Appendix N

Wellfield Decommissioning Plan
for Crow Butte Uranium Project

Wellfield Decommissioning Plan
for
Crow Butte Uranium Project

NRC Source Material License SUA-1534

Docket No. 40-8943

June 2004

Prepared for:

Crow Butte Resources, Inc.

86 Crow Butte Rd.

P. O. Box 169

Crawford, Nebraska 69339-0169

Prepared by:

Environmental Restoration Group, Inc.

8809 Washington NE, Suite 150

Albuquerque, NM 87113

Table of Contents

		Page
1.0	Introduction	1
2.0	Crow Butte Project	3
2.1	Solution Mining Method and Recovery Process	3
2.2	Groundwater Restoration	7
2.3	Radioactive Effluents	7
2.4	Liquid and Solid Waste Generation	8
2.5	Spills	9
2.6	Natural Background Radionuclides in Soil	12
2.6.1	Pre-Operational Data	13
2.6.2	Gamma Surveys and Soil Sample Results in Reference Areas	13
3.0	Current Site Conditions	22
3.1	Gamma Surveys and Soil Sampling	22
3.2	Gamma Survey Results and Soil Sample Data	24
4.0	Wellfield Decommissioning	30
4.1	Well Plugging and Abandonment	30
4.2	Trunklines, Pipes, and Wellfield Equipment	31
4.3	Wellfield Buildings	32
5.0	Disposition Options and Release Surveys	33
5.1	Equipment, Pipe, and Materials to be Released for Unrestricted Use	33
5.2	Buildings to be Released for Unrestricted Use	34
5.3	Contaminated Equipment, Materials, and Buildings Transferred to Another Licensee	34
5.4	Contaminated Equipment, Materials, and Buildings Disposed of as Byproduct Material	35
6.0	Cleanup of Surface and Subsurface Soils	36
6.1	Cleanup Limit for Soils	36
6.1.1	Radiological Dose Assessment	37
6.1.2	Chemical Toxicity Assessment	39
6.2	Soil Cleanup and Verification	44
6.3	Gamma Action Level	44
6.4	Gamma Surveys for Characterization and Verification	48
6.4.1	Gamma Surveys and Mapping using a Global Positioning System	48
6.4.2	Radiological Surveys and Mapping Using Conventional Methods	49
6.5	Excavation Control Monitoring	49
6.6	Soil Cleanup Verification and Sampling Plan	49
6.6.1	Surface Soil Gamma Survey and Sampling Plan	49
6.6.2	Subsurface Soil Gamma Survey and Sampling Plan	52

6.7 Laboratory Quality Assurance 53

7.0 Radiation Safety Program 57
7.1 D&D Task Analysis 57
7.2 Personnel Training 58
7.3 Standard Operating Procedures 59
7.4 Air Monitoring and Respiratory Protection Programs 59
7.5 Radiation Work Permit (RWP) Program 59
7.6 Health Physics Surveys and Dose Calculations 60
7.7 Protective Clothing 61
7.8 Shipments of Radioactive Materials 61
7.9 Records and Reports 61

8.0 Environmental Impacts 62
8.1 Land Use 62
8.2 Air Quality 62
8.3 Wildlife 62
8.4 Surface Water 63
8.5 Archaeological Sites 63
8.6 Groundwater 63
8.7 Environmental Radiological Monitoring 63
8.8 Non-Radiological Impacts 64

9.0 References 65

Appendix A Radium Benchmark Dose Assessment

Table of Tables

		Page
Table 2-1	Mine Unit Status	6
Table 2-2	Radionuclide Concentrations in Injection Water Sample	10
Table 2-3	Reference Area Gamma Survey Data Summary	18
Table 2-4	Reference Area Sample Data	20
Table 3-1	Correlation Area Sample Data	25
Table 6-1	Proposed Limits for the Cleanup of Soils	39
Table 6-2	Annual Intake of Uranium from Ingestion	41
Table 6-3	Criteria for Comparison of Laboratory Results	56

Table of Figures

		Page
Figure 2-1	General Location of Facility	4
Figure 2-2	CBR Project Site	5
Figure 2-3	Reference Area Location Map	14
Figure 2-4	Reference Area 1 Survey Data and Sample Locations	15
Figure 2-5	Reference Area 4 Survey Data and Sample Locations	16
Figure 2-6	Reference Area Survey Data Histogram	17
Figure 3-1	Correlation Survey Area Location Map	23
Figure 3-2	Correlation Survey and Sample Locations for Survey Area 1	26
Figure 3-3	Correlation Survey and Sample Locations for Survey Area 2	27
Figure 3-4	Correlation Survey and Sample Locations for Survey Area 3	28
Figure 3-5	Correlation Survey and Sample Locations for Survey Area 4	29
Figure 6-1	Gamma Count Rate vs. Ra-226 Concentration Correlation with Upper and Lower 95% Confidence Lines	46
Figure 6-2	Exposure Rate vs. Gamma Count Rate Correlation	47

1.0 Introduction

Crow Butte Resources, Inc. (CBR) is required by the Nuclear Regulatory Commission (NRC) and the Nebraska Department of Environmental Quality (NDEQ) to decommission areas within the site boundary following completion of active mining. Part of this decommissioning involves the reclamation of a mine unit following successful completion of groundwater restoration activities. Reclamation involves proper plugging and abandonment of all wells within the mine unit boundary, removal of surface and subsurface structures, utilities, and pipelines, and removal of surface and subsurface radiological contamination.

The NDEQ has authority for groundwater protection including the proper plugging and abandonment of wells. Proper plugging and abandonment of the mining and monitor wells at Crow Butte is regulated under NDEQ Rules and Regulations, Title 122, *Rules and Regulations for Underground Injection and Mineral Production Wells* and CBR's Class III Underground Injection Control (UIC) Permit.

The NRC regulates the decommissioning of facilities and surface and subsurface soils for the cleanup of radiological contamination. Consideration of other hazardous materials is also required. The requirements for surface and subsurface reclamation are contained in 10 CFR Part 40 Appendix A. CBR's Source Materials License SUA-1534 further specifies actions that must be taken for release of facilities and decommissioning planning.

The purpose of this report is to provide instructions for wellfield reclamation that will ensure that CBR complies with the regulatory requirements of NRC.

On April 12, 1999, the U.S. Nuclear Regulatory Commission (NRC) issued a Final Rule (64 FR 17506) that requires the use of the existing soil Ra-226 standard to derive a dose criterion for the cleanup of byproduct material. The amendment to Criterion 6(6) of 10 CFR Part 40, Appendix A was effective on June 11, 1999. This "benchmark approach" requires that NRC licensees model the site-specific dose from the existing Ra-226

standard and then use that dose to determine the allowable quantity of other radionuclides that would result in a similar dose to the average member of the critical group. These determinations must then be submitted to NRC with the site reclamation plan or included in license applications. This report documents this approach for the Crow Butte Resources Project as well as incorporates other guidance included in NUREG-1569, Standard Review Plan for In Situ Leach Uranium Extraction License Applications (for citation, see NRC, 2003a in Section 9 of this document).

2.0 Crow Butte Project

The Crow Butte Project is permitted for portions of Sections 11, 12, 13, and 24 of Township 31 North, Range 52 West and Sections 18, 19, 20, 29, and 30 of Township 31 North, Range 51 West, Dawes County, Nebraska. The plant site is situated approximately 4.0 miles southeast of the City of Crawford. Figure 2-1 shows the general location of the facility and Figure 2-2 shows the Project Site.

The original development of what is now the Crow Butte Project was done by Wyoming Fuel Corporation, who constructed a Research and Development Facility in 1986. The project was subsequently acquired and operated by Ferret Exploration Company of Nebraska until May 1994, when the name was changed to Crow Butte Resources. This change was only a name change and not an ownership change.

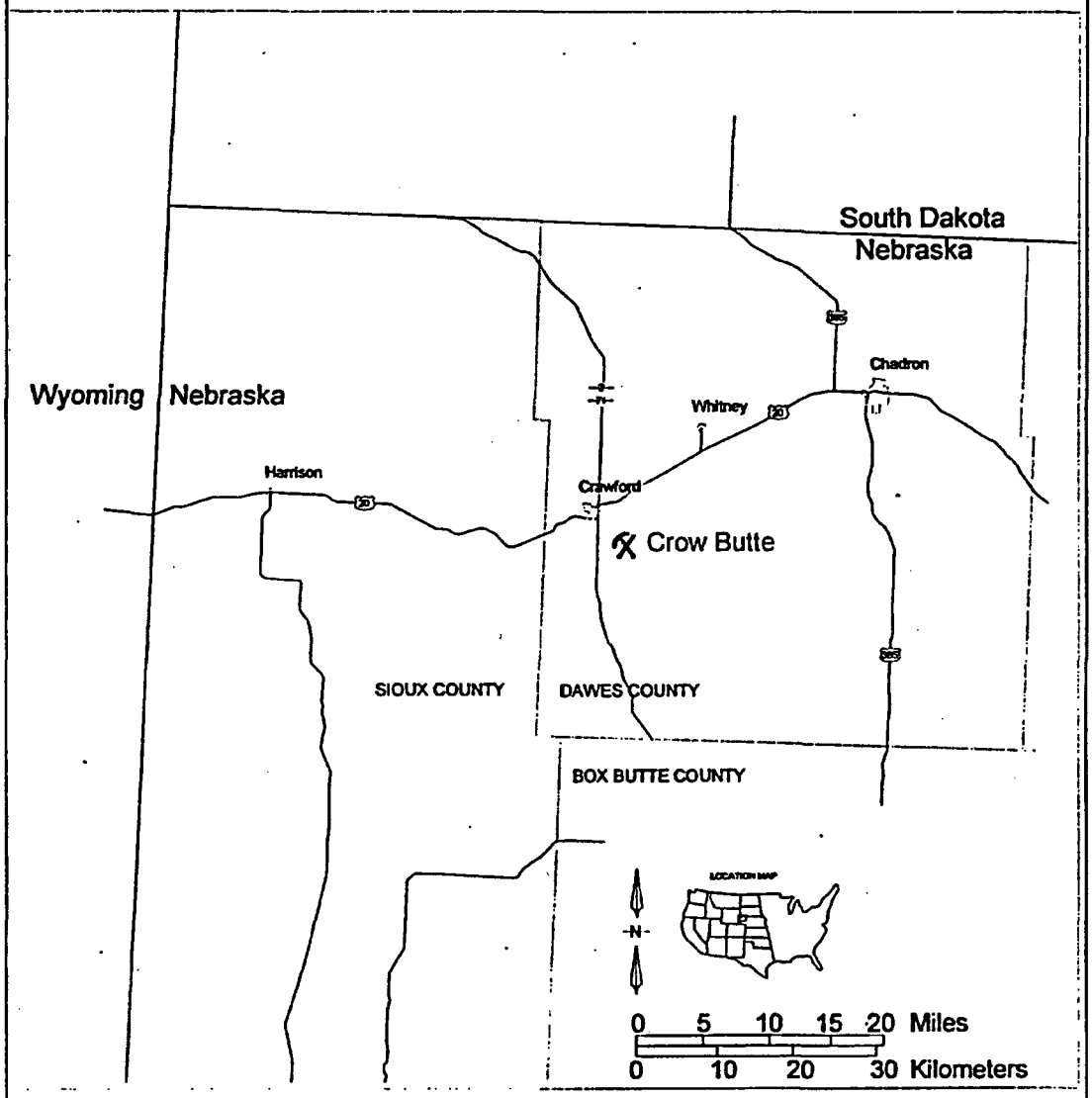
The Research and Development Facility was located in N/2 SE/4 of Section 19, T 31 N, R 51 W. Operations at this facility were initiated in July 1986, and mining took place in two wellfields (WF-1 and WF-2). Mining in WF-2 was completed in 1987 and restoration of that wellfield has been completed. WF-1 was incorporated into Mine Unit One of Commercial Operations.

The production wellfield is located within the permit area as shown in Figure 2-2. The process plant is located in Section 19, Township 31 North, Range 51 West, Dawes County, Nebraska. The permit area is approximately 2,800 acres and the surface area affected over the estimated life of the project is approximately 500 acres.

2.1 Solution Mining Method and Recovery Process

Uranium is recovered by in-situ leaching from the Basal Chadron Sandstone at a depth that varies from 400 feet to 800 feet over the permit area. The overall width of the mineralized area varies from 1000 feet to 5000 feet. The ore body ranges in grade from less than 0.05 to greater than 0.5% U_3O_8, with an average grade estimated at 0.26% equivalent U_3O_8 and 0.31% chemical U_3O_8.

Figure 2-1 CBR General Location



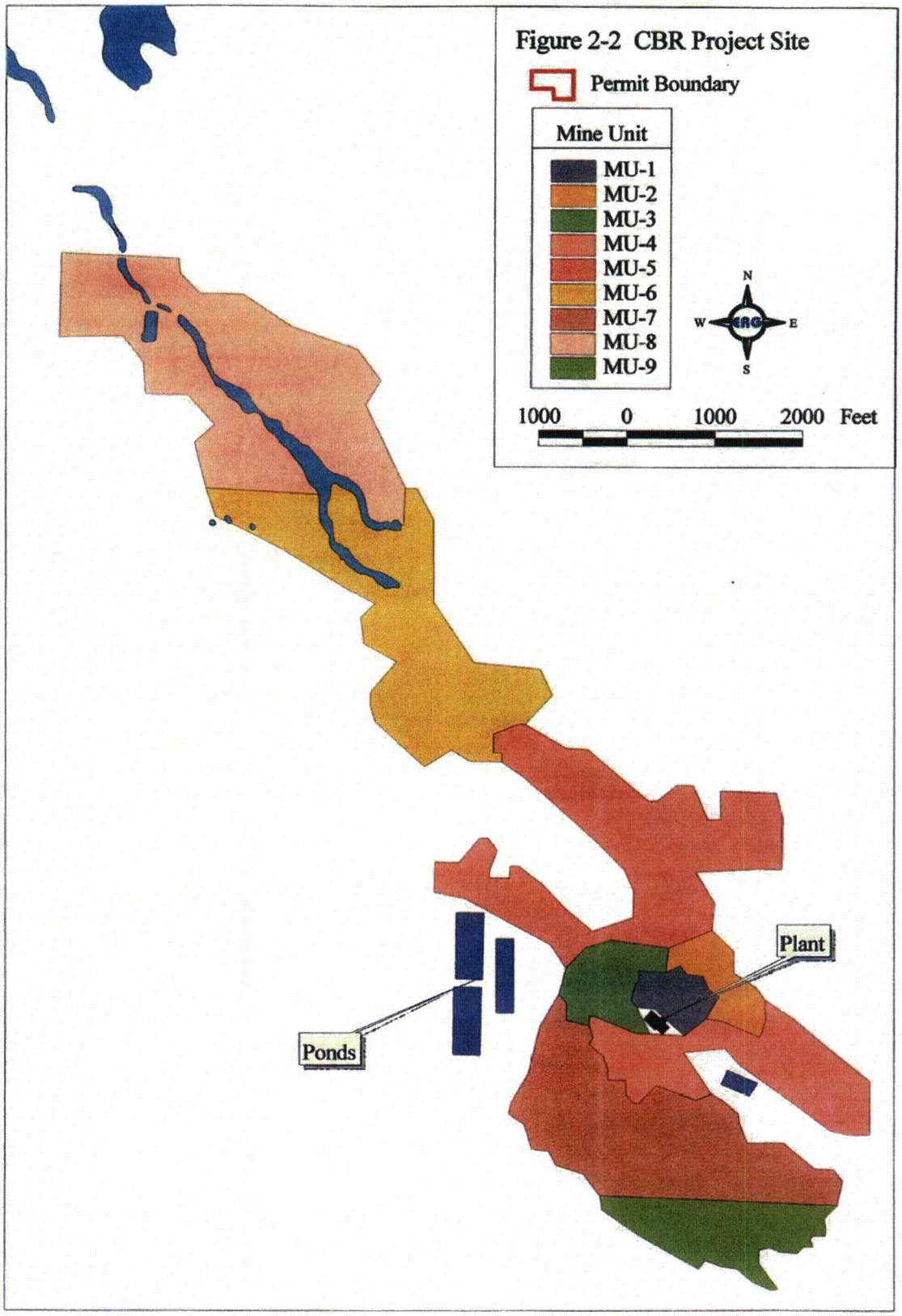


Figure 2-2 CBR Project Site
Permit Boundary
Mine Unit
MU-1
MU-2
MU-3
MU-4
MU-5
MU-6
MU-7
MU-8
MU-9
N
W
E
S
1000
0
1000
2000
Feet
Plant
Ponds

C01

The in-situ leaching process consists of an oxidation step and a dissolution step. Gaseous oxygen or hydrogen peroxide is used to oxidize the uranium, and bicarbonate is used for dissolution. The uranium bearing solution that results from the leaching of uranium underground is recovered from the wellfield and the uranium extracted in the process plant. The plant process uses the following steps:

- Loading of uranium complexes onto ion exchange resin;
- Reconstitution of the solution by the addition of bicarbonate and oxygen;
- Elution of the uranium complexes from the resin;
- Drying and packaging of the uranium.

Sufficient reserves have been estimated to allow mining operations to continue for 10 to 25 years. Status of the current mine unit operations is shown in Table 2-1.

Table 2-1 Mine Unit Status

Mine Unit	Production Initiated	Current Status
Mine Unit 1	April 1991	GroundwaterRestoration Complete
Mine Unit 2	March 1992	Under Restoration
Mine Unit 3	January 1993	Under Restoration
Mine Unit 4	March 1994	Under Restoration
Mine Unit 5	January 1996	Production
Mine Unit 6	March 1998	Production
Mine Unit 7	July 1999	Production
Mine Unit 8	July 2002	Production
Mine Unit 9	October 2003	Production

2.2 Groundwater Restoration

Restoration activities are performed concurrently with mining activities. The restoration process used to successfully restore the R & D Wellfield and Mine Unit No. 1 will be continued. The method consists of four basic activities:

- **Groundwater transfer-** groundwater is transferred between the mining unit commencing restoration and a mine unit commencing production or another water source.

- **Groundwater sweep-** water is pumped from the wellfield which results in an influx of baseline quality water from the wellfield perimeter.

- **Groundwater treatment-** water from injection wells is pumped to the restoration plant where ion exchange, reverse osmosis, filtration or other treatment methods take place.

- **Wellfield recirculation-** water is recirculated by pumping from the production wells and reinjecting the recovered solution. This will act to homogenize the quality of the aquifer.

Following these restoration phases, a groundwater stabilization monitoring program is initiated. Once the restoration values are reached and maintained, restoration is deemed complete. Groundwater restoration activities are conducted under plans submitted to and approved by the NRC and the NDEQ.

2.3 Radioactive Effluents

The only radioactive airborne effluent at the Crow Butte Project is Rn-222 gas. As yellowcake drying and packaging is carried out using a vacuum dryer, there are no airborne effluents from that system.

The Rn-222 is contained in the pregnant lixiviant that comes from the wellfield to the process plant. The majority of this radon is released in the ion exchange columns and process tanks. These vessels are covered and vented to a manifold, which are in turn exhausted to atmosphere outside the building through stacks. The manifolds are equipped with an exhausting fan.

2.4 Liquid and Solid Waste Generation

There are three sources of wastewater and three wastewater disposal options for the Crow Butte Project. The specific method utilized depends upon the volume and characterization of the waste stream.

The operation of the process facility results in three sources of water that are collected on the site. They include the following:

- **Water generated during well development** - This water is recovered groundwater that has not been exposed to any mining process or chemicals. The water is discharged directly to one of the solar evaporation ponds where silt, fines and other suspended matter collected during well development settles out. This water may be land applied.

- **Liquid process waste** - The operation of the process plant results in two primary sources of liquid waste, an eluant bleed and a production bleed. This water is also routed to the evaporation ponds or injected into the deep well.

- **Aquifer restoration** - Following mining operations, restoration of the affected aquifer commences which results in the production of wastewater. The restoration waste is primarily brine from the reverse osmosis unit, which is sent to the waste disposal system. The permeate is either reinjected into the wellfield or sent to the waste disposal system.

Domestic liquid waste is disposed of in an approved septic system.

Solid wastes generated at the site consist of spent resin, resin fines, empty reagent containers, miscellaneous pipe and fittings, and domestic waste. These wastes are classified as contaminated or non-contaminated waste according to their survey results. Contaminated wastes that cannot be decontaminated are stored until they can be shipped to a licensed waste disposal site or licensed mill tailings facility. Non-contaminated solid waste is collected on the site on a regular basis and disposed of in a sanitary landfill.

2.5 Spills

CBR's NRC License requires that all spills of source or 11e.(2) byproduct material and all spills of process chemicals be documented. Radioactive material releases that meet the reporting criteria in 10 CFR 20, Subpart M and 10 CFR §40.60 must be reported to the NRC Operations Center. The license also requires that CBR notify the NRC Project Manager by telephone or electronic mail within 48 hours of any significant spill that may have a radiological impact on the environment and that is reportable to other State or Federal agencies.

The major source of radioactive material releases in the wellfields are broken pipelines that contain injection or production fluid. The potential impact of a radioactive materials release is influenced by several factors such as magnitude of the release, the concentration of radionuclides in the release, and the location of the release. The majority of spills originate in the injection circuit which is under high pressure. A sample of injection water was taken on April 15, 2004 and submitted to a vendor laboratory for analysis. The results are shown in Table 2-2 below.

Table 2-2 Radionuclide Concentrations in Injection Water Sample

Radionuclide	Concentration (pCi/L)	Reporting Limit (pCi/L)
Uranium	4.7	0.2
Ra-226	1140	0.2
Th-230	ND *	0.2
Pb-210	49	2.7

ND – nondetectable at the reporting limit of 0.2 pCi/L

The levels in the production fluid are expected to be similar to the injection water other than the uranium concentrations are much higher, averaging approximately 30,000 pCi/L.

The spill response procedure requires immediate response once a spill has been discovered. A sample of any water that has pooled is taken to verify that it is a process solution. Any water that has pooled is retrieved with a vacuum trailer and placed in the evaporation ponds. The volume of recovered water is recorded.

After all standing water is removed, a measurement of the extent of the release is made and a detailed diagram drawn. Saturation depth measurements are made at several locations to allow determination of an average depth of saturation. A worksheet is prepared showing the exact location of the release, the affected area, the quantity of material released, a description of how the release occurred and how it was discovered.

A data base is maintained that includes the following:

- Release date
- Release location
- Name of individual entering data
- Release area (in square feet)
- Release depth (in inches)
- Injection or Production solution

The following additional information is not required, but is recorded if known:

- Release volume (if estimated from operating data)
- Release volume recovered (if any)
- Solution uranium activity (if known from samples of release)
- Solution Ra-226 activity (if known from samples of release)

A gamma survey is performed and documented. If the results of the gamma survey indicate levels in excess of 20 μR/hr above background, soil sampling may be performed to determine the soil Ra-226 and U-nat concentrations (at the discretion of the RSO).

In release areas adjacent to active wellheads, high background gamma levels from contaminated piping may prevent accurate gamma survey results. Normally these areas are not cleaned up after each release due to the on-going potential for contamination from subsequent releases and the presence of buried utility lines. For these release areas, no soil samples are taken but the release reports are maintained in the Decommissioning File as required by 10 CFR 40.36.

If soil sampling indicates that the Ra-226 concentration exceeds the criteria for final site cleanup standards, the RSO will determine the appropriate corrective actions. Any soil that requires cleanup is treated as byproduct material and handled and disposed of properly.

Following completion of radiological surveys and release reports, the RSO ensures that the following information has been gathered and recorded in the decommissioning file:

- Date
- Release volume
- Total activity of each radionuclide released
- Corrective actions

- Results of remediation surveys
- Map showing release location and impacted area

Records of releases are maintained until NRC license termination. The RSO is responsible for maintaining the release records.

For the four calendar years beginning in the year 2000, 104 spills were reported, releasing an estimated 90,657 gallons of water.

2.6 Natural Background Radionuclides in Soil

USNRC Regulatory Guide 4.14, Section 1.1.4 specifies that one set of pre-operational surface soil samples should be collected to a depth of five centimeters at 300-meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area, and at each of the air particulate sampling locations. This requirement results in the collection of a minimum of 41 surface soil samples. All pre-operational soil samples are to be analyzed for Ra-226. In addition, all soil samples collected from the air particulate sampling locations, plus ten percent of all other soil samples, are to be analyzed for U-nat, Th-230, and Pb-210. The pre-operational data are intended to be compared with data collected during plant operations. The pre-operations data requirements for the Crow Butte Facility were adjusted somewhat to be appropriate for the potential releases from this ISL facility.

MARSSIM (NRC, 2000) recommends that background soil samples be collected to a depth of 15 centimeters (6 inches). The greater depth recommended by MARSSIM is based on the pathway models which consider plow mixing and crop growth to be over a 0 to 15 cm depth. Additionally, NUREG-1569 specifies in Section 2.9.3 that background soil samples must be collected from both 5-cm depth in conformance with Regulatory Guide 4.14 for operations purposes, and 15 cm for decommissioning purposes. Therefore, additional background samples were collected using MARSSIM guidance.

2.6.1 Pre-Operational Data

In July, 1982, 50 surface (to a depth of 5 centimeters) soil samples were collected in and around the permit area and from the air particulate sampling stations. All 50 samples were analyzed for U-nat and Ra-226. The uranium concentrations ranged from 0.36 to 6.7 pCi/g, and averaged 1.6 ± 1.1 pCi/g (1 standard deviation). It was noted at the time that the sample with the highest uranium concentration, 6.7 pCi/g, was collected from a compacted dirt driveway of a local motel. This datum should probably be considered unrepresentative and discarded. The Ra-226 concentrations ranged from 0.1 to 2.0 pCi/g, and averaged 1.1 ± 0.3 pCi/g. These data were considered typical of background concentrations expected for the area.

2.6.2 Gamma Surveys and Soil Sample Results in Reference Areas

Background studies were conducted by ERG personnel from May 10-14, 2004. Four reference areas were selected which were considered to be non-impacted from site operations and representative of the site physically, chemically, geologically, radiologically, and biologically. The four reference areas include areas near the northern and southern boundaries of the current permitted area as shown in Figure 2-3.

A gamma scanning survey was first conducted over each reference area using transect lines spaced at two-meter intervals and a walking speed of about one meter per second. A Ludlum Model 44-10 2-inch by 2-inch NaI detector was coupled to a Ludlum Model 2221 ratemeter/scaler. Gamma-ray count rates were recorded at one-second intervals. The gamma survey data maps for Areas 1 and 4 are shown in Figures 2-4 and 2-5. A histogram of the gamma-ray survey data for the four reference areas is presented in Figure 2-6. These figures demonstrate that the gamma-ray levels are fairly uniform across the surface of the four reference areas. Table 2-3 summarizes the gamma scanning survey data in tabular form. The number of gamma-ray survey points for the four reference areas ranged from 265 to 423. The average count rate ranged from 13,977 cpm to 14,503 cpm. The standard deviation of the count rate data ranged from 774 to 832.

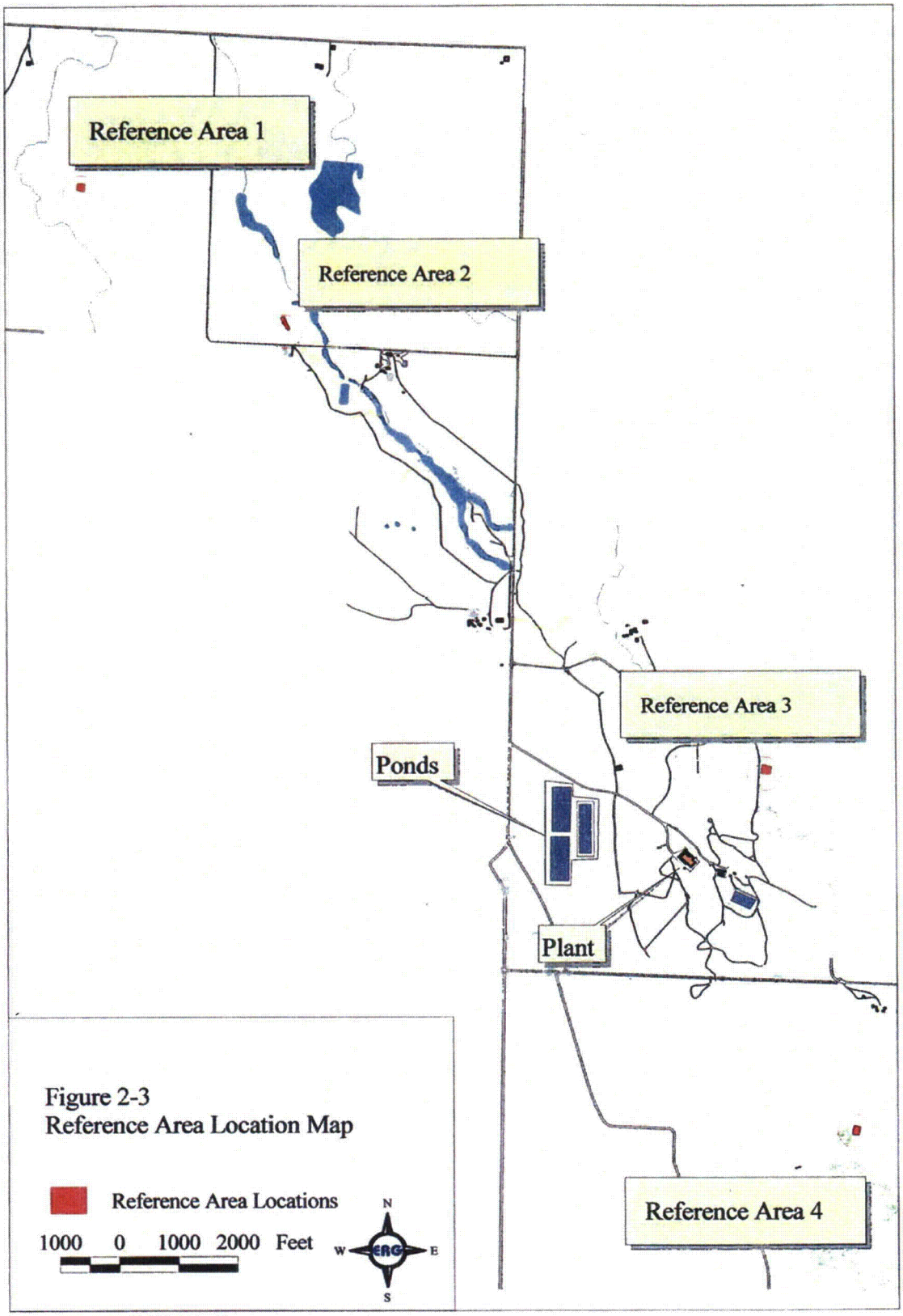


Figure 2-3
Reference Area Location Map

C02

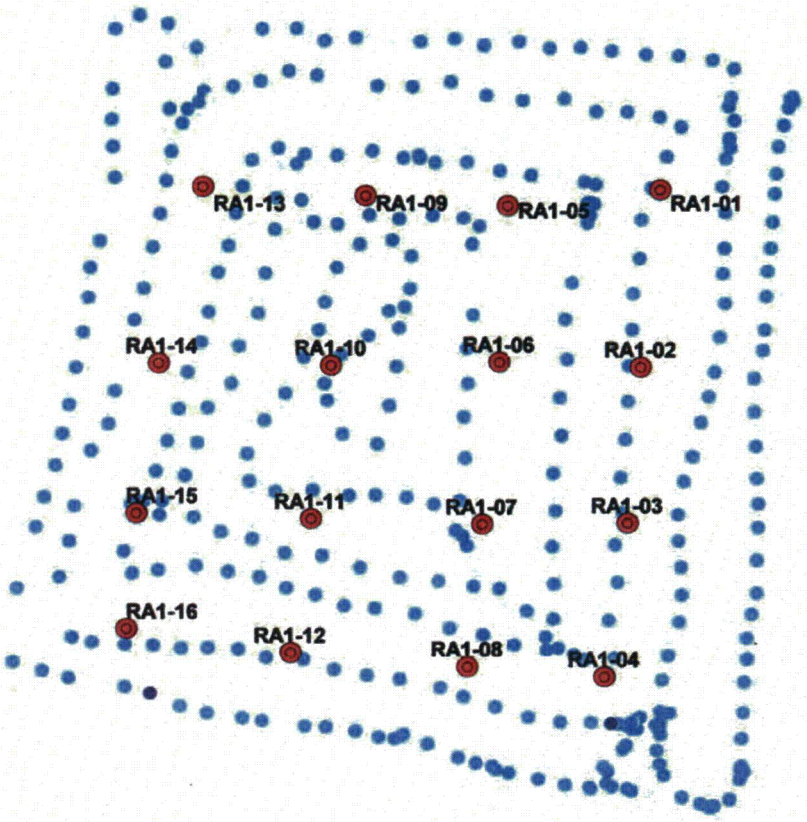


Figure 2-4
Reference Area 1
Survey & Sample Locations

Reference Area Sample Locations

Gamma Survey (CPM)

- < 13,000
- 13,000 - 16,000
- 16,000 - 19,000
- 19,000 - 22,000
- 22,000 - 25,000
- 25,000 - 28,000
- > 28,000

N W E S

25 0 25 Feet

C03

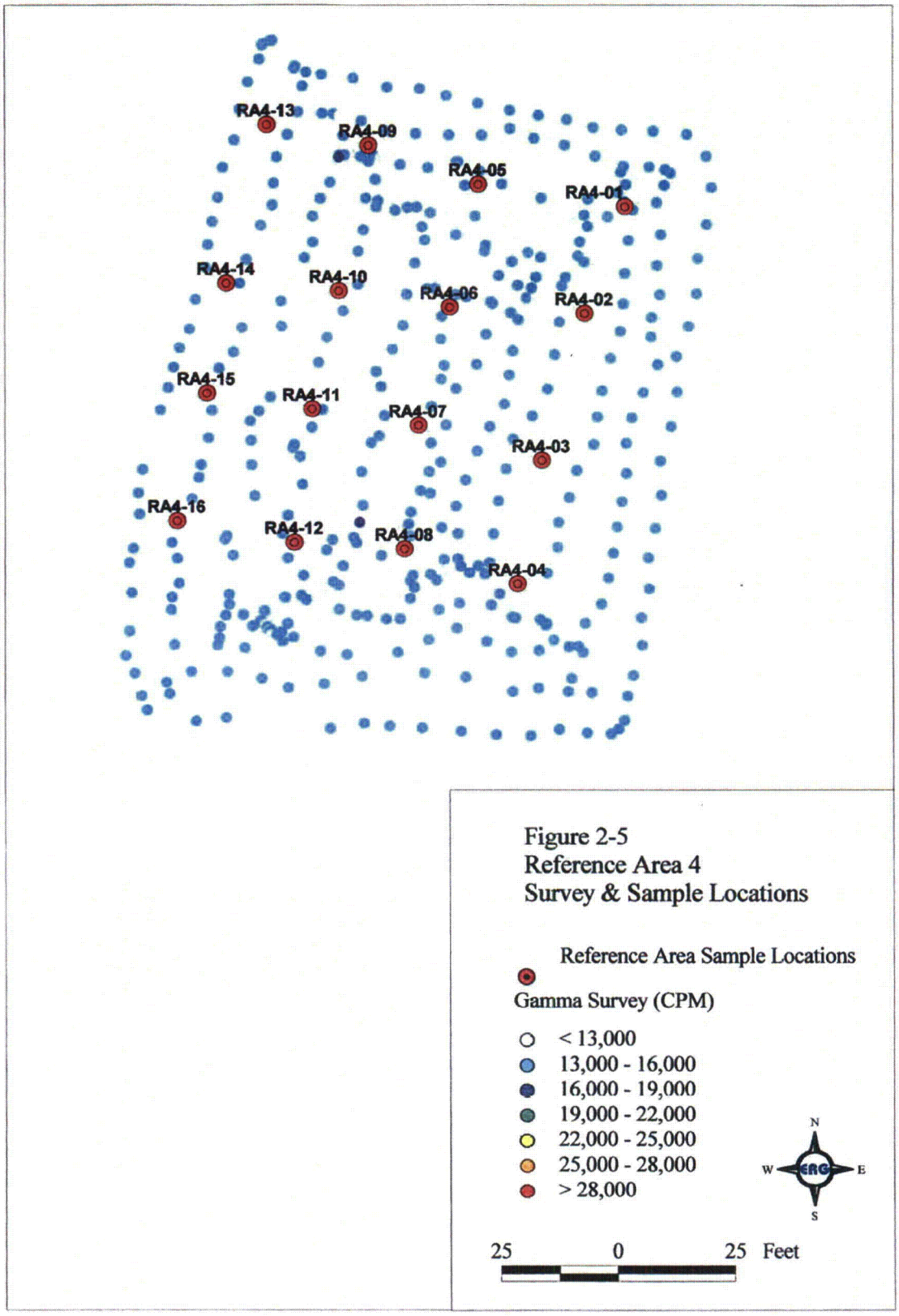


Figure 2-5
Reference Area 4
Survey & Sample Locations

C04

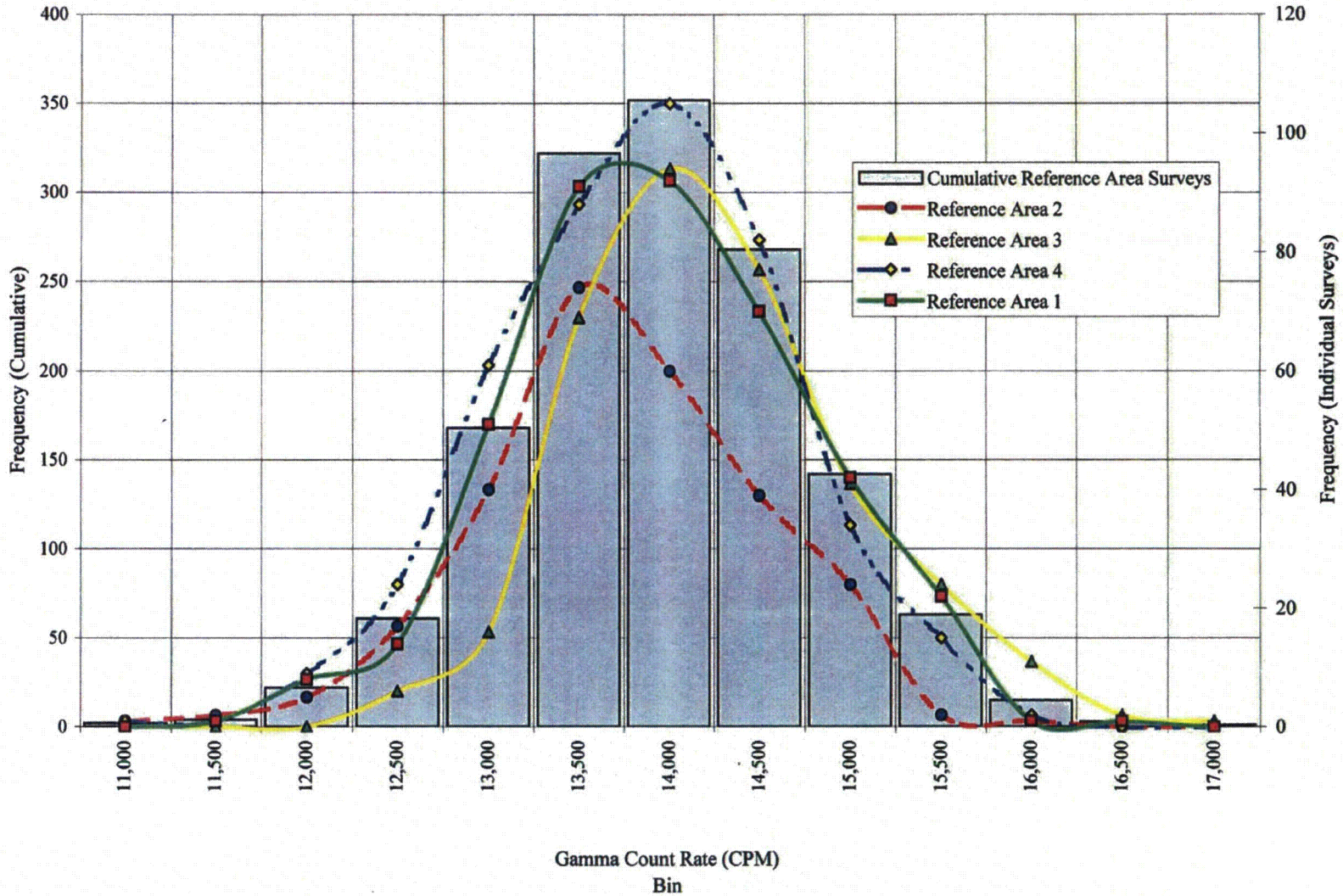


Figure 2-6 Reference Area Survey Data Histogram

05

Table 2-3 Reference Area Gamma Survey Data Summary

Location	Population Size (n)	Avg. Ratemeter Count Rate (cpm)	Standard Deviation
RA-1	393	14199	803
RA-2	265	13977	775
RA-3	341	14503	744
RA-4	423	14098	832

A casual review of the gamma count rate data leads to the conclusion that the four reference areas appear to have uniform background gamma-ray radiation levels, and therefore uniform concentrations of naturally occurring radionuclides. To assess the accuracy of this conclusion, a more detailed characterization of Reference Area 1 and Reference Area 4 was performed. Sixteen survey points were uniformly spaced across the areas for additional study. These survey points are identified as RA1-1 through RA1-16, and RA4-1 through RA4-16 on Figures 2-4 and 2-5, respectively. At these survey points, a static one-minute gamma-ray count was collected using the same portable instruments as the scanning survey. The difference between the measurements is that the scanning survey data is the estimated cpm from a one second count time, whereas the static measurement is a true one-minute data collection. The exposure rate was also measured at a height of 18 inches above each survey point using a Ludlum Model 19. After gamma-ray and exposure rate data were recorded, a soil sample was collected to a depth of six inches (15 cm) using a 5-point composite sampling method. These soil samples were analyzed by a vendor laboratory for total uranium, Ra-226, and Pb-210. The static gamma-ray count, exposure rate, and laboratory analyses for each survey point is presented in Table 2-4.

Any difference in the mean radionuclide concentration between the survey unit and the reference area will be interpreted as caused by residual radioactivity from site activities. If there is a significant variability in background concentration, or when there is a significant difference in backgrounds between reference areas, then the NRC recommends that a Kruskal-Wallis (K-W) test be conducted to determine whether there

are, in fact, significant differences in the mean background between the reference areas. The K-W test is described in NUREG-1505 (NRC, 1997). The test assumes that if the distribution of the measurements in each reference areas are the same, then the average rank for each reference area should also be about the same. A Kruskal-Wallis statistic (K) for each survey unit is calculated, which is a measure of how different the reference areas are from each other. While NUREG-1505 does not recommend a specific value of K_c, the critical value, the NRC staff recommends in DG-4006 (NRC, 1998a) a Type I error rate of an a_{kw}=0.2. From Table 13.3 of NUREG-1505, given that two reference areas are being compared at CBR and an a_{kw} of 0.2, the acceptable K_c is 1.6.

A K-W statistical test was performed on the static one minute gamma-ray data, the Ra-226 soil sample results, and the total uranium soil sample results presented in Table 2-4. In the case of the Ra-226 and total uranium data, several of the analytical results were identical. Abelquist, 2001 (page 134) states "when ranking, if several measurements are tied, they are all assigned the average rank of that group of tied measurements". Also, in the case of total uranium data, several of the analytical results were reported as not detectable at the reporting limit of 0.3 pCi/g. For ranking purposes, the data were ranked as if the concentration reported was 0.3 pCi/g. The K for each measurement type was calculated with the results as follows:

- One minute gamma-ray count rate K = 9.5
- Ra-226 soil data K = 13.1
- Total uranium soil data K = 21.4

In all three statistical tests, the calculated K significantly exceeds the critical value of 1.6. This suggests that the reference areas do have significantly different distributions of gamma-ray count rates and soil concentrations.

While these tests demonstrate that the distribution of all three measurements in Reference Areas 1 and 4 are statistically different, another question to consider is are these differences in backgrounds significant? Guidance presented in Section 2.3.1 of NUREG-

Table 2-4 Reference Area Sample Data

Reference Area 1

Sample ID	1-Minute Integrated Count (cpm)	Exposure Reading (µR/hr)	Pb-210 (pCi/g) *	Ra-226 (pCi/g)	Uranium (pCi/g)	Ra-226 : Uranium Ratio
RA1-01	14317	17	ND	0.8	0.5	1.5
RA1-02	14434	18	ND	0.7	0.5	1.5
RA1-03	14381	17	ND	0.7	0.4	1.7
RA1-04	14373	18	ND	0.6	0.5	1.3
RA1-05	14518	18	ND	0.6	0.5	1.3
RA1-06	14113	17	ND	0.6	0.4	1.5
RA1-07	14543	18	ND	0.6	0.4	1.5
RA1-08	14177	18	ND	0.7	0.5	1.5
RA1-09	14339	18	ND	0.8	0.5	1.7
RA1-10	13967	17	ND	0.6	0.4	1.5
RA1-11	14191	17	ND	0.4	0.4	1.0
RA1-12	14208	16	ND	0.5	0.4	1.2
RA1-13	13842	16	ND	0.6	0.5	1.3
RA1-14	13767	16	ND	0.5	0.4	1.2
RA1-15	13820	17	ND	0.7	0.4	1.7
RA1-16	13496	16	ND	0.8	0.5	1.7
Average	*14155*	*17*		*0.6*	*0.4*	*1.4*
Std. Dev.	*291*	*0.8*		*0.1*	*0.0*	*0.2*

Reference Area 4

Sample ID	1-Minute Integrated Count (cpm)	Exposure Reading (µR/hr)	Pb-210 (pCi/g) *	Ra-226 (pCi/g)	Uranium (pCi/g) **	Ra-226 : Uranium Ratio
RA4-01	13784	17	ND	0.5	0.4	1.2
RA4-02	13778	16	ND	0.6	** *0.3*	1.8
RA4-03	13810	16	ND	0.5	** *0.3*	1.5
RA4-04	13873	16	ND	0.4	0.4	1.0
RA4-05	13808	18	ND	0.7	0.4	1.7
RA4-06	14096	17	ND	0.6	0.3	1.8
RA4-07	13936	17	ND	0.5	** *0.3*	1.5
RA4-08	13732	16	ND	0.4	** *0.3*	1.2
RA4-09	14086	17	ND	0.5	0.3	1.5
RA4-10	13730	16	ND	0.5	0.4	1.2
RA4-11	13843	16	ND	0.4	** *0.3*	1.2
RA4-12	13550	17	ND	0.4	0.3	1.2
RA4-13	14094	16	ND	0.7	0.4	1.7
RA4-14	13781	17	ND	0.5	0.3	1.5
RA4-15	13782	17	ND	0.4	** *0.3*	1.2
RA4-16	13870	16	ND	0.4	0.4	1.0
Average	*13847*	*17*		*0.5*	*0.4*	*1.4*
Std. Dev.	*142*	*0.6*		*0.1*	*0.0*	*0.3*

** ND - nondetectable at the reporting limit of 0.2 pCi/g*
*** 0.3 - nondetectable at the reporting limit of 0.3 pCi/g*

CR/5849 (NRC, 1998b) indicates that if the sum of the mean background and 2 standard deviations of the measurements is less than 10% of the DCGL, variations in background can be considered insignificant. This is the case for the total uranium analyses where the average concentrations and standard deviations for Reference Areas 1 and 4 are 0.5 ± 0.1 pCi/g, and 0.3 ± 0.1 pCi/g respectively and the DCGL is 240 pCi/g. These differences are clearly insignificant. For Ra-226, the average concentrations for Reference Areas 1 and 4 are 0.6 ± 0.1 pCi/g and 0.5 ± 0.1 pCi/g, respectively, and the DCGL is 5 pCi/g. While this comparison is not quite as conclusive, the same argument can be made that the variability in radium background can be neglected for cleanup comparison purposes. A radium background concentration of 0.55 pCi/g is proposed.

3.0 Current Site Conditions

A characterization survey was conducted in May 2004 to provide information needed to develop a final verification plan for contaminated soils. Spill areas within the wellfields and near evaporation ponds were surveyed in an effort to collect data used to develop a gamma count rate to radionuclide soil concentration correlation. This correlation will assist in interpreting the radiological survey data and to develop a gamma-ray action level. Four areas were chosen for survey and soil sampling. Figure 3-1 shows the four areas relative to the overall site. Spill areas involving large quantities of injection well solution were selected. Spills in the proximity of contaminated piping, such as next to the wellheads or trunklines, were not considered since the gamma shine from such features would influence the correlation.

3.1 Gamma Surveys and Soil Sampling

Each area was surveyed using a 2-inch by 2-inch NaI detector (Ludlum Model 44-10), coupled to a Ludlum Model 2221 ratemeter/scaler and a Trimble ProXRS GPS unit. The survey system automatically logged individual gamma count rates with a corresponding coordinate every one second. The GPS system was placed into a backpack and was worn by field personnel while walking at a rate of approximately 2.5 feet per second over the area to be surveyed. The data were managed using ArcView GIS, a geographic information system computer application for managing, displaying, and analyzing data geographically. After review of the survey data maps, the area was further scanned with only the Ludlum Model 2221 and 44-10 to identify locations within a specific range of gamma readings from which to sample. The coordinates of each sample location were recorded using the GPS. A one-minute integrated gamma count was taken using the 2221 and 44-10 at eighteen inches above the sample location. An exposure-rate reading was taken with a Ludlum Model 19 at eighteen inches above the sample location. Lastly, a five point composite surface to 15-cm deep sample was taken. One sample was taken directly beneath the detector and the four other samples were taken at points extending in the compass directions eighteen inches from the center.

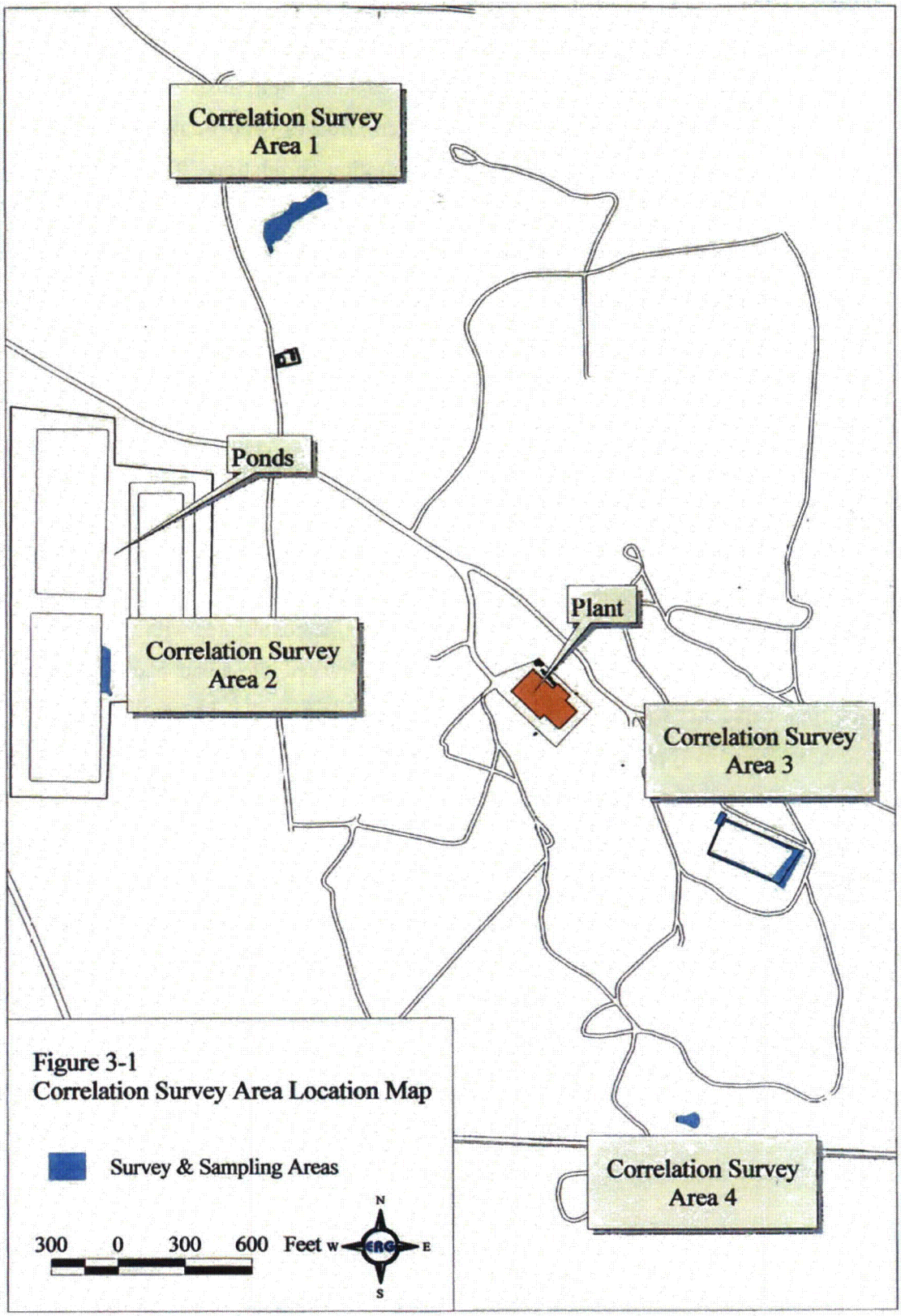


Figure 3-1
Correlation Survey Area Location Map

C06

3.2 Soil Sample Data and Gamma Survey Results

A total of fifteen soil samples were taken from the four correlation survey areas. The results of the one-minute integrated counts, exposure rates, and soil concentrations are shown in Table 3-1. Figures 3-2 through 3-5 show the GPS-radiological survey and correlation sample locations for each of the four areas. Each color dot in the figures represents a recorded count rate within one of the count-rate ranges given in the legends of the figure. Of the few locations that indicate elevated gamma levels, some are near pipes or other gamma-emitting sources. The correlation survey resulted in over 2100 individual gamma records with associated coordinates. The maximum reading observed was 28,272 cpm in Area 4 while the minimum reading was 10,411 cpm in Area 1.

Four samples were taken from Area 1 where a trunkline had leaked and solution had run down the hillside. At Area 2 three samples were taken from a location between two evaporation ponds currently in use. There were three samples taken at Area 3, next to the pilot plant evaporation pond. At Area 4, five samples were taken in an area where a large trunkline spill had occurred. Several elevated areas were not suitable for correlation studies since the source of gamma rays were from nearby process components or from a spill of a very concentrated material in a small localized area.

The high Ra-226 to U-nat concentration ratios for the data in Table 3-1 suggest that all spills were from injection water with the exception of Area 2, which was not wellfield water line spill related. The contamination in Area 2 is believed to have arisen from spillage while transferring water from one evaporation pond to another.

