approximately 0.02 mrad/h. It should be pointed out that readings at typical background levels made with the G-M survey meter are not reproducible; hence, little significance should be attached to variations in on-site beta-gamma dose rate measurements reported at or near the background average.

All direct meter readings reported in this document are gross readings; background radiation levels have not been subtracted. Similarly, background levels have not been subtracted from radionuclide concentrations measured in environmental samples.

Measurement of Beta-Gamma Dose Rates and External Gamma Radiation Levels

Grid block center point measurements of gamma radiation levels at the surface and at 1 m (3 ft) above the surface, and beta-gamma dose rates at 1 cm (0.4 in.) from the surface are reported in Table 2. Maximum gamma radiation levels observed in individual survey blocks and beta-gamma dose rates measured at the point of maximum gamma are given in Table 3. If a survey block showed no elevated external gamma

radiation level equal to or greater than twice the average for that block, the block was considered as having no point of maximum gamma.

The average external gamma radiation level at 1 m (3 ft) from the ground measured at survey block center points was 6 μR/h in both the Shpack (Fig. 5) and Attleboro (Fig. 5) sections of the landfill. There was no significant difference between external gamma radiation levels measured at 1 m (3 ft) and corresponding measurements made at ground surface. The average beta-gamma dose rate at 1 cm (0.4 in.) from ground surface was 0.02 mrad/h. The maximum observed external gamma radiation level at 1 m (3 ft) from the ground on this site was 365 μR/h, and the corresponding gamma radiation level at the surface was 1450 μR/h. The maximum observed beta-gamma dose rate at 1 cm (0.4 in.) was 30 mrad/h.

The external gamma radiation level in the yard of the Shpack residence ranged from 4 to 7 μR/h with the exception of a small cinder-filled area at the entrance to a detached garage where levels of 10 μR/h were observed.

Surface Soil Sampling

As discussed previously, most sampling locations were chosen to provide systematic unbiased sampling. In addition to systematic sampling, samples were collected at a number of locations showing elevated gamma radiation levels. Sample locations are shown in Fig. 6 and results of sample analyses are presented in Table 4. Samples collected from locations showing elevated radiation levels are designated as biased samples and a "B" precedes the sample numbers in Fig. 6 and in Table 4.

Concentrations of ^{226}Ra in systematic soil samples ranged from <1 to 11 pCi/g. Concentrations as high as 47,000 pCi of ^{226}Ra per gram of soil were observed in biased samples. Of the 72 systematic soil samples analyzed for ^{226}Ra, all except 8 were at background levels (≤1 pCi/g). The radioactivity-bearing material was isolated from a number of surface soil and debris samples, and in every case in which the primary radionuclide was identified as ^{226}Ra, the radioactivity was associated with small rings (approximately 1 cm (0.4 in.) in diameter) or hemi-spherical glass beads set in metal holders with threaded shanks.

Examples of these anomalies are shown in Fig. 11. These objects are suggestive of wastes from industries engaged in the manufacture of instruments with luminous markers and/or dials of the type often found in cockpits of airplanes of 1940's and 1950's vintage.

Concentrations of ^{238}U in systematic soil samples ranged from <1 to 140 pCi/g. The maximum concentration observed in a surface soil sample ("biased") was 96,300 pCi of ^{238}U per gram of soil. Concentrations of ^{235}U ranged from 0.03 to 51 pCi/g in systematic samples and from 0.47 to 7,080 pCi/g in biased soil samples. Approximately two-thirds (63 of 91) of the surface soil samples were subjected to isotope dilution-mass spectrometry for isotopic abundance and total uranium determinations; depleted, natural, and enriched uranium were all found on the site. The degree of enrichment was as high as 76% ^{235}U. Of the 63 samples subjected to mass spectrometry, 5 were depleted, 21 were natural, and 37 were enriched. Sixteen soil samples were selected for ^{236}U isotopic abundance determination. All sixteen samples contained significant fractions of ^{236}U. The isotopic abundance of ^{236}U in these samples ranged from 0.0043% to 0.293%. The presence of the isotope ^{236}U is indicative that the uranium contamination found on this site originated with reprocessed reactor fuel.

Subsurface Soil Sampling

Holes were augered at locations shown in Fig. 8. One soil sample was taken from each hole, usually from the point of maximum gamma radiation level as indicated by the gamma-ray log. If the point of maximum gamma was more than three feet below the ground surface, the sample was collected from a depth of 0 to 1 foot.

At locations 17, 18, 38, 51, and 62, a split-spoon sampler was used to collect subsurface soil samples at known depths. Considerable difficulty was encountered in "coring" on this site and the recovery rate of cored material was extremely low.

Concentrations of ^{226}Ra, ^{238}U, and ^{235}U in subsurface soil samples are given in Table 5. The maximum observed concentration of ^{226}Ra in subsurface soil was 4,650 pCi/g. The maximum concentration of ^{238}U was 106,000 pCi/g (hole 62, Table 5), and the maximum concentration of ^{235}U

was 5,640 pCi/g (hole 61, Table 5). Approximately 70% of the subsurface soil samples were subjected to mass spectrometry for isotopic abundance analyses and, as in surface soil, depleted uranium, natural uranium, and enriched uranium were found. Sixty-four percent of the samples subjected to isotopic abundance analyses showed some degree of enrichment. Enrichments as high as 69% ^{235}U were observed.

Each of the auger holes and core holes was "logged" using a gamma-ray scintillation detector as described in the section, "Survey Methods and Procedures". The logging technique used here is not radionuclide-specific, and since the type and composition of the radioactive contamination encountered on this site varied widely, concentrations of radionuclides in soil could not be reliably estimated from the logging data. However, the logging data were used in conjunction with the soil analyses data to estimate the region of contamination in the auger holes. It appears from a comparison of these data that a reading of 1,000 CPM or greater on the shielded scintillator indicates the presence of elevated concentrations of ^{226}Ra and/or uranium. Consequently, soil giving rise to 1,000 CPM or greater on the scintillator, or containing more than 5 pCi/g of either ^{226}Ra or total uranium, as determined from soil analyses, was considered as contaminated soil. Using these criteria, an estimate of the region of contamination in each hole was made. These data are listed in Table 6. Contamination was found at or below the water table in 9 holes and above the water table in 23 holes. A word of caution should be added in the interpretation of the data presented in Table 6. Only those holes yielding a positive indication of contamination, using the previously stated criteria, are listed as having a region of contamination; an entry of "none" opposite a location means only that no positive indication of contamination was observed using the "logging" and sampling procedures employed on this site. Because of the difficulty of detecting uranium with this in-situ hole logging device, concentrations of uranium, in the absence of ^{226}Ra, considerably in excess of 5 pCi/g may have gone undetected.

Concentration of Radionuclides in Surface Water and Groundwater

Water was collected from each auger or core hole where it was encountered in sufficient quantity for sampling. Samples were analyzed for ^{226}Ra, ^{238}U, ^{235}U, ^{230}Th, and ^{210}Pb; results of these analyses are given in Table 7. No sample exceeded the respective Concentration Guide (CG_w) as stated in 10 CFR 20 for uranium, ^{230}Th or ^{210}Pb. Three samples exceeded the CG_w for ^{226}Ra. The maximum concentrations of ^{238}U and ^{235}U found in water taken from bore holes were 4400 pCi/l and 2400 pCi/l, respectively. The maximum concentration of ^{226}Ra was 1400 pCi/l.

Concentrations of ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb in water samples collected from the swamp adjoining the landfill (Fig. 6) are listed in Table 8. Concentration guides for the respective radionuclides in water are included for comparison. In each sample, the concentration of the radionuclide is below the CG_w's stated in 10 CFR 20 (Appendix VI). Concentrations of radionuclides in silt samples collected from the same locations are presented in Table 9. All of the samples showed concentrations of ^{238}U and/or ^{235}U above normal background levels (typically near 1 pCi/g of ^{238}U and 0.04 pCi/g of ^{235}U). Several samples contained ^{226}Ra concentrations in excess of background concentrations (typically 1 pCi/g). Five of the samples were subjected to mass spectrometry for isotopic abundance analyses. All five showed some degree of enrichment in ^{235}U (maximum observed was 6%). These data indicate that the radioactive contamination in the dump site has migrated into and spread across the landlocked portion of the swamp (samples 1 through 7, 12, and 13, Fig. 6) and into the edge of Chartley Swamp (samples 9 and 10, Fig. 6).

Water and silt samples were collected from three locations along drainage pathways leading from Chartley Swamp and Chartley Pond (see Fig. 10 for sampling locations). In addition, a water sample was collected from the Shpack well located approximately 100 feet from the northeast boundary of the landfill (Fig. 8). Concentrations of ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb found in these samples are given in Table 10: concentration guides for the respective radionuclides in water are

included for comparison. All water samples showed concentrations of radionuclides well below the CG_w's for the respective nuclides, and all silt samples (locations 1 and 3) contained radioactive materials at or near the background concentration.

SIGNIFICANCE OF FINDINGS

A radiological survey was conducted of a landfill area near Norton, Massachusetts, known as the Shpack Landfill. The results of this survey indicate the presence of radioactive materials throughout the landfill area. The distribution of the contamination was found to be uneven and spotty, both horizontally and vertically, and in many cases, extended into the groundwater. Contamination was detected in groundwater samples taken from bore holes. In all samples except three, the concentration of radionuclides was below the concentration guide (CG_w) stated in 10 CFR 20. Results of water samples taken from three monitoring wells along the northeast boundary of the site and from the Shpack well indicate that the groundwater contamination is not migrating offsite. Contamination has moved into and across the landlocked portion of the swamp lying on the landfill site and to a lesser extent into the edge of the adjacent Chartley Swamp (Fig. 6). The relatively low level contamination found in the edge of Chartley Swamp ($\sim$1 ft from the surface of the fill material) was likely transported there by the physical washing of contaminated debris from the land surface by storm or flood waters. Silt samples collected from drainageways from the site indicate no significant movement of surface contamination from the site into surface waters.

The primary radioactive contaminants found on the site were ^{226}Ra, and uranium (^{238}U and ^{235}U). The radium and uranium appear to occur independently of each other and their respective characterizations indicate independent origins. The ^{226}Ra appears to be associated with objects (e.g., glass beads and rings) that suggest industrial wastes as their source. The uranium, on the other hand, appears in a variety of forms and occurs as depleted, natural, and enriched uranium. Uranium was found as a metal (alloy), a yellow crystalline compound, and as a contaminant mixed with the soil. Mass spectrometry revealed uranium

enrichments as high as 76% ^{235}U in soil samples and as high as 93% ^{235}U in metal samples. Uranium in both metal and soil showed significant fractions of ^{236}U. The isotopic abundance of ^{236}U ranged as high as 0.29% in soil and as high as 0.45% in metal. The presence of the isotope ^{236}U points to reprocessed reactor fuel as the source of at least a portion of the uranium found on the site.

The maximum external gamma radiation measured at 1 m (3 ft) on the site was 365 μR/h and the maximum beta-gamma dose rate at the surface was 30 mrad/h. Elevated concentrations of ^{226}Ra, ^{238}U, and ^{235}U were found in both surface and subsurface soil. Maximum concentrations observed were: ^{226}Ra - 47,000 pCi/g, ^{238}U - 106,000 pCi/g, and ^{235}U - 7,080 pCi/g.

Concentrations of radionuclides in water samples collected from drainage pathways from the site were well below the concentration guides stated in 10 CFR 20. Off-site soil samples contained normal terrestrial concentrations of ^{226}Ra and ^{238}U.

An evaluation has been made of current radiation exposures at the Shpack Landfill, and is presented in Appendix VII of this report. The purpose of this evaluation is to present information which will permit the reader to compare current radiation exposures from the site to normal background exposures for that part of Massachusetts as well as to scientifically biased guideline values established for the protection of radiation workers and members of the general public.

This survey characterized the radioactive contamination on the surface of the landfill and to the depth of the water table only. If more detailed information as to the depth of subsurface contamination is needed, additional drilling will be necessary. This will require drilling through the fill material until natural formations are encountered. Even with additional depth information, the spotty nature and uneven distribution of the contamination in the landfill will result in very imprecise estimates of the volume of contaminated material contained on the site. The impact on the environment of the additional drilling and sampling has been addressed in the Environmental Impact Evaluation (EIE) (Appendix VIII). The EIE concludes that the proposed drilling and sampling program would have no significant effect on contaminant migration from the site.

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ORNL-Photo 1203A-81

Fig. 1. Aerial view of the Shpack Landfill and surrounding area, September 1979.

ORNL-Photo 3280-81

Fig. 2. Aerial view of the Shpack Landfill and surrounding area, October 1951.

ORNL-Photo 3281-81

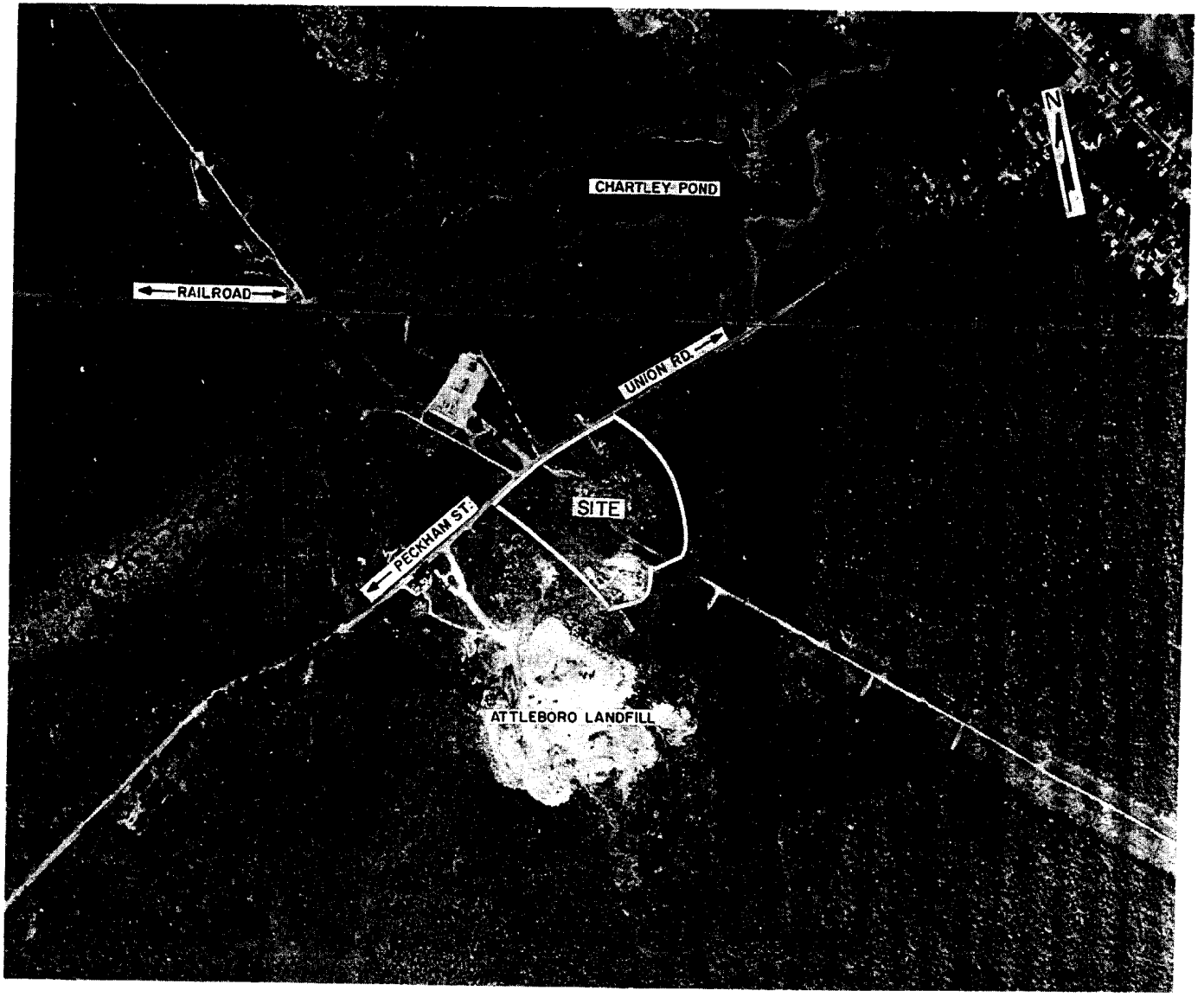


Fig. 3. Aerial view of the Shpack Landfill and surrounding area, October 1970.

ORNL-Photo 3282-81

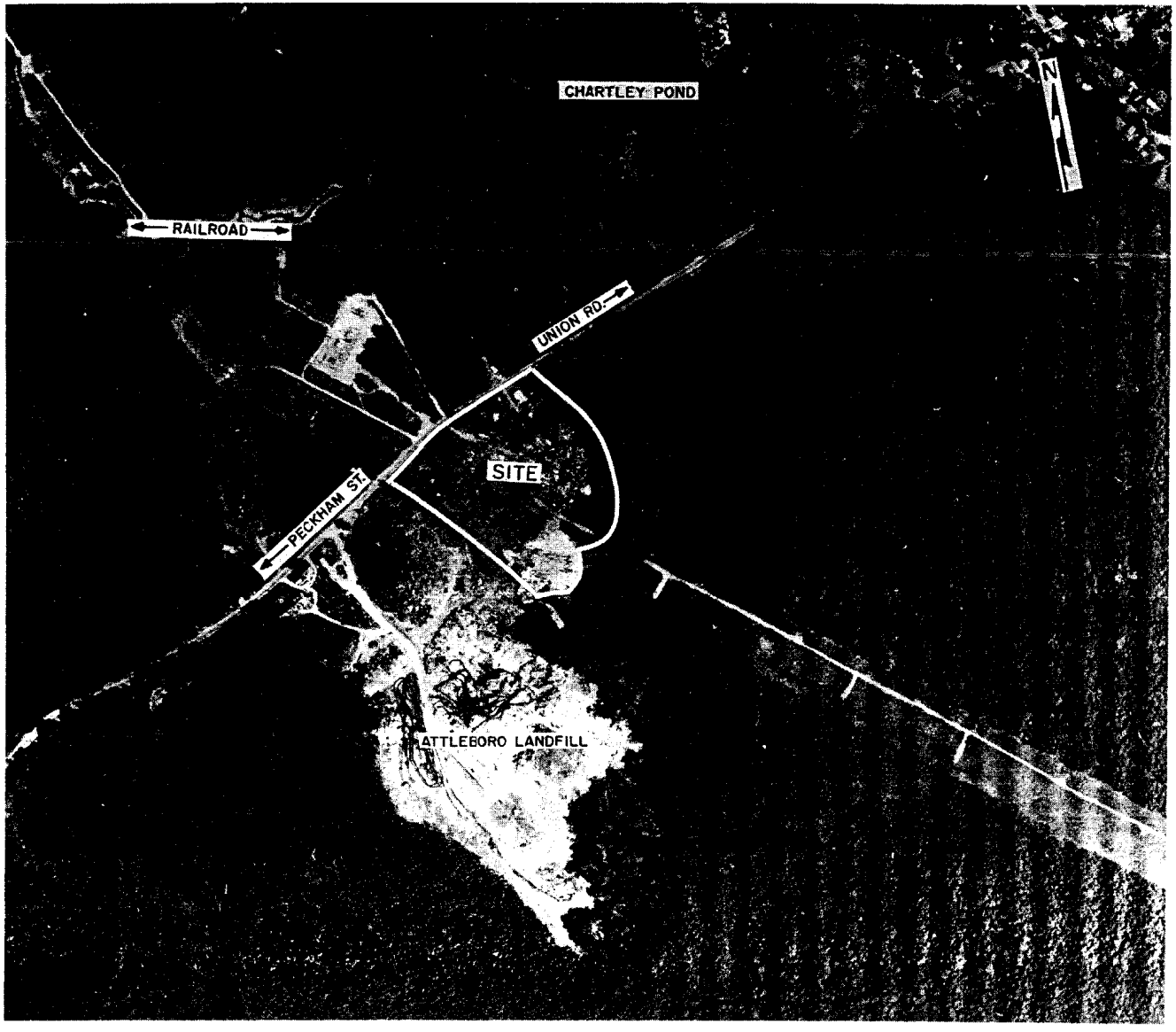


Fig. 4. Aerial view of the Shpack Landfill and surrounding area, August 1971.

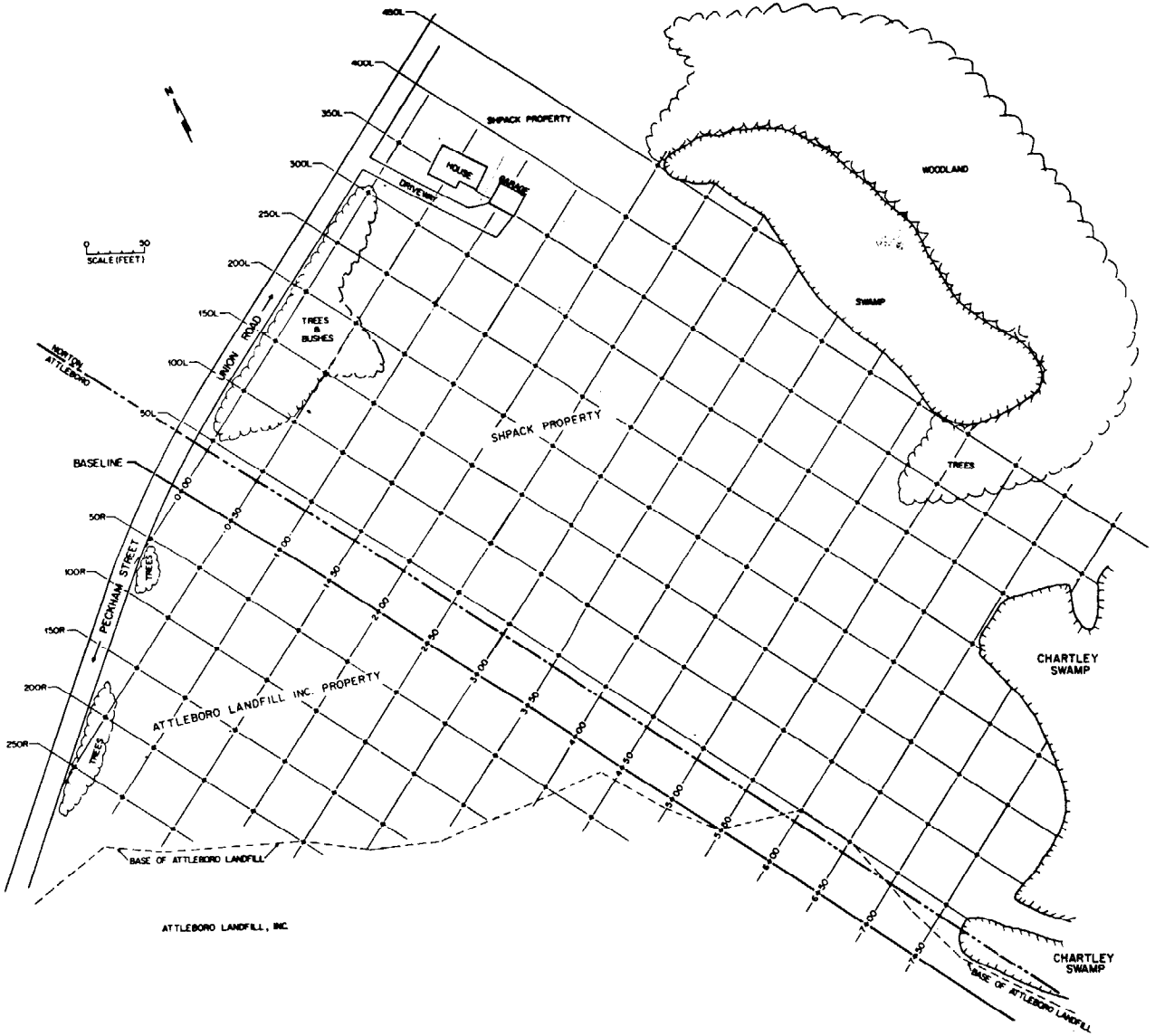


Fig. 5. Scaled drawing showing 50 ft x 50 ft grid system used in survey.

