DOE Review Release 05/01/2013

Document Title:	Document Number:	ORAUT-OTIB-0034
Internal Dosimetry Coworker Data for X-10	Revision:	01
	Effective Date:	04/23/2013
	Type of Document:	OTIB
	Supersedes:	Revision 00

Subject Expert(s): Matthew G. Arno

Approval:	Signature on File Matthew G. Arno, Document Owner	Approval Date:	04/15/2013
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	04/15/2013
Concurrence:	Signature on File Edward F. Maher, Objective 3 Manager	Concurrence Date:	04/15/2013
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	04/15/2013
Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	04/23/2013

☐ New ☐ Total Rewrite ☒ Revision ☐ Page Change

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
12/13/2005	00	New technical information bulletin for assignment of X-10 internal doses based on coworker bioassay data. First approved issue. Training required: As determined by the Task Manager. Initiated by William E. Kennedy, Jr.
04/23/2013	01	Plutonium modeling updated to include best estimate intakes for Type S material. 95th-percentile intakes added for all nuclides. Attachment A data tables expanded to include information on the number of samples and employees used in the statistical analysis. Incorporates formal internal review comments. No changes occurred as a result of formal NIOSH review. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

ACRONYMS AND ABBREVIATIONS

CER	Center for Epidemiologic Research
d	day
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
dpm	disintegrations per minute
EDP	Electronic Data Processing
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
GM	geometric mean
GSD	geometric standard deviation
hr	hour geometric standard deviation
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
m	meter
mL	milliliter
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
POC	probability of causation
TIB	technical information bulletin
U.S.C.	United States Code
µCi	microcurie
µm	micrometer
§	section or sections

1.0 PURPOSE

Technical information bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy [DOE] facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. § 7384l(5) and (12)].

There are instances of energy employees who, for a variety of reasons, were not monitored for internal exposure during the course of their employment at a U.S. Department of Energy (DOE) facility, or whose records of such monitoring are incomplete or unavailable. In such cases, data from coworkers can be used to approximate an individual's possible exposure. The purpose of this document is to provide the details of the calculation and assignment of intakes based on coworker data from Oak Ridge National Laboratory (ORNL) for the purpose of estimating unmonitored exposures or if records of monitoring are incomplete or unavailable, whether for discrete periods or for the entire period of employment.

2.0 OVERVIEW

Analysis of Coworker Bioassay Data for Internal Dose Assignment (ORAUT 2005) describes the general process used for analyzing bioassay data for assigning doses to individuals based on coworker results.

Bioassay results for ORNL were obtained from the Oak Ridge Institute for Science and Education (ORISE) Center for Epidemiologic Research (CER) Dosimetry Database, which contains urinalysis records from the ORNL site for 1951 to 1988. ORISE obtained this database from ORNL for the purpose of conducting an epidemiology study of site workers. The database results are in units of disintegrations per minute (dpm)/24 hours. Because of the varied operations at the different ORNL facilities over time with the potential for exposure from numerous different radionuclides, the database contains urinalysis data for numerous radionuclides. These data are stored using Electronic Data Processing (EDP) codes, as documented in Section 5.2.4.2 of the X-10 site profile (ORAUT 2013).

In summary, data were stored under 64 EDP codes and included measurements for five radioisotopes of uranium, four radioisotopes of plutonium, seven other transuranic radionuclides, numerous fission and activation products, and gross alpha and gross beta measurements. The majority of the EDP codes contained fewer than 100 data entries. In reviewing these data, it was determined that only a few EDP codes contained enough entries to allow statistical evaluation for dose reconstruction. These were SR and SR0 for ^{90}Sr (12,893 entries from 1951 to 1988); UR0 and UR for total uranium (11,434 entries from 1951 to 1988); PU0, PU9, PU, GA0, and GU0 for plutonium alpha emitters (15,476 entries from 1951 to 1988); and TP0 and TP for transplutonium radionuclides, primarily ^{241}Am (5,670 entries from 1968 to 1987). Transplutonium radionuclides are assumed to be and are modeled as ^{241}Am for this coworker study. Further review of these data indicated that, except for follow-up for accidental exposures, they were collected on an annual sampling basis; therefore, the analysis that follows considers chronic exposures to estimate annual intakes. A statistical analysis of these data was performed in accordance with ORAUT (2005). The resultant values were input to the Integrated Modules for Bioassay Analysis (IMBA) Expert OCAS-Edition computer program, and a fit to the data

for each of the four radionuclides was performed to obtain intake rates for assigning dose distributions.

3.0 DATA

3.1 SELECTED BIOASSAY DATA

Data for each of the EDP codes considered were extracted from a series of Microsoft® Access files that contain a version of the ORISE/CER Dosimetry Database. These files were titled "tblORNL_Urinalysis_rawData," for 1951–1978, 1979–1985, and 1986–1988.

3.2 ANALYSIS

A lognormal distribution for the annual data for each of the four radionuclides was assumed, and the 50th and 84th percentiles were calculated, using the method described in ORAUT (2005). Tables A-1 through A-4 in Attachment A show the statistical analysis results for strontium, uranium, plutonium, and americium, respectively.

4.0 INTAKE MODELING

4.1 ASSUMPTIONS

All results were assumed to be representative of a full day (24 hours) of urinary excretion. Each result used in the intake calculation was assumed to be normally distributed, and a uniform absolute error of 1 was applied to all results, thus weighting all results equally. A chronic exposure pattern was assumed; while this is unlikely for workers at ORNL, it will approximate a series of acute intakes with unknown intake dates. Intakes were assumed to be via inhalation using a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter (AMAD) particle size distribution.

4.2 BIOASSAY FITTING

The IMBA Expert OCAS-Edition computer program was used to fit the bioassay results to a series of inhalation intakes. Data for each radionuclide were fit as a series of chronic intakes.

Because the Type S strontium, uranium, and plutonium isotopes and Type M plutonium and americium isotopes present at ORNL have very long half-lives and because the material is retained in the body for long periods, excretion results are not independent. For example, an intake in the early 1950s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at ORNL for relatively short periods, each intake was fit independently, using only the bioassay results from the single intake period. This will result in an overestimate of intakes, particularly for assumed Type S exposures extending through multiple assumed intake periods.

4.3 RADIONUCLIDES AND MATERIAL TYPES

For each radionuclide considered, the bioassay results were entered into IMBA with assumed material types as discussed in more detail in the following sections. The assumed 50th-percentile intakes that result are shown in the figures in Attachment A. In these figures, annual bioassay data used in the fits are shown as dark dots (●), and data that are not used in the fits are shown as lighter dots (●). For certain radionuclides and material types, it is necessary to show figures for both the composite intake over the entire data period and the individual plots of subsets of selected groups of years during the data period that were used to develop the composite figure. The composite plot shows the merged fit for all intake periods to the bioassay data. The IMBA output figures in Attachment A show the fit to the

bioassay data for each annual intake period in terms of days after the date of initial data reporting. For example, for ^{90}Sr, day 1 equals June 1, 1951, and day 13,515 equals June 1, 1988.

4.3.1 Strontium-90

Strontium results were assumed to be ^{90}Sr. Because of the presence of ^{90}Sr both as an effluent from reactor operations and in a highly insoluble titanite form, bioassay results for ^{90}Sr were fit using Type F and S material. Figure A-1 in Attachment A shows the individual fits to the 50th-percentile intake values for Type F ^{90}Sr. Table A-5 summarizes the intake periods and corresponding intake rates for the 50th- and 84th-percentile values, and the geometric standard deviations (GSDs) for Type F ^{90}Sr . The GSDs were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates. Figures A-2 through A-6 show the fits corresponding to each of the subsets of years across the intake period used to develop the composite figure for Type S ^{90}Sr. Figure A-7 shows the composite of the subsets of selected groups of years used to fit the 50th-percentile intake values for Type S ^{90}Sr. Table A-6 summarizes the intake periods and corresponding intake rates for the 50th- and 84th-percentile values, and the calculated GSDs for Type S ^{90}Sr. The same intake periods were applied to the 84th-percentile values for both ^{90}Sr Type F and S material because the values followed a similar pattern; results of the individual fits are not shown here because they were largely in agreement. The urinalysis data for 1964 were insufficient to support a complete analysis and was, therefore, omitted from the sample set.

4.3.2 Uranium-234

Because a variety of uranium enrichments and exposure conditions are possible at the ORNL site, ^{234}U was assumed for the IMBA intake modeling even though the source data are for gross uranium in varying amounts, depending on the enrichment. This does not affect the fitting of the data for intake determination (i.e., the same total intakes would be obtained for any enrichment that was assumed) because all uranium isotopes behave the same biokinetically and the isotopes considered in this analysis have long half-lives in relation to the assumed intake period. The International Commission on Radiological Protection (ICRP) Publication 68 (ICRP 1994) dose coefficients (also referred to as dose conversion factors) for ^{234}U are 7% to 31% larger than those for ^{235}U, ^{236}U, and ^{238}U. Because of the isotopic compositions of the source terms, the ^{234}U dose conversion factor will overestimate doses for any combination of the uranium radioisotopes, but the assumption of intake of 100% ^{234}U is made to ensure the doses are favorable to the claimant.

Because uranium is found in many forms at ORNL, the bioassay data were fit using Type F, M, and S material. Figures A-8 and A-9 in Attachment A show the individual fits for the 50th-percentile values for Type F and M ^{234}U, respectively. Table A-7 summarizes the intake periods for the 50th- and 84th-percentile values, and the calculated GSDs for Type F ^{234}U, while Table A-8 lists similar information for Type M ^{234}U. Again, the GSDs were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates. For Type S ^{234}U, Figures A-10 through A-16 show the fits corresponding to each of the subsets of years across the intake period used to develop the composite figure. Figure A-17 provides the composite of the subsets of selected groups of years used to fit the 50th-percentile intake values. Table A-9 summarizes the intake periods and corresponding intake rates for the 50th- and 84th-percentile values, and the calculated GSDs for Type S ^{234}U. Plots of the results of the individual fits to the 84th-percentile values for all three solubility types are not shown here because they were largely in agreement.

4.3.3 Plutonium-239

For this analysis, the analyzed material types for ^{239}Pu are assumed to be types M and S. Although the bioassay results are for all alpha-emitting isotopes of plutonium, the results were assumed to represent the concentration of ^{239}Pu alone. Figures A-18 through A-21 in Attachment A show the fits

for Type M material corresponding to each of the subsets of years across the intake period used to develop the composite figure. Figure A-22 shows the composite of the subsets of selected years used to fit the 50th-percentile intake values for Type M ^{239}Pu. Table A-10 summarizes the intake periods and corresponding intake rates for the 50th- and 84th-percentile values, and the GSDs for Type M ^{239}Pu. The GSDs were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates. Again, the same intake periods were applied to the 84th-percentile values for Type M ^{239}Pu because the values followed a similar pattern; results of the individual fits are not shown here because they were largely in agreement.

Figures A-23 through A-26 in Attachment A show the fits for Type S material corresponding to each of the subsets of years across the intake period used to develop the composite figure. Figure A-27 shows the composite of the subsets of selected years used to fit the 50th-percentile intake values for Type S ^{239}Pu. Table A-11 summarizes the intake period and corresponding intake rate for the 50th- and 84th-percentile values, and the GSDs for Type S ^{239}Pu. Again, the GSDs were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates. The same intake periods were applied to the 84th-percentile values for Type S ^{239}Pu because the values followed a similar pattern; results of the fit are not shown here because they were largely in agreement.

4.3.4 Americium-241

ICRP Publication 68 (ICRP 1994) assigns all forms of americium to Type M. Figures A-28 and A-29 in Attachment A show the fits corresponding to each of the subsets of years across the intake period used to develop the composite figure. Figure A-30 shows the composite of the subsets of selected years used to fit the 50th-percentile intake values for Type M ^{241}Am. Table A-12 summarizes the intake periods and corresponding intake rates for the 50th- and 84th-percentile values, and the GSDs for Type M ^{241}Am. Again, the GSDs were determined by dividing the 84th-percentile intake rates by the 50th-percentile intake rates. The same intake periods were applied to the 84th-percentile values for Type M ^{241}Am because the values followed a similar pattern; results of the individual fits are not shown here because they were largely in agreement.

