ORAU TEAM
Dose Reconstruction
Project for NIOSH

Oak Ridge Associated Universities | Dade Moeller | MJW Technical Services

DOE Review Release 12/18/2012

Document Title:	Document Number:	ORAUT-OTIB-0078
Internal Dosimetry Coworker Data for the Fernald Environmental Management Project	Revision:	02
	Effective Date:	12/12/2012
	Type of Document:	OTIB
	Supersedes:	Revision 01

Subject Expert(s): Matthew G. Arno and Eugene W. Potter

Approval:	Signature on File Karen S. Kent, Document Owner	Approval Date:	12/10/2012
Concurrence:	Signature on File James P. Griffin, Deputy Project Director	Concurrence Date:	12/12/2012
Concurrence:	Signature on File Edward F. Maher, Objective 3 Manager	Concurrence Date:	12/11/2012
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	12/10/2012
Approval:	Signature on File David S. Sundin, Deputy Director, DCAS	Approval Date:	12/12/2012

☐ 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
08/31/2009	00	New technical information bulletin to provide coworker data for the Fernald Environmental Management Project workers. Incorporates formal internal, NIOSH, and Advisory Board review comments. Training required: As determined by the Objective Manager. Initiated by Robert L. Morris.
06/03/2010	01	Revised to incorporate the option for dose reconstructors to use 95th percentile intake rates in response to an Advisory Board Work Group issue. No changes occurred as a result of formal internal review. Incorporates NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Robert L. Morris.
12/12/2012	02	Revision initiated to incorporate code "50" bioassay results into the modeling and utilize the latest one person–one sample modeling techniques per ORAUT-RPRT-0053, *Analysis of Stratified Coworker Datasets* in response to an Advisory Board Work Group issue. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determine by the Objective Manager. Initiated by Matthew G. Arno and Karen S. Kent.

TABLE OF CONTENTS

SECTION **TITLE** **PAGE**

LIST OF TABLES

TABLE **TITLE** **PAGE**

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

CL	censoring level
d	day
DCAS	Division of Compensation Analysis and Support
DOE	U.S. Department of Energy
FEMP	Fernald Environmental Management Project
GSD	geometric standard deviation
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
L	liter
mL	milliliter
NIOSH	National Institute for Occupational Safety and Health
OPOS	one person–one sample
ORAU	Oak Ridge Associated Universities
pCi	picocurie
ROS	regression on order statistics
TIB	technical information bulletin
SRDB Ref ID	Site Research Database Reference Identification (number)
U.S.C.	United States Code
µg	microgram
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)].

Some employees at DOE sites were not monitored for internal ionizing radiation exposure, or the monitoring records are incomplete or unavailable. In such cases, data from monitored coworkers can be used to estimate an individual’s possible exposure. The purpose of this TIB is to provide monitored coworker information for calculating and assigning occupational internal doses to employees at the Fernald Environmental Management Project (FEMP) for whom there are no or insufficient bioassay monitoring records. FEMP was previously known as the Feed Materials Production Center.

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 6.0.

2.0 DATA AND METHOD OVERVIEW

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment* (ORAUT 2005) describes the general process that is used to analyze bioassay data for assigning doses to individuals based on coworker results. ORAUT-PLAN-0014, *Coworker Data Exposure Profile Development* (ORAUT 2004a) describes the approach and processes to be used to develop reasonable exposure profiles based on available dosimetric information for workers at DOE sites.

2.1 BIOASSAY DATA SELECTION

The bioassay results for this analysis were obtained by extracting data from HIS-20_ORAU, a database of FEMP bioassay results (ORAUT 2007a). One of the database tables, HIS20_V_BIOASSAY, contains results for urinalyses, fecal analyses, and *in vivo* analyses starting in 1952. The radionuclides in the table include ^{228}Ac, ^{36}Cl, ^{137}Cs, ^{3}H, ^{210,211}Pb, ^{210}Po, ^{239}Pu, ^{226,228}Ra, ^{90}Sr, ^{228,230,232}Th, ^{234,235,238}U, and total uranium. The vast majority of data in the table concerns the uranium radionuclides. Data were extracted from the HIS20_V_BIOASSAY table using the field criterion in Table 2-1.

Table 2-1. Criteria applied to extract for uranium bioassay data.

Field name	Field value
TYPE_BIOASSAY	URINALYSIS
NUC_NAME	U-TOTAL or ^{238}U
SAMPLE_TYPE	Not equal to 10, 5C, 70, VF, VR, VE
ACT_UNITS_SU	µg/L

Samples with code 10 and 70 were collected before employment or reemployment to establish the background for the individual and as such are not appropriate for use in a study to establish intake potential. Samples with code 5C were collected to test for possible correlation with abnormal clinical lab findings. The V series (VF, VR, and VE) are visitor samples and likely not representative of the typical worker (ORAUT 2004b). All results in this series were less than the minimum detectable activity. Of the 403,159 uranium urinalysis results not excluded as discussed above, 144 had results of “N/A”; all these results were discarded. The remaining 403,015 sample results were evaluated using the one person–one sample (OPOS) methodology (ORAUT 2012), which yielded 86,964 OPOS results.

2.2 METHOD DESCRIPTION

The reporting methods for bioassay results changed as a function of time. Before 1986 and after 1997, the data appears to be uncensored. That is, the analytical result is reported regardless of magnitude. From 1986 through 1993 the minimum reported value incrementally changed from 3 µg/L to a maximum of 14 µg/L. Table 2-2 lists the reporting levels as a function of time. Part of this change, and especially for 1991 through 1993, appears to be a refinement of the quantification of the detection capabilities of the methods and a change from reporting all results to results at or above the decision level and then to reporting only results above the minimum detectable activity. This censoring of results below a given level will skew the results of the calculated fits, resulting in values that are biased high. Figure 2-1 depicts how recalculating the results for 1986 with varying censoring levels (CLs) alters the Rank Order Statistics (ROS) fits. The original censoring level (lowest line) was 3 µg/L.

Table 2-2. Reporting level.

From	To	CL (µg/L)
Earliest	01/28/86	Uncensored
01/29/86	12/30/88	3
01/01/89	09/17/90	5
09/18/90	10/31/90	8
11/01/90	02/08/91	9
02/09/91	03/04/91	8
03/05/91	04/15/91	7
04/16/91	06/26/91	8
06/27/91	08/03/91	9
08/04/91	12/11/91	10
12/12/91	01/08/92	9
01/09/92	02/12/92	10
02/13/92	04/22/92	11
04/23/92	08/27/92	12
08/28/92	11/30/93	14
12/01/93	06/02/97	0.8
06/03/97	End	Uncensored

The higher results in 1991 through 1993 are believed to be a result of the higher CLs in those years. In 1992 and 1993, over 99% of the results are censored. In 1991, there appear to have been at least 7 censoring levels used that varied with time, resulting in uncertainty regarding what results are censored. The results for all three of these years are inconsistent with the results for years before or after this time period. During this period, uranium production at Fernald ceased and it began the process of site closure. Therefore, the potential for exposure was lower due to the lower production levels and the fact that site closure had not begun. Therefore, the results for 1991 through 1993 have been excluded from the intake modeling.

The excretion rates for each sample were normalized to represent 24-hour samples assuming 1,400 mL/d urine excretion, which is the daily volume that is excreted by Reference Man in International Commission on Radiological Protection (ICRP) Publication 23 (ICRP 1975). Then the intakes that would result in the observed excretion rates were inferred using the Integrated Modules for Bioassay Analysis (IMBA) computer program as described in Section 4.0.