Table 3-1 Correlation Area Sample Data

Correlation Area	Sample ID	1-Minute Integrated Count (cpm)	Exposure Rate (µR/hr)	Pb-210 (pCi/g)	Ra-226 (pCi/g)	Uranium (pCi/g)	Ra-226:U-nat Ratio	Average Ratio
1	CBR-CS-01	16330	20	ND	3.4	0.9	3.6	3.3
	CBR-CS-02	15911	19	ND	4.6	1.4	3.2	
	CBR-CS-03	13868	17	ND	0.7	0.5	1.3	
	CBR-CS-04	17359	21	ND	4.1	0.8	5.0	
4	CBR-CS-05	35132	40	1.5	53.0	1.6	32.6	26.2
	CBR-CS-06	29930	34	ND	45.0	1.8	25.6	
	CBR-CS-07	21756	27	ND	29.0	1.4	20.4	
	CBR-CS-08	19504	24	ND	10.0	1.2	8.2	
	CBR-CS-09	15712	19	ND	0.8	1.0	0.8	
2	CBR-CS-10	16233	19	ND	0.9	3.1	0.3	0.2
	CBR-CS-11	17070	19	ND	1.2	7.6	0.2	
	CBR-CS-12	17981	20	1.2	1.0	11.3	0.1	
3	CBR-CS-13	21606	25	3.9	10.0	1.5	6.7	5.7
	CBR-CS-14	18462	21	2.7	5.0	1.0	4.9	
	CBR-CS-15	23223	27	4.5	11.0	2.0	5.4	

** ND - nondetectable at the reporting limit of 0.2 pCi/g*

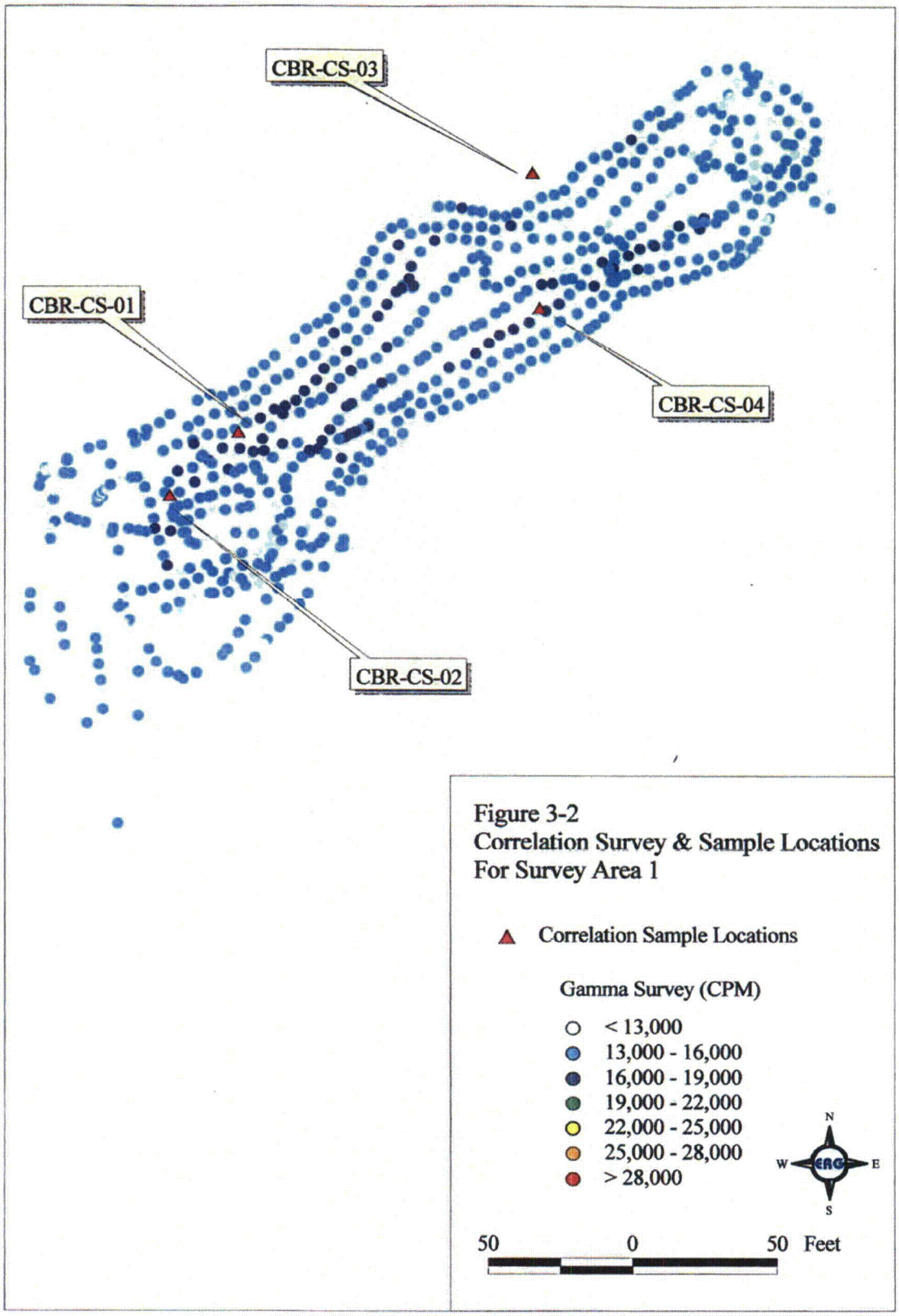


Figure 3-2
Correlation Survey & Sample Locations
For Survey Area 1

C07

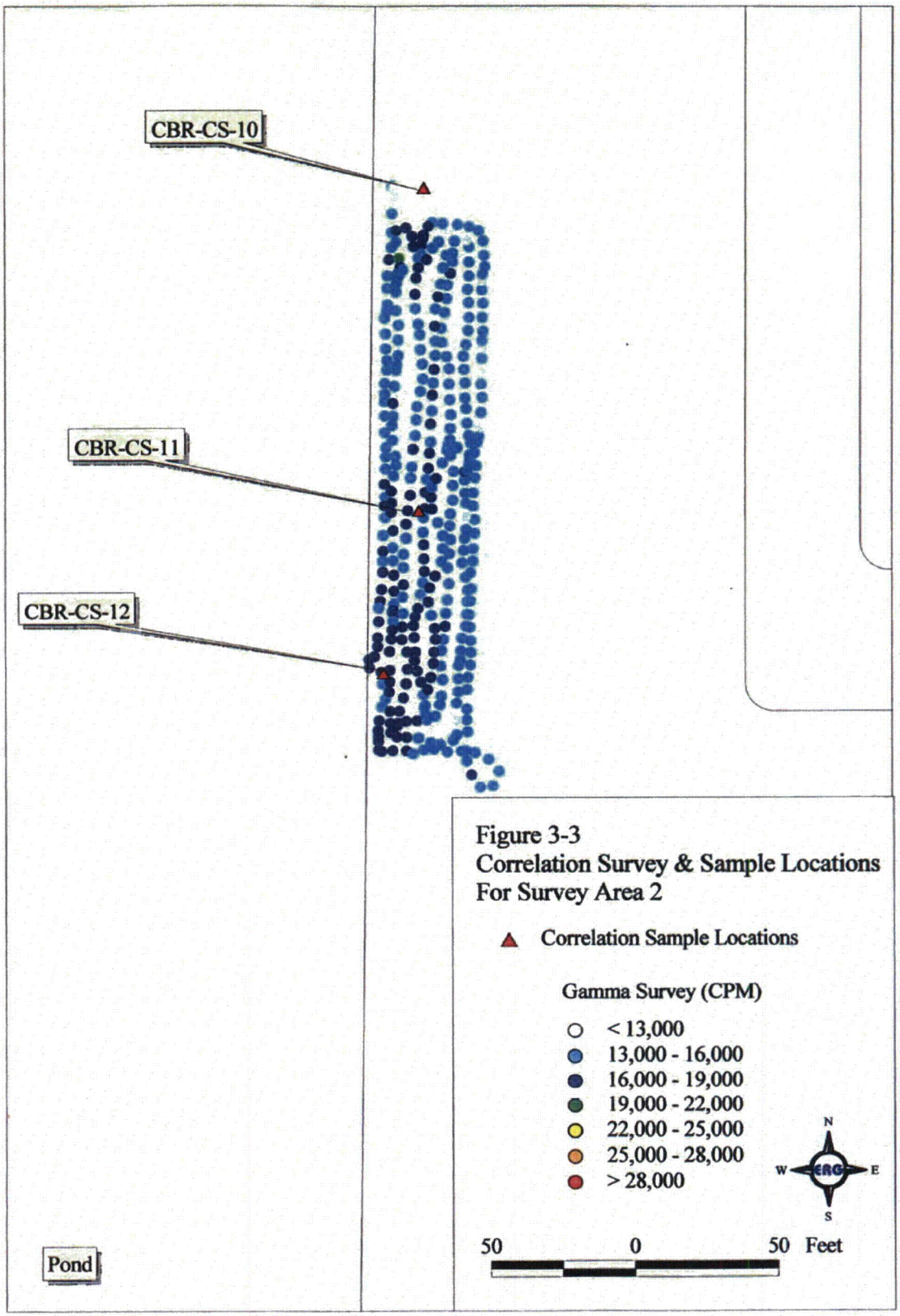


Figure 3-3
Correlation Survey & Sample Locations
For Survey Area 2

C08

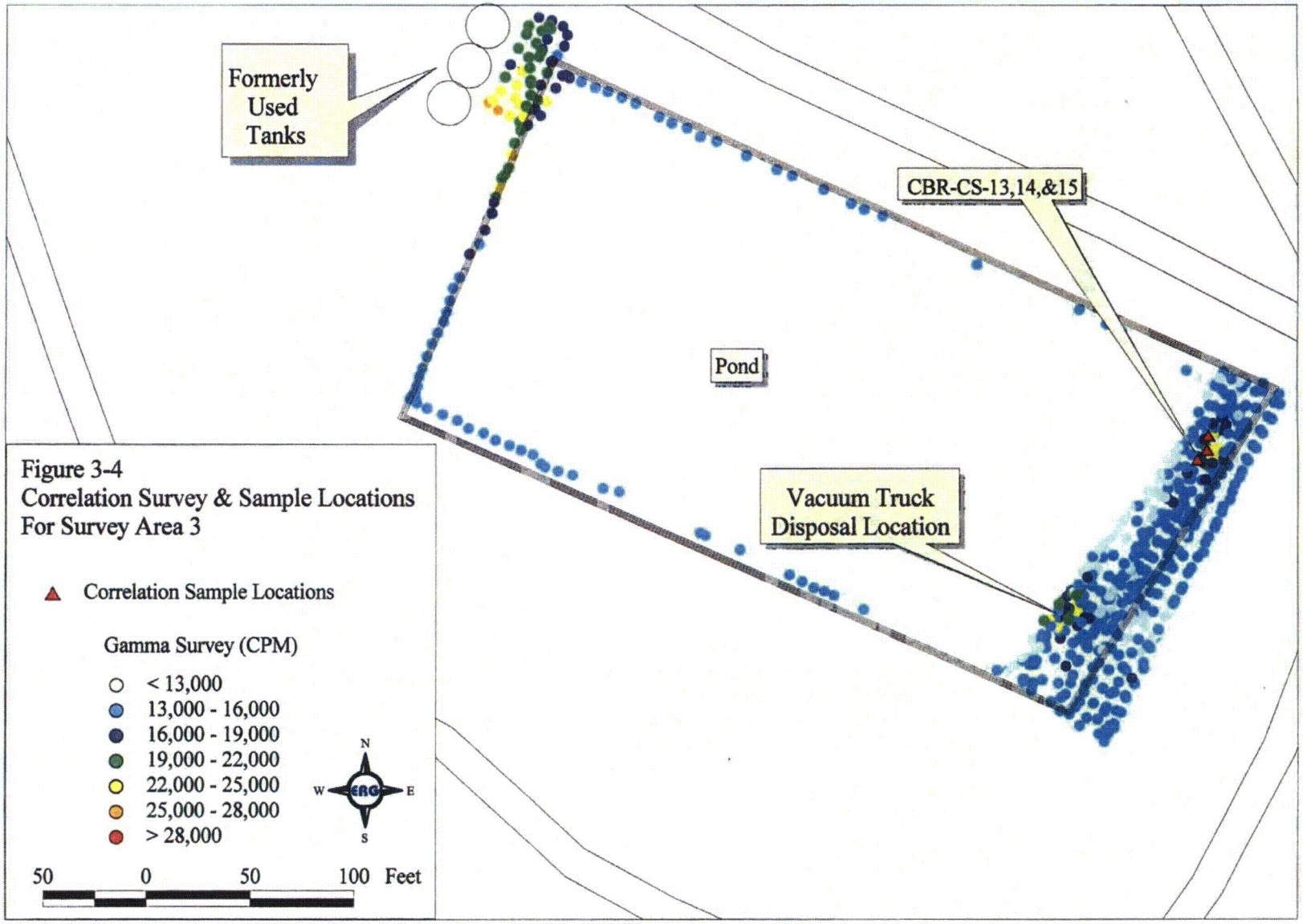


Figure 3-4
Correlation Survey & Sample Locations
For Survey Area 3

C09

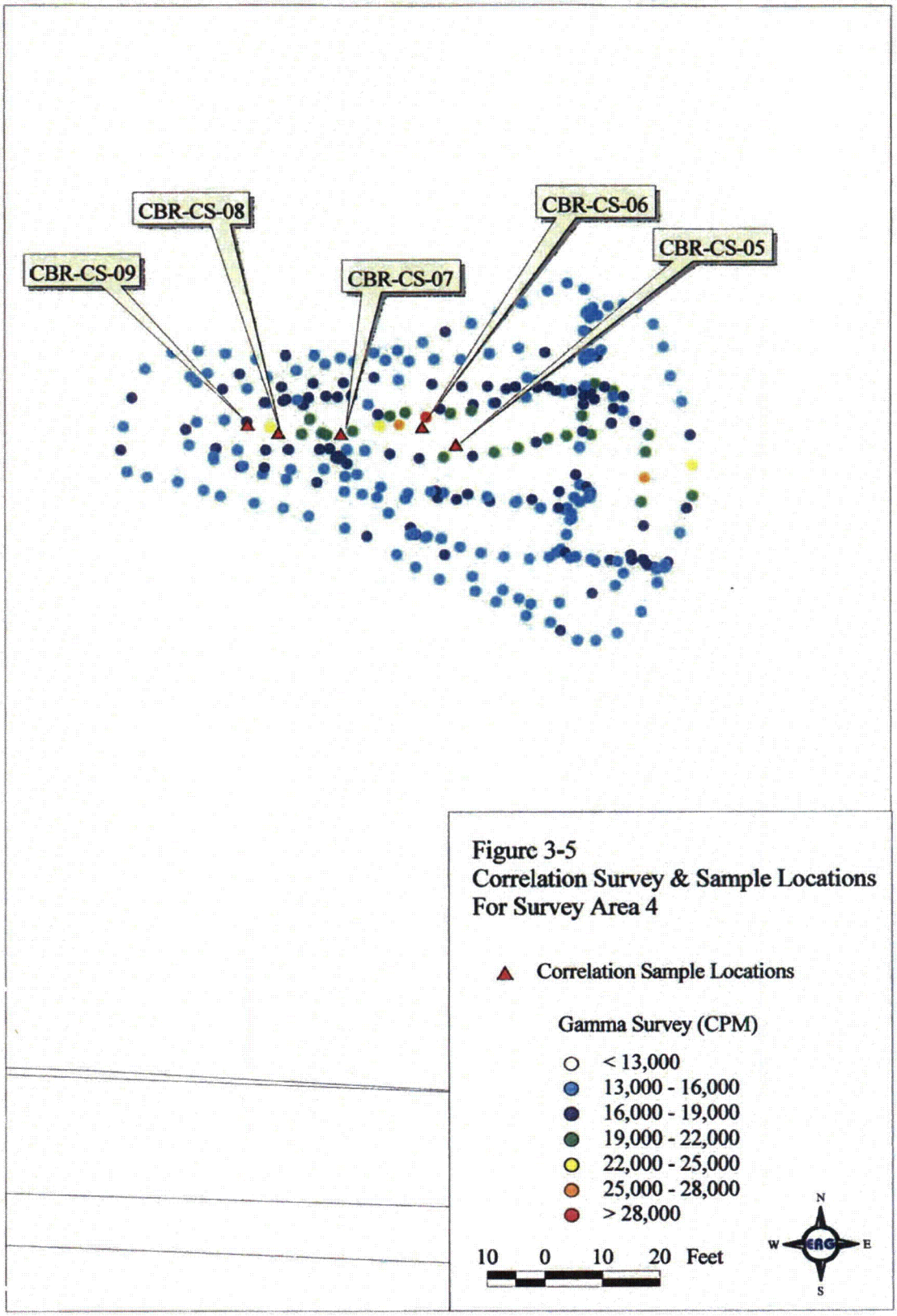


Figure 3-5
Correlation Survey & Sample Locations
For Survey Area 4

C10

4.0 Wellfield Decommissioning

Decommissioning and demolition work will be performed by CBR personnel and outside contractor(s). All workers will receive industrial and radiation safety training according to the Section 7.2 of this plan. As stated in that section, the ESH department will monitor decommissioning activities related to safe work practices and assure compliance with procedures. All personnel have the authority to terminate work when unsafe practices are observed. Section 5.0 lists the disposal options and survey requirements for decommissioned equipment, materials and structures. Contaminated soil and those items that cannot be economically decontaminated below the releasable limits will be disposed of as byproduct material according to Section 5.4.

Wellfield decommissioning includes the removal of surface equipment consisting of feed lines, electrical conduit, well boxes, and wellhead equipment. Wellhead equipment such as valves, meters, or control fixtures will be salvaged when possible. Buried wellfield piping will be removed. Wells will be plugged and abandoned according to the procedure below. Following removal of all equipment and piping, a gamma survey will be performed in potentially contaminated areas to identify and remove contaminated soil above the cleanup criteria. The wellfield area may then be recontoured, if necessary. Additional information regarding each step of the decommissioning is discussed below.

4.1 Well Plugging and Abandonment

Wells no longer useful for continued mining or restoration will be abandoned. This includes injection and recovery wells, monitoring wells, and any other wells used for the collection of hydrologic or water quality data. One known exception may be a well could be transferred to the landowner for personal use.

The objective of the CBR well abandonment program is to seal all wells such that the groundwater supply is protected, and to remove potential physical hazards. All abandoned wells will be plugged and abandoned in accordance with The Plugging and Abandonment Plan approved by the NDEQ and summarized in Section 6.2.3.1 of the CBR license renewal application. This procedure is summarized below.

A hose is lowered to the bottom of the well casing, and an approved abandonment mud is pumped down the hose. After filling the casing, the hose is removed and a cement plug is placed on the top. A hole is dug around the well, and the top three feet of casing are removed. The hole is then backfilled and vegetated.

A well abandonment report will be filed with the appropriate agencies upon completion of the wellfield decommissioning.

4.2 Trunk Lines, Pipes, and Wellfield Equipment

Surface piping used for wellfield activities, such as injection and recovery well lines or trunk lines, will be removed from the wellfields along with the valves, meters, and other related equipment. The underground piping (well lines and trunk lines) will be excavated and removed. Salvageable lines will be held for future use in ongoing mining operations. Non-salvageable lines will either be surveyed for unrestricted release, or disposed of at a licensed disposal facility as radioactive waste.

In some situations, CBR may desire to leave buried pipes in place. If so, studies will be conducted to determine the effectiveness of acid washes or other decontamination methods. The results will be documented and, if successful, used to develop a procedure for submission to the NRC for approval.

Contaminated equipment will be evaluated on a cost-benefit basis to determine if an attempt to decontaminate the item is warranted. Possible decontamination methods include acid wash, sandblasting, and pressurized water spray. During decontamination attempts, the work area will be controlled in accordance with radiological control requirements using procedures from the CBR Health Physics Manual (HPM). If decontamination is not successful, items will be disposed of at a licensed facility. Areas where wash water has been released to the ground will be considered potentially contaminated and monitored in accordance with Section 6 of this plan.

After all surface equipment and piping are removed, and all wells are properly plugged and abandoned, soil monitoring and removal procedures specified in Section 6 of this D&D plan will be applied.

4.3 Wellfield Buildings

Wellfield buildings are small enough to be transported intact and may be reused at another wellfield, transferred to another licensee, or released for unrestricted use if they can be decontaminated to release criteria. These small, industrial structures are not suitable for long-term occupancy by workers or as a residence. Therefore, the release criteria for materials and equipment as specified in Section 5.1 will be applied.

5.0 Disposition Options and Release Surveys

The disposition of potentially contaminated items and materials fall within four broad categories. These categories are the unrestricted release of equipment and pipe, the unrestricted release of wellfield buildings, the transfer of contaminated equipment and buildings to another licensee, and the disposal of contaminated equipment as waste byproduct material.

5.1 Equipment, Pipe and Materials to be Released for Unrestricted Use

Salvageable equipment, pipe and other materials to be released for unrestricted use will be surveyed for alpha radiation contamination in accordance with the NRC guidance document, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated May 1987.

The monitoring for beta-gamma dose rate is a current license requirement, based on the referenced 1987 NRC guidance document. This requirement has been eliminated in subsequent ANSI standards, including the latest ANSI/HPS N13.12-1999 standard, "Surface and Volume Radioactivity Standards for Clearance." CBR has routinely made these measurements but has never found them limiting. The characterization data indicate that the long-lived radionuclides, uranium, Ra-226, and Pb-210 are the principal radionuclides in the process water and thus are the principal constituents in contaminated areas. Anticipated mixtures of these radionuclides anywhere on the CBR site, including within process equipment, result in alpha and beta emission rates that are approximately the same. When Ra-226 is the predominant constituent, then the alpha emission rate should be approximately twice the beta emission rate. Considering that the background count rate is approximately 10 times higher (per unit area surveyed) for a beta-gamma detector compared to an alpha detector, it is reasonable to expect that the alpha measurement will always be more sensitive and limiting. Therefore, CBR proposes to make only alpha surface contamination measurements during release surveys for unrestricted use.

The CBR release limits for alpha radiation are as follows:

- Removable total of 1,000 dpm/100 cm^2.
- Average total of 5,000 dpm/100 cm^2 over an area no greater than 1 square meter.
- Maximum total of 15,000 dpm/100 cm^2 over an area no greater than 100 cm^2.

Decontamination of surfaces will be done to comply with CBR's ALARA policy to reduce the contamination as far below the limits as practical. Decontamination methods include pressurized spray washing, acid treatment, and sandblasting. Decontamination residues will be properly handled and disposed of as byproduct material. Equipment and materials released for unrestricted use will either be placed in an approved landfill, or salvaged.

5.2 Buildings to be Released for Unrestricted Use

The only buildings to be released or disposed of under this plan are the small wellfield buildings which provide environmental protection to valves, meters, and other equipment. These small industrial structures are not suitable for long-term occupancy by workers or others. Therefore, the applicable release criteria for their unrestricted use are the same criteria specified for equipment above. These structures will be surveyed for alpha contamination and released for unrestricted use or disposed of in a licensed facility.

5.3 Contaminated Equipment, Materials, and Buildings Transferred to Another Licensee

Salvageable contaminated equipment such as valves, meters, and other valuable components, along with small movable structures such as wellfield buildings, may be transferred to another licensed facility. If surface contamination exceeds the limits for unrestricted release, the equipment or structures may be shipped to another licensed facility in accordance with Title 49 of the Code of Federal Regulations (CFR). In most cases the equipment or structures will be shipped as Surface Contaminated Object (SCO-I), DOT regulations 49CFR173.427, UN2913, or as Empty Packages as Excepted Packages, DOT regulations 49CFR173.428, UN 2910.

Equipment and structures will be free of any loose exterior contamination and drained of any process liquids prior to shipment. If necessary, the equipment or structures will be washed to ensure that the exterior contamination is not easily removable. External exposure and contamination surveys will be conducted and documented to ensure that the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Surface contaminated objects (SCO-1) may be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

5.4 Contaminated Equipment, Materials, and Buildings Disposed of as Byproduct Material

Non-salvageable contaminated equipment, materials, dismantled structural sections, and soils will be sent to an NRC licensed facility for disposal. Shipments will be conducted per procedures in the HPM. In most cases the byproduct material will be shipped as Low Specific Activity (LSA-I) material, pursuant to DOT regulations in 49 CFR 173.427, UN2912.

External exposure and contamination surveys will be conducted and documented to ensure that the DOT limits in 49 CFR 173.427 (a) (1), 173.441 and 173.443 are met. Byproduct material will normally be transported as an exclusive use shipment in a strong tight container that prevents leakage of the radioactive contents under normal conditions of transport, as specified in 173.427(b) (3).

6.0 Cleanup of Surface and Subsurface Soils

The cleanup of surface and subsurface soils will be done according to the requirements in 10 CFR Part 40, Appendix A. Appendix A indicates that the Ra-226 concentration in soil should be limited to 5 pCi/g above background for 15-cm thick surface layers, averaged over 100-m^2. Similar layers of subsurface contamination are limited to15 pCi/g.

The NRC amended 10 CFR Part 40 on April 12, 1999 (FR/Vol. 64, No. 69, pp17506-17509) to require uranium recovery licensees to consider radionuclides other than Ra-226 in soil cleanup criteria. The existing soil Ra-226 criterion in 10 CFR Part 40, Appendix A, is used to derive a dose criterion (Benchmark Approach) for the cleanup of byproduct material radionuclides, including Ra-226. The radionuclide-specific criteria are adjusted so that the total dose resulting from the mixture of residual radionuclides will not exceed the Benchmark Dose. The dose from radon is excluded from the benchmark calculation. Other recommended guidance documents that were reviewed include NUREG-1620 (NRC, 2003b) and NUREG-1549.

The only radionuclides other than Ra-226 of concern at the CBR Project are from U-nat, a mixture of U-238, U-234, and U-235. The natural abundance activity percentages for these radionuclides are approximately 0.489, 0.489, and 0.022, respectively.

6.1 Cleanup Limits for Soils

The Benchmark Dose was modeled (see Appendix A) using the RESRAD code. The results show that a concentration of 537 pCi/g for uranium (U-nat) in the top 15-cm layer of soil for the resident farmer scenario is equivalent to the Benchmark Dose derived from a concentration of 5 pCi/g of Ra-226. It can conservatively be assumed, from a radiological exposure perspective, that since the subsurface concentration limit for Ra-226 is 15 pCi/g, the subsurface concentration limit for uranium would be 1600 pCi/g. It will be shown below that the uranium concentration should be limited to 230 pCi/g for all soil depths because of chemical toxicity concerns. A maximum soil contamination limit for uranium of 230 pCi/g in the surface and subsurface 15-cm layers is therefore proposed for CBR.

6.1.1 Radiological Dose Assessment

The NRC requires that when more than one radionuclide is present, the unity rule is applied to the radiological concentrations and corresponding radiological limits. The sum of the fractions of concentrations compared to their corresponding limits should be less than one. CBR interprets this to mean that the concentration of uranium in the surface soil layer will be divided by 537 pCi/g (as opposed to the limit based on chemical toxicity). Similarly, the concentration in a subsurface layer will be divided by 1600 pCi/g to obtain the fraction for the uranium concentration.

ALARA considerations require that an effort be made to reduce contaminants to as low as reasonably achievable levels. The ALARA goals are normally based on a cost-benefit analysis. For the cleanup of gamma-emitting radionuclides, the cost of cleanup becomes excessively high as the soil concentrations become either indistinguishable from background or the gamma emission rate corresponding to a soil concentration becomes indistinguishable from the gamma background count-rate. For uranium, the concentrations corresponding to these two situations are quite different.

Cleanup of uranium mill sites has demonstrated that conservatively derived gamma action levels, along with procedures similar to those in this plan, result in near background Ra-226 concentrations for the site. It is therefore believed that no specific ALARA goal is required for surface Ra-226. The proposed gamma action level (See Section 6.3) has been established at near background levels and is considered adequate to limit the concentration of Ra-226 to 5 pCi/g above background levels. The presence of a mixture of Ra-226 and uranium will tend to drive the cleanup to even lower Ra-226 concentrations.

Establishing an ALARA goal for uranium is more difficult. The calculated dose rates from the direct exposure to uranium and Ra-226 in soils are available from the RESRAD runs in Appendix A. The ratio of the Ra-226 dose rate per pCi/g to the uranium dose rate per pCi/g is 120. In this analysis, it is assumed that the dose rate for direct exposure is

proportional to the average photon energy times the emission rate, or:

$$D = k \times E \times R$$

Where:

- k = proportionality constant,
- D = direct dose rate,
- E = average photon energy
- R = emission rate.

Writing an equation for pure uranium and one for Ra-226 plus progeny, and dividing results in the following equation:

$$\frac{R_{Ra}}{R_U} = \frac{D_{Ra} \times E_U}{D_U \times E_{Ra}}$$

The average gamma energy from uranium is approximately 100 keV and the average energy from Ra-226 plus progeny is on the order of 400 keV. Substituting D_{Ra} / D_U = 120 and E_U / E_{Ra} = 100 / 400, then $R_{Ra} / R_U \approx 30$.

For a gross-gamma count rate meter in the field, the count rates are proportional to the emission rate ratios, adjusted for the detection efficiency differences for the two different spectra. Assuming that the difference is small, the ratio of the count rates should be about 30. Therefore if the action level for pure Ra-226 results in cleanup of the site to less than 5 pCi/g, the action level should result in the cleanup of pure uranium to 30 × 5, or 150 pCi/g. When both radionuclides are present, the levels should be somewhat lower. Based on the above argument, CBR proposes an ALARA goal of limiting the U-nat concentration in the top 15-cm layer to 150 pCi/g, averaged over an area of 100 m^2.

Subsurface contamination is expected around some of the well heads, wellfield pipe trenches, and wellfield houses. The difficulty in monitoring for removal is seldom as

favorable under these conditions as for contamination on the surface. It is CBR's desire to reduce the subsurface concentrations to a maximum of two-thirds of the proposed limits of 15 pCi/g above background for Ra-226 and 230 pCi/g for U-nat. Therefore ALARA goals for Ra-226 of 10 pCi/g above background and for U-nat of 230 pCi/g are proposed. The subsurface uranium goal has not been reduced below the limit since it has not been demonstrated that these levels can be detected with readily available field instruments. The limits are summarized in Table 6-1.

Table 6-1 Proposed Limits and ALARA Goals for Cleanup of Soils *

Layer Depth	Ra-226 Limit (pCi/g)	Ra-226 Goal (pCi/g)	U-nat Limit (pCi/g)	U-nat Goal (pCi/g)
Surface 0-15 cm	5	5	230	150
Subsurface 15 cm layers	15	10	230	230

** Averaged over a 100-m² area and 15-cm thickness*

*** Based on chemical toxicity*

It should be recognized that there may be circumstances, especially for subsurface contamination, that could result in the cost overriding the benefit of attempting to reach an ALARA goal. Should this happen, CBR will document why the ALARA goal was knowingly abandoned. It should also be recognized that backfilling may be required (for safety reasons) prior to receiving the confirmation sample laboratory results. In some situations, sample results may surprisingly be higher than the ALARA goals. In this situation, the cost-to-benefit ratio for remediating the backfilled area to meet ALARA goals will normally be prohibitively high.

6.1.2 Chemical Toxicity Assessment

The chemical toxicity effects from uranium exposure are evaluated by assuming the same exposure scenario as that used for the radiation dose assessment. In the Benchmark Dose

assessment for the resident farmer scenario, it was assumed that the diet consisted of 25 percent of the meat, fruits, and vegetables grown at the site. No intake of contaminated food through the aquatic or milk pathways was considered probable. Also, the model showed that the contamination would not affect the groundwater quality. Therefore, the same model will be used in assessing the chemical toxicity. The intake from eating meat was shown to be negligible compared to the plant pathway and therefore is not shown here. This is confirmed by the results of the RESRAD calculations shown in Appendix A.

The method and parameters for estimating the human intake of uranium from ingestion are taken from NUREG/CR-5512 Vol. 1 (NRC, 1992). The uptake of uranium in food is a product of the uranium concentration in soil and the soil-to-plant conversion factor. The annual intake in humans is then calculated by multiplying the annual consumption by the uranium concentration in the food. Since the soil-plant conversion factor is based on a dry weight, the annual consumption must be adjusted to a dry-weight basis by multiplying by the dry-weight to wet-weight ratio. Parameters for these calculations are given in Section 6.5.9 of the NUREG/CR-5512. Table 6-2 provides the parameters used in these calculation and results for leafy vegetables, other vegetables, and fruit. Annual intakes of 14 kg/year and 97 kg/year were assumed for leafy vegetables and other vegetables and fruit, respectively. Consistent with Appendix A dose calculations, it was assumed that 25 percent of the food was grown on the site. It was also assumed that the uranium concentration in the garden or orchard was 537 pCi/g. This corresponds to the uranium Benchmark Concentration for surface soils. Using a conversion factor for U-nat of 1 mg = 677 pCi, then 537 pCi/g is equivalent to 793 mg/kg. The human intake shown in the first column of Table 6-2 is equal to the product of the parameters given in the subsequent columns. Table 6-2 shows that the total annual uranium intake from all sources of food from the site is 92 mg/yr.

The two-compartment model of uranium toxicity in the kidney from oral ingestion was used (ICRP, 1995) to predict the burden of uranium in the kidney following chronic uranium ingestion. This model allows for the distribution of the two forms of uranium in

the blood, and consists of a kidney with two compartments, as well as several other compartments for uranium distribution, storage and elimination including the skeleton, liver, red blood cells (macrophages) and other soft tissues.

Table 6-2 Annual Intake of Uranium from Ingestion

Human Intake (mg/yr)	Soil Concentration (mg/kg)	Soil to Plant Ratio (mg/kg plant to mg/kg soil)	Annual Consumption (kg)	Dry Weight Wet Weight Ratio	Food Source
9.4	793	1.7E-2	3.5	0.2	Leafy Vegetables
36	793	1.4E-2	13	0.25	Other Vegetables
6.9	793	4.0E-3	12	0.18	Fruit
52					Total

The total burden to the kidney is the sum of the two compartments. The mathematical representation for the kidney burden of uranium at steady state can be derived as follows:

$$Q_P = \frac{IR \times f_1}{\lambda_P \left(1 - f_{ps} - f_{pr} - f_{pl} - f_{pk} - f_{pk1}\right)}$$

Where:

Q_P = uranium burden in the plasma, μg

IR = dietary consumption rate, mg U/d

f_I = fractional transfer of uranium from GI tract to blood, unitless

f_{ps} = fractional transfer of uranium from plasma to skeleton, unitless

f_{pr} = fractional transfer of uranium from plasma to red blood cells, unitless

f_{pl} = fractional transfer of uranium from plasma to liver, unitless

f_{pt} = fractional transfer of uranium from plasma to soft tissue, unitless

f_{pk1} = fractional transfer of uranium from plasma to kidney, compartment 1, unitless;

λ_p = biological retention constant in the plasma, d^{-1}.

The burden in kidney compartment 1 is:

$$Q_{k1} = \lambda_P \times Q_P \times \frac{f_{pk1}}{\lambda_{k1}}$$

Where:

Q_{k1} = uranium burden in kidney compartment 1, mg;

λ_{k1} = biological retention constant of uranium in kidney compartment 1, d^{-1}.

Similarly, for compartment 2 in the kidney, the burden is:

$$Q_{k2} = \lambda_P \times Q_P \times \frac{f_{pk2}}{\lambda_{k2}}$$

Where:

Q_{k2} = uranium burden in kidney compartment 2, μg;

λ_{k2} = biological retention constant of uranium in kidney compartment 2, d^{-1};

f_{pk2} = fractional transfer of uranium from plasma to kidney compartment 2, unitless.

The total burden to the kidney is then the sum of the two compartments is:

$$Q_{k1} + Q_{k2} = \frac{IR \times f_1}{\left(1 - f_{ps} - f_{pr} - f_{pl} - f_{pt} - f_{pk1}\right)} \times \left(\frac{f_{pk1}}{\lambda_{k1}} + \frac{f_{pk2}}{\lambda_{k2}}\right)$$

The parameter input values for the two-compartment kidney model include the daily intake of uranium estimated for residents at this site, and the ICRP69 values recommended by the ICRP as listed below (ICRP, 1995). The daily uranium intake rate was estimated to be 0.14 mg/day (52mg/year) from ingestion while residing at this site.

$IR = 0.14$ mg/day
$f_l = 0.02$
$f_{ps} = 0.105$
$f_{pr} = 0.007$
$f_{pl} = 0.0105$
$f_{pt} = 0.347$
$f_{pk1} = 0.00035$
$f_{pk2} = 0.084$
$\lambda_{k1} = \ln(2)/5$ yrs
$\lambda_{k2} = \ln(2)/7$ days
where $\ln(2) = 0.693\ldots$

Given a daily uranium intake of 0.14 mg/day at this site and the above equation, the calculated uranium in the kidneys is 0.0093 μg U, or a concentration of 0.03 μgU/g kidney. This is three percent of the 1.0 μg U/g value that has generally been assumed to protect the kidney from the toxic effects of uranium. Some researchers have suggested that mild effects may be observable at levels as low as 0.1 μg U/g of kidney tissue. Using 0.1 μg U/g as a criterion, then the intake is thirty percent of the considered unsafe level.

The EPA recently evaluated the chemical toxicity data and found that mild proteinuria has been observed at drinking water levels between 20 and 100 μg/liter. Assuming water intake of 2 liters/day, this corresponds to an intake of 0.04 to 0.2 mg/day. Using animal data and a conservative factor of 100, the EPA arrived at a 30 μg/liter limit for use as a National Primary Drinking Water Standard (Federal Register/Vol.65, No.236/ December 7, 2000). This is equivalent to 0.06 mg/day for the average individual. Naturally, since large diverse populations are potentially exposed to drinking water sources regulated using these standards, the EPA is very conservative in developing limits.

This analysis indicates that a soil limit of 537 pCi/g of U-nat would result in an intake of 0.14 mg/day. Using the most conservative daily limit corresponding to the National Primary Drinking Water standard, a soil limit of 230 pCi/g corresponds to the EPA intake

limit from drinking water with a uranium concentration of 0.06 mg/day. Therefore exposure to soils containing 230 pCi/g of U-nat should not result in chemical toxicity effects. Since the roots of a fruit tree would penetrate to a considerable depth, limiting subsurface uranium concentrations to 230 pCi/g will be considered appropriate as well.

6.2 Soil Cleanup and Verification

Gamma surveys will be used to guide the soil remediation efforts. The surveys will identify soil contamination that potentially exceeds the cleanup criteria and will be used to guide the cleanup efforts. After cleanup, the surveys will be used, in conjunction with surface soil sample analyses, to verify that the soil meets the site cleanup criteria. A gamma action level, defined as a gamma count rate level corresponding to the soil cleanup criterion, is used in the interpretation of the data. Normally the action level is conservatively developed to allow only a five percent error rate of exceeding the cleanup criteria at the 95% confidence level.

6.3 Gamma Action Level

The gamma action level is determined from data taken from known contaminated areas of the site, using equipment and methods similar to those that will be used during the soil cleanup verification phase of decommissioning. Verification plans call for sampling all 100-m^2 grid blocks that exceed the gamma action level using a five-point composite sampling procedure. A percentage of the grid blocks with gamma count rates below the action level will also be sampled.

The results of the preliminary site characterization described in Section 3 were used to develop the action level. The gamma survey was conducted in four areas considered to have the potential for being contaminated above cleanup criteria. The survey revealed that the contaminated areas were restricted to areas only a few feet across. The gamma-ray count rate measured above small contaminated areas is significantly lower than those above large areas contaminated at the same level. Therefore, the action level may be overly-conservative when used for assessing large contaminated areas.

An extensive effort at locating additional sampling points was made but, at this time, additional potentially contaminated areas are not evident. Since the contaminated areas were small and the distribution non-uniform, no attempt was made to determine the average count rate and average radionuclide concentration in a 100-m^2 grid block. Instead, the gamma count rate was measured above the soil-sampling location at an 18-inch height above the soil surface. This detector height will be used in the final verification survey.

Table 3-1 in Section 3 provides a summary of the data taken for the purposes of developing an action level along with additional information. The exact sampling locations have been provided in Figures 3-2 through 3-5. Section 2.6 presents the background data and proposes natural background value of 0.55 pCi/g for Ra-226. Figure 6-1 shows the Ra-226 concentration plotted against the gamma count rate using the data in Table 3-1. The linear regression indicates that, on average, a gamma count rate of 17,900 cpm corresponds to 5.55 pCi/g (5 pCi/g above background). This is easily distinguishable from the background count rate of approximately 14,500 cpm. The lower 95% confidence line for the linear regression, based on the available data, shows that 5.5 pCi/g corresponds to slightly less than 14,000 cpm, or approximately equal to the mean background count rate. This lower 95% confidence line therefore does not lead to a practical gamma action level. Until more data are available on which to refine this linear regression, CBR will use 17,900 cpm as the gamma action level for cleanup of areas that are small compared to the 100-m^2 grid block size. This will assure that when averaged over a grid block, the Ra-226 concentration will be less than the 5 pCi/g limit. As indicated above, when the contaminated area is large, the action level will be expected to increase by a few thousand counts per minute. There are no site data, however, on which to obtain an estimate. If large areas are decontaminated, the action level will be used with caution, or a new action level will be developed.

A correlation between the Ludlum Model 19 Micro-R meter and the Ludlum Model 2221/Ludlum Model 44-10 NaI count rate instruments, as shown in Figure 6-2, shows that 17,900 cpm corresponds to about 21 μR/h on the Model 19. While the Model 19

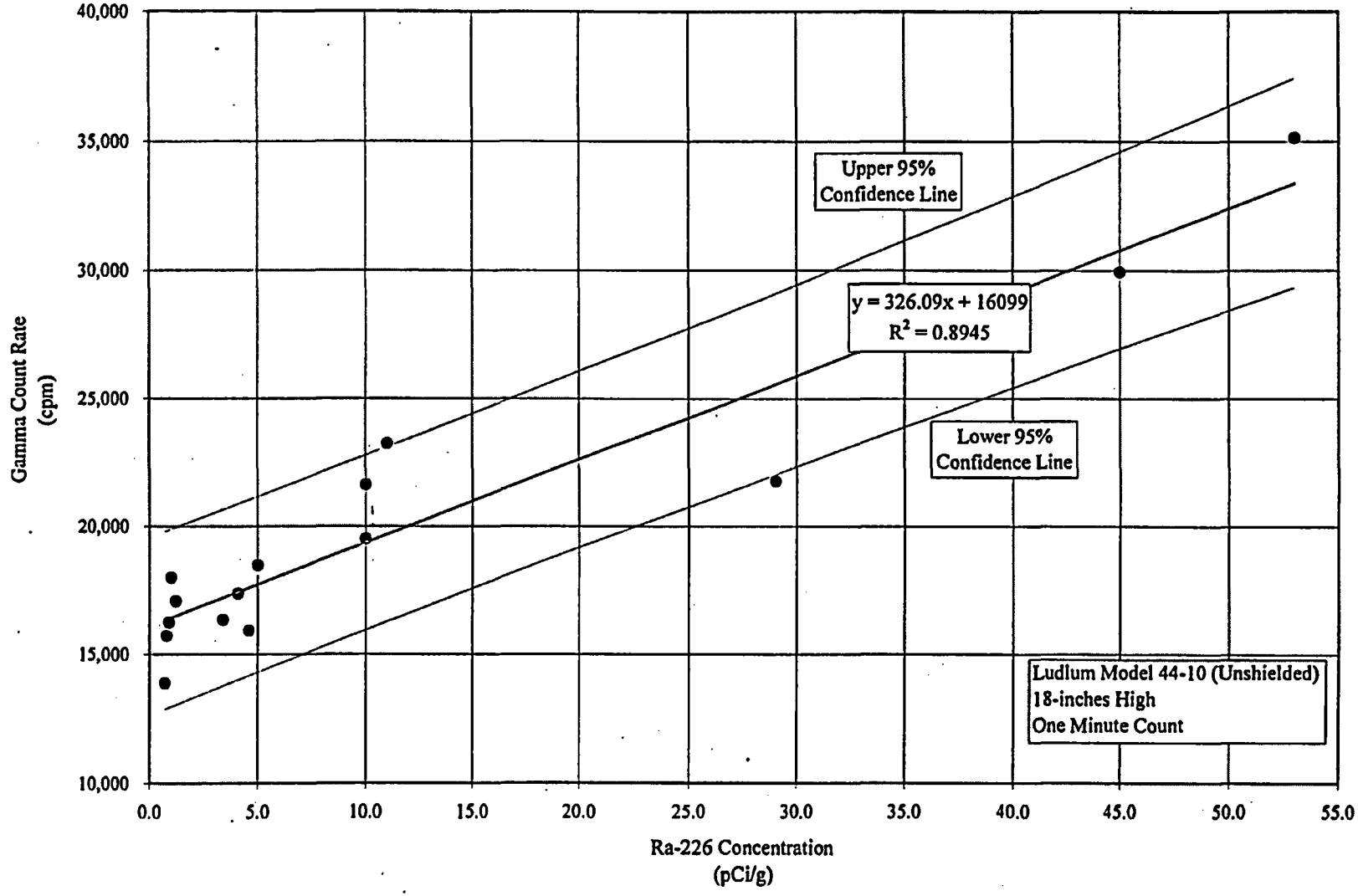


Figure 6-1 Gamma Count Rate vs. Ra-226 Concentration Correlation with Upper and Lower 95% Confidence Lines

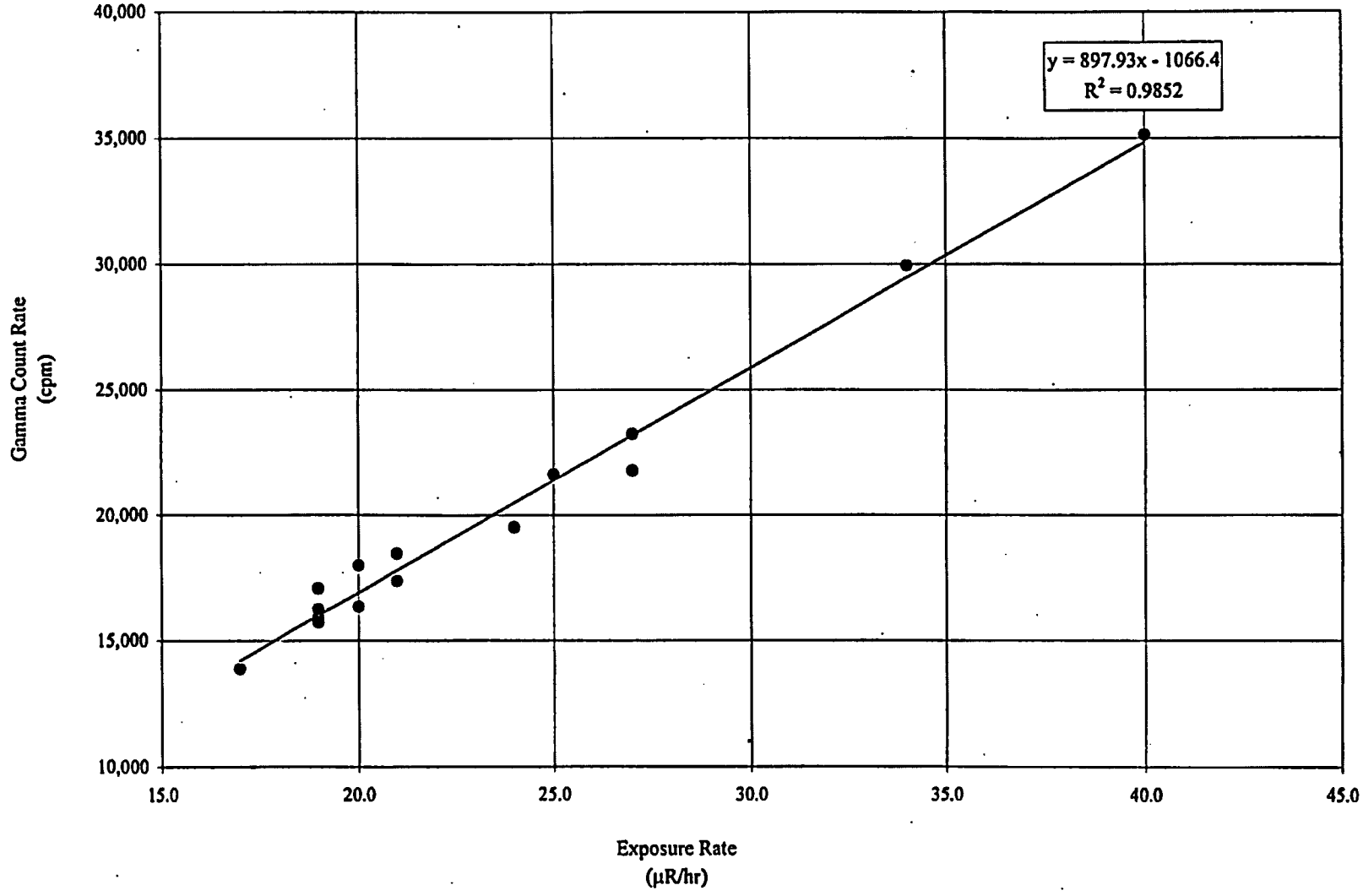


Figure 6-2 Exposure Rate vs. Gamma Count Rate Correlation

may be a useful instrument in some very high exposure rate situations, the factor of approximately five better sensitivity of the Model 44-10 along with the integrating-over-time feature of the Ludlum Model 2221 make it the preferred instrument for use at these low levels. The Model 19 will be used for a rough estimate as to whether an area meets the action level criterion.

At this time, no additional contaminated areas are known to exist where correlation data may be obtained. Therefore, unless areas are identified during remediation, all areas above 17,900 cpm will be remediated or the grid blocks sampled to assure that the cleanup criteria are met. If adequate data are obtained during remediation on which to base a more precise soil cleanup action level corresponding to the cleanup criterion, CBR may choose to petition the NRC for a change in the Decommissioning Plan.

6.4 Gamma Surveys for Characterization and Verification

Two methods are proposed for conducting site gamma surveys, one the GPS-radiological survey system and the second being the equivalent conventional method using a Ludlum 2221 ratemeter/scaler and Model 44-10 detector. Since the methods differ only in data recording and management, there are no apparent differences in the accuracy of the results. The surveys are described and CBR will decide which method to employ.

6.4.1 Gamma Surveys and Mapping Using Global Positioning System

The GPS-radiological surveys will be done using the same or equivalent equipment to that used in the correlation studies. The gamma-mapping system consists of a Ludlum Model 2221 ratemeter/scaler coupled to a Ludlum Model 44-10, a 2-inch by 2-inch NaI(Tl) detector. The digitized radiological count rate data are recorded once every second. The data are transmitted to a Trimble ProXRS GPS receiver which automatically tags the data with the coordinates at the time the data count rate is received. The ProXRS, manufactured by Trimble Navigation, is state-of-the-art mapping grade surveying equipment, employing the use of satellite GPS technology. The accuracy of the coordinates is better than one meter while collecting data.

The data are collected in the GPS data logger and later downloaded into a computer equipped with data management software. The data are then exported into the ArcView GIS file format, or other software for mapping, averaging, and developing isocontours.

A gamma survey will be done over the extent of the affected areas. Gamma count rate contour lines at the action level will be used to define where remediation is required. After the remediation, the area will be resurveyed with the new data added to the database, replacing the obsolete pre-remediation data. This iterative procedure will be applied until all areas are determined to meet the action levels.

In the verification phase, the average count rate over each 100-m^2 grid block is calculated by downloading the data into a data base management computer application. The data records within each grid block are counted, averaged, and assessed as to whether the grid block meets verification criteria.

Function checks for the equipment will be performed at the beginning and end of each work shift using standard operating procedures. In addition, standard operating procedures will be used for operating the GPS-radiological survey equipment.

6.4.2 Radiological Surveys and Mapping Using Conventional Methods

Gamma surveys may be conducted using the same type of radiological survey equipment described above other than the data will be recorded manually and presented on maps with isocontours using computer assisted means. Grid blocks of 33.3-ft by 33.3-ft (approximately 100-m^2 area) will be established over the affected area. In order to determine the average gamma count rate within a grid block, the Ludlum Model 2221/Model 44-10 combination will be used to integrate the count rate while a technician walks the area for one minute. Correlation studies at mill sites have demonstrated that this results in a good correlation with the Ra-226 in the soil.

6.5 Excavation Control Monitoring

Remediation of contaminated soils will be performed by excavation. The purpose of excavation control monitoring is to guide the removal of contaminated material to the point where it is highly probable that an area meets the cleanup criteria. Monitoring equipment and action levels developed in the calibration studies will be used for excavation control monitoring. A technician will monitor the soil after the removal of layers of soil until the instrumentation shows that the levels are below the action level. No documentation of the results is necessary since the verification data will serve to demonstrate compliance with the cleanup standards. For large areas, a GPS based survey may be performed periodically to more accurately assess the progress of the excavation.

For areas exhibiting contamination below the top 15-cm, excavation control monitoring will be performed using the same detector (or equivalent) as used in the calibration study, considering the appropriate action level and adjusting for geometry factors. The cleanup limit for deep excavations where backfill is applied is 15 pCi/g for Ra-226, or the equivalent uranium/radium level developed in the Benchmark Dose Assessment, considering the 230 pCi/g limit for uranium in the surface and subsurface layers based on chemical toxicity.

6.6 Soil Cleanup Verification and Sampling Plan

Existing characterization data indicate that the cleanup of surface soils in the wellfields will be restricted to the cleanup of a few areas where there were known spills and potentially small spills near well heads. Other areas considered potentially contaminated include roads within the well fields. Most of the minor spills are not anticipated to result in measurable levels of contamination. These spill areas have a physical size of a few meters across. The contamination in areas near wells and in pipe trenches may require backfill and thus subsurface soil procedures will apply. All work related to demonstrating compliance with the cleanup criteria will be done using standard operating procedures.

6.6.1 Surface Soil Gamma Survey and Sampling Plan

A final gamma survey will be performed in potentially contaminated areas and areas where cleanup occurred from known spills using the GPS-radiological survey equipment or

conventional equipment as described above. A 10-m wide buffer zone will be established around each area . It is anticipated that the boundary of the wellfield containing areas that have been remediated may extend as far as the outermost production well. The 10-m wide buffer zone would in that case lie between the outermost production wells and the monitoring wells that surround the well fields. A gamma-ray survey will be conducted over the entire area, including the buffer zone. The area will be divided in a non-biased manner into grid blocks of approximately 100 m^2 area. For the GPS-radiological survey, a minimum of seven data records in each 100-m^2 grid block will be used to obtain the average gamma count rate for the grid blocks. For conventional surveys, a one-minute integrated count while walking the area will be used as the average count rate.

All grid blocks containing elevated gamma-ray count rates above the gamma action level (including buffer area) will be sampled for compliance with the cleanup criteria. A five-point composite sample of surface soils will be taken in each 100-m^2 grid block. The sample will be analyzed to assure that the Ra-226 and uranium concentration complies with the cleanup criteria.

All of the remaining grid blocks with average gamma count rate ranking in the top ten percent will be sampled. Grid blocks failing the cleanup criteria will be decontaminated and sampled until the grid block passes. If any grid blocks within the top ten percent fail the cleanup criteria, the second ten percent of the grid blocks will be sampled. This will continue until all grid blocks pass within a 10 percent grouping.

In order to meet the cleanup criterion, each grid block must satisfy the inequality,

$$\sum C_i / C_c < 1$$

where C_i is the concentration of constituent and C_c is the concentration of the constituent that is equivalent to the Benchmark Dose.

After all sampled grids have met the cleanup criterion, an EPA-recommended statistical test will be done to determine whether the mean of the equality defined above for all grid

blocks is 1 or less at the 95 per cent confidence level, using Equation 8-13 of draft NUREG/CR-5849. The EPA recommends that μ_α be compared to the guideline value, where

$$\mu_\alpha = \bar{u} + t_{1-\alpha,df} (s_x/\sqrt{n})$$

and $\bar{u}$ is the mean of the $\sum C_i / C_c$ for each grid block, $t_{1-\alpha,df}$ is the 95% confidence level obtained from Student t Distribution tables where α is the false positive probability, i.e. the probability that μ_α is less than the guideline value if the true mean activity is equal to the guideline value. In this case the guideline value is equal to unity (1). The symbol, df, represents the degrees of freedom (equal to n-1).

Since this represents the mean of a set of biased samples (selected from the grids that have the highest gamma count rate), the passing of this test provides assurance that the cleanup error rate is very low for the entire sample set made up of all the possible grids that could have been sampled.

If the mean of the sample concentrations is less than the criterion but the data fails the statistical test, CBR will follow procedures similar to those recommended in Section 8.6 of draft NUREG/CR-5849. The number of samples will be increased to include the grids with next highest average gamma levels, and the statistical test will be performed again. This will be done until the statistical test is met. In any case, all grid blocks that were sampled and measured to exceed the cleanup criterion will be further decontaminated and resurveyed.

6.6.2 Subsurface Soil Verification Gamma Survey and Sampling Plan

Gamma count rates from the subsurface excavations will be taken at a sufficient frequency to ensure a minimum of seven readings per 100-m^2 of excavated surface. For excavations of less than 100-m^2 area, a minimum of one record per 10-m^2 area will be taken. Data will be recorded and referenced to a drawing of the excavation and/or State Plane Coordinates. The average of the count rate records for each 100-m^2 (or less) will

be calculated for comparison against the instrument action level. If the average exceeds the action level, additional excavation may be considered, followed by another gamma survey of the area. For deep trenches where it is unsafe for entry, a scan of the sidewalls and floor will be done by dropping a detector into the excavation to assure that the count rate is uniform.

For linear excavations (trenches), a single 15-cm deep soil sample at approximately one-half the excavation width at 150-ft. intervals will be taken. The sample may be taken with a backhoe where necessary. Each sampling location will be documented.

For excavations other than long trenches, a minimum of one five-point composite sample from the excavation surface will be taken. If the excavation surface exceeds 100 m^2, a five-point composite for each 100 m^2 of excavation surface will be taken. The sample points for the composite will be more or less evenly spaced to provide adequate representative coverage of the area. The sample locations will be documented. Specific dimensions cannot be predetermined due to the likely variability in excavation shape.

All samples will be submitted to a commercial laboratory for analysis for Ra-226 and U-nat. An alternative that may be used is to establish an on-site laboratory. If an on-site laboratory is used, ten percent of the samples will be selected at random and submitted to a commercial laboratory for analysis. Procedures for selecting the commercial laboratory and comparing test results are described in Section 6.7.

6.7 Laboratory Quality Assurance

Verification soil samples will be sent to a commercial laboratory for analysis of Ra-226 and U-nat. The commercial laboratory will be selected using a performance based approach which allows the laboratory the freedom to propose methods for the specific constituents and matrix that meet the measurement quality objectives required by CBR.

Only laboratories that adhere to a well-defined quality assurance (QA) program will be considered as the commercial laboratory to receive the verification samples. The QA

program must address the laboratory's organization and management, personnel qualifications, physical facilities, equipment and instrumentation, reference materials, measurement traceability and calibration, analytical method validation, standard operating procedures (SOP), sample receipt, handling, and storage, records, and appropriate licenses.

CBR will select the radiochemistry laboratory that best meets the data quality objectives for verification soil samples. USNRC Regulatory Guides 4.14 and 4.15, provide some information, but this guidance is over 25 years old. ANSI N42.23, Measurement and Associated Instrument Quality Assurance for Radioassay Laboratories describes a system in which quality and traceability of performing laboratory measurements to the national standards can be demonstrated through reference laboratories. The most recent guidance on this subject (NRC, 2001a) has not yet been released for publication, but is expected to be released for use during the third quarter of 2004. This guidance is the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP) which was developed by a working group with representatives from USNRC, DOD, DOE, EPA, NIST, USGS, FDA and several states. This guidance document is expected to be a primary reference document and thus will be applied to this project plan.