4.3.5 Additional Radionuclides

Hundreds of different radionuclides were present at ORNL at some point during its operations. However, bioassay data for additional radionuclides beyond ^{90}Sr, ^{238}U, ^{239}Pu, and ^{241}Am were deemed to be of little use for coworker estimations, largely because there were too few measurements to be statistically reliable for intake estimation. For this analysis, three additional radionuclides, both important to internal dosimetry and present in the reported air monitoring data, were considered. These are ^{106}Ru, ^{137}Cs, and ^{144}Ce.

5.0 ASSIGNMENT OF INTAKES AND DOSES

The resulting calculated intake rate information, useful in dose reconstruction for the radionuclides identified for ORNL, is discussed in this section. For each radionuclide, the 50th- and 95th-percentile intake rates, and the GSDs, are provided in specific tables. In most cases, doses for individuals who were potentially exposed routinely should be calculated from the 50th-percentile intake rates by assuming the solubility type that results in the largest probability of causation (POC)[1]. The GSD values have been adjusted from the values in the tables in Appendix A to allow for the addition of doses from different intake periods into a single input line for a given year in the Interactive RadioEpidemiological Program (IREP) input file, and to ensure that none are less than 3, the value used when assigning intakes to individuals from person-specific bioassay results.

[1] The U.S. Department of Labor (DOL) is responsible under EEOICPA for determining the POC.

- **Strontium-90.** For ^{90}Sr, several intake periods were defined as listed in Table 5-1 for Type F material and Table 5-2 for Type S material. There were five intake periods defined for ^{90}Sr Type F intakes and six for ^{90}Sr Type S intakes.

Table 5-1. Combined ^{90}Sr Type F intake periods and rates (dpm/d).

Date range		^{90}Sr Type F intake rate		
From	To	50th percentile	GSD	95th percentile
1/1/1951	12/31/1953	475.2	10.0	20,983
1/1/1954	12/31/1954	80.99	10.0	3,576
1/1/1955	12/31/1960	47.34	4.17	496
1/1/1961	12/31/1964	47.34	3.00	288
1/1/1965	12/31/1988	15.52	3.00	94.57

Table 5-2. Combined ^{90}Sr Type S intake periods and rates (dpm/d).

Date range		^{90}Sr Type S intake rate		
From	To	50th percentile	GSD	95th percentile
1/1/1951	12/31/1953	24,646	9.53	1,005,436
1/1/1954	12/31/1954	7,232	9.53	295,030
1/1/1955	12/31/1960	2,379	5.73	42,030
1/1/1961	12/31/1964	2,379	3.00	14,496
1/1/1965	12/31/1983	795.0	3.00	4,844
1/1/1984	12/31/1988	425.5	4.51	5,070

- **Uranium-234.** Table 5-3 lists the calculated annual intake rates for ^{234}U for 1951 through 1987 for Types F, M, and S material.

- **Plutonium-239.** Tables 5-4 and 5-5 list the calculated annual intake rates for ^{239}Pu for Types M and S material, respectively, for 1951 through 1988.

- **Americium-241.** Table 5-6 lists the combined ^{241}Am Type M material intake periods and rates for 1968 through 1988. There were two defined intake periods.

5.1 CONTRIBUTION FROM ADDITIONAL RADIONUCLIDES

To account for additional intakes, an evaluation of air monitoring data from the ORNL perimeter reporting stations for 1975 through 1984 was conducted. The approach was to develop the ratios of the isotopic concentration ratios of other radionuclides to the concentration ratio of ^{90}Sr reported in the air monitoring data. The results of this evaluation are summarized in Table 5-7, which lists the reported radionuclide concentrations, the ratio of the concentrations of the three selected radionuclides to ^{90}Sr, the peak concentration ratio, range of the concentration ratios, and the average concentration ratio.

5.2 DOSE ASSIGNMENT

In most cases, doses to be assigned to individuals potentially exposed on a routine basis are calculated from the 50th-percentile intake rates; the material type resulting in the largest probability of causation (which is determined by DOL) is selected. A comparison of the intake rates shows:

- For ^{90}Sr, the calculated intake rates for Type S material are 1 to 2 orders of magnitude higher than the intake rates of Type F material for all intake periods. However, because the Type S material remains in the lungs for an extended period while the Type F material is transferred to

the systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the larger dose to the organ of interest.

Table 5-3. ^{234}U Type F, M, and S intake periods and rates (dpm/d).

Year	U-234 Type F intake rate			U-234 Type M intake rate			U-234 Type S intake rate		
	50th percentile	GSD	95th percentile	50th percentile	GSD	95th percentile	50th percentile	GSD	95th percentile
1951	11.19	3.08	71.20	47.03	3.33	340.2	850.7	3.0	5,184
1952	11.19	3.08	71.20	47.03	3.33	340.2	850.7	3.0	5,184
1953	11.19	3.08	71.20	47.03	3.33	340.2	850.7	3.00	5,184
1954	11.19	3.08	71.20	47.03	3.33	340.2	850.7	3.00	5,184
1955	11.19	3.08	71.20	47.03	3.33	340.2	850.7	3.00	5,184
1956	4.213	6.71	96.51	11.45	9.70	480.9	675.7	3.00	4,117
1957	1.942	9.25	75.43	7.49	9.70	314.6	247.7	7.74	7,176
1958	1.942	9.25	75.43	7.49	9.70	314.6	247.7	7.74	7,176
1959	5.171	3.48	40.22	21.81	3.33	157.8	509	4.17	5,331
1960	5.171	3.48	40.22	21.81	3.33	157.8	509	4.17	5,331
1961	5.171	3.48	40.22	21.81	3.33	157.8	509	4.17	5,331
1962	1.881	6.71	43.09	6.56	7.24	170.3	235.3	6.04	4,533
1963	1.881	6.71	43.09	6.56	7.24	170.3	235.3	6.04	4,533
1964	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1965	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1966	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1967	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1968	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1969	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1970	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1971	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1972	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1973	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1974	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1975	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1976	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1977	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1978	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1979	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1980	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1981	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1982	0.413	3.08	2.63	1.641	3.33	11.87	23.7	3.00	144.4
1983	0.413	3.08	2.63	1.641	3.33	11.87	15.25	4.67	192.4
1984	0.413	3.08	2.63	1.641	3.33	11.87	15.25	3.0	92.93
1985	0.0957	3.08	0.609	0.294	3.33	2.127	15.25	3.0	92.93
1986	0.0957	3.08	0.609	0.294	3.33	2.127	15.25	3.0	92.93
1987	0.0957	3.08	0.609	0.294	3.33	2.127	15.25	3.0	92.93

Table 5-4. ^{239}Pu Type M intake periods and rates (dpm/d).

Years	Pu-239 Type M intake rate		
	50th percentile	GSD	95th percentile
1951–1952	40.75	3.0	248
1953–1959	10.98	7.9	329
1960–1968	10.98	3.0	66.9
1969–1984	7.35	3.0	44.8
1985–1988	1.614	4.2	17.1

Table 5-5. ^{239}Pu Type S intake periods and rates (dpm/d).

Year	Pu-239 Type S intake rate		
	50th percentile	GSD	95th percentile
1951–1952	1,489	3.00	7,178
1953–1959	159.8	11.06	8,325
1960–1968	159.8	3.00	730
1969–1972	118.5	3.40	886
1973–1984	118.5	3.00	536
1985–1988	36.26	5.46	592

Table 5-6. ^{241}Am Type M intake periods and rates (dpm/d).

Year	Am-241 Type M intake rate		
	50th percentile	GSD	95th percentile
1968–1984	6.673	3.00	40.66
1985–1988	2.207	3.00	13.45

- For ^{234}U, the calculated intake rates for Type S material are one to two orders of magnitude higher than the intake rates of Type F and M material for all intake periods. Again, because Type S material remains in the lungs while Type F and M material is transferred to the systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the larger dose to the organ of interest.

- For ^{239}Pu, the calculated intake rates for Type S material are 1 to 2 orders of magnitude higher than the intake rates of Type M material for all intake periods. Again, because Type S material remains in the lungs while Type M material is transferred to the systemic organs, it is necessary to compare the annual doses on a case-by-case basis to determine which will deliver the larger dose to the organ of interest.

- For ^{241}Am, the calculated intake rates for Type M material should be used for all organs and intake periods, as listed in Table 5-6.

- When a ^{90}Sr intake is assigned, the worker should also be assigned intakes of ^{106}Ru, ^{137}Cs, and ^{144}Ce, consistent with the average isotopic ratios developed from the air monitoring data listed in Table 5-7, using the ^{90}Sr intake as the basis. For example, if a worker were exposed in 1965 to Type F ^{90}Sr, the intake (from Table 5-1) would be 15.5 dpm/d. Intake of ^{106}Ru would also be assigned at a value of 103.8 dpm/d (i.e., 15.5 dpm/d of ^{90}Sr times 6.7, the average ratio of ^{106}Ru to ^{90}Sr from Table 5-7), along with a 34.1-dpm/d intake of ^{137}Cs and a 170.5-dpm/d intake of ^{144}Ce. Although Table 5-7 is based on data from 1975 through 1984, the average ratios calculated should be used for all years.

The lognormal distribution is selected in IREP, with the calculated dose entered as Parameter 1 and the associated GSD as Parameter 2. The GSD is associated with the intake, so it is applied to all

annual doses determined from the intake period. The GSD for ^{90}Sr should be assigned when intakes of ^{106}Ru, ^{137}Cs, or ^{144}Ce are included.

Table 5-7. Evaluation of the contribution of additional radionuclides.

Year[a]	Reported Sr-90 concentration (10^{-15} µCi/mL)	Reported Ru-106 concentration (10^{-15} µCi/mL)	Ratio: Ru-106 to Sr-90	Reported Cs-137 concentration (10^{-15} µCi/mL)	Ratio: Cs-137 to Sr-90	Reported Ce-144 concentration (10^{-15} µCi/mL)	Ratio: Ce-144 to Sr-90
1975	0.78	6.7	8.6	1.4	1.8	11	14
1976	0.77	0.88	1.1	0.55	0.7	2.4	3.1
1977	1.30	11	8.5	1.60	1.2	21	16
1978	0.81	9.7	12	2.14	2.6	16	19
1979	0.15	1.56	10	0.67	4.5	1.8	12
1980	0.08	0.49	6.1	0.37	4.6	0.98	12
1981	0.46	4.40	9.6	1.2	2.6	11	24
1982	0.15	0.40	2.7	0.24	1.6	0.03	0.2
1983	0.08	0.12	1.5	0.10	1.2	N/A	N/A
1984	0.07	N/A	N/A	0.07	1.0	N/A	N/A
Peak ratio	-	-	12	-	5	-	24
Ratio range	-	-	1.1–12	-	0.7–4.6	-	0.2–24
Average ratio	**-**	**-**	**6.7**	**-**	**2.2**	**-**	**11**

a. References: 1975 – (Union Carbide 1975); 1976 – (Union Carbide 1976); 1977 – (Union Carbide 1977); 1978 – (Union Carbide 1978); 1979 – (Union Carbide 1979); 1980 – (Union Carbide 1980); 1981 – (Union Carbide 1981); 1982 – (Union Carbide 1982); 1983 – (Martin Marietta 1983); and 1984 – (Martin Marietta 1984).

REFERENCES

ICRP (International Commission on Radiological Protection), 1994, *Dose Coefficients for Intakes of Radionuclides by Workers*, Publication 68, Pergamon Press, Oxford, England.

Martin Marietta, 1983, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities – Calendar Year 1983*, Y/UB-19, Oak Ridge, Tennessee. [SRDB Ref ID: 4954]

Martin Marietta, 1984, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities – Calendar Year 1984*, Y/UB-20, Oak Ridge, Tennessee. [SRDB Ref ID: 4955]

ORAUT (Oak Ridge Associated Universities Team), 2005, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 01, Oak Ridge, Tennessee, October 7.

ORAUT (Oak Ridge Associated Universities Team), 2013, *Oak Ridge National Laboratory – Occupational Internal Dose*, ORAUT-TKBS-0012-5, Rev. 02, Oak Ridge, Tennessee, February 8.

