ANL/EAIS/TM-89

Postremediation Dose Assessment for the Elza Gate Site, Oak Ridge, Tennessee

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by M. Nimmagadda and C. Yu

Environmental Assessment and Information Sciences Division,
Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

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The following is a list of acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEC	U.S. Atomic Energy Commission
BNI	Bechtel National, Inc.
DOE	U.S. Department of Energy
FUSRAP	Formerly Utilized Sites Remedial Action Program
MED	Manhattan Engineer District
MSL	mean sea level
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
PCB	polychlorinated biphenyl

UNITS OF MEASURE

cm	centimeter(s)
cm^2	square centimeter(s)
cm^3	cubic centimeter(s)
d	day(s)
dpm	disintegrations per minute
ft	foot (feet)
g	gram(s)
h	hour(s)
ha	hectare(s)
in.	inch(es)
kg	kilogram(s)
km	kilometer(s)
L	liter(s)
m	meter(s)
m^2	square meter(s)
m^3	cubic meter(s)
mi	mile(s)
mrem	millirem(s)
pCi	picocurie(s)
s	second(s)
yd^3	cubic yard(s)
yr	year(s)

POSTREMEDIATION DOSE ASSESSMENT FOR THE ELZA GATE SITE, OAK RIDGE, TENNESSEE

by

M. Nimmagadda and C. Yu

ABSTRACT

Potential maximum radiation dose rates were calculated for the Elza Gate site in Oak Ridge, Tennessee. The RESRAD computer code, which implements the methodology described in the U.S. Department of Energy's manual for implementing residual radioactive material guidelines, was used in this evaluation. Currently, the site is not being used. Four potential future use scenarios were considered for the Elza Gate site; the scenarios vary with regard to time spent at the site, sources of water used, and sources of food consumed. In Scenario A (the expected scenario), industrial use of the site is assumed; in Scenario B (a plausible scenario), recreational use of the site is assumed. Both Scenarios C and D (possible but unlikely scenarios) assume the presence of a resident farmer in the immediate vicinity of the site. The difference between Scenarios C and D is the source of water used. For Scenario C, an adjacent pond provides 100% of the water for drinking, irrigation, and raising livestock; for Scenario D, groundwater drawn from a well located at the downgradient edge of the contaminated zone is the only source of water for drinking, irrigation, and raising livestock. The results of the evaluation indicate that the U.S. Department of Energy dose limit of 100 mrem/yr would not be exceeded for any scenario. The potential maximum dose rates for Scenarios A, B, C, and D are 1.5, 0.66, 12, and 42 mrem/yr, respectively.

1 INTRODUCTION AND HISTORY

The Elza Gate site in Oak Ridge, Tennessee, is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a U.S. Department of Energy (DOE) program for decontaminating or otherwise controlling sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. Elza Gate is a FUSRAP site not owned by DOE.

The Elza Gate site is located in Oak Ridge, Tennessee (Figure 1). Remedial action was conducted at the site in 1991 and 1992. Postremedial action surveys and soil samples

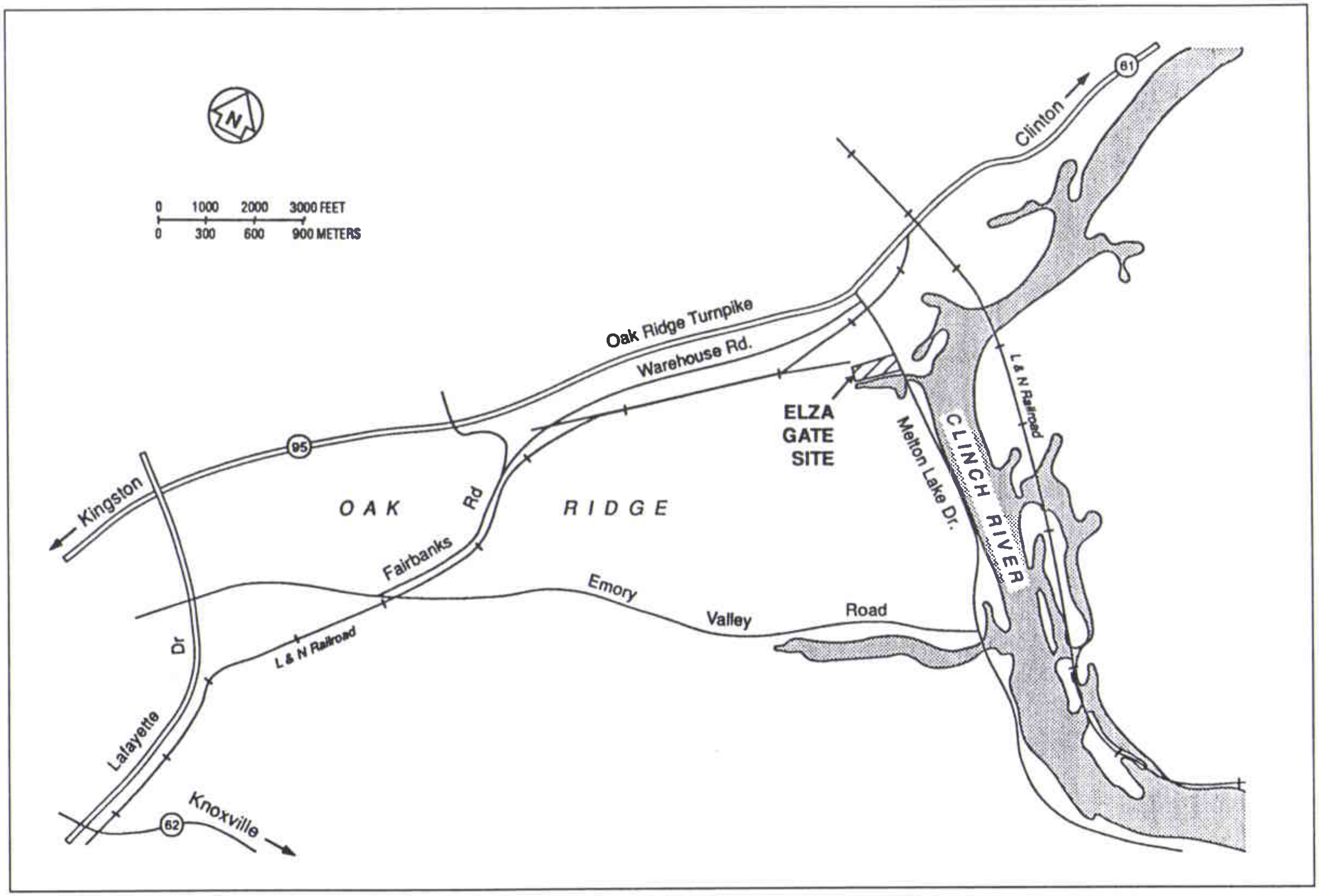

FIGURE 1 Location of the Elza Gate Site (Source: BNI 1992)

