AN ABSTRACT OF THE THESIS OF

Robert E. Miller for the degree of Master of Science in Radiation Health Physics presented on November 16, 2001. Title: Environmental Pathway Analysis of a Radioactive Zirconium Sand Unloading Facility.

Redacted for Privacy

Abstract approved: ______________________________

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The Teledyne Wah Chang facility is a manufacturer of the rare metal zirconium. The facility has been in constant production since 1956. In 1973 an attempt to utilize different sand ore sources from Nigeria and India in a new carbiding process, prior to chlorination, failed. The resulting byproducts of the carbiding process and approximately 2000 kg of zircon sand ore were lost in what is now called the Former Sand Unloading Area. In 1982, Teledyne Wah Chang facility was listed as a Superfund site. The Former Sand Unloading Area was contaminated with naturally-occurring radioactive material. After being listed, Teledyne Wah Change began the Remedial Investigation / Feasibility Study process in an attempt to cleanup the Former Sand Unloading Area and other contaminated sites. Afterwards, it was discovered that the remediation goals for the Former Sand Unloading Area only addressed exposure pathways to current workers on site. No consideration had been given to possible future occupants under

long term exposure scenarios. In this study, three scenarios were modeled to illustrate the most plausible occupancy uses of the Former Sand Unloading Area. The scenarios were: current industrial worker, commercial worker, and a residential occupant. The pathways that were used to model the exposure scenarios were, direct external radiation, inhaled and ingested soil, and plant consumption. The RESRAD computer code was used to estimate the dose rates to current and future occupants working or living on the Former Sand Unloading Facility. The maximum resulting radiation dose received was 16.7 mrem y^{-1} for the industrial worker scenario. The lowest maximum radiation dose received was 13.6 mrem y^{-1} for the commercial worker scenario. The most conservative assumptions and efforts were used to ensure the maximum dose rate was modeled. The maximum radiation dose rate received at the Former Sand Unloading Area was below the regulatory maximum allowable exposure limit of 25 mrem y^{-1}.

Environmental Pathway Analysis of a Radioactive

Zirconium Sand Unloading Facility

by

Robert E. Miller

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed November 16, 2001
Commencement June 2002

Master of Science thesis of Robert E. Miller presented on November 16, 2001

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Redacted for Privacy

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Robert E. Miller, Author

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LIST OF ACRONYMS

ALARA	As Low As Reasonably Achievable
ANL	Argonne National Labs
ARAR	Applicable or Relevant and Appropriate Requirements
CEDE	Committed Effective Dose Equivalent
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	Contaminate of Concern
D&D	Decontamination and Decommissioning
DCF	Dose Conversion Factor
DDE	Deep Dose Equivalent
DOE	Department of Energy
EPA	Environmental Protection Agency
FSUA	Former Sand Unloading Area
HQ	Hazard Quotient
ICRP	International Commission on Radiological Protection
Kd	Distribution Coefficient
LLRW	Low Level Radioactive Waste
MCL	Maximum Contaminant Limit
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NORM	Naturally Occurring Radioactive Material
NPL	National Priorities List
NRC	Nuclear Regulatory Commission
OAR	Oregon Administrative Rules
ODOE	Oregon Department of Energy
OHD	Oregon Health Division
OU	Operable Unit
RD/RA	Remedial Design/Remedial Action
RESRAD	RESidual RADioactive material guidelines
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
RPS	Radiation Protection Services
SAI	Science Applications, Inc.
SCM	Site Conceptual Model
TEDE	Total Effective Dose Equivalent
TWC	Teledyne Wah Chang

Environmental Pathway Analysis of a Radioactive Zirconium Sand Unloading Facility

1 INTRODUCTION

The Teledyne Wah Chang Corporation (TWC) is a company that primarily manufactures rare metals, mainly zirconium and halfnium, from enhanced zircon sand ore. The current TWC facility began the experimental production of zirconium in 1943 as the Regional Laboratory of the U.S. Bureau of Mines. In 1946 the Bureau was busy refining the Kroll process (Riggs, 2001) for the commercial production of zirconium metal. In 1950, the Atomic Energy Commission provided funding for a prototype commercial zirconium production facility located at the current TWC in Millersburg, Oregon. On December 25, 1956 the Bureau (now called Wah Chang) produced the first run of zirconium sponge from the reduction process facility (Riggs, 2001).

Teledyne Industries, Inc. purchased the Wah Chang Corporation facilities in 1967. By 1972, the new TWC Corporation started production of zirconium tetrachloride from Australian zircon sand. A year later, an attempt to utilize different sand ore sources from Nigeria and India in a carbiding process, prior to chlorination, failed (Riggs, 2001). The years between 1974 and 1982 were, for the most part, uneventful. With the exception of 1982, the time between 1983 and 1990 was again uneventful. However, in 1991, the two dewatering ponds, known as Schmidt Lake and Lower River Pond, were remediated and their exempted radioactive contents were shipped to Finley Buttes Landfill in Boardman, Oregon (Riggs, 2001). In 1993, the contaminated Low Level Radioactive Waste (LLRW) (non exempted waste) from the failed zirconium carbide process was extracted from the bank of Schmidt Lake and was disposed of at the Hanford Nuclear Reservation in Eastern Washington (Riggs, 2001). By 1994, the third dewatering pond was remediated and its exempted waste was disposed of at the Columbia Ridge Landfill in Eastern Oregon (Riggs, 2001). In 1997 TWC merged with Allegheny Ludlum to form the new Allegheny Teledyne Corporation (Riggs, 2001). Finally, in 1998, TWC completed decontamination of three sites (the Former Sand Unloading Area (FSUA), the Front Parking Lot Area, and the Solids Area in Schmidt Lake) (Riggs, 2001).

Zirconium metal is produced from technologically enhanced sand ore ZrSiO4 (zircon). The feed stock sand contains approximately 0.03% uranium and 0.02% thorium. Since beginning operations, TWC has processed over 200 million kilograms of zircon sand. This has resulted in approximately 60,000 kilograms of uranium and 40,000 kilograms of thorium as byproducts of the zircon sand chlorination process (Riggs, 2001). The resultant byproducts of the zirconium metal process generated large amounts of Naturally Occurring Radioactive Material (NORM) at TWC. NORM is defined as, "...any nuclide which is radioactive in its natural physical state (i.e. not man-made), but does not include source or special nuclear material" (OAR 333 Division 117, 1995).

1.1 TWC Placed on the National Priorities List

In 1982, TWC was declared a Superfund site and placed on the National Priorities List (NPL). TWC was required under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to perform a Remedial Investigation and Feasibility Study (RI/FS) as a result of potentially hazardous and radioactive byproduct wastes generated at the TWC facilities. The FSUA was a site where byproduct wastes were generated. The Nigerian and India zircon sand ore that was used for the failed carbiding process was spilled and lost under the railroad spur ballast*.

The RI/FS was completed in 1993 (Riggs, 2001). In June of 1994 and September of 1995 the Environmental Protection Agency (EPA) published their Records of Decision (RODs) which described the CERCLA response actions for TWC. The first ROD was for the surface and subsurface Operational Unit (OU), Section 10 and the second ROD was for

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* Personal Communication with Ed Riggs, TWC, March 2, 1998.

the groundwater and sediment OU, Section 7 (CH2M Hill, 1999). The main areas affected by these RODs where the Front Parking Lot Area, the FSUA, and Schmidt Lake. All three of these sites fall under the scope of both OU Section 7 and OU Section 10 (Riggs, 2001).

1.2 Rationale for Environmental Pathway Analysis of the FSUA

The scope of this project study will be limited to what, in the author's opinion, are important analyses of current and future occupancy scenarios and associated pathways at the FSUA. The site characterization and radiation dose assessment of TWC's FSUA will be comprised of modeling three scenarios. The scenarios are: the current/future industrial worker, a future commercial worker, and a future residential occupant. These scenarios will be defined and discussed in Chapter 3.

The purpose for conducting this assessment is to determine what the possible maximum doses would be to current workers and occupants at TWC and to determine what the maximum future dose for occupancy would be if the site is released for unrestricted use following decontamination and decommissioning (D&D) activities.

To the best of the author's knowledge, this type of pathway analysis and dose assessment have never been performed at the TWC site. Risk assessments were performed on the FSUA, the Parking Lot Area, and Schmidt Lake prior to remediation of these sites. However, it is not readily apparent that any of these sites have undergone post remediation pathway analysis or dose assessments. There has been no known consideration given to the build-up of radioactive progeny from the residual parent nuclides at the FSUA and, therefore, no ability to determine long-term radiation exposure levels to future occupants. The nature of long-lived radionuclides in contaminated soil requires a dose assessment and a pathway analysis for future occupancy scenarios.

The final reason for this assessment is to add to the technical knowledge base of information involving the FUSA site.

2 SITE BACKGROUND

2.1 Nature and Extent

During 1973, TWC's FSUA was used for unloading rail cars loaded with Nigerian and Indian zircon sand ores. However, these two types of sand ore contained higher concentrations of natural thorium and uranium than the Australian sand that TWC is currently processing (Riggs, 2001).

The elevated exposure levels and contamination problems at the FSUA were documented in the RI/FS report Addendum 1 – Radiological Survey (CH2M Hill, 1993). The two problems were attributed to the "red" Nigerian sand ore, which contained elevated amounts of natural thorium and uranium. As shown later, it is the thorium progeny in the Nigerian sand that contributes to the majority of the risk and exposure at the FSUA site. Approximately 2000 lbs of the Nigerian sand ore were spilled on to the ground at the unloading site (Riggs, 2001). The sand was spread out over an approximate 35-foot radius. It is unknown how the spreading occurred. The sand sifted down through the railroad ballast into the top one foot of the native soil. As a result, the increased external gamma exposure rates were beyond regulatory limits. This prompted state and federal agencies to require remediation of the FSUA.

The FSUA was remediated by TWC and Bob Barker Trucking Co. (CH2M Hill, 1999) during October 1997 under EPA's guidelines for surface and subsurface soil contamination 40 CFR 192.12. The excavated zone (approximately 70 yd^3) was back-filled to original grade with one-inch-minus gravel and paved with two 2 inch layers of asphalt (CH2M Hill, 1999).

Post-remediation gamma radiation surveys were conducted by TWC and the Oregon Health Division (OHD) Radiation Protection Services (RPS) to determine if the FSUA was in compliance with listed exposure limits. The survey results showed that the site was within regulatory standards for current site use conditions (CH2M Hill, 1999); however, no long-term dose assessments or future land use evaluations had been performed to determine if the site would meet EPA's "Radiation Site Cleanup Regulations" Draft 40 CFR 196 for future use*. The reason why no long-term assessments were performed was the result of TWC and the regulatory agencies reaching an agreement before the RI/FS was performed. The agreement decision was that only the current worker scenario would be evaluated*. To perform the task of long-term dose assessments, a modeling program was needed.

The RESRAD program (the name RESRAD is a partial acronym for RESidual RADioactive material guidelines) has the modeling capability to show possible future exposure risks, associated with radionuclide-

* Personal Communication with Dave Livesay, CH2M Hill, September 18, 2001.

contaminated soil for the different occupancy scenarios, to individuals working on or living near the FSUA (RESRAD, 1998).

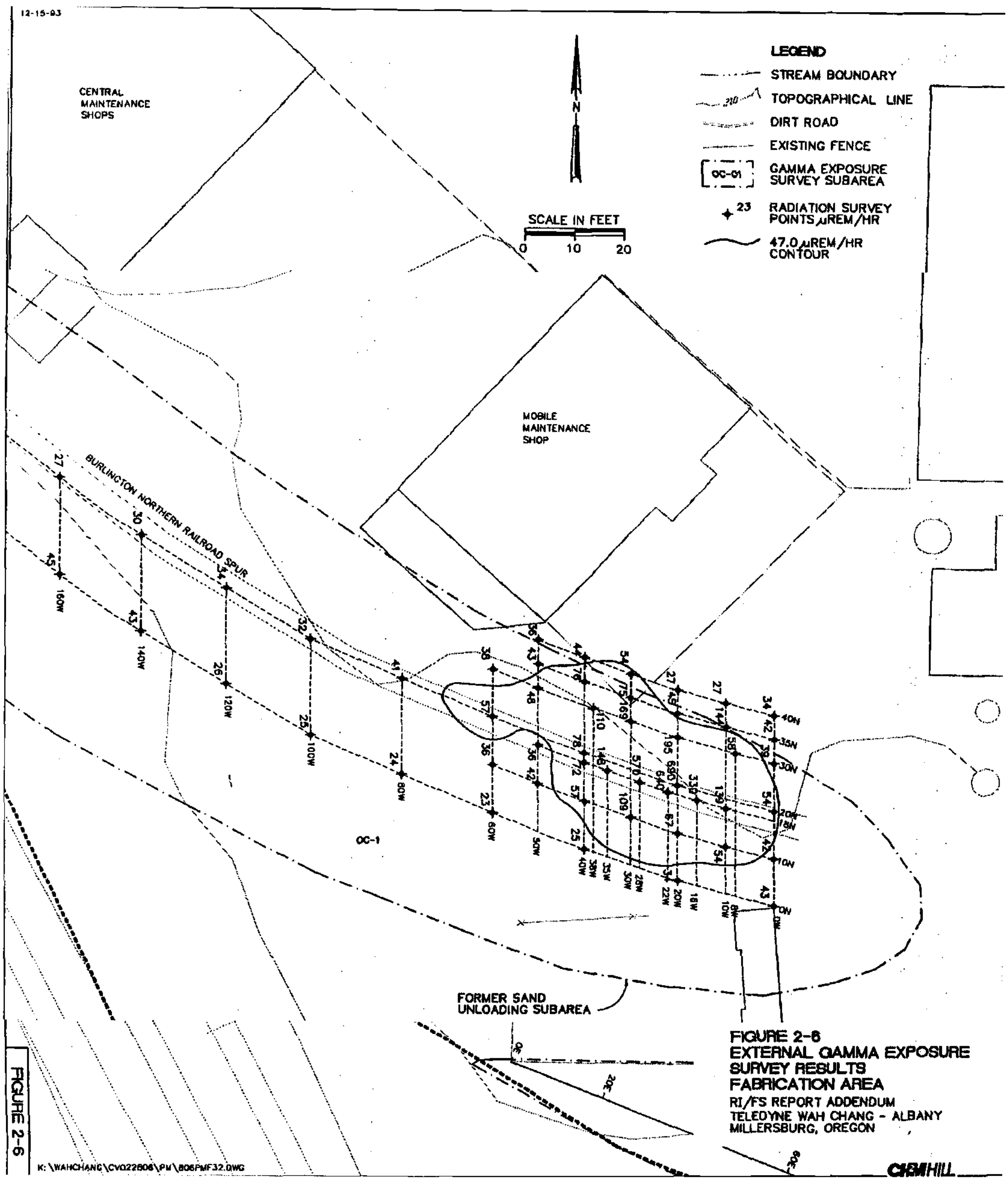
Figure 1 shows the isorads indicating the external radiation exposure rate from the residual radioactive material in the soil. Isorads are curved lines with values on them indicating the radiation exposure at a given point. Isorads are usually given in micro Roentgens per hour (μR/h) for environmental radiological measurements.

2.2 Contaminants of Concern and Associated Hazards

The two primary contaminants of concern (COC) are natural uranium and natural thorium and their respective progeny. From an external dose standpoint, natural uranium is really not a significant source of external radiation. The reason for uranium's relatively low exposure rate can be seen in Figure 2. As uranium decays, the majority of the early progeny decay by alpha particle and relatively weak gamma & beta emissions which contribute virtually nothing to the external exposure dose rate (see the Dose Conversion Factors [DCF] in Appendices B.1, B.2, and B.3).

The natural thorium series (Th-232), on the other hand, produces the majority of external exposure at the FSUA. Natural thorium's progeny, as seen in Figure 3, all have short half-lives which allow the progeny to quickly build up to secular equilibrium. Secular equilibrium is

*Figure 1 External Exposure Survey Results at FSUA**



*CH2M Hill, 1993. Figure 2-6

defined as: a dynamic state in which two or more progeny nuclides are undergoing decay at the same time with a constant rate (i.e. all progeny of the decay series disintegrate the same number of atoms per unit time).

*Figure 2 Uranium Decay Series**

Nuclide	Historical Name	Half-life	Major Radiation Energies (MeV) and Intensities[b]					
			α		β		γ	
			MeV	%	MeV	%	MeV	%
$^{238}_{92}U$	Uranium I	4.468 x 10^9 y	4.15 4.20	22.9 76.8			.0496	.07
$^{234}_{90}Th$	Uranium X_1	24.1 d			.076 .095 .096 .1886	2.7 6.2 18.6 72.5	.0633 .0924 .0928 .1128	3.8 2.7 2.7 .24
$^{234m}_{91}Pa$	Uranium X_2	1.17 m			2.28	98.6	.766 1.001	.207 .59
99.87% | 0.13%								
$^{234}_{91}Pa$ / $^{234}_{91}PaIT$	Uranium Z	6.7 h			22 βs E Avg = 0.224 Emax = 1.26		.132 .570 .883 .926 .946	19.7 10.7 11.8 10.9 12
$^{234}_{92}U$	Uranium II	244,500 y	4.72 4.77	27.4 72.3			.053 .121	.12 .04
$^{230}_{90}Th$	Ionium	7.7 x 10^4 y	4.621 4.688	23.4 76.2			.0677 .142 .144	.37 .07 .045
$^{226}_{88}Ra$	Radium	1600 ± 7 y	4.60 4.78	5.55 94.4			.186	3.28
$^{222}_{86}Rn$	Emanation Radon (Rn)	3.823 d	5.49	99.9			.510	.078
$^{218}_{84}Po$	Radium A	3.05 m	6.00	−100	.33	.02	.837	.0011
99.98% | 0.02%								
$^{214}_{82}Pb$	Radium B	26.8 m			.67 .73 1.03	48 42.5 6.3	.2419 .295 .352 .786	7.5 19.2 37.1 1.1
$^{218}_{85}At$	Astatine	2 s	6.66 6.7 6.757	6.4 89.9 3.6			.053	6.6
$^{214}_{83}Bi$	Radium C	19.9 m	5.45 5.51	.012 .008	1.42 1.505 1.54 3.27	8.3 17.6 17.9 17.7	.609 1.12 1.765 2.204	46.1 15.0 15.9 5.0
99.979% | 0.021%								
$^{214}_{84}Po$	Radium C'	164 μs	7.687	100			.7997	.010
$^{210}_{81}Tl$	Radium C"	1.3 m			1.32 1.87 2.34	25 56 19	.2918 .7997 .860 1.110 1.21 1.310 1.410 2.010 2.090	79.1 99 6.9 6.9 17 21 4.9 6.9 4.9
$^{210}_{82}Pb$	Radium D	22.3 y	3.72	.000002	.016 .063	80 20	.0465	4

*Shleien, 1992. Table 8.9

Again, by looking at Figure 3, it can be seen that all of the decay progeny with the exception of Radium (Ra-228) and thorium (Th-228) have half-lives in days, hours, minutes, and fractions of a second. This means

*Figure 3 Thorium Decay Series**

Nuclide	Historical Name	Half-life	Major Radiation Energies (MeV) and Intensities[b]					
			α		β		γ	
			MeV	%	MeV	%	MeV	%
$^{232}_{90}Th$	Thorium	1.405×10^{10} y	3.83 3.95 4.01	0.2 23 76.8			.059 .126	.19 .04
$^{228}_{88}Ra$	Mesothorium I	5.75 y			.0389	100	.0067	$6x10^{-5}$
$^{228}_{89}Ac$	Mesothorium II	6.13 h			.983 1.014 1.115 1.17 1.74 2.08 (+33 more βs)	7 6.6 3.4 32 12 8	.338 .911 .969 1.588	11.4 27.7 16.6 3.5
$^{228}_{90}Th$	Radiothorium	1.913 y	5.34 5.42	26.7 72.4			0.84 .132 .166 .216	1.19 .11 .08 .27
$^{224}_{88}Ra$	Thorium X	3.66 d	5.45 5.686	4.9 95.1			.241	3.9
$^{220}_{86}Rn$	Emanation Thoron (Tn)	55.6 s	6.288	99.9			.55	.07
$^{216}_{84}Po$	Thorium A	.15 s	6.78	100			.128	.002
$^{212}_{82}Pb$	Thorium B	10.64 h			.158 .334 .573	5.2 85.1 9.9	.239 .300	44.6 3.4
$^{212}_{83}Bi$ 64.07% 35.93%	Thorium C	60.55 m	6.05 6.09	25 9.6	1.59 2.246	8 48.4	.040 .727 1.620	1.0 11.8 2.75
$^{212}_{84}Po$	Thorium C'	305 ns	8.785	100				
$^{208}_{81}Tl$	Thorium C"	3.07 m			1.28 1.52 1.80	25 21 50	.277 .5108 .583 .860 2.614	6.8 21.6 85.8 12 100
$^{208}_{82}Pb$	Thorium D	Stable						

*Shleien, 1992. Table 8.7

that all of these radionuclides are simultaneously giving off radiation at a constant rate. This is why natural thorium produces the majority of the radiation measured at the FSUA.

The progeny in the thorium decay chain that produced the most radiation exposure are: actinium (Ac-228), bismuth (Bi-212), and thallium

(Tl-208). The decay type (alpha, beta, and gamma), energy levels, and probability of decay (in percent) can also be viewed in Figure 3.

The main hazards resulting from the residual radionuclides in the soil at the FSUA are direct external radiation exposure and the leaching of radionuclides (mainly radium) to groundwater sources. While soil ingestion and inhalation are also hazards, they are not as prominent as direct external exposure and groundwater contamination. The pathway analyses will be covered in greater detail in Chapter 3.

2.3 Data Collection and Analysis

Following the remediation performed at the FSUA, three confirmation soil samples were taken to document the residual contamination in the soil. The samples consisted of a composite of three random grab samples. Each grab sample contained equal amounts of soil (CH2M Hill, 1999). The samples were then taken to TWC's on-site lab for analysis. The TWC lab performed a Total Metals Analysis on the three confirmation samples. The results can be seen in Table 1 (CH2M Hill, 1999).

*Table 1 Confirmation Sample Analytical Results**

Sample ID	Tot. Ra-226 (ρCi/g)	Tot. Ra-228 (ρCi/g)	Tot. Th-232 (mg/kg)	Tot. U-238 (mg/kg)
Confirmation 1	<1	<1	5.7	2.1
Confirmation 2	<1	<1	8.2	2.4
Confirmation 3	<1	<1	5.3	2.2

*CH2MHill, 1999. Table 4-2. Data validation not complete at time of report.

2.4 Fate and Transport of Contaminants of Concern

In the 1999 Surface & Subsurface Soil Remedial Design/Remedial Action (RD/RA) Status Report of the FUSA performed by CH2M Hill, a groundwater pathway analysis for future occupancy scenarios was not performed to provide evidence of any future exposures or risk. Based upon water samples taken from monitoring wells PW20A, located west and down gradient within 100 feet of the FSUA, and PW19A located approximately 200 feet northwest of the FSUA, CH2M Hill determined that there was no migration or transport of the radionuclides into the groundwater.

The water samples taken from the wells showed that concentrations for contaminates were less than the maximum contaminant limit (MCL) for drinking water and had a residential risk of less than 1E-6 individual lifetime cancer risk and a hazard quotient (HQ) less than one (CH2M Hill, 1999). A hazard quotient is the ratio of a single substance exposure level over a specified period of time to a reference dose of the same substance derived from a similar exposure period.

2.5 The CERCLA Process

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 USC § 9601 et seq.) set up a national response program to address releases of hazardous substances into the environment. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) is the regulation that implements CERCLA and determines the approach for appropriate remedial actions at CERCLA (Superfund) sites (USEPA, 1989).

The purpose of the Superfund program is to protect the health of humans and the environment from an actual or potential uncontrolled release of hazardous substances. The CERCLA Superfund process established a framework to evaluate the risks posed to human health. A risk assessment is used for assisting in the decision-making process at contaminated sites. The Superfund program was originally intended to deal with contaminated and inactive sites and facilities. TWC is an exception with respect to the CERCLA process because, for the foreseeable future, TWC is likely to continue their current manufacturing operations.

There are several objectives that are used in the risk assessment process. These objectives are:

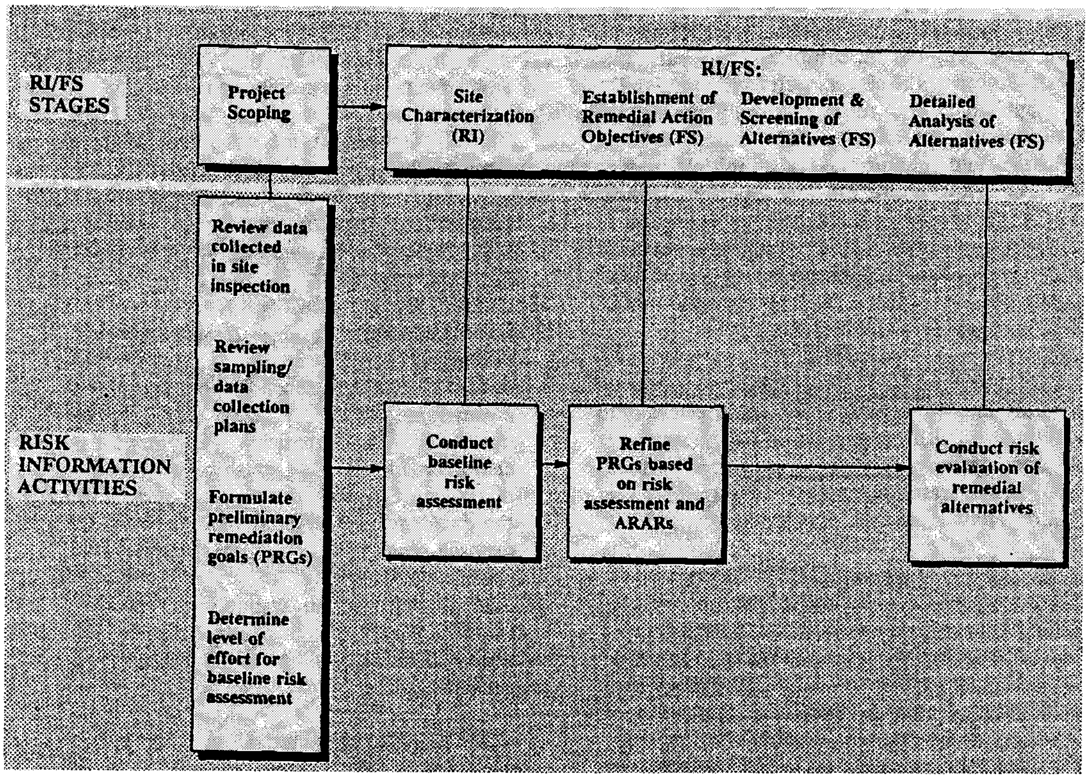
- Develop a risk assessment to help determine the corrective action at the contaminated site(s);
- Provide information for determining levels of residual contaminates that can safely remain at the contaminated site(s);
- Provide information for determining health impacts or effects of different remediation actions;
- Establish uniform process that evaluates and documents health effects or threats at the contaminated site(s).

Risk information created through the human health risk assessment process is intended for use in the RI/FS at Superfund sites (USEPA, 1989). This background information is for illustrating where TWC is at in the CERCLA process. Figure 4 shows a block diagram for how the RI/FS process is laid out.

2.6 Applicable Regulations

The action levels for radionuclides are calculated values based upon target radiation doses to current or future individuals. The target radiation doses are defined by the applicable regulatory agencies. The radiation dose limits are selected according to which regulatory agency (or agencies) have authority. If more than one agency has regulatory authority, then the agency with the most restrictive limits would have the

Figure 4 Risk Information Activities in the RI/FS Process*



*USEPA, 1989. Exhibit 1-1.

lead role of enforcement and their limits would be used. In most cases, the regulations are directly comparable between agencies.

Once the dose limit has been determined, calculations can be performed that will indicate the allowable amount of radioactive material in the soil. The concentration of radioactive material in the soil will correspond to the action level required for clean-up and soil remediation. The applicable regulatory agencies responsible for the TWC site are the EPA, Oregon Department of Energy (ODOE), and the OHD RPS (acting on behalf of the Nuclear Regulatory Commission (NRC) as an agreement state). An "Agreement State" is defined as, "...any state with which the U.S. Nuclear Regulatory Commission or the U.S. Atomic Energy Commission has entered into an effective agreement under subsection 274b. of the Atomic Energy Act of 1954, as amended (73 Stat.689)" (OAR 333 Division 100, 1995). In other words, the agreement state has the same scope and authority that the NRC does and acts on the NRC's behalf in administering applicable federal regulations. The regulatory agencies and the applicable corresponding rules and regulations are shown in Table 2 and will be discussed in detail in the following sub sections.