Union Carbide, 1975, *Environmental Monitoring Report – United States Energy Research and Development Administration, Oak Ridge Facilities - Calendar Year 1975*, Y/UB-4, Oak Ridge, Tennessee. [SRDB Ref ID: 4908]

Union Carbide, 1976, *Environmental Monitoring Report – United States Energy Research and Development Administration, Oak Ridge Facilities - Calendar Year 1976*, Y/UB-6, Oak Ridge, Tennessee. [SRDB Ref ID: 4911]

Union Carbide, 1977, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities - Calendar Year 1977*, Y/UB-8, Oak Ridge, Tennessee. [SRDB Ref ID: 4913

Union Carbide, 1978, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities- Calendar Year 1978*, Y/UB-10, Oak Ridge, Tennessee. [SRDB Ref ID: 4915]

Union Carbide, 1979, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities - Calendar Year 1979*, Y/UB-13, Oak Ridge, Tennessee. [SRDB Ref ID: 4921]

Union Carbide, 1980, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities - Calendar Year 1980*, Y/UB-15, Oak Ridge, Tennessee. SRDB Ref ID: 4924, p. 155]

Union Carbide, 1981, *Environmental Monitoring Report – United States Department of Energy, Oak Ridge Facilities - Calendar Year 1981*, Y/UB-16, Oak Ridge, Tennessee. SRDB Ref ID: 4924, p. 79]

Union Carbide, 1982, *Environmental Monitoring Report – United States Energy Department of Energy, Oak Ridge Facilities - Calendar Year 1982*, Y/UB-18, Oak Ridge, Tennessee. SRDB Ref ID: 4924, p. 3]

ATTACHMENT A
Page 1 of 23

Table A-1. Statistical summary of annual ORNL strontium 24-hour urinary excretion rates (dpm/d), 1951 to 1988.

Effective bioassay date	GM (50th)	GM × GSD (84th)	No. of samples	No. of employees
7/1/1952	109.15	1,008.55	134	16
7/1/1954	24.68	241.98	246	162
7/1/1955	13.10	63.17	722	534
7/1/1956	13.54	82.88	705	538
7/1/1957	15.71	68.85	879	566
7/1/1958	17.01	75.45	1,394	620
7/1/1959	12.20	59.03	1,035	623
7/1/1960	15.67	65.07	624	364
7/1/1961	9.48	28.06	1,328	952
7/1/1962	12.04	29.49	2,440	1,579
7/1/1963	10.08	26.23	2,328	1,524
N/A[a]	N/A[a]	N/A[a]		
7/1/1965	4.86	15.75	2,203	1,649
7/1/1966	3.62	17.78	1,619	1,274
7/1/1967	3.35	12.86	1,609	1,332
7/1/1968	1.02	7.77	1,147	915
7/1/1969	3.89	8.96	1,295	1,028
7/1/1970	6.07	13.96	636	456
7/1/1971	6.91	15.08	607	437
7/1/1972	7.54	22.75	358	211
7/1/1973	5.18	13.45	397	316
7/1/1974	7.66	24.76	282	217
7/1/1975	5.27	10.68	290	239
7/1/1976	5.14	11.59	270	201
7/1/1977	5.19	11.58	168	120
7/1/1978	5.04	9.61	149	109
7/1/1979	2.44	6.68	215	169
7/1/1980	5.69	23.05	242	162
7/1/1981	3.04	7.22	159	127
7/1/1982	5.23	12.06	146	98
7/1/1983	5.71	14.48	145	96
7/1/1984	4.38	14.14	136	88
7/1/1985	2.11	5.93	161	134
7/1/1986	0.67	2.88	221	168
7/1/1987	3.37	15.98	228	151
7/1/1988	0.56	1.96	275	225

a. Insufficient data for analysis.

ATTACHMENT A
Page 2 of 23

Table A-2. Statistical summary of annual ORNL uranium 24-hour urinary excretion rates (dpm/d), 1951 to 1987.

Effective bioassay date	GM (50th)	GM × GSD (84th)	No. of samples	No. of employees
7/1/1951	3.41	7.81	351	262
7/1/1952	2.88	8.01	722	419
7/1/1953	3.64	7.54	615	494
7/1/1954	2.27	5.46	851	665
7/1/1955	3.07	9.34	823	591
7/1/1956	1.20	8.16	783	531
7/1/1957	0.50	3.65	942	664
7/1/1958	0.64	4.74	992	553
7/1/1959	1.43	6.93	745	461
7/1/1960	1.36	3.97	506	324
7/1/1961	1.52	5.73	686	456
7/1/1962	0.52	3.57	439	290
7/1/1963	0.58	3.24	698	389
7/1/1964	0.25	1.29	875	541
7/1/1965	0.17	0.62	1462	1178
7/1/1966	0.18	0.52	782	597
7/1/1967	0.09	0.21	687	530
7/1/1968	0.13	0.34	512	324
7/1/1969	0.10	0.33	457	268
7/1/1970	0.16	0.65	281	176
7/1/1971	0.09	0.26	288	201
7/1/1972	0.13	0.39	256	145
7/1/1973	0.07	0.30	278	206
7/1/1974	0.06	0.22	188	138
7/1/1975	0.08	0.32	219	149
7/1/1976	0.10	0.46	229	135
7/1/1977	0.20	0.48	191	131
7/1/1978	0.14	0.31	240	165
7/1/1979	0.14	0.52	318	213
7/1/1980	0.11	0.39	261	189
7/1/1981	0.13	0.22	179	145
7/1/1982	0.17	0.31	141	99
7/1/1983	0.12	0.28	167	106
7/1/1984	0.10	0.19	203	141
7/1/1985	0.07	0.17	217	158
7/1/1986	0.04	0.08	163	128
7/1/1987	0.00	0.03	212	164

ATTACHMENT A
Page 3 of 23

Table A-3. Statistical summary of annual ORNL plutonium 24-hour urinary excretion rates (dpm/d), 1951 to 1988.

Effective bioassay date	GM (50th)	GM × GSD (84th)	No. of samples	No. of employees
7/1/1951	0.13	0.30	507	260
7/1/1952	0.11	0.31	668	394
7/1/1953	0.04	0.14	446	394
7/1/1954	0.07	0.36	972	583
7/1/1955	0.07	0.26	740	525
7/1/1956	0.04	0.36	627	473
7/1/1957	0.14	0.73	674	423
7/1/1958	0.15	0.52	785	400
7/1/1959	0.12	0.62	889	460
7/1/1960	0.13	0.28	1927	595
7/1/1961	0.07	0.21	1758	983
7/1/1962	0.01	0.08	2680	1658
7/1/1963	0.01	0.09	2825	1624
7/1/1964	0.08	0.23	2147	1446
7/1/1965	0.13	0.26	1237	746
7/1/1966	0.12	0.21	1179	803
7/1/1967	0.10	0.19	1247	927
7/1/1968	0.12	0.24	1262	775
7/1/1969	0.04	0.17	1356	927
7/1/1970	0.08	0.19	828	481
7/1/1971	0.06	0.23	792	484
7/1/1972	0.06	0.18	686	350
7/1/1973	0.03	0.11	675	420
7/1/1974	0.06	0.12	529	350
7/1/1975	0.04	0.12	487	335
7/1/1976	0.05	0.13	532	341
7/1/1977	0.07	0.15	418	272
7/1/1978	0.06	0.15	431	262
7/1/1979	0.08	0.14	380	219
7/1/1980	0.05	0.11	320	215
7/1/1981	0.09	0.16	323	224
7/1/1982	0.10	0.17	345	226
7/1/1983	0.07	0.13	329	211
7/1/1984	0.07	0.11	370	237
7/1/1985	0.01	0.05	368	253
7/1/1986	0.01	0.04	297	212
7/1/1987	0.01	0.04	234	185
7/1/1988	0.00	0.03	169	128

ATTACHMENT A
Page 4 of 23

Table A-4. Statistical summary of annual ORNL americium 24-hour urinary excretion rates (dpm/d), 1968 to 1987.

Effective bioassay date	GM (50th)	GM × GSD (84th)	No. of samples	No. of employees
7/1/1968	0.12	0.31	405	216
7/1/1969	0.10	0.42	455	253
7/1/1970	0.10	0.33	514	267
7/1/1971	0.09	0.24	444	262
7/1/1972	0.12	0.27	503	271
7/1/1973	0.09	0.16	547	336
7/1/1974	0.08	0.15	351	206
7/1/1975	0.12	0.30	367	246
7/1/1976	0.15	0.52	475	274
7/1/1977	0.11	0.18	358	223
7/1/1978	0.10	0.18	403	241
7/1/1979	0.10	0.17	279	196
7/1/1980	0.10	0.14	267	189
7/1/1981	0.07	0.17	289	213
1/1/1983	0.10	0.17	561	272
7/1/1984	0.10	0.15	345	225
7/1/1985	0.05	0.09	342	258
7/1/1986	0.01	0.05	280	217
7/1/1987	0.01	0.04	199	181

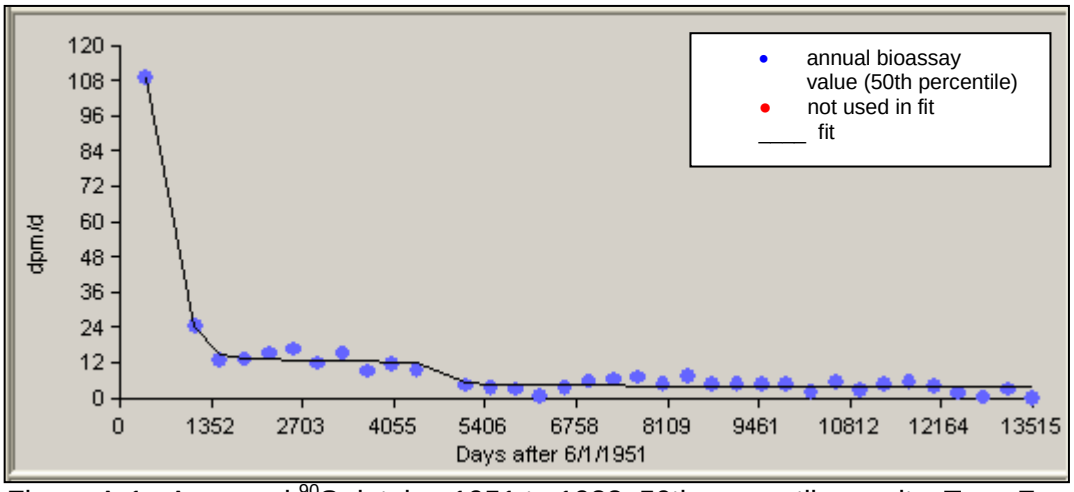

Figure A-1. Assumed ^{90}Sr intake, 1951 to 1988, 50th-percentile results, Type F.

Table A-5. Type F ^{90}Sr intake periods and rates (dpm/d).

Start date	End date	Sr-90 intake rate		GSD
		50th percentile	84th percentile	
1/1/1951	12/31/1953	475.2	4,389	9.24
1/1/1954	12/31/1954	80.99	810.4	10.04
1/1/1955	12/31/1960	47.34	197.3	4.17
1/1/1961	12/31/1964	47.34	62.43	1.32
1/1/1965	12/31/1988	15.52	36.88	2.38

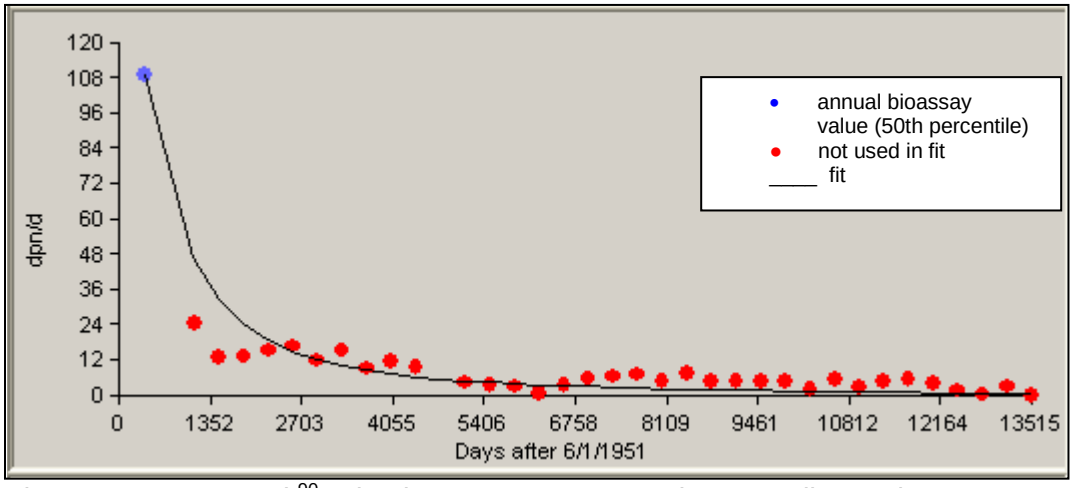

Figure A-2. Assumed ^{90}Sr intake, 1951 to 1953, 50th-percentile results, Type S.