The analytical work performed by the commercial laboratory will be done under a written contract, and includes a scope of work prepared by CBR that defines the data quality objectives. Part of the data quality objectives are the specific analytical sensitivities required by CBR. The anticipated maximum activity levels in each sample is 5 pCi/g Ra-226 and 300 pCi/g U-nat, and their associated daughter products. The minimum sensitivity required for each sample is 0.5 pCi/g dry weight for each analyte, with an estimated overall error of ± 0.5 pCi/g. The contract will also define what is to be required in the data package. At a minimum the data package will include a case narrative, the analytical results, documentation of any deviation from the SOPs, copies of lab personnel notebooks, a chain of custody, a copy of the raw data, initial and continuing instrument and equipment calibration data, and standard and tracer information. This data package contains information equivalent to that required for an EPA Contract Laboratory Program

(CLP)-like level 3 data package, which is the minimum level data package acceptable for verification samples.

A Laboratory QA file shall be maintained to support the selection of the laboratory. The content of the file will include laboratory provided data and audit reports from the following QA activities:

1. The commercial laboratory will provide information needed to assess the quality of the data generated by the laboratory. This may include a copy of the laboratory's quality assurance manual (QAM) and standard operating procedures for the constituents of concern in a soil matrix.

2. CBR will perform an audit of the commercial laboratory before samples are delivered to verify adherence to the requirements of the QAM and SOP's. The laboratory's own QC results such as in-house blanks, duplicates, and spikes will be reviewed. The results from interlaboratory testing programs will be reviewed to obtain a measure of analytical quality and accuracy. Performance evaluation samples should have been prepared from an NIST traceable source. These samples preferably will be of a similar matrix, containing the constituents of concern, with the constituents at anticipated activity levels. Reference material may be obtained from the DOE's Radiological Environmental Sciences Laboratory (RESL) at INEEL (or equivalent). This DOE laboratory is also the NRC's reference laboratory.

U. S. Nuclear Regulatory Commission, Inspection Procedure 84525 will be applied to the results from the interlaboratory comparison program for comparing two data sets. In that procedure, each reference laboratory result is divided by the reported standard deviation to obtain the "resolution". The other lab (CBR's vendor laboratory) result is then divided by the reference laboratory result to obtain the "ratio". The data are considered in agreement if the ratio is within the range given in the following table.

Table 6-3 Criteria for Comparison of Laboratory Results

Resolution	Ratio
< 4	0.40 – 2.5
4 – 7	0.50 – 2.0
8 – 15	0.60 – 1.66
16 – 50	0.75 – 1.33
51 – 200	0.80 – 1.25
> 200	0.85 – 1.18

If significant differences exist, a review will be conducted in order to resolve discrepancies.

7.0 Radiation Safety Program

CBR maintains a performance-based approach to the management of environmental affairs, and employee health and safety. The Environmental Management System (EMS) encompasses licensing, compliance, environmental monitoring, industrial hygiene, and radiation safety. The EMS organization begins with the Company's Board of Directors, and flows down through the President, Senior VP of Operations, Mine Manager, Manager of Health, Safety, and Environmental Affairs, Radiation Safety Officer, and ends with the site workers. The EMS formalizes the company's approach to ES&H management, which operates under the direction of operating procedures, radiation work permits, and a performance-based license condition that allows CBR to make changes to processes or procedures without prior NRC approval. Oversight is provided by the Safety and Environmental Review Panel (SERP), which consists of at least three members of CBR's management team. The SERP is responsible for monitoring any changes to the processes or procedures.

The CBR Environmental, Health and Safety (EHS) staff will monitor decommissioning activities to ensure that occupational radiation exposure levels are kept as low as reasonably achievable. The Radiation Safety Officer (RSO), Radiation Safety Technician, or designee by way of specialized training will be on site during decommissioning activities where potential radiation exposure hazards exist. EHS staff will evaluate radiological hazards to employees and the environment, implementing the necessary controls to maintain exposures ALARA during decommissioning. The EHS staff routinely report to management any departure from safe work practices, any item of noncompliance with accepted practices or procedures, and any need for improvement in the radiation safety programs. They have sufficient authority to terminate work when unsound radiological or work safety practices exist.

7.1 D&D Task Analysis

Most of the decommissioning activities are not significantly different from those conducted during mining operations and, as such, the standard operating procedures (SOP) in the CBR Health Physics Manual (HPM) will be followed. The first task

includes cutting and/or removal of contaminated piping and surface equipment, including injection and production feed lines, electrical conduit, well boxes, and well head equipment. Some of the equipment, such as valves, meters, and control fixtures will be surveyed for contamination and salvaged, if possible. Following removal of the surface equipment, buried well field piping will be removed, and the wells will be plugged and abandoned. Finally, any contaminated soils will be removed for disposal. The RSO will evaluate each task and prepare a Radiation Work Permit (RWP) if an SOP is not already in existence. This RWP will be reviewed with employees prior to conducting each task. Slip, trip, and fall hazards will be a concern during dismantling of the piping and any buildings and equipment. All workers will be required to wear hard hats and take other safety measures in accordance with the Mine Safety and Health Administration (MSHA) requirements.

7.2 Personnel Training

All workers employed during decommissioning, whether contractor employees or CBR employees, will be given specialized training for minimizing radiological exposures in addition to industrial safety training.

Initial radiation and industrial safety training for CBR and contractor employees will be conducted as outlined in the HPM and in the EMS Training Manual. This training is in accordance with NRC Reg. Guide 8.31 and the approved MSHA training plan. In addition, new assignment training and indoctrination is required whenever a worker is assigned to an unfamiliar task. The project will also conduct periodic safety meetings.

The extent of contractor's training will be based on the type and degree of hazards applicable to their specific work. At a minimum, they will receive hazard training as outlined in the HPM and in the EMS Training Manual, which covers both radiation and industrial hazards. Additional specialized safety training will be given to all affected employees whenever new or unusual hazards become evident during decommissioning.

7.3 Standard Operating Procedures

The radiation safety program utilized during decommissioning will be based upon the existing ALARA program and the HPM, which have provided a sound radiation safety program during production operations. The HPM, supplemented by any specific RWPs or standing radiation work permits (SRWP) and Decommissioning Procedures will govern the radiation safety program during decommissioning. The CBR health physics standard operating procedures are embedded in the HPM.

7.4 Air Monitoring and Respiratory Protection Programs

The existing airborne radioactivity monitoring program and respiratory protection program will be maintained during decommissioning. The HPM provides guidance for determining and controlling the quantity of airborne material in the work area and the environment. This guidance includes the method to evaluate the need for air sampling, and the selection and location of sampling equipment. It provides sampling procedures for uranium dust and radon daughters. Air sampling is required if the estimated annual intake is greater than 0.1 ALI. D&D tasks will be evaluated by the RSO to determine if air monitoring is required.

The HPM gives guidance on respirator selection, use, care, and maintenance, in the event air monitoring indicates the need for respiratory protection. This program is considered appropriate for the decommissioning work.

7.5 Radiation Work Permit (RWP) Program

All routine tasks will be performed in accordance with the procedures embedded within the HPM. Any non-routine task where the potential for significant exposure to radioactive materials exists, and for which no standing RWP or SOP exists, will require the preparation of a Radiation Work Permit (RWP). Examples of D&D tasks that may require an RWP include cutting, sandblasting, or grinding on any potentially contaminated surface such as pipelines, tanks, vessels, and process equipment.

The RSO may also issue Standing Radiation Work Permits (SRWPs) for periodic or repetitive tasks that require similar radiological protection measures (e.g., piping removal). The SRWP will describe the scope of the work, precautions necessary to maintain radiation exposures to ALARA, and any supplemental radiological monitoring and sampling requirements. The SRWP shall be reviewed and approved in writing by the RSO (or qualified designee in the absence of the RSO) prior to initiation of the work.

ESH staff will review the planned decommissioning activities in order to determine what RWPs are needed, if any. The industrial safety hazards and associated protective measures will also be identified in accordance with MSHA requirements.

7.6 Health Physics Surveys and Dose Calculations

Health physics surveys conducted during decommissioning will be guided by applicable sections of 10 CFR 20 and USNRC Regulatory Guide No. 8.30 entitled "Health Physics Surveys in Uranium Recovery Facilities" and the many applicable Health Physics Manual SOPs.

Health physics surveys can be broadly classified into two categories, those required for contamination control, and those required for employee exposure monitoring. The intent of contamination control is to control the release of radioactive material to the work area, to control personnel exposures in the work place, to prevent the intake of contaminants by the work force, and to identify contaminated areas requiring remediation. The HPM provides guidance on survey methods and procedures, and allowable limits for the unrestricted release of equipment from CBR.

Surveys required for employee exposure monitoring include programs for external monitoring and internal, or bioassay, monitoring. CBR will evaluate the decommissioning tasks and determine appropriate monitoring requirements, consistent with the policy and requirements in the HPM.

7.7 Protective Clothing

There are two types of protective clothing (PPE) available to workers at CBR, disposable and non-disposable. The selection of PPE required will depend on the type of work to be accomplished. If an RWP is written, it will list the necessary PPE which may include coveralls, head covers, gloves, rain suits, and shoe covers. When the potential for contamination is high, the RWP may require rubber boots, plastic gloves, and taping of cuffs and sleeves. The HPM provides guidance regarding the selection of appropriate PPE. It is anticipated that for D&D tasks involving the potential exposure to loose radioactive material, the workers will normally be issued coveralls, gloves, and shoe covers, at a minimum.

7.8 Shipments of Radioactive Materials

Shipments of radioactive equipment and materials will be conducted to meet Department of Transportation (DOT) requirements, as specified under 49 CFR Subchapter C, "Hazardous Materials Regulations". NRC also has regulations governing the shipment of radioactive materials under 10 CFR Parts 20 and 71. Shipment of radioactive materials from CBR is discussed in the HPM. Specific guidance regarding the shipment of byproduct material is also presented.

7.9 Records and Reports

Personnel monitoring and other records required under 10 CFR Part 20, Subpart L will be maintained as a part of the normal mining operations radiation protection program. Specific records on transfer and disposal of byproduct or source material addressed in 10 CFR Part 40, §40.51 will be maintained as required by the current license. Specific records associated with wellfield decommissioning will be retained until the NRC has terminated the license. These records include radiation verification surveys and soil sample results for areas released for unconditional use.

8.0 Environmental Impacts

Normal site production operations will continue during decommissioning of the well fields. Therefore, the operational environmental monitoring program will continue unabated as defined by license conditions and CBR's standard operating procedures. Only those impacts that are incremental to normal operations will be discussed here.

8.1 Land Use

The primary impact on the land use through the life of the project, including decommissioning of the well field, is the loss of grazing capacity. The impact is temporary and will be reversed during decommissioning.

8.2 Air Quality

Air quality impacts from decommissioning activities will be minimal but likely increase from operational status but decrease as the decommissioning progresses. After decommissioning, fugitive dust will decrease due to less road traffic from employees and vendors. The decommissioned well field will eventually be returned to grazing status. Road traffic will increase at various times during decommissioning, particularly with the transport of byproduct and decommissioned materials. Byproduct material shipments will be transported in tarped or enclosed containers, pursuant to DOT regulations and procedures in the HPM. Engine exhaust and dust from local soil disturbances will increase during decommissioning. Measurable levels of radioactive particulate are not anticipated due to the low concentrations of radionuclides in the soil.

8.3 Wildlife

No significant adverse impact to wildlife was noted during operations or is expected during decommissioning. There are no threatened or endangered mammals, birds, reptiles, amphibians, or fish in the well field remediation area. Section 2.8 of the license renewal application (CBR, 1998) discusses the ecology of the area and concludes there has been minimal impact due to mining operations. This is expected to also be the case during remediation of the well field.

8.4 Surface Water

Sediment yields and total runoff may increase for a very short period of time during and immediately following decommissioning and reclamation activities. The impacts to surface waters within and adjacent to the licensed area will not be significant because of the limited size and duration of the disturbance. Efforts to minimize soil erosion will follow CBR's storm water best practices program.

The current surface water sampling (for operations) program will continue as listed in the operational environmental monitoring plan. No additional surface water impoundments are expected to be generated from D&D activities.

8.5 Archaeological Sites

Field investigations in 1982 and 1987 (CBR, 1998) identified 21 possible archeological sites within the permit area. During plant operations these sites have been avoided and not directly impacted. These sites will also be avoided during decommissioning. However, if a new archeological site is discovered, all work in the immediate area will cease until authorization to proceed is received from the NRC.

8.6 Groundwater

Well plugging and abandonment will not adversely affect groundwater during the well field decommissioning phase. As stated in Section 6.2.3.1 of CBR's license renewal application, the objective is to "seal and abandon all wells in such a manner as to assure the groundwater supply is protected and to eliminate any potential physical hazard."

8.7 Environmental Radiological Monitoring

The current environmental radiological effluent monitoring program (for production) will continue per CBR's license requirements. During remediation of the well field, some components and equipment such as pipe, buildings, and valves may be decontaminated by high pressure water and acids, or by sandblasting. Wash water or sandblasting material will be collected and disposed of as byproduct material. Contaminated soils in the decontamination area will be monitored and removed for disposal, if required. No

release of contaminated surface water is anticipated.

Excavation of trunklines may generate a small amount of potentially contaminated dust. However, this will be minimized by application of a water spray or misting. Pipe cutting, sand blasting and building demolition may also generate a small amount of dust. The air in the vicinity of these activities will be sampled for particulates as part of the occupational monitoring program. While specific decommissioning activities will result in short-term task-specific employee safety and environmental monitoring, the operational environmental and effluent monitoring program is considered adequate to detect any incremental environmental impacts from wellfield reclamation.

8.8 Non-Radiological Impacts

The potential impacts from non-radiological components of byproduct material from wellfield decommissioning are small. Solutions from decontaminating pipe or other items may be acidic and may harm vegetation if spilled. Normally, these solutions will be collected and placed in the byproduct waste disposal system. Should small quantities spill on the ground, the acids will quickly be neutralized by the soil with little or no long-term effects.

9.0 References

Abelquist, 2001. E. W. Abelquist, Decommissioning Health Physics, Institute of Physics Publishing, The Public Ledger Building, Suite 1035, 150 So. Independence Mall West, Philadelphia, PA 19106.

ANL-1993. "Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0." Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439

CBR. 1998. "SUA-1534 License Renewal Application," December 1995. Crow Butte Resources, Inc., P. O. Box 169, Crawford, Nebraska 69339-0169.

ICRP, 1995. ICRP Publication 69. "Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 3 Ingestion Dose Coefficients." 1995. International Commission on Radiation Protection. Elsevier Science Inc., 660 White Plains Road, Tarrytown, New York 10591

NRC, 1992. NUREG/CR-5512, Vol. 1. "Residual Radioactive Contamination from Decommissioning." Final Report. October 1992. Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent (Also PNL-7994R). Pacific Northwest Laboratory, Richland, WA. 99352

NRC, 1997 NUREG-1505. "A Non-Parametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys. 1977. Division of Regulatory Applications, Office of Nuclear Research, U. S. Nuclear Regulatory Commission, Washington, DC 20555

NRC, 1998a. draft Regulatory Guide DG-4006. "Demonstrating Compliance with the Radiological Criteria for License Termination." August 1998. Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washing to, DC 20555.

NRC, 1998b. NUREG-1549 (draft). "Decision Methods for Dose Assessment to Comply with Radiological Criteria for License Termination." July 1998. Division of Regulatory Applications, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D. C. 20555.

NRC-2000. NUREG-1575. "Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)." August 2000. Published jointly by the U.S. Nuclear Regulatory Commission, U. S. Environmental Protection Agency, U. S. Department of Energy, and the U. S. Department of Defense.

NRC, 2001a. NUREG 1576 (draft). "Multi-Agency Radiological Laboratory Analytical Protocols Manual." Interagency publication for public comment August 2001.

NRC, 2003a. NUREG-1569. "Standard Review Plan for In Situ Leach Uranium Extraction License Applications," June 2003. Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washington, DC 20555-0001

NRC, 2003b. NUREG-1620. "Standard Review Plan for the review of a Reclamation Plan for Mill Tailings Sites under Title II of the Uranium Mill Tailings Radiation Control Act of 1978," June 2003. Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washington, DC 20555-0001

Wellfield Decommissioning Plan
for
Crow Butte Uranium Project

Appendix A

Radium Benchmark Dose Assessment

Radium Benchmark Dose Assessment

A.1 Introduction

On April 12, 1999, the U.S. Nuclear Regulatory Commission (NRC) issued a Final Rule (64 FR 17506) that requires the use of the existing soil radium standard to derive a dose criterion for the cleanup of byproduct material. The amendment to Criterion 6(6) of 10 CFR Part 40, Appendix A was effective on June 11, 1999. This "benchmark approach" requires that NRC licensees model the site-specific dose from the existing radium standard and then use that dose to determine the allowable quantity of other radionuclides that would result in a similar dose to the average member of the critical group. These determinations must then be submitted to NRC with the site reclamation plan or included in license applications. This Appendix documents the modeling and assumptions made by Crow Butte Resources, Inc. (CBR) to derive a standard for U-nat in soil for the Crow Butte Uranium Project.

Concurrent with publication of the Final Rule, NRC published draft guidance (64 FR 17690) for performing the benchmark dose modeling required to implement the final rule. Final guidance (NRC, 2003) was published as Appendix E to the Standard Review Plan for In Situ Leach License Applications (NUREG-1569). This guidance discusses acceptable models and input parameters. This guidance, guidance from the RESRAD Users Manual (ANL, 2001), and site-specific parameters were used in the modeling as discussed in the following sections.

A.2 Determination of Radium Benchmark Dose

RESRAD Version 6.22 computer code was used to model the Crow Butte site and calculate the annual dose from the current radium cleanup standard. A sensitivity analysis was run for each input parameter that was not based upon local data.

The following supporting documentation for determination of the radium benchmark dose is attached:

- The RESRAD Data Input Basis (Attachment 1) provides a summary of the modeling performed with RESRAD and the values that were used for the input parameters. A discussion of the sensitivity analysis for each parameter is also included. The sensitivity analysis indicated that many of the parameters had little, if any, effect on the maximum dose. The parameters that had a noticeable affect on the maximum dose included the distribution coefficient (K_d) for each radionuclide; the soil density in the contaminated zone; the external gamma shielding factor; the fruit, vegetable and grain consumption rate; the leafy vegetable consumption rate; and the depth of roots. Each of these parameters, the sensitivity analysis and the chosen input value are discussed.
- Selected graphs produced with RESRAD that present the results of the sensitivity analysis performed on the input parameters are attached (Attachment 2).
- A full printout of the final RESRAD modeling results for the resident farmer scenario with the chosen input values is attached (Attachment 3). The printout provides the modeled maximum annual dose for calculated times for the 1,000-year time span and provides a breakdown of the fraction of dose due to each pathway.
- Graphs produced by RESRAD in Attachment 4 provide the modeling results for the maximum dose during the 1,000 year time span. A series of graphs depicts the summed dose for all pathways and the component pathways that contribute to the total dose. Additional graphs show the soil concentration and the dose to source ratio over time for each radionuclide.

The maximum dose from Ra-226 contaminated soil at the 5 pCi/g cleanup standard level, as determined by RESRAD, for the residential farmer scenario was 42.4 mrem/yr. This dose was based upon the 5 pCi/g above background surface (0 to 6-inch) Ra-226 standard and was noted at time, t = 0 years. This dose was used to determine the U-nat soil standard for use at Crow Butte as described in the following section.

A.3 Determination of Natural Uranium Soil Standard

RESRAD was used to determine the concentration of U-nat in soil distinguishable from background that would result in a maximum dose of 42.4 mrem/yr. The method involved modeling the dose from a set concentration of U-nat in soil. This dose was then compared to the radium benchmark dose and scaled to arrive at the maximum allowable U-nat concentration in soil.

For ease of calculations, a preset concentration of 100 pCi/g U-nat was used for modeling the dose. The fractions used were 48.9 percent (or pCi/g) U-234, 48.9 percent (or pCi/g) U-238 and 2.2 percent (or pCi/g) U-235. The distribution coefficients that were selected for each radionuclide were based upon the local soil types. All other input parameters were the same as those used in the Ra-226 benchmark modeling. A sensitivity analysis was conducted of the hydraulic conductivity and other parameters of the unsaturated zone and compared to the baseline case. The results showed no affect on the dose. The RESRAD output showing the input parameters is provided in Attachment 5.

Using a U-nat concentration in soil of 100 pCi/g, RESRAD determined a maximum dose of 7.9 mrem/yr. at time, t = 0 years. The printout of the RESRAD data summary is provided in Attachment 5.

To determine the uranium soil standard, the following formula was used:

$$\text{Uranium Limit} = \left(\frac{100\ \text{pCi/g natural uranium}}{7.9\ \text{mrem/yr.natural uranium dose}} \right) \text{x } 42.4\ \text{mrem/yr radium benchmark dose}$$

$$\text{Uranium Limit} = 537\ \text{pCi/g natural uranium}$$

The U-nat limit is applied to soil cleanup with the Ra-226 limit using the unity rule. To determine whether an area exceeds the cleanup standards, the standards are applied according to the following formula:

$$\left(\frac{\text{Soil Uranium Concentration}}{\text{Soil Uranium Limit}}\right)+\left(\frac{\text{Soil Radium Concentration}}{\text{Soil Radium Limit}}\right) < 1$$

This approach will be used at the Crow Butte site to determine the radiological impact on the environment from releases of source and byproduct materials.

A.4 References

ANL, 1993. *"Data Collection Handbook to Support Modeling the Impacts of Radioactive Material in Soil"*, Argonne National Laboratory (for the U.S. Department of Energy), ANL/EAIS-8, 1993. ." Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

ANL, 2001. C. Yu, A. J. Zielen, J.-J. Cheng, D. J. LePoire, E. Gnanapragasam, S. Kamboj, J. Arnish, A. Wallo III, W. A. Williams, and H. Peterson. " *User's Manual for RESRAD Version 6.*" Environmental Assessment Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

CBR, 1995. "Application for Renewal of USNRC Source Materials License SUA-1534." December 1995. Crow Butte Resources, P. O. Box 169, Crawford, Nebraska 69339-0169.

NRC, 1992. *"Residual Radioactive Contamination from Decommissioning,"* NUREG/CRR-5512 (PNL-7994) Vol. 1, U.S. Nuclear Regulatory Commission, Washington, D. C. 20555

NRC, 1999. NUREG/CR-5512, Vol. 3. "Residual Radioactive Contamination From Decommissioning. Parameter Analysis". Draft Report for Comment. October 1999. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

NRC, 2001b. NUREG/CR-5512, Vol. 2. "Residual Radioactive Contamination From Decommissioning. User's Manual," draft, April 2001. U. S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, Washington, DC 20555-0001

NRC, 2003. *"Standard Review Plan for In situ Leach Uranium Extraction License Applications."* NUREG-1569. Division of Fuel Cycle Safety and Safeguards, Office of Nuclear Material Safety and Safeguards, U. S. Nuclear Regulatory Commission, Washington, D.C. 20555-0001.

Radium Benchmark Dose Assessment

Attachment 1

RESRAD Data Input Basis Parameters

RESRAD Data Input Basis

Parameters

This document summarizes the data input and modeling scenario that was used to determine the radium benchmark dose for the Crow Butte Project well fields near Crawford, Nebraska. The modeling was performed using RESRAD for Windows Version 6.22 developed by the Environmental Assessment Division at Argonne National Laboratory.

Two possible scenarios for future land having the highest maximum dose to the most critically affected individual were evaluated:

1. The resident farmer scenario where an indoor occupancy time factor of 50% and an outdoor occupancy time factor of 25% is recommended (NRC, 2003).

2. The work at home scenario where a 70% factor for indoor occupancy and a 15% factor for outdoors occupancy is recommended (NRC, 2003).

The scenarios were run using RESRAD after all other parameters in the model were set and a sensitivity analysis had been run. The scenarios were then run with all other factors held constant.

The working at home scenario resulted in a slightly higher maximum dose of 43.0 mrem/year at time = 0 years compared with the resident farmer scenario which resulted in a dose of 42.4 mrem/year at time = 0 years. The resident farmer scenario is, however, the most likely future use of the land within the Crow Butte permit area. Therefore, this scenario was used to determine the radium benchmark dose. The use of the lower maximum dose value will result in a slightly lower uranium soil concentration and thus be conservative.

The following sections describe the data parameters that were used to model site-specific conditions. Where a sensitivity analysis was run on a particular factor, the results are noted.

The data input was based upon four principal sources:

1. The RESRAD Data Collection Handbook (ANL, 1993)

2. The RESRAD Users' Manual (ANL, 2003)

3. The NUREG-1569

4. Crow Butte Resources, Inc. License Renewal Application (LRA) CBR, "Application for Renewal of USNRC Radioactive Source Materials License SUA-1534,"December 1995.

Soil Concentration

1. Lead 210: Used 5.0 pCi/g per the NUREG-1569.

2. Radium 226: Used 5.0 pCi/g regulatory limit as basis for determining benchmark.

Distribution Coefficient (K_d) (values based upon data in RESRAD Handbook)

1. Lead 210: Used a distribution coefficient of 270 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

    - Sand = 270
    - Loam = 16,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 2.7, 270 (mid range), and 27,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

2. Radium 226: Used a distribution coefficient of 500 cm^3/g for sandy soil based upon soil type at the mine. The RESRAD User's Manual specifies the following values:

    - Sand = 500
    - Loam = 36,000

Sensitivity analysis indicates with a multiple of 100, no appreciable impact on maximum dose using higher K_d. Used values of 5, 500 (mid range), and 50,000 which covers the range of potential values at the site based upon sandy and loamy soil types. Graph attached.

Contaminated Zone

1. Area: Used default value of 10,000 square meters.

Sensitivity analysis was performed with a 2 multiple (5,000, 10,000 and 20,000 square meters). There was no impact on maximum dose. Graph attached.

2. Thickness: 15 cm (6 inches) based upon regulatory requirement (minimum in RESRAD Handbook)

3. Length parallel to aquifer flow: Default of 100 meters was used and is based upon the square root of a 10,000 square meter contaminated zone.

Sensitivity analysis was performed with a multiple of 5 (20, 100 and 500 square meters). There was no impact on maximum dose. Graph attached.

Cover and Contaminated Zone

1. Cover depth: 0 inches (in accordance with NUREG-1569).

2. Density of contaminated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25) and resulted in changes in the maximum dose with a higher dose projected with a higher density. See graph. However, the standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in CBR, 1995.

3. Contaminated zone erosion rate: Used the default value of 0.001 meters/year. NUREG-1569 states that the erosion rate should be lower at uranium recovery sites due to the semi-arid environment. The RESRAD Handbook states that this value should be adequate for screening purposes. It also states that, while water erosion is the primary factor, wind erosion can also be significant.

Sensitivity analysis was run using a multiple of 5 (i.e., 0.0002, 0.001 and 0.005). The lower erosion rate resulted in the total dose remaining at a higher level over a longer period of time. However, there was minimal impact on the maximum dose.

4. Contaminated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

5. Contaminated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. Contaminated zone hydraulic conductivity: The range given in RESRAD handbook for silty sand is 1×10^1 to 1×10^4. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^3. Very fine sand is given a K_{sat} of 3.0×10^3 in the RESRAD Handbook. A midrange value of 4.0×10^3 was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr). There was no impact on maximum dose.

7. Contaminated zone b parameter: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, 8.76). There was no impact on maximum dose.

8. Evapotranspiration Coefficient: The RESRAD default value is 0.5. NUREG-1569 suggests that a value of 0.6 to 0.99 for uranium recovery sites is appropriate because

they are located in a semiarid environment. For screening purposes, a mid-value (0.75) was used.

Sensitivity analysis was run with a multiple of 1.33 (i.e., 0.564, 0.75 and 0.998) which is the maximum sensitivity set by RESRAD. There was no impact on the maximum dose.

9. Wind Speed: The RESRAD default is 2 m/s. The average for the Crow Butte site is 4.3 m/s (8.4 knots). Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

10. Precipitation: The RESRAD default is 1 m/yr. The average for the Crow Butte site is 0.39 m/yr. Site data was used. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

11. Irrigation Rate: The RESRAD default is 0.2 m/yr. The actual site data should be 0 m/yr. since use of irrigation is limited in Dawes County and there is no irrigated land near the mine. Sources of irrigation are expected to be limited in the future. No sensitivity analysis was performed since this is actual site data as recommended in NUREG-1569.

12. Runoff Coefficient: The RESRAD default value is 0.2. This is the value for open rolling land in the RESRAD Handbook and was used for Crow Butte. The potential range in the RESRAD handbook for the site would be 0.1 to 0.4.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.1, 0.2 and 0.4) which covers the potential range for the site. There was no impact on maximum dose.

13. Watershed Area for nearby stream or pond: The RESRAD default value is 1×10^6 m^2. Used the estimated area of the Squaw Creek watershed, which is approximately 14 sections, or 3.63×10^7 m^2.

Although this is actual data for the site, a sensitivity analysis with a multiple of 2 was run (i.e., 1.82, 3.63 and 7.26 x 10^7 m^2). There was no impact on maximum dose.

14. Accuracy: Used the default value of 0.001.

Saturated Zone

1. Density of saturated zone: Used the default value of 1.5 g/cc, which corresponds to sandy soil in the RESRAD Handbook. This compares with the soil types at Crow Butte and the engineering data in the Dawes County Soil Survey.

Sensitivity analysis was run using a factor of 1.5 (i.e., 1, 1.5, 2.25). There were no changes in the maximum dose. See graph. The standard range given in the Handbook is 1.1 to 1.6 g/cc. 1.5 is the most representative density of the soil types at Crow Butte based upon the Soil Survey as discussed in the CBR, 1995.

2. Saturated zone total porosity: Default value of 0.4 is the same as used for the spill impact analysis and is based upon the soil types at Crow Butte and the Soil Survey engineering data.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

3. Saturated zone effective porosity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 5 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

4. Contaminated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.04, 0.2 and 1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Saturated zone hydraulic conductivity: The range given in RESRAD handbook for silty sand is 1×10^1 to 1×10^4. The soil types on Section 19 are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^3. Very fine sand is given a K_{sat} of 3.0×10^3 in the RESRAD Handbook. A midrange value of 4.0×10^3 was chosen since site specific data is unavailable.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

6. Saturated zone hydraulic gradient: The default value of 0.02 was used for screening purposes.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.01, 0.02 and 0.04.). There was no impact on maximum dose.

7. Saturated zone b parameter: Default parameter is 5.3 for silty loam. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Sensitivity analysis was run with a multiple of 2 (i.e., 2.19, 4.38, and 8.76). There was no impact on maximum dose.

8. Water Table Drop Rate: The default value of 0.001 m/yr. was used for screening purposes. The site specific drop rate should be similar because there is little consumptive use of groundwater in the immediate area other than ranches that use local wells for domestic and livestock.

Sensitivity analysis was run with a multiple of 10 (i.e., 0.0001, 0.001 and 0.01). There was no impact on maximum dose.

9. Well Pump Intake Depth: The RESRAD default is 10 m. Since the depth to saturated zone is 15 meters and most local wells are completed from 60 to 80 feet, a value of 20 meters was chosen.

Sensitivity analysis was run with a multiple of 2 (i.e., 10m, 20m and 40m). There was no impact on maximum dose

10. Model for Water Transport Parameters: Used non-dispersion per NUREG-1569.

11. Well Pumping Rate: Used default of 250 m^3/yr. (66,000 gal/yr.).

Sensitivity analysis was run with a multiple of 2 (i.e., 125, 250m and 500 m^3/yr.). There was no impact on maximum dose

Unsaturated Zone

1. Unsaturated zone thickness: Used 15 meters (50 ft) per Reg.Guide-1569.

2. Density of unsaturated zone: Used 1.5 g/cc, which is similar to the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.75, 1.5 and 3.0 g/cc) There was no impact on maximum dose.

3. Unsaturated zone total Porosity: The default value of 0.4 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.2, 0.4 and 0.8). The range given in the RESRAD handbook for sandy and silty soils is 0.25 to 0.53 and is covered in this sensitivity analysis. There was no impact on maximum dose.

4. Unsaturated zone effective porosity: The default value of 0.2 is the same as used for the saturated zone as discussed in NUREG-1569.

Sensitivity analysis was run with a multiple of 1.5 (i.e., 0.3, 0.2 and 0.13). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

5. Unsaturated zone field capacity: Default value of 0.2 was used. This value was used because it is at the midpoint of the range for the soil types at Crow Butte.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.4, 0.2 and 0.1). The range given in the RESRAD handbook for sandy and silty soils is 0.01 to 0.46. The maximum value is covered in this range. There was no impact on the maximum dose.

6. Unsaturated zone hydraulic conductivity: The range given in the RESRAD handbook for silty sand is 1×10^1 to 1×10^4. The soil types in the licensed area are principally Busher loamy very fine sand. The hydraulic conductivity (K_{sat}) in m/yr. given in the RESRAD Manual for loamy sand is 4.93×10^3. Very fine sand is given a K_{sat} of 3.0×10^3 in the RESRAD Handbook. A midrange value of 4.0×10^3 and is the same as used for the saturated zone as discussed in NUREG 1569.

Sensitivity analysis was run with a multiple of 2 (i.e., 2000, 4000 and 8000 m/yr.). There was no impact on maximum dose.

7. Saturated zone b parameter: Used 4.28 rather than the default parameter of 5.3. The RESRAD Handbook and RESRAD Manual specify a value of 4.38 for loamy sand, which corresponds to the soil classification used for the hydraulic conductivity. The range from sand to loam is 4.05 to 5.39.

Occupancy

1. Inhalation Rate: Used default value of 8,400 m^3/yr.

2. Mass Loading for Inhalation: Default is 0.0001 g/m^3. Handbook gives a value of 0.0003 g/ m^3 for agricultural generated dust loading.

Sensitivity analysis run with a multiple of 3 (i.e., 0.0001, 0.0003 and 0.0009 g/m^3) which will cover the range from the default value. There was no impact on maximum dose.

3. Exposure Duration: Used default value of 30 years.

4. Indoor dust filtration factor: Used default value of 0.4.

5. External gamma shielding factor: The RESRAD default is 0.7, which assumes that the indoor gamma radiation level is 30% lower than the outdoor gamma radiation

level. NUREG-1569 requires that a value between 0.33 and 0.55 be used. The screening level was set at 0.55. This is a value suitable for a 7-inch thick concrete slab on grade house (NUREG/CR-5512 Vol.3, p 6-25). This is representative of the thickness of the local slab or basement floor thicknesses.

Sensitivity analysis using a 1.5 multiple (i.e., 0.367, 0.55 and 0.825 resulted in a change in the maximum dose. See graph. The low range (0.367) resulted in a maximum dose of approximately 38 mrem/yr compared to a dose of 42 mrem/yr for a shielding factor of 0.55. Based upon the fact that most construction of rural homes in the local area includes a thick concrete basement floor or slab, a shielding factor of 0.55 for the Crow Butte area is justified.

6. Indoor/Outdoor Fractions: Used defaults of 0.5 indoors and 0.25 outdoors for farmer scenario and 0.7 indoors and 0.15 outdoors for the work at home scenario. As discussed above, the resident farmer scenario was chosen as the most likely land use for the foreseeable future (i.e., 200 years).

7. Shape of contaminated zone: NUREG-1569 suggests use of actual shape. However, the shape is unknown at this time. Various shapes were assumed including a rectangle having a length of up to four times the width. The results were independent of these shapes as long as the receptor was centered. When the receptor was at the edge of the area, the dose was reduced significantly as expected. A circular shape was adopted for the modeling.

Ingestion: Dietary

1. **Consumption Rates:**

   A. Fruit, vegetable and grain: RESRAD default is 160 kg/yr. This value was used based upon EPA estimated consumption. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 190 kg/yr. Screening level set at default of 160 kg/yr.

This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis with 1.25 factor (i.e., 152, mid of 190 and high of 237.5 kg/yr) had an impact on maximum dose. This factor covers the range for the consumption discussed in Reg. Guide 1.109. See Graph. Based upon NRC Reg. Guide 1.109, adjusted the consumption to 190 kg/yr.

B. Leafy Vegetable: Used default value of 14 kg/yr. NRC Reg. Guide 1.109 has an estimated consumption for an adult of 64 kg/yr, while NRC estimates for dose from nuclear power plants uses a consumption rate of 30 kg/yr. Screening level for total set at default of 190 kg/yr (see above entry). This amount is the total consumption. RESRAD adjusts for contaminated and uncontaminated fractions based upon the size of the contaminated area.

Sensitivity analysis was run with a multiple of 5 (i.e., 2.8, 14 and 70 kg/yr.) to cover the range of NRC estimated consumption. There was an impact on maximum dose. Based upon these results, the consumption rate was left at the default value of 14 kg/yr. for ALARA purposes.

C. Milk: No consumption of locally produced and consumed milk per NUREG-1569. Dairy operations are not prevalent in the area.

D. Meat and Poultry: Used RESRAD default value of 63 kg/yr. According to NRC Regulatory Guide 1.109 (NRC, 1977), the recommended average value for consumption of meat and poultry is 37 kg/yr for children, 59 kg/yr for teenagers, and 95 kg/yr. for adults.

Sensitivity analysis was run with a multiple of 2 (i.e., 31.5, 63 and 126 kg/yr.) which covers the range between the RESRAD default and the rates in Reg. Guide 1.109. There

was minimal impact on the maximum dose. The default consumption rate from RESRAD was used.

E. Fish/Seafood: No consumption of locally produced and consumed fish or seafood products was considered as recommended by NUREG-1569.

F. Soil ingestion: Used the RESRAD default value of 36.5 g/yr.

Sensitivity analysis was run with a multiple of 2 (i.e., 18.25, 36.5 and 73 kg/yr). There was minimal impact on the maximum dose. The RESRAD default value was chosen.

G. Drinking water intake: Used the RESRAD default of 510 l/yr. (1.4 L/d) as a screening level. This value is based upon EPA estimates of drinking water intake. The EPA (1990) has suggested that the average adult drinking water consumption rate is 1.4 L/d; the reasonable worst-case value is 2.0 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 255, 510 and 1020 L/yr.). There was no impact on the maximum dose. The RESRAD default value was chosen.

2. Contaminated Fractions:

NUREG-1569 states that for sites with over 25 acres (10,117 square meters) of contamination, the fraction of diet from contaminated area should be assumed to be 25% (0.25). A sensitivity analysis on these parameters was not performed based upon the guidance.

A. Water: Used the default value of 1 (i.e., 100% of consumption is from contaminated well water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

B. Livestock Water: Used default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

C. Irrigation Water: Used the RESRAD default of 1 (i.e., 100% is from contaminated water). All current water use in rural areas around the site is from private wells and will likely continue to be in the foreseeable future.

D. Plant food: Used 0.25 as percentage of plant food that is contaminated.

E. Meat: Used 0.25 as percentage of meat that is contaminated.

Ingestion: Nondietary

1. **Consumption Rates:**

A. Livestock fodder intake for meat: Used the RESRAD default of 68 kg/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 34, 68, and 136 kg/d). There was no significant impact on maximum dose.

B. Livestock water intake for meat: Used the RESRAD default of 50 L/day. According to NRC Regulatory Guide 1.109 (NRC 1977), the water ingestion rate for beef cattle is 50 L/d.

Sensitivity analysis was run with a multiple of 2 (i.e., 25, 50, and 100 L/d). There was no impact on maximum dose.

C. Livestock intake of soil for meat: Used the RESRAD default of 0.5 g/day.

Sensitivity analysis was run with a multiple of 2 (i.e., 0.25, 0.5, and 1 g/d). There was no significant impact on maximum dose.

D. Mass loading for foliar deposition: Used the same value of 0.0003 g/m^3 for agricultural generated dust loading as the inhalation parameter discussed above.

E. Depth of soil mixing layer: Used the RESRAD default of 0.15 meters.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.9, 03, and 0.1 meters). There was a minimal (i.e., less than 1 mrem/yr) impact on maximum dose

F. Depth of roots: Used 0.3 meters as a screening level based upon NUREG-1569 instead of the RESRAD default of 0.9. The root depth varies for different plants. For some plants, such as beets, carrots, lettuce, and so forth, it does not extend below about 0.3 m, which is the basis of the NRC guidance. For others, such as fruit trees, the roots may extend 2 or 3 m below the surface. Tap roots for some crops (e.g., alfalfa) can extend to 5 m. Most of the plant roots from which nutrients are obtained, however, usually extend to less than 1 m below the surface. Due to the common use of grazing crops such as alfalfa in the immediate area surrounding the Crow Butte site, a sensitivity analysis was chosen that would determine the dose using the 0.3 m NRC guidance as the screening level as well as the 0.9 m RESRAD default.

Sensitivity analysis was run with a multiple of 3 (i.e., 0.1, 0.3, and 0.9 meters). There was a significant impact on the maximum dose. Assumption of a shallow root system increased the dose significantly. In a review of the exposure pathways, the plant pathway resulted in approximately 38% of the total maximum dose. The meat pathway, which would be the primary pathway affected by deeper roots such as alfalfa, accounted for approximately 1.4% of the total maximum dose. Therefore, the root depth recommended in the NRC NUREG-1569 was chosen for this parameter.

G. Groundwater fractional usage:

- Drinking water: Used the RESRAD default of 1 (i.e., 100% from well).
- Livestock water: Used the RESRAD default of 1 (i.e., 100% from well).
- Irrigation water: Used the RESRAD default of 1 (i.e., 100% from well).

Storage Times

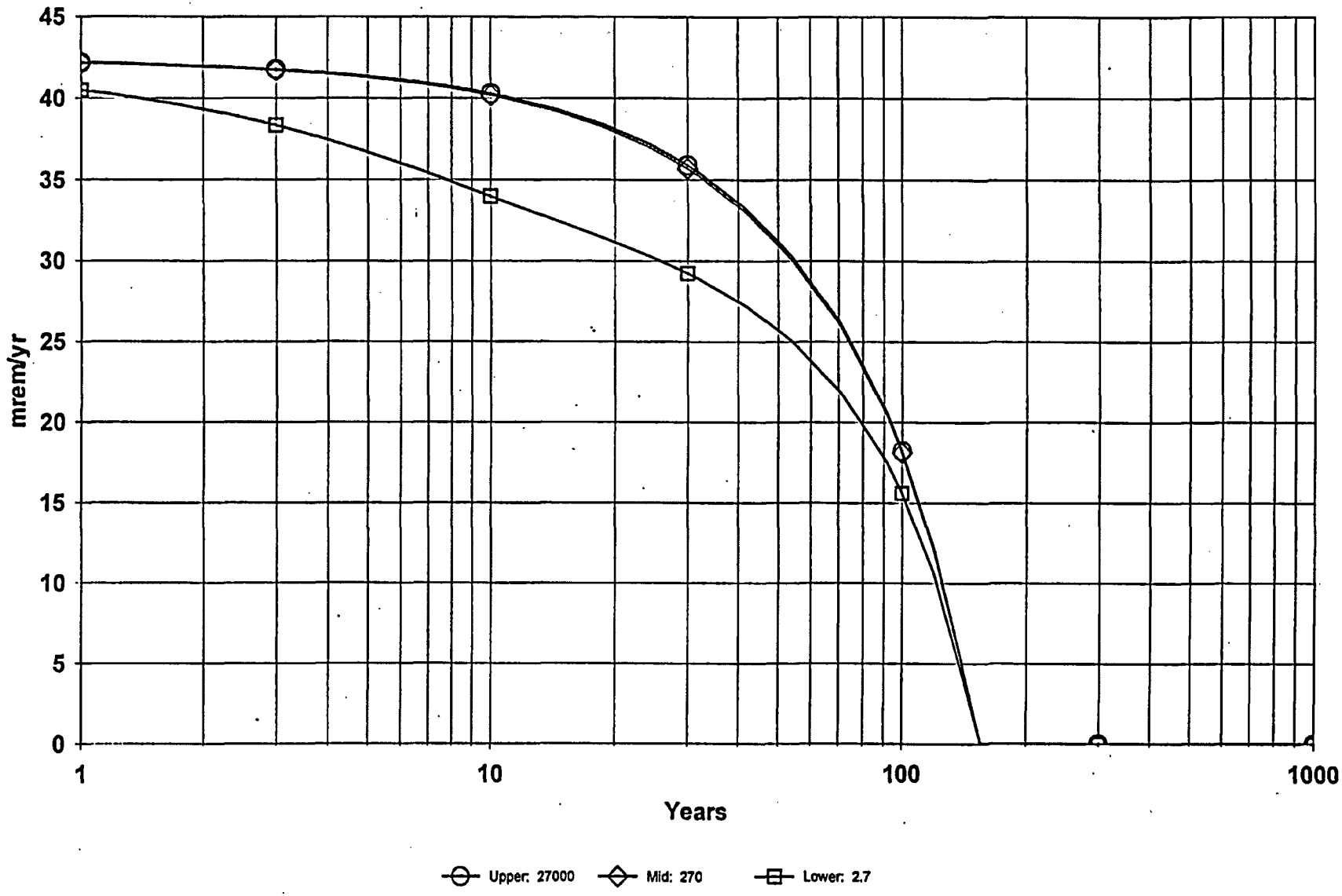
Used the RESRAD default values for all storage times (for vegetables, meats, fodder, etc.).

Radium Benchmark Dose Assessment

Attachment 2

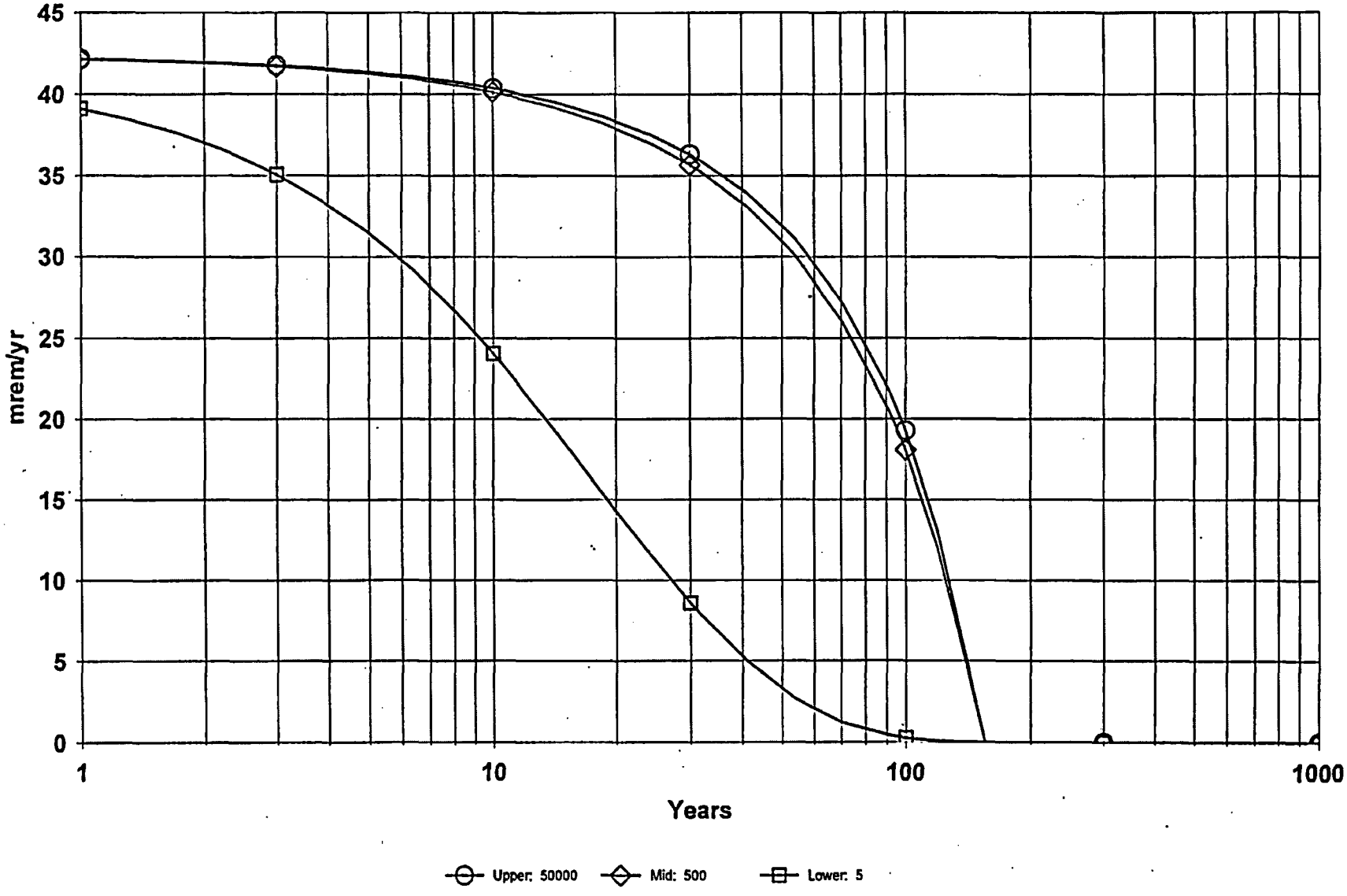
RESRAD Input Parameter Sensitivity Analysis

DOSE: All Nuclides Summed, All Pathways Summed With SA on Pb-210 Contaminated Zone Distribution Coef.



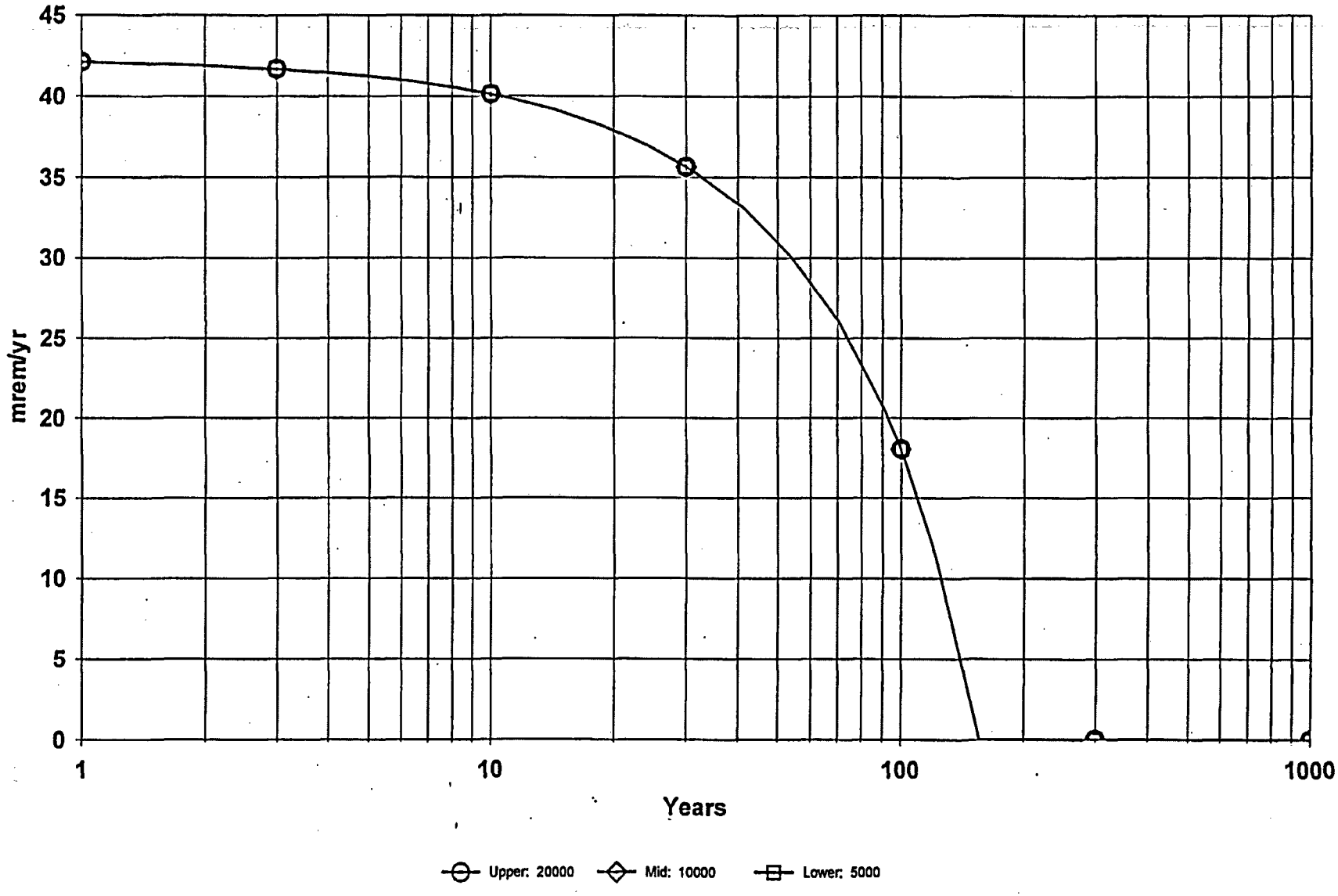
CBR1.rad 02/26/2004 11:07 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Ra-226 Contaminated Zone Distribution Coef.