confirm that no radioactivity exceeding DOE guidelines remains in the remediated areas (Bechtel National, Inc. [BNI] 1992). In addition, an independent verification survey confirmed that the site was adequately characterized to identify the types and areal extent of contaminants and that remedial actions were effective in reducing contamination to levels below the DOE guidelines and authorized limits (Vitkus and Bright 1992). The purpose of this report is to calculate potential maximum radiation dose rates for both present and possible future use conditions on the basis of postremediation concentration levels. The RESRAD computer code, which implements the methodology described in DOE's manual for implementing residual radioactive material guidelines (Gilbert et al. 1989), was used to perform a dose assessment for the Elza Gate site.

1.1 SITE DESCRIPTION AND SETTING

The Elza Gate site covers about 8 ha (20 acres) in the southeastern part of the city of Oak Ridge, Tennessee, near the intersection of Melton Lake Drive and Oak Ridge Turnpike (Figure 1). Access to the site is unrestricted. The site became contaminated with radioactive materials when the Manhattan Engineer District (MED) and, subsequently, the U.S. Atomic Energy Commission (AEC) stored uranium ore and ore-processing residues there between 1940 and 1972. Polychlorinated biphenyls (PCBs) found on the site resulted from the storage of electrical equipment by DOE predecessor agencies. The site, also known as the Melton Lake Industrial Park, is owned by MECO, a real estate development company. Currently, the site is not being used; however, MECO is developing it for future use as an industrial park.

The regional topography is characterized by a series of northeast-southwest trending ridges and intervening valleys. The ridges are breached at irregular intervals by stream channels that otherwise follow the trend of the valleys. Ridges in the area reach elevations of approximately 300 m (1,000 ft) above mean sea level (MSL). The elevation of the Elza Gate site is approximately 250 m (820 ft) above MSL; it is about 150 m (500 ft) from the western shore of a tributary of the Clinch River (Figure 1). The Clinch River, which eventually discharges into the Tennessee River, is the source of most of the water used in the Oak Ridge area. The Melton Hill Reservoir lies south of the site (Figure 2). The site lies outside the 100-year floodplain (Poligone 1990). Soils in the site area are sandy loams.

The climate at Oak Ridge is warm and humid. Summers are dominated by warm, moist air from the Gulf of Mexico. In the winter, cold, dry air masses from Canada are warmed as the air crosses the Cumberland Mountains and moves down the eastern slopes to the Oak Ridge area. Precipitation averages 140 cm (55 in.) annually; the relative humidity averages 70%. The maximum 24-hour rainfall is about 20 cm (8 in.). Approximately 70% of the average annual precipitation is lost through evapotranspiration; the rest becomes runoff to surface waters and recharge to the groundwater. Snow is infrequent but sometimes falls in sufficient quantity to hinder traffic and outdoor activities. Winds on the ridges blow predominantly from the southwest, although winds from the northeast are also frequent. Remnants of hurricanes and tropical storms occasionally affect the area.