During onsite regulatory compliance checks by the OHD RPS, direct radiation exposure measurements were made at the FSUA on

Table 2 Regulatory Agencies and Applicable Regulations

Agency	Dose Limit (mrem/yr)	Regulations
EPA	15/85	EPA Title 40 of the Code of Federal Regulations, Parts 192.12 and 196, "Radiation Site Cleanup Regulations," dated October 21, 1993.
ODOE	500	ODOE Oregon Pathway Exemption Rule, OAR 345 Division 50 Radioactive Waste Materials.
OHD	25	OHD Radiation Protection Services Rules for the Control of Radiation, OAR 333 Division 117 Regulation and Licensing of NORM.
OHD	100	OHD Radiation Protection Services Rules for the Control of Radiation, OAR 333 Division 120 Standards for Protection Against Radiation.

September 4, 1997 (CH2M Hill, 1999). The reasoning for making direct measurements was to ensure that the external radiation exposures at the FSUA were at or below the appropriate action level. The EPA, Department of Energy (DOE), and the NRC are moving away from using risk assessment modeling for determining action levels to using radiation dose to assess and remediate radioactive materials in the environment (RFCA, 1996). This approach provides for a more accurate exposure scenario under the current occupant model; however, risk assessments using models such as RESRAD are still needed for future exposure scenarios. One of the key reasons that a future site exposure model needs to be performed is because direct measurements do not take into account the decay of the long-lived parent nuclide(s) and the resulting radiation exposure from the buildup of progeny. In addition, direct measurements are not adequate for modeling the transport of radionuclide contamination through the vadose zone to the groundwater aquifers or other environmental transport mechanisms.

2.6.1 40 CFR 192.12 and Draft 40 CFR 196

The ROD, that TWC signed for the surface and subsurface soil operational unit, established the gamma radiation action level (CH2M Hill, 1999). The action level was determined by Title 40 Code of Federal Regulations Part 192.12 (40 CFR 192.12) to be 20 μR/hr above background, measured at one meter above the surface and averaged over 100 m^2. The background gamma radiation reading was determined to be 10.5 μR/hr (CH2M Hill, 1999).

The EPA, in drafting 40 CFR 196, has determined that CERCLA sites containing radioactive materials in the soils and surrounding environment be remediated to a standard of 15 mrem/yr. Remediated sites are divided into two future use categories – restricted and unrestricted. Under the restricted future use (open space or "Park") scenario, the 15 mrem/yr exposure limit would apply. Additionally, an unrestricted use (residential occupancy) scenario would also have to be performed to ensure that the radiation dose received will not exceed the 85 mrem/yr limit set by Draft 40 CFR 196. The reasoning being that if future uses diverge from the original site release agreement, that no individual will exceed the International Commission on Radiological Protection (ICRP) recommended dose limit of 100 mrem/yr (RFCA, 1996).

The time requirement of a 1,000-year assessment period was to specifically address contaminated sites containing radionuclides with extremely long half-lives (typically all the uranium and thorium isotopes and the man made transuranic elements like neptunium, plutonium, americium, etc.). This aided in the risk assessment of the progeny formed from the parent radionuclide(s) in the contaminated area. Many of the radioactive progeny also have long half-lives (1600 years for Radium 226).

The 1,000-year modeling scenario will provide an adequate and reasonable amount of time to ensure the integrity of the land use restrictions (Argonne, 1993a). The 1,000-year time period also satisfies the assessment requirements in Draft 40 CFR 196.

2.6.2 OAR 345 Division 50 Oregon Pathway Exemption Rule

Under the pathway exemption rule of Oregon Administrative Rule 345-050-0035 (OAR 345-050-0035), the facility or site in question would have to demonstrate that the radionuclide contaminated soil would not produce an external gamma radiation field greater than 500 mrem/yr. Additionally, the facility or site could not release effluents into the groundwater or atmosphere in an annual average concentration that exceeded the values listed, for thorium, uranium, and their progeny, in Table 3 of Division 50.

Any potential radiation exposures or leaching of contaminated material is to be evaluated under the following conditions: "External gamma radiation exposures shall be based on actual measurements and allowance may be made for the degree of equilibrium and for self-shielding" (OAR 345 Division 50, 1998). This rule is one of the reasons why RPS and TWC performed the external gamma survey of the FSUA in 1997.

The Gamma Pathway Exemption Interpretive Rule (345-050-0036) is the basis for determining compliance with OAR 345-050-0035 when considering external gamma radiation from materials containing NORM. Actual measurements of the contaminated area should be conducted to ensure that the compliance levels of less than 500 mrem/yr are maintained. The levels are based upon the dose an individual might be exposed to given a 90 percent occupancy rate in a structure or home constructed on the NORM contaminated site (OAR 345 Division 50, 1998). The significance of this rule is to insure that contamination at the FSUA and other sites are not above levels set in this division and that any exposure pathway would meet the release criteria. This is one of the Applicable or Relevent and Appropriate Requirements (ARARs) for the FSUA site.

2.6.3 OAR 333 Division 117 Regulation and Licensing of NORM

The OHD Radiation Section established the following exposure guidelines and limits to provide for the protection of the general public from the release(s) of radioactive materials into the general environment. The release pathways are: external radiation exposure, leaching of NORM to groundwater, surface water, soil, air, plants, and animals. The regulatory limits of exposure are not to result in an annual dose above background radiation levels exceeding an equivalent of 25 mrem/yr of (whole body) exposure.

Exposure to the different isotopes of radon and respective progeny are exempt from this rule. However, the effort to maintain exposures and radioactive material releases as low as reasonably possible shall be made. This part is consistent with promulgated NRC regulations (OAR 333 Division 117, 1995).

2.6.4 OAR 333 Division 120 Standards for Protection Against Radiation

The OHD RPS established the following standards for protection against ionizing radiation produced from activities at licensed facilities. This regulation is an ARAR because TWC is still an operating facility with a current radioactive materials license.

The regulatory limits of exposure for individual members of the public are not to result in an annual total effective dose equivalent (TEDE) above 100 mrem/yr. Additionally, the dose rate limit for individual members of the public in any unrestricted area from external sources should not exceed 2 mrem/hr.

The annual occupational dose limit for adults is a TEDE of 5000 mrem/yr. The annual occupational dose limit is reduced to 500 mrem/yr for minors and "declared" pregnant employees. In all cases, to the extent practicable, occupational doses and doses to the general public should be kept as low as reasonably achievable (ALARA) (OAR 333 Division 120, 1995). This part is also consistent with promulgated NRC regulations.

3 SITE CONCEPTUAL MODEL

3.1 Introduction

The Site Conceptual Model (SCM) is a process that describes the current physical setting and conditions of the site. Additionally, the SCM aides in describing how land at the contaminated site is predicted or expected to be used in the future. A SCM is a crucial tool used for performing risk and dose assessments. It is the risk and dose assessments that will be used to determine what remedial action to perform or what limits to impose on future site occupation and land use.

The SCM will provide three different types of future occupancy scenarios. The three occupancy scenarios that will be assessed are: industrial worker (continuing current operations), commercial worker, and the residential occupant. Other scenarios could be included, such as a recreational area (open park) scenario or an ecological scenario (how would the contaminated site impact the local plants and animals). Other scenarios were not included because the three scenarios mentioned are, in the author's opinion, the most plausible under the current trends for growth (in both population and businesses) in the Willamette valley.

The three scenarios were designed to produce the worst exposure conditions for each case. Typically, the exposure scenarios are determined through agreements between the regulatory agencies (both state and federal) and the cited company or individual party. However, the agencies may have mandatory rules or regulations that stipulate which scenarios will be evaluated separate from any agreements between the parties involved.

3.2 Scenario Pathways

There are a number of different exposure pathways under each of the mentioned scenarios. The residential occupant scenario, for example, could have an external gamma ray, an inhalation, a soil ingestion, a drinking water, a plant ingestion (home grown produce), and radon exposure pathways all under one scenario. This same scenario could only use two or three of these pathways to describe the residential occupant scenario.

The driving issues that determine which pathways are included in the scenario(s) could include, but are not limited to, what the regulatory agencies require or what physical characteristics are present at the site. Another driving issue is whether or not sampling data exists to support a particular exposure route (groundwater samples from a down-gradient monitoring well for example). If a particular exposure pathway requiring data is included in the scenario, then some type of sampling would have to be performed.

Finally, not all pathways involve human exposure. There are cases in which the regulatory agencies have required an ecological pathway analysis to be included in the site scenario(s).

The exposure pathways chosen for the three scenarios are shown in Table 3. The rationale for choosing the pathways were, in the author's opinion, the most realistic and plausible. Additionally, TWC in their agreement with the regulatory agencies, agreed that the only scenario that would be considered in the RI/FS, that CH2M Hill performed, would be a scenario similar to the industrial worker scenario presented here*.

Table 3 Scenarios and Related Pathways

Industrial Worker	Commercial Worker	Future Resident
External Gamma Inhalation Soil Ingestion	External Gamma Inhalation Soil Ingestion	External Gamma Inhalation Soil Ingestion Plant Ingestion

The pathways not considered were: groundwater, surface water, and drinking water. The following sections give reasons for why these pathways were not considered.

* Personal Communication with Dave Livesay, CH2M Hill, September 18, 2001.

3.2.1 Groundwater Pathway

The groundwater contamination pathway was not performed for any of the three scenarios. The reason is that the TWC site has nearly four feet of stiff clays (with a neutral pH) starting at one to three feet below grade. This layer of clay acts as a natural leachate barrier. "A characteristic of these sediments is the widespread distribution of clays in the coarser alluvial materials; often these 'cemented gravels' have permcabilities (sic) so low as to act as groundwater barriers" (Ziskind et al., 1981).

It is not likely that the uranium, thorium, or their progeny will migrate through this layer of clay. This is due to the large distribution coefficient (K_d) factors associated with this type of soil. The K_d parameter is discussed in section 4.5.2.

3.2.2 Surface Water Pathway

The surface water contamination pathway was originally analyzed in 1981 by Science Applications, Inc. (SAI). The possibility exists that radionuclides in the contaminated zone could migrate to the Willamette River through surface water runoff. However, the results of their study indicated that this pathway was not a health and safety concern. In April of 1980, SAI performed sampling on Truax Creek. The radionuclide concentrations (for thorium, uranium, and radium) were shown to be decreasing monotonically downstream. Sampling and analysis also indicated that TWC's normal effluent releases "...dominate and mask out the effects of any secondary (and controlled) releases from other sources..." (Ziskind et al., 1981). In essence, any down gradient radionuclide contamination present is being produced by normal plant operations and not as a result of contamination being released by the FSUA, Schmidt Lake, or the Lower River pond. Based upon SAI's extensive study and conclusions, the surface water pathway will not be reconsidered for this analysis.

3.2.3 Drinking Water Pathway

The reason for not including the drinking water pathway is that the residential, commercial, and continued industrial land use scenarios would fall under the incorporated area of Millersburg and would use municipal water supplies for irrigation and drinking water. The scope of the SCM will only cover the three mentioned scenarios and associated pathways.

It will be noted that the author did run a RESRAD drinking water only scenario to determine if there would have been groundwater contamination from the COCs leaching from the FSUA to the aquifer. The results showed no groundwater contamination from any of the COCs. The results are consistent with previous studies (Ziskind et al., 1981) and groundwater monitoring results from monitoring wells PW 19A and PW 20A (CH2M Hill, 1999).

3.3 TWC Site Description

The TWC plant site is approximately 100 acres and is located in Millersburg, Oregon. The TWC corporation employs approximately 2000 workers. Millersburg is an industrial suburb that is north and adjacent to Albany, Oregon (Ziskind et al., 1981). The Albany and Millersburg area is in the central part of the Willamette valley and both municipalities are bordered by the Willamette River. The river defines the two communities' western boundary.

The populations of Albany and Millersburg are 40,852 and 650 people respectively*. The Albany and Millersburg municipalities are predominantly industrial communities based on timber product manufacturing (paper, pulp, and particle board), manufactured housing, rare metals production & fabrication industries, and agriculture. Areas north and east of Millersburg are mainly row crop and grass seed farms with light population densities.

The TWC facility is bounded by the Willamette River to the west, Murder Creek to the north, Willamette Industries Duraflake Division on

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* Personal Communications with Cities of Albany & Millersburg Clerks, September 21, 2001.

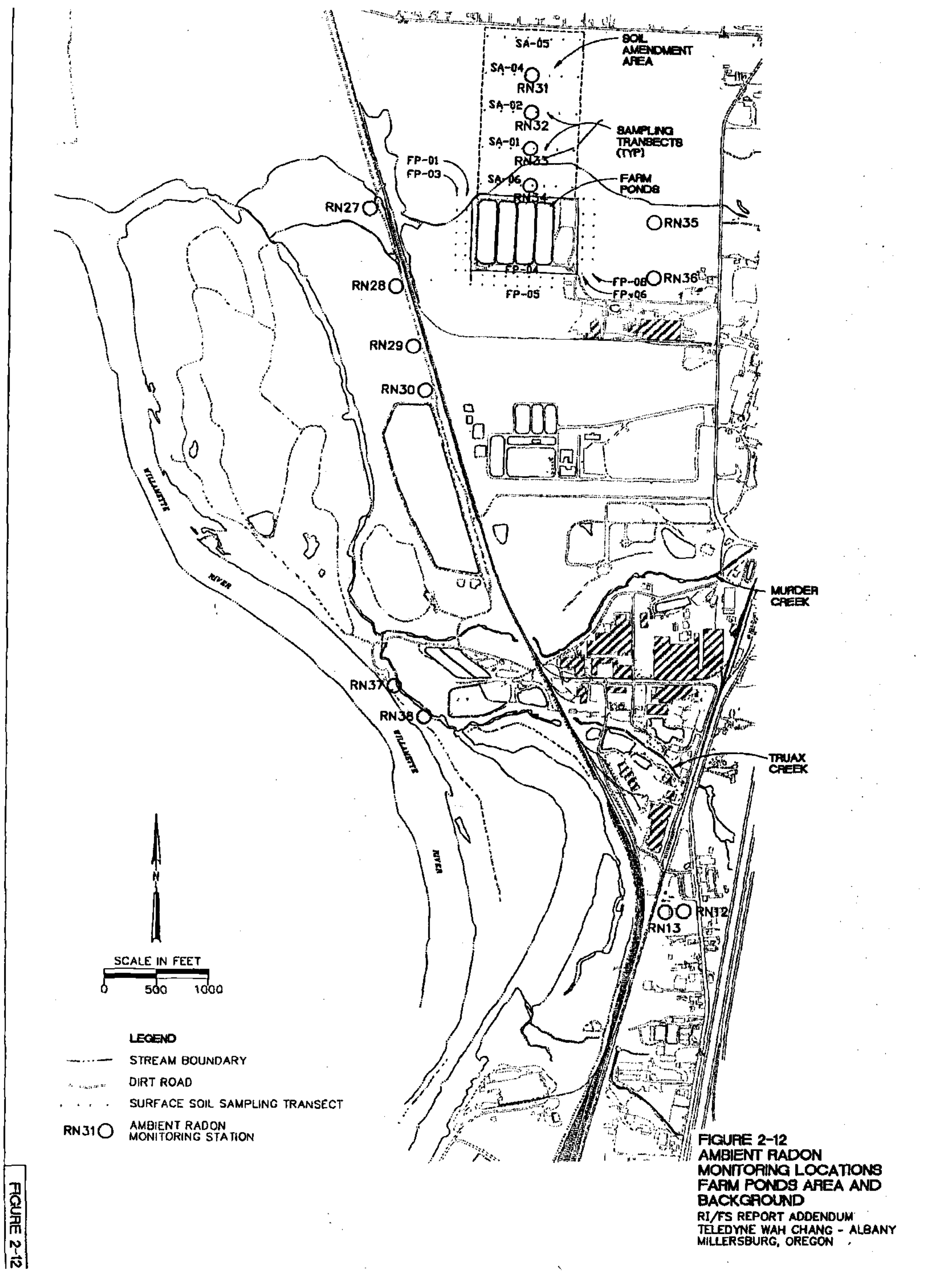
the northeast corner, the Interstate 5 freeway as the eastern boundary, and numerous small light industrial & commercial businesses comprise the southern boundary. The overall makeup of the TWC facilities and surrounding area are heavy to light industrial facilities surrounded by rural housing and farms. The Albany residential areas closest to the TWC facility are approximately one and a half miles south of the plant. All areas south of the TWC facility are generally upwind and are hydrologically up-gradient of the FSUA contaminated area.

The TWC site is split into two main functional areas (see Figures 5, 6, & 7 on the following pages). The first area is the Extraction facilities (Figure 6). The second area is made up of the Fabrication facilities (Figure 7). The FSUA is located in the fabrication area of the plant. The key physical feature separating the two main areas of the site is Truax Creek. The two dark black lines (in Figure 5) represent where Truax and Murder Creek flow through the TWC facility and where their confluence is physically located. Figure 5 also illustrates the location of the TWC facility in relation to the Willamette River.

3.3.1 FSUA Site Description

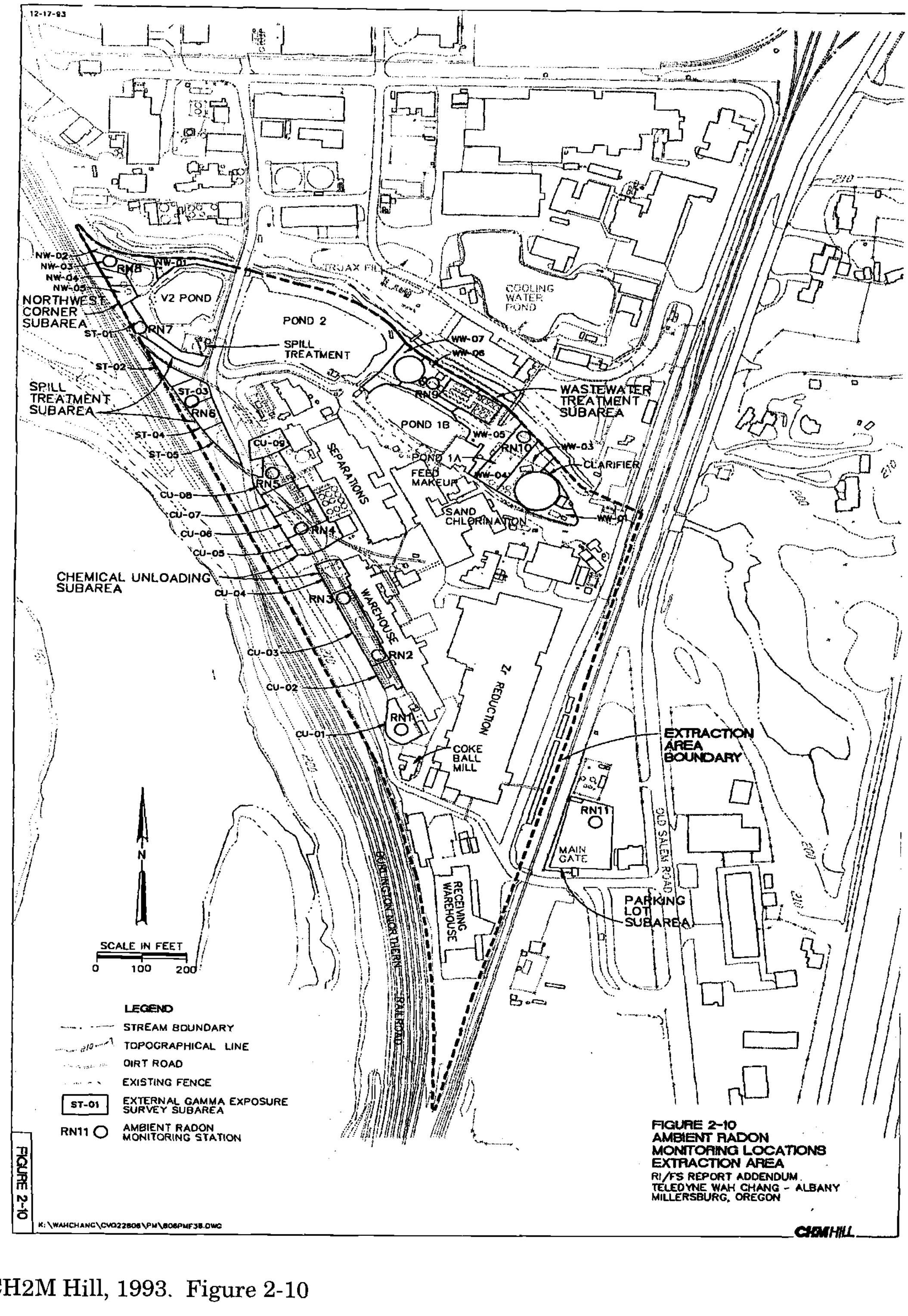
The FSUA site was comprised mainly of the former Burlington Northern rail spur where the sand ore cars were unloaded. The railroad spur was removed during the 1997 remediation process (CH2M Hill, 1999).

*Figure 5 Overview of TWC Site and Key Surface Water Attributes**



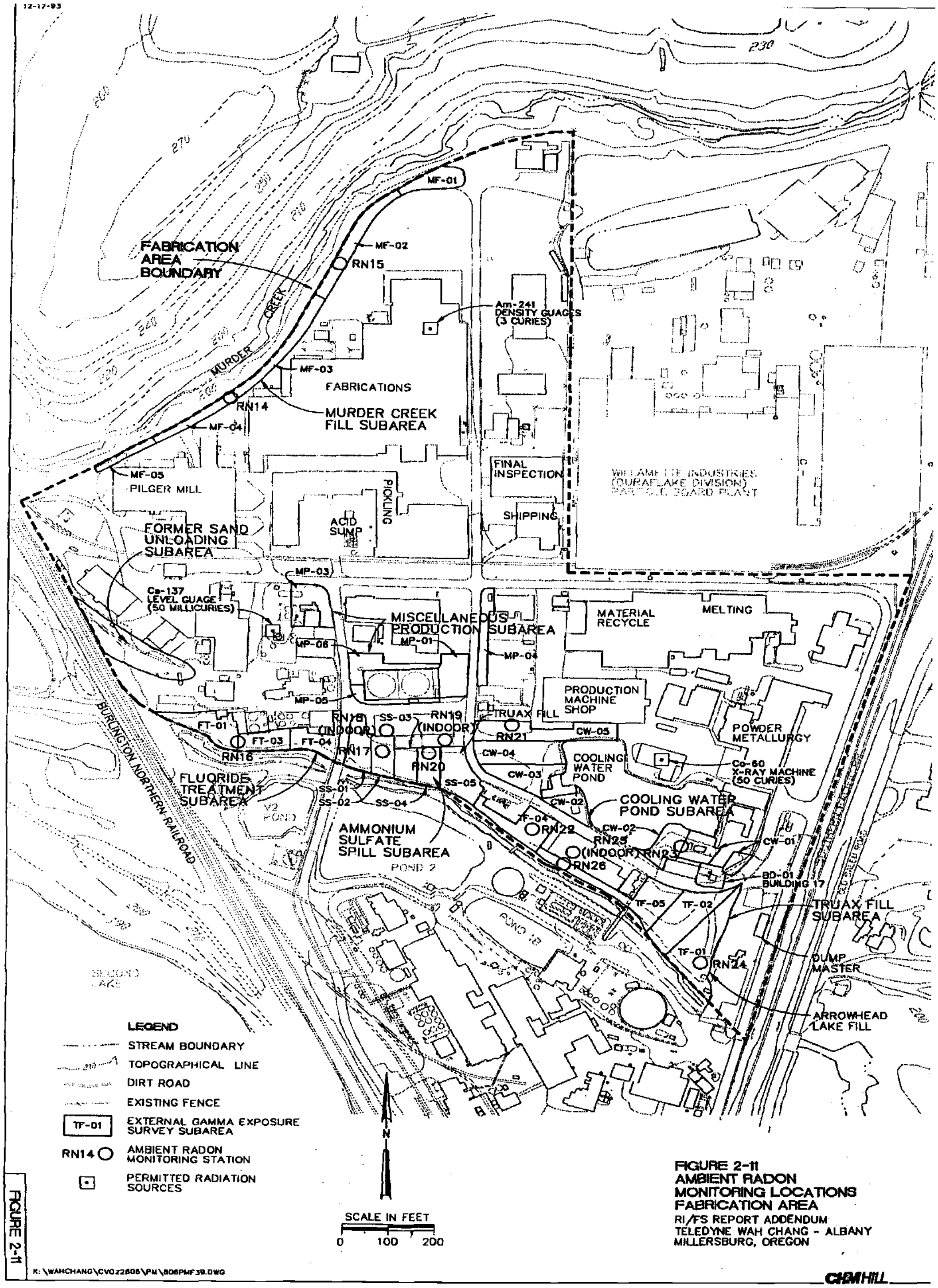
*CH2M Hill, 1993. Figure 2-12

*Figure 6 Extraction Facilities Area at TWC**



*CH2M Hill, 1993. Figure 2-10

*Figure 7 Fabrication Facilities Area at TWC**



*CH2M Hill, 1993. Figure 2-11

The FSUA was located adjacent to and south of the mobile maintenance shop. The site was approximately 50 feet wide and 70 feet long.

A natural clay/silt soil was discovered approximately one foot below the surface grade during the removal of contaminated soil (CH2M Hill, 1999). After the contaminated soil was removed, the FSUA was backfilled with one-inch-minus gravel to the original grade then two 2-inch layers of asphalt were put on top of the gravel (CH2M Hill, 1999). The FSUA is currently a sealed asphalt pad.

3.3.2 Soil Geology

The geology at the TWC facility is comprised of three different alluvial layers. The sedimentary layers are: younger alluvium, older alluvium, and terrace deposits. The pH for the soils surrounding the TWC site ranged from 6.0 to 7.5.

The younger alluvium comprises the uppermost layers of soil that make up the floodplain of the Willamette River and surrounding tributaries. The younger alluvium consists mainly of sand, gravel, and silt with minimal amount of clay mixed in. Thicknesses for the younger alluvium range from a few feet to more than 50 feet.

The older alluvium consists of sand, gravel, silt and clay with some cemented gravels. This alluvium also contained thick beds of clay that were shown in the drillers log for borehole #7 (P790-WC/HEA #7). The older alluvium contains the primary groundwater aquifer for the Albany and Millersburg area and most of valley plain. The older alluvium ranges from 30 to 300 feet thick (Ziskind et al., 1981).

The terrace deposits are made up of silts, clays, sand, and gravel. However, the gravels and sands in this layer tend to be cemented or hardened. This particular layer is greater than 100 feet thick around the TWC site and is generally unsaturated (Ziskind et al., 1981).

The geology surrounding the Albany and Millersburg area near the Willamette River can generally be summed up as: sand, silt, and fine gravels over thick layers of various clays covering stiff and cemented gravels. Permeabilities ranged from moderate in the shallow sandy and silty areas to very slow at the levels containing clays.

3.3.3 Groundwater Characteristics

The three alluvial layers previously mentioned are all capable of producing groundwater. The alluvium best suited for groundwater production is the older alluvium. The younger alluvium tends to have significant seasonal fluctuations (5 to 15 feet) in the water table. Additionally, wells in the younger alluvium showed significant draw down during pumping and the recharge rates were slow. The general flow of groundwater at the TWC site is toward the west and the Willamette River.

The gradient for groundwater is approximately 10 feet per mile or 0.002 ft/ft. The lateral flow of groundwater toward the south or the east is not likely (Ziskind et al., 1981).

3.3.4 Surface Water Characteristics

The surface hydrology of the TWC site is generally an east to west flow toward the Willamette River. Truax Creek is a small seasonal creek that is normally one to five feet deep in most places and approximately three to five feet wide. It is also used for post-process water discharges from the Extraction facilities. Murder Creek is quite similar to Truax Creek in size and seasonal flow rates. The FUSA lies between both creeks and is approximately 100 feet north of Truax Creek. Truax and Murder Creeks come together roughly 2000 feet west of the FUSA and flow northward for nearly one and a half miles before discharging into the Willamette River (see Figure 5).

