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## Results of the Outdoor Radiological Survey at the Portsmouth Gaseous Diffusion Plant Site, Piketon, Ohio

R. E. Rodriguez  
L. M. Floyd  
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**Health and Safety Research Division**

Environmental Restoration and Waste Management Non-Defense Programs  
(Activity No. 64 70 33 50 1; NAC)

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Gaseous Diffusion Plant Site, Piketon, Ohio**

R. E. Rodriguez, L. M. Floyd, and R. F. Carrier

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**U.S. Department of Energy**  
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## ABSTRACT

At the request of the Portsmouth Environmental Safety and Health Division, Portsmouth Gaseous Diffusion Plant, Piketon, Ohio, (PORTS) the Measurement Applications and Development Group of the Health and Safety Research Division, Oak Ridge National Laboratory, conducted a radiological survey of the outdoor surface environment of the PORTS plant site. The survey was performed between July 1990 and April 1991 and covered an area of approximately 150 acres. The purpose of the survey was to determine the extent of radiological contamination and to locate and prioritize areas of concern from both a worker health/safety and an environmental standpoint. The survey included mobile gamma scans, surface gamma scans, gamma radiation measurements at 1 m above the surface, selected direct and removable measurements of alpha and beta-gamma surface radiation levels, and soil sampling for radionuclide analyses. The survey and sampling covered all accessible land areas.

Results of the survey demonstrate that, of the 150 acres surveyed, a total of 2.7 acres were found to be contaminated. Concentrations of radionuclides in several areas totalling 1.0 acre in size were elevated above typical background levels observed for the Portsmouth, Ohio, area. Furthermore, 5 separate areas totalling 1.7 acres were found to have radionuclide surface activity levels exceeding DOE Order 5480.11 guidelines for zoning a contamination area.



# RESULTS OF THE OUTDOOR RADIOLOGICAL SURVEY AT THE PORTSMOUTH GASEOUS DIFFUSION PLANT SITE, PIKETON, OHIO\*

## INTRODUCTION

The Portsmouth Gaseous Diffusion Plant (PORTS) is owned by the U.S. Department of Energy (DOE) and managed by Martin Marietta Energy Systems, Inc. As shown in Fig. 1, the plant is located in sparsely populated, rural Pike County, Ohio. PORTS began in 1952 as part of the Atomic Energy Commission's (AEC) proposed expansion of the gaseous diffusion program in order to increase the production of enriched uranium. The 3,708-acre site is about a half mile east of U.S. Interstate 23 (Fig. 2) and approximately 1 mile east of the Scioto River Valley (Fig. 3). The current layout of the plant is shown on Fig. 4. The principal site process is the separation of uranium isotopes  $^{235}\text{U}$  and  $^{238}\text{U}$  through gaseous diffusion. This uranium enrichment process involves the more rapid diffusion of lighter molecules of  $\text{UF}_6$  (uranium hexafluoride) through the barrier walls of a porous tube. The end result is a  $\text{UF}_6$  stream that is slightly enriched in the  $^{235}\text{U}$  isotope. The separation process is repeated in a cascade arrangement until the desired concentration is reached.<sup>1,2</sup>

At the request of the PORTS Environmental Safety and Health Division, the Health and Safety Research Division (HASRD), Oak Ridge National Laboratory (ORNL), conducted a radiological survey of the outdoor surface environment of the PORTS site. The surveyed area covered approximately 150 acres of fenced ground consisting of dirt, asphalt, and concrete.<sup>3</sup> The survey was performed between July 1990 and April 1991, and the results reported to PORTS, Health Physics Department. The survey purpose was to determine the extent of radiological contamination and to locate and prioritize areas of concern from both a worker health/safety and an environmental standpoint. Specifically, the objectives of the survey were to assess the areal radioactive status of the site and to analyze surface soil samples for the presence of selected radionuclides. The principal radionuclide of concern is uranium.

## SURVEY METHODS

The radiological survey included: (1) a mobile gamma scan of the accessible thoroughfares within the fenced areas of the property; (2) a surface gamma scan in all

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\*The survey was performed by members of the Measurement Applications and Development Group of the Health and Safety Research Division at Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

accessible areas of the property outdoors; (3) gamma radiation levels at 1 m above the ground surface; (4) collection and radionuclide analyses of systematic and biased soil samples; and (5) direct and removable alpha and beta-gamma surface activity levels in selected locations. Comprehensive descriptions of all survey methods and instrumentation are presented in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, Oak Ridge National Laboratory, ORNL/TM-8600 (April 1987) and in *A Mobile Gamma-Ray Scanning System for Detecting Radiation Anomalies Associated with Ra-226 Bearing Materials*, Oak Ridge National Laboratory, ORNL/TM-8475 (November 1982).<sup>4,5</sup>

## MOBILE GAMMA SCANNING VAN METHODS

Standard operating procedures for the mobile gamma scanning van were used to conduct the survey.<sup>6</sup> A brief description of the methods and instrumentation used for the mobile scanning of the accessible areas (i.e., areas detectable from passable roads) is included here. Anomalies were verified in the system's identification mode.

The initial step in searching for gamma radiation anomalies with the scanning van is to obtain the baseline (background) data with which to compare measurements taken in the relevant areas. Background exposure rates were measured along thoroughfares in similar, but radiologically unenhanced regions in the vicinity of the areas of interest. Scans were then performed of the suspect areas at a slow speed (<5 mph), minimizing the distance between the detectors and the properties. All accessible areas were scanned in both directions to maximize the number of views obtained for each surveyed property. Anomaly locations were highlighted by the computer system when the preset "hit" criteria (described as follows) were exceeded during the scan.

The gamma radiation detection system employed in the ORNL scanning van is operator-controlled through keyboard instructions to an on-board computer on which data output is displayed. The data can be simultaneously printed and stored on a dual floppy disk drive. The system consists of three  $4 \times 4 \times 16$ -in. NaI(Tl) log crystals housed in a lead-shielded steel frame that is mounted on the right side of the van to provide two detector surface areas for acceptance of gamma radiation. A  $12 \times 16$ -in. surface measures radiation coming from sources on the right side of the van. The second surface is  $4 \times 12$ -in. and detects radiation from directly beneath the van. The detector and shield height can be varied with a hydraulic lift mechanism to optimize the detector field-of-view. The detector output is transferred to a computer-controlled eight-channel discriminator and interface that provides for continuous analysis of data inputs for correlation of system location with count rate information. Separate energy regions-of-interest are analyzed and a radionuclide-specific algorithm is employed to identify locations containing residual radium materials. Multichannel analysis capabilities are included in the system for additional qualitative radionuclide identification.<sup>7</sup>

## SURFACE GAMMA SCANNING AND SOIL SAMPLING METHODS

Using a 1.5 × 1.25-in. NaI gamma scintillation detector with a hand-held ratemeter, a gamma scan was performed in all outdoor areas not amenable to mobile van scanning capabilities. The detectors were held approximately 2 in. above the ground surface, and ranges of measurements were recorded and then converted to  $\mu\text{R/h}$ . Where the surface gamma radiation levels were elevated, biased soil samples were taken from the location of the maximum gamma level. Because NaI scintillators are energy dependent, measurements of gamma radiation levels are normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates. Systematic soil samples were taken at various locations irrespective of gamma radiation levels. The samples were analyzed for  $^{137}\text{Cs}$ ,  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{235}\text{U}$ , and  $^{238}\text{U}$  content. These radionuclides were selected for analysis by gamma spectrometry for the following reasons.

A chain of successive radionuclides are formed from the decay process that natural uranium undergoes over time. Radium-226 is one of the longer-lived gamma-emitting progeny that result from this decay and is therefore present wherever there is uranium. In natural uranium, the activity contributed by  $^{226}\text{Ra}$  is approximately equal to that contributed by  $^{238}\text{U}$ . The chemical separation of uranium and  $\text{UF}_6$  in milling removes nearly all of the naturally occurring uranium progeny prior to delivery to the PORTS site. Only trace quantities are present due to decay since separation. The radioisotopes  $^{235}\text{U}$  and  $^{238}\text{U}$  both occur naturally, and both result from PORTS operations. However, the PORTS enrichment process changes the naturally occurring ratios of these nuclides. Depleted uranium has a lower percentage of its total activity from  $^{235}\text{U}$  than does natural uranium; conversely, enriched uranium contains a lessened contribution from  $^{238}\text{U}$  to the total percent activity. In natural uranium, 0.7% of the total uranium by weight is due to  $^{235}\text{U}$ ; 4.7% of the total activity comes from  $^{235}\text{U}$ . Any significant deviation from those percentages is likely to result from enrichment operations. In natural uranium, the amount of activity from  $^{234}\text{U}$  is approximately equal to that from  $^{238}\text{U}$ . However, only the  $^{235}\text{U}$  and  $^{238}\text{U}$  emit sufficient gamma radiation for gamma spectrometry analysis.

Although neither  $^{137}\text{Cs}$  nor  $^{40}\text{K}$  were directly associated with any operations or processing activities at the PORTS site, samples are routinely analyzed for their presence. Cesium-137 is a man-made radionuclide present worldwide in atmospheric fallout from nuclear weapons testing. It is frequently found in soil taken from areas where rainwater collects, such as the driplines of roofs and low-lying areas in and around parking lots or thoroughfares. Potassium-40 is a naturally occurring, pervasive radionuclide found in many biological and environmental materials, including soil, normal food, and human tissues. Thorium-232 is a primordial radionuclide and is found in all soil.

Direct alpha and beta-gamma radiation measurements were taken outdoors on hard surfaces (e.g., concrete, asphalt) in the same areas as the soil samples. An ORNL (ZnS) alpha meter was used to measure alpha activity levels, and a GM pancake probe was used

to determine beta-gamma activity levels. Smears were taken at selected locations to disclose any removable alpha and/or beta-gamma activity levels.

## SURVEY RESULTS

DOE guidelines are summarized in Table 1.<sup>8,9</sup> Typical background radiation levels for the southern Ohio area are presented in Table 2.<sup>10</sup> These data are provided for comparison with survey results presented in this section. Measurements for alpha and beta radiation levels are reported directly in disintegrations per minute (dpm) per 100 cm<sup>2</sup>; general radiation levels are reported in gross  $\mu\text{R}/\text{h}$ . Background concentrations have not been subtracted from radionuclide concentrations measured in soil samples.

### MOBILE GAMMA SCANNING VAN RESULTS

The results of the mobile gamma scanning van activity inside the fenced site revealed no detectable anomalies on the roads. However, gamma radiation "shine" \* from the UF<sub>6</sub> storage yard was readily detected. The origin of the shine was established using NaI scintillometers and PIC instruments.

### SURFACE GAMMA SCAN RESULTS

At the time of the survey, the UF<sub>6</sub> cylinders were stored in the northeast and northwest portions of the site. Gamma radiation levels at 1 m in the immediate storage vicinities (Fig. 5) were all greater than 60  $\mu\text{R}/\text{h}$  as a result of the considerable gamma radiation shine produced by the contents of these cylinders. Exposure rates at 1 m in areas outside of and surrounding the cylinder storage dropped significantly, ranging from 12 to 60  $\mu\text{R}/\text{h}$ . Gamma radiation fields in the immediate vicinity of UF<sub>6</sub> cylinders were not fully characterized because PORTS health physics personnel had already implemented radiation zone restrictions.