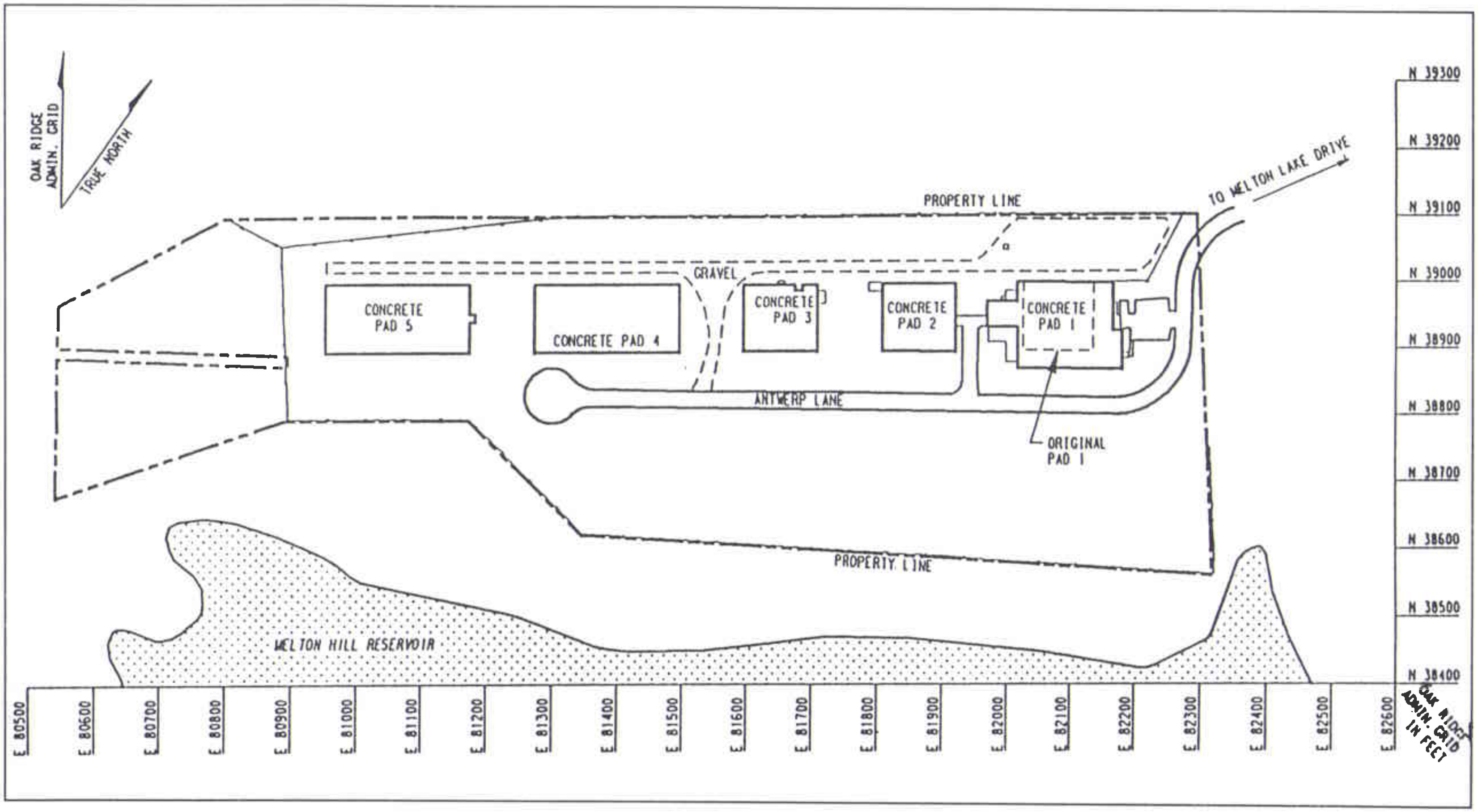

FIGURE 2 Plan View of the Elza Gate Site (Source: DOE 1991)

1.2 SITE HISTORY

During the 1940s, the MED stored pitchblende (a high-grade uranium ore from Africa), residue from ore processing, and other radioactive material at the Elza Gate site. Originally, the site housed five warehouses, at least three of which stored radioactive material. In 1946, ownership of the site passed to the AEC, which used the warehouses for storage until they were vacated in 1972. During the MED/AEC era, the complex was accessed by a railroad spur to the southeast and by a road that entered from what is now Melton Lake Drive. The railroad spur has since been removed.

After a radiological survey and decontamination by Oak Ridge National Laboratory (ORNL) in 1972, it was recommended that the site be released for use without radiological restrictions (Sapirie 1972). The original warehouse buildings were removed; however, the concrete pads were left in place (Figure 2). The property was then relinquished by the AEC in 1972, and the city of Oak Ridge assumed title to the property. That same year, the city sold the property to Jet Air, Inc., which operated a fabricating and metal plating facility on the site. Jet Air, in turn, sold the property to MECO in 1988.

In 1987, at the request of the Tennessee Department of Health and Environment, Oak Ridge Associated Universities (ORAU) conducted a survey at the site because of the possibility of contamination from the Jet Air metal plating facility (Egli 1988). The survey confirmed the presence of heavy metal contamination. In addition, uranium was discovered in the soil at concentrations above background levels.

In 1988, MECO added offices to the structure on Pad 1 built by Jet Air and constructed a new access road to develop the property for lease and sale as an industrial park (Figure 2). In October and November 1988, the pad area along Antwerp Lane was radiologically surveyed by the Measurement Applications and Development Group of ORNL (Cottrell et al. 1989). This area and the original site access road were found to exceed DOE's radiological criteria for unrestricted use of a site, making the site eligible for inclusion in FUSRAP. On November 30, 1988, the entire Melton Lake Industrial Park was authorized for inclusion in FUSRAP (Fiore 1988).

In 1989 and 1990, comprehensive radiological, chemical, and hydrogeological characterization activities were conducted at the Elza Gate site to determine the boundaries of contamination that exceed DOE guidelines. In general, these surveys indicated levels of radioactive contamination exceeding DOE guidelines around the edges of the concrete pads, in the cul-de-sac of the access road, and in several other small areas on the site (BNI 1991). Remedial action was conducted at the site in 1991 and 1992 on the basis of these characterization data.

1.3 SUMMARY OF REMEDIAL ACTION ACTIVITIES

The DOE remedial action guidelines for alpha activity on concrete surfaces are 5,000 dpm/100 cm^2 average, 15,000 dpm/100 cm^2 maximum, and 1,000 dpm/100 cm^2 removable (DOE 1990). The DOE guidelines for radium-226, thorium-232, and thorium-230 concentrations in soil are 5 pCi/g when averaged over the first 15 cm (6 in.) of soil below the surface and 15 pCi/g when averaged over any soil layer 15 cm (6 in.) thick below the surface layer, excluding background concentrations (DOE 1990, 1992). For uranium-238, a site-specific guideline of 35 pCi/g was derived (Wagoner 1991). Where contamination exceeded applicable guidelines, remedial action was conducted until measurements indicated that DOE guidelines had been met.

Remedial action at the Elza Gate site was conducted in two phases. Details of the remedial action sampling are provided by BNI (1992). The estimated dose to the remedial action workers is given by DOE (1991). Phase I consisted of removing the original concrete Pad 1, excavating contaminated soil beneath the pad, and excavating soil from five other areas outside the building (Figure 3). The soil beneath Pad 1 was removed to a depth of approximately 0.5 m (1.5 ft). The five remediated areas outside the industrial building were excavated to the depths indicated in Figure 3. In 1992, a new concrete pad was laid in the area of the preexisting concrete Pad 1 (Keller 1993). A total of 373 m^3 (488 yd^3) of contaminated soil was removed from beneath Pad 1; 112 m^3 (146 yd^3) was removed from the five areas outside the building (BNI 1992). Phase II of the remedial action consisted of completely removing concrete Pads 2, 3, and 4 (including their associated foundations), removing a small section of Pad 5, and excavating contaminated soil from beneath the pads and at other locations across the site (Duffy 1991). Figure 4 shows the areas of radioactive contamination remediated during Phase II. The maximum depth of radioactive contamination was 2.1 m (7 ft).