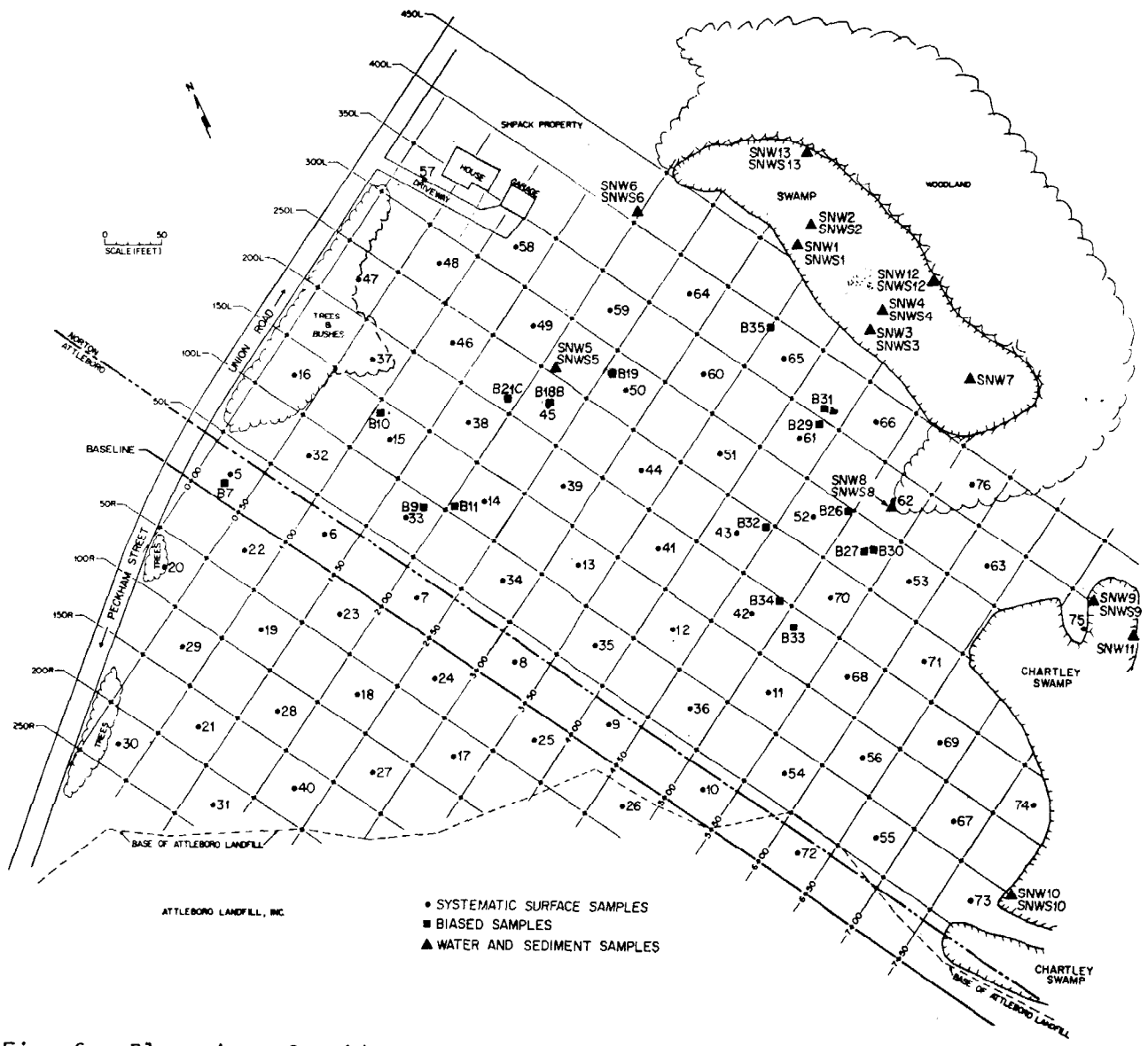


Fig. 6. Plan view of grid system for the site showing numbered locations of surface soil, water, and silt samples.

ORNL-Photo 2344-81

Fig. 7. Shpack Landfill showing barrels and debris on surface of landfill.

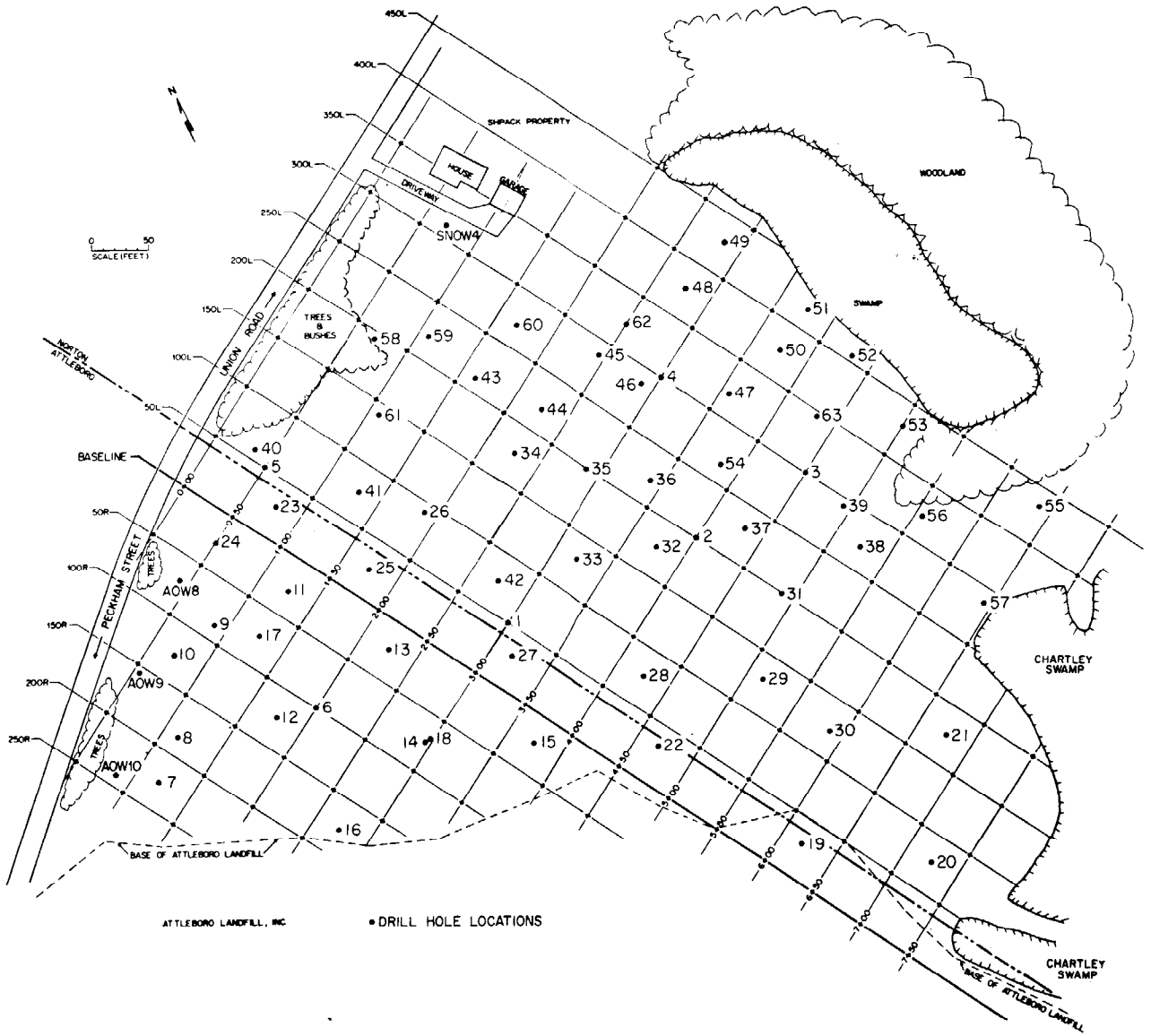


Fig. 8. Location of drill holes, monitoring wells (AOW), and Shpack potable water well (SNOW4).

ORNL Photo 2343-81

Fig. 9. Shpack residence located approximately 150 ft from the northeast boundary of the landfill.

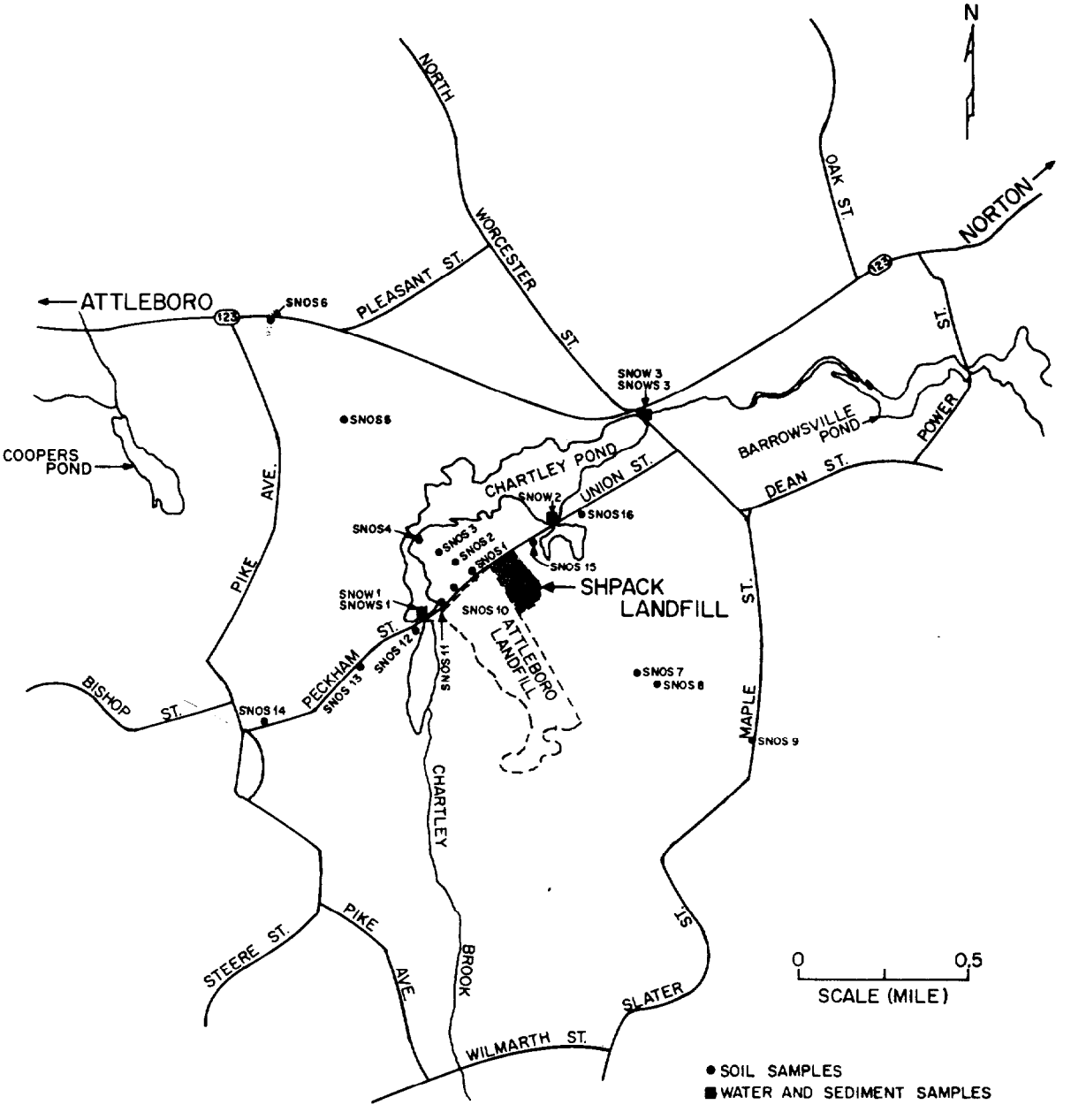
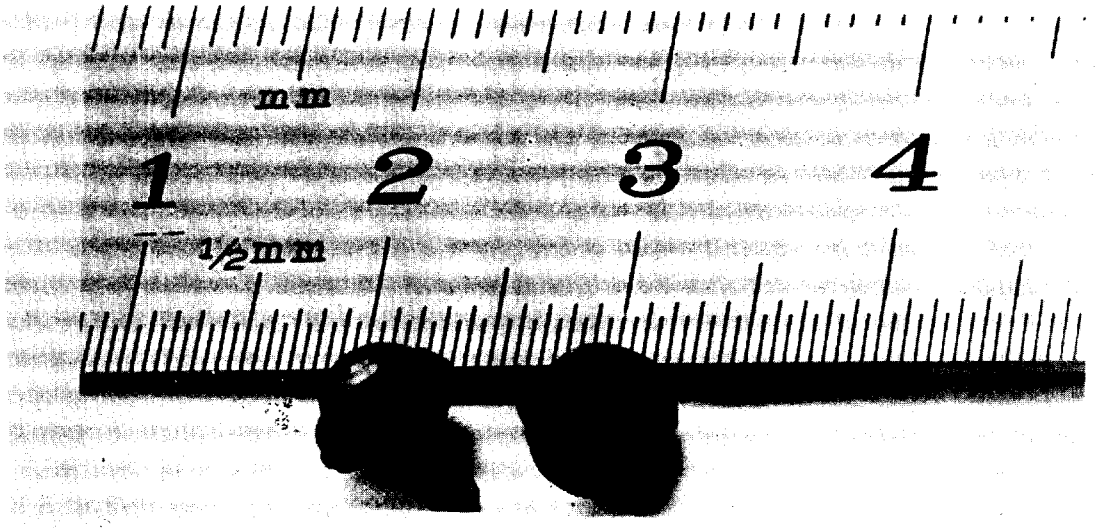


Fig. 10. Locations of off-site soil, water, and silt samples, and background external gamma radiation measurements.

ORNL-Photo 3081-81



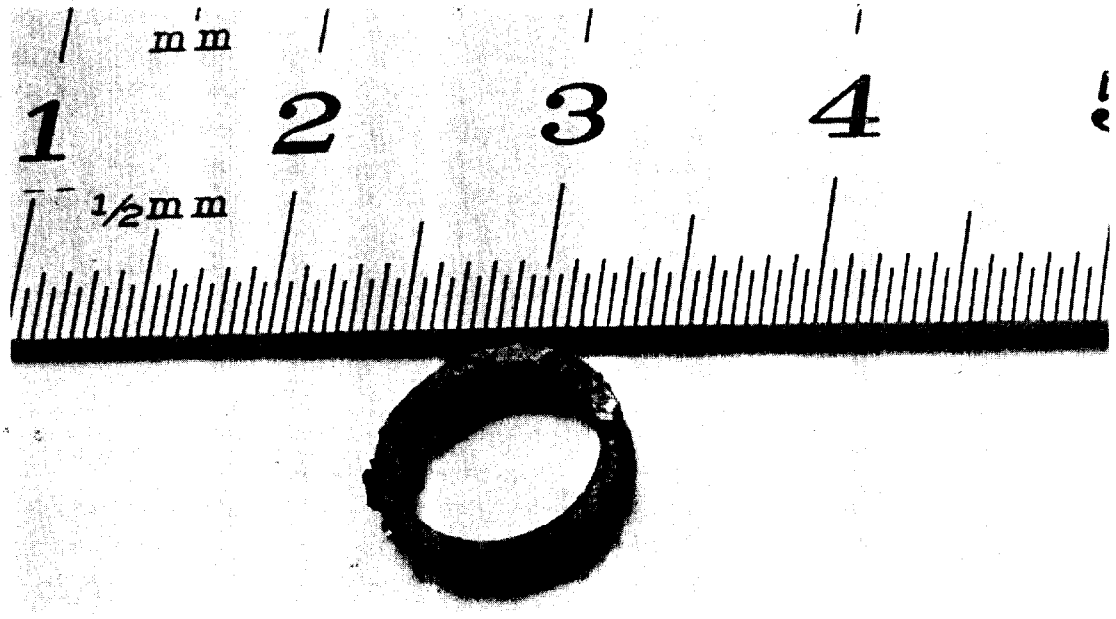


Fig. 11. View of two types of ^{226}Ra-bearing objects found in the Shpack Landfill.

Table 1. Concentration of ^{226}Ra and ^{238}U in Off-Site Soil Samples

Sample No.[a]	Concentration of Radionuclide (pCi/g)	
	^{226}Ra	^{238}U
SNOS 1	0.71	0.71
SNOS 2	0.66	0.65
SNOS 3	0.63	0.60
SNOS 4	0.57	0.67
SNOS 5	0.57	0.57
SNOS 6	0.70	0.63
SNOS 7	0.57	0.57
SNOS 8	0.77	0.79
SNOS 9	0.63	0.60
SNOS 10	0.57	0.64
SNOS 11	0.62	0.85
SNOS 12	0.48	0.58
SNOS 13	0.64	0.56
SNOS 14	0.79	0.73
SNOS 15	0.58	0.57
SNOS 16	0.80	0.79
Average	0.64 ± 0.09	0.66 ± 0.09

[a]Refer to Figure 10 for sample location.

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
	Shpack Property		
0 + 25, 75L	9	8	0.02
0 + 75, 75L	7	7	0.03
1 + 25, 75L	6	6	0.02
1 + 75, 75L	6	8	0.02
2 + 25, 75L	5	5	0.02
2 + 75, 75L	5	4	0.02
3 + 25, 75L	5	5	0.02
3 + 75, 75L	5	5	0.02
4 + 25, 75L	5	5	0.02
4 + 75, 75L	5	5	0.02
5 + 25, 75L	4	5	0.02
5 + 75, 75L	*b*	*b*	0.02
6 + 25, 75L	4	4	0.02
6 + 75, 75L	5	5	0.03
7 + 25, 75L	6	6	0.01
7 + 75, 75L	6	5	0.02
0 + 25, 125L	6	6	0.02
0 + 75, 125L	12	9	0.05
1 + 25, 125L	6	7	0.02
1 + 75, 125L	15	8	0.10
2 + 25, 125L	18	17	0.05
2 + 75, 125L	5	5	0.02
3 + 25, 125L	4	5	0.02
3 + 75, 125L	5	5	0.02
4 + 25, 125L	4	5	0.02
4 + 75, 125L	5	5	0.03

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
5 + 25, 125L	9	8	0.02
5 + 75, 125L	7	5	0.04
6 + 25, 125L	6	5	0.03
6 + 75, 125L	7	6	0.03
7 + 25, 125L	7	6	0.03
7 + 75, 125L	4	5	0.02
0 + 25, 175L	6	6	0.02
0 + 75, 175L	6	6	0.03
1 + 25, 175L	6	7	0.03
1 + 75, 175L	7	6	0.04
2 + 25, 175L	5	5	0.02
2 + 75, 175L	6	5	0.01
3 + 25, 175L	5	5	0.02
3 + 75, 175L	7	7	0.02
4 + 25, 175L	5	5	0.02
4 + 75, 175L	4	4	0.01
5 + 25, 175L	4	4	0.02
5 + 75, 175L	5	5	0.02
6 + 25, 175L	4	5	0.02
6 + 75, 175L	5	5	0.02
0 + 25, 225L	6	6	0.01
0 + 75, 225L	6	5	0.01
1 + 25, 225L	6	6	0.01
1 + 75, 225L	5	5	0.02
2 + 25, 225L	6	10	0.02
2 + 75, 225L	38	9	0.09
3 + 25, 225L	4	4	0.02

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
3 + 75, 225L	4	4	0.01
4 + 25, 225L	5	6	0.03
4 + 75, 225L	6	7	0.02
5 + 25, 225L	7	7	0.02
5 + 75, 225L	4	4	0.02
6 + 25, 225L	5	5	0.02
6 + 75, 225L	5	5	0.02
0 + 25, 275L	7	6	0.02
0 + 75, 275L	7	6	0.02
1 + 25, 275L	7	6	0.02
1 + 75, 275L	6	6	0.02
2 + 25, 275L	5	5	0.01
2 + 75, 275L	4	5	0.01
3 + 25, 275L	5	5	0.02
3 + 75, 275L	4	5	0.01
4 + 25, 275L	5	6	0.02
4 + 75, 275L	7	7	0.01
5 + 25, 275L	52	53	0.12
5 + 75, 275L	8	7	0.02
6 + 25, 275L	6	6	0.10
0 + 25, 325L	7	6	0.02
0 + 75, 325L	7	7	0.02
1 + 25, 325L	7	6	0.10
1 + 75, 325L	6	6	0.02
2 + 25, 325L	6	7	0.02
2 + 75, 325L	5	7	0.02
3 + 25, 325L	4	5	0.10

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
3 + 75, 325L	7	5	0.02
4 + 25, 325L	9	9	0.02
4 + 75, 325L	7	7	0.02
5 + 25, 325L	9	10	0.03
5 + 75, 325L	6	6	0.02
6 + 25, 325L	5	6	0.02
6 + 75, 325L	7	6	0.02
2 + 25, 375L	3	4	0.01
2 + 75, 375L	6	5	0.01
3 + 25, 375L	7	7	0.02
3 + 75, 375L	5	4	0.02
4 + 25, 375L	4	5	0.10
4 + 75, 375L	3	4	0.01
6 + 25, 375L	6	5	0.02
6 + 75, 375L	6	5	0.03
Attleboro Landfill, Inc., Property			
0 - 25, R25	6	6	0.02
0 + 25, R25	7	7	0.02
0 + 75, R25	8	7	0.03
1 + 25, R25	17	9	0.03
1 + 75, R25	5	5	0.02
2 + 25, R25	5	5	0.02
2 + 75, R25	5	5	0.02
3 + 25, R25	6	5	0.02
3 + 75, R25	4	4	0.02
4 + 25, R25	5	5	0.02

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
4 + 75, R25	5	5	0.02
5 + 25, R25	5	5	0.02
5 + 75, R25	6	6	0.02
6 + 25, R25	7	6	0.02
0 - 25, R75	7	6	0.03
0 + 25, R75	8	7	0.03
0 + 75, R75	8	7	0.02
1 + 25, R75	6	6	0.02
1 + 75, R75	6	5	0.02
2 + 25, R75	6	5	0.02
2 + 75, R75	5	5	0.02
3 + 25, R75	6	6	0.03
3 + 75, R75	5	6	0.02
4 + 25, R75	6	5	0.02
0 + 25, R125	8	7	0.02
0 + 75, R125	7	7	0.02
1 + 25, R125	6	6	0.02
1 + 75, R125	7	7	0.02
2 + 25, R125	7	6	0.02
2 + 75, R125	5	5	0.02
3 + 25, R125	6	6	0.02
0 + 25, R175	7	7	0.03
0 + 75, R175	7	7	0.04
1 + 25, R175	7	7	0.04
1 + 75, R175	7	7	0.02
2 + 25, R175	8	7	0.03
2 + 75, R175	6	6	0.03

Table 2. External Gamma Radiation Levels and Beta-Gamma Dose Rates Measured at the Center Point of Grid Blocks (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
0 + 25, R225	7	7	0.04
0 + 75, R225	7	7	0.02
1 + 25, R225	7	7	0.02
1 + 75, R225	7	7	0.02
2 + 25, R225	6	6	0.02
0 + 25, R275	8	7	0.02
0 + 75, R275	7	7	0.02
1 + 25, R275	8	7	0.04
0 - 25, 25L	6	7	0.02
0 + 25, 25L	6	6	0.02
0 + 75, 25L	6	7	0.02
1 + 25, 25L	5	5	0.02
1 + 75, 25L	5	5	0.02
2 + 25, 25L	6	6	0.02
2 + 75, 25L	4	5	0.02
3 + 25, 25L	5	5	0.03
3 + 75, 25L	5	4	0.02
4 + 25, 25L	5	5	0.02
4 + 75, 25L	5	5	0.02
5 + 25, 25L	5	5	0.02
5 + 75, 25L	5	5	0.02
6 + 25, 25L	15	6	0.02

[a]Refer to Fig. 5 for location.

[b]No reading taken.