Figure 6 shows the areas of the property surveyed both at the surface and at 1 m above the surface. Gamma exposure rates measured near the ground surface in areas of the site not affected by shine from the cylinder storage generally ranged from 6 to 11  $\mu\text{R}/\text{h}$ . However, values ranging from 12 to 550  $\mu\text{R}/\text{h}$  were measured at the surface in scattered locations. Biased soil samples were taken in those locations as shown on Figs. 7 and 8. Exposure rates at 1 m above the surface in those areas generally ranged from 6 to 11  $\mu\text{R}/\text{h}$ , with a maximum of 20  $\mu\text{R}/\text{h}$  in elevated locations. The higher values did exceed the range of gamma exposure rates typical of the southern Ohio area (3–11  $\mu\text{R}/\text{h}$ , Table 2), but gamma levels measured by ORNL in these areas were all well below DOE Order 5480.11 personnel protection guidelines. There were areas exceeding

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\*The term "shine" refers to gamma radiation emanating from a source or sources extrinsic to the area being defined. Unless special precautions are taken, such as shielding the instrument, the extraneous radiation can confound measurement of the gamma radiation levels associated with the area of interest.

5 mR/h at 30 cm above the surface but these had been previously posted by PORTS health physics personnel.<sup>9</sup>

### SYSTEMATIC AND BIASED SOIL SAMPLES

Biased and systematic soil samples were taken from selected outdoor locations within the fenced portion of the property (Figs. 7, 8, and 9) and subjected to radionuclide analyses (Table 3). Concentrations of radionuclides in systematic samples S1 through S85 are 0.53 to 2.5 pCi/g (<sup>226</sup>Ra), 0.16 to 1.9 pCi/g (<sup>232</sup>Th), 0.03 to 1.3 pCi/g (<sup>235</sup>U), 0.51 to 6.5 pCi/g (<sup>238</sup>U), 0.01 to 0.87 pCi/g (<sup>137</sup>Cs), and 0.01 to 35 pCi/g (<sup>40</sup>K). Biased sample concentrations were 0.56 to 81 pCi/g (<sup>226</sup>Ra), 0.21 to 77 pCi/g (<sup>232</sup>Th), 0.08 to 1600 pCi/g (<sup>235</sup>U), 1.8 to 5600 pCi/g (<sup>238</sup>U), 0.01 to 11 pCi/g (<sup>137</sup>Cs) and 0.01 to 24 pCi/g (<sup>40</sup>K) in samples B1–33. Most of the biased soil samples contained significantly elevated concentrations of uranium. The highest <sup>238</sup>U concentration (5600 pCi/g) was found in biased sample B30A, taken northeast of Building X-700. All samples collected around Building X-705 contained elevated uranium radionuclide concentrations. Only two samples, B32A and B32B, showed elevated concentrations of radium and thorium in addition to elevated concentrations of <sup>235</sup>U and <sup>238</sup>U. Concentrations of <sup>226</sup>Ra, <sup>232</sup>Th, <sup>235</sup>U, and <sup>238</sup>U were 81, 77, 61, and 880 pCi/g, respectively, in sample B32A. Sample B32B contained concentrations of <sup>226</sup>Ra, <sup>232</sup>Th, <sup>235</sup>U, and <sup>238</sup>U of 58, 59, 23, and 280 pCi/g, respectively. These samples were collected east of Building X-105, which is near the Perimeter Road as it turns west between the East Access Road and the Entrance Road (Fig. 8). Most systematic samples (Fig. 9) contained radionuclides in concentrations near typical background levels for the Ohio area (Table 2).

### ALPHA AND BETA-GAMMA SURFACE ACTIVITY LEVELS

Direct and removable radioactivity levels were measured on hard (concrete and asphalt) surfaces in the five areas of highest gamma radiation levels on the site. The results of these measurements, taken in selected locations around Buildings X-700, X-705, X-705A, X-720, X-746, and X-770, are summarized in Table 4. Direct alpha measurements in these areas were above the DOE average guideline of 5000 dpm/100 cm<sup>2</sup> for uranium alpha emitters (Table 1, DOE Order 5480.11). Directly measured beta-gamma activity levels in these five areas were also above the DOE average guideline of 5000 dpm/100 cm<sup>2</sup> for beta-gamma emitters (Table 1). Areas exceeding these guidelines are shown on Figs. 7 and 8.

Removable surface contamination was assessed by taking smear samples from selected asphalt and concrete surfaces within these same 5 elevated areas and analyzing for alpha activity levels. Results (Table 4) showed removable alpha contamination around Buildings X-705 and X-746 above the DOE guideline of 1000 dpm/100 cm<sup>2</sup> for removable uranium contamination (Table 1).

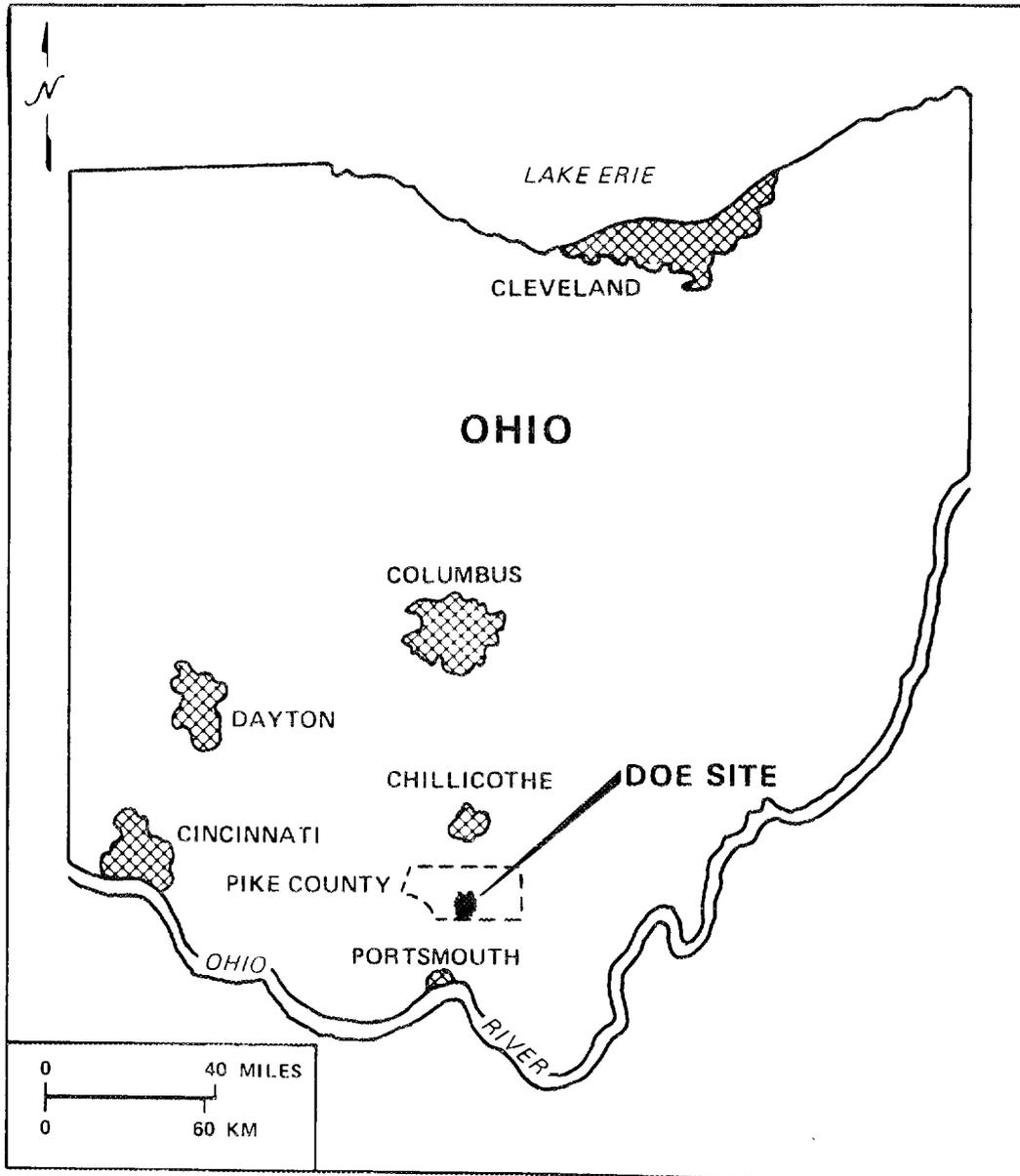
## SIGNIFICANCE OF FINDINGS

Results of laboratory analyses for radionuclide concentrations in soil samples collected from the PORTS plant site demonstrate  $^{235}\text{U}$  and  $^{238}\text{U}$  radionuclides in elevated concentrations in most of the biased soil samples. Furthermore, concentrations of  $^{226}\text{Ra}$  and  $^{232}\text{Th}$  were elevated in samples B32A and B32B. Of the 150 acres surveyed, 2.7 acres were found to be contaminated. Some of the contamination, found over several scattered areas totalling 1.0 acre in size, was located in the top six inches of soil. These results are not typical of background values in the Portsmouth, Ohio, area. The areas of elevated radionuclide concentrations coincided with the areas of elevated surface gamma radiation and elevated alpha and beta-gamma surface activity; the most significant of which were found around Buildings X-770, X-705, X-705A, X-720, and the east loading dock of Building X-746. These 5 areas, described in Table 4 and totalling 1.7 acre in size, exceed DOE Order 5480.11 average guidelines for surface contamination.