All contaminated concrete and soil removed during both phases of remedial action was transported to the DOE Oak Ridge Reservation and used as fill material in the closure of the United Nuclear Corporation disposal site. Approximately 5,124 m^3 (6,700 yd^3) of material was taken to the disposal site (Wagoner 1991). The structures that currently exist at the site include the building, the concrete pad laid on the perimeter of the original concrete Pad 1, the new concrete pad laid in the area of the preexisting concrete Pad 1, concrete Pad 5, and Antwerp Lane Road (Keller 1993).

Radiological surveys were conducted as remedial actions were completed to confirm that no radioactivity exceeding DOE guidelines remained in the remediated areas. These surveys included direct surface measurements on the concrete pads and analysis of soil samples collected from excavated areas. Survey results indicated that the areas identified as exceeding guidelines during characterization activities were successfully brought into compliance with applicable DOE cleanup guidelines for radioactive contamination (BNI 1992; Vitkus and Bright 1992). Compliance with U.S. Environmental Protection Agency guidelines for chemical contamination was also achieved during cleanup of areas contaminated with lead and PCBs (BNI 1992; Vitkus and Bright 1992).

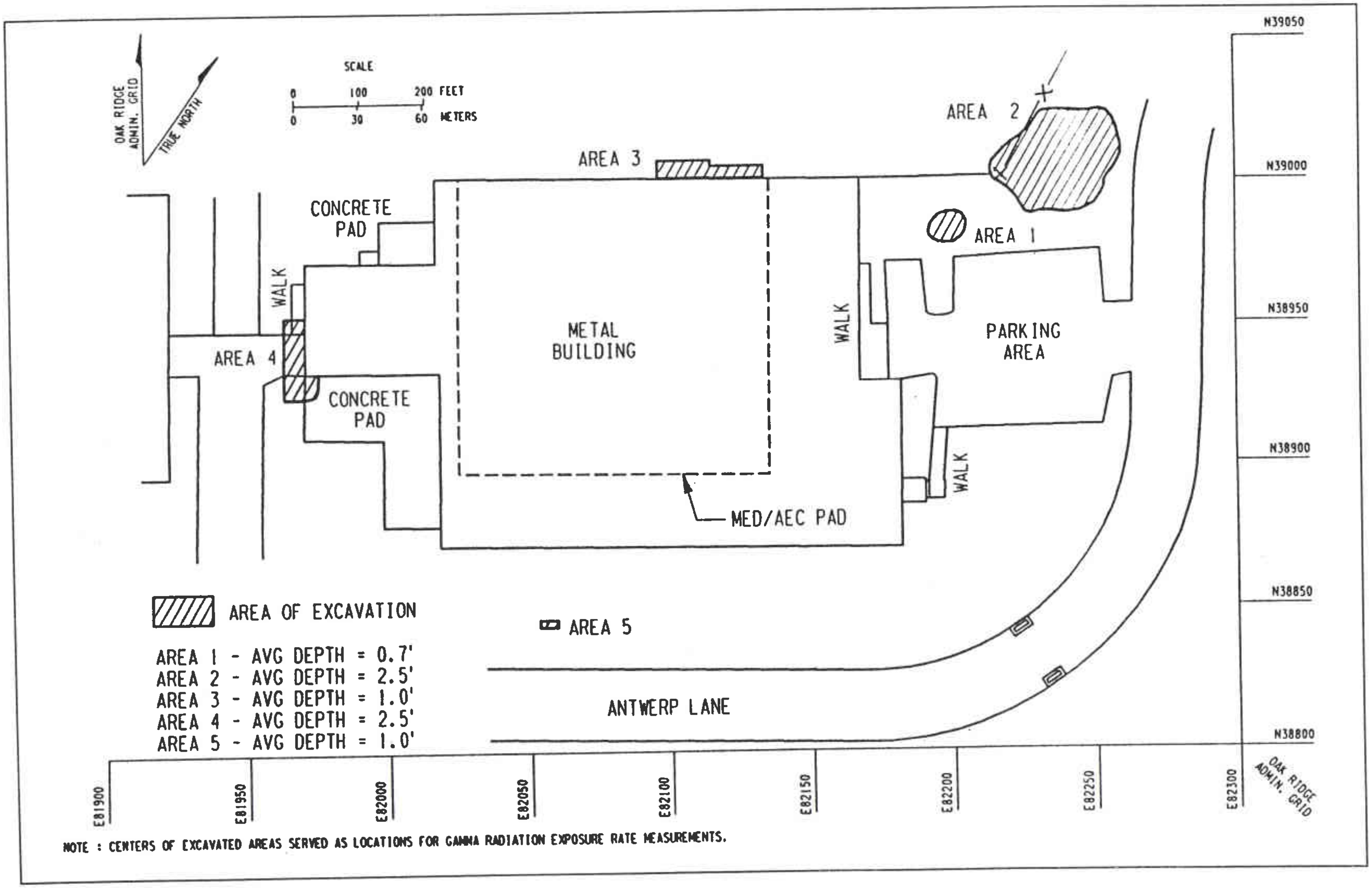

FIGURE 3 Excavated Areas at Parcel 1A (Source: BNI 1992)