Table 3. External Gamma Radiation Levels and Beta-Gamma Dose Rates in Survey Blocks Measured at Points Showing Maximum Gamma Radiation Levels

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
	Shpack Property		
0 + 15, 70L	11	6	ND[b]
1 + 42, 65L	50	8	0.05
1 + 95, 91L	1300	110	9.0
4 + 96, 57L	55	6	0.13
5 + 20, 82L	35	7	ND[b]
5 + 66, 94L	18	5	0.04
6 + 35, 54L	22	5	0.06
7 + 10, 98L	22	5	0.07
0 + 82, 128L	60	12	0.08
1 + 20, 138L	450	45	0.75
1 + 80, 104L	80	20	0.17
2 + 03, 105L	360	36	0.63
2 + 50, 106L	250	22	0.40
3 + 15, 125L	9	4	0.03
3 + 85, 120L	18	1	0.04
4 + 92, 125L	33	1	ND[b]
5 + 14, 124L	50	9	0.07
0 + 88, 150L	110	12	0.33
1 + 04, 190L	120	7	0.18
1 + 51, 176L	110	6	ND[b]
2 + 00, 199L	90	8	0.75
2 + 83, 200L	55	6	0.10
3 + 46, 163L	55	6	0.18
3 + 95, 170L	27	6	0.06
4 + 33, 180L	36	6	0.05
4 + 88, 199L	180	7	0.28

Table 3. External Gamma Radiation Levels and Beta-Gamma Dose Rates in Survey Blocks Measured at Points Showing Maximum Gamma Radiation Levels (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
5 + 08, 190L	27	5	0.03
6 + 00, 158L	13	6	0.04
1 + 25, 205L	145	7	0.23
1 + 85, 207L	230	9	2.0
2 + 25, 220L	550	40	7.0
2 + 37, 202L	65	6	0.18
3 + 23, 348L	55	9	0.10
3 + 60, 208L	27	5	0.08
4 + 48, 245L	180	29	0.50
4 + 86, 237L	45	12	0.09
5 + 10, 250L	365	80	0.75
2 + 44, 300L	75	16	0.13
1 + 95, 255L	365	9	0.13
2 + 84, 285L	90	10	0.06
3 + 10, 265L	25	6	0.05
3 + 70, 300L	200	22	0.45
4 + 30, 250L	110	15	0.30
4 + 98, 294L	1450	72	8.5
5 + 28, 275L	590	80	20
2 + 49, 318L	1450	365	30
2 + 66, 318L	270	27	0.5
3 + 03, 303L	73	10	0.19
3 + 69, 300L	225	27	0.25
4 + 34, 347L	1450	320	5.0
4 + 90, 315L	100	25	0.14
5 + 25, 300L	180	45	0.16
2 + 10, 395L	18	ND[b]	ND[b]

Table 3. External Gamma Radiation Levels and Beta-Gamma Dose Rates in Survey Blocks Measured at Points Showing Maximum Gamma Radiation Levels (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
2 + 55, 350L	105	6	0.13
3 + 50, 384L	73	9	0.12
3 + 51, 380L	62	9	0.09
4 + 48, 380L	125	6	0.25
4 + 80, 390L	36	10	0.07
5 + 02, 370L	12	7	ND[b]
2 + 35, 412L	73	5	0.13
2 + 95, 435L	40	13	0.03
3 + 07, 438L	320	33	0.60
3 + 65, 470L	15	9	ND[b]
4 + 30, 406L	110	11	0.40
4 + 90, 403L	15	6	ND[b]
	Attleboro Landfill, Inc., Property		
0 + 47, 30R	73	5	0.11
0 + 85, 30R	67	7	0.17
1 + 20, 40R	110	9	0.50
2 + 00, 50R	17	5	0.03
2 + 12, 30R	13	7	0.04
3 + 05, 38R	18	6	0.03
0 + 90, 90R	62	9	0.13
1 + 40, 98R	58	9	0.10
2 + 16, 66R	15	8	0.05
2 + 87, 66R	55	9	0.09
3 + 15, 68R	36	8	0.06
3 + 52, 78R	22	7	0.05
1 + 50, 113R	13	9	0.03

Table 3. External Gamma Radiation Levels and Beta-Gamma Dose Rates in Survey Blocks Measured at Points Showing Maximum Gamma Radiation Levels (continued)

Grid Location[a]	External Gamma Radiation Levels at Surface (μR/h)	External Gamma Radiation Levels at 1 m (μR/h)	Beta-Gamma Dose Rates at 1 cm (mrad/h)
1 + 59, 115R	14	10	0.04
1 + 12, 188R	82	9	0.18
2 + 12, 200R	15	8	0.04
2 + 60, 175R	36	5	0.05
0 + 93, 249R	22	5	0.05
1 + 14, 233R	36	7	0.08
1 + 94, 202R	135	6	5.0
2 + 05, 215R	110	6	0.40
0 + 85, 50L	70	6	ND[b]
0 + 25, 15L	230	7	0.30
0 + 80, 30L	730	11	1.5
1 + 62, 09L	20	7	0.03
2 + 50, 16L	15	5	0.02
2 + 70, 08L	50	5	0.08
3 + 20, 35L	180	5	0.25
4 + 15, 12L	9	5	0.05
4 + 70, 35L	110	5	0.15
5 + 70, 35L	11	5	0.04

[a]See Fig. 5 for location.

[b]ND - Not determined at this location.

Table 4. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Surface Soil Samples

Sample Number[a]	Grid Location	Concentration of Radionuclide (pCi/g)		
		^{226}Ra	^{238}U	^{235}U
		Shpack Property		
11	5 + 25, 125L	0.86	140	3.2
12	4 + 25, 125L	0.84	1.7	0.18
13	3 + 25, 125L	0.61	0.75	0.20
14	2 + 25, 125L	1.0	6.7	0.37
15	1 + 25, 125L	0.67	2.9	0.14
16	0 + 25, 125L	0.70	3.1	0.12
32	0 + 75, 75L	0.77	0.84	0.06
33	1 + 75, 75L	0.43	0.84	0.62
34	2 + 75, 75L	0.69	0.68	0.04
35	3 + 75, 75L	0.79	2.1	0.10
36	4 + 75, 75L	0.83	1.0	0.05
37	0 + 75, 175L	0.71	0.58	0.17
38	1 + 75, 175L	0.79	14	0.22
39	2 + 75, 175L	4.3	8.4	0.13
41	3 + 75, 175L	0.69	1.2	0.22
42	4 + 75, 175L	1.1	5.8	0.27
43	4 + 25, 225L	0.54	8.2	1.8
44	3 + 25, 225L	0.66	2.9	0.22
45	2 + 25, 225L	2.8	6.9	0.57
46	1 + 25, 225L	0.83	54	3.5
47	0 + 25, 225L	0.90	2.4	0.04
48	0 + 75, 275L	0.98	0.83	0.04
49	1 + 75, 275L	0.82	1.1	0.05
50	2 + 75, 275L	0.40	4.4	0.33
51	3 + 75, 275L	0.62	3.4	0.23
52	4 + 75, 275L	0.63	4.7	0.22
53	5 + 75, 275L	0.80	1.3	0.06

Table 4. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Surface Soil Samples (continued)

Sample Number[a]	Grid Location	Concentration of Radionuclide (pCi/g)		
		^{226}Ra	^{238}U	^{235}U
54	5 + 75, 75L	0.89	1.1	0.05
55	6 + 75, 75L	0.81	1.1	0.05
56	6 + 25, 125L	0.78	1.1	0.05
57	0 + 25, 325L	1.4	1.4	0.06
58	1 + 25, 325L	1.1	1.2	0.07
59	2 + 25, 325L	NF[b]	8.2	13
60	3 + 25, 325L	0.45	1.9	0.20
61	4 + 25, 325L	0.59	17	1.2
62	5 + 25, 325L	0.55	11	0.51
63	6 + 25, 325L	0.73	1.5	0.11
64	2 + 75, 375L	1.3	5.0	1.3
65	3 + 75, 375L	0.35	5.0	0.30
66	4 + 75, 375L	11	1.2	0.06
67	7 + 25, 125L	0.90	6.8	0.89
68	5 + 75, 175L	0.87	1.1	3.5
69	6 + 75, 175L	0.63	2.5	9.2
70	5 + 25, 225L	0.97	2.9	51
71	6 + 25, 225L	0.55	0.54	0.03
72	6 + 25, 25L	0.82	0.96	0.04
73	7 + 75, 75L	0.60	0.63	0.03
74	7 + 75, 175L	0.37	0.57	0.07
75	7 + 25, 325L	0.69	0.91	0.04
76	5 + 75, 375L	0.94	1.4	0.17
B9	1 + 85, 91L	9850	6.7	0.47
B10	1 + 06, 140L	NF[b]	410	7080
B11	2 + 03, 105L	1600	3.2	2.0
B18B	2 + 25, 225L	3450	8.4	0.78
B19	2 + 60, 280L	5.2	2.0	790

Table 4. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Surface Soil Samples (continued)

Sample Number[a]	Grid Location	Concentration of Radionuclide (pCi/g)		
		^{226}Ra	^{238}U	^{235}U
B21C	1 + 90, 210L	36	11	0.25
B26	4 + 97, 294L	47,000	2,570	65
B27	5 + 28, 275L	NF[b]	40,700	1,480
B29	4 + 34, 348L	10,500	70	4.7
B30	5 + 30, 272L	NF[b]	96,300	1,050
B31	4 + 30, 360L	1,450	36	0.77
B32	4 + 48, 245L	NF[b]	31,900	460
B33	5 + 14, 180L	NF[b]	120	870
B35	3 + 50, 384L	0.51	190	3.0
	Attleboro Landfill, Inc., Property			
5	0 + 25, 25L	0.79	0.60	0.09
6	1 + 25, 25L	0.78	1.5	0.07
7	2 + 25, 25L	0.59	0.63	0.04
8	3 + 25, 25L	0.80	1.3	0.07
9	4 + 25, 25L	0.50	1.7	1.2
10	5 + 25, 25L	0.67	1.2	0.05
17	3 + 25, 75R	0.91	1.1	0.05
18	2 + 25, 75R	0.80	3.5	0.16
19	1 + 25, 75R	0.78	1.3	0.10
20	0 + 25, 75R	0.51	0.86	0.04
21	1 + 25, 175R	1.3	1.4	0.06
22	0 + 75, 25R	0.63	0.66	0.03
23	1 + 75, 25R	1.0	1.2	0.05
24	2 + 75, 25R	0.54	0.84	0.11
25	3 + 75, 25R	0.83	0.73	0.09
26	4 + 75, 25R	0.56	0.74	0.03
27	2 + 75, 125R	0.74	0.86	0.04

Table 4. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Surface Soil Samples (continued)

Sample Number[a]	Grid Location	Concentration of Radionuclide (pCi/g)		
		^{226}Ra	^{238}U	^{235}U
28	1 + 75, 125R	0.18	1.6	0.08
29	0 + 75, 125R	0.78	0.74	0.03
30	0 + 75, 225R	0.73	0.77	0.03
31	1 + 75, 225R	0.68	0.98	0.05
40	2 + 25, 175R	1.2	1.2	0.06
B2	0 + 90, 90R	1,550	0.95	0.39
B3A	3 + 15, 68R	740	0.59	0.53
B38	1 + 09, 234R	1,000	1.3	1.7

[a]See Fig. 6 for location.

[b]NF - Looked for, not found.

Table 5. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Subsurface Soil Samples

Hole Number[a]	Grid Location	Depth ft.	Concentration of Radionuclide (pCi/g)		
			^{226}Ra	^{238}U	^{235}U
		Shpack Property			
20	7 + 25, 75L	0-1.0	0.57	0.46	0.02
21	6 + 75, 175L	0-1.0	0.66	0.93	0.04
26	1 + 85, 90L	0-1.0	750	1.2	0.52
28	4 + 25, 75L	0-1.0	0.75	1.7	0.80
29	5 + 15, 130L	0-1.0	0.61	180	44
30	5 + 88, 120L	0-1.0	<0.03	0.43	0.10
31	4 + 86, 200L	0-1.0	0.61	1.8	0.08
32	3 + 75, 175L	0-0.5	0.78	2.5	0.10
33	3 + 20, 130L	0-0.5	0.56	0.79	0.10
34	2 + 25, 175L	0-0.5	0.88	6.6	0.30
35	2 + 85, 200L	0-0.5	6.0	3.2	0.15
36	3 + 40, 220L	0-0.5	0.99	5.4	0.25
37	4 + 35, 230L	0-0.5	0.64	17	2.6
38	5 + 25, 270L	0-0.5	NF[b]	730	17
		0.5-1.0	NF[b]	2,060	49
		1.0-1.5	NF[b]	1,280	82
		1.5-2.0	NF[b]	1,150	37
39	4 + 96, 296L	0-0.5	435	28	4.2
40	0 + 35, 60L	2-2.5	1.1	3.7	0.14
41	1 + 32, 75L	0-0.5	1.2	1.9	0.25
42	2 + 75, 75L	0-0.5	1.1	0.93	0.04
43	1 + 62, 215L	0-0.5	1.1	0.93	0.04
44	2 + 25, 220L	0-0.5	530	0.70	0.2
45	2 + 45, 285L	0-0.5	1.3	2.3	1.9
46	2 + 85, 285L	0-0.5	3.1	4.5	1.1
47	3 + 56, 320L	0-0.5	1.3	160	31
48	2 + 75, 375L	0-0.5	0.58	4.2	15

Table 5. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Subsurface Soil Samples (continued)

Hole Number[a]	Grid Location	Depth ft.	Concentration of Radionuclide (pCi/g)		
			^{226}Ra	^{238}U	^{235}U
49	2 + 85, 430L	2.5-3.5	0.80	105	23
50	3 + 75, 375L	0-0.5	0.49	0.17	1.2
51	3 + 75, 420L	0-0.5	0.75	2.5	1.8
52	4 + 35, 405L	0-0.5	<0.08	55	9.8
53	5 + 00, 380L	0-0.5	0.69	1.4	0.33
54	3 + 85, 265L	1.0-1.5	NF[b]	66	78
55	6 + 35, 380L	0-0.5	0.70	1.4	.02
56	5 + 55, 325L	0-0.5	0.81	0.93	.04
		3.0-4.0	1.0	2.7	0.12
57	6 + 42, 275L	0-0.5	0.75	2.0	0.82
58	0 + 70, 190L	0-0.5	0.74	0.93	0.04
59	1 + 10, 220L	0-0.5	0.72	0.93	0.04
60	1 + 65, 265L	0-0.5	2.2	1.3	0.14
61	1 + 10, 140L	0-0.5	NF[b]	470	5,640
		0.5-1.0	NF[b]	260	4,430
		1.0-2.0	11	75	400
		2.0-2.5	5.4	30	120
62	2 + 50, 320L	0-0.3	NF[b]	106,000	2,200
		0.3-1.0	NF[b]	2,550	40
63	4 + 35, 348L	0-0.5	4,650	26	4.0
		0.5-1.0	790	0.27	4.7
		1.0-1.5	750	15	3.1
		1.5-2.0	295	19	0.87
	Attleboro Landfill, Inc., Property				
7	1 + 22, 228R	0-1.0	1.5	1.5	0.07
8	1 + 12, 188R	0-1.0	4.2	1.6	0.07
9	0 + 80, 80R	0.5-1.0	1.0	0.81	0.04
10	0 + 70, 125R	0-1.0	0.94	1.1	0.05

Table 5. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Subsurface Soil Samples (continued)

Hole Number[a]	Grid Location	Depth ft.	Concentration of Radionuclide (pCi/g)		
			^{226}Ra	^{238}U	^{235}U
11	1 + 25, 35L	0-1.0	1.2	1.2	0.06
12	1 + 75, 125R	0-1.0	1.1	0.93	0.04
13	2 + 25, 25R	0-1.0	0.76	0.93	0.04
14	2 + 94, 70R	0-1.0	0.84	1.2	0.05
15	3 + 75, 25R	0-1.0	0.78	0.62	0.07
16	2 + 70, 175R	0-1.0	1.0	0.93	0.04
17	1 + 25, 75R	0-0.5	0.50	0.43	0.09
		0.5-1.0	0.57	0.77	0.07
		1.0-2.0	0.50	0.93	0.02
		2.0-3.0	0.93	2.2	0.11
		3.0-4.0	1.2	1.2	0.07
		4.0-5.0	0.98	1.1	0.05
18	2 + 94, 70R	0-1.0	0.86	1.2	0.05
		1.0-2.0	0.81	1.1	0.05
		2.0-2.5	0.46	0.46	0.02
19	6 + 22, 30L	0-1.0	0.68	0.60	0.03
22	4 + 70, 35L	0-1.0	0.60	3.0	1.5
23	0 + 75, 30L	0-0.5	1.1	7.8	29
		1.0-2.0	1.6	1.5	0.54
24	0 + 50, 30R	0-1.0	0.80	0.93	0.04
25	1 + 75, 25L	0-1.0	1.2	1.0	0.10
27	3 + 20, 30L	0-1.0	9.0	0.80	0.11

[a]See Fig. 8 for location.

[b]NF - Looked for, not found.

Table 6. Extent of Subsurface Contamination as Indicated by Scintillation Probe Loggings and Sample Analyses

Hole Number[a]	Depth at which water was encountered (ft.)	Estimated extent of contaminated[b] soil (ft.)
	Shpack Property	
20	6.0	None
21	7.0	None
26	3.0	0 - 3.0[c]
28	3.0	None
29	4.5	0 - 1.0
30	6.0	None
31	1.5	At surface
32	1.0	At surface
33	1.0	None
34	1.0	0 - 0.5
35	1.0	0 - 1.0[c]
36	1.0	0 - 0.5
37	1.5	0 - 0.5
38	2.0	0 - 2.0[c]
39	3.5	0 - 3.5[c]
40	3.5	0.5 - 3.5[c]
41	3.5	None
42	2.0	None
43	6.0	2.5 - 4.0
44	4.5	0 - 4.0
45	4.5	0 - 0.5
46	2.5	0 - 0.5
47	3.0	0 - 1.0
48	2.5	0 - 0.5
49	4.0	1.0 - 4.0[c]
50	3.0	None
51	6.0	0 - 0.5

Table 6. Extent of Subsurface Contamination as Indicated by Scintillation Probe Loggings and Sample Analyses (continued)

Hole Number[a]	Depth at which water was encountered (ft.)	Estimated extent of contaminated[b] soil (ft.)
52	6.5	0 - 1.0
53	8.0	None
54	1.5	0 - 1.0
55	5.0	None
56	5.0	None
57	2.0	None
58	No water	None
59	8.0	None
60	13.0	0.5 - 1.5
61	3.0	0 - 3.0[c]
62	2.5	0 - 2.5[c]
63	1.5	0 - 1.5[c]
	Attleboro Landfill, Inc., Property	
7	4.5	None
8	4.5	0 - 1.5
9	5.0	0 - 3.0
10	4.5	None
11	6.5	Not Logged
12	6.0	None
13	4.0	None
14	3.5	None
15	4.0	None
16	3.0	None
17	4.5	2.5 - 4.0
18	3.5	At surface
19	8.0	None
22	7.0	0 - 1.0

Table 6. Extent of Subsurface Contamination as Indicated by Scintillation Probe Loggings and Sample Analyses (continued)

Hole Number[a]	Depth at which water was encountered (ft.)	Estimated extent of contaminated[b] soil (ft.)
23	4.0	0 - 2.0
24	3.5	None
25	4.0	None
27	1.5	At surface

[a]See Fig. 8 for location.

[b]Contaminated soil is defined as soil having 5 pCi/g or greater of ^{226}Ra and/or total uranium; or giving rise to 1,000 cpm or more on the shielded scintillator.

[c]Contamination extends to or below water table.

Table 7. Concentration of Radionuclides in Water Samples Taken from Auger Holes

Hole[a] Number	Depth at which water was encountered (ft.)	Concentration of Radionuclide (pCi/L)				
		^{226}Ra	^{238}U[b]	^{235}U[b]	^{230}Th[c]	^{210}Pb[c]
1	1.0	<1.4	≤34	≤1.6	<0.05	4.9 ± 2.5
2	1.5	<1.1	≤34	≤1.6	<0.05	<2.4
3	0.5	4.6 ± 1.4	4.4 ± 4.4	0.2 ± 0.2	<0.54	0.27 ± 2.7
4	2.0	0.81 ± 0.54	≤34	≤1.6	<0.81	1.1 ± 2.2
5	3.0	1400 ± 54	≤34	≤1.6	<0.03	70 ± 8.1
7	3.0	<11	0.11	0.01	<1.9	0.54 ± 3.0
8	3.0	<11	0.09	0.01	<0.81	2.7 ± 2.7
9	4.0	<2.7	0.07	0.05	<0.54	0.54 ± 2.7
10	4.0	<8.1	0.12	0.01	<0.54	<5.4
11	6.0	<2.7	0.03	<0.01	<0.81	<1.4
12	6.0	<11	0.08	0.01	<0.54	<2.2
13	4.0	<8.1	0.07	0.01	<0.54	<1.9
14	3.0	<14	0.06	0.02	<0.54	<2.7
15	3.5	<2.7	0.09	0.02	<0.54	1.4 ± 2.7
16		No Sample				
17	4.5	4.0 ± 0.27	0.04	0.38	<1.4	0.54 ± 2.7
18	3.0	0.81 ± 0.81	0.24	0.01	<1.4	1.4 ± 3.2
19	8.0	<2.7	0.10	0.01	<0.54	<2.2
20	6.0	6.8 ± 1.9	0.40	0.08	<1.9	2.2 ± 3.5
21	7.0	<5.4	3.0	0.13	<0.54	<2.7
22	4.5	<1.4	0.20	0.07	<5.4	5.4 ± 6.5
23	4.0	1.8 ± 1.4	0.10	0.21	<0.81	6.8 ± 6.5
24	4.5	0.19 ± 0.30	0.08	0.01	<0.54	2.2 ± 2.4
25	4.0	0.30 ± 1.1	0.06	0.12	<1.1	0.81 ± 4.1
26	3.5	40 ± 5.4	0.08	0.01	<1.6	4.6 ± 3.8
27	1.5	1.5 ± 1.0	0.09	0.05	<0.27	0.54 ± 2.7
28	6.0	14 ± 2.0	0.23	0.11	<0.54	2.7 ± 5.7
29	5.0	<0.03	1.4	0.57	<0.54	1.4 ± 4.1
30	6.0	<0.03	18	0.46	<0.27	4.9 ± 3.2
31	1.5	<1.4	2.4	0.40	<0.27	8.6 ± 6.8
32	1.0	<0.54	0.47	0.06	<0.81	<2.7
33	1.5	<1.1	0.10	<0.01	<1.4	5.7 ± 3.8

Table 7. Concentration of Radionuclides in Water Samples Taken from Auger Holes (continued)

Hole[a] Number	Depth at which water was encountered (ft.)	Concentration of Radionuclide (pCi/L)				
		^{226}Ra	^{238}U[b]	^{235}U[b]	^{230}Th[c]	^{210}Pb[c]
34	1.0	0.95 ± 0.76	1.2	0.06	<1.1	3.5 ± 2.4
35	1.0	<0.03	0.74	0.17	<1.9	2.2 ± 2.4
36	1.5	<0.81	0.04	0.01	<0.81	5.4 ± 2.7
37	1.5	<0.81	0.94	0.19	<0.03	<2.7
38	2.0	<0.81	4,400	100	3.0 ± 0.3	5.4 ± 2.7
39	3.5	27 ± 22	0.46	0.06	<0.81	<5.4
40	3.5	<0.81	0.42	0.04	<1.4	8.1 ± 2.7
41	3.5	35 ± 22	0.13	0.22	<0.81	<2.7
42	2.0	1.4 ± 1.4	1.3	0.06	<1.6	<2.7
43	6.5	<0.81	0.31	0.10	<0.03	<2.7
44	4.5	<1.9	0.39	0.23	<0.03	8.1 ± 2.7
45	4.5	<0.81	0.81	0.34	<0.54	8.1 ± 5.4
46	2.5	4.1 ± 2.4	0.43	0.13	<0.05	2.7 ± 5.4
47	3.0	<0.81	0.16	0.02	<0.81	<2.7
48	2.5	<0.81	0.28	0.04	<0.05	<2.7
49	4.0	<1.4	27	1.0	<0.81	8.1 ± 5.4
50	3.0	<0.81	13	1.0	<0.81	<5.4
51	6.0	<0.81	0.18	0.03	<0.03	<5.4
52	6.5	0.81 ± 0.81	0.38	0.05	0.54 ± 0.27	<5.4
53	8.0	<0.54	4.2	0.29	0.54 ± 0.27	<2.7
54	1.5	<0.54	3.5	0.64	<0.54	<2.7
55	5.0	<1.4	1.3	2.6	<0.27	<5.4
56	5.0	<1.4	24	0.80	<0.54	<5.4
57	2.0	<0.81	0.60	0.13	<0.54	<2.7
58		No Sample				
59	8.0	<0.54	0.50	0.79	0.81 ± 0.27	<5.4
60	13	<0.54	18	0.45	0.81 ± 0.27	<5.4
61	3.0	<0.54	1,140	2,400	0.27	8.1 ± 2.7
62	2.5	1.1 ± 0.81	2,020	340	6.8 ± 0.81	8.1 ± 2.7
63	1.5	23 ± 2.4	3.4	2.6	1.4 ± 0.27	17 ± 4.6

Table 7. Concentration of Radionuclides in Water Samples Taken from Auger Holes (continued)

Hole[a] Number	Depth at which water was encountered (ft.)	Concentration of Radionuclide (pCi/L)				
		^{226}Ra	^{238}U[b]	^{235}U[b]	^{230}Th[c]	^{210}Pb[c]
AOW[d] 8	9.0	<1.4	<30	<200	<1.1	1.4 ± 2.2
AOW 9	4.0	<0.54	<30	<200	<0.27	1.1 ± 2.2
AOW 10	4.5	1.4 ± 3.2	<30	<200	<0.27	0.27 ± 1.9

[a]See Fig. 8 for location.

