ANL/D&D/98-2

Investigation of the Potential Impacts From Tritium Soil Contamination in the CP-5 Yard

Decontamination and Decommissioning Program

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1.0 INTRODUCTION

1.1 Background

The Chicago Pile-Five (CP-5) reactor is an inactive research reactor located in the Building 330 complex in the southwest quadrant of the Argonne National Laboratory-East (ANL-E) site (Figure 1.1). The CP-5 reactor first achieved criticality in 1954 and was shut down in September 1979. By January 1980, all of the spent fuel and heavy water that could be drained from the cooling system were shipped to the Savannah River Site.

CP-5 operated at a thermal power of 1 MW (million watt) from 1954 to 1960 and 5 MW from 1960 to 1979. The purpose of the reactor was to produce neutrons for experimentation. Essentially all of the thermal energy produced by CP-5 was dissipated to the atmosphere by cooling towers that were located at 330H and 330G in the CP-5 yard south of the reactor building (Figure 1.2). Initially, fuel was stored in below-grade storage holes. Wet-fuel storage was added after the reactor thermal power was increased to 5 MW. The spent fuel pool was located in E-Wing of the Building 330 complex, adjacent to the CP-5 yard.

In 1989, water was detected in the below-grade storage holes in the rod storage area (Figure 1.3). A shallow monitoring well (330011) was installed shortly after discovering the potential leakage into the storage holes to determine whether contamination was migrating from the building into the surrounding soil. Figure 1.4 presents the levels of tritium detected in the well since its installation. Tritium concentrations have never exceeded the 20 pCi/ml U.S. Environmental Protection Agency (EPA) drinking water limit for tritium. In 1993, extensive sampling of the CP-5 yard was performed. While radioactive contamination and some hazardous constituents were detected, the levels were low enough to indicate that no further action was necessary to release the yard for unrestricted use. Pending Illinois Environmental Protection Agency (IEPA) approval, the CP-5 yard could be removed from the list of Solid Waste Management Units (SWMU). The de-listing of the CP-5 yard as a SWMU was unsuccessful due to the level of hazardous constituents (antimony and chromium in soil and antimony and manganese in groundwater).

In June 1997, the deep groundwater monitoring well 330012D shown in Figure 1.2 was installed south of CP-5 to determine if any contaminants were migrating down to the Niagara Dolomite bedrock. Initial monitoring results from the deep dolomite well did not indicate that tritium had reached the groundwater; however, subsequent sampling results from November 1997 and March 1998 did indicate slightly elevated tritium levels in the dolomite groundwater.

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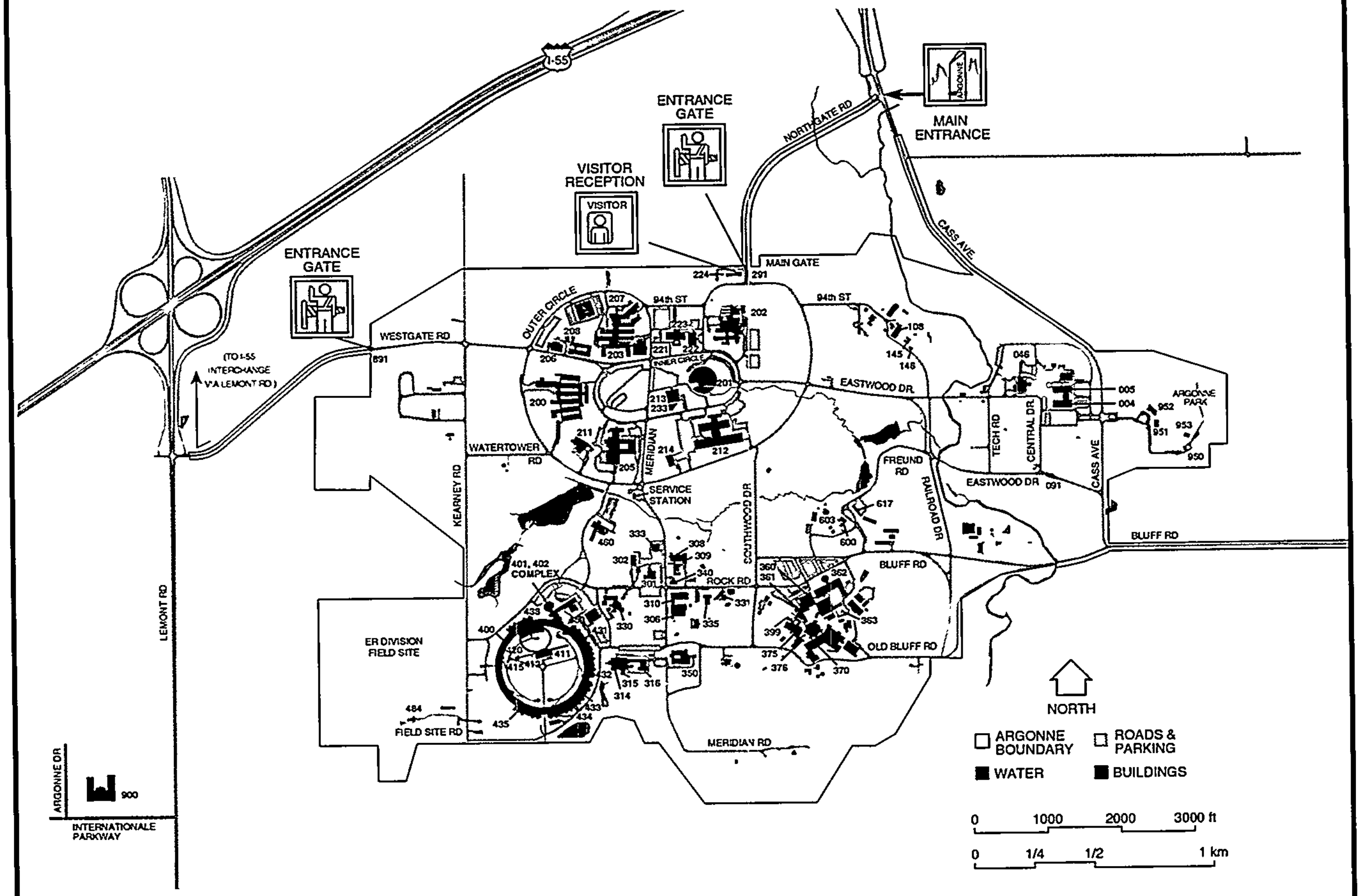

Figure 1.1 Map of Argonne National Laboratory-East

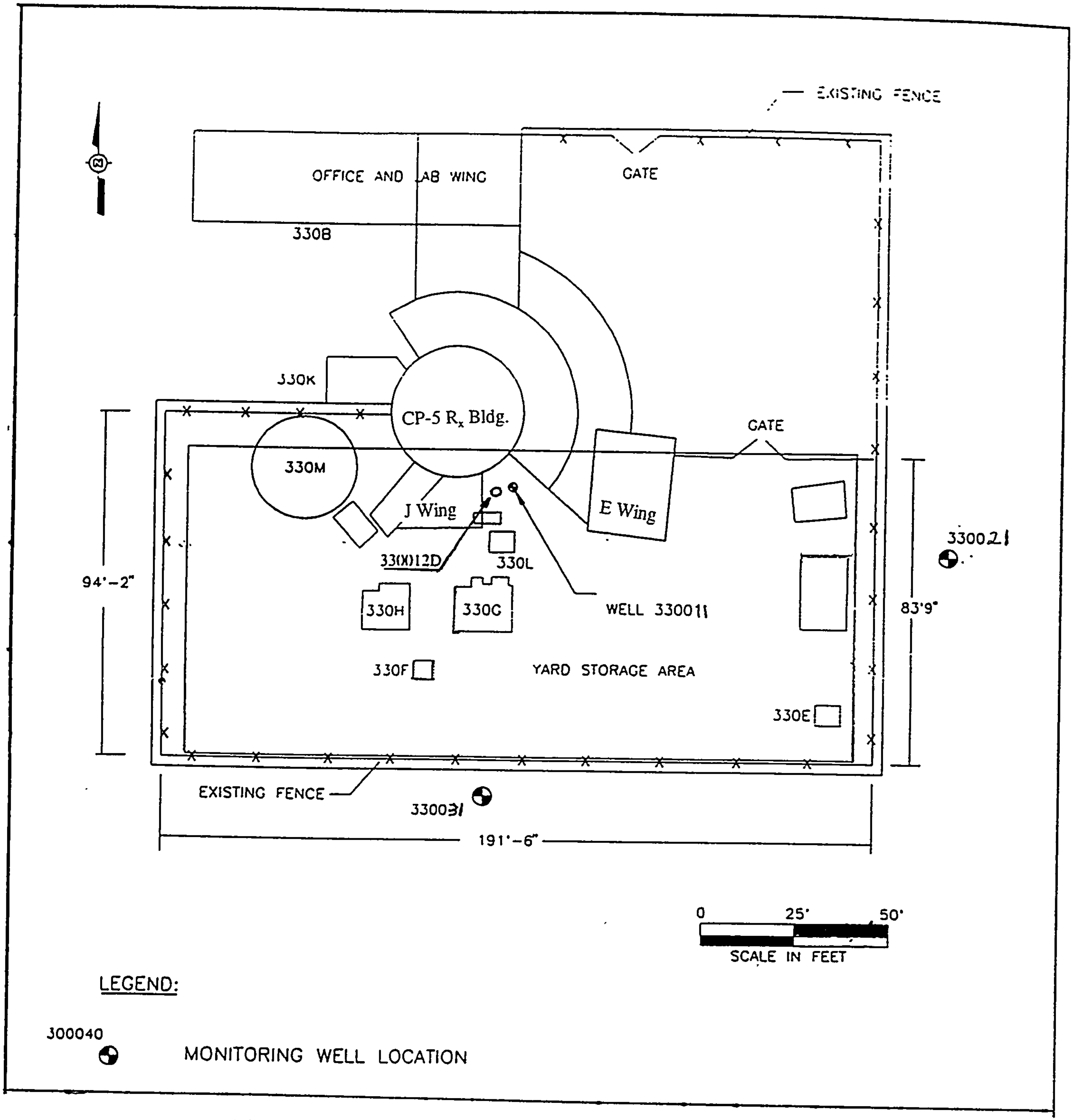

Figure 1.2 CP-5 Reactor Area and Monitoring Well Locations

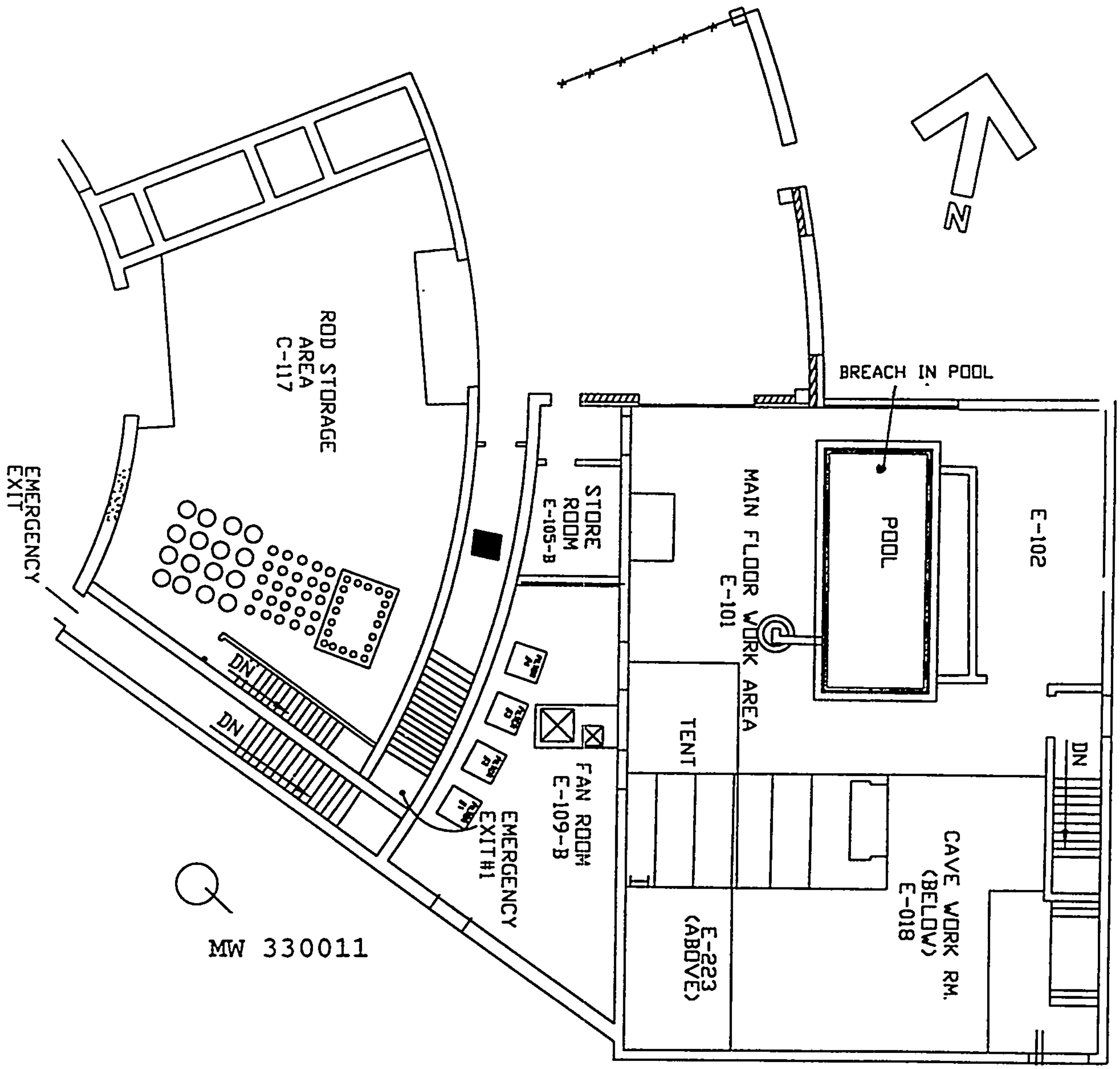

Figure 1.3 Location of Spent Fuel Pool in E-Wing

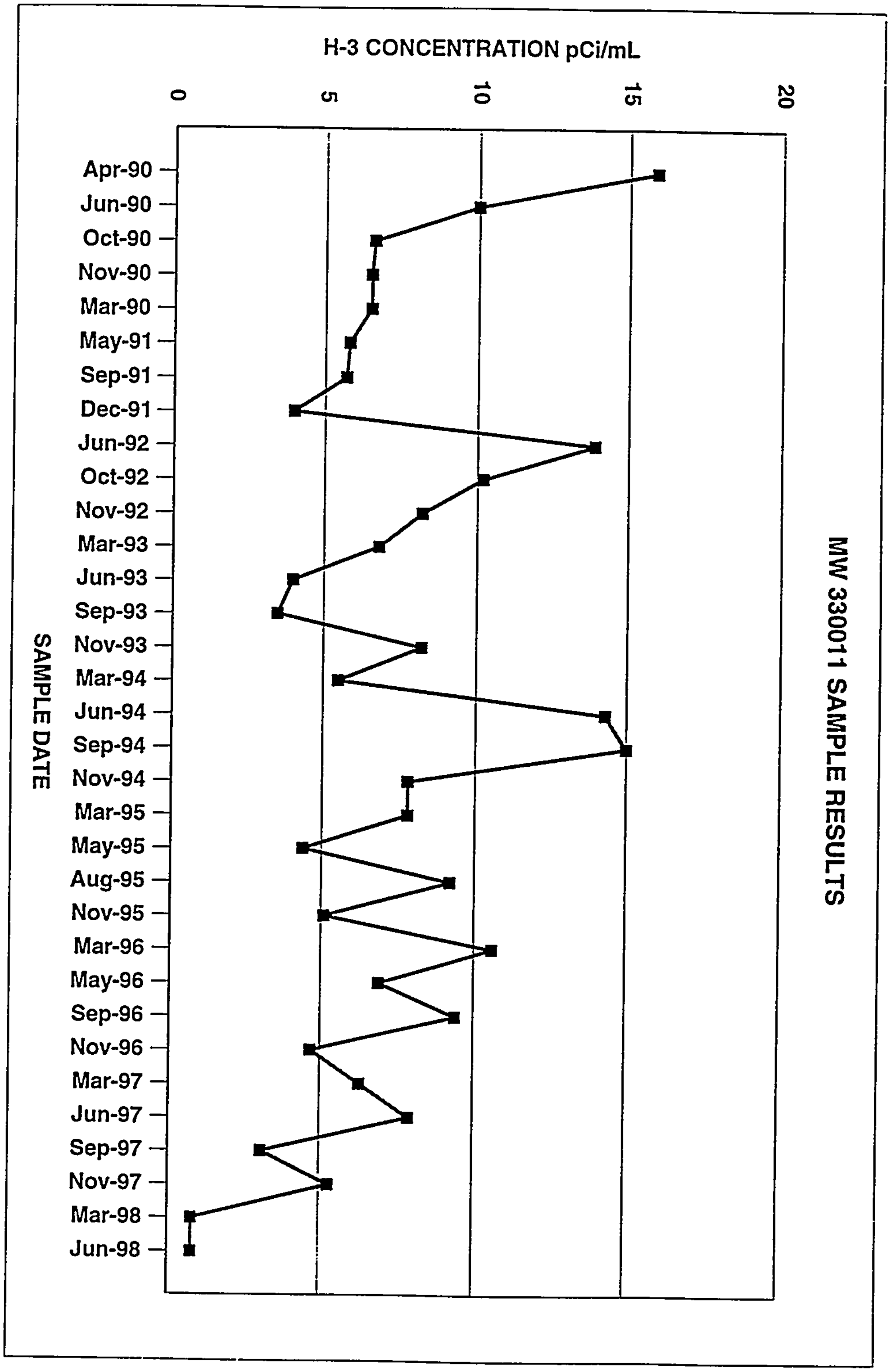

Figure 1.4 Shallow Well 330011 Groundwater Monitoring Results

In November 1997, after removal and disposal of fuel pool water, a small, 1/8 in-diameter hole was discovered in the bottom of the spent fuel pool stainless steel liner (Figure 1.3). If the 3-ft concrete foundation of the pool had been breached, there may be a potential pathway to the soil surrounding Building 330. Consequently, additional core-bore sampling was performed to determine if the source of the tritium in CP-5 yard soil could be the fuel pool.

1.2 Purpose and Scope of This Investigation

The purpose of this investigation was to estimate the magnitude of potential radiological impacts from tritium-contaminated soil and groundwater at the CP-5 site and to determine whether remediation of tritium-contaminated soil is required for the restricted or unrestricted release of the CP-5 yard. This investigation consisted of a review of the CP-5 operating history, a radiological monitoring data review (soil, water, and miscellaneous sampling), and a pathway analysis/dose assessment using the **RES**idual **RAD**ioactive material guidelines (RESRAD) computer code, version 5.82. The results of this investigation are also intended to guide future surveillance, sampling, and surveying of outdoor areas encompassing the Building 330 complex for eventual restricted or unrestricted release.

2.0 GEOLOGY/HYDROGEOLOGY OF THE CP-5 SITE

2.1 Geology

The CP-5 yard area is generally flat with a ground elevation of approximately 745 ft above mean sea level (AMSL). The yard overlies a 126-ft thick deposit of heterogeneous glacial till on top of dolomite bedrock on the eastern edge of the Advanced Photon Source (APS) area of the ANL-E site. The northern portion of this area is known as the Argonne Advanced Research Reactor (A^2R^2) area, because it had been the proposed location for the $A^2 R^2$ project before its cancellation. The location of the APS/A^2R^2 area and the location of the geologic cross sections are shown in Figures 2.1 and 2.2. The west-to-east trending geologic section, APS-A, is shown in Figure 2.3. APS-B trends south to north, as shown in Figure 2.4. Appendix A contains the IEPA Well Completion Report and Field Boring Log for deep well 330012D (Figure 2.2) installed south of the CP-5 reactor building.

The upper layer (Wadsworth Formation) of glacial till has a relatively uniform composition across the ANL-E site and consists of silty clay, clay loam, and silty clay loam glacial deposits with lenses of sand, silt, and clay (Killey and Trask 1994). The thickness of the Wadsworth layer under CP-5 is approximately 65 ft (Argonne 1997). Deposits of sand and gravel occur as discontinuous lenses throughout the glacial till of the Argonne site. The thin sand lenses occurring in the Wadsworth till of the APS/A^2R^2 area are of limited hydrologic significance (Argonne 1998).

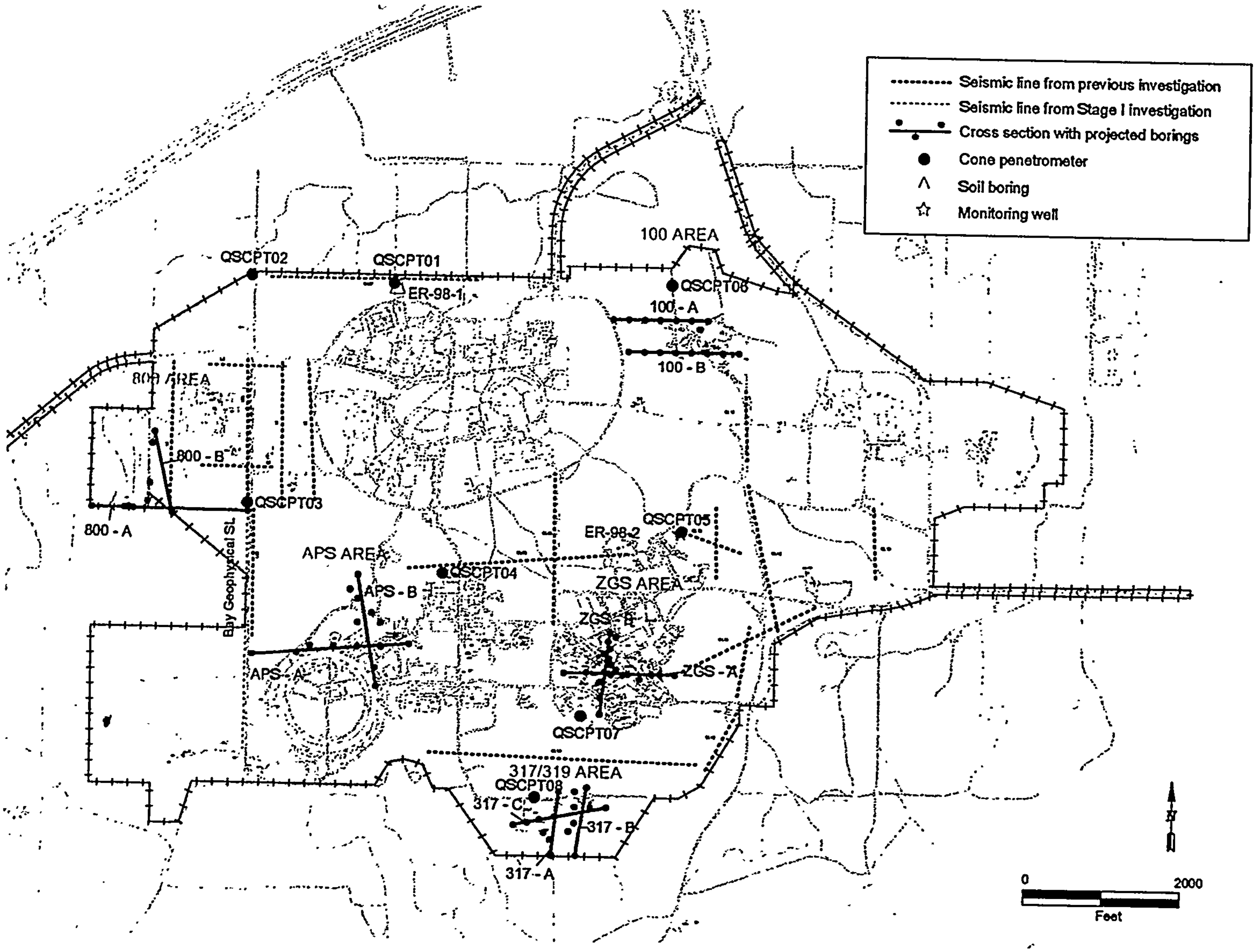

Figure 2.1 Locations Selected for Detailed Geologic Study and Locations of Geologic Cross Sections at ANL-E

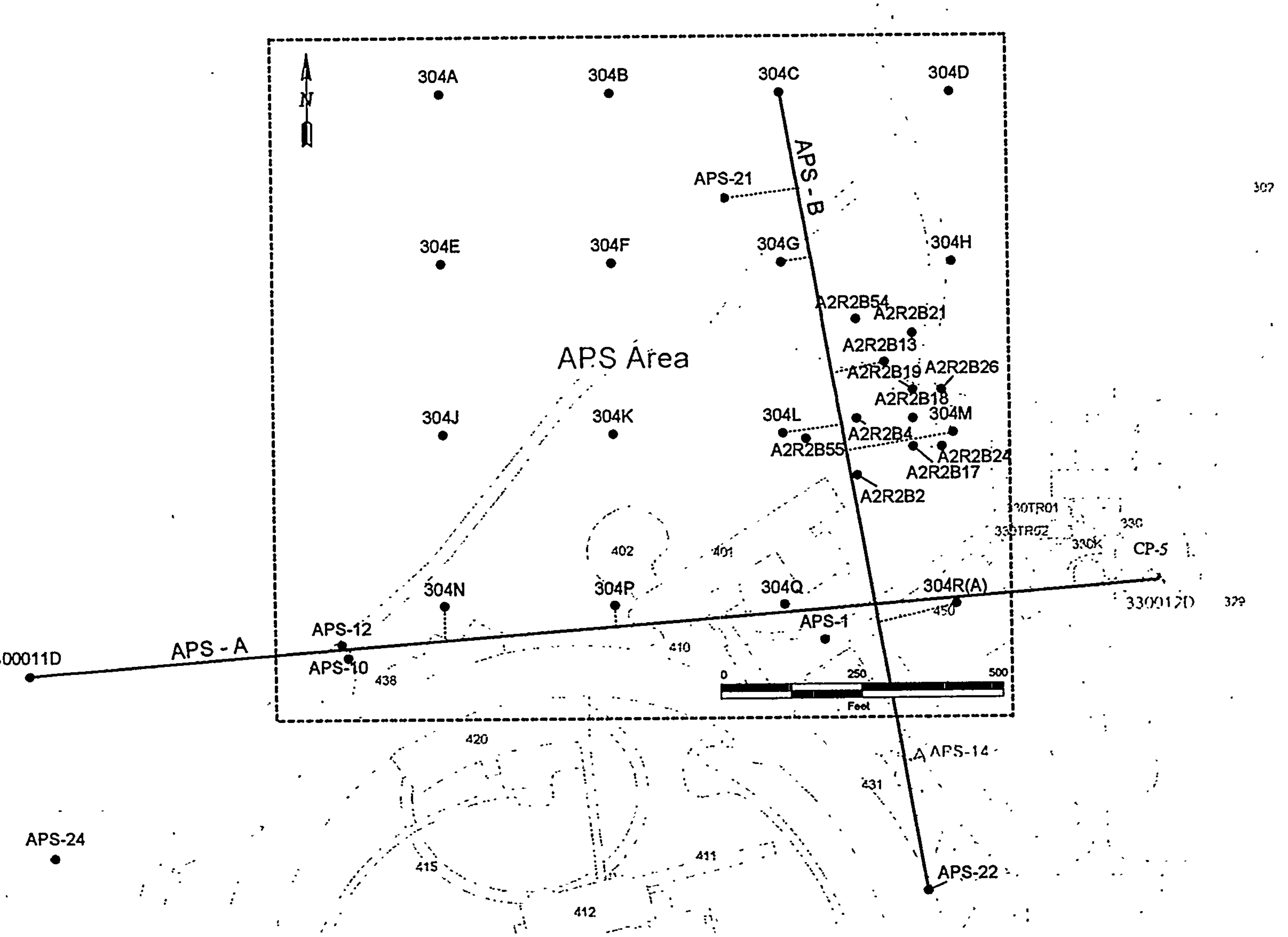

Figure 2.2 Locations Selected for Detailed Geologic Study and Locations of Geologic Cross Sections in the APS/A^{2}R^2 Area