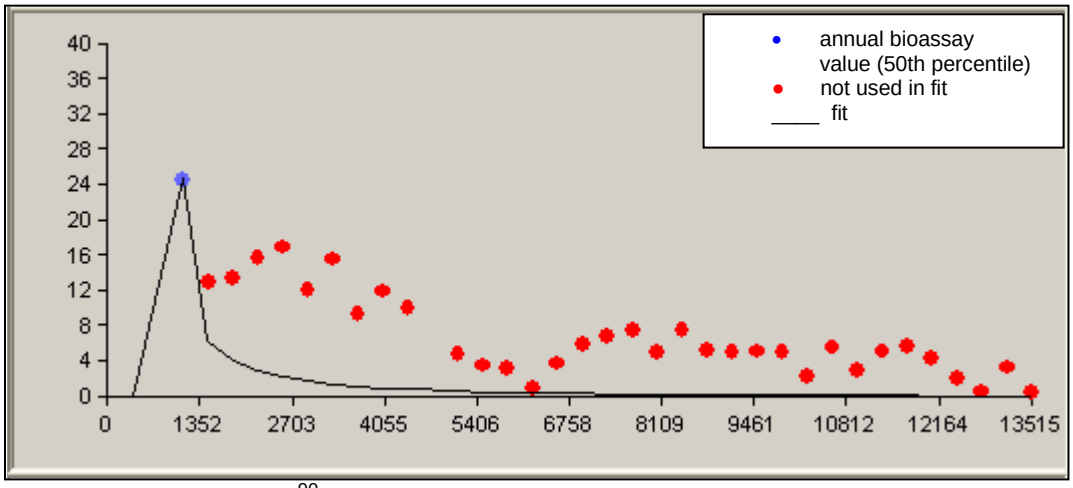

Figure A-3. Assumed ^{90}Sr intake, 1954, 50th-percentile results, Type S.

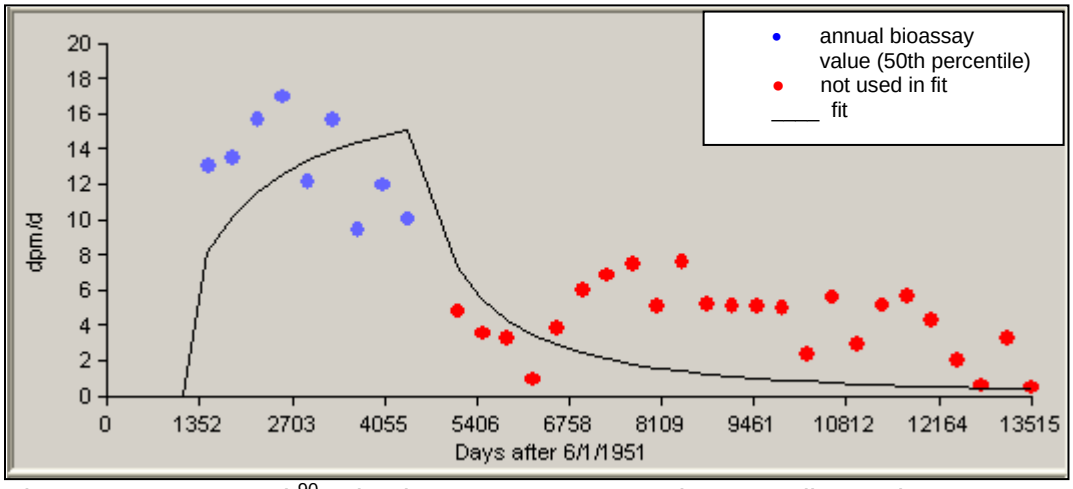

Figure A-4. Assumed ^{90}Sr intake, 1955 to 1964, 50th-percentile results, Type S.

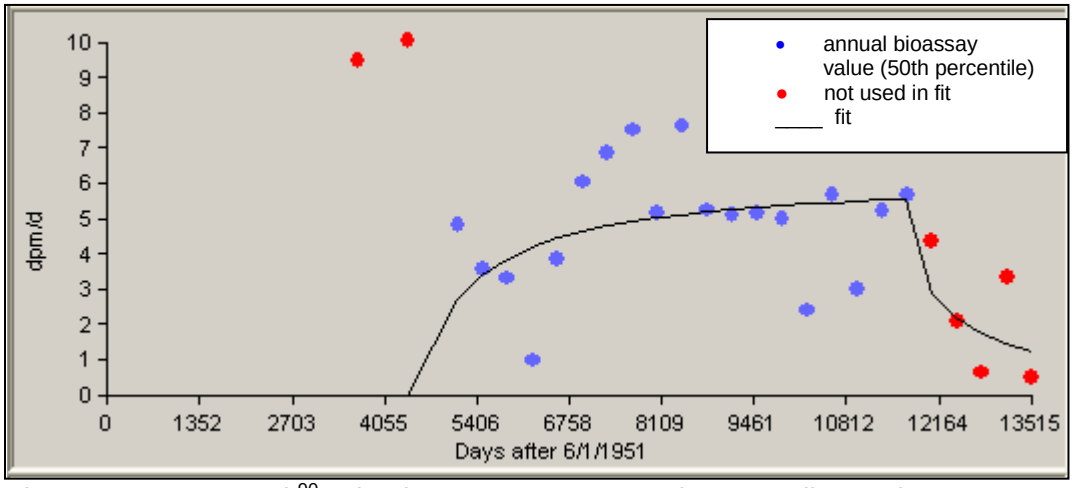

Figure A-5. Assumed ^{90}Sr intake, 1965 to 1983, 50th-percentile results, Type S.

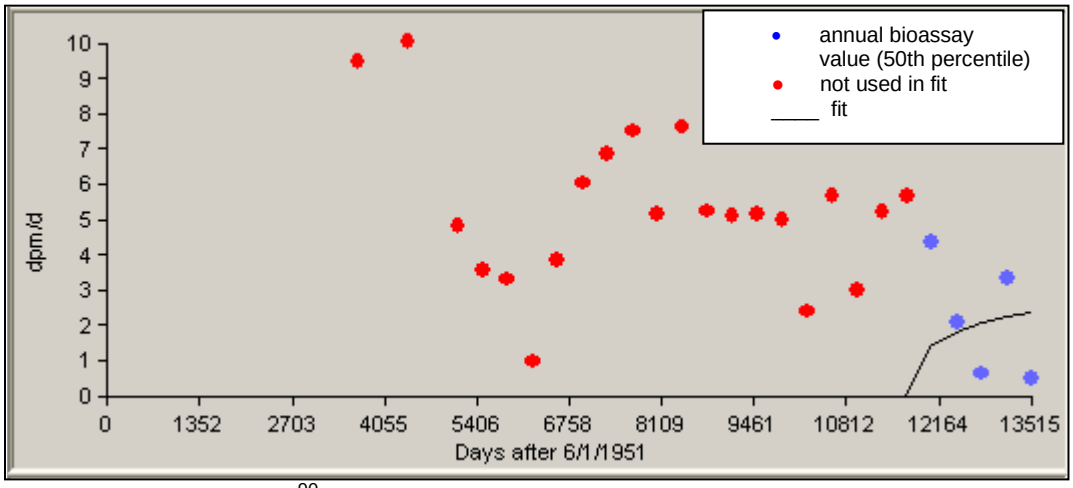

Figure A-6. Assumed ^{90}Sr intake, 1983 to 1988, 50th-percentile results, Type S.

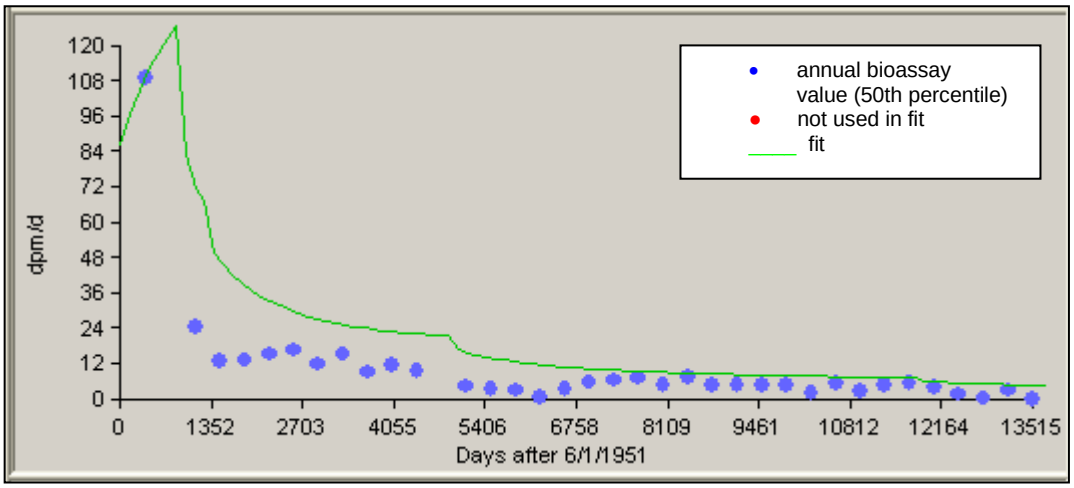

Figure A-7. Predicted strontium excretion rate from independently fit intakes, 1951 to 1988, 50th-percentile results, Type S.

ATTACHMENT A
Page 7 of 23

Table A-6. Type S ^{90}Sr intake periods and rates (dpm/d).

Start date	End date	Sr-90 intake rate		GSD
		50th percentile	84th percentile	
1/1/1951	12/31/1953	24,646	227,730	9.24
1/1/1954	12/31/1954	7,232	68,924	9.53
1/1/1955	12/31/1960	2379	13,628	5.73
1/1/1961	12/31/1964	2,389	6,431	2.69
1/1/1965	12/31/1983	795.0	1,917	2.41
1/1/1984	12/31/1988	425.5	1,917	4.51

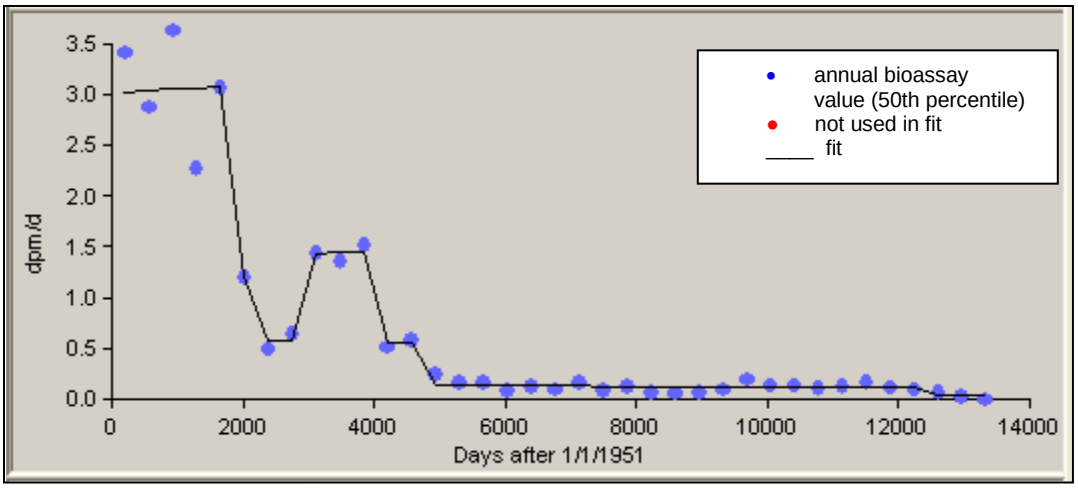

Figure A-8. Assumed ^{234}U intake, 1951 to 1987, 50th-percentile results, Type F.