There are five man-made ponds near the FSUA. The 1B, V2, and Pond 2 ponds are all up-gradient of the FUSA. Schmidt Lake and the Lower River Pond are both directly down-gradient of the FUSA. Schmidt Lake and the Lower River Pond have berms on the south and west sides of the ponds. Truax Creek runs adjacent to the southern berms and eventually turns north down-gradient of the Lower River Pond at the west end. Both Schmidt Lake and the Lower River Pond were drained and decommissioned and are no longer used for post-process water storage (Ziskind et al., 1981).

3.3.5 Climate

The climate in the central Willamette valley is temperate and mild. The average monthly temperatures for January and July are 39° F and 67° F respectively. Annual precipitation ranges from 25 inches in the driest years to more than 60 inches in the wettest years. The overall average precipitation is about 41 inches per year. The average annual potential evapotranspiration is approximately 27 inches of moisture (Ziskind et al., 1981). A typical year for the Willamette valley would be nine months of measurable precipitation with three months (June, July, and August) being almost completely dry with no measurable rainfall.

3.3.6 Meteorology

The average annual wind speed recorded at McNary Air Field in Salem, Oregon was seven mph. The wind predominately blows from the southwest to the northeast (NOAA, 1999). Salem is located approximately 25 miles north of Albany. McNary Air Field was the closest monitoring station to TWC that recorded meteorological data.

3.4 Possible Future Land Uses at the TWC Site

Future uses for the TWC site are continuing current operations as they are today or releasing the site for unrestricted development. Unrestricted use includes developing residential subdivisions, commercial business zones, or agricultural areas. For the scope of this study, the future use of this site as an agricultural area will not be considered due to the geographic location (high value real estate bordering the Willamette River) of the site and the rate of urban growth in the Willamette valley. However, the likelihood of the site being developed for residential, commercial, or continued industrial occupancy is quite high.

3.4.1 Pathway Assessment for Industrial Occupancy

The most likely future scenario is continued industrial occupancy. This scenario assumes that a common TWC employee is working on or very near the FSUA site. The pathways that are assumed for this individual are inhalation of resuspended contaminated soils, ingestions of contaminated soils, and external gamma ray exposure through the asphalt cover material. This individual is assumed to be doing moderate to strenuous manual labor outdoors a majority of the time. To account for all the detailed parameters used to model this particular scenario, see Appendix A, "Parameter Justification for RESRAD code." The dose limit used was 15 millirem per year to the TWC employee for the 1000-year model period.

3.4.2 Pathway Assessment for Commercial Occupancy

The next scenario assumed is the commercial occupancy employee. For this case, an office building has been erected next to or on the FSUA and utilizes the asphalt cover over the contaminated site as a parking lot. Here the individual would spend the majority of their time indoors at a resting level or performing light activities. The pathways assumed for this individual are external gamma ray exposure through the cover material, inhalation of resuspended contaminated soils from outside air circulation, and ingestion of contaminated soil. To account for all the detailed parameters used to model this particular CERCLA site, see Appendix A, "Parameter Justification for RESRAD code." The dose limit used was 15 millirem per year for the commercial employee for the 1000-year model period.

3.4.3 Pathway Assessment for Residential Occupancy

The last scenario modeled assumes a future residential or suburbanite occupancy exposure. In this case, the house and yard are built right on the FSUA site. The individual is assumed to be exposed from external gamma exposure from contaminated soil without the asphalt cover material, inhalation of resuspended contaminated soils, ingesting produce grown in contaminated soil, and directly ingesting contaminated soils. Exposures from meat and milk are not included. The current zoning laws and rapid population growth in the Willamette valley would prohibit raising livestock in a suburban scenario. The probability of zoning the TWC facility into small farm parcels would be extremely remote. To account for all the detailed parameters used to model this particular scenario, see Appendix A, "Parameter Justification for RESRAD code." The dose limit used was 15 millirem per year or 85 millirem for the hypothetical resident for the 1000-year model period.

4 THE RESRAD CODE

4.1 Introduction

Researchers at the Environmental Assessment Division of the Argonne National Laboratories (ANL) originally developed the RESRAD computer code for the DOE. DOE Order 5400.5 describes the guidelines for establishing allowable residual concentrations of radionuclides in soils at contaminated sites*. The RESRAD code was written to address these guidelines and to determine an estimated dose to a current or future hypothetical occupant of the contaminated site based on measured residual soil contamination. On the other hand, RESRAD can determine what the allowable residual soil concentration can be based on a specified dose limit.

The RESRAD code incorporates a library of radionuclides in a database to aid in calculating doses and soil concentrations of radioactive material. RESRAD also integrates a DCF database, developed by the ICRP, for performing inhalation, ingestion, and external exposure dose calculations. The version of RESRAD used for this study was 5.82, released in April 1998.

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* The DOE guidelines were included into DOE Order 5400.5 in February 1990 and were also included in proposed 10 CFR 834 in March 1993.

4.2 RESRAD Code Selection

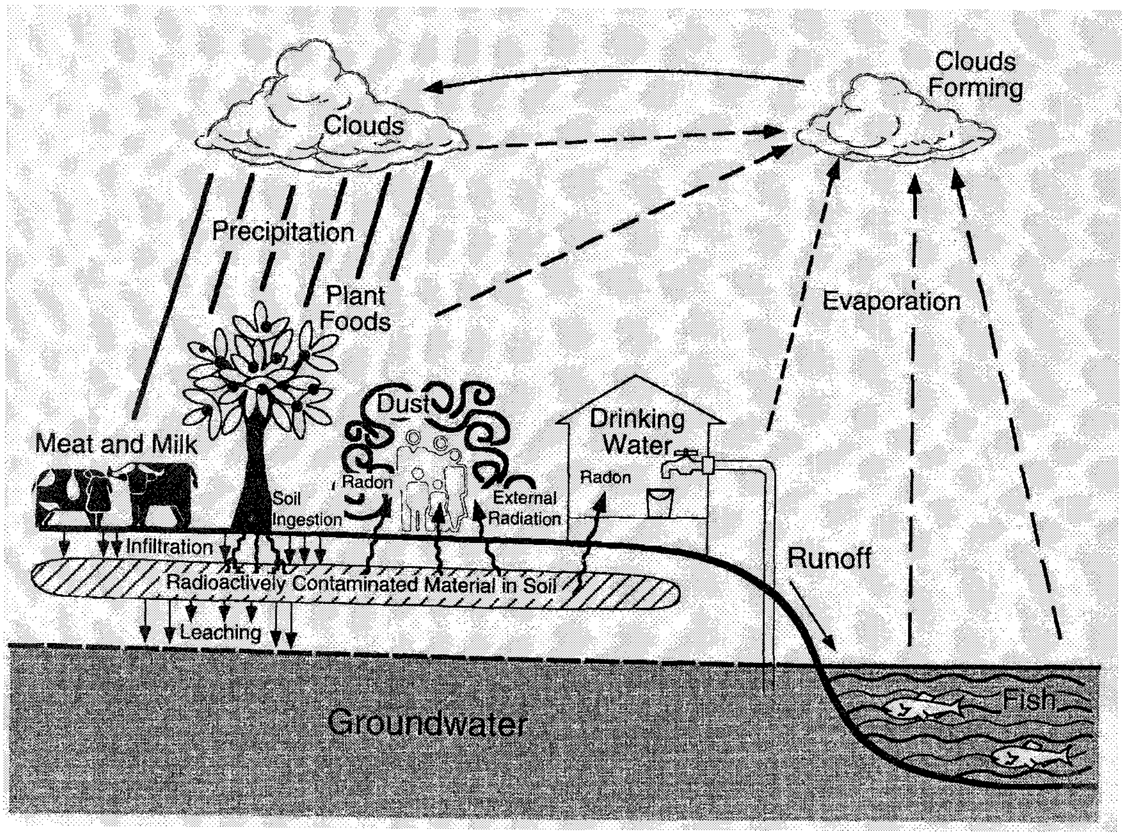
The RESRAD code was selected for modeling the FSUA site for a number of reasons. The main reason for selecting the RESRAD code for this study was its extensive pedigree and documented past performance records as illustrated by the following quote, "The RESRAD code is the most extensively tested, verified, and validated code in the environmental risk assessment field. It has been widely used by DOE, other federal and state agencies, and their contractors. In 1994, the NRC approved the use of RESRAD for several applications, including dose evaluation by licensees involved in decommissioning…" (Argonne, 2001).

Additionally, RESRAD is an industry standard software package used by the NRC, EPA, DOE, and numerous private companies performing D&D activities and operating facilities/companies performing cleanup activities.

Finally, RESRAD can model the necessary analysis requirements of this study. These are the environmental transport processes and the exposure pathways previously discussed.

The RESRAD code can be easily broken down into two main topics: exposure and transport. From here the code can be further broken down into pathways, which incorporate both exposure and transport processes. There are nine main pathways that RESRAD allows the modeler to select based upon a current or hypothetical scenario in the future. These pathways are: external gamma exposure, inhalation, radon, drinking water, plant ingestion, meat ingestion, milk ingestion, aquatic food ingestion, and finally soil ingestion as shown in Figure 8 below.

Figure 8 Exposure Pathways Considered in RESRAD*



*Argonne, 1993. Figure 1.1

4.3 Verification, Validation, and Benchmarking the RESRAD Code

Verification, Validation, and benchmarking of a code are essential functions that a modeler must consider before publishing the results of a study performed with the aid of a computer code.

Verification is a process where an experimenter or modeler confirms that a given mathematical solution to a problem, performed by computer code, performs correctly and consistently as designed. Additionally, verification is to ensure that the program algorithms and processes are accurate and appropriate for the scenario being modeled. RESRAD has been, and continues to be, verified as new features to the code are added by ANL staff and independent corporations. The ANL staff perform verifications using hand calculations and calculators. In cases where long repetitive calculations are required, spreadsheets and computers are used. The RESRAD code was independently verified in 1994 by Halliburton NUS Corporation. The published report was titled *Verification of RESRAD – A Code for Implementing Residual Radioactive Material Guidelines Version 5.03*. There were some deficiencies in the code along with some typos that were identified in the verification process. These were corrected (Argonne, 2001).

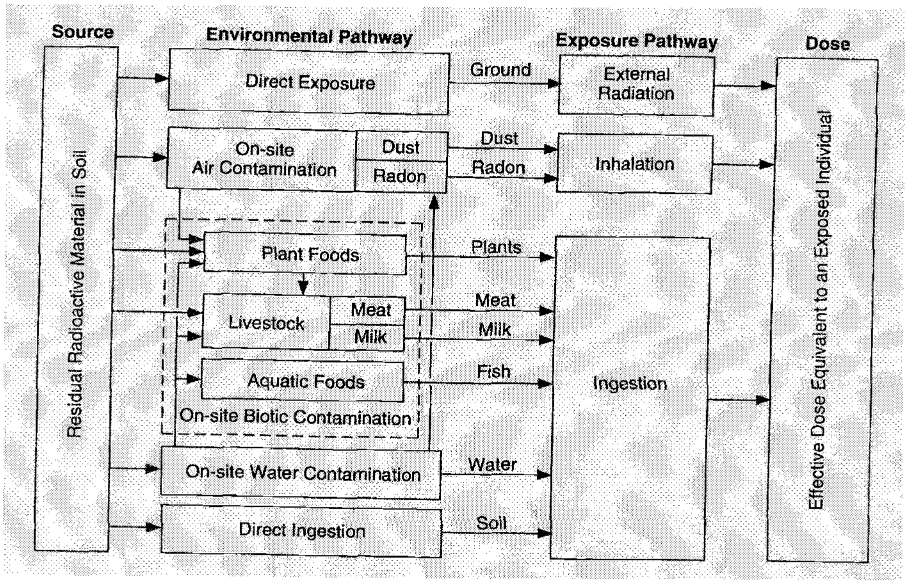
The validation process is a procedure that tests a program's algorithms for applicable model conditions against independent laboratory or field observations. The leaching subprogram used in the RESRAD code was validated against several batch and column tests for uranium and thorium to see how well RESRAD performed. These tests were performed by ANL in the early 1990s. The RESRAD code was also validated against real world data sets from the Chernobyl accident (Argonne, 2001).

Benchmarking a computer code is nothing more than comparing the output results of different computers codes, given the same problem set, against one another. In some cases, the complete modeling codes may not be directly comparable. For instance, the GWSCREEN groundwater model code (Rood, 1998) could only be compared to the leaching subprogram of the RESRAD code. Between 1990 and 1994, RESRAD was benchmarked against several other codes: GENII-S, DECOM, PRESTO-EPA-CPG, and NUREG/CR-5512. Of all the modeling codes listed, RESRAD was the only code to include the radon pathway (Argonne, 2001).

4.4 RESRAD Input Parameters

The pathways are further divided into input parameters that represent site-specific details about the physical, geological, and hydrological characteristics of the site to be modeled. In Figure 9, the parameters are in block diagram or schematic form to show the differences between parameters and how they relate to the pathways. In the event

Figure 9 Schematic Representation of RESRAD Pathways*



*Argonne,1993. Figure 2.2

that site-specific data is not available or does not yet exist for the input parameters, RESRAD provides default values that "have been carefully selected and are realistic although conservative parameter values" (Argonne, 1993a). A more specific discussion on parameter selection and site-specific input data used is discussed in Chapter 3. A detailed explanation and justification for specific values used for modeling the three exposure scenarios is presented in Appendix A.

4.5 Key Input Parameters for the Occupancy Scenarios

The number of input parameters used for modeling the TWC site and possible future scenarios for occupancy exceeded 80 separate entries of data. As a result of the tremendous amount of input data required to run the RESRAD code, only those key input parameters will be addressed due to their pivotal role in running the modeling code. In the cases where site-specific input data was not available, default values from RESRAD's internal library were used.

Key input parameters are values that (with minor variations) can greatly affect the results of the model output. For instance, the soil contamination concentration variable is crucial in affecting the amount of exposure that occurs in each of the three scenarios. Under these scenarios, an increase/decrease in the amount of radioactive contamination in the soil would mean the exposure rate would increase/decrease proportionally with a change in contamination concentration.

On the other hand, large or small changes in the K_d factors do not produce changes in the permeablity of the soil for uranium and thorium. The primary reason why K_d factors are considered a key parameter for this analysis is that the K_d values chosen represent qualitative and quantitative evidence that the uranium and thorium have not migrated through the vadose zone to the groundwater aquifer (Ziskind et al., 1981) (CH2M Hill, 1999). A second reason for the K_d factors being a key input was that the extremely large K_d values chosen were meant to reinforce the position that it is unlikely the COCs would migrate (transport) through the vadose zone.

4.5.1 Soil Concentration Parameters

These parameters represent the nuclide(s) (COCs) present at the site, the amount of activity in pico (1×10^{-12}) curies per gram (ρCi/g), and the amount of time (in years) since the material was lost or placed. The nuclides present in the contaminated area were 1.7 ρCi/g of natural uranium and 1.8 ρCi/g of natural thorium. The RESRAD code performed all the exposure and transport algorithms based on the amount of these two nuclides plus their progeny. The soil samples used for this modeling activity were based on physical soil samples collected and analyzed by TWC employees and analyzed at the TWC on-site laboratory (CH2M Hill, 1999). The amount of time elapsed since initial unloading activities began until soil samples were collected was approximately 25 years (Riggs, 2001).

4.5.2 Soil Distribution Coefficients (K_d Factors)

The equilibrium distribution coefficient (K_d) of a radionuclide can be quantitatively described as its potential to adsorb or absorb with other materials. Sorption is the physical affinity of one type of matter with another by way of absorption or adsorption. Absorption is defined as a solute attaching within a sorbent. Adsorption is the attachment of a solute to the surface of a sorbent (Stewart, 1996). The distribution coefficients are further broken down for individual nuclides in a given soil type for the following three areas: the contaminated zone, the unsaturated and uncontaminated (vadose) zone, and the saturated (aquifer) zone. The mathematical expression that shows the sorptive relationship of radionuclides with soils is

$$\mathbf{K_d} = \frac{\textbf{Amount of radionuclide sorbed on sediment}}{\textbf{Amount of radionuclide in solution}}$$

The K_d factors were chosen according to the type of soil present at the site (Till and Meyer, 1983). The soil composition was based on actual borehole analyses from well BH #7 (P790-WC/HEA #7) drilled approximately 400 feet west of the FSUA site (Ziskind et al., 1981). Table 4 shows the soil type for each zone, the associated K_d factors chosen for the soil type, and the nuclides of primary concern.

4.5.3 Contaminated Zone Parameters

These parameters describe the physical characteristics of the contaminated zone. First is the physical area, measured in m^2, of the FSUA where Nigerian and Indian zircon sand ore containing NORM spilled into the soil. The contaminated area measured approximately

Table 4 Distribution Coefficients for Th and U (K_d)

Zone	Soil Type	K_d for Th (cm^3/g)	K_d for U (cm^3/g)
Contaminated	Clay/silt soils	60,000†	4,400‡
Vadose	Stiff clays	160,000‡	4,400‡
Saturated	Coarse sand/fine gravels	6,000†	50†

†Argonne, 1993b. Table E.3

‡Till and Meyer, 1983. Table 4.7

15.24 m (50 ft) by 21.34 m (70 ft) for a total of 325 m^2 (CH2M Hill, 1999). The site was modeled as a circular area with a diameter of 19.8 m (65 ft). The rough shape of the contaminated area was an oval. Modeling the site as a circle more easily depicted the geometry of the contaminated area rather than trying to define an oval in the RESRAD code. The default geometry for a contaminated area in RESRAD is a circle.

4.5.4 Contaminated Zone Erosion Rate Parameter

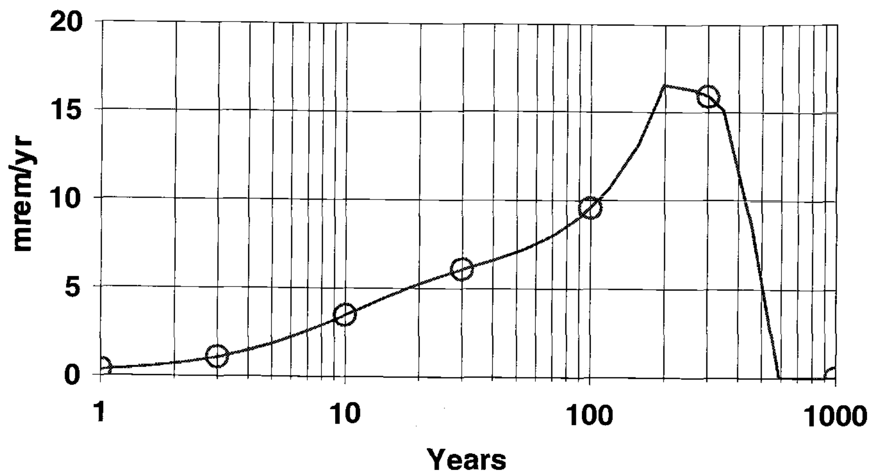
This parameter represents the affects of erosion on the contaminated soil from the FSUA. The rate of erosion that occurs in the contaminated zone at the FSUA significantly affects the amount of residual contamination (and the resulting dose rate) that migrates from the FSUA. It must be noted that this parameter only becomes significant after the cover material has been removed or is no longer in place (Argonne, 1993a). The erosion rate is a key transport factor that allows for the mobilization of the residual contamination in the soil. A sensitivity analysis was performed for this parameter and the results showed that small increases in the erosion rate produce a significant drop-off in the dose rate. The reason being is that the erosion of the soil is migrating the contaminates away from the FSUA at a rate that is faster than the buildup rate of decay progeny from the parent nuclides.

4.5.5 Cover Material Erosion Rate Parameter

This parameter describes the erosion rate of the cover material over the contaminated zone. This parameter will affect how long the residual thorium, uranium, and their progeny will remain in the soil.

Under two of the three scenarios (industrial and commercial), this parameter is critical in determining the external exposure rate to a future occupant at the site. The significance of this parameter is that the asphalt cap largely prevents surface water runoff from migrating the COCs away from the FSUA and allows for the decay progeny to build up over time. It is the decay progeny that causes the dose rate to increase over time. This is depicted in Figure 10. Once the asphalt cap fails, the erosion rate of the contaminated zone soil becomes dominate (Argonne, 1993a) and, as shown in Figure 10, the dose rate drops off significantly. This topic will be discussed in further detail in Chapter 5. For the residential scenario, it is assumed that all of the asphalt cover material has been removed for building the future home and surrounding landscaping.

Figure 10 Exposure Drop-off Depicting Asphalt Cap Failure



The erosion rate, which resulted in the asphalt cap having an approximate 200-year lifespan*, was calculated using the RESRAD cover erosion rate formula. The value of X_1 was the final cap thickness (0 m), X_2

$$X_1 = X_0 - V^{(cv)}t$$

was the initial thickness (0.1016 m), $V^{(cv)}$ was the erosion rate

* Personal Communication with Jim Huddleston. Asphalt Pavement Association of Oregon, April 14, 2000. This value was based on an approximate 100 to 500-year lifespan of asphalt pavement assuming a linear degradation rate.

(0.000508 m/y), and t represented the time (200 y). The 200-year value for time was chosen because it was approximately half of the predicted life expectancy for the asphalt pad covering the FSUA.

4.5.6 Runoff Coefficient Parameter

This parameter also showed that small changes in the input values, produced significant changes in the exposure rates. Given that the TWC site is in the flood plain of the Willamette River, the slope of the site is assumed to be less than two percent. However, since the TWC site is built-up with large areas being paved, large surface area buildings, and an extensive rainwater drainage system, much of the surface runoff is directed toward drainage tiles and the storm water sewer system. This is the reason for assigning the value of 0.8 for the runoff coefficient. This coefficient corresponds to the FSUA site being approximately 70% impervious to water percolating through the contaminated zone (Argonne, 1993a).

The runoff coefficient parameter, along with the precipitation, irrigation rate, and evapotranspiration coefficient parameters, are used to determine how much surface water percolates through the vadose zone to the groundwater. These parameters would be used if the groundwater pathway were assessed. Since the groundwater pathway was not evaluated, these parameters do not have the magnitude of importance that the runoff and erosion rate parameters have on soil leaving the contaminated zone at the FSUA. These parameters are key input values for the mass balance equation which would ultimately be used for determining the leaching rate of the COCs to the groundwater system.

5 RESULTS AND DISCUSSION

5.1 Summary of Results for the RESRAD Model

The results of the three scenarios modeled using RESRAD are presented both graphically and through summary tables. The outputs of the summary tables are listed in Appendix B. The results from the three exposure scenarios display doses (in mrem/yr) over a period of time with a standard time window of 1000 years. The graphical outputs are in a linear/logarithmic layout with dose being on a linear scale and time being on a logarithmic scale. Overall summaries of the three exposure scenarios are listed in Table 5 below.

Table 5 Maximum Doses and Corresponding Year

Scenario	Maximum Dose (mrem/yr)	Corresponding Year (@Yr)
Industrial Worker	16.7	198
Commercial Worker	13.6	198
Future Resident	16.6	40

5.1.1 Results for the Industrial Worker Scenario

The results for the industrial worker scenario indicate that the major contributing factor to the dose rate came from the radionuclide

Th-232 and its associated progeny (Figures 11 & 16). The U-238 contributed only a fraction of additional exposure (0.05 mrem/yr). This is due mainly to the small amount of dose contributed by the U-238 and its associated progeny (Figure, 15)

Figure 12 clearly shows that the external radiation pathway was the dominate source of exposure for all pathways considered. This result was enhanced by the asphalt cap over the contaminated area. It would be nearly impossible for an industrial worker to ingest or inhale (through re-suspension – wind blowing the contaminated soil into the air) radioactively contaminated soil under the asphalt cap. This is one contributing reason why the exposures through the inhalation and ingestion pathways are negligible.

Figure 11 Dose for All Nuclides and Pathways Summed for the Industrial Worker Scenario

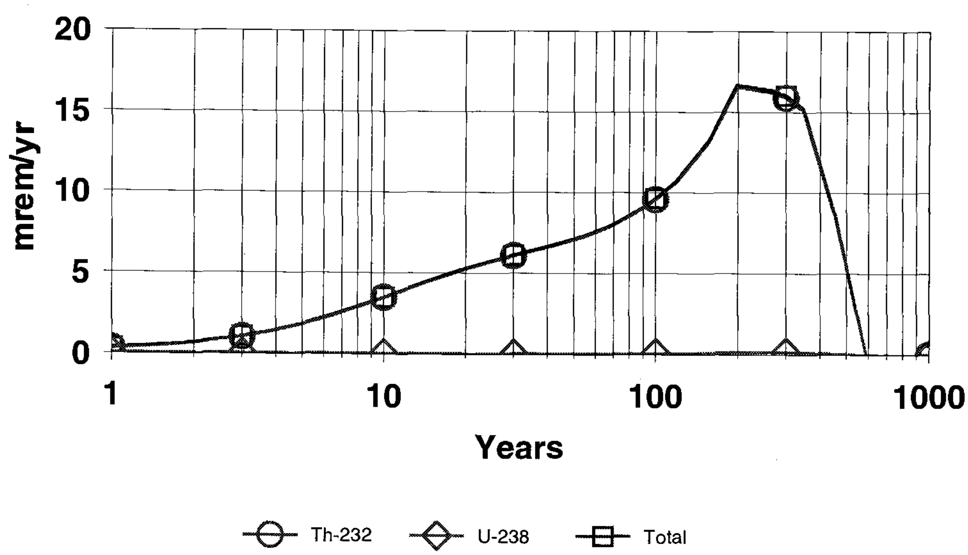


Figure 12 Dose for All Nuclides Summed, External Pathway for the Industrial Worker Scenario

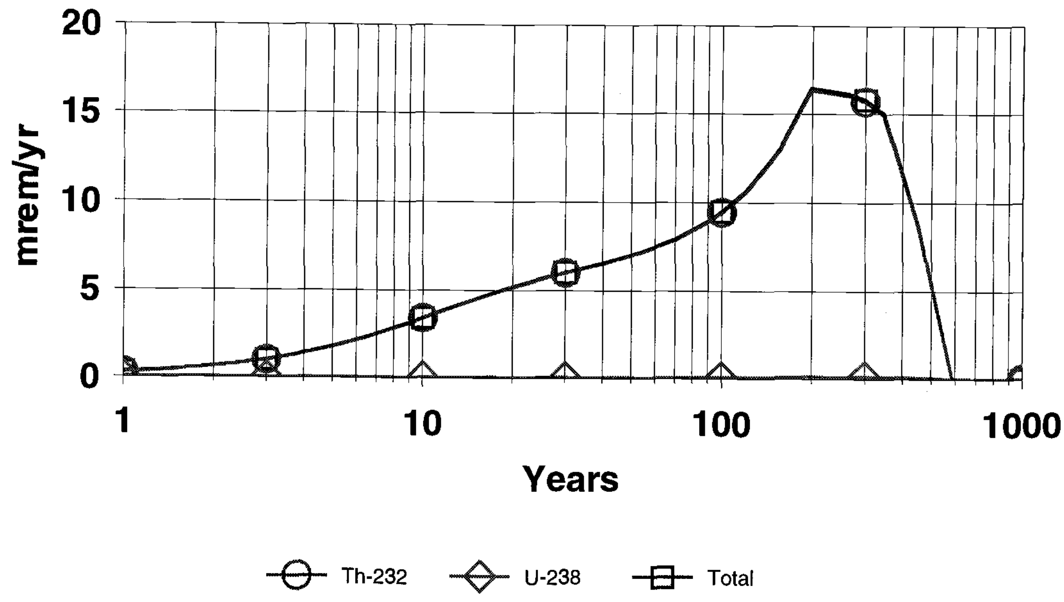


Figure 13 Dose for All Nuclides Summed, Inhalation Pathway for the Industrial Worker Scenario