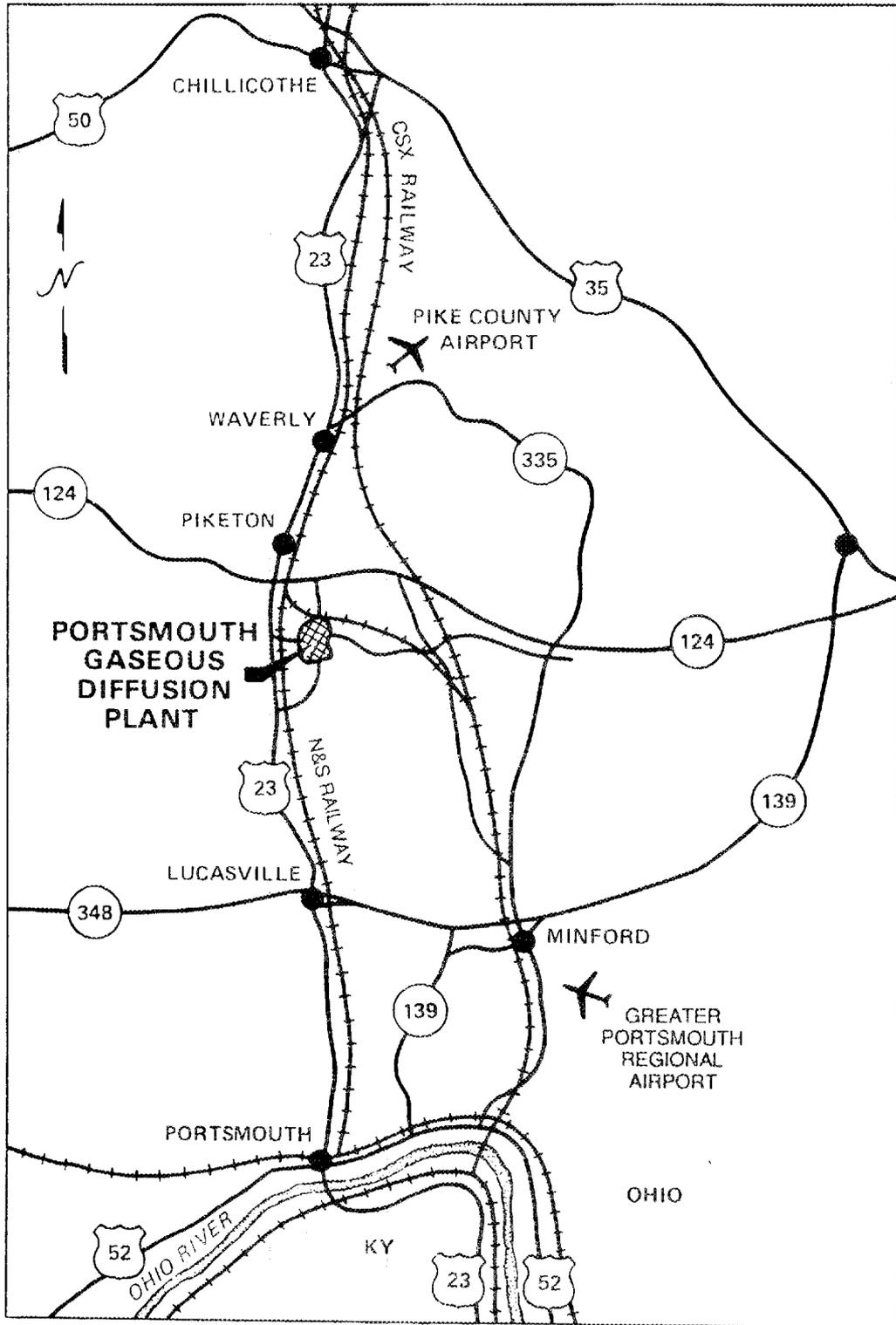
Analyses showed elevated concentrations of  $^{137}\text{Cs}$  in samples from 22 of 33 biased locations where elevated concentrations of uranium were also found. Elevated levels of  $^{137}\text{Cs}$  were not found in samples from the 85 systematic locations. The concentrations of cesium found at this site are not sufficient to pose any significant health hazard to either employees or the public. By comparison, the  $^{137}\text{Cs}$  concentrations in soil at PORTS are well below the recommended value of 80 pCi/g that is used by DOE in applying FUSRAP guidelines to release sites for unrestricted use.<sup>11</sup>

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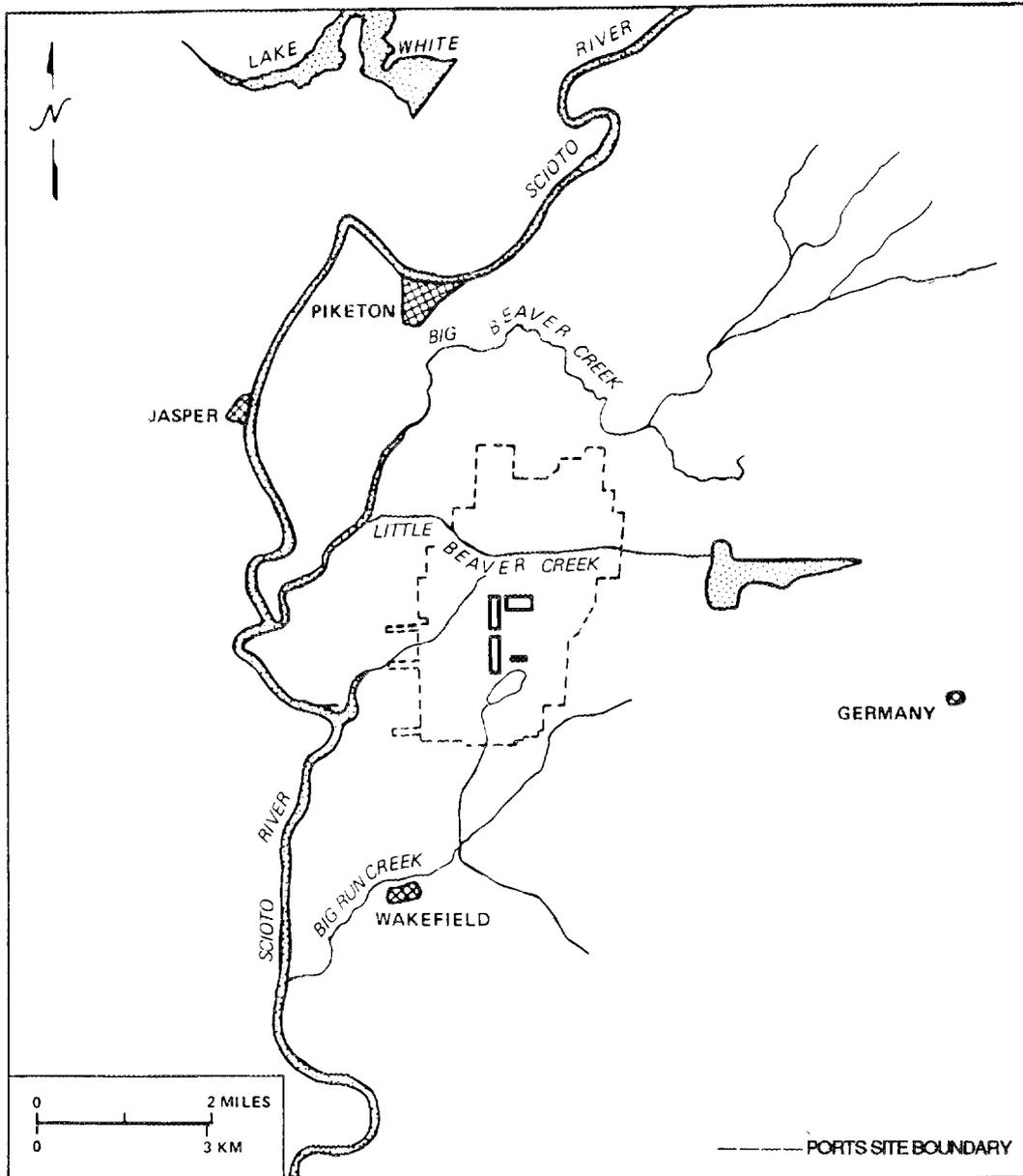
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**Fig. 1. Map showing the location of the Portsmouth Gaseous Diffusion Plant within the state of Ohio.**



**Fig.2. Map showing the location of the Portsmouth Gaseous Diffusion Plant within Pike County in relation to neighboring highways.**



**Fig. 3. Map showing the location of the Portsmouth Gaseous Diffusion Plant in relation to the surrounding rivers.**

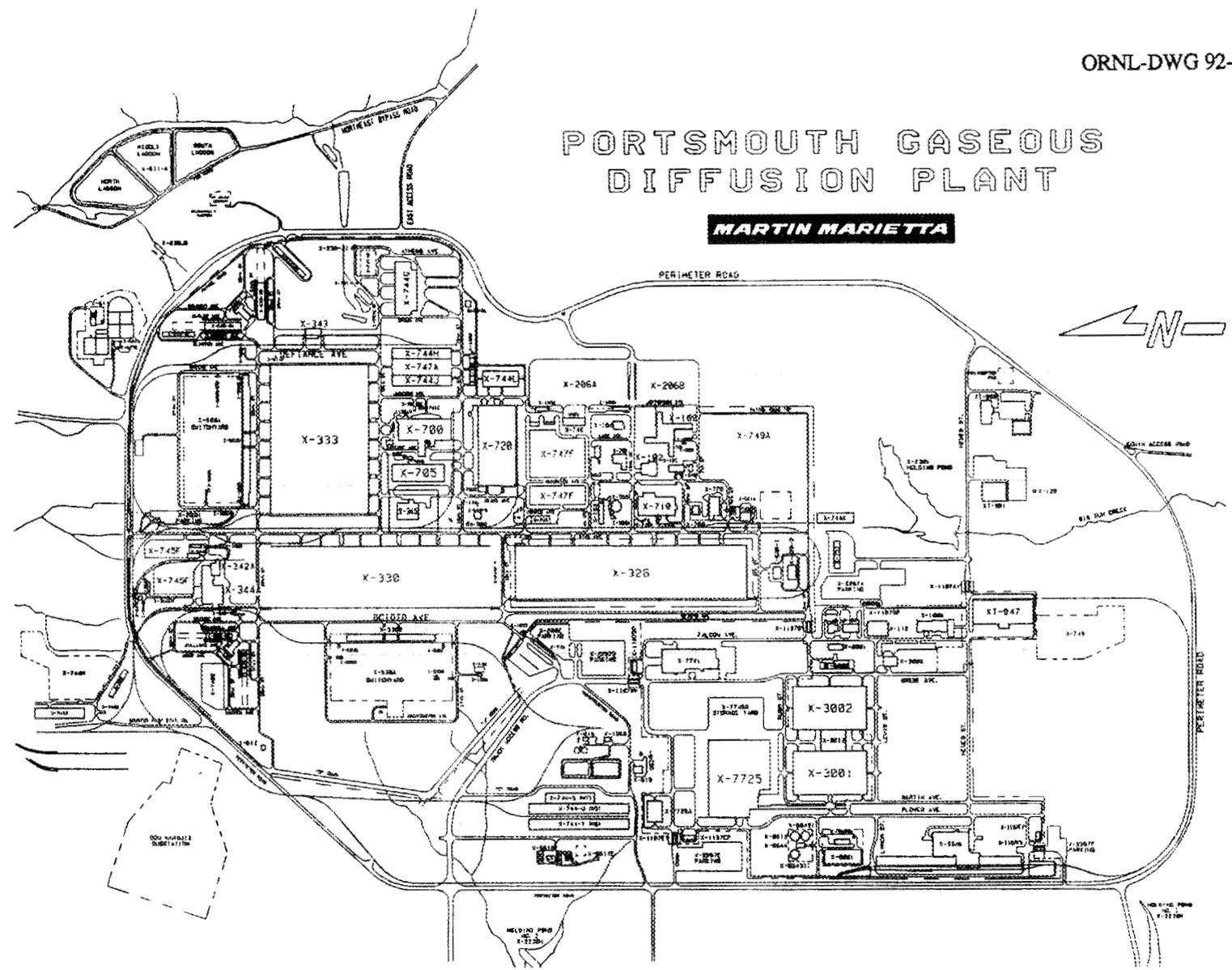


Fig. 4. Map showing the current layout of the Portsmouth Gaseous Diffusion Plant. Source: ORNL, Portsmouth Gaseous Diffusion Plant Environmental Report for 1989, October, 1990.