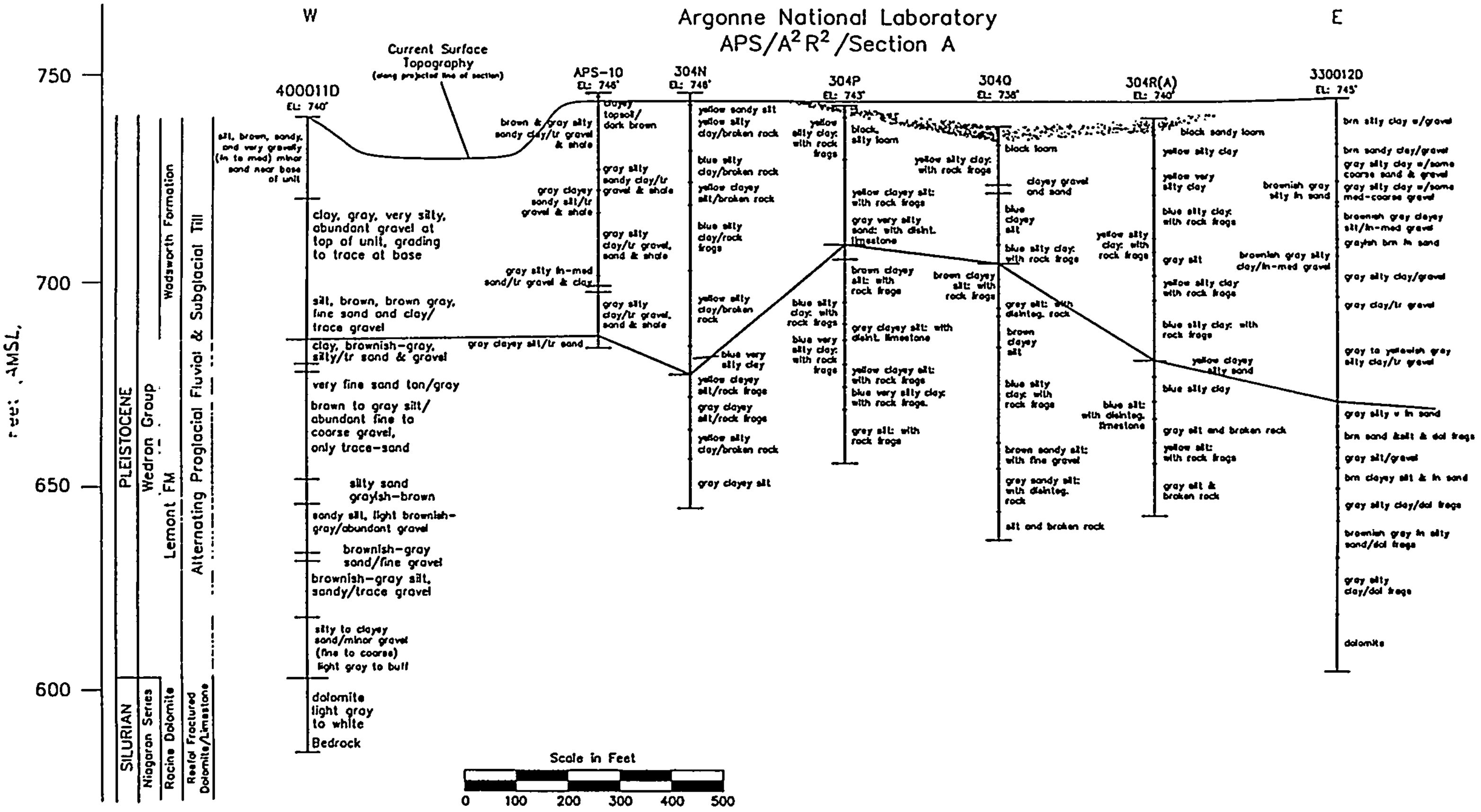

Figure 2.3 West-to-East Geologic Section APS-A, Illustrating the Stratigraphic and Depositional Relationships in the APS/A²R² Area of ANL-E

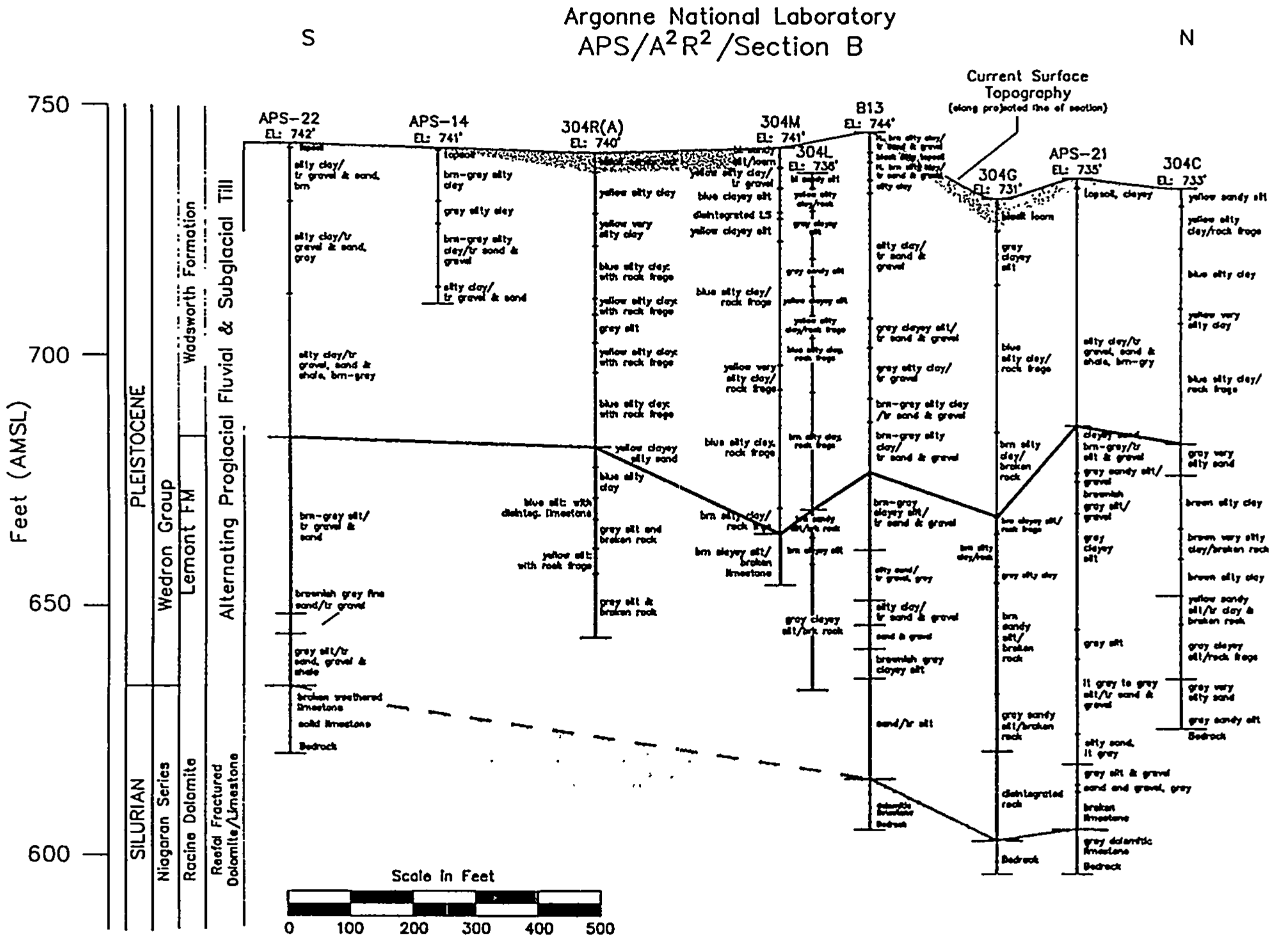

Figure 2.4 South-to-North Geologic Section APS-B, Illustrating the Stratigraphic and Depositional Relationships in the APS/A^2R^2 Area of ANL-E

Shallow monitoring wells (monitoring zones ranging from 2 to 20 ft in depth) installed south and east of the CP-5 complex and soil boring logs performed by IT Corporation in 1993, indicated that relatively porous, water-bearing regions of soil (sandy, gravelly, clay) do exist within the upper Wadsworth clay-till region around CP-5 (IT 1994). Lithologic and hydraulic-head relationships identified primarily in the 317/319/ENE and 800 Areas indicated that shallow groundwater may exist locally under unconfined to marginally confined conditions as relatively isolated perched accumulations within discontinuous deposits of coarser-grained materials above the dolomite water table at the ANL-E site (Argonne 1997). Appendix B contains the stratigraphic column and split-spoon core log for the shallow water well (330011) installed south of the CP-5 reactor building in 1989.

The underlying Lemont Formation beneath the Wadsworth layer consists of considerably more silt and less clay than the overlying Wadsworth layer. A study conducted by the Illinois State Geologic Survey (ISGS) at the APS site indicated that the Lemont drift, which consists of silty clay loam to silt loam, has an average fine-grained matrix (less than 2 mm) of 16% sand, 64% silt, and 20% clay compared with the average of 16% sand, 45% silt, and 39% clay in the overlying Wadsworth till (Killey and Trask 1994). The thickness of the Lemont Formation under the CP-5 complex is approximately 60 ft (Argonne 1997).

2.2 Hydrogeology

The downward velocity of water through the glacial till at ANL-E was determined by W. J. Drescher of the U.S. Geologic Survey (USGS) in 1952 to average 0.25 cm/day (0.91 m/yr). More recent estimates of the downward velocity of water through the till were made in the vicinity of the 800 Area landfill (located in the northeast quadrant). They indicate a downward velocity of 6×10^{-3} cm/day (Geraghty and Miller, 1995).

Available data indicate that the direction of groundwater movement within the dolomite bedrock aquifer under ANL-E is predominantly east (Argonne 1998). Groundwater within the dolomite aquifer originating in the western and central portions of ANL-E flows off-site both to the south and east, toward discharge areas along the Des Plaines River Valley (583 ft AMSL). The horizontal groundwater velocity calculated using a horizontal hydraulic conductivity of 4×10^{-3} cm/sec and an estimated fracture porosity of 10% is 1.9 cm/day, but channelized flow in fractures may be significantly higher (Geraghty and Miller, 1995). Recharge of the dolomite aquifer occurs via precipitation through the unconsolidated glacial sediments that cover the ANL-E site. Since no drinking water supplies are located between the CP-5 complex and the Des Plaines River (located south of CP-5), the potential for human consumption is low (Argonne 1998).

2.3 Surface Water

Natural surface runoff from the ANL-E site, including CP-5, occurs primarily via a network of streams and ditches that are tributary to Sawmill Creek. The creek discharges into the Des Plaines River, located approximately 1.2 miles south of CP-5.

3.0 POTENTIAL SOURCES OF TRITIUM IN CP-5 YARD SOIL

Tritium (H-3) is a radioactive isotope of hydrogen with an atomic number of 1 and atomic weight of 3. It decays with a half-life of 12.35 years by emission of a low-energy beta particle (electron with a mean energy of 5.7 keV). Tritium is primarily an internal dose hazard. The low-energy beta emitted during the decay process from tritium is unable to penetrate the skin. In heavy water reactors like CP-5, neutron activation of deuterium (H-2) is the main source of tritium. Tritium was normally released by CP-5 both in the form of tritiated water vapor released by the CP-5 stack and in the form of water that circulated in the CP-5 cooling system that may have leaked during off-normal conditions into the surrounding soil. Once tritiated water has entered the soil, its transport will involve the same processes and follow the same paths as other water. Tritiated water is carried by bulk flow with the liquid water in the soil. At the same time, there is mixing of water in the soil because the water is dispersed among the different pores in the soil as it is transported. Tritium concentration units in this report either specify tritium radioactivity per unit mass of dry soil from which the water and tritium have been removed for analysis or tritium radioactivity per unit of water volume that has been removed from soil or simply well water. There are several potential tritium sources that may have contributed to the tritium identified in soil samples and monitoring well samples around the CP-5 yard. Several documented incidents and hypothetical scenarios are discussed below.

3.1 Tritium Releases From Primary to Secondary Cooling System

A primary-to-secondary coolant leak through a small hole in the main heat exchanger of CP-5 occurred in 1964 (Argonne 1965). The leak allowed between 364 and 738 Ci of tritiated water to enter the secondary cooling system.[1,2,3] In 1971, another primary-to-secondary cooling system leak allowed between 40 to 80 Ci to enter the secondary cooling system.[4]

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[1] Memo, R. Ditch to R. Rose, "Heat Exchanger Leaks Discharging Tritium Contaminated Heavy Water to Cooling Towers", 2/16/98

[2] Reactor Operations Memo #55 titled: "Failure and Repair of the Main Heat Exchanger of CP-5," September 2, 1964

[3] Data log "Tritium Concentration in CP-5 Heavy Water"

[4] CP-5 Operations Log Concerning Heat Exchanger Leak in 1971, Talboy, J.

3.2 Draining Secondary System Water to Footing Drains

The service floor of CP-5 contains several iron rod-out holes (similar to manholes) joined by clay piping located under and around the outer circumference of the service floor approximately 14 ft below grade. The piping leads to the laboratory sanitary drain system. The purpose of this circular ring of piping or drain-tile system under the service floor is to prevent shallow groundwater from damaging the building foundation. The system allowed groundwater to enter the clay pipe at loose or "leaky" connections between pipe segments, thereby draining the groundwater into the clay piping. It also provided a convenient route for the release of water from the secondary side of the main heat exchanger that had been located on the service floor.

3.3 Secondary System Water Leakage to CP-5 Yard Soil

3.3.1 Tritiated Water Leaks From Cooling Tower Piping

The CP-5 secondary cooling system water is believed to have been normally contaminated with low levels of tritium from small primary-to-secondary system leaks. On at least two documented occasions, as discussed in Section 3.1, large quantities of tritium entered the secondary cooling system water. Some tritiated water may have been released through a postulated leak in the secondary cooling system piping leading from the service floor of the CP-5 reactor building to the cooling towers located in the south yard. Based on an old photograph of the excavated secondary piping leading to the cooling towers, the piping was located approximately 12 ft below grade, or 732 ft AMSL, and contained at least two flanged pipe-segment connections.

3.3.2 Tritiated Water Leaks From CP-5 Drain Tile System

In February 1998, sludge and water samples were collected from the rod-out holes in the service floor of CP-5 (see Section 4.3.2). Based on the tritium levels found in the holes, it appears likely that CP-5 operational personnel drained contaminated secondary coolant water to the drain tile system, causing a small fraction of the tritiated water to escape the pipe at the loose or "leaky" pipe connection points and thereby making a contribution to the tritium concentrations in CP-5 yard soil. These subsurface leaks would have occurred at approximately 14 ft below grade or 731 ft AMSL.

3.3.3 Tritiated Water Releases to a Storm Drain

In 1964, 3,000 gal of tritiated water were mistakenly sent directly to a storm drain located in the south end of the CP-5 yard rather than to the laboratory drain for processing.[5] The extent to which this release may have contributed to tritium in CP-5 yard soil is unknown.

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[5] Memo, J. Aldana to R. Rose, "Possible Sources of Tritium Around Building 330", 3/3/98

3.4 Fuel Pool Liner Hole Leakage

In November 1997, a small, 1/8-in diameter hole was discovered in the spent fuel pool's liner (located in E-Wing) approximately 25 ft below grade. Subsequent sampling of the concrete pool foundation and adjacent soil core bores did not indicate that the fuel pool had contributed to CP-5 yard tritium (see section 4.1.6).

3.5 Water Identified in the Rod Storage Area Below-Grade Holes

In 1989, water was detected in the below-grade storage holes in the rod storage area in Room C-117. Follow-up sampling and monitoring did not indicate that the rod storage area below-grade holes had contributed to CP-5 yard tritium.

3.6 Airborne Tritium Fallout

3.6.1 Cooling Tower Evaporation

Evaporation and subsequent fallout or rainout of tritium-contaminated secondary cooling system water as it flowed within the cooling towers during the operational life of CP-5 would have contributed to tritium identified in CP-5 yard soil.

3.6.2 Ventilation System Stack

The normal operation of CP-5 (1954-1979) released significant amounts of water vapor containing tritium (up to 3 Ci/day and 1,000 Ci/yr) from the main ventilation system stack located 56 ft above the ground on the east side of the CP-5 Reactor Building. The water vapor emitted from the stack would have either condensed and fallen to the ground as precipitation or been brought to the ground by rain (rainout) and would have contributed significantly to tritium in CP-5 yard soil.

In 1967, an excavation was dug approximately 150 m northwest of CP-5 for the foundation of the proposed A^2R^2. The project was canceled, but the 40-m diameter, 13-m deep excavation eventually filled with water, creating a pond. Radiological monitoring of the water and fish that eventually populated the A^2R^2 pond began in 1973. The pond water monitoring results shown in Table 3.1 indicate that tritium emissions from CP-5 accumulated in the pond as a result of rainout. The tritium concentration in pond water increased until 1978 and then decreased as the tritium released from CP-5 decreased (Golchert et al. 1983). Based on the levels of tritium measured in the pond 150 m away, rainout of tritium near the point of exhaust from the east side of CP-5 would have significantly contributed to the tritium levels identified in CP-5 yard soil and water.

Table 3.1 Average Tritiated Water Content of Water and Fish Samples from A^2R^2 Excavation

Year	Number Of Water Samples	Tritium Concentration in Water (pCi/ml)	Number of Fish Samples	Tritium Concentration in Fish Tissue Water (pCi/ml)
1973	2	8.1	1	6.0
1974	3	6.8	3	5.9
1975	3	9.1	1	8.8
1976	2	11.1	2	8.9
1978	1	11.4	1	11.0
1979	1	8.7	1	9.0
1980	1	8.4	2	7.8
1981	4	4.3	-	-
Jan.-June 1982	6	3.7	-	-
July-Dec. 1982	5	2.1	-	-

4.0 CP-5 RADIOLOGICAL MONITORING

4.1 Soil Sampling

4.1.1 1980 CP-5 Area Soil Sampling Results

In June 1980, twelve surface soil samples were collected from depth intervals of 0 – 2 in and 2 – 6 in below the surface at eight locations around the CP-5 reactor building. Each sample was analyzed by ANL-E Environment, Safety and Health (ESH) personnel using gamma-ray spectrometry. Soil moisture tritium concentrations were determined by liquid scintillation. The analytical results are presented in Table 4.1.[6] Tritium levels measured in surface soil moisture ranged from 0.3 to 3.9 pCi/g with the highest tritium levels occurring at sample location B (Figure 4.1) located closest to the CP-5 ventilation system stack on the east side of the CP-5 reactor building roof. Cs-137 and Co-60 soil concentrations are within the range normally present in environmental samples.

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[6] Memo, N. Golchert to M. Robinet, "Analysis of CP-5 Soil Samples", 9/18/80

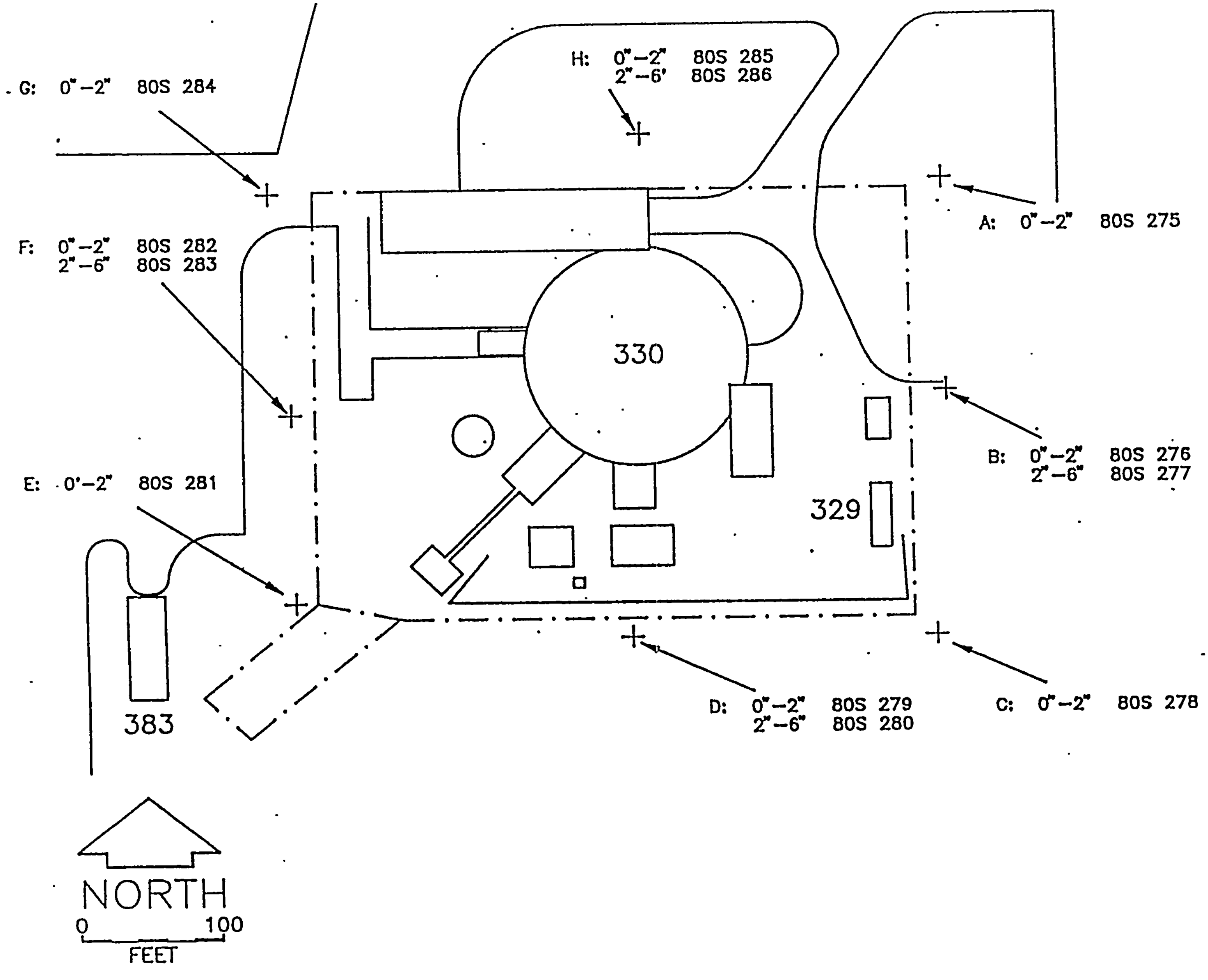

Figure 4.1 Location of 1980 Soil Samples Around CP-5

Table 4.1 1980 CP-5 Soil Sample Results

Sample Number	Location in Figure 4.1	Sampling Depth Interval (in)	H-3 (pCi/g)	Co-60 (pCi/g)	Cs-137 (pCi/g)
80S275	A	0-2	0.48 ± 0.04	<0.1	0.3 ± 0.1
80S276	B	0-2	3.90 ± 0.07	<0.1	1.2 ± 0.1
80S277	B	2-6	2.96 ± 0.05	<0.1	0.4 ± 0.1
80S278	C	0-2	0.31 ± 0.05	<0.1	1.1 ± 0.1
80S279	D	0-2	0.51 ± 0.05	0.1 ± 0.1	1.3 ± 0.1
80S280	D	2-6	0.46 ± 0.03	<0.1	0.3 ± 0.1
80S281	E	0-2	0.42 ± 0.05	<0.1	1.2 ± 0.1
80S282	F	0-2	0.56 ± 0.05	<0.1	1.3 ± 0.1
80S283	F	2-6	0.46 ± 0.04	<0.1	0.9 ± 0.1
80S284	G	0-2	0.93 ± 0.05	<0.1	0.7 ± 0.1
80S285	H	0-2	0.30 ± 0.04	<0.1	0.4 ± 0.1
80S286	H	2-6	0.31 ± 0.03	<0.1	0.1 ± 0.1

4.1.2 1989 20-ft Soil Core Sampling Results

In August 1989, a shallow well (330011) was installed in a relatively porous, saturated soil region approximately 20 ft south of the CP-5 reactor building and 8 ft from E-Wing (Figure 1.3) after tritiated water was identified in the rod storage area below-grade holes. Core bore sampling was performed at 2-ft intervals from the surface to a 20-ft depth during well installation. Tritium soil concentration measurements performed by ESH ranged from 0.013 to 2.9 pCi/g with the highest level occurring in the 14 – 16-ft below-grade depth interval. Soil water content ranged from 10.3% to 15.3%, averaging 12.85%[7] (see Appendix C). This water content is in good agreement with the mean water content (15.9%) of glacial till measured at the APS site (STS 1990) and the water content of glacial till (10% to 20%) cited in Fetter 1980.

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[7] Memo with Attachments, N. Golchert to R. Wynveen, "Analysis of CP-5 Monitoring Well Soil Cores", 11/16/89

4.1.3 1993 IT Corporation CP-5 Yard Characterization

In 1993, IT Corporation performed a radiological and hazardous material characterization of the CP-5 yard to determine whether the storage in the yard of equipment and lead shielding had resulted in contamination of the soil from radioactivity or hazardous material. A total of 21 soil borings were drilled at locations SB01 through SB21, as shown in Figure 4.2. At each location, one sample was obtained from the 0.5 – 1.5-ft interval using a stainless steel hand auger. Continuous split-spoon samples were collected in all borings from 2 ft to total depth (between 4 and 14 ft deep). IT Laboratory results for the tritium levels obtained from soil moisture by the cryogenic distillation method are provided in Appendix C. Assuming that the samples had a 13% water content, typical of CP-5 yard soils, tritium concentrations in surface soils (0.5 – 1.5 ft) and subsurface soils (4 – 14 ft) ranged from <0.03 to 2.8 pCi/g and <0.05 to 18.5 pCi/g, respectively. The highest tritium levels were detected approximately 40 ft south and 40 ft east of the CP-5 reactor building within an area of approximately 150 m^2, encompassing samples SB03, SB04, SB05, and SB13 in the 8 – 10-ft deep sampling interval. The average subsurface (8 – 10-ft deep) tritium level at these locations is 10.4 pCi/g, assuming a soil water content of 13%.

The IT Laboratory analytical results (Appendix D) indicated that concentrations of naturally occurring radionuclides (K-40, Ra-226, Ra-228, and U-238) were within the range normally present in environmental samples. One surface sample, however, contained 8.6 pCi/g of Cs-137, approximately eight times the concentration of Cs-137 typically present in environmental samples from fallout. IT also identified Co-57, Co-60 and Eu-152 in several samples that were collected from 0.5 – 1.5 ft deep. All of these radionuclides were present in levels of less than 2 pCi/g and were not included in this analysis. The focus of this analysis was tritium due to its mobility in the environment and prevalence in soils around the CP-5 yard.

4.1.4 1997 Dolomite Well Installation

In June 1997, a deep monitoring well (330012D) was installed approximately 10 ft west of shallow monitoring well 330011 (Figure 1.2) to monitor the tritium concentration in the dolomite groundwater. During well construction, an attempt was made to save selected soil cores for tritium analysis. No samples were collected between the ground surface and 50 ft below grade. Only four samples collected between 50 to 125 ft yielded sufficient water content for tritium analysis. Of these four samples, two contained soil water tritium concentrations <0.1 pCi/ml. Samples collected from the 50 – 52-ft deep and 103 – 105-ft deep intervals contained soil water tritium concentrations of 0.41 pCi/ml and 0.54 pCi/ml, respectively.[8] These low tritium concentrations reflect the low permeability of the glacial till underlying the CP-5 yard. Assuming a moisture content of 13%, the measured soil water concentrations of 0.41 pCi/ml and 0.54 pCi/ml correspond to tritium soil concentrations of only 0.05 and 0.07 pCi/g, respectively.