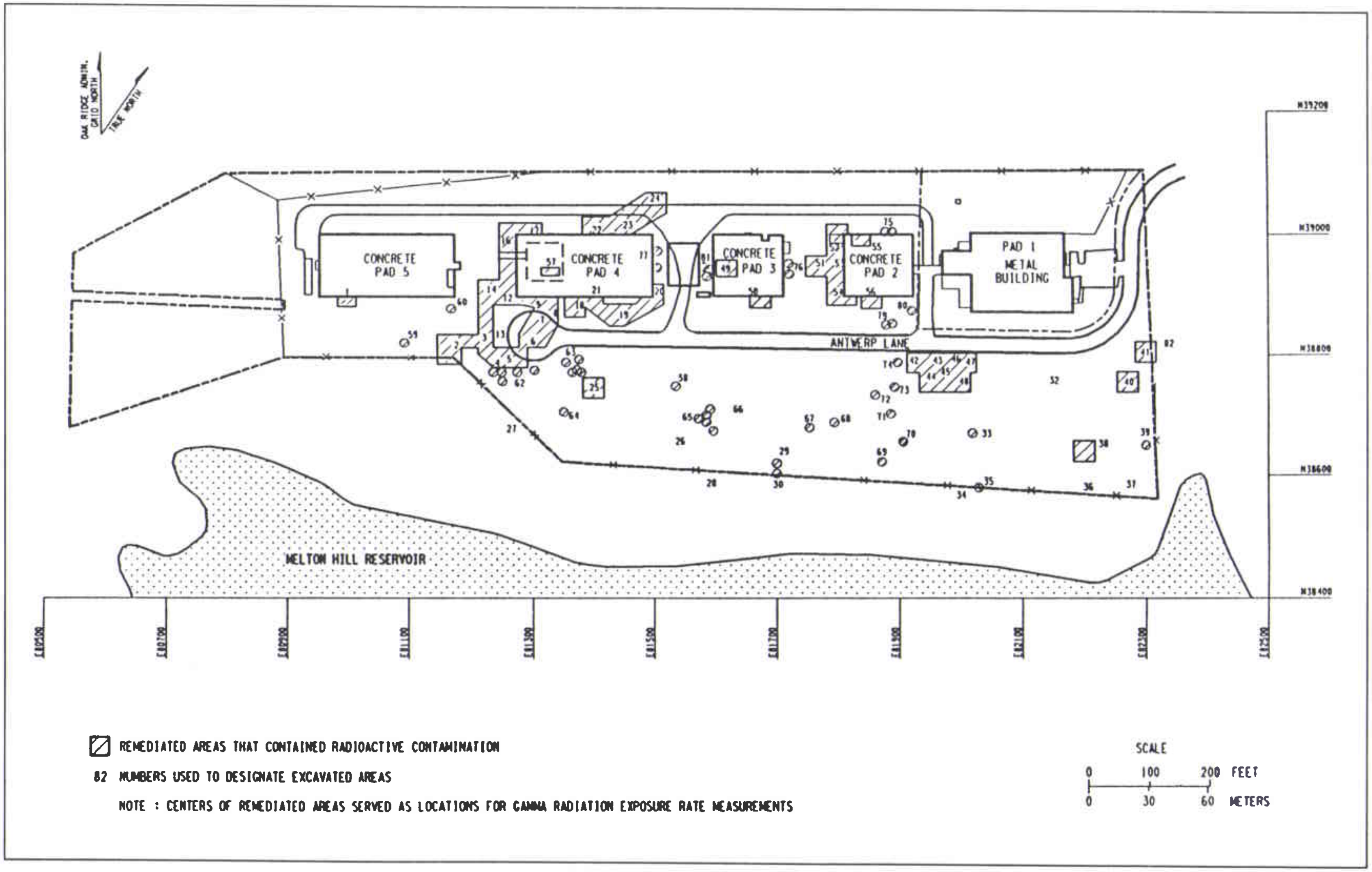

FIGURE 4 Remediated Areas of Radioactive Contamination (Source: BNI 1992)

2 SCENARIO DEFINITIONS

Currently, the Elza Gate site is not being used; however, for assessing post-remediation dose, four potential exposure scenarios were considered. All scenarios assumed that at some time within 1,000 years the Elza Gate site will be released for use without radiological restrictions. Potential radiation doses resulting from nine exposure pathways were analyzed: (1) direct exposure to external radiation from the decontaminated soil material, (2) internal radiation from inhalation of contaminated dust, (3) internal radiation from inhalation of emanating radon-222, (4) internal radiation from ingestion of on-site soil, (5) internal radiation from ingestion of plant foods grown in the decontaminated area and irrigated with water drawn from the pond or well adjacent to the decontaminated area on the downgradient side, (6) internal radiation from ingestion of meat from livestock fed with fodder grown in the decontaminated area and water drawn from the pond or well, (7) internal radiation from ingestion of milk from livestock fed with fodder grown in the decontaminated area and water drawn from the pond or well, (8) internal radiation from ingestion of aquatic food (fish) from the pond, and (9) internal radiation from drinking water drawn from the pond or well.

Scenario A (the expected scenario) assumes industrial use of the site. A hypothetical person is assumed to work in the area of the site for 8 hours per day (6 hours outdoors and 2 hours indoors), 5 days per week, 50 weeks per year. The industrial worker does not ingest drinking water, plant foods, or fish from the remediated area; neither does the worker ingest meat or milk from livestock raised in the remediated area.

Scenario B (a plausible scenario) assumes recreational use of the site. It is assumed that, at some time in the future, the site will be used as a public park. A hypothetical person spends 15 hours per week, 50 weeks per year in the decontaminated area of the park. The recreationist does not ingest drinking water, plant foods, or fish from the decontaminated area or ingest meat or milk from livestock raised in the decontaminated area.

Scenario C (a possible but unlikely scenario) assumes the presence of a resident farmer in the immediate vicinity of the site who drinks water obtained from a pond adjacent to and downstream of the decontaminated area, ingests plant foods grown in a garden in the decontaminated area, and ingests meat and milk from livestock raised in the decontaminated area. All water used by the farmer is drawn from the pond adjacent to the decontaminated area. The individual also ingests fish taken from the pond.

As in Scenario C, Scenario D (a possible but unlikely scenario) assumes the presence of a resident farmer; however, in this scenario, groundwater drawn from a well located at the downgradient edge of the contaminated zone is the only water source for drinking, irrigation, and raising livestock.

The RESRAD computer code (Gilbert et al. 1989) was used to calculate the radiation doses for the hypothetical future worker, recreationist, or resident for the four scenarios, on the basis of the following assumptions.