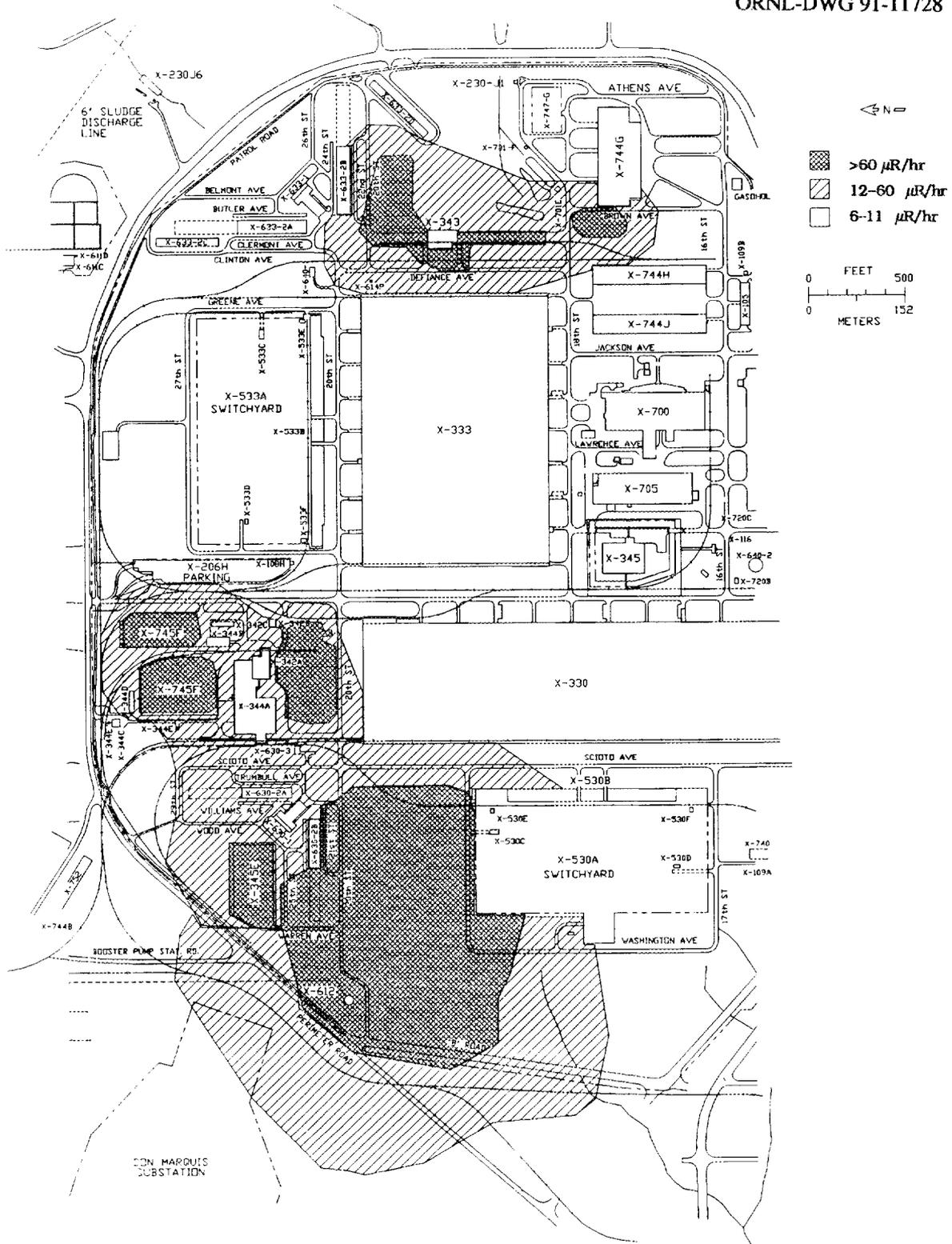
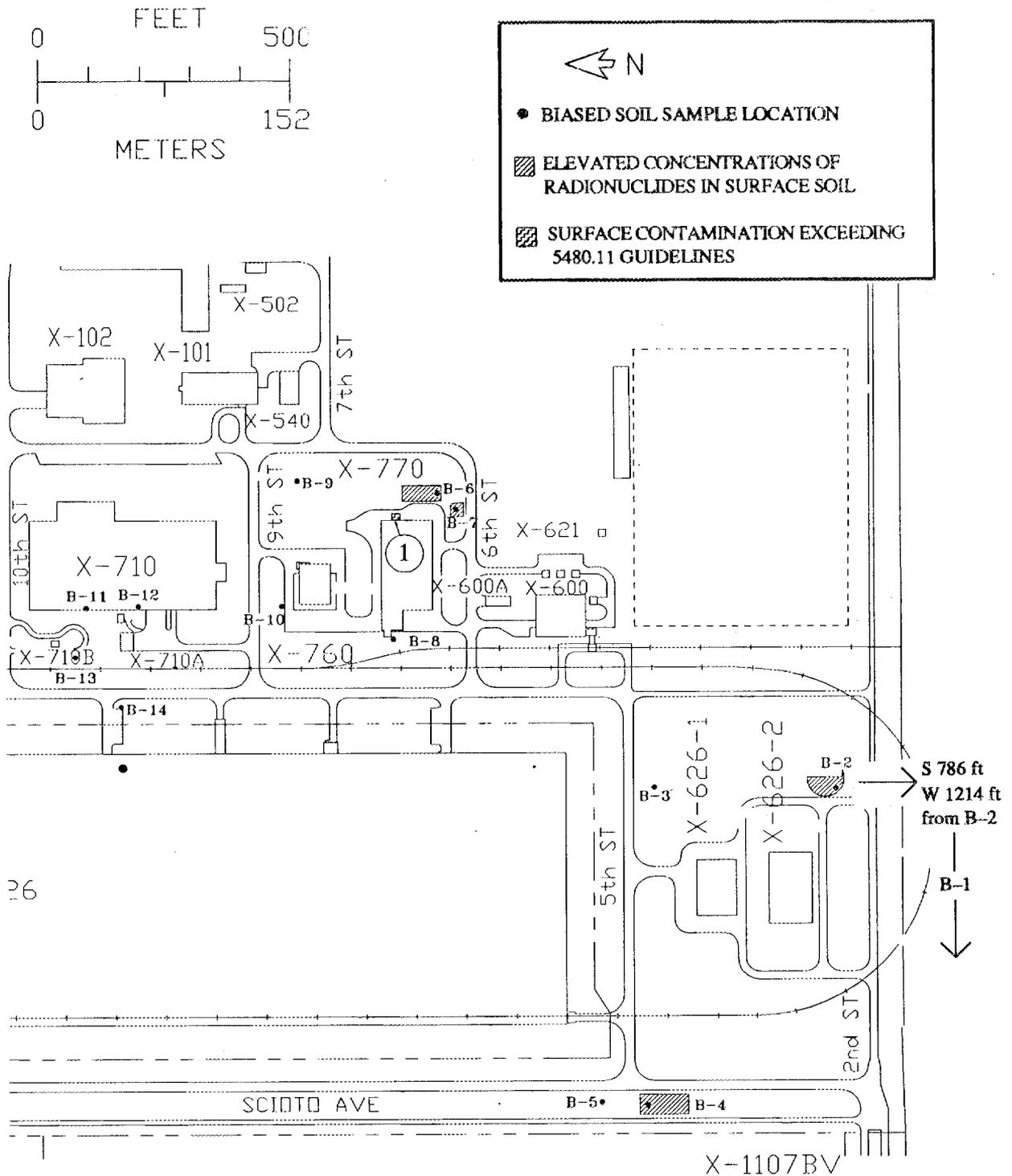
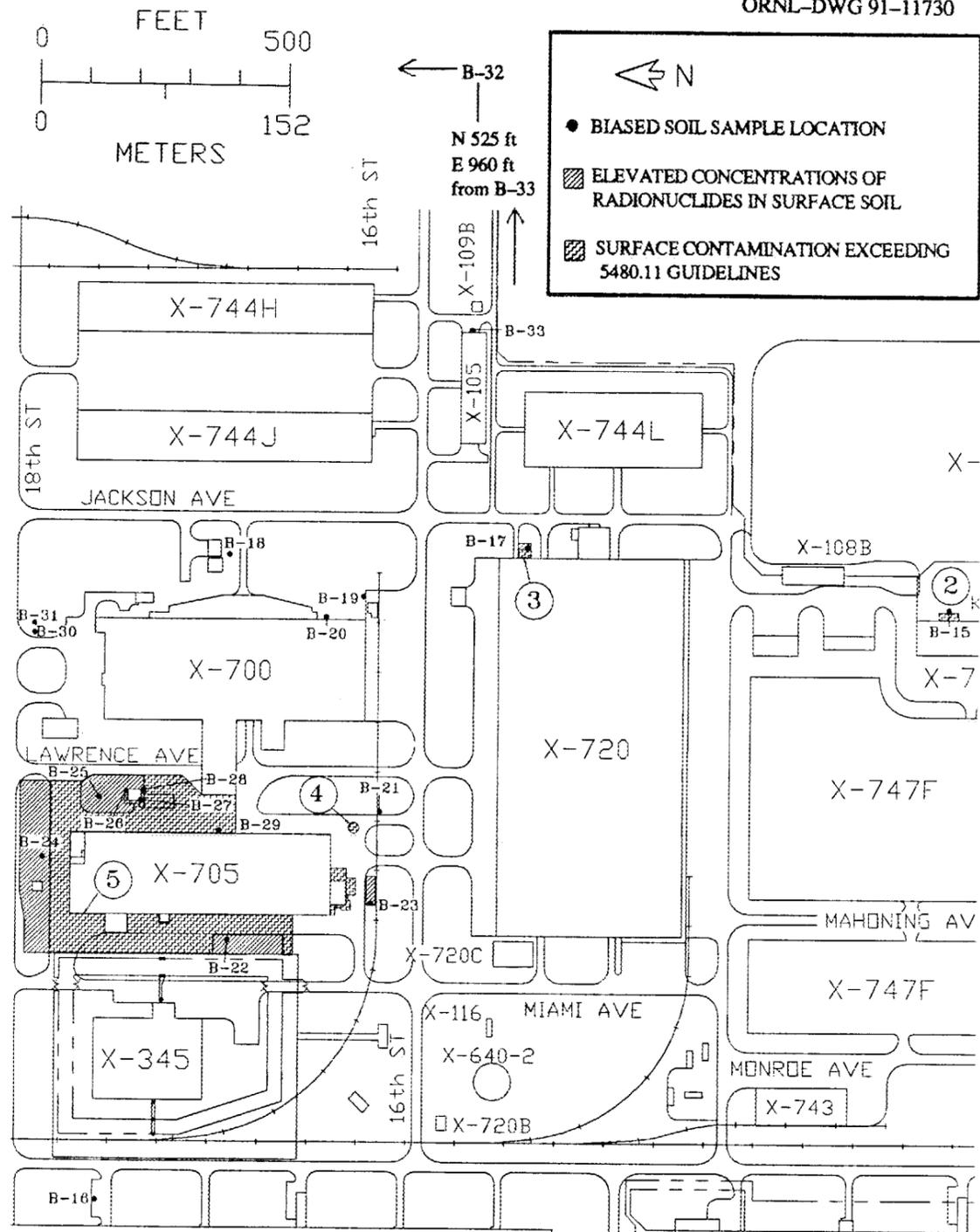


Fig. 5. Gamma radiation levels at 1 m above the surface in areas surrounding UF<sub>6</sub> cylinder storage at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio.