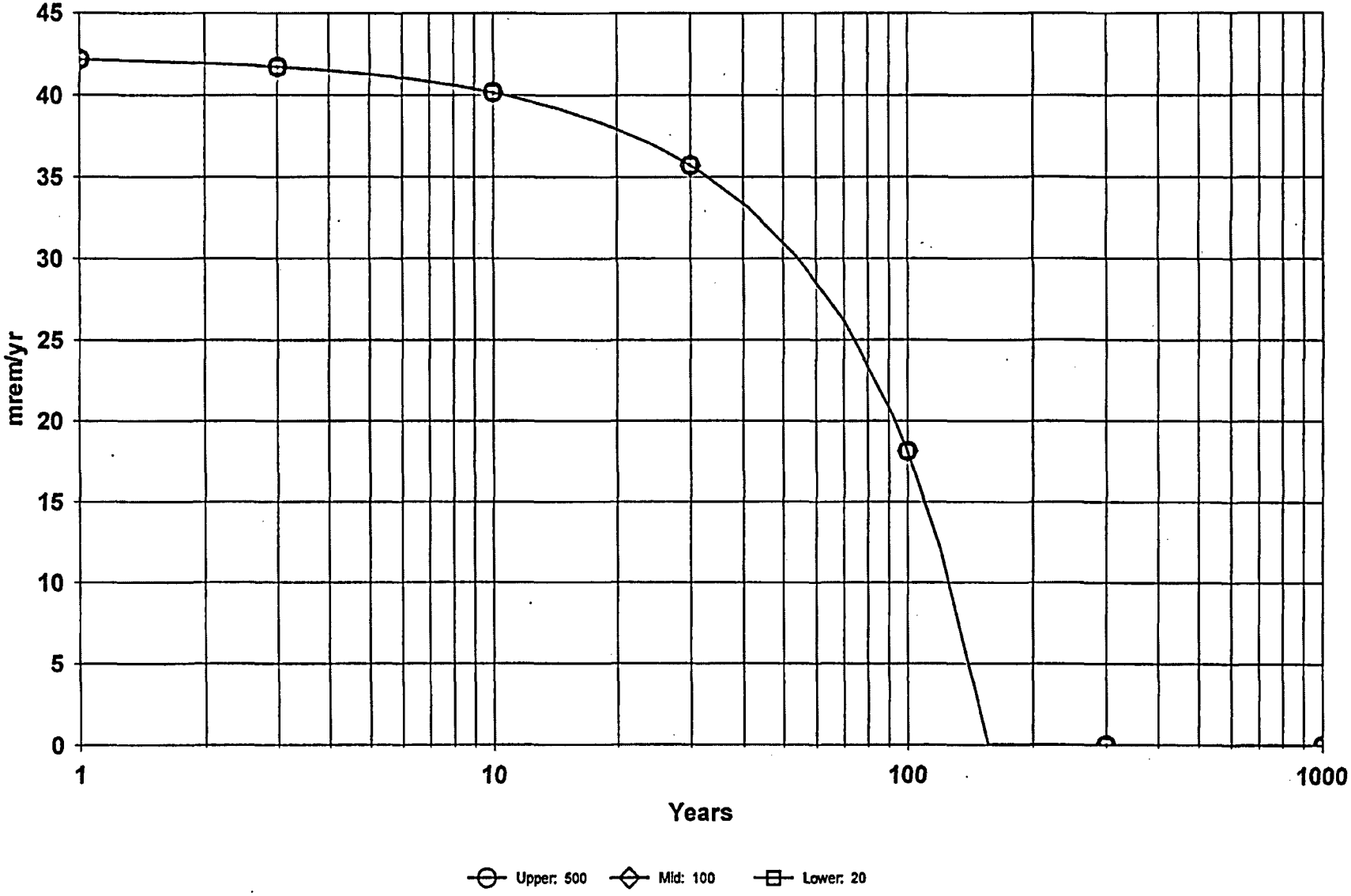
Ra022704.RAD 02/27/2004 09:40 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Area of contaminated zone



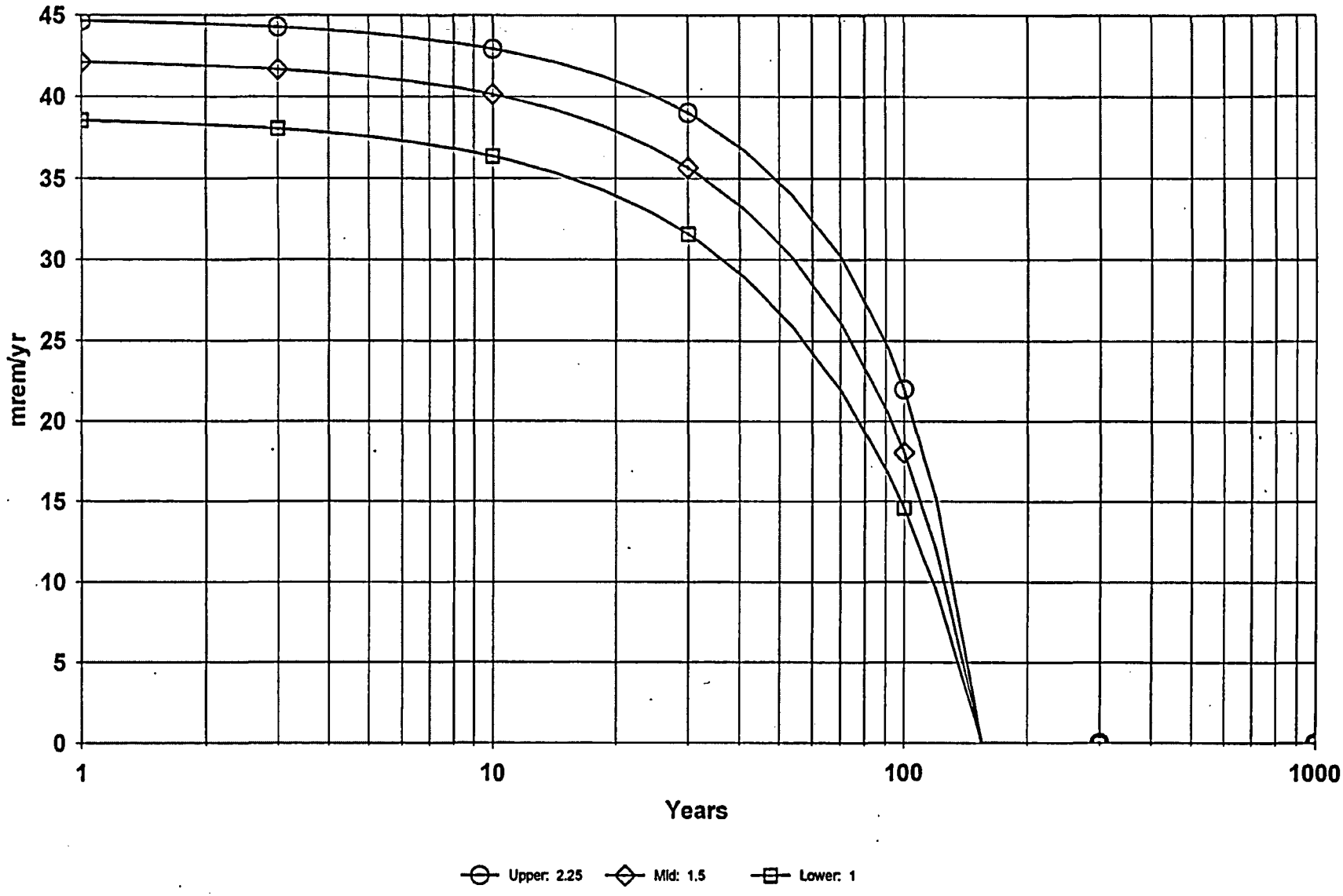
Ra022704.RAD 02/27/2004 09:56 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Length parallel to aquifer flow



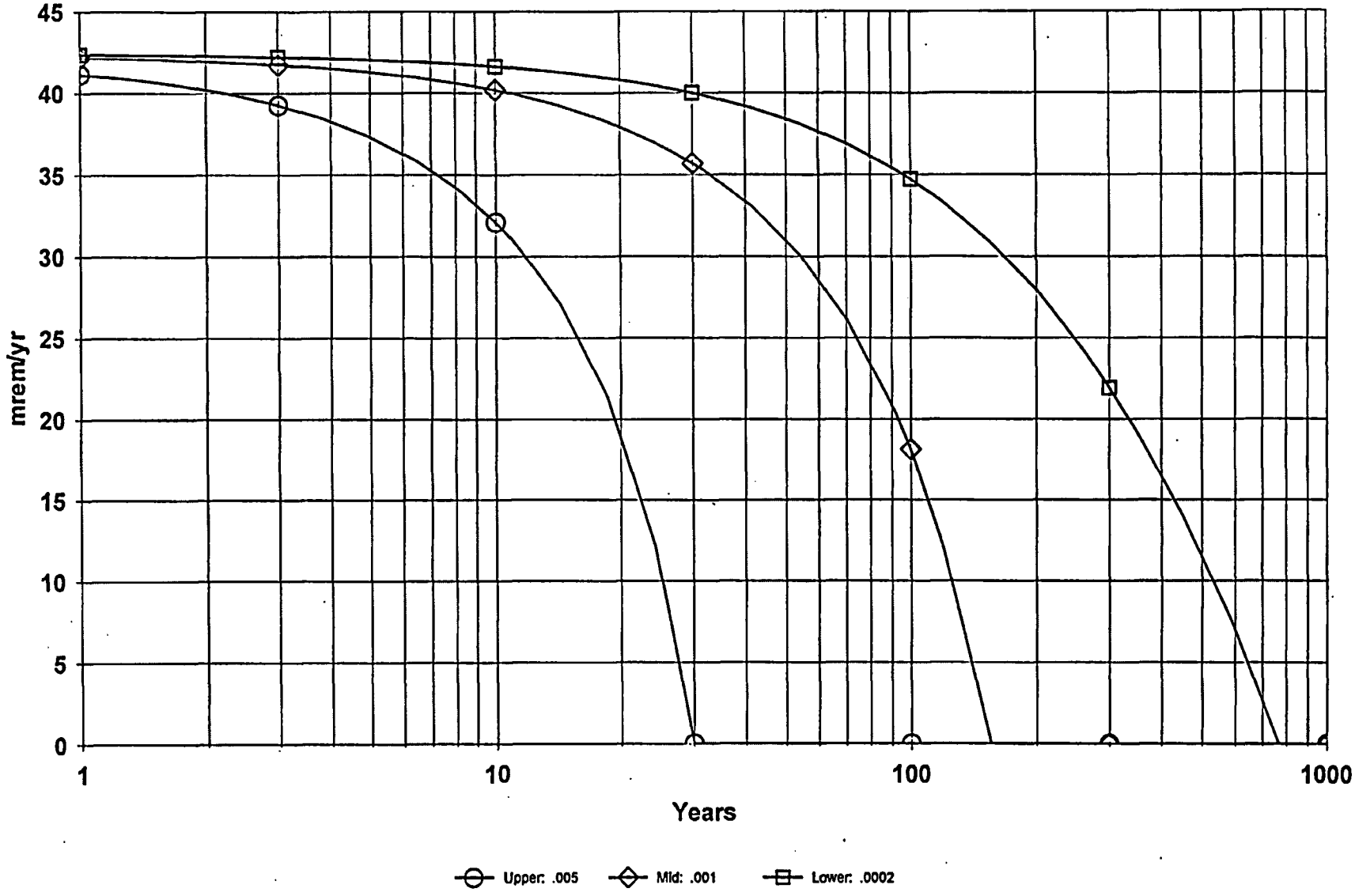
Ra022704.RAD 02/27/2004 15:40 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of contaminated zone



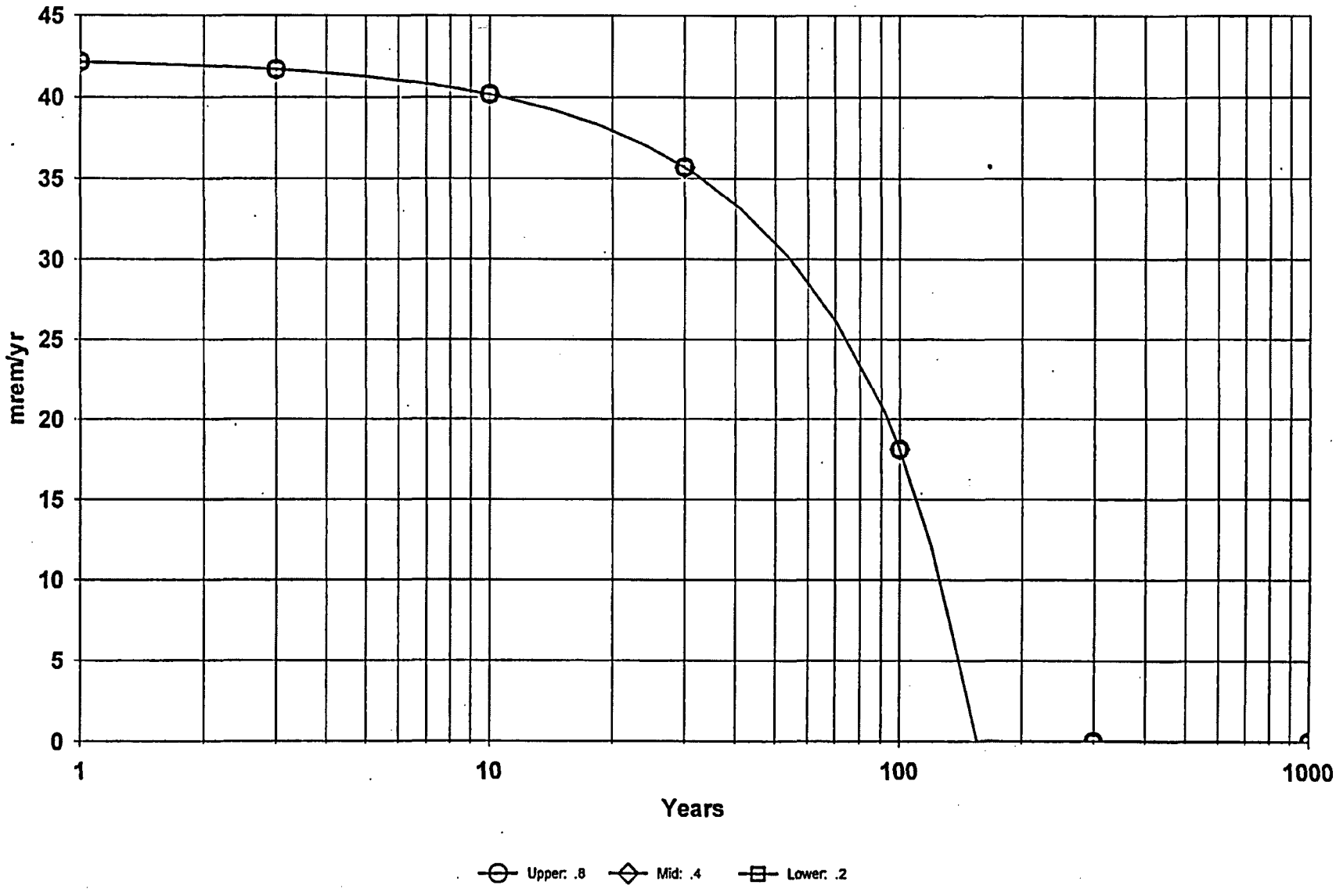
Ra022704.RAD 02/27/2004 09:56 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone erosion rate



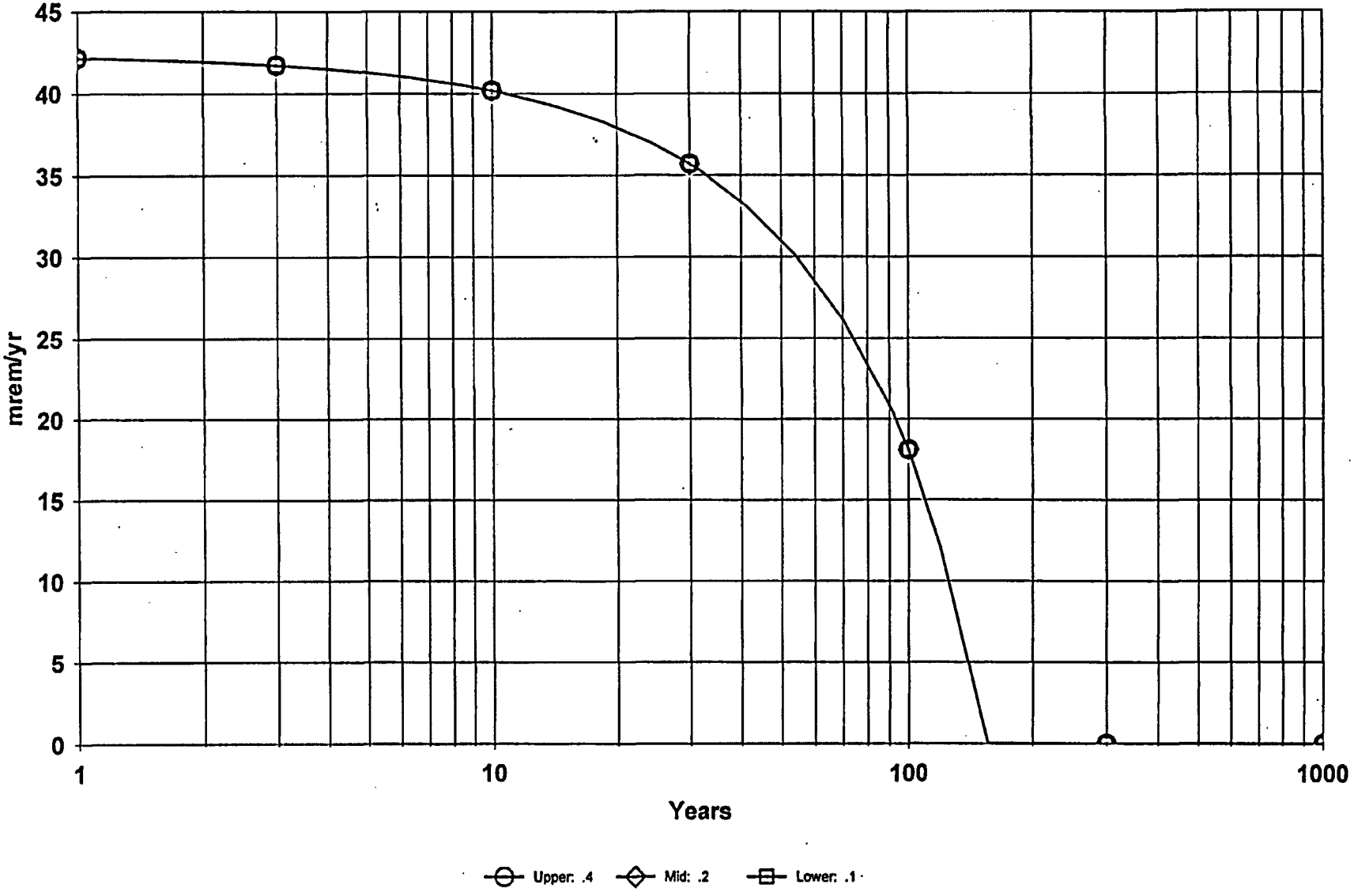
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone total porosity



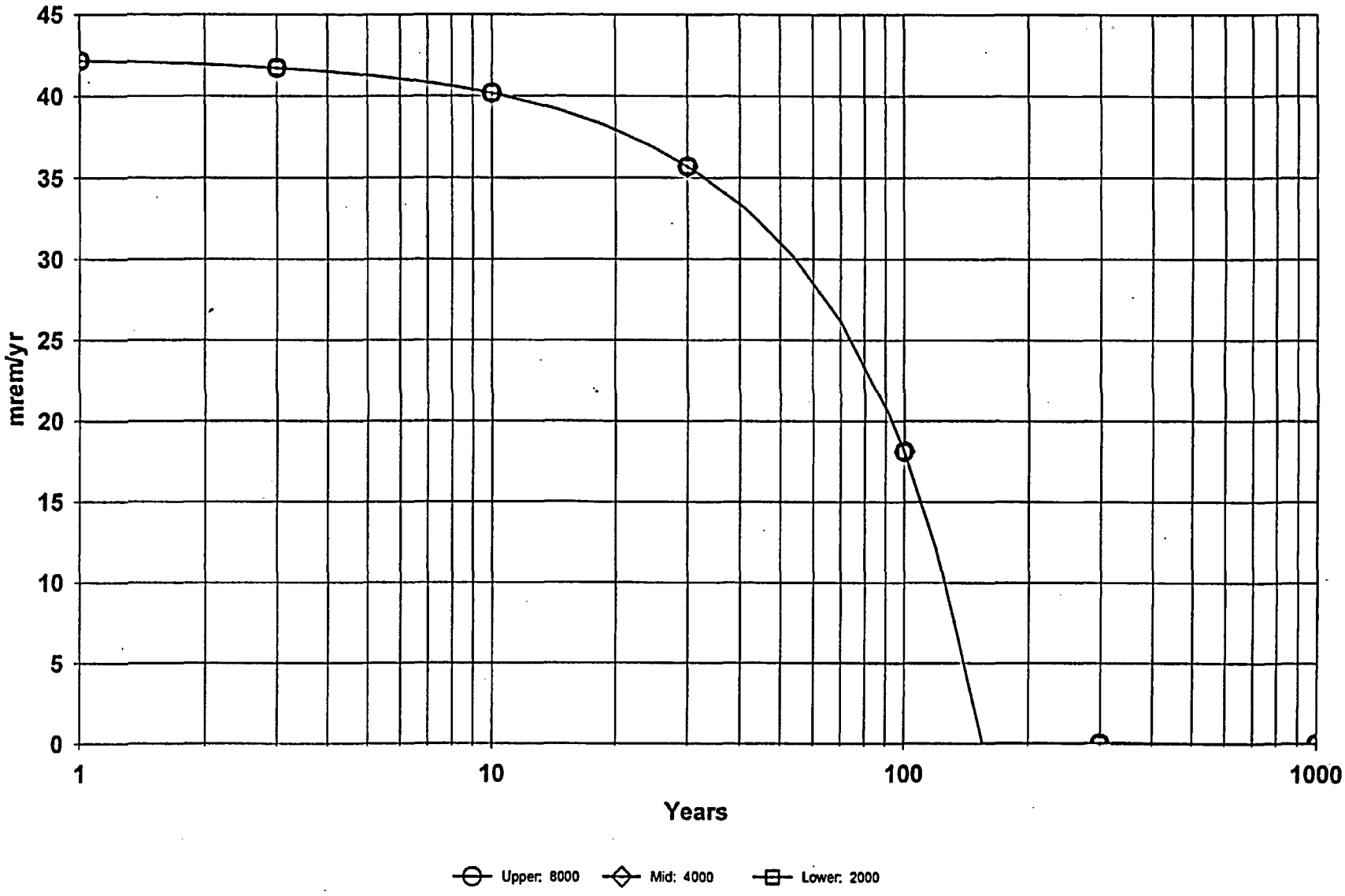
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone field capacity



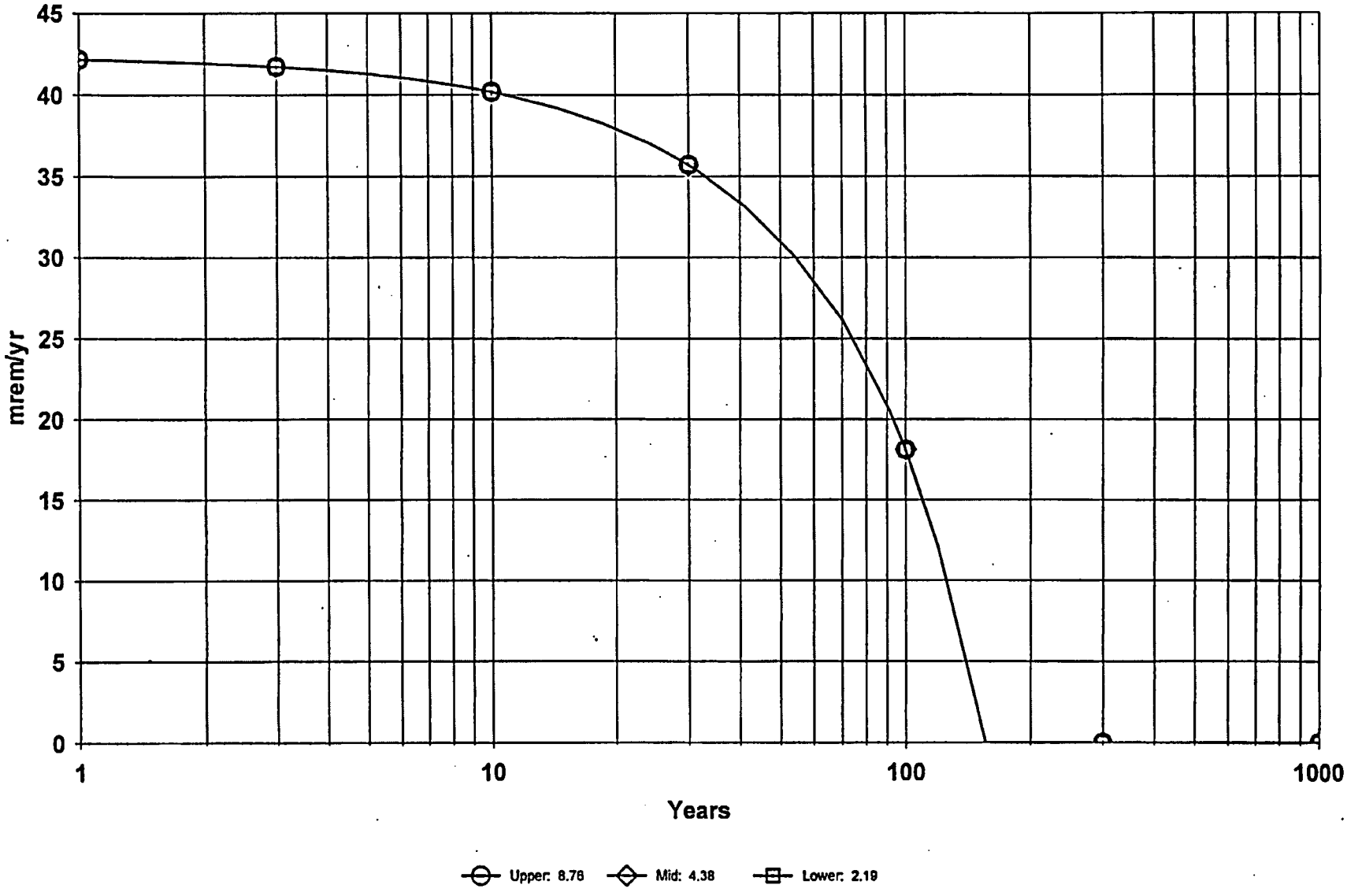
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone hydraulic conductivity



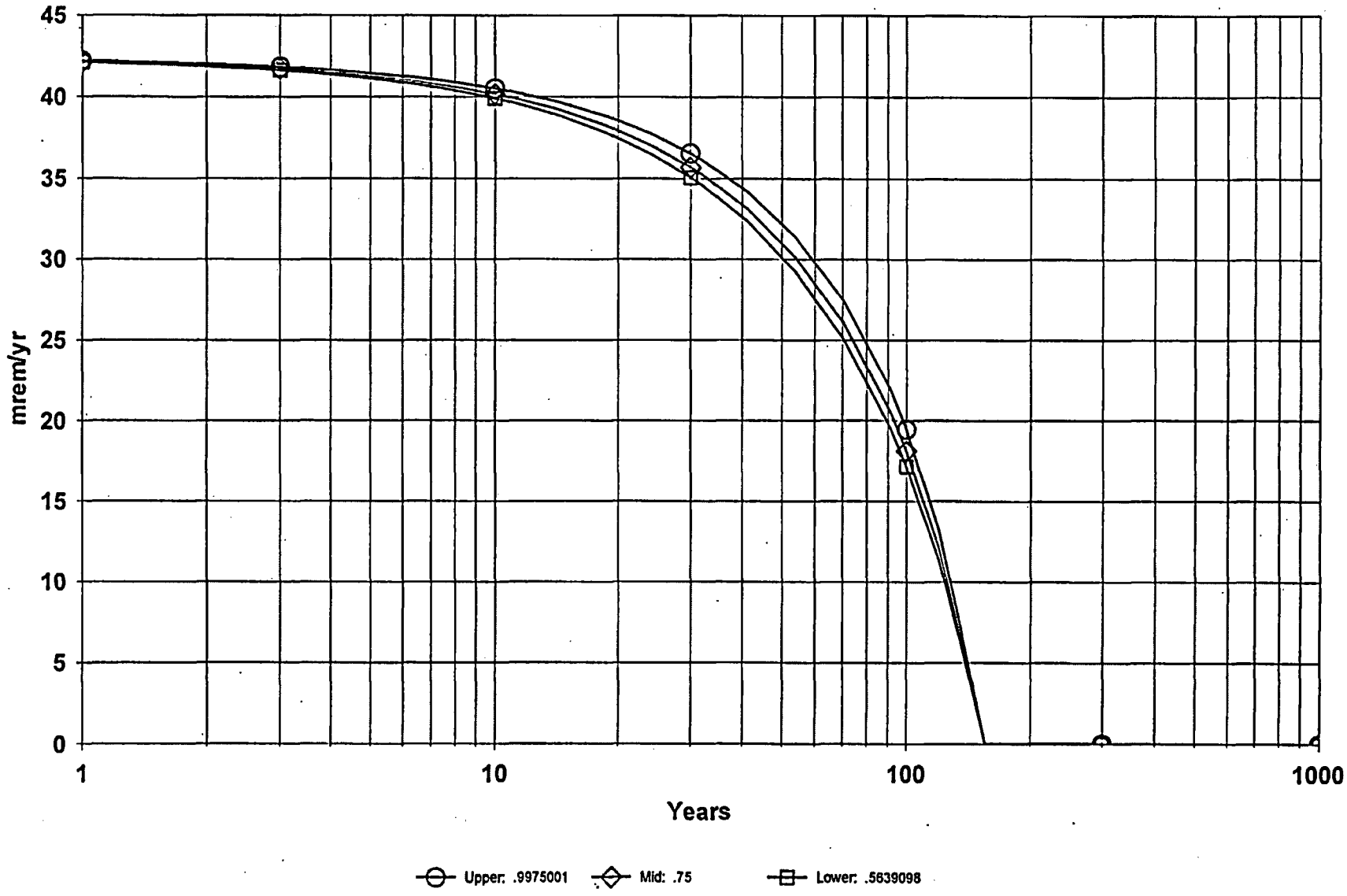
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Contaminated zone b parameter



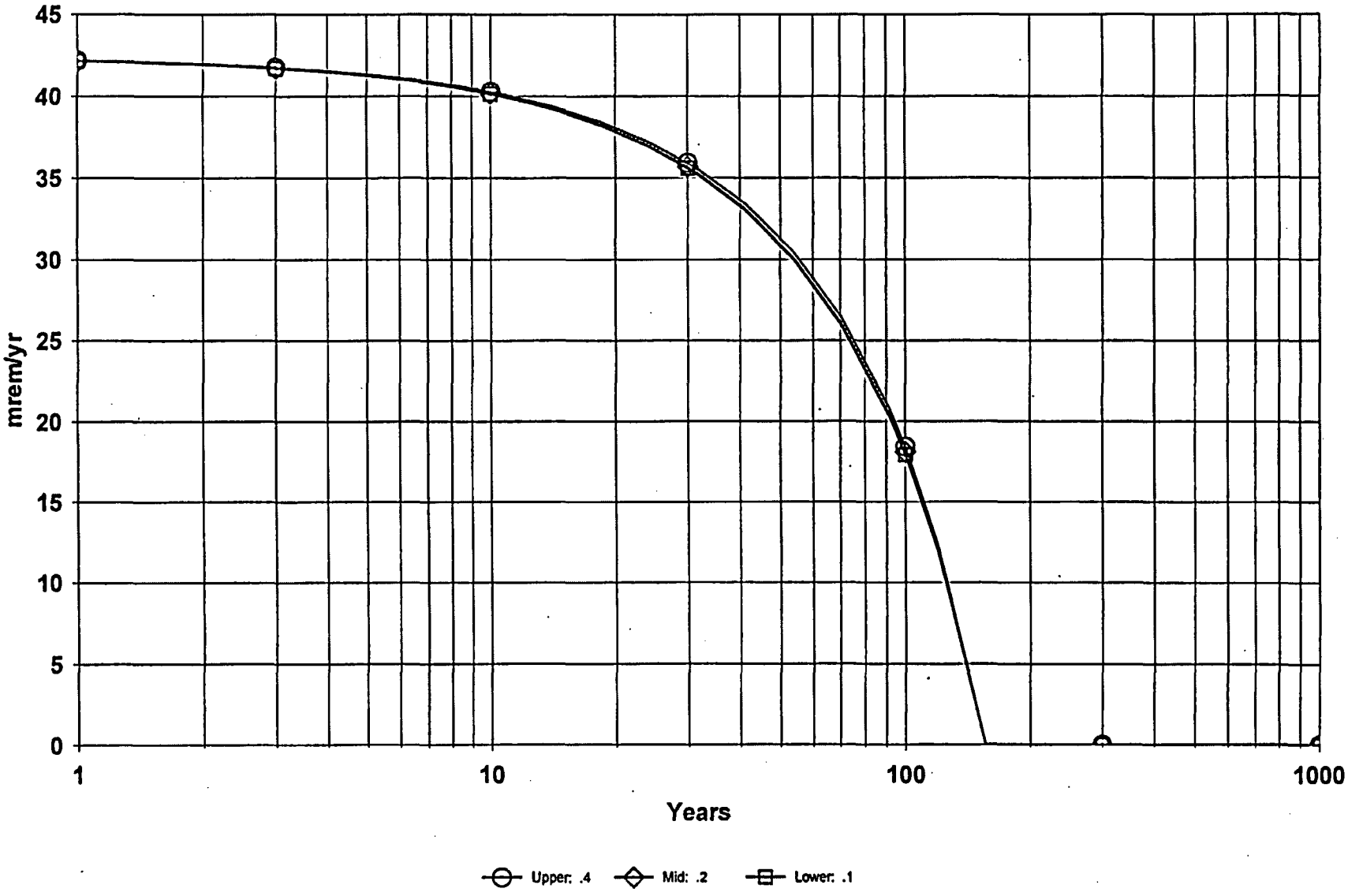
Ra022704.RAD 02/27/2004 10:14 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Evapotranspiration coefficient



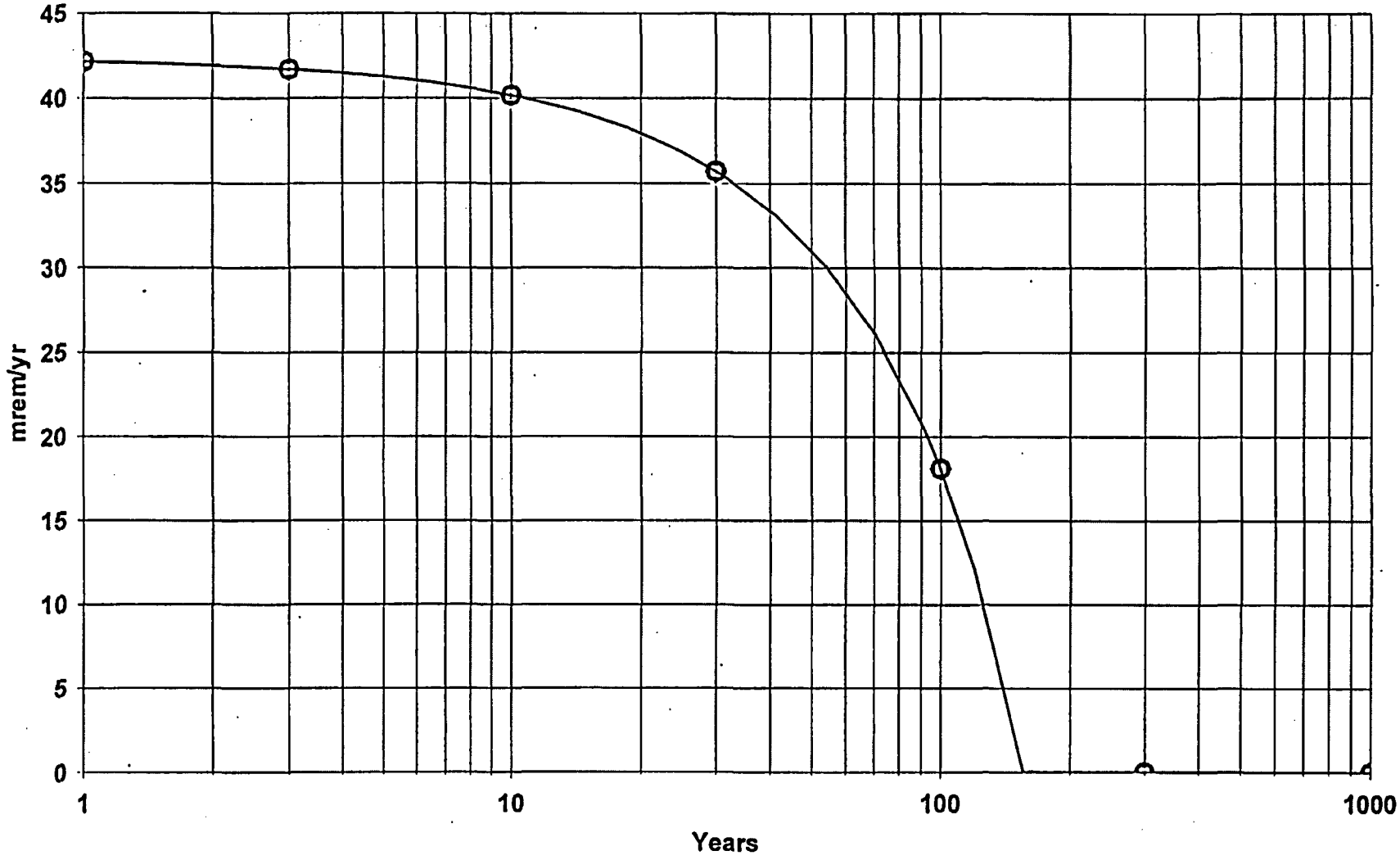
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Runoff coefficient



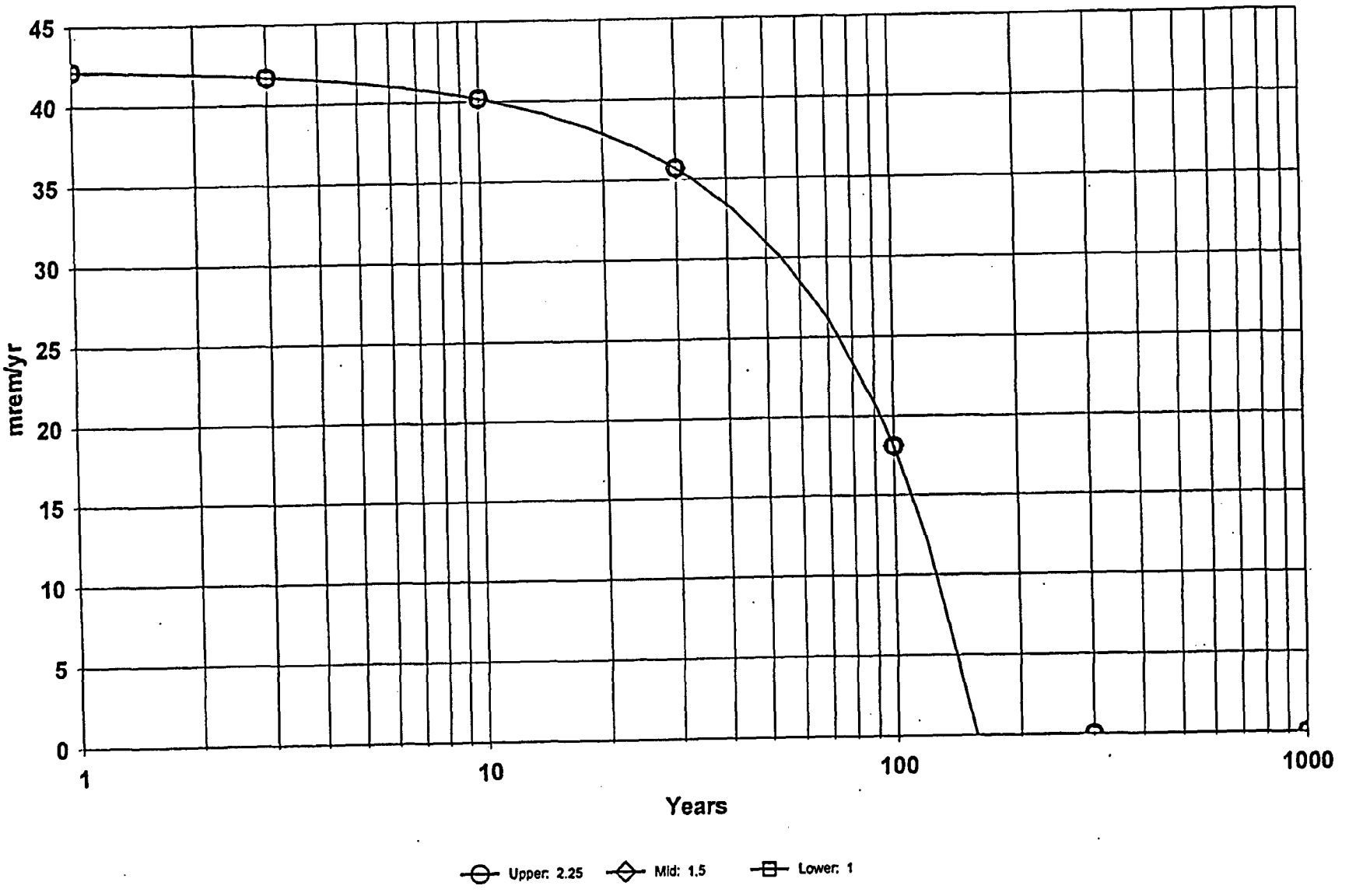
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Watershed area for nearby stream or pond



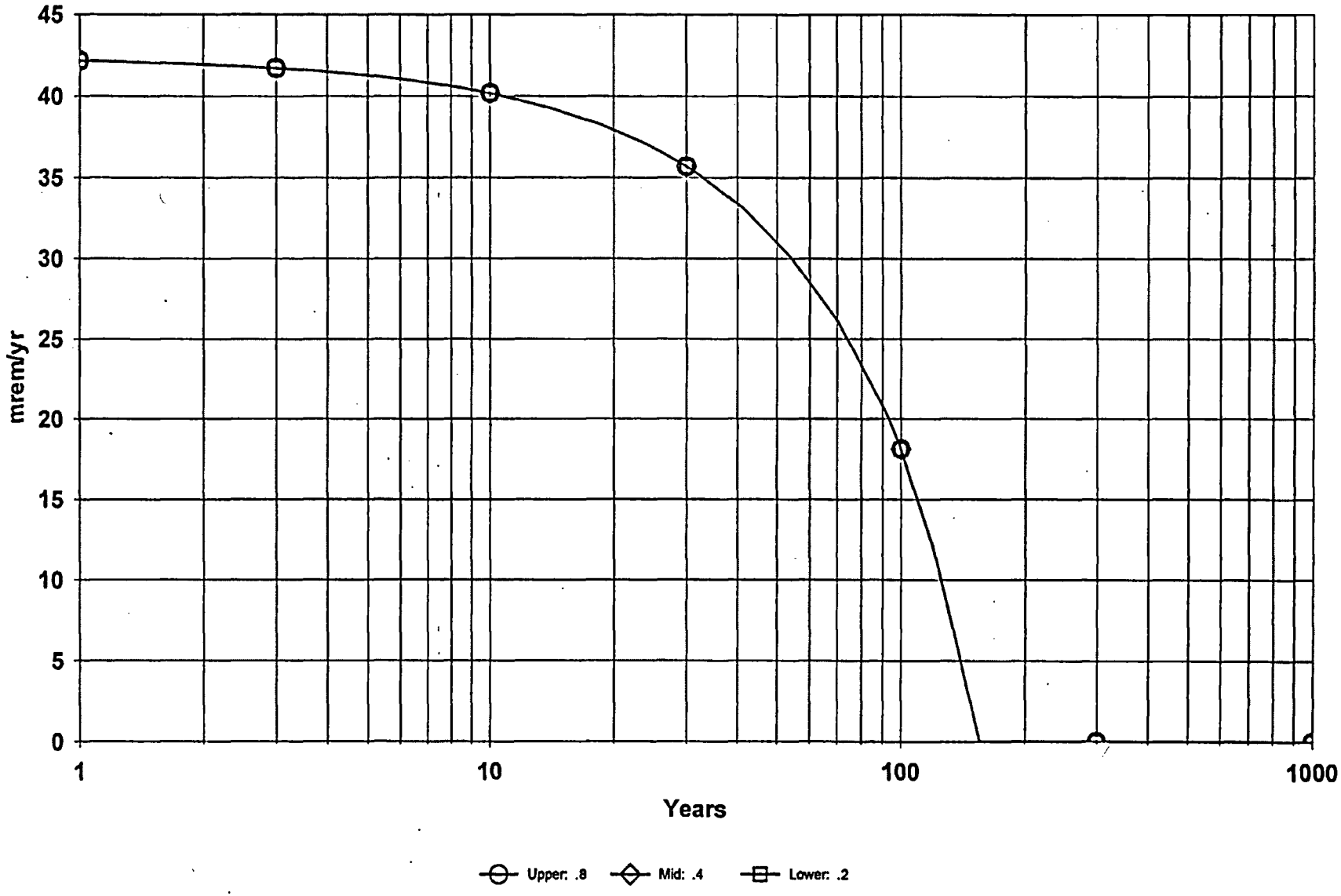
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of saturated zone



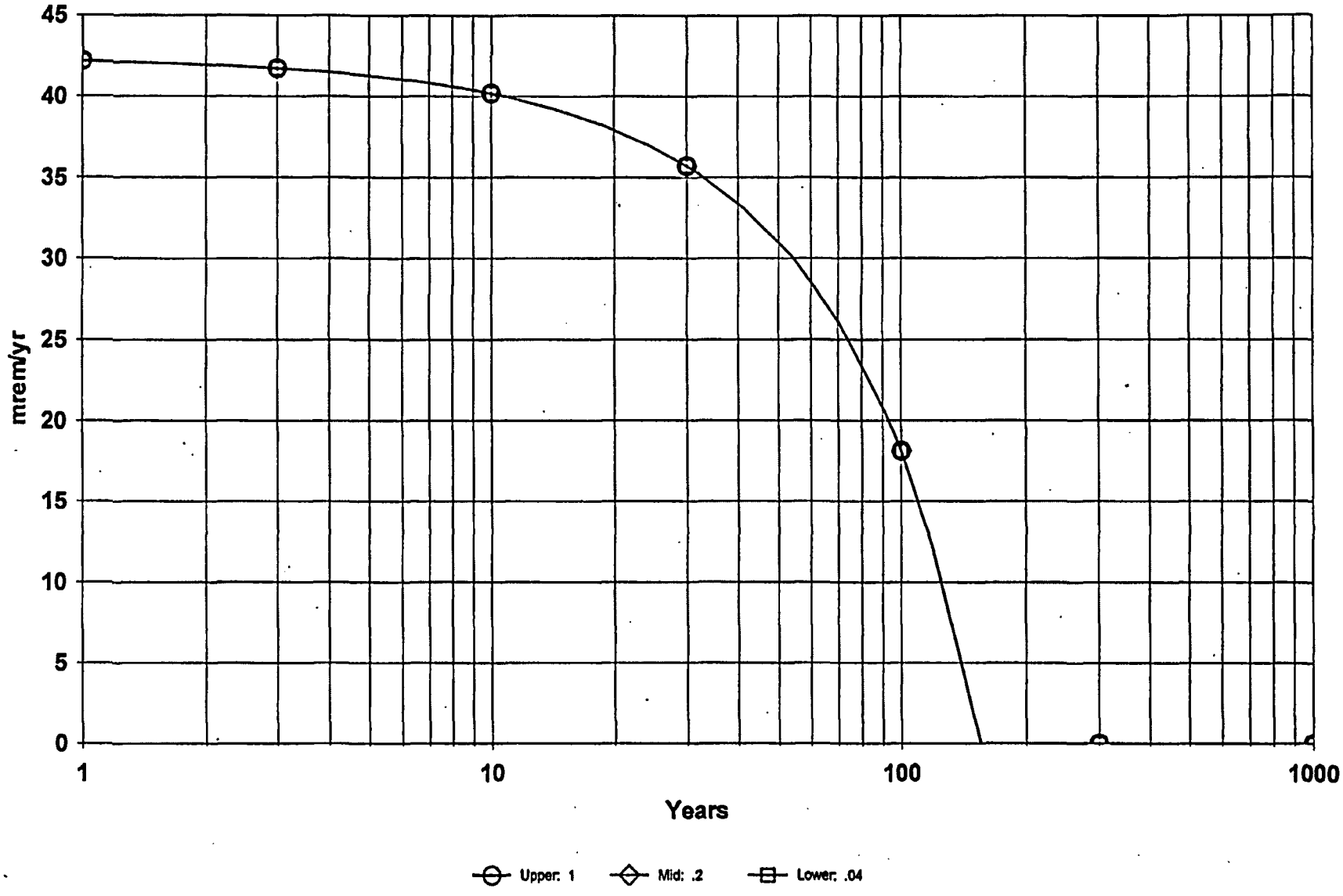
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone total porosity



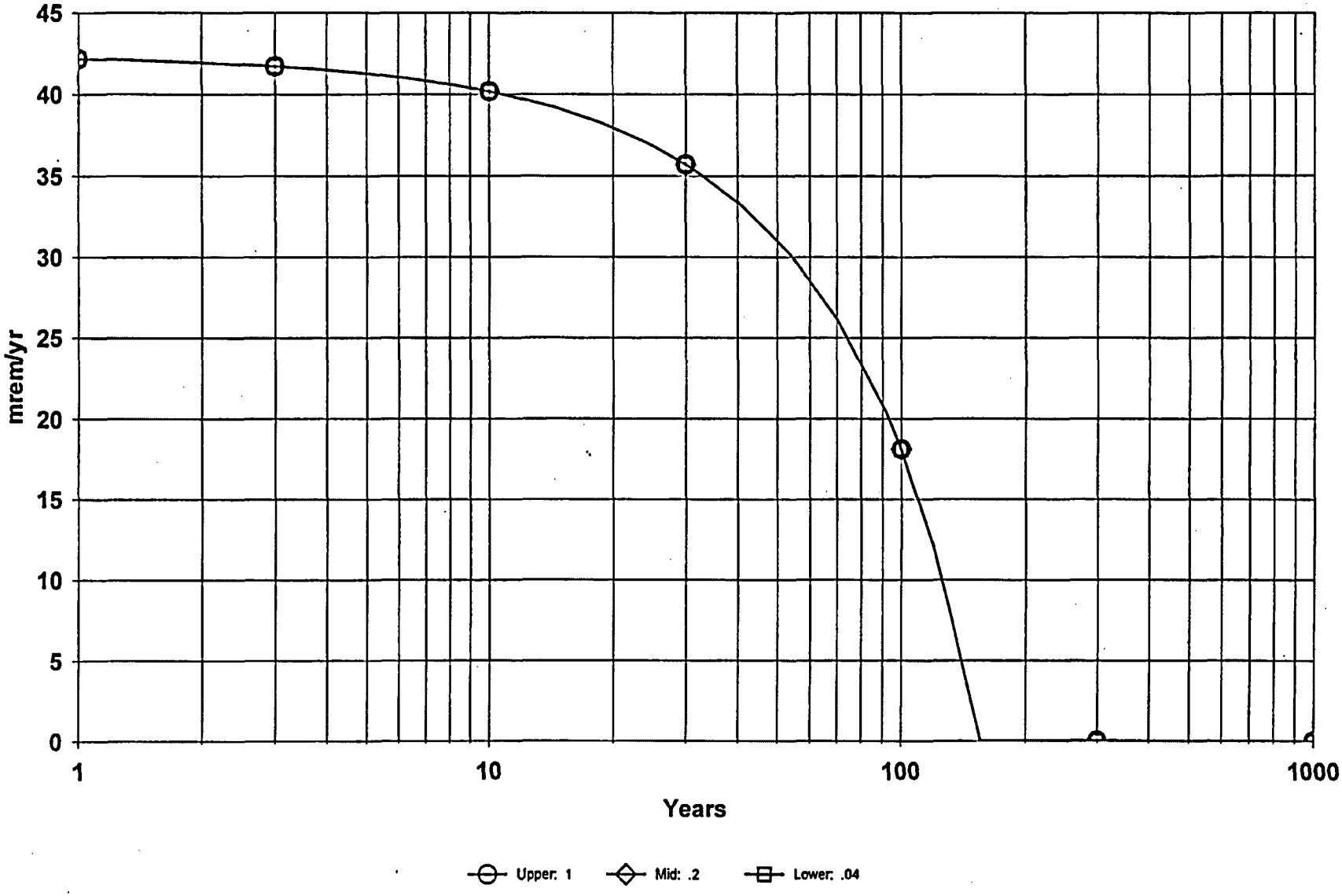
Ra022704.RAD 02/27/2004 10:22 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone effective porosity



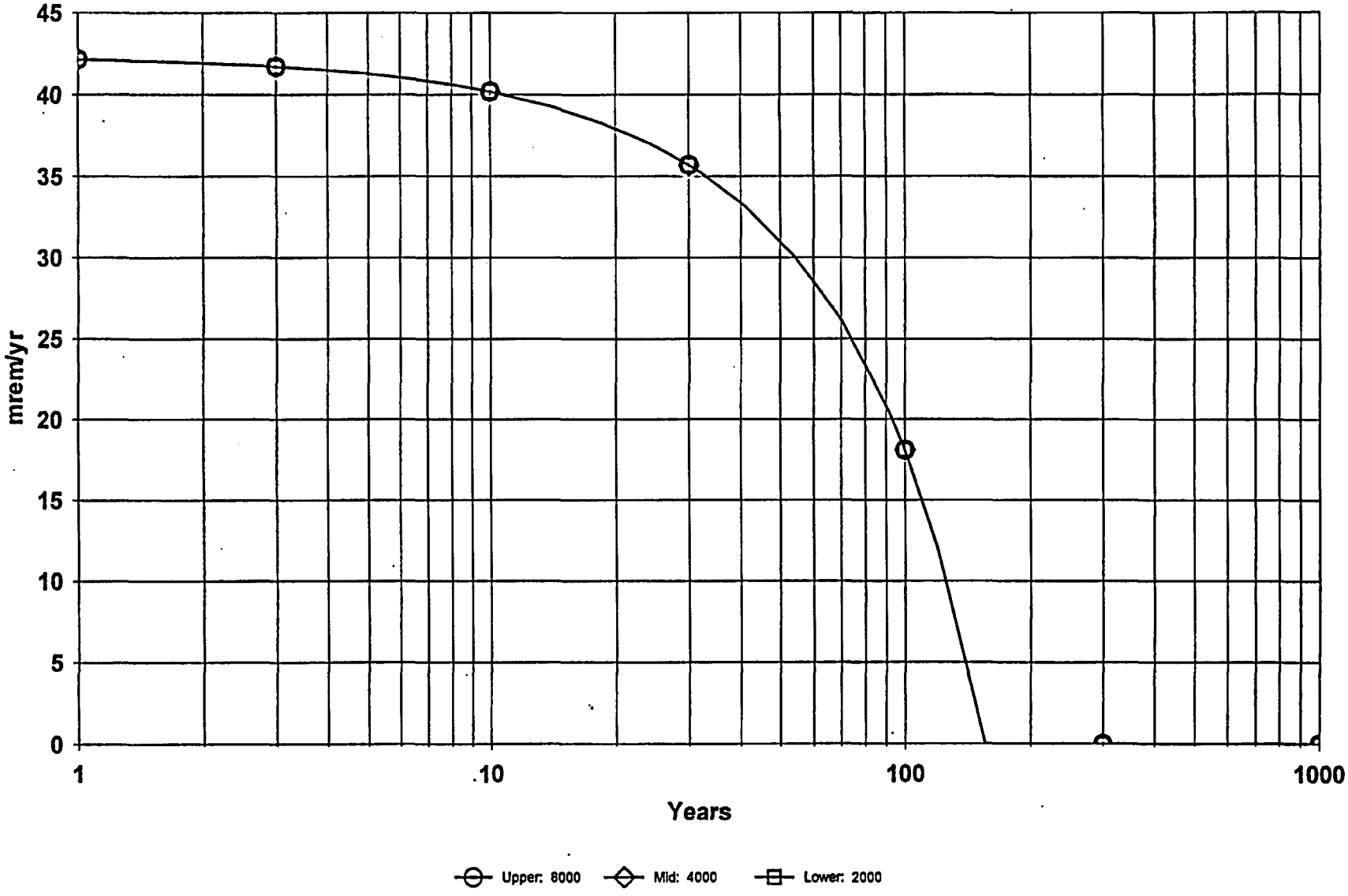
Ra022704.RAD 05/24/2004 16:52 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone field capacity



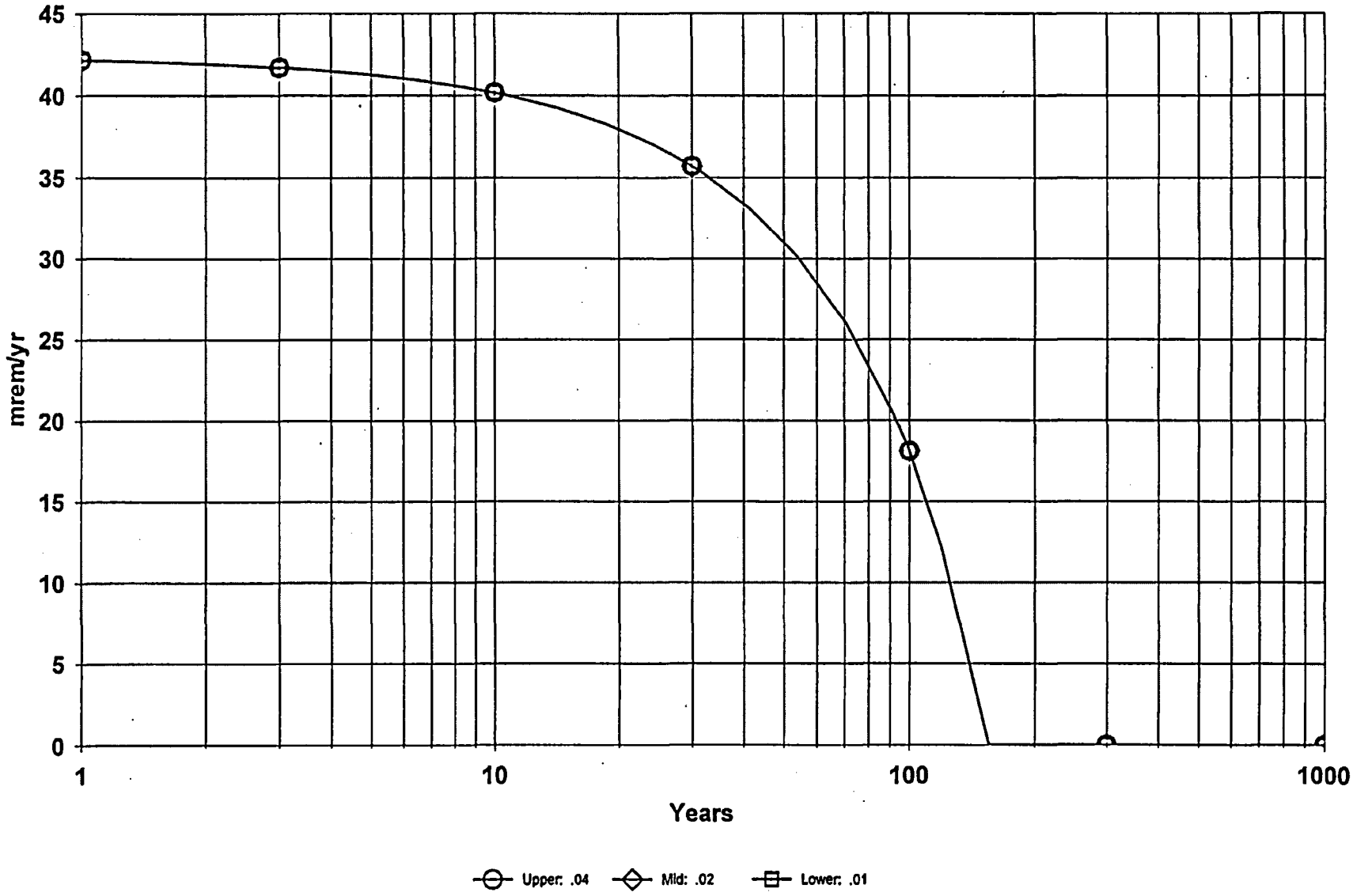
Ra022704.RAD 02/27/2004 16:11 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone hydraulic conductivity