- Scenario A
  - The industrial worker spends 2,000 hours per year on-site (25% indoors and 75% outdoors).
  - The worker does not consume any meat, milk, water, aquatic food, or vegetables from the site.
  - The walls, floor, and foundation of the industrial building reduce external exposure by 30%; the indoor dust level is 40% of the outdoor dust level (Gilbert et al. 1989).
  - The depth of the house or building foundation is 1 m (3 ft) below the ground surface, with an effective radon diffusion coefficient of 2×10^{-6} m^2/s.
- Scenario B
  - The recreationist spends 750 hours per year on-site, all outdoors.
  - The recreationist does not consume any meat, milk, water, aquatic food, or vegetables from the site.
- Scenario C
  - The resident farmer spends 50% of the time indoors in the remediated area, 25% outdoors in the remediated area, and 25% away from the remediated area.
  - The decontaminated area is large enough that 50% of the plant food diet consumed by the resident farmer is grown in a garden in the decontaminated area.
  - The decontaminated area is large enough to provide sufficient meat and milk for the resident farmer from livestock raised (i.e., foraged) in the remediated area.
  - Vegetables are irrigated by and livestock are provided with water drawn from the pond located adjacent to the decontaminated area.
  - The adjacent pond provides 50% of the aquatic food consumed by the resident farmer.
  - The adjacent pond provides 100% of the drinking water consumed by the resident farmer.

- The depth of the house or building foundation is 1 m (3 ft) below the ground surface, with an effective radon diffusion coefficient of 2×10^{-6} m^2/s.

- Scenario D

  - All assumptions are the same as for Scenario C; however, groundwater drawn from a well at the downgradient edge of the contaminated zone is the only water source for drinking, irrigation, and raising livestock.

All pathways considered for Scenarios A, B, C, and D are summarized in Table 1.

TABLE 1 Summary of Pathways for Scenarios A, B, C, and D at the Elza Gate Site[a]

Pathway	Scenario A	Scenario B	Scenario C	Scenario D
External gamma exposure	Yes	Yes	Yes	Yes
Inhalation				
Dust	Yes	Yes	Yes	Yes
Radon	Yes	Yes	Yes	Yes
Ingestion				
Plant foods	No	No	Yes	Yes
Meat	No	No	Yes	Yes
Milk	No	No	Yes	Yes
Fish	No	No	Yes	Yes
Soil	Yes	Yes	Yes	Yes
Water[b]	No	No	Yes	Yes

[a] Scenario A, industrial worker; Scenario B, recreationist; Scenarios C and D, resident farmer.

[b] Source of water used: 100% pond water for drinking, irrigation, and livestock for Scenario C; 100% well water for Scenario D.

3 SOURCE TERMS

The source term concentrations used in the RESRAD computer code were calculated with data collected from a postremedial soil survey (BNI 1992). Approximately 150 soil samples were collected from areas excavated during Phases I and II of the remedial action. The survey included measured residual concentrations of uranium-238, radium-226, thorium-230, and thorium-232. The results of the soil samples indicate that radionuclide concentrations do not exceed the DOE remedial action guidelines (BNI 1992). Depths of residual contamination ranged from 0 to 3.4 m (0 to 11 ft), but residual contamination was typically confined to the top 1.5 m (5 ft) of soil. Average background concentrations were also reported in the postremedial soil survey report (BNI 1992). The average concentrations are based on soil concentrations taken from three background locations within an 8-km (5-mi) radius of the site.

All scenarios assumed that the construction of a house or industrial building would result in excavation and mixing of on-site soil. Because of the excavation and mixing of soil, radionuclide concentrations for the entire site were based on the arithmetic average of soil data given in Tables 4-1 and 4-2 of the postremedial survey report (BNI 1992). The average radionuclide concentrations for uranium-238 and thorium-230 for the entire site were used in this assessment (background concentrations were subtracted). The average radium-226 and thorium-232 concentrations were comparable to background levels; therefore, they were not considered in this analysis (Table 2). Concentrations of uranium-234 and uranium-235 were inferred on the basis of the assumption that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046. In addition, the concentrations of actinium-227 and protactinium-231 were assumed to be in secular equilibrium with uranium-235. The radionuclide concentrations used in the RESRAD computer code are presented in Table 2. The various parameters used in the RESRAD code are listed in the Appendix. Except for the radionuclide concentrations and the area of contamination, all values used in the RESRAD computer code were those used in deriving the uranium guidelines for the site (Cheng et al. 1991).

TABLE 2 Radionuclide Concentrations (pCi/g) Used in the RESRAD Code for Analysis of the Elza Gate Site

Radionuclide	Average Radionuclide Concentration[a]	Average Background Radionuclide Concentration[b]	Radionuclide Concentration Used in RESRAD[c]
Uranium-238	5.9	1.0	4.9
Radium-226	1.0	1.3	NA[d]
Thorium-232	1.3	1.5	NA
Thorium-230	2.5	1.0	1.5
Uranium-234	-[e]	-	4.9[f]
Uranium-235	-	-	0.22[f]
Actinium-227	-	-	0.22[g]
Protactinium-231	-	-	0.22[g]

[a] Average radionuclide concentrations were calculated on the basis of soil data given in Tables 4-1 and 4-2 of BNI (1992).

[b] Source: BNI (1992).

[c] The background radionuclide concentration is subtracted from the average radionuclide concentration.

[d] NA = not applicable because the concentration is below background.

[e] A hyphen indicates that the concentration was not measured for this radionuclide.

[f] Concentration based on the assumption that uranium-238, uranium-234, and uranium-235 are present in their natural activity concentration ratio of 1:1:0.046.

[g] Concentration based on the assumption that the radionuclide is in secular equilibrium with uranium-235.

4 RESULTS

The RESRAD computer code was used to calculate the potential radiation doses for each exposure scenario. The time frame considered in this analysis was 1,000 years. Radioactive decay and ingrowth were considered in calculating the maximum dose rates. The various parameters used in the RESRAD code for this analysis are listed in the Appendix. The calculated maximum dose rates for Scenarios A, B, C, and D are presented in Table 3.