[b]Errors associated with ^{235}U and ^{238}U concentrations are: U $\geq$ 1PPB, error = ±10%; U < 1PPB, error = ±50%.

[c]Indicated errors associated with ^{230}Th and ^{210}Pb concentrations are two sigma (95% confidence level).

[d]AOW - Monitoring wells, northeast edge of site (see Fig. 8).

Table 8. Concentration of ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb in Water Samples Taken from Swamp Adjoining the Landfill

Sample Number	Grid Location[a]	Concentration[b] of Radionuclide (pCi/L)			
		^{226}Ra	^{238}U	^{230}Th	^{210}Pb
SNW 1	3 + 25, 450L	0.54 ± 100%	8.7 ± 50%	<0.54	8.9 ± 30%
SNW 2	3 + 25, 465L	0.11 ± 250%	9.4 ± 50%	<0.05	1.6 ± 150%
SNW 3	4 + 25, 455L	<1.1	21 ± 20%	<0.10	1.9 ± 140%
SNW 4	4 + 25, 465L	1.6 ± 65%	6.0 ± 70%	<1.1	1.6 ± 200%
SNW 5	2 + 15, 255L	1.4 ± 60%	≤34	0.14 ± 60%	3.2 ± 100%
SNW 6	1 + 99, 407L	0.03 ± 600%	1.7 ± 100%	<0.05	<2.2
SNW 7	5 + 25, 450L	0.54 ± 100%	8.7 ± 50%	0.11 ± 50%	2.2 ± 100%
SNW 8	5 + 25, 320L	12 ± 25%	155	0.95 ± 15%	2.2 ± 100%
SNW 9	7 + 18, 350L	0.54 ± 100%	≤34	<1.4	6.8 ± 50%
SNW 10	8 + 00, 100L	0.27 ± 200%	≤34	<1.6	<4.1
SNW 11	[c]	0.27 ± 200%	≤34	<1.1	<3.8
SNW 12	[c]	0.05 ± 450%	0.67 ± 100%	<2.2	1.9 ± 190%
SNW 13	[c]	0.54 ± 100%	3.7 ± 100%	<1.4	2.4 ± 150%
CGw[d]		30	40,000	2,000	100

[a] See Fig. 6 for location.

[b] Indicated errors associated with concentrations are two sigma (95% confidence level).

[c] Grid system did not extend to this area.

[d] CGw - Concentration guide for water, 10 CFR 20.

Table 9. Concentration of ^{226}Ra, ^{238}U, and ^{235}U in Silt Collected from Swamp Adjoining Landfill

Sample Number	Grid Location[a]	Concentration of Radionuclide (pCi/g)		
		^{226}Ra	^{238}U	^{235}U
SNWS 1	3 + 25, 450L	<0.09	9	3.3
SNWS 2	3 + 25, 465L	1.3	2.8	1.2
SNWS 3	4 + 25, 455L	1.1	16	4.3
SNWS 4	4 + 25, 465L	3.7	330	16
SNWS 5	2 + 15, 255L	5.2	7	0.33
SNWS 6	1 + 99, 407L	1.4	7	0.32
SNWS 8	5 + 25, 320L	4.3	24	2.3
SNWS 9	7 + 18, 350L	5.3	14	0.66
SNWS 10	8 + 00, 100L	1.1	1	0.18
SNWS 12	[b]	<0.14	51	2.4
SNWS 13	[b]	<0.18	40	1.9

[a] See Fig. 6 for location.

[b] Grid system did not extend to this area.

Table 10. Concentration of ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb in Off-Site Water and Silt Samples

Sample Designation and Type[a]	Concentration of Radionuclide			
	^{226}Ra	^{238}U	^{230}Th	^{210}Pb
SNOW 1 - water (pCi/L)	0.27 ± 200%	2.4 ± 100%	<1.6	<2.4
SNOWS 1 - silt (pCi/g)	0.82	1.8	*b*	*b*
SNOW 2 - water (pCi/L)	<0.54	≤34	<1.4	0.27 ± 900%
No Silt Collected				
SNOW 3 - water (pCi/L)	<0.27	≤34	<0.81	0.81 ± 300%
SNOWS 3 - silt (pCi/g)	0.57	0.72	*b*	*b*
SNOW 4[c] - water (pCi/L)	<1.1	≤34	<1.4	4.6 ± 60%
(Shpack Well)				
CGw[d]	30	40,000	2,000	100

[a] See Fig. 10 for location.

[b] This sample was not analyzed for this radionuclide.

[c] See Fig. 8 for location.

[d] CGw - Concentration guide for water, 10 CFR 20.

APPENDIX I

GEOLOGIC SUMMARY OF THE SHPACK LANDFILL, NORTON, MASSACHUSETTS

GEOLOGIC SUMMARY OF THE SHPACK LANDFILL, NORTON, MASSACHUSETTS

The Shpack Landfill site is located in the northwestern portion of the Narragansett Basin. This 960-mi^2 topographic and structural depression contains terrigenous clastic sediments of Late Pennsylvanian Age (200 to 275 m.y. old). Directly underlying the Shpack site, the bedrock unit is the Rhode Island Formation. It consists of feldspathic sandstone, shale, siltstone, pebble to boulder conglomerate, and locally, coal. Deposition of the Rhode Island Formation was predominantly in a fluviatile environment, possibly associated with active alluvial fans.[1]

The Narragansett Basin has been divided into six structural domains. The Shpack site is located in the Taunton Domain, which is characterized by a series of large scale ENE striking folds.[1]

Although the bedrock structures have had some influence on the present topography, Pleistocene glacial deposits overlying the bedrock have had the dominant surficial influence.

Glacial units include unstratified deposits of till consisting of poorly sorted silt, sand, angular to rounded pebbles, cobbles, and boulders forming a mantle on the bedrock surface. Stratified glacial units include beds and lenses of outwash or other glaciofluvial deposits which grade into glaciolacustrine deposits. These deposits consist of sandy gravel, sand, and fine sand, silt, and clay.[1]

At the Shpack property, till deposits form the slightly raised ground at the Shpack residence. Till extends northwestward across Union Street to Chartley Pond and also forms a finger of high ground extending southward into the large swamp south of Union Street. These unstratified deposits grade into stratified deposits along the margins of the high ground and give way to glaciolacustrine deposits which underlie the swamp areas west and south of the Shpack residence. Unconsolidated deposits overlying bedrock at the Shpack Landfill are approximately 20 to 25 ft thick.[2]

Organic deposits (peat) overlie unconsolidated glacial deposits in the swamp areas of the region. Depth of the peat ranges from 5 to 30 ft depending on the age and depth of the swamp.[3]

Although several auger holes were bored into fill material to the depth of the water table, no actual determination of the thickness of the peat layer in the swamp underlying the Shpack Landfill was made. Because the Shpack site is at the margin of the swamp and the nearby high ground is underlain by till, it is safe to assume only a thin layer of peat separates the fill material from the underlying glacial deposits.

The Soil Conservation Service[4] has classified the surface soil types of the Norton-Attleboro area. Presently the Shpack and the adjacent Attleboro Landfills are classed as "dumps." Three original surface soil types were represented previous to the introduction of the fill material at these sites. Surface soil developed in the swamp which underlies most of the Shpack and Attleboro Landfills was originally classified as Medisaprists. Medisaprists soil is characterized by very poorly drained, variable-composition organic material more than 16 in. thick overlying mineral soil composed of outwash, glacial till, or lacustrine sediments. On areas of higher ground underlain by glacial outwash, Windsor (sandy outwash) or Hinckley (gravelly outwash) series soils are developed. Both Windsor and Hinckley series soils are excessively drained sandy loam soils.

Hydrology

Groundwater in the area of the Shpack Landfill is produced from both bedrock and surficial aquifers. The Rhode Island Formation underlying the Shpack site was metamorphosed, folded, and faulted during deformation of the Narragansett Basin. This deformation fractured the bedrock and allows groundwater to pass through at a higher rate than in the original sediments. This is known as secondary porosity.[5]

As previously mentioned in this report, the deformation of the northwestern portion of the Narragansett Basin resulted in the formation of several ENE trending folds. Favorable zones for bedrock groundwater reservoirs parallel these folds. One of the zones is located just north of the Shpack site.[6] Geologic mapping[7] indicates an anticlinal axis paralleling and located north of the groundwater trend. Since the bedrock unit dips towards the south, it is reasonable to assume that the

primary groundwater recharge for this aquifer also lies to the north between the anticlinal axis and the favorable groundwater trend.

Due to the relatively impermeable nature of the glacial till which mantles the more permeable bedrock, wells drilled into the bedrock aquifers often flow with their own pressure. These wells are referred to as being artesian.[5]

Favorability for groundwater reservoirs and recharge areas in the unconsolidated glacial deposits is directly related to the composition of the deposits. Therefore, the unstratified till and other silt or clay-rich deposits have the lowest groundwater potential. Sandy stratified deposits have moderate groundwater potential. Coarse stratified sandy-gravel deposits have the highest groundwater potential. Principal aquifers in unconsolidated deposits also tend to follow present surface drainage courses. Wells producing from these surfical deposits in general stand at the level where encountered during drilling and are considered to be under water table conditions.[5]

The Shpack Landfill site is located on an area of moderate potential for groundwater reservoir and recharge conditions. This moderate potential is modified locally by the extensive swamp present. East of the site is an area of low potential till deposits. West of both the Shpack and adjacent Attleboro Landfills is an area of high potential along Chartley Brook.[6]

Chartley Brook is in the uppermost reaches of the Taunton River Basin. Depth to bedrock information[2] indicates that Chartley Brook may follow a course influenced by a preglacial drainage pattern which flowed into a basin to the east.

Potential for contamination of the aquifers present in the area of the Shpack site parallels the reservoir and recharge potential of the various bedrock and surficial units.[8] However, the soil underneath the Shpack landfill was originally classified as Medisaprists, consisting of up to 5 feet or more of organic-rich swamp deposits developed on top of impermeable lacustrine and hard pan deposits (Appendix VIII). Because of the low permeability of these underlying formations and of the fill material itself, the potential for groundwater movement and the consequent contamination of aquifiers beneath the landfill is minimal.

This and other geologic and hydrologic factors affecting the Shpack site should be considered in any remedial action taken at the site.

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APPENDIX II

DESCRIPTION OF RADIATION SURVEY METERS AND SMEAR COUNTERS

RADIATION SURVEY METERS

Alpha Survey Meters

The type of alpha survey meter used at this site to measure alpha radioactivity on surfaces uses a ZnS(Ag) scintillator to detect the alpha radiation.

The alpha scintillation survey meter consists of a large area (100 cm^2) ZnS(Ag) detector with a photomultiplier tube in the probe which is coupled to a portable scaler/ratemeter (Fig. II-A). The ZnS(Ag) detector is covered with a 0.28-mil aluminized mylar sheet in order to make the instrument light-tight. A metal grid is used to avoid puncturing the mylar when surveying over rough surfaces. This instrument is capable of measuring alpha surface contamination levels of a few disintegrations per minute per 100 cm^2 but must be used in the scaler mode for this purpose. It is highly selective for densely ionizing radiation such as alpha particles; the instrument is relatively insensitive to beta and gamma radiation. This instrument is calibrated at ORNL using ^{239}Pu alpha sources. Calibration factors are typically 5 to 7 dpm/cpm.

Beta-Gamma Survey Meter

A portable Geiger-Mueller (G-M) survey meter (Fig. II-B) is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a 30 mg/cm^2 wall thickness and presenting a cross-sectional area of approximately 10 cm^2. Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open- and a closed-window configuration. Beta radiation cannot penetrate the closed window, thus, the beta reading can be determined by taking the difference between the open- and closed-window readings.

The G-M survey meters were calibrated by comparison with a pre-calibrated Victoreen Model 440 ionization chamber (Fig. II-C). The open-window calibration factor was found to be 1,900 cpm/(mrad/h) for surfaces contaminated with initially pure uranium. The closed-window (gamma) calibration factor, determined by use of a National Bureau of Standards (NBS) standard ^{226}Ra source, was 3,200 cpm/(mR/h).

Gamma Scintillation Survey Meter

A portable survey meter with a NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2 × 3.8-cm NaI crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (Fig. II-D). This unit is capable of measuring radiation levels from a few microroentgens per hour to several hundred microroentgens per hour. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are of the order of 300 cpm/(μR/h).

SMEAR COUNTERS

Alpha Smear Counter

This detector assembly, used for the assay of alpha emitters on smear paper samples, consists of a light-tight sample holder, a zinc sulfide phosphor, and a photomultiplier tube. This detector assembly was used with electronic components housed in a portable NIM bin (Fig. II-E). The electronics package consisted of a preamplifier, an ORTEC 456 high voltage power supply, a Tennelec TC 211 linear amplifier, and a Tennelec TC 545 counter-timer.

The alpha smear counter was used in the field and was calibrated daily using an alpha source with a known disintegration rate.

Beta Smear Counter

The beta smear counter consisted of a thin mica window (~2 mg/cm^2) G-M tube mounted on a sample holder and housed in a 23-cm-diam x 35-cm-high lead shield. Located under the counter window is a slotted sample holder, accessible through a hinged door on the shield. An absorber can be interposed in the slot between the sample and the counter window to determine relative beta and gamma contributions to the observed sample counting rate. The electronics for this counter were housed in a portable NIM bin and consisted of a Tennelec TC 148 preamplifier, an ORTEC 456 high voltage power supply, and a Tennelec TC 545 counter-timer.

This unit was used in the field to measure beta activity on smear papers and was calibrated daily using a beta standard of known activity (Fig. II-E).

MOBILE LABORATORIES

The mobile laboratories (Fig. II-F) are used during each formal survey to serve as a control center, and to house instruments and other equipment needed during the survey. Each lab is equipped with its own electric generator, mobile radio-telephone, and contains a wide range of well maintained and calibrated instruments. One of the mobile labs has its own microcomputer for data reduction in remote locations.

ORNL-Photo 6705-76

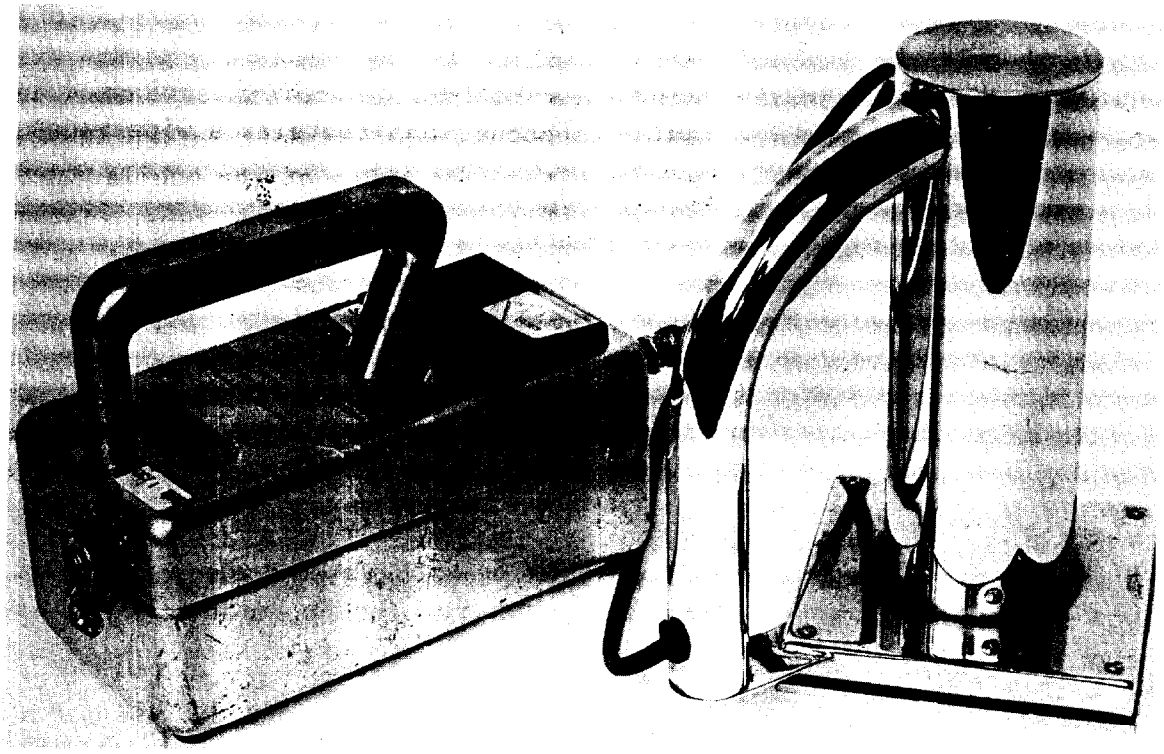

Fig. II-A. Alpha scintillation survey meter.

ORNL-Photo 6707-76

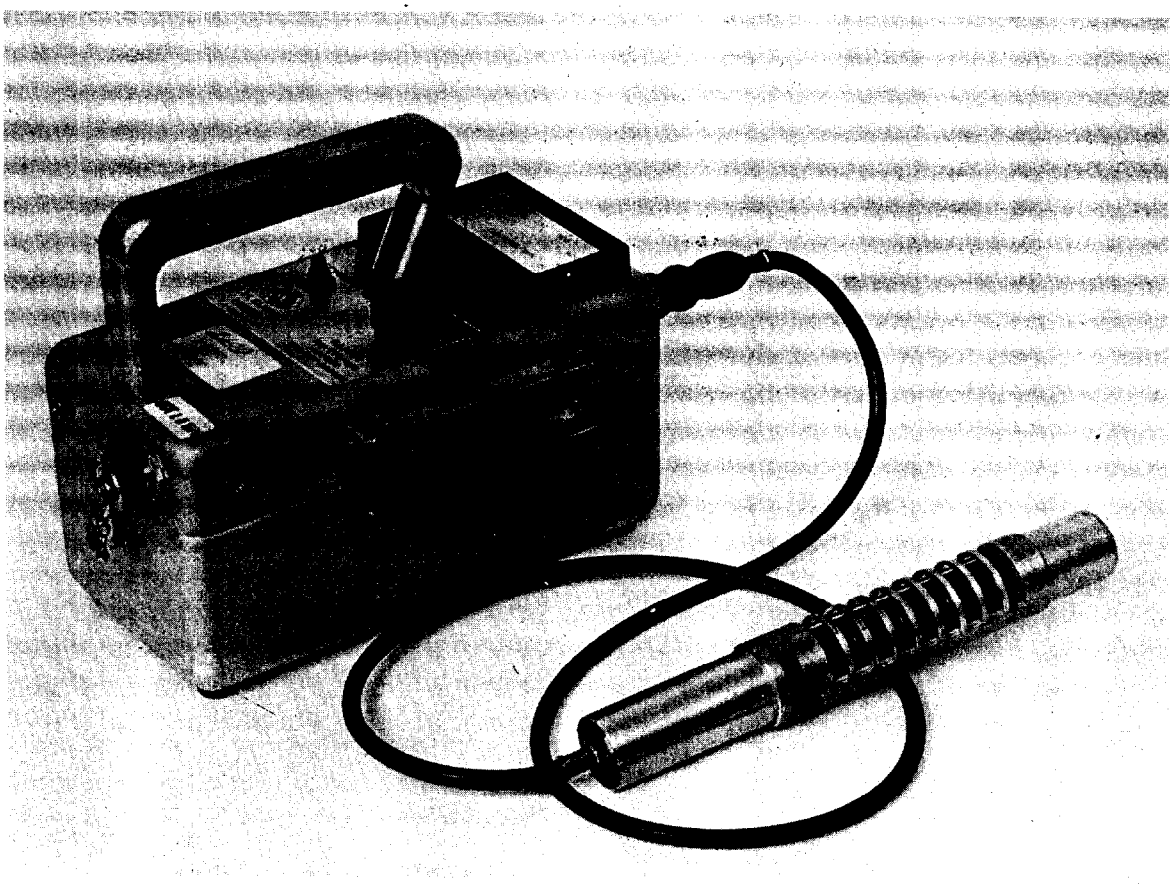

Fig. II-B. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

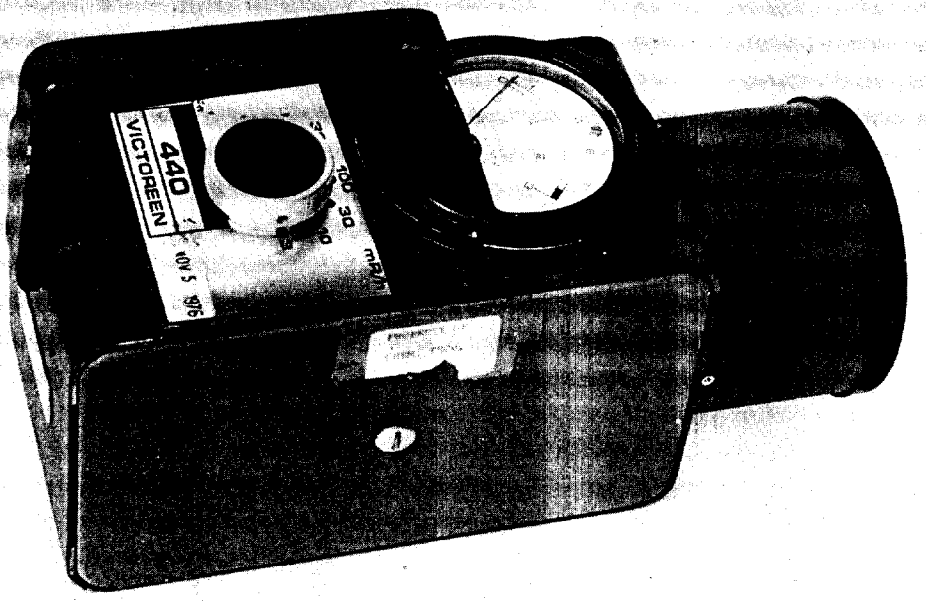

Fig. II-C. Victoreen Model 440 ionization chamber.

ORNL-Photo 6707-76

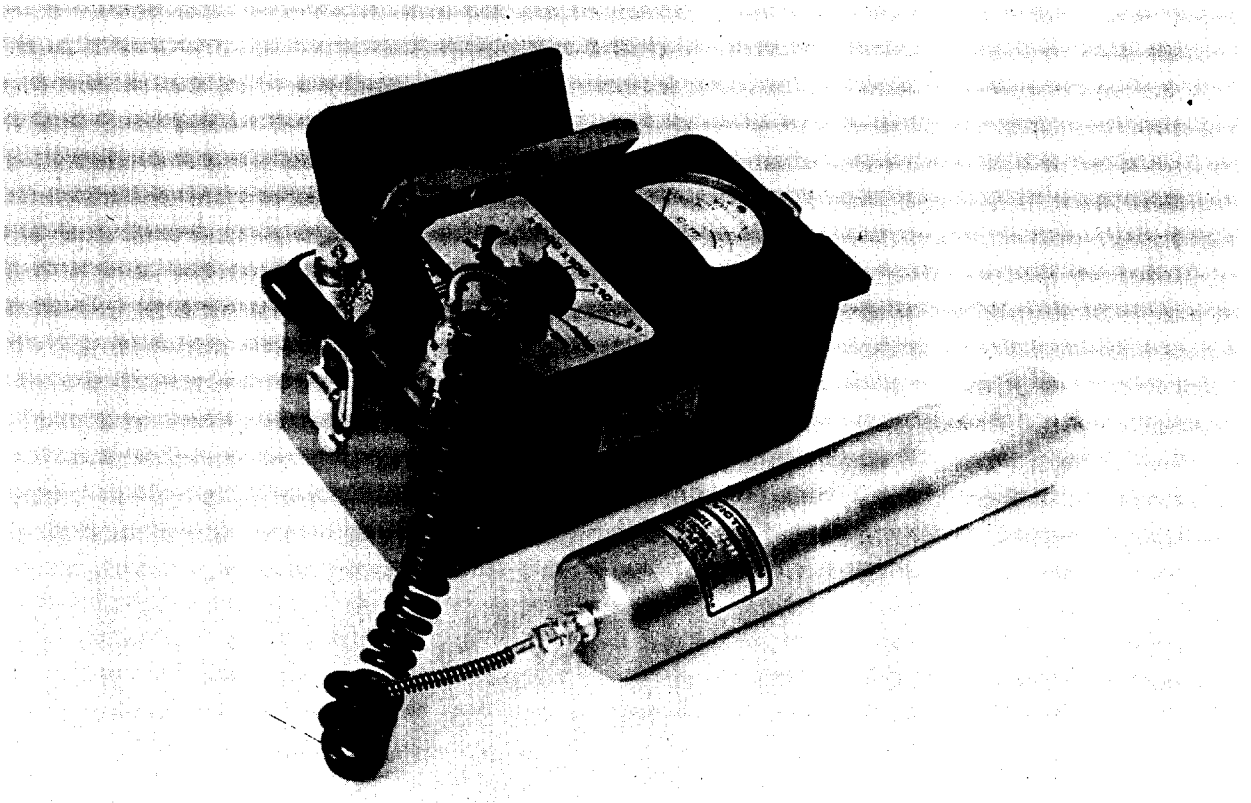

Fig. II-D. Gamma scintillation survey meter.