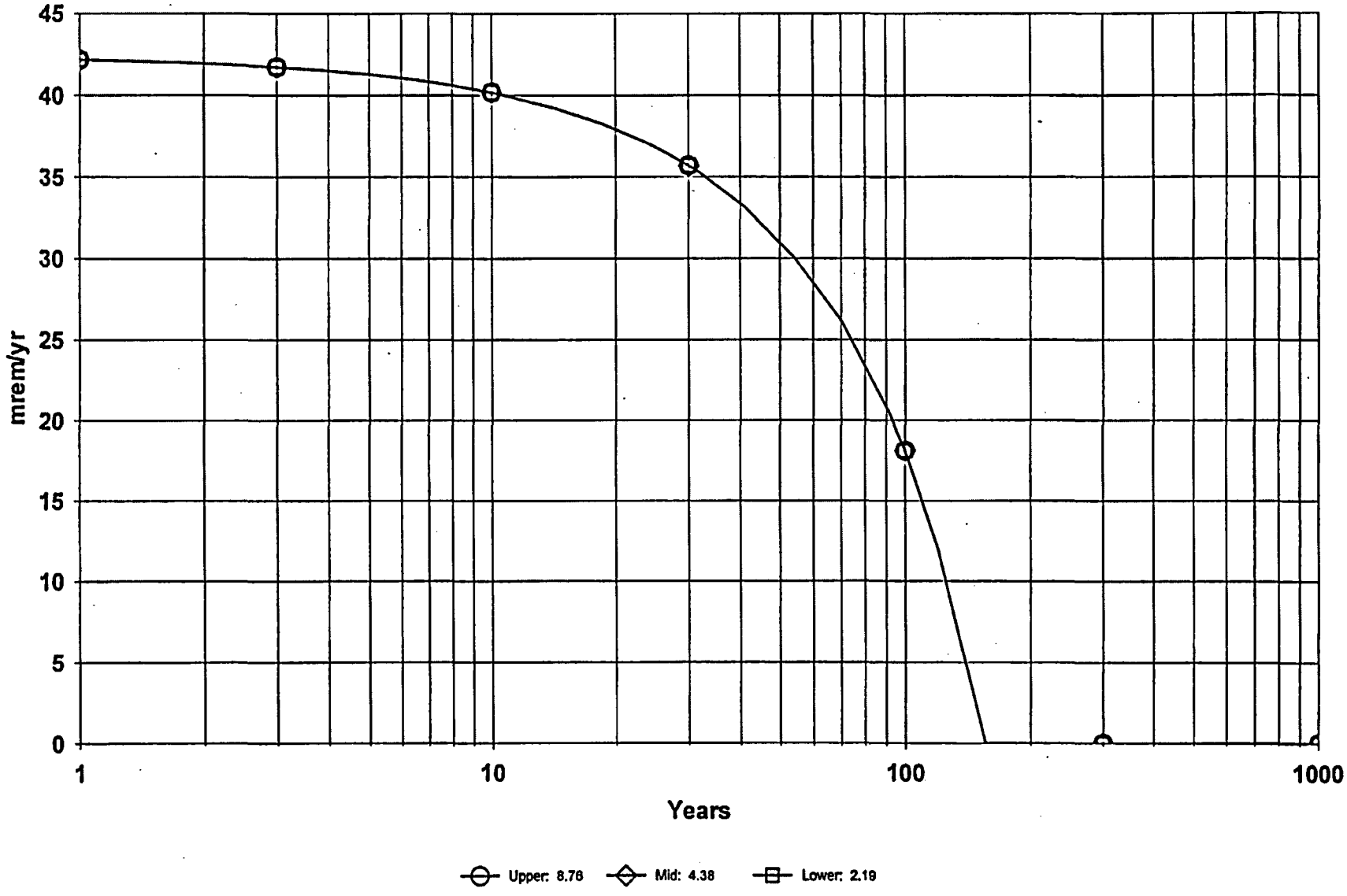
Ra022704.RAD 02/27/2004 15:34 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone hydraulic gradient



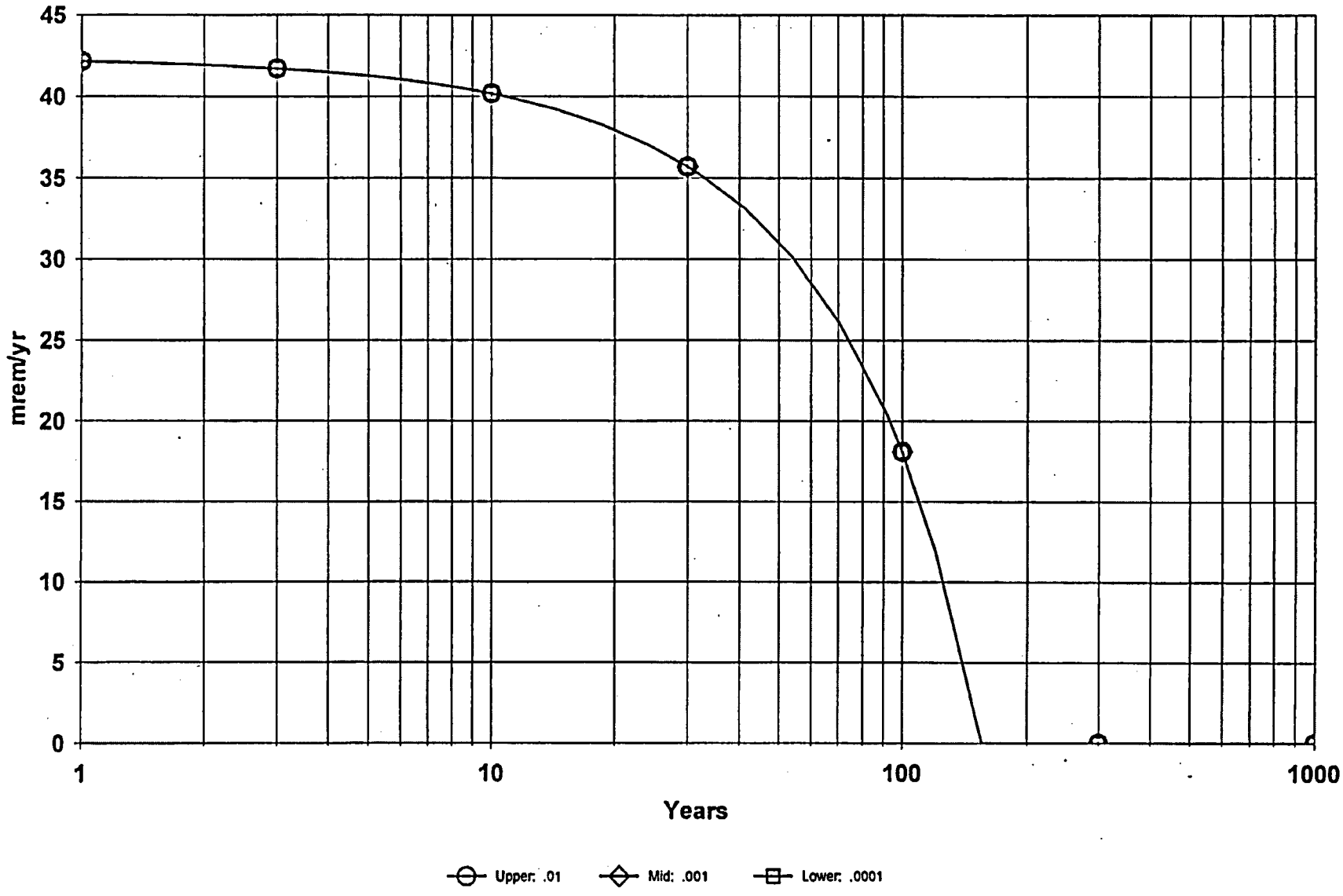
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Saturated zone b parameter



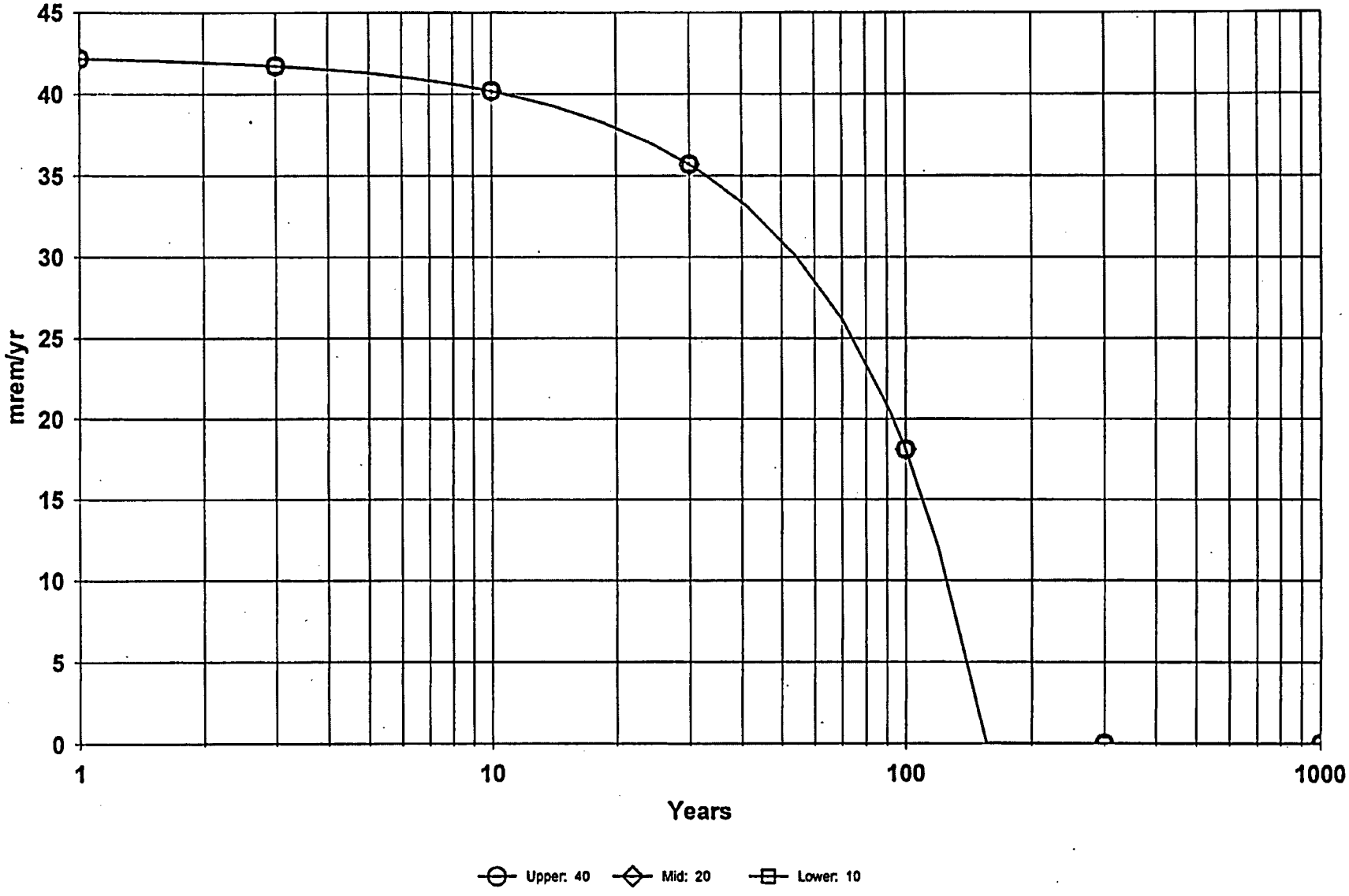
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Water table drop rate



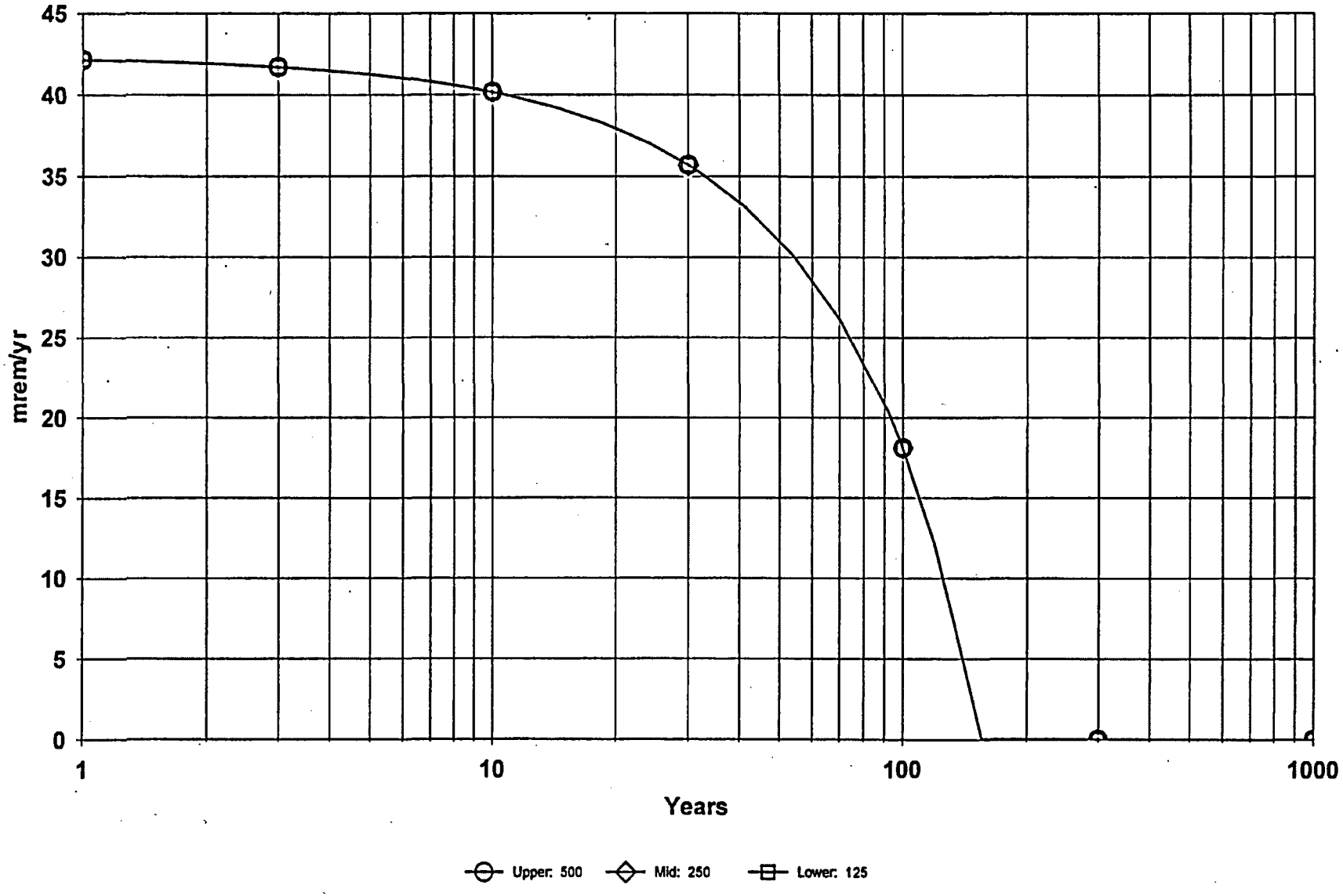
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Well pump intake depth



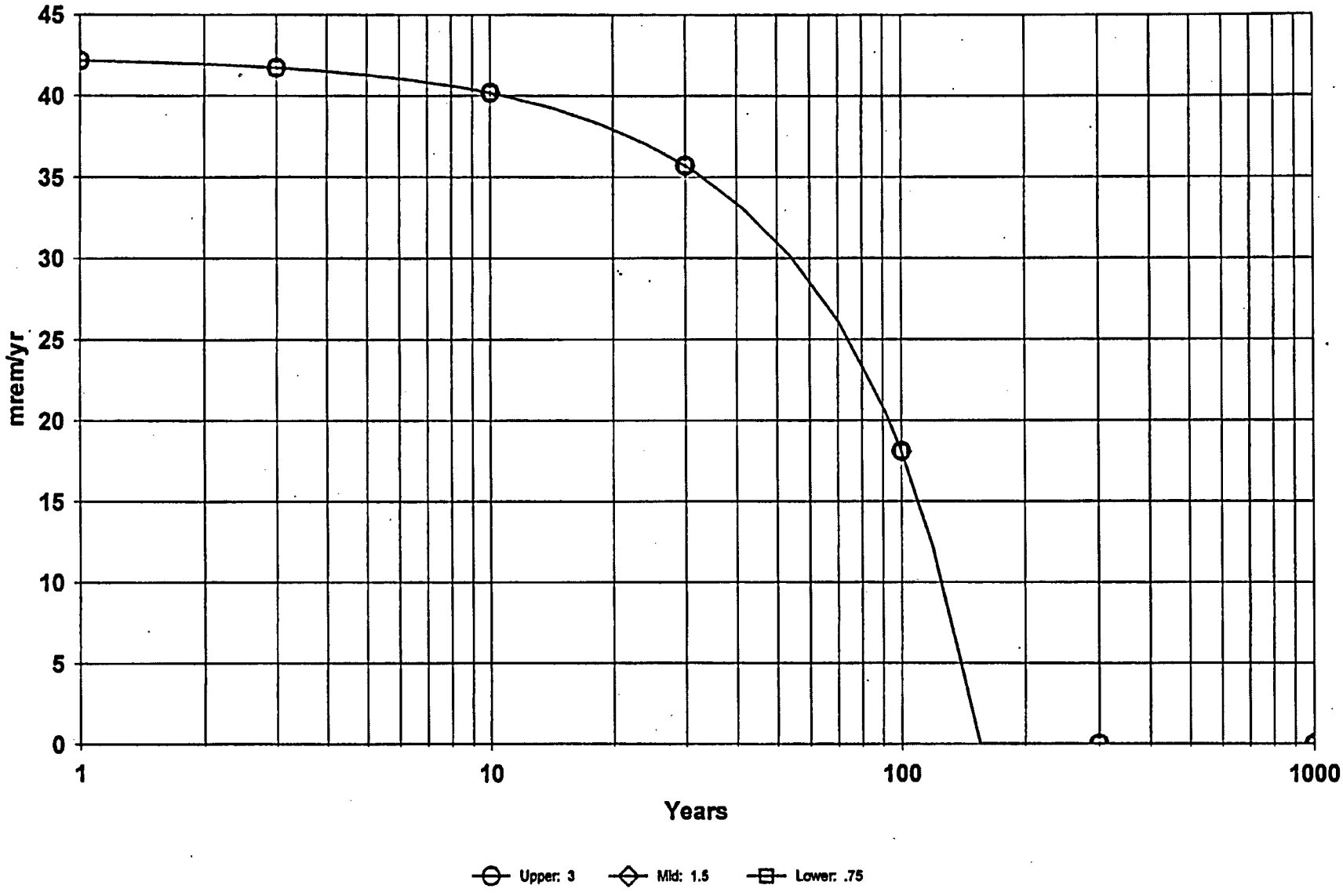
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Well pumping rate



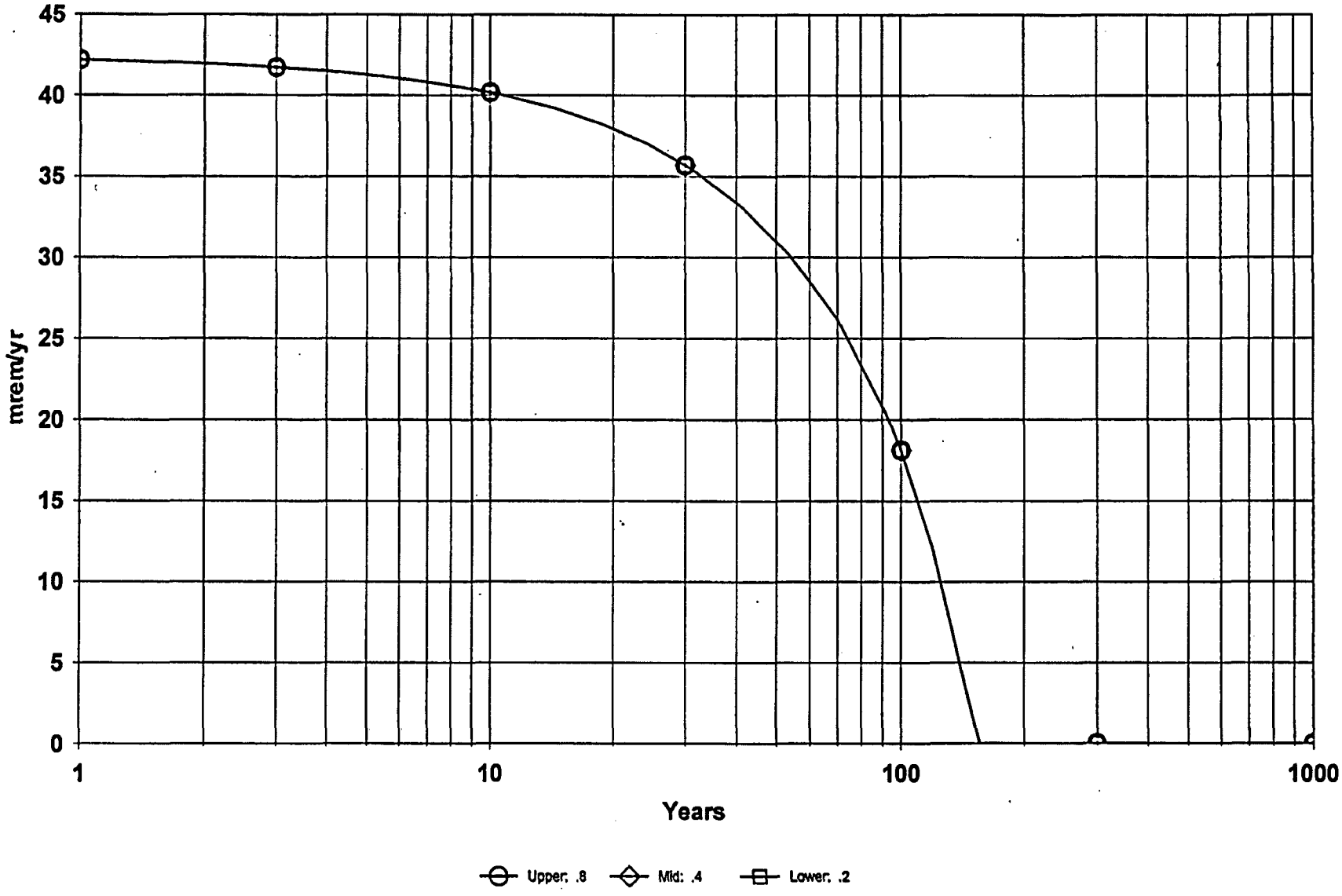
Ra022704.RAD 02/27/2004 10:35 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Density of Unsaturated Zone 1



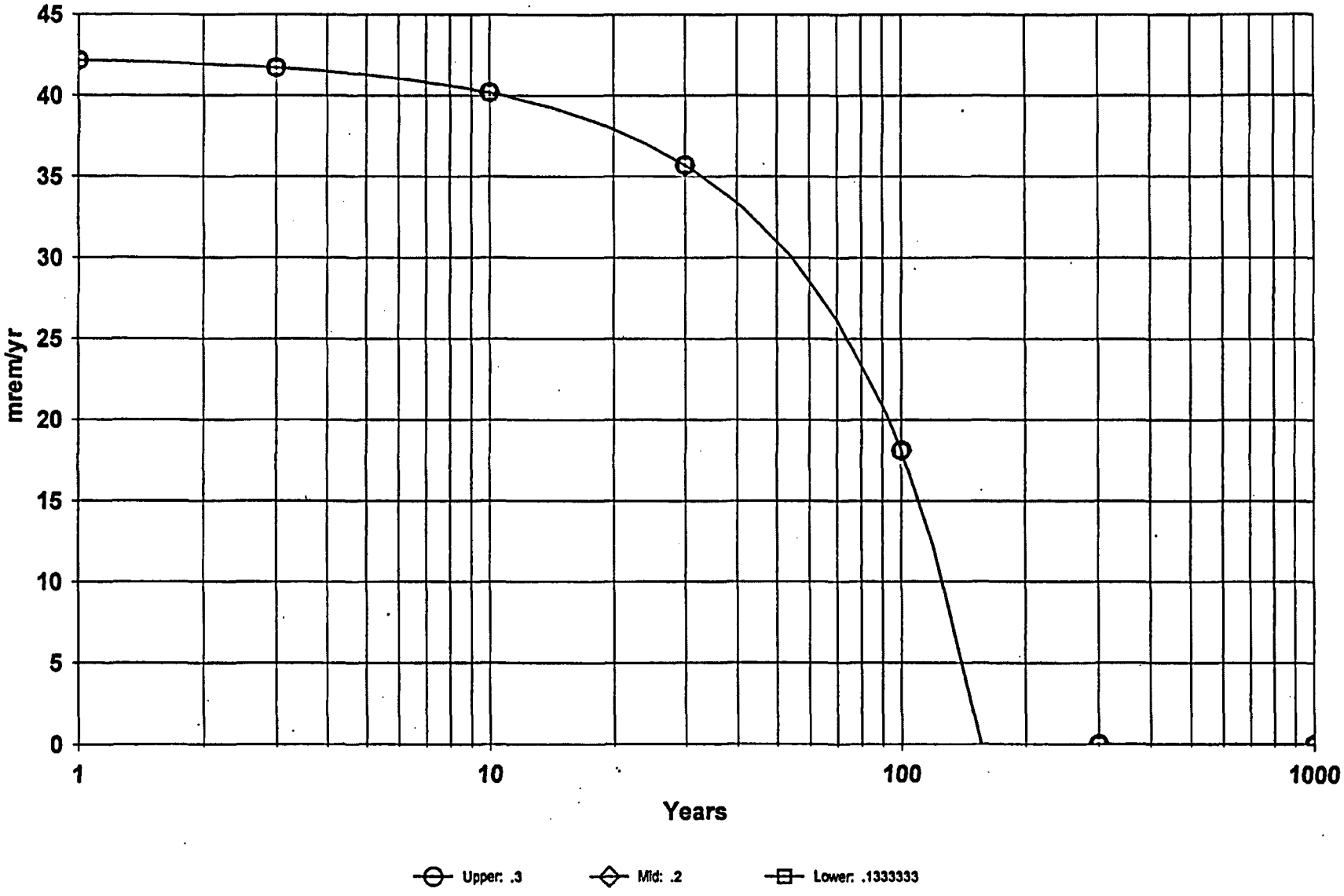
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Total Porosity of Unsaturated Zone 1



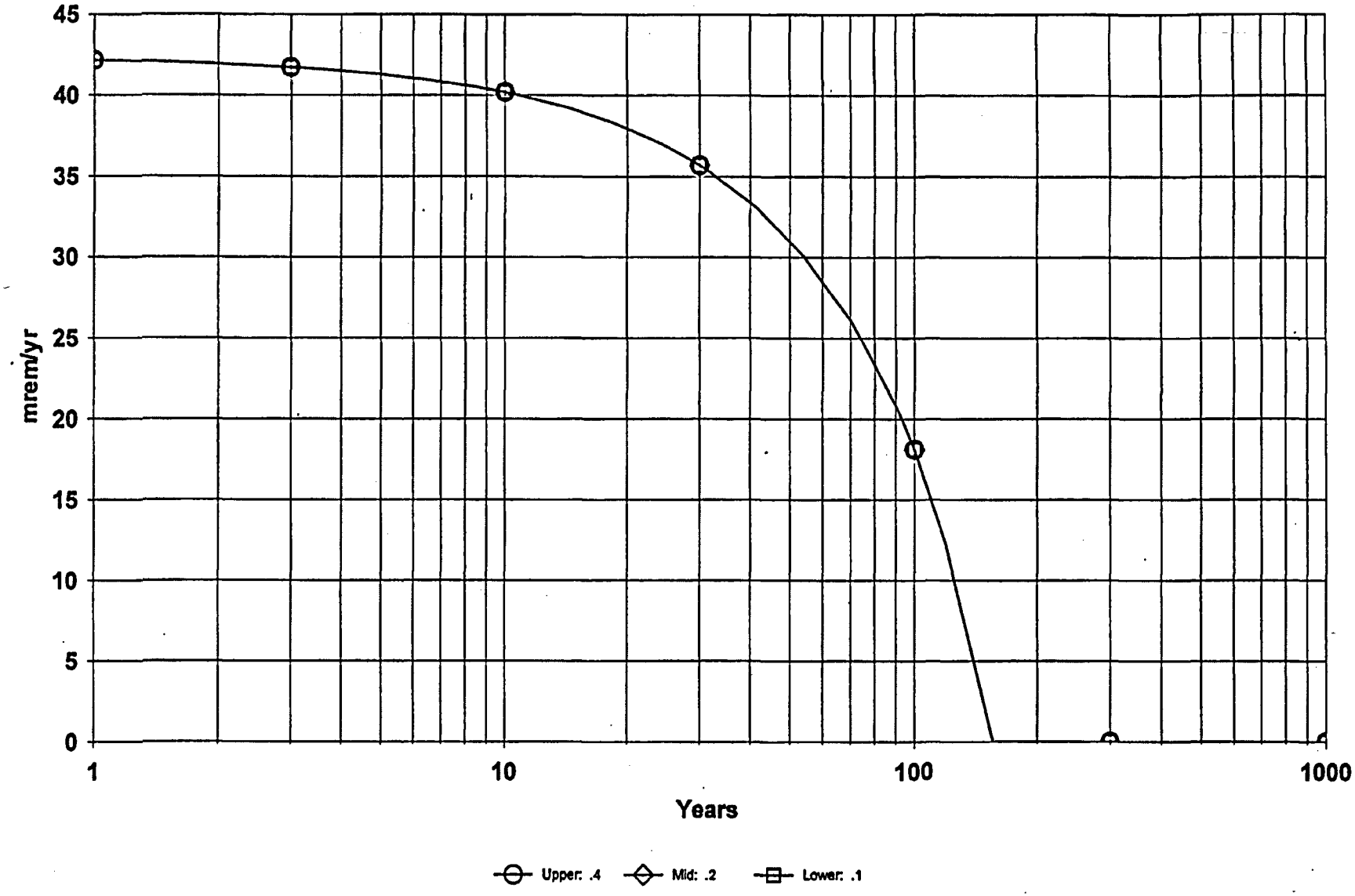
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Effective Porosity of Unsaturated Zone 1



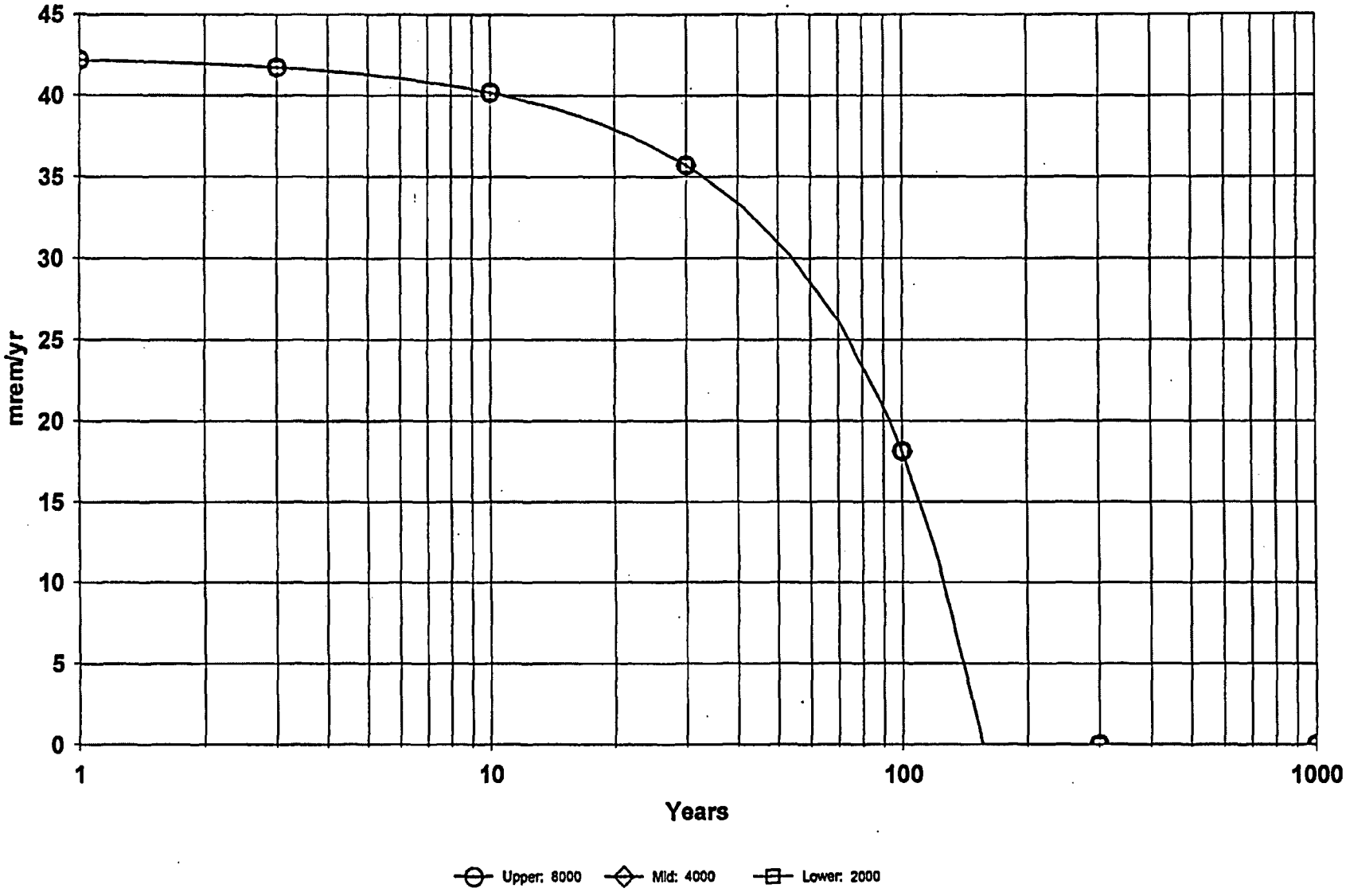
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Field Capacity of Unsaturated Zone 1



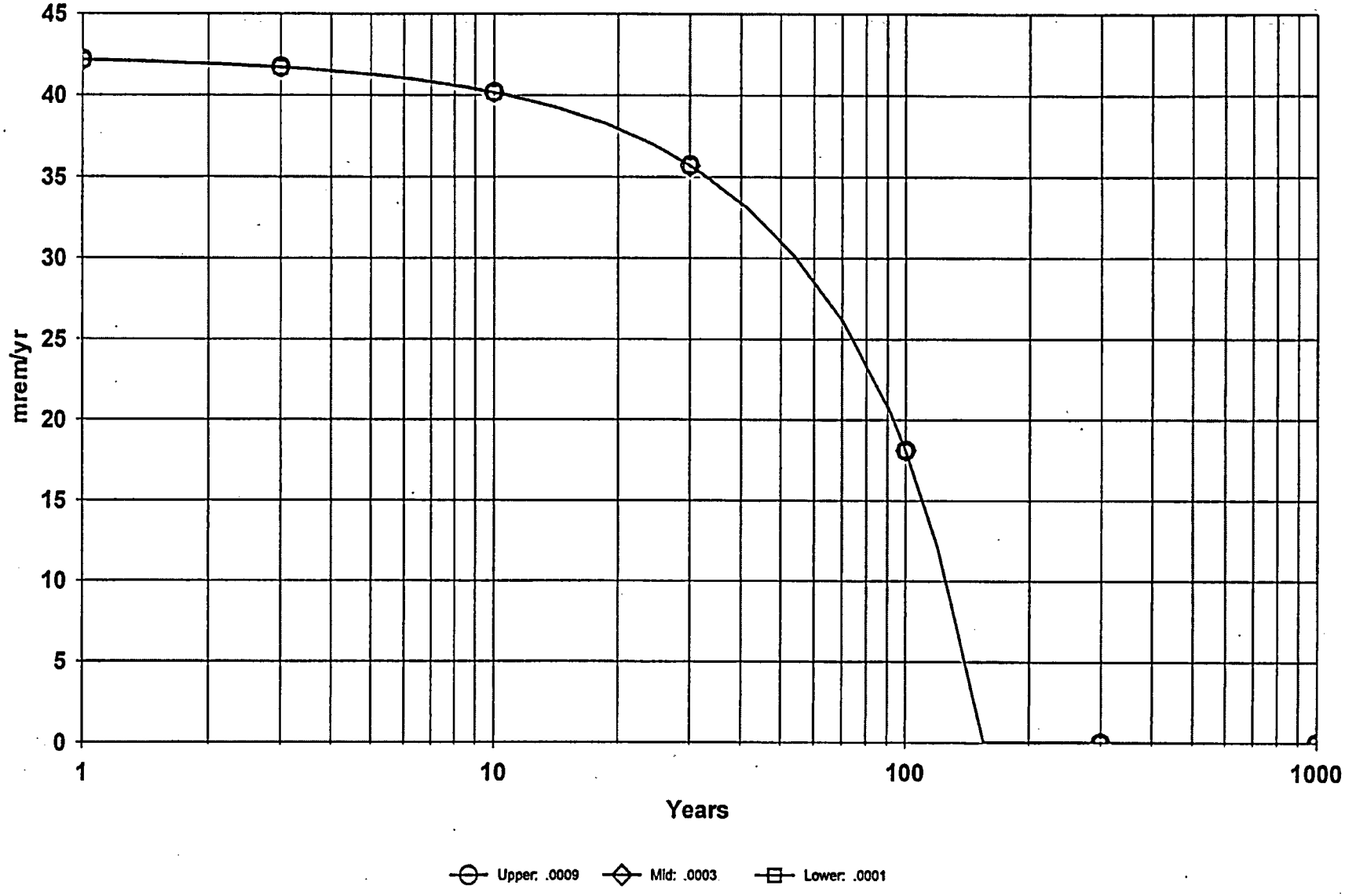
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Hydraulic Conductivity of Unsaturated Zone 1



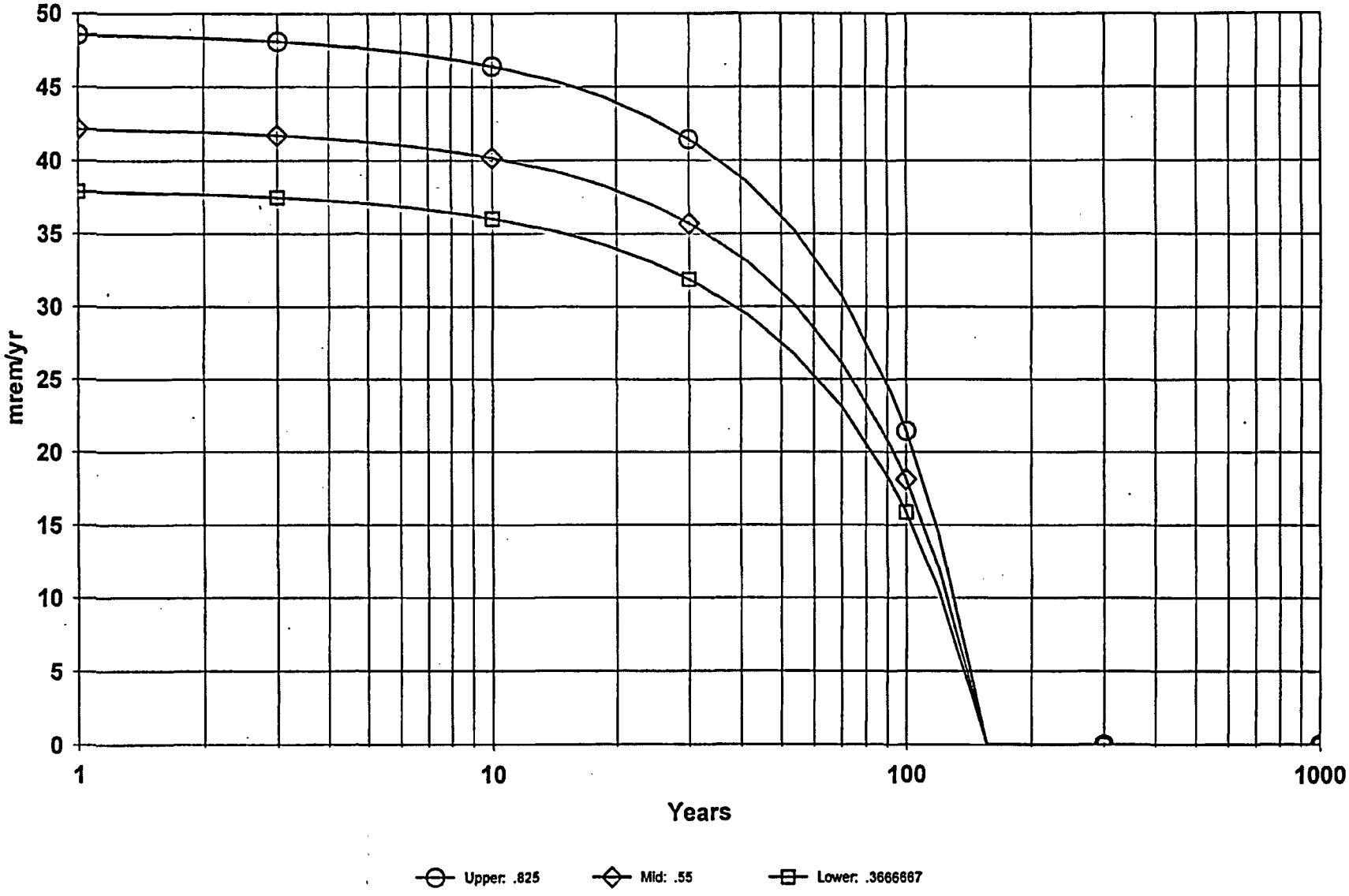
Ra022704.RAD 05/24/2004 17:32 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Mass loading for inhalation



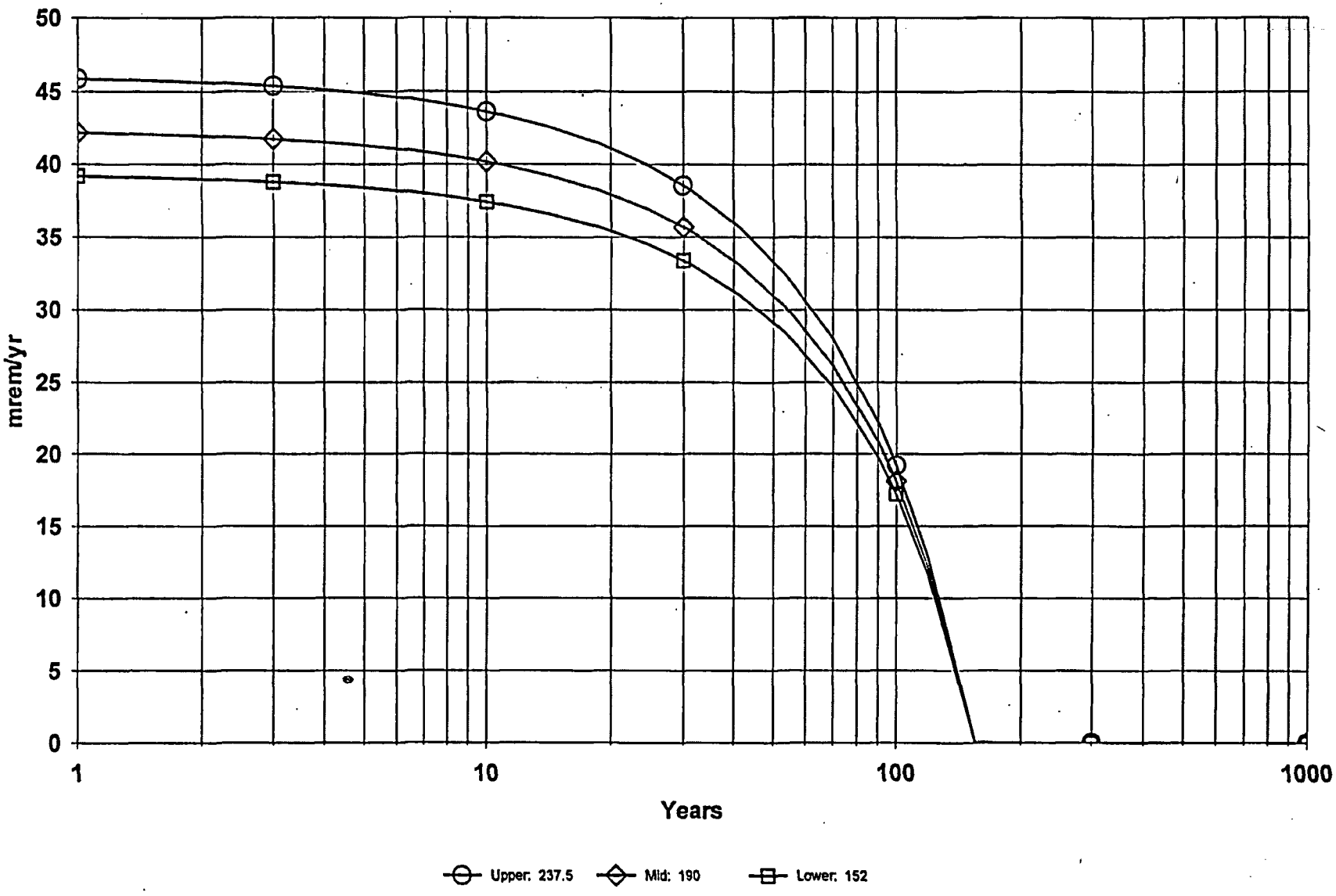
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on External Gamma Shielding factor



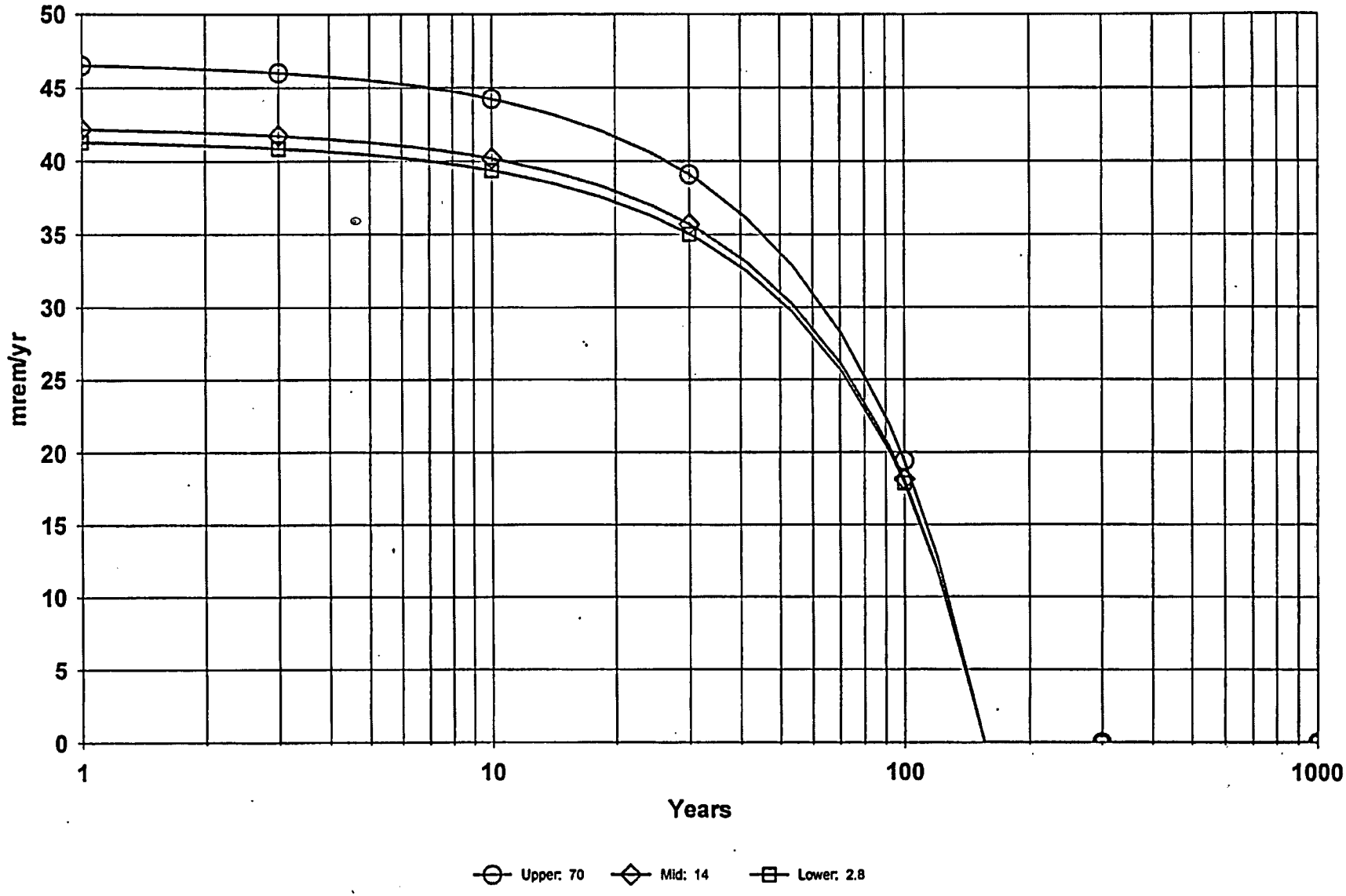
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Fruit, vegetable, and grain consumption



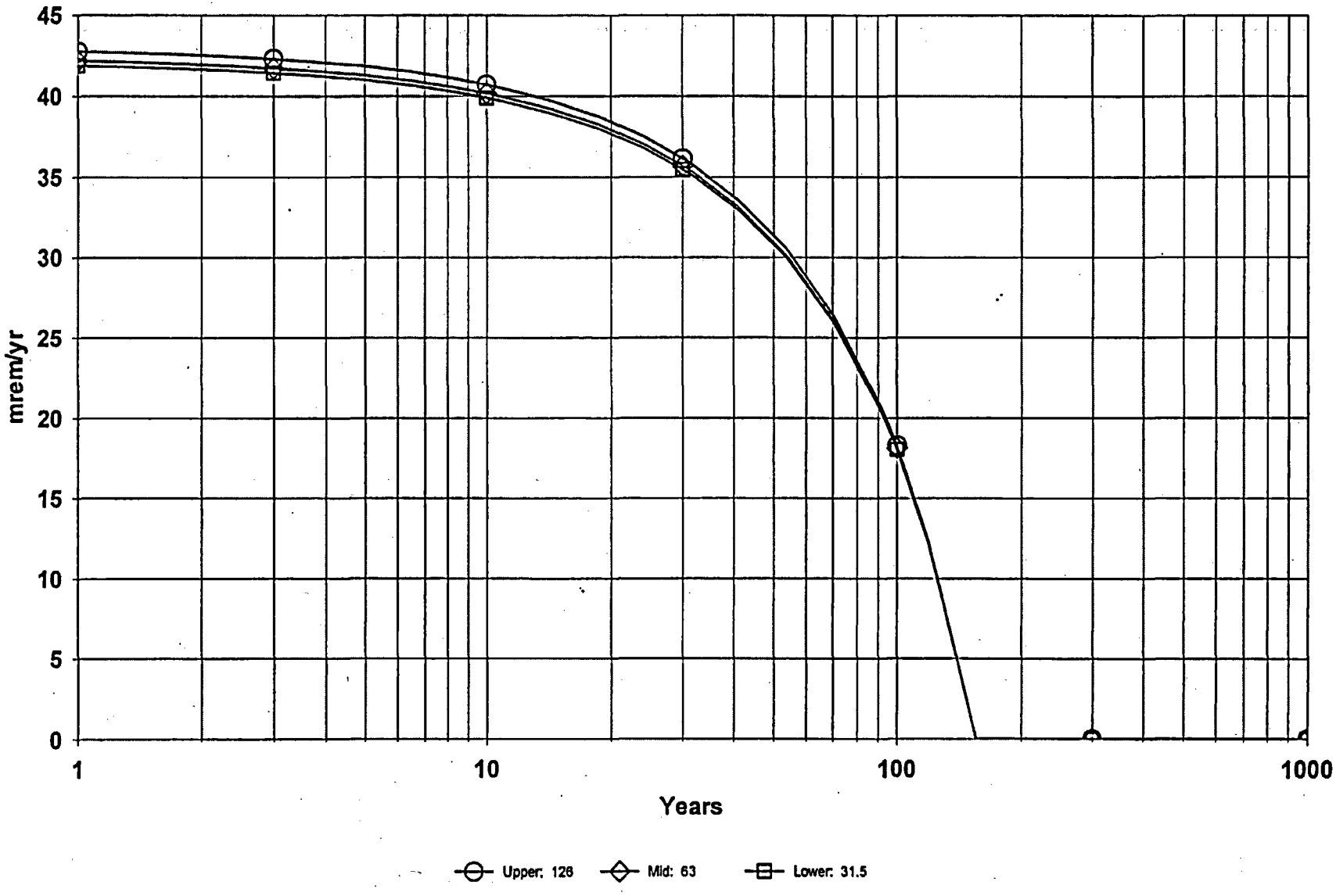
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Leafy vegetable consumption



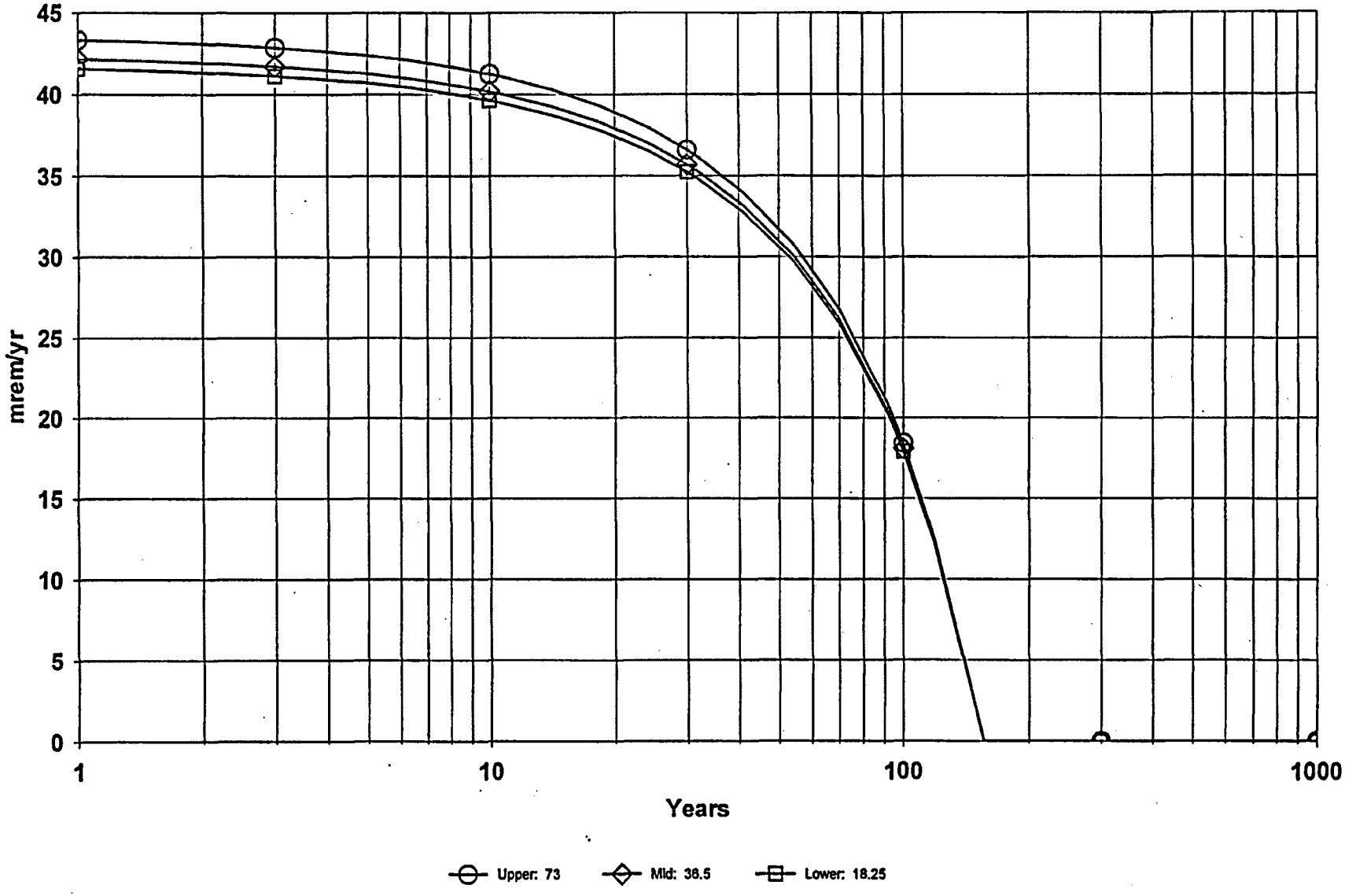
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Meat and poultry consumption