ATTACHMENT A
Page 8 of 23

Table A-7. Type F ^{234}U intake periods and rates (dpm/d).

Year	Type F U-234 intake rate		GSD
	50th percentile	84th percentile	
1951	11.19	28.28	2.53
1952	11.19	28.28	2.53
1953	11.19	28.28	2.53
1954	11.19	28.28	2.53
1955	11.19	28.28	2.53
1956	4.213	28.28	6.71
1957	1.942	17.97	9.25
1958	1.942	17.97	9.25
1959	5.171	17.97	3.48
1960	5.171	17.97	3.48
1961	5.171	17.97	3.48
1962	1.881	12.05	6.41
1963	1.881	12.05	6.41
1964	0.413	1.272	3.08
1965	0.413	1.272	3.08
1966	0.413	1.272	3.08
1967	0.413	1.272	3.08
1968	0.413	1.272	3.08
1969	0.413	1.272	3.08
1970	0.413	1.272	3.08
1971	0.413	1.272	3.08
1972	0.413	1.272	3.08
1973	0.413	1.272	3.08
1974	0.413	1.272	3.08
1975	0.413	1.272	3.08
1976	0.413	1.272	3.08
1977	0.413	1.272	3.08
1978	0.413	1.272	3.08
1979	0.413	1.272	3.08
1980	0.413	1.272	3.08
1981	0.413	1.272	3.08
1982	0.413	1.272	3.08
1983	0.413	1.272	3.08
1984	0.413	1.272	3.08
1985	0.0957	0.227	2.37
1986	0.0957	0.227	2.37
1987	0.0957	0.227	2.37

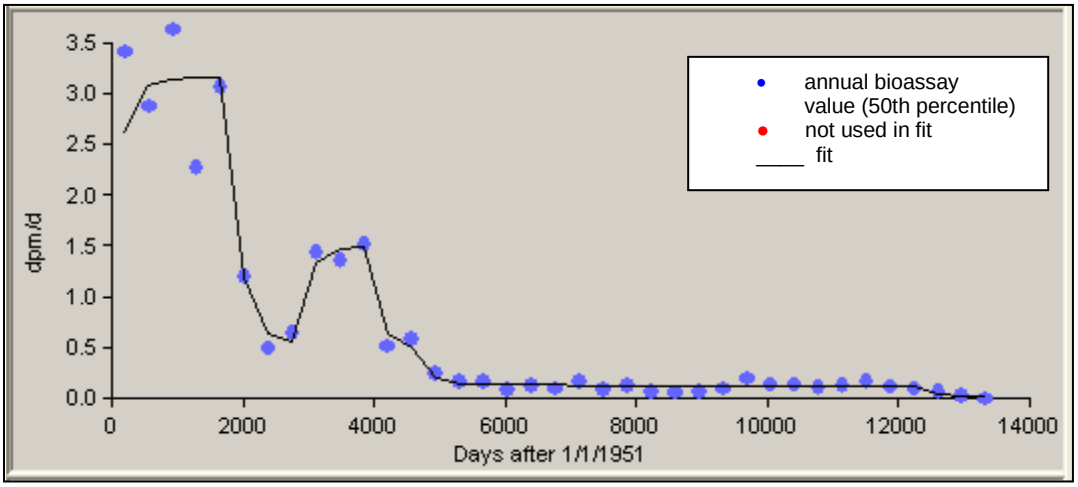

Figure A-9. Assumed ^{234}U intake, 1951 to 1987, 50th-percentile results, Type M.

ATTACHMENT A
Page 10 of 23

Table A-8. Type M ^{234}U intake periods and rates (dpm/d).

Year	Type M U-234 intake rate		GSD
	50th percentile	84th percentile	
1951	47.03	117.8	2.50
1952	47.03	117.8	2.50
1953	47.03	117.8	2.50
1954	47.03	117.8	2.50
1955	47.03	117.8	2.50
1956	11.45	117.8	10.29
1957	7.49	72.66	9.70
1958	7.49	72.66	9.70
1959	21.81	72.66	3.33
1960	21.81	72.66	3.33
1961	21.81	72.66	3.33
1962	6.56	47.49	7.24
1963	6.56	47.49	7.24
1964	1.641	4.809	2.93
1965	1.641	4.809	2.93
1966	1.641	4.809	2.93
1967	1.641	4.809	2.93
1968	1.641	4.809	2.93
1969	1.641	4.809	2.93
1970	1.641	4.809	2.93
1971	1.641	4.809	2.93
1972	1.641	4.809	2.93
1973	1.641	4.809	2.93
1974	1.641	4.809	2.93
1975	1.641	4.809	2.93
1976	1.641	4.809	2.93
1977	1.641	4.809	2.93
1978	1.641	4.809	2.93
1979	1.641	4.809	2.93
1980	1.641	4.809	2.93
1981	1.641	4.809	2.93
1982	1.641	4.809	2.93
1983	1.641	4.809	2.93
1984	1.641	4.809	2.93
1985	0.294	0.659	2.24
1986	0.294	0.659	2.24
1987	0.294	0.659	2.24

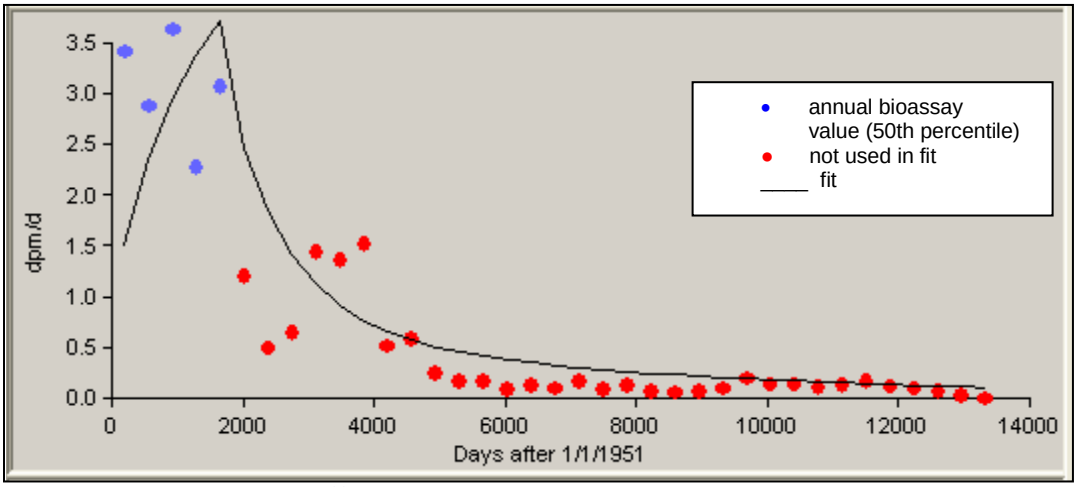

Figure A-10. Assumed ^{234}U intake, 1951 to 1955, 50th-percentile results, Type S.

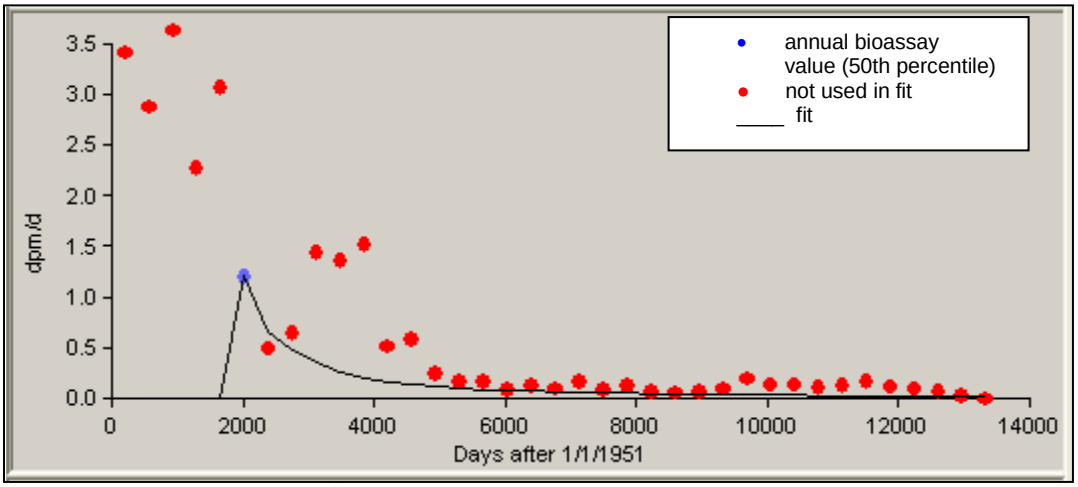

Figure A-11. Assumed ^{234}U intake, 1956, 50th-percentile results, Type S.

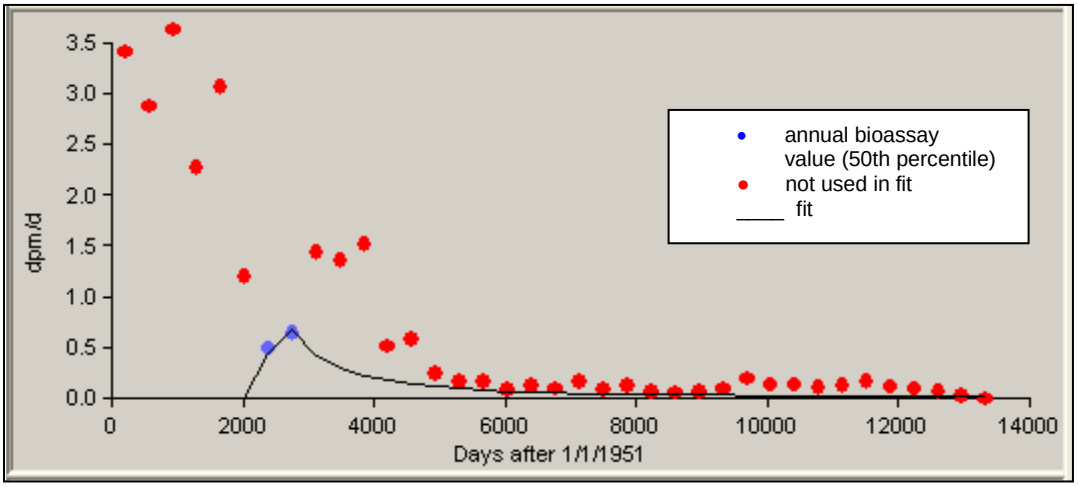

Figure A-12. Assumed ^{234}U intake, 1957 to 1958, 50th-percentile results, Type S.

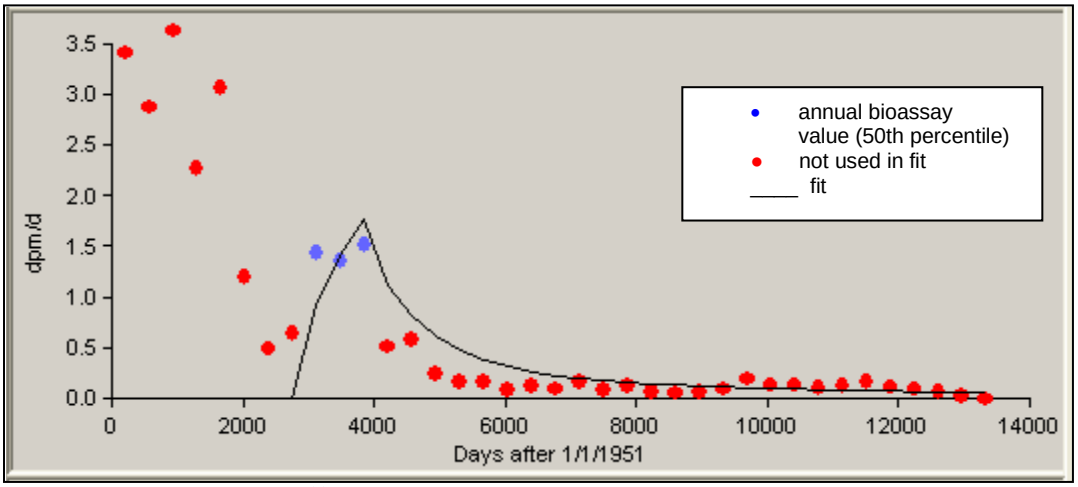

Figure A-13. Assumed ^{234}U intake, 1959 to 1961, 50th-percentile results, Type S.