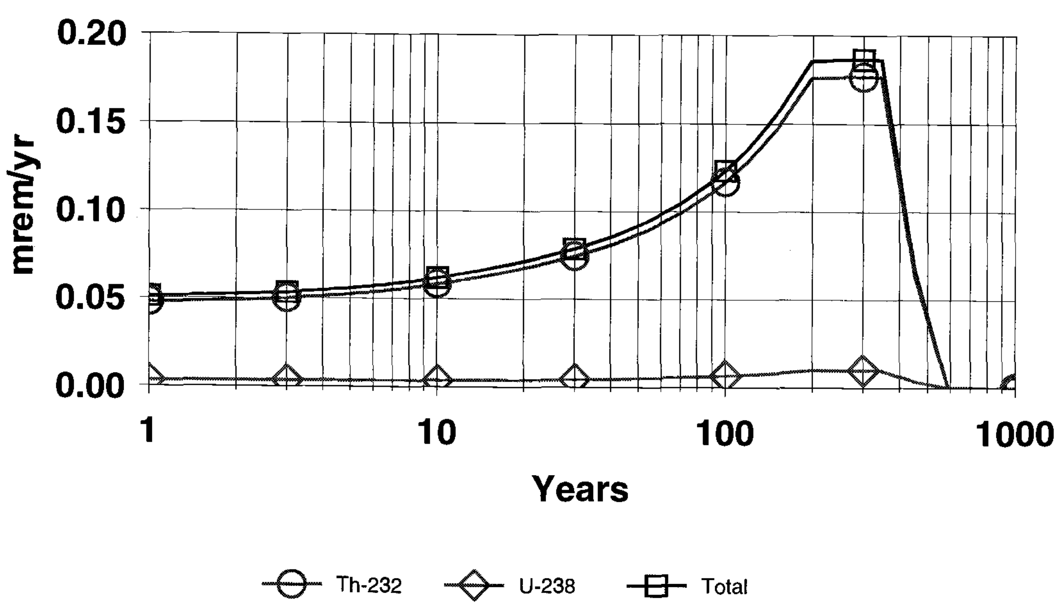


Figure 14 Dose for All Nuclides Summed, Soil Ingestion Pathway for the Industrial Worker Scenario

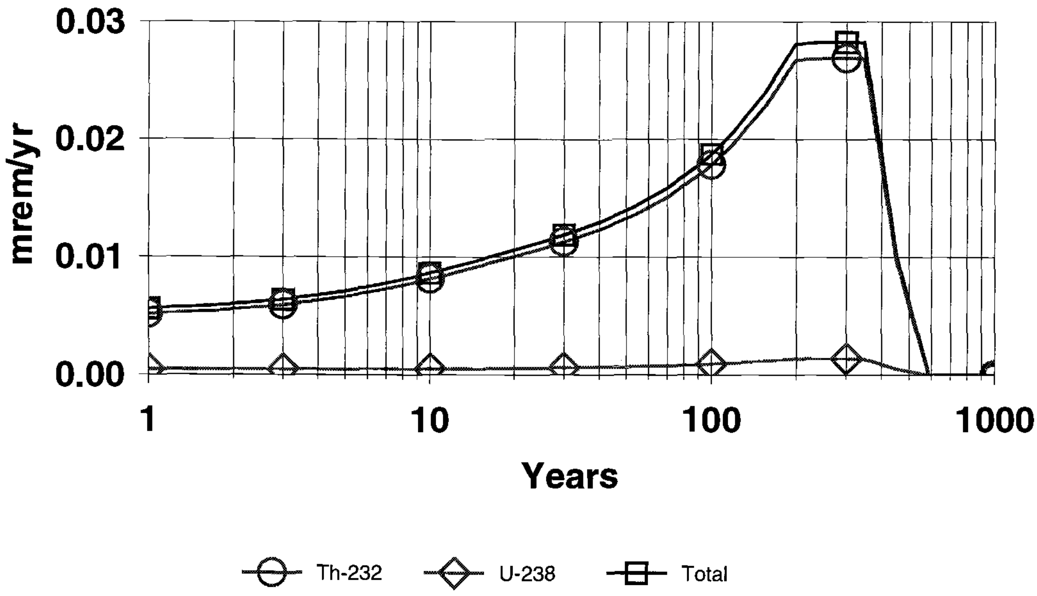


Figure 15 Dose for U-238 Exposure: All Pathways Summed for the Industrial Worker Scenario

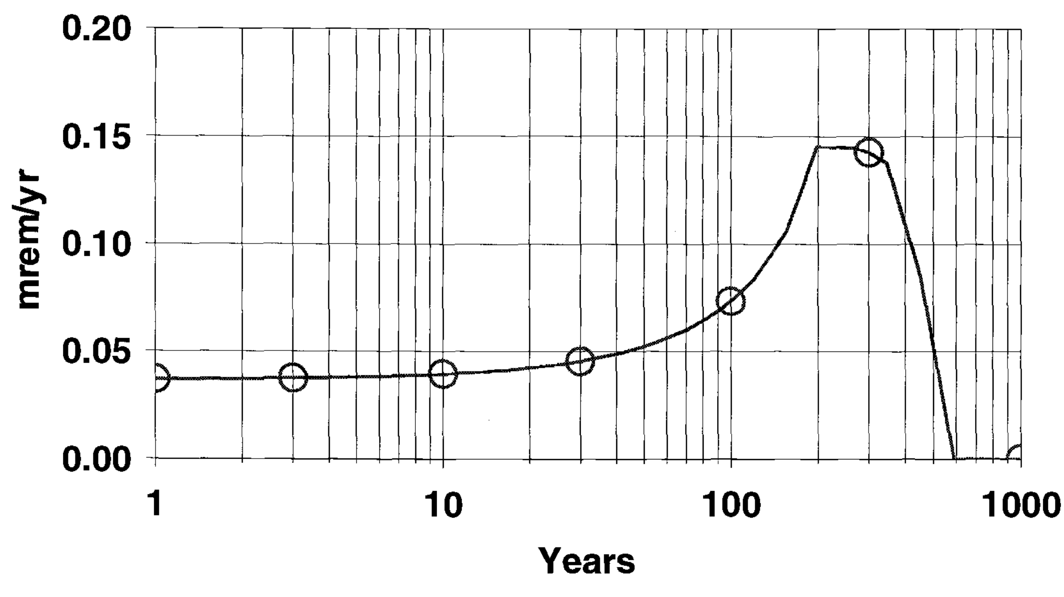
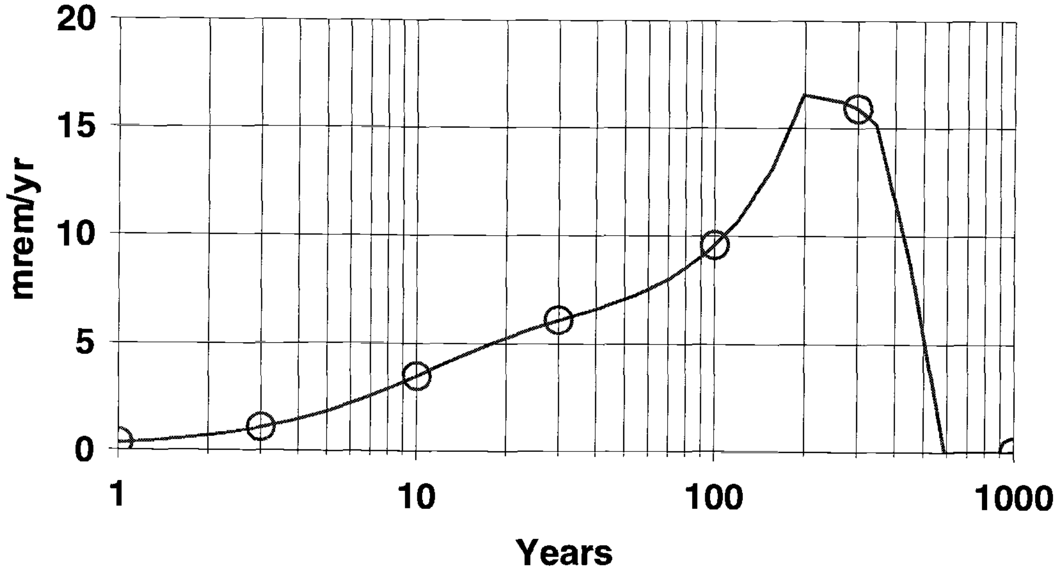


Figure 16 Dose for Th-232 Exposure: All Pathways Summed for the Industrial Worker Scenario



The inhalation and ingestion exposure pathways are shown in Figures 13 and 14 respectively. The general shape of the dose rate curve is similar to that of the external exposure pathway curve. It should be noted that these two pathways contribute only a small fraction exposure (approximately 0.18 mrem/yr for inhalation and 0.028 mrem/yr for ingestion) to the total dose rate for the industrial worker scenario.

The ingestion pathway dose rate is identical (approximately 0.028 mrem/yr) for both the industrial and commercial worker scenarios (Figures 14 & 20). The occurrence of a worker ingesting contaminated soil is extremely remote. This is why the ingestion pathway contributes the least amount of exposure to the three scenarios. An example of this exposure pathway would be where contaminated soil is airborne and the resulting particulates of dust are deposited on the worker's coffee cup. The worker would then, through non-dietary ingestion, consume the contaminated particulates of dust. Contaminated dust is not readily available for ingestion because of the asphalt cap.

5.1.2 Results for the Commercial Worker Scenario

The results for the commercial worker scenario were quite similar to that of the industrial worker. Again, a majority of the dose came from Th-232 and its associated progeny (Figures 17 & 22). The U-238 contributed only a fraction of additional exposure (Figure 21). Also, the external radiation pathway yielded the largest portion of the dose rate over time (Figure 18).

The rationale for these results are nearly identical to the reasons given for the industrial worker scenario results in the preceding section. However, the commercial worker's dose rate was slightly lower over time than the industrial worker. The effects of time, distance, and shielding had an effect on lowering the dose rates for the external radiation pathway results. The reason was that the fraction of time spent indoors for the commercial worker was 65% while the industrial worker spent only 25% of the time indoors. This accounted for the commercial worker receiving a lower dose rate from external radiation.

Figure 17 Dose for All Nuclides and Pathways Summed for the Commercial Worker Scenario

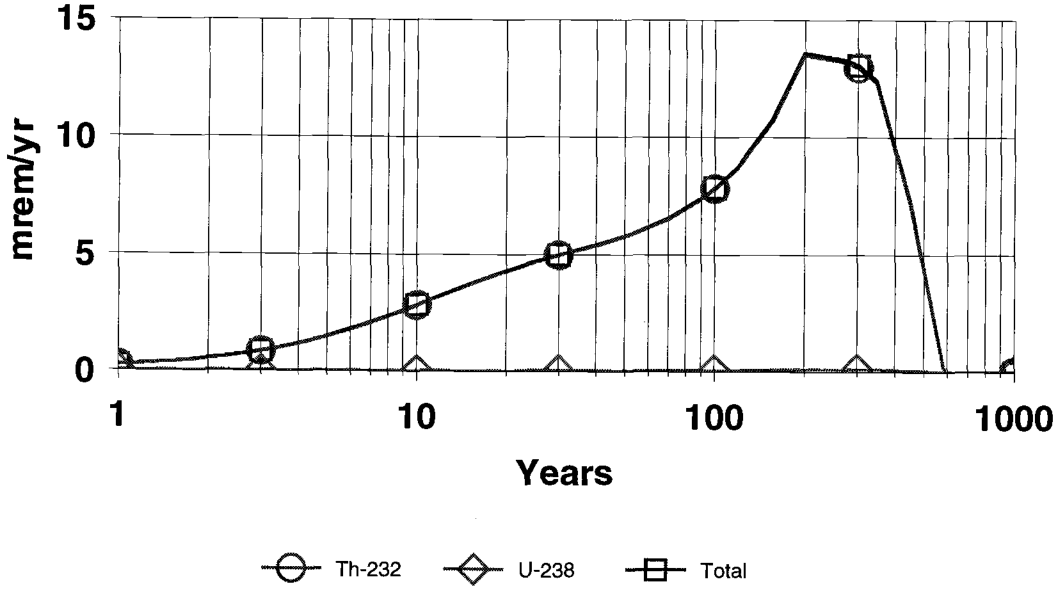


Figure 18 Dose for All Nuclides Summed, External Pathway for the Commercial Worker Scenario

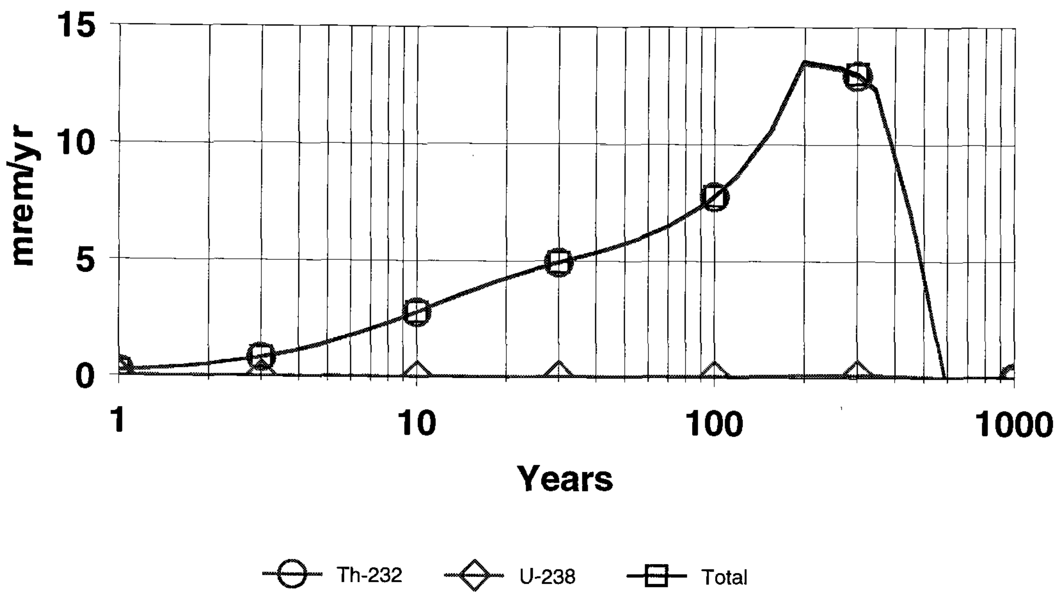


Figure 19 Dose for All Nuclides Summed, Inhalation Pathway for the Commercial Worker Scenario

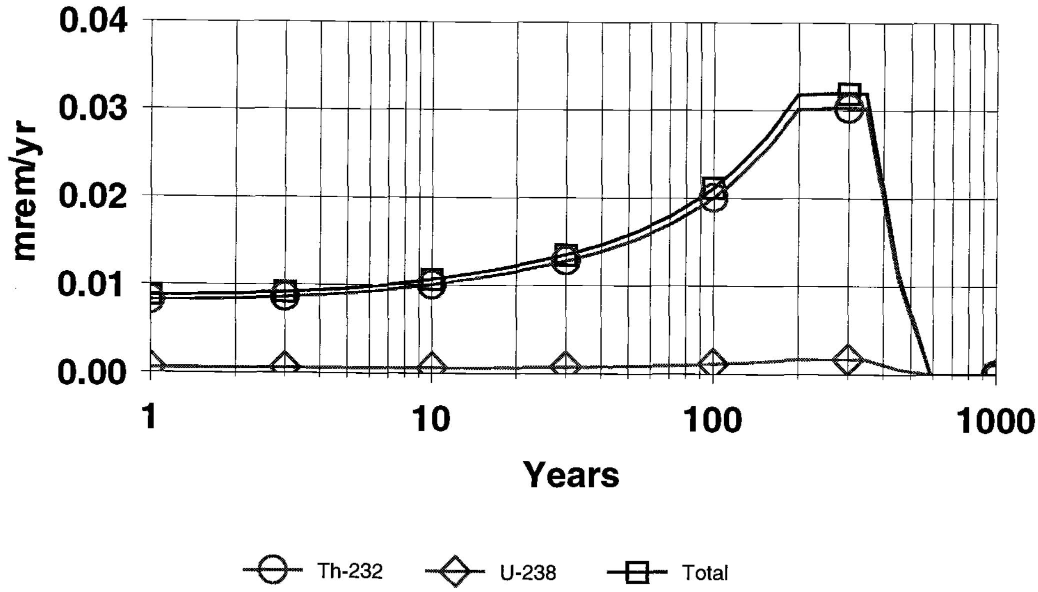


Figure 20 Dose for All Nuclides Summed, Soil Ingestion Pathway for the Commercial Worker Scenario

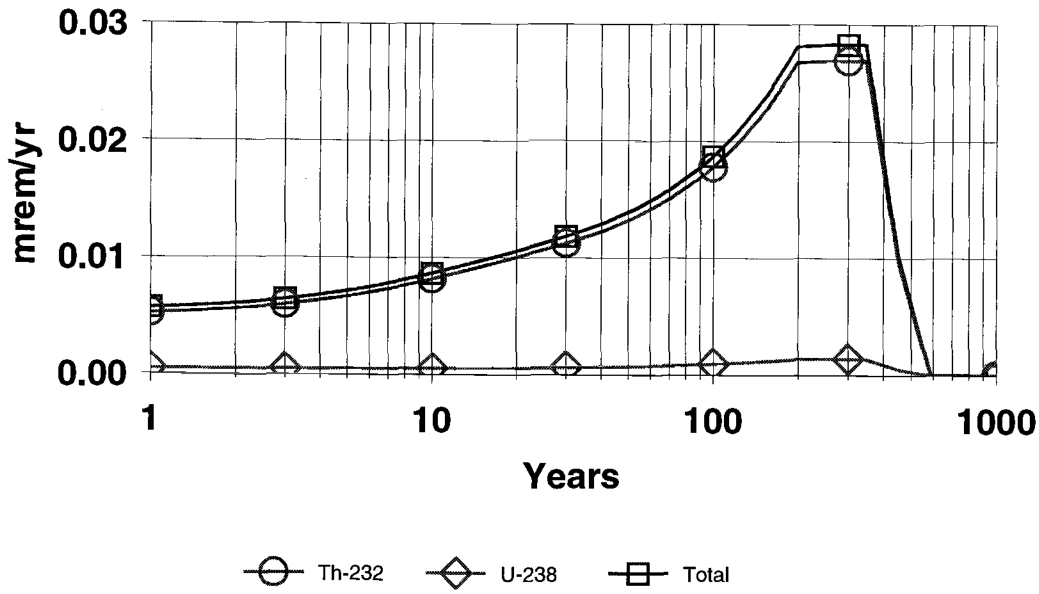


Figure 21 Dose for U-238 Exposure: All Pathways Summed for the Commercial Worker Scenario

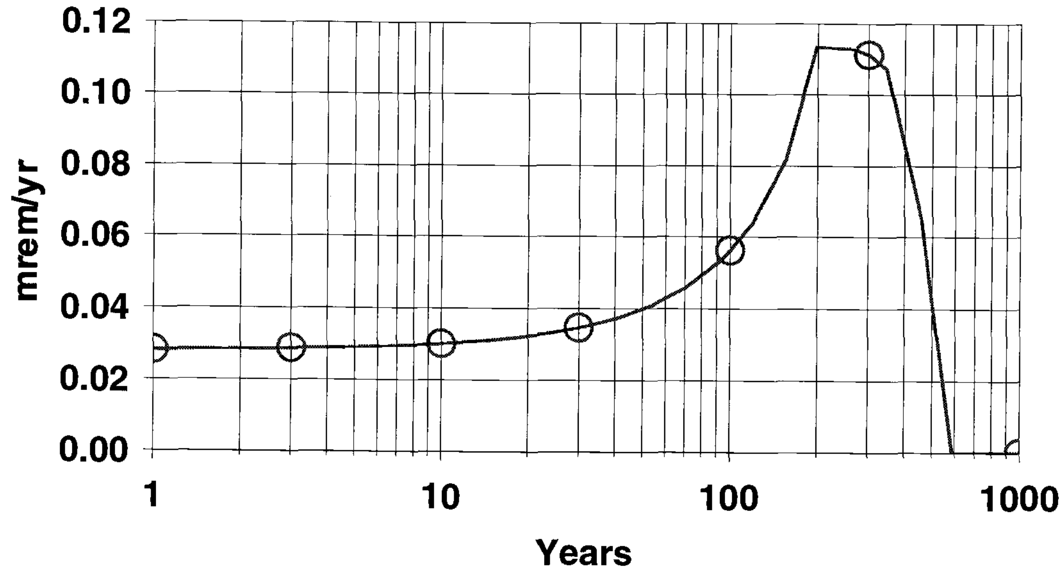
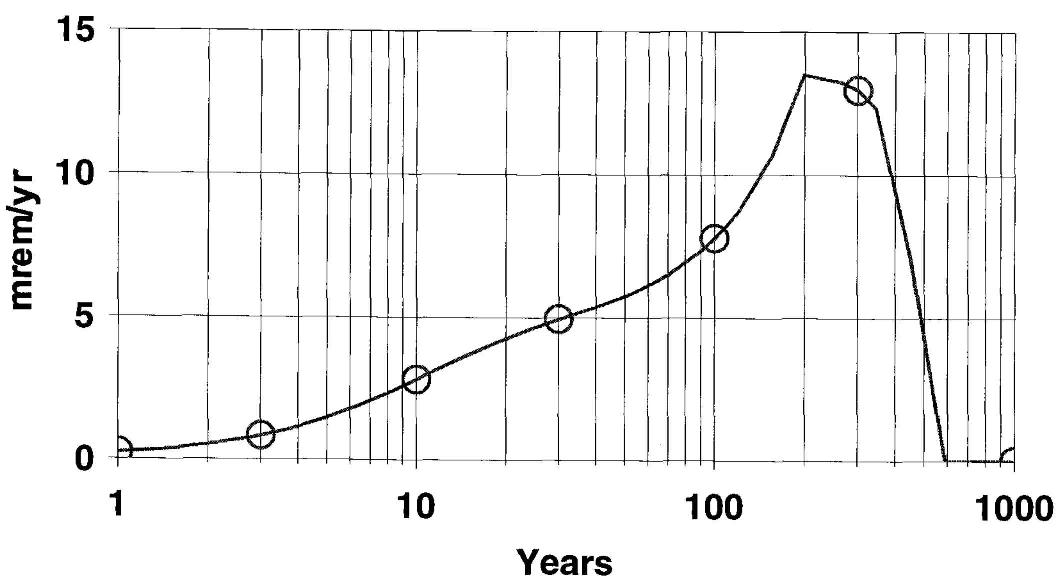


Figure 22 Dose for Th-232 Exposure: All Pathways Summed for the Commercial Worker Scenario



The inhalation and ingestion exposure pathways are shown in Figures 19 and 20 respectively. The general shape of the dose rate curves for these two exposure pathways are similar to those shown in the industrial worker scenario output graphs.

The dose rate for the inhalation pathway is slightly lower in the commercial worker scenario than in the industrial worker scenario. The reason is that the industrial worker is directly breathing air that is, for the most part, contaminated with resuspended particles. For the commercial worker, there is less contaminated air mixing with the uncontaminated air indoors. Buildings usually have air filtration systems that filter out dust and fine particulates. Also, a percentage of air indoors is recirculated and is not mixed with contaminated outside air. This decreases the amount of air available for mixing and dilutes the concentration of contaminated air. On the other hand, the industrial worker is spending more time outside where air is mixing with the resuspended contaminated soil. Additionally, for the industrial worker, the volume of air available for mixing is nearly infinite.

As mentioned in the previous section, the exposure rates for the ingestion pathways were identical for both the commercial and industrial scenarios.

5.1.3 Results for the Residential Occupant Scenario

The results for the residential occupant scenario produced a dose rate of 17.5 mrem/yr, which was similar to the industrial worker scenario results. However, the reasons and pathways causing the dose rates differed. The external exposure pathway was again the predominant source of exposure (Figures 23 & 24). The residential occupant scenario also showed that the major contributing factor to the dose rate came from the radionuclide Th 232 and its associated progeny (Figures 23 & 29). Again, the U-238 contributed virtually no additional exposure (Figure 28).

The inhalation pathway dose rate for the residential occupant was more than 10 times the dose rate for the commercial worker scenario and more than double the dose rate for the industrial worker scenario (Figure 25). The main reasons for this are that the residential occupant is growing food on the contaminated site and the asphalt cap is not present. The amount of soil resuspension (dust) in the air is greater because the contaminated soil is being cultivated. Additionally, the residential occupant is physically closer to the contaminated dust and is directly breathing it in.

The soil ingestion pathway dose rate was more than double the dose rate for the industrial and commercial worker scenarios. The direct non-dietary soil ingestion of contaminated soil was much higher due to the

Figure 23 Dose for All Nuclides and Pathways Summed for the Residential Occupant Scenario

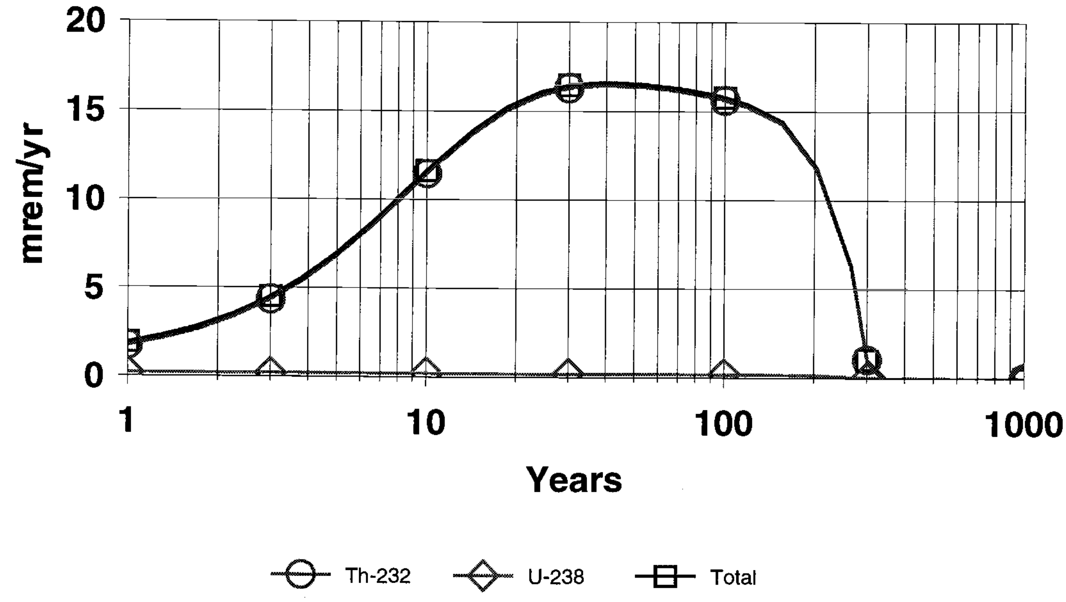


Figure 24 Dose for All Nuclides Summed for the External Pathway for the Residential Occupant Scenario

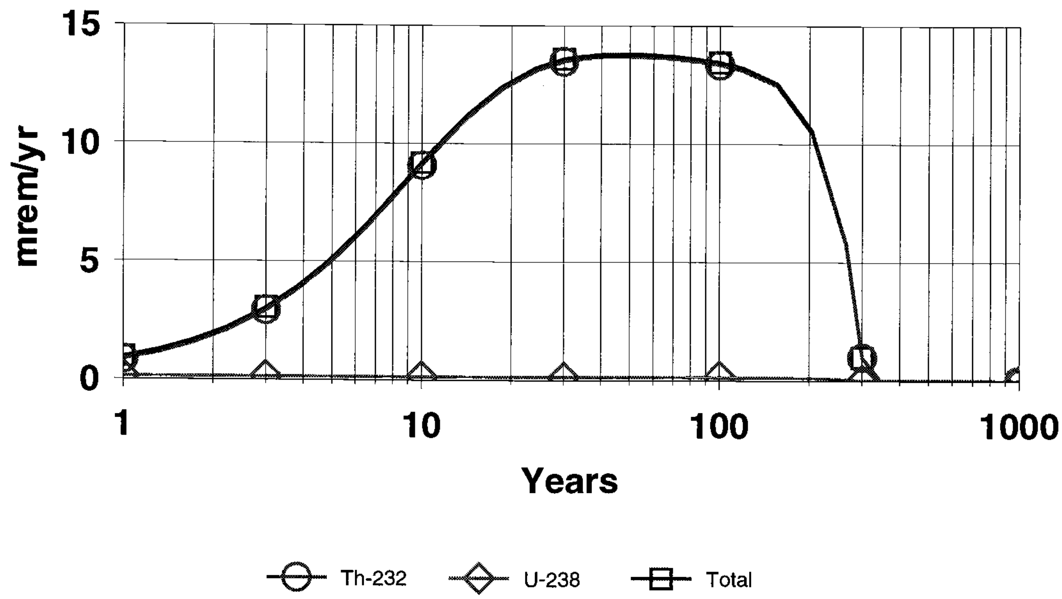


Figure 25 Dose for All Nuclides Summed for the Inhalation Pathway for the Residential Occupant Scenario