The uranium in urine bioassay data from the HIS-20_ORAU database were chronologically grouped into annual intervals by calendar year. The data in each year were fit to a lognormal distribution as described in Section 3.0. The analysis of the fits resulted in calculated excretion rates at the 50th- and 84th-percentile values at the midpoint date of the analysis interval as shown in Table 2-3.

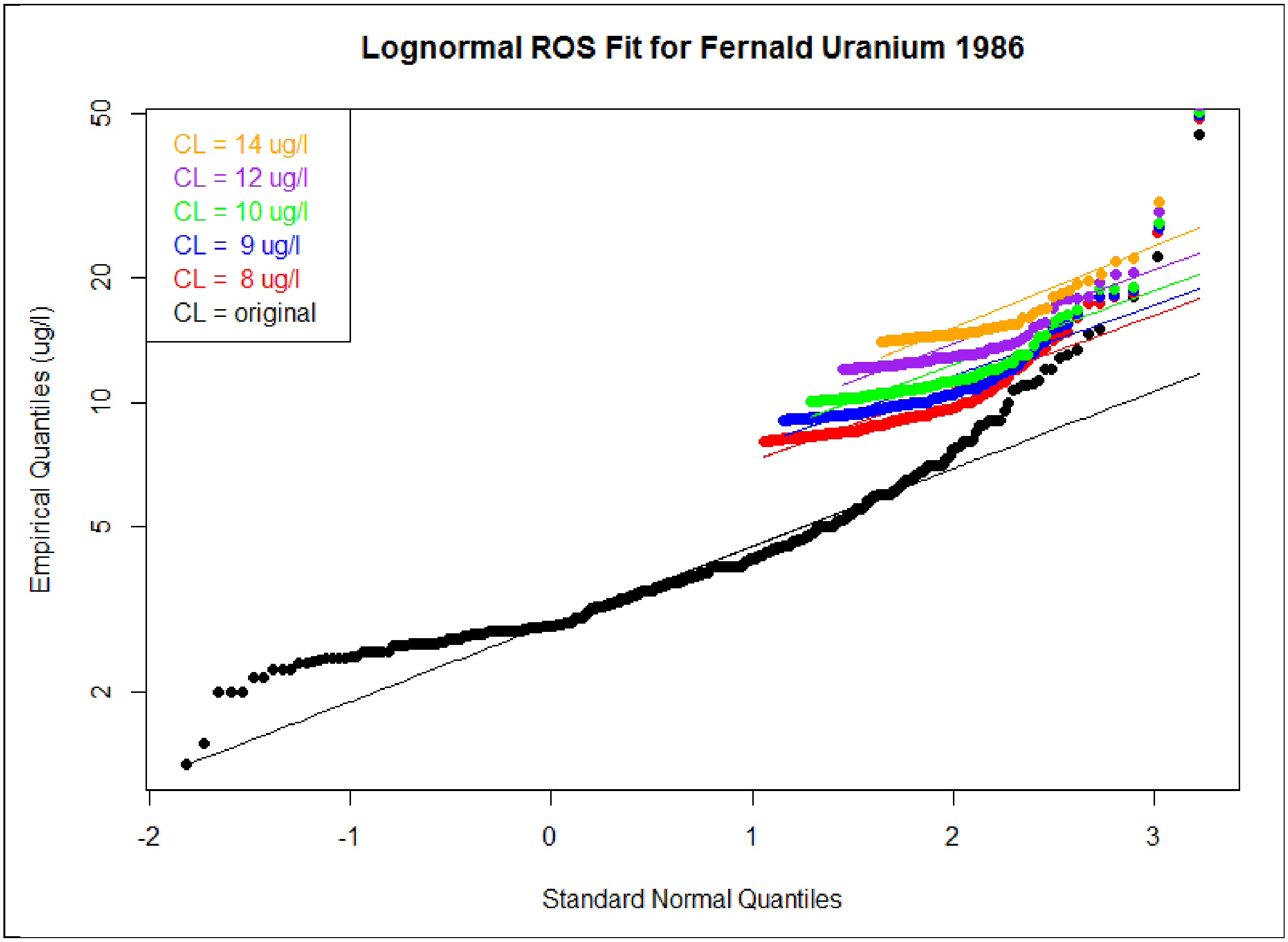

Figure 2-1. Change in lognormal fit for various CLs.

Table 2-3. Summary of uranium urinary excretion rate analyses, 1952 to 2006.

Year	Effective bioassay date	Number of OPOS results	50th percentile (µg/d)	84th percentile (µg/d)
1952	07/01/1952	71	22.30	69.16
1953	07/01/1953	701	18.82	55.73
1954	07/01/1954	1,376	22.08	60.42
1955	07/01/1955	1,973	46.62	116.98
1956	07/01/1956	2,497	26.85	68.80
1957	07/01/1957	2,937	18.27	50.25
1958	07/01/1958	2,485	13.67	34.01
1959	07/01/1959	2,540	13.34	28.45
1960	07/01/1960	2,630	17.61	32.79
1961	07/01/1961	2,395	19.05	33.62
1962	07/01/1962	2,131	12.82	25.14
1963	07/01/1963	1,983	12.99	25.70
1964	07/01/1964	1,900	11.74	24.50

Year	Effective bioassay date	Number of OPOS results	50th percentile (µg/d)	84th percentile (µg/d)
1965	07/01/1965	1,663	8.21	17.65
1966	07/01/1966	1,484	9.36	23.00
1967	07/01/1967	1,602	6.78	15.44
1968	07/01/1968	1,398	6.07	13.85
1969	07/01/1969	1,281	5.53	12.96
1970	07/01/1970	1,119	4.51	9.95
1971	07/01/1971	881	5.30	11.75
1972	07/01/1972	634	4.65	12.14
1973	07/01/1973	735	5.03	11.83
1974	07/01/1974	678	4.99	11.42
1975	07/01/1975	697	5.00	10.83
1976	07/01/1976	697	4.90	10.47
1977	07/01/1977	664	4.80	10.02
1978	07/01/1978	644	5.17	10.32
1979	07/01/1979	599	5.26	10.52
1980	07/01/1980	893	5.40	12.23
1981	07/01/1981	623	2.89	7.13
1982	07/01/1982	262	5.42	10.44
1983	07/01/1983	785	3.77	8.85
1984	07/01/1984	696	4.71	10.93
1985	07/01/1985	858	4.63	9.07
1986	07/01/1986	1,565	4.07	6.27
1987	07/01/1987	1,611	2.82	5.48
1988	07/01/1988	1,609	2.92	4.75
1989	07/01/1989	2,029	1.28	2.98
1990	07/01/1990	2,044	5.51	7.21
1991	07/01/1991	2,163	12.12	12.63
1992	07/01/1992	2,803	10.47	12.50
1993	07/01/1993	3,166	12.07	13.97
1994	07/01/1994	2,817	0.195	0.426
1995	07/01/1995	2,901	0.279	0.536
1996	07/01/1996	2,298	0.111	0.338
1997	07/01/1997	2,159	0.232	0.722
1998	07/01/1998	2,382	0.021	0.071
1999	07/01/1999	2,351	0.025	0.070
2000	07/01/2000	2,076	0.034	0.097
2001	07/01/2001	1,809	0.065	0.145
2002	07/01/2002	1,835	0.062	0.130
2003	07/01/2003	1,787	0.056	0.134
2004	07/01/2004	1,217	0.058	0.115
2005	07/01/2005	1,040	0.091	0.167
2006	07/01/2006	790	0.082	0.154

3.0 ANALYSIS

Bioassay data statistics were generated for each analysis interval. A lognormal distribution was assumed [1]. After log-transforming the data, the 50th- and 84th-percentile values were determined for each period using the method in ORAUT (2006). Table 2-3 shows the statistical analysis results for uranium urinary excretion parameters.