For all scenarios, the maximum dose rate does not exceed the DOE annual limit of 100 mrem/yr (DOE 1990, 1992). For Scenarios A (industrial worker) and B (recreationist), the maximum dose occurs at time 0 (the year the postremediation radiological survey was conducted). The times at which the maximum dose rate would occur are 729 and 792 years following the postremediation radiological survey for Scenarios C and D (resident farmers), respectively. The maximum dose rates for Scenarios A (industrial worker) and B (recreationist) are less than 2 mrem/yr. For these two scenarios, inhalation of dust is the dominant pathway, contributing approximately 73% of the total annual dose. For Scenarios C (resident farmer: 100% pond water) and D (resident farmer: 100%

TABLE 3 Summary of Potential Maximum Dose Rates (mrem/yr) for Scenarios A, B, C, and D at the Elza Gate Site[a]

Pathway	Scenario A	Scenario B	Scenario C	Scenario D
External gamma exposure	0.31	0.13	1.9	1.8
Inhalation				
Dust	1.1	0.50	0.78	0.72
Radon	0	0	0.66	0.66
Ingestion				
Plant foods	NA[b]	NA	7.2	11
Meat	NA	NA	0.51	3.8
Milk	NA	NA	0.014	0.24
Fish	NA	NA	0.24	0.25
Soil	0.064	0.028	0.059	0.056
Water[c]	NA	NA	0.31	23
Total	1.5	0.66	12	42

[a] For Scenarios A and B, the maximum dose occurs at time 0 (the year the postremediation radiological survey was conducted). The times at which the maximum dose rate would occur are 729 and 792 years following the postremediation radiological survey for Scenarios C and D, respectively.

[b] NA = not applicable because it is not a pathway of concern.

[c] Source of water used: 100% pond water for drinking, irrigation, and livestock for Scenario C; 100% well water for Scenario D.

groundwater), the maximum dose rates are 12 and 42 mrem/yr, respectively. The plant ingestion pathway contributes approximately 60% of the dose, and the external gamma irradiation contributes approximately 16% of the total annual dose for Scenario C. For Scenario D, the plant ingestion pathway contributes approximately 26% of the total annual dose, while the external gamma irradiation and the ingestion of meat contribute approximately 4 and 9%, respectively, of the dose. Ingestion of groundwater for Scenario D (resident farmer: 100% groundwater) accounts for about 55% of the total annual dose, whereas ingestion of water from the pond (Scenario C) contributes only 3% of the total annual dose.

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APPENDIX:

PARAMETERS USED IN THE ANALYSIS OF THE ELZA GATE SITE

The parametric values used in the RESRAD code for the analysis of the Elza Gate Site are listed in Table A.1. All parametric values are reported to three significant figures. Some parametric values are specific to the Elza Gate Site; other values are generic.

TABLE A.1 Parameters Used in the RESRAD Code for Analysis of the Elza Gate Site

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Area of contaminated zone[a]	m^2	80,930	80,930	80,930	80,930
Thickness of contaminated zone	m	1.5	1.5	1.5	1.5
Length parallel to aquifer flow[a]	m	284	284	284	284
Initial principal radionuclide concentration					
Actinium-227	pCi/g	0.22	0.22	0.22	0.22
Protactinium-231	pCi/g	0.22	0.22	0.22	0.22
Thorium-230	pCi/g	1.5	1.5	1.5	1.5
Uranium-234	pCi/g	4.9	4.9	4.9	4.9
Uranium-235	pCi/g	0.22	0.22	0.22	0.22
Uranium-238	pCi/g	4.9	4.9	4.9	4.9
Cover depth	m	0	0	0	0
Density of contaminated zone	g/cm^3	1.8	1.8	1.8	1.8
Contaminated zone erosion rate	m/yr	0.0004	0.0004	0.0004	0.0004
Contaminated zone total porosity	–[b]	0.4	0.4	0.4	0.4
Contaminated zone effective porosity	–[b]	0.3	0.3	0.3	0.3
Contaminated zone hydraulic conductivity	m/yr	18.7	18.7	18.7	18.7
Contaminated zone b parameter	–[b]	7.12	7.12	7.12	7.12
Evapotranspiration coefficient	–[b]	0.7	0.7	0.7	0.7
Precipitation	m/yr	1.4	1.4	1.4	1.4
Irrigation	m/yr	0.3	0.3	0.3	0.3
Irrigation mode	–[b]	not used	not used	overhead	overhead
Runoff coefficient	–[b]	0.3	0.3	0.3	0.3
Watershed area for nearby pond	m^2	not used	not used	7,560,000	7,560,000
Density of saturated zone	g/cm^3	2.0	2.0	2.0	2.0
Saturated zone total porosity	–[b]	not used	not used	0.4	0.4
Saturated zone effective porosity	–[b]	not used	not used	0.3	0.3
Saturated zone hydraulic conductivity	m/yr	not used	not used	192	192
Saturated zone hydraulic gradient	–[b]	not used	not used	0.084	0.084
Saturated zone b parameter	–[b]	7.75	7.75	7.75	7.75
Water table drop rate	m/yr	not used	not used	0.0004	0.0004
Well pump intake depth (below water table)[c]	m	not used	not used	10	10
Model: nondispersion (ND) or mass-balance (MB)	–[b]	not used	not used	ND	ND
Number of unsaturated zone strata	–[b]	not used	not used	2	2
Unsaturated zone 1, thickness	m	not used	not used	1.4	1.4
Unsaturated zone 1, soil density	g/cm^3	not used	not used	1.8	1.8
Unsaturated zone 1, total porosity	–[b]	not used	not used	0.4	0.4
Unsaturated zone 1, effective porosity	–[b]	not used	not used	0.3	0.3
Unsaturated zone 1, soil-specific b parameter	–[b]	not used	not used	7.12	7.12
Unsaturated zone 1, hydraulic conductivity	m/yr	not used	not used	18.7	18.7
Unsaturated zone 2, thickness	m	not used	not used	1.7	1.7
Unsaturated zone 2, soil density	g/cm^3	not used	not used	2.0	2.0
Unsaturated zone 2, total porosity	–[b]	not used	not used	0.4	0.4

TABLE A.1 (Cont.)