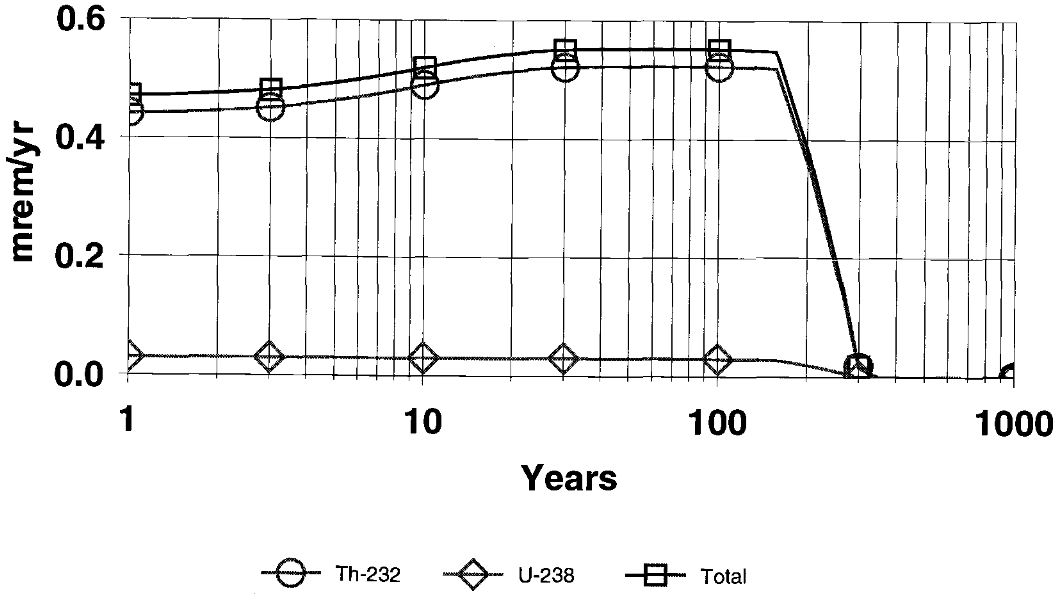


Figure 26 Dose for All Nuclides Summed for the Soil Ingestion Pathway for the Residential Occupant Scenario

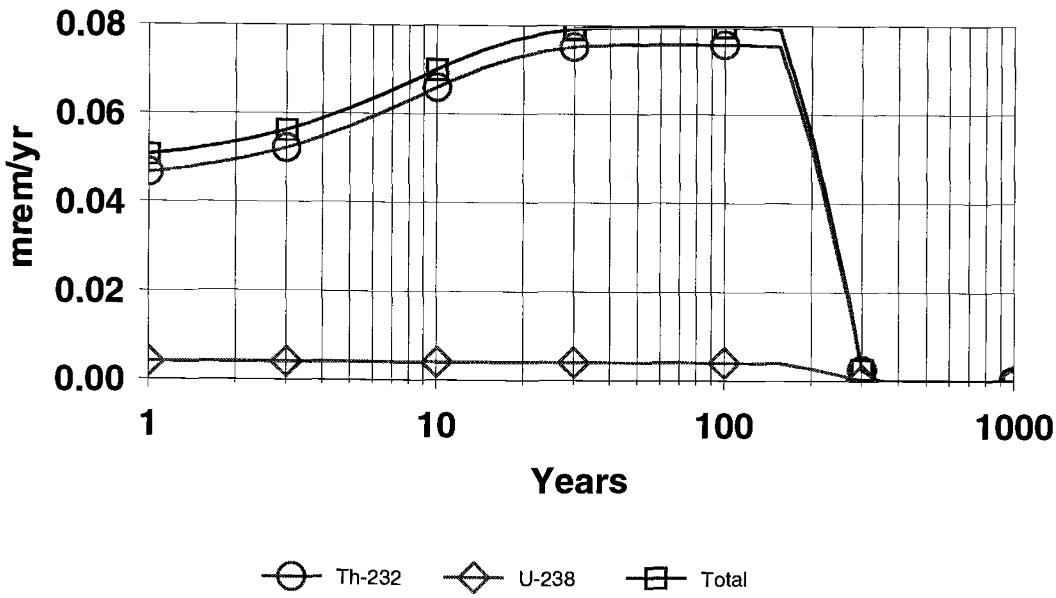


Figure 27 Dose for All Nuclides Summed for the Plant Ingestion Pathway for the Residential Occupant Scenario

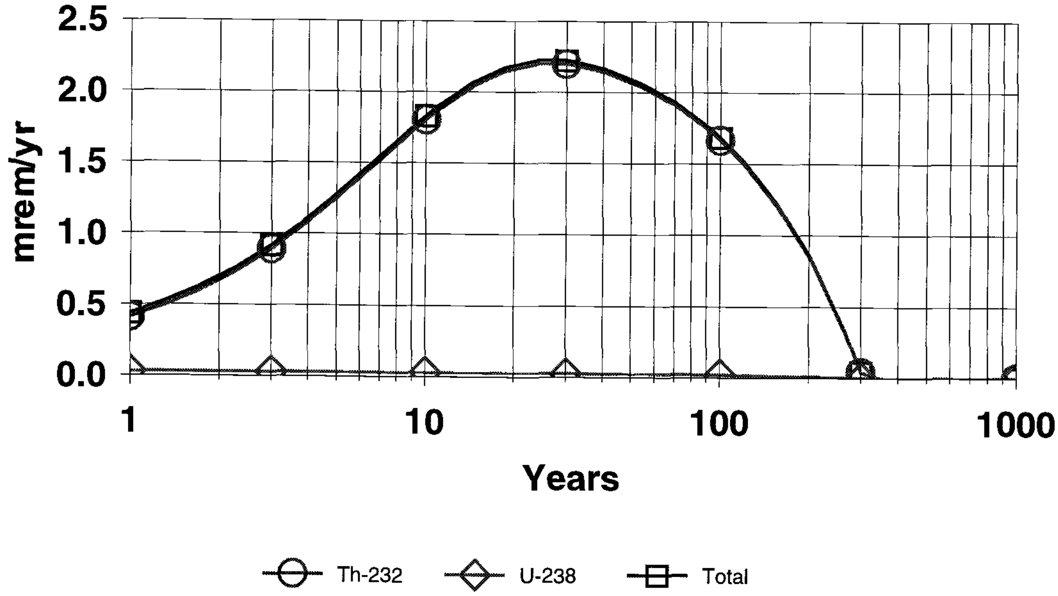


Figure 28 Dose for U-238 Exposure: All Pathways Summed for the Residential Occupant Scenario

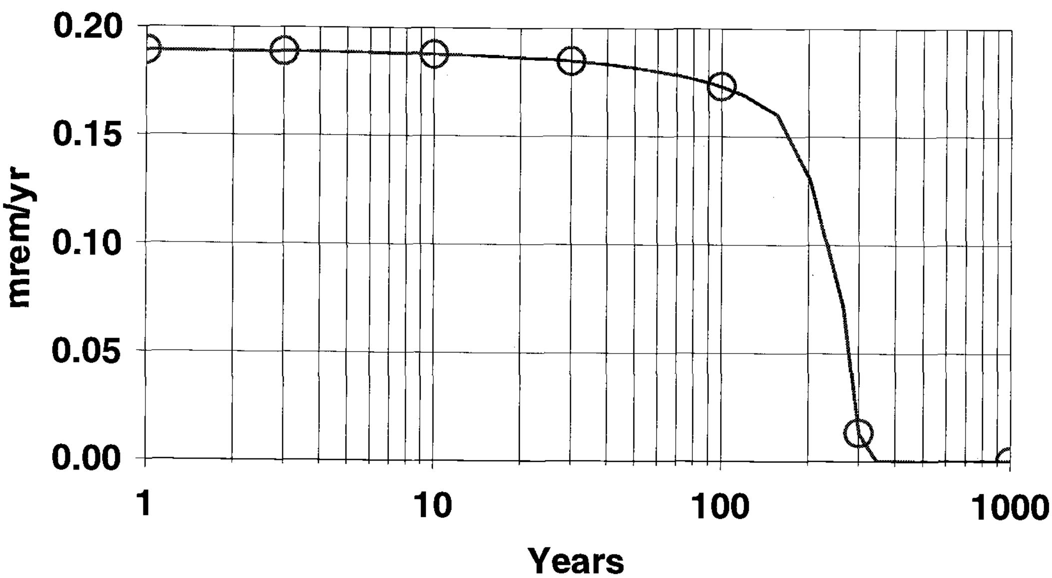
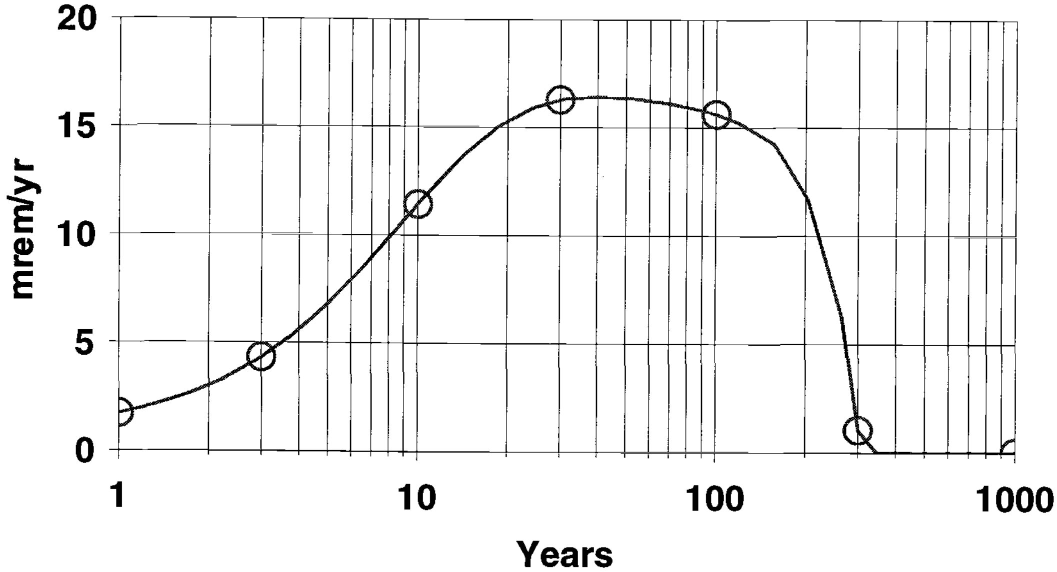


Figure 29 Dose for Th-232 Exposure: All Pathways Summed for the Residential Occupant Scenario



increased amount of contaminated dust particles in the air and the close proximity to the cultivated soil.

The ingestion of homegrown produce added approximately 2 mrem/yr of exposure to the overall dose rate for this scenario (Figure 27). This is the result of foliar deposition of contaminated dust on the produce that is consumed from the garden. Direct plant uptake of radionuclides from the contaminated soil is also an additional source of contamination contributing to the dose rate for the ingestion pathway.

5.2 Analyses of Pathway Graphical Outputs

The two most significant trends of the modeled scenarios graphical outputs were the appearance of geometric growth of the dose rate and the pronounced drop off in the dose rate at the 200-year mark (see Figures 11 & 17 in the previous sections). Another important trend of the output graphs, for the inhalation pathway, was the constant dose rate followed by a sharp decline at the 150-year mark. These trends will be discussed in the following sections.

5.2.1 Analysis of the External Pathway Graphical Outputs

In both the industrial and commercial worker scenarios (Figures 12 & 18), the external exposure dose rate curves are roughly the same. The curves are showing a geometric growth rate in exposure up until the point that the asphalt cover cap fails. This is a result of the asphalt cap keeping air and water from eroding the contaminated soil beneath the cap.

A sensitivity analysis was conducted to determine the upper limit of the exposure rate. To perform this test, the cover erosion rate for the asphalt cap was slowed to almost no erosion occurring. It was expected that the dose rate would continue its geometric climb to a maximum level. The result was inconclusive. The maximum dose rate did not increase over time, but remained constant. The only change observed by slowing the cover cap erosion rate was the time at which the cover cap experienced catastrophic failure.

The relatively sharp decrease in the dose rate after the 200-year mark is the result of the catastrophic failure of the asphalt cap. As the contaminated soil erodes, the contaminants and their progeny are removed thereby dropping the dose rate. The cover material (asphalt cap) erosion rate (0.000507m/y) is the dominant parameter until the 200-year mark is reached. At this point it is replaced by the contaminated zone erosion rate (0.001 m/y), which is significantly faster (Argonne, 1993a). The results are depicted in Figures 11 through 22 in the previous sections. In reality, the asphalt would develop cracks and fissures gradually over the first 50 to 100 years allowing for some runoff water from rain to leach into the contaminated zone and to start migrating the contaminants out of the contaminated zone. Once the asphalt cap has started to lose its integrity, surface water runoff would migrate the contamination down gradient to nearby drainage tiles, storm drains, or possibly to Truax Creek.

In the case of the residential scenario (Figure 24), the "bell" shaped external exposure rate curve is a result of the contaminated zone erosion rate verses the in-growth of progeny rate. In other words, initially, the rate of external exposure (from the buildup of the progeny nuclides) is greater early on than the rate of soil erosion. At approximately 40 years, the two rates reach an equilibrium. By 100 years, the erosion rate becomes dominant by removing the remaining contaminated soil thereby reducing the dose rate.

5.2.2 Analysis of the Inhalation Pathway Graphical Outputs

In both the industrial and commercial future worker scenarios (Figures 13 & 19), the rationale for the overall shape of the inhalation pathway dose rate curve was the same as it was for the external pathway dose rate. However, there is a difference at the point of where the asphalt cover cap fails. The "flat" area in the curve resembles the same curve shape of the inhalation pathway under the residential scenario (Figure 25). The inhalation pathway dose rate in all three scenarios show a relatively flat curve for the first 150 years. After the 150-year mark the dose rate curve becomes a straight line with a negative slope that ends at approximately the 300-year mark. The complete erosion of the contaminated zone occurs at the 305-year mark. The reason for the "flat" area of the dose rate curves was due to the **Depth of Soil Mixing Layer** parameter. The parameter is defined as: "the fraction of resuspendable soil particles at the ground surface that are contaminated" (RESRAD, 1998). In essence, it is this mixing layer that contributes to the dose rate until erosion removes it from the contaminated zone. The value assigned for this parameter was the default value of 0.15 m.

5.2.3 Analysis of the Ingestion Pathway Graphical Outputs

In both the industrial and commercial future worker scenarios (Figures 14 & 20), the ingestion pathway had the same dose rate curves that the inhalation pathway dose rate curves had. The explanations for the shapes of the ingestion pathway dose rate curves were the same as the inhalation pathway dose rate curves.

5.3 Uncertainties with the RESRAD Model and Scenarios

There are a number of sources of uncertainty associated with this study. They can be broken down into two categories. One is the physical uncertainties with the RESRAD code itself. The other category is the uncertainties of the scenario models.

At this time, the RESRAD code has no known capability to model the linear (gradual) degradation of contaminated zone cover material, such as an asphalt cap. RESRAD can only model a complete instantaneous failure of contaminated zone cover material. Therefore, this should be noted as an uncertainty in the predicted results. There were no other known or discovered uncertainties associated with the RESRAD code.

The uncertainties associated with the scenario models can be broken down into two main categories. The first would be uncertainties with the exposure pathways. The second category is the actual parameter values used for running the RESRAD code.

There were nine exposure pathways available in RESRAD. Of the nine, only a total of four were used. The pathways for drinking water and radon were omitted from this study. The author did include these pathways in test runs of the residential occupant scenario. The results were trivial in the amounts of dose added to the exposure scenarios. By not including these pathways, an amount of uncertainty is added to the overall study.

The uncertainties associated with the parameter input values were numerous. However, only the key parameters will be mentioned. The biggest uncertainty of all the parameters was the longevity (the erosion rate) of the asphalt cap. It is not known what the true lifespan of asphalt caps really are. They have only been in existence for a little more than 100 years. The factors affecting the longevity of asphalt are: "stripping" the separation of the asphalt and the aggregate, thermal cracking, ozone and UV degradation, and finally, the dominate driver is the weight loads put on the asphalt cap*.

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* Personal Communication with Gary Thompson. Asphalt Pavement Association of Oregon, March 23, 2000.

Another uncertainty was the erosion rate of the contaminated zone. Without more information about TWC's site geology, it was impossible to accurately determine the true erosion rate for the site.

A final uncertainty would also be related to the asphalt cover cap. As shown in the output graphs for external radiation pathways, the dose rate is increasing on a geometric scale. It is not clear if this trend will continue or if it is an algorithm coding issue in RESRAD. It can be noted that when the asphalt cover cap erosion rate was reduced to virtually 0, the dose rates changed to what the dose rates were for no cap at all (similar to the residential scenario external exposure rates). This is a significant and key uncertainty.

6 CONCLUSION

6.1 Regulatory Limits for Radiation Exposure to the Public

The results for the three scenarios clearly show no unacceptable health risks or excess exposures to the current or future occupants. The EPA is currently proposing a regulatory exposure limit of 85 mrem/yr. The modeled exposure levels are well below the 85 mrem/yr TEDE limit for all three exposure scenarios.

In the case of the OAR 333 Division 117, Regulation and Licensing of NORM, the 25 mrem/yr TEDE is the prevailing exposure limit. Even under this limit, the FSUA still meets the regulatory requirements for both current and future exposure limits. The modeled exposures for these three scenarios are acceptable, in the author's opinion, because of the reasonableness of the occupancy scenarios, the applicability of the exposure pathways, and because the most conservative values were chosen for unknown site specific parameters.

6.2 Limitations of this Study

One of the main limitations of this study was that there was no ecological impact scenario performed. This study only addresses the human health impacts and effects of radiation on the general public. It does not address what the impacts would be on environmental receptors. A second limitation is that this study is not applicable to the other OU sites at the TWC facility. Each one of those individual site would have to go through the same type of study that the FSUA did in order to determine long-term regulatory compliance. Finally, this study does not indicate where contaminated soil migrates to or what the impacts are once it has left the TWC site.

6.3 Recommendations for Future Study

A follow-on study of the asphalt cover cap erosion could be performed using a different model. A comparison of two model results could address some of the uncertainties associated with this parameter. Another key area of future study would be the previously mentioned ecological assessment. In addition to an ecological study, further effort could be spent on tracking the fate and transport of radionuclide contaminated surface water and runoff from the TWC site. Lastly, future studies could also address the impacts of radionuclide contamination to the Willamette River and the ecological systems around it.

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APPENDICES

APPENDIX A

Parameter Justification for RESRAD Code

A.1 Introduction

This appendix will account for all of the detailed parameters used to model TWC's FSUA. A short explanation and rationale for why parameter values were chosen or derived will be given for each input parameter used in the RESRAD code. Every site-specific value or input parameter was utilized to ensure that RESRAD would model the site as accurately as possible. For cases where site-specific values or data could not be determined, calculated, or were not available, the RESRAD default parameter values were used.

This was the case for some of the external gamma ray pathway and food ingestion pathway parameters. It would be impossible to determine certain future parameters especially in the areas of homegrown produce. The actual amount of food produced and consumed could vary widely depending on the individual. In the case of shielding factors for a future structure, radiological surveys would have to be performed to provide site-specific information about the actual exposure rates both inside and outside the future structures. Here another unpredictable situation occurs. There is no way to determine what type of building material would be used to construct future homes and businesses or how the buildings would be utilized. The building materials used could greatly affect the shielding and gamma ray exposure rates for future occupants. This is the reason why the RESRAD default values were used for these pathway parameters.

The three scenarios (future residential, future commercial office worker, and current/future industrial worker) share some of the exposure pathways. For instance, all three scenarios share the external gamma exposure, soil inhalation, and soil ingestion pathways; however, the similarities between the scenarios end with the pathways. The commercial and industrial worker scenarios share the same exposure pathways. In contrast, there are a few differences between the two scenarios. A couple of examples are the fraction of time spent indoors vs. outdoors and the respiration rates for the two different types of workers. For instance, it would be unrealistic for a commercial office worker to spend 60 to 70 percent of their time outdoors. On the other hand, these percentages would be normal of an industrial worker. The respiration rates for the two workers would also be significantly different. An industrial worker's respiration rate would be expected to be greater (4200 m^3/yr) than an office worker's rate (1200 m^3/yr). While the pathways may be similar for the scenarios, the specific input parameters may differ significantly.

The future residential scenario incorporates the three previously mentioned exposure pathways in addition to the homegrown produce ingestion pathway. All four of the exposure pathways were assessed for the residential scenario according to the site conceptual model listed in Chapter 3. In all three cases, the drinking water (on-site water contamination) and the Radon pathways were not assessed. The rationale for not modeling these parameters are listed in Chapter 3. Tables A1 through A7 in this appendix contain and display the input parameters used in the RESRAD code for each of the three future site scenarios.

Table A1 Contaminated Zone Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value
Area of Contaminated Zone	m^2	325	325	325	N
Thickness of Contaminated Zone	m	0.305	0.305	0.305	N
Length Parallel to Aquifer Flow	m	19.81	19.81	19.81	N
Radiation Dose Limit	mrem/yr	15	15	15	N
Elapsed Time of Waste Placement	yr	25	25	25	N
Times for Calculations	yr	1-1000	1-1000	1-1000	N

Table A2 Initial Concentrations and Distribution Coefficients of Principal Radionuclides

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value
Thorium-232	ρCi/g	1.8	1.8	1.8	N
Uranium-238	ρCi/g	1.7	1.7	1.7	N
Thorium-232 K_d	cm^2/g	60,000	60,000	60,000	Y
Uranium-238 K_d	cm^2/g	4,400	4,400	4,400	N

Table A3 Cover and Contaminated Zone Hydrological Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value C I R
Cover Depth	m	0.1016	0.1016	N/A	N N
Density of Cover Material	g/cm^3	1.5	1.5	N/A	N N
Cover Material Erosion Rate	m/y	0.000508	0.000508	N/A	N N
Density of Contaminated Zone	g/cm^3	1.7	1.7	1.7	N N N
Contaminated Zone Erosion Rate	m/y	0.001	0.001	0.001	Y Y Y
Contaminated Zone Total Porosity	N/A	0.45	0.45	0.45	N N N
Contaminated Zone Effective Porosity	N/A	0.13	0.13	0.13	N N N
Contaminated Zone Hydraulic Cond.	m/y	32.6	32.6	32.6	N N N
Contaminated Zone b Parameter	N/A	10.4	10.4	10.4	N N N
Evapotranspiration Coefficient	N/A	0.56	0.56	0.56	N N N
Annual Average Wind Speed	m/s	3.13	3.13	3.13	N N N
Precipitation	m/y	1.52	1.52	1.52	N N N
Irrigation Rate	m/y	N/A	N/A	0.0	N
Irrigation Mode	N/A	N/A	N/A	Overhead	N
Runoff Coefficient	N/A	0.8	0.8	0.2	N N Y
Watershed Area for Nearby Stream or Pond	m^2	N/A	N/A	24155	N

Table A4 Uncontaminated and Unsaturated (Vadose) Zone Hydrological Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value
Thickness of Vadose Zone 1	m	N/A	N/A	1.524	N
Thickness of Vadose Zone 2	m	N/A	N/A	1.524	N
Thickness of Vadose Zone 3	m	N/A	N/A	3.084	N
Density of Vadose Zone 1	g/cm^3	N/A	N/A	2.0	N
Density of Vadose Zone 2	g/cm^3	N/A	N/A	1.7	N
Density of Vadose Zone 3	g/cm^3	N/A	N/A	1.5	Y
Total Porosity of Vadose Zone 1	N/A	N/A	N/A	0.42	N
Total Porosity of Vadose Zone 2	N/A	N/A	N/A	0.43	N
Total Porosity of Vadose Zone 3	N/A	N/A	N/A	0.34	N
Effective Porosity of Vadose Zone 1	N/A	N/A	N/A	0.06	N
Effective Porosity of Vadose Zone 2	N/A	N/A	N/A	0.33	N
Effective Porosity of Vadose Zone 3	N/A	N/A	N/A	0.28	N
Hydraulic Cond. of Vadose Zone 1	m/y	N/A	N/A	40.5	N
Hydraulic Cond. of Vadose Zone 2	m/y	N/A	N/A	199	N
Hydraulic Cond. of Vadose Zone 3	m/y	N/A	N/A	5550	N
b Parameter of Vadose Zone 1	N/A	N/A	N/A	11.4	N
b Parameter of Vadose Zone 2	N/A	N/A	N/A	7.12	N
b Parameter of Vadose Zone 3	N/A	N/A	N/A	4.05	N

Table A5 Saturated Zone Hydrological Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value
Density of Saturated Zone	g/cm^3	N/A	N/A	1.7	N
Saturated Zone Total Porosity	N/A	N/A	N/A	0.43	N
Saturated Zone Effective Porosity	N/A	N/A	N/A	0.33	N
Saturated Zone Hydraulic Cond.	m/y	N/A	N/A	5550.0	N
Saturated Zone b Parameter	N/A	N/A	N/A	4.05	N
Saturated Zone Hydraulic Gradient	N/A	N/A	N/A	0.002	N
Water Table Drop Rate	m/y	N/A	N/A	3.048	N
Well Pump Intake Depth	m/bwt†	N/A	N/A	0.9144	N
Accuracy for Water/Soil Computations	N/A	N/A	N/A	0.001	Y
Nondispersion or Mass Balance	N/A	N/A	N/A	Mass Bal.	N
Well Pumping Rate	m^3/y	N/A	N/A	1	N

† Indicates meters below water table.

Table A6 Occupancy, Inhalation, and External Gamma Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value C I R
Inhalation Rate	m^3/y	1200	4200	8400	N N Y
Mass Loading	g/m^3	0.0002	0.0002	0.0003	Y Y N
Exposure Duration	y	25	25	30	Y Y Y
Inhalation Shielding Factor	N/A	0.4	0.4	0.4	Y Y Y
External Gamma Shielding Factor	N/A	0.7	0.7	0.5	Y Y N
Indoor Time Fraction	N/A	0.65	0.25	0.25	N N N
Outdoor Time Fraction	N/A	0.1	0.5	0.5	N N N
Shape Factor	N/A	1.0	1.0	1.0	Y Y Y

Table A7 Vegetable and Fruit Ingestion Parameter Values

RESRAD Parameter	Units	Commercial Surface Soils Parameters	Industrial Surface Soils Parameters	Residential Surface Soils Parameters	Default Value C I R
Fruits, Nonleafy Veg. & Grain Consmp.	kg/y	N/A	N/A	44	N
Leafy Vegetable Consumption	kg/y	N/A	N/A	30	N
Soil Ingestion Rate	g/y	12.5	12.5	36.5	N N Y
Irrigation Water, Contamination Frac.	N/A	N/A	N/A	0.0	N
Plant Food, Contamination Frac.	N/A	N/A	N/A	1.0	N
Mass Loading for Foliar Deposition	g/m^3	N/A	N/A	0.0001	Y
Depth of Soil Mixing Layer	m	0.15	0.15	0.15	Y Y Y
Depth of Roots	m	N/A	N/A	0.9	Y
Groundwater Frac. Usage, Irrigation	N/A	N/A	N/A	0.0	N
Fruits, Nonleafy Veg. & Grain Consmp. Average Storage Time	d	N/A	N/A	14	Y
Leafy Vegetables, Average Storage Time	d	N/A	N/A	1	Y
Well Water, Average Storage Time	d	N/A	N/A	1	Y
Surface Water, Average Storage Time	d	N/A	N/A	1	Y

A.2 Parameter Definitions

The **Area of Contaminated Zone** parameter is used to define the area that encompasses the location(s) of soil samples where the radionuclide contamination exceeds background concentrations (Argonne, 1993a). The background concentration for radionuclides is a quantity measured in pico curies per gram (ρCi/g) that occurs naturally in the soil. This parameter has a default value of 10,000 m^2 (2.47 acres). The area used for all three scenarios was 325 m^2. This value was calculated from site maps showing the FSUA and is a site specific value that is more representative of the actual conditions at the FSUA than the default value given by RESRAD (CH2M Hill, 1999).

The **Thickness of Contaminated Zone** parameter is the distance between the top and bottom soil samples that contain radionuclide contamination above background levels (Argonne, 1993a). The contaminated zone thickness at the FSUA was 0.305 m (12 inches). This value was determined as a result of post remediation samples that were taken in the contaminated zone following remediation of the site (CH2M Hill, 1999).

The **Length Parallel to Aquifer Flow** parameter is the maximum distance between the contaminated zone up gradient boundary to the down gradient boundary and parallel to the direction of the groundwater flow in the aquifer below the contaminated site (Argonne, 1993a). The value used for this parameter was 19.81 meters (65 ft). None of the exposure scenarios discussed require a groundwater exposure assessment because in all cases, a municipal water source will be used.