4.0 INTAKE MODELING

This section discusses intake modeling assumptions and intake fitting for three different material types of uranium compounds.

4.1 ASSUMPTIONS

Each result in the intake calculations was assumed to have normal distribution [2]. A uniform absolute error of 1 was applied to all results to assign the same weight to each result. Because of the nature of work at FEMP, it is possible that intakes could have been either chronic or acute. However, a series of acute intakes can be approximated as a chronic intake. Therefore, intakes were assumed to be chronic and to occur through inhalation using a default breathing rate of 1.2 m^3/hr and a particle size distribution of 5 μm activity median aerodynamic diameter (ICRP 1995).

4.2 BIOASSAY FITTING

The IMBA computer program was used to fit the bioassay results to a series of inhalation intakes. Data from 1952 through 2006 were fit as a series of chronic intakes. The intake assumptions were based on observed patterns in the bioassay data. Periods with constant chronic intake rates were chosen by selecting periods where the bioassay results were similar. A new chronic intake period was started if the data indicated a significant and sustained change in the bioassay results. By this method, the period 1952 through 2006 was divided into multiple chronic intake periods.

Because the uranium isotopes at FEMP have long radiological half-lives and the material is retained in the body for long periods, excretion results are not independent. For example, an intake in the 1950s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at FEMP for relatively short periods, each chronic intake was fit independently using only the bioassay results from the single intake period for type S solubility. For types M and F solubility, this approach was used where it was determined that earlier intake rates significantly biased later intake rates, i.e., 1994 through 2006 was evaluated separately from earlier time periods. This method results in a potential overestimate of intakes for exposures that extend through multiple assumed intake periods. Uranium urinalysis results were analyzed with IMBA to derive intake rates for 1952 to 2006. Attachment A contains the plots that compare predicted uranium bioassay results based on IMBA-derived uranium intake rates with the measured urine results.

5.0 ASSIGNING INTAKES AND DOSES

This section describes the derived intake rates and provides guidance for assigning doses. For each intake period below, the geometric standard deviations (GSDs) were determined by dividing the 84th-percentile intake rates by the 50th-percentile rates. For the calculation of doses to individuals from bioassay data, a GSD of 3 is used to account for biological variation and uncertainty in the models (ORAUT 2007b). The same models are used for fitting the coworker data, so the same uncertainty applies. Therefore, a minimum GSD of 3 was assigned for each of the intake periods.

5.1 INTAKE RATE SUMMARY

Multiple intake periods were fit to the derived 50th- and 84th-percentile uranium excretion data. Table 5-1 summarizes the 50th- and 95th-percentile uranium intake rates that correspond to an intake of type F materials that was inferred from the excretion rates. The 95th-percentile intake rates were calculated using the following equation: $\textit{95th-percentile intake} = \textit{50th-percentile intake} \times GSD^{1.645}$. Table 5-2 lists the same information for type M materials, and Table 5-3 lists the information for type S materials. Periods with the same intake rate and GSD were combined for clarity. For periods after 2006 in which intakes were feasible, dose reconstructors should assume the 2006 intake rates.

5.2 DOSE ASSIGNMENT

For most cases, individual doses should be calculated from the 50th-percentile intake rates. For cases where there is justification that the individual may have had larger intakes than the 50th-percentile intake rates, dose reconstructors should use the

Table 5-1. Derived FEMP uranium intake rates for type F materials, 1952 to 2006.

Dates	50th percentile (µg/d)	50th percentile (pCi/d)[a]	GSD	95th percentile (µg/d)	95th percentile (pCi/d)[a]
01/01/52–12/31/54	77.6	53.0	3.00	473	323
01/01/55–12/31/55	171.9	117	3.00	1,047	715
01/01/56–12/31/56	97.17	66.4	3.00	592	404
01/01/57–12/31/57	58.81	40.2	3.00	358	245
01/01/58–12/31/61	58.81	57.4	3.00	358	350
01/01/62–12/31/64	39.06	38.1	3.00	238	232
01/01/65–12/31/66	39.06	63.1	3.00	238	385
01/01/67–12/31/93	16.14	26.1	3.00	98	159
01/01/94–12/31/06	0.365	0.590	3.00	2.22	3.59

a. The specific activities used to compute this column were 0.683 pCi/µg (natural uranium) for 1952 through 1957, 0.976 pCi/µg (1% enrichment) for 1958 through 1964, and 1.616 pCi/µg (2% enrichment) for 1965 to the present.

Table 5-2. Derived FEMP uranium intake rates for type M materials, 1952 to 2006.

Dates	50th percentile (µg/d)	50th percentile (pCi/d)[a]	GSD	95th percentile (µg/d)	95th percentile (pCi/d)[a]
01/01/52–12/31/54	334	228	3.00	2,035	1,390
01/01/55–12/31/55	770.4	526	3.00	4,694	3,206
01/01/56–12/31/56	339.5	232	3.00	2,069	1,413
01/01/57–12/31/57	235.7	161	3.00	1,436	981
01/01/58–12/31/61	235.7	230	3.00	1,436	1,402
01/01/62–12/31/64	156.8	153	3.00	955	933
01/01/65–12/31/66	156.8	253	3.00	955	1,544
01/01/67–12/31/93	65.17	105	3.00	397	642
01/01/94–12/31/06	1.487	2.40	3.00	9.06	14.6

a. The specific activities used to compute this column were 0.683 pCi/µg of natural uranium for 1952 through 1957, 0.976 pCi/µg (1% enrichment) for 1958 through 1964, and 1.616 pCi/µg of 2% enrichment uranium for 1965 to the present.

Table 5-3. Derived FEMP uranium intake rates for type S materials, 1952 to 2006.

Dates	50th percentile (µg/d)	50th percentile (pCi/d)[a]	GSD	95th percentile (µg/d)	95th percentile (pCi/d)[a]
01/01/52–12/31/54	7,393	5,049	3.00	45,049	30,768
01/01/55–12/31/55	26,230	17,915	3.00	159,832	109,165
01/01/56–12/31/56	15,080	10,300	3.00	91,889	62,761
01/01/57–12/31/57	4,681	3,197	3.00	28,524	19,482
01/01/58–12/31/61	4,681	4,569	3.00	28,524	27,839
01/01/62–12/31/64	2,999	2,927	3.00	18,274	17,836
01/01/65–12/31/66	2,999	4,846	3.00	18,274	29,531
01/01/67–12/31/93	799.1	1,291	3.00	4,869	7,869
01/01/94–12/31/06	17.84	28.8	3.00	108.7	176

a. The specific activities used to compute this column were 0.683 pCi/µg of natural uranium for 1952 through 1957, 0.976 pCi/µg (1% enrichment) for 1958 through 1964, and 1.616 pCi/µg of 2% enrichment uranium for 1965 to the present.