**Fig. 7. Biased soil sample locations, areas of elevated concentrations of radionuclides in surface soil, and areas exceeding DOE 5480.11 guidelines in the south end of the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. Areas exceeding guidelines are numbered ① - ⑤ as indicated in Table 4.**



**Fig. 8. Biased soil sample locations, areas of elevated concentrations of radionuclides in surface soil, and areas exceeding DOE 5480.11 guidelines in the north end of the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio. Areas exceeding guidelines are numbered ① - ⑤ as indicated in Table 4.**

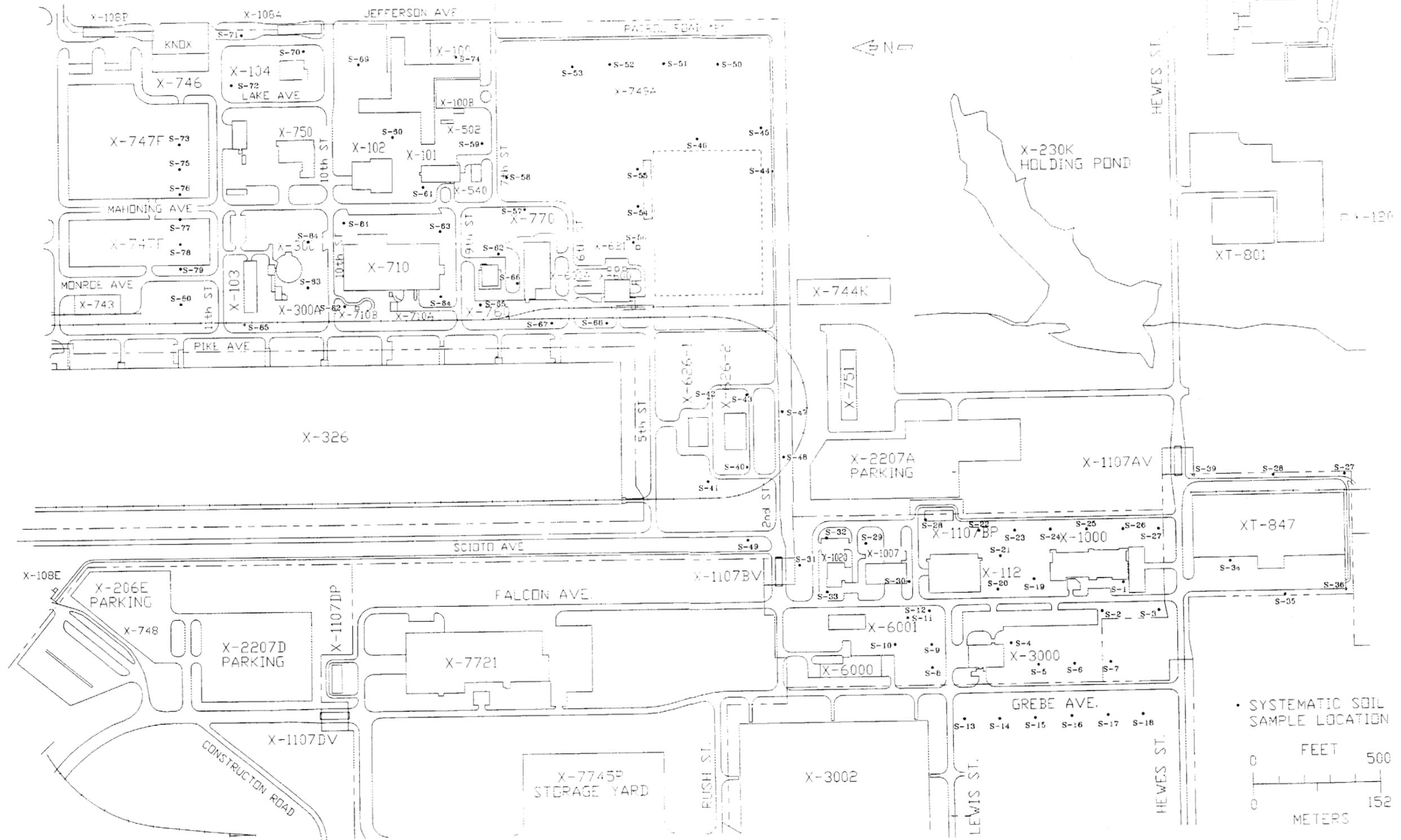


Fig. 9. Locations of systematic soil samples taken at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio.

**Table 1. DOE guidelines for protection against radiation**

Mode of exposure	Exposure condition <sup>a</sup>	Guideline value <sup>b</sup>	
Total residual surface contamination <sup>c</sup>	<sup>238</sup> U, <sup>235</sup> U, U-natural ( <i>alpha emitters</i> ) or Beta-gamma emitter <sup>d</sup>	Fixed & removable <sup>e</sup>	
		Removable	
	<sup>232</sup> Th, Th-natural ( <i>alpha emitters</i> ) or <sup>90</sup> Sr ( <i>beta-gamma emitter</i> )	Fixed & removable <sup>e</sup>	
		Removable	
	<sup>226</sup> Ra, <sup>230</sup> Th, transuranics	Fixed & removable <sup>e</sup>	
		Removable	
			5,000 dpm/100 cm <sup>2</sup>
			1,000 dpm/100 cm <sup>2</sup>
			1,000 dpm/100 cm <sup>2</sup>
			200 dpm/100 cm <sup>2</sup>
		300 dpm/100 cm <sup>2</sup>	
		20 dpm/100 cm <sup>2</sup>	

<sup>a</sup>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.

<sup>b</sup>As used in this table, dpm 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.

<sup>c</sup>DOE surface contamination guidelines are consistent with the Nuclear Regulatory Commission guidelines found in ref. 10.

<sup>d</sup>Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except <sup>90</sup>Sr, <sup>228</sup>Ra, <sup>223</sup>Ra, <sup>227</sup>Ac, <sup>133</sup>I, <sup>129</sup>I, <sup>126</sup>I, <sup>125</sup>I. This category of radionuclides includes mixed fission products, including the <sup>90</sup>Sr which is present in them. It does not apply to <sup>90</sup>Sr which has been separated from the other fission products or mixtures where the <sup>90</sup>Sr has been enriched.

<sup>e</sup>The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm<sup>2</sup> is less than three times the guide values. For purposes of averaging, any square meter of surface shall be considered to be above the activity guide G if: (1) from measurements of a representative number n of sections it is determined that  $1/n \sum S_i \geq G$ , where S<sub>i</sub> is the dis/min-100 cm<sup>2</sup> determined from measurement of section i; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm<sup>2</sup> area exceeds 3G.

Source: DOE Order 5480.11, December 21, 1988.

**Table 2. Background radiation levels and radionuclide concentrations for the Portsmouth, Ohio, area**

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above ground surface ( $\mu\text{R/h}$ ) <sup>a</sup>	3-11	7
Concentrations of radionuclides in soil (pCi/g) <sup>b</sup>		
<sup>226</sup> Ra	0.85-1.8	1.2
<sup>232</sup> Th	0.33-1.1	0.50
<sup>235</sup> U	0.04-0.11	0.06
<sup>238</sup> U	0.68-1.5	1.2
<sup>137</sup> Cs	0.02-0.38	0.2
<sup>40</sup> K	0.01-12.0	4.5

<sup>a</sup>Average of 5 gamma exposure rate measurements taken in southern Ohio. *Source:* T. E. Myrick, B. A. Berven, and F. F. Haywood, *State Background Radiation Levels: Results of Measurements Taken During 1975-1979*, ORNL/TM-7343, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., November 1981.

<sup>b</sup>Results are for 6 soil samples designated X1A, X1B, X2A, X2B, X3A, and X3B taken from depths of 0-6 or 6-12 in. from undisturbed background regions near the PORTS site.

Table 3. Concentrations of radionuclides in outdoor soil samples at the Portsmouth Gaseous Diffusion Plant, Piketon, Ohio

