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Prepared by
Oak Ridge Associated Universities

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# RADIOLOGICAL CHARACTERIZATION OF THE WASTE AND SLAG STORAGE AREA WHITTAKER METALS CORPORATION PROPERTY GREENVILLE, PENNSYLVANIA

**J. D. BERGER AND M. R. LANDIS**

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

FINAL REPORT
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RADIOLOGICAL CHARACTERIZATION
OF THE
WASTE AND SLAG STORAGE AREA
WHITTAKER METALS CORPORATION PROPERTY
GREENVILLE, PENNSYLVANIA

## INTRODUCTION

Beginning in the 1960's, the Greenville, PA, firm of Mercer Alloys, a predecessor of Whittaker Metals Corporation, produced ferro-columbian and ferro-nickel alloys by an aluminathermic melting process. Columbian ores and nickel scrap used in this operation contained licensable concentrations up to approximately 2% of thorium. Process slag containing thorium was retained on-site. Natural and depleted uranium were unwanted contaminants of some of the feed-metal scrap; slags containing low levels of uranium contamination are also present on the site. Elevated concentrations of Ra-226 have been noted in some of the waste slags.

By early 1974, Whittaker had terminated operations involving licensable material. The property was sold to Exomet, Inc. in late 1974, with Whittaker retaining responsibility for source materials on the premises. Beginning in July 1974, Applied Health Physics conducted a radiological survey of the property and identified areas exceeding the radionuclide contamination levels for unrestricted release. Decontamination was performed and portions of the site were certified by Applied Health Physics in June 1975 as acceptable for release for unrestricted use.[1] In 1983, Radiation Management Corporation conducted a radiological survey of an additional section of the property, and this area was decontaminated also.[2] Contaminated equipment, rubble, and slag, removed during these decontamination efforts, were relocated to the waste and slag storage areas along the eastern portion of the site.

As a result of the previous operations, decontamination efforts and surveys, the property has been divided into two radiologically different areas: (1) the area of slag and waste storage and (2) the main manufacturing area of the plant, which is presently operated by Greenville Metals. At the request of the Nuclear Regulatory Commission (NRC), a confirmatory radiological survey of this latter portion of the property was performed by Oak Ridge Associated

Universities (ORAU) during the summer of 1984; the results of that survey are presented in a November 1984 report to the NRC.[3]

Since 1975, Whittaker has been negotiating with the Nuclear Regulatory Commission on plans for terminating the storage license, based on the average source material concentration in the slags. Westinghouse Environmental Systems and Energy Impact Associates have served as consultants to Whittaker on this issue. Estimates prepared by Westinghouse indicate from 1.55 to 1.72 x $10^4$ $m^3$ of this slag remain on the property. Some of the slag material has thorium concentrations of up to 1 to 2% by weight; however, the average thorium concentration is estimated to be less than 0.05%.[4]

The Nuclear Regulatory Commission requested that the Radiological Site Assessment Program of ORAU conduct radiological measurements to characterize the waste and slag storage area and evaluate the potential for environmental contamination. This report describes the procedures and findings of that survey.

## SITE DESCRIPTION

The Whittaker Metals Corporation property is located on Crestview Drive in the Reynolds Development, approximately 6 km south of Greenville, PA (see Figure 1). The site is an irregularly shaped parcel of about 2.3 hectares, located between the Greenville Metals plant and the Shenango River (Figures 2 and 3). The surface of this property has been built up over a period of approximately 40-50 years through repeated disposal of building rubble, scrap metal, general trash, and foundry slag. The present surface is generally level, and in some areas the surface is as much as 10 to 12 meters above the original river flood plain. Central and southern portions of this property are predominantly slag. The northern portion contains slag mixed with other rubble and waste - some dating to the early site use as an Army supply base (during World War II). There are several storage bins containing contaminated and non-contaminated metal scrap and drums of thorium waste.

The property contains one structure - a small open metal building, known as the Reclaimation Building, along the west central property boundary.

## SURVEY PROCEDURES

At the request of the U.S. Nuclear Regulatory Commission's Division of Fuel Cycle and Material Safety, a radiological characterization of the Whittaker Corporation slag and waste storage area was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities. The survey was conducted during the period of June 11-29, 1984. This section describes the survey objectives and the procedures followed.

### Objectives

The objectives of the ORAU survey were:

1. to determine the distribution, quantities, and radionuclide contents of thorium contaminated slag and other waste; and
2. to evaluate the effect of the contaminated wastes and slag on direct radiation levels and radionuclide contamination in the environment.

Radiological information collected included:

1. direct radiation exposure rates;
2. surface locations of contaminated slag and waste;
3. subsurface distribution of radioactive material;
4. concentrations of radionuclides in surface and subsurface slag, waste, and soil; and
5. concentrations of radionuclides in surface and subsurface water.

### Procedures

1. A 40 m grid system was established by E.A. Winslow and Associates of Sharpsville, PA, under contract to Energy Impact Associates. This

grid system, shown on Figure 3, was subdivided by the ORAU survey team into 8 m intervals.

2. Walkover surface scans were performed to identify contaminated wastes outside the main slag pile boundary and to locate possible migration of contamination from the storage area.

3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 8 m grid intervals and at selected locations identified by surface scans. Measurements were performed using portable gamma NaI(Tl) scintillation survey meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at 8 m grid intervals.

5. Three samples of surface water were collected from the Shenango River - one upriver from the site; one at the site; and one downriver from the site (see Figure 4).

6. Five sediment samples were collected from drainage streams and the Shenango River (see Figure 5).

7. Representative pieces of slag were collected at random from the surface of the site to assist in determining the range of radionuclide concentrations in slags.

8. Thirty-five boreholes were drilled in or near the slag and waste storage area to provide a mechanism for logging subsurface radiation profiles and collecting subsurface samples. Drilling was performed by

Continental Drilling Co. of New Alexandria, PA, using a truck-mounted 20 cm diameter hollow-stem auger. These holes were drilled, where possible, to the depth of the original soil surface. In some areas, subsurface debris prevented penetration to the desired depth. Boreholes were located to provide representative coverage of the storage area. Locations of these boreholes are shown on Figure 6.

A gamma scan of the boreholes was performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were determined by measuring gamma radiation at 30 cm intervals between the surface and the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements wherever possible; however, at some locations logging was performed using an uncollimated detector inside the auger stem because of the tendency of the borehole to cave in. At locations where ground conditions permitted, samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of the borehole with an ORAU designed sampling tool or by split-spoon sampling through the hollow stem auger.

9. Samples of ground water were obtained from six boreholes where it was available, from a site artesian well, and from four monitoring wells, previously installed by Energy Impact Associates. These water sampling locations are indicated on Figure 4.

10. Fifteen shallow boreholes were drilled in the flood plain, between the waste area and the Shenango River. These holes were drilled to a depth of approximately 1 m using a portable motorized auger. Soil samples were collected from the surface and the bottom of these boreholes. Locations of these holes are shown on Figure 7.

11. Three soil samples and three water samples were collected from the Greenville area to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured at locations where baseline soil samples were collected. The

locations of the baseline samples and background measurements are shown on Figure 8.

Sample Analysis and Interpretation of Results

Soil, sediment, and slag samples were analyzed by gamma spectrometry. Radionuclides of primary interest were Th-232, Th-228, U-238, and Ra-226; however, spectra were reviewed for other gamma emitters. Water was analyzed for gross alpha and gross beta concentrations. Isotopic radium analyses were performed on three water samples containing greater than 15 pCi/l gross alpha.

Borehole logging measurements were converted to thorium concentrations using empirically derived calibration factors.

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

## RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for three locations (Figure 8) in the vicinity of the Whittaker Corporation site, are presented in Table 1-A. Exposure rates ranged from 9 to 10 μR/h (typical for this area of Pennsylvania). Concentrations of radionuclides in soil were: Th-232, 0.6 to 1.2 pCi/g (picocuries per gram); Th-228, 0.5 to 1.0 pCi/g; U-238, <0.7 to 1.5 pCi/g; and Ra-226, 0.6 to 0.8 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and beta concentrations ranged from 0.3 to 0.8 pCi/l (picocuries per liter) and 2.6 to 4.6 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Exposure rates measured at 8 m intervals throughout the waste and slag storage area are presented in Table 2. Gamma levels ranged from 8 to 490 μR/h at 1 m above the surface and from 6 to 800 μR/h at surface contact. The highest exposure rates were at grid coordinate 216,I+32, which is near a storage bin containing drums of a thorium compound. High levels were also present in the vicinity of coordinate 304,J; a large quantity of thorium slag was stored on the surface at this location. Figure 9 indicates the distribution of direct radiation levels at 1 m above the surface as determined from the 8 m grid interval measurements.

Walkover scans identified locations of elevated contact radiation levels outside the boundaries of the main slag storage piles. These locations are indicated on Figure 10 and associated radiation levels are presented in Table 3. The maximum contact radiation level was 800 μR/h near the base of the slag pile at grid coordinate 408,H+36. A barrel at this location appeared to be the source of the elevated radiation. At two other locations (370,G+25 and 412,H+38), the radiation levels were also associated with metal barrels. Other locations of elevated radiation were caused by pieces of slag. At several locations, the radioactive material is beyond the eastern boundary of the Whittaker property. Of particular note is grid coordinate 320,J+38 where slag was identified in the bed of the Shenango River.

Radionuclide Concentrations in Surface Samples

Table 4 presents the results of analyses on samples collected at 8 m intervals from the surface of the waste and slag storage area. Many of these samples contained radionuclide concentrations near the ranges of the baseline samples. Of the 260 samples collected, only 15 had total thorium (Th-232 plus Th-228) concentrations exceeding 10 pCi/g. The highest total thorium levels were in samples from coordinates 272,J (438 pCi/g) and 296,I+8 (157.3 pCi/g). The maximum U-238 concentrations were 303 pCi/g and 77.9 pCi/g and the maximum Ra-226 levels were 121 pCi/g and 13.7 pCi/g. Samples containing the highest levels of U-238 and Ra-226 were the same ones indicated above as having the highest thorium contents.

Radionuclide concentrations in surface samples from the area between the waste area and the Shenango River are presented in Table 5. Of 37 samples collected, only one (1) exceeded 10 pCi/g of total thorium. This was the sample from 360,I+24 which contained 13.8 pCi/g of thorium. This sample also contained the highest Ra-226 concentration (3.1 pCi/g) of the samples from this area. Most of these samples from the river flood plain contained concentrations of radionuclides near the ranges of baseline soil samples.

## Radionuclide Concentrations in Subsurface Soil

Table 6 presents the thorium concentrations calculated from borehole logging data. Total thorium levels exceeded 10 pCi/g at one or more locations in 11 of the 35 boreholes. These were boreholes B17, B18, B19, B20, B23, B24, B25, B26, B27, B31, and B34. Boreholes B23, B24, B25, and B26, in the slag pile area east of the Aluminathermic Building, contained the highest concentrations. The maximum was 2,072 pCi/g at 1.8 m deep at borehole location B23. Only four isolated locations in the southern most slag area (i.e. east of the New Melt Shop) had thorium levels above 10 pCi/g. The highest level in this area was 18.4 pCi/g at a depth of 0.9 m in borehole B27. None of the boreholes drilled in the northern section of the waste and slag storage area contained thorium concentrations exceeding 10 pCi/g.

Samples from shallow boreholes, drilled in the area between the waste storage and the Shenango River, did not contain thorium concentrations exceeding 10 pCi/g (see Table 7). The highest levels of Th-232 and Th-228 measured were 2.2 pCi/g (B45, 1 m deep) and 2.6 pCi/g (B50, 1 m deep), respectively. Other samples contained radionuclide concentrations similar to those in baseline soil.

## Radionuclide Concentrations in Sediment Samples

Radionuclide concentrations in sediment samples from the river and several drainage ditches are presented in Table 8. None of these samples contained radionuclide levels differing significantly from baseline soil concentrations.

## Radionuclide Concentrations in Water Samples

Table 9 presents the radioactivity levels measured in water from the site. No significant gross alpha or gross beta concentrations were noted in the three (3) samples from the Shenango River or the Artesian Well. Water sample W8 from borehole B23 contained 26.1 pCi/l of gross alpha and 55.1 pCi/l of gross beta. Samples W11 and W14, collected from previously installed monitoring wells, contained gross alpha concentrations of 29.8 pCi/l and 17.2 pCi/l, respectively. Gross beta levels in these samples were 16.0 pCi/l and 10.4 pCi/l, respectively. Other samples contained less than 15 pCi/l gross alpha and 50 pCi/l gross beta. Analyses of the radium concentrations in samples W8, W11, and W14, indicated slightly elevated Ra-226 (up to 0.5 pCi/l and Ra-228 (up to 1.48 pCi/l).

## Radionuclide Concentrations in Slag Samples

Miscellaneous representative samples of slag, obtained from throughout the site were analyzed and results are presented in Table 10. As can be noted from these results, there is a wide range of radionuclide levels in the different slags. Total thorium ranged from <0.3 pCi/g to 6,779 pCi/g. Concentrations of U-238 and Ra-226 also varied considerably with the highest levels being 2,179 pCi/g and 226 pCi/g, respectively.

# DISCUSSION

The survey identified areas of elevated direct gamma radiation up to approximately 0.5 mR/h at 1 m above the surface. These elevated levels (see Figure 9) were primarily near the northwest corner of the property and in the mid-central section, east of the Aluminathermic Building. There were several smaller isolated areas where exposure rates exceeded 20 $\mu$R/h at 1 m above the surface. Several of these areas were located beyond the eastern Whittaker property boundary. Along the other property boundaries, the direct radiation levels are less than 20 $\mu$R/h.

The source of the elevated radiation levels in the northwest section is surface or near surface thorium waste. Highest levels are in the vicinity of metal drums, indicated to contain a liquid thorium compound. Little subsurface slag was noted in the northwest section during drilling and no subsurface thorium concentrations exceeding 7.7 pCi/g were identified in this portion of the property. The average thorium level calculated, based on the borehole logging data, is 3.5 pCi/g.

Near the central portion of the site there is a large quantity of thorium contaminated slag, both on the surface and subsurface. This section is composed primarily of slag fill with a depth of up to 7.6 m. Four boreholes (B23, B24, B25, and B26) in this area contained average total thorium levels of 339 pCi/g. At these borehole locations 58 of the 74 logging measurements indicated thorium levels exceeding 10 pCi/g. The other 12 boreholes in this area contained an average thorium concentrations of 4.2 pCi/g, with only 9 of 105 logging measurements above 10 pCi/g.

The southern portion of the site is also mostly slag fill. Depth of the slag in this section ranges up to 5.8 m. There is little evidence of thorium contaminated slag, either surface or subsurface, in this section. Only 4 of 99 logging measurements exceed 10 pCi/g of thorium. The average total thorium concentrations for this portion of the property was 3.3 pCi/g. However several areas of thorium slag were identified at the base of the slag pile slope, along the eastern border of the property (see Figure 10).

Analysis of miscellaneous samples of slag indicated a wide range of thorium contamination, ranging from less than detectable levels to 6,779 pCi/g of total thorium. Radium 226 concentrations average 15% of the thorium concentrations; U-238 averages 41% of the thorium concentrations.

Based on the results of the borehole logging and slag depth observations, the average thorium concentrations of the slag were estimated. The procedures used for these estimates are described in Appendix C. The total slag volume is estimated to be $2.97 \times 10^4$ $m^3$. For comparison, the earlier Westinghouse estimates were 1.55 to $1.72 \times 10^4$ $m^3$.[4] The average thorium content of the slag was estimated to be 80.3 pCi/g of total thorium, or approximately 0.037% by weight, by one method, and 60.3 pCi/g, or 0.028% by weight, by a second method. The Westinghouse study indicated a thorium content of less than 0.05% by weight.[4] It should be noted that the calculated value of the average thorium content of the slag is strongly influenced by the high levels measured in only 4 of the 35 deep boreholes. Without considering the high levels from these boreholes the average concentration of thorium would have been less than 4 pCi/g (0.0018% by weight).

Several subsurface water samples from the slag pile area contained gross alpha concentrations exceeding the EPA Primary Drinking Water Standard of 15 pCi/g.[5] Radium 226 plus Ra-228 concentrations were, however, less than 5 pCi/l. (The EPA Standard is used here only for comparison purposes, because the source of these samples is not a drinking water supply.)

Samples of water from the Shenango River and sediment from the river flood plain did not contain concentrations of radionuclides differing from baseline levels. This indicates that the radionuclides in the slag and waste are not migrating from the storage area.