95th-percentile intake rates applicable to the solubility class of the material from Table 5-1, 5-2, or 5-3, as appropriate. Dose reconstructors should select the material type that is the most favorable to claimants and apply other recycled uranium component calculations that are required by other TIBs and procedures.

Select the lognormal distribution in the Interactive RadioEpidemiological Program (IREP) with the calculated dose entered as Parameter 1 and the associated GSD as Parameter 2. The GSD relates to the intake, so apply it to all annual doses that are determined from the intake period. If used, assign the 95th-percentile intakes as a constant distribution.

6.0 ATTRIBUTIONS AND ANNOTATIONS

Where appropriate in this document, bracketed callouts have been inserted to indicate information, conclusions, and recommendations provided to assist in the process of worker dose reconstruction. These callouts are listed here in the Attributions and Annotations section, with information to identify the source and justification for each associated item. Conventional References, which are provided in the next section of this document, link data, quotations, and other information to documents available for review on the Project's Site Research Database (SRDB).

[1] Arno, Matthew. Oak Ridge Associated Universities (ORAU) Team. Dose Reconstructor. June 18, 2007.
Lognormal distributions typically provide the best fit to the available data and are a distribution suitable for input into IREP.

[2] Arno, Matthew. ORAU Team. Dose Reconstructor. June 18, 2007.
The error in individual bioassay results has a normal distribution because the dominant source of uncertainty is the counting statistics. Although the underlying group statistics have normal distribution, each result was treated as if it had a normal distribution to match what was done for analysis of an individual's bioassay data and because the lognormal distribution of the data is addressed by analyzing both the 50th and 84th percentiles of the data.

REFERENCES

ICRP (International Commission on Radiological Protection), 1975, *Reference Man: Anatomical, Physiological, and Metabolic Characteristics*, Publication 23, Pergamon Press, Oxford, England. [SRDB Ref ID: 22735]

ICRP (International Commission on Radiological Projection), 1995, *Dose Coefficients for Intake of Radionuclides by Workers*, Publication 68, Pergamon Press, Oxford, England.

ORAUT (Oak Ridge Associated Universities Team), 2004a, *Coworker Data Exposure Profile Development*, ORAUT-PLAN-0014, Rev. 00, Oak Ridge, Tennessee, November 24.

ORAUT (Oak Ridge Associated Universities Team), 2004b, *Technical Basis Document for the Fernald Environmental Management Project (FEMP) – Occupational Internal Dose*, ORAUT-TKBS-0017-5 Rev 00, Oak Ridge, Tennessee, May 28.

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), 2006, *Generating Summary Statistics for Coworker Bioassay Data*, ORAUT-PROC-0095, Rev. 00, Oak Ridge, Tennessee, June 5.

ORAUT (Oak Ridge Associated Universities Team), 2007a, *HIS-20 Access Database for FEMP*, Oak Ridge, Tennessee. [SRDB Ref ID: 31643]

ORAUT (Oak Ridge Associated Universities Team), 2007b, *Internal Dose Reconstruction*, ORAUT-OTIB-0060, Rev. 00, Oak Ridge, Tennessee, February 6.

ORAUT (Oak Ridge Associated Universities Team), 2012, *Analysis of Stratified Coworker Datasets*, ORAUT-RPRT-0053, Rev. 01, Oak Ridge, Tennessee, July 16.

ATTACHMENT A
COWORKER DATA FIGURES
Page 1 of 10

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

This attachment shows comparisons of measured uranium urine bioassay results with predicted results that were calculated using IMBA-derived uranium intake rates. Blue dots represent the measured values that were retained for the fit. Red dots represent results that were excluded because they were outside the intake period being fit. The green lines represent the predicted values. The figures provide the fits as follows:

- Figures A-1 and A-2 show the individual fits to the 50th-percentile excretion rates for type F material.
- Figures A-3 and A-4 show the individual fits to the 84th-percentile excretion rates for type F material.
- Figures A-5 and A-6 show the individual fits to the 50th-percentile excretion rates for type M material.

ATTACHMENT A
COWORKER DATA FIGURES

- Figures A-7 and A-8 show the individual fits to the 84th-percentile excretion rates for type M material.
- Figures A-9 through A-15 show the individual fits to the 50th-percentile excretion rates for type S material. Figure A-16 summarizes the results for the period from 1952 through 2006.
- Figures A-17 through A-24 show the individual fits to the 84th-percentile excretion rates for type S material. Figure A-25 summarizes the type S results for the period from 1952 through 2006.

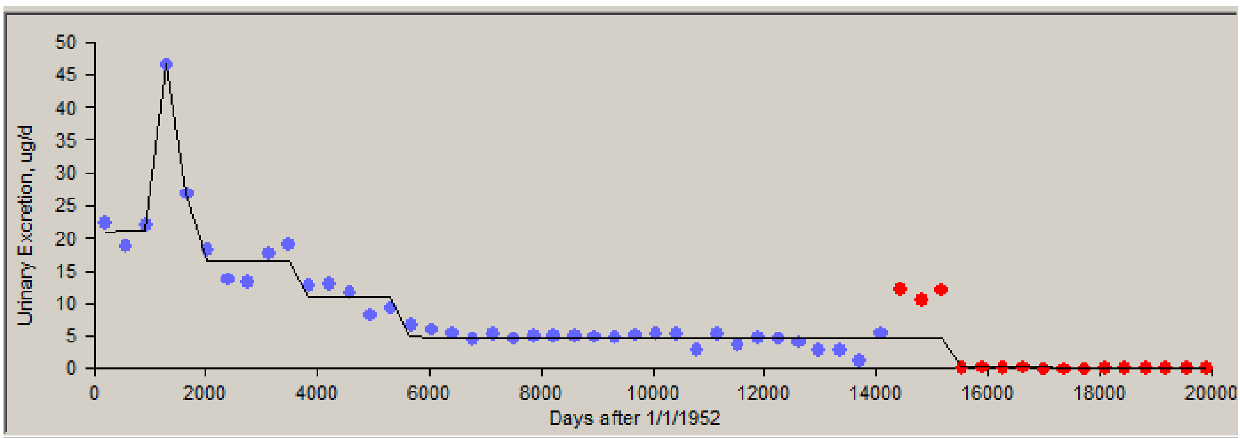

Figure A-1. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1993, 50th percentile, type F.

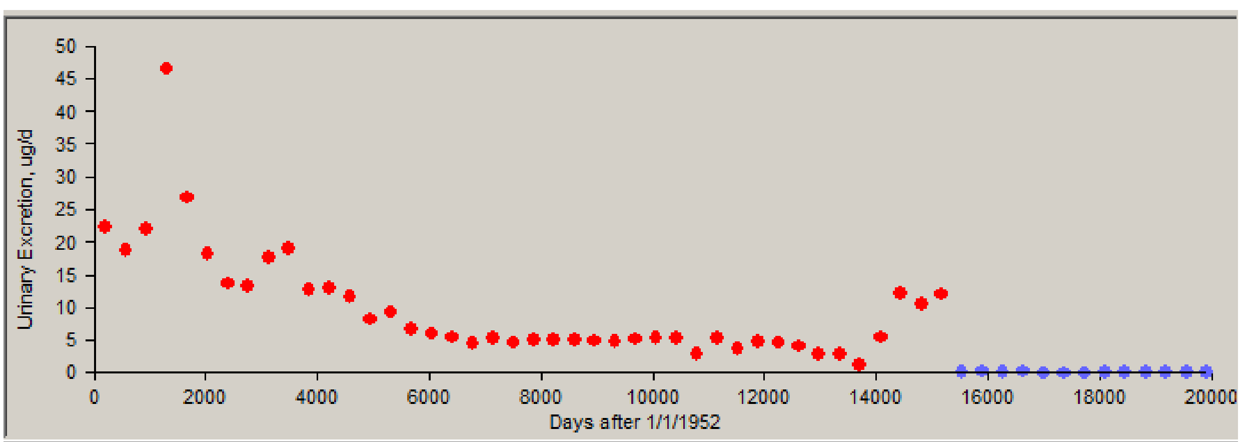

Figure A-2. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 50th percentile, type F.