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[8] Memo, N. Golchert to R. Coley, "Tritium Concentrations in CP-5 Soil Cores", 12/04/97

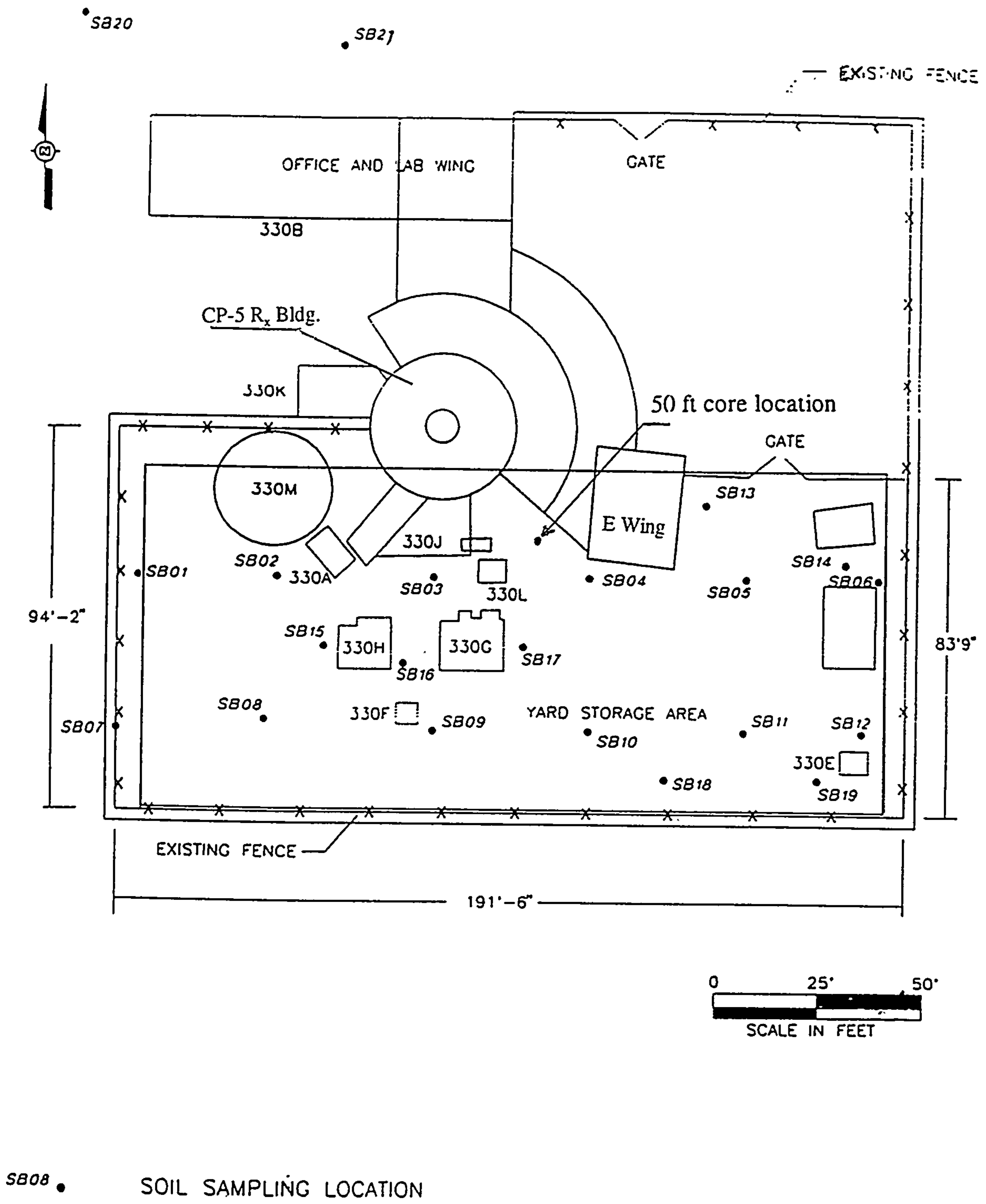

Figure 4.2 CP-5 Soil Sample Locations

4.1.5 1997 50-ft Deep Split-Spoon Sampling

In December 1997, a 50-ft deep core boring was made at a location approximately 10 ft south of shallow monitoring well 330011 and adjacent to E-Wing (Figure 4.2) to determine whether a hole in the stainless steel liner of the fuel pool floor had contributed to tritium identified in CP-5 yard soil (see section 4.3.1). Split-spoon samples were obtained from 10 – 52.5 ft deep at 1.5 ft intervals. Table 4.2 contains the results of samples selected for tritium analysis by the ANL-E Analytical Chemistry Laboratory (ACL). Soil concentrations ranged from <0.04 to 14.4 pCi/g with concentrations reaching a maximum in the 20 – 21.5-ft deep interval. Beyond 21.5 ft deep, soil sample tritium concentrations declined with sample depth and showed no indication of tritium from the adjacent fuel pool concrete foundation located approximately 27 ft below grade.[9] The tritium concentration in the sample from the 14 – 15.5-ft below grade sampling interval (11.5 pCi/g) was consistent with the results obtained during the 1993 IT sampling at locations SB03, SB04, and SB05 in the 8 – 10-ft below grade sample interval.

Table 4.2 1997 Split-Spoon Sample Results

Sample ID	Depth (ft)	H-3 (pCi/ml)	H-3 (pCi/g)	% Moisture
03	14 – 15.5	91.0 ± 2.0	11.5 ± 0.2	12.6
03 (Dup)	14 – 15.5	88.4 ± 1.8	11.1 ± 0.2	----
06	20 – 21.5	109 ± 2	14.4 ± 0.2	13.3
07	22 – 23.5	52.3 ± 0.9	6.8 ± 0.1	12.9
08	24 – 25.5	45.3 ± 0.7	5.7 ± 0.1	12.6
11	30 – 31.5	39.8 ± 0.7	5.6 ± 0.1	14.1
15	39 – 40.5	5.5 ± 0.2	0.74 ± 0.03	13.5
20	51 – 52.5	<0.33	<0.04	12.6

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[9] ANL Analytical Chemistry Laboratory "Report of Analytical Results", Sample Nos. 98-2027-01 thru 06, 12/22/97

4.1.6 1998 Split-Spoon Sampling Adjacent to Fuel Pool

In February 1998, split-spoon samples were obtained from a 41-ft-deep soil boring made through the floor of a room adjacent to the fuel pool in E Wing to determine whether the fuel pool was the source of tritium in CP-5 yard soil (Figure 4.3). Most of the samples were analyzed by Paragon Analytics, but some were "split" with the ACL. Note that the samples were not "split" in accordance with the technical meaning of "split sample." The split-spoon samples were simply divided with the upper portion going to Paragon and the lower portion going to the ACL. Other samples were analyzed only by the ACL. The Paragon Lab soil moisture tritium results from each 2-ft sampling interval from 13 – 41-ft deep ranged from 0.1 pCi/g to 42.3 pCi/g[10] (Table 4.3). The highest tritium concentration reported by Paragon (42.3 pCi/g) was obtained from the 13 – 15-ft deep sampling interval. This result is somewhat anomalous, because the other portion of sample, which was analyzed by ACL, yielded only 3.52 pCi/g tritium.[11] Excluding the 42.3 pCi/g anomalous sample result, the range of concentrations obtained from the entire core was 0.1 to 3.8 pCi/g with an average of 1.7 pCi/g. Sample concentrations generally showed a decline with sample depth beyond 15 ft deep and showed no indication of tritium from the adjacent fuel pool floor located approximately 27 ft below grade.

Assuming that the Paragon Laboratory sample result of 42.3 pCi/g at the 13 – 15-ft interval is correct, the mean concentration in the 41-ft core is 4.73 pCi/g. A high tritium concentration (42.3 pCi/g) adjacent to a low concentration (3.52 pCi/g) would be indicative of a highly impermeable, retarding layer within the 13 – 15-ft interval (between the Paragon sample and ACL sample) beneath the E-Wing and/or CP-5 Complex. No construction drawings indicated that such a man-made layer existed, but the existence of such a layer composed of engineered fill cannot be ruled out.

4.1.7 1998 CP-5 Yard Sampling

In March 1998, soil samples were obtained at various distances from the CP-5 reactor building at various depths in the approximate location of the secondary system piping that led to the valve pit (330L in Figure 4.2) and cooling towers (330G and 330H in Figure 4.2) south of the CP-5 reactor building prior to the dismantlement of the cooling system in 1979. The soil tritium concentrations reported by Paragon Lab are presented below in Table 4.4. Tritium concentrations ranged from 0.79 to 8.8 pCi/g[12] with the highest sample result obtained 42 ft south of the CP-5 reactor building at the 14 – 16-ft below grade depth interval. Tritium concentrations generally increased with distance

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[10] Paragon Analytics, Inc., "Tritium Analysis Results Summary", PAI ID Nos. 98-02-210-09 through -19, 3/3/98

[11] ANL Analytical Chemistry Laboratory, "Report of Analytical Results" Sample Nos. 98-8135-01A through 01C,02;98-8139-01 and -02

[12] Paragon Analytics Inc., "Tritium Analysis Results Summary", PAI ID Nos. 98-02-210-09 through -19, 3/2/98

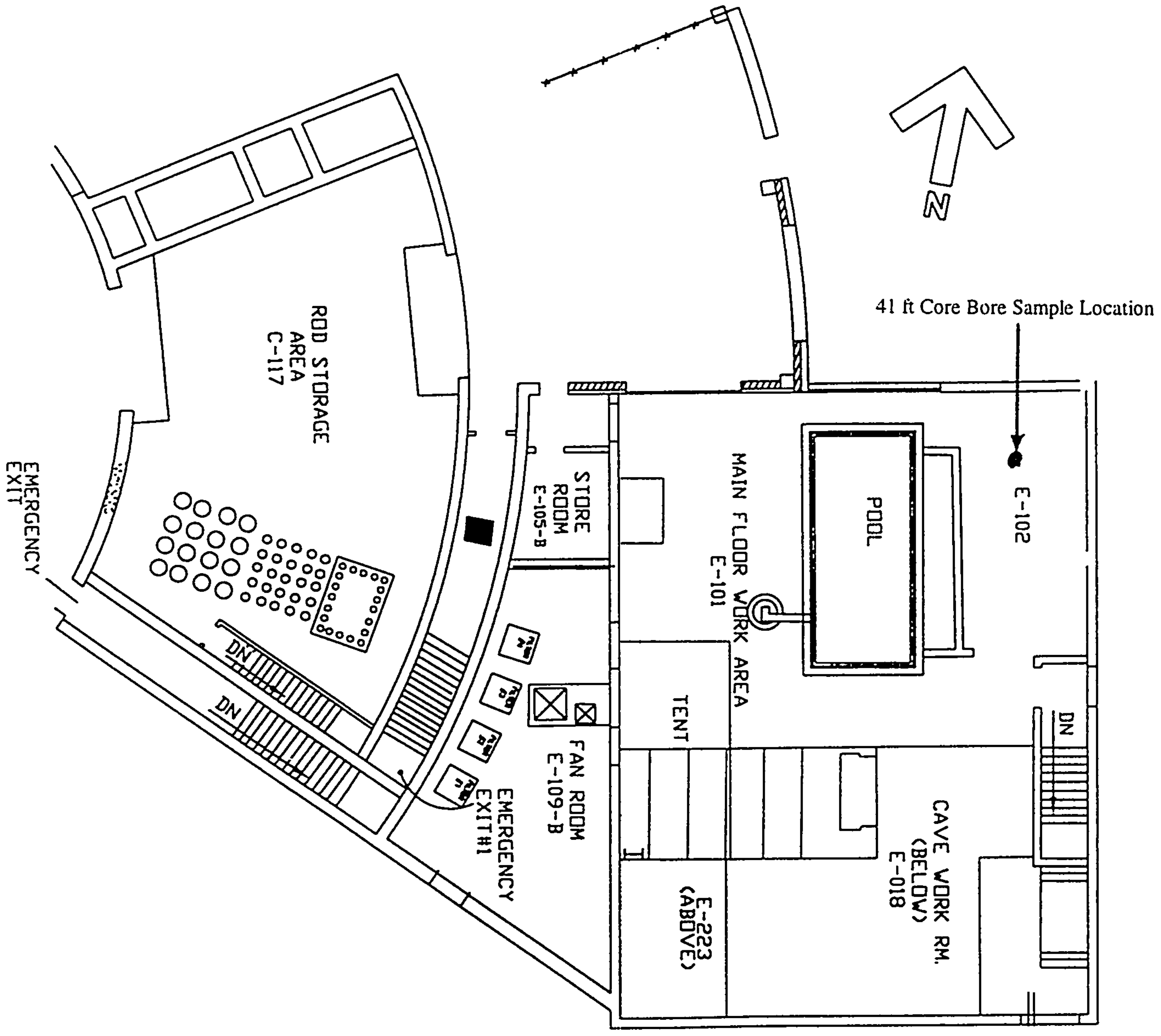
41 ft Core Bore Sample Location

Figure 4.3 Location of 41-ft Core Bore in E-Wing

Table 4.3 E-Wing Boring Split-Spoon Sample Results

Sample ID	Depth Interval (ft)	Paragon Lab H-3 (pCi/g)	ANL-E ACL H-3 (pCi/g)	% Moisture
FP01 09-11	9 – 11	----------	3.8 ± 0.1	2.9
FP01 11-13	11 – 13	----------	1.3 ± 0.1	1.3
FP01 13-15	13 – 15	42.3 ± 5.5	3.52 ± 0.08	14.9/12.0
FP01 15-17	15 – 17	3.73 ± 0.49	----------	14.1
FP01 17-19	17 – 19	2.42 ± 0.32	-----------	13.8
FP01 19-21	19 – 21	2.69 ± 0.36	-----------	11.7
FP01 21-23	21 – 23	1.26 ± 0.17	-----------	12.5
FP01 23-25	23 – 25	2.24 ± 0.3	1.15 ± 0.05	18.4/15.7
FP01 25-27	25 – 27	0.73 ± 0.1	-----------	11.0
FP01 33-35	33 – 35	0.19 ± 0.03	-----------	6.6
FP01 35-37	35 – 37	0.55 ± 0.08	-----------	16
FP01 37-39	37 – 39	0.18 ± 0.04	-----------	13.3
FP01 39-41	39 – 41	0.1 ± 0.04	<0.05	13.8/11.5

from the CP-5 reactor building and reached their highest levels in the same vicinity as the 1993 IT SB03 sample location (Figure 4.2), suggesting that leaks in piping associated with the cooling towers may have significantly contributed to the tritium in the CP-5 yard soil. Paragon also performed gamma spectroscopy and Sr-90 analysis on each soil sample. All of the sample Sr-90 results were <0.67 pCi/g.[13] Gamma-ray emitting radionuclides identified were naturally occurring decay chain progeny or fallout radionuclides in their typical environmental concentrations.

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[13] Paragon Analytics Inc., "Sr-90 Analysis Results Summary" & "Gamma Spec Results" PAI ID Nos. 98-02-210-01 thru -08, 3/19/98

Table 4.4 1998 CP-5 Yard Sample Results

Sample ID	Depth Interval (ft)	Distance from R_x Bldg. (ft)	Paragon H-3 (pCi/g)	ANL-E ACL H-3 (pCi/g)	% Moisture
YA1 10-12	10 – 12	2.7	1.3 ± 0.18	--------	19.6
YA1 12-14	12 – 14	2.7	0.82 ± 0.11	0.7±0.03	12/11.5
YA2 11-13	11 – 13	12	0.79 ± 0.11	--------	12
YA2 13-15	13 – 15	12	0.89 ± 0.12	--------	16.9
YA3 12-14	12 – 14	25	1.27 ± 0.17	--------	10.7
YA3 14-16	14 – 16	25	2.14 ± 0.28	--------	12.9
YA4 12-14	12 – 14	42	3.82 ± 0.50	--------	11.9
YA4 14-16	14 – 16	42	8.8 ± 1.2	--------	13.2

4.2 CP-5 Yard Area Water Sampling

4.2.1 Shallow Groundwater Monitoring

In addition to the exploratory well installed in 1989 south of CP-5, two downgradient, shallow groundwater monitoring wells were installed as part of the 1993 IT Corporation CP-5 yard characterization. Monitoring well 330021 is located on the east side of the CP-5 yard, and monitoring well 330031 is located on the south end of the CP-5 yard (Figure 1.2). Monitoring well specifications from the annual ANL-E Site Environmental Reports are shown in Table 4.5. A fourth upgradient monitoring well was to be located on the north side of the CP-5 complex; however, the drilling of two separate boreholes, SB20 to 32 ft deep and SB21 to 24 ft deep (Figure 4.2), resulted in no water yields.

Sampling of the CP-5 monitoring wells is performed quarterly. The ESH tritium sampling results are published annually in the ANL-E Site Environmental Report and are summarized in Table 4.6. The highest tritium concentrations are associated with shallow groundwater monitoring well 330011 installed in 1989, where tritium concentrations ranged from 15.9 pCi/ml to 0.8 pCi/ml with significant fluctuation between 1990 and 1997 (Figure 1.4). Levels of tritium in the other two shallow wells are lower by at least a factor of ten. Even though soil moisture tritium concentrations have exceeded the EPA drinking water standard of 20 pCi/ml, no shallow well water sample has ever been above the EPA drinking water standard of 20 pCi/ml. The discrepancy between soil water

Table 4.5 CP-5 Monitoring Well Specifications

ID No.	Depth[1]	Ground Elevation[2]	Monitoring Zone[3]	Well Type[4]	Date Drilled
330011	20	745.5	10 – 20/736 – 726	2/PVC	8/89
330021	19	746.5	4 – 19/743 – 728	2/SS	9/93
330031	17.1	742.1	2 – 17/740 – 725	2/SS	9/93
330012D	140	745	122 – 137/623 – 608	2/SS	6/97

[1] Feet Below Ground
[2] Feet Mean Sea Level
[3] Depth/Elevation
[4] Inner Diam.(in)/Well Material

Table 4.6 Tritium Concentrations in CP-5 Monitoring Wells

Sample Date	MW 330011 South (pCi/ml)	MW 330021 East (pCi/ml)	MW 330031 South (pCi/ml)	MW 330012D South pCi/ml)
4-09-90	15.9	N/A	N/A	N/A
6-19-90	10.0	N/A	N/A	N/A
10-24-90	6.6	N/A	N/A	N/A
11-16-90	6.5	N/A	N/A	N/A
3-22-90	6.5	N/A	N/A	N/A
5-14-91	5.8	N/A	N/A	N/A
9-10-91	5.7	N/A	N/A	N/A
12-6-91	4.0	N/A	N/A	N/A
6-26-92	13.9	N/A	N/A	N/A
10-16-92	10.2	N/A	N/A	N/A
11-09-92	8.2	N/A	N/A	N/A
3-24-93	6.8	N/A	N/A	N/A
6-24-93	4	N/A	N/A	N/A
9-20-93	3.5	N/A	N/A	N/A
11-19-93	8.2	N/A	N/A	N/A
3-15-94	5.5	0.20	0.33	N/A

Sample Date	MW 330011 South (pCi/ml)	MW 330021 East (pCi/ml)	MW 330031 South (pCi/ml)	MW 330012D South pCi/ml)
6-22-94	14.3	0.14	0.46	N/A
9-16-94	15	0.48	0.22	N/A
11-29-94	7.8	0.30	0.44	N/A
3-09-95	7.8	0.23	0.34	N/A
5-31-95	4.4	0.10	0.28	N/A
8-29-95	9.2	0.15	0.31	N/A
11-10-95	5.1	0.18	0.27	N/A
3-05-96	10.6	0.20	0.21	N/A
5-28-96	6.9	0.12	0.27	N/A
9-16-96	9.4	0.19	0.33	N/A
11-14-96	4.7	0.17	0.29	N/A
3-11-97	6.3	0.12	0.22	N/A
6-17-97	7.9	0.16	0.24	<0.10[14]
9-10-97	3.1	0.17	0.23	0.140
11-24-97	5.3	0.26	0.21	0.330
3-19-98	0.8	<0.1	0.16	0.16[15]
6-01-98	0.8	0.20	0.3	<0.10[15]

tritium concentration data, which indicate tritium concentrations in excess of 20 pCi/ml (2.6 pCi/g dry soil with a 13% moisture content) and shallow groundwater tritium concentrations which are all <20 pCi/ml, may be a reflection of the dilution occurring within the water bearing, courser grained soils (sandy, gravelly, clay) in the CP-5 yard compared to the tritium-saturated pore space in impermeable clay soil. Nevertheless, these results suggest that deep ground water concentrations of tritium under CP-5 are unlikely to approach 20 pCi/ml in the future. In addition, the slowly decreasing tritium concentrations indicated by shallow groundwater well monitoring data reflect the slow migration of tritium through the impermeable glacial till underlying CP-5.

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[14] Memo, N. Golchert to R. Coley, "Results of initial tritium sampling from the CP-5 Dolomite Well, 7/1/97

[15] Monitoring results from N. Golchert to R. Hysong

4.2.2 Dolomite Groundwater Monitoring

In June 1997, a deep monitoring well (330012D) was installed approximately 12 ft west of shallow monitoring well 330011 (Figure 1.2) to monitor the tritium levels in the dolomite groundwater. Dolomite bedrock was encountered while drilling the deep well at the 126-ft deep point, but drilling continued for 14 ft prior to well installation. The deep well monitoring results first indicated a slight increase in tritium concentration in November 1997, but the latest results from the June 1998 sampling are again below detection limits (<0.1 pCi/ml).

4.3 Miscellaneous Sampling Results

4.3.1 Fuel Pool Liner Investigation

In November 1997, a small, 1/8-in diameter hole was discovered in the spent fuel pool stainless steel liner. As indicated in Figure 1.3, the hole is located at the north end of the fuel pool floor (25 ft below grade) approximately 2 feet from the north pool wall midway between the east and west walls.[16] Thirty gallons of tritium-contaminated water (1,520 pCi/ml) were pumped from between the metal pool liner and the concrete pool foundation.[17] Tritium concentrations in an 8-in core of the upper fuel pool foundation (pool side) concrete are shown in Table 4.7 below. The deepest (5 to 9 in) section of concrete core contained 56 pCi/g H-3. Since the pool foundation is 3-ft thick, it would appear that migration of tritium from the pool concrete was minimal. Cs-137 concentrations in each core section were <0.2 pCi/g.

Table 4.7 Tritium Concentration in Fuel Pool Floor Concrete[18]

Core Section (in deep from pool floor)	**Tritium Concentration (pCi/g)**
0 – 1	210
1 – 2.5	125
2.5 – 5	54
5 – 9	56

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[16] Memo, R. Ditch to R. Rose, "Discovery of a hole in the CP-5 Fuel Pool Liner", 11/21/97

[17] ANL-E Analytical Chemistry Laboratory, "Report of Analytical Results", Sample No. 98-8036-01

[18] ANL-E Analytical Chemistry Laboratory, "Report of Analytical Results", Sample Nos. 98-8094-01 through -04

4.3.2 CP-5 Reactor Building Drain Tile System

In March 1998, sampling of sludge and water from the rod-out holes on the south and west sides of the CP-5 service floor was performed. The water levels in the rod-out holes were all well below the level at which the clay pipes enter the rod-out holes (at approximately 14 ft below grade). Tritium water concentrations from the holes shown in Table 4.8 below ranged from <0.33 pCi/ml to 327 pCi/ml with the highest concentration coming from a rod-out hole (DR2) located on the south side of CP-5 adjacent to the CP-5 yard (Figure 4.4). The tritium concentrations measured in DR1, DR2 and DR3 suggest that operational personnel may have released secondary system cooling water contaminated with tritium into the drain tile system which leads to the ANL-E sanitary drain system.

Table 4.8 Rod-Out Hole Sampling Results[19]

Sample ID	**Water H-3 (pCi/ml)**	**Sludge Ra-226 (pCi/g)**	**Sludge Cs-137 (pCi/g)**	**Sludge Co-60 (pCi/g)**
DR1 S/W	190 ± 2	0.5 ± 0.1	2.6 ± 0.1	1.1 ± 0.1
DR2 S/W	327 ± 3	0.5 ± 0.1	3.9 ± 0.2	< 0.2
DR3 S/W	26.2 ± 0.7	1.2 ± 0.1	28 ± 1	1.7 ± 0.1
DR4 S/W	< 0.33	0.4 ± 0.1	< 0.2	< 0.2
AW SUMP	< 0.33	0.6 ± 0.06	< 0.2	< 0.2

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[19] ANL-E ACL "Report of Analytical Results" Sample No.s 98-8140-01 through -05

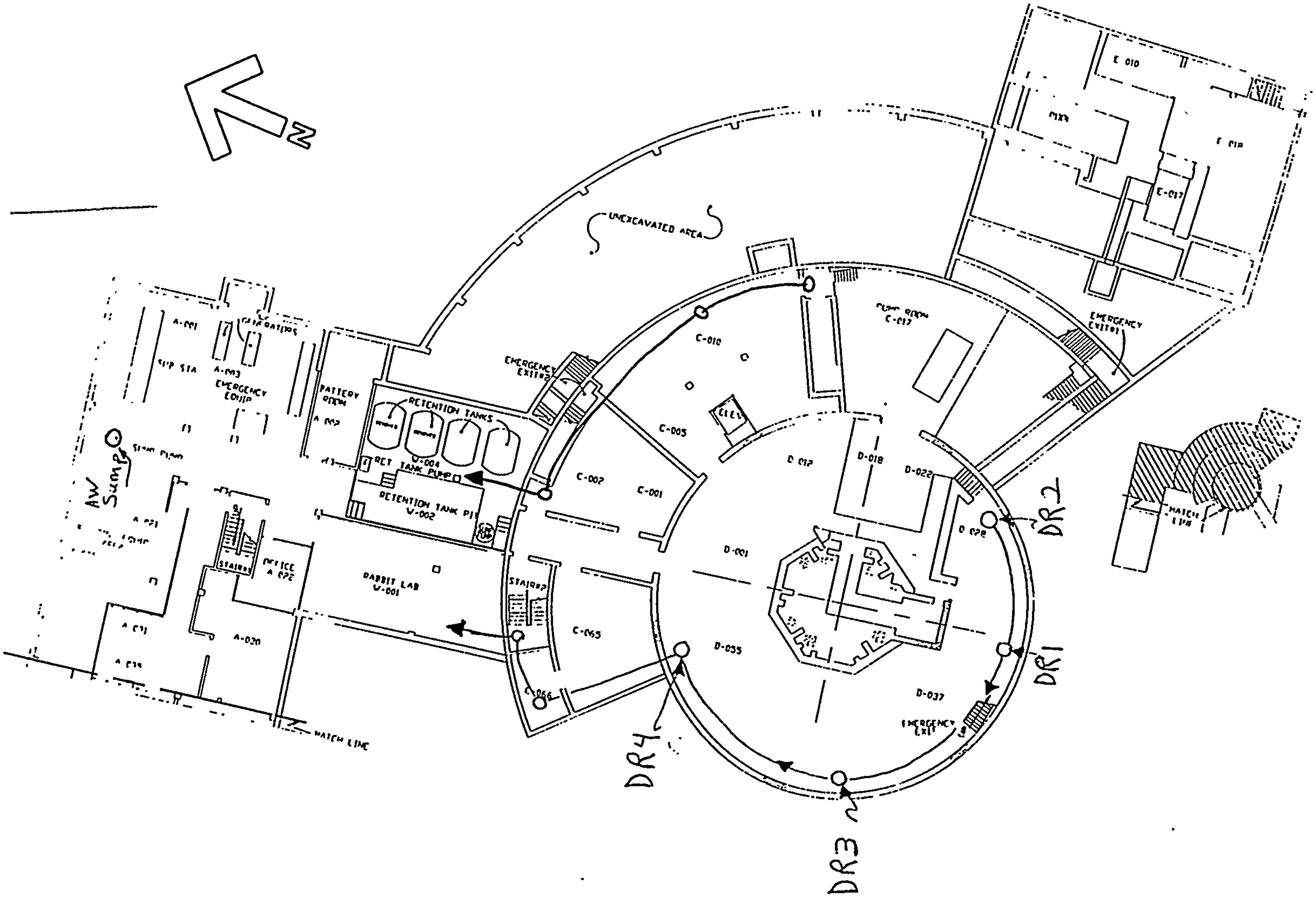

Figure 4.4 CP-5 Service Floor

5.0 RESRAD DOSE ASSESSMENT INPUT PARAMETERS

One RESRAD calculation has been performed to estimate the conservative, upper-bound potential radiological impacts from tritium soil contamination in the CP-5 yard. This case is based on the worst-case residential family-farm scenario in which the source of water for drinking, household uses, irrigation, and livestock watering is assumed to be a local well drilled at the downgradient edge of the contaminated zone which contains a homogeneous concentration of tritium. A graphical representation of RESRAD residential family-farm scenario pathways is shown in Figure 5.1.

The soil guideline concentration has been derived using a 25 mrem/yr basic dose limit in order to ensure that potential doses from residual tritium at the CP-5 site are well below the requirements of DOE Order 5400.5, which specifies an annual dose limit of 100 mrem. In addition, a 25 mrem/yr dose limit was chosen because it represents the lowest dose limit criterion used by a federal agency (Nuclear Regulatory Commission) for the unrestricted release of property containing residual radioactive material.[20] EPA has a dose-based limit of 4 mrem/yr for the drinking water pathway, as well as a concentration-based limit of 20 pCi/ml for tritium.

Table 5.1 contains a summary of RESRAD input parameters used in this analysis and the references on which they are based. Appendices E and F contain the RESRAD Summary Report and Detailed RESRAD Report, respectively.