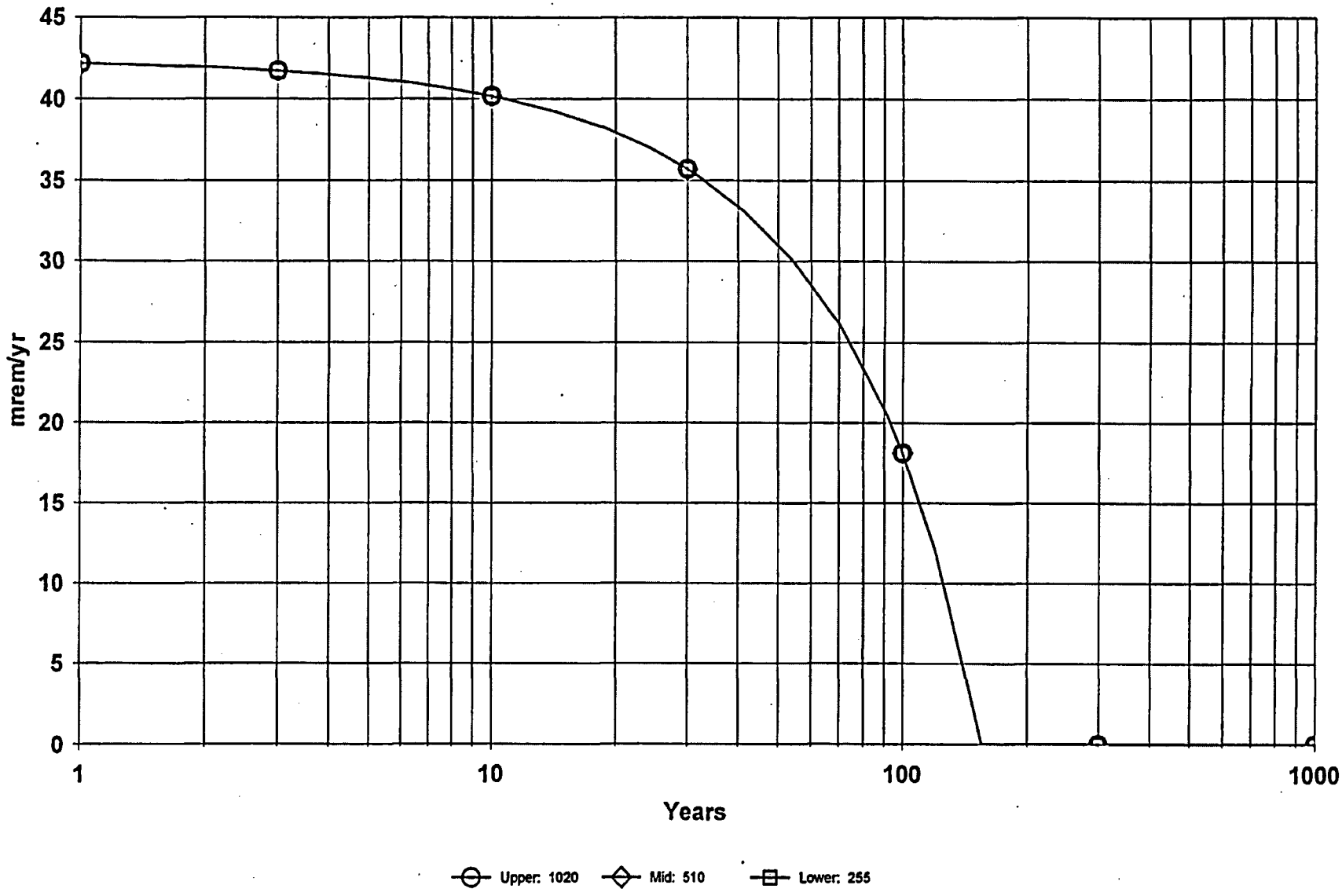
Ra022704.RAD 02/27/2004 14:38 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Soil ingestion



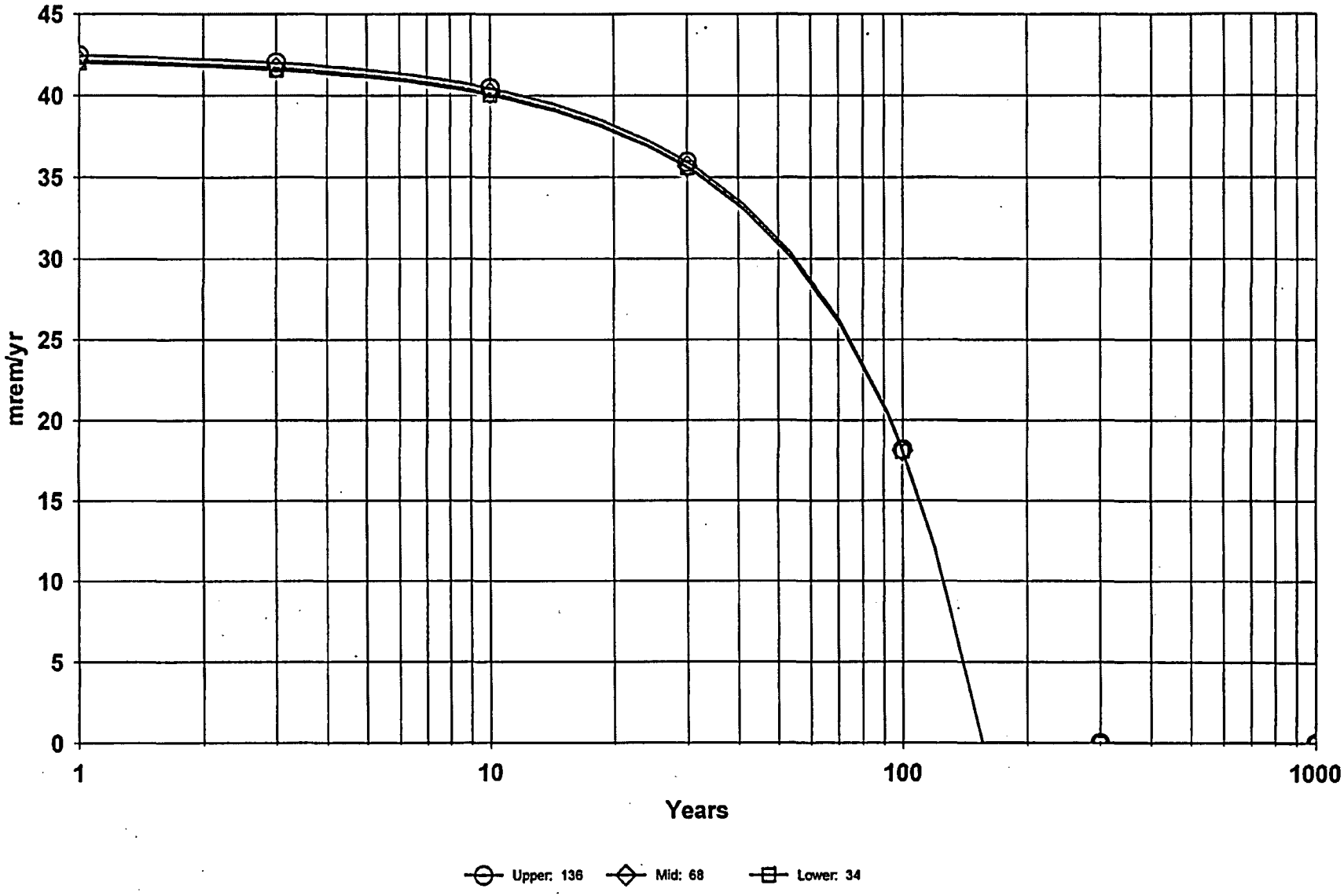
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Drinking water intake



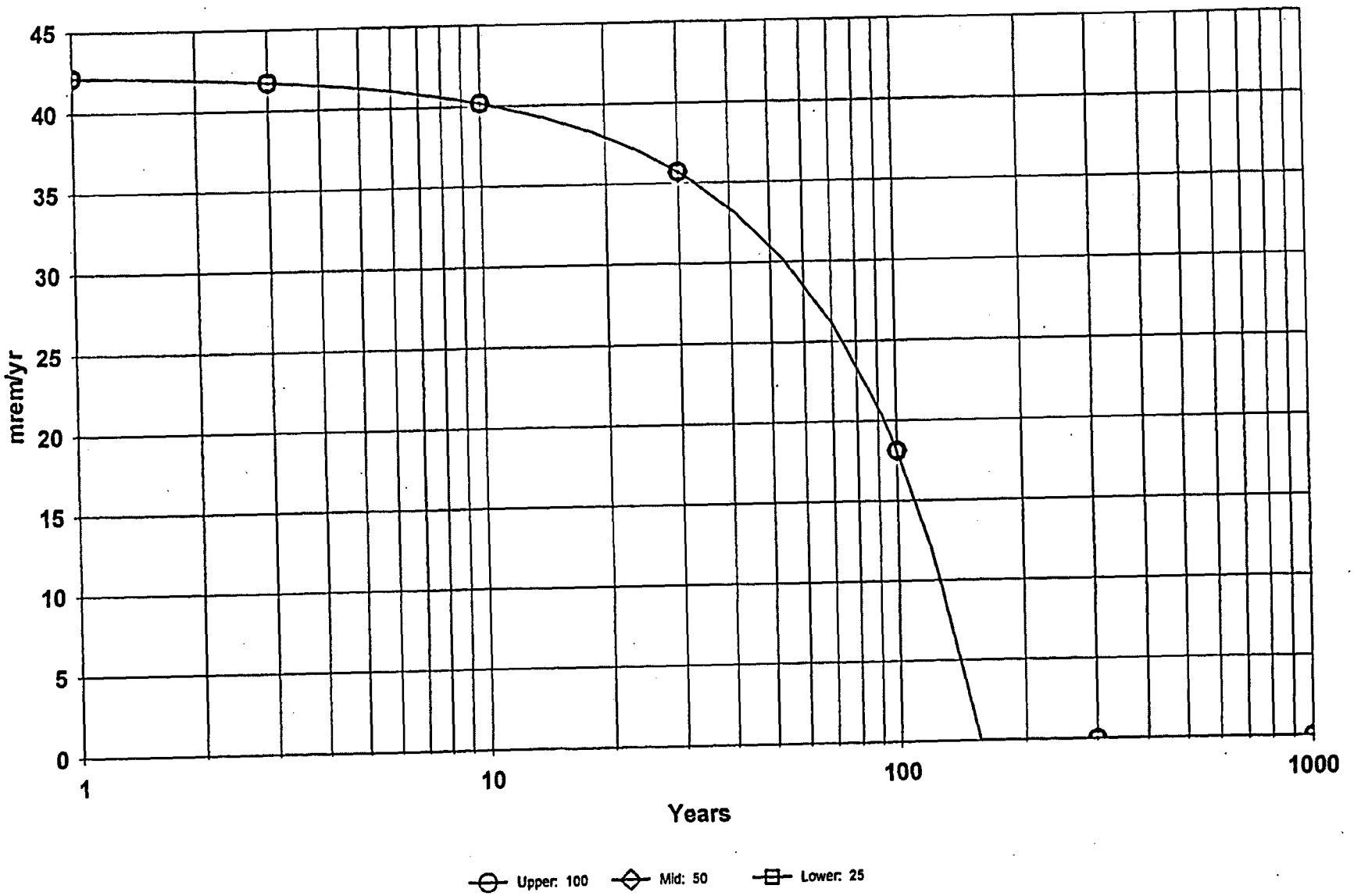
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock fodder intake for meat



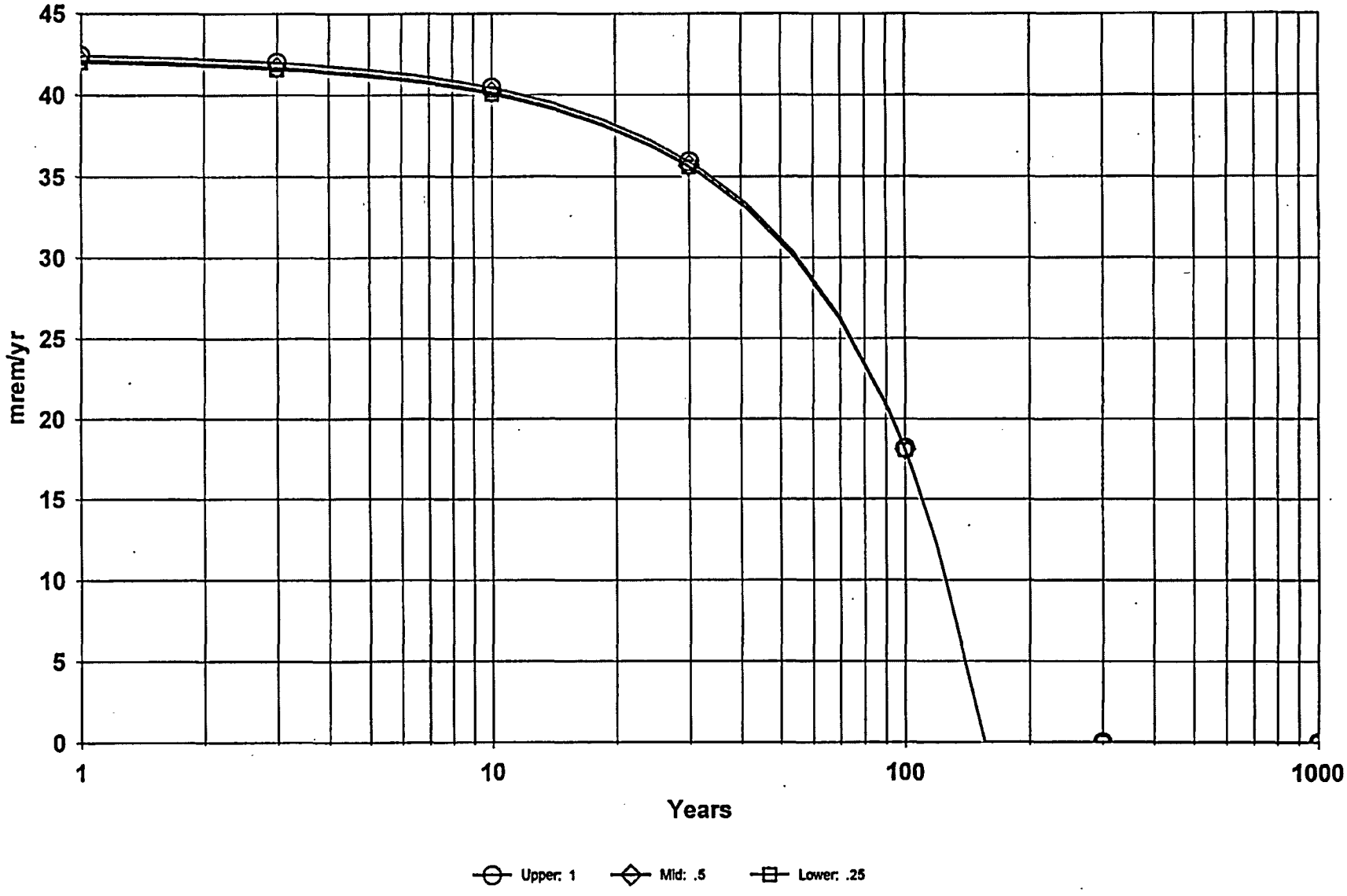
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock water intake for meat



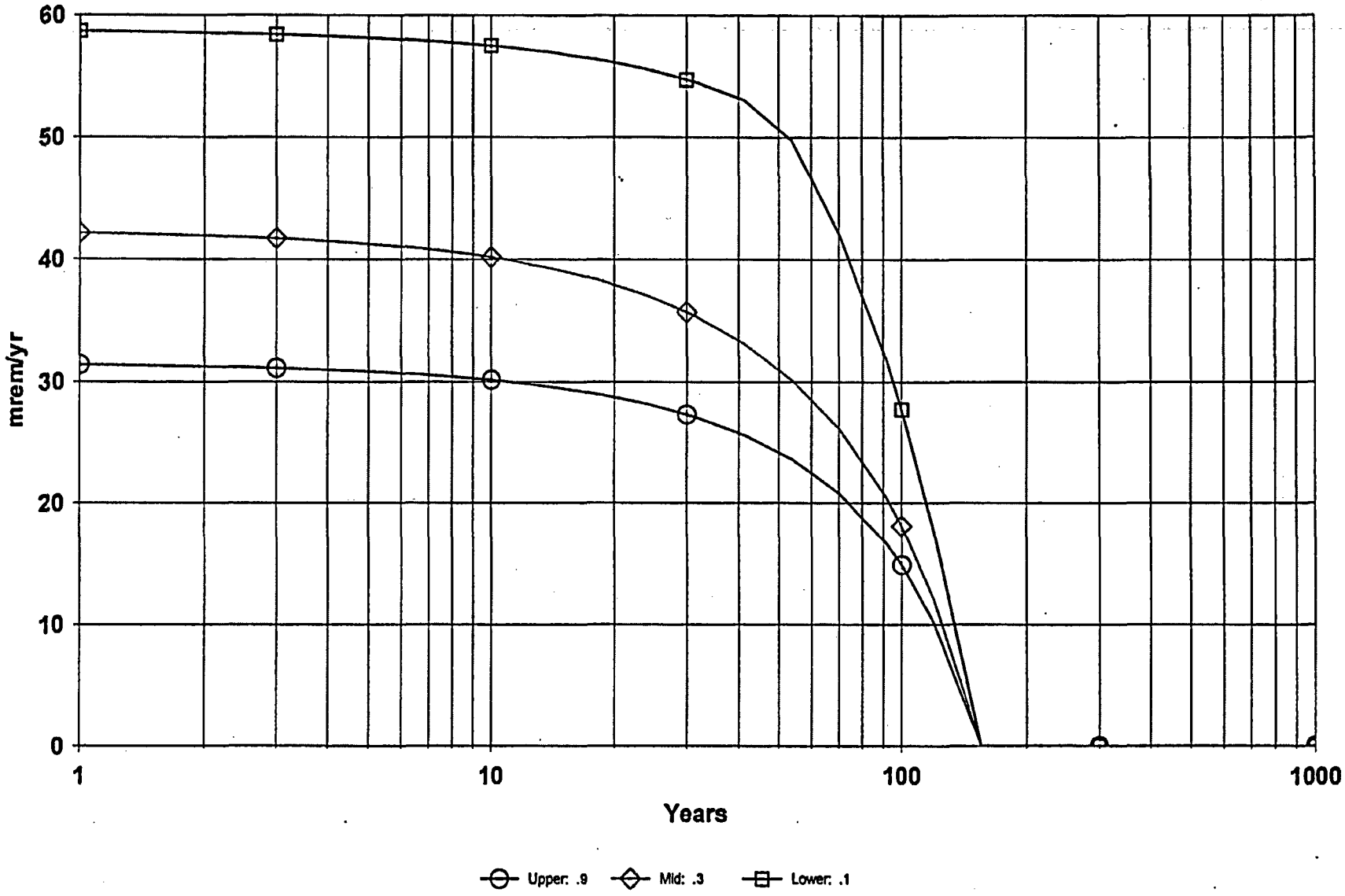
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Livestock intake of soil



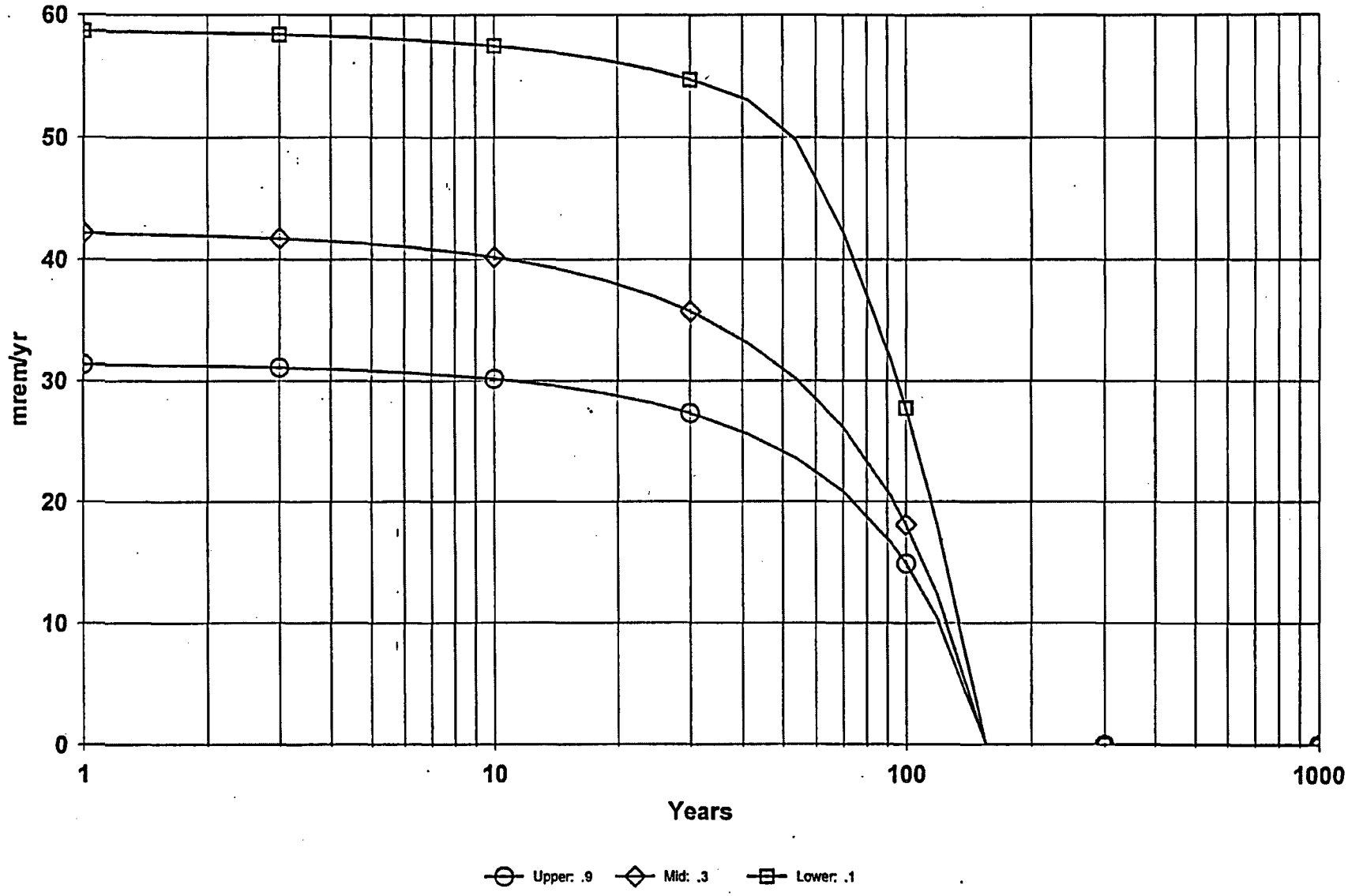
Ra022704.RAD 02/27/2004 11:01 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Depth of roots



Ra022704.RAD 05/25/2004 08:46 Includes All Pathways

DOSE: All Nuclides Summed, All Pathways Summed With SA on Depth of roots



Ra022704.RAD 02/27/2004 11:09 Includes All Pathways

Radium Benchmark Dose Assessment

Attachment 3

RESRAD Model Output
Radium

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary ... 2
Site-Specific Parameter Summary 3
Summary of Pathway Selections 7
Contaminated Zone and Total Dose Summary 8
Total Dose Components
Time = 0.000E+00 9
Time = 1.000E+00 10
Time = 3.000E+00 11
Time = 1.000E+01 12
Time = 3.000E+01 13
Time = 1.000E+02 14
Time = 3.000E+02 15
Time = 1.000E+03 16
Dose/Source Ratios Summed Over All Pathways 17
Single Radionuclide Soil Guidelines 17
Dose Per Nuclide Summed Over All Pathways 18
Soil Concentration Per Nuclide 18

Dose Conversion Factor (and Related) Parameter Summary
File: HEAST 1995 Morbidity

	Parameter	Current Value	Default	Parameter Name
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF2(1)
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF2(2)
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF3(1)
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF3(2)
D-34	Food transfer factors:			
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF(1,1)
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF(1,2)
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF(1,3)
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF(2,1)
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,2)
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF(2,3)
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIOFAC(1,1)
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIOFAC(1,2)
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIOFAC(2,1)
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIOFAC(2,2)

Site-Specific Parameter Summary

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
[illegible]	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	---	AREA
R011	Thickness of contaminated zone (m)	1.500E-01	2.000E+00	---	THICK0
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	---	LCZPAQ
R011	Basic radiation dose limit (mrem/yr)	1.000E+02	2.500E+01	---	BRDL
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	---	TI
R011	Times for calculations (yr)	1.000E+00	1.000E+00	---	T(2)
R011	Times for calculations (yr)	3.000E+00	3.000E+00	---	T(3)
R011	Times for calculations (yr)	1.000E+01	1.000E+01	---	T(4)
R011	Times for calculations (yr)	3.000E+01	3.000E+01	---	T(5)
R011	Times for calculations (yr)	1.000E+02	1.000E+02	---	T(6)
R011	Times for calculations (yr)	3.000E+02	3.000E+02	---	T(7)
R011	Times for calculations (yr)	1.000E+03	1.000E+03	---	T(8)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(9)
R011	Times for calculations (yr)	not used	0.000E+00	---	T(10)
R012	Initial principal radionuclide (pCi/g): Pb-210	5.000E+00	0.000E+00	---	S1(1)
R012	Initial principal radionuclide (pCi/g): Ra-226	5.000E+00	0.000E+00	---	S1(2)
R012	Concentration in groundwater (pCi/L): Pb-210	not used	0.000E+00	---	W1(1)
R012	Concentration in groundwater (pCi/L): Ra-226	not used	0.000E+00	---	W1(2)
R013	Cover depth (m)	0.000E+00	0.000E+00	---	COVER0
R013	Density of cover material (g/cm**3)	not used	1.500E+00	---	DENSCV
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	---	VCV
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	---	DENSCZ
[illegible]	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	---	VCZ
[illegible]	Contaminated zone total porosity	4.000E-01	4.000E-01	---	TPCZ
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	---	FCCZ
R013	Contaminated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	---	HCCZ
R013	Contaminated zone b parameter	4.380E+00	5.300E+00	---	BCZ
R013	Average annual wind speed (m/sec)	4.300E+00	2.000E+00	---	WIND
R013	Humidity in air (g/m**3)	not used	8.000E+00	---	HUMID
R013	Evapotranspiration coefficient	7.500E-01	5.000E-01	---	EVAPTR
R013	Precipitation (m/yr)	3.900E-01	1.000E+00	---	PRECIP
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	---	RI
R013	Irrigation mode	overhead	overhead	---	IDITCH
R013	Runoff coefficient	2.000E-01	2.000E-01	---	RUNOFF
R013	Watershed area for nearby stream or pond (m**2)	3.630E+07	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	4.000E-01	4.000E-01	---	TPSZ
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	---	EPSZ
R014	Saturated zone field capacity	2.000E-01	2.000E-01	---	FCSZ
R014	Saturated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+02	---	HCSZ
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	---	HGWT
R014	Saturated zone b parameter	4.380E+00	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)	2.000E+01	1.000E+01	---	DWIBWT
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	---	MODEL
R0[illegible]	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	---	UW

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
[illegible]	Number of unsaturated zone strata	1	1	---	NS
R015	Unsat. zone 1, thickness (m)	1.500E+01	4.000E+00	---	H(1)
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	---	DENSUZ(1)
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	---	TPUZ(1)
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	---	EPUZ(1)
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	---	FCUZ(1)
R015	Unsat. zone 1, soil-specific b parameter	4.380E+00	5.300E+00	---	BUZ(1)
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	---	HCUZ(1)
R016	Distribution coefficients for Pb-210				
R016	Contaminated zone (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCC(1)
R016	Unsaturated zone 1 (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCU(1,1)
R016	Saturated zone (cm**3/g)	2.700E+02	1.000E+02	---	DCNUCS(1)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.283E-03	ALEACH(1)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(1)
R016	Distribution coefficients for Ra-226				
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCC(2)
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCU(2,1)
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	---	DCNUCS(2)
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.931E-04	ALEACH(2)
R016	Solubility constant	0.000E+00	0.000E+00	not used	SOLUBK(2)
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	---	INHALR
[illegible]	Mass loading for inhalation (g/m**3)	3.000E-04	1.000E-04	---	MLINH
[illegible]	Exposure duration	3.000E+01	3.000E+01	---	ED
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	---	SHF3
R017	Shielding factor, external gamma	5.500E-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)

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter 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)	1.900E+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)	not used	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)	not used	5.400E+00	---	DIET(5)
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	---	DIET(6)
R018	Soil ingestion rate (g/yr)	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	not used	5.000E-01	---	FR9
R018	Contamination fraction of plant food	2.500E-01	-1	---	FPLANT
R018	Contamination fraction of meat	2.500E-01	-1	---	FMEAT
R018	Contamination fraction of milk	not used	-1	---	FMILK
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	---	LFI5
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	---	LFI6
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	---	LWI5
R019	Livestock water intake for milk (L/day)	not used	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)	3.000E-04	1.000E-04	---	MLFD
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	---	DM
R019	Depth of roots (m)	3.000E-01	9.000E-01	---	DROOT
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	---	FGWDW
R019	Household water fraction from ground water	not used	1.000E+00	---	FGWHH
R019	Livestock water fraction from ground water	1.000E+00	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)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter 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
C14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	---	CO2F
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	---	FLOOR1
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)
	Number of graphical time points	32	---	---	NPTS
	Maximum number of integration points for dose	17	---	---	LYMAX

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used by RESRAD (If different from user input)	Parameter Name
[illegible]	Maximum number of integration points for risk	257	---	---	KYMAX

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	suppressed
6 -- aquatic foods	suppressed
7 -- drinking water	active
8 -- soil ingestion	active
9 -- radon	suppressed
Find peak pathway doses	active

Contaminated Zone Dimensions		Initial Soil Concentrations, pCi/g	
Area:	10000.00 square meters	Pb-210	5.000E+00
Thickness:	0.15 meters	Ra-226	5.000E+00
Depth:	0.00 meters		

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.000E+02 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
TDOSE(t):	4.237E+01	4.216E+01	4.172E+01	4.018E+01	3.570E+01	1.810E+01	0.000E+00	0.000E+00
M(t):	4.237E-01	4.216E-01	4.172E-01	4.018E-01	3.570E-01	1.810E-01	0.000E+00	0.000E+00

Maximum TDOSE(t): 4.237E+01 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)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.528E-02	0.0004	1.027E-02	0.0002	0.000E+00	0.0000	9.096E+00	0.2147	3.778E-01	0.0089	0.000E+00	0.0000	9.759E-01	0.0230
Ra-226	2.457E+01	0.5798	4.028E-03	0.0001	0.000E+00	0.0000	6.927E+00	0.1635	2.027E-01	0.0048	0.000E+00	0.0000	1.966E-01	0.0046
Total	2.458E+01	0.5802	1.430E-02	0.0003	0.000E+00	0.0000	1.602E+01	0.3781	5.805E-01	0.0137	0.000E+00	0.0000	1.172E+00	0.0277

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

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	1.048E+01	0.2472
Ra-226	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	3.190E+01	0.7528
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	4.237E+01	1.0000

* [illegible]f 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)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.479E-02	0.0004	9.879E-03	0.0002	0.000E+00	0.0000	8.748E+00	0.2075	3.634E-01	0.0086	0.000E+00	0.0000	9.385E-01	0.0223
Ra-226	2.449E+01	0.5809	4.309E-03	0.0001	0.000E+00	0.0000	7.154E+00	0.1697	2.130E-01	0.0051	0.000E+00	0.0000	2.247E-01	0.0053
Total	2.451E+01	0.5812	1.419E-02	0.0003	0.000E+00	0.0000	1.590E+01	0.3772	5.764E-01	0.0137	0.000E+00	0.0000	1.163E+00	0.0276

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	1.007E+01	0.2389
Ra-226	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	3.209E+01	0.7611
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	4.216E+01	1.0000

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 = 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.385E-02	0.0003	9.135E-03	0.0002	0.000E+00	0.0000	8.089E+00	0.1939	3.360E-01	0.0081	0.000E+00	0.0000	8.678E-01	0.0208
Ra-226	2.433E+01	0.5832	4.827E-03	0.0001	0.000E+00	0.0000	7.561E+00	0.1812	2.312E-01	0.0055	0.000E+00	0.0000	2.768E-01	0.0066
Total	2.435E+01	0.5835	1.396E-02	0.0003	0.000E+00	0.0000	1.565E+01	0.3751	5.672E-01	0.0136	0.000E+00	0.0000	1.145E+00	0.0274

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	9.316E+00	0.2233
Ra-226	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	3.241E+01	0.7767
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	4.172E+01	1.0000

* [illegible]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)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	1.101E-02	0.0003	6.935E-03	0.0002	0.000E+00	0.0000	6.141E+00	0.1528	2.551E-01	0.0063	0.000E+00	0.0000	6.588E-01	0.0164
Ra-226	2.376E+01	0.5914	6.247E-03	0.0002	0.000E+00	0.0000	8.636E+00	0.2150	2.805E-01	0.0070	0.000E+00	0.0000	4.217E-01	0.0105
Total	2.377E+01	0.5917	1.318E-02	0.0003	0.000E+00	0.0000	1.478E+01	0.3678	5.356E-01	0.0133	0.000E+00	0.0000	1.081E+00	0.0269

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	7.073E+00	0.1760
Ra-226	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	3.311E+01	0.8240
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	4.018E+01	1.0000

* 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 = 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	5.691E-03	0.0002	3.110E-03	0.0001	0.000E+00	0.0000	2.754E+00	0.0771	1.144E-01	0.0032	0.000E+00	0.0000	2.954E-01	0.0083
Ra-226	2.196E+01	0.6153	7.917E-03	0.0002	0.000E+00	0.0000	9.611E+00	0.2693	3.338E-01	0.0093	0.000E+00	0.0000	6.083E-01	0.0170
Total	2.197E+01	0.6154	1.103E-02	0.0003	0.000E+00	0.0000	1.237E+01	0.3464	4.482E-01	0.0126	0.000E+00	0.0000	9.037E-01	0.0253

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	3.172E+00	0.0889
Ra-226	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	3.252E+01	0.9111
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	3.570E+01	1.0000

* 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)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	4.873E-04	0.0000	1.337E-04	0.0000	0.000E+00	0.0000	1.184E-01	0.0065	4.923E-03	0.0003	0.000E+00	0.0000	1.270E-02	0.0007
Ra-226	1.284E+01	0.7097	4.082E-03	0.0002	0.000E+00	0.0000	4.613E+00	0.2549	1.667E-01	0.0092	0.000E+00	0.0000	3.328E-01	0.0184
Total	1.284E+01	0.7097	4.216E-03	0.0002	0.000E+00	0.0000	4.731E+00	0.2614	1.716E-01	0.0095	0.000E+00	0.0000	3.455E-01	0.0191

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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	1.367E-01	0.0076
Ra-226	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	1.796E+01	0.9924
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	1.810E+01	1.0000

*f 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 = 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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
Ra-226	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 = 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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
Ra-226	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

* [illegible]f 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+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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
Ra-226	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+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All Pathways*	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
Pb-210	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
Ra-226	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

*f all water independent and dependent pathways.

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

Parent	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	2.095E+00	2.015E+00	1.863E+00	1.415E+00	6.345E-01	2.733E-02	0.000E+00	0.000E+00
Ra-226	Ra-226	1.000E+00	6.341E+00	6.315E+00	6.260E+00	6.069E+00	5.494E+00	2.989E+00	0.000E+00	0.000E+00
Ra-226	Pb-210	1.000E+00	3.846E-02	1.028E-01	2.207E-01	5.525E-01	1.011E+00	6.028E-01	0.000E+00	0.000E+00
Ra-226	ΣDSR(j)		6.380E+00	6.417E+00	6.481E+00	6.621E+00	6.505E+00	3.592E+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.

Single Radionuclide Soil Guidelines G(i,t) in pCi/g
Basic Radiation Dose Limit = 1.000E+02 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	4.773E+01	4.963E+01	5.367E+01	7.069E+01	1.576E+02	3.659E+03	*7.631E+13	*7.631E+13
Ra-226	1.567E+01	1.558E+01	1.543E+01	1.510E+01	1.537E+01	2.784E+01	*9.882E+11	*9.882E+11

*At specific activity limit

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 (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
Pb-210	5.000E+00	0.000E+00	2.095E+00	4.773E+01	2.095E+00	4.773E+01
Ra-226	5.000E+00	15.93 ± 0.03	6.654E+00	1.503E+01	6.380E+00	1.567E+01

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

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	1.048E+01	1.007E+01	9.316E+00	7.073E+00	3.172E+00	1.367E-01	0.000E+00	0.000E+00
Pb-210	Ra-226	1.000E+00	1.923E-01	5.138E-01	1.103E+00	2.763E+00	5.054E+00	3.014E+00	0.000E+00	0.000E+00
Pb-210	ΣDOSE(j)		1.067E+01	1.059E+01	1.042E+01	9.835E+00	8.226E+00	3.151E+00	0.000E+00	0.000E+00
Ra-226	Ra-226	1.000E+00	3.171E+01	3.157E+01	3.130E+01	3.034E+01	2.747E+01	1.494E+01	0.000E+00	0.000E+00

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

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Pb-210	Pb-210	1.000E+00	5.000E+00	4.841E+00	4.537E+00	3.617E+00	1.894E+00	1.965E-01	3.034E-04	4.391E-14
Pb-210	Ra-226	1.000E+00	0.000E+00	1.528E-01	4.436E-01	1.320E+00	2.926E+00	4.249E+00	3.548E+00	1.613E+00
Pb-210	ΣS(j):		5.000E+00	4.994E+00	4.981E+00	4.937E+00	4.819E+00	4.446E+00	3.548E+00	1.613E+00
Ra-226	Ra-226	1.000E+00	5.000E+00	4.994E+00	4.983E+00	4.944E+00	4.834E+00	4.467E+00	3.566E+00	1.621E+00

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

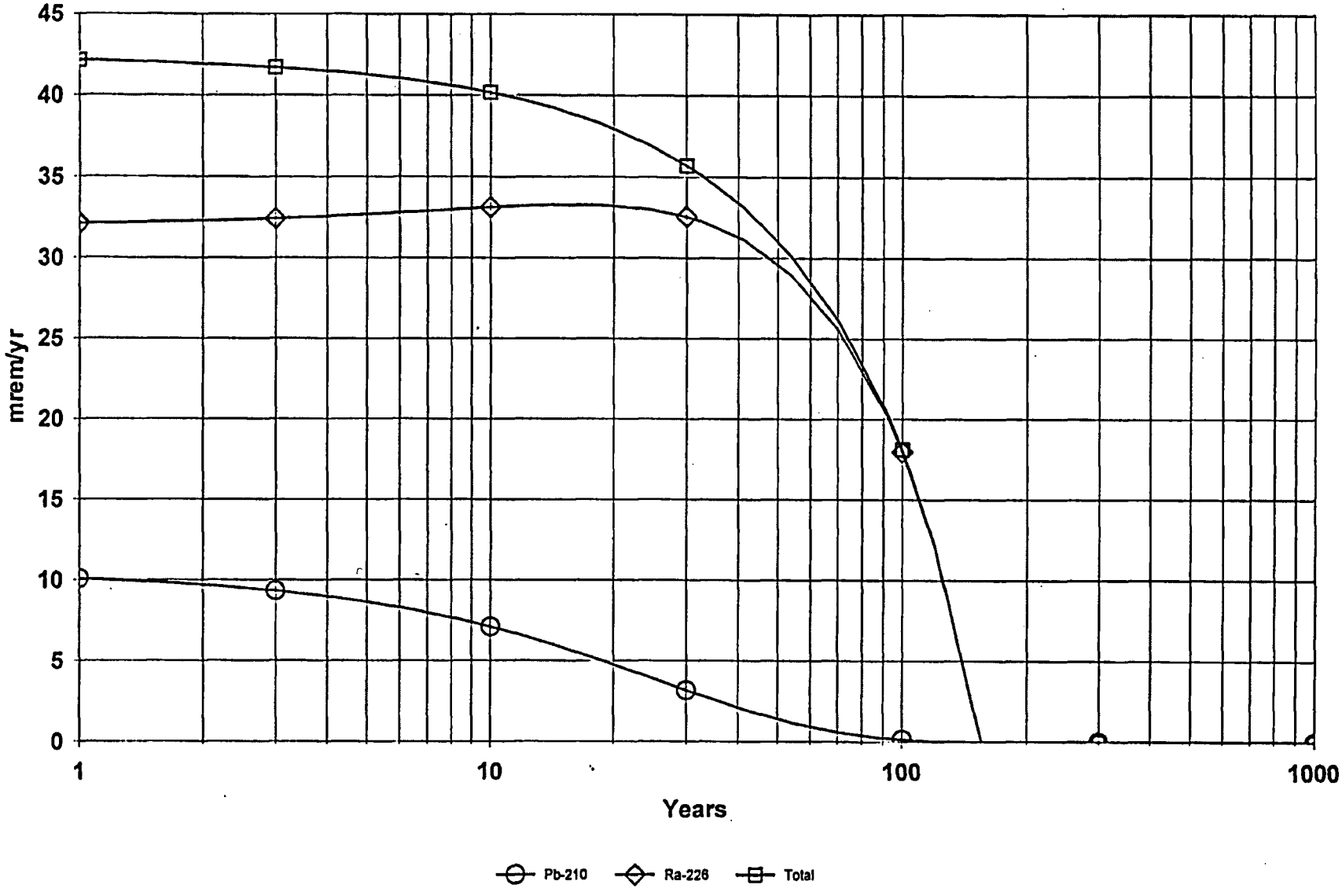
RESRALC.EXE execution time = 0.71 seconds

Radium Benchmark Dose Assessment

Attachment 4

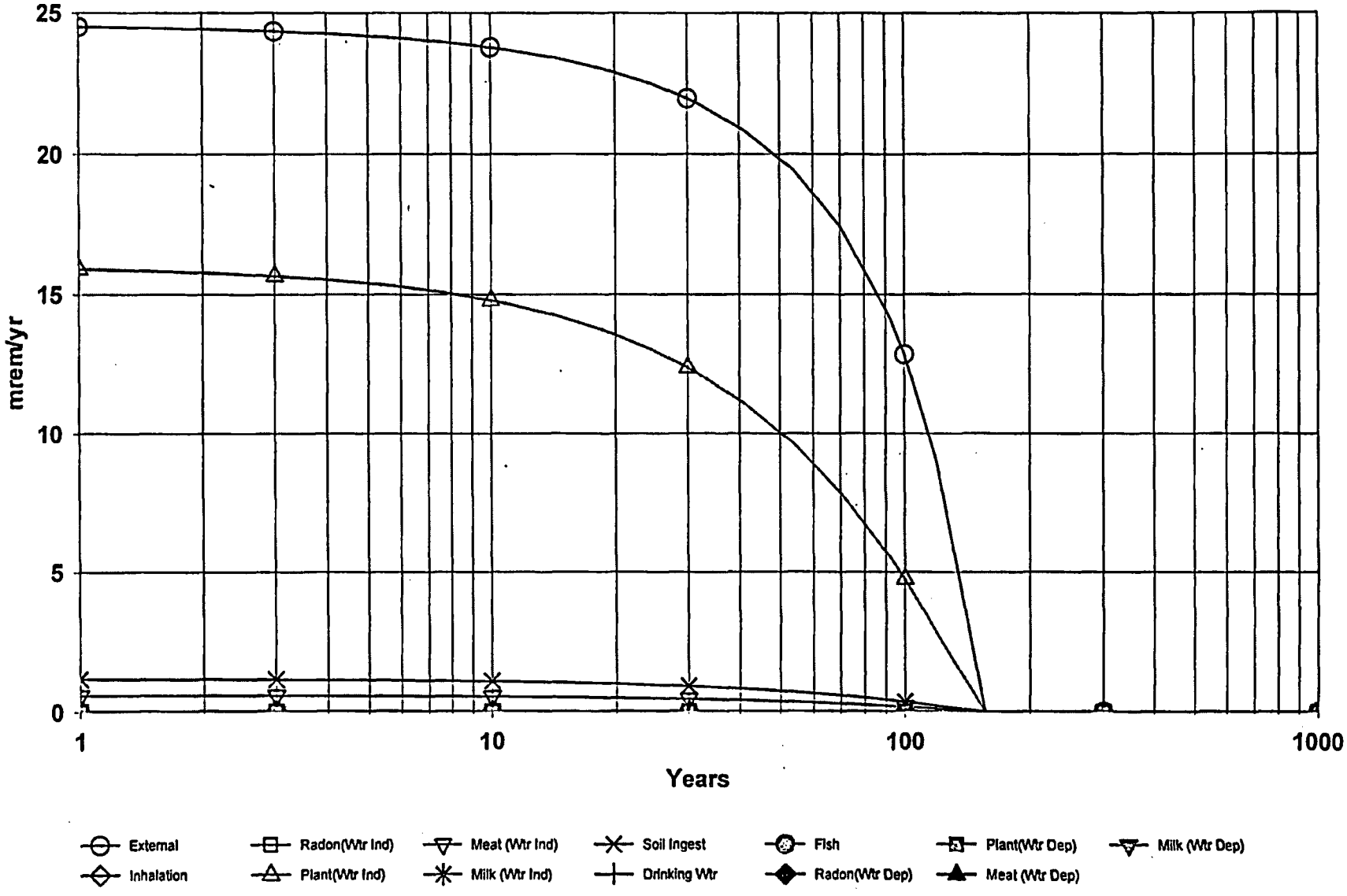
RESRAD Model Output
Standard Graphics

DOSE: All Nuclides Summed, All Pathways Summed



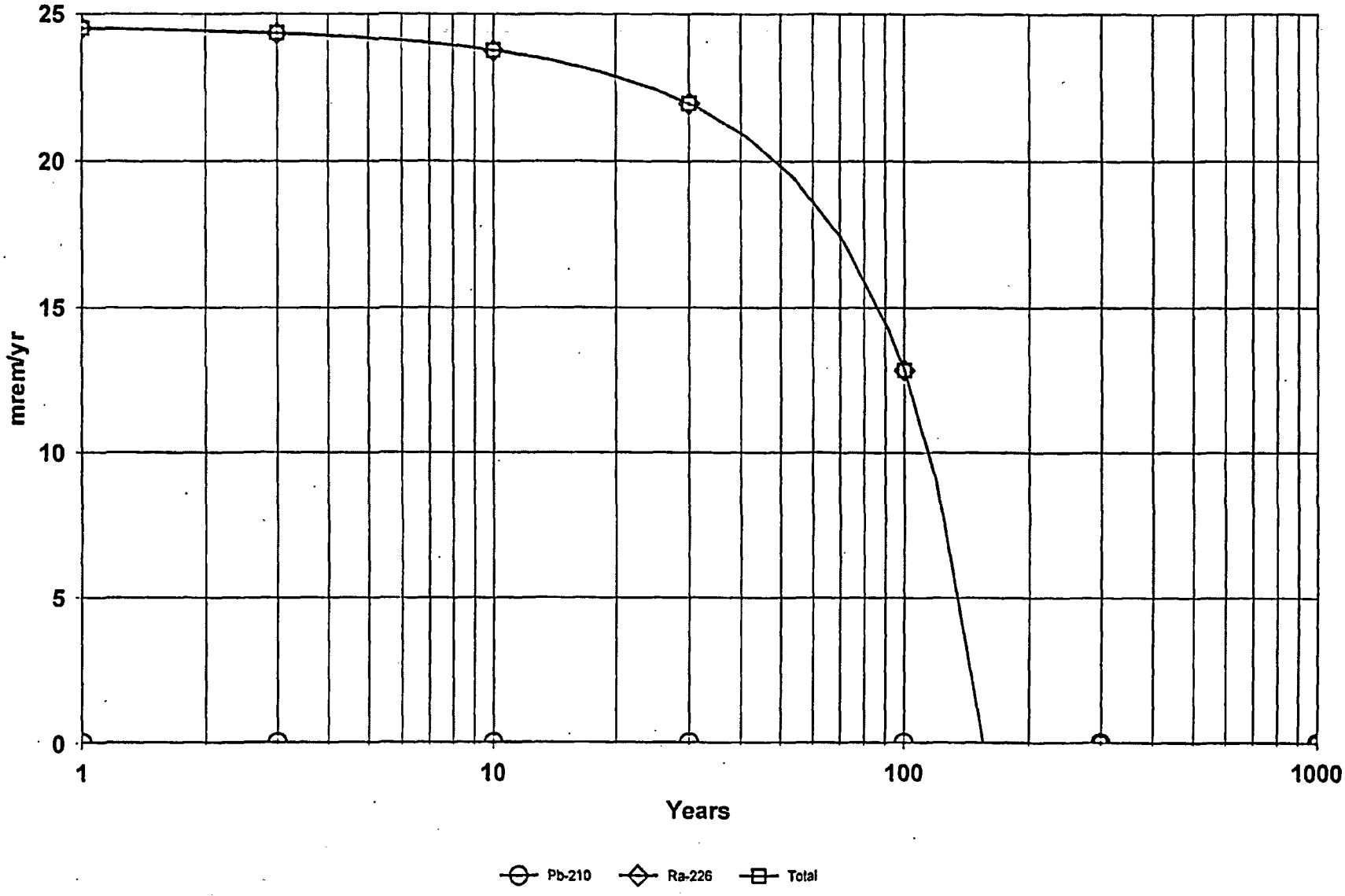
Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

DOSE: All Nuclides Summed, Component Pathways



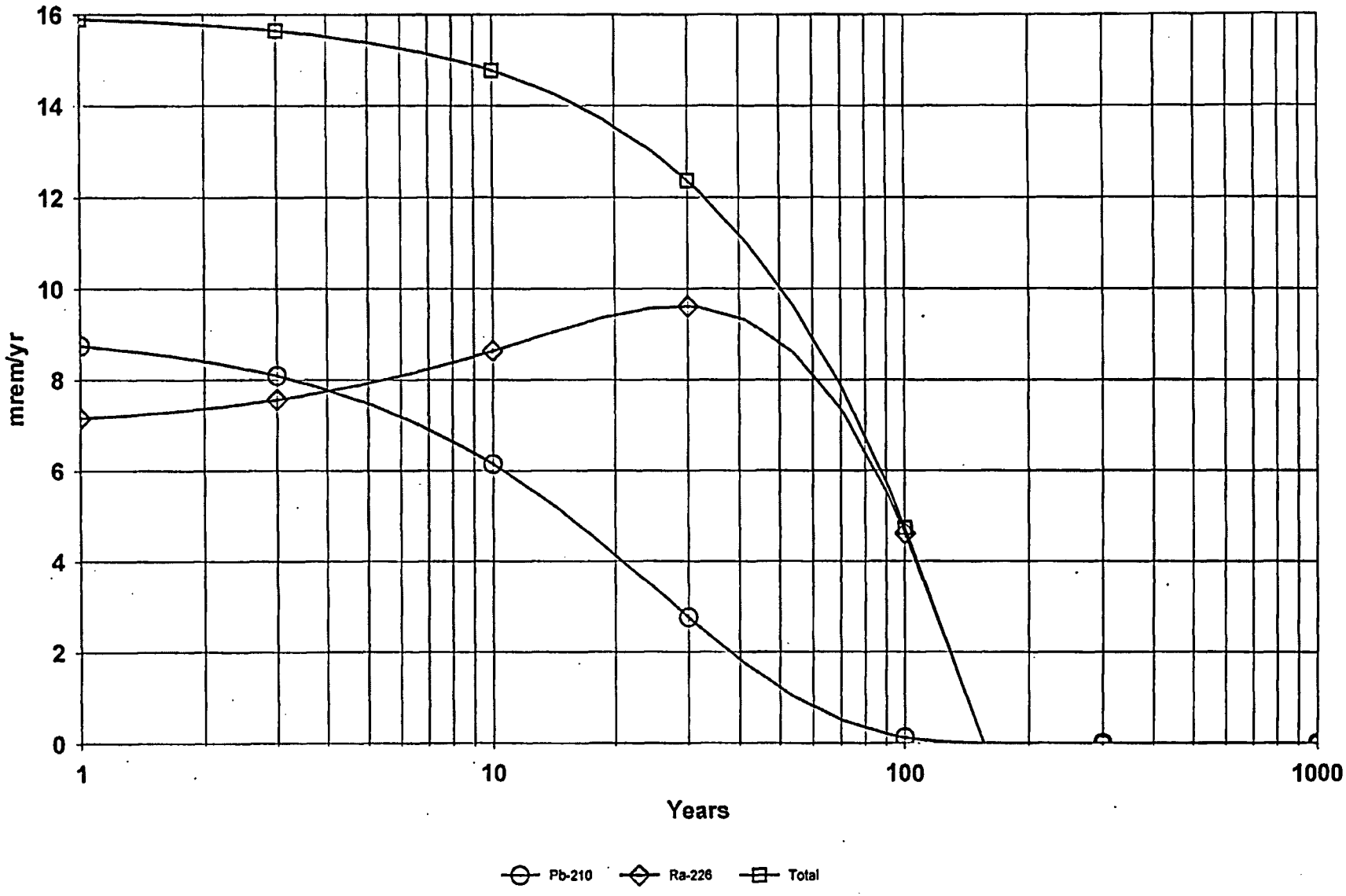
Ra022704.RAD 03/05/2004 10:01

DOSE: All Nuclides Summed, External



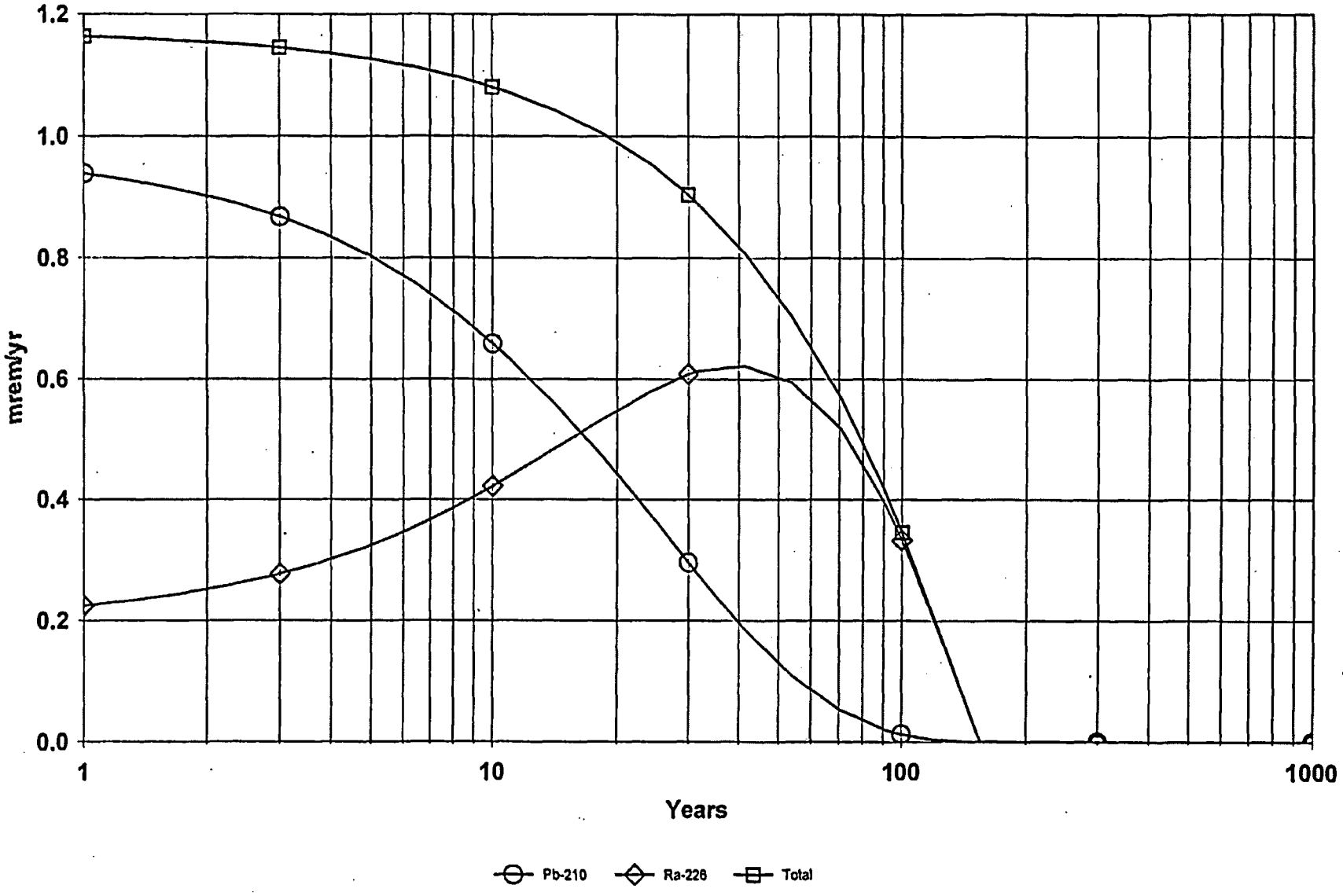
Ra022704.RAD 03/05/2004 10:01 Pathways: External

DOSE: All Nuclides Summed, Plant(Wtr Ind)