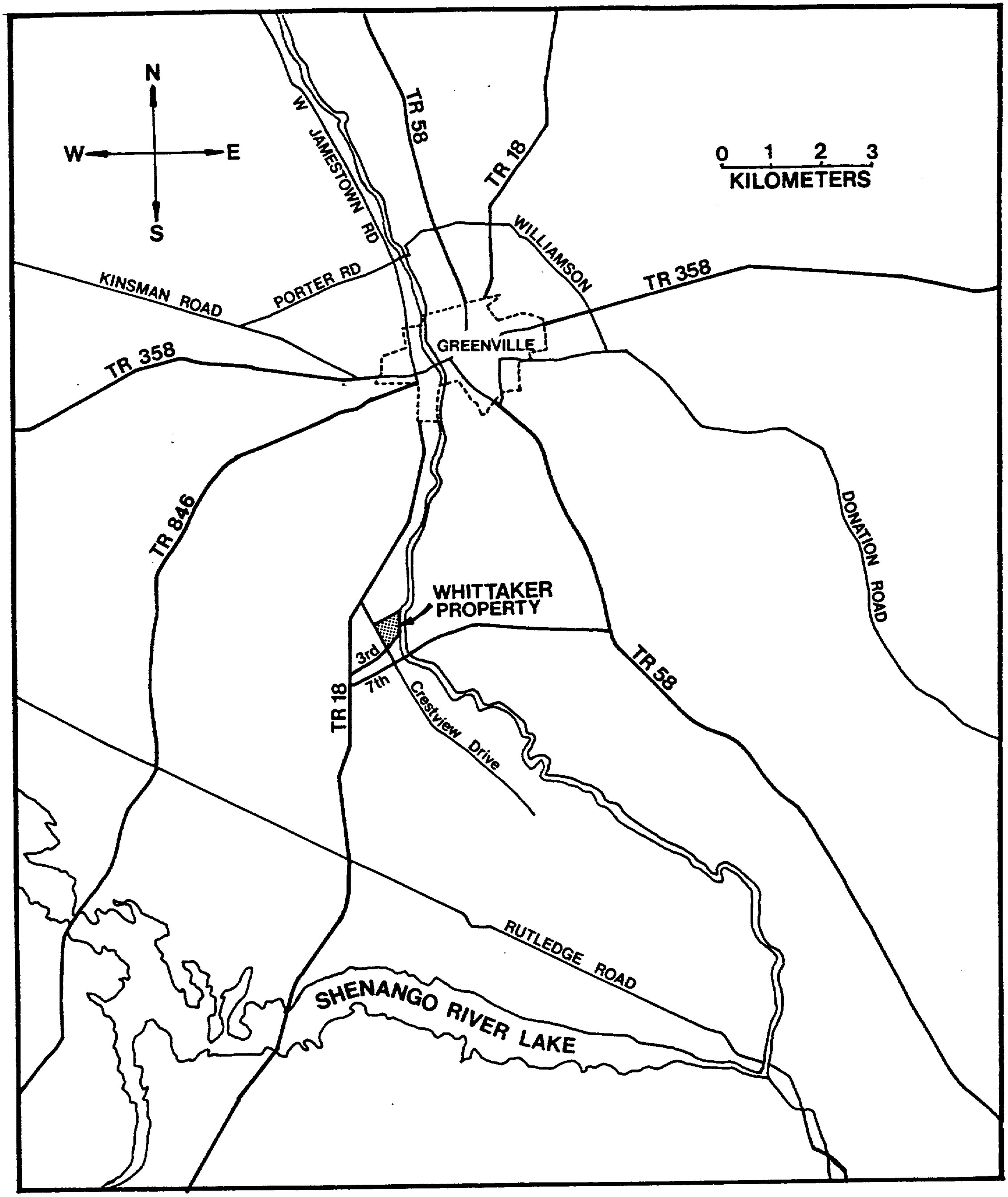


FIGURE 1: Map Indicating the Location of the Whittaker Site, Greenville, Pennsylvania

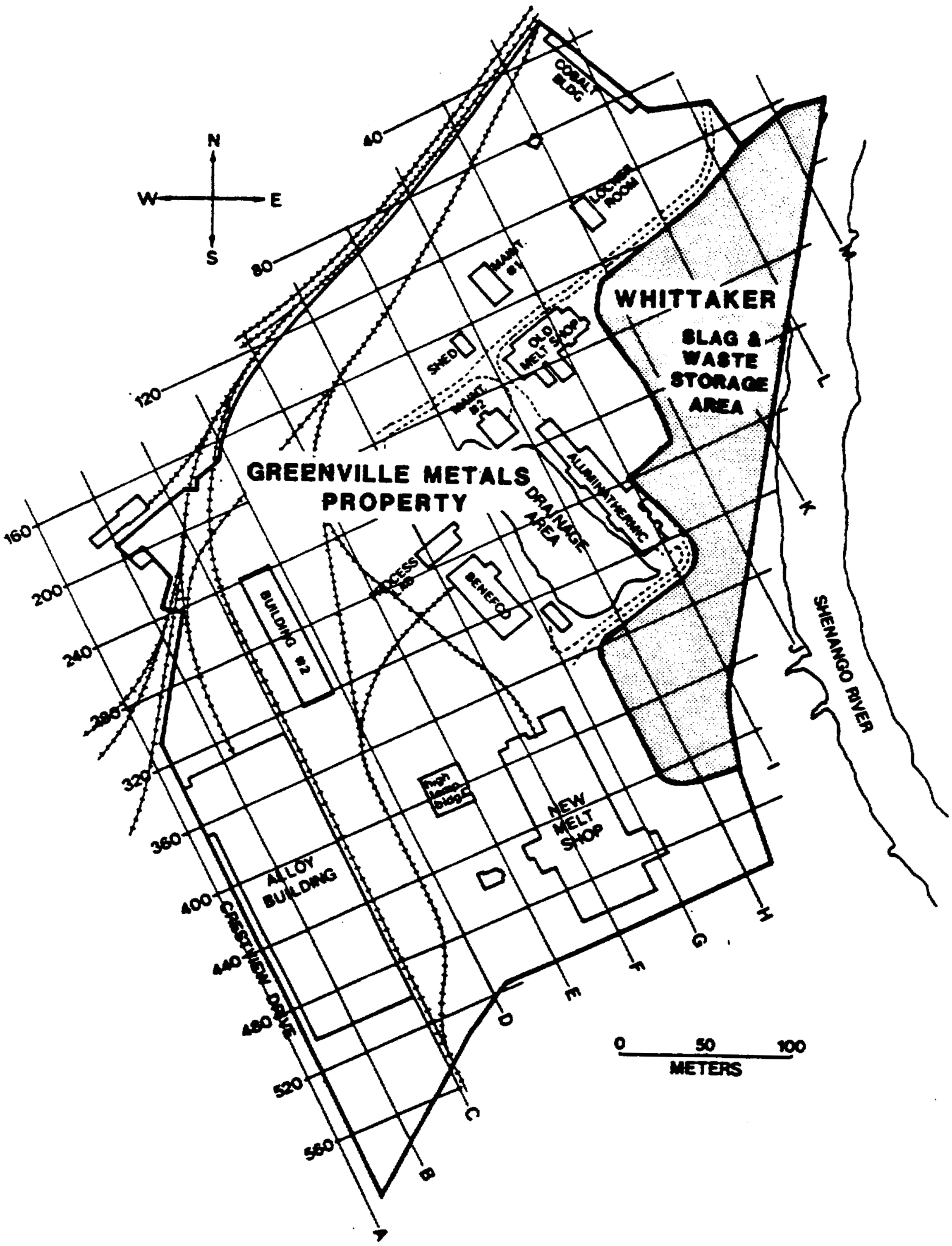


FIGURE 2: Map of the Former Whittaker Metals Corporation Site Indicating the Current Whittaker and Greenville Metal's Properties.

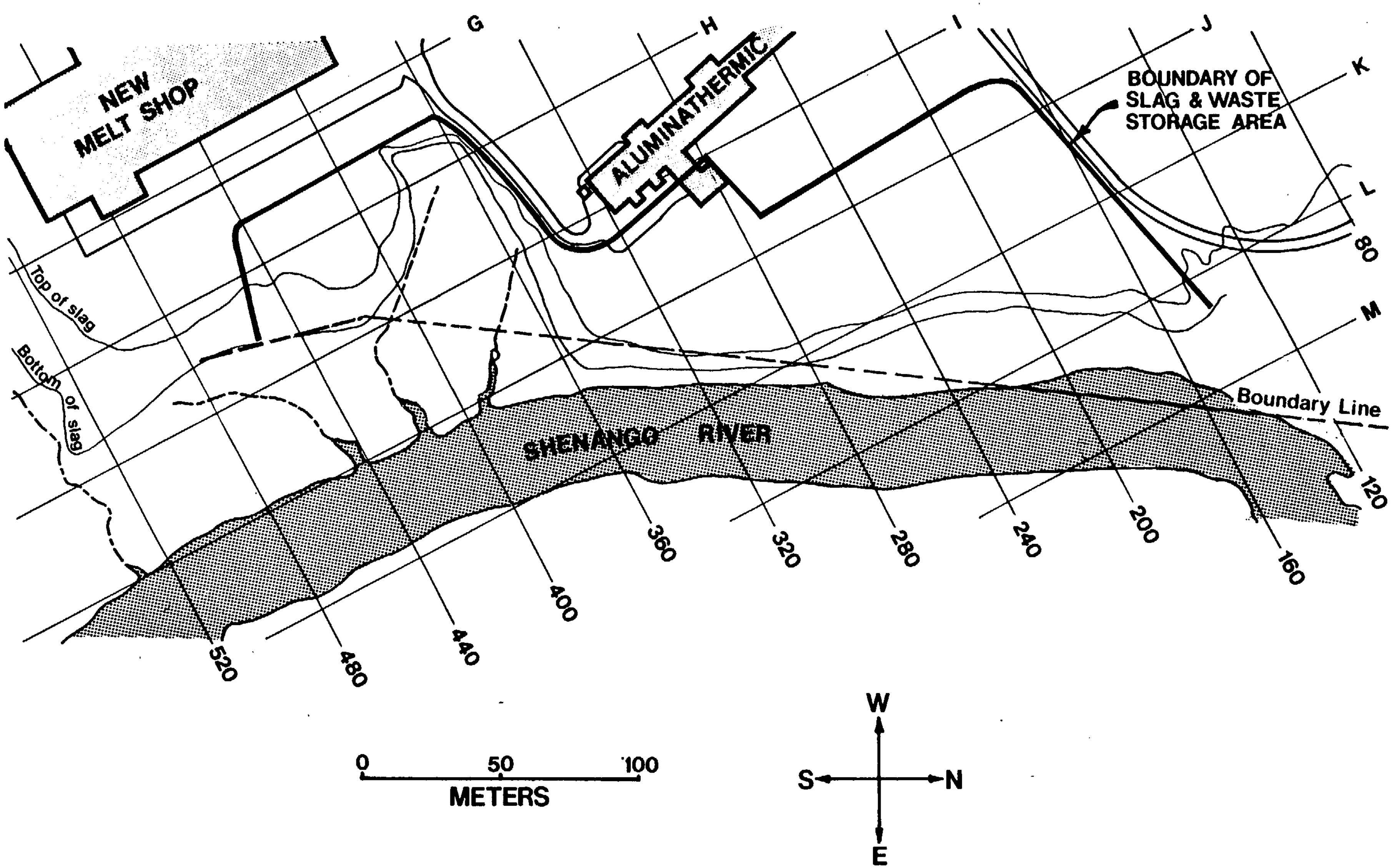


FIGURE 3: Map of the Whittaker Waste and Slag Storage Area Showing the Grid System Established for Survey Reference.

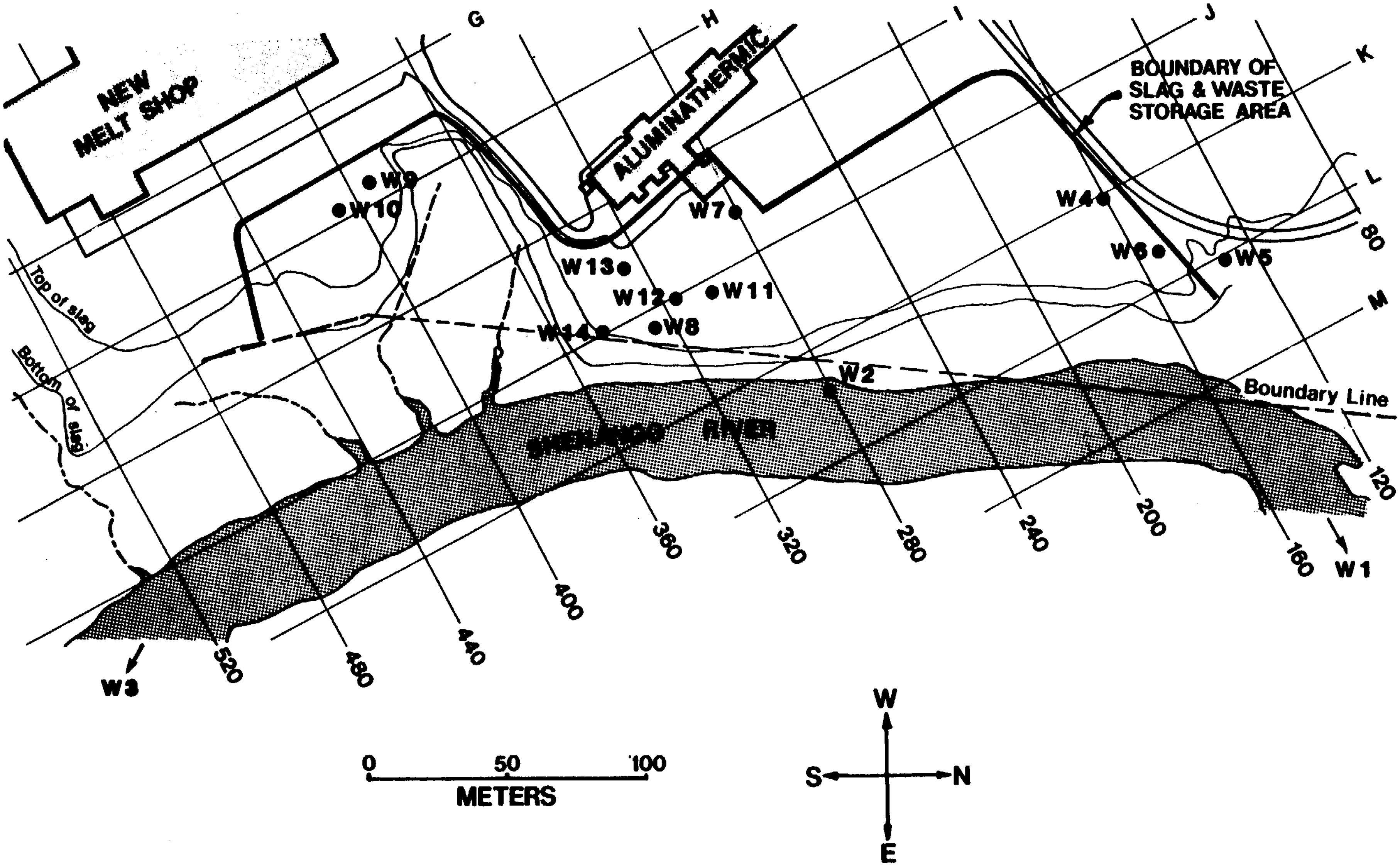


FIGURE 4: Locations of Water Samples Collected from the Whittaker Site.

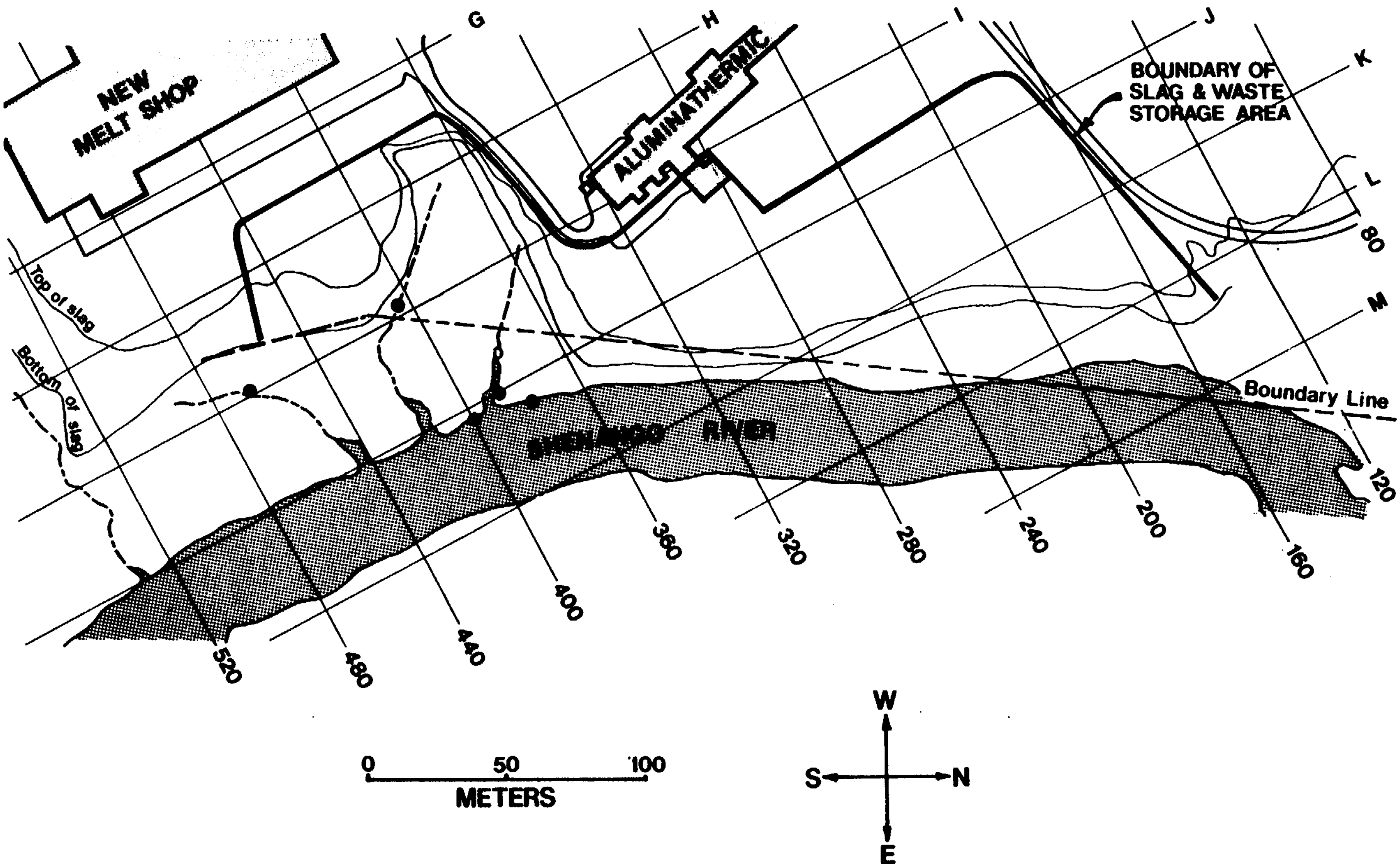


FIGURE 5: Locations of Sediment Samples Collected from the Whittaker Site.