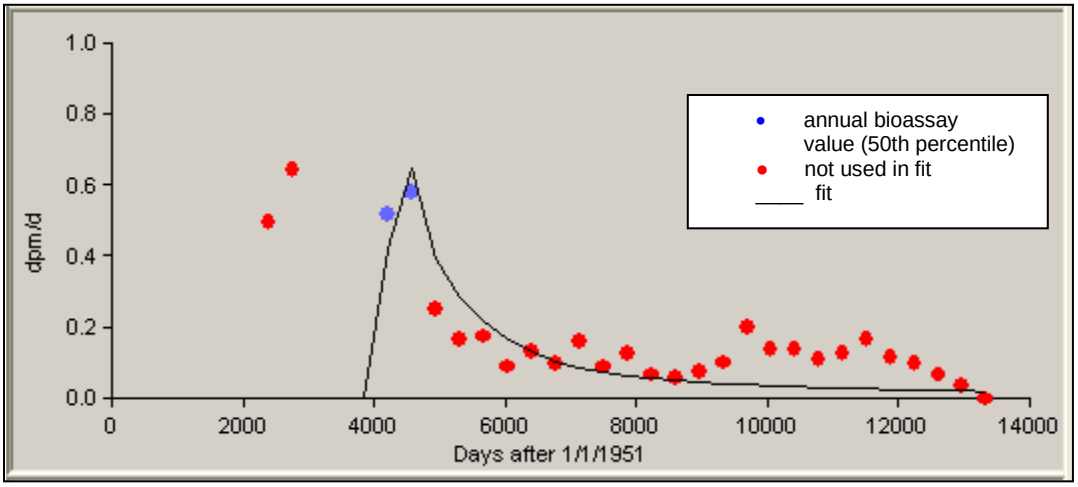

Figure A-14. Assumed ^{234}U intake, 1962 to 1963, 50th-percentile results, Type S.

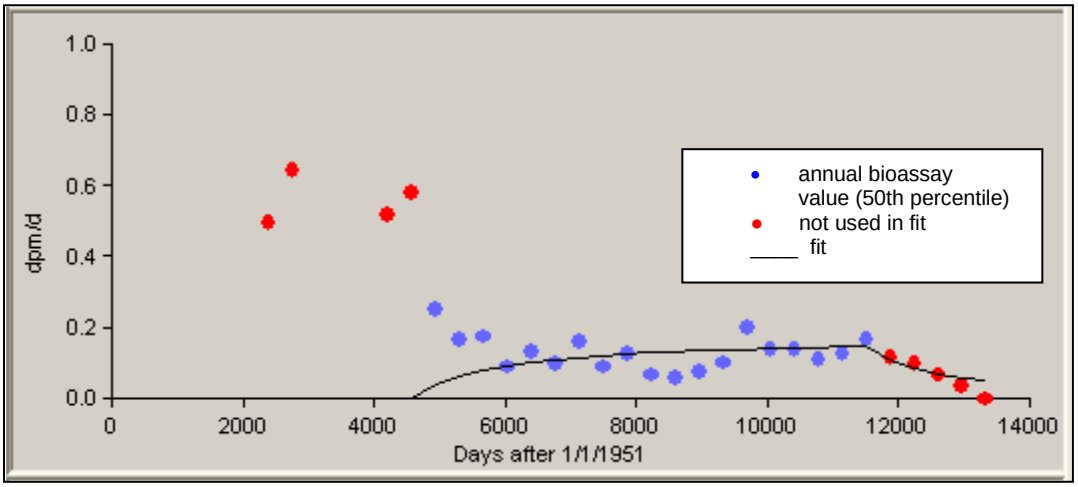

Figure A-15. Assumed ^{234}U intake, 1964 to 1982, 50th-percentile results, Type S.

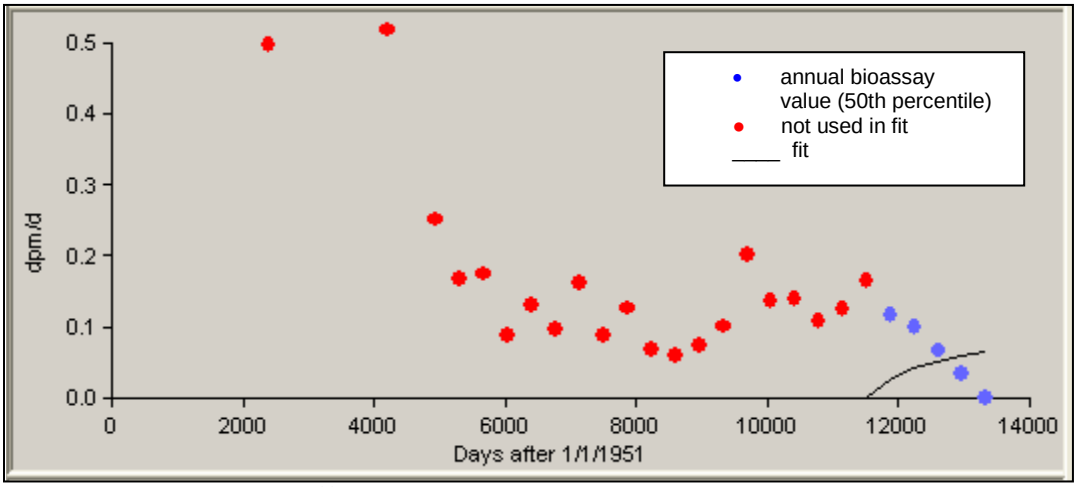

Figure A-16. Assumed ^{234}U intake, 1983 to 1987, 50th-percentile results, Type S.

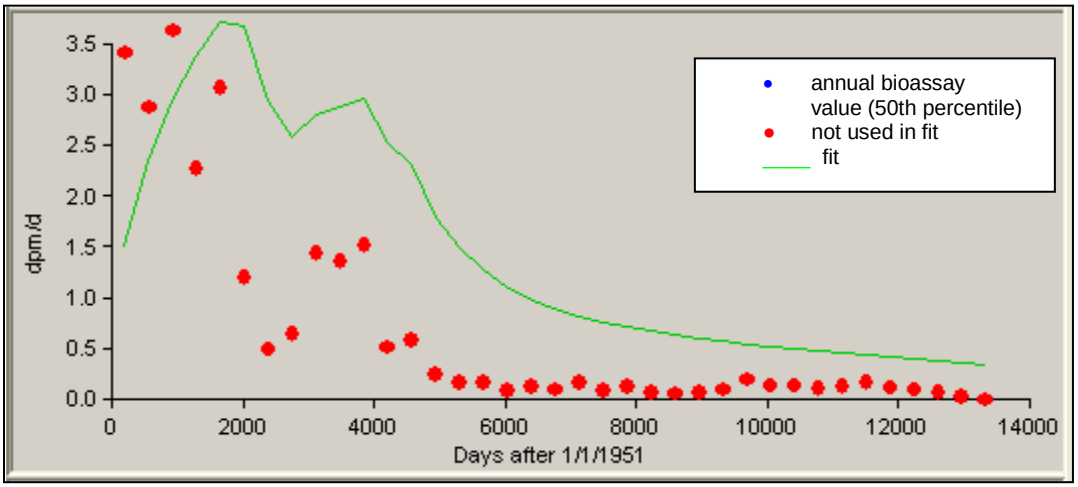

Figure A-17. Predicted uranium excretion rate from independently fit intakes, 1951 to 1987, 50th-percentile, Type S.

ATTACHMENT A
Page 15 of 23

Table A-9. Type S ^{234}U intake periods and rates (dpm/d).

Year	Type S U-234 intake rate		GSD
	50th percentile	84th percentile	
1951	850.7	2048	2.41
1952	850.7	2048	2.41
1953	850.7	2048	2.41
1954	850.7	2048	2.41
1955	850.7	2048	2.41
1956	675.7	2048	3.03
1957	247.7	1,917	7.74
1958	247.7	1,917	7.74
1959	509	1,917	3.77
1960	509	2,125	4.17
1961	509	2,125	4.17
1962	235.3	1,422	6.04
1963	235.3	1,422	6.04
1964	23.7	71.203	3.00
1965	23.7	71.203	3.00
1966	23.7	71.203	3.00
1967	23.7	71.203	3.00
1968	23.7	71.203	3.00
1969	23.7	71.203	3.00
1970	23.7	71.203	3.00
1971	23.7	71.203	3.00
1972	23.7	71.203	3.00
1973	23.7	71.203	3.00
1974	23.7	71.203	3.00
1975	23.7	71.203	3.00
1976	23.7	71.203	3.00
1977	23.7	71.203	3.00
1978	23.7	71.203	3.00
1979	23.7	71.203	3.00
1980	23.7	71.203	3.00
1981	23.7	71.203	3.00
1982	23.7	71.203	3.00
1983	15.25	71.203	4.67
1984	15.25	31.58	2.07
1985	15.25	31.58	2.07
1986	15.25	31.58	2.07
1987	15.25	31.58	2.07

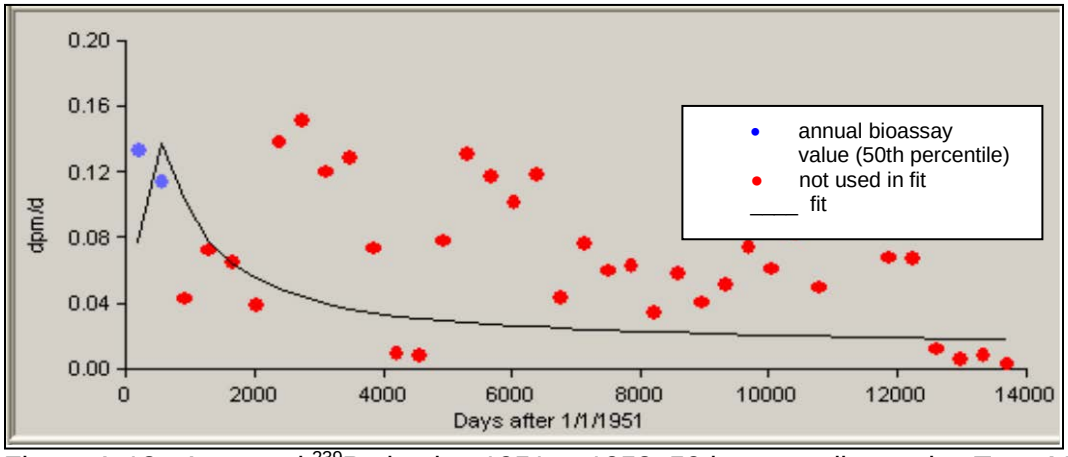

Figure A-18. Assumed ^{239}Pu intake, 1951 to 1952, 50th-percentile results, Type M.