Sample <sup>a</sup>	Depth (in)	Radionuclide concentration (pCi/g) <sup>b</sup>					
		<sup>226</sup> Ra	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U	<sup>137</sup> Cs	<sup>40</sup> K
<i>Biased samples<sup>c</sup></i>							
B1A	0-6	1.30±0.02	1.60±0.04	0.08±0.05	2.20±1.2	<0.02	24 ±0.39
B1B	6-12	1.20±0.04	1.50±0.07	<0.08	1.80±0.99	0.01±0.01	20 ±0.59
B2A	0-6	1.40±0.13	1.80±0.26	340 ±3.0	130 ±14	0.87±0.14	12 ±1.6
B2B	6-12	1.40±0.10	1.40±0.15	66 ±0.87	31 ±5.6	0.22±0.05	13 ±1.2
B3A	0-6	1.40±0.11	1.30±0.17	14 ±0.55	73 ±8.8	0.59±0.09	14 ±1.3
B3B	6-12	1.40±0.03	1.20±0.05	2.50±0.07	15 ±1.1	0.06±0.01	13 ±0.37
B4A	0-6	1.20±0.08	1.20±0.11	19 ±1.6	37 ±5.6	0.68±0.07	12 ±0.94
B4B	6-12	1.10±0.12	1.00±0.19	11 ±0.48	29 ±6.9	0.49±0.10	11 ±1.4
B5A	0-6	1.40±0.08	1.20±0.13	7.20±0.82	32 ±4.6	0.92±0.09	13 ±1.0
B5B	6-12	1.50±0.02	1.50±0.04	1.20±0.05	9.70±1.3	0.17±0.01	16 ±0.32
B6A	0-2	1.80±0.28	1.20±0.37	27 ±2.0	830 ±32	3.30±0.31	9.10±2.1
B6B	2-6	1.50±0.06	1.20±0.10	3.40±0.20	150 ±7.2	0.54±0.06	13 ±0.71
B6C	6-12	1.60±0.04	1.40±0.07	0.29±0.09	12 ±1.7	0.03±0.02	14 ±0.55
B7A	0-2	1.70±0.05	0.92±0.07	16 ±0.20	500 ±4.0	3.90±0.07	11 ±0.41
B7B	2-6	1.20±0.03	0.70±0.05	2.00±0.08	96 ±2.9	0.89±0.03	12 ±0.39
B7C	6-12	1.50±0.03	1.30±0.05	0.41±0.06	19 ±1.5	0.10±0.01	13 ±0.37
B8A	0-2	3.00±0.14	1.20±0.15	22 ±1.7	23 ±5.3	1.30±0.11	13 ±1.3
B8B	2-6	2.80±0.07	0.91±0.08	28 ±0.33	24 ±3.0	0.86±0.05	8.40±0.60
B8C	6-12	1.70±0.07	1.40±0.11	2.10±0.19	3.70±2.5	0.11±0.03	13 ±0.81
B9A	0-2	6.60±0.19	2.60±0.23	59 ±2.1	170 ±11	4.90±0.17	11 ±1.1
B9B	2-6	1.60±0.04	1.40±0.07	1.90±0.09	6.90±1.6	0.23±0.02	13 ±0.53
B9C	6-12	1.50±0.03	1.40±0.05	0.31±0.05	2.70±1.0	0.02±0.01	14 ±0.38
B10A	0-2	1.50±0.09	1.20±0.13	28 ±1.7	15 ±5.0	2.00±0.12	13 ±1.0
B10B	2-6	1.50±0.05	1.30±0.09	10 ±0.19	8.30±2.4	0.46±0.03	14 ±0.69
B10C	6-12	1.50±0.02	1.30±0.03	3.50±0.19	3.40±0.67	0.13±0.01	14 ±0.29
B11A	0-2	1.40±0.10	1.30±0.19	140 ±5.0	110 ±10	2.20±0.12	11 ±1.1
B11B	2-6	1.40±0.05	1.30±0.09	46 ±1.4	38 ±3.8	0.71±0.04	13 ±0.62
B11C	6-12	1.40±0.07	1.30±0.10	9.40±0.75	11 ±3.0	0.08±0.03	13 ±0.92
B12A	0-2	1.50±0.07	1.50±0.13	56 ±1.5	55 ±5.0	1.80±0.08	13 ±0.94
B12B	2-6	1.40±0.04	1.30±0.07	7.60±0.51	9.10±2.4	0.49±0.03	12 ±0.55
B12C	6-12	1.30±0.03	1.40±0.05	0.95±0.05	2.10±0.80	0.07±0.01	13 ±0.36
B13A	0-2	1.70±0.08	1.10±0.08	10 ±0.31	22 ±4.5	1.00±0.06	13 ±0.78
B13B	2-6	1.90±0.12	1.30±0.17	1.60±0.28	6.00±3.9	0.10±0.06	20 ±1.6
B13C	6-12	2.10±0.03	1.50±0.03	0.96±0.07	4.50±1.2	0.03±0.01	19 ±0.31
B14	0-2	1.10±0.08	0.85±0.12	270 ±1.7	38 ±5.5	5.00±0.15	6.60±0.65
B15	0-0	0.69±0.17	1.60±0.29	380 ±2.8	120 ±3.9	0.39±0.17	0.01±0.01
B16	0-0	0.95±0.03	0.59±0.05	15 ±0.18	85 ±8.4	3.20±0.05	0.01±0.01
B17A	0-2	0.91±0.07	1.10±0.14	1200 ±14	560 ±22	2.20±0.07	0.01±0.01
B17B	2-6	1.20±0.04	1.20±0.07	140 ±1.2	65 ±4.9	0.24±0.03	0.01±0.01
B17C	6-12	1.10±0.03	1.10±0.05	34 ±0.85	19 ±2.6	0.02±0.01	12 ±0.47
B18A	0-2	1.50±0.08	0.89±0.12	69 ±0.78	110 ±5.1	4.40±0.12	0.01±0.01
B18B	2-6	1.60±0.15	1.40±0.18	16 ±0.62	33 ±5.3	1.80±0.15	0.01±0.01
B18C	6-12	1.50±0.03	1.40±0.06	2.60±0.28	7.90±0.82	0.22±0.02	24 ±0.52
B19A	0-2	1.10±0.05	6.30±0.09	4.30±0.13	16 ±1.5	11 ±0.10	0.01±0.01
B19B	2-6	1.50±0.05	1.80±0.08	0.26±0.08	2.80±0.53	0.51±0.03	23 ±0.71

Table 3. (continued)

Sample <sup>a</sup>	Depth (in)	Radionuclide concentration (pCi/g) <sup>b</sup>					
		<sup>226</sup> Ra	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U	<sup>137</sup> Cs	<sup>40</sup> K
B19C	6-12	0.94±0.04	1.60±0.10	<0.16	3.00±0.63	0.19±0.03	0.01±0.01
B20A	0-2	0.62±0.13	0.84±0.19	40 ±0.82	690 ±12	1.40±0.15	0.01±0.01
B20B	2-6	0.56±0.04	0.21±0.05	2.20±0.21	45 ±2.7	0.37±0.03	2.10±0.33
B21A	0-2	1.20±0.03	0.73±0.04	22 ±0.19	120 ±3.0	2.80±0.04	0.01±0.01
B21B	2-6	1.10±0.06	0.65±0.08	18 ±0.40	94 ±4.5	6.80±0.16	0.01±0.01
B21C	6-12	0.90±0.02	0.45±0.03	5.50±0.25	30 ±1.2	7.10±0.06	4.70±0.18
B22A	0-2	<0.26	2.70±0.87	930 ±2.4	1200 ±21	6.20±0.16	0.01±0.01
B22B	2-6	1.50±0.11	1.20±0.16	250 ±1.6	240 ±5.8	6.70±0.19	0.01±0.01
B22C	6-12	1.10±0.15	0.84±0.18	59 ±2.2	62 ±4.1	0.76±0.12	0.01±0.01
B23A	0-2	0.97±0.08	0.76±0.12	150 ±4.0	30 ±5.9	1.00±0.09	6.80±0.82
B23B	2-6	1.20±0.02	1.20±0.03	46 ±0.18	16 ±1.3	0.58±0.02	15 ±0.28
B23C	6-12	1.50±0.04	1.50±0.06	13 ±0.41	7.20±0.94	0.03±0.02	17 ±0.55
B24A	0-2	1.20±0.06	1.10±0.08	590 ±1.2	520 ±7.4	3.50±0.07	0.01±0.01
B24B	2-6	1.40±0.07	1.20±0.12	34 ±1.3	76 ±4.1	1.20±0.09	14 ±0.89
B24C	6-12	1.20±0.04	1.20±0.06	4.70±0.14	15 ±1.0	0.09±0.02	0.01±0.01
B25A	0-2	1.10±0.06	1.30±0.10	230 ±1.2	110 ±7.7	0.49±0.04	13 ±0.80
B25B	2-6	0.89±0.05	0.57±0.06	43 ±4.5	25 ±3.5	0.94±0.06	6.30±0.49
B25C	6-12	1.20±0.02	1.10±0.04	13 ±0.13	10 ±1.0	0.17±0.01	12 ±0.30
B26B	2-6	2.6 ±0.12	2.8 ±0.37	840 ±2.4	310 ±10	0.55±0.06	0.01±0.01
B26C	6-12	1.7 ±0.06	1.9 ±0.14	54 ±0.61	34 ±4.2	0.05±0.03	<0.01
B27A	0-2	0.97±0.08	0.66±0.36	270 ±1.3	440 ±9.7	0.41±0.07	0.01±0.01
B27B	2-6	0.67±0.05	0.27±0.04	72 ±2.0	120 ±5.0	0.36±0.03	2.0 ±0.24
B27C	6-12	1.4 ±0.03	0.78±0.05	18 ±0.24	29 ±1.8	0.31±0.02	3.6 ±0.25
B28A	0-2	1.4 ±0.07	1.4 ±0.29	310 ±1.2	190 ±4.7	1.0 ±0.05	0.01±0.01
B28B	2-6	1.3 ±0.03	1.3 ±0.10	280 ±1.0	140 ±3.0	0.68±0.02	12 ±0.29
B28C	6-12	1.7 ±0.08	1.7 ±0.11	37 ±0.56	27 ±4.6	0.11±0.04	0.01±0.01
B29A	0-2	<0.26	4.4 ±0.19	1600 ±2.8	2100 ±17	<0.12	<0.01
B29B	2-6	0.66±0.05	1.3 ±0.10	280 ±1.2	360 ±7.2	<0.05	<0.01
B30A	0-2	2.2 ±0.33	1.3 ±0.35	240 ±1.8	5600 ±33	6.3 ±0.24	0.01±0.01
B30B	2-6	1.8 ±0.08	1.2 ±0.10	69 ±1.0	1500 ±10	0.58±0.06	12 ±0.40
B30C	6-12	1.5 ±0.06	1.1 ±0.10	11 ±0.26	230 ±3.8	0.20±0.03	0.01±0.01
B31A	0-2	1.5 ±0.08	1.0 ±0.12	26 ±0.40	550 ±6.0	0.29±0.06	0.01±0.01
B31B	2-6	1.7 ±0.13	1.3 ±0.17	60 ±0.76	1300 ±11	0.70±0.08	0.01±0.01
B31C	6-12	1.6 ±0.06	1.4 ±0.09	5.8 ±0.28	140 ±5.1	0.04±0.03	19 ±0.70
B32A	0-2	81 ±0.66	77 ±0.58	61 ±1.3	880 ±15	0.38±0.13	<0.01
B32B	2-6	58 ±0.44	59 ±1.2	23 ±1.1	280 ±12	0.40±0.13	0.01±0.01
B33	0-2	0.89±0.05	1.0 ±0.29	280 ±0.97	280 ±5.1	1.8 ±0.06	0.01±0.01
<i>Systematic<sup>d</sup></i>							
S1A	0-6	1.7 ±0.03	1.2 ±0.04	0.08±0.04	1.9 ±0.85	<0.01	14 ±0.37
S1B	6-12	1.7 ±0.02	1.3 ±0.08	0.07±0.04	3.0 ±0.53	<0.01	13 ±0.28
S2A	0-6	1.5 ±0.02	1.3 ±0.03	0.09±0.05	2.2 ±0.76	<0.01	16 ±0.31
S2B	6-12	1.5 ±0.02	1.3 ±0.03	<0.06	2.3 ±0.86	<0.01	17 ±0.29
S3A	0-6	1.4 ±0.03	1.1 ±0.04	<0.08	1.8 ±1.1	0.09±0.01	12 ±0.31
S3B	6-12	1.5 ±0.03	1.1 ±0.04	0.14±0.05	1.6 ±0.85	0.13±0.01	13 ±0.38
S4A	6-12	0.93±0.02	0.64±0.02	0.05±0.03	1.3 ±0.32	0.02±0.01	8.1 ±0.20
S4B	6-12	1.1 ±0.03	0.82±0.04	<0.05	2.3 ±1.1	0.10±0.01	8.3 ±0.32

Table 3. (continued)