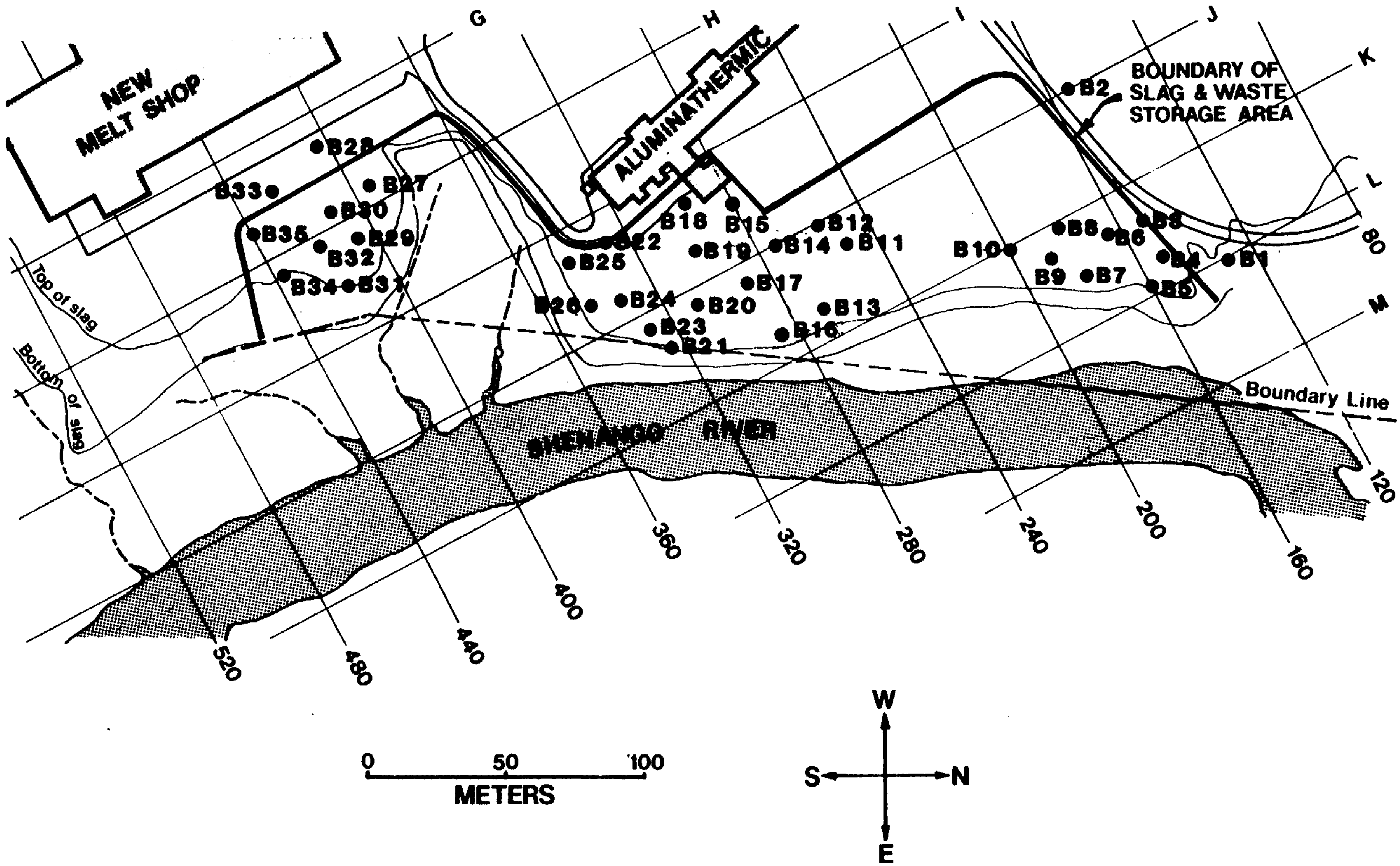


FIGURE 6: Locations of Boreholes Drilled in the Waste and Slag Area for Subsurface Investigations.

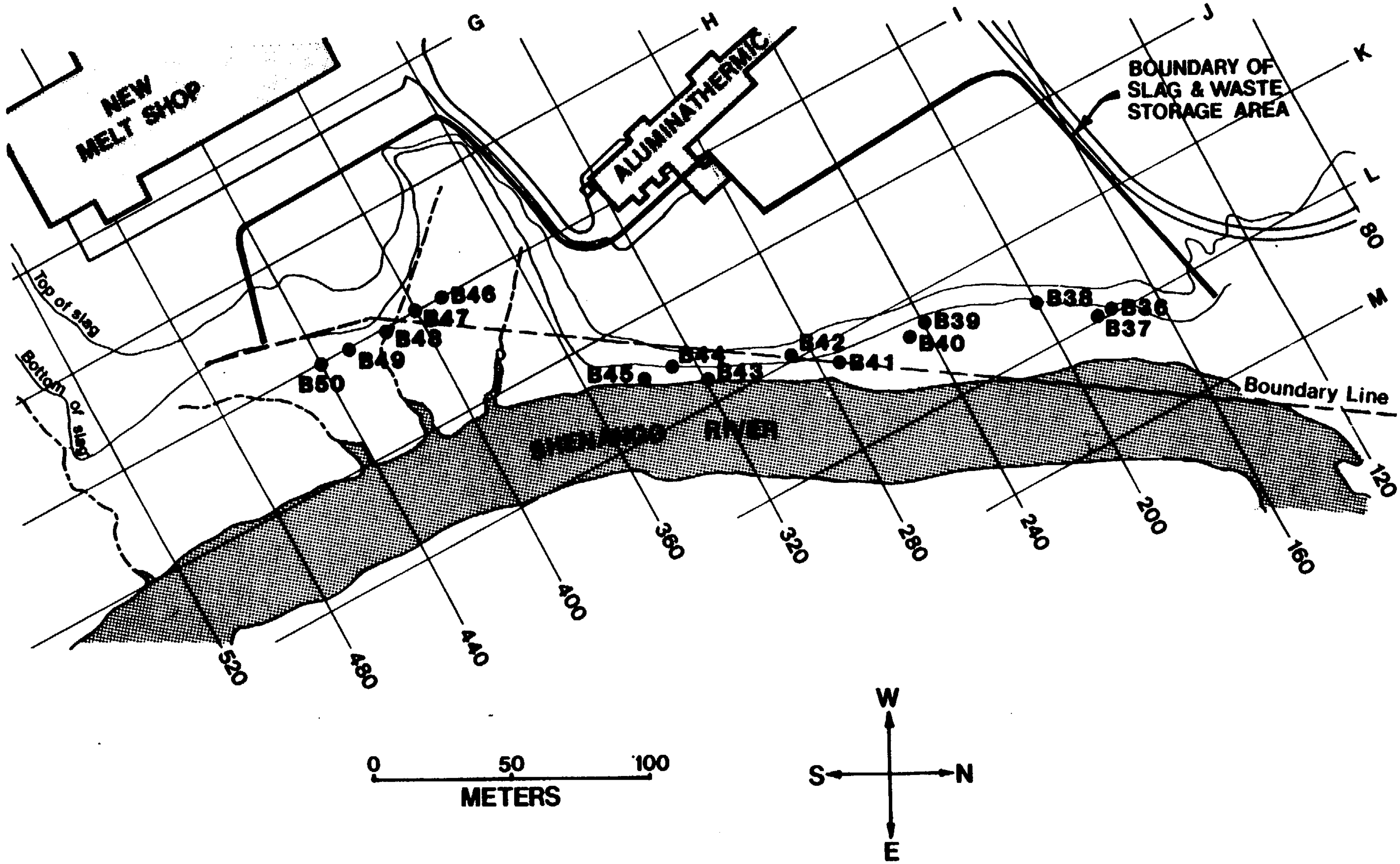


FIGURE 7: Locations of Shallow Boreholes Drilled Between the Slag Areas and the Shenango River.

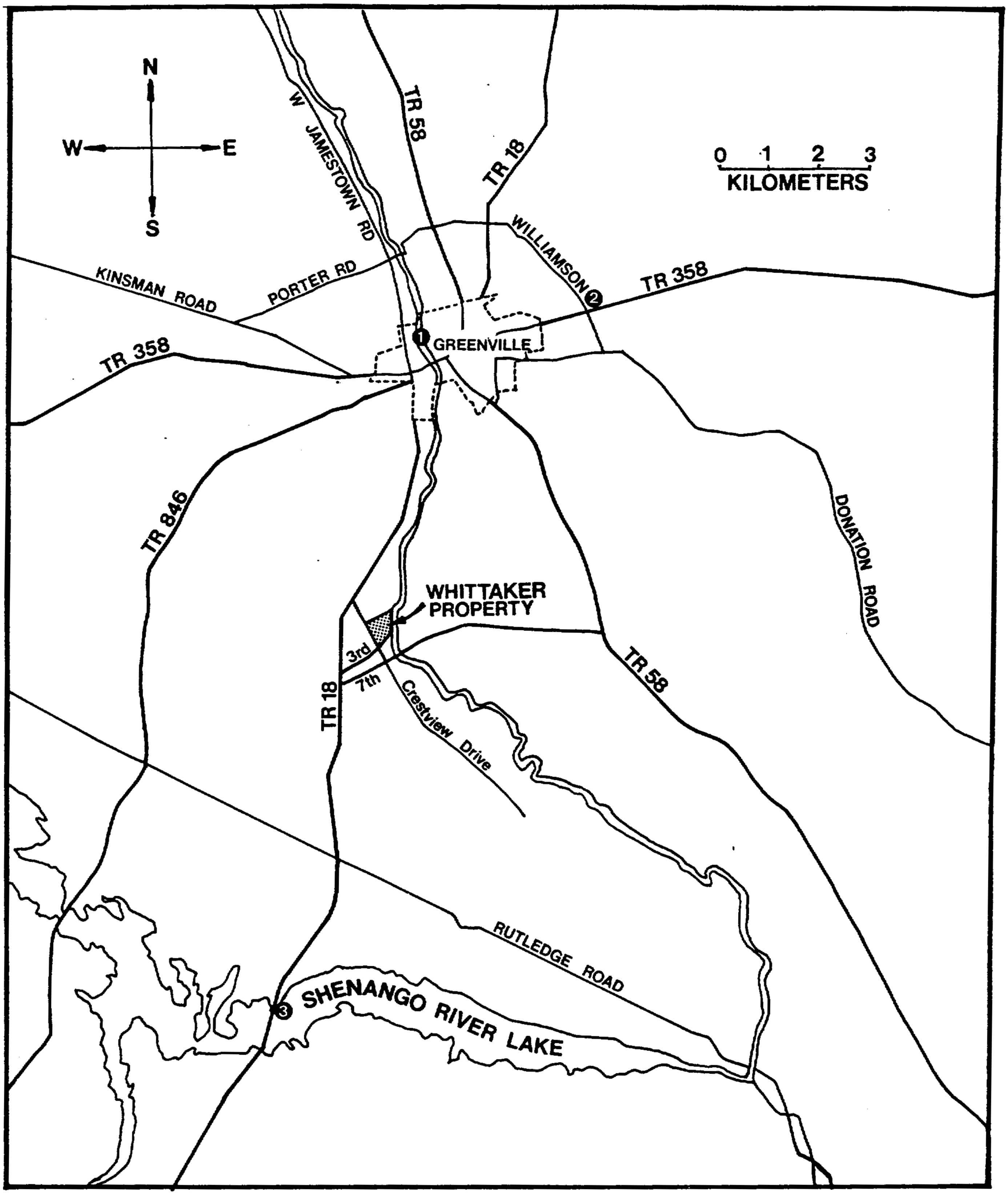


FIGURE 8: Map of Area Surrounding the Whittaker Site Showing Locations of Background Measurements and Baseline Samples.

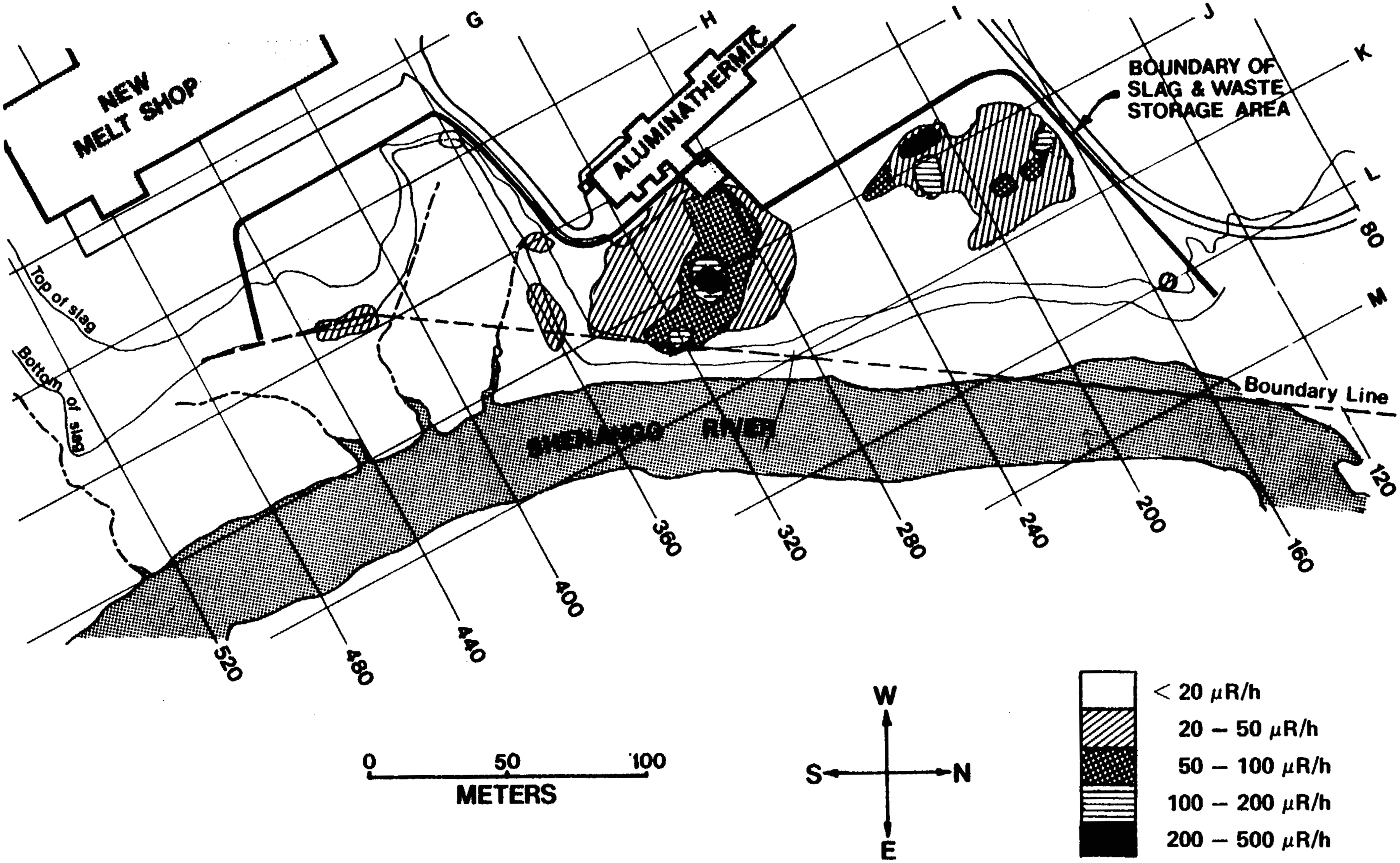


FIGURE 9: Exposure Rates at 1 m above the Surface in the Waste and Slag Storage Area.

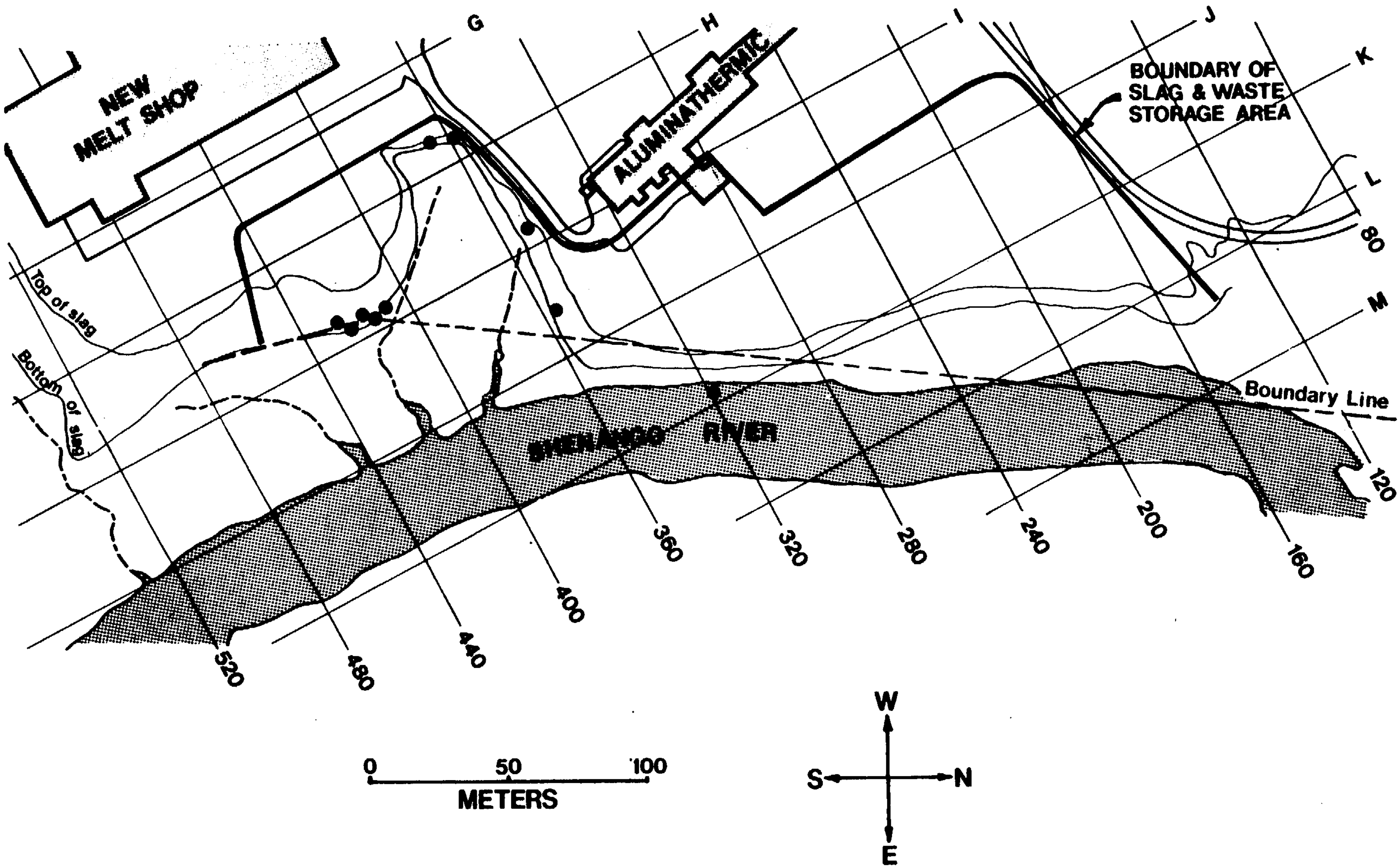


FIGURE 10: Locations of Elevated Direct Radiation Outside the Main Slag Storage Piles.

TABLE 1-A

BACKGROUND EXPOSURE RATES AND BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL

| Location[a] | Gamma Exposure Rate at 1 m Above the Surface (μR/h) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|
| | | Th-232 | Th-228 | U-238 | Ra-226 |
| 1 | 10 | 0.6 ± 0.3[b] | 0.6 ± 0.2 | 0.8 ± 1.1 | 0.8 ± 0.2 |
| 2 | 9 | 1.2 ± 0.6 | 1.0 ± 0.5 | 1.5 ± 1.6 | 0.7 ± 0.3 |
| 3 | 10 | 0.7 ± 0.3 | 0.5 ± 0.3 | <0.7 | 0.6 ± 0.2 |

[a]Refer to Figure 8.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainites of ± 6 to 10% have not been propagated into these data.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

| Location[a] | Radionuclide Concentrations (pCi/l) | |
|---|---|---|
| | Gross Alpha | Gross Beta |
| 1 | 0.4 ± 0.5[b] | 2.6 ± 1.0 |
| 2 | 0.3 ± 0.4 | 3.2 ± 1.0 |
| 3 | 0.8 ± 0.5 | 4.6 ± 1.0 |

[a] Refer to Figure 8.
[b] Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainites of ± 6 to 10% have not been propagated into these data.