The **Radiation Dose Limit** is used to determine action levels for radionuclide contaminated soil and is set by current EPA regulations (Argonne, 1993a). The radiation dose limits for all three scenarios were set at 15 millirem per year as prescribed by EPA regulations. However, since soil concentrations for radionuclides are given, this parameter becomes moot in respect to running the RESRAD code (Argonne, 1993a). The dose assessment methodology and definitions for radiation dose terms are listed in EPA's Draft 40 CFR 196, "Radiation Site Cleanup Regulations." The radiation dose used in the RESRAD code is the TEDE. The TEDE is the sum of the deep dose equivalent (DDE) from external exposure plus the committed effective dose equivalent (CEDE) from internal radiation exposure.

The **Elapsed Time of Waste Placement** site-specific input value for RESRAD was 25 years. The Nigerian and Indian sand ores were originally spilled in 1973 (Riggs, 2001). This parameter is the amount of time, in years, that has elapsed since the release or placement of radioactive materials (Argonne, 1993a). The two key functions of this variable are to aid in the determination of the buildup of radionuclide progeny from parent nuclides and to help predict future radionuclide concentrations in the groundwater.

The **Times for Calculations** parameter consists of seven time intervals, in years, following soil sampling or other radiological survey. The default time interval is 0 years (Argonne, 1993a). The time period of 1,000 years was used for all three scenarios and is in accordance with EPA's Draft 40 CFR 196.

The **Initial Concentrations of Principal Radionuclides** values were input based on the post remediation soil concentration samples. The activity for natural uranium was 1.7 pico curies/gram (ρCi/g) and 1.8 ρCi/g for natural thorium (CH2M Hill, 1999). These samples were analyzed on site using Mass Spectroscopy. The resulting values of the samples were presented in parts per million (ppm or mg/kg). Conversions of the concentrations were performed by dividing the given radionuclides' specific activity (SpA) given in (Ci/g) by ppm (1E6) and then multiplying by the concentration of the soil samples. The specific activity values used were for natural uranium and thorium (10 CFR 71 App. A Table A-1 and Table A-4). A principal radionuclide is a nuclide with a half-life longer than one-half year and is assumed to be in secular equilibrium with all of the progeny radionuclides in the contaminated zone (Argonne, 1993a).

The **Cover Depth** is the distance, in meters (m), from the ground or cover surface to the top edge of the contaminated zone soil (Argonne, 1993a). For the commercial and industrial worker scenarios, it was assumed that the current 4-inch (0.1016 m) cap of asphalt over the contaminated site would be used (CH2M Hill, 1999). However, the residential scenario assumes no asphalt cap or cover material. This scenario assumes a surface soil exposure where the contaminated soil is considered to be in the top 0.15 m of soil.

The **Density of Cover Material** parameters for the commercial and industrial worker scenarios were given a value of 1.5 grams/cubic centimeter (g/cm^3) for the asphalt cover (Shleien, 1992)*. There was no cover material for the residential scenario.

The **Density of Contaminated Zone** parameter was given a value of 1.7 g/cm^3 for all three scenarios. Justification was based upon the average value for soil densities (Shleien, 1992)*.

The **Density of Uncontaminated Zone** parameter was divided into three sections. The sections corresponded to the three different soil types in the uncontaminated (vadose) zone. The Zone 1 density was

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* The Health Physics and Radiological Health Handbook, Table 5.4 Density of Common Materials.

2 g/cm^3 based upon the stiff solid clay found in this zone (Shleien, 1992)* (Ziskind et al., 1981)†. The Zone 2 density was 1.7 g/cm^3 for the sandy clay loam in this region (Ziskind et al., 1981)†. Finally, for Zone 3, the density was 1.5 g/cm^3 due to the very fine gravels and coarse sands located in this layer (Ziskind et al., 1981)†. The **Density of Uncontaminated Zone** parameter did not apply to the industrial and commercial worker exposure scenarios because there was no groundwater exposure pathway for this exposure scenario.

The **Density of the Saturated Zone** parameter is not applicable to any of the three scenarios; however, this variable is needed for determining if any transport of radionuclides occurs in the aquifer beneath the site. The value used was 1.7 g/cm^3 based on the fine sand soil found at the bottom of monitoring well P790-WC/HEA #7 (BH #7) (Ziskind et al., 1981)†. The **Density of the Saturated Zone** parameter did not apply to the industrial and commercial worker exposure scenarios because there was no groundwater exposure pathway for this exposure scenario.

The **Cover Material Erosion Rate** value was 0.000508 m/y for both the industrial and commercial worker scenarios. The use of asphalt

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* The Health Physics and Radiological Health Handbook, Table 5.4 Density of Common Materials.

† Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

pavement, since it was developed, has not exceeded 200 years. Therefore, it is unknown what the true lifespan of asphalt pavement is. The **Cover Material Erosion Rate** value was chosen based upon a 200-year lifespan which was approximately half of the 500-year lifespan predicted by asphalt pavement experts*. The value was derived by using the RESRAD equation for calculating the cover erosion rate. This parameter did not apply to the residential scenario. The erosion rate is the average depth of soil or cover material that is removed from the ground surface per unit of time at the site (Argonne, 1993a)

The **Contaminated Zone Erosion Rate** value was the RESRAD default value of 0.001 m/y for all three of the exposure scenarios. The default value was chosen because of the lack of site-specific information. The erosion rate is the average depth of soil that is removed from the ground surface per unit of time at the site (Argonne, 1993a)

The value used for the **Contaminated Zone Total Porosity** was 0.45 for all three of the exposure scenarios. This was based upon two sources of available information. First, the type of contaminated soil was determined to be a clay/silt mixture as reported in the RD/RA status report for the FSUA (CH2M Hill, 1999). Given that the soil was a silt/clay

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* Personal Communication with Jim Huddleston. Asphalt Pavement Association of Oregon, April 14, 2000. This value was based on an approximate 100 to 500 year lifespan of asphalt pavement assuming a linear degradation rate.

combination, the corresponding total porosity value was chosen from Table E.7 of the RESRAD Guidance Manual (Argonne, 1993b). The **Uncontaminated Zone Total Porosity** was comprised of three sub zones. The soil strata and composition was based upon monitoring well P790-WC/HEA #7 (BH #7) drilled in 1980 (Ziskind et al., 1981)†. The driller's log indicated three distinct changes in the alluvial material between the wellhead and the aquifer. Zone one was comprised of very stiff solid clays. Zone two was a sandy clay loam soil. And finally, Zone three was comprised of very fine gravels and coarse sands. The **Uncontaminated Zone Total Porosity** parameter did not apply to the industrial and commercial worker exposure scenarios because there was no groundwater exposure pathway for this exposure scenario. The **Total Porosity** values chosen for the **Uncontaminated Zone** were 0.42, 0.43, and 0.34 respectively. Again, these values were based on the soil type in the drillers log and matched to their respective soil type listed in Table E.7 of the RESRAD Guidance Manual (Argonne, 1993b). The **Saturated Zone Total Porosity** value was again determined by data presented in BH #7's well log. The value was 0.43 and was based upon the fine sands found in the saturated zone. The **Saturated Zone Total Porosity** parameter did not apply to the industrial and commercial worker exposure scenarios because there were no groundwater exposure pathways for these

† Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

exposure scenarios. The **Total Porosity** variable is one of many parameters used to calculate the amount of time (breakthrough time) it takes for water to transport through soils. **Total Porosity** is defined as the ratio of the pore volume to the total volume of a given soil sample.

The **Contaminated Zone Effective Porosity** was determined to be 0.13 for all three scenarios (residential, commercial worker, and industrial worker). Once again, the values were determined by the soil composition of a silt/clay mixture as reported in the RD/RA status report for the FSUA (CH2M Hill, 1999) and the corresponding effective porosity value chosen from Table E.7 of the RESRAD Guidance Manual (Argonne, 1993b). The value was derived by taking the average of the Arithmetic Means for silt (0.20) and clay (0.06) soils. The **Uncontaminated Zone Effective Porosity** was comprised of three sub zones. The soil strata and composition was based upon monitoring well P790-WC/HEA #7 (BH #7) drilled in 1980 (Ziskind et al., 1981)†. The driller's log indicated three distinct changes in the alluvial material between the wellhead and the aquifer. Zone one was comprised of very stiff solid clays. Zone two was a sandy clay loam soil. And finally, Zone three was comprised of very fine gravels and coarse sands. The **Effective Porosity** values chosen for the **Uncontaminated Zone** were 0.06, 0.33, and 0.28 respectively. Again,

† Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

these values were based on the soil type in the drillers log and matched to their respective soil type listed in Table E.7 of the RESRAD Guidance Manual (Argonne, 1993b). The **Uncontaminated Zone Effective Porosity** parameter did not apply to the industrial and commercial worker exposure scenarios because there were no groundwater exposure pathways for these exposure scenarios.

The **Saturated Zone Effective Porosity** value was again determined by data presented in BH #7's well log. The value was 0.33 and was based upon the fine sands found in the saturated zone. The **Saturated Zone Effective Porosity** parameter did not apply to the industrial and commercial worker exposure scenarios because there was no groundwater exposure pathway for this exposure scenario. The **Effective Porosity** is the ratio of the pore volume where water circulates to the total volume of the soil sample.

The **Contaminated Zone Hydraulic Conductivity** value was determined to be 32.6 m/yr for all three of the exposure scenarios (residential, commercial worker, and industrial worker). The value was determined by the soil composition of a clay/silt mixture as reported in the RD/RA status report for the FSUA (CH2M Hill, 1999) and the corresponding hydraulic conductivity value chosen from Table E.2 of the RESRAD Guidance Manual (Argonne, 1993b). The **Uncontaminated Zone Hydraulic Conductivity** and **Saturated Zone Hydraulic**

Conductivity did not apply to the industrial worker or the commercial worker scenarios because there were no groundwater exposure pathways for these exposure scenarios. However, the **Uncontaminated Zone Hydraulic Conductivity** for the residential scenario was comprised of three sub zones. The values that were determined for hydraulic conductivity in sub zones one, two, and three, were 40.5, 199.0, and 5550.0 m/y respectively. A value of 5550 m/y was chosen for the **Hydraulic Conductivity** in the **Saturated Zone**. These values were based on the soil strata and composition in the drillers log for monitoring well P790-WC/HEA #7 (BH #7) drilled in 1980 (Ziskind et al., 1981)[†] and matched to their respective soil type listed in Table E.2 of the RESRAD Guidance Manual (Argonne, 1993b). Hydraulic conductivity is determined by the rate at which water moves through the porous medium for a given hydraulic gradient. The properties of both the medium and fluid, which have units of velocity (cm/s), influence the properties of hydraulic conductivity (Till and Meyer, 1983).

The **Contaminated Zone b Parameter** was determined to be 10.40 for all three of the exposure scenarios (residential, commercial worker, and industrial worker). The value was determined by the soil composition of a clay/silt mixture as reported in the RD/RA status report

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† Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

for the FSUA (CH2M Hill, 1999) and the corresponding b parameter value chosen from Table E.2 of the RESRAD Guidance Manual (Argonne, 1993b). The **Uncontaminated Zone b Parameter** and **Saturated Zone b Parameter** did not apply to the industrial worker or the commercial worker scenarios because there were no groundwater exposure pathways for these exposure scenarios. However, the **Uncontaminated Zone b Parameter** for the residential scenario was comprised of three sub zones. The values that were determined for the b Parameter in sub zones one, two, and three, were 11.40, 7.12, and 4.05 respectively. A value of 4.05 was chosen for the **b Parameter** in the **Saturated Zone**. These values were based on the soil strata and composition in the drillers log for monitoring well P790-WC/HEA #7 (BH #7) drilled in 1980 (Ziskind et al., 1981)[†] and matched to their respective soil type listed in Table E.2 of the RESRAD Guidance Manual (Argonne, 1993b). The **b Parameter** value of 4.05 was applicable for the **Saturated Zone** under the residential scenario because the water table at the TWC site varies on average approximately 10 feet per year between the dry and rainy seasons. The b parameter is a dimensionless parameter that is required for determining the saturation ratio of soil.

[†] Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

The **Thickness of the Uncontaminated, Unsaturated (Vadose) Zone** parameter was assigned a total value of 6.096 m (Ziskind et al., 1981). The Vadose zone was divided into three sub zones. The three sub zone thicknesses for were 1.524, 1.524, and 3.048 m respectively. The values were taken from the well drillers log for monitoring well P790-WC/HEA #7 (BH #7)†. The vadose zone is the portion of the uncontaminated zone that lies below the bottom of the contaminated zone and above the aquifer or saturated zone (Argonne, 1993a). This parameter only applies to the residential scenario.

The **Evapotranspiration Coefficient (C_e)** parameter had a determined value of 0.56 for all three scenarios (residential, commercial worker, and industrial worker). The **Evapotranspiration coefficient** is a dimensionless parameter that is described by the equation

$$C_e = \frac{ET_r}{(1-C_r)P_r + IR_r}$$

where ET_r is the evapotranspiration rate with a value of 0.686 m/y (Ziskind et al., 1981); C_r is the runoff coefficient with a value of 0.2 from table E1 of the RESRAD Guidance Manual (Argonne, 1993b); P_r is the precipitation rate with a value of 1.52 m/y (Ziskind et al., 1981); and IR_r is the irrigation rate with a value of 0.0 m/y. The reason for assigning a value of 0.0 m/y for the irrigation rate was that municipal water would be

† Scientific Applications, Inc., Well Drillers Log for borehole P790-WC/HEA #7, pg 301.

used for any irrigation activities for all three scenarios. The TWC facility is located within the incorporated city limits of Millersburg, Oregon and the possibility of obtaining a well drilling permit for the purpose of irrigation is not plausible. The Evapotranspiration Coefficient is a ratio of the total water volume leaving the soil to the total volume of water still within the root zone over a fixed period of time (RFCA, 1996).

The **Annual Average Wind Speed** parameter was given a value of 3.13 m/s (NOAA, 1999). This was the average wind speed recorded at the closest weather monitoring station (McNary Air Field in Salem, Oregon).

The **Precipitation Rate** parameter used was 1.52 m/y (Ziskind et al., 1981). The value of 1.52 m/y was the greatest average amount of precipitation and was chosen because it was the most conservative value. The range for average annual precipitation for TWC was 0.762 m/y to 1.52 m/y (Ziskind et al., 1981). The precipitation rate is the average amount of water in the form of rain, snow, hail, or sleet that falls per unit of area and time at a given site (Argonne, 1993a).

The **Irrigation Rate** for the residential scenario was 0.0 m/y. The reason for assigning a value of 0.0 m/y for the irrigation rate was that municipal water would be used for any irrigating activities. The irrigation rate was not used for any of the three scenarios. However, if the residential scenario had a well, then this parameter would be used because the homegrown produce exposure pathway is assessed. The **Irrigation Rate** is defined as the average volume of water that is added to the soil at the site, per unit of surface area and per unit of time (Argonne, 1993a).

The **Irrigation Mode** was determined to be the overhead configuration even though municipal water would be used for irrigation. The irrigation mode is not used for the commercial or industrial worker scenario because the homegrown produce exposure pathway was not assessed for these two scenarios. The irrigation mode is one of two methods; either sprinkler/overhead or ditch/flooding. Within the RESRAD code it is assumed that the application of irrigation water is under controlled conditions and irrigation water is not lost to runoff (RFCA, 1996).

The site-specific values of 0.2 and 0.8 were assigned to the **Runoff Coefficient** for the residential scenario and the commercial & industrial worker scenarios respectively. The residential scenario value of 0.2 was used because the value was based on the soil strata and composition (intermediate combinations of clay & loam) as indicated in the RD/RA status report for the FSUA (CH2M Hill, 1999) and it also corresponded to the value listed in Table E.1 of the RESRAD Guidance Manual (Argonne, 1993b). The value of 0.8 was used for the commercial and industrial worker scenarios because the TWC facility already matches the urban environment description of a built-up area that also corresponded to the value listed in Table E.1 of the RESRAD Guidance Manual (Argonne, 1993b). The Runoff Coefficient is the fraction of the average annual rainfall that does not leach into the soil and is not transferred back to the atmosphere through evapotranspiration (Argonne, 1993a).

The **Watershed Area for Nearby Stream or Pond** was assigned a value of 24155 m^2 (CH2M Hill, 1999). This value represents the surface area of the Lower River Pond, which is directly down gradient of the FSUA. The groundwater transport to surface water parameter is only being assessed/modeled for the residential scenario. This parameter is not applicable to the industrial worker or the commercial worker scenarios because there were no groundwater transport to surface water assessments for these two exposure scenarios. This pond was dewatered and is no longer in use. However, during the Winter months when precipitation is the heaviest, the pond does accumulate surface water runoff.

The **Accuracy for Water/Soil Computations** is the fractional accuracy desired (convergence criterion) in the Romberg integration used to obtain water/soil concentration ratios (RFCA, 1996). The value used for this parameter is dimensionless and was the RESRAD default of 0.001. The parameter was only applied to the residential scenario.

The value of 0.002 was assigned to the **Saturated Zone Hydraulic Gradient**. The site-specific value was determined by SAI in a previous groundwater hydrology study (Ziskind et al., 1981). This parameter only applies to the residential scenario because there were no groundwater exposure pathways for the industrial worker or the commercial worker scenarios. The hydraulic gradient is the change in hydraulic head per unit of distance of the groundwater flow in a given direction (RFCA, 1996).

The **Water Table Drop Rate** parameter value was determined to be 3.048 m/y. This was the average of the confined alluvial aquifer fluctuation over a one-year period (Ziskind et al., 1981). The water table drop rate is the annual rate at which the depth of the water table is lowered (Argonne, 1993a). This parameter only applies to the residential scenario.

The **Well Pump Intake Depth** parameter value was 0.9144 m below the top of the aquifer. This was the screen depth within the aquifer for monitoring well BH#7. The well pump intake depth is the screened depth of the well within the (groundwater) aquifer zone (Argonne, 1993a). This parameter only applies to the residential scenario.

The **Nondispersion/Mass Balance** parameter determines which method will be used for calculating the water to soil concentration ratios. Mass balance was used for the residential scenario because the total contaminated area was less that 1000 m^2 (CH2M Hill, 1999). This parameter did not apply to the commercial or industrial worker scenarios.

The **Well Pumping Rate** is defined as the rate of total volume of well water withdrawn for use per individual (RFCA, 1996). This parameter was not used for any of the three scenarios. The reason is that municipal water is the sole source of water in the incorporated urban areas of Millersburg and Albany.

The **Inhalation Rate** for all three scenarios was based upon an average adult breathing dust contaminated air at a rate of 1.0 (between moderate & light), 2.1 (moderate), 0.6 (light) m^3/h for the residential, industrial, and commercial worker scenarios respectively. These values were taken from Table 43.1 of the Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil (Argonne, 1993a). The **Inhalation Rate** for the residential scenario was calculated to be 8400 m^3/yr (this was the RESRAD default). The **Inhalation Rate** for the industrial worker scenario was calculated to be 4200 m^3/yr. This was based on 16.8 m^3/d for 250 d/yr. The **Inhalation Rate** for the commercial worker scenario was calculated to be 1200 m^3/yr. This was based on

4.8 m^3/d for 250 d/yr. The on-site and off-site occupancy factor does not affect this parameter. "... in the RESRAD calculation, an occupancy factor is automatically derived and used for adjusting the calculated dose" (Argonne, 1993a).

The default RESRAD value of 0.0002 g/m^3 was used for the **Mass Loading** parameter for two of the three scenarios (industrial and commercial). This value is considered quite conservative for these two urban scenarios. It is not plausible that a commercial worker or an industrial worker will be digging in the contaminated soil at the site. This is especially true due to the fact that the cover cap of asphalt has not eroded away. A value of 0.0003 g/m^3 was used for the residential scenario. The reason for increasing the value of the **Mass Loading** parameter for this scenario was to facilitate the resident tilling the garden soil in the contaminated area. "The mass loading parameter is the concentration of soil particles in the air and is obtained directly from empirical data for locations and condition similar to those applicable for the scenario used" (Argonne, 1993a).

The **Exposure Duration** value was again the RESRAD default value of 30 years for the residential scenario. The **Exposure Duration** for both the industrial and commercial worker was 25 years. The exposure duration is the amount of time that an individual spends at or near the contaminated area. These duration times are the standard EPA time parameters for occupancy.

The **Inhalation Shielding Factor** is the ratio of airborne particle concentration indoors on-site to the concentration outdoors on-site (Argonne, 1993a). The RESRAD default value of 0.4 was used for all three scenarios. The reason for this value is that there is no site specific indoor air sampling data available. The **Inhalation Shielding Factor** of 0.4 represents an indoor dust level that is 40% of the dust level outdoors. This value is conservative without being unrealistic.

The **External Gamma Shielding Factor** is the ratio of the external gamma radiation indoors to the radiation level outdoors, on-site (Argonne, 1993a). In essence, it is the amount of shielding a building provides against external gamma radiation. The RESRAD default value of 0.7 was used for the industrial and commercial scenarios. A value of 0.5 was used for the residential scenario. An **External Gamma Shielding Factor** of 0.7 represents an indoor exposure rate that is 30% of the exposure rate outdoors. Again, there is no site specific data for this parameter. The value is realistic considering that most industrial and commercial buildings are typically constructed with concrete floors and often times concrete or steel walls. In the case of residential structures, the value of 0.7 may be low (30% of the exposure rate outdoors) depending on whether or not the homebuilder used brick for home construction or traditional wood. Therefore, the value of 0.5 (50% of the exposure rate outdoors) was chosen for the residential scenario.

The **Indoor Time Fraction** values were 0.25, 0.25, and 0.65 for the residential, industrial, and commercial scenarios respectively. The values for the residential and industrial scenarios were considered conservative. It was assumed that the individual would spend 25% of their time inside the building or home near or on the contaminated area. The value chosen for the commercial scenario was a more consistent and realistic assumption.

The **Outdoor Time Fraction** values were 0.50, 0.50, and 0.10 for the residential, industrial, and commercial scenarios respectively. The values for the residential and industrial scenarios were considered very conservative. It was assumed that the individual would spend 50% of their time outside the building or home on or near the contaminated area. Again, the value chosen for the commercial scenario was a more realistic assumption. The value of 0.10 allows for the worker coming to and from work and for breaks taken outside.

In all three scenarios, the total time fraction only amounts to 75% of the time being spent on or around the contaminated site. The remaining

25% is considered to be the amount of time that a person spends away from the site.

The **Shape Factor** value used was the RESRAD default of 1.0. The contaminated zone shape for all three scenarios was a circle. Therefore, no correction factor for a noncircular-shaped contamination zone was needed.

The **Fruits, Nonleafy Vegetables and Grain Consumption** rate of intake was 44 kg/yr for fruits and nonleafy vegetables. Grains were not included due to the fact that people rarely plant grain crops in their gardens. Grain crops are not economical or feasible for small-scale home gardeners. The average adult intake of vegetables per person is 73 kg/yr. The average adult intake of fruit per person is 51 kg/yr. The 44 kg/yr intake was based on the worst-case scenario for homegrown produce consumption and was presented in Table 42.1 of the Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil (Argonne, 1993a). Based on a total of 124 kg/yr for fruit and vegetable consumption, 44 kg/yr represents 35% of the total intake for a year. This parameter is an annual dietary factor for the home grown human food consumption of fruits, nonleafy vegetables, and grains grown in the contaminated area (Argonne, 1993a). The value for this parameter is reasonable because the Willamette valley is considered an ideal area for gardening and is the state's leading agricultural area. This parameter only applies to the residential scenario.

The **Leafy Vegetable Consumption** rate of intake was 30 kg/yr for this parameter. According to the NRC (Regulatory Guide 1.109), this was the average consumption rate for adults used to perform environmental dose analyses for radioactive air releases from nuclear power plants. The total average consumption for rate for **Leafy Vegetables** was 64 kg/yr (Argonne, 1993a). This accounts for 47% of **Leafy Vegetables** being home grown. Again, the Willamette valley is considered an ideal area for gardening; therefore, the consumption rate of home grown produce is very conservative but plausible. Once again, this value would represent the worst case scenario. This parameter only applies to the residential scenario.

The **Soil Ingestion Rate** of intake for the residential scenario was the RESRAD default value of 36.5 g/yr. This value results in an ingestion rate of 0.1 g/d, which happens to be the EPA's recommended value for this parameter. The **Soil Ingestion Rate** of intake for the industrial and commercial worker scenarios 12.5 g/yr for both cases. This value was again based on the EPA recommendation of 0.05 g/d for a workplace scenario. This was based on a 250-day work year and a 25-year career. The residential scenario was based on 365-day year and for a 30-year duration. The **Soil Ingestion Rate** is defined as the unintentional ingestion rate of soil or soil dust (Argonne, 1993a).

The **Contamination Fraction for Irrigation Water** is the fraction amount of contaminated water that is used for irrigating homegrown produce. This parameter only applies to the residential scenario. The value used for modeling purposes was 0.0. The reason for assigning this value was that municipal water would be used for any irrigating activities.

The **Contamination Fraction for Plant Food** is the fraction of homegrown produce nutrients that are contaminated and was assigned a value of 1.0. In other words, the homegrown produce is completely grown in contaminated soil and the plant's intake of nutrients is also contaminated. This parameter only applies to the residential scenario.

The RESRAD default value of 0.0001 g/m^3 was assigned to the **Mass Loading for Foliar Deposition** parameter. The foliar deposition variable is the air/soil concentration ratio, specified as the average mass loading of airborne contaminated soil particles in a garden during growing season (RFCA, 1996). This parameter only applies to the residential scenario.

The RESRAD default value of 0.15 m was assigned to the **Depth of Soil Mixing Layer** parameter. The mixing layer is the depth over which the surface soil is uniformly mixed and is used in calculating the depth factor for the soil ingestion, dust inhalation, and foliar deposition pathways (RFCA, 1996). This parameter applied to all three scenarios.

The RESRAD default value of 0.9 m was assigned to the **Depth of Roots** parameter. This parameter is the average root depth of various plants grown in contaminated soil (Argonne, 1993a). This parameter only applies to the residential scenario.

The value of 0.0 was assigned to the **Groundwater Fractional Usage, Irrigation** parameter. This irrigation parameter is the fraction of contaminated groundwater used to irrigate produce. The reason for assigning this value was that municipal water would be used for any irrigating activities. However, for modeling purposes, it is necessary to indicate a source of water for irrigation. This parameter only applies to the residential scenario (RFCA, 1996).

The **Average Storage Time for Fruits, Nonleafy Vegetables and Grain Consumption** was assigned the RESRAD default value of 14 days for the residential scenario. The storage time parameter allows for the ingrowth and decay of radionuclides over the storage time specified before consumption occurs. Due to the long half-lives of the radionuclides being assessed, this parameter has no significant effect on the action level (RFCA, 1996).

The **Average Storage Time for Leafy Vegetables Consumption** was assigned the RESRAD default value of one day for the residential scenario. The storage time parameter allows for the ingrowth and decay of radionuclides over the storage time specified before consumption occurs. Due to the long half-lives of the radionuclides being assessed, this parameter has no significant effect on the action level (RFCA, 1996).

The **Average Storage Time for Well Water and Surface Water Use** were both assigned the RESRAD default value of one day for the residential scenario. The storage time parameter allows for the ingrowth and decay of radionuclides over the storage time specified before consumption occurs. Due to the long half-lives of the radionuclides being assessed, this parameter has no significant effect on the action level (RFCA, 1996).