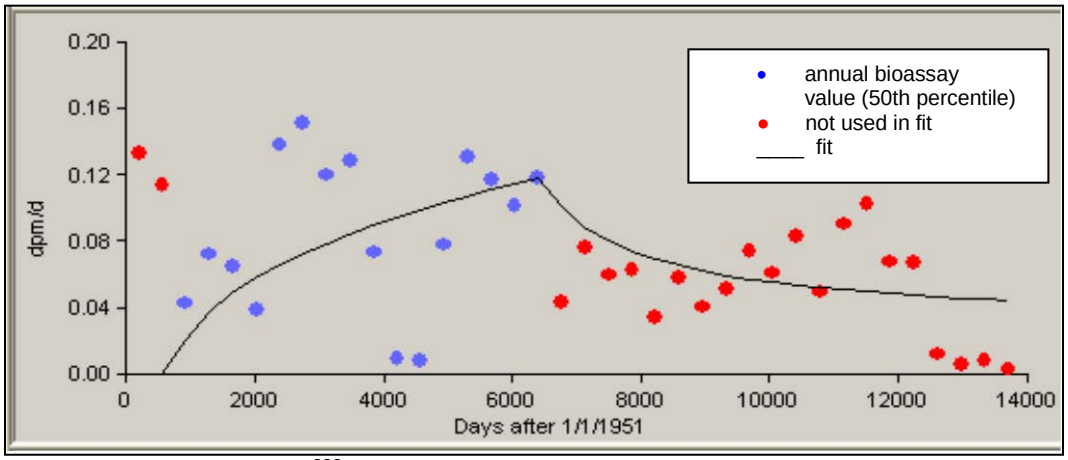

Figure A-19. Assumed ^{239}Pu intake, 1953 to 1968, 50th-percentile results, Type M.

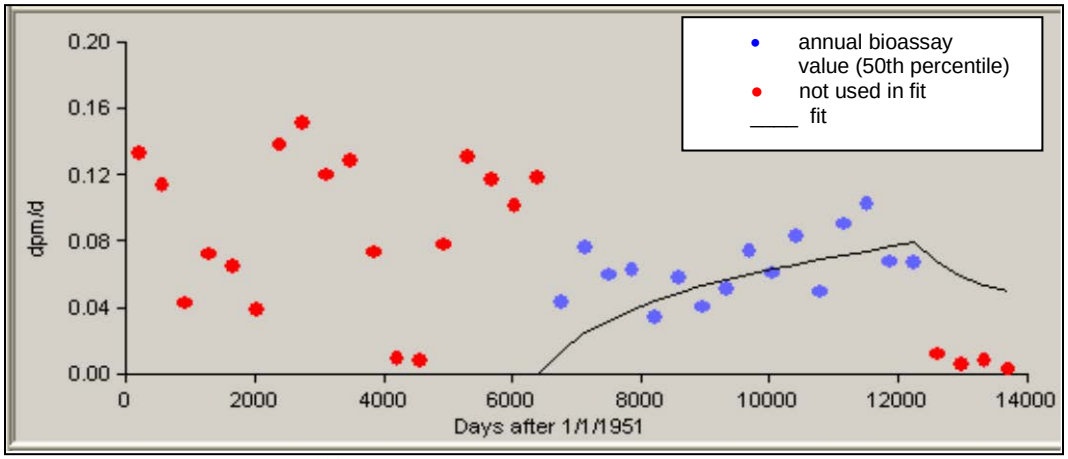

Figure A-20. Assumed ^{239}Pu intake, 1969 to 1984, 50th-percentile results, Type M.

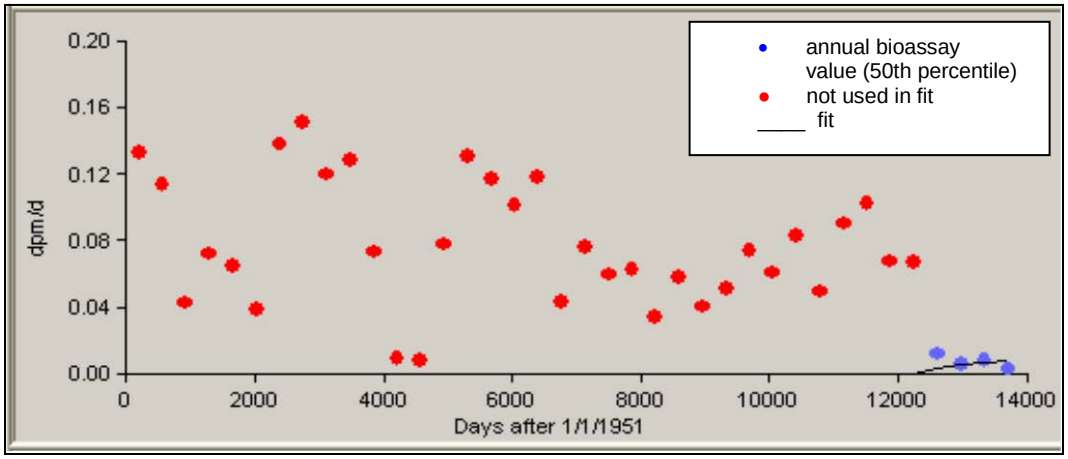

Figure A-21. Assumed ^{239}Pu intake, 1985 to 1988, 50th-percentile results, Type M.

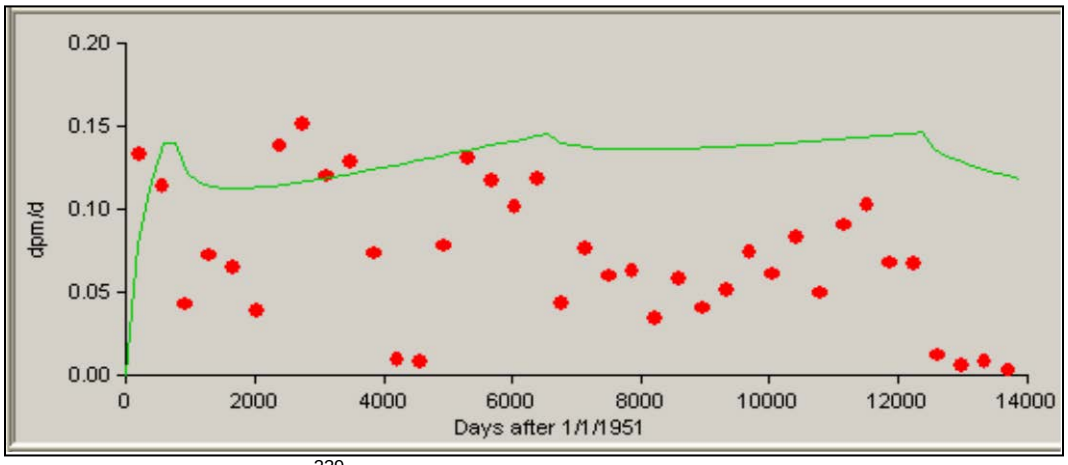

Figure A-22. Predicted ^{239}Pu intake, 1951 to 1988, 50th-percentile composite results, Type M.

ATTACHMENT A
Page 18 of 23

Table A-10. Type M ^{239}Pu intake periods and rates (dpm/d).

	Pu-239 intake rate		
Year	50th percentile	84th percentile	GSD
1951	40.75	109.8	2.69
1952	40.75	109.8	2.69
1953	10.98	86.42	7.87
1954	10.98	86.42	7.87
1955	10.98	86.42	7.87
1956	10.98	86.42	7.87
1957	10.98	86.42	7.87
1958	10.98	86.42	7.87
1959	10.98	86.42	7.87
1960	10.98	22.45	2.04
1961	10.98	22.45	2.04
1962	10.98	22.45	2.04
1963	10.98	22.45	2.04
1964	10.98	22.45	2.04
1965	10.98	22.45	2.04
1966	10.98	22.45	2.04
1967	10.98	22.45	2.04
1968	10.98	22.45	2.04
1969	7.35	22.45	3.05
1970	7.35	22.45	3.05
1971	7.35	22.45	3.05
1972	7.35	22.45	3.05
1973	7.35	18.4	2.50
1974	7.35	18.4	2.50
1975	7.35	18.4	2.50
1976	7.35	18.4	2.50
1977	7.35	18.4	2.50
1978	7.35	18.4	2.50
1979	7.35	18.4	2.50
1980	7.35	18.4	2.50
1981	7.35	18.4	2.50
1982	7.35	18.4	2.50
1983	7.35	18.4	2.50
1984	7.35	18.4	2.50
1985	1.614	6.811	4.22
1986	1.614	6.811	4.22
1987	1.614	6.811	4.22
1988	1.614	6.811	4.22

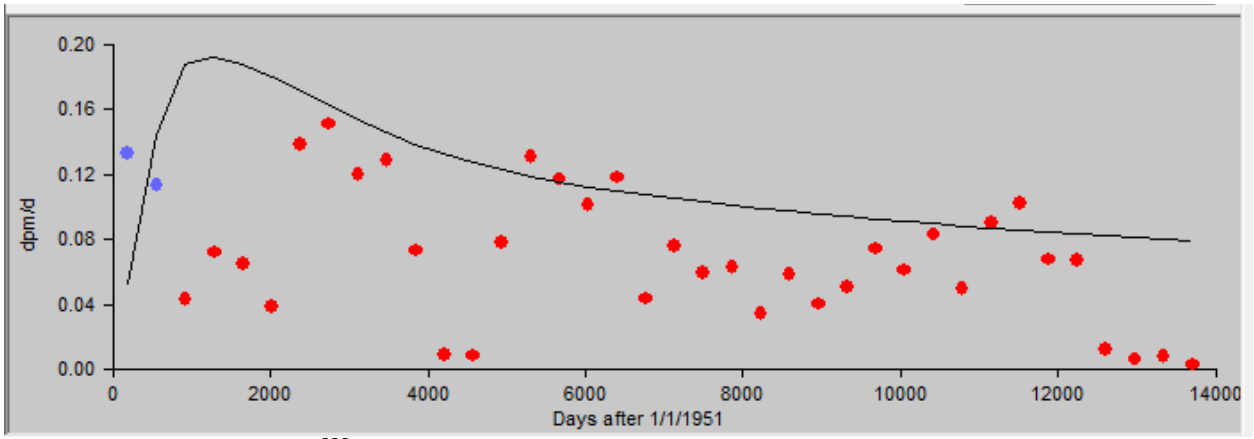

Figure A-23. Assumed ^{239}Pu intake, 1951 to 1952, 50th-percentile results, Type S.

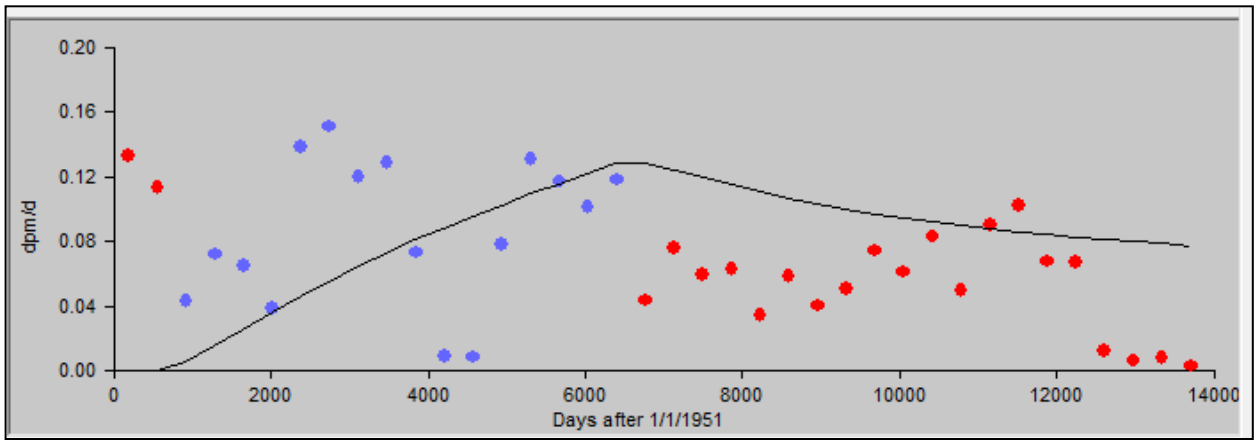

Figure A-24. Assumed ^{239}Pu intake, 1953 to 1968, 50th-percentile results, Type S.