The area of the rectangular-contaminated zone is conservatively assumed to extend from underneath the middle of the CP-5 reactor building southward 38 m to monitoring well 330031, and from the west yard fence line east 64 m to monitoring well 330021 (Figure 4.1). This area encompasses the area under E-Wing and approximately half the area under the CP-5 reactor building. Tritium concentrations in the east and south wells drop off significantly and are indicative of a much lower tritium soil concentration (approximately 0.05 pCi/g assuming a 13% water content) averaged over their monitoring zones. Two thousand four hundred thirty square meters is a very conservative estimation of the contaminated area, given the results of CP-5 yard sampling which indicate that less than one quarter of the yard is contaminated with over 1 pCi/g tritium (i.e., 7.7 pCi/ml tritium in soil water).

The thickness of the contaminated zone is 15.24 m based on the 1997, 50-ft soil core results obtained from the most contaminated 100 m^2 area identified in the 1993 IT characterization encompassing sample locations SB03, SB04 and SB05. The thickness of the contaminated zone under the reactor building and under E-Wing are conservatively over estimated because of the presence of the reactor building foundation and E-Wing pool foundation. An uncontaminated, 1.5-m thick cover has also been used because the concentration of tritium in surface soil at CP-5 is negligible (IT 1994).

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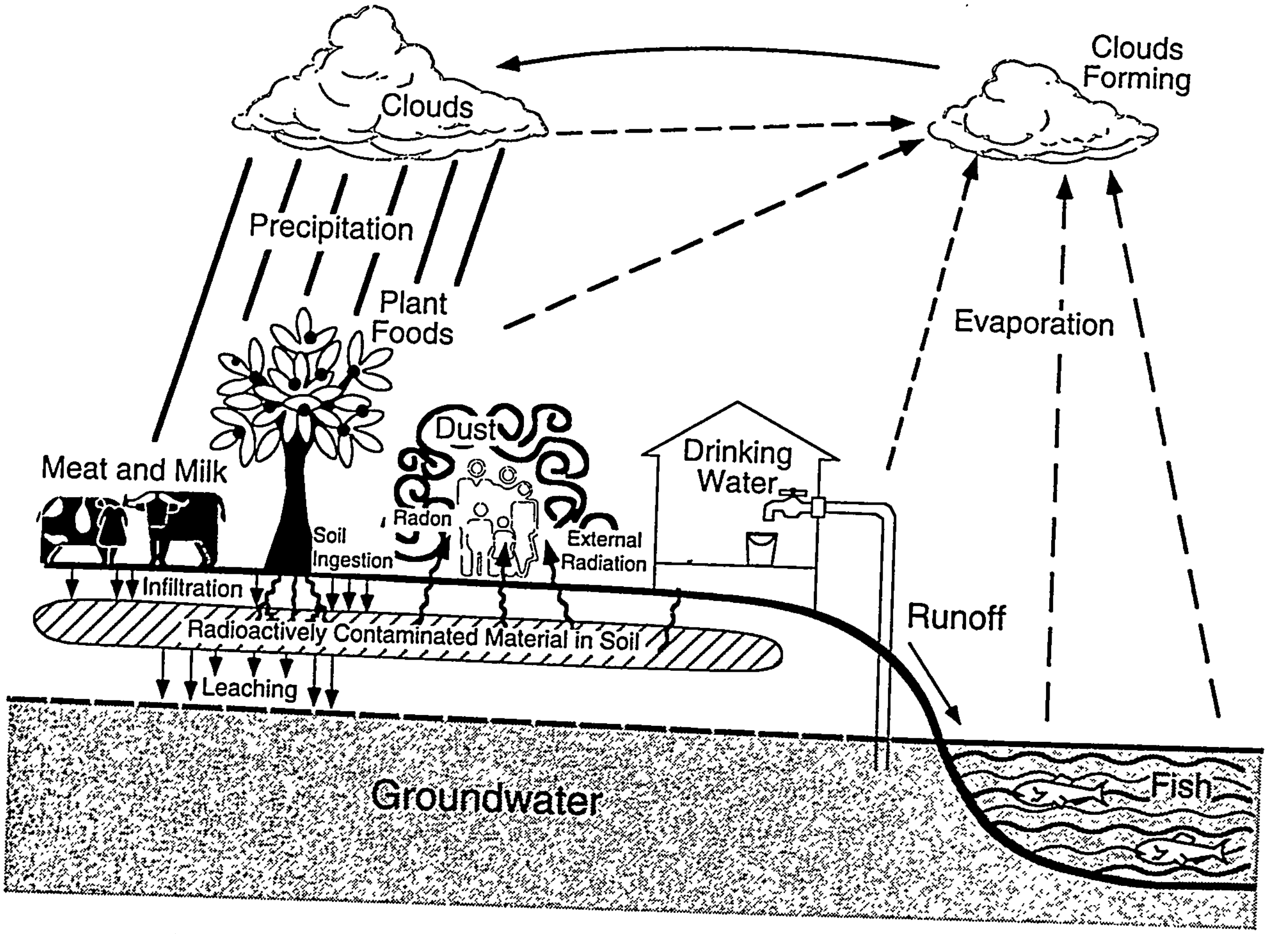
[20] Federal Register, Vol.2, No. 139. Monday, July 21, 1997



Exposure Pathways Considered in RESRAD

Figure 5.1 RESRAD Family-Farm Pathways

The length parallel to aquifer flow is the horizontal dimension of contaminated zone parallel to the groundwater flow direction. The length of contaminated zone parallel to aquifer flow is conservatively assumed to be the maximum horizontal distance within the contaminated zone or the diagonal line cutting across the contaminated zone (38 m x 64 m rectangle) from NW to SE (74 m).

The initial principle radionuclide concentration in the homogeneous contaminated zone (6.9 pCi/g) has been derived by averaging the results of the 1997, 50-ft core samples obtained from an area of relatively high tritium soil contamination compared to the rest of the yard.

Geological and hydrogeological parameters relating to the contaminated and underlying unsaturated zone 1 are based on previous RESRAD evaluations at ANL-E in the 317 area (Kou et al. 1997). Based on a review of core logs and well installation stratigraphic columns, the Wadsworth layer of the 317/319 Area appears to be composed of the same glacial till (silty clay) as that found in the CP-5 area. The 317/319 Area also contains shallow groundwater where precipitation is able to migrate through small fractures in the weathered portions of the clay and in small sand and gravel lenses similar to the CP-5 yard (Patton et al. 1990). The well pump intake depth is conservatively assumed to be 5 m below the water table instead of the 10-m RESRAD default. The parameters used for the second underlying unsaturated zone (Unsat-2 consisting of upper and middle Lemont Formation units) are based on the parameters for silty clay loam (Yu et al. 1993).

Table 5.1 RESRAD Input Parameters

RESRAD Input Parameter	**Family-Farm Scenario**	**Reference**
Area of the contaminated zone (m^2)	2430	CP-5 Yard Sampling
Thickness contaminated zone (m)	15.24	50-ft Soil Boring 1997
Length (m) parallel to aquifer flow	74	Calculated Based on Worst Case Geometry
Dose limit (mrem)	25	Lowest Federal Limit
Initial H-3 soil conc. (pCi/g)	6.9	50-ft Soil Boring 1997
Density of contaminated zone	1.76	Kou et al. 1997
Contaminated zone total porosity	0.3	Kou et al. 1997
Contaminated zone effective porosity	0.2	Kou et al. 1997
Contaminated zone hydraulic conductivity (m/y)	0.95	Kou et al. 1997
Contaminated zone b parameter	11.4	Kou et al. 1997
Cover thickness (m)	1.5	IT 1994

RESRAD Input Parameter	Family-Farm Scenario	Reference
Humidity (g/cm^3)	7	Yu et al. 1993
Precipitation (m/y)	0.8	Golchert et al. 1996
Saturated zone total porosity	0.3	Kou et al. 1997
Saturated zone effective porosity	0.2	Kou et al. 1997
Saturated zone hydraulic conductivity (m/y)	950	Kou et al. 1997
Saturated zone b parameter	11.4	Kou et al. 1997
Well pump intake depth (m below water table)	5	Kou et al. 1997
Number unsat zones	2	Argonne 1997
Unsat zone 1 thickness (m)	2.5	Argonne 1997
Unsat zone 1 total porosity	0.3	Kou et al. 1997
Unsat zone 1 effective porosity	0.2	Kou et al. 1997
Unsat zone 1 b parameter	11.4	Kou et al. 1997
Unsat zone 1 hydraulic conductivity (m/y)	1	Kou et al. 1997
Unsat zone 2 thickness (m)	18.3	Argonne 1997
Unsat zone 2 total porosity	0.3	Yu et al. 1993
Unsat zone 2 effective porosity	0.2	Yu et al. 1993
Unsat zone 2 b parameter	7.75	Yu et al. 1993
Unsat zone 2 hydraulic conductivity (m/y)	50	Yu et al. 1993

6.0 RESULTS OF DETERMINISTIC DOSE ASSESSMENT

The RESRAD computer code, version 5.82 was used to calculate the potential radiation dose for a residential family-farm scenario at the CP-5 complex. The time frame considered in this analysis was only 100 years due to the short half-life of tritium (12.35 y). Doses calculated by RESRAD are always relative to the time at which the radiological survey was performed to collect input data (December 1997). A summary of the RESRAD results is presented in Table 6.1 below.

Table 6.1 Potential Radiological Impacts Estimate Summary

Soil Guideline (pCi/g)	**RESRAD Well H_2o pCi/l @ t=0 yr. 12/97**	**RESRAD Well H_2o pCi/l @ t=1 yr. 12/98**	**Year of Maximum Dose**	**Maximum Dose (mrem)**	**Dose Limit (mrem)**	**Percent of Dose Limit**
164	28,000	24,000	1997	1.05	25	4

The soil guideline level for a 15.24-m thick contaminated zone having an area of 2,430 m^2 is 164 pCi/g, approximately four times higher than the highest tritium concentration measured (42 pCi/g) during CP-5 investigative sampling. In addition, the 42 pCi/g measurement was from a sample less than 1 m thick. The concentration in drinking water from a theoretical well located at the downgradient edge of the contaminated zone at the time of obtaining the 50-ft core (December 1997) is 28,000 pCi/l (28 pCi/ml). Note that RESRAD output data and graphical output is in units of pCi/l. The annual effective dose equivalent resulting from all pathways is 1.05 mrem. Figure 6.1 shows the dose from all pathways as a function of time measured from year zero or December 1997.

7.0 PARAMETER SENSITIVITY ANALYSIS

Figure 7.1 shows the individual dose component pathways. As illustrated in Figure 7.1, the drinking water pathway is the dominant pathway for dose from tritium-contaminated soil in the CP-5 yard. Consequently, the calculated doses will be sensitive to parameters that affect the drinking water pathway. Figure 7.2 shows the concentration of tritium in well water used for drinking as a function of time.

A sensitivity analysis was performed on the geologic and hydrogeologic parameters which affect the concentration of tritium in well water used in the family-farm scenario. Significant parameters identified in the sensitivity analyses were the length parallel to aquifer flow, the hydraulic conductivities of the saturated and contaminated zones, and the effective porosity of the unsaturated and saturated zones. The effect of these parameters can be seen in Figures 7.3 through 7.7. Note

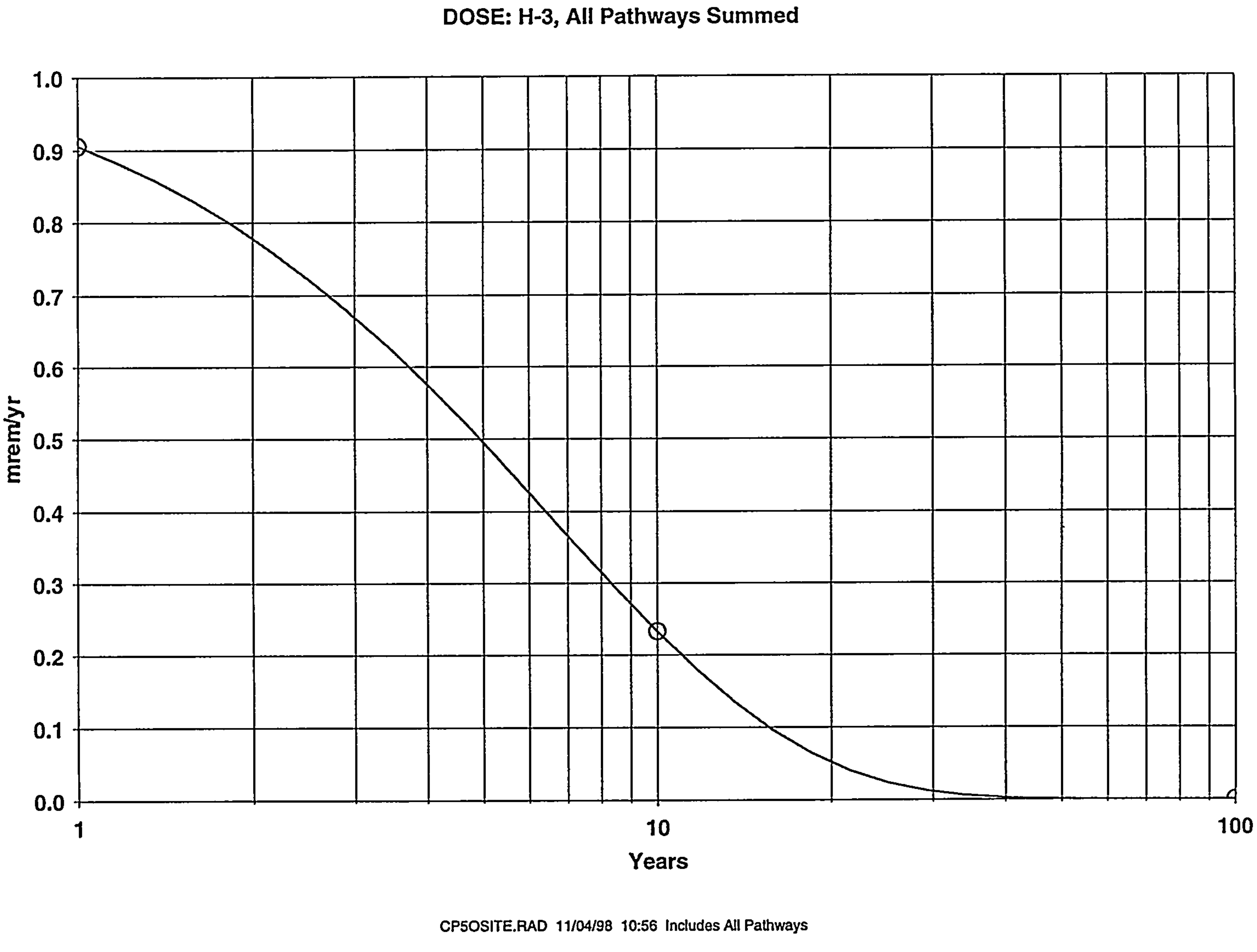


Figure 6.1 Family-Farm Scenario Dose as a Function of Time

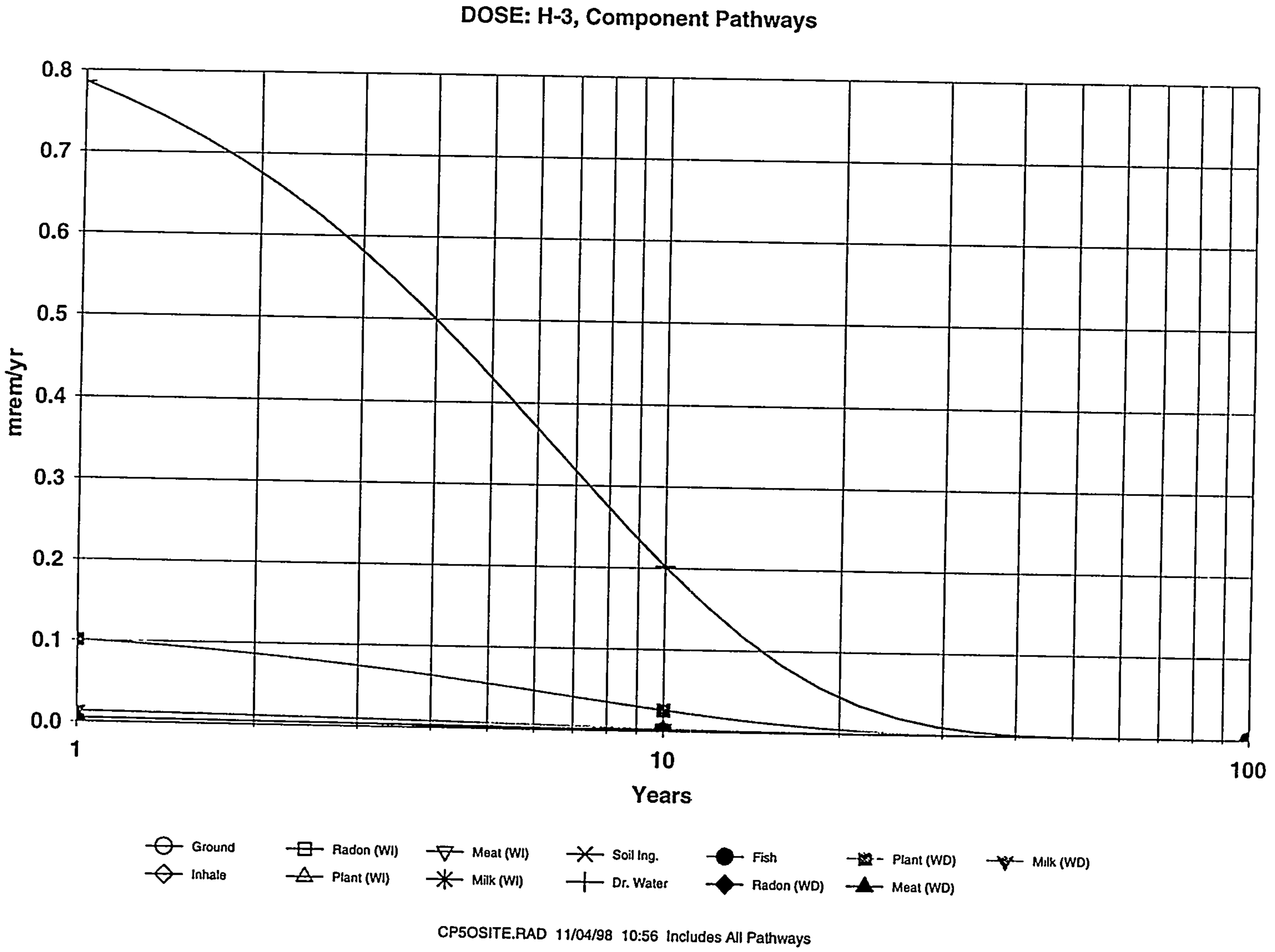


Figure 7.1 Family-Farm Dose Component Pathways

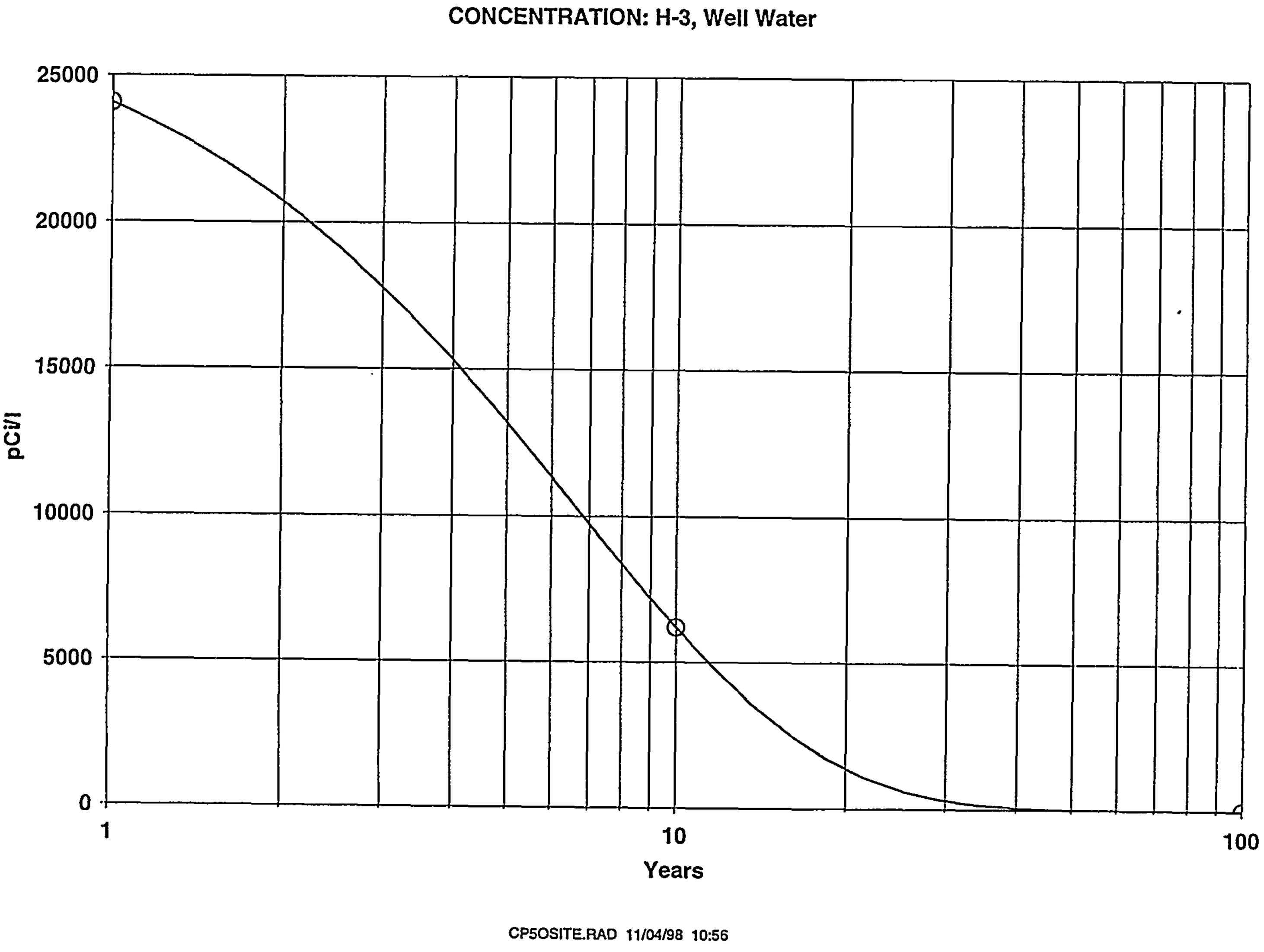
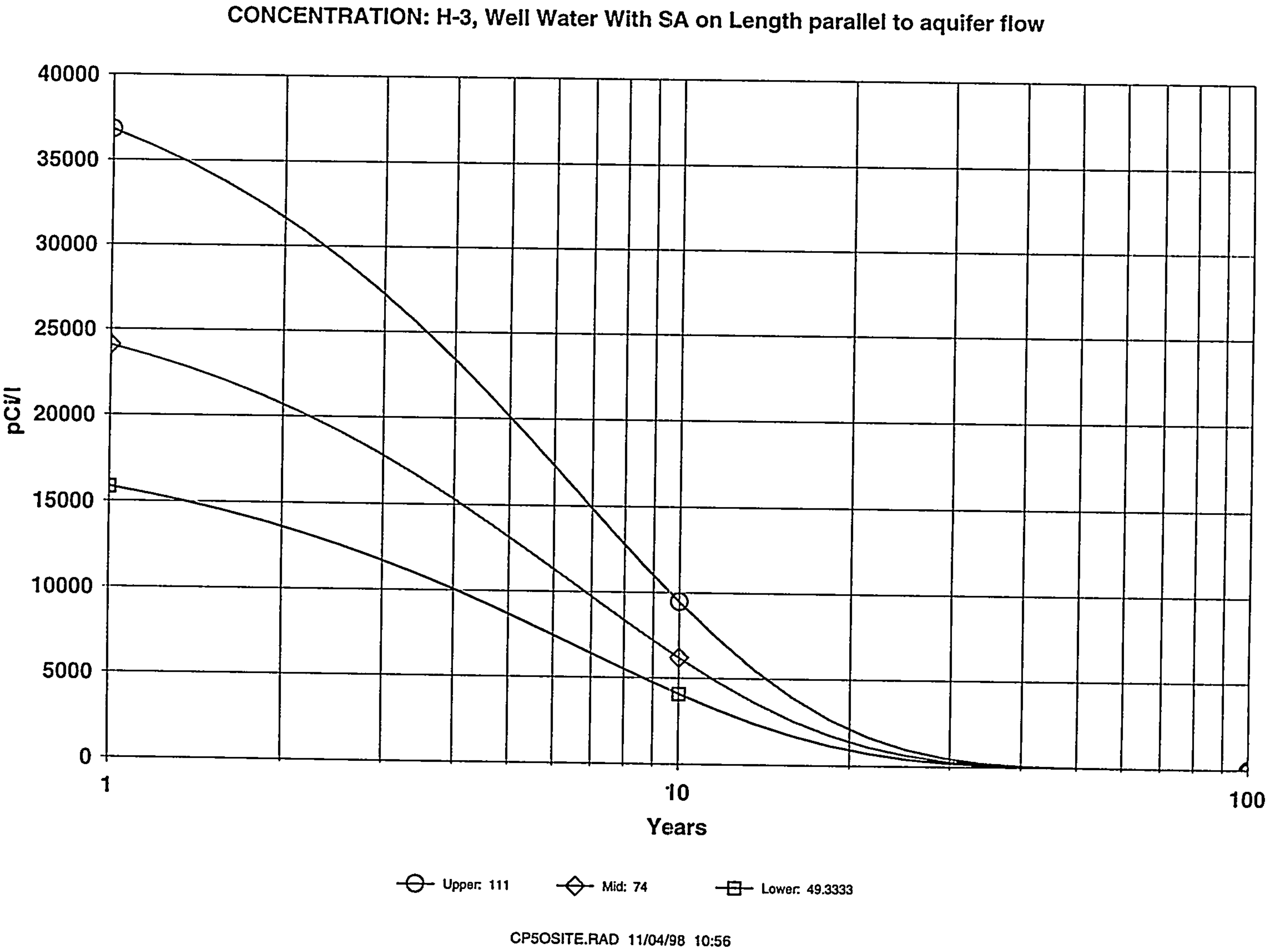


Figure 7.2 Concentration of Tritium in Well Water as a Function of Time



CONCENTRATION: H-3, Well Water With SA on Length parallel to aquifer flow

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Figure 7.3 Sensitivity Analysis on Length Parallel to Aquifer Flow