APPENDIX B

Output of RESRAD Computer Code

This appendix will account for all of the detailed RESRAD code output files used to model TWC's FSUA. The summary outputs will be listed in the following order starting with the output for the industrial worker scenario, then the output for the commercial worker scenario, and lastly the output for the residential scenario.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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Dose Conversion Factor (and Related) Parameter Summary
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(3)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(4)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(5)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(6)
B-1	U-234	1.320E-01	1.320E-01	DCF2(7)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(8)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(3)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(4)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(5)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(6)
D-1	U-234	2.830E-04	2.830E-04	DCF3(7)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(8)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(4,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(4,2)

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D-34   Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      5.000E-06   5.000E-06   RTF( 4,3)
D-34
D-34   Th-230   , plant/soil concentration ratio, dimensionless     1.000E-03   1.000E-03   RTF( 5,1)
D-34   Th-230   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     1.000E-04   1.000E-04   RTF( 5,2)
D-34   Th-230   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      5.000E-06   5.000E-06   RTF( 5,3)
D-34
D-34   Th-232   , plant/soil concentration ratio, dimensionless     1.000E-03   1.000E-03   RTF( 6,1)
D-34   Th-232   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     1.000E-04   1.000E-04   RTF( 6,2)
D-34   Th-232   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      5.000E-06   5.000E-06   RTF( 6,3)
D-34
D-34   U-234    , plant/soil concentration ratio, dimensionless     2.500E-03   2.500E-03   RTF( 7,1)
D-34   U-234    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     3.400E-04   3.400E-04   RTF( 7,2)
D-34   U-234    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      6.000E-04   6.000E-04   RTF( 7,3)
D-34
```

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(8,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(8,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(4,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(4,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(5,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(5,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(7,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(7,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(8,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(8,2)

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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Summary : Industrial   File: INDUSTR2.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.250E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.050E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	2.500E+01	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.800E+00	0.000E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-238	1.700E+00	0.000E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.000E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	---	W1(8)
R013	Cover depth (m)	1.016E-01	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	1.500E+00	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	5.080E-04	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.500E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	1.300E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	3.260E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	3.130E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.520E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.00E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	8.000E-01	2.000E-01	---	RUNOFF

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	3.300E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	5.550E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.050E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	3.048E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	9.144E-01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	MB	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	1.000E+00	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(6)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	4.400E+03	5.000E+01	---	DCNUCC(8)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.863E-05	ALEACH(8)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(8)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.574E-03	ALEACH(1)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.674E-03	ALEACH(2)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(2)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(3)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.674E-03	ALEACH(3)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(4)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(4)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(4)

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(5)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter U-234				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.138E-03	ALEACH(7)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(7)
R017	Inhalation rate (m**3/yr)	4.200E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	*2.000E-04*	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	2.500E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	5.000E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.00E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.00E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.00E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.00E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.00E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.00E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.00E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.00E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.00E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.00E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.00E+00	---	FRACA(3)
R017	Ring 4	not used	0.00E+00	---	FRACA(4)
R017	Ring 5	not used	0.00E+00	---	FRACA(5)
R017	Ring 6	not used	0.00E+00	---	FRACA(6)
R017	Ring 7	not used	0.00E+00	---	FRACA(7)
R017	Ring 8	not used	0.00E+00	---	FRACA(8)
R017	Ring 9	not used	0.00E+00	---	FRACA(9)
R017	Ring 10	not used	0.00E+00	---	FRACA(10)
R017	Ring 11	not used	0.00E+00	---	FRACA(11)
R017	Ring 12	not used	0.00E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)

R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.250E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN

C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	0.00E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	0.00E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.00E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 01:31 Page 9
Summary : Industrial File: INDUSTR2.RAD

Contaminated Zone Dimensions			Initial Soil Concentrations, pCi/g	
Area:	325.00	square meters	Th-232	1.800E+00
Thickness:	0.31	meters	U-238	1.700E+00
Cover Depth:	0.10	meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 15 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	8.869E-02	3.558E-01	1.081E+00	3.504E+00	6.117E+00	9.642E+00	1.604E+01	0.00E+00
M(t):	5.913E-03	2.372E-02	7.206E-02	2.336E-01	4.078E-01	6.428E-01	1.069E+00	0.00E+00

Maximum TDOSE(t): 1.668E+01 mrem/yr at t = 198.1 ñ 0.4 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.981E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.634E+01	0.9792	1.754E-01	0.0105	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.674E-02	0.0016
U-238	1.341E-01	0.0080	9.772E-03	0.0006	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.369E-03	0.0001
Total	1.647E+01	0.9872	1.852E-01	0.0111	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.811E-02	0.0017

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.981E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.654E+01	0.9913
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.453E-01	0.0087
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.668E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 01:31 Page 10
Summary : Industrial File: INDUSTR2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.167E-05	0.0002	4.723E-02	0.5325	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.831E-03	0.0545
U-238	3.295E-02	0.3715	3.210E-03	0.0362	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.496E-04	0.0051
Total	3.297E-02	0.3718	5.044E-02	0.5687	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.281E-03	0.0595

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.208E-02	0.5872
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.661E-02	0.4128
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.869E-02	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 01:31   Page 11
Summary : Industrial   File: INDUSTR2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.658E-01	0.7470	4.793E-02	0.1347	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.201E-03	0.0146
U-238	3.318E-02	0.0933	3.243E-03	0.0091	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.543E-04	0.0013
Total	2.989E-01	0.8403	5.117E-02	0.1438	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.655E-03	0.0159

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.189E-01	0.8963
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.688E-02	0.1037
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.558E-01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 01:31   Page 12
Summary : Industrial   File: INDUSTR2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	9.874E-01	0.9136	5.003E-02	0.0463	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.959E-03	0.0055
U-238	3.364E-02	0.0311	3.310E-03	0.0031	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.637E-04	0.0004
Total	1.021E+00	0.9447	5.334E-02	0.0494	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	6.423E-03	0.0059

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.043E+00	0.9654
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.742E-02	0.0346
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.081E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year       10/28/01  01:31    Page  13
Summary : Industrial                                           File: INDUSTR2.RAD
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	3.398E+00	0.9698	5.842E-02	0.0167	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.162E-03	0.0023
U-238	3.532E-02	0.0101	3.545E-03	0.0010	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.965E-04	0.0001
Total	3.434E+00	0.9798	6.196E-02	0.0177	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.659E-03	0.0025

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.465E+00	0.9888
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.936E-02	0.0112
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.504E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 01:31 Page 14
Summary : Industrial File: INDUSTR2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.986E+00	0.9786	7.449E-02	0.0122	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.128E-02	0.0018
U-238	4.057E-02	0.0066	4.213E-03	0.0007	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.902E-04	0.0001
Total	6.026E+00	0.9852	7.870E-02	0.0129	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.187E-02	0.0019

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	6.071E+00	0.9926
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.537E-02	0.0074
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	6.117E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  01:31    Page  15
Summary : Industrial                                          File: INDUSTR2.RAD
```

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	9.434E+00	0.9784	1.168E-01	0.0121	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.781E-02	0.0018
U-238	6.590E-02	0.0068	6.542E-03	0.0007	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	9.163E-04	0.0001
Total	9.500E+00	0.9853	1.234E-01	0.0128	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.872E-02	0.0019

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	9.569E+00	0.9924
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	7.336E-02	0.0076
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	9.642E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 01:31 Page 16
Summary : Industrial File: INDUSTR2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.569E+01	0.9784	1.765E-01	0.0110	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.690E-02	0.0017
U-238	1.315E-01	0.0082	9.778E-03	0.0006	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.370E-03	0.0001
Total	1.582E+01	0.9866	1.863E-01	0.0116	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.827E-02	0.0018

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.590E+01	0.9911
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.427E-01	0.0089
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.604E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  01:31    Page  17
Summary : Industrial                                           File: INDUSTR2.RAD
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

*Sum of all water independent and dependent pathways.

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 01:31   Page 18
Summary : Industrial   File: INDUSTR2.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	2.894E-02	2.924E-02	2.985E-02	3.197E-02	3.805E-02	5.932E-02	8.984E-02	0.00E+00
Th-232	Ra-228	1.000E+00	0.00E+00	1.105E-01	2.984E-01	7.148E-01	1.121E+00	1.835E+00	3.291E+00	0.00E+00
Th-232	Th-228	1.000E+00	0.00E+00	3.738E-02	2.515E-01	1.178E+00	2.214E+00	3.422E+00	5.450E+00	0.00E+00
Th-232	DSR(j)		2.894E-02	1.772E-01	5.797E-01	1.925E+00	3.373E+00	5.316E+00	8.831E+00	0.00E+00
U-238	U-238	1.000E+00	2.154E-02	2.169E-02	2.201E-02	2.315E-02	2.669E-02	4.315E-02	8.393E-02	0.00E+00
U-238	U-234	1.000E+00	0.00E+00	6.859E-09	2.090E-08	7.329E-08	2.487E-07	1.092E-06	3.281E-06	0.00E+00
U-238	Th-230	1.000E+00	0.00E+00	7.460E-14	6.830E-13	8.034E-12	8.322E-11	1.292E-09	1.345E-08	0.00E+00
U-238	Ra-226	1.000E+00	0.00E+00	3.610E-15	9.826E-14	3.743E-12	1.095E-10	5.388E-09	1.636E-07	0.00E+00
U-238	Pb-210	1.000E+00	0.00E+00	1.109E-19	9.019E-18	1.125E-15	9.252E-14	1.102E-11	5.114E-10	0.00E+00
U-238	DSR(j)		2.154E-02	2.169E-02	2.201E-02	2.315E-02	2.669E-02	4.315E-02	8.394E-02	0.00E+00

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life ó 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 15 mrem/yr

Nuclide (i)	t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	5.184E+02	8.467E+01	2.588E+01	7.793E+00	4.447E+00	2.822E+00	1.699E+00	*1.096E+05
U-238	6.965E+02	6.915E+02	6.815E+02	6.479E+02	5.621E+02	3.476E+02	1.787E+02	*3.360E+05

*At specific activity limit

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

```
            Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
            and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
         at tmin = time of minimum single radionuclide soil guideline
     and at tmax = time of maximum total dose =   198.1 ñ 0.4 years
```

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.800E+00	198.1 ñ 0.4	9.188E+00	1.632E+00	9.188E+00	1.632E+00
U-238	1.700E+00	200.2 ñ 0.4	8.602E-02	1.744E+02	8.545E-02	1.755E+02

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  01:31    Page  19
Summary : Industrial                                            File: INDUSTR2.RAD
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Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	5.208E-02	5.263E-02	5.372E-02	5.755E-02	6.848E-02	1.068E-01	1.617E-01	0.00E+00
Ra-228	Th-232	1.000E+00	0.00E+00	1.990E-01	5.370E-01	1.287E+00	2.018E+00	3.302E+00	5.924E+00	0.00E+00
Th-228	Th-232	1.000E+00	0.00E+00	6.728E-02	4.527E-01	2.121E+00	3.985E+00	6.159E+00	9.810E+00	0.00E+00
U-238	U-238	1.000E+00	3.661E-02	3.688E-02	3.742E-02	3.936E-02	4.537E-02	7.336E-02	1.427E-01	0.00E+00
U-234	U-238	1.000E+00	0.00E+00	1.166E-08	3.552E-08	1.246E-07	4.228E-07	1.857E-06	5.578E-06	0.00E+00
Th-230	U-238	1.000E+00	0.00E+00	1.268E-13	1.161E-12	1.366E-11	1.415E-10	2.197E-09	2.287E-08	0.00E+00
Ra-226	U-238	1.000E+00	0.00E+00	6.138E-15	1.670E-13	6.362E-12	1.861E-10	9.160E-09	2.781E-07	0.00E+00
Pb-210	U-238	1.000E+00	0.00E+00	1.886E-19	1.533E-17	1.913E-15	1.573E-13	1.873E-11	8.693E-10	0.00E+00

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	1.800E+00	1.800E+00	1.800E+00	1.800E+00	1.800E+00	1.799E+00	1.798E+00	1.792E+00
Ra-228	Th-232	1.000E+00	0.00E+00	2.040E-01	5.434E-01	1.242E+00	1.705E+00	1.746E+00	1.745E+00	1.739E+00
Th-228	Th-232	1.000E+00	0.00E+00	3.352E-02	2.229E-01	1.004E+00	1.683E+00	1.746E+00	1.745E+00	1.739E+00
U-238	U-238	1.000E+00	1.700E+00	1.700E+00	1.700E+00	1.699E+00	1.697E+00	1.690E+00	1.670E+00	1.603E+00
U-234	U-238	1.000E+00	0.00E+00	4.807E-06	1.435E-05	4.696E-05	1.339E-04	3.756E-04	7.289E-04	8.888E-04

Appendix B.1 RESRAD Summary Output for Industrial Worker Scenario

Th-230	U-238	1.000E+00		0.00E+00	2.165E-11	1.942E-10	2.132E-09	1.854E-08	1.836E-07	1.231E-06	6.603E-06

Nuclide (j)	Parent (i)	BRF(i)		S(j,t), pCi/g							
			t=	0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ra-226	U-238	1.000E+00		0.00E+00	3.125E-15	8.399E-14	3.060E-12	7.890E-11	2.495E-09	4.411E-08	5.012E-07
Pb-210	U-238	1.000E+00		0.00E+00	2.413E-17	1.922E-15	2.237E-13	1.541E-11	1.155E-09	3.223E-08	4.410E-07

BRF(i) is the branch fraction of the parent nuclide.

APPENDIX B.2

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  03:41    Page   1
Summary : Commercial                                           File: COMERCL2.RAD
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Part I: Mixture Sums and Single Radionuclide Guidelines

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year       10/28/01  03:41    Page   2
Summary : Commercial                                           File: COMERCL2.RAD

                    Dose Conversion Factor (and Related) Parameter Summary
                                     File: DOSFAC.BIN
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Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(3)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(4)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(5)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(6)
B-1	U-234	1.320E-01	1.320E-01	DCF2(7)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(8)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(3)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(4)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(5)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(6)
D-1	U-234	2.830E-04	2.830E-04	DCF3(7)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(8)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(4,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(4,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(4,3)

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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D-34
D-34   Th-230   , plant/soil concentration ratio, dimensionless     1.000E-03   1.000E-03   RTF( 5,1)
D-34   Th-230   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     1.000E-04   1.000E-04   RTF( 5,2)
D-34   Th-230   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      5.000E-06   5.000E-06   RTF( 5,3)
D-34
D-34   Th-232   , plant/soil concentration ratio, dimensionless     1.000E-03   1.000E-03   RTF( 6,1)
D-34   Th-232   , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     1.000E-04   1.000E-04   RTF( 6,2)
D-34   Th-232   , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      5.000E-06   5.000E-06   RTF( 6,3)
D-34
D-34   U-234    , plant/soil concentration ratio, dimensionless     2.500E-03   2.500E-03   RTF( 7,1)
D-34   U-234    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)     3.400E-04   3.400E-04   RTF( 7,2)
D-34   U-234    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)      6.000E-04   6.000E-04   RTF( 7,3)
D-34
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Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(8,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(8,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(4,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(4,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(5,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(5,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(7,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(7,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(8,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(8,2)

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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Summary : Commercial File: COMERCL2.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.250E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.050E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	not used	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	2.500E+01	0.00E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.800E+00	0.00E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-238	1.700E+00	0.00E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.00E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.00E+00	---	W1(8)
R013	Cover depth (m)	1.016E-01	0.00E+00	---	COVER0
R013	Density of cover material (g/cm**3)	1.500E+00	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	5.080E-04	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.500E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	1.300E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	3.260E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	3.130E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.520E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.00E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	8.000E-01	2.000E-01	---	RUNOFF

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

R013	Watershed area for nearby stream or pond (m**2)	not used	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	not used	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	3.300E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	5.550E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.050E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	3.048E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	9.144E-01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	MB	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	1.000E+00	2.500E+02	---	UW
R015	Number of unsaturated zone strata	not used	1	---	NS

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(6)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	4.400E+03	5.000E+01	---	DCNUCC(8)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(8)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.863E-05	ALEACH(8)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(8)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Saturated zone (cm**3/g)	not used	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.574E-03	ALEACH(1)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(1)
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.674E-03	ALEACH(2)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(2)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(3)
R016	Saturated zone (cm**3/g)	not used	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	3.674E-03	ALEACH(3)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(4)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(4)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(4)
R016	Distribution coefficients for daughter Th-230				

R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Saturated zone (cm**3/g)	not used	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	4.300E-06	ALEACH(5)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter U-234				
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Saturated zone (cm**3/g)	not used	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	5.138E-03	ALEACH(7)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(7)
R017	Inhalation rate (m**3/yr)	1.200E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	2.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	2.500E+01	3.000E+01	---	ED

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	7.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	6.500E-01	5.000E-01	---	FIND
R017	Fraction of time spent outdoors (on site)	1.000E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.00E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.00E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.00E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.00E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.00E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.00E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.00E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.00E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.00E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.00E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.00E+00	---	FRACA(3)
R017	Ring 4	not used	0.00E+00	---	FRACA(4)
R017	Ring 5	not used	0.00E+00	---	FRACA(5)
R017	Ring 6	not used	0.00E+00	---	FRACA(6)
R017	Ring 7	not used	0.00E+00	---	FRACA(7)
R017	Ring 8	not used	0.00E+00	---	FRACA(8)
R017	Ring 9	not used	0.00E+00	---	FRACA(9)
R017	Ring 10	not used	0.00E+00	---	FRACA(10)
R017	Ring 11	not used	0.00E+00	---	FRACA(11)
R017	Ring 12	not used	0.00E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	not used	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	not used	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	1.250E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	not used	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	not used	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	not used	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	not used	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	not used	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	not used	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	not used	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	not used	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	not used	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	not used	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	not used	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	not used	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	not used	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5
STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	0.00E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	0.00E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.00E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	suppressed
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 03:41 Page 9
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Contaminated Zone Dimensions	
Area:	325.00 square meters
Thickness:	0.31 meters
Cover Depth:	0.10 meters

Initial Soil Concentrations, pCi/g	
Th-232	1.800E+00
U-238	1.700E+00

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 15 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	4.104E-02	2.602E-01	8.551E-01	2.842E+00	4.980E+00	7.851E+00	1.307E+01	0.00E+00
M(t):	2.736E-03	1.735E-02	5.701E-02	1.895E-01	3.320E-01	5.234E-01	8.714E-01	0.00E+00

Maximum TDOSE(t): 1.360E+01 mrem/yr at t = 198.1 0.4 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.981E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.343E+01	0.9875	3.007E-02	0.0022	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.674E-02	0.0020
U-238	1.103E-01	0.0081	1.675E-03	0.0001	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.369E-03	0.0001
Total	1.354E+01	0.9956	3.174E-02	0.0023	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.811E-02	0.0021

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.981E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.349E+01	0.9917
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.133E-01	0.0083
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.360E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 03:41   Page 10
Summary : Commercial   File: COMERCL2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.782E-05	0.0004	8.097E-03	0.1973	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.831E-03	0.1177
U-238	2.709E-02	0.6602	5.502E-04	0.0134	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.496E-04	0.0110
Total	2.711E-02	0.6606	8.647E-03	0.2107	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.281E-03	0.1287

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.295E-02	0.3155
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.809E-02	0.6845
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.104E-02	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.185E-01	0.8397	8.217E-03	0.0316	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.201E-03	0.0200
U-238	2.728E-02	0.1048	5.560E-04	0.0021	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.543E-04	0.0017
Total	2.458E-01	0.9446	8.773E-03	0.0337	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.655E-03	0.0217

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.319E-01	0.8913
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.829E-02	0.1087
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.602E-01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 03:41 Page 12
Summary : Commercial File: COMERCL2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	8.119E-01	0.9494	8.577E-03	0.0100	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.959E-03	0.0070
U-238	2.766E-02	0.0323	5.674E-04	0.0007	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.637E-04	0.0005
Total	8.396E-01	0.9818	9.145E-03	0.0107	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	6.423E-03	0.0075

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.264E-01	0.9664
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.869E-02	0.0336
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.551E-01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  03:41    Page  13
Summary : Commercial                                            File: COMERCL2.RAD
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	2.794E+00	0.9830	1.001E-02	0.0035	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.162E-03	0.0029
U-238	2.904E-02	0.0102	6.076E-04	0.0002	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.965E-04	0.0002
Total	2.823E+00	0.9932	1.062E-02	0.0037	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	8.659E-03	0.0030

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.812E+00	0.9894
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.014E-02	0.0106
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.842E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  03:41     Page  14
Summary : Commercial                                           File: COMERCL2.RAD
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	4.922E+00	0.9882	1.277E-02	0.0026	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.128E-02	0.0023
U-238	3.335E-02	0.0067	7.223E-04	0.0001	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.902E-04	0.0001
Total	4.955E+00	0.9949	1.349E-02	0.0027	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.187E-02	0.0024

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.946E+00	0.9930
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	3.467E-02	0.0070
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.980E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 03:41 Page 15
Summary : Commercial File: COMERCL2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	7.757E+00	0.9880	2.002E-02	0.0026	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.781E-02	0.0023
U-238	5.418E-02	0.0069	1.121E-03	0.0001	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	9.163E-04	0.0001
Total	7.811E+00	0.9949	2.115E-02	0.0027	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.872E-02	0.0024

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	7.795E+00	0.9928
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	5.622E-02	0.0072
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	7.851E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 03:41 Page 16
Summary : Commercial File: COMERCL2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.290E+01	0.9871	3.025E-02	0.0023	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.690E-02	0.0021
U-238	1.082E-01	0.0083	1.676E-03	0.0001	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.370E-03	0.0001
Total	1.301E+01	0.9954	3.193E-02	0.0024	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	2.827E-02	0.0022

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.296E+01	0.9915
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.112E-01	0.0085
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.307E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year        10/28/01  03:41    Page  17
Summary : Commercial                                          File: COMERCL2.RAD
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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

*Sum of all water independent and dependent pathways.

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 03:41   Page 18
Summary : Commercial   File: COMERCL2.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	7.192E-03	7.268E-03	7.419E-03	7.947E-03	9.458E-03	1.476E-02	2.249E-02	0.00E+00
Th-232	Ra-228	1.000E+00	0.00E+00	9.091E-02	2.454E-01	5.879E-01	9.222E-01	1.509E+00	2.707E+00	0.00E+00
Th-232	Th-228	1.000E+00	0.00E+00	3.067E-02	2.063E-01	9.665E-01	1.816E+00	2.807E+00	4.471E+00	0.00E+00
Th-232	DSR(j)		7.192E-03	1.288E-01	4.591E-01	1.562E+00	2.748E+00	4.330E+00	7.200E+00	0.00E+00
U-238	U-238	1.000E+00	1.653E-02	1.664E-02	1.688E-02	1.773E-02	2.039E-02	3.307E-02	6.541E-02	0.00E+00
U-238	U-234	1.000E+00	0.00E+00	1.854E-09	5.647E-09	1.981E-08	6.732E-08	2.981E-07	9.372E-07	0.00E+00
U-238	Th-230	1.000E+00	0.00E+00	1.888E-14	1.729E-13	2.034E-12	2.111E-11	3.323E-10	3.655E-09	0.00E+00
U-238	Ra-226	1.000E+00	0.00E+00	2.969E-15	8.080E-14	3.078E-12	9.004E-11	4.431E-09	1.345E-07	0.00E+00
U-238	Pb-210	1.000E+00	0.00E+00	1.060E-19	8.616E-18	1.075E-15	8.834E-14	1.049E-11	4.809E-10	0.00E+00
U-238	DSR(j)		1.653E-02	1.664E-02	1.688E-02	1.773E-02	2.039E-02	3.307E-02	6.541E-02	0.00E+00

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life 6 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 15 mrem/yr

Nuclide (i)	t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	2.086E+03	1.164E+02	3.267E+01	9.601E+00	5.459E+00	3.464E+00	2.083E+00	*1.096E+05
U-238	9.077E+02	9.013E+02	8.887E+02	8.460E+02	7.356E+02	4.536E+02	2.293E+02	*3.360E+05

*At specific activity limit

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 198.1 0.4 years

Nuclide (i)	Initial pCi/g	tmin (years)		DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.800E+00	198.1	0.4	7.494E+00	2.002E+00	7.494E+00	2.002E+00
U-238	1.700E+00	200.2	0.4	6.711E-02	2.235E+02	6.666E-02	2.250E+02

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 03:41 Page 19
Summary : Commercial File: COMERCL2.RAD

Individual Nuclide Dose Summed Over All Pathways
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	1.295E-02	1.308E-02	1.335E-02	1.431E-02	1.703E-02	2.657E-02	4.048E-02	0.00E+00
Ra-228	Th-232	1.000E+00	0.00E+00	1.636E-01	4.417E-01	1.058E+00	1.660E+00	2.716E+00	4.872E+00	0.00E+00
Th-228	Th-232	1.000E+00	0.00E+00	5.521E-02	3.714E-01	1.740E+00	3.269E+00	5.052E+00	8.047E+00	0.00E+00
U-238	U-238	1.000E+00	2.809E-02	2.829E-02	2.869E-02	3.014E-02	3.467E-02	5.622E-02	1.112E-01	0.00E+00
U-234	U-238	1.000E+00	0.00E+00	3.151E-09	9.601E-09	3.368E-08	1.144E-07	5.068E-07	1.593E-06	0.00E+00
Th-230	U-238	1.000E+00	0.00E+00	3.209E-14	2.939E-13	3.458E-12	3.589E-11	5.649E-10	6.213E-09	0.00E+00
Ra-226	U-238	1.000E+00	0.00E+00	5.047E-15	1.374E-13	5.232E-12	1.531E-10	7.532E-09	2.287E-07	0.00E+00
Pb-210	U-238	1.000E+00	0.00E+00	1.802E-19	1.465E-17	1.827E-15	1.502E-13	1.784E-11	8.176E-10	0.00E+00

BRF(i) is the branch fraction of the parent nuclide.

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	1.800E+00	1.800E+00	1.800E+00	1.800E+00	1.800E+00	1.799E+00	1.798E+00	1.792E+00
Ra-228	Th-232	1.000E+00	0.00E+00	2.040E-01	5.434E-01	1.242E+00	1.705E+00	1.746E+00	1.745E+00	1.739E+00
Th-228	Th-232	1.000E+00	0.00E+00	3.352E-02	2.229E-01	1.004E+00	1.683E+00	1.746E+00	1.745E+00	1.739E+00
U-238	U-238	1.000E+00	1.700E+00	1.700E+00	1.700E+00	1.699E+00	1.697E+00	1.690E+00	1.670E+00	1.603E+00
U-234	U-238	1.000E+00	0.00E+00	4.807E-06	1.435E-05	4.696E-05	1.339E-04	3.756E-04	7.289E-04	8.888E-04

Appendix B.2 RESRAD Summary Output for Commercial Worker Scenario

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-230	U-238	1.000E+00	0.00E+00	2.165E-11	1.942E-10	2.132E-09	1.854E-08	1.836E-07	1.231E-06	6.603E-06
Ra-226	U-238	1.000E+00	0.00E+00	3.125E-15	8.399E-14	3.060E-12	7.890E-11	2.495E-09	4.411E-08	5.012E-07
0										
Pb-210	U-238	1.000E+00	0.00E+00	2.413E-17	1.922E-15	2.237E-13	1.541E-11	1.155E-09	3.223E-08	4.410E-07

BRF(i) is the branch fraction of the parent nuclide.