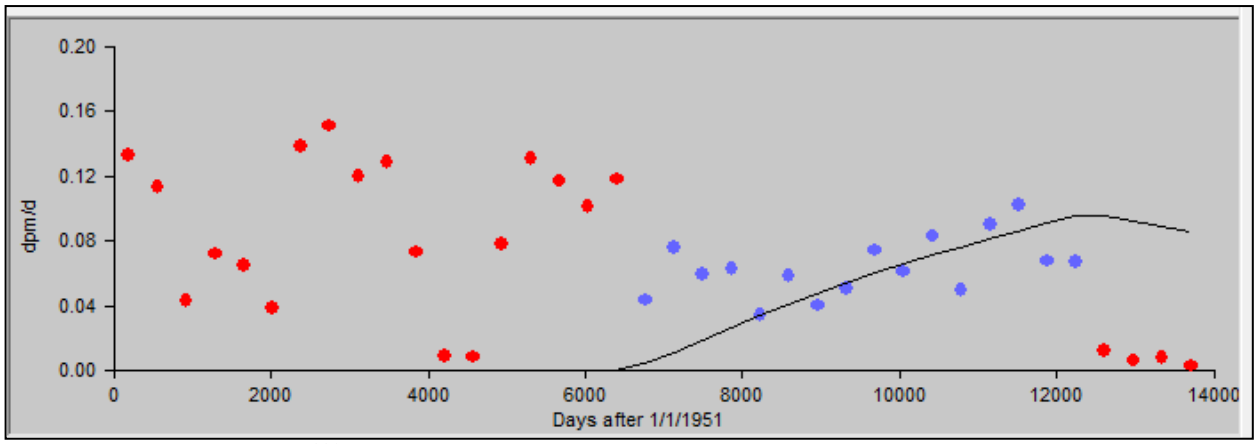

Figure A-25. Assumed ^{239}Pu intake, 1969 to 1984, 50th-percentile results, Type S.

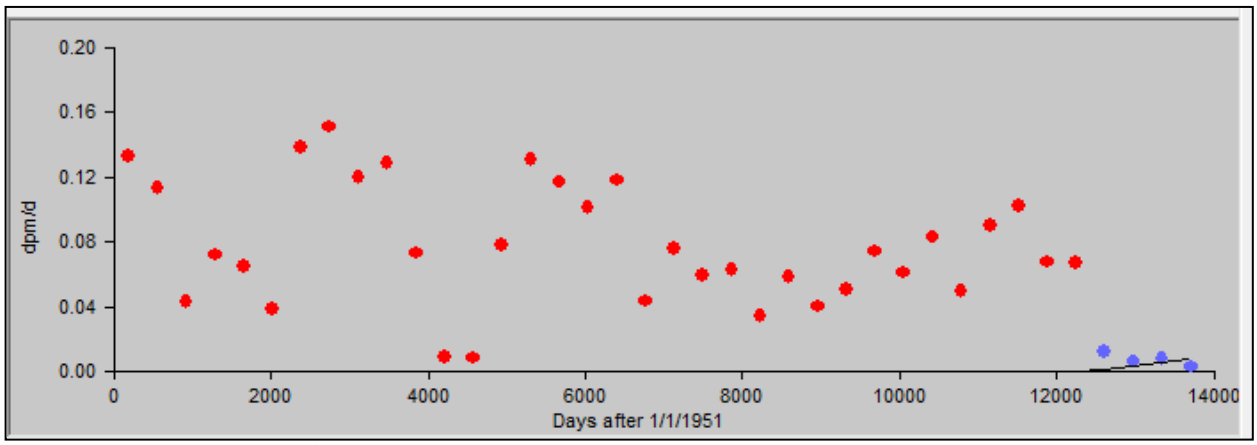

Figure A-26. Assumed ^{239}Pu intake, 1985 to 1988, 50th-percentile results, Type S.

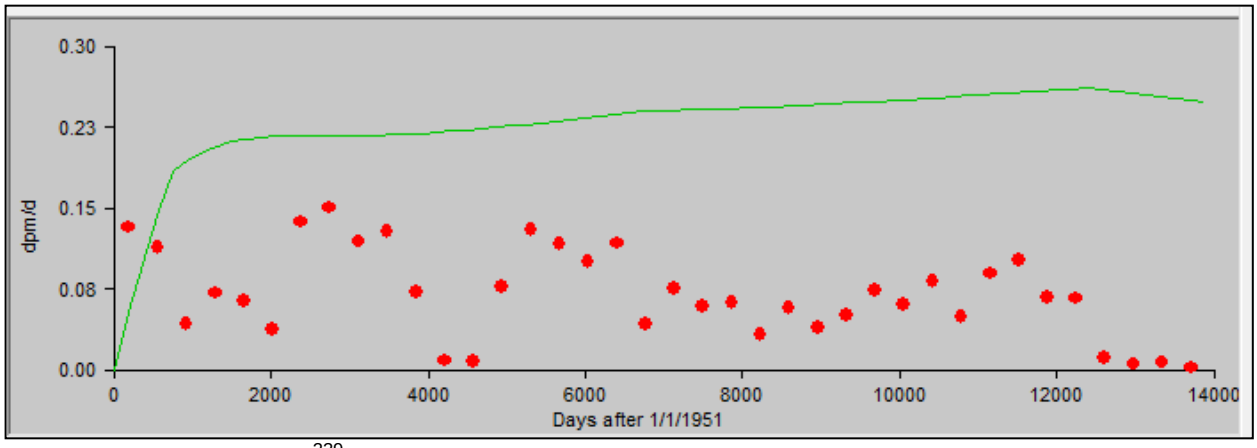

Figure A-27. Predicted ^{239}Pu intake, 1951 to 1988, 50th-percentile composite results, Type S.

ATTACHMENT A
Page 21 of 23

Table A-11. Type S ^{239}Pu intake periods and rates (dpm/d).

	Pu-239 intake rate		
Year	50th percentile	84th percentile	GSD
1951	1489	3874	2.60
1952	1489	3874	2.60
1953	159.8	1767	11.06
1954	159.8	1767	11.06
1955	159.8	1767	11.06
1956	159.8	1767	11.06
1957	159.8	1767	11.06
1958	159.8	1767	11.06
1959	159.8	1767	11.06
1960	159.8	402.5	2.52
1961	159.8	402.5	2.52
1962	159.8	402.5	2.52
1963	159.8	402.5	2.52
1964	159.8	402.5	2.52
1965	159.8	402.5	2.52
1966	159.8	402.5	2.52
1967	159.8	402.5	2.52
1968	159.8	402.5	2.52
1969	118.5	402.5	3.40
1970	118.5	402.5	3.40
1971	118.5	402.5	3.40
1972	118.5	402.5	3.40
1973	118.5	296.5	2.5
1974	118.5	296.5	2.5
1975	118.5	296.5	2.5
1976	118.5	296.5	2.5
1977	118.5	296.5	2.5
1978	118.5	296.5	2.5
1979	118.5	296.5	2.5
1980	118.5	296.5	2.5
1981	118.5	296.5	2.5
1982	118.5	296.5	2.5
1983	118.5	296.5	2.5
1984	118.5	296.5	2.5
1985	36.26	198	5.46
1986	36.26	198	5.46
1987	36.26	198	5.46
1988	36.26	198	5.46

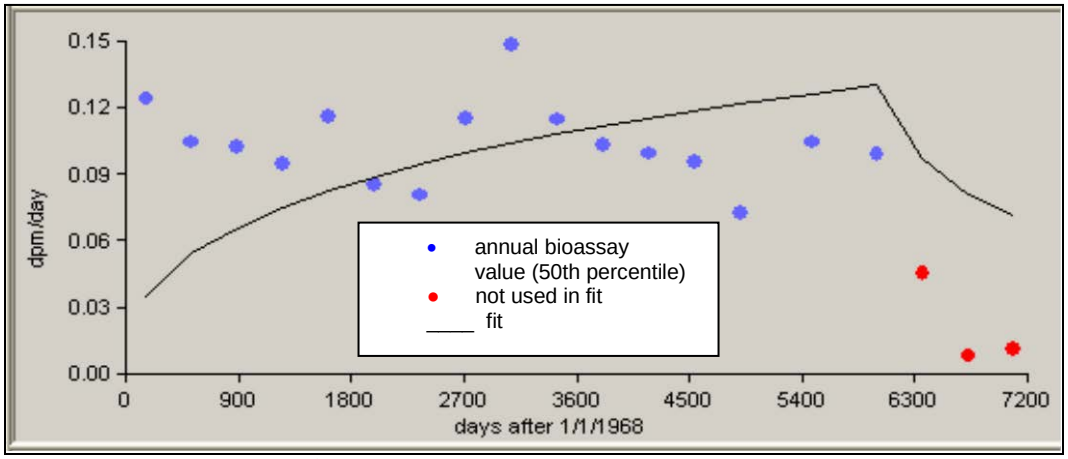

Figure A-28. Assumed ^{241}Am intake, 1968 to 1984, 50th-percentile results, Type M.

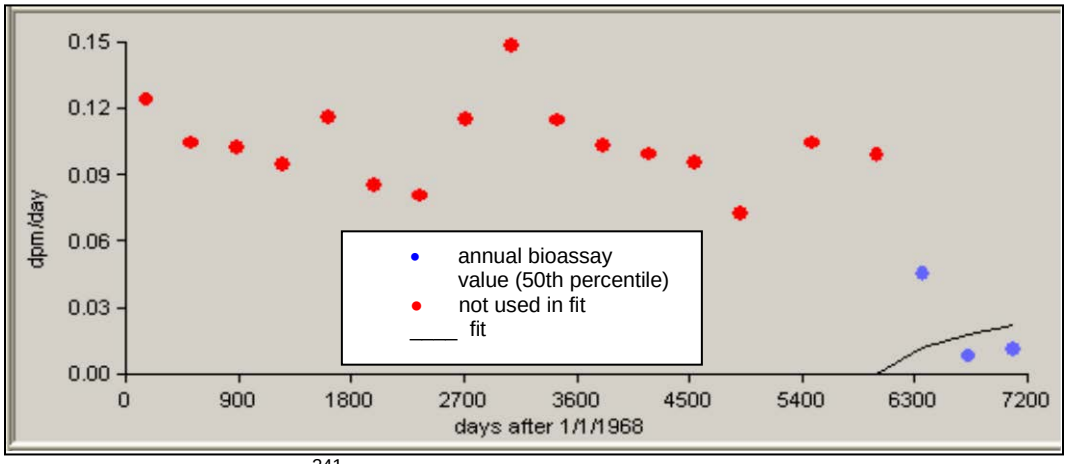

Figure A-29. Assumed ^{241}Am intake, 1985 to 1988, 50th-percentile results, Type M.

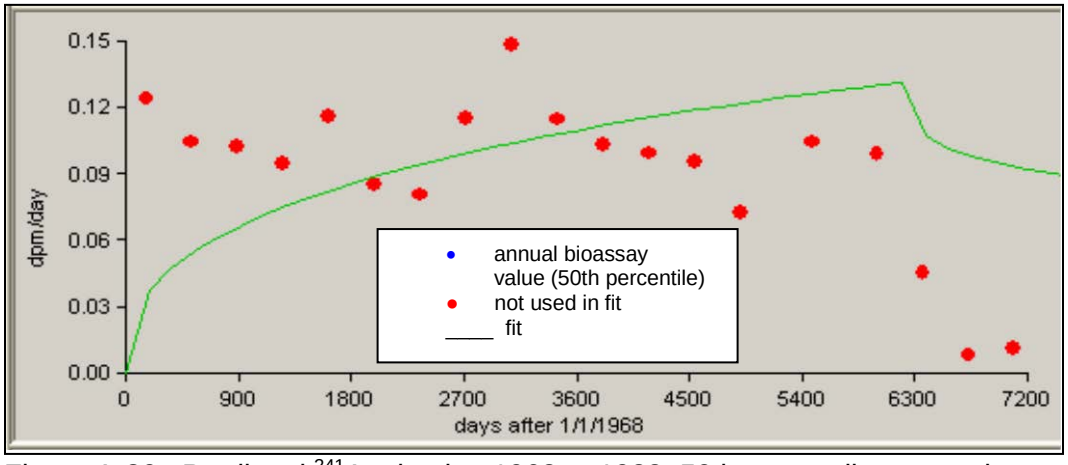

Figure A-30. Predicted ^{241}Am intake, 1968 to 1988, 50th-percentile composite results, Type M.

ATTACHMENT A
Page 23 of 23

Table A-12. Type M ^{241}Am intake periods and rates (dpm/d).

		Am-241 intake rate		
Start	**Stop**	**50th percentile**	**84th percentile**	**GSD**
1968	1984	6.673	14.61	2.19
1985	1988	2.207	6.659	2.99