TABLE 2

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS
ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 128 L | 11 | 11 |
| 136 L | 11 | 10 |
| 144 K+32 | 12 | 11 |
| 144 L | 10 | 10 |
| 152 K | 13 | 13 |
| 152 K+8 | 12 | 12 |
| 152 K+16 | 12 | 12 |
| 152 K+24 | 12 | 11 |
| 152 K+32 | 13 | 12 |
| 152 L | 32 | 38 |
| 160 I+32 | 12 | 13 |
| 160 J | 16 | 12 |
| 160 J+8 | 13 | 13 |
| 160 J+16 | 13 | 14 |
| 160 J+24 | 13 | 13 |
| 160 J+32 | 16 | 14 |
| 160 K | 14 | 12 |
| 160 K+8 | 11 | 11 |
| 160 K+16 | 14 | 28 |
| 160 K+24 | 11 | 11 |
| 160 K+32 | 10 | 10 |
| 160 L | 11 | 10 |
| 168 I+24 | 11 | 10 |
| 168 I+32 | 16 | 13 |
| 168 J | 24 | 22 |
| 168 J+8 | 20 | 24 |
| 168 J+16 | 110 | 120 |
| 168 J+24 | 41 | 32 |
| 168 J+32 | 24 | 20 |
| 168 K | 12 | 11 |
| 168 K+8 | 12 | 12 |
| 168 K+16 | 12 | 12 |
| 168 K+24 | 10 | 8 |
| 168 K+32 | 10 | 9 |
| 176 I+24 | 12 | 12 |
| 176 I+32 | 24 | 22 |
| 176 J | 41 | 28 |
| 176 J+8 | 30 | 28 |
| 176 J+16 | 28 | 20 |
| 176 J+24 | 180 | 45 |
| 176 J+32 | 24 | 20 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 176 K | 11 | 12 |
| 176 K+8 | 12 | 12 |
| 176 K+16 | 11 | 12 |
| 176 K+24 | 11 | 10 |
| 184 I+24 | 11 | 12 |
| 184 I+32 | 32 | 66 |
| 184 J | 45 | 32 |
| 184 J+8 | 32 | 24 |
| 184 J+16 | 24 | 16 |
| 184 J+24 | 24 | 20 |
| 184 J+32 | 18 | 14 |
| 184 K | 11 | 10 |
| 184 K+8 | 11 | 12 |
| 184 K+16 | 12 | 10 |
| 184 K+24 | 10 | 10 |
| 192 I+24 | 12 | 12 |
| 192 I+32 | 16 | 16 |
| 192 J | 28 | 20 |
| 192 J+8 | 28 | 20 |
| 192 J+16 | 24 | 20 |
| 192 J+24 | 70 | 36 |
| 192 J+32 | 20 | 18 |
| 192 K | 11 | 10 |
| 192 K+8 | 12 | 12 |
| 192 K+16 | 11 | 11 |
| 200 I+24 | 16 | 16 |
| 200 I+32 | 16 | 18 |
| 200 J | 41 | 28 |
| 200 J+8 | 45 | 6 |
| 200 J+16 | 24 | 16 |
| 200 J+24 | 22 | 22 |
| 200 J+32 | 18 | 18 |
| 200 K | 11 | 11 |
| 200 K+8 | 12 | 12 |
| 200 K+16 | 10 | 10 |
| 208 I+24 | 16 | 14 |
| 208 I+32 | 110 | 92 |
| 208 J | 32 | 16 |
| 208 J+8 | 28 | 20 |
| 208 J+16 | 16 | 16 |
| 208 J+24 | 12 | 11 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 208 J+32 | 20 | 16 |
| 208 K | 9 | 9 |
| 216 I+24 | 14 | 12 |
| 216 I+32 | 490 | 800 |
| 216 J | 110 | 83 |
| 216 J+8 | 180 | 130 |
| 216 J+16 | 13 | 14 |
| 216 J+24 | 8 | 8 |
| 216 J+32 | 10 | 10 |
| 216 K | 12 | 12 |
| 224 I+24 | 12 | 12 |
| 224 I+32 | 45 | 24 |
| 224 J | 45 | 45 |
| 224 J+8 | 13 | 12 |
| 224 J+16 | 10 | 10 |
| 224 J+24 | 10 | 10 |
| 224 J+32 | 10 | 12 |
| 224 K | 11 | 12 |
| 232 I+24 | 13 | 16 |
| 232 I+32 | 10 | 10 |
| 232 K | 66 | 55 |
| 232 J+8 | 9 | 9 |
| 232 J+16 | 12 | 10 |
| 232 J+24 | 9 | 10 |
| 232 J+32 | 10 | 8 |
| 232 K | 11 | 11 |
| 240 I+32 | 10 | 8 |
| 240 J | 12 | 8 |
| 240 J+8 | 10 | 8 |
| 240 J+16 | 12 | 12 |
| 240 J+24 | 11 | 12 |
| 240 J+32 | 12 | 12 |
| 240 K | 12 | 12 |
| 248 I+32 | 11 | 10 |
| 248 J | 11 | 12 |
| 248 J+8 | 12 | 12 |
| 248 J+16 | 12 | 12 |
| 248 J+24 | 12 | 12 |
| 248 J+32 | 12 | 14 |
| 248 K | 12 | 11 |
| 256 I+32 | 10 | 10 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS
ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 256 J | 11 | 12 |
| 256 J+8 | 16 | 14 |
| 256 J+16 | 14 | 14 |
| 256 J+24 | 14 | 13 |
| 264 I+32 | 16 | 13 |
| 264 J | 114 | 12 |
| 264 J+8 | 16 | 12 |
| 264 J+16 | 12 | 12 |
| 264 J+24 | 14 | 16 |
| 264 J+32 | 13 | 16 |
| 272 I+8 | 13 | 13 |
| 272 I+16 | 32 | 32 |
| 272 I+24 | 22 | 16 |
| 272 I+32 | 28 | 18 |
| 272 J | 16 | 16 |
| 272 J+8 | 24 | 20 |
| 272 J+16 | 16 | 16 |
| 272 J+24 | 16 | 16 |
| 272 J+32 | 14 | 16 |
| 280 I | 11 | 12 |
| 280 I+8 | 11 | 12 |
| 280 I+16 | 70 | 45 |
| 280 I+24 | 77 | 66 |
| 280 I+32 | 53 | 34 |
| 280 J | 32 | 34 |
| 280 J+8 | 28 | 24 |
| 280 J+16 | 22 | 22 |
| 280 J+24 | 16 | 14 |
| 280 J+32 | 14 | 16 |
| 288 I | 12 | 12 |
| 288 I+8 | b | b |
| 288 I+16 | 66 | 49 |
| 288 I+24 | 15 | 28 |
| 288 I+32 | 51 | 45 |
| 288 J | 55 | 28 |
| 288 J+8 | 45 | 28 |
| 288 J+16 | 30 | 28 |
| 288 J+24 | 20 | 16 |
| 296 I | 14 | 14 |
| 296 I+8 | 22 | 22 |
| 296 I+16 | 66 | 55 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 296 I+24 | 70 | 55 |
| 296 I+32 | 53 | 38 |
| 296 J | 130 | 55 |
| 296 J+8 | 280 | 280 |
| 296 J+16 | 26 | 22 |
| 296 J+24 | 34 | 34 |
| 304 I+8 | 20 | 16 |
| 304 I+16 | 32 | 22 |
| 304 I+24 | 36 | 28 |
| 304 I+32 | 130 | 130 |
| 304 J | 350 | 350 |
| 304 J+8 | 180 | 180 |
| 304 J+16 | 79 | 79 |
| 312 I+8 | 16 | 14 |
| 312 I+16 | 22 | 22 |
| 312 I+24 | 28 | 20 |
| 312 I+32 | 41 | 24 |
| 312 J | 88 | 77 |
| 312 J+8 | 62 | 34 |
| 312 J+16 | 75 | 36 |
| 320 I+8 | 16 | 18 |
| 320 I+16 | 16 | 22 |
| 320 I+24 | 45 | 55 |
| 320 I+32 | 32 | 22 |
| 320 J | 41 | 28 |
| 320 J+8 | 55 | 34 |
| 320 J+16 | 130 | 180 |
| 328 I | 18 | 22 |
| 328 I+8 | 14 | 14 |
| 328 I+16 | 41 | 66 |
| 328 I+24 | 20 | 20 |
| 328 I+32 | 20 | 16 |
| 328 J | 24 | 20 |
| 328 J+8 | 79 | 55 |
| 328 J+16 | 88 | 32 |
| 336 I | 14 | 16 |
| 336 I+8 | 16 | 16 |
| 336 I+16 | 16 | 16 |
| 336 I+24 | 43 | 22 |
| 336 I+32 | 20 | 16 |
| 336 J | 20 | 16 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS
ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 336 J+8 | 24 | 16 |
| 344 H | 12 | 12 |
| 344 H+8 | 11 | 11 |
| 344 H+16 | 14 | 11 |
| 344 H+24 | 14 | 11 |
| 344 H+32 | 13 | 13 |
| 344 I | 13 | 13 |
| 344 I+8 | 20 | 20 |
| 344 I+16 | 16 | 14 |
| 344 I+24 | 14 | 12 |
| 344 I+32 | 20 | 16 |
| 344 J | 28 | 16 |
| 352 G+6 | 11 | 12 |
| 352 G+24 | 11 | 11 |
| 352 G+32 | 10 | 10 |
| 352 H | 11 | 11 |
| 352 H+8 | 12 | 12 |
| 352 H+16 | 12 | 13 |
| 352 H+32 | 12 | 11 |
| 352 I | 24 | 24 |
| 352 I+8 | 14 | 13 |
| 352 I+16 | 18 | 14 |
| 352 I+24 | 24 | 20 |
| 352 I+32 | 12 | 12 |
| 352 J | 12 | 14 |
| 360 G+8 | 11 | 12 |
| 360 G+16 | 11 | 12 |
| 360 G+24 | 10 | 12 |
| 360 G+32 | 24 | 55 |
| 360 H | 12 | 14 |
| 360 H+8 | 12 | 12 |
| 360 H+16 | 12 | 13 |
| 360 H+24 | 12 | 12 |
| 360 H+32 | 13 | 14 |
| 360 I | 14 | 14 |
| 360 I+8 | 16 | 14 |
| 360 I+16 | 28 | 66 |
| 360 I+24 | 36 | 66 |
| 360 I+32 | 20 | 16 |
| 360 J | 16 | 16 |
| 368 G+8 | 12 | 11 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS
ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 368 G+16 | 11 | 11 |
| 368 G+24 | 10 | 12 |
| 376 G+8 | 10 | 10 |
| 376 G+16 | 11 | 11 |
| 376 G+24 | 12 | 12 |
| 384 G+8 | 10 | 10 |
| 392 G+8 | 10 | 12 |
| 392 G+16 | 11 | 10 |
| 392 G+24 | 12 | 16 |
| 392 G+32 | 11 | 11 |
| 392 H | 14 | 14 |
| 392 H+8 | 13 | 15 |
| 400 G+8 | 11 | 11 |
| 400 G+16 | 12 | 12 |
| 400 G+24 | 18 | 18 |
| 400 G+32 | 10 | 11 |
| 400 H | 12 | 14 |
| 400 H+8 | 13 | 13 |
| 400 H+16 | 14 | 14 |
| 408 G+8 | 10 | 10 |
| 408 G+16 | 11 | 10 |
| 408 G+24 | 14 | 14 |
| 408 G+32 | 12 | 11 |
| 408 H | 14 | 14 |
| 408 H+8 | 14 | 14 |
| 408 H+16 | 14 | 16 |
| 408 H+24 | 14 | 24 |
| 416 G+8 | 10 | 10 |
| 416 G+16 | 16 | 21 |
| 416 G+24 | 12 | 14 |
| 416 G+32 | 12 | 12 |
| 416 H | 12 | 14 |
| 416 H+8 | 14 | 16 |
| 416 H+16 | 16 | 22 |
| 416 H+24 | 12 | 24 |
| 424 G+8 | 10 | 10 |
| 424 G+16 | 11 | 12 |
| 424 G+24 | 12 | 12 |
| 424 G+32 | 14 | 12 |
| 424 H | 14 | 14 |
| 424 H+8 | 16 | 18 |

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT 8 M GRID INTERVALS
ON THE WASTE AND SLAG STORAGE AREA

| Grid Location[a] | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 424 H+16 | 22 | 28 |
| 424 H+24 | 16 | 16 |
| 432 G+8 | 10 | 10 |
| 432 G+16 | 10 | 11 |
| 432 G+24 | 12 | 14 |
| 432 G+32 | 14 | 18 |
| 432 H | 14 | 16 |
| 432 H+8 | 16 | 12 |
| 432 H+16 | 14 | 12 |
| 432 H+24 | 14 | 16 |
| 440 G+16 | 10 | 10 |
| 440 G+24 | 10 | 10 |
| 440 G+32 | 11 | 11 |
| 440 H | 12 | 11 |
| 440 H+8 | 12 | 12 |
| 440 H+16 | 12 | 12 |
| 448 G+16 | 11 | 9 |
| 448 G+24 | 13 | 11 |
| 448 G+32 | 12 | 12 |
| 448 H | 11 | 12 |

[a]Refer to Figure 3.
[b]Area not accessible.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED BY WALKOVER SCANS OUTSIDE THE MAIN SLAG STORAGE PILES

| Grid Location[a] | Source | Gamma Exposure Rates at the Surface (μR/h) |
|---|---|---|
| 320 J+38 | Slag | 130 |
| 350 H+35 | Slag | 650 |
| 353 I+23 | Slag | 88 |
| 357 G+30 | Slag | 45 |
| 370 G+25 | Barrel | 240 |
| 408 H+36 | Barrel | 800 |
| 412 H+38 | Barrel | 45 |
| 418 H+30 | Slag | 32 |
| 421 H+34 | Slag | 62 |
| 424 H+31 | Slag | 70 |