Sample <sup>a</sup>	Depth (in)	Radionuclide concentration (pCi/g) <sup>b</sup>					
		<sup>226</sup> Ra	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U	<sup>137</sup> Cs	<sup>40</sup> K
S5A	0-6	1.5 ±0.03	1.0 ±0.04	0.08±0.04	1.5 ±0.90	0.04±0.01	12 ±0.35
S5B	6-12	1.6 ±0.02	1.2 ±0.04	0.08±0.05	2.1 ±0.55	0.04±0.01	13 ±0.30
S6A	0-6	1.5 ±0.02	1.2 ±0.03	<0.07	1.5 ±0.59	0.01±0.01	13 ±0.25
S6B	6-12	1.5 ±0.03	1.3 ±0.06	<0.05	2.7 ±0.95	0.04±0.01	13 ±0.35
S7A	0-6	1.4 ±0.02	1.1 ±0.07	<0.05	1.8 ±0.84	0.02±0.01	12 ±0.31
S7B	6-12	1.3 ±0.02	1.1 ±0.03	0.10±0.06	1.6 ±0.73	0.03±0.01	12 ±0.33
S8A	0-6	1.3 ±0.02	1.3 ±0.03	0.07±0.04	1.4 ±0.46	0.03±0.01	16 ±0.31
S8B	6-12	1.3 ±0.02	1.1 ±0.03	<0.04	1.2 ±0.43	0.11±0.01	12 ±0.25
S9A	0-6	1.3 ±0.02	1.1 ±0.04	<0.05	2.0 ±0.72	0.03±0.01	14 ±0.34
S9B	6-12	1.3 ±0.02	1.1 ±0.03	0.07±0.05	1.3 ±0.84	0.01±0.01	14 ±0.29
S10A	0-6	1.3 ±0.03	1.0 ±0.04	<0.05	1.4 ±0.75	<0.01	13 ±0.34
S10B	6-12	1.7 ±0.03	1.4 ±0.04	0.12±0.04	3.0 ±1.2	0.01±0.01	18 ±0.34
S11A	0-6	1.4 ±0.02	1.2 ±0.03	<0.04	2.0 ±0.47	0.04±0.01	16 ±0.31
S11B	6-12	1.3 ±0.03	1.3 ±0.04	0.04±0.05	1.9 ±0.67	0.03±0.01	17 ±0.41
S12A	0-6	1.3 ±0.02	1.3 ±0.10	<0.07	1.8 ±1.0	0.02±0.01	19 ±0.34
S12B	6-12	1.4 ±0.02	1.2 ±0.04	<0.07	1.1 ±0.87	<0.02	16 ±0.31
S12C	12-18	1.4 ±0.02	1.2 ±0.04	<0.04	1.7 ±0.52	0.01±0.01	16 ±0.31
S13A	0-6	1.6 ±0.03	1.4 ±0.03	<0.08	2.0 ±0.93	<0.02	14 ±0.30
S13B	6-12	1.4 ±0.02	1.4 ±0.03	<0.07	2.0 ±0.72	<0.01	13 ±0.29
S14A	0-6	1.2 ±0.02	1.1 ±0.03	<0.04	2.2 ±0.51	<0.01	12 ±0.26
S14B	6-12	1.5 ±0.02	1.4 ±0.04	<0.08	2.7 ±1.0	<0.01	13 ±0.29
S15A	0-6	0.67±0.02	0.39±0.03	<0.03	1.1 ±0.50	<0.01	4.9 ±0.20
S15B	6-12	0.79±0.02	0.64±0.02	<0.05	1.6 ±0.71	<0.01	5.6 ±0.17
S16A	0-6	1.3 ±0.02	1.1 ±0.03	<0.05	1.5 ±0.82	0.02±0.01	11 ±0.33
S16B	6-12	1.4 ±0.02	1.1 ±0.03	0.06±0.03	1.7 ±0.37	0.01±0.01	12 ±0.26
S17A	0-6	1.2 ±0.03	0.76±0.02	<0.05	1.2 ±0.62	0.04±0.01	0.01±0.01
S17B	6-12	0.87±0.02	0.53±0.03	0.17±0.09	0.80±0.31	0.08±0.01	5.9 ±0.22
S18A	0-6	1.0 ±0.03	0.84±0.03	0.09±0.04	2.0 ±0.73	<0.01	8.2 ±0.30
S18B	6-12	1.3 ±0.02	1.1 ±0.03	<0.06	1.5 ±0.75	<0.01	10 ±0.24
S19A	0-6	1.1 ±0.02	0.92±0.03	0.06±0.03	1.7 ±0.47	0.02±0.01	12 ±0.26
S19B	6-12	1.1 ±0.02	0.91±0.03	0.06±0.04	1.1 ±0.38	0.03±0.01	12 ±0.25
S20A	0-6	1.3 ±0.02	0.92±0.03	0.17±0.10	1.2 ±0.35	0.03±0.01	11 ±0.24
S20B	6-12	1.2 ±0.02	0.99±0.03	<0.06	1.4 ±0.73	<0.01	11 ±0.23
S21A	0-6	1.2 ±0.02	1.2 ±0.04	<0.06	1.3 ±0.78	0.02±0.01	11 ±0.33
S21B	6-12	1.3 ±0.04	1.1 ±0.04	0.06±0.04	1.2 ±0.55	0.02±0.01	0.01±0.01
S22A	0-6	1.3 ±0.02	1.1 ±0.03	<0.05	1.4 ±0.40	0.02±0.01	13 ±0.27
S22B	6-12	1.4 ±0.02	1.0 ±0.03	0.08±0.04	1.5 ±0.73	0.03±0.01	12 ±0.23
S23A	0-6	1.2 ±0.02	1.1 ±0.03	0.09±0.04	1.4 ±0.92	0.03±0.01	13 ±0.33
S23B	6-12	1.3 ±0.02	1.1 ±0.03	<0.06	1.6 ±0.84	0.03±0.01	14 ±0.27
S24A	0-6	1.6 ±0.05	1.5 ±0.12	<0.08	1.3 ±0.75	0.04±0.01	0.01±0.01
S24B	6-12	1.3 ±0.02	1.1 ±0.04	<0.07	2.2 ±0.94	0.06±0.02	13 ±0.34
S25A	0-6	1.6 ±0.05	1.4 ±0.04	<0.07	1.8 ±0.82	0.04±0.01	0.01±0.01
S25B	6-12	1.3 ±0.03	1.1 ±0.04	<0.05	2.1 ±0.98	0.04±0.01	13 ±0.37
S26A	0-6	1.3 ±0.02	1.2 ±0.03	<0.07	1.8 ±0.76	0.02±0.01	15 ±0.28
S26B	6-12	1.4 ±0.04	1.4 ±0.07	<0.12	3.0 ±1.8	<0.03	18 ±0.61
S27A	0-6	1.2 ±0.02	1.1 ±0.03	0.06±0.03	1.3 ±0.44	<0.01	15 ±0.28
S27B	6-12	1.2 ±0.02	0.96±0.04	0.06±0.04	1.9 ±0.72	<0.01	12 ±0.31
S28A	0-6	1.6 ±0.04	1.2 ±0.03	<0.05	1.1 ±0.66	0.04±0.01	0.01±0.01
S28B	6-12	1.3 ±0.02	1.1 ±0.04	<0.05	1.8 ±0.91	0.02±0.01	12 ±0.33
S29A	0-6	1.3 ±0.03	1.0 ±0.05	0.06±0.06	1.6 ±0.86	0.13±0.02	11 ±0.46
S29B	6-12	1.1 ±0.02	0.78±0.03	0.03±0.04	1.2 ±0.73	0.04±0.01	9.5 ±0.28

Table 3. (continued)

Sample <sup>a</sup>	Depth (in)	Radionuclide concentration (pCi/g) <sup>b</sup>					
		<sup>226</sup> Ra	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U	<sup>137</sup> Cs	<sup>40</sup> K
S30A	0-6	1.2 ±0.02	1.2 ±0.03	0.09±0.05	1.7 ±0.80	0.01±0.01	13 ±0.34
S30B	6-12	1.3 ±0.02	1.3 ±0.04	0.10±0.04	1.5 ±0.78	<0.01	13 ±0.36
S31A	0-6	1.3 ±0.04	1.4 ±0.06	0.10±0.07	2.0 ±0.89	<0.02	13 ±0.50
S31B	6-12	1.1 ±0.02	1.1 ±0.03	<0.05	1.8 ±0.76	<0.01	9.1 ±0.25
S31C	12-18	1.2 ±0.04	1.1 ±0.07	<0.12	2.1 ±1.5	<0.02	11 ±0.53
S31D	18-24	1.1 ±0.02	1.1 ±0.03	0.08±0.03	1.5 ±0.34	0.01±0.01	13 ±0.24
S32A	0-6	0.74±0.01	0.54±0.06	<0.04	1.3 ±0.48	0.26±0.01	5.6 ±0.16
S32B	6-12	0.85±0.02	0.64±0.02	<0.05	0.90±0.50	0.06±0.008	6.6 ±0.22
S33A	0-6	1.7 ±0.05	1.6 ±0.06	<0.06	1.6 ±0.79	0.02±0.01	0.01±0.01
S33B	6-12	1.5 ±0.02	1.4 ±0.04	<0.06	1.6 ±0.79	0.02±0.01	17 ±0.29
S33C	12-18	1.6 ±0.03	1.5 ±0.04	0.10±0.06	3.0 ±1.1	<0.02	20 ±0.41
S34A	0-6	0.78±0.02	0.48±0.03	<0.04	1.3 ±0.68	0.44±0.02	5.8 ±0.22
S34B	6-12	1.1 ±0.02	1.1 ±0.03	<0.06	1.5 ±0.70	0.16±0.01	14 ±0.26
S35A	0-6	1.4 ±0.02	1.2 ±0.03	<0.08	1.8 ±0.80	0.02±0.01	12 ±0.29
S35B	6-12	1.3 ±0.02	1.2 ±0.03	0.06±0.04	1.7 ±0.48	<0.01	12 ±0.27
S36A	0-6	1.2 ±0.02	0.92±0.03	0.10±0.04	2.0 ±1.0	0.13±0.01	11 ±0.26
S36B	6-12	1.0 ±0.02	0.75±0.04	0.08±0.04	1.2 ±0.66	0.33±0.02	8.2 ±0.27
S37A	0-6	0.92±0.02	0.69±0.02	0.07±0.03	1.1 ±0.37	0.02±0.006	9.2 ±0.21
S37B	6-12	1.1 ±0.02	0.84±0.03	0.06±0.03	1.5 ±0.41	0.06±0.01	9.7 ±0.23
S38A	0-6	0.88±0.01	0.63±0.02	0.07±0.03	1.3 ±0.37	0.03±0.01	8.3 ±0.21
S38B	6-12	0.99±0.02	0.75±0.02	0.17±0.07	1.3 ±0.36	0.03±0.01	11 ±0.25
S39A	0-6	1.2 ±0.04	1.0 ±0.05	<0.06	1.4 ±0.62	0.03±0.01	0.01±0.01
S39B	6-12	1.2 ±0.02	1.0 ±0.03	<0.07	1.3 ±0.80	0.06±0.01	10 ±0.24
S40A	0-6	1.4 ±0.02	1.1 ±0.03	0.08±0.04	2.1 ±0.58	0.41±0.01	13 ±0.28
S41A	0-6	1.7 ±0.05	1.6 ±0.14	0.19±0.06	1.4 ±0.74	0.23±0.02	0.01±0.01
S41B	6-12	1.4 ±0.02	1.4 ±0.03	<0.07	1.4 ±0.75	0.03±0.01	13 ±0.27
S42A	0-6	1.4 ±0.03	1.3 ±0.04	0.12±0.06	1.4 ±0.74	0.15±0.01	11 ±0.34
S42B	6-12	1.4 ±0.03	1.2 ±0.04	<0.05	1.6 ±0.66	0.02±0.01	12 ±0.32
S43A	0-6	1.5 ±0.02	1.3 ±0.03	0.09±0.04	1.5 ±0.73	0.44±0.01	13 ±0.27
S43B	6-12	1.3 ±0.04	1.2 ±0.09	<0.05	1.5 ±0.59	0.04±0.01	0.01±0.01
S44A	0-6	1.2 ±0.03	1.2 ±0.10	0.33±0.05	1.5 ±0.65	0.02±0.01	0.01±0.01
S44B	6-12	1.5 ±0.02	1.3 ±0.03	<0.07	2.2 ±1.0	<0.01	11 ±0.32
S45A	0-6	1.7 ±0.03	1.3 ±0.05	0.19±0.05	2.3 ±0.81	0.05±0.01	11 ±0.36
S45B	6-12	1.6 ±0.03	1.2 ±0.04	0.09±0.05	1.9 ±0.90	0.04±0.01	11 ±0.35
S46A	0-6	1.6 ±0.02	1.2 ±0.04	<0.06	1.9 ±0.79	0.07±0.01	12 ±0.32
S46B	6-12	1.7 ±0.03	1.3 ±0.04	0.08±0.04	2.0 ±0.91	0.05±0.01	11 ±0.33
S47A	0-6	1.4 ±0.02	1.3 ±0.03	0.10±0.04	2.2 ±0.45	0.03±0.01	13 ±0.28
S47B	6-12	1.5 ±0.02	1.4 ±0.03	0.08±0.04	1.7 ±0.46	<0.01	14 ±0.29
S48A	0-6	1.4 ±0.02	1.1 ±0.04	0.27±0.12	1.6 ±0.45	0.13±0.01	12 ±0.28
S48B	6-12	1.4 ±0.02	1.3 ±0.03	0.06±0.04	1.6 ±0.73	0.07±0.01	12 ±0.26
S49A	0-6	1.2 ±0.02	0.91±0.03	0.11±0.04	2.1 ±0.75	0.05±0.01	9.2 ±0.22
S49B	6-12	1.7 ±0.02	1.5 ±0.04	0.06±0.04	2.0 ±0.62	<0.01	18 ±0.35
S50A	0-6	1.5 ±0.02	1.2 ±0.03	0.10±0.04	1.9 ±0.49	0.03±0.01	14 ±0.29
S50B	6-12	1.5 ±0.02	1.2 ±0.03	<0.07	1.5 ±0.66	0.06±0.01	13 ±0.26
S51A	0-6	1.6 ±0.03	1.3 ±0.05	0.21±0.17	2.1 ±0.59	0.04±0.01	14 ±0.41
S51B	6-12	1.8 ±0.06	1.4 ±0.13	0.13±0.07	2.0 ±0.78	0.09±0.03	0.01±0.01
S52A	0-6	1.7 ±0.03	1.3 ±0.05	0.08±0.04	2.2 ±0.95	0.07±0.01	14 ±0.39
S52B	6-12	1.7 ±0.03	1.3 ±0.03	<0.05	1.6 ±0.47	0.13±0.01	13 ±0.29
S53A	0-6	1.4 ±0.03	1.2 ±0.04	<0.05	1.5 ±0.71	0.03±0.01	12 ±0.35
S53B	6-12	1.6 ±0.02	1.3 ±0.03	<0.05	1.9 ±0.53	0.01±0.01	13 ±0.26
S54A	0-6	1.5 ±0.02	1.1 ±0.03	0.08±0.05	1.9 ±0.66	0.37±0.01	11 ±0.25