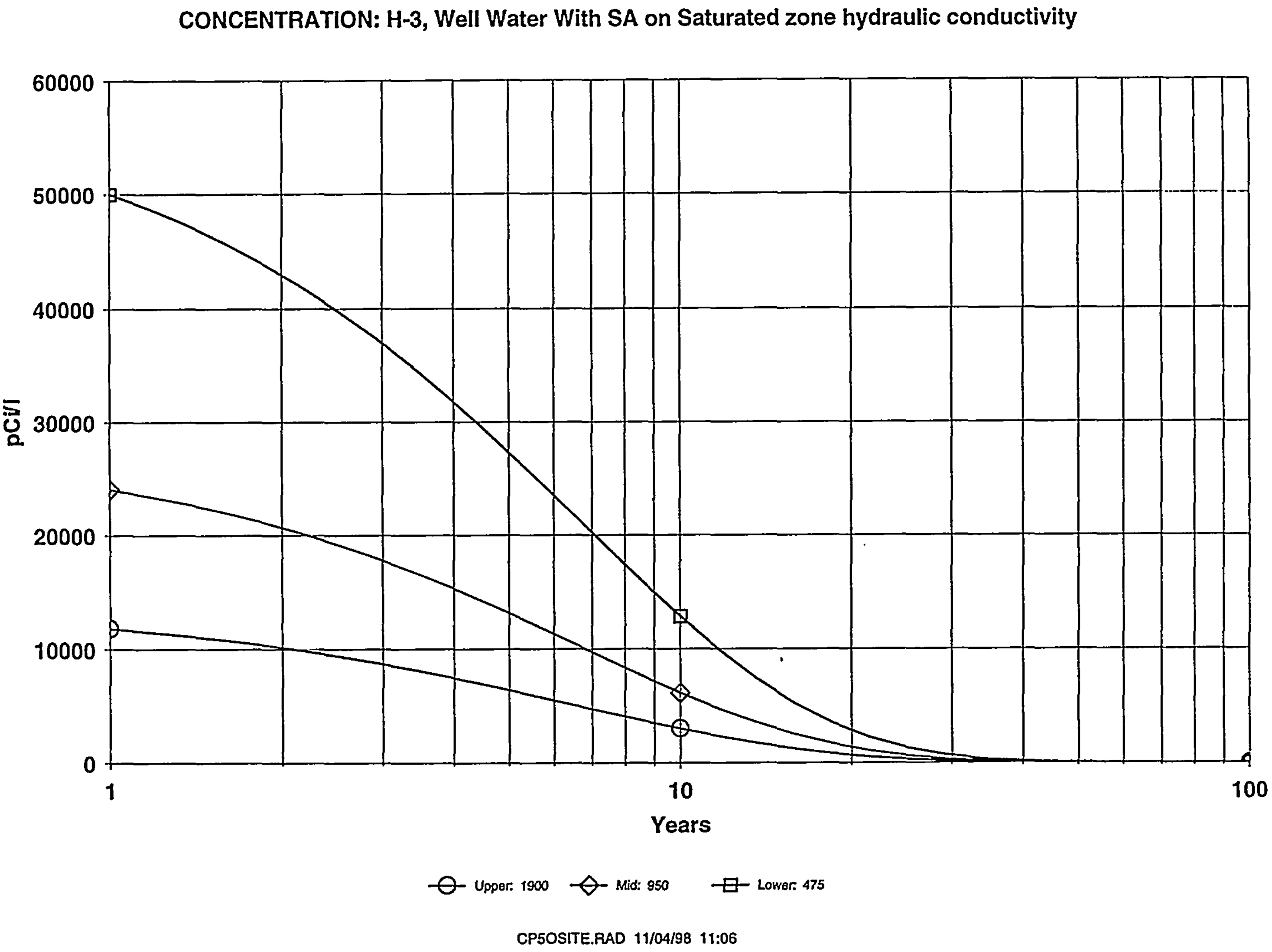
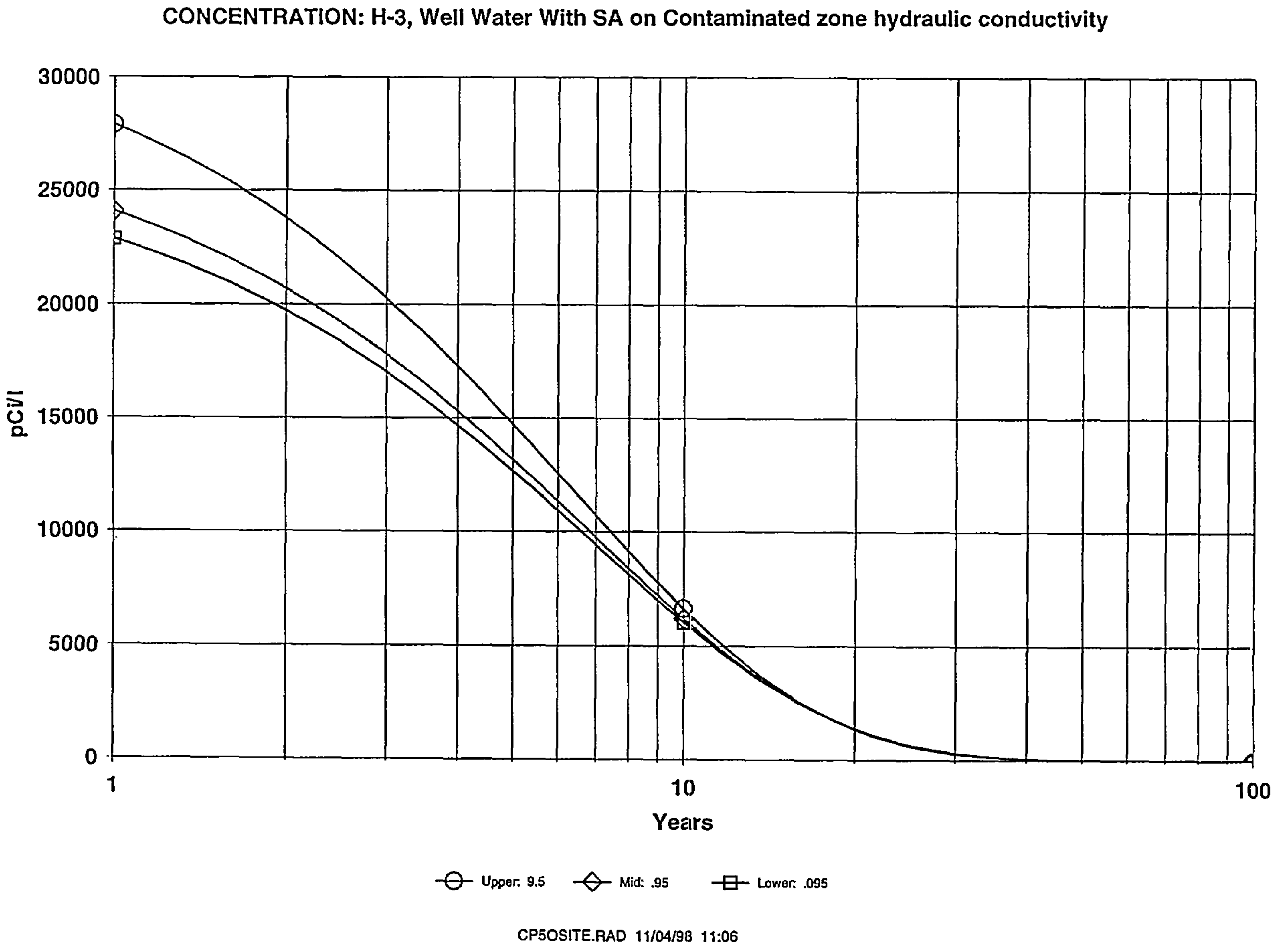


Figure 7.4 Sensitivity Analysis on Saturated Zone Hydraulic Conductivity



CONCENTRATION: H-3, Well Water With SA on Contaminated zone hydraulic conductivity

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Figure 7.5 Sensitivity Analysis on Contaminated Zone Hydraulic Conductivity

CONCENTRATION: H-3, Well Water With SA on Effective Porosity of Unsaturated Zone 1

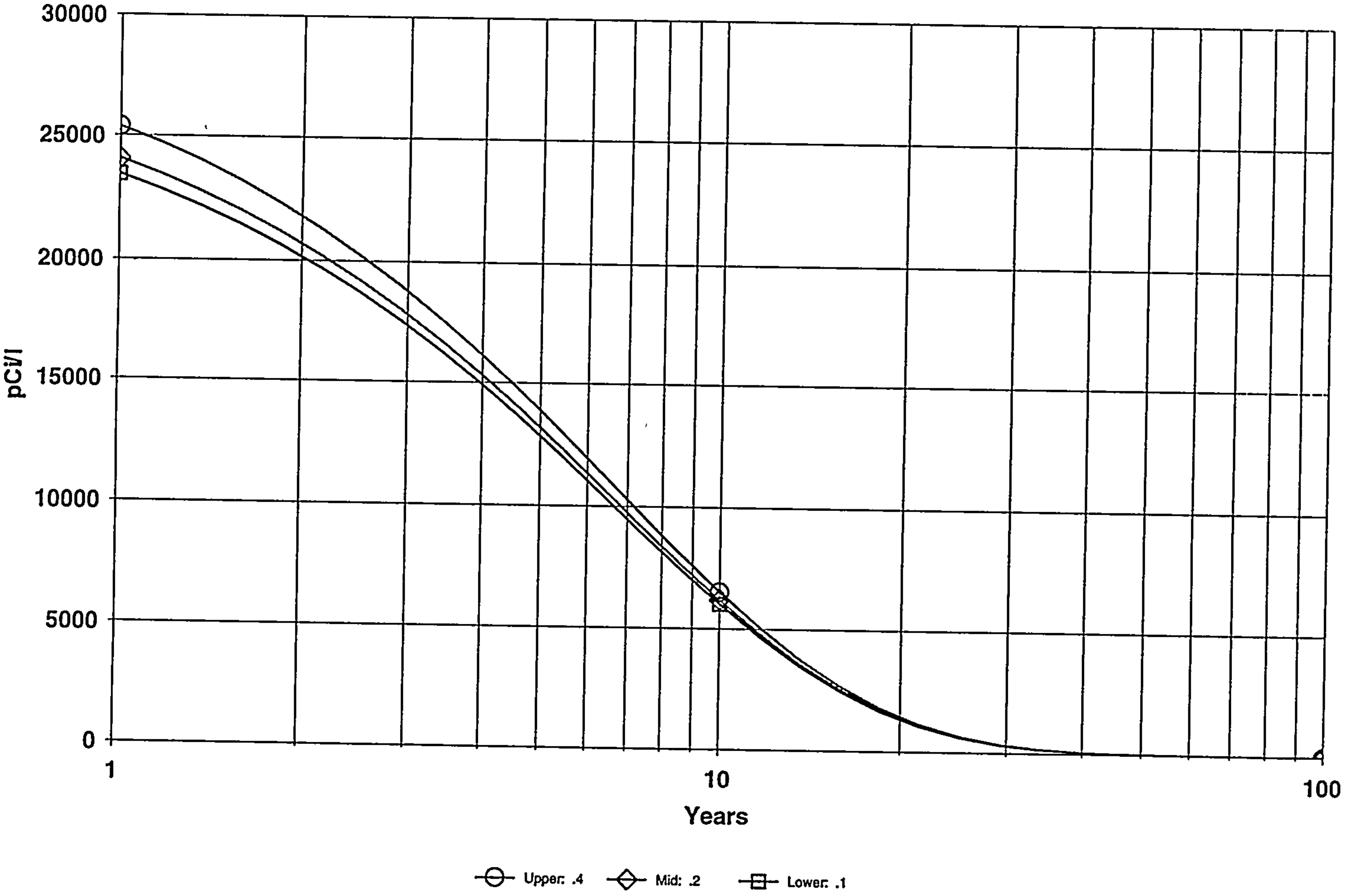

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Figure 7.6 Sensitivity Analysis on Unsaturated Zone 1 Effective Porosity

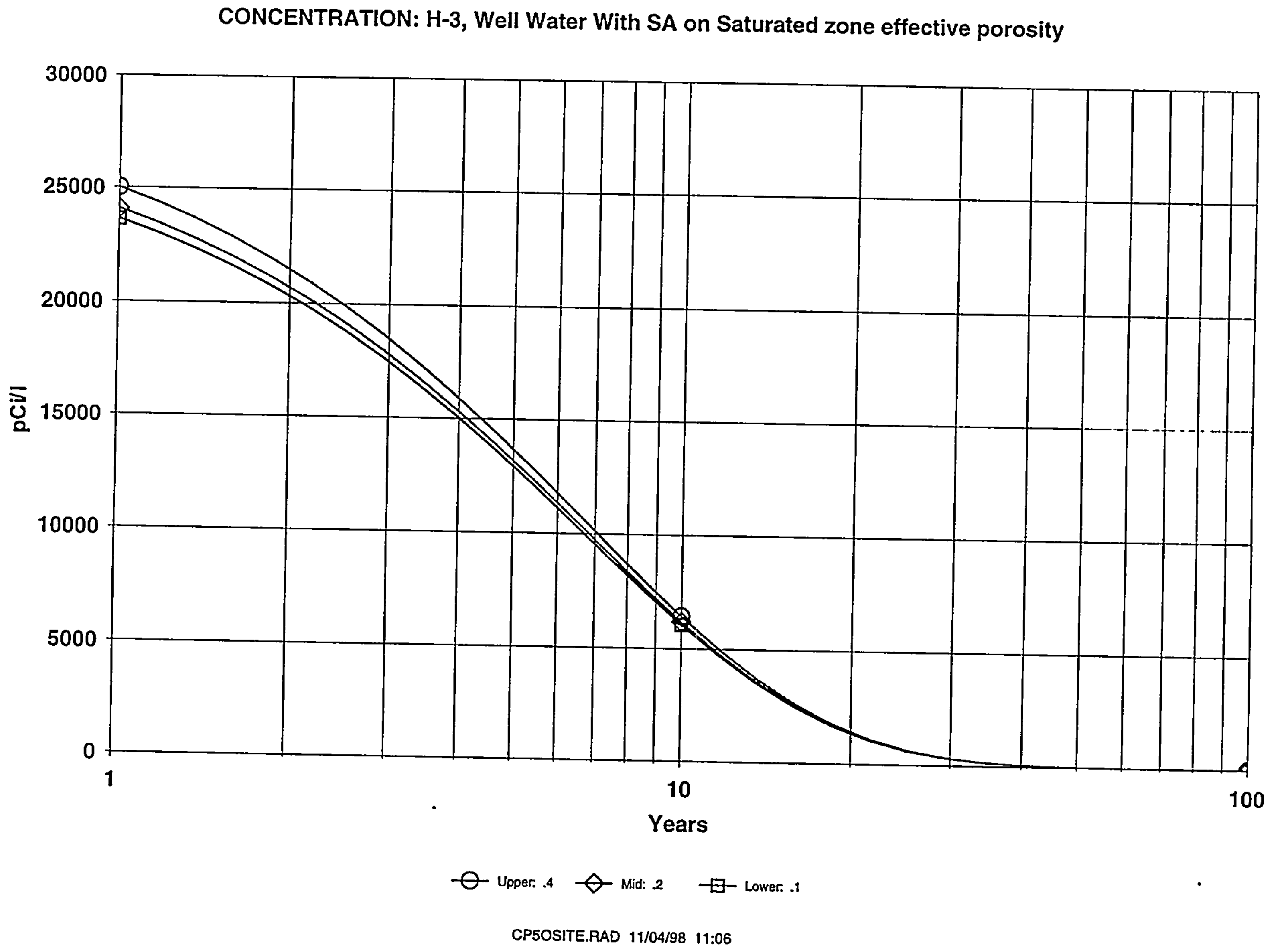

Figure 7.7 Sensitivity Analysis on Saturated Zone Effective Porosity

that RESRAD graphical output data is in units of pCi/l. Based on CP-5 yard soil sampling and well monitoring, the actual length parallel to aquifer flow of 74 m used in this analysis is much more likely to approach the lower value of 49 m shown in Figure 7.3, because of the conservative overestimate of the area of the contaminated zone. In addition, the saturated hydraulic conductivity of the saturated zone is more likely to be greater than 500 m/y as shown in Figure 7.4 due to the presence of sands and gravels in the basal Lemont unit of the glacial till directly overlying the dolomite and due to channelized flow in fractures in the dolomite aquifer. In any case, the peak dose (at time zero) changes by less than a factor of approximately 2.5 within a wide, conservative range of parameter change.

8.0 DISCUSSION

8.1 Residential Family-Farm Scenario Impacts

A residential family-farm scenario located on the tritium-contaminated soil around the CP-5 complex has been evaluated to conservatively estimate the magnitude of the on-site radiological impacts from tritium-contaminated soil in the CP-5 yard. The geological and hydrogeological parameters used in this analysis are generally conservative with respect to the rate of downward tritium migration to the dolomite aquifer, the concentration of tritium in the yard, and the size of the contaminated zone. In addition, the presence of the CP-5 Reactor Building foundation and E-Wing pool foundation have been ignored and are assumed to contain tritium-contaminated soil. Lastly, the infiltration rate of water into the contaminated zone has been overestimated by neglecting the presence of the Reactor Building and E-Wing roof tops, which intercept rainfall.

Sampling results from the deep, dolomite aquifer well (330012D) located within the contaminated zone south of the CP-5 reactor building do not indicate that significant migration of tritium down to the dolomite groundwater has occurred. The slow decrease in tritium concentrations in samples from the shallow well (330011) behind the CP-5 reactor building also indicate that the downward migration of tritium through the glacial till is very slow. Based on the time that has elapsed since the deposition of tritium into and onto CP-5 yard soils, and given the decreasing tritium concentration profile in the 50-ft soil boring, it is likely that the family-farm scenario dose estimate of 1.05 mrem represents a significant overestimate of radiological impacts. Likewise, off-site radiological impacts, if any, would be small to negligible.

In the very worst case, one would have to assume that a series of interconnected sand and/or gravel formations exists in the glacial till underlying CP-5. Experimental leaching tests of tritium in a sand and gravel column with a water content of 20% (similar to the volumetric water content of ANL-E glacial till) indicate that 85% of the tritium in the sand and gravel column are only released from the column after water weighing 20% of the weight of the column percolates through the column (Baker 1975). In other words, there would be a dilution factor of about 2.3 simply due to the amount of water necessary to leach and transport the tritium from its present location. If a series of sand and gravel lenses containing an average of 6.9 pCi/g (34.5 pCi/ml soil water) of tritium existed in a narrow channel (over 60 ft long) from the tritium-contaminated volume in the CP-5 yard soil down to the dolomite groundwater, a pulse-type release of tritium would be expected to produce a peak concentration of approximately 15 pCi/ml before depleting 85% of the tritium along the channel. A tritium concentration of 15 pCi/ml is less than the EPA drinking water standard of 20 pCi/ml.

8.2 Industrial Use Scenario

The current plans are to complete the D&D of the entire CP-5 Complex in the near future. Under the less conservative, but more realistic industrial-use scenario, one might expect that soil excavation activities may proceed in the CP-5 yard for approximately one year for some type of construction project. Since tritium only decays by a low energy beta emission, it is primarily an internal hazard. Consequently, the inhalation dose equivalent from working 2,000 hr/yr would be no greater than the inhalation dose at time zero in the residential scenario considered above with no clean soil cover, or 2.7×10^{-3} mrem. Likewise, the ingestion dose from incidental soil ingestion would not be expected to be greater than the ingestion dose equivalent of 1.2×10^{-5} mrem. Consequently, under the industrial-use scenario in the year 2000, the worst case, realistic dose equivalent would be 2.4×10^{-3} mrem under an industrial use scenario.

9.0 CONCLUSIONS/RECOMMENDATIONS

Based on a review of available data, significant contributions to low-level tritium soil contamination in the CP-5 yard have been made by airborne tritium fallout and rainout from the CP-5 ventilation system stack. Based on the distribution of tritium in the yard, it is also likely that leaks in secondary system piping which lead to the cooling towers were a significant contributor to tritium in CP-5 yard subsurface soil.

Based on the foregoing analysis, low-level tritium contamination will not prohibit the release of the yard for unrestricted use in the future. Worst case dose estimates based on very conservative assumptions indicate that a 25 mrem annual effective dose equivalent limit will not be exceeded under the most restrictive residential-use family farm scenario. Given the impermeable nature of the glacial till under CP-5, low-level concentrations of tritium may be occasionally detected in the deep well (330012D), but the peak concentration will not approach the levels calculated by RESRAD; however, continued monitoring of the deep well is recommended.

To ensure that all sources of potential tritium release have been removed from the CP-5 complex, removal of tritiated water from each rod-out hole and an evaluation of the physical integrity of the rod-out holes is recommended. This will also allow for an evaluation of tritium concentrations in shallow groundwater under CP-5 by sampling groundwater that is currently being forced into the drain tile system.

Additional surface and subsurface soil sampling and analysis will be required to determine the final release status of soils around the Building 330 complex relative to elevated concentrations of Cs-137, Co-60, Co-57, and Eu-152 identified during the 1993 IT Corporation characterization. The potential radiological impact from isolated elevations of the latter radionuclides is relatively low and can be evaluated as part of the final status survey of outdoor areas surrounding the Building 330 complex.

In summary, the following activities are recommended:

- Remove tritiated water from each rod-out hole
- Monitor rod-out hole tritium concentrations as they fill up with shallow groundwater
- Continue groundwater monitoring
- Perform surface and subsurface soil sampling around the CP-5 complex as part of the final status survey

10.0 REFERENCES

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11.0 ACRONYMS AND ABBREVIATIONS

ACL	Analytical Chemistry Laboratory, Argonne National Laboratory
AMSL	Above Mean Sea Level
ANL-E	Argonne National Laboratory-East, Argonne, Illinois
APS	Advanced Photon Source
A^2R^2	Argonne Advanced Research Reactor
Ci	curies
cm	centimeter
CP-5	Chicago Pile-Five
EPA	U. S. Environmental Protection Agency
ESH	Environment, Safety and Health Division, Argonne National Laboratory
ft	foot
g	gram
gal	gallon
IEPA	Illinois Environmental Protection Agency
ISGS	Illinois State Geologic Survey
in	inch
keV	kilo electron volt
m	meter
ml	milliliter
MW	million watt
pCi	pico curie
RESRAD	RESidual RADioactive computer code
SWMU	Solid Waste Management Units
yr	year

APPENDIX A

ILLINOIS ENVIRONMENTAL PROTECTION AGENCY WELL COMPLETION REPORT AND FIELD BORING LOG FOR WELL # MW330012D AND BOREHOLE # 330012D

CP-5 Deep Well

Illinois Environmental Protection Agency Well Completion Report

SITE #: ____ COUNTY: DuPage WELL #: MW330012D

SITE NAME: Argonne National Laboratory BOREHOLE #: SB330012D

STATE PLANE COORDINATE: X ____ Y ____ (or) LATITUDE: ____° ____' ____" LONGITUDE: ____° ____' ____"

SURVEYED BY: (not surveyed: referenced to adjacent surveyed well) IL. REGISTRATION #: ____

DRILLING CONTRACTOR: Patrick Drilling, Inc. DRILLER: T. Zwolinski

CONSULTING FIRM: - GEOLOGIST: G. Wittman, ANL

DRILLING METHOD: Hollow-stem auger & hydraulic rotary DRILLING FLUIDS (TYPE): potable water

LOGGED BY: G. Wittman, ANL DATE STARTED: 6/16/97 DATE FINISHED: 6/17/97

REPORT FORM COMPLETED BY: G. Wittman DATE: 7/8/97

ANNULAR SPACE DETAILS

TYPE OF SURFACE SEAL: Cement pad

TYPE OF ANNULAR SEALANT: Wyo-Ben "Grout-Well"

INSTALLATION METHOD: tremie pipe

SETTING TIME: 24 hours

TYPE OF BENTONITE SEAL – GRANULAR, PELLET, SLURRY (CIRCLE ONE)

INSTALLATION METHOD: tremie pipe

SETTING TIME: 2 hours

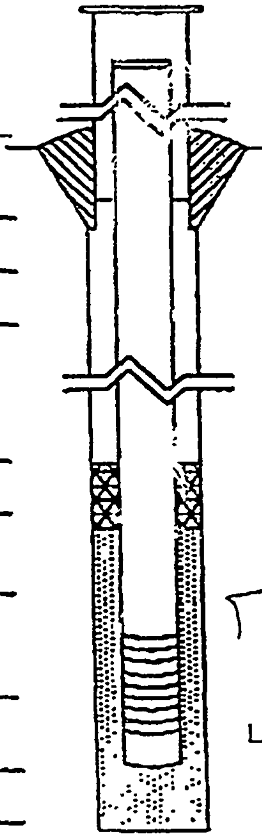
TYPE OF SAND PACK: GA-9 silica sand

GRAIN SIZE: 10-20 (SIEVE SIZE)

INSTALLATION METHOD: tremie pipe

TYPE OF BACKFILL MATERIAL: None (IF APPLICABLE)

INSTALLATION METHOD: ____



ELEVATIONS (MSL)*	DEPTHS (BGS)	(.01 ft)
747.5	+ 2.5	TOP OF PROTECTIVE CASING
747.3	+ 2.3	TOP OF RISER PIPE
745	0	GROUND SURFACE
745	0	TOP OF ANNULAR SEALANT
627	118	STATIC WATER LEVEL (AFTER COMPLETION)
627	118	TOP OF SEAL
X 624 (121')	121	TOP OF SANDPACK
X 623	122	TOP OF SCREEN
X 608	137	BOTTOM OF SCREEN
608	137	BOTTOM OF WELL
605	140	BOTTOM OF BOREHOLE

* REFERENCED TO A NATIONAL GEODETIC VERTICAL DATUM

WELL CONSTRUCTION MATERIALS

(CIRCLE ONE)

PROTECTIVE CASING	SS304, SS316, PTFE, PVC OR [✓ OTHER] steel
RISER PIPE ABOVE W.T.	[✓ SS304], SS316, PTFE, PVC OR OTHER:
RISER PIPE BELOW W.T.	[✓ SS304], SS316, PTFE, PVC OR OTHER:
SCREEN	[✓ SS304], SS316, PTFE, PVC OR OTHER:

(941014)

CASING MEASUREMENTS

DIAMETER OF BOREHOLE (in)	8
ID OF RISER PIPE (in)	2
PROTECTIVE CASING LENGTH (ft)	5
RISER PIPE LENGTH (ft)	124
BOTTOM OF SCREEN TO END CAP (ft)	0
SCREEN LENGTH (1st SLOT TO LAST SLOT) (ft)	15
TOTAL LENGTH OF CASING (ft)	140
SCREEN SLOT SIZE **	10

** HAND-SLOTTED WELL SCREENS ARE UNACCEPTABLE

Illinois Environmental Protection Agency   Field Boring Log

Page 1 of 3

Site File No.:
County DuPage
Boring No. SB330012D
Monitor Well No. MW330012D
Site File Name Argonne National Laboratory
Surface Elevation 745 ft msl
Completion Depth 140 ft
Fed. ID. No.
Auger Depth 126 ft
Rotary Depth 140 ft
Quadrangle Sag Bridge Sec. 9 T. 37N R. 11E
Date Start 6/9/97
Finish 6/13/97
UTM (or State Plane) Coord. N.(X) E.(Y)
Latitude ° ' " Longitude ° ' "
Boring Location S.E. of Building 330, adjacent to MW330011
Drilling Equipment CME - Patrick Drilling, Inc.

Personnel

G - G. Wittman
D - T. Zwolinski
H - M. Gajos
H -

	Elev.	DESCRIPTION OF MATERIALS	Graphic Log	Depth in feet	SAMPLES SAMPLE NO.	SAMPLE TYPE	SAMPLE RECOVERY (%)	PENETROMETER	N VALUES (BLOW COUNTS)	OVA or HNU READINGS	REMARKS
	745	Brown silty clay w/gravel		0							Blind drill from 0 to 20 ft: description of materials taken from log of MW330011, drilled 8/11/89.
	740			5							
		Dark brown silty clay w/gravel									
10	735	Brown silty clay w/some gravel		10							
		Brown sandy clay w/gravel									
	730	Gray silty clay w/some coarse sand and gravel pebbles		15							
20	725			20							
		Gray silty clay w/some medium-coarse gravel, moist									
	720			25							
		Brownish gray silty fine sand, moist									
		Brownish gray clayey silt w/fine-medium gravel, moist									
	715			30							
	710	Grayish brown fine sand, dry		35							
		Brownish gray silty clay w/fine-medium gravel, moist									
	705	Gray silty clay w/fine-coarse gravel, moist		40							
	700			45							
50	695	Gray clay w/trace fine gravel		50							
											Bag sample, 50'-52'

([illegible])

Illinois Environmental Protection Agency **Field Boring Log** Page 2 of 3

Site File No.:
County DuPage
Boring No. SB330012D
Monitor Well No. MW330012D
Site File Name Argonne National Laboratory
Surface Elevation 745 ft msl
Completion Depth 140 ft
Fed. ID. No.
Auger Depth 126 ft
Rotary Depth 140 ft
Quadrangle Sag Bridge Sec. 9 T. 37N R. 11E
Date: Start 6/9/97
Finish 6/13/97
UTM (or State Plane) Coord. N.(X) E.(Y)
Latitude ° ' " Longitude ° ' "
Boring Location S.E. of Building 330, adjacent to MW330011
Drilling Equipment CME - Patrick Drilling, Inc.

Personnel
G -
D -
H -
H -

Elev.	DESCRIPTION OF MATERIALS	Graphic Log	Depth in feet	SAMPLES SAMPLE NO.	SAMPLE TYPE	SAMPLE RECOVERY (%)	PENETROMETER	N VALUES (BLOW COUNTS)	OVA or HNU READINGS	REMARKS
690	Gray silty clay w/trace fine gravel, moist		55							Bag sample, 58'-60'
685	Yellowish gray silty clay w/trace sand and fine gravel, moist		60							
680	Dark gray silty clay w/trace fine gravel, moist		65							Bag sample, 64'-66'
675			70							
670	Gray silty clay to silty very fine sand w/weathered dolomite fragments, moist		75							Bag sample, 72'-74'
665	Weathered dolomite fragments, brown sand and silt, moist		80							Bag samples, 80'-82'
660	Gray silt w/some medium-coarse gravel, ~~dry~~		85							Bag sample, 85'-87'
655	Brown clayey silt and fine sand, dry - moist		90							Bag sample, 90'-92'
650	Gray silty clay w/ weathered dolomite fragments		95							Bag sample, 97'-98.5'
645			100							Bag sample, 98.5'-100'
640	Brownish gray silty fine sand, moist, w/dolomite fragments		105							Bag sample, 103'-105'

([illegible])

Illinois Environmental Protection Agency Field Boring Log

Page 3 of 3

Site File No.:
County DuPage
Boring No. SB330012D
Monitor Well No.: MW330012D
Site File Name Argonne National Laboratory
Surface Elevation 745 ft msl
Completion Depth 140 ft
Fed. ID. No.
Auger Depth 126 ft
Rotary Depth 140 ft
Quadrangle Sag Bridge Sec. 9 T. 37N R. 11E
Date Start 6/9/97
Finish 6/13/97
UTM (or State Plane) Coord. N.(X) E.(Y)
Latitude ° ' " Longitude ° ' "
Boring Location S.E. of Building 330, adjacent to MW330011
Drilling Equipment CME - Patrick Drilling, Inc.