[a]Refer to Figure 10.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 128 L | 1.7 ± 0.1[b] | 0.9 ± 0.4 | 1.6 ± 1.5 | 1.6 ± 0.4 |
| 136 L | 1.0 ± 0.4 | 1.5 ± 0.4 | 1.7 ± 1.8 | 0.9 ± 0.2 |
| 144 K+32 | 0.9 ± 0.3 | 0.8 ± 0.2 | <0.6 | 0.6 ± 0.2 |
| 144 L | 2.3 ± 0.5 | 1.4 ± 0.5 | 1.2 ± 1.8 | 0.8 ± 0.2 |
| 152 K | 0.6 ± 0.5 | 0.8 ± 0.3 | 1.0 ± 0.8 | 1.0 ± 0.2 |
| 152 K+8 | 1.1 ± 0.4 | 0.9 ± 0.3 | 2.3 ± 0.9 | 0.9 ± 0.2 |
| 152 K+16 | 0.8 ± 0.4 | 1.1 ± 0.3 | 1.9 ± 1.0 | 0.8 ± 0.2 |
| 152 K+24 | 3.5 ± 0.6 | 4.6 ± 0.6 | 2.4 ± 2.3 | 0.8 ± 0.3 |
| 152 K+32 | 3.0 ± 0.6 | 2.1 ± 0.3 | <1.1 | 1.1 ± 0.2 |
| 152 L | 1.9 ± 0.5 | 1.5 ± 0.6 | 3.4 ± 1.1 | 1.1 ± 0.3 |
| 160 I+32 | 0.9 ± 0.2 | 0.8 ± 0.2 | 1.3 ± 0.8 | 0.9 ± 0.2 |
| 160 J | 0.5 ± 0.4 | 0.8 ± 0.3 | 2.0 ± 0.7 | 0.8 ± 0.2 |
| 160 J+8 | c | c | c | c |
| 160 J+16 | 1.3 ± 0.3 | 1.4 ± 0.3 | 1.2 ± 1.5 | 0.9 ± 0.2 |
| 160 J+24 | c | c | c | c |
| 160 J+32 | 0.6 ± 0.3 | <0.2 | <0.6 | 0.6 ± 0.2 |
| 160 K | 2.7 ± 0.5 | 2.2 ± 0.4 | 4.3 ± 1.3 | 1.0 ± 0.3 |
| 160 K+8 | 1.0 ± 0.5 | 1.4 ± 0.3 | <1.1 | 0.9 ± 0.2 |
| 160 K+16 | 1.2 ± 0.4 | 1.2 ± 0.3 | 1.9 ± 0.9 | 0.8 ± 0.2 |
| 160 K+24 | 1.3 ± 0.5 | 1.1 ± 0.4 | <1.5 | 0.8 ± 0.2 |
| 160 K+32 | 1.0 ± 0.3 | 1.3 ± 0.3 | 0.8 ± 1.3 | 0.8 ± 0.2 |
| 160 L | 0.7 ± 0.2 | 1.2 ± 0.3 | 1.7 ± 1.0 | 1.0 ± 0.2 |
| 168 I+24 | 0.9 ± 0.3 | 0.9 ± 0.2 | 1.4 ± 1.1 | 0.6 ± 0.2 |
| 168 I+32 | 3.6 ± 0.7 | 3.8 ± 0.7 | <1.2 | 1.3 ± 0.3 |
| 168 J | 1.0 ± 0.3 | 2.0 ± 0.4 | <1.0 | 0.9 ± 0.2 |
| 168 J+8 | 0.9 ± 0.3[b] | 1.2 ± 0.3 | 1.7 ± 1.3 | 0.7 ± 0.2 |
| 168 J+16 | 1.5 ± 0.7 | 1.4 ± 0.3 | 1.4 ± 2.0 | 0.9 ± 0.2 |
| 168 J+24 | 1.5 ± 0.4 | 1.6 ± 0.3 | 4.1 ± 2.7 | 1.3 ± 0.2 |
| 168 J+32 | 0.6 ± 0.3 | 0.6 ± 0.2 | 1.3 ± 0.7 | 0.5 ± 0.2 |
| 168 K | 1.4 ± 0.4 | 1.8 ± 0.4 | 3.8 ± 1.8 | 1.0 ± 0.2 |
| 168 K+8 | 0.8 ± 0.4 | 1.4 ± 0.4 | 1.8 ± 1.8 | 0.8 ± 0.2 |
| 168 K+16 | 1.0 ± 0.4 | 1.0 ± 0.3 | 3.6 ± 1.9 | 0.7 ± 0.2 |
| 168 K+24 | 1.5 ± 0.6 | 1.8 ± 0.3 | <0.9 | 0.9 ± 0.2 |
| 168 K+32 | 1.7 ± 0.3 | 1.8 ± 0.3 | 2.1 ± 1.4 | 1.1 ± 0.3 |
| 176 I+24 | 0.6 ± 0.2 | 0.5 ± 0.2 | 0.8 ± 0.8 | 0.5 ± 0.1 |
| 176 I+32 | 1.9 ± 0.5 | 1.6 ± 0.4 | 4.2 ± 1.4 | 0.9 ± 0.3 |
| 176 J | 0.9 ± 0.4 | 1.1 ± 0.3 | 0.8 ± 1.5 | 0.6 ± 0.1 |
| 176 J+8 | 0.8 ± 0.5 | 1.0 ± 0.2 | 1.7 ± 1.4 | 0.6 ± 0.2 |
| 176 J+16 | 1.8 ± 0.5 | 2.4 ± 0.4 | 2.8 ± 1.2 | 1.6 ± 0.3 |
| 176 J+24 | c | c | c | c |
| 176 J+32 | 1.7 ± 0.4 | 1.7 ± 0.3 | 3.2 ± 1.5 | 0.9 ± 0.2 |
| 176 K | 1.3 ± 0.4 | <0.3 | 2.0 ± 0.9 | 0.8 ± 0.2 |
| 176 K+8 | 1.2 ± 0.4 | 1.2 ± 0.4 | 0.9 ± 1.2 | 0.7 ± 0.2 |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 176 K+16 | 1.7 ± 0.6 | 2.1 ± 0.4 | 1.2 ± 2.1 | 0.7 ± 0.2 |
| 176 K+24 | 21.2 ± 1.5 | 23.0 ± 1.2 | 12.7 ± 3.5 | 2.6 ± 0.5 |
| 184 I+24 | 1.1 ± 0.3 | 0.9 ± 0.2 | 2.4 ± 0.8 | 0.5 ± 0.2 |
| 184 I+32 | 4.9 ± 0.7 | 4.3 ± 0.5 | 2.0 ± 2.5 | 1.6 ± 0.3 |
| 184 J | 1.6 ± 0.4 | 3.2 ± 0.5 | 1.1 ± 1.3 | 0.8 ± 0.2 |
| 184 J+8 | 1.4 ± 0.6 | 1.5 ± 0.4 | <0.8 | 0.7 ± 0.2 |
| 184 J+16 | 3.6 ± 0.5 | 3.5 ± 0.5 | 2.1 ± 2.2 | 1.4 ± 0.3 |
| 184 J+24 | c | c | c | c |
| 184 J+32 | c | c | c | c |
| 184 K | 0.8 ± 0.3 | 0.7 ± 0.3 | 0.7 ± 0.2 | 0.5 ± 0.3 |
| 184 K+8 | 1.2 ± 0.3 | 1.2 ± 0.3 | 1.1 ± 1.3 | 0.8 ± 0.2 |
| 184 K+16 | 1.3 ± 0.4 | 1.5 ± 0.4 | 2.4 ± 1.4 | 0.6 ± 0.2 |
| 184 K+24 | 1.2 ± 0.3 | 0.7 ± 0.2 | 1.5 ± 1.3 | 0.6 ± 0.1 |
| 192 I+24 | 2.0 ± 0.4 | 2.0 ± 0.5 | 2.1 ± 1.1 | 0.4 ± 0.2 |
| 192 I+32 | 0.8 ± 0.3 | 1.1 ± 0.3 | 1.8 ± 1.8 | 0.7 ± 0.2 |
| 192 J | 1.7 ± 0.6 | 1.9 ± 0.5 | 1.3 ± 1.9 | 1.0 ± 0.3 |
| 192 J+8 | 1.2 ± 0.4 | 1.0 ± 0.3 | 0.9 ± 1.3 | 0.7 ± 0.2 |
| 192 J+16 | c | c | c | c |
| 192 J+24 | c | c | c | c |
| 192 J+32 | c | c | c | c |
| 192 K | 1.1 ± 0.3 | 1.2 ± 0.3 | 4.1 ± 1.1 | 0.9 ± 0.2 |
| 192 K+8 | 0.9 ± 0.3 | 1.3 ± 0.3 | 0.9 ± 2.1 | 1.0 ± 0.2 |
| 192 K+16 | 1.1 ± 0.4 | 1.2 ± 0.5 | 2.4 ± 2.6 | 0.8 ± 0.2 |
| 200 I+24 | 0.8 ± 0.2 | 0.8 ± 0.2 | 1.2 ± 0.9 | 0.6 ± 0.1 |
| 200 I+32 | 1.8 ± 0.4 | 1.5 ± 0.4 | 2.1 ± 1.6 | 1.0 ± 0.2 |
| 200 J | ± | ± | 1.5 ± 2.7 | 2.5 ± 0.4 |
| 200 J+8 | 0.9 ± 0.5 | 1.1 ± 0.4 | 1.1 ± 1.4 | 1.0 ± 0.3 |
| 200 J+16 | c | c | c | c |
| 200 J+24 | c | c | c | c |
| 200 J+32 | c | c | c | c |
| 200 K | 1.5 ± 0.4 | 1.4 ± 0.3 | 1.2 ± 1.0 | 0.7 ± 0.2 |
| 200 K+8 | 0.9 ± 0.4 | 1.0 ± 0.3 | 2.2 ± 1.3 | 0.7 ± 0.2 |
| 200 K+16 | 0.7 ± 0.4 | 1.3 ± 0.4 | <1.0 | 0.8 ± 0.3 |
| 208 I+24 | 1.0 ± 0.2 | 0.8 ± 0.2 | 1.2 ± 0.9 | 0.5 ± 0.2 |
| 208 I+32 | c | c | c | c |
| 208 J | 2.9 ± 0.5 | 3.0 ± 0.5 | <1.3 | 1.4 ± 0.3 |
| 208 J+8 | c | c | c | c |
| 208 J+16 | c | c | c | c |
| 208 J+24 | c | c | c | c |
| 208 J+32 | c | c | c | c |
| 208 K | 1.1 ± 0.4 | 1.1 ± 0.3 | 1.5 ± 0.8 | 0.8 ± 0.2 |
| 216 I+24 | 0.6 ± 0.2 | 0.7 ± 0.2 | 8.2 ± 6.8 | 0.5 ± 0.1 |
| 216 I+32 | c | c | c | c |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 216 J | c | c | c | c |
| 216 J+8 | c | c | c | c |
| 216 J+16 | c | c | c | c |
| 216 J+24 | c | c | c | c |
| 216 J+32 | c | c | c | c |
| 216 K | 1.5 ± 0.4 | 0.9 ± 0.3 | <0.9 | 0.7 ± 0.2 |
| 224 I+24 | 1.2 ± 0.3 | 1.0 ± 0.2 | 1.0 ± 1.2 | 0.6 ± 0.1 |
| 224 I+32 | c | c | c | c |
| 224 J | 0.5 ± 0.3 | 0.6 ± 0.2 | <0.4 | 0.4 ± 0.1 |
| 224 J+8 | c | c | c | c |
| 224 J+16 | c | c | c | c |
| 224 J+24 | c | c | c | c |
| 224 J+32 | c | c | c | c |
| 224 K | 1.0 ± 0.3 | 1.2 ± 0.4 | 1.3 ± 1.2 | 0.8 ± 0.3 |
| 232 I+24 | 1.6 ± 0.4 | 1.3 ± 0.3 | 2.3 ± 0.8 | 1.2 ± 0.2 |
| 232 I+32 | 1.1 ± 0.2 | 0.7 ± 0.3 | 1.0 ± 1.0 | 0.7 ± 0.2 |
| 232 J | 0.5 ± 0.2 | 0.5 ± 0.2 | <0.5 | 0.2 ± 0.1 |
| 232 J+8 | 2.1 ± 0.5 | 2.9 ± 0.5 | 2.2 ± 1.2 | 1.1 ± 0.3 |
| 232 J+16 | 1.1 ± 0.3 | 1.2 ± 0.2 | 2.5 ± 1.3 | 0.5 ± 0.2 |
| 232 J+24 | 0.5 ± 0.2 | 0.7 ± 0.2 | 0.9 ± 1.1 | 0.3 ± 0.2 |
| 232 J+32 | 0.9 ± 0.3 | 0.9 ± 0.2 | 0.9 ± 0.1 | 0.4 ± 0.2 |
| 232 K | 1.0 ± 0.3 | 1.3 ± 0.3 | 3.0 ± 1.0 | 0.7 ± 0.2 |
| 240 I+32 | 1.4 ± 0.4 | 1.5 ± 0.3 | 1.9 ± 0.8 | 0.9 ± 0.2 |
| 240 J | 0.5 ± 0.2 | 0.4 ± 0.3 | <0.4 | 0.1 ± 0.2 |
| 240 J+8 | c | c | c | c |
| 240 J+16 | c | c | c | c |
| 240 J+24 | c | c | c | c |
| 240 J+32 | c | c | c | c |
| 240 K | 1.2 ± 0.4 | 1.6 ± 0.4 | 0.4 ± 1.2 | 0.8 ± 0.2 |
| 248 I+32 | 1.0 ± 0.3 | 1.0 ± 0.3 | 1.6 ± 1.9 | 0.8 ± 0.2 |
| 248 J | 0.8 ± 0.3 | 0.8 ± 0.4 | 1.0 ± 0.8 | 1.2 ± 0.2 |
| 248 J+8 | c | c | c | c |
| 248 J+16 | 0.8 ± 0.3 | 0.8 ± 0.2 | <0.6 | 0.5 ± 0.1 |
| 248 J+24 | 1.4 ± 0.4 | 1.4 ± 0.3 | 1.0 ± 0.3 | 0.8 ± 0.2 |
| 248 J+32 | 0.8 ± 0.3 | 1.0 ± 0.3 | 0.9 ± 1.6 | 0.7 ± 0.2 |
| 248 K | 1.0 ± 0.3 | 1.1 ± 0.3 | 1.0 ± 1.2 | 0.6 ± 0.2 |
| 256 I+32 | c | c | c | c |
| 256 J | 1.1 ± 0.4 | 1.1 ± 0.3 | 2.2 ± 1.5 | 1.0 ± 0.2 |
| 256 J+8 | 1.7 ± 0.5 | 1.0 ± 0.3 | 0.5 ± 0.1 | 0.7 ± 0.2 |
| 256 J+16 | 1.1 ± 0.3 | 1.2 ± 0.4 | 1.1 ± 2.0 | 1.1 ± 0.2 |
| 256 J+24 | 1.0 ± 0.5 | 0.9 ± 0.3 | <0.7 | 1.1 ± 0.3 |
| 256 J+32 | 1.1 ± 0.3 | 1.0 ± 0.2 | 1.5 ± 1.9 | 0.7 ± 0.2 |
| 256 K | 1.0 ± 0.5 | 1.4 ± 0.4 | <0.8 | |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 264 I+32 | c | c | c | c |
| 264 J | c | c | c | c |
| 264 J+8 | 1.1 ± 0.4 | 0.9 ± 0.3 | 1.5 ± 0.8 | 1.0 ± 0.2 |
| 264 J+16 | 1.3 ± 0.3 | <0.3 | 2.2 ± 0.9 | 1.2 ± 0.2 |
| 264 J+24 | 0.9 ± 0.4 | 1.5 ± 0.4 | 3.1 ± 1.8 | 0.9 ± 0.3 |
| 264 J+32 | 1.1 ± 0.4 | 1.4 ± 0.4 | 2.3 ± 1.2 | 0.7 ± 0.2 |
| 272 I+8 | c | c | c | c |
| 272 I+16 | c | c | c | c |
| 272 I+24 | 1.2 ± 0.3 | 1.1 ± 0.3 | 3.0 ± 1.0 | 1.5 ± 0.2 |
| 272 I+32 | 1.1 ± 0.3 | 1.4 ± 0.3 | 0.3 ± 1.3 | 0.5 ± 0.2 |
| 272 J | 218 ± 4 | 220 ± 4 | 303 ± 11 | 121 ± 2 |
| 272 J+8 | 1.1 ± 0.3 | 1.5 ± 0.4 | 1.4 ± 2.0 | 1.1 ± 0.2 |
| 272 J+16 | 1.8 ± 0.3 | 1.4 ± 0.4 | 0.8 ± 2.1 | 1.9 ± 0.3 |
| 272 J+24 | 1.3 ± 0.4 | 1.5 ± 0.4 | 2.4 ± 1.1 | 1.4 ± 0.3 |
| 272 J+32 | 2.2 ± 0.4 | 2.0 ± 0.4 | 6.6 ± 1.9 | 2.0 ± 0.3 |
| 280 I | c | c | c | c |
| 280 I+8 | 1.1 ± 0.3 | 1.4 ± 0.3 | 0.3 ± 1.3 | 0.5 ± 0.2 |
| 280 I+16 | 14.1 ± 1.0 | 13.9 ± 0.9 | 29.3 ± 3.0 | 11.8 ± 0.6 |
| 280 I+24 | 4.1 ± 0.2 | 4.5 ± 0.6 | 4.0 ± 1.5 | 4.4 ± 0.4 |
| 280 I+32 | 0.9 ± 0.2 | 0.9 ± 0.2 | 1.4 ± 1.0 | 0.5 ± 0.1 |
| 280 J | 6.5 ± 0.8 | 7.6 ± 0.7 | 2.9 ± 1.6 | 3.8 ± 0.4 |
| 280 J+8 | 2.9 ± 0.5 | 3.0 ± 0.5 | 8.9 ± 1.4 | 1.9 ± 0.3 |
| 280 J+16 | 1.4 ± 0.4 | 1.4 ± 0.4 | 7.5 ± 1.4 | 2.2 ± 0.3 |
| 280 J+24 | 2.6 ± 0.6 | 2.8 ± 0.5 | 6.2 ± 1.3 | 2.2 ± 0.3 |
| 280 J+32 | 0.5 ± 0.2 | 0.5 ± 0.2 | <0.5 | 0.4 ± 0.1 |
| 288 I | 3.3 ± 0.4 | 2.4 ± 0.3 | 6.5 ± 1.2 | 1.4 ± 0.2 |
| 288 I+8 | c | c | c | c |
| 288 I+16 | 6.1 ± 1.0 | 7.6 ± 1.0 | 22.3 ± 3.2 | 9.1 ± 0.7 |
| 288 I+24 | 4.6 ± 0.8 | 5.1 ± 0.5 | 18.9 ± 2.6 | 3.9 ± 0.3 |