ATTACHMENT A
COWORKER DATA FIGURES

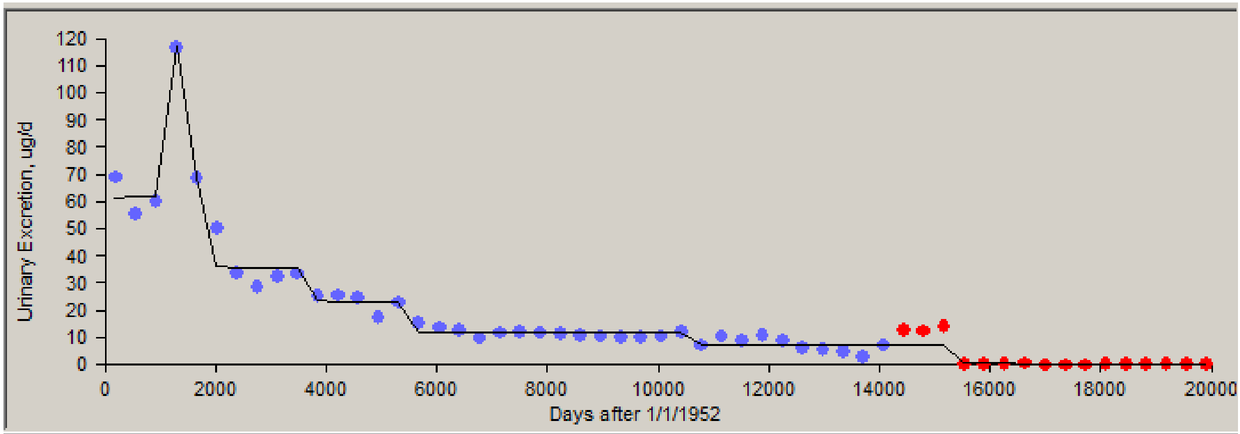

Figure A-3. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1993, 84th percentile, type F.

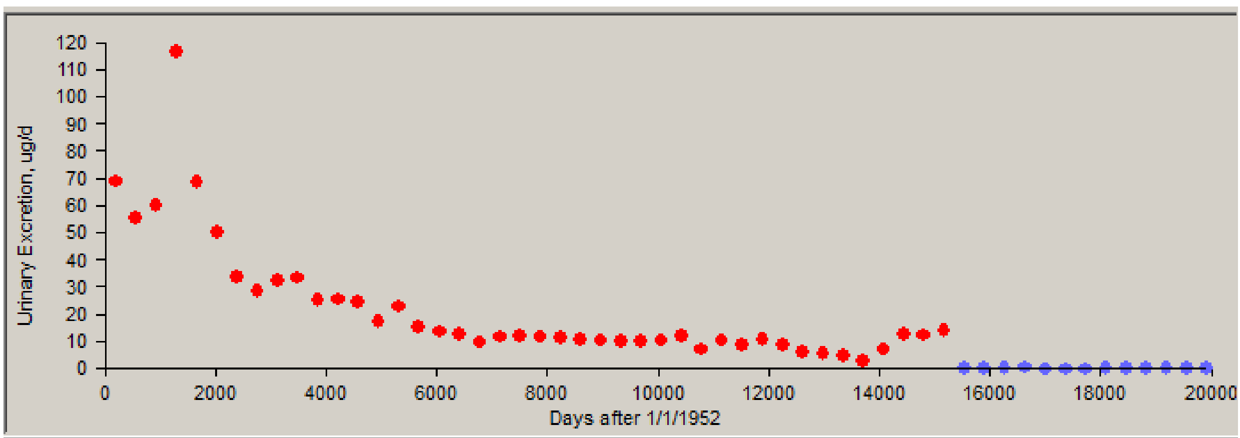

Figure A-4. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 84th percentile, type F.

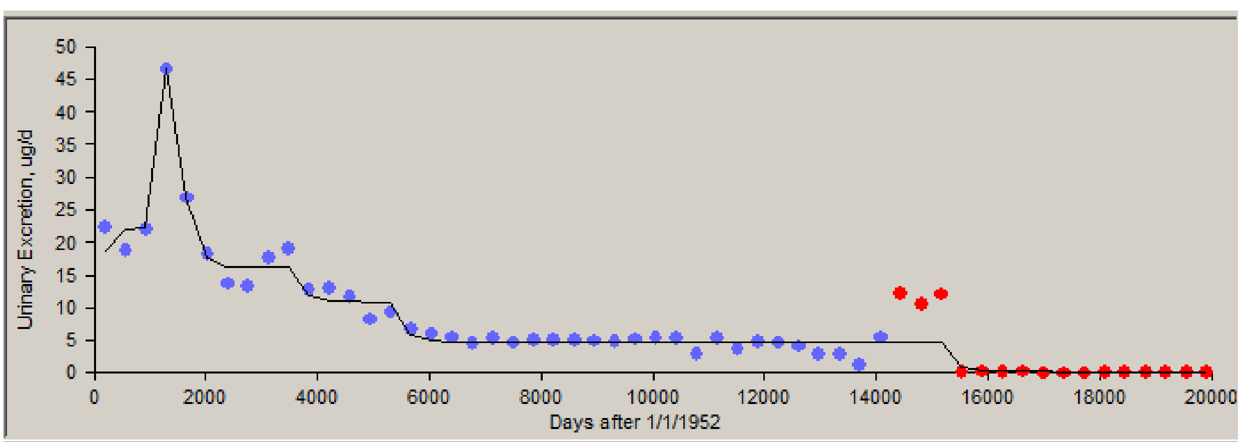

Figure A-5. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1993, 50th percentile, type M.

ATTACHMENT A
COWORKER DATA FIGURES

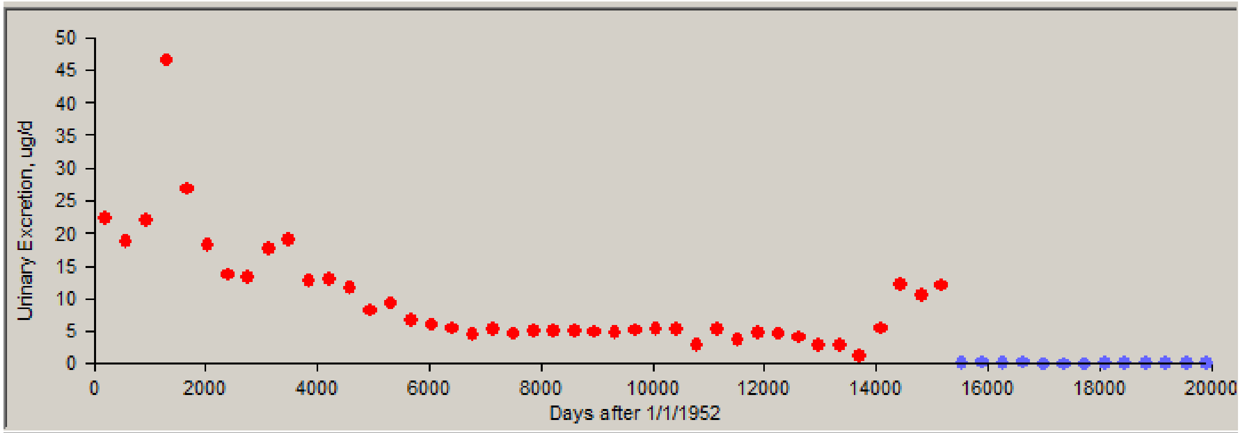

Figure A-6. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 50th percentile, type M.