Personnel
G -
D -
H -
H -

SAMPLES

Elev.	DESCRIPTION OF MATERIALS	Graphic Log	Depth in feet	SAMPLE NO.	SAMPLE TYPE	SAMPLE RECOVERY (X)	PENETROMETER	N VALUES (BLOW COUNTS)	OVA or HNU READINGS	REMARKS
635			110							
632										
630	Gray silty clay w/weathered dolomite fragments		115							Bag sample, 118'-120'
625			120							Bag sample, 123'-125'
620			125							Auger refusal at 126'
619	Competent bedrock at 126'. Cored dolomite from 126'-140'									
615			130							
610			135							
605			140							
	End of boring.									

BR 126' BGL

SCREENED INTERVAL

No Basal unit Described

(90C226)

Not Wet/Saturated Zone Described

APPENDIX B

STRATIGRAPHIC COLUMN AND SPLIT-SPOON CORE LOG FOR WELL # MW330011

NEW WELL AT CP-5

SPLIT SPOON CORE LOG

Location: Behind the reactor at CP-5
Date Drilled: August 11, 1989
Total Depth: 20 ft
Water Level While Drilling: Approximately 14 ft
8/17/89: 10.31 ft from top of casing
Completion: Schedule 40 PVC blank casing and screen

0-10 ft blank casing
10-20 ft screen

0-2 ft cement
2-8 ft bentonite
8-20 ft silica sand

Geologist: T.L. Patton, ANL

Depth (ft)	Description
0 - 0.5	Limestone gravel fill, coarse grained sand
0.5 - 2	Clay, brown-ocre (fill)
2 - 4	Clay, brown, damp, with limestone gravel
4 - 6	Clay, brown-ocre, red streaks, gravel
6 - 8	Clay, dark brown-ocre, red streaks, gravel
8 - 10	Clay, dark brown, some red streaks, changing to a lighter brown, fairly damp clay at 9 ft
10 - 11	Clay, brown, some limestone gravel, wet at 11 ft
11 - 12	Clay, brown-ocre, some red streaks, sandy, gravel
12 - 14	Clay, brown, sandy, some red streaks, gravel
14 - 16	Clay, gray, with some coarse sand
16 - 18	Poor return, Gray clay with gravel
18 - 20	Drilling hard, hitting rock - Gray clay with rounded pebbles, wet

NEW WELL AT CP-5

STRATIGRAPHIC COLUMN

Location: behind reactor
Date Drilled: August 11, 1989
Total Depth: 20 ft
Water Level While Drilling: approximately 14 ft
8/17/89: 10.31 ft from top of casing
Completion: Schedule 40 PVC blank casing and screen

0-10 ft blank casing	0-2 ft cement
10-20 ft screen	2-8 ft bentonite
	8-20 ft silica sand

Geologist: T.L. Patton, ANL

Depth (ft)	Description
0	
	Limestone gravel fill, coarse grained sand
0.5	
	Brown clay, contains some gravel
4	
	Brown-ocre clay, red streaking, gravel, fairly damp at 9 ft, wet at 11 ft
11	
	Sandy, brown to brown-ocre clay with some red streaking, gravel, wet
14	
	Gray clay with some coarse sand, gravel, and pebbles, wet
20	Total depth

APPENDIX C

1989 20-ft SOIL BORING SAMPLING RESULTS

TABLE 1
SUMMARY OF RADIOLOGICAL ANALYSIS OF SOIL FROM EXISTING MONITORING WELL 330012 IN CP-5 YARD, 1989
CP-5 YARD CHARACTERIZATION
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS
(Page 1 of 1)

SAMPLE NO.	DEPTH	WATER CONTENT	HYDROGEN-3 (pCi/L)	HYDROGEN-3 (pCi/g)	POTASSUIM-40 (pCi/g)	CESIUM-137 (pCi/g)	RADIUM-226 (pCi/g)	THORIUM-228 (pCi/g)	THORIUM-232 (pCi/g)
89S0-1360	0-2'	10.3%	128 ± 96	0.013 ± 0.010	17.87 ± 0.74	0.04 ± 0.02	1.45 ± 0.07	0.85 ± 0.04	0.63 ± 0.09
89S0-1361	2-4'	10.6%	346 ± 100	0.037 ± 0.011	17.06 ± 0.45	0.07 ± 0.01	1.32 ± 0.04	0.80 ± 0.02	0.60 ± 0.05
89S0-1362	4-6'	13.7%	398 ± 102	0.055 ± 0.014	20.50 ± 0.77	<0.03	1.83 ± 0.07	0.91 ± 0.04	0.80 ± 0.10
89S0-1363	6-8'	14.5%	386 ± 101	0.056 ± 0.015	19.10 ± 0.76	0.08 ± 0.02	1.20 ± 0.06	0.94 ± 0.04	0.66 ± 0.09
89S0-1364	8-10'	14.5%	850 ± 110	0.123 ± 0.016	19.63 ± 0.79	<0.03	1.37 ± 0.07	0.94 ± 0.04	0.75 ± 0.09
89S0-1365	10-12'	12.7%	1.40x10^{4} ± 258	1.778 ± 0.033	19.68 ± 0.76	<0.03	1.22 ± 0.06	0.73 ± 0.04	0.70 ± 0.09
89S0-1366	12-14'	12.5%	1.61x10^{4} ± 275	2.020 ± 0.034	19.33 ± 0.76	<0.03	1.30 ± 0.07	0.77 ± 0.04	0.69 ± 0.09
89S0-1367	14-16'	15.3%	1.90x10^{4} ± 297	2.915 ± 0.045	20.09 ± 0.79	<0.03	1.18 ± 0.07	0.88 ± 0.04	0.73 ± 0.09
89S0-1368	16-18'	11.0%	1.96x10^{4} ± 400	2.156 ± 0.044	21.68 ± 1.34	<0.03	1.52 ± 0.12	0.93 ± 0.07	0.86 ± 0.16
89S0-1369	18-20'	13.4%	1.82x10^{4} ± 291	2.439 ± 0.038	17.99 ± 0.75	<0.03	1.24 ± 0.07	0.75 ± 0.04	0.63 ± 0.09

APPENDIX D

1993 IT CORPORATION RADIOLOGICAL SAMPLING RESULTS

ANALYTICAL SUMMARY - SURFACE SOIL RADIOLOGICAL PARAMETERS
CP-5 YARD CHARACTERIZATION
ARGONNE NATIONAL LABORATORY
ARGONNE, ILLINOIS
(Page 1 of 4)

	Result +/- 2-Sigma Error			
Sample ID Number	H-3 (pCi/L) (1)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	K-40 (pCi/g)
SB20-0.5-1.5	2.75E+02 ± 1.22E+02	6.15E+00 ± 4.06E+00	2.87E+01 ± 7.20E+00	1.99E+01 ± 2.90E+00
SB01-0.5-1.5	3.95E+02 ± 1.70E+02	6.34E+00 ± 4.18E+00	2.28E+01 ± 6.20E+00	1.13E+01 ± 1.90E+00
SB02-0.5-1.5	3.07E+02 ± 1.65E+02	7.52E+00 ± 4.58E+00	2.64E+01 ± 6.70E+00	1.50E+01 ± 2.40E+00
DUP SB02-0.5-1.5	3.35E+02 ± 1.81E+02	NA (2)	NA	NA
SB03-0.5-1.5	4.06E+02 ± 1.30E+02	1.13E+01 ± 5.40E+00	2.87E+01 ± 7.30E+00	2.36E+01 ± 3.40E+00
SB04-0.5-1.5	2.30E+03 ± 3.00E+02	< 6.00E+00	2.56E+01 ± 6.70E+00	2.08E+01 ± 3.10E+00
SB05-0.5-1.5	1.23E+03 ± 2.00E+02	< 5.60E+00	1.25E+01 ± 4.40E+00	8.61E+00 ± 1.67E+00
SB06-0.5-1.5 (3)	1.51E+03 ± 3.90E+02	< 5.50E+00	2.80E+01 ± 7.10E+00	2.28E+01 ± 3.00E+00
SB06-0.5-1.5D	3.24E+03 ± 4.30E+02	8.26E+00 ± 4.78E+00	2.89E+01 ± 7.50E+00	2.40E+01 ± 3.40E+00
DUP SB06-0.5-1.5D	NA	1.32E+01 ± 5.80E+00	3.03E+01 ± 7.60E+00	NA
SB07-0.5-1.5	6.24E+02 ± 1.82E+02	< 5.50E+00	1.22E+01 ± 4.30E+00	6.60E+00 ± 1.30E+00
SB08-0.5-1.5 (3)	2.15E+04 ± 2.40E+03	8.23E+00 ± 4.74E+00	2.48E+01 ± 6.50E+00	1.93E+01 ± 2.80E+00
SB09-0.5-1.5	9.29E+02 ± 1.69E+02	< 4.70E+00	7.42E+00 ± 3.75E+00	3.92E+00 ± 8.40E-01
SB10-0.5-1.5	2.43E+02 ± 1.24E+02	7.69E+00 ± 4.57E+00	2.60E+01 ± 6.70E+00	2.05E+01 ± 3.00E+00
SB11-0.5-1.5	1.21E+03 ± 2.20E+02	8.25E+00 ± 4.55E+00	2.66E+01 ± 6.80E+00	1.94E+01 ± 2.90E+00
SB12-0.5-1.5	< 3.50E+02	< 5.90E+00	8.64E+00 ± 3.73E+00	5.63E+00 ± 1.15E+00
SB13-0.5-1.5	3.12E+02 ± 1.33E+02	< 5.70E+00	1.30E+01 ± 4.70E+00	2.73E+01 ± 4.90E+00
SB14-0.5-1.5	6.58E+02 ± 1.75E+02	< 6.20E+00	2.28E+01 ± 6.20E+00	6.05E+01 ± 8.20E+00
DUP SB14-0.5-1.5	4.98E+02 ± 1.50E+02	< 5.50E+00	2.21E+01 ± 6.00E+00	2.03E+01 ± 3.00E+00
SB15-0.5-1.5	9.45E+02 ± 1.70E+02	8.37E+00 ± 4.40E+00	1.85E+01 ± 5.50E+00	1.55E+01 ± 2.20E+00
SB16-0.5-1.5	3.70E+01 ± 1.10E+02	< 6.10E+00	2.50E+01 ± 6.90E+00	2.21E+01 ± 3.20E+00
SB17-0.5-1.5	< 2.40E+02	< 5.10E+00	2.70E+01 ± 6.80E+00	2.18E+01 ± 2.90E+00
SB17-0.5-1.5D	5.56E+02 ± 1.44E+02	9.37E+00 ± 5.02E+00	2.60E+01 ± 6.80E+00	1.94E+01 ± 2.90E+00
SB18-0.5-1.5	1.52E+03 ± 2.50E+02	9.51E+00 ± 5.38E+00	2.17E+01 ± 5.90E+00	1.63E+01 ± 2.40E+00
SB19-0.5-1.5 (3)	5.22E+03 ± 7.30E+02	6.01E+00 ± 4.35E+00	1.91E+01 ± 5.50E+00	1.21E+01 ± 1.80E+00
SB21-0.5-1.5	1.54E+03 ± 2.90E+02	6.38E+00 ± 4.09E+00	2.63E+01 ± 6.70E+00	2.10E+01 ± 3.20E+00

See page 4 for footnotes.

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	Result +/- 2-Sigma Error			
Sample ID Number	RA-226 (pCi/g)	RA-228 (pCi/g)	CS-137 (pCi/g)	CO-57 (pCi/g)
SB20-0.5-1.5	1.43E+00 ± 2.30E-01	1.01E+00 ± 3.10E-01	< 7.80E-02	ND (4)
SB01-0.5-1.5	6.74E-01 ± 1.46E-01	5.26E-01 ± 2.38E-01	5.82E-01 ± 1.15E-01	ND
SB02-0.5-1.5	1.21E+00 ± 2.10E-01	9.48E-01 ± 3.14E-01	5.00E-01 ± 1.14E-01	ND
DUP SB02-0.5-1.5	NA	NA	NA	ND
SB03-0.5-1.5	1.64E+00 ± 2.60E-01	6.07E-01 ± 2.85E-01	< 1.00E-01	ND
SB04-0.5-1.5	1.29E+00 ± 2.30E-01	9.32E-01 ± 3.13E-01	6.57E-02 ± 6.01E-02	ND
SB05-0.5-1.5	7.30E-01 ± 1.59E-01	4.78E-01 ± 2.60E-01	4.42E-01 ± 1.04E-01	5.52E-02 ± 2.22E-02
SB06-0.5-1.5 (3)	1.17E+00 ± 1.80E-01	1.08E+00 ± 2.60E-01	< 6.40E-02	ND
SB06-0.5-1.5D	1.47E+00 ± 2.30E-01	1.30E+00 ± 3.40E-01	< 1.10E-01	ND
DUP SB06-0.5-1.5D	NA	NA	NA	ND
SB07-0.5-1.5	3.24E-01 ± 9.50E-02	2.37E-01 ± 1.80E-01	2.10E-01 ± 6.50E-02	ND
SB08-0.5-1.5 (3)	1.26E+00 ± 2.10E-01	9.99E-01 ± 3.09E-01	< 9.00E-02	ND
SB09-0.5-1.5	1.78E-01 ± 6.90E-02	< 1.30E-01	2.55E-01 ± 5.60E-02	ND
SB10-0.5-1.5	1.30E+00 ± 2.10E-01	9.49E-01 ± 2.96E-01	< 1.10E-01	ND
SB11-0.5-1.5	1.49E+00 ± 2.30E-01	1.12E+00 ± 3.20E-01	< 9.50E-02	ND
SB12-0.5-1.5	3.40E-01 ± 9.70E-02	2.42E-01 ± 1.68E-01	8.00E-01 ± 1.29E-01	ND
SB13-0.5-1.5	2.09E+00 ± 4.80E-01	1.31E+00 ± 7.00E-01	8.64E+00 ± 1.09E+00	ND
SB14-0.5-1.5	3.31E+00 ± 5.20E-01	2.51E+00 ± 7.10E-01	< 2.20E-01	ND
DUP SB14-0.5-1.5	1.04E+00 ± 2.00E-01	1.03E+00 ± 3.30E-01	< 1.00E-01	ND
SB15-0.5-1.5	1.07E+00 ± 1.70E-01	1.04E+00 ± 2.60E-01	1.91E-01 ± 6.20E-02	ND
SB16-0.5-1.5	1.77E+00 ± 2.70E-01	8.73E-01 ± 3.24E-01	< 9.90E-02	ND
SB17-0.5-1.5	1.52E+00 ± 2.20E-01	9.32E-01 ± 2.69E-01	< 7.60E-02	ND
SB17-0.5-1.5D	1.47E+00 ± 2.30E-01	1.07E+00 ± 3.30E-01	< 1.00E-01	ND
SB18-0.5-1.5	1.07E+00 ± 1.80E-01	8.67E-01 ± 2.91E-01	4.70E-01 ± 1.04E-01	2.03E-01 ± 3.70E-02
SB19-0.5-1.5 (3)	8.94E-01 ± 1.45E-01	6.31E-01 ± 2.11E-01	1.18E+00 ± 1.60E-01	ND
SB21-0.5-1.5	1.67E+00 ± 2.60E-01	9.68E-01 ± 3.50E-01	1.70E-01 ± 8.60E-02	ND

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	Result +/- 2-Sigma Error			
Sample ID Number	CO-60 (pCi/g)	AM-241 (pCi/g)	U-238 (ug/g)	EU-152 (pCi/g)
SB20-0.5-1.5	ND	ND	< 2.60E+00 (5)	ND
SB01-0.5-1.5	ND	ND	NA	ND
SB02-0.5-1.5	ND	ND	3.66E+00 ± 2.51E+00	ND
DUP SB02-0.5-1.5	ND	ND	NA	ND
SB03-0.5-1.5	ND	ND	5.36E+00 ± 2.72E+00	ND
SB04-0.5-1.5	ND	ND	4.70E+00 ± 3.52E+00	ND
SB05-0.5-1.5	1.32E+00 ± 2.10E-01	ND	9.67E+00 ± 2.69E+00	ND
SB06-0.5-1.5 (3)	ND	ND	4.42E+00 ± 2.08E+00	ND
SB06-0.5-1.5D	ND	ND	4.79E+00 ± 2.59E+00	ND
DUP SB06-0.5-1.5D	ND	ND	NA	ND
SB07-0.5-1.5	ND	ND	NA	ND
SB08-0.5-1.5 (3)	ND	ND	5.87E+00 ± 2.42E+00	ND
SB09-0.5-1.5	ND	ND	< 1.60E+00 (5)	ND
SB10-0.5-1.5	ND	ND	4.23E+00 ± 2.16E+00	ND
SB11-0.5-1.5	ND	ND	5.83E+00 ± 2.36E+00	ND
SB12-0.5-1.5	ND	ND	NA	ND
SB13-0.5-1.5	2.51E+00 ± 4.50E-01	4.63E-01 ± 1.92E-01 (6)	NA	ND
SB14-0.5-1.5	ND	ND	1.04E+01 ± 2.30E+00	ND
DUP SB14-0.5-1.5	ND	ND	3.69E+00 ± 3.49E+00	ND
SB15-0.5-1.5	ND	ND	2.33E+00 ± 2.02E+00	ND
SB16-0.5-1.5	ND	ND	4.97E+00 ± 2.40E+00	ND
SB17-0.5-1.5	ND	ND	4.24E+00 ± 2.19E+00	ND
SB17-0.5-1.5D	ND	ND	< 3.10E+00	ND
SB18-0.5-1.5	1.68E-01 ± 7.20E-02	ND	2.67E+00 ± 2.20E+00	9.90E-01 ± 5.18E-01
SB19-0.5-1.5 (3)	1.22E-01 ± 5.20E-02	ND	3.68E+00 ± 1.81E+00	ND
SB21-0.5-1.5	ND	ND	7.36E+00 ± 3.16E+00 (5)	ND

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(1) Tritium (H-3) analyses are performed on the moisture present in the soil which is distilled from the sample and counted on a liquid scintillation counter; therefore, results are reported in pCi/L.

(2) NA = Not Analyzed

(3) For these tritium samples, the count rates were inconsistent indicating possible matrix interference. Therefore, only the first count was used to calculate the activity.

(4) ND = Not Detected (the analysis did not detect the parameter and, therefore, no result was indicated).

(5) Parameter is U-Total.

(6) The gamma spectrum for this sample showed a peak at 0.059 Mev which was identified by the gamma system software library as Am-241. Th-232 also has a low abundance peak at the same energy. Since both radioisotopes are single gamma line isotopes, it is impossible to determine by gamma spectroscopy which isotope is responsible for this peak.

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	Result +/- 2-Sigma Error			
Sample ID Number	H-3 (pCi/L) (1)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	K-40 (pCi/g)
SB20-6.0-8.0	6.27E+02 ± 1.45E+02	< 5.30E+00	2.63E+01 ± 6.90E+00	2.18E+01 ± 3.10E+00
SB01-8.0-10.0	8.88E+03 ± 9.70E+02	1.08E+01 ± 5.40E+00	2.82E+01 ± 7.10E+00	2.04E+01 ± 2.90E+00
DUP SB01-8.0-10.0	NA (2)	NA	NA	2.19E+01 ± 2.90E+00
SB02-8.0-10.0	6.41E+03 ± 7.10E+02	8.43E+00 ± 4.54E+00	2.59E+01 ± 6.70E+00	2.16E+01 ± 3.00E+00
SB03-8.0-10.0	1.07E+05 ± 1.10E+04	5.24E+00 ± 3.78E+00	2.69E+01 ± 6.90E+00	2.12E+01 ± 3.20E+00
SB03-8.0-10.0D	7.98E+04 ± 8.10E+03	1.03E+01 ± 4.70E+00	2.71E+01 ± 7.10E+00	2.28E+01 ± 3.30E+00
SB04-8.0-10.0	5.14E+04 ± 5.20E+03	< 6.60E+00	2.62E+01 ± 6.80E+00	2.36E+01 ± 3.60E+00
SB05-8.0-10.0	1.42E+05 ± 1.40E+04	8.78E+00 ± 4.83E+00	2.58E+01 ± 6.80E+00	2.71E+01 ± 3.90E+00
SB06-6.0-8.0	6.13E+03 ± 7.00E+02	< 6.00E+00	2.60E+01 ± 6.70E+00	2.43E+01 ± 3.50E+00
SB07-4.0-6.0	5.82E+02 ± 1.79E+02	8.48E+00 ± 4.46E+00	2.34E+01 ± 6.50E+00	1.29E+01 ± 1.80E+00
SB07-4.0-6.0D	9.36E+02 ± 2.25E+02	< 5.10E+00	1.50E+01 ± 4.90E+00	1.70E+01 ± 2.50E+00
DUP SB07-4.0-6.0	NA	NA	NA	1.49E+01 ± 2.20E+00
SB08-4.0-6.0	3.18E+03 ± 4.20E+02	8.30E+00 ± 4.91E+00	3.05E+01 ± 7.80E+00	2.03E+01 ± 3.10E+00
SB09-8.0-10.0	7.34E+03 ± 7.90E+02	< 5.60E+00	2.86E+01 ± 7.30E+00	2.20E+01 ± 3.20E+00
SB10-2.0-4.0 (3)	9.33E+02 ± 2.75E+02	6.12E+00 ± 4.43E+00	2.83E+01 ± 7.30E+00	2.09E+01 ± 2.80E+00
DUP SB10-2.0-4.0	NA	7.10E+00 ± 4.60E+00	2.67E+01 ± 6.90E+00	2.16E+01 ± 3.00E+00
SB11-2.0-4.0	6.16E+02 ± 1.81E+02	6.10E+00 ± 4.42E+00	8.77E+00 ± 3.87E+00	2.48E+01 ± 3.30E+00
SB12-4.0-6.0	< 3.50E+02	7.62E+00 ± 4.74E+00	3.11E+01 ± 7.60E+00	2.04E+01 ± 3.00E+00
SB13-8.0-10.0	1.99E+04 ± 2.10E+03	< 5.90E+00	2.16E+01 ± 5.90E+00	2.14E+01 ± 3.00E+00
SB14-6.0-8.0	1.61E+02 ± 1.24E+02	< 5.70E+00	2.68E+01 ± 6.80E+00	2.34E+01 ± 3.10E+00
SB15-2.0-4.0	5.87E+03 ± 6.40E+02	7.62E+00 ± 4.32E+00	2.90E+01 ± 7.30E+00	2.10E+01 ± 3.10E+00
SB16-6.0-8.0	8.99E+03 ± 9.50E+02	7.64E+00 ± 4.44E+00	2.17E+01 ± 6.00E+00	2.37E+01 ± 3.10E+00
SB17-6.0-8.0	1.36E+03 ± 2.10E+02	< 5.20E+00	2.66E+01 ± 6.80E+00	2.23E+01 ± 3.20E+00
SB18-6.0-8.0	1.67E+03 ± 2.90E+02	9.39E+00 ± 4.83E+00	2.83E+01 ± 7.00E+00	2.21E+01 ± 3.20E+00
DUP SB18-6.0-8.0	5.07E+03 ± 6.00E+02	NA	NA	NA
SB19-6.0-8.0	< 3.50E+02	6.60E+00 ± 4.42E+00	2.86E+01 ± 7.20E+00	2.11E+01 ± 3.00E+00
SB21-12.0-14.0	< 3.50E+02	1.19E+01 ± 5.70E+00	2.50E+01 ± 6.60E+00	2.42E+01 ± 3.60E+00
DUP SB21-12.0-14.0	NA	1.17E+01 ± 5.40E+00	2.89E+01 ± 7.40E+00	NA

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	Result +/- 2-Sigma Error			
Sample ID Number	RA-226 (pCi/g)	RA-228 (pCi/g)	CS-137 (pCi/g)	U-238 (ug/g)
SB20-6.0-8.0	1.45E+00 ± 2.20E-01	5.22E-01 ± 2.29E-01	< 6.90E-02	2.50E+00 ± 2.37E+00
SB01-8.0-10.0	1.72E+00 ± 2.50E-01	8.03E-01 ± 2.50E-01	< 7.60E-02	4.04E+00 ± 2.07E+00
DUP SB01-8.0-10.0	1.59E+00 ± 2.20E-01	7.79E-01 ± 2.40E-01	< 6.80E-02	4.19E+00 ± 2.07E+00
SB02-8.0-10.0	1.28E+00 ± 2.00E-01	8.28E-01 ± 2.00E-01	< 7.40E-02	NA
SB03-8.0-10.0	1.67E+00 ± 2.60E-01	1.03E+00 ± 3.40E-01	< 1.00E-01	6.12E+00 ± 2.91E+00
SB03-8.0-10.0D	1.28E+00 ± 2.20E-01	1.01E+00 ± 3.20E-01	< 8.80E-02	3.86E+00 ± 2.43E+00
SB04-8.0-10.0	1.46E+00 ± 2.70E-01	9.77E-01 ± 3.80E-01	< 1.10E-01	3.73E+00 ± 4.40E+00
SB05-8.0-10.0	1.42E+00 ± 2.80E-01	1.03E+00 ± 3.40E-01	< 1.10E-01	1.52E+01 ± 3.60E+00
SB06-6.0-8.0	1.72E+00 ± 2.70E-01	1.26E+00 ± 4.10E-01	< 9.90E-02	3.70E+00 ± 2.95E+00
SB07-4.0-6.0	1.15E+00 ± 1.60E-01	6.85E-01 ± 1.90E-01	7.65E-02 ± 4.38E-02	3.99E+00 ± 1.74E+00
SB07-4.0-6.0D	1.34E+00 ± 2.00E-01	9.84E-01 ± 2.65E-01	< 8.70E-02	5.76E+00 ± 2.12E+00
DUP SB07-4.0-6.0	1.18E+00 ± 1.80E-01	7.07E-01 ± 2.59E-01	8.71E-02 ± 6.40E-02	3.92E+00 ± 1.80E+00
SB08-4.0-6.0	1.41E+00 ± 2.40E-01	8.99E-01 ± 3.63E-01	< 1.20E-01	3.28E+00 ± 2.99E+00
SB09-8.0-10.0	1.50E+00 ± 2.40E-01	7.84E-01 ± 2.83E-01	< 9.90E-02	5.34E+00 ± 2.52E+00
SB10-2.0-4.0	1.42E+00 ± 2.10E-01	1.03E+00 ± 2.60E-01	< 7.00E-02	4.22E+00 ± 2.13E+00
DUP SB10-2.0-4.0	1.46E+00 ± 2.30E-01	1.11E+00 ± 3.10E-01	< 9.10E-02	5.06E+00 ± 2.50E+00
SB11-2.0-4.0	1.83E+00 ± 2.60E-01	1.09E+00 ± 3.00E-01	< 7.70E-02	4.69E+00 ± 2.39E+00
SB12-4.0-6.0	1.39E+00 ± 2.20E-01	1.07E+00 ± 3.10E-01	< 9.50E-02	5.34E+00 ± 2.30E+00
SB13-8.0-10.0	1.21E+00 ± 1.90E-01	7.09E-01 ± 2.47E-01	< 7.10E-02	9.09E+00 ± 2.42E+00
SB14-6.0-8.0	1.37E+00 ± 2.00E-01	8.94E-01 ± 2.53E-01	< 7.50E-02	9.88E+00 ± 2.31E+00
SB15-2.0-4.0	1.40E+00 ± 2.30E-01	1.17E+00 ± 3.50E-01	< 1.10E-01	2.94E+00 ± 2.52E+00
SB16-6.0-8.0	1.38E+00 ± 2.10E-01	9.44E-01 ± 2.64E-01	< 8.10E-02	4.65E+00 ± 2.29E+00
SB17-6.0-8.0	1.41E+00 ± 2.30E-01	8.17E-01 ± 3.10E-01	< 8.50E-02	5.52E+00 ± 2.60E+00
SB18-6.0-8.0	1.53E+00 ± 2.40E-01	1.03E+00 ± 3.10E-01	< 8.90E-02	4.33E+00 ± 2.48E+00
DUP SB18-6.0-8.0	NA	NA	NA	NA
SB19-6.0-8.0	1.17E+00 ± 2.00E-01	9.78E-01 ± 3.24E-01	< 8.60E-02	3.70E+00 ± 2.36E+00
SB21-12.0-14.0	1.59E+00 ± 2.70E-01	1.14E+00 ± 3.70E-01	< 1.00E-01	5.27E+00 ± 3.07E+00 (4)
DUP SB21-12.0-14.0	NA	NA	NA	NA

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(1) Tritium (H-3) analyses are performed on the moisture present in the soil which is distilled from the sample and counted on a liquid scintillation counter; therefore, results are reported in pCi/L.