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Unsaturated zone 2, effective porosity	_[b]	not used	not used	0.3	0.3
Unsaturated zone 2, soil-specific b parameter	_[b]	not used	not used	7.75	7.75
Unsaturated zone 2, hydraulic conductivity	m/yr	not used	not used	192	192
Distribution coefficient					
Contaminated zone	cm^3/g				
Uranium-234		114	114	114	114
Uranium-235		114	114	114	114
Uranium-238		114	114	114	114
Actinium-227[c,d]		20	20	20	20
Protactinium-231[c,d]		50	50	50	50
Lead-210[c,d]		100	100	100	100
Radium-226[c,d]		70	70	70	70
Thorium-230[d]		276	276	276	276
Unsaturated zone 1	cm^3/g				
Uranium-234		114	114	114	114
Uranium-235		114	114	114	114
Uranium-238		114	114	114	114
Actinium-227[c,d]		20	20	20	20
Protactinium-231[c,d]		50	50	50	50
Lead-210[c,d]		100	100	100	100
Radium-226[c,d]		70	70	70	70
Thorium-230[d]		276	276	276	276
Unsaturated zone 2	cm^3/g				
Uranium-234		6.8	6.8	6.8	6.8
Uranium-235		6.8	6.8	6.8	6.8
Uranium-238		6.8	6.8	6.8	6.8
Actinium-227[c,d]		20	20	20	20
Protactinium-231[c,d]		50	50	50	50
Lead-210[c,d]		100	100	100	100
Radium-226[c,d]		70	70	70	70
Thorium-230[d]		276	276	276	276
Saturated zone	cm^3/g				
Uranium-234		6.8	6.8	6.8	6.8
Uranium-235		6.8	6.8	6.8	6.8
Uranium-238		6.8	6.8	6.8	6.8
Actinium-227[c,d]		20	20	20	20
Protactinium-231[c,d]		50	50	50	50
Lead-210[c,d]		100	100	100	100
Radium-226[c,d]		70	70	70	70
Thorium-230[d]		276	276	276	276
Inhalation rate[c]	m^3/yr	8,400	8,400	8,400	8,400
Mass loading for inhalation[c]	g/m^2	0.0002	0.0002	0.0002	0.0002
Shielding factor, inhalation	_[b]	0.40	0.40	0.40	0.40
Shielding factor, external gamma	_[b]	0.70	0.70	0.70	0.70
Fraction of time spent indoors	_[a]	0.057	0	0.50	0.50
Fraction of time spent outdoors (on-site)	_[a]	0.171	0.086	0.25	0.25
Shape factor, external gamma[c]	_[b]	1	1	1	1
Dilution length for airborne dust, inhalation[c]	m	3	3	3	3
Fruit, vegetable, and grain consumption[c]	kg/yr	not used	not used	160	160
Leafy vegetable consumption[c]	kg/yr	not used	not used	14	14
Milk consumption[c]	L/yr	not used	not used	92	92
Meat and poultry consumption[c]	kg/yr	not used	not used	63	63
Fish consumption[c]	kg/yr	not used	not used	5.4	5.4
Other seafood consumption[c]	kg/yr	not used	not used	0.9	0.9
Soil ingestion rate[c]	g/yr	36.5	36.5	36.5	36.5
Drinking water intake[c]	L/yr	not used	not used	510	510
Fraction of drinking water from site[a]	_[b]	not used	not used	1	1

TABLE A.1 (Cont.)

Parameter	Unit	Value			
		Scenario A	Scenario B	Scenario C	Scenario D
Fraction of aquatic food from site[a]	-[b]	not used	not used	0.5	0.5
Livestock fodder intake for meat[c]	kg/d	not used	not used	68	68
Livestock fodder intake for milk[c]	kg/d	not used	not used	55	55
Livestock water intake for meat[c]	L/d	not used	not used	50	50
Livestock water intake for milk[c]	L/d	not used	not used	160	160
Mass loading for foliar deposition[c]	g/m^3	not used	not used	0.0001	0.0001
Depth of soil mixing layer[c]	m	0.15	0.15	0.15	0.15
Depth of roots[c]	m	not used	not used	0.9	0.9
Groundwater fractional usage (balance from surface water)[a]	-[b]				
Drinking water		not used	not used	0	1
Livestock water		not used	not used	0	1
Irrigation		not used	not used	0	1
Total porosity of the cover material[c]	-[b]	not used	not used	not used	not used
Total porosity of the house or building foundation[c]	-[b]	0.1	not used	0.1	0.1
Volumetric water content of the cover material[c]	-[b]	not used	not used	not used	not used
Volumetric water content of the foundation[c]	-[b]	0.05	not used	0.05	0.05
Diffusion coefficient for radon gas[c]	m/s				
In cover material		not used	not used	not used	not used
In foundation material		2.0×10^{-8}	not used	2.0×10^{-8}	2.0×10^{-8}
In contaminated zone soil		2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}	2.0×10^{-6}
Emanating power of radon gas[c]	-[b]	0.2	0.2	0.2	0.2
Radon vertical dimension of mixing[c]	m	2.0	2.0	2.0	2.0
Average annual wind speed[c]	m/s	2.0	2.0	2.0	2.0
Average building air exchange rate[c]	1/h	1.0	not used	1.0	1.0
Height of the building (room)[c]	m	2.5	not used	2.5	2.5
Bulk density of house or building foundation[c]	g/cm^3	2.4	not used	2.4	2.4
Thickness of house or building foundation[c]	m	0.15	not used	0.15	0.15
Building depth below ground surface[c]	m	1.0	not used	1.0	1.0

a Values based on site specifications or scenario assumptions.

b Parameter is dimensionless.

c RESRAD default values.

d Radionuclide is a decay product.

Source: Liedle, S.D., 1990, letter from Liedle (Project Manager-FUSRAP, Bechtel National, Inc., Oak Ridge, Tenn.) to J.S. Devgun (Argonne National Laboratory, Argonne, Ill.), Sept. 20, except where indicated by footnotes "a" or "c."