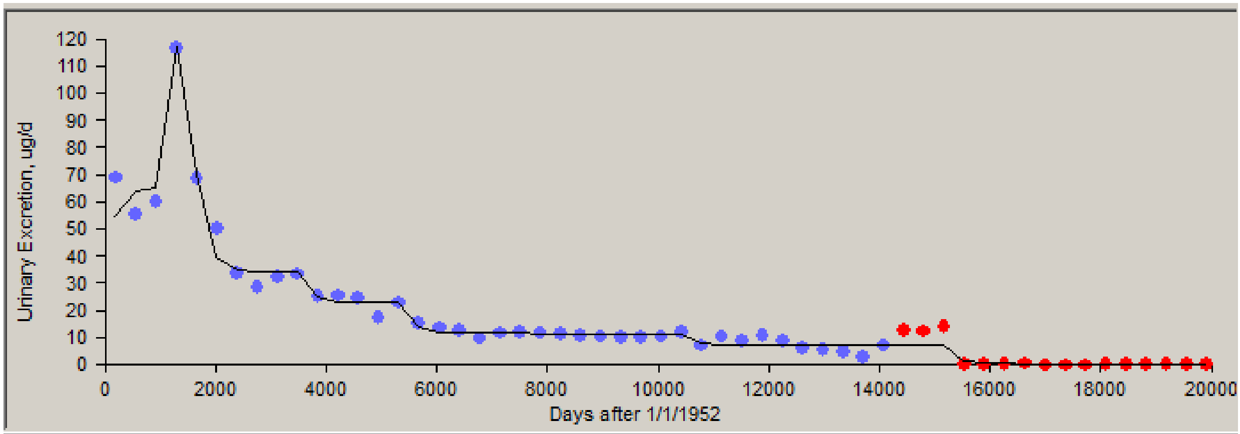

Figure A-7. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1993, 84th percentile, type M.

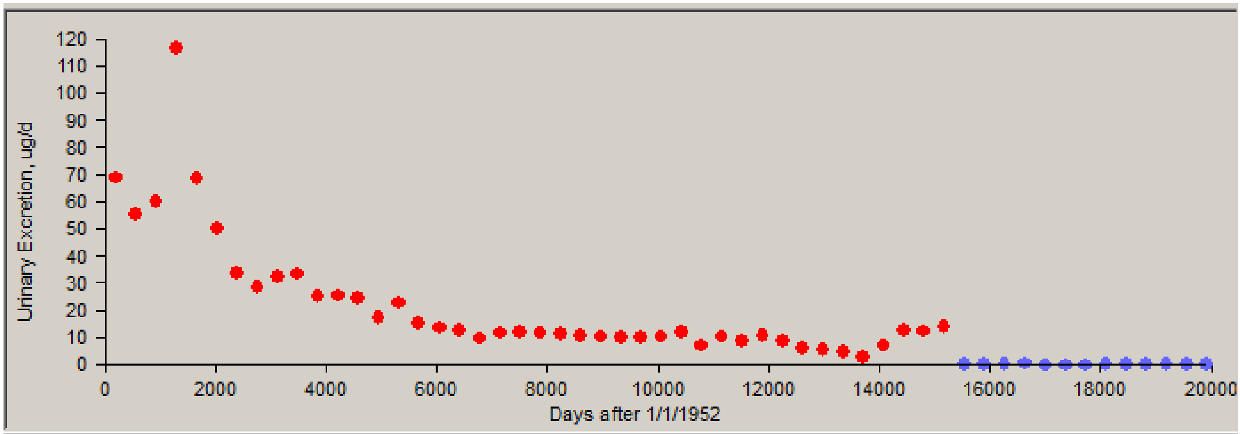

Figure A-8. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 84th percentile, type M.

ATTACHMENT A
COWORKER DATA FIGURES

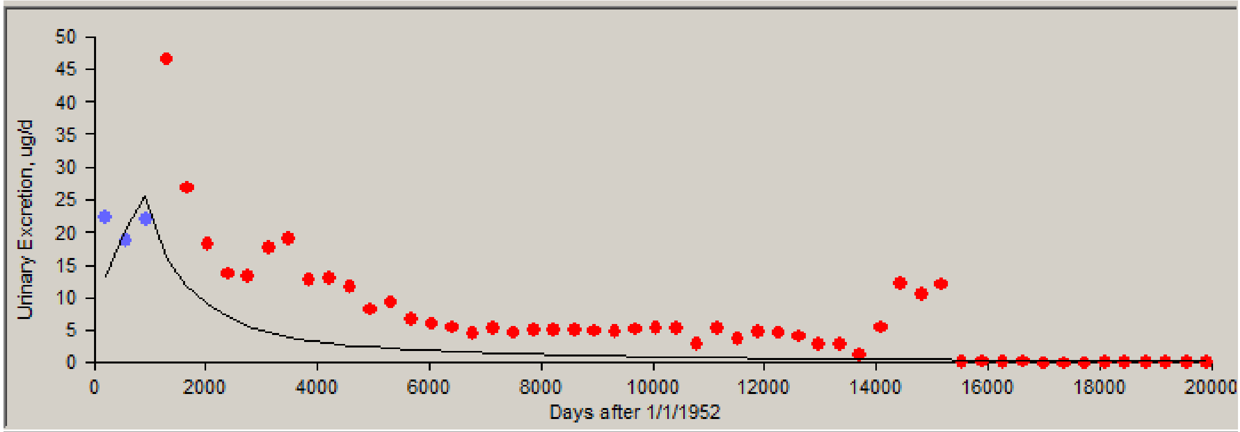

Figure A-9. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1954, 50th percentile, type S.