ORNL-Photo 1070-78

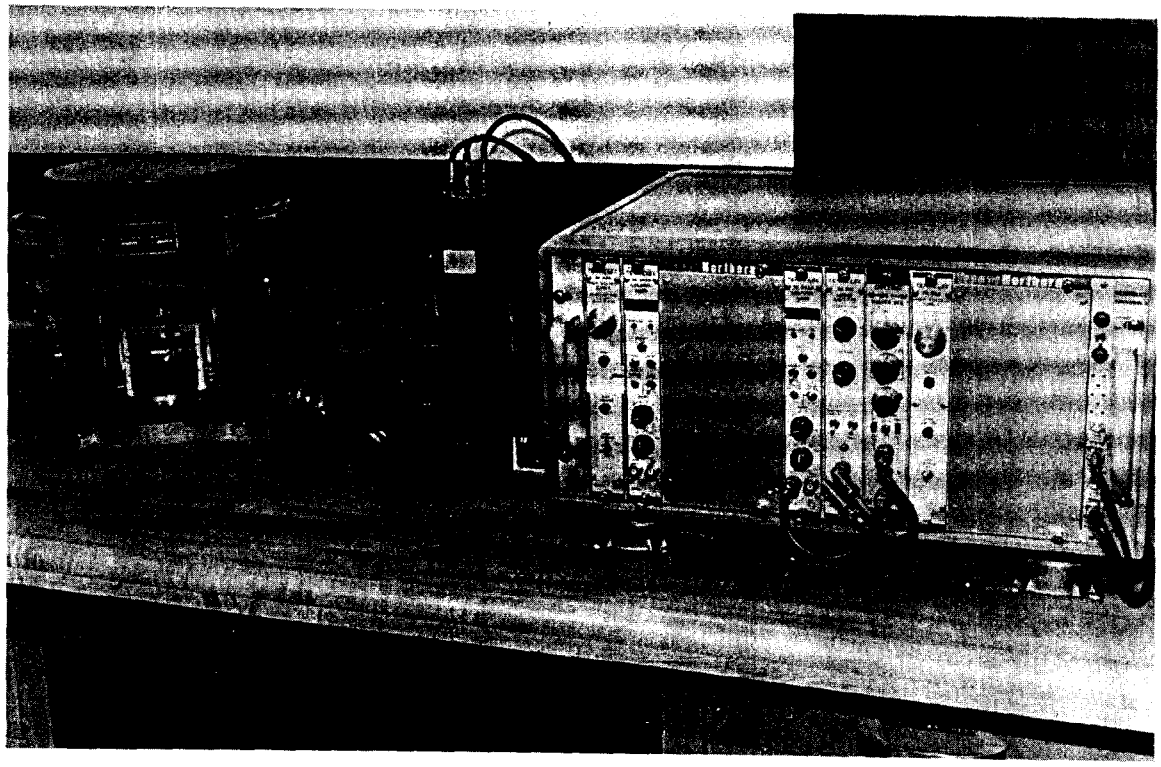

Fig. II-E. Smear counter and associated electronics. The beta counter is on the left and the alpha counter is on the right.

ORNL-Photo 1068-78

Fig. II-F. Mobile laboratories used for logistic support during surveys.

APPENDIX III

DESCRIPTION OF Ge(Li) DETECTOR AND SOIL COUNTING PROCEDURES

DESCRIPTION OF Ge(Li) DETECTOR SYSTEM

A holder for twelve 30-cm^3 polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cm^3 Ge(Li) detector system in laboratory counts of radioactivity in environmental samples (Fig. III-A). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm^3 sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less and ^{227}Ac within an error of ±30%.

Pulses are sorted by a multichannel analyzer (Fig. III-B), stored on magnetic tape, and subsequently entered into a computer program which uses an iterative least squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes which contains approximately 700 isotopes and 2500 gamma-rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 keV. An estimate of the concentration of ^{238}U is obtained from an analysis of the 93 keV line from its daughter ^{234}Th.

ORNL-Photo 2172-75

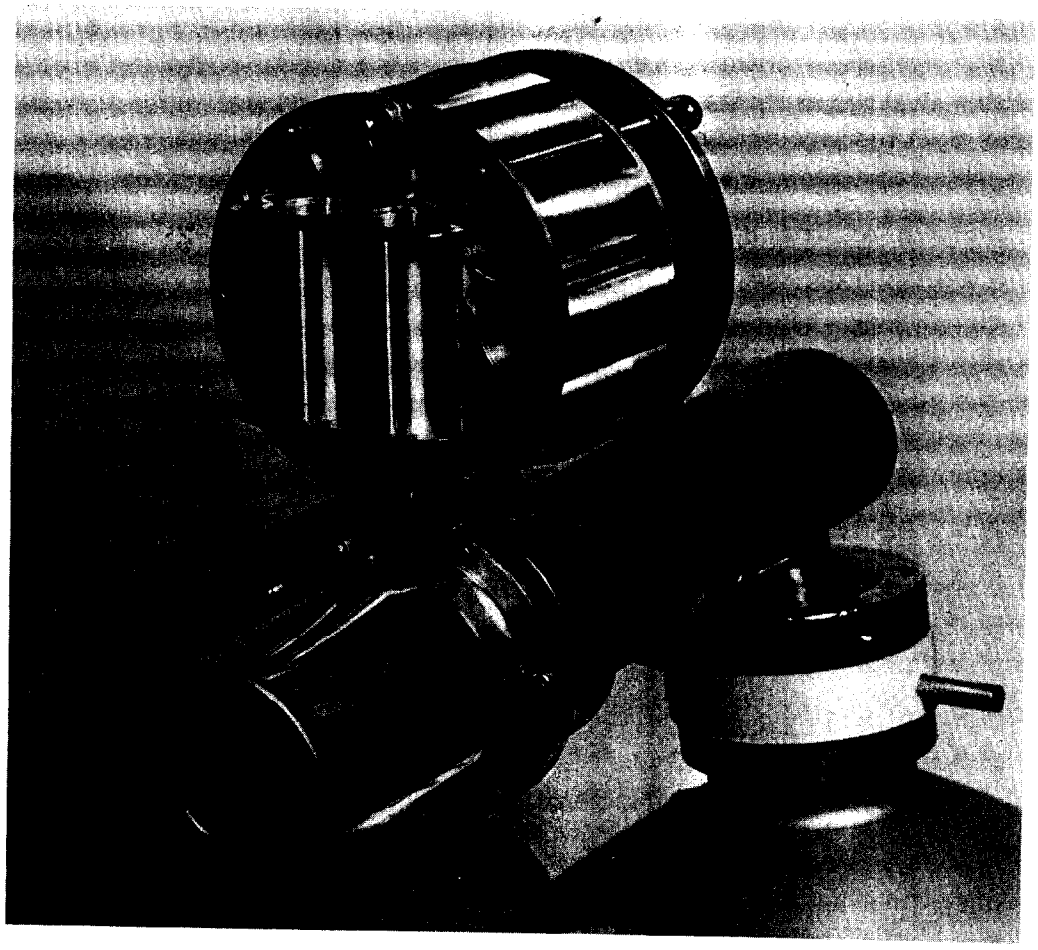

Fig. III-A. Holder for Ge(Li) detector system.

ORNL-Photo 4351-81

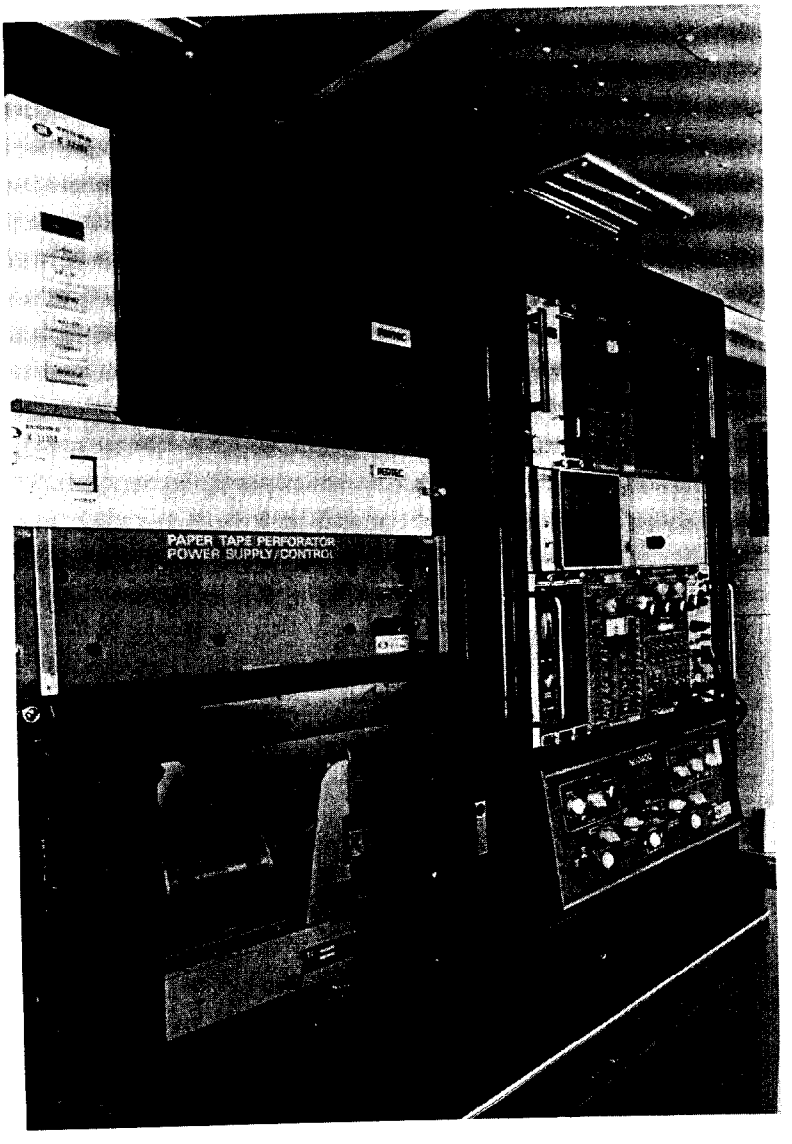

Fig. III-B. Multichannel analyzer with magnetic tape storage for vertical Ge(Li) detector system.

APPENDIX IV

RESULTS OF GROUND PENETRATING RADAR SURVEY

GC-TR-80-1085

TECHNICAL REPORT RESULTS OF GROUND PENETRATING RADAR SURVEY AT NORTON/ATTLEBORO, MASSACHUSETTS

PREPARED FOR THE
NUCLEAR DIVISION
OAK RIDGE NATIONAL LABORATORY
P.O. BOX X
OAK RIDGE, TENNESSEE 37830

PREPARED BY
GEO-CENTERS, INC.
381 ELLIOT STREET
NEWTON UPPER FALLS, MA 02164

under Subcontract No. 40X40453

OCTOBER 1980

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INTRODUCTION

A Ground Penetrating Radar (GPR) survey was conducted at the site of the adjacent Shpack properties and Attleboro Landfill during the week of August 4, 1980. The survey was conducted under contract to the Oak Ridge National Laboratory (ORNL) as part of their ongoing mission to assess the radiological conditions at sites that may be contaminated by residual radioactive materials from operations conducted in support of the Manhattan Engineering District (MED) or the Atomic Energy Commission (AEC).

ORNL personnel had previously conducted a surface radiological survey over these properties, and subsequent activities necessitated drilling and taking of core samples to determine the depth of any contamination. There was sufficient evidence to suggest that potentially hazardous materials, both nuclear and chemical, were buried in various undesignated sectors of the site. To preclude the inadvertent disturbance of such substances, the GPR system was used to locate these materials prior to drilling operations.

The total area of interest was approximately 10 acres, about half of which was accessible to the GPR equipment. Unsurveyed portions were either too wet to permit access or they were covered with metallic debris. However, all areas of radiological interest, as designated by ORNL personnel, were surveyed.

SITE DESCRIPTION

The Shpack properties are located in Norton, Massachusetts, and the adjacent Attleboro Landfill is located across the county line in Attleboro, Massachusetts. The properties have been owned and operated by the Shpack and Dumont families, respectively, throughout the time of interest — 1946 to the present.

In addition to the radioactive materials first discovered by the U.S. Nuclear Regulatory Commission in 1978, and confirmed by ORNL, there is considerable evidence that chemical wastes were dumped into the swamp in both bulk and containerized forms. The uncertainties as to the types, quantities, and forms of these materials dictate that care be taken in all remedial actions.

The sites were originally under moderate to deep water. Initially, disposable liquids and powders — including alkalines, weak acids, chemicals, oils, and slurries — were dumped into the swamp. Fill was then advanced to cover the liquids and to establish an area for burning. In addition to ordinary fill, the material included debris, building materials, tins, cleaning slurries, fine grinding/polishing materials, sweepings, and sludges of both tanks and lagoons. The shipping containers for many of these materials were metal drums, which were emptied before disposal and burning. The drums have been stored on the surface immediately behind the Shpack residence.

A primary source of chemical material was the Thompson Chemical Company which provided warehouse debris, warehouse chemicals, PVC liquids, and powder in containers. There is some speculation that other hazardous chemicals, in addition to the PVC, were buried in containers. The evidence, however, suggests that this material was confined to a single area, away from the location of nuclear materials.

EQUIPMENT DESCRIPTION

Subsurface radar detection systems have been the object of study for over a decade by both military and environmental agencies for locating and identifying buried or submerged objects otherwise not detectable.

The principle of operation involves the generation of a pulse train of electromagnetic (EM) 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 dielectric properties, the wave becomes partially reflected. This reflected wave is then detected, and the time interval between transmission and detection is recorded. As part of the calibration, the velocity of the EM wave propagation in the particular medium is measured. Hence, the time interval can be converted to a distance or depth. Depending on the intensity and phase of the return signal, inference as to the composition of the reflecting material is possible. For example, metallic objects have much different dielectric properties than soils and give rise to strong reflections and a phase shift; geological interfaces, on the other hand, give relatively weak reflections and no significant phase shift.

Antennas designed to operate at different frequencies are available. There is a tradeoff between penetration depth achieved at low frequencies, and spatial resolution at higher frequencies. Thus, the system yields better resolution at the expense of penetration depth; conversely, greater penetration is achieved at the expense of resolution.

A Geophysical Survey Systems, Inc. (GSSI) System 7 was used for the study. The antenna system used was a standard GSSI 300 MHz model with penetration depths of 10-15 feet (under soil conditions at Norton/Attleboro), and a spatial resolution of less than one foot.

The electronics consisted of a portable, gasoline-powered electrical generator, a control unit, a graphic recorder, and a tape recorder, which were all mounted in a 4-wheel drive Civil Defense vehicle made available by the City of Attleboro. The antenna was attached by a harness behind the vehicle at a distance of approximately 20 feet and was pulled across the survey area at a speed of 2-3 miles per hour.

The data were recorded on magnetic tape and on strip chart paper, the latter information being compressed because of the high input data rate. After the field survey, the magnetic tape was played back at a slower speed to generate full resolution hardcopy for visual analysis.

ORNL-DWG 81-22183

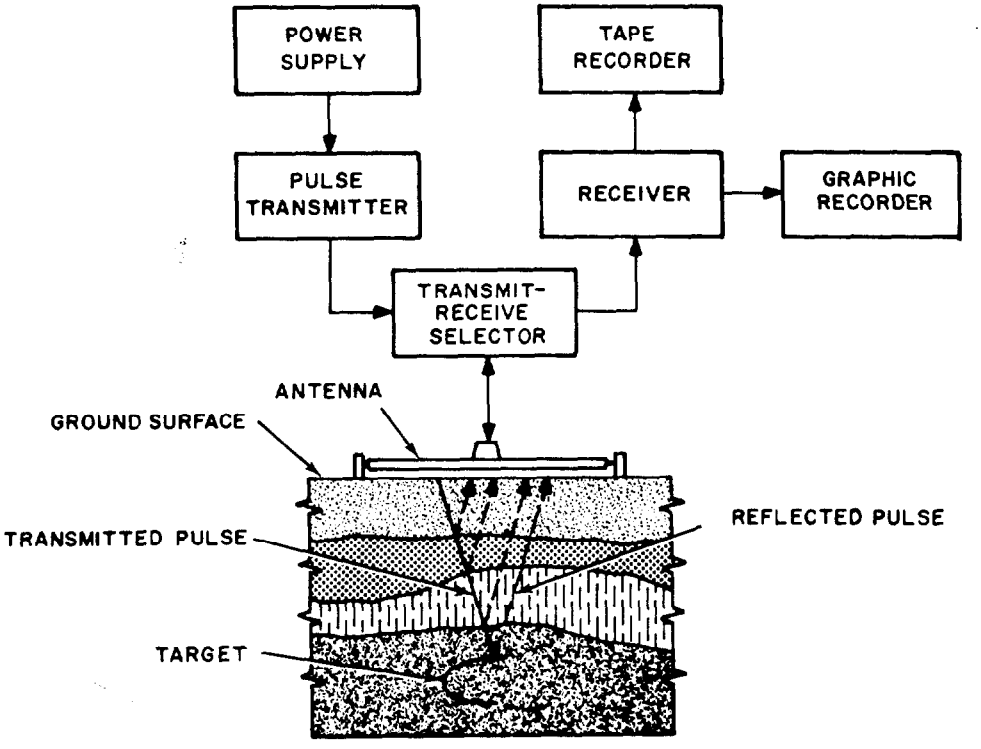


Figure 1. Impulse radar system block diagram.

EXPERIMENTAL OBJECTIVES

The Ground Penetrating Radar was used to generate a subsurface map of the areas where drilling operations were planned. Under the soil and moisture conditions at the Norton/Attleboro site, the GPR was capable of penetrating to depths of 10-15 feet using a high-frequency (300-MHz) antenna while resolving objects as small as one foot. This resolving power permits detection of any storage containers, drums, or barrels in which the hazardous materials would likely be stored. The penetration depth of 10-15 feet reaches well into the water table, which is approximately 2 feet below the surface over most of the site.

Planned drilling operations were of two types: specific and random. Those locations already confirmed as contaminated were designated for further study including drilling. In addition, a random sample of locations throughout the site was selected. The GPR survey, therefore, was directed toward all designated areas and spanned enough of the remaining site to permit a good statistical sampling.

OPERATIONS

In support of their radiological operations, ORNL personnel established a grid system over the Shpack/Attleboro site consisting of numbered stakes placed on 50-foot centers. This grid was used as the coordinate system for the radar measurements.

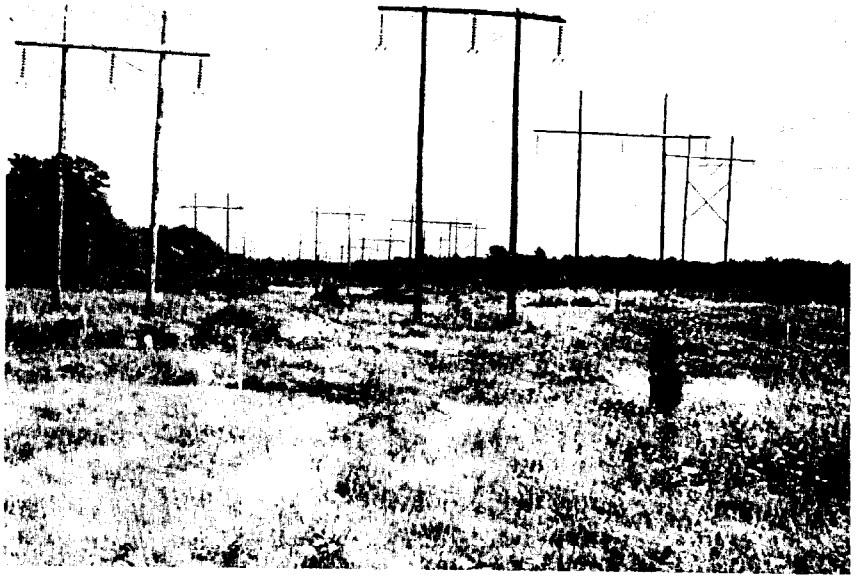
Requirements for the Ground Penetrating Radar survey required mapping the entire site, with particular emphasis on those areas where elevated radiation readings had been recorded. Therefore, the survey consisted of two subsurveys: 1) a wide area survey having a coarse grid, and (2) a series of smaller surveys having a tight grid.

For the wide area (coarse grid) survey, the electronics were mounted in the rear of a 4-wheel drive vehicle made available by the Civil Defense organization of Attleboro. Three lines were surveyed along each 50-foot corridor of the grid system: (a) one each to the left and right of the grid markers, and (b) one down the center. Major obstructions such as utility poles, piled debris, and swampy areas limited the accessibility to much of the site. Representative photographs of the site are shown in Figure 2. The grid system, with actual survey lines superimposed, is shown in Figure 3.

The tight grid subsurveys over areas exhibiting elevated radiation readings were conducted by manually drawing the radar antenna in a serpentine pattern with 5-foot line spacing over accessible portions of the inclusive 50-foot x 50-foot grid. These 22 designated areas are also shown in Figure 3.

ORNL-PHOTO 8315-81

a. Looking west from 300 left, 5+00.



b. Looking southeast from 50 left, 2+50.

Figure 2. Photographs showing portions of Norton/Attleboro Dumpsite.

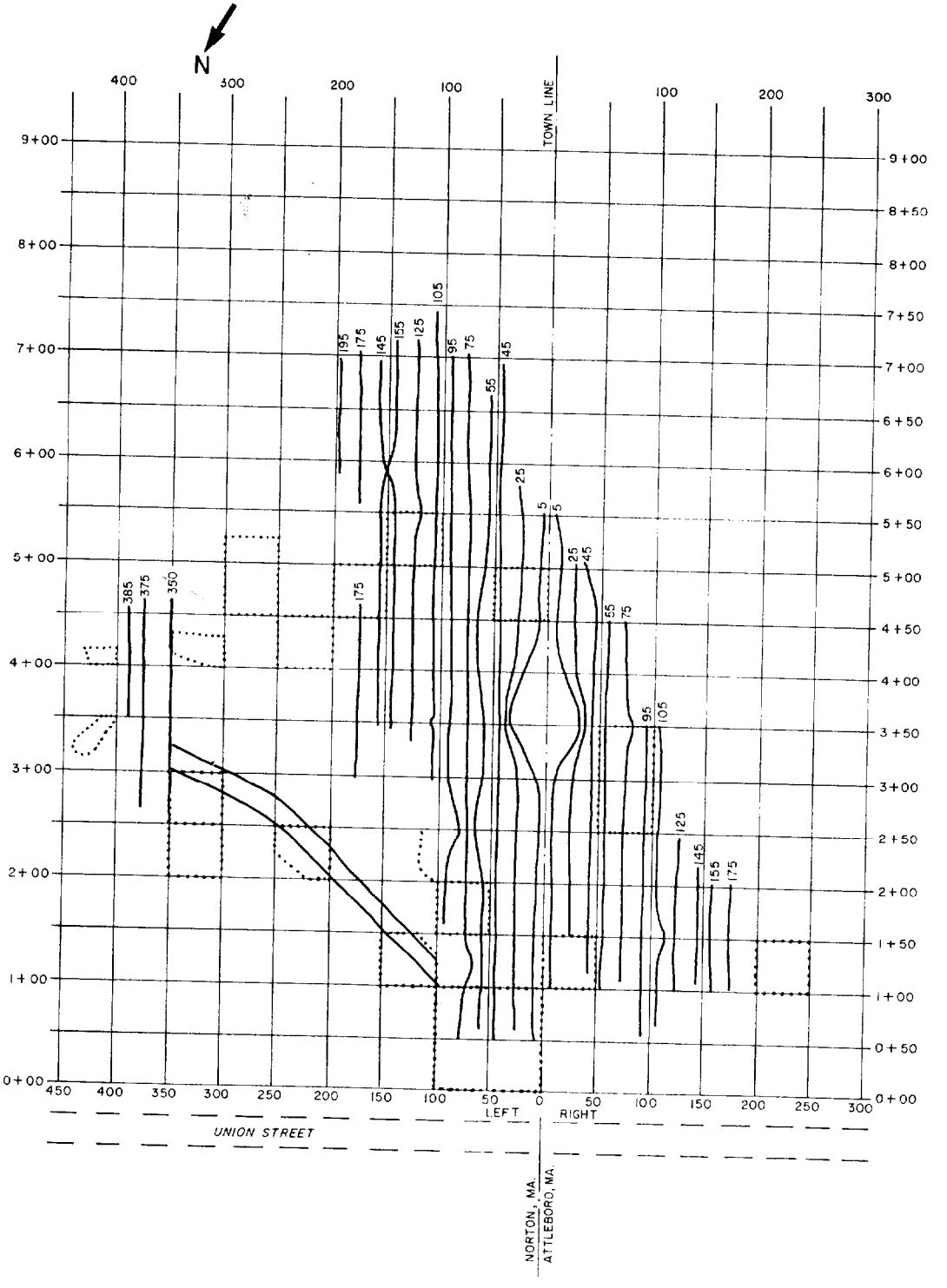


Figure 3. Norton/Attleboro Site Lay-Out Showing Survey Lines and High Resolution Survey Areas.