| 288 I+32 | 2.0 ± 0.4 | 1.9 ± 0.4 | 1.3 ± 1.6 | 0.8 ± 0.2 |
| 288 J | 15.2 ± 1.1 | 14.9 ± 0.9 | 10.9 ± 2.0 | 3.7 ± 0.5 |
| 288 J+8 | 3.4 ± 0.5 | 3.3 ± 0.5 | 5.3 ± 2.3 | 2.9 ± 0.4 |
| 288 J+16 | 1.0 ± 0.4 | 0.9 ± 0.4 | 2.3 ± 1.2 | 0.9 ± 0.3 |
| 288 J+24 | 4.9 ± 0.8 | 4.7 ± 0.6 | 6.2 ± 1.8 | 3.3 ± 0.5 |
| 296 I | 0.6 ± 0.2 | 0.5 ± 0.2 | <0.4 | 0.4 ± 0.1 |
| 296 I+8 | 77.2 ± 2.2 | 80.1 ± 2.1 | 77.9 ± 6.3 | 13.7 ± 0.9 |
| 296 I+16 | 0.8 ± 0.3 | 0.7 ± 0.3 | <0.5 | 0.5 ± 0.1 |
| 296 I+24 | 1.1 ± 0.3 | 1.1 ± 0.3 | 1.9 ± 1.2 | 1.0 ± 0.2 |
| 296 I+32 | 1.7 ± 0.4 | 1.7 ± 0.4 | 2.2 ± 3.3 | 1.7 ± 0.3 |
| 296 J | 2.8 ± 0.5 | 3.6 ± 0.5 | 3.4 ± 1.3 | 1.0 ± 0.3 |
| 296 J+8 | 1.1 ± 0.3 | 1.1 ± 0.3 | 2.0 ± 0.8 | 0.8 ± 0.1 |
| 296 J+16 | 0.5 ± 0.3 | 0.5 ± 0.4 | 1.6 ± 0.8 | 0.9 ± 0.2 |
| 296 J+24 | 4.4 ± 0.7 | 4.9 ± 0.6 | 9.0 ± 2.0 | 4.6 ± 0.5 |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 304 I+8 | 5.8 ± 0.8 | 6.3 ± 0.8 | 2.8 ± 1.9 | 3.4 ± 0.5 |
| 304 I+16 | 2.7 ± 0.5 | 2.7 ± 0.5 | 4.3 ± 1.4 | 1.2 ± 0.2 |
| 304 I+24 | 2.9 ± 0.6 | 3.5 ± 0.6 | 6.2 ± 2.8 | 1.7 ± 0.3 |
| 304 I+32 | 2.2 ± 0.4 | 2.2 ± 0.4 | 3.5 ± 1.2 | 1.0 ± 0.2 |
| 304 J | 0.6 ± 0.4 | 0.8 ± 0.3 | <0.6 | 0.5 ± 0.2 |
| 304 J+8 | 2.1 ± 0.5 | 2.5 ± 0.5 | 0.4 ± 0.1 | 2.0 ± 0.3 |
| 304 J+16 | 1.4 ± 0.3 | 1.2 ± 0.3 | 0.6 ± 0.9 | 0.8 ± 0.2 |
| 304 J+24 | 4.2 ± 0.7 | 3.6 ± 0.5 | 8.9 ± 2.0 | 7.8 ± 0.5 |
| 312 I+8 | 0.9 ± 0.4 | 0.7 ± 0.2 | 2.5 ± 1.4 | 0.5 ± 0.1 |
| 312 I+16 | 0.9 ± 0.4 | 1.1 ± 0.3 | 0.6 ± 0.8 | 0.8 ± 0.2 |
| 312 I±24 | 1.3 ± 0.4 | 1.9 ± 0.3 | 3.3 ± 0.5 | 2.1 ± 0.3 |
| 312 I+32 | 1.3 ± 0.4 | 1.2 ± 0.3 | 1.7 ± 0.9 | 0.6 ± 0.2 |
| 312 J | 2.1 ± 0.6 | 3.0 ± 0.5 | 5.3 ± 2.4 | 3.4 ± 0.5 |
| 312 J+8 | 2.2 ± 0.5 | 0.5 ± 0.2 | <0.9 | 0.7 ± 0.2 |
| 312 J+16 | 6.2 ± 0.7 | 6.5 ± 0.7 | 4.4 ± 2.2 | 1.2 ± 0.3 |
| 320 I+8 | 3.5 ± 0.5 | 4.1 ± 0.6 | 2.4 ± 2.0 | 1.0 ± 0.3 |
| 320 I+16 | 9.7 ± 1.2 | 10.7 ± 0.7 | 6.6 ± 2.9 | 1.7 ± 0.4 |
| 320 I+24 | 13.6 ± 1.0 | 14.8 ± 1.1 | 15.1 ± 3.0 | 3.8 ± 0.5 |
| 320 I+32 | 2.7 ± 0.5 | 2.0 ± 0.5 | 1.0 ± 1.9 | 1.1 ± 0.3 |
| 320 J | 2.1 ± 0.4 | 2.2 ± 0.3 | 21.8 ± 2.6 | 2.2 ± 0.3 |
| 320 J+8 | 1.9 ± 0.4 | 1.4 ± 0.3 | 2.7 ± 1.9 | 1.1 ± 0.2 |
| 320 J+16 | 9.4 ± 1.0 | 10.2 ± 1.1 | 6.4 ± 3.7 | 1.8 ± 0.3 |
| 328 I | 10.3 ± 0.8 | 10.3 ± 0.8 | 7.1 ± 1.5 | 2.7 ± 0.4 |
| 328 I+8 | 0.8 ± 0.3 | 1.0 ± 0.4 | <0.7 | 0.4 ± 0.2 |
| 328 I+16 | 3.1 ± 0.6 | 4.0 ± 0.8 | 1.3 ± 2.3 | 1.1 ± 0.3 |
| 328 I+24 | 15.5 ± 1.1 | 16.2 ± 1.1 | 10.8 ± 4.1 | 3.7 ± 0.5 |
| 328 I+32 | 1.6 ± 0.5 | 1.4 ± 0.3 | 0.9 ± 1.5 | 0.7 ± 0.2 |
| 328 J | 2.8 ± 0.6 | 3.2 ± 0.5 | <1.5 | 1.9 ± 0.3 |
| 328 J+8 | 4.5 ± 0.5 | 4.4 ± 0.5 | 8.2 ± 1.8 | 2.0 ± 0.3 |
| 328 J+16 | 1.4 ± 0.4 | 1.5 ± 0.3 | 1.3 ± 1.5 | 1.1 ± 0.2 |
| 336 I | 1.6 ± 0.5 | 1.4 ± 0.4 | 1.0 ± 1.6 | 0.8 ± 0.2 |
| 336 I+8 | 1.2 ± 0.3 | 1.4 ± 0.3 | 1.3 ± 1.3 | 0.7 ± 0.2 |
| 336 I+16 | 1.2 ± 0.3 | 1.3 ± 0.4 | 1.3 ± 1.8 | 0.8 ± 0.2 |
| 336 I+24 | 4.7 ± 0.6 | 4.5 ± 0.6 | <0.6 | 0.5 ± 0.3 |
| 336 I+32 | 2.9 ± 0.5 | 3.2 ± 0.5 | 2.3 ± 1.5 | 1.1 ± 0.2 |
| 336 J | 2.8 ± 0.5 | 2.9 ± 0.5 | 1.9 ± 2.1 | 1.1 ± 0.4 |
| 336 J+8 | 1.3 ± 0.4 | 1.2 ± 0.4 | 1.7 ± 1.7 | 1.4 ± 0.3 |
| 344 H | 1.1 ± 0.4 | 0.8 ± 0.4 | 0.9 ± 1.6 | 0.8 ± 0.2 |
| 344 H+8 | 0.6 ± 0.3 | 0.6 ± 0.2 | <0.6 | 0.6 ± 0.2 |
| 344 H+16 | 0.8 ± 0.5 | 0.8 ± 0.4 | 2.6 ± 1.1 | 0.8 ± 0.2 |
| 344 H+24 | 1.6 ± 0.5 | 1.3 ± 0.3 | 5.4 ± 1.5 | 0.9 ± 0.2 |
| 344 H+32 | 0.8 ± 0.3 | 1.2 ± 0.3 | 1.7 ± 0.9 | 1.1 ± 0.2 |
| 344 I | 0.8 ± 0.3 | 1.4 ± 0.4 | 3.0 ± 1.4 | 1.2 ± 0.3 |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 344 I+8 | 2.7 ± 0.5 | 2.8 ± 0.5 | 1.8 ± 2.0 | 1.0 ± 0.3 |
| 344 I+16 | 0.7 ± 0.2 | 1.4 ± 0.3 | <0.7 | 0.6 ± 0.2 |
| 344 I+24 | 1.1 ± 0.3 | 0.9 ± 0.3 | 0.9 ± 1.1 | 0.7 ± 0.2 |
| 344 I+32 | 1.0 ± 0.3 | 1.1 ± 0.2 | 0.3 ± 1.6 | 0.5 ± 0.2 |
| 344 J | 2.0 ± 0.5 | 2.1 ± 0.5 | 1.9 ± 1.5 | 0.6 ± 0.3 |
| 352 G+16 | 0.9 ± 0.3 | 0.9 ± 0.2 | 1.5 ± 0.8 | 0.8 ± 0.2 |
| 352 G+24 | 0.8 ± 0.5 | 1.1 ± 0.3 | <0.8 | 1.1 ± 0.2 |
| 352 G+32 | 1.2 ± 0.4 | 1.3 ± 0.4 | 2.4 ± 1.0 | 1.1 ± 0.2 |
| 352 H | 0.9 ± 0.4 | 0.9 ± 0.3 | 2.1 ± 0.8 | 0.8 ± 0.2 |
| 352 H+8 | 0.9 ± 0.4 | 1.4 ± 0.4 | 1.9 ± 1.0 | 1.2 ± 0.2 |
| 352 H+16 | 1.1 ± 0.4 | 1.1 ± 0.4 | 1.7 ± 2.4 | 1.1 ± 0.2 |
| 352 H+24 | 0.9 ± 0.3 | 0.7 ± 0.4 | 1.0 ± 2.2 | 0.7 ± 0.3 |
| 352 H+32 | 1.2 ± 0.5 | 1.0 ± 0.4 | 3.2 ± 1.6 | 1.1 ± 0.2 |
| 352 I | 0.8 ± 0.6 | 0.9 ± 0.5 | 1.6 ± 2.4 | 1.5 ± 0.4 |
| 352 I+8 | 0.5 ± 0.3 | 0.5 ± 0.2 | <0.5 | 0.4 ± 0.2 |
| 352 I+16 | 0.7 ± 0.2 | 0.9 ± 0.2 | <0.6 | 0.4 ± 0.1 |
| 352 I+24 | 0.5 ± 0.2 | 0.7 ± 0.2 | <0.5 | 0.4 ± 0.1 |
| 352 I+32 | 0.5 ± 0.2 | 0.6 ± 0.2 | <0.7 | <0.1 |
| 352 J | 0.9 ± 0.7 | 1.1 ± 0.4 | <0.8 | 1.2 ± 0.3 |
| 360 G+8 | 0.7 ± 0.3 | 0.8 ± 0.3 | 1.8 ± 0.7 | 0.7 ± 0.2 |
| 360 G+16 | 1.1 ± 0.4 | 1.2 ± 0.3 | 1.5 ± 0.8 | 0.9 ± 0.2 |
| 360 G+24 | <0.1 | <0.1 | 0.9 ± 1.0 | <0.1 |
| 368 G+8 | 1.6 ± 0.4 | 1.5 ± 0.3 | 2.1 ± 0.8 | 2.5 ± 0.2 |
| 368 G+16 | 2.9 ± 0.5 | 2.9 ± 0.4 | 1.8 ± 2.0 | 1.5 ± 0.3 |
| 368 G+24 | 1.4 ± 0.4 | 1.9 ± 0.3 | 4.6 ± 2.4 | 0.8 ± 0.2 |
| 376 G+8 | 1.2 ± 0.3 | 0.8 ± 0.2 | 1.4 ± 1.5 | 0.8 ± 0.3 |
| 376 G+16 | 1.3 ± 0.4 | 1.1 ± 0.3 | 1.8 ± 1.6 | 0.6 ± 0.2 |
| 376 G+24 | 1.1 ± 0.5 | 1.3 ± 0.4 | <0.8 | 1.0 ± 0.2 |
| 384 G+8 | 0.8 ± 0.3 | 0.5 ± 0.2 | 1.0 ± 0.5 | 0.4 ± 0.2 |
| 392 G+8 | 0.8 ± 0.3 | 0.8 ± 0.3 | 1.3 ± 0.8 | 0.6 ± 0.2 |
| 392 G+16 | 0.6 ± 0.4 | 0.6 ± 0.3 | 1.6 ± 1.7 | 0.9 ± 0.3 |
| 392 G+24 | 1.1 ± 0.3 | 0.8 ± 0.2 | 6.2 ± 1.7 | 0.6 ± 0.2 |
| 392 G+32 | 0.9 ± 0.4 | 0.8 ± 0.3 | <0.6 | 0.7 ± 0.2 |
| 392 H | 1.5 ± 0.5 | 1.4 ± 0.4 | 1.9 ± 1.6 | 0.8 ± 0.2 |
| 392 H+8 | 1.2 ± 0.3 | 1.3 ± 0.5 | 1.8 ± 1.5 | 0.9 ± 0.2 |
| 400 G+8 | 1.0 ± 0.3 | 0.8 ± 0.3 | <5.9 | 0.7 ± 0.2 |
| 400 G+16 | 3.1 ± 0.4 | 3.1 ± 0.5 | 8.9 ± 1.6 | 1.0 ± 0.2 |
| 400 G+24 | 1.4 ± 0.6 | 1.8 ± 0.7 | 1.0 ± 2.3 | 0.8 ± 0.3 |
| 400 G+32 | 0.8 ± 0.3 | 0.6 ± 0.3 | 0.4 ± 0.8 | 0.4 ± 0.2 |
| 400 H | 1.5 ± 0.4 | 1.3 ± 0.3 | 3.2 ± 1.7 | 0.8 ± 0.2 |
| 400 H+8 | 3.0 ± 0.5 | 2.8 ± 0.4 | 1.6 ± 1.6 | 0.8 ± 0.2 |
| 400 H+16 | 2.6 ± 0.5 | 2.8 ± 0.5 | 2.8 ± 1.3 | 0.8 ± 0.3 |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 408 G+8 | 0.7 ± 0.3 | 1.1 ± 0.2 | 0.8 ± 1.2 | 0.8 ± 0.2 |
| 408 G+16 | 1.5 ± 0.6 | 1.6 ± 0.3 | 1.0 ± 0.9 | 1.0 ± 0.2 |
| 408 G+24 | 1.6 ± 0.4 | 1.7 ± 0.4 | 2.8 ± 1.0 | 0.7 ± 0.2 |
| 408 G+32 | 0.8 ± 0.3 | 0.9 ± 0.3 | <0.8 | 0.7 ± 0.2 |
| 408 H | 1.2 ± 0.3 | 1.2 ± 0.3 | 2.4 ± 0.9 | 0.9 ± 0.2 |
| 408 H+8 | 1.7 ± 0.4 | 1.9 ± 0.3 | 2.1 ± 1.1 | 0.9 ± 0.2 |
| 408 H+16 | 2.3 ± 0.5 | 2.3 ± 0.5 | 2.4 ± 1.5 | 1.2 ± 0.3 |
| 408 H+24 | 2.1 ± 0.5 | 2.3 ± 0.5 | <0.9 | 0.8 ± 0.3 |
| 416 G+8 | 1.1 ± 0.2 | 1.1 ± 0.2 | <0.7 | 0.5 ± 0.1 |
| 416 G+16 | 0.7 ± 0.3 | 0.9 ± 0.4 | 1.0 ± 1.1 | 0.8 ± 0.2 |
| 416 G+24 | 2.2 ± 0.5 | 2.6 ± 0.5 | 1.8 ± 1.2 | 1.0 ± 0.3 |
| 416 G+32 | 1.7 ± 0.4 | 1.3 ± 0.3 | 1.0 ± 0.9 | 0.6 ± 0.2 |
| 416 H | 1.5 ± 0.4 | 2.0 ± 0.4 | 2.8 ± 1.1 | 0.8 ± 0.2 |
| 416 H+8 | 1.4 ± 0.3 | 1.6 ± 0.3 | <0.8 | 0.9 ± 0.2 |
| 416 H+16 | 2.9 ± 0.5 | 3.0 ± 0.5 | 2.5 ± 1.9 | 0.9 ± 0.3 |
| 416 H+24 | 2.4 ± 0.5 | 2.6 ± 0.5 | 2.5 ± 2.2 | 0.7 ± 0.2 |
| 424 G+8 | 1.0 ± 0.3 | 0.9 ± 0.3 | 1.8 ± 1.1 | 0.9 ± 0.2 |
| 424 G+16 | 4.8 ± 0.6 | 4.7 ± 0.5 | 4.4 ± 2.6 | 0.9 ± 0.2 |
| 424 G+24 | 1.4 ± 0.4 | 1.1 ± 0.3 | 2.5 ± 1.5 | 0.6 ± 0.2 |
| 424 G+32 | 1.0 ± 0.4 | 1.0 ± 0.3 | 2.8 ± 1.1 | 1.1 ± 0.2 |
| 424 H | 1.9 ± 0.4 | 1.8 ± 0.4 | 1.6 ± 0.9 | 0.7 ± 0.2 |
| 424 H+8 | 3.2 ± 0.5 | 3.0 ± 0.5 | 3.5 ± 1.1 | 0.9 ± 0.3 |
| 424 H+16 | 2.6 ± 0.5 | 2.7 ± 0.5 | 2.6 ± 2.3 | 0.8 ± 0.2 |
| 424 H+24 | 5.4 ± 0.7 | 4.5 ± 0.7 | 2.2 ± 3.9 | 0.9 ± 0.2 |
| 432 G+8 | 0.9 ± 0.3 | 0.9 ± 0.3 | 2.5 ± 1.0 | 0.9 ± 0.2 |
| 432 G+16 | 0.7 ± 0.5 | 1.1 ± 0.3 | <0.6 | 0.5 ± 0.2 |
| 432 G+24 | 3.2 ± 0.5 | 3.2 ± 0.5 | 5.8 ± 2.8 | 1.5 ± 0.3 |
| 432 G+32 | 2.1 ± 0.4 | 2.3 ± 0.5 | 1.8 ± 1.5 | 0.9 ± 0.2 |
| 432 H | 0.4 ± 0.2 | 0.4 ± 0.2 | <0.6 | 0.4 ± 0.1 |
| 432 H+8 | 1.8 ± 0.5 | 1.7 ± 0.4 | 2.4 ± 1.5 | 1.8 ± 0.2 |
| 432 H+16 | 1.6 ± 0.5 | 1.6 ± 0.4 | 2.5 ± 0.9 | 0.6 ± 0.2 |
| 434 H+24 | 2.2 ± 0.5 | 2.6 ± 0.5 | <1.2 | 1.0 ± 0.2 |
| 440 G+16 | 1.0 ± 0.3 | 0.7 ± 0.3 | 1.3 ± 1.5 | 0.5 ± 0.1 |
| 440 G+24 | 5.6 ± 0.8 | 5.2 ± 0.6 | 2.7 ± 2.4 | 0.8 ± 0.3 |
| 440 G+32 | 1.3 ± 0.4 | 0.9 ± 0.4 | 1.7 ± 1.9 | 0.6 ± 0.3 |
| 440 H | 0.6 ± 0.3 | 0.9 ± 0.3 | 1.0 ± 1.7 | 0.5 ± 0.3 |
| 440 H+8 | 1.6 ± 0.5 | 1.7 ± 0.5 | 2.4 ± 1.0 | 0.8 ± 0.3 |
| 440 H+16 | 1.4 ± 0.4 | 1.4 ± 0.4 | 1.0 ± 2.8 | 1.8 ± 0.2 |
| 440 H+24 | 0.4 ± 0.3 | 0.5 ± 0.2 | 1.2 ± 1.3 | 0.7 ± 0.2 |
| 448 G+16 | 0.9 ± 0.5 | 0.8 ± 0.4 | <0.6 | 0.6 ± 0.2 |