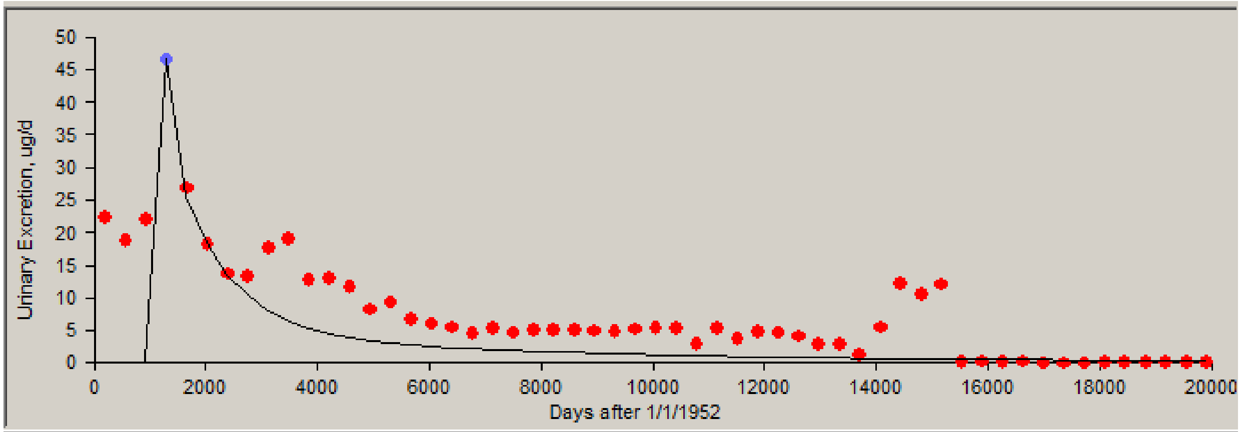

Figure A-10. Predicted values (line) versus measured results (blue dots), 01/01/1955 to 12/31/1955, 50th percentile, type S.

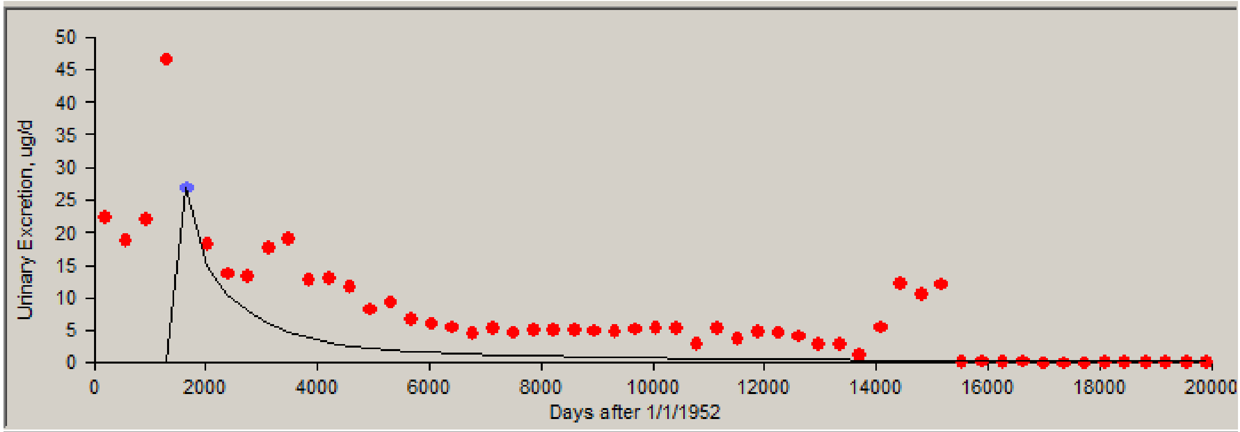

Figure A-11. Predicted values (line) versus measured results (blue dots), 01/01/1956 to 12/31/1956, 50th percentile, type S.

ATTACHMENT A
COWORKER DATA FIGURES
Page 6 of 10

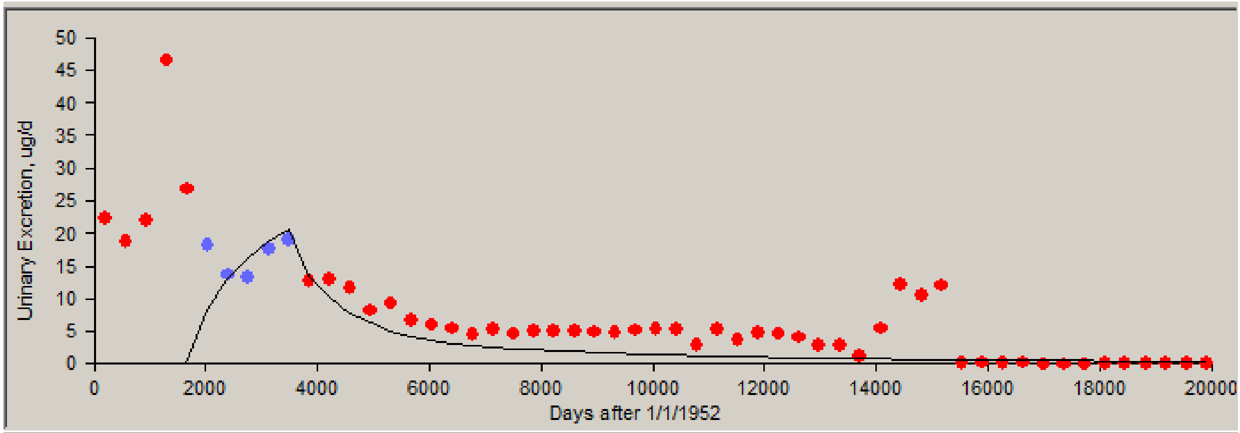

Figure A-12. Predicted values (line) versus measured results (blue dots), 01/01/1957 to 12/31/1961, 50th percentile, type S.

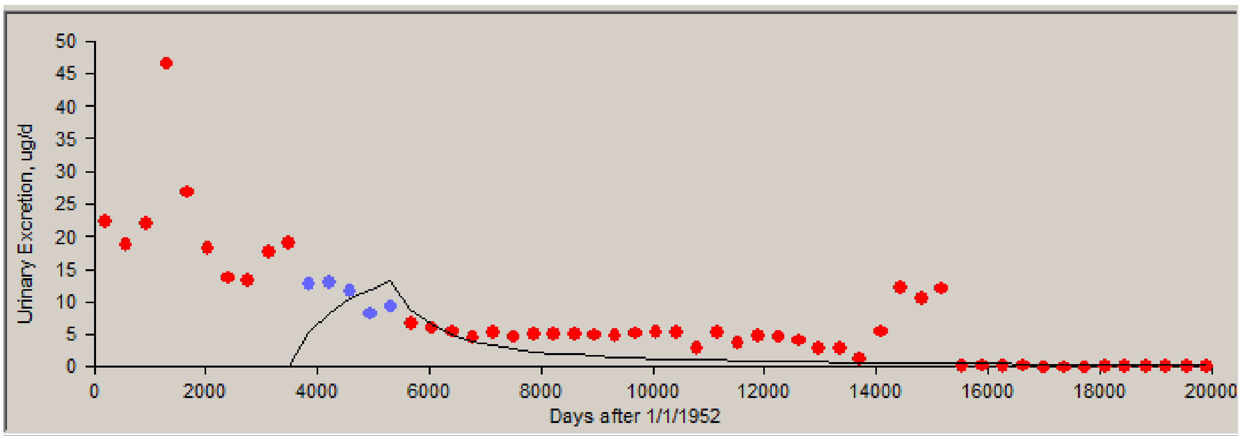

Figure A-13. Predicted values (line) versus measured results (blue dots), 01/01/1962 to 12/31/1966, 50th percentile, type S.