DISCUSSION OF RESULTS

Several antenna systems were evaluated and calibration measurements were made to tailor the radar system for the specifics of the Norton/Attleboro site. A 300-MHz antenna having a spatial resolution of better than 1 foot and a probing depth of approximately 10-15 feet was selected for use.

This Ground Penetrating Radar system detected the presence of many subsurface disturbances, some identifiable as metallic. Because metallic targets totally reflect electromagnetic signals, such large targets at or near the surface preclude the detection of additional objects beneath them. Every effort was made to remove surface debris prior to surveying an area.

A typical example of radar data is shown in Figure 4. This figure depicts a scan from station 3 + 40 to 7 + 20 along line Left 125 (see Figure 3 for a description of the coordinate system). While appearing complex, the information in this record can readily be sorted into four generic categories:

1) moderate-to-heavily populated areas of near-surface and subsurface metallic debris, e.g. from station 3 + 40 to 5 + 50.

2) dense concentration of subsurface reflective objects (nonmetallic), e.g. from station 5 + 50 to 6 + 20.

3) lightly populated areas of subsurface metallic debris, e.g. from station 6 + 20 to 7 + 20.

4) individual subsurface objects, not associated with general clutter, e.g. stations 6 + 20 and 6 + 40.

To better resolve strong individual targets, the data were processed and displayed at various gain settings. For example, Figure 5 shows the same scan line data as Figure 4 but with noise and secondary targets suppressed.

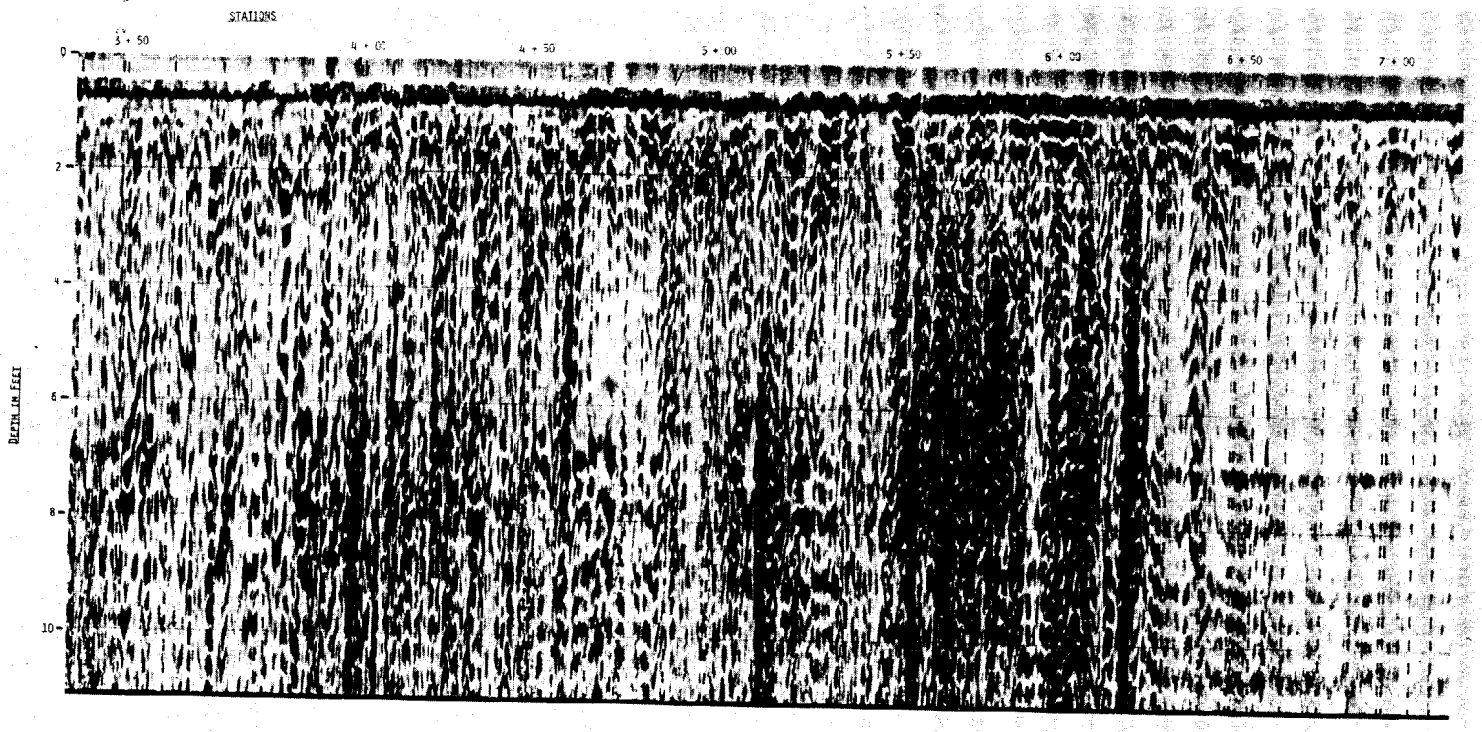


Figure 4. Example of Radar Profile Along Line 125 Left.

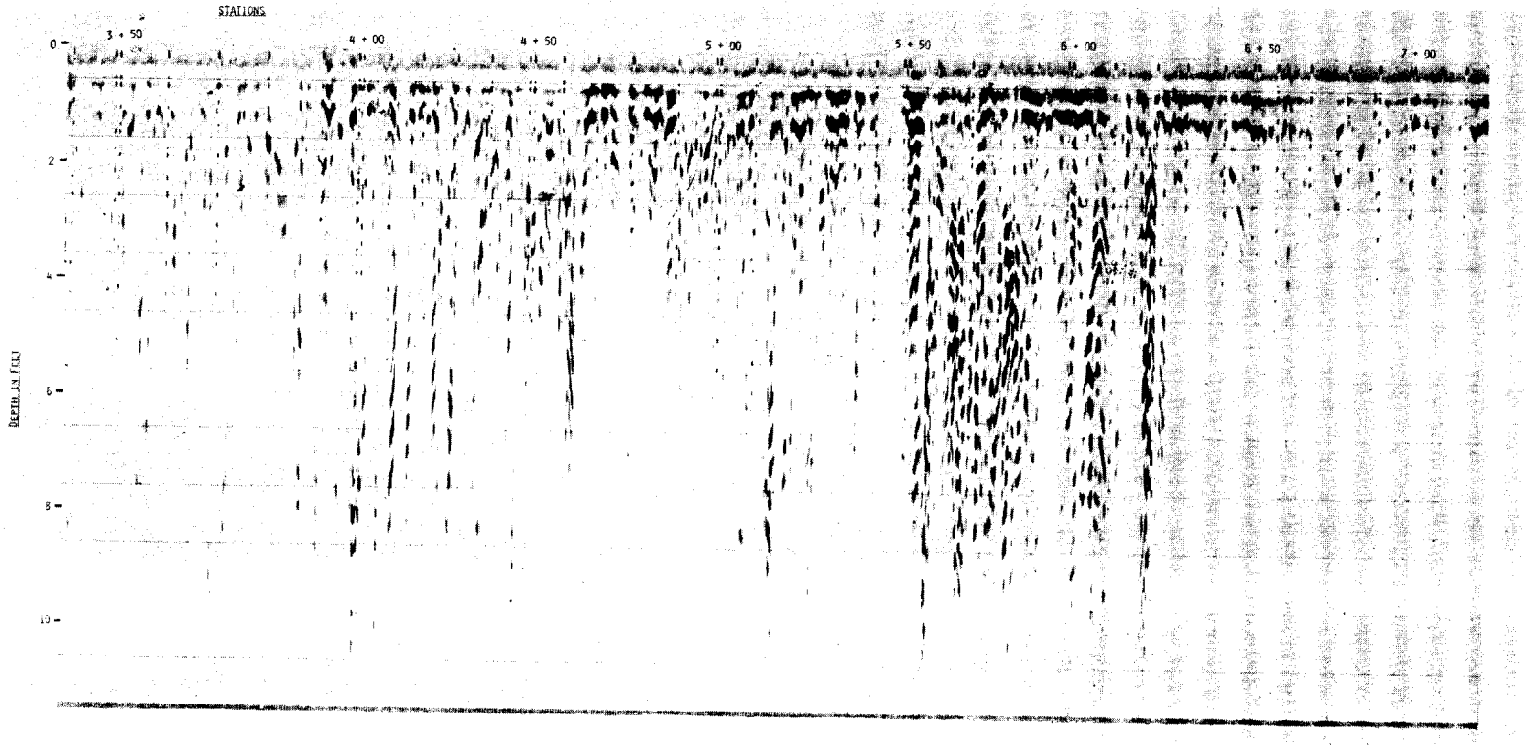


Figure 5. Example of Radar Profile Along Line Left 125 (Printed at Lower Gain Setting than Figure 4).

All data were visually analyzed at a number of gain settings, and the results sorted into one of the four generic categories described above. The results are summarized in Plate 1. The width of the path swept out by the radar antenna as a line was being scanned is approximately 5 feet. The tight grid surveys (5-foot line spacing) of individual sectors are, therefore, comprehensive, while the wide area survey (with approximately 15-foot line spacing) provides about 30% coverage. The spatial accuracy of the high resolution survey data is estimated at ±5 feet in any direction, while that for the wide area survey data is estimated at ±10 feet laterally and ±5 feet along a scan line.

As expected, the site was uniformly littered with a variety of debris, much of it metallic and most of it small. These findings are consistent with site operations as understood. The number of large, discrete subsurface targets was relatively small and generally very near the surface. While such targets could be buried metal drums, the nature of the surface debris, and the general clutter observed in the radar signals, suggest that these targets are probably large portions of scrap metal or portions of empty drums.

The only area in which the data strongly suggest the systematic burial of containers (nonmetallic) is in that sector bounded by Left 100 and Left 150, and stations 5 + 50 and 6 + 00. (Refer to Plate 1.)

In the drilling operations that followed this survey work, areas containing significant subsurface disturbances were avoided. To identify the nature of the targets in that one particular sector (described in the above paragraph), a single test hole was carefully drilled, but nothing was discovered. Time constraints on the drilling contractor precluded further exploration.

While the radar technique is new and not fully demonstrated, the existence of these data provided an added degree of assurance that intrusive activities could be undertaken at minimal risk. Subsequent drilling activities proceeded uneventfully.

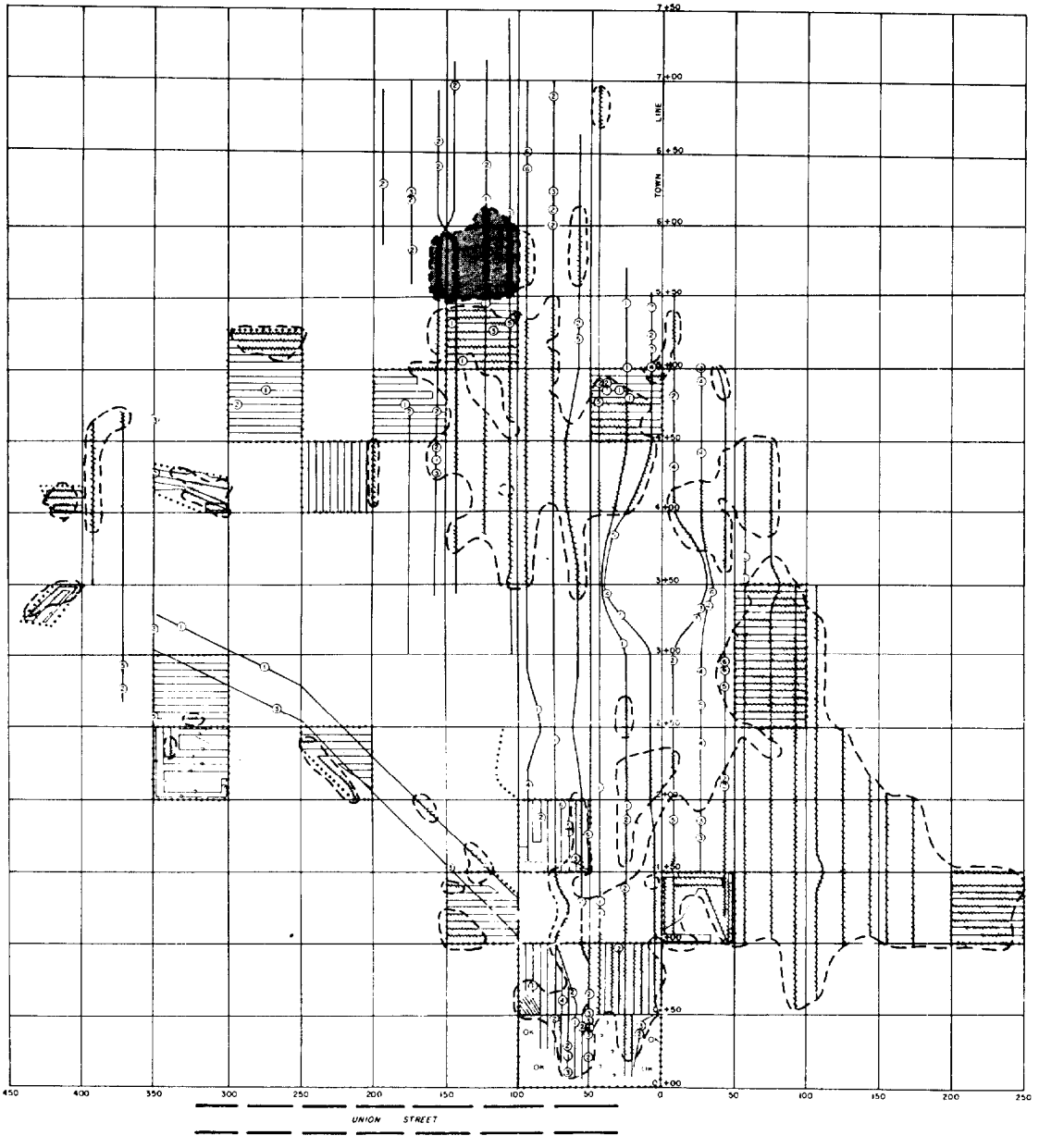


PLATE 1. INTERPRETATION OF GROUND PENETRATING RADAR SURVEY AT NORTON/ATTLEBORO, MA DUMP SITE.

LEGEND

= MODERATELY TO HEAVILY POPULATED AREAS OF NEAR-SURFACE AND SUB-SURFACE METALLIC "TRASH"

(2) = INDIVIDUAL METALLIC TARGETS (NUMBER INDICATES APPROXIMATE DEPTH IN FEET)

= DENSE CONCENTRATION OF REFLECTIVE OBJECTS

= UNMARRED TRAVERSES ARE LIGHTLY POPULATED WITH SUBSURFACE METALLIC "TRASH"

? = DATA TAKEN BUT NOT INTERPRETABLE.

APPENDIX V

SI METRIC CONVERSION TABLE

SI METRIC CONVERSION TABLE

The following table has been developed for use with this report in the conversion of units of measurement from those utilized in the text to the newly adopted International System of Units (SI). Units used in the text which do not appear in this table are considered as standard under the new system.

Standard units of measurement

To convert from	Into SI units	Multiply by
Gallons (gal)	Liters (l)	3.785
Inches (in)	Centimeters (cm)	2.540
Square inches (in^2)	Square centimeters (cm^2)	6.452
Feet (ft)	Meters (m)	0.3048
Square feet (ft^2)	Square meters (m^2)	0.0929
Acres (a)	Hectare (ha)	0.4047
Miles (mi)	Kilometer (km)	1.609
Millirad (mrad)	Microgray (μGy)	10.0
Microroentgen (μR)	Coulomb per kilogram (C/kg)	2.58×10^{-10}
Disintegrations per minute (dpm)	Becquerel (Bq)	0.0167
Picocurie (pCi)	Becquerel (Bq)	0.037
Microcurie (μCi)	Becquerel (Bq)	3.7×10^4

APPENDIX VI

PERTINENT RADIOLOGICAL REGULATIONS, STANDARDS, AND GUIDELINES

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

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

November 1976

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

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

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

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

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

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

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

5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table VI-1. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D. C. 20555, and also the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:

   a. Identify the premies.

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

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

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

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

Table VI-1. Acceptable surface contamination levels

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

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

[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

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

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

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

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

Excerpts from
Proposed
ANSI N328-197

Proposed American National Standard

Control of Radioactive Surface Contamination on Materials, Equipment, and Facilities to be Released for Uncontrolled Use

Secretariat
Health Physics Society

Property shall not be released for uncontrolled use unless documented measurements show the total and removable contamination levels to be no greater than the values in Table VI-2 or Table VI-3. (Table VI-3 is easier to apply when the contaminants cannot be individually identified.)

Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but made the subject of case-by-case evaluation. Credit shall not be taken for coatings over contamination.

TABLE VI-2

SURFACE CONTAMINATION LIMITS

The levels may be averaged[a] over the 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

Nuclide	Limit (Activity) dpm/100 cm^2	
	Total	Removable
Group 1: Nuclides for which the non-occupational MPC_a[b] is 2 x 10^{-13} Ci/m^3 or less or for which the nonoccupational MPC_w[c] is 2 x 10^{-7} Ci/m^3 or less; includes Ac-227; Am-241; -242m, -243; Cf-249; -250, -251, -252; Cm-243, -244, -245, -246, -247, -248; I-125, -129; Np-237; Pa-231; Pb-210; Pu-238, -239, -240, -242, -244; Ra-226, -228; Th-228, -230.	100	20
Group 2: Those nuclides not in Group 1 for which the nonoccupational MPC_a[b] is 1 x 10^{-12} Ci/m^3 or less or for which the nonoccupational MPC_w[c] is 1 x 10^{-6} Ci/m^3 or less; includes Es-254; Fm-256; I-126, -131, -133; Po-210; Ra-223; Sr-90; Th-232, U-232.[d]	1000	200
Group 3: Those nuclides not in Group 1 or Group 2.	5000	1000

[a] See note following table on application of limits.

[b] MPC_a: Maximum Permissible Concentration in Air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as NCRP, ICRP or NRC (10 CFR 20, Appendix B, Table 2, Column 1).

[c] MPC_w: Maximum Permissible Concentration in Water applicable to members of the public.

[d] Values presented here are obtained from 10 CFR Part 20. The most limiting of all given MPC values (e.g., soluble vs insoluble) are to be used. In the event of the occurrence of a mixture of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fractions must be less than one.

TABLE VI-3

ALTERNATE SURFACE CONTAMINTION LIMITS

(All alpha emitters, except U-nat and Th-nat are considered as a group.) The levels may be averaged over 1 m^2* provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

Nuclide	Limit (Activity) dpm/100 cm^2	
	Total	Removable
If the contaminant cannot be identified; or if alpha emitters other than U-nat and Th-nat are present; or if the beta emitters comprise Ac-227, Ra-226, Ra-228, I-125, and I-129	100	20
If it is known that all alpha emitters are generated from U-nat and Th-nat; and beta emitters are present which, while not identified, do not include Ac-227, I-125, I-129, Ra-226, and Ra-228	1,000	200
If it is known that alpha emitters are generated only from U-nat and Th-nat; and the beta emitters, while not identified, do not include Ac-227, I-125, I-129, Sr-90, Ra-223, Ra-228, I-126, I-131, and I-133	5,000	1,000

*NOTE ON APPLICATION OF TABLES 1 AND 2 TO ISOLATED SPOTS OR ACTIVITY:

For purposes of averaging, any m^2 of surface shall be considered to be contaminated above the limit, L, applicable to 100 cm^2 if:

a. From measurements of a representative number, n, of sections, it is determined that $1/n \sum_{n} S_i \geqq L$, where S_i is the dpm/100 cm^2 determined from measurement of section i; or

b. On surfaces less than 1 m^2, it is determined that $1/n \sum_{n} S_i \geqq AL$, where A is the area of the surface in units of m^2; or

c. It is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 exceeds 3L.

SURGEON GENERAL'S GUIDELINES
10 CFR 712
Grand Junction Remedial Action Criteria

Federal Register, Vol. 41, No. 253, pp. 56777-8,
Thursday, December 30, 1976

PART 712 - GRAND JUNCTION REMEDIAL ACTION CRITERIA

712.1 Purpose

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailings which have been used as construction-related material.

(b) The regulations in this part are issued pursuant to Publ. L. 92-314 (86 Stat. 222) of June 16, 1972.

712.2 Scope

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

712.3 Definitions

As used in this part:

(a) "Administrator" means the Administrator of the Energy Research and Development Administration or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the Energy Research and Development Administration or duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) averaging the results of 6 air samples, each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "Milliroentgen (mR) means a unit equal to one-thousandth (1/1000) of a roentgen which roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally these include Radium A (polonium-218), Radium B (lead-218), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium mill operation involved in the federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

712.4 Interpretations

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

712.5 Communications

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

712.6 General radiation exposure level criteria for remedial action

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr	Greater than 0.05 WL	Remedial action indicated
From 0.05 to 0.1 mR/hr	From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.05 mR/hr	Less than 0.01 WL	No remedial action indicated

712.7 Criteria for determination of possible need for remedial action

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial

measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr above background, the indoor radon daughter concentration level is less than 0.01 WL above background and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr above background but is less than 0.02 mR/hr above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures:

(i) An external gamma radiation level of 0.15 mR/hr above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

712.8 Determination of possible need for remedial action where criteria have not been met

The possible need for remedial action may be determined where the criteria in 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

712.9 Factors to be considered in determination of order or priority for remedial action

In determining the order or priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

(a) Classification of structure. Dwellings and schools shall be considered first.

(b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in 712.7 will be considered first.

(c) Order of application. Insofar as feasible remedial action will be taken in the order which the application is received.

(d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.

(e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.

(f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.

(g) Climatic conditions. Climatic conditions or other seasonable considerations may affect the scheduling of certain remedial measures.

712.10 Selection of appropriate remedial action

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr above background in the case of dwellings and schools and 0.15 mR/hr above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding, may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determined to be the most appropriate under the circumstances.

ENVIRONMENTAL PROTECTION AGENCY

Title 40-Part 141

Interim Primary Drinking Water Regulations
Promulgation of Regulations on Radionuclides

Federal Register, Vol 41, No. 133, pp. 28402-9
Friday, July 9, 1976

Part 141.15 *Federal Register*
Vol. 41, No. 133, p. 28404, Friday, July 9, 1976

Maximum contaminant levels for ^{226}Ra, ^{228}Ra, and gross alpha particle radioactivity.

(a) Combined ^{226}Ra and ^{228}Ra - 5 pCi/liter.

(b) Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium) - 15 pCi/liter.