APPENDIX B.3

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 1
Summary : Residential File: RESIDNT2.RAD

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Part I: Mixture Sums and Single Radionuclide Guidelines

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 2
Summary : Residential File: RESIDNT2.RAD

Dose Conversion Factor (and Related) Parameter Summary
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
B-1	Ra-228+D	5.080E-03	5.080E-03	DCF2(3)
B-1	Th-228+D	3.450E-01	3.450E-01	DCF2(4)
B-1	Th-230	3.260E-01	3.260E-01	DCF2(5)
B-1	Th-232	1.640E+00	1.640E+00	DCF2(6)
B-1	U-234	1.320E-01	1.320E-01	DCF2(7)
B-1	U-238+D	1.180E-01	1.180E-01	DCF2(8)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-1	Ra-228+D	1.440E-03	1.440E-03	DCF3(3)
D-1	Th-228+D	8.080E-04	8.080E-04	DCF3(4)
D-1	Th-230	5.480E-04	5.480E-04	DCF3(5)
D-1	Th-232	2.730E-03	2.730E-03	DCF3(6)
D-1	U-234	2.830E-04	2.830E-04	DCF3(7)
D-1	U-238+D	2.690E-04	2.690E-04	DCF3(8)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-34				
D-34	Ra-228+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(3,1)
D-34	Ra-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,2)
D-34	Ra-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(3,3)
D-34				
D-34	Th-228+D , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF(4,1)
D-34	Th-228+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF(4,2)
D-34	Th-228+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF(4,3)

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D-34
D-34   Th-230    , plant/soil concentration ratio, dimensionless       1.000E-03   1.000E-03   RTF( 5,1)
D-34   Th-230    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)       1.000E-04   1.000E-04   RTF( 5,2)
D-34   Th-230    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)        5.000E-06   5.000E-06   RTF( 5,3)
D-34
D-34   Th-232    , plant/soil concentration ratio, dimensionless       1.000E-03   1.000E-03   RTF( 6,1)
D-34   Th-232    , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)       1.000E-04   1.000E-04   RTF( 6,2)
D-34   Th-232    , milk/livestock-intake ratio, (pCi/L)/(pCi/d)        5.000E-06   5.000E-06   RTF( 6,3)
D-34
D-34   U-234     , plant/soil concentration ratio, dimensionless       2.500E-03   2.500E-03   RTF( 7,1)
D-34   U-234     , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)       3.400E-04   3.400E-04   RTF( 7,2)
D-34   U-234     , milk/livestock-intake ratio, (pCi/L)/(pCi/d)        6.000E-04   6.000E-04   RTF( 7,3)
D-34
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Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 15:43   Page   3
Summary : Residential   File: RESIDNT2.RAD

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: DOSFAC.BIN

Menu	Parameter	Current Value	Default	Parameter Name
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF(8,1)
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF(8,2)
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF(8,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)
D-5				
D-5	Ra-228+D , fish	5.000E+01	5.000E+01	BIOFAC(3,1)
D-5	Ra-228+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(3,2)
D-5				
D-5	Th-228+D , fish	1.000E+02	1.000E+02	BIOFAC(4,1)
D-5	Th-228+D , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(4,2)
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIOFAC(5,1)
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(5,2)
D-5				
D-5	Th-232 , fish	1.000E+02	1.000E+02	BIOFAC(6,1)
D-5	Th-232 , crustacea and mollusks	5.000E+02	5.000E+02	BIOFAC(6,2)
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIOFAC(7,1)
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(7,2)
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIOFAC(8,1)
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIOFAC(8,2)

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 4
Summary : Residential File: RESIDNT2.RAD

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R011	Area of contaminated zone (m**2)	3.250E+02	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	3.050E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.981E+01	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.500E+01	3.000E+01	---	BRDL
R011	Time since placement of material (yr)	2.500E+01	0.00E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.00E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Th-232	1.800E+00	0.00E+00	---	S1(6)
R012	Initial principal radionuclide (pCi/g): U-238	1.700E+00	0.00E+00	---	S1(8)
R012	Concentration in groundwater (pCi/L): Th-232	not used	0.00E+00	---	W1(6)
R012	Concentration in groundwater (pCi/L): U-238	not used	0.00E+00	---	W1(8)
R013	Cover depth (m)	0.00E+00	0.00E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSCZ
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
R013	Contaminated zone total porosity	4.500E-01	4.000E-01	---	TPCZ
R013	Contaminated zone effective porosity	1.300E-01	2.000E-01	---	EPCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	3.260E+01	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	1.040E+01	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	3.130E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	5.600E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	1.520E+00	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.00E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF

R013	Watershed area for nearby stream or pond (m**2)	2.416E+04	1.000E+06	---	WAREA
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	---	EPS
R014	Density of saturated zone (g/cm**3)	1.700E+00	1.500E+00	---	DENSAQ
R014	Saturated zone total porosity	4.300E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	3.300E-01	2.000E-01	---	EPSZ
R014	Saturated zone hydraulic conductivity (m/yr)	5.550E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-03	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.050E+00	5.300E+00	---	BSZ
R014	Water table drop rate (m/yr)	3.048E+00	1.000E-03	---	VWT
R014	Well pump intake depth (m below water table)	9.144E-01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	MB	ND	---	MODEL
R014	Well pumping rate (m**3/yr)	1.000E+00	2.500E+02	---	UW
R015	Number of unsaturated zone strata	3	1	---	NS

Appendix B.3 RESRAD Summary Output for Residential Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R015	Unsat. zone 1, thickness (m)	1.524E+00	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	2.000E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.200E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	6.000E-02	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	1.140E+01	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.050E+01	1.000E+01	---	HCUZ(1)
R015	Unsat. zone 2, thickness (m)	1.524E+00	0.00E+00	---	H(2)
R015	Unsat. zone 2, soil density (g/cm**3)	1.700E+00	1.500E+00	---	DENSUZ(2)
R015	Unsat. zone 2, total porosity	4.300E-01	4.000E-01	---	TPUZ(2)
R015	Unsat. zone 2, effective porosity	3.300E-01	2.000E-01	---	EPUZ(2)
R015	Unsat. zone 2, soil-specific b parameter	7.120E+00	5.300E+00	---	BUZ(2)
R015	Unsat. zone 2, hydraulic conductivity (m/yr)	1.990E+02	1.000E+01	---	HCUZ(2)
R015	Unsat. zone 3, thickness (m)	3.084E+00	0.00E+00	---	H(3)
R015	Unsat. zone 3, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(3)
R015	Unsat. zone 3, total porosity	3.400E-01	4.000E-01	---	TPUZ(3)
R015	Unsat. zone 3, effective porosity	2.800E-01	2.000E-01	---	EPUZ(3)
R015	Unsat. zone 3, soil-specific b parameter	4.050E+00	5.300E+00	---	BUZ(3)
R015	Unsat. zone 3, hydraulic conductivity (m/yr)	5.550E+03	1.000E+01	---	HCUZ(3)
R016	Distribution coefficients for Th-232				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(6)
R016	Unsaturated zone 1 (cm**3/g)	1.600E+05	6.000E+04	---	DCNUCU(6,1)
R016	Unsaturated zone 2 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(6,2)
R016	Unsaturated zone 3 (cm**3/g)	6.000E+03	6.000E+04	---	DCNUCU(6,3)
R016	Saturated zone (cm**3/g)	6.000E+03	6.000E+04	---	DCNUCS(6)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.720E-05	ALEACH(6)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(6)
R016	Distribution coefficients for U-238				
R016	Contaminated zone (cm**3/g)	4.400E+03	5.000E+01	---	DCNUCC(8)
R016	Unsaturated zone 1 (cm**3/g)	4.400E+03	5.000E+01	---	DCNUCU(8,1)
R016	Unsaturated zone 2 (cm**3/g)	4.400E+03	5.000E+01	---	DCNUCU(8,2)
R016	Unsaturated zone 3 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(8,3)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(8)

R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.345E-04	ALEACH(8)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(8)
R016	Distribution coefficients for daughter Pb-210				
R016	Contaminated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,1)
R016	Unsaturated zone 2 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,2)
R016	Unsaturated zone 3 (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCU(1,3)
R016	Saturated zone (cm**3/g)	1.000E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.030E-02	ALEACH(1)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(1)

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R016	Distribution coefficients for daughter Ra-226				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,1)
R016	Unsaturated zone 2 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,2)
R016	Unsaturated zone 3 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(2,3)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.469E-02	ALEACH(2)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(2)
R016	Distribution coefficients for daughter Ra-228				
R016	Contaminated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCC(3)
R016	Unsaturated zone 1 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(3,1)
R016	Unsaturated zone 2 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(3,2)
R016	Unsaturated zone 3 (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCU(3,3)
R016	Saturated zone (cm**3/g)	7.000E+01	7.000E+01	---	DCNUCS(3)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.469E-02	ALEACH(3)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(3)
R016	Distribution coefficients for daughter Th-228				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(4)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(4,1)
R016	Unsaturated zone 2 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(4,2)
R016	Unsaturated zone 3 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(4,3)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(4)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.720E-05	ALEACH(4)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(4)
R016	Distribution coefficients for daughter Th-230				
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCC(5)
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(5,1)
R016	Unsaturated zone 2 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(5,2)
R016	Unsaturated zone 3 (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCU(5,3)
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	---	DCNUCS(5)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	1.720E-05	ALEACH(5)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(5)
R016	Distribution coefficients for daughter U-234				

R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCC(7)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(7,1)
R016	Unsaturated zone 2 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(7,2)
R016	Unsaturated zone 3 (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCU(7,3)
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	---	DCNUCS(7)
R016	Leach rate (/yr)	0.00E+00	0.00E+00	2.055E-02	ALEACH(7)
R016	Solubility constant	0.00E+00	0.00E+00	not used	SOLUBK(7)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
R017	Mass loading for inhalation (g/m**3)	3.000E-04	1.000E-04	---	MLINH
R017	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.000E-01	7.000E-01	---	SHF1
R017	Fraction of time spent indoors	2.500E-01	5.000E-01	---	FIND

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R017	Fraction of time spent outdoors (on site)	5.000E-01	2.500E-01	---	FOTD
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows circular AREA.	FS
R017	Radii of shape factor array (used if FS = -1):				
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	---	RAD_SHAPE(1)
R017	Outer annular radius (m), ring 2:	not used	7.071E+01	---	RAD_SHAPE(2)
R017	Outer annular radius (m), ring 3:	not used	0.00E+00	---	RAD_SHAPE(3)
R017	Outer annular radius (m), ring 4:	not used	0.00E+00	---	RAD_SHAPE(4)
R017	Outer annular radius (m), ring 5:	not used	0.00E+00	---	RAD_SHAPE(5)
R017	Outer annular radius (m), ring 6:	not used	0.00E+00	---	RAD_SHAPE(6)
R017	Outer annular radius (m), ring 7:	not used	0.00E+00	---	RAD_SHAPE(7)
R017	Outer annular radius (m), ring 8:	not used	0.00E+00	---	RAD_SHAPE(8)
R017	Outer annular radius (m), ring 9:	not used	0.00E+00	---	RAD_SHAPE(9)
R017	Outer annular radius (m), ring 10:	not used	0.00E+00	---	RAD_SHAPE(10)
R017	Outer annular radius (m), ring 11:	not used	0.00E+00	---	RAD_SHAPE(11)
R017	Outer annular radius (m), ring 12:	not used	0.00E+00	---	RAD_SHAPE(12)
R017	Fractions of annular areas within AREA:				
R017	Ring 1	not used	1.000E+00	---	FRACA(1)
R017	Ring 2	not used	2.732E-01	---	FRACA(2)
R017	Ring 3	not used	0.00E+00	---	FRACA(3)
R017	Ring 4	not used	0.00E+00	---	FRACA(4)
R017	Ring 5	not used	0.00E+00	---	FRACA(5)
R017	Ring 6	not used	0.00E+00	---	FRACA(6)
R017	Ring 7	not used	0.00E+00	---	FRACA(7)
R017	Ring 8	not used	0.00E+00	---	FRACA(8)
R017	Ring 9	not used	0.00E+00	---	FRACA(9)
R017	Ring 10	not used	0.00E+00	---	FRACA(10)
R017	Ring 11	not used	0.00E+00	---	FRACA(11)
R017	Ring 12	not used	0.00E+00	---	FRACA(12)
R018	Fruits, vegetables and grain consumption (kg/yr)	4.400E+01	1.600E+02	---	DIET(1)
R018	Leafy vegetable consumption (kg/yr)	3.000E+01	1.400E+01	---	DIET(2)
R018	Milk consumption (L/yr)	not used	9.200E+01	---	DIET(3)
R018	Meat and poultry consumption (kg/yr)	not used	6.300E+01	---	DIET(4)
R018	Fish consumption (kg/yr)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)

Appendix B.3 RESRAD Summary Output for Residential Scenario

R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	---	SOIL
R018	Drinking water intake (L/yr)	not used	5.100E+02	---	DWI
R018	Contamination fraction of drinking water	not used	1.000E+00	---	FDW
R018	Contamination fraction of household water	not used	1.000E+00	---	FHHW
R018	Contamination fraction of livestock water	not used	1.000E+00	---	FLW
R018	Contamination fraction of irrigation water	0.00E+00	1.000E+00	---	FIRW
R018	Contamination fraction of aquatic food	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	1.000E+00	-1	---	FPLANT
R018	Contamination fraction of meat	not used	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	not used	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	not used	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	---	LWI6

Appendix B.3 RESRAD Summary Output for Residential Scenario

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R019	Livestock soil intake (kg/day)	not used	5.000E-01	---	LSI
R019	Mass loading for foliar deposition (g/m**3)	1.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	9.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	not used	1.000E+00	---	FGWLW
R019	Irrigation fraction from ground water	not used	1.000E+00	---	FGWIR
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	---	YV(1)
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	---	YV(2)
R19B	Wet weight crop yield for Fodder (kg/m**2)	not used	1.100E+00	---	YV(3)
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	---	TE(1)
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	---	TE(2)
R19B	Growing Season for Fodder (years)	not used	8.000E-02	---	TE(3)
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	---	TIV(1)
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	---	TIV(2)
R19B	Translocation Factor for Fodder	not used	1.000E+00	---	TIV(3)
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RDRY(1)
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RDRY(2)
R19B	Dry Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RDRY(3)
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	---	RWET(1)
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	---	RWET(2)
R19B	Wet Foliar Interception Fraction for Fodder	not used	2.500E-01	---	RWET(3)
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	---	WLAM
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	---	C12WTR
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	---	C12CZ
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	---	CSOIL
C14	Fraction of vegetation carbon from air	not used	9.800E-01	---	CAIR
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	---	DMC
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	---	EVSN
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	---	REVSN
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	---	AVFG4
C14	Fraction of grain in milk cow feed	not used	2.000E-01	---	AVFG5

Appendix B.3 RESRAD Summary Output for Residential Scenario

STOR	Storage times of contaminated foodstuffs (days):				
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	---	STOR_T(1)
STOR	Leafy vegetables	1.000E+00	1.000E+00	---	STOR_T(2)
STOR	Milk	1.000E+00	1.000E+00	---	STOR_T(3)
STOR	Meat and poultry	2.000E+01	2.000E+01	---	STOR_T(4)
STOR	Fish	7.000E+00	7.000E+00	---	STOR_T(5)
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	---	STOR_T(6)
STOR	Well water	1.000E+00	1.000E+00	---	STOR_T(7)
STOR	Surface water	1.000E+00	1.000E+00	---	STOR_T(8)
STOR	Livestock fodder	4.500E+01	4.500E+01	---	STOR_T(9)
R021	Thickness of building foundation (m)	not used	1.500E-01	---	FLOOR
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	---	DENSFL
R021	Total porosity of the cover material	not used	4.000E-01	---	TPCV
R021	Total porosity of the building foundation	not used	1.000E-01	---	TPFL

Appendix B.3 RESRAD Summary Output for Residential Scenario

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Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
R021	Volumetric water content of the cover material	not used	5.000E-02	---	PH2OCV
R021	Volumetric water content of the foundation	not used	3.000E-02	---	PH2OFL
R021	Diffusion coefficient for radon gas (m/sec):				
R021	in cover material	not used	2.000E-06	---	DIFCV
R021	in foundation material	not used	3.000E-07	---	DIFFL
R021	in contaminated zone soil	not used	2.000E-06	---	DIFCZ
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	---	HMIX
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	---	REXG
R021	Height of the building (room) (m)	not used	2.500E+00	---	HRM
R021	Building interior area factor	not used	0.00E+00	---	FAI
R021	Building depth below ground surface (m)	not used	-1.000E+00	---	DMFL
R021	Emanating power of Rn-222 gas	not used	2.500E-01	---	EMANA(1)
R021	Emanating power of Rn-220 gas	not used	1.500E-01	---	EMANA(2)

Summary of Pathway Selections

Pathway	User Selection
1 -- external gamma	active
2 -- inhalation (w/o radon)	active
3 -- plant ingestion	active
4 -- meat ingestion	suppressed
5 -- milk ingestion	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	suppressed
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	suppressed

Appendix B.3 RESRAD Summary Output for Residential Scenario

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Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	325.00 square meters	Th-232	1.800E+00
Thickness:	0.31 meters	U-238	1.700E+00
Cover Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 15 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.00E+03
TDOSE(t):	7.962E-01	1.923E+00	4.502E+00	1.162E+01	1.645E+01	1.578E+01	1.038E+00	0.00E+00
M(t):	5.308E-02	1.282E-01	3.001E-01	7.746E-01	1.096E+00	1.052E+00	6.918E-02	0.00E+00

Maximum TDOSE(t): 1.660E+01 mrem/yr at t = 40.14 ñ 0.08 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.014E+01 years

Water Independent Pathways (Inhalation excludes radon)

	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Radio-Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.367E+01	0.8239	5.218E-01	0.0314	0.00E+00	0.000	2.142E+00	0.1291	0.00E+00	0.000	0.00E+00	0.000	7.559E-02	0.0046
U-238	1.249E-01	0.0075	2.956E-02	0.0018	0.00E+00	0.000	2.471E-02	0.0015	0.00E+00	0.000	0.00E+00	0.000	4.031E-03	0.0002
Total	1.380E+01	0.8314	5.513E-01	0.0332	0.00E+00	0.000	2.167E+00	0.1306	0.00E+00	0.000	0.00E+00	0.000	7.962E-02	0.0048

Appendix B.3 RESRAD Summary Output for Residential Scenario

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 4.014E+01 years

Water Dependent Pathways

	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Radio-Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.641E+01	0.9890
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.832E-01	0.0110
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.660E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

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Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	5.256E-04	0.0007	4.391E-01	0.5515	0.00E+00	0.000	1.237E-01	0.1554	0.00E+00	0.000	0.00E+00	0.000	4.372E-02	0.0549
U-238	1.265E-01	0.1589	2.984E-02	0.0375	0.00E+00	0.000	2.872E-02	0.0361	0.00E+00	0.000	0.00E+00	0.000	4.069E-03	0.0051
Total	1.270E-01	0.1595	4.690E-01	0.5890	0.00E+00	0.000	1.524E-01	0.1915	0.00E+00	0.000	0.00E+00	0.000	4.779E-02	0.0600

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 0.00E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	6.071E-01	0.7625
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.891E-01	0.2375
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	7.962E-01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 15:43   Page 12
Summary : Residential   File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	8.359E-01	0.4347	4.410E-01	0.2293	0.00E+00	0.000	4.104E-01	0.2134	0.00E+00	0.000	0.00E+00	0.000	4.656E-02	0.0242
U-238	1.265E-01	0.0658	2.983E-02	0.0155	0.00E+00	0.000	2.862E-02	0.0149	0.00E+00	0.000	0.00E+00	0.000	4.068E-03	0.0021
Total	9.624E-01	0.5005	4.708E-01	0.2449	0.00E+00	0.000	4.390E-01	0.2283	0.00E+00	0.000	0.00E+00	0.000	5.063E-02	0.0263

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.734E+00	0.9017
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.890E-01	0.0983
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.923E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 15:43   Page 13
Summary : Residential   File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	2.921E+00	0.6489	4.508E-01	0.1001	0.00E+00	0.000	8.890E-01	0.1975	0.00E+00	0.000	0.00E+00	0.000	5.216E-02	0.0116
U-238	1.264E-01	0.0281	2.982E-02	0.0066	0.00E+00	0.000	2.842E-02	0.0063	0.00E+00	0.000	0.00E+00	0.000	4.066E-03	0.0009
Total	3.047E+00	0.6769	4.807E-01	0.1068	0.00E+00	0.000	9.174E-01	0.2038	0.00E+00	0.000	0.00E+00	0.000	5.622E-02	0.0125

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.313E+00	0.9581
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.887E-01	0.0419
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	4.502E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 14
Summary : Residential File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	9.074E+00	0.7809	4.896E-01	0.0421	0.00E+00	0.000	1.802E+00	0.1551	0.00E+00	0.000	0.00E+00	0.000	6.591E-02	0.0057
U-238	1.261E-01	0.0109	2.977E-02	0.0026	0.00E+00	0.000	2.771E-02	0.0024	0.00E+00	0.000	0.00E+00	0.000	4.059E-03	0.0003
Total	9.200E+00	0.7918	5.194E-01	0.0447	0.00E+00	0.000	1.830E+00	0.1575	0.00E+00	0.000	0.00E+00	0.000	6.997E-02	0.0060

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.143E+01	0.9838
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.877E-01	0.0162
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.162E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 15
Summary : Residential File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.347E+01	0.8190	5.201E-01	0.0316	0.00E+00	0.000	2.197E+00	0.1336	0.00E+00	0.000	0.00E+00	0.000	7.510E-02	0.0046
U-238	1.254E-01	0.0076	2.963E-02	0.0018	0.00E+00	0.000	2.572E-02	0.0016	0.00E+00	0.000	0.00E+00	0.000	4.040E-03	0.0002
Total	1.359E+01	0.8266	5.498E-01	0.0334	0.00E+00	0.000	2.223E+00	0.1352	0.00E+00	0.000	0.00E+00	0.000	7.914E-02	0.0048

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.626E+01	0.9888
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.848E-01	0.0112
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.645E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 15:43 Page 16
Summary : Residential   File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	1.334E+01	0.8457	5.218E-01	0.0331	0.00E+00	0.000	1.664E+00	0.1055	0.00E+00	0.000	0.00E+00	0.000	7.568E-02	0.0048
U-238	1.211E-01	0.0077	2.915E-02	0.0018	0.00E+00	0.000	1.887E-02	0.0012	0.00E+00	0.000	0.00E+00	0.000	3.975E-03	0.0003
Total	1.346E+01	0.8534	5.510E-01	0.0349	0.00E+00	0.000	1.683E+00	0.1067	0.00E+00	0.000	0.00E+00	0.000	7.966E-02	0.0050

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.560E+01	0.9890
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.731E-01	0.0110
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.578E+01	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82   T« Limit = 0.5 year   10/28/01 15:43   Page 17
Summary : Residential   File: RESIDNT2.RAD

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	9.642E-01	0.9292	1.733E-02	0.0167	0.00E+00	0.000	4.064E-02	0.0392	0.00E+00	0.000	0.00E+00	0.000	2.514E-03	0.0024
U-238	1.152E-02	0.0111	9.273E-04	0.0009	0.00E+00	0.000	4.417E-04	0.0004	0.00E+00	0.000	0.00E+00	0.000	1.264E-04	0.0001
Total	9.757E-01	0.9403	1.826E-02	0.0176	0.00E+00	0.000	4.108E-02	0.0396	0.00E+00	0.000	0.00E+00	0.000	2.640E-03	0.0025

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.025E+00	0.9875
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.302E-02	0.0125
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	1.038E+00	1.0000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground mrem/yr	Ground fract.	Inhalation mrem/yr	Inhalation fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	Soil mrem/yr	Soil fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As mrem/yr and Fraction of Total Dose At t = 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water mrem/yr	Water fract.	Fish mrem/yr	Fish fract.	Radon mrem/yr	Radon fract.	Plant mrem/yr	Plant fract.	Meat mrem/yr	Meat fract.	Milk mrem/yr	Milk fract.	All Pathways* mrem/yr	All Pathways* fract.
Th-232	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
U-238	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000
Total	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000	0.00E+00	0.000

*Sum of all water independent and dependent pathways.

Appendix B.3 RESRAD Summary Output for Residential Scenario

RESRAD, Version 5.82 T« Limit = 0.5 year 10/28/01 15:43 Page 19
Summary : Residential File: RESIDNT2.RAD

Dose/Source Ratios Summed Over All Pathways
Parent and Progeny Principal Radionuclide Contributions Indicated

Parent (i)	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	3.373E-01	3.371E-01	3.366E-01	3.350E-01	3.304E-01	3.143E-01	1.010E-02	0.00E+00
Th-232	Ra-228	1.000E+00	0.00E+00	5.233E-01	1.383E+00	3.057E+00	3.963E+00	3.668E+00	2.362E-01	0.00E+00
Th-232	Th-228	1.000E+00	0.00E+00	1.029E-01	6.760E-01	2.959E+00	4.741E+00	4.686E+00	3.229E-01	0.00E+00
Th-232	DSR(j)		3.373E-01	9.633E-01	2.396E+00	6.351E+00	9.034E+00	8.668E+00	5.693E-01	0.00E+00
U-238	U-238	1.000E+00	1.113E-01	1.112E-01	1.110E-01	1.104E-01	1.087E-01	1.018E-01	7.659E-03	0.00E+00
U-238	U-234	1.000E+00	0.00E+00	1.125E-07	3.297E-07	1.013E-06	2.429E-06	4.067E-06	1.435E-07	0.00E+00
U-238	Th-230	1.000E+00	0.00E+00	8.714E-13	7.653E-12	8.044E-11	6.268E-10	4.484E-09	6.413E-10	0.00E+00
U-238	Ra-226	1.000E+00	0.00E+00	1.330E-14	3.550E-13	1.233E-11	2.762E-10	5.482E-09	2.955E-09	0.00E+00
U-238	Pb-210	1.000E+00	0.00E+00	3.318E-17	2.267E-15	2.322E-13	1.287E-11	4.754E-10	1.435E-10	0.00E+00
U-238	DSR(j)		1.113E-01	1.112E-01	1.110E-01	1.104E-01	1.087E-01	1.018E-01	7.659E-03	0.00E+00

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The DSR includes contributions from associated (half-life 6 0.5 yr) daughters.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 15 mrem/yr

Nuclide (i)	t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	4.447E+01	1.557E+01	6.260E+00	2.362E+00	1.660E+00	1.730E+00	2.635E+01	*1.096E+05
U-238	1.348E+02	1.349E+02	1.351E+02	1.359E+02	1.380E+02	1.473E+02	1.959E+03	*3.360E+05

*At specific activity limit

Appendix B.3 RESRAD Summary Output for Residential Scenario

Summed Dose/Source Ratios DSR(i,t) in (mrem/yr)/(pCi/g)
and Single Radionuclide Soil Guidelines G(i,t) in pCi/g
at tmin = time of minimum single radionuclide soil guideline
and at tmax = time of maximum total dose = 40.14 ñ 0.08 years

Nuclide (i)	Initial pCi/g	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Th-232	1.800E+00	40.22 ñ 0.08	9.119E+00	1.645E+00	9.119E+00	1.645E+00
U-238	1.700E+00	0.00E+00	1.113E-01	1.348E+02	1.078E-01	1.392E+02

Appendix B.3 RESRAD Summary Output for Residential Scenario

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RESRAD, Version 5.82      T« Limit = 0.5 year       10/28/01  15:43    Page  20
Summary : Residential                                         File: RESIDNT2.RAD

                                 Individual Nuclide Dose Summed Over All Pathways
                                   Parent Nuclide and Branch Fraction Indicated
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Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.00E+03
Th-232	Th-232	1.000E+00	6.071E-01	6.067E-01	6.059E-01	6.030E-01	5.947E-01	5.657E-01	1.818E-02	0.00E+00
Ra-228	Th-232	1.000E+00	0.00E+00	9.420E-01	2.490E+00	5.503E+00	7.133E+00	6.603E+00	4.252E-01	0.00E+00
Th-228	Th-232	1.000E+00	0.00E+00	1.852E-01	1.217E+00	5.326E+00	8.533E+00	8.434E+00	5.813E-01	0.00E+00
U-238	U-238	1.000E+00	1.891E-01	1.890E-01	1.887E-01	1.877E-01	1.847E-01	1.731E-01	1.302E-02	0.00E+00
U-234	U-238	1.000E+00	0.00E+00	1.913E-07	5.605E-07	1.722E-06	4.130E-06	6.915E-06	2.440E-07	0.00E+00
Th-230	U-238	1.000E+00	0.00E+00	1.481E-12	1.301E-11	1.367E-10	1.066E-09	7.624E-09	1.090E-09	0.00E+00
Ra-226	U-238	1.000E+00	0.00E+00	2.261E-14	6.036E-13	2.097E-11	4.695E-10	9.319E-09	5.024E-09	0.00E+00
Pb-210	U-238	1.000E+00	0.00E+00	5.640E-17	3.854E-15	3.948E-13	2.189E-11	8.082E-10	2.439E-10	0.00E+00

BRF(i) is the branch fraction of the parent nuclide.

Appendix B.3 RESRAD Summary Output for Residential Scenario

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.00E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Th-232	Th-232	1.000E+00	1.800E+00	1.800E+00	1.800E+00	1.800E+00	1.799E+00	1.797E+00	1.791E+00	1.769E+00
Ra-228	Th-232	1.000E+00	0.00E+00	2.030E-01	5.351E-01	1.189E+00	1.576E+00	1.602E+00	1.596E+00	1.577E+00
Th-228	Th-232	1.000E+00	0.00E+00	3.339E-02	2.205E-01	9.678E-01	1.560E+00	1.602E+00	1.596E+00	1.577E+00
U-238	U-238	1.000E+00	1.700E+00	1.700E+00	1.699E+00	1.696E+00	1.688E+00	1.661E+00	1.585E+00	1.345E+00
U-234	U-238	1.000E+00	0.00E+00	4.770E-06	1.402E-05	4.351E-05	1.075E-04	2.013E-04	2.206E-04	1.876E-04
Th-230	U-238	1.000E+00	0.00E+00	2.154E-11	1.912E-10	2.026E-09	1.602E-08	1.203E-07	5.132E-07	1.777E-06
Ra-226	U-238	1.000E+00	0.00E+00	3.104E-15	8.233E-14	2.866E-12	6.507E-11	1.382E-09	1.103E-08	4.771E-08
Pb-210	U-238	1.000E+00	0.00E+00	2.397E-17	1.883E-15	2.089E-13	1.261E-11	6.197E-10	7.290E-09	3.496E-08

BRF(i) is the branch fraction of the parent nuclide.