Table 3. (continued)

Sample <sup>a</sup>	Depth (in)	Radionuclide concentration (pCi/g) <sup>b</sup>					
		<sup>226</sup> Ra	<sup>232</sup> Th	<sup>235</sup> U	<sup>238</sup> U	<sup>137</sup> Cs	<sup>40</sup> K
S54B	6-12	1.4 ±0.02	1.2 ±0.03	<0.04	1.6 ±0.40	0.03±0.01	12 ±0.26
S55A	0-6	1.1 ±0.03	0.55±0.07	<0.05	1.2 ±0.46	0.30±0.01	0.01±0.01
S55B	6-12	1.4 ±0.03	0.99±0.05	0.36±0.17	1.2 ±0.69	0.05±0.02	10 ±0.42
S56A	0-6	1.4 ±0.03	0.91±0.04	0.09±0.05	1.6 ±0.80	0.14±0.01	9.5 ±0.31
S56B	6-12	1.0 ±0.02	0.67±0.02	0.06±0.03	0.97±0.55	0.11±0.01	6.8 ±0.18
S57	0-6	2.3 ±0.03	1.4 ±0.04	0.11±0.05	2.3 ±0.51	0.11±0.01	11 ±0.28
S58	0-6	2.5 ±0.07	0.48±0.02	<0.07	1.9 ±0.75	0.45±0.02	0.01±0.01
S59	0-6	1.9 ±0.02	1.2 ±0.03	0.11±0.04	1.3 ±0.42	0.36±0.01	13 ±0.29
S60	0-6	1.7 ±0.06	1.2 ±0.03	<0.08	2.0 ±0.87	0.17±0.01	0.01±0.01
S61	0-6	1.7 ±0.03	1.3 ±0.03	0.10±0.05	1.9 ±0.50	0.26±0.01	13 ±0.30
S62	0-6	1.6 ±0.03	1.1 ±0.05	0.29±0.06	3.7 ±0.71	0.91±0.03	12 ±0.35
S63	0-6	1.6 ±0.03	1.2 ±0.04	0.13±0.06	1.7 ±1.1	0.29±0.02	13 ±0.37
S64	0-6	1.5 ±0.02	1.2 ±0.03	0.11±0.04	1.7 ±0.44	0.31±0.01	13 ±0.27
S65	0-6	1.6 ±0.03	1.3 ±0.05	0.46±0.06	4.4 ±0.97	0.48±0.02	13 ±0.34
S66	0-6	1.5 ±0.02	0.99±0.03	0.22±0.04	2.2 ±0.44	0.51±0.01	11 ±0.25
S67	0-6	1.6 ±0.02	1.3 ±0.04	0.29±0.05	2.3 ±0.73	0.41±0.01	14 ±0.27
S68	0-6	1.3 ±0.03	0.97±0.04	0.30±0.07	1.6 ±0.97	0.60±0.02	0.01±0.01
S69	0-6	1.7 ±0.03	1.4 ±0.03	0.06±0.04	2.0 ±0.81	0.64±0.02	14 ±0.30
S70	0-6	1.4 ±0.02	1.2 ±0.03	0.10±0.05	1.9 ±0.76	0.63±0.02	14 ±0.28
S71	0-6	1.5 ±0.03	1.3 ±0.04	0.18±0.05	1.8 ±0.70	0.28±0.02	14 ±0.34
S72	0-6	1.6 ±0.03	1.5 ±0.04	<0.06	1.7 ±1.0	0.45±0.02	15 ±0.36
S73A	0-6	0.56±0.01	0.17±0.01	0.04±0.02	0.54±0.24	0.48±0.01	3.4 ±0.13
S73B	6-12	1.1 ±0.02	0.78±0.03	0.05±0.03	1.3 ±0.41	0.14±0.01	8.4 ±0.23
S74	0-6	1.4 ±0.05	1.5 ±0.08	<0.11	2.6 ±1.8	0.34±0.03	19 ±0.68
S75	0-6	0.76±0.02	0.23±0.02	0.07±0.03	0.90±0.50	0.23±0.01	5.0 ±0.15
S76	0-6	1.5 ±0.03	1.7 ±0.04	0.16±0.05	1.9 ±0.52	0.22±0.01	32 ±0.46
S77	0-6	0.53±0.01	0.17±0.02	<0.02	0.75±0.25	0.42±0.01	3.5 ±0.12
S78	0-6	0.54±0.02	0.16±0.02	<0.04	0.51±0.39	0.45±0.01	0.01±0.01
S79	0-6	1.3 ±0.03	1.3 ±0.04	0.09±0.05	2.2 ±1.1	0.84±0.02	17 ±0.41
S80A	0-6	1.7 ±0.03	1.7 ±0.04	1.3 ±0.07	6.5 ±1.2	0.70±0.02	28 ±0.42
S80B	6-12	1.5 ±0.03	1.9 ±0.04	0.16±0.06	1.5 ±1.1	0.17±0.01	35 ±0.46
S81	0-6	1.5 ±0.03	1.4 ±0.04	0.28±0.06	2.5 ±0.94	0.28±0.02	11 ±0.31
S82	0-6	0.93±0.03	0.54±0.03	0.18±0.04	1.0 ±0.56	0.45±0.01	0.01±0.01
S83	0-6	1.3 ±0.02	1.0 ±0.03	0.12±0.04	1.6 ±0.38	0.35±0.01	12 ±0.26
S84	0-6	1.5 ±0.02	1.3 ±0.03	0.12±0.05	2.2 ±0.86	0.51±0.02	11 ±0.25
S85	0-6	1.5 ±0.02	1.2 ±0.03	0.11±0.04	1.6 ±0.43	0.87±0.02	13 ±0.27

<sup>a</sup>Locations of soil samples are shown on Figs. 7, 8, and 9.

<sup>b</sup>Indicated counting error is at the 95% confidence level ( $\pm 2 \sigma$ ).

<sup>c</sup>Biased samples are taken from areas with elevated gamma exposure rates.

<sup>d</sup>Systematic samples are taken from areas irrespective of gamma exposure rates.

**Table 4. Areas exceeding 5480.11 surface contamination guidelines at PORTS, Piketon, Ohio**

Area location (size) <sup>a</sup>	Directly measured contamination <sup>b,c</sup>		Removable contamination	
	Alpha (dpm/100 cm <sup>2</sup> )	Beta-gamma <sup>d</sup> (dpm/100 cm <sup>2</sup> )	Alpha (dpm/100 cm <sup>2</sup> )	Beta-gamma (dpm/100 cm <sup>2</sup> )
1. Bldg. X-770 east side blower assembly (1-2 m <sup>2</sup> )	6100	900,000	<25	<200
2. Bldg. X-746, east side loading dock (~12 m <sup>2</sup> )	33,000-140,000	70,000	1500	1000
3. Bldg. X-720, east side by E-9 concrete pad used for cylinder storage (~5 m <sup>2</sup> )	3500-260,000	200,000	<25	<200
4. Between Bldg. X-700 & Bldg. X-705, south parking lot (0.6 m <sup>2</sup> )	14,000	300,000	<25	<200
5. Bldg. X-705 & Bldg. X-705A, extensive high-level contamination around and on building (6800 m <sup>2</sup> )	5000-1,000,000	2,000,000 (100,000 with paper alpha shield)	200-4200	200-4200

<sup>a</sup>Areas are shown on Figs. 7 and 8.

<sup>b</sup>Numbers represent either a maximum value or a range of values for the area. The respective minimum detectable activity levels for directly measured alpha and beta-gamma contamination levels are 100 and 1000 dpm/100 cm<sup>2</sup>.

<sup>c</sup>Measurements of removable radioactivity are net disintegration rates. Background radiation levels have been subtracted. The MDAs for removable alpha and beta-gamma contamination levels are 25 and 200 dpm/100 cm<sup>2</sup>.

<sup>d</sup>A conversion factor of 20 dpm/100 cm<sup>2</sup> per cpm was used to convert cpm to dpm/100 cm<sup>2</sup> assuming depleted uranium. Actual beta-gamma activity levels may be lower.

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