APPENDIX VII

EVALUATION OF RADIATION EXPOSURES AT THE SHPACK LANDFILL, NORTON, MASSACHUSETTS

EVALUATION OF RADIATION EXPOSURES AT THE SHPACK LANDFILL, NORTON, MASSACHUSETTS

The U.S. Department of Energy, (DOE) has determined that the Shpack Landfill is presently contaminated with radioactive materials resulting from its prior use as a dump site. This site began receiving wastes in late 1946, and continued to receive both domestic and industrial wastes until 1965. It is believed that the radioactive materials were inadvertantly deposited on this landfill during its active lifetime. Some of these radioactive materials were wastes associated with uranium processing by companies under contract with the Manhattan Engineer District (MED) or the Atomic Energy Commission (AEC). This site is privately owned and lies approximately three miles southwest of the Town of Norton, Massachusetts.

Contamination at the Shpack site is due to deposits of naturally occurring radioactive materials – primarily uranium-238, uranium-235, and radium-226. The concentration of radioactivity in some of these materials, however, may have been substantially increased by prior use and processing. This contamination will yield slight radiation exposures to persons who might occupy the site. These slight radiation exposures result primarily from beta and gamma radiations emitted by the radionuclides in the soil. The present condition of the site renders the soil unsuitable for growing vegetables or fruit for human consumption. Consequently, it is highly unlikely that any significant additional radiation exposure would be received by way of ingestion from eating vegetables or fruit grown on the site. The heavy cover of naturally occurring vegetation on the site precludes any significant resuspension of particulate contamination from the land surface by wind or air currents; hence, radiation exposures from inhalation of radioparticulates is currently not a problem. If operations which involve considerable scraping or turning of dry soil were performed in areas showing high concentrations of radionuclides, radiation exposures from the inhalation pathway would need to be reevaluated. A summary of radiation exposures is provided in Table VII-1 along with appropriate guidelines and background values.

The naturally occurring radionuclides present at the Shpack site are also present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry and, to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

Uranium-238 is believed to have been created when the earth was formed. It is still present today because it takes a very long time to decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if 4.5 billion years ago you had a curie* of uranium-238, today you would have one-half curie; 4.5 billion years hence, this would only be one-fourth curie. As the uranium-238 decays, it changes into another substance, thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table VII-2 until stable lead is formed. The "decay product" listed in Table VII-2 is the radiation produced as the parent decays.

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*The curie is a unit used to measure the amount of radioactivity in a substance; one curie represents 37 billion radioactive disintegrations per second.

Direct Beta and Gamma-Ray Exposures

Nuclear Regulatory Commission (NRC) guidelines state that the combined dose from weakly penetrating beta particles and from gamma-rays, measured at a distance of 1 centimeter from any surface, should not exceed 0.2 millirad* per hour when averaged over an area of 1 square meter. The combined dose rate should not exceed 1.0 millirad per hour in a small area of 100 square centimeters. These guidelines are exceeded at many locations on the site with individual measurements ranging up to 30 millirads per hour.

The primary concern of the NRC guidelines is exposure of skin surfaces. The thickness of ordinary shoe soles is adequate to protect the skin of the feet from beta radiation. Other areas of body skin are adequately protected from these exposures if they remain away from these surfaces. In most cases, exposures are negligible at a distance of 1 foot away from these surfaces.

Direct contact with the most contaminated area on site (30 millirads per hour) for one hour would produce a beta-gamma dose of 30 millirads to the skin. For comparison, the skin dose which would be expected from a normal year's watching of color television by an adult is 1.6 millirads; for a child less than 15 years of age, the comparable dose is 3.6 millirads per year (according to the United Nations Scientific Committee on the Effects of Atomic Radiation). For another comparison, the NRC limit for beta-gamma dose rate for skin of the whole body of radiation workers would be equivalent to 15 millirads per hour for 500 hours in any calendar quarter; the dose rate limit for hands, forearms, feet, and ankles would be equivalent to 37.5 millirads per hour for radiation workers.

External Gamma-Ray Exposure

As may be seen in Table VII-2, several of the daughters of uranium-238 and of radium-226 emit gamma radiation (gamma-rays are penetrating radiation like X-rays). Hence, the residues on this site

*The millirad is a unit for measuring the amount of radiation energy absorbed by human tissue.

are sources of external gamma radiation exposure. External gamma-ray exposures measured at 1 meter above the ground at the Shpack site ranged from 4 to 365 microRoentgens* per hour, with an average of 12 microRoentgens per hour. Exposure to this average level for 2,000 hours per year, a typical work year, would lead to an exposure of 24,000 microRoentgens. For comparison, a typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of 27,000 microRoentgens. Background radiation levels in the Attleboro/Norton area averaged 7 microRoentgens per hour.

The National Council on Radiation Protection and Measurement (NCRP) has recommended a maximum annual whole-body exposure rate of 500,000 microRoentgens per year to an individual continually exposed in the general public. This value corresponds to 250 microRoentgens per hour for 2,000 exposure hours (40 hours per week and 50 weeks per year). This guideline would be exceeded at two locations on site. At the present time, the landfill is not occupied and access to the site is discouraged by "No Trespassing" and "Warning - Radioactive Materials" signs posted along the Union Road - Peckham Street border of the site. Nevertheless, the site shows signs of occasional use for hunting and refuse disposal. It is highly unlikely that any individual would occupy any part of the site for more than a few hours each month and, hence, it appears that gamma radiation exposures received from the site would be very little different from background.

Inhalation of Radionuclides

Radon-222, the daughter of radium-226, is an inert gas which may leave the soil and enter the atmosphere. Furthermore, radon can seep through concrete floors and accumulate in poorly ventilated buildings. At the present, no structures exist on the site. However, if buildings were to be constructed over areas contaminated with radium-226, radon concentrations in the buildings could be slightly elevated above normal

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*The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A micro-Roentgen is one-millionth of a Roentgen.

levels. Because the distribution of the radium-226 contamination is uneven and the total quantity is small, it is unlikely that the radon concentration in any structures built over the most contaminated soil could exceed the guideline value of 3 picocuries* per liter for exposure of the general public as set forth in 10 CFR 20.†

As may be seen in Table VII-2, the decay of radon-222 produces a series of short-lived daughters. The unit which has been developed to measure the concentration of daughters is the working level.§ It is estimated that present radon daughter concentrations in air on the site are much less than 0.001 working level. These concentrations are well below the guideline value of 0.03 working level suggested in 10 CFR 20. It is also doubtful that this guideline value could be exceeded in structures built over the most contaminated soil. However, careful consideration should be given to the location of any structure built on or near presently contaminated areas of this site.

Other Considerations of Exposure

The concentration of radionuclides in groundwater samples taken at the site were generally below the concentration guide for water (CG_w) set forth in 10 CFR 20. Three samples taken from holes drilled on the site showed concentrations of radionuclides that exceeded the guidelines. The maximum concentration observed, 1400 pCi of radium-226 per liter of water, was from hole 5. For comparison, the concentration guide for radium-226 is 30 picocuries per liter. Water samples taken from drainageways leading from the site indicate that at the present time no significant radioactive contamination is moving from the site into surface streams. Also, results of analyses of water samples taken from

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*One picocurie is one million-millionth of a curie, previously defined.

†Title 10, Code of Federal Regulations, Part 20, is a regulatory document published by the Nuclear Regulatory Commission and may be found in the *Federal Register*.

§The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

the Shpack well and from three monitoring wells located along the northeast boundary of the site indicate that at the present time radioactivity found in groundwater in holes drilled onsite is not moving into potable water supplies. No crops are currently being grown on the site and it is highly questionable if they could be grown successfully. However, should this occur, consumption of such crops which have incorporated radium-226, uranium-238, or uranium-235 could produce additional human exposure. In addition, actions which involve considerable scraping or tilling of dry soil, particularly in the areas showing high concentrations of radionuclides in surface soil, could lead to human exposures through inhalation of airborne radioactive dust.

Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, risks to health may be classified in four categories:

1. Unacceptable--problems with risk so high as to require immediate action, such as severe diseases where medical treatment is required to save a life.
2. Concerned--problems where people are willing to spend time and money to reduce potential hazards. Examples of this include the maintenance of public highways and signs, signals, fire departments, and rescue squads.
3. Recognized--problems where people may accept some inconvenience to avoid certain activities such as flying in airplanes, swimming alone, etc.
4. No great concern--problems with a low frequency of occurrence. There is an awareness of potential hazard but an accompanying feeling that these problems occur only to other people.

An individual may be exposed to risks over which he can exercise some control (voluntary) and risks over which he feels he has no personal control or choice (involuntary).

Daily, an individual is confronted with decisions about risk which have an associated benefit--for example, driving a car. This can serve as an illustration that a voluntary, concerned risk may be deemed appropriate due to the desirable perceived benefit. As another example, an individual who smokes cigarettes has subjected himself to a risk of lung cancer which is about ten times higher than that for a nonsmoker.

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancer deaths in the relatively small population exposed at the Shpack Landfill.

The annual death rate* from all types of cancer among all population groups in Bristol County (as of 1970) was 168 deaths per 100,000 population. At the same time, the death rates from all types of cancer for all population groups in the United States and in the State of Massachusetts were 151 and 163 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 micro-Roentgen might increase the risk of death due to all types of cancer by about one-tenth of a percent. Exposures in excess of these guideline values would be expected to result in proportionately higher increases in risk. Consequently, any action taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

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*Mortality statistics were obtained from data in *U.S. Cancer Mortality by County: 1950-1969*, prepared by the National Cancer Institute, 1973, available from the U.S. Government Printing Office.

There are no data at present which give evidence of a relationship between low-level exposure of the skin by beta-gamma radiation and the development of skin cancers. This does not mean that skin cancer cannot be produced by low-level exposures. This does mean that the risk associated with guideline level exposures of the skin is so small that it cannot be quantified.

Remedial Measures

The radiation exposures at the Shpack Landfill are attributable to the presence of natural uranium, enriched uranium, and radium-226 deposits in soil on the site. This contamination leads to exposures due to external beta and gamma radiation. Remedial measures such as fencing the site to control access would be applicable as a short-term action to reduce population exposure to external beta and gamma radiation. The long-term solution to the problem might involve such actions as the removal of all contaminated soil from the site and backfilling with uncontaminated soil. The Department of Energy is now actively evaluating this and other alternative measures under a priority program designed to assure public protection.

Summary

The Shpack Landfill is contaminated with residues containing uranium-238, uranium-235, and radium-226. The uranium contamination results from the unauthorized disposal of wastes originating from uranium processing under MED and AEC contracts. The radium-226 residue appears to have its origin in industrial wastes disposed of in the landfill. This contamination is leading to slight radiation exposures to persons who occasionally enter or work on this site. More importantly, this site has the potential for contributing to human exposure through the use of the site for residences, business, or using the contaminated soil to grow crops for human consumption. Consequently, remedial measures are in order. The Department of Energy has developed a coordinated plan which addresses the specific problems at this landfill and other formerly utilized MED/AEC sites. Currently, work is underway to implement the elements of this plan.

Table VII-1. Summary of Exposure Data at the Shpack Site in Norton, Massachusetts

Exposure source	Background levels	Guideline value for general public	Guideline value for radiation workers	Average levels at the Shpack site
Gamma radiation from daughters of uranium, radium, and thorium.	Background averages 7 microRoentgens[a] per hour in Norton, MA area.	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 0.5 Roentgen per year.	2,500 microRoentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 Roentgens per year.	Values ranged from approximately 4 to 365 microRoentgens per hour at one meter, and averaged about 12 microRoentgens per hour.
Radon in air.	Less than one picocurie[b] per liter of air.	Continuous exposure to 3 picocuries per liter of air.	Exposure for 40 hours per week and 50 weeks per year to 30 picocuries per liter of air.	Estimated concentration is less than one picocurie per liter of air.
Radon daughters in air.	Less than 0.01 working level.[c]	0.01 working level for residences and school rooms, and 0.03 working level for other structures.	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year.	Estimated average concentration is less than 0.001 working level.

[a]The Roentgen is a unit of exposure to penetrating X or gamma radiation. A microRoentgen is one-millionth of a Roentgen.

[b]The picocurie is a unit which was defined for expressing the amount of radioactivity present in a substance.

[c]The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

Table VII-2. Uranium-238 decay series

Parent	Half-life	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 thousand years	alpha	thorium-230
thorium-230	80 thousand years	alpha	radium-226
radium-226	1,600 years	alpha	radon-222
radon-222	3.8 days	alpha	polonium-218
polonium-218[a]	3 minutes	alpha	lead-214
lead-214[a]	27 minutes	beta, gamma	bismuth-214
bismuth-214[a]	20 minutes	beta, gamma	polonium-214
polonium-214[a]	$\frac{2}{10,000}$ 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

[a]Short-lived radon daughters.

APPENDIX VIII

ENVIRONMENTAL IMPACT EVALUATION: PROPOSED RADIOLOGICAL SURVEY OF SHAPACK LANDFILL, NORTON, MASSACHUSETTS

Environmental Impact Evaluation:
Proposed radiological survey of Shpack landfill, Norton, Massachusetts

Purpose and need of activity

Citizen reports of surface radioactivity at the former Shpack landfill, Norton, Massachusetts, have been confirmed by measurements performed for the Department of Energy (DOE). This former landfill may have been used by a government contractor who processed radioactive materials. Consequently, DOE has accepted responsibility for determination of need for and implementation of remedial action at the site to reduce human radiation exposure to the lowest reasonably achievable levels. The DOE needs information about the distribution of subsurface radioactivity at the site in order to determine the need for remedial action. This information can be obtained from a radiological survey performed in conjunction with subsurface drilling and sampling.

A portion of the landfill is known locally as the "Thompson chemical dump" and is thought to contain chemical wastes of undetermined composition. Concern for possible health hazards posed by the chemical wastes has been expressed, but determination of need for and implementation of remedial action relative to the chemical wastes lies outside the authority of the Department of Energy. This environmental impact evaluation therefore addresses only the proposed radiological survey of the Shpack landfill which is being conducted as part of the determination of need for remedial action for radioactive materials.

Description of activity

A radioactivity profile of the Shpack landfill will be determined by means of drilling and subsurface sampling. Approximately 40 holes (15 cm diameter) will be augered so that a 10 cm diameter, closed-end PVC pipe may be inserted. Instrumentation to measure gamma radiation intensity as a function of depth will be lowered into the PVC pipe. Approximately 10 additional holes will be cored (7 cm diameter minimum) to obtain subsurface samples for radioassay. After core samples are obtained, core holes will be augered and radiologged, as described above. Neither auger nor core holes will be permitted to penetrate the peat layer which is thought to underly the landfill. All material produced during drilling will be retained on the landfill surface and used to refill holes at completion of the survey. If additional fill is required, it will be obtained on-site.

Location, extent, timing, and duration of activity

The Shpack landfill (Fig. 1) is located between the towns of Attleboro and Norton, Massachusetts. The site is bounded on the northwest by Union Street (town of Norton) and Peckham Street (town of Attleboro), on the southwest by the Attleboro landfill and on the remaining sides by a swamp which drains into Chartley Pond to the north.

Drilling will occur on approximately 2.2 ha acquired by the Norton Conservation Commission and leased to the Department of Energy. Permission has not been obtained to drill on the approximately one hectare owned by Attleboro Landfill, Inc.

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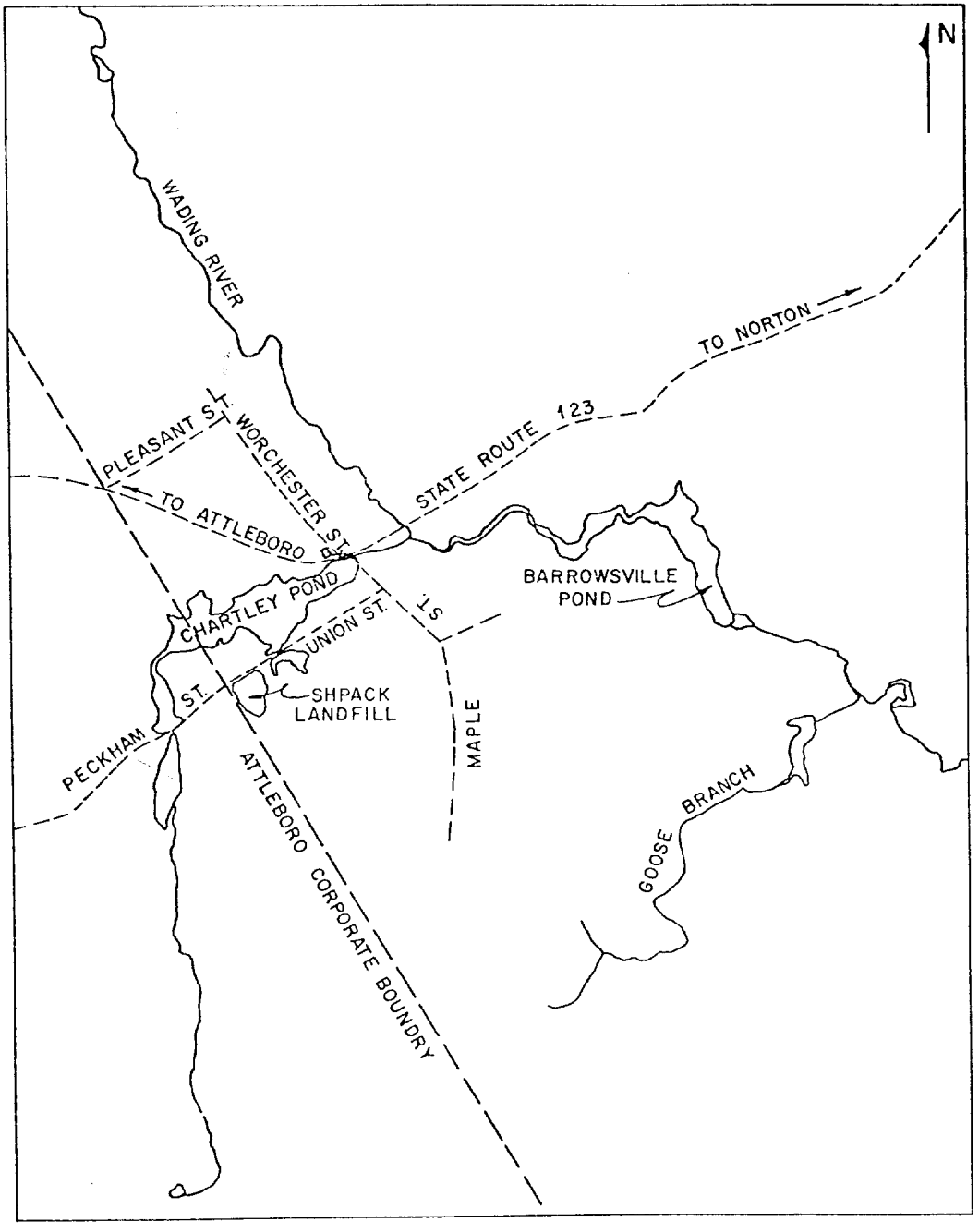

Figure 1. The Shpack landfill site and vicinity, Norton/Attleboro, Massachusetts.

Sampling will occur over a three-day period, yet to be determined, but coming in late summer when the water table is lowest and the landfill surface is sufficiently dry to support the drilling equipment. Two vehicles, one a truck with a drilling rig, will be required. Approximately six people will work on the activity.

Alternatives (other than "no action")

No alternatives exist which could be used to characterize the distribution of radioactivity in the landfill.

Description of Existing Environment

o Topography and geography

The 3.25 ha site was formerly swampland and water still covers much of the site in spring and early summer. It lies below the raised Attleboro landfill and adjacent to State Route 123 (Union/Peckham Street). The site is nearly level with drainage toward the south into the swamp.

o Soils and geology

Bedrock in the area is folded, faulted and metamorphosed sedimentary rock of Pennsylvanian age and is buried beneath 9 to 15 m of glacial tills and soils. The tills and deep soils consist of interstratified beds and lenses of sand, silt, clay and gravels. The tills are generally 8 to 10 m thick under the high ground and approximately 3 m thinner under the swamps.[7]

The Shpack dumpsite was originally an extension of the "kettle hole" swamp to the south. Surface drainage is primarily southward to

the swamp. Soil underneath the dump fill was originally classified as a medisaprist, consisting of up to 1.5 m or more of organic-rich swamp deposits developed on top of impermeable lacustrine and hard pan deposits. During landfill operations the swamp was buried under a variety of industrial and construction debris and soil fill. Observations made at the site indicate the fill to be poorly drained, suggesting very low permeability.

High ground encircling the swamp site is developed on deltaic sand and gravels with soils classified as Windsor or Hinckley Series, depending on gravel content. Both soil types are highly permeable. Mrs. Shpack reported that her shallow well (depth approximately 3.8 m) responded readily to rainfall and drought conditions.

The hydrogeologic situation at the Shpack-Attleboro landfill site appears to consist of the topographically-low, impermeable, swamp - landfill deposits lying between the well-drained high ground areas at the Attleboro landfill and the Shpack residence. It appears that drainage of storm or flood waters from the dumpsite is a more likley pathway for contaminant migration than subsurface movement. Transport would occur mainly by the physical washing of contaminated debris from the land surface into the swamp southeast of the site (Figure 2). During flooding severe enough to inundate most of the site it may be possible for contaminated water from the small pond on the east side of the landfill to move into the permeable sand and gravel deposits under the adjacent high ground (Figure 2). However, the proposed sampling program would have no significant effect on either of the pathways described.

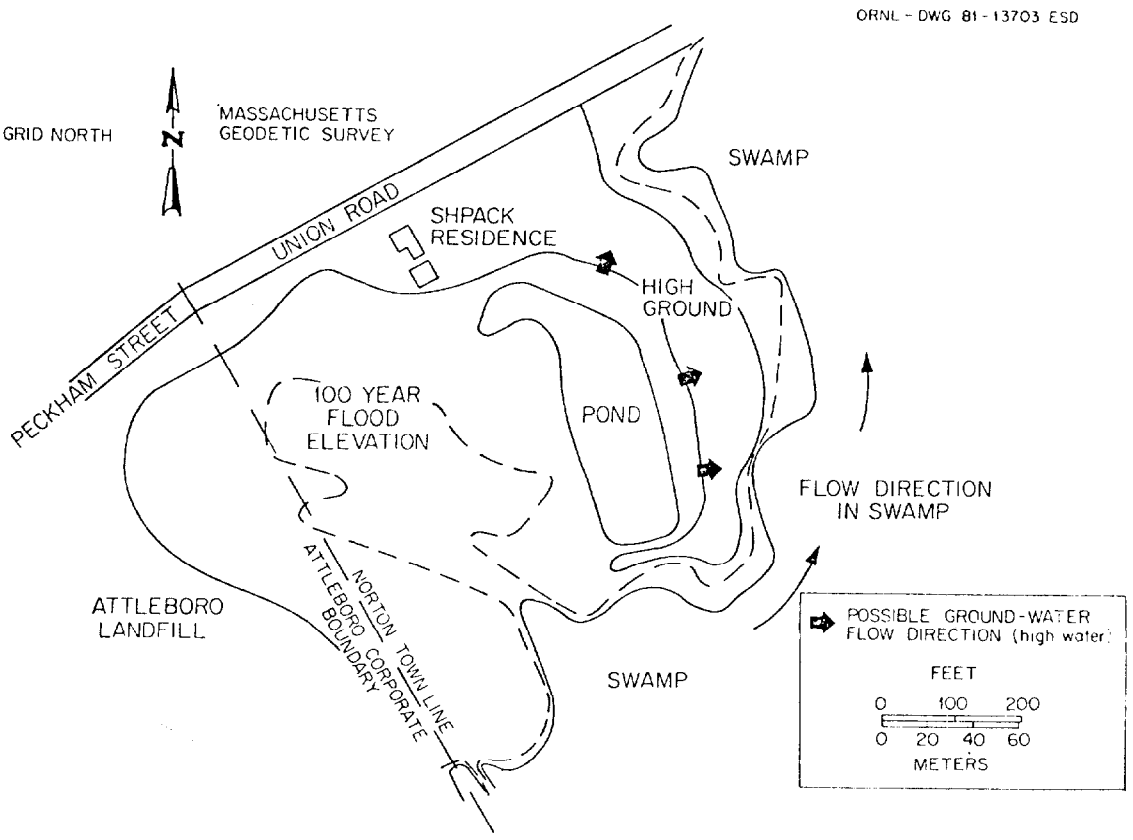

Figure 2. Surface water flow paths at the Shpack landfill site (potential contaminant pathways).

o Meteorology and air quality[3]

The prevailing wind, on an annual basis, is westerly, with northwesterly winds predominating in winter and southwesterly winds predominating in summer. Winds are generally light except during thunderstorms, which occur 20 to 30 days per year. Mean annual temperature is approximately 4°C with January being the coldest month (-3°C) and July the warmest (22°C). Air quality is typical of the urbanized northeast.

o Surface and ground water characteristics and water quality

Surface water in the vicinity of the Shpack site drains via Chartley Brook and Chartley Pond into the Wading River at Norton, Massachusetts. Based on U.S.G.S. water resources data for Massachusetts,[5] the long-term runoff for the area averages about 603 mm/y per unit area or 54% of precipitation.[6] Highest flows occur in late winter and early spring, and minimum flows during the July-September period. The peak discharge for the 100-y flood[1] is estimated to be 27.7 m^3/s at the mouth of Chartley Brook, where the contributing area is 74.3 km^2.