(2) NA = Not Analyzed

(3) Distilled water was used to increase the volume for this sample in order to perform the tritium analysis.

(4) Sample was analyzed for total uranium (U-Total).

APPENDIX E

RESIDENTIAL FAMILY-FARM RESRAD SUMMARY REPORT

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

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

      |                                                        | Current  |           | Parameter
Menu  |                     Parameter                          |  Value   |  Default  |   Name
------+--------------------------------------------------------+----------+-----------+------------
B-1   | Dose conversion factors for inhalation, mrem/pCi:      |          |           |
B-1   | H-3                                                    | 6.400E-08| 6.400E-08 | DCF2( 1)
      |                                                        |          |           |
D-1   | Dose conversion factors for ingestion, mrem/pCi:       |          |           |
D-1   | H-3                                                    | 6.400E-08| 6.400E-08 | DCF3( 1)
      |                                                        |          |           |
D-34  | Food transfer factors:                                 |          |           |
D-34  | H-3      , plant/soil concentration ratio, dimensionless| 4.800E+00| 4.800E+00 | RTF( 1,1)
D-34  | H-3      , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)| 1.200E-02| 1.200E-02 | RTF( 1,2)
D-34  | H-3      , milk/livestock-intake ratio, (pCi/L)/(pCi/d) | 1.000E-02| 1.000E-02 | RTF( 1,3)
      |                                                        |          |           |
D-5   | Bioaccumulation factors, fresh water, L/kg:            |          |           |
D-5   | H-3      , fish                                        | 1.000E+00| 1.000E+00 | BIOFAC( 1,1)
D-5   | H-3      , crustacea and mollusks                      | 1.000E+00| 1.000E+00 | BIOFAC( 1,2)
======+========================================================+==========+===========+============
```

```
                                    Site-Specific Parameter Summary

     |                                                 | User      |           |      Used by RESRAD             | Parameter
Menu |                   Parameter                     | Input     | Default   | (If different from user input)  |   Name
-----+-------------------------------------------------+-----------+-----------+---------------------------------+------------
R011 | Area of contaminated zone (m**2)                | 2.430E+03 | 1.000E+04 |             ---                 | AREA
R011 | Thickness of contaminated zone (m)              | 1.524E+01 | 2.000E+00 |             ---                 | THICK0
R011 | Length parallel to aquifer flow (m)             | 7.400E+01 | 1.000E+02 |             ---                 | LCZPAQ
R011 | Basic radiation dose limit (mrem/yr)            | 2.500E+01 | 3.000E+01 |             ---                 | BRDL
R011 | Time since placement of material (yr)           | 3.000E+01 | 0.000E+00 |             ---                 | TI
R011 | Times for calculations (yr)                     | 1.000E+00 | 1.000E+00 |             ---                 | T( 2)
R011 | Times for calculations (yr)                     | 1.000E+01 | 3.000E+00 |             ---                 | T( 3)
R011 | Times for calculations (yr)                     | 1.000E+02 | 1.000E+01 |             ---                 | T( 4)
R011 | Times for calculations (yr)                     | not used  | 3.000E+01 |             ---                 | T( 5)
R011 | Times for calculations (yr)                     | not used  | 1.000E+02 |             ---                 | T( 6)
R011 | Times for calculations (yr)                     | not used  | 3.000E+02 |             ---                 | T( 7)
R011 | Times for calculations (yr)                     | not used  | 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):  H-3    | 6.900E+00 | 0.000E+00 |             ---                 | S1( 1)
R012 | Concentration in groundwater   (pCi/L):  H-3    | not used  | 0.000E+00 |             ---                 | W1( 1)
     |                                                 |           |           |                                 |
R013 | Cover depth (m)                                 | 1.500E+00 | 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)                 | 1.000E-03 | 1.000E-03 |             ---                 | VCV
R013 | Density of contaminated zone (g/cm**3)          | 1.760E+00 | 1.500E+00 |             ---                 | DENSCZ
R013 | Contaminated zone erosion rate (m/yr)           | 1.000E-03 | 1.000E-03 |             ---                 | VCZ
R013 | Contaminated zone total porosity                | 3.000E-01 | 4.000E-01 |             ---                 | TPCZ
R013 | Contaminated zone effective porosity            | 2.000E-01 | 2.000E-01 |             ---                 | EPCZ
R013 | Contaminated zone hydraulic conductivity (m/yr) | 9.500E-01 | 1.000E+01 |             ---                 | HCCZ
R013 | Contaminated zone b parameter                   | 1.140E+01 | 5.300E+00 |             ---                 | BCZ
R013 | Average annual wind speed (m/sec)               | 2.000E+00 | 2.000E+00 |             ---                 | WIND
R013 | Humidity in air (g/m**3)                        | 7.000E+00 | 8.000E+00 |             ---                 | HUMID
R013 | Evapotranspiration coefficient                  | 5.000E-01 | 5.000E-01 |             ---                 | EVAPTR
R013 | Precipitation (m/yr)                            | 8.000E-01 | 1.000E+00 |             ---                 | PRECIP
R013 | Irrigation (m/yr)                               | 2.000E-01 | 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) | 1.000E+06 | 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)             | 1.500E+00 | 1.500E+00 |             ---                 | DENSAQ
R014 | Saturated zone total porosity                   | 3.000E-01 | 4.000E-01 |             ---                 | TPSZ
R014 | Saturated zone effective porosity               | 2.000E-01 | 2.000E-01 |             ---                 | EPSZ
R014 | Saturated zone hydraulic conductivity (m/yr)    | 9.500E+02 | 1.000E+02 |             ---                 | HCSZ
R014 | Saturated zone hydraulic gradient               | 2.000E-02 | 2.000E-02 |             ---                 | HGWT
R014 | Saturated zone b parameter                      | 1.140E+01 | 5.300E+00 |             ---                 | BSZ
R014 | Water table drop rate (m/yr)                    | 1.000E-03 | 1.000E-03 |             ---                 | VWT
R014 | Well pump intake depth (m below water table)    | 5.000E+00 | 1.000E+01 |             ---                 | DWIBWT
R014 | Model: Nondispersion (ND) or Mass-Balance (MB)  | ND        | ND        |             ---                 | MODEL
R014 | Well pumping rate (m**3/yr)                     | 2.500E+02 | 2.500E+02 |             ---                 | UW
     |                                                 |           |           |                                 |
R015 | Number of unsaturated zone strata               | 2         | 1         |             ---                 | NS
```

```
                              Site-Specific Parameter Summary (continued)

     |                                                   |   User    |           |       Used by RESRAD        | Parameter
Menu |                     Parameter                     |   Input   |  Default  | (If different from user input) |   Name
-----+---------------------------------------------------+-----------+-----------+--------------------------------+--------------
R015 | Unsat. zone 1, thickness (m)                      | 1.200E+00 | 4.000E+00 |             ---                | H(1)
R015 | Unsat. zone 1, soil density (g/cm**3)             | 1.760E+00 | 1.500E+00 |             ---                | DENSUZ(1)
R015 | Unsat. zone 1, total porosity                     | 3.000E-01 | 4.000E-01 |             ---                | TPUZ(1)
R015 | Unsat. zone 1, effective porosity                 | 2.000E-01 | 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)      | 9.500E-01 | 1.000E+01 |             ---                | HCUZ(1)
     |                                                   |           |           |                                |
R015 | Unsat. zone 2, thickness (m)                      | 1.800E+01 | 0.000E+00 |             ---                | H(2)
R015 | Unsat. zone 2, soil density (g/cm**3)             | 1.500E+00 | 1.500E+00 |             ---                | DENSUZ(2)
R015 | Unsat. zone 2, total porosity                     | 4.000E-01 | 4.000E-01 |             ---                | TPUZ(2)
R015 | Unsat. zone 2, effective porosity                 | 2.000E-01 | 2.000E-01 |             ---                | EPUZ(2)
R015 | Unsat. zone 2, soil-specific b parameter          | 7.750E+00 | 5.300E+00 |             ---                | BUZ(2)
R015 | Unsat. zone 2, hydraulic conductivity (m/yr)      | 5.000E+01 | 1.000E+01 |             ---                | HCUZ(2)
     |                                                   |           |           |                                |
R016 | Distribution coefficients for H-3                 |           |           |                                |
R016 |   Contaminated zone (cm**3/g)                     | 0.000E+00 | 0.000E+00 |             ---                | DCNUCC( 1)
R016 |   Unsaturated zone 1 (cm**3/g)                    | 0.000E+00 | 0.000E+00 |             ---                | DCNUCU( 1,1)
R016 |   Unsaturated zone 2 (cm**3/g)                    | 0.000E+00 | 0.000E+00 |             ---                | DCNUCU( 1,2)
R016 |   Saturated zone (cm**3/g)                        | 0.000E+00 | 0.000E+00 |             ---                | DCNUCS( 1)
R016 |   Leach rate (/yr)                                | 0.000E+00 | 0.000E+00 |          9.482E-02             | ALEACH( 1)
R016 |   Solubility constant                             | 0.000E+00 | 0.000E+00 |          not used              | SOLUBK( 1)
     |                                                   |           |           |                                |
R017 | Inhalation rate (m**3/yr)                         | 8.400E+03 | 8.400E+03 |             ---                | INHALR
R017 | Mass loading for inhalation (g/m**3)              | 2.000E-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                  | 7.000E-01 | 7.000E-01 |             ---                | SHF1
R017 | Fraction of time spent indoors                    | 5.000E-01 | 5.000E-01 |             ---                | FIND
R017 | Fraction of time spent outdoors (on site)         | 2.500E-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  | 0.000E+00 |             ---                | RAD_SHAPE( 3)
R017 |   Outer annular radius (m), ring  4:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 4)
R017 |   Outer annular radius (m), ring  5:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 5)
R017 |   Outer annular radius (m), ring  6:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 6)
R017 |   Outer annular radius (m), ring  7:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 7)
R017 |   Outer annular radius (m), ring  8:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 8)
R017 |   Outer annular radius (m), ring  9:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE( 9)
R017 |   Outer annular radius (m), ring 10:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE(10)
R017 |   Outer annular radius (m), ring 11:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE(11)
R017 |   Outer annular radius (m), ring 12:              | not used  | 0.000E+00 |             ---                | RAD_SHAPE(12)
     |                                                   |           |           |                                |
```

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                            Site-Specific Parameter Summary (continued)

     |                                                  |  User     |           |      Used by RESRAD              | Parameter
Menu |                   Parameter                      |  Input    |  Default  | (If different from user input)   |   Name
-----+--------------------------------------------------+-----------+-----------+----------------------------------+------------
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  | 0.000E+00 |             ---                  | FRACA( 3)
R017 |   Ring  4                                        | not used  | 0.000E+00 |             ---                  | FRACA( 4)
R017 |   Ring  5                                        | not used  | 0.000E+00 |             ---                  | FRACA( 5)
R017 |   Ring  6                                        | not used  | 0.000E+00 |             ---                  | FRACA( 6)
R017 |   Ring  7                                        | not used  | 0.000E+00 |             ---                  | FRACA( 7)
R017 |   Ring  8                                        | not used  | 0.000E+00 |             ---                  | FRACA( 8)
R017 |   Ring  9                                        | not used  | 0.000E+00 |             ---                  | FRACA( 9)
R017 |   Ring 10                                        | not used  | 0.000E+00 |             ---                  | FRACA(10)
R017 |   Ring 11                                        | not used  | 0.000E+00 |             ---                  | FRACA(11)
R017 |   Ring 12                                        | not used  | 0.000E+00 |             ---                  | FRACA(12)
     |                                                  |           |           |                                  |
R018 | Fruits, vegetables and grain consumption (kg/yr) | 1.600E+02 | 1.600E+02 |             ---                  | DIET(1)
R018 | Leafy vegetable consumption (kg/yr)              | 1.400E+01 | 1.400E+01 |             ---                  | DIET(2)
R018 | Milk consumption (L/yr)                          | 9.200E+01 | 9.200E+01 |             ---                  | DIET(3)
R018 | Meat and poultry consumption (kg/yr)             | 6.300E+01 | 6.300E+01 |             ---                  | DIET(4)
R018 | Fish consumption (kg/yr)                         | 5.400E+00 | 5.400E+00 |             ---                  | DIET(5)
R018 | Other seafood consumption (kg/yr)                | 9.000E-01 | 9.000E-01 |             ---                  | DIET(6)
R018 | Soil ingestion rate (g/yr)                       | 3.650E+01 | 3.650E+01 |             ---                  | SOIL
R018 | Drinking water intake (L/yr)                     | 5.100E+02 | 5.100E+02 |             ---                  | DWI
R018 | Contamination fraction of drinking water         | 1.000E+00 | 1.000E+00 |             ---                  | FDW
R018 | Contamination fraction of household water        | not used  | 1.000E+00 |             ---                  | FHHW
R018 | Contamination fraction of livestock water        | 1.000E+00 | 1.000E+00 |             ---                  | FLW
R018 | Contamination fraction of irrigation water       | 1.000E+00 | 1.000E+00 |             ---                  | FIRW
R018 | Contamination fraction of aquatic food           | 5.000E-01 | 5.000E-01 |             ---                  | FR9
R018 | Contamination fraction of plant food             |-1         |-1         |          0.500E+00               | FPLANT
R018 | Contamination fraction of meat                   |-1         |-1         |          0.122E+00               | FMEAT
R018 | Contamination fraction of milk                   |-1         |-1         |          0.122E+00               | FMILK
     |                                                  |           |           |                                  |
R019 | Livestock fodder intake for meat (kg/day)        | 6.800E+01 | 6.800E+01 |             ---                  | LFI5
R019 | Livestock fodder intake for milk (kg/day)        | 5.500E+01 | 5.500E+01 |             ---                  | LFI6
R019 | Livestock water intake for meat (L/day)          | 5.000E+01 | 5.000E+01 |             ---                  | LWI5
R019 | Livestock water intake for milk (L/day)          | 1.600E+02 | 1.600E+02 |             ---                  | LWI6
R019 | Livestock soil intake (kg/day)                   | 5.000E-01 | 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       | 1.000E+00 | 1.000E+00 |             ---                  | FGWHH
R019 | Livestock water fraction from ground water       | not used  | 1.000E+00 |             ---                  | FGWLW
R019 | Irrigation fraction from ground water            | 1.000E+00 | 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)    | 1.100E+00 | 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)            | 8.000E-02 | 8.000E-02 |             ---                  | TE(3)
R19B | Translocation Factor for  Non-Leafy              | 1.000E-01 | 1.000E-01 |             ---                  | TIV(1)
```

```
                              Site-Specific Parameter Summary (continued)

     |                                                 |   User    |           |       Used by RESRAD           |  Parameter
Menu |                   Parameter                     |   Input   |  Default  | (If different from user input) |    Name
-----+-------------------------------------------------+-----------+-----------+--------------------------------+-------------
R19B | Translocation Factor for  Leafy                 | 1.000E+00 | 1.000E+00 |              ---               | TIV(2)
R19B | Translocation Factor for  Fodder                | 1.000E+00 | 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    | 2.500E-01 | 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    | 2.500E-01 | 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
     |                                                 |           |           |                                |
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
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  | 0.000E+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             |      active
   5 -- milk ingestion             |      active
   6 -- aquatic foods              |      active
   7 -- drinking water             |      active
   8 -- soil ingestion             |      active
   9 -- radon                      |    suppressed
   Find peak pathway doses         |    suppressed
  =================================#=====================
```

```
     Contaminated Zone Dimensions           Initial Soil Concentrations, pCi/g
     ____________________________           __________________________________

       Area:   2430.00 square meters               H-3        6.900E+00
  Thickness:     15.24 meters
Cover Depth:      1.50 meters


                       Total Dose TDOSE(t), mrem/yr
                 Basic Radiation Dose Limit =  25 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)
__________________________________________________________________________

   t (years):  0.000E+00  1.000E+00  1.000E+01  1.000E+02
    TDOSE(t):  1.053E+00  9.059E-01  2.329E-01  2.943E-07
        M(t):  4.211E-02  3.624E-02  9.318E-03  1.177E-08

Maximum TDOSE(t):  1.053E+00 mrem/yr   at t = 0.000E+00 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 = 0.000E+00 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.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
H-3     0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
======= ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======
Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000


                        Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) and Pathways (p)
                                     As mrem/yr and Fraction of Total Dose At t = 0.000E+00 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.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
H-3     9.141E-01 0.8683  4.194E-05 0.0000  0.000E+00 0.0000  1.174E-01 0.1115  5.776E-03 0.0055  1.545E-02 0.0147  1.053E+00 1.0000
======= ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======
Total   9.141E-01 0.8683  4.194E-05 0.0000  0.000E+00 0.0000  1.174E-01 0.1115  5.776E-03 0.0055  1.545E-02 0.0147  1.053E+00 1.0000

*Sum of all water independent and dependent pathways.
```

```
                         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)

              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.
------- ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------
H-3     0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000
======= =========  ======   =========  ======   =========  ======   =========  ======   =========  ======   =========  ======   =========  ======
Total   0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000    0.000E+00 0.0000


                         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

              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.
------- ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------   ---------  ------
H-3     7.863E-01 0.8679    3.613E-05 0.0000    0.000E+00 0.0000    1.013E-01 0.1118    5.013E-03 0.0055    1.331E-02 0.0147    9.059E-01 1.0000
======= =========  ======   =========  ======   =========  ======   =========  ======   =========  ======   =========  ======   =========  ======
Total   7.863E-01 0.8679    3.613E-05 0.0000    0.000E+00 0.0000    1.013E-01 0.1118    5.013E-03 0.0055    1.331E-02 0.0147    9.059E-01 1.0000

*Sum of all water independent and dependent pathways.
```

```
                            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)

             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.
-------  ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------
H-3     0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000
=======  =========  ======    =========  ======    =========  ======    =========  ======    =========  ======    =========  ======    =========  ======
Total   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000   0.000E+00 0.0000


                            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

             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.
-------  ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------    ---------  ------
H-3     2.022E-01 0.8679   9.290E-06 0.0000   0.000E+00 0.0000   2.604E-02 0.1118   1.289E-03 0.0055   3.423E-03 0.0147   2.329E-01 1.0000
=======  =========  ======    =========  ======    =========  ======    =========  ======    =========  ======    =========  ======    =========  ======
Total   2.022E-01 0.8679   9.290E-06 0.0000   0.000E+00 0.0000   2.604E-02 0.1118   1.289E-03 0.0055   3.423E-03 0.0147   2.329E-01 1.0000

*Sum of all water independent and dependent pathways.
```

```
                          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)

             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.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
H-3     0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000
======= ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======
Total   0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000  0.000E+00 0.0000


                          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

             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.
------- --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------  --------- ------
H-3     2.554E-07 0.8679  1.174E-11 0.0000  0.000E+00 0.0000  3.290E-08 0.1118  1.629E-09 0.0055  4.324E-09 0.0147  2.943E-07 1.0000
======= ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======  ========= ======
Total   2.554E-07 0.8679  1.174E-11 0.0000  0.000E+00 0.0000  3.290E-08 0.1118  1.629E-09 0.0055  4.324E-09 0.0147  2.943E-07 1.0000

*Sum of all water independent and dependent pathways.
```

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

Parent  Product  Branch           DSR(j,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.526E-01 1.313E-01 3.376E-02 4.265E-08
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.


   Single Radionuclide Soil Guidelines G(i,t) in pCi/g
        Basic Radiation Dose Limit =  25 mrem/yr

Nuclide
  (i)    t= 0.000E+00   1.000E+00   1.000E+01   1.000E+02
-------     ---------   ---------   ---------   ---------
H-3         1.639E+02   1.904E+02   7.405E+02   5.861E+08
=======     =========   =========   =========   =========


            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 = 0.000E+00 years

Nuclide  Initial         tmin        DSR(i,tmin) G(i,tmin) DSR(i,tmax) G(i,tmax)
  (i)     pCi/g        (years)                    (pCi/g)               (pCi/g)
------- ---------  ----------------  ---------  ---------  ---------  ---------
H-3     6.900E+00     0.000E+00      1.526E-01  1.639E+02  1.526E-01  1.639E+02
======= =========  ================  =========  =========  =========  =========
```

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

Nuclide Parent   BRF(i)                  DOSE(j,t), mrem/yr
  (j)     (i)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3     1.000E+00     1.053E+00 9.059E-01 2.329E-01 2.943E-07
======= ======= =========     ========= ========= ========= =========
BRF(i) is the branch fraction of the parent nuclide.


               Individual Nuclide Soil Concentration
            Parent Nuclide and Branch Fraction Indicated

Nuclide Parent   BRF(i)                    S(j,t), pCi/g
  (j)     (i)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3     1.000E+00     6.900E+00 5.933E+00 1.525E+00 1.921E-06
======= ======= =========     ========= ========= ========= =========
BRF(i) is the branch fraction of the parent nuclide.
```

APPENDIX F

RESIDENTIAL FAMILY-FARM RESRAD DETAILED REPORT

Table of Contents

Part II: Source Terms, Factors, and Parameters for Individual Pathways

Table of Contents (cont.)