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM 8 M GRID INTERVALS ON THE WASTE AND SLAG STORAGE AREA

| Grid[a] Location | Radionuclide Concentrations (pCi/g) Th-232 | Th-228 | U-238 | Ra-226 |
|---|---|---|---|---|
| 448 G+24 | 1.1 ± 0.4 | 1.2 ± 0.4 | 1.2 ± 1.8 | 0.7 ± 0.3 |
| 448 G+32 | 1.2 ± 0.6 | 1.1 ± 0.5 | <0.9 | 0.8 ± 0.2 |
| 448 H | 1.8 ± 0.4 | 1.2 ± 0.4 | 0.9 ± 2.3 | 0.6 ± 0.2 |

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

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
COLLECTED BETWEEN THE WASTE AREA AND THE SHENANGO RIVER

| Grid[a] Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Th-232 | Th-228 | U-238 | Ra-226 |
| 110 L+15 | 1.2 ± 0.4[b] | 1.2 ± 0.5 | 1.4 ± 2.0 | 1.1 ± 0.3 |
| 130 L+25 | 2.3 ± 0.8 | 2.4 ± 0.7 | 2.5 ± 3.7 | 1.0 ± 0.5 |
| 140 L+30 | 1.2 ± 0.6 | 1.3 ± 0.4 | <0.9 | 0.8 ± 0.3 |
| 160 L+20 | 1.0 ± 0.2 | 1.1 ± 0.5 | <1.7 | 0.9 ± 0.5 |
| 179 K+37 | 1.0 ± 0.4 | 0.9 ± 0.3 | 2.2 ± 0.9 | 1.3 ± 0.4 |
| 186 K+39 | 1.3 ± 0.4 | 1.0 ± 0.4 | <0.9 | 0.8 ± 0.2 |
| 200 K+20 | 1.1 ± 0.4 | 1.1 ± 0.3 | <0.6 | 0.8 ± 0.3 |
| 240 K+10 | 1.1 ± 0.4 | 1.3 ± 0.3 | 0.9 ± 0.5 | 0.7 ± 0.2 |
| 250 K+12 | 1.1 ± 0.3 | 1.0 ± 0.2 | <1.0 | 0.8 ± 0.2 |
| 275 K+10 | 1.3 ± 0.5 | 1.5 ± 0.5 | <1.4 | 0.8 ± 0.4 |
| 290 K+8 | 1.1 ± 0.5 | 1.4 ± 0.5 | 1.9 ± 2.2 | 1.3 ± 0.4 |
| 320 J+38 | 1.3 ± 0.4 | 1.4 ± 0.4 | 1.6 ± 1.0 | 0.8 ± 0.3 |
| 330 J+20 | 1.8 ± 0.6 | 0.9 ± 0.5 | 0.9 ± 1.7 | 0.9 ± 0.2 |
| 340 K+20 | 1.0 ± 0.5 | 1.2 ± 0.4 | 1.5 ± 1.5 | 1.0 ± 0.3 |
| 360 G+32 | 1.9 ± 0.5 | 1.0 ± 0.2 | <0.9 | 0.9 ± 0.2 |
| 360 H | 0.7 ± 0.4 | 1.2 ± 0.4 | 1.5 ± 1.1 | 1.1 ± 0.3 |
| 360 H+8 | 1.2 ± 0.5 | 1.0 ± 0.4 | 3.2 ± 1.6 | 1.1 ± 0.3 |
| 360 H+16 | 1.0 ± 0.4 | 0.8 ± 0.3 | <0.8 | 0.9 ± 0.3 |
| 360 H+24 | 0.9 ± 0.5 | 1.7 ± 0.5 | <1.2 | 0.8 ± 0.3 |
| 360 H+32 | 0.9 ± 0.3 | 0.7 ± 0.2 | <0.7 | 0.8 ± 0.2 |
| 360 I | 0.7 ± 0.4 | 1.3 ± 0.4 | <0.9 | 0.6 ± 0.2 |
| 360 I+8 | 1.0 ± 0.4 | 1.0 ± 0.4 | <1.0 | 0.7 ± 0.2 |
| 360 I+16 | 1.8 ± 0.4 | 1.1 ± 0.5 | 1.5 ± 1.6 | 0.9 ± 0.2 |
| 360 I+24 | 6.8 ± 1.0 | 7.1 ± 0.7 | 1.2 ± 1.9 | 3.1 ± 0.5 |
| 360 I+32 | 1.2 ± 0.6 | 1.4 ± 0.4 | <1.1 | 0.9 ± 0.2 |
| 360 J | 0.6 ± 0.3 | 0.9 ± 0.3 | <0.8 | 0.6 ± 0.3 |
| 368 G+32 | 1.6 ± 0.4 | 1.6 ± 0.3 | 1.6 ± 1.5 | 1.0 ± 0.3 |
| 390 I | 0.8 ± 0.3 | 0.7 ± 0.2 | <0.5 | 0.6 ± 0.2 |
| 400 H+24 | 2.0 ± 0.4 | 1.4 ± 0.3 | <1.0 | 0.8 ± 0.3 |
| 400 I | 1.0 ± 0.6 | 1.0 ± 0.4 | 1.2 ± 1.1 | 1.0 ± 0.2 |
| 408 I | 1.0 ± 0.4 | 0.9 ± 0.3 | <0.7 | 0.4 ± 0.2 |
| 415 I | 1.0 ± 0.4 | <0.3 | <1.2 | 1.1 ± 0.2 |
| 416 I | 0.9 ± 0.2 | 0.9 ± 0.4 | <0.7 | 0.9 ± 0.3 |
| 424 I | 1.1 ± 0.5 | 0.9 ± 0.3 | 1.9 ± 1.5 | 0.9 ± 0.3 |
| 430 I | 1.2 ± 0.7 | 1.1 ± 0.4 | 2.7 ± 1.2 | 1.0 ± 0.3 |
| 432 I | 3.4 ± 0.9 | 2.9 ± 0.7 | 4.7 ± 2.9 | 3.4 ± 0.5 |
| 440 I | 0.9 ± 0.4 | 1.1 ± 0.4 | 1.2 ± 1.5 | 0.6 ± 0.3 |

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

TABLE 6

TOTAL THORIUM CONCENTRATIONS (pCi/g)
AT VARIOUS DEPTHS IN THE WASTE STORAGE AREA

| Borehole ID[a] | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9 | B10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Grid Location | 131 L | 154 J | 154 K+14 | 154 K+27 | 160 K+36 | 162 K+15 | 176 K+23 | 180 K+1 | 186 K+13 | 200 K |
| DEPTH (m) | | | | | | | | | | |
| Surface | 0.6 | 1.0 | 2.4 | 5.0 | <0.3 | 1.4 | 1.3 | 2.0 | 1.7 | 1.7 |
| 0.30 | 2.4 | 3.1 | 4.6 | 3.3 | 0.6 | 3.7 | 3.3 | 3.0 | 3.2 | 3.0 |
| 0.60 | 3.1 | 3.7 | 4.6 | 3.7 | 0.7 | 3.3 | 2.9 | 3.7 | 5.0 | 2.7 |
| 0.90 | 2.9 | 3.9 | 4.4 | 3.0 | <0.3 | 3.7 | 1.7 | 4.8 | 7.0 | 3.7 |
| 1.20 | 2.9 | 3.3 | 2.5 | 2.6 | <0.3 | 4.4 | 2.2 | 3.4 | 7.7 | 3.5 |
| 1.50 | 3.3 | 2.6 | 2.0 | 3.4 | 1.0 | 3.7 | 3.0 | 2.8 | 6.2 | 3.6 |
| 1.80 | 3.7 | 3.0 | 3.7 | 3.0 | 1.0 | 2.7 | 5.7 | 1.9 | 4.2 | 2.9 |
| 2.10 | 3.4 | | 4.0 | 2.9 | 0.6 | 3.8 | 3.9 | 3.2 | 4.8 | 3.0 |
| 2.40 | 3.0 | | 4.3 | 3.1 | 0.4 | 5.0 | 3.2 | 2.9 | 3.6 | 3.7 |
| 2.70 | 2.4 | | 4.2 | | <0.3 | 3.0 | 3.8 | 4.6 | 3.4 | 4.0 |
| 3.00 | 3.7 | | 4.3 | | <0.3 | 3.1 | 2.8 | 5.0 | 2.4 | 2.8 |
| 3.30 | 3.0 | | 4.4 | | <0.3 | 3.2 | 3.5 | 5.4 | 2.4 | 3.3 |
| 3.60 | 3.2 | | | | <0.3 | | 3.0 | | | |
| 3.90 | 3.0 | | | | <0.3 | | | | | |
| 4.20 | | | | | <0.3 | | | | | |
| 4.50 | | | | | <0.3 | | | | | |
| 4.80 | | | | | 0.4 | | | | | |
| 5.10 | | | | | 0.8 | | | | | |
| 5.40 | | | | | 1.0 | | | | | |
| 5.70 | | | | | <0.3 | | | | | |
| 6.00 | | | | | 1.7 | | | | | |
| 6.30 | | | | | 1.8 | | | | | |
| 6.60 | | | | | 1.6 | | | | | |
| 6.90 | | | | | 1.8 | | | | | |
| 7.20 | | | | | | | | | | |
| Depth of Slag Fill (m) | 0 | 1.5* | 0.9* | 2.1* | 0 | 2.4* | 0.9* | 1.2* | 1.5* | 0.9* |

*Clay and slag mixed.

TABLE 6 (Continued)

TOTAL THORIUM CONCENTRATIONS (pCi/g)
AT VARIOUS DEPTHS IN THE WASTE STORAGE AREA

| Borehole ID | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 |
|---|---|---|---|---|---|---|---|---|---|---|
| Grid Location | 253 J+13 | 257 J | 267 J+27 | 276 J | 280 I+20 | 285 J+35 | 290 J+7 | 293 I+14 | 297 I+25 | 308 J+4 |
| DEPTH (m) | | | | | | | | | | |
| Surface | 1.8 | <0.5 | 1.0 | 1.4 | 2.1 | 1.0 | 11.0 | 23.0 | 31.9 | 10.5 |
| 0.30 | 6.3 | <0.5 | 1.4 | 3.1 | 5.0 | 1.9 | 6.1 | 6.5 | 15.3 | 6.0 |
| 0.60 | 7.7 | 1.0 | 2.3 | <0.3 | 2.9 | 2.4 | 2.3 | 4.2 | 13.0 | 10.7 |
| 0.90 | 3.1 | <0.5 | 1.8 | 0.3 | 0.5 | <0.3 | 1.2 | | 4.0 | 42.6 |
| 1.20 | 1.7 | <0.5 | 2.1 | <0.3 | <0.5 | 1.0 | 1.9 | | 0.5 | 68.5 |
| 1.50 | 0.8 | <0.5 | 2.6 | 0.6 | <0.5 | 0.9 | 3.0 | | 1.3 | 8.2 |
| 1.80 | 1.3 | <0.5 | 3.4 | 0.9 | <0.5 | 0.8 | 5.4 | | 0.4 | 2.7 |
| 2.10 | 1.3 | <0.5 | 5.7 | <0.3 | <0.5 | 0.9 | 2.5 | | 0.7 | 1.8 |
| 2.40 | 2.4 | <0.5 | 1.6 | 0.6 | <0.5 | | 2.0 | | 0.3 | 2.3 |
| 2.70 | 4.2 | 1.5 | 1.4 | 0.6 | <0.5 | | 1.7 | | 0.5 | 1.2 |
| 3.00 | 5.5 | 2.5 | <0.5 | 0.3 | <0.5 | | <0.5 | | 0.6 | 0.9 |
| 3.30 | 8.3 | 2.1 | <0.5 | 0.3 | 1.5 | | | | | 0.9 |
| 3.60 | 4.3 | 2.2 | 0.5 | <0.3 | 1.2 | | | | | 0.6 |
| 3.90 | 1.9 | 3.2 | 0.6 | 1.1 | 1.2 | | | | | 0.9 |
| 4.20 | | 3.0 | | 1.0 | 1.7 | | | | | |
| 4.50 | | | | 1.2 | | | | | | |
| 4.80 | | | | 1.6 | | | | | | |
| 5.10 | | | | <0.3 | | | | | | |
| 5.40 | | | | 1.4 | | | | | | |
| 5.70 | | | | | | | | | | |
| 6.00 | | | | | | | | | | |
| 6.30 | | | | | | | | | | |
| 6.60 | | | | | | | | | | |
| 6.90 | | | | | | | | | | |
| 7.20 | | | | | | | | | | |
| Depth of Slag Fill (m) | 2.7 | 3.0 | 2.7 | 2.7 | 4.2 | 0.9 | 2.7 | 0.3 | 2.1 | 3.3 |

TABLE 6 (Continued)

TOTAL THORIUM CONCENTRATIONS (pCi/g)
AT VARIOUS DEPTHS IN THE WASTE STORAGE AREA

| Borehole ID | B21 | B22 | B23 | B24 | B25 | B26 | B27 | B28 | B29 | B30 |
|---|---|---|---|---|---|---|---|---|---|---|
| Grid Location | 323 J+18 | 328 I+11 | 330 J+5 | 334 I+33 | 348 I+13 | 348 I+30 | 394 G+32 | 404 G+13 | 406 H+13 | 408 G+36 |
| DEPTH (m) | | | | | | | | | | |
| Surface | 7.9 | 2.1 | 66.4 | 4.9 | 47.1 | 47.3 | 1.7 | 0.5 | <0.3 | 1.3 |
| 0.30 | 8.4 | 8.1 | 44.1 | 90.0 | 93.0 | 84.3 | 4.8 | 3.0 | 4.6 | 3.6 |
| 0.60 | 5.6 | 3.7 | 432 | --- | 91.3 | 9.7 | 13.5 | 2.4 | 4.4 | <0.3 |
| 0.90 | 8.2 | 2.2 | 337 | 188 | 104 | 25.7 | 18.4 | 2.1 | 3.4 | 2.4 |
| 1.20 | 7.1 | 1.6 | 665 | --- | 88.7 | 55.0 | 3.2 | 3.3 | <0.3 | 2.3 |
| 1.50 | 1.7 | 2.2 | 1570 | --- | 143 | 29.3 | 5.0 | 3.7 | 1.9 | 1.7 |
| 1.80 | 0.5 | 2.2 | 2072 | 301 | 203 | 44.4 | 3.2 | 4.0 | 3.7 | 1.3 |
| 2.10 | <0.3 | | 1035 | --- | 203 | 14.8 | 2.4 | 3.8 | 1.8 | <0.3 |
| 2.40 | <0.3 | | 1061 | --- | 147 | 155 | 1.8 | 3.4 | 1.0 | 3.8 |
| 2.70 | 0.4 | | 608 | 90.0 | 140 | 318 | 0.7 | 3.8 | <0.3 | 4.6 |
| 3.00 | 0.8 | | 1307 | --- | 763 | 458 | 1.5 | 4.2 | 0.5 | 5.7 |
| 3.30 | | | 800 | 10.4 | 870 | 787 | 1.5 | 4.2 | 0.6 | 2.2 |
| 3.60 | | | 371 | 0.3 | 1383 | 292 | 1.3 | 4.4 | 0.5 | <0.3 |
| 3.90 | | | 188 | | 1617 | 534 | | | 0.4 | 1.4 |
| 4.20 | | | 51.7 | | 1154 | 572 | | | <0.3 | 1.7 |
| 4.50 | | | 15.0 | | 1399 | 180 | | | 0.6 | 1.1 |
| 4.80 | | | 11.0 | | 373 | 30.3 | | | 0.5 | 0.5 |
| 5.10 | | | 8.4 | | 1103 | 9.7 | | | 0.4 | 0.7 |
| 5.40 | | | 6.9 | | 167 | 12.7 | | | <0.3 | 0.3 |
| 5.70 | | | 12.4 | | 4.9 | 3.2 | | | <0.3 | <0.3 |
| 6.00 | | | 1.7 | | 2.3 | 2.4 | | | 0.6 | <0.3 |
| 6.30 | | | 2.6 | | 1.5 | <0.3 | | | 1.7 | |
| 6.60 | | | 2.4 | | 1.3 | 2.1 | | | 1.8 | |
| 6.90 | | | 2.6 | | 1.6 | 2.2 | | | <0.3 | |
| 7.20 | | | 2.9 | | <0.3 | 1.7 | | | 1.9 | |
| Depth of Slag Fill (m) | 2.7 | 0.9 | 4.6 | 5.2 | 7.6 | 7.6 | 2.7 | 0.5 | 4.2 | 5.8 |

TABLE 6 (Continued)

TOTAL THORIUM CONCENTRATIONS (pCi/g)
AT VARIOUS DEPTHS IN THE WASTE STORAGE AREA

| Borehole ID | B31 | B32 | B33 | B34 | B35 |
|---|---|---|---|---|---|
| Grid Location | 418 H+25 | 420 H+3 | 427 G+18 | 437 H+8 | 440 G+30 |
| DEPTH (m) | | | | | |
| Surface | 2.9 | 1.7 | 2.2 | 1.8 | 1.5 |
| 0.30 | 4.7 | 3.9 | 6.1 | 5.1 | 3.9 |
| 0.60 | 4.1 | 3.4 | 9.3 | 4.9 | 3.5 |
| 0.90 | 5.0 | 3.2 | 6.5 | 3.6 | 4.3 |
| 1.20 | 3.7 | 2.9 | 5.4 | 5.5 | 3.2 |
| 1.50 | 8.2 | 2.9 | 4.8 | 11.2 | 2.4 |
| 1.80 | 10.1 | 4.2 | 4.8 | 5.0 | |
| 2.10 | 2.1 | 4.0 | 3.7 | 2.2 | |
| 2.40 | 1.0 | 3.7 | 3.0 | 2.1 | |
| 2.70 | <0.3 | 3.3 | 4.6 | 2.6 | |
| 3.00 | 0.8 | 3.7 | 3.8 | 3.6 | |
| 3.30 | 0.4 | 4.0 | 2.9 | 3.7 | |
| 3.60 | 0.5 | | 4.0 | 3.3 | |
| 3.90 | 0.3 | | | 2.9 | |
| 4.20 | 0.3 | | | 2.5 | |
| 4.50 | <0.3 | | | 2.3 | |
| 4.80 | <0.3 | | | 2.2 | |
| 5.10 | <0.3 | | | 2.0 | |
| 5.40 | <0.3 | | | | |
| 5.70 | <0.3 | | | | |
| 6.00 | <0.3 | | | | |
| 6.30 | 0.7 | | | | |
| 6.60 | 1.0 | | | | |
| 6.90 | 1.0 | | | | |
| 7.20 | 0.8 | | | | |
| Depth of Slag Fill (m) | 4.2 | 1.5 | 2.7 | 4.2 | 0.9 |

[a] Refer to Figure 6.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN SHALLOW BOREHOLE SAMPLES FROM BETWEEN THE WASTE AREA AND THE SHENANGO RIVER

| Borehole[a] No. | Grid Location | Depth (m) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|---|
| | | | Th-232 | Th-228 | U-238 | Ra-226 |
| B36 | 179 K+37 | Surface | 1.0 ± 0.4[b] | 0.9 ± 0.3 | 2.2 ± 0.9 | 1.3 ± 0.4 |
| | | 1.0 | 1.2 ± 0.8 | 0.7 ± 0.6 | <1.3 | 0.6 ± 0.4 |
| B37 | 186 K+39 | Surface | 1.3 ± 0.4 | 1.0 ± 0.4 | <0.9 | 0.8 ± 0.2 |
| | | 1.0 | 1.1 ± 0.5 | 1.6 ± 0.3 | 1.3 ± 1.3 | 0.6 ± 0.5 |
| B38 | 200 K+20 | Surface | 1.1 ± 0.4 | 1.1 ± 0.3 | <0.6 | 0.8 ± 0.3 |
| | | 1.0 | 1.0 ± 0.4 | 0.8 ± 0.2 | <0.9 | 0.6 ± 0.1 |
| B39 | 240 K+10 | Surface | 1.1 ± 0.4 | 1.3 ± 0.3 | 0.9 ± 0.5 | 0.7 ± 0.2 |
| | | 1.0 | 1.0 ± 0.5 | 1.2 ± 0.3 | <0.6 | 0.7 ± 0.2 |
| B40 | 250 K+12 | Surface | 1.1 ± 0.3 | 1.0 ± 0.2 | <1.0 | 0.8 ± 0.2 |
| | | 1.0 | 1.0 ± 0.4 | 0.8 ± 0.2 | 1.2 ± 0.5 | 0.6 ± 0.2 |
| B41 | 275 K+10 | Surface | 1.3 ± 0.5 | 1.5 ± 0.5 | <1.4 | 0.8 ± 0.4 |
| | | 1.0 | 0.8 ± 0.3 | 0.7 ± 0.2 | 0.7 ± 0.9 | 0.7 ± 0.2 |
| B42 | 290 K+8 | Surface | 1.1 ± 0.5 | 1.4 ± 0.5 | 1.9 ± 2.2 | 1.3 ± 0.4 |
| | | 1.0 | 1.2 ± 0.5 | 1.2 ± 0.4 | 1.9 ± 1.9 | 0.9 ± 0.2 |
| B43 | 320 J+30 | Surface | 1.3 ± 0.4 | 1.4 ± 0.4 | 1.6 ± 1.0 | 0.8 ± 0.3 |
| | | 1.0 | 1.2 ± 0.5 | 1.1 ± 0.4 | 1.2 ± 1.6 | 1.0 ± 0.2 |
| B44 | 330 J+20 | Surface | 1.8 ± 0.6 | 0.9 ± 0.5 | 0.9 ± 1.7 | 0.9 ± 0.2 |
| | | 1.0 | 1.0 ± 0.4 | 1.0 ± 0.3 | 0.7 ± 0.8 | 0.7 ± 0.2 |