Groundwater in unconsolidated glacial deposits in the near vicinity of the Shpack site exhibits an unconfined water-table. In other words, the top of the saturated zone is at atmospheric pressure. The general direction of flow is to the north, toward Chartley Pond. This is inferred from the gradient between surface water adjacent to the site (31.7 m on 3/3/81) and that in Chartley Pond (spillway elevation 31.3 m).[4] Water elevation in Chartley Pond exerts control

on ground water flow in the marsh adjacent to the Shpack site and contributes to the generally-low water-table gradients present. Observation of depth to water, obtained during the drilling survey (Table 1 and Figure 3), were combined with results from a topographic survey (Freeman Engineering) to estimate the distribution of water-table elevations within the fill. These results indicated that within the Shpack landfill, depth to the water table is generally 1.5 m or less. The elevation of the water-table is approximately 1 m higher in the central portion of the fill material than at the edges near the surrounding swamp, indicating that the flow direction is generally in a radial pattern from the center of the fill toward the swamp. Poorly drained organic deposits beneath the fill material can be expected to greatly restrict vertical movement of groundwaters.

Surface water is generally soft (<60 mg/l hardness), slightly acid, and low in dissolved mineral content. Ground water is soft (<60 mg/l hardness) and is acid to neutral (pH 5 to 7). Municipal and domestic water supplies are derived exclusively from groundwater, which tends to be high in dissolved iron and manganese.[6]

Based upon maps and related data supplied by the U.S. Geological Survey, the nearest water well owned by the Town of Norton (along possible flow pathways) is about 1.9 km from the Shpack Landfill. Staff at the Norton Town Hall indicate that the closest municipal supply well in use is on Pine Street, about 6 km distant from the site. According to the U.S. Geological Survey Hydrologic Atlas (HA)-460, there are no sources of municipal water other than groundwater. To reach the nearest municipal wells, groundwater contaminants would have to migrate from

Table 1. Approximate Relative Water-Table Elevations at the Shpack Landfill Site.

Drill-Hole Identifier	Estimated[a] Relative Elevation	Observed[b] Depth of Water	Relative Water-Table Elevation	Drill-Hole Identifier	Estimated[a] Relative Elevation	Observed[b] Depth to Water	Relative Water-Table Elevation	Drill-Hole Identifier	Estimated[a] Relative Elevation	Observed[b] Depth of Water	Relative Water-Table Elevation
7	97.5	3	94.5	28	98.8	6	92.8	48	96.	2.5	93.5
8	98.4	3	95.4	29	97.5	5	92.5	49	96.8	4	92.8
9	98.5	4	94.5	30	98.9	6	92.9	50	96.	3	93
10	98.8	4	94.8	31	95.3	1.5	93.8	51	97.7	6	91.7
11	99.5	6	93.5	32	95.0	1	94.0	52	97.3	6.5	90.8
12	98.3	6	92.3	33	97.4	1.5	95.9	53	96.7	8	88.7
13	95.8	4	91.8	34	95.2	1	94.2	54	95.0	1.5	93.5
14	96.4	3	93.4	35	94.7	1	93.7	55	95.0	5	90.
15	97.0	3.5	93.5	36	94.5	1.5	93.0	56	96.2	5	91.2
17	98.3	4.5	93.8	37	94.7	1.5	93.2	57	93.8	2	91.8
18	96.4	3	93.4	38	95.2	2	93.2	59	98.	8	90
19	100	8	92	39	95.6	3.5	92.1	60	97.4	13	84.4
20	99.2	6	93.2	40	97.0	3.5	93.5	61	97.2	3	94.2
21	99.3	7	92.3	41	96.4	3.5	92.9	62	96.6	2.5	94.1
22	98.5	4.5	94.0	42	95.	2	93	63	95.7	1.5	94.2
23	96.5	4	92.5	43	98.	6.5	91.5	AOW8	98.0	9	91.0
24	98.5	4.5	94.0	44	96.5	4.5	92.0	AOW9	96.8	4	92.8
25	95.8	4	91.8	45	97.1	4.5	92.6	AOW10	96.5	4.5	92.0
26	95.0	3.5	91.5	46	95.7	2.5	93.2				
27	95.5	1.5	94.	47	95.8	3	92.8				

[a]This estimate is based upon a topographic map of the Shpack site prepared by Freeman Engineering. The assumed datum is 100.0' at the top of a concrete post in the center of the landfill area.

[b]The depth to water was measured after the sample drill hole was completed, prior to re-filling. It is likely that the water level in the hole had not yet risen to the equilibrium depth in many cases. Thus these observation should be considered as only approximate. The depth to water is probably overestimated in general.

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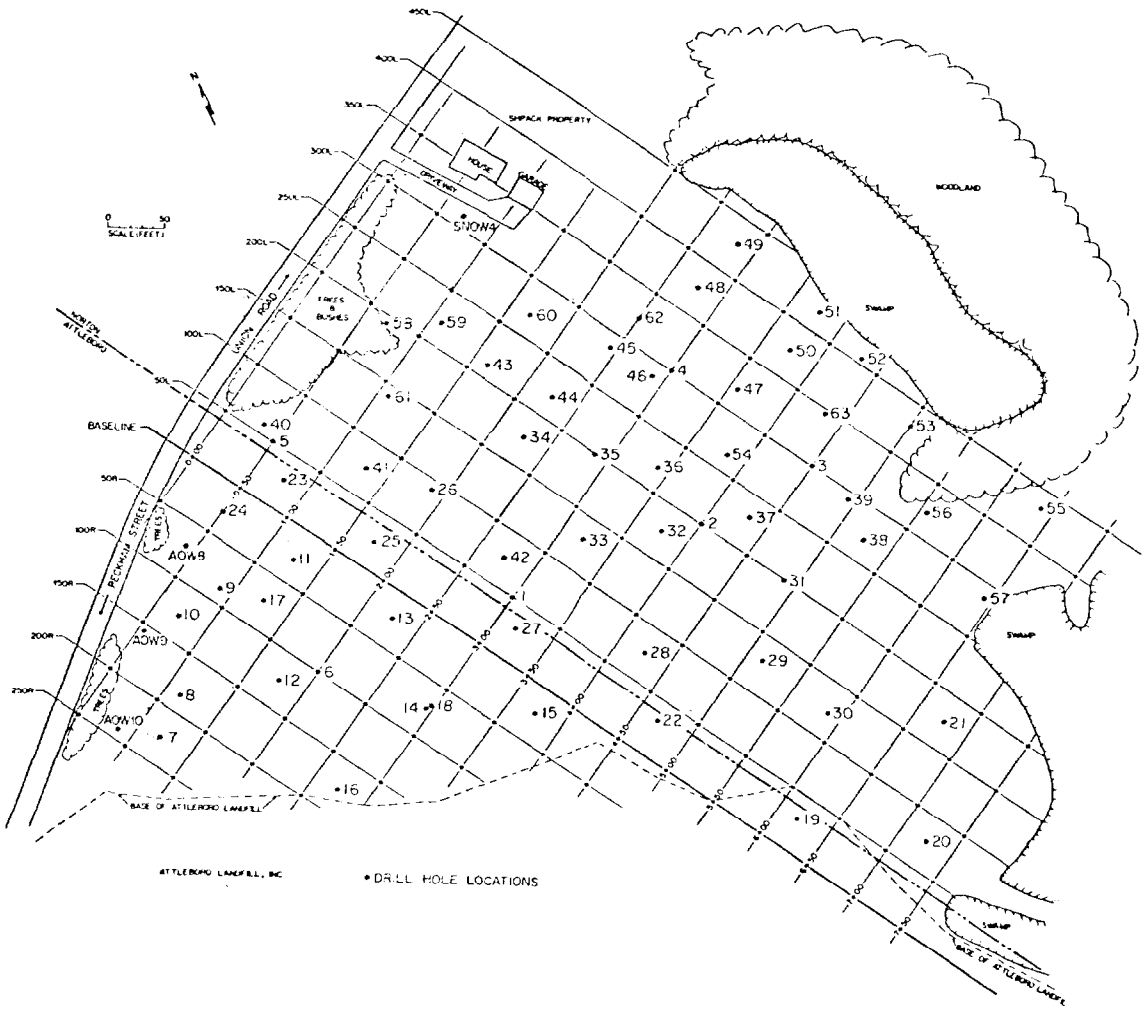

Figure 3. Map of drill hole locations at the Shpack Landfill site.

the Shpack site along the bedrock valley containing Chartley Pond, enter the bedrock valley that contains the Wading River and move into the region where groundwater is intercepted by the well in question. Because of dilution and degradation that would occur along the flow path, one would not expect measurable quantities of contaminants from the Shpack site to ever appear in existing municipal wells.

o Ambient noise levels

The site is adjacent to Attleboro landfill where heavy equipment is operated and has a moderate noise level.

o Land use

The site is an inactive dump which was used for approximately 20 years. It is adjacent to the active Attleboro landfill.

o Plant and animal life

The site is covered with early successional vegetation and may contain resident and transient birds, small mammals, and other small wildlife. Insects are abundant. Organisms observed at the site include the following:

Growing generally over the site:

Black cherry
Poplar
Red maple
Red oak
Eastern red cedar
Yellow birch
Serviceberry
Poison ivy
Curled dock
Common mullein
Yarrow
Cinquefoil
Common cattail
Dandelion
Black mustard

Growing in and at margins of the water:

Spadderdock
Leatherleaf
Haircap moss
Serviceberry
Gray birch

Animals seen or heard:

Prairie warbler
Black-capped chickadee
Greater yellowlegs
Red-winged blackbird
Common grackle
Robin
Mockingbird
Gray catbird
Yellow warbler
Yellow-throat
Swamp sparrow
Song sparrow

o Rare and endangered species

Rare or endangered species of plants and animals characteristically are not found on sites in the early stages of plant succession. None are known to be present and none would be expected.

o Cultural, historical, archaeological, and paleontological sites

The dump is not of sufficient age to be of interest.

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3. NOAA. 1977. Climate of Massachusetts. Climatography of the United States No. 60. National Oceanic and Atmospheric Administration, Asheville, North Carolina.

4. U.S. Corps of Engineers. 1979. Phase I Inspection Report, Chartley Pond Dam (MA 00814), Norton, Massachusetts. New England Division, U.S. Corps of Engineers, Waltham, Massachusetts.

5. Williams, J. R. 1968. Availability of groundwater in the northern part Tenmile and Taunton River basins, southeastern Massachusetts. Hydrologic investigations, Atlas HA-300. U.S. Geological Survey, Washington, D.C.

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7. Williams, J.R., and R. E. Willey. 1973. Bedrock topography and texture of unconsolidated deposits, Taunton River basin, southeastern Massachusetts. Misc. geologic investigations, Map I-742. U.S. Geological Survey, Washington, D.C.

Significant Environmental Impacts of Project or Activity

Land Form - Will the project result in:	Yes	Maybe	No
o Unstable slopes, embankments, or excavations?	___	___	X
Drilling would not be likely to involve excavations, mounds or any other extensive earth moving operations.			
o Significant modifications of geological structures?	___	___	X
Drilling and radioassay would be restricted to the landfill material only. The project site is not extensive enough to affect geologic structures that may exist in the area.			
o Extensive disruption, displacement, compaction, or covering of the soil? ___	___		X
Any disruption, displacement, compaction or covering of surface soils will be of a local nature and easily repairable if necessary.			
o Changes in ground contours, shorelines, stream channels, river banks, or tidelands?	___	___	X
No changes are foreseen from the described sampling program.			
o Destruction, covering, or modification of unique geologic or physical features?	___	___	X
No unique geologic or physical features occur at the Shpack landfill site.			
o Increased wind or water erosion of soils, either on or off the site?	___	___	X
Because of the wet conditions at the site, wind erosion is unlikely. Water erosion is not likely due to the lack of free flowing water at the site.			
o Changes in deposition or erosion of beach sands or changes in siltation, deposition, or erosion that may modify the channel of a river or stream or the bed of the ocean or any bay, inlet, or lake?	___	___	X
The radioassay project is not expected to affect local sedimentation - erosion conditions.			

	Yes	Maybe	No
o Exposure of people to or property affected by earthquakes, landslides, mudslides, or ground failure?	___	___	X

The Shpack site is not prone to earthquakes and the drilling operations are not of a nature to produce such effects. No people will be in residence at the site when the survey is conducted.

o Foreclosure on future uses of site on a long-term basis?	___	X	___

Should the radioassay indicate the existence of large volumes of contaminated materials, the site would most likely be closed to future use until such time as the radioactive substances are removed or effectively isolated.

Air - Will the project result in:

o Substantial air pollutant emissions or deterioration of ambient air quality?	___	___	X

The only air emissions will come from equipment used in sampling.

o Objectionable odors?	___	X	___

It is possible that malodorous material will be brought to the surface during sampling. However, an odor problem now exists with the adjacent Attleboro landfill and no significant increase in odor strength would be expected.

o Alteration of air movements, temperature, or humidity (e.g., fogging or icing)?	___	___	X
o Local or regional climatic changes?	___	___	X

The sampling program is small in scale and will have neither microclimatic nor macroclimatic effect.

Water - Will the project result in:

o Changes in currents or water movements in marine or fresh water?	___	___	X

	Yes	Maybe	No
There will be no involvement with the freshwater system during the project.			
o Changes in absorption rates, drainage patterns, or the rate and amount of surface water runoff?	___	_____	X
The land surface will not be modified during the drilling and sampling program.			
o Alteration to the course or flow of flood waters?	___	_____	X
No changes to the drainage system will occur.			
o Changes in the amount of surface water in any water body?	___	_____	X
No surface water bodies will be affected since only drilling on dry landfill areas is involved.			
o Discharges into surface waters or alteration of surface water quality, including but not limited to temperature, dissolved oxygen, or turbidity?	___	_____	X
No discharges into surface waters or alteration of surface water quality will result from drilling sample holes below the water table at the Shpack landfill site. Since the surface of the saturated zone is at atmospheric pressure (unconfined aquifer) water will not flow from the drill hole. The direction of any flow that might take place would be toward the drill hole. It is expected that this flow would be negligible since the permeability of the fill material appears to be low and the sampling plan calls for re-filling the holes after sampling is complete.			
o Alteration of the direction or rate of flow of groundwaters?	___	_____	X
Only the fill materials will be augered or drilled and drilling will cease when the underlying organic deposits are encountered. In addition, all holes will be refilled after sampling is complete. Thus there will not be opportunity for modification of the direction or flow rate of groundwaters as a result of the drilling project.			
o Change in the quantity of groundwaters, either through direct additions or withdrawals or through interception of an aquifer by drilling or excavations?	___	_____	X

	Yes	Maybe	No
Since drilling will only penetrate the fill materials and not the underlying deposits and no pumping will occur, the quantity of groundwaters present will not be affected.			
o. Alterations in groundwater quality?	___	_____	X
Drilling sampling access holes to the base of the fill material will not change the inventory or distribution of materials present in the groundwaters. Since the fill is only approximately 3 meters thick with the lower 2 meters in the saturated zone, the potential for vertical mixing of groundwaters via bore holes is negligible. Ground-penetrating radar surveys have been done to show areas where barrels or other large metallic objects[2] are located beneath the surface, so they can be avoided during drilling. The holes will be refilled after each survey is complete, thus minimizing the time available for vertical migration. The differences in total head (combined pressure and elevation) will not favor any migration from the hole. The materials present in the fill appear to be rather poorly drained, indicating low permeability. Thus, the act of drilling holes through the fill will not alter the existing quality of groundwaters in and around the Shpack site.			
o Contamination of public water supplies?	___	_____	X
The sampling project will not affect groundwater quality (as discussed above). Thus, no contamination of public water supplies will result.			
o The requirement to obtain an NPDES (National Pollutant Discharge Eliminate System) permit (Clean Water Act)?	___	_____	X
No discharges will occur as a result of sampling activities.			
o Violation of State Stream Quality Standards?	___	_____	X
Sampling will not result in changes in quality of adjacent stream waters.			
o Discharge to a public sewer system?	___	_____	X
No discharges will occur.			
o Location in a riverine or coastal floodplain (especially high hazard areas)?	___	_____	X

	Yes	Maybe	No
The project will not be conducted during the flood season, nor will drill holes be left unfilled. The HUD Flood Insurance maps indicate that the site is not within the 100-yr flood zone, although detailed surveys indicate that a portion of the site would be inundated at a water level of 32.2 m, msl, which is cited as the elevation where the Chartley Pond dam would be overtopped.[4]			
o Substantial reduction in the amount of water otherwise available for public water supplies?	___	___	X
The project will not change surface or groundwater quantity.			
o Exposure of people or property to water-related hazards such as flooding or tidal waves and subject to DOE floodplain/wetlands regulations (10 CFR 1022)?	___	___	X
There will be no water-related hazards such as flooding or tidal waves associated with the project.			
o Location in a state's coastal zone and subject to consistency with the state CZM plan?	___	___	X
The site is not in the state coastal zone.			
Solid Waste - Will the project generate significant solid waste or litter?	___	___	X
Noise - Will the project:			
o Increase existing noise and vibration?	___	X	___
o Expose people to excessive noise?	___	___	X
Noise will be generated by the drilling equipment and will add to the noise generated by heavy equipment on the adjacent landfill. At the distances to which the public will be exposed, however, no increase in perceived level of noise is likely.			

	Yes	Maybe	No
Light and Glare - Will the project create problems involving light and glare?	___	___	X

Drilling and sampling will be carried out during daylight hours.

Plant Life - Will the project:

o Change the diversity or productivity of species or number of any species of plants (including trees, shrubs, grass, crops, microflora, and aquatic plants)?	___	___	X
o Reduce the numbers or affect the habitat of any unique, rare, or endangered species of plants? (Check State and Federal list of endangered species.)	___	___	X
o Reduce acreage or create damage to any agricultural crop?	___	___	X

Plants present on the Shpack landfill are invaders of disturbed sites. The disturbance caused by sampling will help to perpetuate the conditions favored by these plants.

Animal Life - Will the project:

o Change the diversity of species or affect breeding or numbers of any species of animals (including birds, mammals, reptiles, amphibians, fish and shellfish, benthic organisms, insects, or microfauna)?	___	___	X
o Reduce the habitat or numbers of any unique, rare, or endangered species of animals? (Check State and Federal list of endangered species).	___	___	X
o Introduce new species of animals into an area or create a barrier to the migration or movement of animals or fish?	___	___	X
o Harm existing fish or wildlife habitat?	___	___	X
o Cause attraction, entrapment, impingement, or entrainment of animal life?	___	___	X

	Yes	Maybe	No
o Cause emigration resulting in human-wildlife interaction problems?	___	___	X

Like the plants present, animals present utilize disturbed sites and will not be unfavorably affected by further disturbance.

Land Use - Will the project substantially alter the present or planned land use of an area?	___	___	X

The land use impacts of the described drilling activities will be confined to the site.

Natural Resources - Will the project:

o Increase the rate of use of any natural resources?	___	___	X
o Substantially deplete any nonreusable natural resources?	___	___	X
o Be located in an area designated or being considered for wilderness, wild and scenic river, national park, or ecological preserve?	___	___	X

A limited volume of fossil fuel will be required for the sampling program.

Energy - Will the project:

o Use substantial amounts of fuel or energy?	___	___	X
o Substantially increase the demand upon existing sources of energy or require the development of new sources of energy?	___	___	X

Drilling equipment will be operated intermittently for three days. We estimate fewer than 150 gallons of gasoline-equivalent will be consumed.

Accident Risk - Does the project involve risk of explosion or release of potentially hazardous substances (including, but not limited to oil, pesticides, chemicals, radiation, or other toxic substances) in the event of an accident or upset conditions?	___	___	X

	Yes	Maybe	No
Only the usual, industrial-type accidents associated with drilling activities could occur. The low levels of radioactivity present on the site could not be a factor in the causes or consequences of any accident. Buried metal containers, thought possibly to contain chemicals of unknown composition, have been located by means of ground penetrating radar. Locations of known metallic objects deliberately will be avoided in designating drilling and coring locations.			
Population - Will the project alter the location, distribution, density, or growth rate of the human population in an area?	___	___	X
Housing - Will the project affect housing patterns or create a demand for additional housing?	___	___	X
The impacts of the drilling activities are expected to be negligible on the physical environment and will have no secondary impacts on the location, distribution, density or growth rate of the human population. There will be no demand for additional housing since only six people are to work during the three days of drilling.			
Transportation and Traffic Circulation - Will the project result in:			
o Generation of substantial additional vehicular movements.	___	___	X
o Effects on existing parking facilities or demands for new parking?	___	___	X
o Substantial impact upon existing transportation systems?	___	___	X
o Alterations to present patterns of circulation or movement of people and/or goods?	___	___	X
o Alterations to waterborne, rail, or air traffic?	___	___	X
o Increase in traffic hazards to motor vehicles, bicyclists, or pedestrians?	___	___	X
o Construction of new roads or trails?	___	___	X

	Yes	Maybe	No
The project will require the use of only one truck with a drilling rig and one other small vehicle.			
Public Service - Will the project have an effect upon, or result in, a need for new or altered governmental services in any of the following areas:			
o Fire protection?	___	___	X
o Police protection?	___	___	X
o Schools?	___	___	X
o Parks or other recreational facilities?	___	___	X
o Other governmental services?	___	___	X
Utilities - Will the project result in a need for new systems or substantial alterations to the following utilities:			
o Power or natural gas?	___	___	X
o Communications systems?	___	___	X
o Water?	___	___	X
o Sewer or septic tanks?	___	___	X
o Storm water drainage?	___	___	X
o Solid waste and disposal?	___	___	X
Human Health - Will the project:			
o Create any health hazard or potential health hazard?	___	___	X
o Expose people to potential health hazards?	___	___	X

The small amounts of radioactivity and low levels of radiation involved in the drilling and sampling may result in radiation exposures to on-site workers and the general public. These radiation exposures would not be distinguishable from those received daily from normal background radiation. Care will be taken to

	Yes	Maybe	No
avoid any buried metallic objects while drilling and coring. Care will also be taken to avoid penetrating any peat layer which may exist beneath the landfill.			
Economic - Will the project have any adverse effect on local, regional, or national economic conditions?	___	___	X
o Will the project cause boom-town type of development?	___	___	X
o Will the project have any adverse effect on tourism?	___	___	X
o Will the project have any adverse effect on local income levels?	___	___	X
o Will the project have any adverse effect on land values?	___	___	X
o Will the project have any adverse effect on employment?	___	___	X

The project will employ only six people from outside the impact area for three days. Such a small intrusion does not result in noticeable or measureable public service, utility or economic impacts.

Community Reaction - Is the project:			
o Potentially controversial?	___	X	___
o In conflict with locally adopted environmental plans and goals?	___	___	X

The drilling activity as well as the problems associated with the site have generated considerable public concern. One issue raised with respect to the drilling activity is the implacement of monitoring wells on site prior to drilling.

The purpose of the drilling activity is to characterize the radioactive waste associated with the site. Such characterization is necessary before the need for remedial action can be determined. Because of this function, the drilling activity meets the local environmental plans and goals.

	Yes	Maybe	No
Aesthetics - Will the project:			
o Change any scenic vista or view open to the public?	___	___	X
o Create an aesthetically offensive site open to the public view? (out of place in an aesthetic sense with character or design of surrounding area)	___	___	X
o Significantly change the visual scale or character of the vicinity?	___	___	X

The two trucks, which will be visable on site for three days, will be normal for the site.

Recreational, Educational, Religious, and Scientific - Will the project affect the quality or quantity of existing recreational, education, religious, or scientific opportunities?	___	___	X

The site has no recreational, educational or religions uses at this time. Impacts of the drilling activity will be confined to the site.

Archaeological, Cultural, and Historical - Will the project alter significant archaeological, anthropological, paleontological, cultural, or historical sites, structures, objects, or buildings? (e.g., be subject to the Historic Preservation Act of 1974)	___	___	X

There are no important archaeological, cultural or historical dimensions to the site other than those associated with the waste on the site.

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