Part II: Source Terms, Factors, and Parameters for Individual Pathways

```
               Source Factors for Ingrowth and Decay
                     Radioactivity Factors Only
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch        ID(j,t) = CUMBRF(j)*S1(j,t)/S1(i,0)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 9.454E-01 5.705E-01 3.652E-03
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).


               Source Factors for Ingrowth and Decay
            Combined Radioactivity and Leaching Factors
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          SF(j,t) = BRF(i)*S1(j,t)/S1(i,0)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 8.599E-01 2.210E-01 2.784E-07
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
The effect of volatilization was also considered when computing the source factors for H-3 and C-14.
```

```
         Parameters Used for Calculating Cover Depth and Contaminated Zone Thicknesses


            Cover Erosion rate (vcv):  0.001000 m/yr
Contaminated Zone Erosion rate (vcz):  0.001000 m/yr
        Water Table Drop rate (vwt):  0.001000 m/yr
             Precipitation rate (Pr):  0.800000 m/yr
             Cover Removal Time (Tc): 1.500E+03 yr
Overhead irrigation rate (Irr):  0.200 m/yr          Runoff coefficient (Cr):  0.200
Evapotranspiration coeff. (Ce):  0.500                Infiltration rate (In):  0.420 m/yr
      Bulk soil density (rhob):  1.760 g/cm**3        Effective porosity (pe):  0.200


Radio-     Distribution    Leaching
nuclide    Coefficient       Ratio
  (i)     Kd(i),cm**3/g      q(i)
-------  -------------  ----------

H-3        0.000000E+00   1.000E+00
=======  =============  ==========


           Time Dependence of Source Geometry

        Time Dependence of Cover Depth [Cd(i,t)]

Nuclide                 Cd(i,t) (meters)
  (i)    t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
-------     ----------  ----------  ----------  ----------

H-3         1.5000E+00  1.4990E+00  1.4900E+00  1.4000E+00
=======     ==========  ==========  ==========  ==========


Time Dependence of Contaminated Zone Thicknesses [T(i,t)]

Nuclide                T(i,t) (meters)
  (i)    t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
-------     ----------  ----------  ----------  ----------

H-3         1.5240E+01  1.5240E+01  1.5240E+01  1.5240E+01
=======     ==========  ==========  ==========  ==========
```

```
  Occupancy, Cover/Depth, and Area Factors for Ground Pathway

                Occupancy Factor (FO1):      0.600
                              Area (A):      2430. sq. meters
              Initial cover depth (Cd):      1.500 meters
Initial contaminated zone thickness (T):    15.240 meters

  Time Dependence of Cover/Depth Factor [FCTR_COV_DEPTH(i,t)]

Nuclide       FCTR_COV_DEPTH(i,t) (dimensionless)
  (i)   t= 0.000E+00  1.000E+00  1.000E+01  1.000E+02
-------    ---------  ---------  ---------  ---------
H-3        1.000E+00  1.000E+00  1.000E+00  1.000E+00
=======    =========  =========  =========  =========


        Time Dependence of Area Factor [FCTR_AREA(i,t)]

Nuclide          FCTR_AREA(i,t) (dimensionless)
  (i)   t= 0.000E+00  1.000E+00  1.000E+01  1.000E+02
-------    ---------  ---------  ---------  ---------
H-3        1.000E+00  1.000E+00  1.000E+00  1.000E+00
=======    =========  =========  =========  =========


Dose Conversion and Environmental Transport Factors for the Ground Pathway (p=1)

Parent Product  DCF(j,1)*         ETF(j,1,t) (dimensionless)
 (i)     (j)                t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ ------- ---------      --------- --------- --------- ---------
H-3    H-3     0.000E+00      6.000E-01 6.000E-01 6.000E-01 6.000E-01
====== ======= =========      ========= ========= ========= =========
* - The dose conversion factor units are (mrem/yr)/(pCi/g) at infinite depth and area.


  Dose/Source Ratios for External Radiation from the Ground (p=1)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,1,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
```

```
  Dose/Source Ratios for Inhalation Pathway, Excluding Radon (p=2)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,2,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.


                    Pathway Factors for the Inhalation Pathway (radon excluded)

                             Area (A):  2.4300E+03 m**2       Occupancy Factor (FO2):  4.5000E-01
                     Area Factor (FA2):  1.4630E-01          Annual Air Intake (F12):  8.4000E+03 m**3/yr
                   Cover Depth [Cd(0)]:  1.5000E+00 m            Mass Loading (ASR2):  2.0000E-04 g/m**3
Contaminated Zone Thickness [T(0)]:  1.5240E+01 m         FA2 * FO2 * F12 * ASR2:  1.1060E-01 g/yr

Nuclide      Depth Factor [FD(i,2,t)] (dimensionless)
  (i)     t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
________    __________  __________  __________  __________

H-3         0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
========    ==========  ==========  ==========  ==========


Dose Conversion and Environmental Transport Factors for the Inhalation Pathway, Excluding Radon (p=2)

Parent Product  DCF(j,2)*             ETF(j,2,t) (g/yr)
 (i)     (j)                t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________      _________ _________ _________ _________

H-3    H-3      6.400E-08      0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========      ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.
```

```
Transport Time Parameters for Unsaturated Zone Stratum  No. 1

            Stratum thickness [h(1)]:      1.200000 m
Bulk soil material density [rhob(1)]:      1.760000 g/cm**3
        Effective porosity [peuz(1)]:      0.200000
    Hydraulic conductivity [Khuz(1)]:      0.950000 m/yr
            Total porosity [ptuz(1)]:      0.300000
  Soil specific b parameter [buz(1)]:     11.400000
          Saturation ratio [sruz(1)]:      0.968859

 Radio-      Distribution      Retardation      Transport
nuclide       Coefficient        Factor           Time
  (i)     Kduz(i,1), cm**3/g   Rduz(i,1)     Dtuz(i,1), yr
_______   __________________  _____________  _____________

H-3           0.0000E+00        1.0000E+00     5.5363E-01
=======   ==================  =============  =============


Transport Time Parameters for Unsaturated Zone Stratum  No. 2

            Stratum thickness [h(2)]:     18.000000 m
Bulk soil material density [rhob(2)]:      1.500000 g/cm**3
        Effective porosity [peuz(2)]:      0.200000
    Hydraulic conductivity [Khuz(2)]:     50.000000 m/yr
            Total porosity [ptuz(2)]:      0.400000
  Soil specific b parameter [buz(2)]:      7.750000
          Saturation ratio [sruz(2)]:      0.772323

 Radio-      Distribution      Retardation      Transport
nuclide       Coefficient        Factor           Time
  (i)     Kduz(i,2), cm**3/g   Rduz(i,2)     Dtuz(i,2), yr
_______   __________________  _____________  _____________

H-3           0.0000E+00        1.0000E+00     6.6199E+00
=======   ==================  =============  =============


Transport Time Parameters for Unsaturated Zone created by the Falling Water Table

        Water table drop rate [vwt]:      0.001000 m/yr
Bulk soil material density [rhobaq]:      1.500000 g/cm**3
          Effective porosity [peaq]:      0.200000
      Hydraulic conductivity [Khaq]:    950.000000 m/yr
              Total porosity [ptaq]:      0.300000
    Soil specific b parameter [baq]:     11.400000
           Saturation ratio [sruaq]:      0.741279

 Radio-      Distribution      Retardation      Minimum
nuclide       Coefficient        Factor        Transport
                                                  Time
  (i)      Kdaq(i), cm**3/g     Rduaq(i)     Dtuaq(i), yr
_______   __________________  _____________  _____________

H-3           0.0000E+00        1.0000E+00     2.5331E-03
=======   ==================  =============  =============
```

```
        Dilution Factor and Rise Time Parameters for Nondispersion (ND) Model

                    Aquifer contamination depth at well (z):  1.63579E+00 m
               Depth of water intake below water table (dw):  5.00000E+00 m
                                      Infiltration rate (In):  4.20000E-01 m/yr
                            Aquifer water flow rate (Vwfr):  1.90000E+01 m/yr
                                    Hydraulic gradient (J):  2.00000E-02
                   Hydraulic conductivity of aquifer (Kszh):  9.50000E+02 m/yr
          Contaminated zone extent parallel to gradient (l):  7.40000E+01 m
        Distance below contaminated zone to water table (h):  0.19200E+02 m
             Initial thickness of uncontaminated cover (Cd):  0.15000E+01 m
                 Initial thickness of contaminated zone (T):  0.15240E+02 m
                Effective porosity of saturated zone (pesz):  0.20000E+00

 Radio-     Dilution      Retardation     Horizontal Transport Time       Rise         Decay Time
nuclide      Factor          Factor                      Onsite           Time          Parameter
  (i)         f(i)          Rdsz(i)                   Tauh(i), yr       dt(i), yr    1/lamda(i),yr
_______  _____________  _____________  _____________  _____________  _____________  _____________

H-3        3.272E-01      1.000E+00                      7.789E-01      7.789E-01      1.782E+01
=======  =============  =============  =============  =============  =============  =============


                     Primary Parameters Used for Calculating Water/Soil
                     Concentration Ratios for Groundwater Pathway Segment

                                         Model used:  Nondispersion (ND)
 Bulk soil density in contaminated zone (rhob):  1.760 g/cm**3

 Radio-     Dilution      Retardation        Breakthrough Time             Rise
nuclide      Factor          Factor         Chain      Single Nuclide      Time
  (i)         f(i)          Rdcz(i)         year        Dt(i), yr        dt(i), yr
_______  _____________  _____________  _____________  _____________  _____________

H-3        3.272E-01      1.000E+00      7.176E+00      7.176E+00      7.789E-01
=======  =============  =============  =============  =============  =============
```

```
Water/Soil Concentration Ratios [WSR(j,1,t)] for Groundwater Pathway Segment

Parent  Product  Branch          WSR(j,1,t) in (pCi/L)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    4.059E+03 3.490E+03 8.975E+02 1.134E-03
======= ======= =========    ========= ========= ========= =========


Water/Soil Concentration Ratios [WSR(j,2,t)] for Surface Water Pathway Segment

                      Watershed Area (Aw) = 1.0000E+06 m**2
               Contaminated Zone Area (A) = 2.4300E+03 m**2
                     Dilution Factor (f') = 2.4300E-03
                      Soil Density (rhob) = 1.7600E+00 kg/m**3

Parent  Product  Branch          WSR(j,2,t) in (pCi/L)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    3.015E+01 2.593E+01 6.666E+00 8.422E-06
======= ======= =========    ========= ========= ========= =========
```

```
                    Storage Times For Contaminated Foodstuffs

                     k |    Food Item       | STOR_T(k), days
                    ---+--------------------+----------------
                     1 | non-leafy plants   |       14
                     2 | leafy plants       |        1
                     3 | milk               |        1
                     4 | meat               |       20
                     5 | fish               |        7
                     6 | crustacea          |        7
                     7 | well water         |        1
                     8 | surface water      |        1
                     9 | livestock fodder   |       45
                    ===+====================+================


                                          Storage Time Ingrowth and Decay Factors
                                   Storage Time for k'th Foodstuff:  t = STOR_T(k), days

Parent  Product  Branch                                   STOR_ID(i,j,t) = CONCE(i,j,t)/CONCE(i,i,0)
 (i)      (j)    Fraction  t= 1.400E+01 1.000E+00 1.000E+00 2.000E+01 7.000E+00 7.000E+00 1.000E+00 1.000E+00 4.500E+01
------  -------  ---------    --------- --------- --------- --------- --------- --------- --------- --------- ---------
H-3     H-3      1.000E+00    9.979E-01 9.998E-01 9.998E-01 9.969E-01 9.989E-01 9.989E-01 9.998E-01 9.998E-01 9.931E-01
======  =======  =========    ========= ========= ========= ========= ========= ========= ========= ========= =========
CONCE(i,j,t)/CONCE(i,i,0) is the concentration ratio of Product(j) at time t to Parent(i) at start of storage time.
```

```
                    Storage Time Correction Factors
               Drinking Water from Well and/or Surface
      Harvest Time = t - 2.74E-03 yr; Consumption Time = t yr

Parent  Product  Branch                  CFWW(j,t,1)#
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


                    Storage Time Correction Factors
   Irrigation Water for Nonleafy Plants from Well and/or Surface
 Harvest Time = t - 4.11E-02 yr; Consumption Time = t - 3.83E-02 yr

Parent  Product  Branch                  CFWW(j,t,2)#
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


                    Storage Time Correction Factors
     Irrigation Water for Leafy Plants from Well and/or Surface
 Harvest Time = t - 5.48E-03 yr; Consumption Time = t - 2.74E-03 yr

Parent  Product  Branch                  CFWW(j,t,3)#
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


                    Storage Time Correction Factors
Irrigation Water for Livestock (Milk) Fodder from Well and/or Surface
 Harvest Time = t - 1.29E-01 yr; Consumption Time = t - 1.26E-01 yr

Parent  Product  Branch                  CFWW(j,t,5)#
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======= ======= =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).
```

```
                 Storage Time Correction Factors
Irrigation Water for Livestock (Meat) Fodder from Well and/or Surface
 Harvest Time = t - 1.81E-01 yr; Consumption Time = t - 1.78E-01 yr

Parent  Product  Branch                     CFWW(j,t,7)#
 (i)     (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______  ______  _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======  ======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


                 Storage Time Correction Factors
         Livestock (Milk) Water from Well and/or Surface
 Harvest Time = t - 5.48E-03 yr; Consumption Time = t - 2.74E-03 yr

Parent  Product  Branch                     CFWW(j,t,4)#
 (i)     (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______  ______  _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======  ======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


                 Storage Time Correction Factors
         Livestock (Meat) Water from Well and/or Surface
 Harvest Time = t - 5.75E-02 yr; Consumption Time = t - 5.48E-02 yr

Parent  Product  Branch                     CFWW(j,t,6)#
 (i)     (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______  ______  _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
======  ======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


        Storage Time Correction Factors for Nonleafy Plants
      Harvest Time = t -  3.83E-02 yr; Consumption Time = t yr

Parent  Product  Branch                      CF3(j,1,t)#
 (i)     (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______  ______  _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    1.000E+00 9.979E-01 9.979E-01 9.979E-01
======  ======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).
```

```
          Storage Time Correction Factors for Leafy Plants
      Harvest Time = t -  2.74E-03 yr; Consumption Time = t yr

Parent  Product  Branch                  CF3(j,2,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------     --------- --------- --------- ---------
H-3     H-3      1.000E+00     1.000E+00 9.998E-01 9.998E-01 9.998E-01
======= ======= =========     ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


    Storage Time Correction Factors for Livestock (Meat) Fodder
Harvest Time = t -  1.78E-01 yr; Consumption Time = t - 5.48E-02 yr

Parent  Product  Branch                  CFLF(j,1,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------     --------- --------- --------- ---------
H-3     H-3      1.000E+00     1.000E+00 9.931E-01 9.931E-01 9.931E-01
======= ======= =========     ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


    Storage Time Correction Factors for Livestock (Milk) Fodder
Harvest Time = t -  1.26E-01 yr; Consumption Time = t - 2.74E-03 yr

Parent  Product  Branch                  CFLF(j,2,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------     --------- --------- --------- ---------
H-3     H-3      1.000E+00     1.000E+00 9.931E-01 9.931E-01 9.931E-01
======= ======= =========     ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


              Storage Time Correction Factors for Meat
      Harvest Time = t -  5.48E-02 yr; Consumption Time = t yr

Parent  Product  Branch                  CF45(j,1,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------     --------- --------- --------- ---------
H-3     H-3      1.000E+00     1.000E+00 9.969E-01 9.969E-01 9.969E-01
======= ======= =========     ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).
```

```
              Storage Time Correction Factors for Milk
      Harvest Time = t -  2.74E-03 yr; Consumption Time = t yr

Parent  Product  Branch                   CF45(j,2,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------

H-3     H-3     1.000E+00    1.000E+00 9.998E-01 9.998E-01 9.998E-01
=======  =======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).


        Storage Time Correction Factors for Fish & Crustacea
      Harvest Time = t -  1.92E-02 yr; Consumption Time = t yr

Parent  Product  Branch                   CFF(j,1,t)#
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------

H-3     H-3     1.000E+00    1.000E+00 9.989E-01 9.989E-01 9.989E-01
=======  =======  =========    ========= ========= ========= =========
*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter:  CUMBRF(j) = BRF(1)*BRF(2)* ... BRF(j).
#Correction factor = (concentration in media at consumption time)/(concentration at harvest time).
```

```
Area and Depth Factors for Plant (p=3), Meat (p=4), and Milk (p=5) Pathways
                 Root Uptake from Contaminated Soil (q=1)

                    Area Factor for Plant Foods [FA(3)] = 0.50

Nuclide      Depth Factor FD(i,1,t) (dimensionless)
  (i)    t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
_______     __________  __________  __________  __________

H-3         0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
=======     ==========  ==========  ==========  ==========


Area and Depth Factors for Plant (p=3), Meat (p=4), and Milk (p=5) Pathways
                Foliar Uptake from Contaminated Dust (q=2)

                    Area Factor for Plant Foods [FA(3)] = 0.50

Nuclide      Depth Factor FD(i,2,t) (dimensionless)
  (i)    t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
_______     __________  __________  __________  __________

H-3         0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00
=======     ==========  ==========  ==========  ==========


Area and Depth Factors for Plant (p=3), Meat (p=4), and Milk (p=5) Pathways
                          Ditch Irrigation (q=3)

                    Area Factor for Plant Foods [FA(3)] = 0.50

Nuclide      Depth Factor FD(i,3,t) (dimensionless)
  (i)    t=  0.000E+00   1.000E+00   1.000E+01   1.000E+02
_______     __________  __________  __________  __________

H-3         1.0000E+00  1.0000E+00  1.0000E+00  1.0000E+00
=======     ==========  ==========  ==========  ==========
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```
   Area and Depth Factors for Plant (p=3), Meat (p=4), and Milk (p=5) Pathways
                            Overhead Irrigation (q=4)

                   Area Factor for Plant Foods [FA(3)] = 0.50

                            The Depth Factor Value
                           FD(i,p,q,t) = 1.0000E+00
            is applicable for all radionuclides(i) and times(t).


          Area and Depth Factors for Meat (p=4) and Milk (p=5) Pathways
            Transfer from Livestock Water (q=5) and Soil (q=6) Intake

            Area Factor for Meat and Milk [FA(p),p=4,5] = 0.12

The livestock water subpathway (q=5) and livestock soil intake subpathway (q=6)
           occur only for the meat (p=4) and milk (p=5) pathways.


    Area and Depth Factors for Meat (p=4) and Milk (p=5) Pathways
      Transfer from Livestock Water (q=5) and Soil (q=6) Intake

            Area Factor for Meat and Milk [FA(p),p=4,5] = 0.12

The livestock water subpathway (q=5) and livestock soil intake subpathway (q=6)
           occur only for the meat (p=4) and milk (p=5) pathways.
```

```
Dose Conversion and Environmental Transport Factors for the Plant Food Pathway (p=3)
        Subpathway: Root Uptake from Contaminated Soil (q=1)

Parent Product  DCF(j,3)*            ETF(j,3,1,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________    _________ _________ _________ _________

H-3    H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========    ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Plant Food Pathway (p=3)
       Subpathway: Foliar Uptake from Contaminated Dust (q=2)

Parent Product  DCF(j,3)*            ETF(j,3,2,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________    _________ _________ _________ _________

H-3    H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========    ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Plant Food Pathway (p=3)
                 Subpathway: Ditch Irrigation (q=3)

Parent Product  DCF(j,3)*       ETF(j,3,3,t) * SF(j,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________    _________ _________ _________ _________

H-3    H-3      6.400E-08    2.658E+05 2.293E+05 5.897E+04 7.450E-02
====== =======  =========    ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Plant Food Pathway (p=3)
                Subpathway: Overhead Irrigation (q=4)

Parent Product  DCF(j,3)*       ETF(j,3,4,t) * SF(j,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________    _________ _________ _________ _________

H-3    H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========    ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.
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```
Dose Conversion and Environmental Transport Factors for the Meat Pathway (p=4)
     Subpathway: Fodder Root Uptake from Contaminated Soil (q=1)

Parent Product  DCF(j,4)*             ETF(j,4,1,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======  =======  =========    ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Meat Pathway (p=4)
    Subpathway: Fodder Foliar Uptake from Contaminated Dust (q=2)

Parent Product  DCF(j,4)*             ETF(j,4,2,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======  =======  =========    ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Meat Pathway (p=4)
                 Subpathway: Ditch Irrigation (q=3)

Parent Product  DCF(j,4)*        ETF(j,4,3,t) * SF(j,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      6.400E-08    4.159E+03 3.639E+03 9.356E+02 1.182E-03
======  =======  =========    ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Meat Pathway (p=4)
                Subpathway: Overhead Irrigation (q=4)

Parent Product  DCF(j,4)*        ETF(j,4,4,t) * SF(j,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      6.400E-08    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======  =======  =========    ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Meat Pathway (p=4)
                  Subpathway: Livestock Water (q=5)

Parent Product  DCF(j,4)*        ETF(j,4,5,t) * SF(j,t) (g/yr)
 (i)     (j)              t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      6.400E-08    8.921E+03 7.713E+03 1.983E+03 2.506E-03
======  =======  =========    ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.
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Dose Conversion and Environmental Transport Factors for the Milk Pathway (p=5)
     Subpathway: Fodder Root Uptake from Contaminated Soil (q=1)

Parent Product  DCF(j,5)*             ETF(j,5,1,t) (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ -------  ---------     --------- --------- --------- ---------
H-3    H-3      6.400E-08     0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Milk Pathway (p=5)
    Subpathway: Fodder Foliar Uptake from Contaminated Dust (q=2)

Parent Product  DCF(j,5)*             ETF(j,5,2,t) (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ -------  ---------     --------- --------- --------- ---------
H-3    H-3      6.400E-08     0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Milk Pathway (p=5)
                 Subpathway: Ditch Irrigation (q=3)

Parent Product  DCF(j,5)*        ETF(j,5,3,t) * SF(j,t) (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ -------  ---------     --------- --------- --------- ---------
H-3    H-3      6.400E-08     3.689E+03 3.211E+03 8.257E+02 1.043E-03
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Milk Pathway (p=5)
                Subpathway: Overhead Irrigation (q=4)

Parent Product  DCF(j,5)*        ETF(j,5,4,t) * SF(j,t) (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ -------  ---------     --------- --------- --------- ---------
H-3    H-3      6.400E-08     0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Milk Pathway (p=5)
                  Subpathway: Livestock Water (q=5)

Parent Product  DCF(j,5)*        ETF(j,5,5,t) * SF(j,t) (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------ -------  ---------     --------- --------- --------- ---------
H-3    H-3      6.400E-08     3.130E+04 2.693E+04 6.925E+03 8.749E-03
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.
```

```
Dose Conversion and Environmental Transport Factors for the Fish Pathway (p=6)

Parent Product  DCF(j,6)*         ETF(j,6,t) * SF(j,t) (g/yr)
 (i)     (j)             t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________   _________ _________ _________ _________

H-3    H-3      6.400E-08   9.497E+01 8.181E+01 2.104E+01 2.658E-05
====== =======  =========   ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.


Dose Conversion and Environmental Transport Factors for the Drinking Water Pathway (p=7)

Parent Product  DCF(j,7)*         ETF(j,7,t) * SF(j,t) (g/yr)
 (i)     (j)             t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________   _________ _________ _________ _________

H-3    H-3      6.400E-08   2.070E+06 1.781E+06 4.578E+05 5.784E-01
====== =======  =========   ========= ========= ========= =========

* - The dose conversion factor units are mrem/pCi.
```

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Dose/Source Ratios for Internal Radiation from Ingestion of Plant Foods (p=3)
       Subpathway:  Root Uptake from Contaminated Soil (q=1)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,3,1,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Plant Foods (p=3)
      Subpathway:  Foliar Uptake from Contaminated Dust (q=2)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,3,2,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Plant Foods (p=3)
               Subpathway:  Ditch Irrigation (q=3)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,3,3,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.701E-02 1.468E-02 3.774E-03 4.768E-09
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Plant Foods (p=3)
              Subpathway:  Overhead Irrigation (q=4)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,3,4,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Plant Foods (p=3)
                    Total for All Subpathways
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,3,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    1.701E-02 1.468E-02 3.774E-03 4.768E-09
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
    Subpathway:  Fodder Root Uptake from Contaminated Soil (q=1)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,4,1,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      1.000E+00     0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
   Subpathway:  Fodder Foliar Uptake from Contaminated Dust (q=2)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,4,2,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      1.000E+00     0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
               Subpathway:  Ditch Irrigation (q=3)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,4,3,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      1.000E+00     2.662E-04 2.329E-04 5.988E-05 7.565E-11
=======  =======  =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
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```
Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
              Subpathway:  Overhead Irrigation (q=4)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,4,4,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
-------  -------  ---------    --------- --------- --------- ---------
H-3     H-3      1.000E+00     0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
                 Subpathway:  Livestock Water (q=5)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,4,5,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    5.709E-04 4.937E-04 1.269E-04 1.604E-10
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Meat (p=4)
                     Total for All Subpathways
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch           DSR(j,4,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    8.371E-04 7.265E-04 1.868E-04 2.360E-10
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
    Subpathway:  Fodder Root Uptake from Contaminated Soil (q=1)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch        DSR(j,5,1,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
   Subpathway:  Fodder Foliar Uptake from Contaminated Dust (q=2)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch        DSR(j,5,2,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
                Subpathway:  Ditch Irrigation (q=3)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch        DSR(j,5,3,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    2.361E-04 2.055E-04 5.284E-05 6.676E-11
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
               Subpathway:  Overhead Irrigation (q=4)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch        DSR(j,5,4,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+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 ≤ 0.5 yr) daughters.
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Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
                 Subpathway:  Livestock Water (q=5)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch         DSR(j,5,5,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3      1.000E+00     2.003E-03 1.724E-03 4.432E-04 5.599E-10
======= ======= =========     ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.


Dose/Source Ratios for Internal Radiation from Ingestion of Milk (p=5)
                     Total for All Subpathways
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,5,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3      1.000E+00     2.239E-03 1.929E-03 4.960E-04 6.267E-10
======= ======= =========     ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from the Ingestion of Fish (p=6)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,6,t)  (mrem/yr)/(pCi/g)
 (i)      (j)   Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    6.078E-06 5.236E-06 1.346E-06 1.701E-12
======= ======= =========    ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
```

```
Dose/Source Ratios for Internal Radiation from the Ingestion of Drinking Water (p=7)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch           DSR(j,7,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3     1.000E+00     1.325E-01 1.140E-01 2.930E-02 3.702E-08
======= ======= =========     ========= ========= ========= =========
*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 ≤ 0.5 yr) daughters.
```

```
                 Plant/Air and Plant/Water Concentration Ratios

                      Mass loading [ASR(3)]: 1.000E-04 g/m**3
        Area Factor for Mass Loading [FA(2)]: 1.463E-01

Nuclide  FAR(i,3,2,1)  FAR(i,3,2,2)  FWR(i,3,3,1)  FWR(i,3,3,2)  FWR(i,3,4,1)  FWR(i,3,4,2)
  (i)       m**3/g        m**3/g          L/g           L/g           L/g           L/g
-------  ------------  ------------  ------------  ------------  ------------  ------------

H-3       5.4545E-02    2.6156E-01    7.2542E-04    1.0628E-03    0.0000E+00    0.0000E+00
=======  ============  ============  ============  ============  ============  ============
FAR(i,p,q,k) is the plant/air concentration ratio for airborne contaminated dust,
and FWR(i,p,q,k) is the plant/water concentration ratio.  See groundwater displays
for water/soil concentration ratios.


                Plant/Soil Concentration Ratios, FSR(i,3,q,k,t)

               Root Uptake (q=1) and Foliar Dust Deposition (q=2)
                  Nonleafy (k=1) and/or Leafy (k=2) Vegetables

              Nuclide(i)
            Parent Product  FSR(i,3,1,k)  FSR(i,3,2,1)  FSR(i,3,2,2)
            ------ -------  ------------  ------------  ------------

            H-3    H-3       4.8393E+00    7.9797E-07    3.8265E-06
            ====== =======  ============  ============  ============


           Plant/Soil Concentration Ratio, FSR(j,3,q,k,t)
                       Ditch Irrigation (q=3)

Parent  Product  Branch                FSR(j,3,3,k,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------

H-3     H-3      1.000E+00    2.944E+00 2.547E+00 6.550E-01 8.275E-07
======  =======  =========    ========= ========= ========= =========


           Plant/Soil Concentration Ratio, FSR(j,3,q,k,t)
     Overhead Irrigation (q=4) and Nonleafy Vegetables (k=1)

Parent  Product  Branch             FSR(j,3,4,1,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------

H-3     H-3      1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======  =======  =========    ========= ========= ========= =========


           Plant/Soil Concentration Ratio, FSR(j,3,q,k,t)
       Overhead Irrigation (q=4) and Leafy Vegetables (k=2)

Parent  Product  Branch             FSR(j,3,4,2,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------  -------  ---------    --------- --------- --------- ---------
```

```
           Plant/Soil Concentration Ratio, FSR(j,3,q,k,t)
        Overhead Irrigation (q=4) and Leafy Vegetables (k=2)

Parent  Product  Branch             FSR(j,3,4,2,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________    _________ _________ _________ _________

H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======= ======= =========    ========= ========= ========= =========
```

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Meat/Fodder, Milk/Fodder, Fodder/Air and Fodder/Water Concentration Ratios

     FI(4,q):   68.0 kg/day     FI(5,q):   55.0 kg/day   q=1,2,3,4
     FI(4,q):   50.0  L/day     FI(5,q):  160.0  L/day   q=5
     FI(4,q):    0.5 kg/day     FI(5,q):

Nuclide    FQR(i,4)      FQR(i,5)     FAR(i,3,2,3)  FWR(i,3,3,3)  FWR(i,3,4,3)
  (i)        d/kg          d/kg          m**3/g         L/g           L/g
-------  ------------  ------------  ------------  ------------  ------------
H-3       5.7426E-03    4.3120E-03    2.8659E-01    3.4283E-04    0.0000E+00
=======  ============  ============  ============  ============  ============
FI(p,q) are the fodder (q=1,2,3,4), livestock water (q=5) and soil (q=6) intake rates;
FQR(i,p) are the transfer coefficients from contaminated fodder of livestock
water to meat (p=4) or milk (p=5).  FAR(i,3,2,3) are the fodder/air
concentration ratios, and FWR(i,3,3,3) and FWR(i,3,4,3) are the fodder/
water concentration ratios for ditch and overhead irrigation, respectively.
```

```
   Fodder/Soil Concentration Ratios, QSR(i,p,q,t), for Meat and Milk Pathways
                 Root Uptake (q=1) and Foliar Dust Deposition (q=2)

                          Nuclide(i)
                       Parent Product  QSR(i,p,1)  QSR(i,p,2)
                       ______ _______  __________  __________

                       H-3    H-3      4.8393E+00  4.1927E-06
                       ====== =======  ==========  ==========


Fodder/Soil Concentration Ratio, QSR(j,p,q,t),for Meat and Milk Pathways
                          Ditch Irrigation (q=3)

Parent   Product  Branch              QSR(j,p,3,t)  * SF(j,t)
 (i)       (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______  _______  _________    _________ _________ _________ _________

H-3      H-3      1.000E+00    1.392E+00 1.392E+00 1.230E+00 1.220E+00
=======  =======  =========    ========= ========= ========= =========


Fodder/Soil Concentration Ratio, QSR(j,p,q,t),for Meat and Milk Pathways
                        Overhead Irrigation (q=4)

Parent   Product  Branch              QSR(j,p,4,t)  * SF(j,t)
 (i)       (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______  _______  _________    _________ _________ _________ _________

H-3      H-3      1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
=======  =======  =========    ========= ========= ========= =========


Fodder/Soil Concentration Ratio, QSR(j,p,q,t),for Meat and Milk Pathways
                          Livestock Water (q=5)

Parent   Product  Branch              QSR(j,p,5,t)  * SF(j,t)
 (i)       (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______  _______  _________    _________ _________ _________ _________

H-3      H-3      1.000E+00    4.059E+00 4.059E+00 3.520E+00 3.493E+00
=======  =======  =========    ========= ========= ========= =========
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                   Meat/Soil Concentration Ratios, FSR(i,4,q,t)
                Root Uptake (q=1) and Foliar Dust Deposition (q=2)

                        Nuclide(i)
                      Parent Product  FSR(i,4,1)  FSR(i,4,2)
                      ------ -------  ----------  ----------

                      H-3    H-3      0.0000E+00  0.0000E+00
                      ====== =======  ==========  ==========


            Meat/Soil Concentration Ratio, FSR(j,4,q,t)
                       Ditch Irrigation (q=3)

Parent  Product  Branch             FSR(j,4,3,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- -------  ---------    --------- --------- --------- ---------

H-3     H-3      1.000E+00    5.434E-01 4.768E-01 1.226E-01 1.549E-07
======= =======  =========    ========= ========= ========= =========


            Meat/Soil Concentration Ratio, FSR(j,4,q,t)
                     Overhead Irrigation (q=4)

Parent  Product  Branch             FSR(j,4,4,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- -------  ---------    --------- --------- --------- ---------

H-3     H-3      1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======= =======  =========    ========= ========= ========= =========


            Meat/Soil Concentration Ratio, FSR(j,4,q,t)
                       Livestock Water (q=5)

Parent  Product  Branch             FSR(j,4,5,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- -------  ---------    --------- --------- --------- ---------

H-3     H-3      1.000E+00    1.165E+00 1.011E+00 2.599E-01 3.284E-07
======= =======  =========    ========= ========= ========= =========
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                   Milk/Soil Concentration Ratios, FSR(i,5,q,t)
                Root Uptake (q=1) and Foliar Dust Deposition (q=2)

                        Nuclide(i)
                      Parent Product  FSR(i,5,1)  FSR(i,5,2)
                      ------ -------  ----------  ----------
                      H-3    H-3      0.0000E+00  0.0000E+00
                      ====== =======  ==========  ==========


             Milk/Soil Concentration Ratio, FSR(j,5,q,t)
                        Ditch Irrigation (q=3)

Parent  Product  Branch              FSR(j,5,3,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    3.300E-01 2.873E-01 7.388E-02 9.334E-08
======= ======= =========    ========= ========= ========= =========


             Milk/Soil Concentration Ratio, FSR(j,5,q,t)
                      Overhead Irrigation (q=4)

Parent  Product  Branch              FSR(j,5,4,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
======= ======= =========    ========= ========= ========= =========


             Milk/Soil Concentration Ratio, FSR(j,5,q,t)
                        Livestock Water (q=5)

Parent  Product  Branch              FSR(j,5,5,t) * SF(j,t)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
------- ------- ---------    --------- --------- --------- ---------
H-3     H-3     1.000E+00    2.800E+00 2.410E+00 6.196E-01 7.828E-07
======= ======= =========    ========= ========= ========= =========
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        Dose/Source Ratios for Soil Ingestion Pathway (p=8)
 Parent and Progeny Principal Radionuclide Contributions Indicated

Parent  Product  Branch          DSR(j,8,t)  (mrem/yr)/(pCi/g)
 (i)      (j)    Fraction* t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
_______ _______ _________     _________ _________ _________ _________

H-3     H-3      1.000E+00    0.000E+00 0.000E+00 0.000E+00 0.000E+00
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*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 ≤ 0.5 yr) daughters.


Dose Conversion and Environmental Transport Factors for the Soil Ingestion Pathway (p=8)

Parent Product  DCF(j,8)*              ETF(j,8,t)  (g/yr)
 (i)     (j)               t= 0.000E+00 1.000E+00 1.000E+01 1.000E+02
______ _______  _________     _________ _________ _________ _________

H-3    H-3      6.400E-08     0.000E+00 0.000E+00 0.000E+00 0.000E+00
====== =======  =========     ========= ========= ========= =========
* - The dose conversion factor units are mrem/pCi.
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