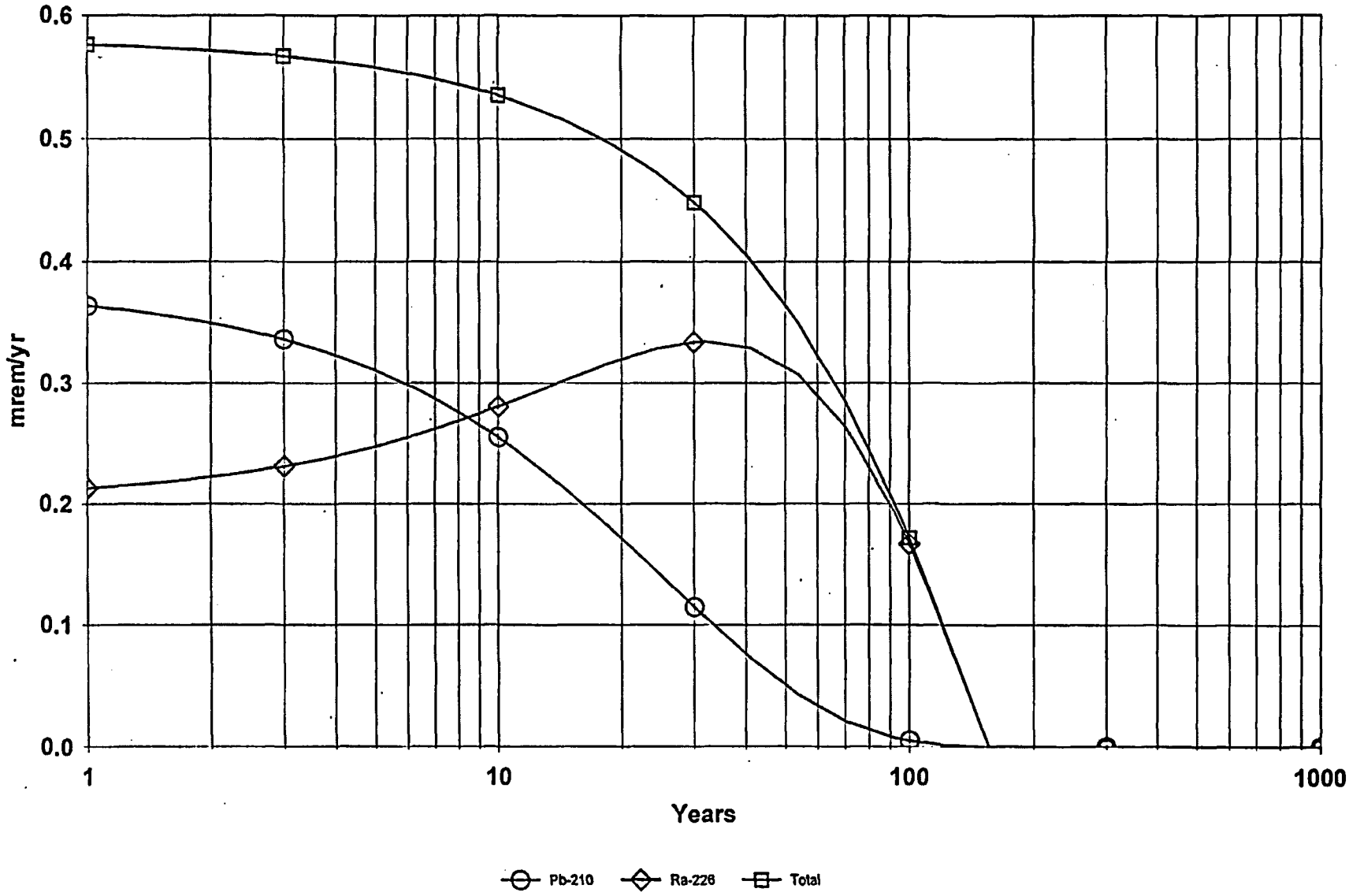
Ra022704.RAD 03/05/2004 10:01 Pathways: Plant(Wtr Ind)

DOSE: All Nuclides Summed, Soil Ingest



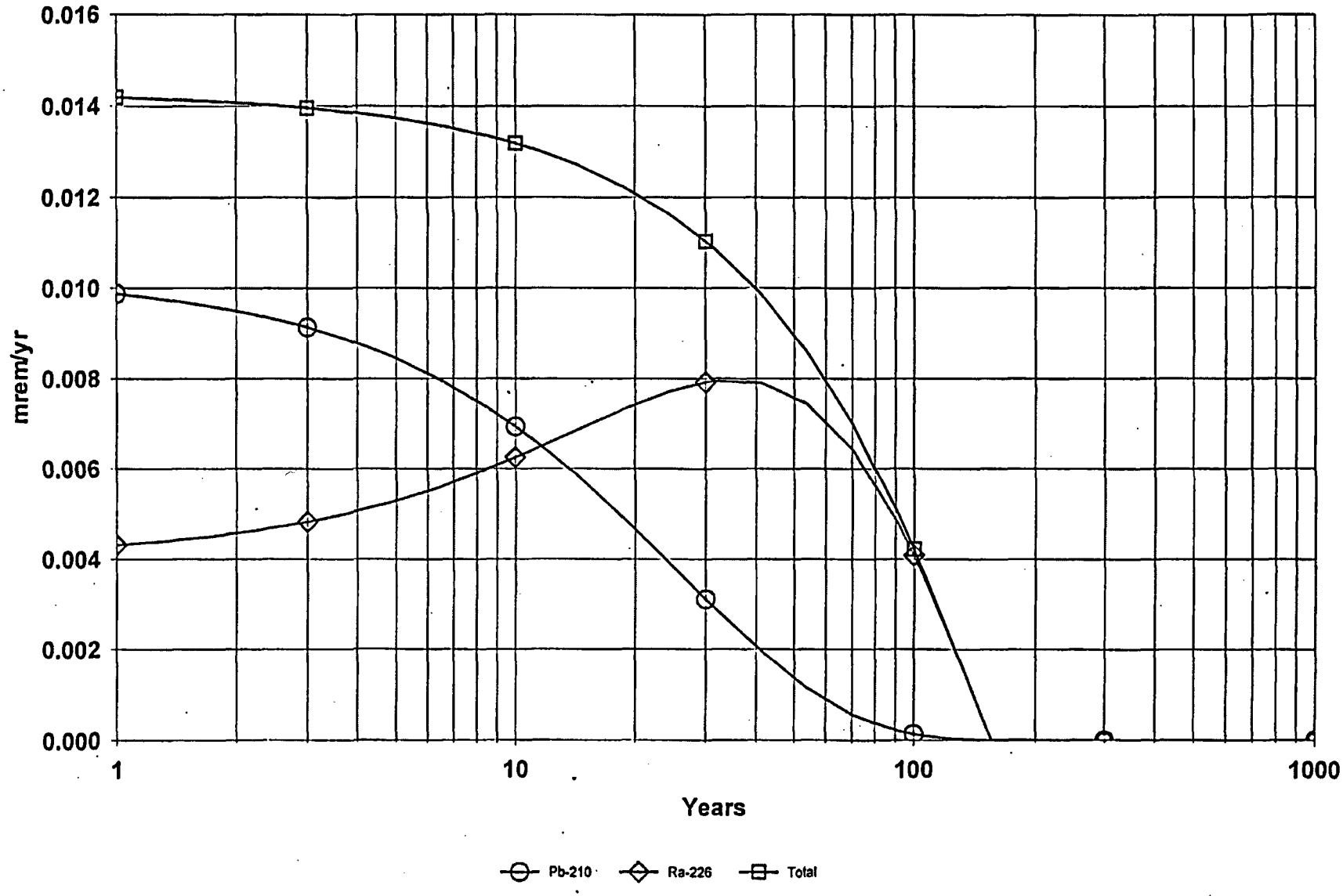
Ra022704.RAD 03/05/2004 10:01 Pathways: Soil Ingest

DOSE: All Nuclides Summed, Meat (Wtr Ind)



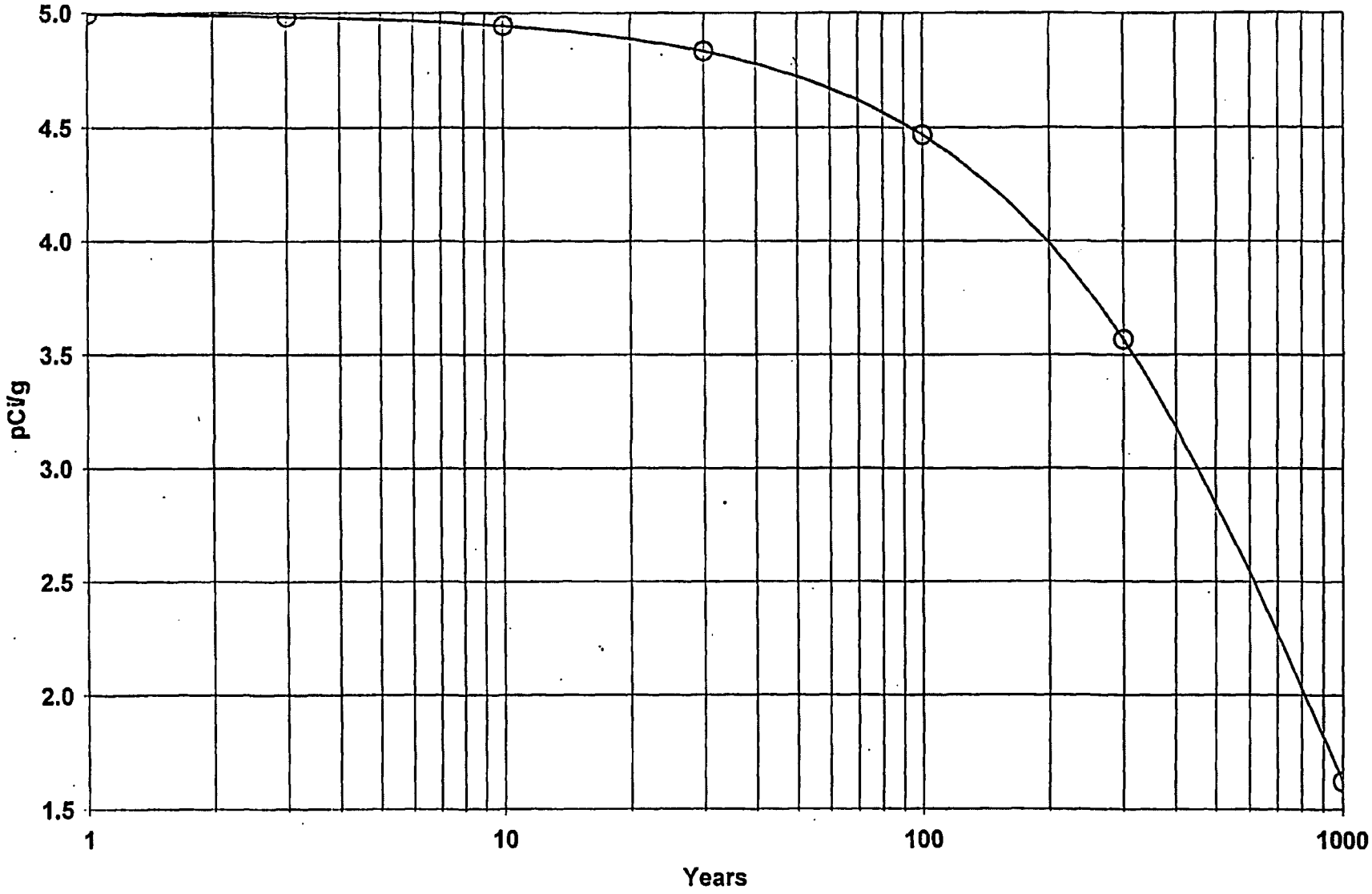
Ra022704.RAD 03/05/2004 10:01 Pathways: Meat (Wtr Ind)

DOSE: All Nuclides Summed, Inhalation



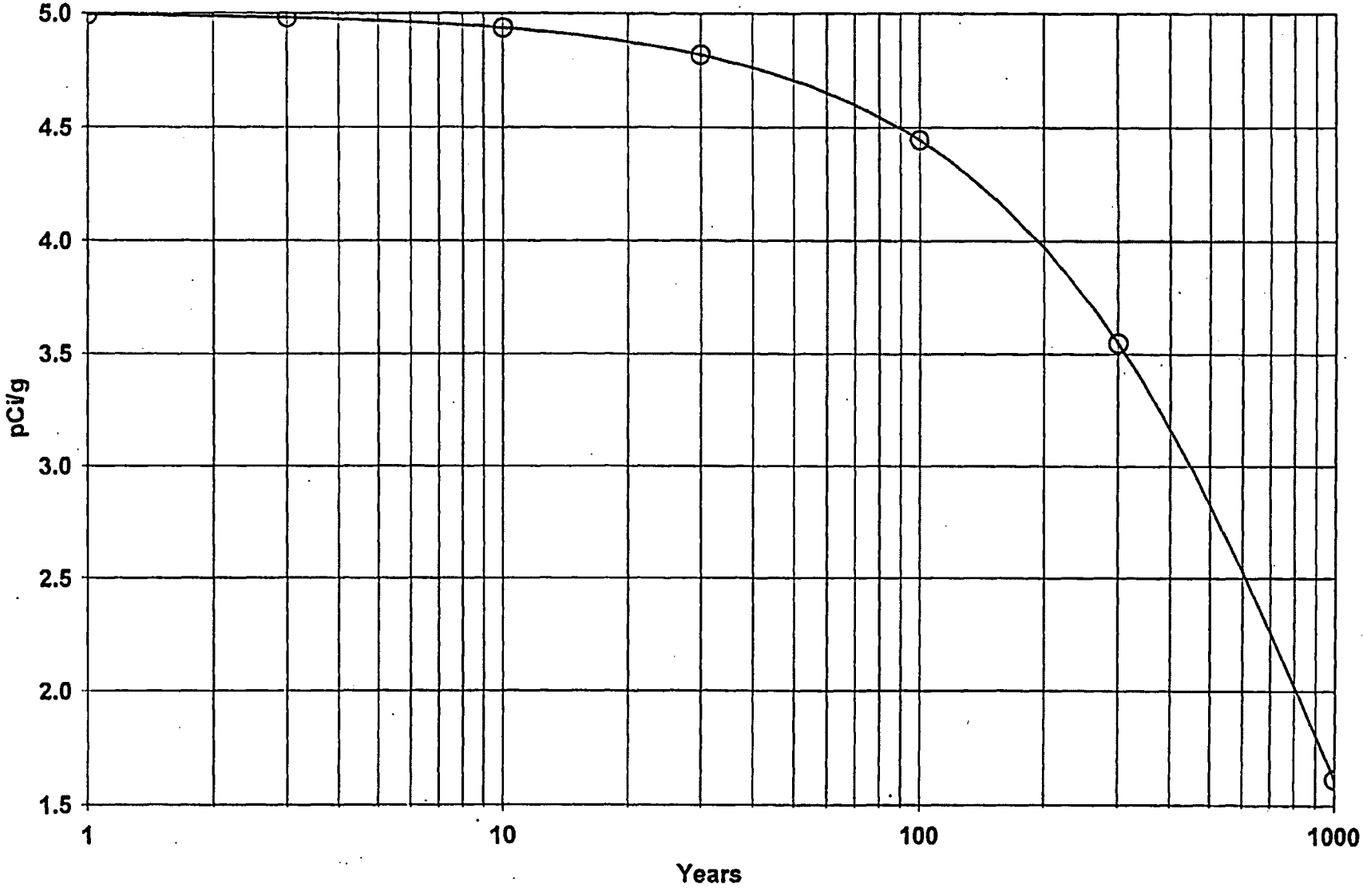
Ra022704.RAD 03/05/2004 10:01 Pathways: Inhalation

CONCENTRATION: Ra-226, Contaminated Zone Soil



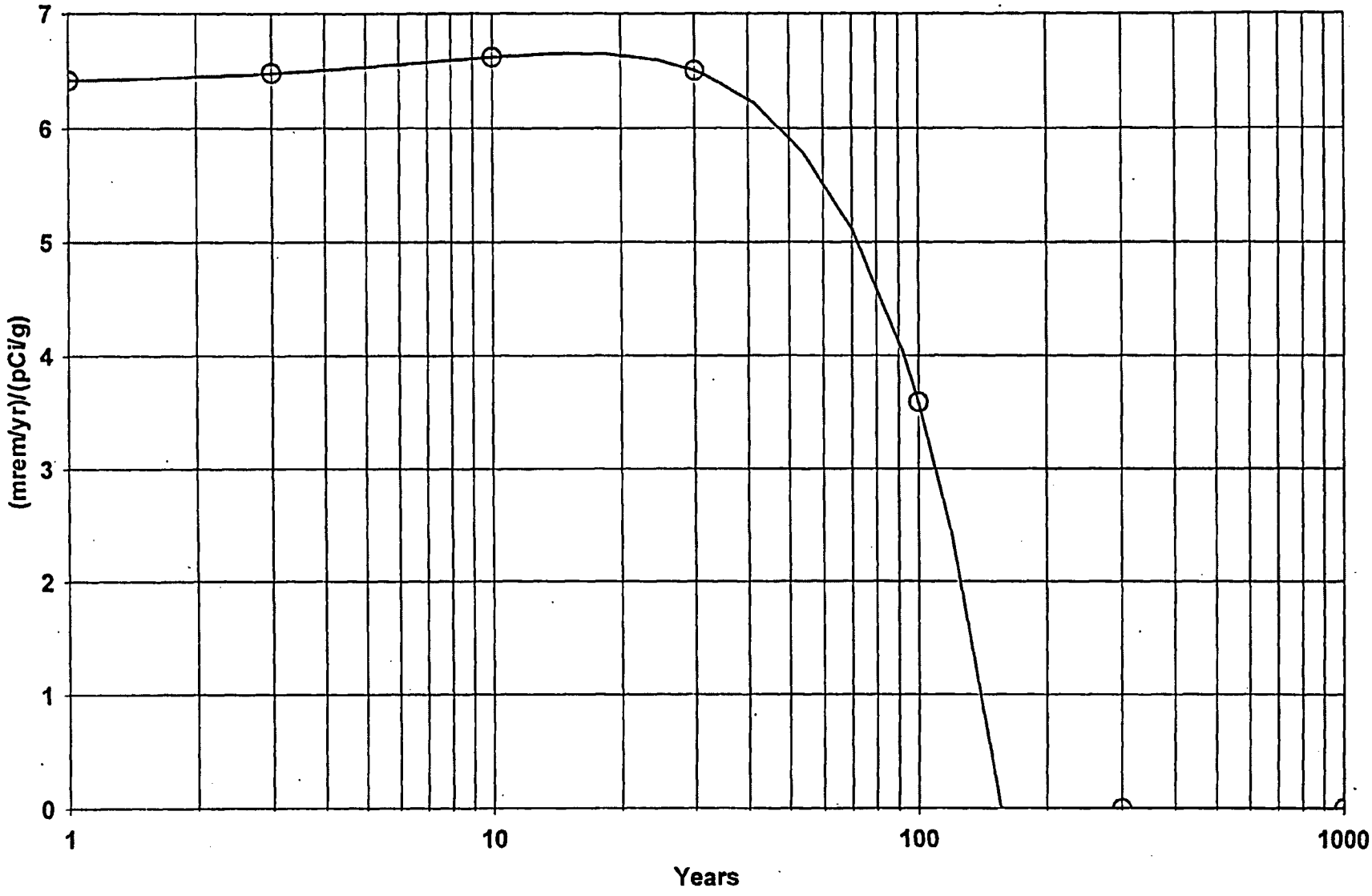
Ra022704.RAD 03/05/2004 10:01

CONCENTRATION: Pb-210, Contaminated Zone Soil



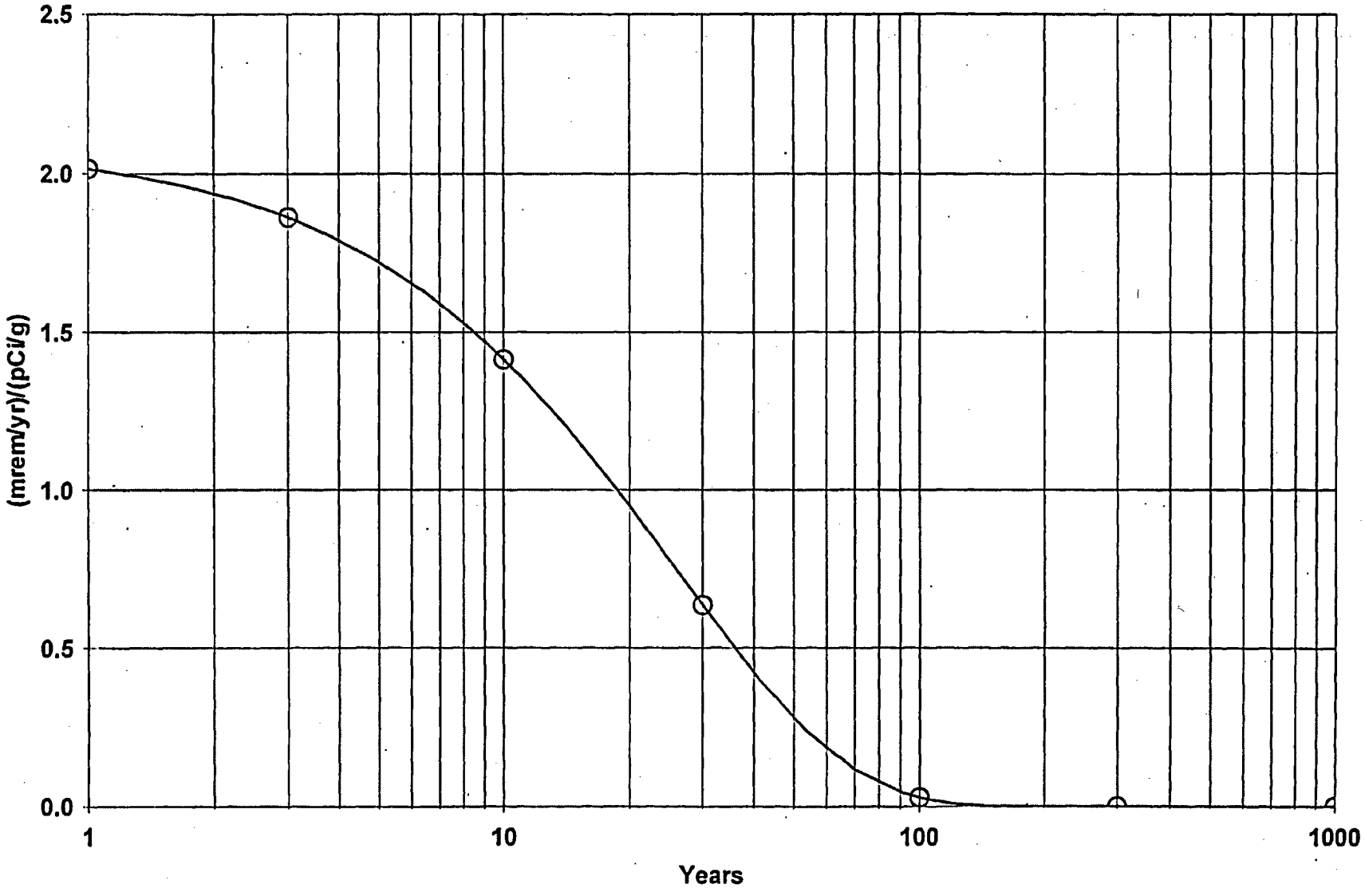
Ra022704.RAD 03/05/2004 10:01

DOSE/SOURCE RATIO: Ra-226, All Pathways Summed



Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

DOSE/SOURCE RATIO: Pb-210, All Pathways Summed



Ra022704.RAD 03/05/2004 10:01 Includes All Pathways

Radium Benchmark Dose Assessment

Attachment 5

RESRAD Model Output
Uranium Analysis

Table of Contents

Part I: Mixture Sums and Single Radionuclide Guidelines

Dose Conversion Factor (and Related) Parameter Summary ... 2
Site-Specific Parameter Summary 4
Summary of Pathway Selections 9
Contaminated Zone and Total Dose Summary 10
Total Dose Components
Time = 0.000E+00 11
Time = 1.000E+00 12
Time = 3.000E+00 13
Time = 1.000E+01 14
Time = 3.000E+01 15
Time = 1.000E+02 16
Time = 3.000E+02 17
Time = 1.000E+03 18
Dose/Source Ratios Summed Over All Pathways 19
Single Radionuclide Soil Guidelines 19
Dose Per Nuclide Summed Over All Pathways 20
Soil Concentration Per Nuclide 21

Dose Conversion Factor (and Related) Parameter Summary
File: HEAST 1995 Morbidity

	Parameter	Current Value	Default	Pa
B-1	Dose conversion factors for inhalation, mrem/pCi:			
B-1	Ac-227+D	6.720E+00	6.720E+00	DCF
B-1	Pa-231	1.280E+00	1.280E+00	DCF
B-1	Pb-210+D	2.320E-02	2.320E-02	DCF
B-1	Ra-226+D	8.600E-03	8.600E-03	DCF
B-1	Th-230	3.260E-01	3.260E-01	DCF
B-1	U-234	1.320E-01	1.320E-01	DCF
B-1	U-235+D	1.230E-01	1.230E-01	DCF
B-1	U-238+D	1.180E-01	1.180E-01	DCF
D-1	Dose conversion factors for ingestion, mrem/pCi:			
D-1	Ac-227+D	1.480E-02	1.480E-02	DCF
D-1	Pa-231	1.060E-02	1.060E-02	DCF
D-1	Pb-210+D	7.270E-03	7.270E-03	DCF
D-1	Ra-226+D	1.330E-03	1.330E-03	DCF
D-1	Th-230	5.480E-04	5.480E-04	DCF
D-1	U-234	2.830E-04	2.830E-04	DCF
D-1	U-235+D	2.670E-04	2.670E-04	DCF
D-1	U-238+D	2.690E-04	2.690E-04	DCF
D-34	Food transfer factors:			
D-34	Ac-227+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	Ac-227+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	2.000E-05	2.000E-05	RTF
D-34	Ac-227+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	2.000E-05	2.000E-05	RTF
D-34				
D-34	Pa-231 , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF
D-34	Pa-231 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	5.000E-03	5.000E-03	RTF
D-34	Pa-231 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF
D-34				
D-34	Pb-210+D , plant/soil concentration ratio, dimensionless	1.000E-02	1.000E-02	RTF
D-34	Pb-210+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	8.000E-04	8.000E-04	RTF
D-34	Pb-210+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	3.000E-04	3.000E-04	RTF
D-34				
D-34	Ra-226+D , plant/soil concentration ratio, dimensionless	4.000E-02	4.000E-02	RTF
D-34	Ra-226+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-03	1.000E-03	RTF
D-34	Ra-226+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	1.000E-03	1.000E-03	RTF
D-34				
D-34	Th-230 , plant/soil concentration ratio, dimensionless	1.000E-03	1.000E-03	RTF
D-34	Th-230 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	1.000E-04	1.000E-04	RTF
D-34	Th-230 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	5.000E-06	5.000E-06	RTF
D-34				
D-34	U-234 , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-234 , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
D-34	U-234 , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF
D-34				
D-34	U-235+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-235+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
D-34	U-235+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF

Dose Conversion Factor (and Related) Parameter Summary (continued)
File: HEAST 1995 Morbidity

Cu	Parameter	Current Value	Default	Pa
D-34	U-238+D , plant/soil concentration ratio, dimensionless	2.500E-03	2.500E-03	RTF
D-34	U-238+D , beef/livestock-intake ratio, (pCi/kg)/(pCi/d)	3.400E-04	3.400E-04	RTF
D-34	U-238+D , milk/livestock-intake ratio, (pCi/L)/(pCi/d)	6.000E-04	6.000E-04	RTF
D-5	Bioaccumulation factors, fresh water, L/kg:			
D-5	Ac-227+D , fish	1.500E+01	1.500E+01	BIO
D-5	Ac-227+D , crustacea and mollusks	1.000E+03	1.000E+03	BIO
D-5				
D-5	Pa-231 , fish	1.000E+01	1.000E+01	BIO
D-5	Pa-231 , crustacea and mollusks	1.100E+02	1.100E+02	BIO
D-5				
D-5	Pb-210+D , fish	3.000E+02	3.000E+02	BIO
D-5	Pb-210+D , crustacea and mollusks	1.000E+02	1.000E+02	BIO
D-5				
D-5	Ra-226+D , fish	5.000E+01	5.000E+01	BIO
D-5	Ra-226+D , crustacea and mollusks	2.500E+02	2.500E+02	BIO
D-5				
D-5	Th-230 , fish	1.000E+02	1.000E+02	BIO
D-5	Th-230 , crustacea and mollusks	5.000E+02	5.000E+02	BIO
D-5				
D-5	U-234 , fish	1.000E+01	1.000E+01	BIO
D-5	U-234 , crustacea and mollusks	6.000E+01	6.000E+01	BIO
	U-235+D , fish	1.000E+01	1.000E+01	BIO
D-5	U-235+D , crustacea and mollusks	6.000E+01	6.000E+01	BIO
D-5				
D-5	U-238+D , fish	1.000E+01	1.000E+01	BIO
D-5	U-238+D , crustacea and mollusks	6.000E+01	6.000E+01	BIO

Site-Specific Parameter Summary

	Parameter	User Input	Default	Used (If different
R011	Area of contaminated zone (m**2)	1.000E+04	1.000E+04	-
R011	Thickness of contaminated zone (m)	1.500E-01	2.000E+00	-
R011	Length parallel to aquifer flow (m)	1.000E+02	1.000E+02	-
R011	Basic radiation dose limit (mrem/yr)	1.000E+02	2.500E+01	-
R011	Time since placement of material (yr)	0.000E+00	0.000E+00	-
R011	Times for calculations (yr)	1.000E+00	1.000E+00	-
R011	Times for calculations (yr)	3.000E+00	3.000E+00	-
R011	Times for calculations (yr)	1.000E+01	1.000E+01	-
R011	Times for calculations (yr)	3.000E+01	3.000E+01	-
R011	Times for calculations (yr)	1.000E+02	1.000E+02	-
R011	Times for calculations (yr)	3.000E+02	3.000E+02	-
R011	Times for calculations (yr)	1.000E+03	1.000E+03	-
R011	Times for calculations (yr)	not used	0.000E+00	-
R011	Times for calculations (yr)	not used	0.000E+00	-
R012	Initial principal radionuclide (pCi/g): U-234	4.890E+01	0.000E+00	-
R012	Initial principal radionuclide (pCi/g): U-235	2.200E+00	0.000E+00	-
R012	Initial principal radionuclide (pCi/g): U-238	4.890E+01	0.000E+00	-
R012	Concentration in groundwater (pCi/L): U-234	not used	0.000E+00	-
R012	Concentration in groundwater (pCi/L): U-235	not used	0.000E+00	-
R012	Concentration in groundwater (pCi/L): U-238	not used	0.000E+00	-
R013	Cover depth (m)	0.000E+00	0.000E+00	-
R013	Density of cover material (g/cm**3)	not used	1.500E+00	
R013	Cover depth erosion rate (m/yr)	not used	1.000E-03	
R013	Density of contaminated zone (g/cm**3)	1.500E+00	1.500E+00	-
R013	Contaminated zone erosion rate (m/yr)	1.000E-03	1.000E-03	-
R013	Contaminated zone total porosity	4.000E-01	4.000E-01	-
R013	Contaminated zone field capacity	2.000E-01	2.000E-01	-
R013	Contaminated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	-
R013	Contaminated zone b parameter	4.380E+00	5.300E+00	-
R013	Average annual wind speed (m/sec)	4.300E+00	2.000E+00	-
R013	Humidity in air (g/m**3)	not used	8.000E+00	-
R013	Evapotranspiration coefficient	7.500E-01	5.000E-01	-
R013	Precipitation (m/yr)	3.900E-01	1.000E+00	-
R013	Irrigation (m/yr)	0.000E+00	2.000E-01	-
R013	Irrigation mode	overhead	overhead	-
R013	Runoff coefficient	2.000E-01	2.000E-01	-
R013	Watershed area for nearby stream or pond (m**2)	3.630E+07	1.000E+06	-
R013	Accuracy for water/soil computations	1.000E-03	1.000E-03	-
R014	Density of saturated zone (g/cm**3)	1.500E+00	1.500E+00	-
R014	Saturated zone total porosity	4.000E-01	4.000E-01	-
R014	Saturated zone effective porosity	2.000E-01	2.000E-01	-
R014	Saturated zone field capacity	2.000E-01	2.000E-01	-
R014	Saturated zone hydraulic conductivity (m/yr)	4.000E+03	1.000E+02	-
R014	Saturated zone hydraulic gradient	2.000E-02	2.000E-02	-
R014	Saturated zone b parameter	4.380E+00	5.300E+00	-
R014	Water table drop rate (m/yr)	1.000E-03	1.000E-03	-
R014	Well pump intake depth (m below water table)	2.000E+01	1.000E+01	-
R014	Model: Nondispersion (ND) or Mass-Balance (MB)	ND	ND	

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used b (If different
R014	Well pumping rate (m**3/yr)	2.500E+02	2.500E+02	-
R015	Number of unsaturated zone strata	1	1	-
R015	Unsat. zone 1, thickness (m)	1.500E+01	4.000E+00	-
R015	Unsat. zone 1, soil density (g/cm**3)	1.500E+00	1.500E+00	-
R015	Unsat. zone 1, total porosity	4.000E-01	4.000E-01	-
R015	Unsat. zone 1, effective porosity	2.000E-01	2.000E-01	-
R015	Unsat. zone 1, field capacity	2.000E-01	2.000E-01	-
R015	Unsat. zone 1, soil-specific b parameter	4.380E+00	5.300E+00	-
R015	Unsat. zone 1, hydraulic conductivity (m/yr)	4.000E+03	1.000E+01	-
R016	Distribution coefficients for U-234			
R016	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for U-235			
R016	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for U-238			
R016	Contaminated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	3.500E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	3.500E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	9.86
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Ac-227			
R016	Contaminated zone (cm**3/g)	2.000E+01	2.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	2.000E+01	2.000E+01	-
R016	Saturated zone (cm**3/g)	2.000E+01	2.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.72
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Pa-231			
R016	Contaminated zone (cm**3/g)	5.000E+01	5.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	5.000E+01	5.000E+01	-
R016	Saturated zone (cm**3/g)	5.000E+01	5.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.91
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Pb-210			
R016	Contaminated zone (cm**3/g)	2.700E+02	1.000E+02	-
R016	Unsaturated zone 1 (cm**3/g)	2.700E+02	1.000E+02	-
R016	Saturated zone (cm**3/g)	2.700E+02	1.000E+02	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	1.28
R016	Solubility constant	0.000E+00	0.000E+00	not

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used (If different
R016	Distribution coefficients for daughter Ra-226			
R016	Contaminated zone (cm**3/g)	5.000E+02	7.000E+01	-
R016	Unsaturated zone 1 (cm**3/g)	5.000E+02	7.000E+01	-
R016	Saturated zone (cm**3/g)	5.000E+02	7.000E+01	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	6.93
R016	Solubility constant	0.000E+00	0.000E+00	not
R016	Distribution coefficients for daughter Th-230			
R016	Contaminated zone (cm**3/g)	6.000E+04	6.000E+04	-
R016	Unsaturated zone 1 (cm**3/g)	6.000E+04	6.000E+04	-
R016	Saturated zone (cm**3/g)	6.000E+04	6.000E+04	-
R016	Leach rate (/yr)	0.000E+00	0.000E+00	5.77
R016	Solubility constant	0.000E+00	0.000E+00	not
R017	Inhalation rate (m**3/yr)	8.400E+03	8.400E+03	-
R017	Mass loading for inhalation (g/m**3)	3.000E-04	1.000E-04	-
R017	Exposure duration	3.000E+01	3.000E+01	-
R017	Shielding factor, inhalation	4.000E-01	4.000E-01	-
R017	Shielding factor, external gamma	5.500E-01	7.000E-01	-
R017	Fraction of time spent indoors	5.000E-01	5.000E-01	-
R017	Fraction of time spent outdoors (on site)	2.500E-01	2.500E-01	-
R017	Shape factor flag, external gamma	1.000E+00	1.000E+00	>0 shows ci
R017	Radii of shape factor array (used if FS = -1):			
R017	Outer annular radius (m), ring 1:	not used	5.000E+01	
	Outer annular radius (m), ring 2:	not used	7.071E+01	
R017	Outer annular radius (m), ring 3:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 4:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 5:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 6:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 7:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 8:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 9:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 10:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 11:	not used	0.000E+00	-
R017	Outer annular radius (m), ring 12:	not used	0.000E+00	-
R017	Fractions of annular areas within AREA:			
R017	Ring 1	not used	1.000E+00	-
R017	Ring 2	not used	2.732E-01	-
R017	Ring 3	not used	0.000E+00	-
R017	Ring 4	not used	0.000E+00	-
R017	Ring 5	not used	0.000E+00	-
R017	Ring 6	not used	0.000E+00	-
R017	Ring 7	not used	0.000E+00	-
R017	Ring 8	not used	0.000E+00	-
R017	Ring 9	not used	0.000E+00	-
R017	Ring 10	not used	0.000E+00	-
R017	Ring 11	not used	0.000E+00	-
R017	Ring 12	not used	0.000E+00	-
R018	Fruits, vegetables and grain consumption (kg/yr)	1.900E+02	1.600E+02	

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used b (If different
R018	Leafy vegetable consumption (kg/yr)	1.400E+01	1.400E+01	-
R018	Milk consumption (L/yr)	not used	9.200E+01	-
R018	Meat and poultry consumption (kg/yr)	6.300E+01	6.300E+01	-
R018	Fish consumption (kg/yr)	not used	5.400E+00	-
R018	Other seafood consumption (kg/yr)	not used	9.000E-01	-
R018	Soil ingestion rate (g/yr)	3.650E+01	3.650E+01	-
R018	Drinking water intake (L/yr)	5.100E+02	5.100E+02	-
R018	Contamination fraction of drinking water	1.000E+00	1.000E+00	-
R018	Contamination fraction of household water	not used	1.000E+00	-
R018	Contamination fraction of livestock water	1.000E+00	1.000E+00	-
R018	Contamination fraction of irrigation water	1.000E+00	1.000E+00	-
R018	Contamination fraction of aquatic food	not used	5.000E-01	-
R018	Contamination fraction of plant food	2.500E-01	-1	-
R018	Contamination fraction of meat	2.500E-01	-1	-
R018	Contamination fraction of milk	not used	-1	-
R019	Livestock fodder intake for meat (kg/day)	6.800E+01	6.800E+01	-
R019	Livestock fodder intake for milk (kg/day)	not used	5.500E+01	-
R019	Livestock water intake for meat (L/day)	5.000E+01	5.000E+01	-
R019	Livestock water intake for milk (L/day)	not used	1.600E+02	-
R019	Livestock soil intake (kg/day)	5.000E-01	5.000E-01	-
R019	Mass loading for foliar deposition (g/m**3)	3.000E-04	1.000E-04	-
R019	Depth of soil mixing layer (m)	1.500E-01	1.500E-01	-
R019	Depth of roots (m)	3.000E-01	9.000E-01	-
R019	Drinking water fraction from ground water	1.000E+00	1.000E+00	-
R019	Household water fraction from ground water	not used	1.000E+00	-
R019	Livestock water fraction from ground water	1.000E+00	1.000E+00	-
R019	Irrigation fraction from ground water	1.000E+00	1.000E+00	-
R19B	Wet weight crop yield for Non-Leafy (kg/m**2)	7.000E-01	7.000E-01	-
R19B	Wet weight crop yield for Leafy (kg/m**2)	1.500E+00	1.500E+00	-
R19B	Wet weight crop yield for Fodder (kg/m**2)	1.100E+00	1.100E+00	-
R19B	Growing Season for Non-Leafy (years)	1.700E-01	1.700E-01	-
R19B	Growing Season for Leafy (years)	2.500E-01	2.500E-01	-
R19B	Growing Season for Fodder (years)	8.000E-02	8.000E-02	-
R19B	Translocation Factor for Non-Leafy	1.000E-01	1.000E-01	-
R19B	Translocation Factor for Leafy	1.000E+00	1.000E+00	-
R19B	Translocation Factor for Fodder	1.000E+00	1.000E+00	-
R19B	Dry Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	-
R19B	Dry Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	-
R19B	Dry Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Non-Leafy	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Leafy	2.500E-01	2.500E-01	-
R19B	Wet Foliar Interception Fraction for Fodder	2.500E-01	2.500E-01	-
R19B	Weathering Removal Constant for Vegetation	2.000E+01	2.000E+01	-
C14	C-12 concentration in water (g/cm**3)	not used	2.000E-05	-
C14	C-12 concentration in contaminated soil (g/g)	not used	3.000E-02	-
C14	Fraction of vegetation carbon from soil	not used	2.000E-02	-
C14	Fraction of vegetation carbon from air	not used	9.800E-01	-
C14	C-14 evasion layer thickness in soil (m)	not used	3.000E-01	-

Site-Specific Parameter Summary (continued)

Menu	Parameter	User Input	Default	Used (If different
C14	C-14 evasion flux rate from soil (1/sec)	not used	7.000E-07	-
C14	C-12 evasion flux rate from soil (1/sec)	not used	1.000E-10	-
C14	Fraction of grain in beef cattle feed	not used	8.000E-01	-
C14	Fraction of grain in milk cow feed	not used	2.000E-01	-
C14	DCF correction factor for gaseous forms of C14	not used	8.894E+01	-
STOR	Storage times of contaminated foodstuffs (days):			
STOR	Fruits, non-leafy vegetables, and grain	1.400E+01	1.400E+01	-
STOR	Leafy vegetables	1.000E+00	1.000E+00	-
STOR	Milk	1.000E+00	1.000E+00	-
STOR	Meat and poultry	2.000E+01	2.000E+01	-
STOR	Fish	7.000E+00	7.000E+00	-
STOR	Crustacea and mollusks	7.000E+00	7.000E+00	-
STOR	Well water	1.000E+00	1.000E+00	-
STOR	Surface water	1.000E+00	1.000E+00	-
STOR	Livestock fodder	4.500E+01	4.500E+01	-
R021	Thickness of building foundation (m)	not used	1.500E-01	-
R021	Bulk density of building foundation (g/cm**3)	not used	2.400E+00	-
R021	Total porosity of the cover material	not used	4.000E-01	-
R021	Total porosity of the building foundation	not used	1.000E-01	-
R021	Volumetric water content of the cover material	not used	5.000E-02	-
R021	Volumetric water content of the foundation	not used	3.000E-02	-
R021	Diffusion coefficient for radon gas (m/sec):			
R021	in cover material	not used	2.000E-06	-
R021	in foundation material	not used	3.000E-07	-
R021	in contaminated zone soil	not used	2.000E-06	-
R021	Radon vertical dimension of mixing (m)	not used	2.000E+00	-
R021	Average building air exchange rate (1/hr)	not used	5.000E-01	-
R021	Height of the building (room) (m)	not used	2.500E+00	-
R021	Building interior area factor	not used	0.000E+00	-
R021	Building depth below ground surface (m)	not used	-1.000E+00	-
R021	Emanating power of Rn-222 gas	not used	2.500E-01	-
R021	Emanating power of Rn-220 gas	not used	1.500E-01	-
TITL	Number of graphical time points	32	---	-
TITL	Maximum number of integration points for dose	17	---	-
TITL	Maximum number of integration points for risk	513	---	-

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	suppressed
6 -- aquatic foods	suppressed
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:	10000.00 square meters	U-234	4.890E+01
Thickness:	0.15 meters	U-235	2.200E+00
Cover Depth:	0.00 meters	U-238	4.890E+01

Total Dose TDOSE(t), mrem/yr
Basic Radiation Dose Limit = 1.000E+02 mrem/yr
Total Mixture Sum M(t) = Fraction of Basic Dose Limit Received at Time (t)

t (years):	0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.00
TDOSE(t):	7.898E+00	7.791E+00	7.578E+00	6.874E+00	5.153E+00	1.485E+00	0.000E+00	0.00
M(t):	7.898E-02	7.791E-02	7.578E-02	6.874E-02	5.153E-02	1.485E-02	0.000E+00	0.00

Maximum TDOSE(t): 7.898E+00 mrem/yr at t = 0.000E+00 years

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	9.872E-03	0.0012	5.781E-01	0.0732	0.000E+00	0.0000	8.766E-01	0.1110	4.307E-02	0.0055
U-235	8.127E-01	0.1029	2.424E-02	0.0031	0.000E+00	0.0000	3.727E-02	0.0047	1.842E-03	0.0002
U-238	3.375E+00	0.4273	5.168E-01	0.0654	0.000E+00	0.0000	8.332E-01	0.1055	4.094E-02	0.0052
Total	4.198E+00	0.5315	1.119E+00	0.1417	0.000E+00	0.0000	1.747E+00	0.2212	8.586E-02	0.0109

Total Dose Contributions TDOSE(i,p,t) for Individual Radionuclides (i) an
As mrem/yr and Fraction of Total Dose At t = 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
*1	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	9.775E-03	0.0013	5.686E-01	0.0730	0.000E+00	0.0000	8.622E-01	0.1107	4.237E-02	0.0054
U-235	8.040E-01	0.1032	2.384E-02	0.0031	0.000E+00	0.0000	3.678E-02	0.0047	1.844E-03	0.0002
U-238	3.337E+00	0.4283	5.083E-01	0.0652	0.000E+00	0.0000	8.196E-01	0.1052	4.028E-02	0.0052
Total	4.150E+00	0.5327	1.101E+00	0.1413	0.000E+00	0.0000	1.719E+00	0.2206	8.449E-02	0.0108

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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	0.000

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	9.587E-03	0.0013	5.500E-01	0.0726	0.000E+00	0.0000	8.340E-01	0.1100	4.099E-02	0.0054
U-235	7.870E-01	0.1039	2.308E-02	0.0030	0.000E+00	0.0000	3.582E-02	0.0047	1.846E-03	0.0002
U-238	3.260E+00	0.4302	4.916E-01	0.0649	0.000E+00	0.0000	7.927E-01	0.1046	3.896E-02	0.0051
Total	4.057E+00	0.5353	1.065E+00	0.1405	0.000E+00	0.0000	1.663E+00	0.2194	8.179E-02	0.0108

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
...l	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	8.984E-03	0.0013	4.888E-01	0.0711	0.000E+00	0.0000	7.412E-01	0.1078	3.643E-02	0.0053
U-235	7.298E-01	0.1062	2.057E-02	0.0030	0.000E+00	0.0000	3.264E-02	0.0047	1.837E-03	0.0003
U-238	3.004E+00	0.4371	4.369E-01	0.0636	0.000E+00	0.0000	7.045E-01	0.1025	3.462E-02	0.0050
Total	3.743E+00	0.5445	9.463E-01	0.1377	0.000E+00	0.0000	1.478E+00	0.2151	7.289E-02	0.0106

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
[illegible]l	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	7.655E-03	0.0015	3.439E-01	0.0667	0.000E+00	0.0000	5.214E-01	0.1012	2.562E-02	0.0050
U-235	5.840E-01	0.1133	1.469E-02	0.0029	0.000E+00	0.0000	2.477E-02	0.0048	1.703E-03	0.0003
U-238	2.356E+00	0.4573	3.073E-01	0.0596	0.000E+00	0.0000	4.955E-01	0.0962	2.435E-02	0.0047
Total	2.948E+00	0.5721	6.659E-01	0.1292	0.000E+00	0.0000	1.042E+00	0.2021	5.168E-02	0.0100

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
[illegible]l	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	5.111E-03	0.0034	7.161E-02	0.0482	0.000E+00	0.0000	1.089E-01	0.0734	5.345E-03	0.0036
U-235	2.140E-01	0.1442	3.308E-03	0.0022	0.000E+00	0.0000	6.774E-03	0.0046	6.964E-04	0.0005
U-238	8.041E-01	0.5416	6.381E-02	0.0430	0.000E+00	0.0000	1.029E-01	0.0693	5.061E-03	0.0034
Total	1.023E+00	0.6892	1.387E-01	0.0934	0.000E+00	0.0000	2.186E-01	0.1473	1.110E-02	0.0075

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
1	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
[illegible]l	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

*Sum of all water independent and dependent pathways.

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

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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

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

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat	
Nuclide	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.	mrem/yr	fract.
U-234	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
U-235	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
U-238	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
.1	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.000

*Sum of all water independent and dependent pathways.

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

Parent	Product (j)	Branch Fraction*	DSR(j,t) (mrem/yr)/(pCi/g) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	3.851E-02	3.788E-02	3.664E-02	3.257E-02	2.293E-02	4.793E-03	0.000E+
U-234	Th-230	1.000E+00	2.722E-07	7.968E-07	1.808E-06	4.980E-06	1.127E-05	1.143E-05	0.000E+
U-234	Ra-226	1.000E+00	4.014E-09	2.830E-08	1.485E-07	1.269E-06	9.239E-06	4.666E-05	0.000E+
U-234	Pb-210	1.000E+00	1.434E-11	1.855E-10	1.926E-09	4.292E-08	7.206E-07	5.689E-06	0.000E+
U-234	∑DSR(j)		3.851E-02	3.788E-02	3.665E-02	3.258E-02	2.295E-02	4.857E-03	0.000E+
U-235	U-235	1.000E+00	4.054E-01	4.009E-01	3.920E-01	3.621E-01	2.867E-01	1.013E-01	0.000E+
U-235	Pa-231	1.000E+00	3.847E-05	1.183E-04	2.716E-04	7.372E-04	1.560E-03	1.210E-03	0.000E+
U-235	Ac-227	1.000E+00	3.673E-07	2.347E-06	1.138E-05	8.310E-05	4.157E-04	7.009E-04	0.000E+
U-235	∑DSR(j)		4.054E-01	4.010E-01	3.923E-01	3.629E-01	2.886E-01	1.032E-01	0.000E+
U-238	U-238	1.000E+00	1.048E-01	1.034E-01	1.007E-01	9.166E-02	6.944E-02	2.086E-02	0.000E+
U-238	U-234	1.000E+00	5.444E-08	1.609E-07	3.635E-07	9.695E-07	1.982E-06	1.366E-06	0.000E+
U-238	Th-230	1.000E+00	2.606E-13	1.766E-12	9.008E-12	7.299E-11	4.633E-10	1.364E-09	0.000E+
U-238	Ra-226	1.000E+00	2.820E-15	4.267E-14	4.938E-13	1.240E-11	2.539E-10	3.787E-09	0.000E+
U-238	Pb-210	1.000E+00	8.516E-18	2.256E-16	4.989E-15	3.234E-13	1.565E-11	3.944E-10	0.000E+
U-238	∑DSR(j)		1.048E-01	1.034E-01	1.007E-01	9.166E-02	6.945E-02	2.086E-02	0.000E+

*Branch Fraction is the cumulative factor for the j't principal radionuclide daughter: CUMBRF(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 = 1.000E+02 mrem/yr

Nuclide (i)	t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	
U-234	2.597E+03	2.640E+03	2.729E+03	3.069E+03	4.358E+03	2.059E+04	*6.245E+09	*
U-235	2.466E+02	2.494E+02	2.549E+02	2.755E+02	3.465E+02	9.687E+02	*2.160E+06	*
U-238	9.545E+02	9.672E+02	9.932E+02	1.091E+03	1.440E+03	4.794E+03	*3.360E+05	*

*At specific activity limit

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 (i)	Initial (pCi/g)	tmin (years)	DSR(i,tmin)	G(i,tmin) (pCi/g)	DSR(i,tmax)	G(i,tmax) (pCi/g)
U-234	4.890E+01	0.000E+00	3.851E-02	2.597E+03	3.851E-02	2.597E+03
U-235	2.200E+00	0.000E+00	4.054E-01	2.466E+02	4.054E-01	2.466E+02
U-238	4.890E+01	0.000E+00	1.048E-01	9.545E+02	1.048E-01	9.545E+02

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

Nuclide (j)	Parent (i)	BRF(i)	DOSE(j,t), mrem/yr t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	1.883E+00	1.852E+00	1.792E+00	1.593E+00	1.121E+00	2.344E-01	0.000E+
U-234	U-238	1.000E+00	2.662E-06	7.870E-06	1.777E-05	4.741E-05	9.693E-05	6.679E-05	0.000E+
U-234	∑DOSE(j)		1.883E+00	1.852E+00	1.792E+00	1.593E+00	1.121E+00	2.345E-01	0.000E+
Th-230	U-234	1.000E+00	1.331E-05	3.896E-05	8.839E-05	2.435E-04	5.513E-04	5.590E-04	0.000E+
Th-230	U-238	1.000E+00	1.274E-11	8.635E-11	4.405E-10	3.569E-09	2.265E-08	6.672E-08	0.000E+
Th-230	∑DOSE(j)		1.331E-05	3.896E-05	8.839E-05	2.435E-04	5.513E-04	5.591E-04	0.000E+
Ra-226	U-234	1.000E+00	1.963E-07	1.384E-06	7.261E-06	6.208E-05	4.518E-04	2.282E-03	0.000E+
Ra-226	U-238	1.000E+00	1.379E-13	2.086E-12	2.415E-11	6.064E-10	1.242E-08	1.852E-07	0.000E+
Ra-226	∑DOSE(j)		1.963E-07	1.384E-06	7.261E-06	6.208E-05	4.518E-04	2.282E-03	0.000E+
Pb-210	U-234	1.000E+00	7.011E-10	9.070E-09	9.419E-08	2.099E-06	3.524E-05	2.782E-04	0.000E+
Pb-210	U-238	1.000E+00	4.164E-16	1.103E-14	2.440E-13	1.582E-11	7.651E-10	1.929E-08	0.000E+
Pb-210	∑DOSE(j)		7.011E-10	9.070E-09	9.419E-08	2.099E-06	3.524E-05	2.782E-04	0.000E+
U-235	U-235	1.000E+00	8.919E-01	8.819E-01	8.624E-01	7.967E-01	6.306E-01	2.229E-01	0.000E+
Pa-231	U-235	1.000E+00	8.463E-05	2.602E-04	5.974E-04	1.622E-03	3.431E-03	2.662E-03	0.000E+
Ac-227	U-235	1.000E+00	8.080E-07	5.164E-06	2.504E-05	1.828E-04	9.145E-04	1.542E-03	0.000E+
U-238	U-238	1.000E+00	5.123E+00	5.056E+00	4.923E+00	4.482E+00	3.396E+00	1.020E+00	0.000E

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

Individual Nuclide Soil Concentration
Parent Nuclide and Branch Fraction Indicated

Nuclide (j)	Parent (i)	BRF(i)	S(j,t), pCi/g t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+
U-234	U-234	1.000E+00	4.890E+01	4.842E+01	4.747E+01	4.430E+01	3.637E+01	1.822E+01	2.531E+
U-234	U-238	1.000E+00	0.000E+00	1.373E-04	4.038E-04	1.256E-03	3.093E-03	5.167E-03	2.154E-
U-234	∑S(j):		4.890E+01	4.842E+01	4.747E+01	4.431E+01	3.637E+01	1.823E+01	2.534E+
Th-230	U-234	1.000E+00	0.000E+00	4.380E-04	1.301E-03	4.191E-03	1.143E-02	2.795E-02	4.216E-
Th-230	U-238	1.000E+00	0.000E+00	6.199E-10	5.506E-09	5.844E-08	4.620E-07	3.322E-06	1.016E-
Th-230	∑S(j):		0.000E+00	4.380E-04	1.301E-03	4.191E-03	1.143E-02	2.796E-02	4.217E-
Ra-226	U-234	1.000E+00	0.000E+00	9.500E-08	8.488E-07	9.194E-06	7.703E-05	6.761E-04	3.451E-
Ra-226	U-238	1.000E+00	0.000E+00	8.964E-14	2.395E-12	8.554E-11	2.084E-09	5.464E-08	6.155E-
Ra-226	∑S(j):		0.000E+00	9.500E-08	8.488E-07	9.194E-06	7.704E-05	6.762E-04	3.451E-
Pb-210	U-234	1.000E+00	0.000E+00	9.773E-10	2.582E-08	8.879E-07	1.955E-05	3.872E-04	2.885E-
Pb-210	U-238	1.000E+00	0.000E+00	6.928E-16	5.494E-14	6.301E-12	4.161E-10	2.670E-08	4.868E-
Pb-210	∑S(j):		0.000E+00	9.773E-10	2.582E-08	8.879E-07	1.955E-05	3.872E-04	2.885E-
U-235	U-235	1.000E+00	2.200E+00	2.178E+00	2.136E+00	1.993E+00	1.636E+00	8.202E-01	1.140E-
Pa-231	U-235	1.000E+00	0.000E+00	4.616E-05	1.362E-04	4.280E-04	1.086E-03	2.016E-03	1.160E-
Ac-227	U-235	1.000E+00	0.000E+00	7.249E-07	6.246E-06	5.976E-05	3.589E-04	1.196E-03	8.300E-
U-238	U-238	1.000E+00	4.890E+01	4.842E+01	4.747E+01	4.431E+01	3.637E+01	1.823E+01	2.534E+

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

RESCALC.EXE execution time = 0.55 seconds

This page intentionally left blank

Appendix O

Swift Fox Survey Protocol

Appendix O
Swift Fox Survey Protocol

The following protocol is a modification of a swift fox protocol included in Mineral Exploration Permit Number NE0210824 (dated August 19, 2009) issued by the Department of Environmental Quality (NDEQ) to Crow Butte Resources, Inc (NDEQ 2009). This permit primarily addresses impacts associated with drilling of boreholes for purposes of mineral exploration. The primary modification of the Appendix 10 protocol is expanding the type of activities potentially impacting the swift fox to include, in addition to drilling of boreholes, uranium in situ satellite project development activities. Satellite "project development" includes construction of satellite facilities (process building and associated storage structures, evaporation ponds, wellfield development (surface preparation, monitor and injection/recovery wells, wellhouses, and trunklines/piping), well workover, boreholes outside of wellfields, and project roadways. Reference to "project development" in this protocol refers to these activities. Project development activities apply to initial construction/wellfield development, operations and decommissioning. Decommissioning includes decontaminating, dismantling, and removing satellite facilities and associated wellfield buildings/equipment/wells and, site reclamation and groundwater restoration.