TABLE 7 (Continued)

RADIONUCLIDE CONCENTRATIONS IN SHALLOW BOREHOLE SAMPLES FROM BETWEEN THE WASTE AREA AND THE SHENANGO RIVER

| Borehole[a] No. | Grid Location | Depth (m) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|---|
| | | | Th-232 | Th-228 | U-238 | Ra-226 |
| B45 | 340 J+20 | Surface | 1.0 ± 0.5 | 1.2 ± 0.4 | 1.5 ± 1.5 | 1.0 ± 0.3 |
| | | 1.0 | 2.2 ± 0.7 | 1.0 ± 0.3 | 2.8 ± 1.4 | 1.3 ± 0.3 |
| B46 | 390 I | Surface | 0.8 ± 0.3 | 0.7 ± 0.2 | <0.5 | 0.6 ± 0.2 |
| | | 1.0 | 1.0 ± 0.3 | 0.7 ± 0.2 | 1.4 ± 1.4 | 0.5 ± 0.1 |
| B47 | 400 I | Surface | 1.0 ± 0.6 | 1.0 ± 0.4 | 1.2 ± 1.1 | 1.0 ± 0.2 |
| | | 1.0 | 1.1 ± 0.6 | 1.0 ± 0.3 | 2.3 ± 2.3 | 1.7 ± 0.4 |
| B48 | 415 I | Surface | 1.0 ± 0.4 | <0.3 | <1.2 | 1.1 ± 0.2 |
| | | 1.0 | 0.8 ± 0.3 | 0.6 ± 0.3 | 0.8 ± 0.5 | 0.6 ± 0.2 |
| B49 | 430 I | Surface | 1.2 ± 0.7 | 1.1 ± 0.4 | 2.7 ± 1.2 | 1.0 ± 0.3 |
| | | 1.0 | 0.6 ± 0.4 | 0.8 ± 0.4 | <0.9 | 0.9 ± 0.3 |
| B50 | 440 I | Surface | 0.9 ± 0.4 | 1.1 ± 0.4 | 1.2 ± 1.5 | 0.6 ± 0.3 |
| | | 1.0 | 1.1 ± 0.6 | 2.6 ± 0.4 | 1.4 ± 1.8 | 0.9 ± 0.3 |

[a]Refer to Figure 7.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainites of ± 6 to 10% have not been propagated into these data.

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES

| Grid Location[a] | | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|
| | | Th-232 | Th-228 | U-238 | Ra-226 |
| 465 | H+35 | <0.4 | 0.7 ± 0.5[b] | <6.8 | 0.6 ± 0.2 |
| 410 | H+34 | 2.4 ± 0.5 | 1.5 ± 0.5 | <5.0 | 0.9 ± 0.3 |
| 380 | J+10 | 1.1 ± 0.4 | 1.2 ± 0.3 | 7.0 ± 8.0 | 0.8 ± 0.2 |
| 390 | J | 0.5 ± 0.3 | 0.4 ± 0.2 | <3.2 | 0.4 ± 0.1 |
| 400 | J+5 | 1.2 ± 0.3 | 0.9 ± 0.3 | <3.1 | 0.9 ± 0.1 |

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

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

| Sample Identification[a] | Sample Source | Grid Location | Radionuclide Concentrations (pCi/l) | | | |
|---|---|---|---|---|---|---|
| | | | Gross Alpha | Gross Beta | Ra-226 | Ra-228 |
| W1 | Shenango River | Wasser Road Bridge | 0.4 ± 0.5[b] | 3.7 ± 1.0 | --- | --- |
| W2 | Shenango River | 280 K+15 | 0.6 ± 0.5 | 3.8 ± 1.0 | --- | --- |
| W3 | Shenango River | 7th St. Bridge | <0.3 | 3.3 ± 1.0 | --- | --- |
| W4 | Artesian Well | 160 K | 0.7 ± 0.6 | 2.5 ± 1.0 | --- | --- |
| W5 | Borehole B1 | 131 L | 4.1 ± 5.6 | 39.3 ± 9.2 | --- | --- |
| W6 | Borehole B4 | 154 K+27 | 4.1 ± 1.1 | 10.5 ± 1.4 | --- | --- |
| W7 | Borehole B15 | 280 I+20 | 1.3 ± 0.7 | 4.0 ± 1.1 | --- | --- |
| W8 | Borehole B23 | 330 J+5 | 26.1 ± 2.9 | 55.1 ± 3.9 | 0.5 ± 0.1 | 1.5 ± 0.5 |
| W9 | Borehole B27 | 394 G+32 | 10.8 ± 2.8 | 14.1 ± 3.3 | --- | --- |
| W10 | Borehole B30 | 408 G+36 | 2.4 ± 1.5 | 12.0 ± 2.2 | --- | --- |
| W11 | Monitoring Well | 307 J+2 | 29.8 ± 3.7 | 16.0 ± 2.7 | 0.1 ± 0.1 | 0.8 ± 0.3 |
| W12 | Monitoring Well | 318 J | 6.5 ± 2.1 | 10.4 ± 3.1 | --- | --- |
| W13 | Monitoring Well | 329 I+20 | 3.7 ± 1.6 | 9.5 ± 2.5 | --- | --- |
| W14 | Monitoring Well | 345 J | 17.2 ± 2.4 | 10.4 ± 1.9 | 0.3 ± 0.1 | 1.1 ± 0.4 |

[a]Refer to Figure 4.

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

TABLE 10

RADIONUCLIDE CONCENTRATIONS IN MISCELLANEOUS SAMPLES OF SLAG

| Sample | Description (appearance) | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|---|
| | | Th-232 | Th-228 | U-238 | Ra-226 |
| 1 | White-Blue/Glassy | <0.2 | <0.1 | 0.5 ± 1.6[a] | 0.2 ± 0.1 |
| 2 | Gray/Porous | 187 ± 7 | 195 ± 6 | 83.8 ± 9.2 | 70.4 ± 3.3 |
| 3 | Blue-Gray/Porous | 1.3 ± 0.5 | 1.3 ± 0.5 | 1.3 ± 0.5 | 1.3 ± 0.5 |
| 4 | Gray/Porous | 61 ± 12 | 63 ± 4 | 439 ± 15 | 15 ± 5 |
| 5 | Green-Blue/Porous | 1.0 ± 0.7 | 0.6 ± 0.3 | 1.9 ± 1.8 | 0.9 ± 0.4 |
| 6 | White | 8.6 ± 0.3 | 6.5 ± 0.2 | 17 ± 4 | 32 ± 2 |
| 7 | Black/Porous | 1.5 ± 0.7 | 0.9 ± 0.6 | <0.8 | 0.8 ± 0.4 |
| 8 | White | 1.6 ± 0.8 | 0.9 ± 0.2 | <0.8 | 0.9 ± 0.4 |
| 9 | White | 506 ± 12 | 507 ± 12 | 206 ± 16 | 81 ± 5 |
| 10 | Black | <0.4 | <0.4 | <1.1 | 1.1 ± 0.4 |
| 11 | Gray/Metallic | 2215 ± 17 | 1815 ± 15 | 1295 ± 20 | 7.5 ± 3.8 |
| 12 | Gray/Porous | 0.9 ± 1.7 | <0.3 | 0.4 ± 0.5 | 0.4 ± 0.3 |
| 13 | Gray/Porous | 904 ± 18 | 933 ± 18 | 450 ± 22 | 226 ± 8 |
| 14 | Gray | 747 ± 11 | 753 ± 3 | 492 ± 16 | 165 ± 5 |
| 15 | Gray | 3728 ± 28 | 3051 ± 25 | 2179 ± 34 | 13 ± 6 |
| 16 | Gray | 1206 ± 26 | 1800 ± 19 | 1833 ± 18 | 72 ± 6 |
| 17 | Gray/Porous | 1548 ± 17 | 1560 ± 16 | 1148 ± 26 | 69 ± 5 |
| 18 | Gray/Porous | 371 ± 9 | 384 ± 9 | 271 ± 15 | 141 ± 4 |
| 19 | Black | <1.4 | <0.1 | <1.6 | <0.6 |

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

## REFERENCES


1. Phase 1 - Health Physics Report for Whittaker Metals, Alloy Division, Greenville, Pennsylvania, Applied Health Physics, March 1975.

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3. Confirmatory Radiological Survey of the Former Whittaker Metals Corporation Property, Greenville, Pennsylvania, M.R. Landis, Oak Ridge Associated Universities, November 1984.

4. Assessment of the Quality of On-Site Source Material for Alternate Planning Consideration, J.C. Terrill, Jr., Westinghouse Electric Corporation, March 1975.

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

# APPENDIX A

# MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

## APPENDIX A

## MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

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

A. Direct Radiation Measurements

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

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

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

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

B. Laboratory Analyses

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

Ge (Li) Detector
Model LGCC2220-SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

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

Intrinsic Germanium Detector
Model LGC2525-SD/8
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, Model 121212-RT
(Electronic Counter, Co., Okmulgee, OK)

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

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

Low Background Alpha-Beta Counter
Model LB-5110-2080
(Tennelec, Inc., Oak Ridge, TN)

# APPENDIX B

# MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX B

# MEASUREMENT AND ANALYTICAL PROCEDURES

## Gamma Scintillation Measurements

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

## Borehole Logging and Calculation of Thorium Concentration

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. At locations where the borehole had a tendency to cave in and a PVC liner could not be inserted, the probe was used without a collimator by lowering it through the inside of the hollow stem auger. For measurements in other boreholes, the scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 x 7 mm holes evenly spaced around the region of the scintillation detector. The probe was lowered into each hole using a tripod holder with a small winch. Gross gamma measurements were performed at 15-30 cm intervals between the surface and the bottom of the hole.

The collimated and uncollimated NaI(Tl) probes were calibrated for response to thorium gamma radiation (counts per minute/pCi/g of thorium) using monazite sand. Probes were calibrated for two geometries: (1) the collimated probe inside a 15 cm diameter PVC pipe, and (2) the uncollimated probe inside a 0.64 cm (1/4 inch) thick steel pipe (simulating the auger stem) with an outside 20 cm diameter sleeve of thin sheet metal. Two different concentrations of sand were used for the calibrations. The factors determined from these calibrations were then used to convert the net (gross minus background) gamma count rates from the logging measurements to total thorium concentrations.

Although the system calibration was based on the assumption that essentially all gamma photons recorded would be from the thorium decay series, analysis of slag samples indicated that Ra-226 to total thorium is variable but averages approximately 15%. The thorium series in equilibrium and Ra-226 in equilibrium with its daughters will yield nearly the same total photon emission rates per unit activity. The distribution of photon energies about 50 kev - the approximate threshold settings for the instruments used for this study - is such that the response of the small NaI detector can be assumed comparable for the two decay series. The initially determined thorium concentrations were therefore adjusted for the average Ra-226 to Th-232 ratio of 0.15 by dividing all positive values by 1.15. These adjusted gamma logging results are presented in Table 6.

Soil and Sediment Sample Analysis

Soil samples were dried, mixed, and a portion sealed in 0.5-liter Marinelli beaker. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry and typically ranged from 400 to 800 g of sample. Net dry weights were determined and the samples counted using Ge(Li) and intrinsic germanium detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

| | |
|---|---|
| Th-232 | 0.911 MeV from Ac-228* |
| Th-228 | 0.583 MeV from Tl-208* |
| U-238 | 0.094 MeV from Th-234 or 1.001 MeV from Pa-234 m* |
| Ra-226 | 0.609 MeV from Bi-214* |

*Secular equilibrium was assumed.

Water Sample Analysis

Water samples were filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by filtration through 0.45 m pore size membrane filters and the filtrate was acidified by the addition of 10 ml of concentrated nitric acid.

Gross Alpha and Gross Beta Analysis

Fifty milliliters of each sample was evaporated to dryness. The dried samples and, in the case of the storm sewer sample, the filters, were counted on a Tennelec Model LB5100 low background proportional counter.

Radium Analyses

Radium 226 and 228 analyses were performed using EPA method 600/4-80-032 (August 1980).

## Uncertainties and Detection Limits

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

## Calibration and Quality Assurance

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

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

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and DOE/EML Quality Assurance Programs.

# APPENDIX C

# ESTIMATION OF SLAG VOLUME AND THORIUM CONTENT

## APPENDIX C

## ESTIMATION OF SLAG VOLUME AND THORIUM CONTENT

The property was divided into 4 sections (see Figure C-1). Depths of slag at borehole locations were determined from the drilling logs; extrapolations and interpolations of depth profiles were then used to estimate the depth of the slag at the property boundary and edges of the slag piles. Sections 1 and 2 were subdivided into areas ranging from 100 to 400 $m^2$. The surface area of each subdivision was multiplied by the average depth of the subdivision to determine the volume; volumes of subdivisions within each section were summed. These calculations provided volumes of $8.21 \times 10^3$ $m^3$ and $2.09 \times 10^4$ $m^3$ for sections 1 and 2, respectively.

The fill in section 3 was determined from drilling logs to contain only a small amount of slag, mixed with clay and miscellaneous scrap. It was estimated that the average depth of fill in this section by these depth and content estimates provides a volume $3.20 \times 10^2$ $m^3$ of slag in section 3.

Section 4 is a narrow layer of slag, along the roadway between sections 1 and 2. The depth of this section ranges from 1.7 to 3 meters with an average of about 2 meters. The volume of this section is calculated to be $1.00 \times 10^2$ $m^3$.

The total slag volume for the 4 sections is therefore estimated to be $2.97 \times 10^4$ $m^3$.

Thorium concentrations in the slag were determined from borehole logging measurements described in Appendix B. The data, presented in Table 6, represent the average thorium concentrations in "slices" about 0.6 m in diameter and 0.17 m thick. Those "slices" which are within slag fill were averaged to determine the average thorium concentrations of the slag. The resulting value is 80.3 pCi/g of total thorium or 40.15 pCi/g each of Th-232 and Th-228. Based on a specific activity of $1.09 \times 10^{-7}$ Ci/g for Th-232, the thorium concentration can also be expressed as 0.037% by weight.

A different method of calculating the average concentration, uses the products of the sectional volumes multiplied by their respective concentrations. The volume element represented by the 4 high level boreholes (B-23 - B-26) is estimated as approximately $5.0 \times 10^3\ m^3$ for this calculation. The results yield an average thorium concentration of 60.3 pCi/g or 0.028% by weight.

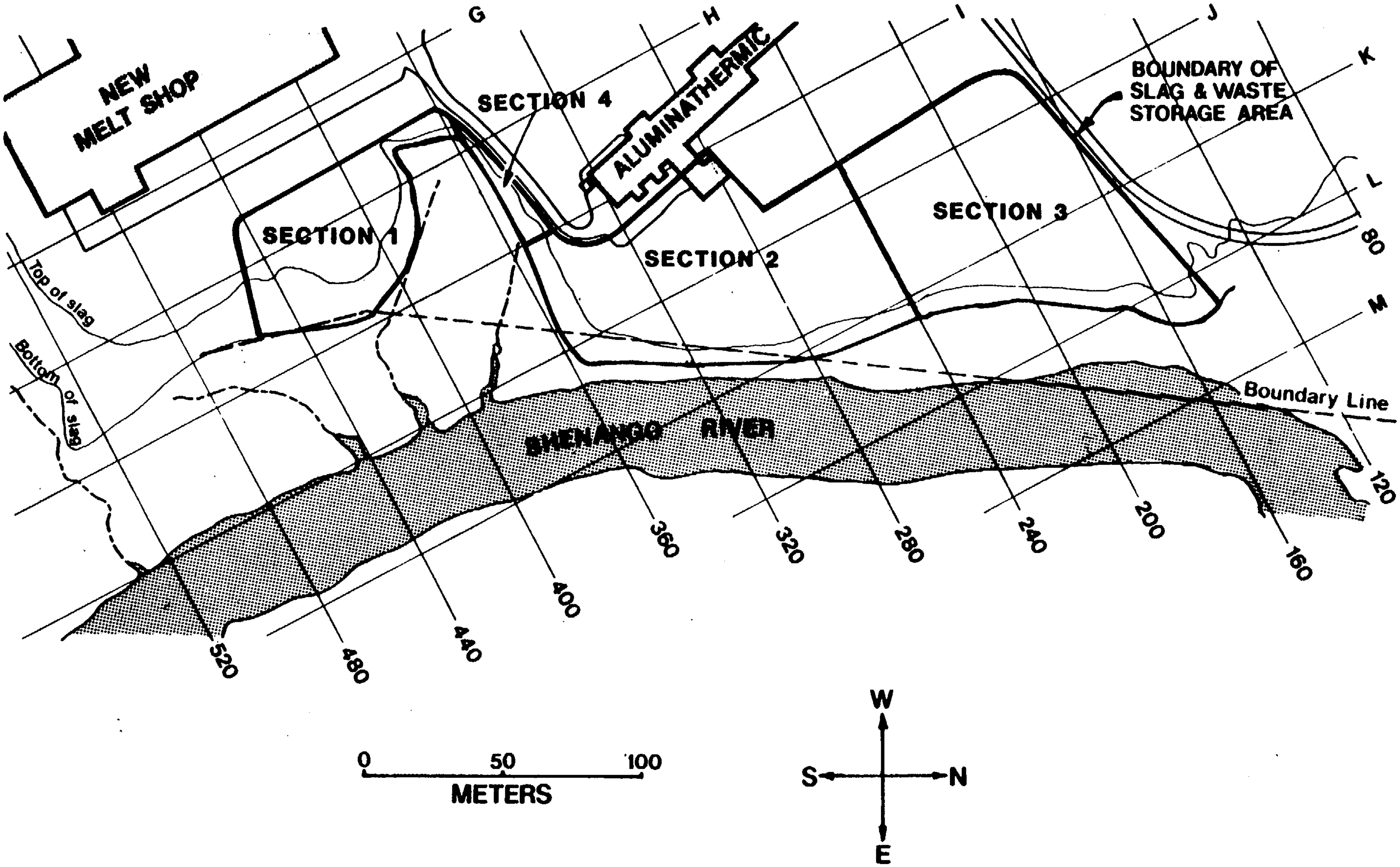


FIGURE C-1: Sections used for calculation of slag volume.