Swift fox are typically found in topographically flat (slopes <20%) arid regions. In Nebraska, suitable habitat is in the short-grass prairie ecoregion where vegetation is less than 40 cm tall. They can be found in large expanses of prairie as well as prairie intermixed with agriculture. Dens are also found in anthropogenic areas such as near roads and trails, and in agricultural fields, culverts pipes and buildings (Tannerfeldt et al 2003). Swift fox are highly mobile and will use a variety of dens throughout the year. However, a female swift fox with young pups will typically be tied to one den until the pups are old enough to disperse from the den. Swift fox den entrances have a diameter of 17 to 23 cm.

Required Surveys:

CBR will avoid impacting the swift fox species by avoiding certain locations during specific times of the year. Surveys shall be conducted that are consistent with the Nebraska Game and Parks Commission (NG&PC) standard protocol included in CBR's Mineral Exploration Permit Number NE0210824 as Attachment 1.

The survey form to be used for swift fox surveys is attached to this protocol.

Project development activities will occur within a designated permit boundary. If project development activities within this permit boundary are such that specific protocol requirements (e.g., designated distances from swift fox dens) cannot be avoided as stated in this protocol, CBR will consult with the NDEQ and NG&PC as to the feasibility of

alternate actions. No work will be conducted until any such issue has been resolved with the NDEQ and NG&PC.

Surveyors:

Surveys shall be conducted by a qualified individual who has experience working with the species or has been trained to identify swift fox burrows, dens and sign (scat, tracks, etc.).

Location:

Surveys shall be conducted at project development sites discussed above where suitable habitat is present within the range of the species.

Season:

Surveys shall be conducted year-around in areas of suitable habitat where project development activities are planned.

Timing:

Surveys shall be conducted within one week of initiating project development activities described above under Location.

Survey Technique:

The "denning season" is defined as the period of time when adult swift fox give birth and raise pups. In Nebraska, the swift fox denning season is from April 1 through August 31.

During the denning season, the area that must be surveyed for dens includes project development activities plus an additional 230 meters around the affected areas. When developing wellfields, numerous boreholes will initially be drilled. In this situation, the "affected area" will be the perimeter of the wellfield for the addition of 230 meters to the survey area, as opposed to each drill site. Under such conditions (i.e. work over multiple days or months), only one survey shall be submitted for that period indicating the duration of planned activities in the survey area. During other periods of time (e.g., operations), when individual boreholes are drilled at one time or a workover rig is used for well maintenance, then the additional 230 meters will be applied to the drill site. The above procedures will allow the operator the option of the most effective type of survey to use - wellfield boundary or individual drill site. The satellite facilities will be located within a 1.8-acre fenced-in site. The swift fox survey will be conducted prior to construction using an additional 230 meters around the fence boundary.

During the non-denning season (September 1 through March 31), the area that must be surveyed for dens includes the project development activities plus an additional 100 meters around the affected areas. When developing wellfields, numerous boreholes will initially be drilled. In this situation, the "affected area" will be the perimeter of the

wellfield for the addition of 100 meters to the survey area, as opposed to each drill site. Under such conditions (i.e. work over multiple days or months), only one survey shall be submitted for that period indicating the duration of planned activities in the survey area. During other periods of time (e.g., operations), when individual boreholes are drilled at one time or a workover rig is used for well maintenance, then the additional 100 meters will be applied to the drill site. The above procedures will allow the operator the option of the most effective type of survey to use - wellfield boundary or individual drill site. The satellite facilities will be located within a 1.8-acre fenced-in site. The swift fox survey will be conducted using an additional 100 meters around the fence boundary.

The survey will consist of walking transects and searching for dens within the survey area. Transects will be no more that 50 meters apart in order to thoroughly cover the area.

An active den may have fresh digging at the entrance, although this is not always the case (Jackson and Choate 2000). Sign, such as scat or tracks, can also be indicate an active den. Swift fox tracks are approximately 2.54 cm wide and 3.8 cm long. Although this is the smallest canid species, tracks can be confused with other species, especially young coyotes. Inactive dens may be overgrown with vegetation, have spider webs over the entrance, or be caving in.

Conservative Measures:

If a potentially active swift fox den is identified, one of two conservation measures should be implemented:

1. The area of project development activities shall be done so activities are at least 230 meters from the den during the denning season, or 100 meters from the den during the non-denning season. For drilling sites, these can be moved to an appropriate distance from the den. A survey around any of these new activities must be conducted.

2. A track or scent station can be set up to determine if the den is being used by swift fox. If track or scent stations indicate swift fox are using the den, then project development activities within a minimum of 100 meters or 230 meters (whichever is appropriate for the season) of the den would be postponed until the den is abandoned. For drilling sites, they can be moved as outlined in #1 above. If track or scent stations indicate swift fox are not using the den, then drilling activities may proceed if there are not any other dens or swift fox within the survey area.

Track Station: Den use can be determined by clearing vegetation around the den and sifting a mixture of fine dry sand and unscented glycerin in a circular patter (~1 m in diameter) around the den hole, approximately 0.5 inches thick. Tracks of the animal using the den can then be identified the following morning as most animals using underground dens are nocturnal and will exit the den at night. Track stations are only

good for one night. If the track station cannot be checked the following morning, a new sand and glycerin mixture should be applied to the area around the den hole and surveyed the next morning.

Scent Station: Swift fox scent station surveys can be conducted any time of the year, although tracks will not show on bare, frozen ground. However, snow can be used as a tracking medium in winter. Scent stations are created by clearing any vegetation in an area and sifting a mixture of fine dry sand and unscented glycerin in a circular patter (~1 m in diameter) approximately 0.5 inches thick. A plaster tablet soaked in cod/salmon oil mixture (or either) is placed in the center of the station. Scent stations are then placed at locations selected based on the suitability of the surrounding habitat and the presence of certain structures (fence rows, gates, intersections, trails, etc.) that facilitate movement. Weather permitting, they are reset for 3 consecutive days or until at least one station shows sign of swift fox visitation (tracks, feces). Scent stations should not be used within 300 meters of a known or suspected active den as these methods may attract predators.

Survey Reports

A monthly survey report shall be submitted to Nebraska Game and Parks Commission (NG&PC) and Nebraska Department of Environmental Quality (NDEQ) describing all surveys for the swift fox that were conducted during the previous month in connection with project development activities. The survey report shall include the names of the surveyors and their credentials, date and time of the survey, weather conditions, locations surveyed, methods, results, and a discussion of applicable conservation measures implemented. If the swift fox is not identified, the above information must be recorded and included in the report to be submitted at the end of the month. If a swift fox is identified within the survey area, NG&PC must be notified by telephone within twenty-four (24) hours of identification. Written documentation of identification and the survey report shall be submitted with five (5) days of species identification, along with indication of conservation measures. All survey reports shall be submitted no later than the 28th day of the month following the end of the reporting period, even if the species being surveyed are not detected at a particular site. Copies of the reports shall be kept on site for inspection by the NDEQ.

References:

Jackson, V.I. and J.R. Chaote. 2000. *Dens and den sites of the swift fox, Vulpes velox.* The Southwestern Naturalist 45(2):212:220).

Nebraska Department of Environmental Quality (NDEQ). 2009. *Mineral Exploration Permit Number NE0210824.* August 19, 2009.

Tannerfeldt, M., A. Moehrenschlager and A. Angerbjorn. 2003. *Den ecology of swift, kit, and arctic foxes. A review. In the Swift Fox: Ecology and conservation of swift foxes in a changing world,* M. Sovada and L. Carbyn editors. Canadian Plains Research Center, University of Regima.

August 2009

Nebraska Department of Environmental Quality

Threatened and Endangered Species Survey Report

Surveyor' Name(s)_____

Credentials: (e.g., who certified the surveyor and date of certification or surveyor's knowledge of surveyed species)

_____

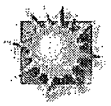
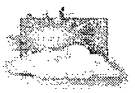
_____

Date of Survey: _____ Time of Survey: _____

Weather Condition:

Temperature: _____°F Wind Speed & Direction: _____

Other

Sunny Partly Cloudy Cloudy Snowing Raining _____

Legal Location or GPS coordinates (Lat/Long or UTM) of survey area (include datum, i.e., NAD83, WGS84:_____

County: _____

Vegetative Cover (i.e. corn stubble, plowed field, wetland, short grass prairie 10-20 cm tall

Methods used to survey affected area (.i.e. Mountain Plover Survey Protocol, 5 transects 50 ft apart)

_____

_____

Were any of the following species identified in the area?

Mountain Plover	Yes/No
River Otter	Yes/No
Swift Fox	Yes/No

If so, what conservation measures were taken? (Attach if necessary)

_____

_____

If species is identified, record the location of the species in GPS coordinates. Also indicate locational certainty (i.e. 3 birds were flushed 50 yards NW from this point). Photographs may be sent with survey reports to aid in site description and species identification.

Submit survey reports <u>monthly</u> to:

Nebraska Game & Parks Commission
Attn: Env. Analyst Supervisor
Nebraska Natural Heritage Program
2200 N 33rd Street
Lincoln, NE 68503

Nebraska Dept. of Env. Quality
Attn: Mineral Exploration Program
P.O. Box 98922
Lincoln, NE 68509

Appendix P

Cost Estimate for Decontamination, Decommissioning and Reclamation of Proposed Marsland Expansion Area (One Mine Unit)

Table P.1-1 Primary Assumptions Serving as the basis for Surety Cost Estimates Associated with Restoration and Reclamation of One (1) Mine Unit

Assumptions	Quantity
Total number of production wells	30*
Total number of injection wells	50*
Total number of shallow monitor wells	0
Total number of perimeter wells	11
Total number of restoration wells	10
Wellfield Area (ft^2)	403,712
Wellfield Area (acres)	9.27
Affected Ore Zone Area (ft^2)	403.712
Average Completed Thickness (ft)	19.6
Porosity	0.29
Affected Volume (ft^3)	7,942,755
Flare Factor	1.2
K gallons per Pore Volume	20,597
Number of Patterns in Unit(s)	30
Estimated Number of Pore Volumes for Restoration	11
Number of Wells per Wellfield	91
Total Number of Wells	91
Average Well Depth (ft) – Deep Wells	1,100
Average Well Depth (ft) – Shallow Depth	400

Revised 10/13/2011
Estimated costs are shown in Table S.1-2 and S.1-3
*Number of wells per wellhouse typically 3 wellhouses per wellfield

Table P.1-2 Marsland Total Restoration and Reclamation Cost Estimate - 2011 Surety Estimate

	Task			Cost $
I.	Groundwater Restoration (Sheets 3 to 6)			$270,971
II.	Wellfield Reclamation (Sheets 7 to 10)			$127,579
III.	Commercial Plant Reclamation/Decommissioning (Sheets 11 to 14)			$762,205
IV.	Miscellaneous Site Reclamation (Sheets 19 to 21)			$86,346
V.	Deep Disposal Well Reclamation (Sheet 22)			$66,474
Subtotal Reclamation and Restoration Cost Estimate				$1,313,575
		Contract Administration	**10%**	$131,358
		Contingency	**15%**	$197,036
	TOTAL			**$1,641,969**

Revised 10/13/2011

Table P.1-3 Marsland Ground Water Restoration - 2011 Surety Estimate

Task		MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Total
I. IX Treatment Costs													
PV's Required		3	3	3	3	3	3	3	3	3	3	3	
Total Kgals for Treatment		61791	0	0	0	0	0	0	0	0	0	0	0
IX Treatment Unit Cost ($/Kgal)	(Sheet 25)	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	$0.35	
Subtotal IX Treatment Costs per Wellfield		**$21,626.85**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total IX Treatment Costs		**$21,626.85**	**$0.00**										
II. Reverse Osmosis Costs													
PV's Required		6	6	6	6	6	6	6	6	6	6	6	
Total Kgals for Treatment		123582	0	0	0	0	0	0	0	0	0	0	0
Reverse Osmosis Unit Cost ($/Kgal)	(Sheet 26)	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31	$1.31
Subtotal Reverse Osmosis Costs per Wellfield		**$161,892.42**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total Reverse Osmosis Costs		**$161,892.42**	**$0.00**										
III. Recirculation Costs													
PV's Required		2	2	2	2	2	2	2	2	2	2	2	
Total Kgals for Treatment		41194	0	0	0	0	0	0	0	0	0	0	0
Recirculation Unit Cost ($/Kgal)	(Sheet 27)	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28	$0.28
Subtotal Recirculation Costs per Wellfield		**$11,534.32**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total Recirculation Costs		**$11,534.32**	**$0.00**										
IV. Consumables													
Spare parts, filters and consumables =	$25,875.00 year												
Active restoration period (months)		5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Consumable usage (months restoration x annual rate estimate)		$10,889.06	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Subtotal Consumables per Mine Unit		**$10,889.06**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total Consumables Costs		**$10,889.06**	**$0.00**										

Table P.1-3 Marsland Ground Water Restoration -2011 Surety Estimate, Continued

Task		MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Total
V. Monitoring and Sampling Costs													
Guideline 8 analysis =	$200.00 analysis												
6 parameter in-house analysis =	$52.79 analysis												
Total restoration wells		10	0	0	0	0	0	0	0	0	0	0	0
Total monitor wells		11	0	0	0	0	0	0	0	0	0	0	0
IX Treatment duration (months)		1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reverse Osmosis duration (months)		2.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recirculation duration (months)		0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stabilization duration (months)		12	12	12	12	12	12	12	12	12	12	12	
A. Restoration Well Sampling													
1. Well Sampling prior to restoration start													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	0
$/sample		$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	
2. IX Treatment Sampling													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	
Total # samples		20	0	0	0	0	0	0	0	0	0	0	0
$/sample		$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	
3. RO Sampling													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	
Total # samples		30	0	0	0	0	0	0	0	0	0	0	0
$/sample		$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	
4. Recirculation Sampling													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	
Total # samples		10	0	0	0	0	0	0	0	0	0	0	0
$/sample		$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	
5. Stabilization Sampling (Guideline 8)													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	
Total # samples		120	0	0	0	0	0	0	0	0	0	0	0
$/sample		$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	$200.00	
6. Stabilization Sampling (6 parameter in-house)													
# of Wells		10	0	0	0	0	0	0	0	0	0	0	
Total # samples		120	0	0	0	0	0	0	0	0	0	0	0
$/sample		$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	
7. Monitor Well Sampling													
# of Wells		11	0	0	0	0	0	0	0	0	0	0	
$/sample		$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	$52.79	
Total # samples (2.2/mo for entire period)		413	0	0	0	0	0	0	0	0	0	0	0

Table P.1-3 Marsland Ground Water Restoration -2011 Surety Estimate, Continued

Task			MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Total
8. Other Laboratory Costs														
Radon, urinalysis, etc. =	$957.38	month												
Total for Other Laboratory Costs:			$4,834.77	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Subtotal Monitoring and Sampling Costs per Mine Unit			**$63,611.34**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total Monitoring and Sampling Costs			**$63,611.34**	**$0.00**										
VI. MIT Costs														
MIT Costs per Well			$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	$107.94	
Restoration period, plus stabilization			17.05	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	
Remaining MIT's per 5 year cycle			1	1	1	1	1	2	2	2	3	3	3	
Number of Wells MIT'd for Life of Mine Unit			91	0	0	0	0	0	0	0	0	0	0	
Subtotal MIT Mine Unit			**$9,822.54**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	
5-year MIT Costs for Disposal Wells	$6,425													
Number of DDWs	1													
Number of MITs per DDW	1													
Subtotal MIT DDW Costs		**$6,425**												
Total MIT Costs		**$6,425**												
VI. Supervisory Labor Cost														
Engineer Support =	$9,004.50	month												
HP Technician support =	$5,692.50	month												
Active restoration period (months)			5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Stabilization period (months)			12	12	12	12	12	12	12	12	12	12	12	
1 Engineer support during active restoration			$45,472.73	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2 HP Technician support during active restoration			$28,747.13	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
3 Engineer support during final stabilization											$108,054.00	$108,054.00	$108,054.00	$324,162.00
4 HP Technician support during final stabilization											$68,310.00	$68,310.00	$68,310.00	$204,930.00
5 Cost reduction due to concurrent restoration of Mine Units						0.00	0.00	0.00	0.00	0.00	-88,182.00	-88,182.00	-88,182.00	-$264,546.00
Subtotal Supervisory Labor per Mine Unit			**$74,219.86**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$88,182.00**	**$88,182.00**	**$88,182.00**	**$264,546.00**
Total Supervisory Labor Costs			**$250,583.86**	**$264,546.00**										
TOTAL RESTORATION COST PER WELLFIELD			**$343,773.85**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$88,182.00**	**$88,182.00**	**$88,182.00**	**$264,546.00**

TOTAL GROUND WATER RESTORATION COSTS **$270,971.00**

MU = Mine Unit

Revised 10/13/2011

Table P.1-4 Marsland Wellfield Reclamation - 2011 Surety Estimate

	MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Totals
Wellfield Piping												
Assumptions:												
Number of Wellhouses	1	0	0	0	0	0	0	0	0	0	0	1
Total Mine Unit surface area (acres)	9.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.27
Total length of small diameter production and injection lines (laterals) (ft)	0	0	0	0	0	0	0	0	0	0	0	0
Total length of 3/8-inch hose (ft)			0	0	0	0	0	0	0	0	0	0
Total length 1-1/4-inch stinger pipe (ft)	0	0	0	0	0	0	0	0	0	0	0	0
Total length of 2-inch downhole production pipe (ft)	1200	0	0	0	0	0	0	0	0	0	0	1200
Total Length of Trunkline (6-inch) (ft)	1000	0	0	0	0	0	0	0	0	0	0	1000
Total Length of Trunkline (8-inch) (ft)	4400	0	0	0	0	0	0	0	0	0	0	4400
Total Length of Trunkline (10-inch) (ft)												0
Total Length of Trunkline (12-inch) (ft)			0	0	0	0	0	0	0	0	0	0
Total Length of All Trunkline (ft)	5400	0	0	0	0	0	0	0	0	0	0	5400
Total number of production wells	30	0	0	0	0	0	0	0	0	0	0	30
Total number of injection wells	50	0	0	0	0	0	0	0	0	0	0	50
Total number of shallow monitor wells	0	0	0	0	0	0	0	0	0	0	0	0
Total number of perimeter monitor wells	11	0	0	0	0	0	0	0	0	0	0	11
I. Production and Injection Piping												
A. Removal and Loading												
Production and Injection Piping Removal Unit Cost ($/ft of pipe)	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	$0.70	
Subtotal Production and Injection Piping Removal and Loading Costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
B. Pipe Shredding												
Production and Injection Piping Shredding Unit Cost ($/ft of pipe)	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08	
Subtotal Production and Injection Piping Removal and Loading Costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
C. Equipment Costs												
Cat 924G Loader Unit Costs for removal (450'/day)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Shredder Unit Costs for shredding (450'/day)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal Equipment Costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
D. Transport and Disposal Costs (NRC-Licensed Facility)												
Chipped Volume Reduction (ft^3/ft)	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	0.0069	
Chipped Volume per Wellfield (yd^3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Volume for Disposal Assuming 25% Void Space (yd^3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transportation and Disposal Unit Cost ($/$yd^3$)												
Unpackaged Bulk	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	
Subtotal Production and Injection Piping Transport and Disposal Costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**
Total Production and Injection Piping Costs	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

Table P.1-4 Marsland Wellfield Reclamation - 2011 Surety Estimate, Continued

	MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Totals
II. Trunklines												
A. Removal and Loading												
Trunkline Removal Unit Cost ($/ft of pipe)	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	
Subtotal Trunkline Removal and Loading Costs	**$8,478.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$8,478.00**
B. Pipe Shredding												
Trunkline Shredding Unit Cost ($/ft of pipe)	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	$1.57	
Subtotal Trunkline Shredding Costs	**$8,478.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$8,478.00**
C. Equipment Costs												
Cat 924G Loader Unit Costs for removal (200'/day)	$12,921.12	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Shredder Unit Costs for shredding (200'/day)	$2,592.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal Equipment Costs	**$15,513.12**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$15,513.12**
D. Transport and Disposal Costs (NRC-Licensed Facility)												
Chipped Volume Reduction (6-inch) (ft^3/ft)	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	0.0651	
Chipped Volume Reduction (8-inch) (ft^3/ft)	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	0.1103	
Chipped Volume Reduction (10-inch) (ft^3/ft)	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	0.1712	
Chipped Volume Reduction (12-inch) (ft^3/ft)	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	0.2408	
Chipped Volume per Wellfield (yd^3)	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Volume for Disposal Assuming 25% Void Space (ft^3)	25.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.5
Transportation and Disposal Unit Cost ($/$ft^3$)	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	
Subtotal Transport and Disposal Costs	**$5,651.82**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$5,651.82**
Total Trunkline Costs	**$38,120.94**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$38,120.94**
III. Downhole Pipe												
A. Removal and Loading												
Downhole Piping Removal Unit Cost ($/ft of pipe)	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	$0.080	
Downhole Hosing Removal Unit Cost ($/ft of pipe)	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	$0.160	
Removal of 1-1/4-inch stinger pipe	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Removal of downhole production pipe	$96.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Removal of downhole hose	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal Downhole Piping	**$96.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$96.00**
B. Pipe Shredding												
Downhole Piping Shredding Unit Cost ($/ft of pipe)	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	$0.070	
Subtotal Downhole Piping Shredding Costs	**$84.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$84.00**
C. Equipment Costs												
Smeal Unit Costs for removal	$60.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Shredder Unit Costs for shredding	$25.60	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal Equipment Costs	**$85.60**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$85.60**
D. Transport and Disposal Costs (NRC-Licensed Facility)												
Chipped Volume Reduction - 1-1/4-inch stinger (ft^3/ft)	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	0.0044	
Chipped Volume Reduction - 2-inch downhole	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	0.0074	
Volume Reduction - 3/8-inch hose (ft3/ft)	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	0.0313	
Chipped Volume - 1-1/4-inch stinger (ft^3)	0	0	0	0	0	0	0	0	0	0	0	
Chipped Volume - 2-inch downhole production (ft^3)	9	0	0	0	0	0	0	0	0	0	0	

Table P.1-4 Marsland Wellfield Reclamation - 2011 Surety Estimate, Continued

	MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Totals
Volume 3/8-inch hose (ft3)	0	0	0	0	0	0	0	0	0	0	0	
Volume for Disposal Assuming 25% Void Space (yd^3)	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	$221.64	
Subtotal Downhole Piping Transport and Disposal Costs	**$88.66**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$88.66**
Total Downhole Piping Costs	**$354.26**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$354.26**
IV. Surface Reclamation												
A. wells												
Volume of contaminated soil (0.37 yd3 per injection and production well)	29.6	0	0	0	0	0	0	0.00	0	0.00	0	29.60
Disposal of contaminated soil $250.05 per yd3	$7,401.48	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$7,401.48
Equipment (Cat 924G loader at 2 yd3/hr)	$885.34	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Labor (1 man-hour per 2 Yd3)	$291.04	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal removal and disposal of contaminated soil	**$8,577.86**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$8,577.86**
B. Recontour and seeding												
Recontour and seeding (est. $300/acre)	$2,781.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
Subtotal Recontour and Seeding	**$2,781.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$2,781.00**
Total Surface Reclamation	**$11,358.86**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$11,358.86**
IV. Well Houses												
Total Quantity	1	0	0	0	0	0	0	0	0	0	0	
Average Well House Weight (Lbs.) (Includes wellhead covers for each well)	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200	9200	
A. Removal												
Dismantlement at 2-man-days per wellhouse (man-days)	2	0	0	0	0	0	0	0	0	0	0	
Dismantlement Labor Costs	$314.64	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$314.64
Equipment (Cat 924G at 2 hours per wellhouse) (hrs)	2	0	0	0	0	0	0	0	0	0	0	
Equipment Costs	$119.64	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$119.64
Subtotal Well House Dismantlement Costs	**$434.28**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$434.28**
Total Disposal Weight (9200 lbs per wellhouse) (Lbs)	9200	0	0	0	0	0	0	0	0	0	0	
Subtotal Disposal Costs	**$233.68**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$233.68**
Total Well House Removal and Disposal Costs	**$667.96**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$667.96**
TOTAL REMOVAL AND DISPOSAL COSTS PER WELLFIELD	**$50,502.02**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$50,502.02**
TOTAL WELLFIELD BUILDINGS AND EQUIPMENT REMOVAL AND DISPOSAL COSTS	**$50,502.02**											

MU - Mine Unit
Revised 10/13/2011

Table P.1-5 Marsland Well Abandonment - 2011 Surety Estimate

		MU 1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11	Total
I. Well Abandonment (Wellfields)													
# of Production Wells		30	0	0	0	0	0	0	0	0	0	0	
# of Injection Wells		50	0	0	0	0	0	0	0	0	0	0	
# of Perimeter Monitoring Wells		11	0	0	0	0	0	0	0	0	0	0	
# of Shallow Monitoring Wells		0	0	0	0	0	0	0	0	0	0	0	
Total Number of Deep Wells		91	0	0	0	0	0	0	0	0	0	0	91
Total Number of Shallow Wells		0	0	0	0	0	0	0	0	0	0	0	0
Average Diameter of Casing (inches)		5	5	5	5	5	5	5	5	5	5	5	
Production, Injection and Perimeter Well Average Depth (ft)		1100	0	0	0	0	0	0	0	0	0	0	100
Shallow Well Average Depth (ft)		400	0	0	0	0	0	0	0	0	0	0	36
Total Mine Unit Well Depth (ft)		100100	0	0	0	0	0	0	0	0	0	0	100100
Well Abandonment Unit Cost ($/ft. of well)		$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	$0.77	
Subtotal Abandonment Cost per Wellfield		**$77,077.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$77,077.00**
II. Downhole Pump Disposal													
Number of Downhole Pumps	0												
Pump Disposal Volume(ft3)	0.5												
Total Pump Disposal Volume(yd3)	0.0												0.0
Downhole Pump Disposal Rate ($/yd3)	$221.64												221.64
Subtotal Downhole Pump Disposal		**$0.00**											**$0.00**
Total Wellfield Abandonment Costs		**$77,077.00**											

MU = Mine Unit
Revised 10/13/2011

Table P.1-6 Marsland Satellite Facility Equipment Decommissioning - 2011 Surety Estimate

I. Removal and Loading Costs	
Tankage	
Number of Contaminated Tanks	10
Volume of Contaminated Tank Construction Material (ft^3)	193
Number of Chemical Tanks	0
Disposal Void Factor	1.25
A. Labor to Remove and Load Tankage	
Number of Persons	2
Tanks/Day	1
Number of Days	10
$/Day/Person	$157.32
Subtotal Removal Labor Costs	**$3,146.40**
B. Labor to Clean Chemical Tankage	
Number of Persons	1
Tanks/Day	1
Number of Days	0
$/Day/Person	$157.32
Subtotal Cleaning Labor Costs	**$0.00**
C. Equipment	
Saws, scaffolding, etc.	$6,000
Subtotal Equipment Costs	**$6,000**
Total Equipment Removal and Loading Costs	**$9,146.40**
II. Transportation and Disposal Costs (NRC-Licensed Facility)	
A. Tankage	
Volume of Tank Construction Material (ft^3)	193
Volume for Disposal Assuming Void Space (yd^3)	8.9
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Subtotal Tankage Transportation and Disposal Costs	**$1,972.60**
B. Contaminated PVC Pipe	
Volume of Shredded PVC Pipe (ft^3)	153.6
Volume for Disposal Assuming Void Space (yd^3)	7.1
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Subtotal Contaminated PVC Pipe Transportation and Disposal Costs	**$1,573.64**
C. Pumps	
Volume of Process Pumps (yd^3) (no void factor used)	2.4
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Subtotal Pump Transportation and Disposal Costs	**$531.94**
D. Filters (injection, backwash and yellowcake filters)	
Volume of Filters (yd^3) (no void factor used)	0.0
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Subtotal Filter Transportation and Disposal Costs	**$0.00**

Table P.1-6 Marsland Satellite Facility Equipment Decommissioning - 2011 Surety Estimate, Continued

E. Dryer	
Dryer Volume (yd^3) (no void factor used)	0.0
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Total Dryer Transportation and Disposal Costs	**$0.00**
Total Contaminated Equipment Transportation and Disposal Costs	**$4,078.18**
III. Transportation and Disposal (Solid Waste for Landfill Disposal)	
A. Cleaned Tankage	
Volume of Tank Construction Material (ft^3)	0
Number of Landfill Trips	1
Transportation and Disposal Unit Cost ($/Load)	$912.00
Subtotal Tankage Transportation and Disposal Costs	**$912.00**
B. Uncontaminated PVC Pipe	
Volume of Shredded PVC Pipe (ft^3)	0
Number of Landfill Trips	1
Transportation and Disposal Unit Cost ($/Load)	$912.00
Subtotal PVC Pipe Transportation and Disposal Costs	**$912.00**
Total Uncontaminated Equipment Transportation and Disposal Costs	**$1,824.00**
IV. Supervisory Labor Costs During Plant Decommissioning	
Estimated Duration (months)	6
Engineer	$54,027.00
Radiation Technician	$34,155.00
Total Supervisory Labor Costs	**$88,182.00**
SUBTOTAL EQUIPMENT REMOVAL AND DISPOSAL COSTS PER FACILITY	$103,230.58
Building Area (Ft2)	34,000
Building Equipment Removal and Disposal Cost per Square Foot	$3.04
TOTAL EQUIPMENT REMOVAL AND DISPOSAL COSTS	**$103,230.58**

Revised 10/13/2011

Table P.1-7 Marsland Building Demolition - 2011 Surety Estimate

I.	Decontamination Costs		
	A.	Wall Decontamination	
		Area to be Decontaminated (ft2)	30,000
		HCl Application Rate (Gallons/ft2)	1
		HCl Acid Cost	$1.47
	Subtotal Wall Decontamination Materials Costs		$44,100.00
	B.	Concrete Floor Decontamination	
		Area to be Decontaminated (ft2)	9000
		HCl Application Rate (Gallons/ft2)	2
		HCl Acid Cost	$1.47
	Subtotal Floor Decontamination Materials Costs		$26,460.00
	C.	Decontamination Labor	
		Labor (man-days)	2
	Subtotal Decontamination Labor Cost		$314.64
	D.	Decontamination Equipment Costs	
		Sprayer pump	$500
		Recycle pump	$500
		Sprayer with hose	$1,000
	Subtotal Decontamination Equipment Costs		$2,000
	E.	Decontamination Waste Disposal (to Ponds)	
		Total gallons HCl waste	48,000
		Pumping costs (5 HP/30 gpm)	$476.60
	Subtotal Decontamination Costs		$73,351.24
	Total Decontamination Costs		$73,351.24
II.	Demolition Costs		
		Assumptions (based on 2007 costs):	
		Dismantling interior steel, tanks, pumps, etc.	$198,800.00
		Dismantling plant building	$99,400.00
	A.	Building Dismantling	
		Dismantle interior components (2007 $'s escalated by CPI)	$205,758.00
		Plant building dismantling (2007 $'s escalated by CPI)	$102,879.00
	Subtotal Building Dismantling		$308,637.00
	B.	Concrete Floor Removal	
		Area of direct-dispose concrete floors (ft2)	13,400
		Removal Rate ($/ft2)	$14.04
	Subtotal Concrete Floor Removal		$188,136.00
	Total Demolition Costs		$496,773.00

Table P.1-7 Marsland Building Demolition - 2011 Surety Estimate, Continued

III.	Disposal Costs		
	A.	Concrete Floor	
		Area of Direct-Dispose Concrete Floor (ft2)	13,400
		Average Thickness of Concrete Floor (ft)	0.75
		Volume of Concrete Floor (ft3)	10,050
		Volume of Concrete Floor (Yd3)	372
		Transportation and Disposal Unit Cost ($/Yd3) (Unpackaged Bulk)	$221.64
	Subtotal Concrete Floor Disposal Costs		$82,450.08
	Total Disposal Costs		$82,450.08
IV	Plant Site Reclamation		
	A.	Plant Site Earthwork	
		Material to be Moved (Yd3)	20,000
		D8N Bulldozer Earthwork Rate (Yd3/hr)	700
		D8N Hourly Rate	$182.00
	Subtotal Plant Site Earthwork		$5,200.00
	B.	Revegetation	
		Area requiring Revegetation (Ac)	4
		Revegetation Unit Cost ($/Ac)	$300
	Subtotal Plant Site Revegetation		$1,200.00
	Total Plant Site Reclamation Costs		$6,400.00
SUBTOTAL BUILDING DEMOLITION AND DISPOSAL COSTS			$658,974.32
		Building Area (Ft2)	34,138
		Building Demolition Cost per Square Foot	$19.30
TOTAL BUILDING DEMOLITION AND DISPOSAL COSTS			$658,974.32

Revised 10/13/2011

Table P.1-8 Marsland Miscellaneous Site Reclamation - 2011 Surety Estimate

I. Access Road Reclamation	
Assumptions	
Road Reclamation production rate (Yd3/hr)	200
Length of Main Access Roads (ft)	500
Average Main Access Road width (ft)	25
Depth of Main Access Road Gravel Surface (ft)	1
Surface Area of Main Access Road (Ac)	0.3
Length of Wellfield Access Roads (ft)	500
Average Wellfield Access Road width (ft)	12
Depth of Wellfield Access Road Gravel Surface (ft)	0.5
Surface Area of Wellfield Road (Ac)	0.1
A. Main Access Road Dirtwork	
Main Access Road Gravel Volume (Yd3)	463
Total reclamation time (hrs)	2
D8N Unit Operating Cost ($/hr)	$182.00
Subtotal Main Access Road Gravel Roadbase Removal Costs	**$364.00**
B. Wellfield Road Dirtwork	
Wellfield Road Gravel Volume (Yd3)	111
Total reclamation time (hrs)	1
D8N Unit Operating Cost ($/hr)	$182.00
Subtotal Wellfield Road Gravel Roadbase Removal Costs	**$182.00**
C. Discing/Seeding	
Assumptions	
Surface Area (acres)	0.4
Discing/Seeding Unit Cost ($/acre)	$300.00
Subtotal Discing/Seeding Costs	**$120.00**
Total Access Road Reclamation Costs	**$666.00**
II. Wastewater Pipeline Reclamation	
Assumptions	
Pipeline Removal Rate (ft./man-day)	67
Pipeline Shredding Rate (ft./man-day)	1,500
Number of Pond Pipelines	2
Length of Pond Pipelines (ft)	2,000
Average Pipe Size (Sch 40)	4
A. Pipeline Removal Costs	
Length of Pipelines (ft)	4,000
Removal Rate (ft/man-day)	67
Removal Labor Rate ($/man-day)	$157.32
Cat 924G Loader Use (days)	60
Cat 924G Loader Cost	$28,713.60
Subtotal Pipeline Removal Costs	**$38,152.80**

Table P.1-8 Marsland Miscellaneous Site Reclamation - 2011 Surety Estimate, Continued

B. Pipeline Shredding Costs	
Length of Pipelines (ft)	4,000
Shredding Rate (ft/man-day)	1,500
Shredding Labor Rate ($/man-day)	$157.32
Shredder Use (days)	3
Shredder Cost	$288.00
Subtotal Pipeline Shredding Costs	**$759.96**
C. Pipeline Transportation and Disposal (NRC-Licensed Facility)	
Pipe Diameter (inches)	4
Chipped Volume Reduction (ft^3/ft)	0.0103
Subtotal Volume of Shredded PVC Pipe (yd^3)	1.5
Disposal Void Factor	1.25
Final Disposal Volume (yd3)	1.88
Transportation and Disposal Unit Cost ($/$yd^3$) (Unpackaged Bulk)	$221.64
Subtotal Pipeline Disposal Costs	**$416.68**
Total Wastewater Pipeline Reclamation Costs	**$39,329.44**
III. Electrical Distribution System Removal	
Assumptions	
Length of High Voltage Lines	500
High Voltage Line Removal Rate ($/ft.)	$2.17
High Voltage Line Removal Cost ($/ft.)	$1,085.00
Substation Removal	$1,175.00
Subtotal Electrical Distribution System Removal Costs	**$2,260.00**
IV. Supervisory Labor Costs During Miscellaneous Reclamation	
Estimated Duration (months)	3
Engineer Rate ($/month)	$9,004.50
Total Engineer Labor	$27,013.50
Radiation Technician Rate ($/month)	$5,692.50
Total Radiation Technician Labor	$17,077.50
Total Supervisory Labor Costs	**$44,091.00**
TOTAL MISCELLANEOUS RECLAMATION COSTS	**$86,346.44**

Sch = Schedule
Revised 10/13/2011

Table P.1-9 Marsland Deep Disposal Well Reclamation - 2011 Surety Estimate

I. Cost Basis	
A. Plugging and Abandonment	
Cost Estimate from April 2009 2nd Well Permit Application for plugging and abandonment	$60,292.00
April 2009 CPI	$213.20
June 2011 CPI	$225.70
Subtotal Escalated April 2009 Plugging and Abandonment Costs	**$63,826.94**
B. Site Reclamation	
Cost Estimate from April 2009 2nd Well Permit Application for site reclamation	$2,500.00
April 2009 CPI	$213.20
June 2011 CPI	$225.70
Subtotal Escalated April 2009 Reclamation Costs	**$2,646.58**
Subtotal Abandonment cost per well	**$66,473.52**
TOTAL DEEP DISPOSAL WELL RECLAMATION COSTS	**$66,473.52**

CPI: Consumer Price Index

Revised 10/13/2011

Table P.1-10 Marsland Groundwater IX Treatment (GIX) Restoration (Unit Costs) - 2011 Surety Estimate

Assumptions:

1. All pumps are 5 hp pumping at 32 gpm
2. Cost of electricity = $0.0797 Kw hr
3. Horsepower to kilowatt conversion = 0.746 Kw/HP
4. Operator labor costs = $157.32 man-day
5. Labor costs are based on 36 pumps at 1,150 gpm

Wellfield Pumping Electrical Costs per 1000 Gallons (Includes bleed to the Deepwell)

$$\frac{1000\ \text{gal}}{} \times \frac{5\ \text{hp}}{32\ \text{gpm}} \times \frac{1\ \text{hr}}{60\ \text{min}} \times \frac{0.746\ \text{kwh}}{\text{hp}} \times \frac{\$\ 0.0797}{\text{kwh}} = \$\ 0.155$$

Wellfield Pumping Labor Costs per 1000 Gallons

$$\frac{1000\ \text{gal}}{} \times \frac{1\ \text{min}}{1150\ \text{gal}} \times \frac{1\ \text{man-day}}{1440\ \text{min}} \times \frac{\$157.32}{\text{man-day}} \times 2\ \text{operators} = \$\ \$0.190$$

Groundwater IX Production Rate

$$\frac{1000\ \text{gal}}{\text{min}} \times \frac{60\ \text{min}}{\text{hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{365\ \text{day}}{\text{year}} \times \frac{1\ \text{year}}{12\ \text{month}} = \frac{43{,}800{,}000\ \text{gallons}}{\text{month}}$$

TOTAL GWS COSTS PER 1000 GALLONS = $ 0.35

Revised 10/13/2011

Table P.1-11 Marsland Groundwater Reverse Osmosis (RO) Treatment (Unit Costs) - 2011 Surety Estimate

Assumptions:

1. All pumps are 5 hp pumping at 32 gpm
2. Membrane Replacement — $0.015 per 1000 gal
3. Cost of electricity = — $0.0797 Kw hr
4. Horsepower to kilowatt conversion = — 0.746 Kw/HP
5. Operator labor costs = — $157.32 man-day
6. RO System horsepower requirements for 600 gpm rated flow based upon

RO Unit Pump	195 hp
Permeate/Injection pump	60 hp
Waste pump (1(Bleed - Deepwell / Evap Ponds)	12 hp
TOTAL:	267 hp

7. Chemical costs:
   - Reductant = — $0.200 lb
   - Antiscalant = — $15.45 gal

Membrane Replacement Costs per 1000 Gallons

1000 gal X $660 membrane cost / month / 43,800,000 gallons month = $ 0.015 per Kgal

Wellfield Pumping Electrical Costs per 1000 Gallons

1000 gal X 5 hp / 32 gpm X 1 hr / 60 min X 0.746 kwh / hp X $ 0.0797 / kwh = $ 0.155 per Kgal

Reverse Osmosis Electrical Costs per 1000 Gallons

1000 gal X 267 hp / 600 gpm X 1 hr / 60 min X 0.746 kwh / hp X $ 0.0797 / kwh = $ 0.441 per Kgal

Reverse Osmosis Labor Costs per 1000 Gallons

1000 gal X 1 min / 600 gal X 1 man-day / 1440 min X $157.32 / man-day X 2 operators = $ $0.364 per Kgal

Treatment chemical costs per 1000 Gallons

Antiscalant:

1000 gal X 0.000008330 gal antiscalant / 1 gal X $15.45 / gal antiscalant = $ $0.129 per Kgal

Reductant:

1000 gal X 0.001040 lbs reductant / 1 gal X $0.200 / lb reductant = $ $0.208 per Kgal

Reverse Osmosis Production Rate

1000 gal / min X 60 min / hr X 24 hr / day X 365 day / year X 1 year / 12 month = *43,800,000 gallons / month*

TOTAL RO COSTS PER 1000 GALLONS = $ 1.31

RO = Reverse Osmosis

Revised 10/13/2011

Table P.1-12 Marsland Groundwater Recirculation (Unit Costs) - 2011 Surety Estimate

Assumptions:

1. All pumps are 5 hp pumping at 32 gpm
2. Cost of electricity = $0.0797 Kw hr
3. Horsepower to kilowatt conversion = 0.746 Kw/HP
4. Operator labor costs = $157.32 man-day
5. System horsepower requirements for 1,150 gpm rated flow based upon:
   injection pump 30 hp

Wellfield Pumping Electrical Costs per 1000 Gallons

1000	gal	X	5	hp	X	1	hr	X	0.746	kwh	X	$ 0.0797		= $	0.155	per Kgal
			32	gpm		60	min		hp			kwh				

Wellfield Injection Electrical Costs per 1000 Gallons

1000	gal	X	30	hp	X	1	hr	X	0.746	kwh	X	$ 0.0797		= $	0.026	per Kgal
			1150	gpm		60	min		hp			kwh				

Recirculation Labor Costs per 1000 Gallons

1000	gal	X	1	min	X	1	man-day	X	$157.32		X	1	operators	= $	0.095	per Kgal
			1150	gal		1440	min		man-day							

Recirculation Production Rate

1150	gal	X	60	min	X	24	hr	X	365	day	X	1	year	=	*50,370,000*	*gallons*
	min			hr			day			year		12	month			*month*

TOTAL RECIRCULATION COSTS PER 1000 GALLONS = $ **0.28**

Revised 10/13/2011

Table P.1-13 Marsland Well Abandonment (Unit Costs) - 2011 Surety Estimate

Assumptions:

1. Use backhoe for 0.25 hr/well to dig, cut off, and cap well.
2. Drill rig used 2.5 hrs to plug well.
3. Labor for installing chips, etc. will require 2 workers at 0.5 hrs per well

Well Abandonment Costs						**Cost per ft (based on 700 ft wells)**
Labor Costs	1 hours	X $	19.67 per hour	=$	19.67	$0.0281
Cat 416 Backhoe	0.25 hours	X $	50.28 per hour	=$	12.57	$0.0180
Drill rig	2.5 hours	X $	164.00 per hour	=$	410.00	$0.5857
Well Cap	1 each	X $	9.00 each	=$	9.00	$0.0129
Materials per foot of well (Variable Cost)						
Cement	0.0714 lbs/ft	X $	0.080 per pound	=$		$0.0057
Bentonite Chips	0.007 tubes/ft	X $	7.46 per tube	=$		$0.0522
Plug Gel	0.0086 sacks/ft	X $	8.00 per sack	=$		$0.0688
Total Estimated Cost per Foot:						**$0.77**

Revised 10/13/2011

Table P.1-14 Marsland Five Year Mechanical Integrity Tests (MIT)

Assumptions:

1. Pulling Unit for 8 hr/day
2. MIT Unit for 8 hr/day
3. Labor for operation of pulling unit requires 2 workers (one operator & one laborer)
4. Labor for operation of MIT Unit requires 1 worker

MIT Costs per Well

Equipment and Labor:

Pulling Unit includes one operator						
	8 hours	X	$ 30.66	per hour	=$	245.28
Laborer						
	8 hours	X	$ 19.67	per hour	=$	157.36
MIT Unit includes one operator						
	8 hours	X	$ 30.66	per hour	=$	245.00
				TOTAL MIT COST PER DAY	**=$**	647.64
Wells Completed			6	per day		
MIT COSTS PER WELL					**=$**	107.94
MIT COSTS PER DEEP DISPOSAL WELL (2011 Cost)					**=$**	**6425.00**

Revised 10/13/2011

Table P.1-15 Marsland Master Cost Basis - 2011 Surety Estimate

		MU1	MU2	MU3	MU4	MU5	MU6	MU7	MU8	MU9	MU10	MU11
Total number of production wells		30	0	0	0	0	0	0	0	0	0	0
Total number of injection wells		50	0	0	0	0	0	0	0	0	0	0
Total number of shallow monitor wells		0	0	0	0	0	0	0	0	0	0	0
Total number of perimeter monitor wells		11	0	0	0	0	0	0	0	0	0	0
Total number of restoration wells		10	0	0	0	0	0	0	0	0	0	0
Wellfield Area (ft2)		403,712	0	0	0	0	0	0	0	0	0	0
Wellfield Area (acres)		9.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Affected Ore Zone Area (ft2)		403,712	0	0	0	0	0	0	0	0	0	0
Avg. Completed Thickness		19.6	0	0	0	0	0	0	0	0	0	0
Porosity		0.29	0	0	0	0	0	0	0	0	0	0
Affected Volume (ft3)		7,912,755	0	0	0	0	0	0	0	0	0	0
Flare Factor		1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Kgallons per Pore Volume		20,597	0	0	0	0	0	0	0	0	0	0
Number of Patterns in Unit(s)												
	Current	0	0	0	0	0	0	0	0	0	0	0
	Estimated next report	30	0	0	0	0	0	0	0	0	0	0
	Total Estimated	30	0	0	0	0	0	0	0	0	0	0
Number of Wells in Unit(s)												
Production Wells												
	Current	0	0	0	0	0	0	0	0	0	0	0
	Estimated next report	30	0	0	0	0	0	0	0	0	0	0
	Total Estimated	30	0	0	0	0	0	0	0	0	0	0
Injection Wells												
	Current	0	0	0	0	0	0	0	0	0	0	0
	Estimated next report	50	0	0	0	0	0	0	0	0	0	0
	Total Estimated	50	0	0	0	0	0	0	0	0	0	0
Shallow Monitor Wells												
	Current	0	0	0	0	0	0	0	0	0	0	0
	Estimated next report	0	0	0	0	0	0	0	0	0	0	0
	Total Estimated	0	0	0	0	0	0	0	0	0	0	0
Perimeter Monitor Wells												
	Current	11	0	0	0	0	0	0	0	0	0	0
	Estimated next report	0	0	0	0	0	0	0	0	0	0	0
	Total Estimated	11	0	0	0	0	0	0	0	0	0	0
Number of Wells per Wellfield		91	0	0	0	0	0	0	0	0	0	0
Total Number of Wells		91										
Average Well Depth (ft) - Deep Wells		1100	0	0	0	0	0	0	0	0	0	0
Average Well Depth (ft) - Shallow Well:		400	0	0	0	0	0	0	0	0	0	0

Revised 10/13/2011

Table P.1-15 Marsland Master Cost Basis - 2011 Surety Estimate (continued)

Electrical Costs	2011 Rate	2012 Est Rate	
Power cost (adj for current actual cost)	$0.0797	$0.0797	kwHr
Kilowatt to Horsepower	0.746	0.746	Kw/HP
Horsepower per gallon per minute	0.167	0.167	HP/gpm

Labor Rates	2011 Rate	2012 Est Rate (CPI)	
Operator Labor Cost	$152.00	$157.32	day
Pulling Unit Operator	$237.00	$245.30	day
Engineer Cost	$8,700.00	$9,004.50	month
Radiation Technician Costs	$5,500.00	$5,692.50	month

Chemical Costs	2011 Rate	2012 Est Rate	
Antiscalant for RO (adj for current actual cost)	$15.45	$15.45	gal
Reductant (adj for current actual cost)	$0.20	$0.20	lb
Cement (adj for current actual cost)	$0.07	$0.08	pound
Bentonite Tubes (adj for current actual cost)	$7.46	$7.46	tube
Salt (adj for current actual cost)	$218.00	$218.00	ton
Plug Gel (adj for current actual cost)	$8.00	$8.00	sack
Well Cap (adj for current actual cost)	$9.00	$9.00	each
Hydrochloric Acid (adj for current actual cost)	$1.13	$1.47	gallon

Analytical Costs			
Guideline 8 (contract lab adjusted for current contract cost)	$200.00	$200.00	analysis
6 parameter (in-house) Est Rate (CPI)	$51.00	$52.79	analysis
Other (radon, bio, etc.) Est Rate (CPI)	$925.00	$957.38	month

Spare Parts	2011 Rate	2012 Est Rate (CPI)	
Restoration spare parts estimate	$25,000.00	$25,875.00	year

CPI Escalators (CPI-U, U.S. City Average)	
1988 CPI (average)	118.3
April 2009 CPI (deep well estimate)	213.2
2010 CPI (June 2010 used in last update)	218.0
Current CPI (June 2011)	225.7
Factor	1.035

Revised 10/13/2011

Table P.1-15 Marsland Master Cost Basis - 2011 Surety Estimate (continued)

Equipment Costs

Equipment	Rental Rate ($/hr)	Labor Costs ($/hr)	Repair Reserve Costs ($/hr)	Fuel Costs ($/hr)	Mob & Demob ($/hr)	Total ($/hr)
Cat 924G Loader	$26.50	$19.67	$3.00	$10.65	inc.	$59.82
Cat 416 Backhoe	$16.50	$19.67	$3.10	$11.01	inc.	$50.28
Shredder	$12.00			inc	inc	$12.00
Cat D8N Bulldozer	$110.00	$19.67	$11.50	$40.83	inc.	$182.00
Pulling Unit	$37.50	inc	inc	inc	inc	$37.50
Mixing Unit	$5.00			inc	inc	$5.00
Drill Rig	$164.00	inc	inc	inc	inc	$164.00

Basis:
Drill rig based on current 2011 contract.
Equipment rates based on Cost Reference Guide - Equipment Watch 2011 updated addition.
Aug 11 costs for off-road fuel: $3.550 gallon

Labor rate based on current operator labor rate

Pipe Volumes

Nominal Pipe Size	Wall Thickness (in.)	Pipe OD (in.)	Volume per foot (ft3/ft)
3/8-inch O2 hose		0.37500	0.03130
2-inch Sch. 40 downhole	0.15400	2.37500	0.00740
1-1/4-inch Sch. 40 stinger	0.14000	1.66000	0.00440
2-inch SDR 13.5 inj & prod.	0.14815	2.29630	0.00690
4-inch SDR 35	0.11430	4.22860	0.01030
6-inch Sch. 40 process pipe	0.28000	6.56000	0.03840
6-inch Trunkline	0.49100	6.56600	0.06510
8-inch Trunkline	0.63900	8.54800	0.11030
10-inch Trunkline	0.79600	10.65400	0.17120
12-inch Trunkline	0.94400	12.63700	0.24080

Revised 10/13/2011

Table P.1-15 Marsland Master Cost Basis - 2011 Surety Estimate (continued)

Pipe Removal and Shredding Costs

Activity	Removal Rate (ft/man-day)	Shredding Rate (ft/man-day)	Labor Rate (day)	Activity Cost per foot
2-inch SDR 13.5 inj & prod. Removal	225		$157.32	$0.70
2-inch SDR 13.5 inj & prod. Shredding		1920	$157.32	$0.08
Trunkline Removal	100		$157.32	$1.57
Trunkline Shredding		100	$157.32	$1.57
Downhole Pipe Removal	2000		$157.32	$0.08
Downhole Pipe Shredding		2250	$157.32	$0.07
Downhole Hose Removal	1000		$157.32	$0.16
Waste and RO Building Pipeline Removal	67		$157.32	$2.35
Waste and RO Building Pipeline Shredding		1500	$157.32	$0.10

Waste Disposal Costs

Waste Form	Fee		Density Correction Factor (Tons/Yd3)	Fee per Cubic Yard	Transport Cost		Total Transportation and Disposal	
Soil, Bulk Byproduct Material	$166.75	per Ton	0.54	$90.05	$160.00	per Yd3	$250.05	per Yd3
Unpackaged Bulk Byproduct Material (e.g., pipe, equipm	$146.75	per Ton	0.42	$61.64	$160.00	per Yd3	$221.64	per Yd3
Solid Waste (landfill)	$0.02540	per Lb			Incl.	per Lb	$0.02540	per Lb
Solid Waste (landfill)	$912.00	per Load			Incl.	per Load	$912.00	per Load
Void Factor (for disposal)	$1.25							

Plant Dismantling

Plant Components:	Number	Units	Estimated Disposal Volume	Units	Activity	Units	2010Cost
Contaminated Tanks	10	each	19.3	Ft3 each	Dismantle interior steel, tanks, piping and electrical:		$ 198,800.00
Uncontaminated Tanks	0	each	19.3	Ft3 each	Dismantle Plant Building		$ 99,400.00
Pumps	13	each	5	Ft3 each			
Downhole Pumps	0	each	0.5	Ft3 each	Concrete floor removal rate	Current Cost $/ft2	14.04
Contaminated Piping	4000	feet	See estimate by piping size and material				
Uncontaminated Piping	0	feet					
Filters	0	each	100	Ft3 each			
Dryer	0	each	400	Ft3 each			
Average PVC Pipe Diameter (inches)	3						

Revised 10/13/2011

Table P.1-15 Marsland Master Cost Basis - 2011 Surety Estimate (continued)

Plant Decontamination				
Direct Dispose Plant Floor Area	13400 ft2	Decon Solution (HCl) Floor Application Rate	2	gal/ft2
Uncontaminated Plant Floor Area	4400 ft2			
Decontaminated Plant Floor Area*	9000 ft2			
Average concrete thickness	0.75 ft			
Plant Wall Area	30000 ft2	Decon Solution (HCl) Wall Application Rate	1	gal/ft2

CPI = Consumer Price Index
HCL = Hydrochloric Acid
Revised 10/13/11

Appendix Q

Energy Laboratories, Inc.
Explanation of Lower Limits of Detection for Marsland Baseline Samples

Crow Butte Resources
Marsland Project
Page 1 of 2

April 23, 2012

Rhonda Grantham
Supervisor Radiation Safety & Regulatory Affairs/RSO
86 Crow Butte Rd
Crawford, NE 69339

Subject: United States Nuclear Regulatory Commission (USNRC) Regulatory Guide 4.14 Lower Limits of Detection for the Marsland Baseline Samples.

Dear Rhonda:

As requested in conversation with David Blaida, Energy Laboratories, Inc. (ELI) Radiochemical Supervisor on April 20, 2012, the following is an explanation verifying the reported Minimum Detectable Concentrations/Lower Limits of Detection (MDC/LLD) values for the Marsland Baseline Project samples are in compliance with the USNRC regulatory guide 4.14, Section 5 "LLD" for the following requested analytes:

Analyte	MDC/LLD	MDC/LLD
Matrix	Water	Water
Radium 226	2E-10 uCi/ml	0.2 pCi/L
Thorium 230	2E-10 uCi/ml	0.2 pCi/L
Polonium 210	1E-9 uCi/ml	1.0 pCi/L
Lead 210	1E-9 uCi/ml	1.0 pCi/L
Uranium	2E-10 uCi/ml	0.2 pCi/L
Matrix	Soil/sediment (dry)	Soil/sediment (dry)
Radium 226	2E-7 uCi/g	0.2 pCi/g
Thorium 230	2E-7 uCi/g	0.2 pCi/g
Polonium 210	No guidance	No guidance
Lead 210	2E-7 uCi/g	0.2 pCi/g
Uranium	2E-7 uCi/g	0.2 pCi/g
Matrix	Vegetation, food & Fish (wet)	Vegetation, food & Fish (wet)
Radium 226	5E-8 uCi/kg	0.05 pCi/g
Thorium 230	2E-7 uCi/kg	0.2 pCi/g
Polonium 210	1E-6 uCi/kg	1.0 pCi/g
Lead 210	1E-6 uCi/kg	1.0 pCi/g
Uranium	2E-7 uCi/kg	0.2 pCi/g

ELI has met the criteria per the guidance suggested by the USNRC when reasonably achievable by available conventional laboratory methodology. If for some reason the MDC/LLD was not be met on the original analysis, the samples were recounted or re-analyzed until the 4.14 MDC/LLDs were achieved. If after

reanalysis these criteria still could not be met, the laboratory report included a narrative explanation with respect to one or more of the following:

1. Matrix interferences
2. Matrix effects
3. Inadequate sample volumes
4. Radiochemical concentrations were reported above the MDC/LLD

In addition, some of the analytes were reported to two significant figures. Regulatory Guide, 4.14 lists the LLDs to only one significant figure, therefore, it is of ELI's opinion that these should be rounded to the nearest significant figure. For example, 1.3 pCi/L equals 1 pCi/L.

Also, as mutually agreed, the concept of MDC vs. LLD is effectively a "non-issue" in that each calculation is slightly different but clearly generates identical sets of results.

Hopefully this is an adequate explanation of the issues as it pertains to the Marsland Expansion Area. If you have any questions, please do not hesitate to contact Dave Blaida or me.

Thank you,

Client Services Supervisor

Digitally signed by
Steve Dobos
Date: 2012.04.25 15:21:29 -06:00

Steve Dobos
Senior Project manager/Client Relations