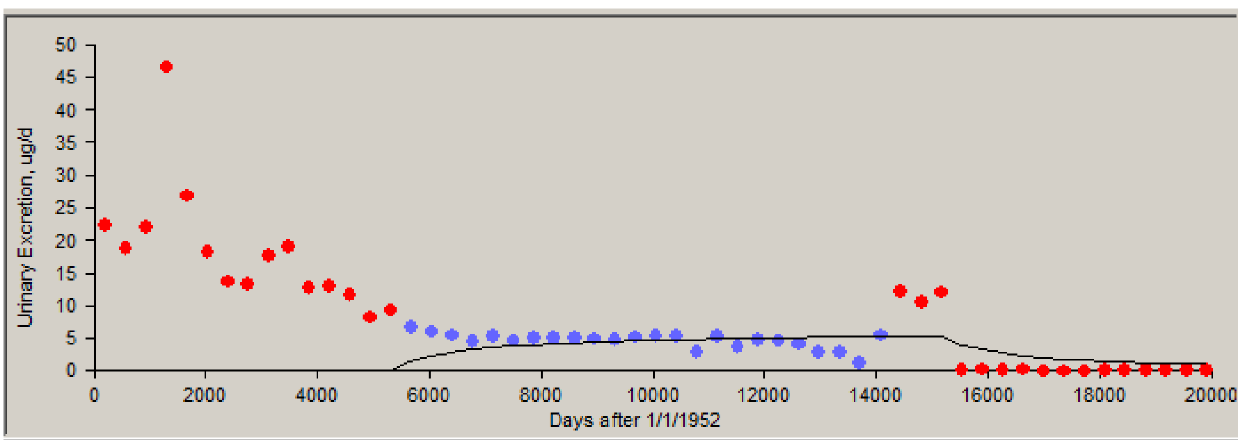

Figure A-14. Predicted values (line) versus measured results (blue dots), 01/01/1967 to 12/31/1993, 50th percentile, type S.

ATTACHMENT A
COWORKER DATA FIGURES
Page 7 of 10

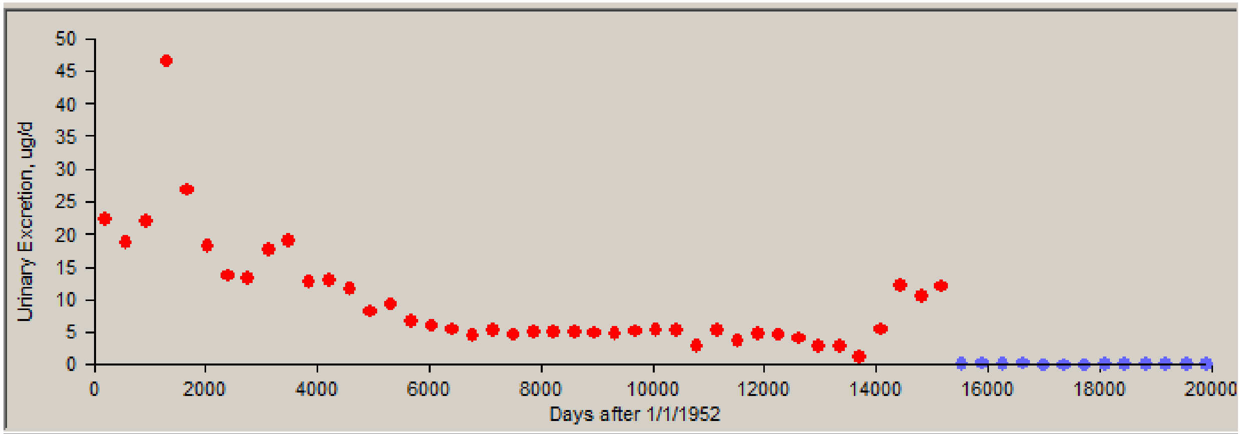

Figure A-15. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 50th percentile, type S.

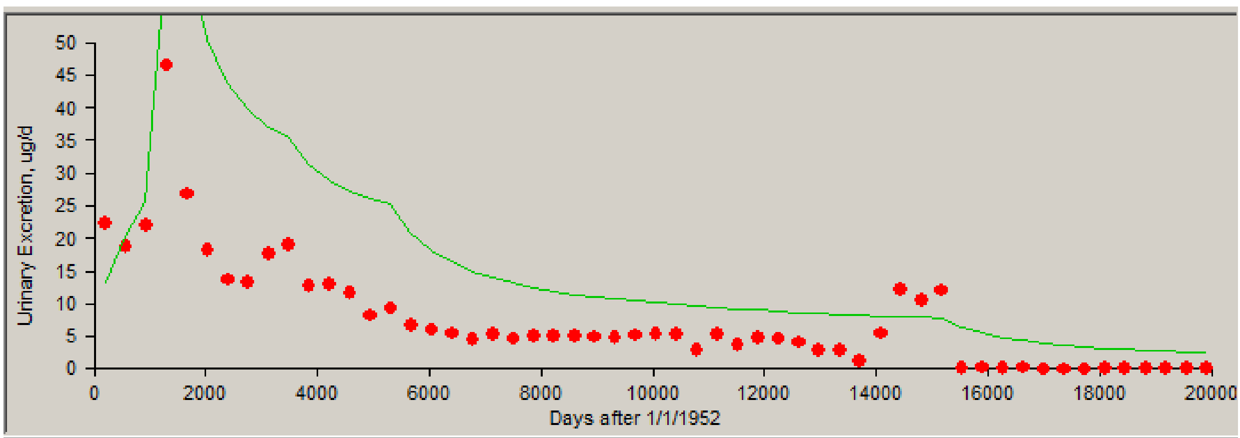

Figure A-16. Summarized results of the predicted values (line) versus the excluded results (red dots), 01/01/1952 to 12/31/2006, 50th percentile, type S.

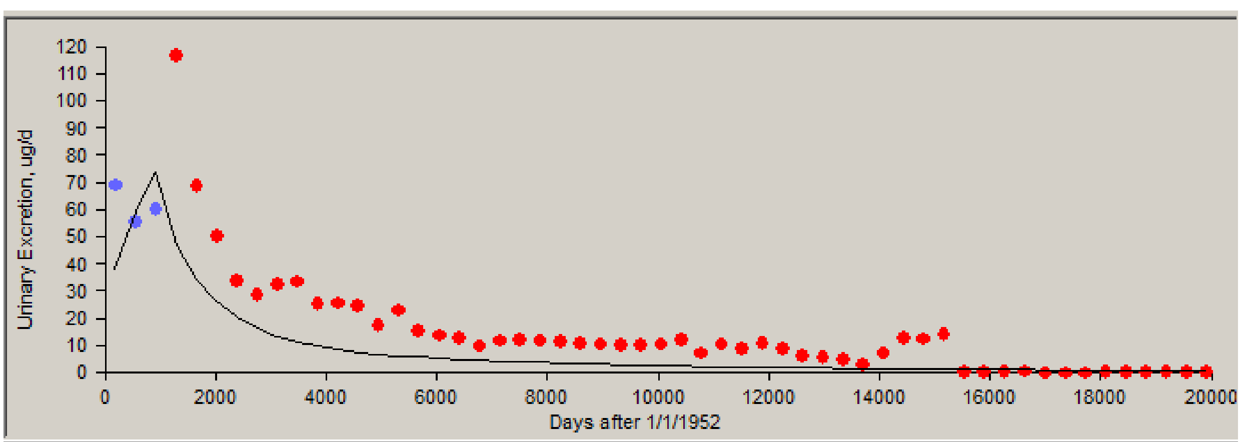

Figure A-17. Predicted values (line) versus measured results (blue dots), 01/01/1952 to 12/31/1954, 84th percentile, type S.

ATTACHMENT A
COWORKER DATA FIGURES

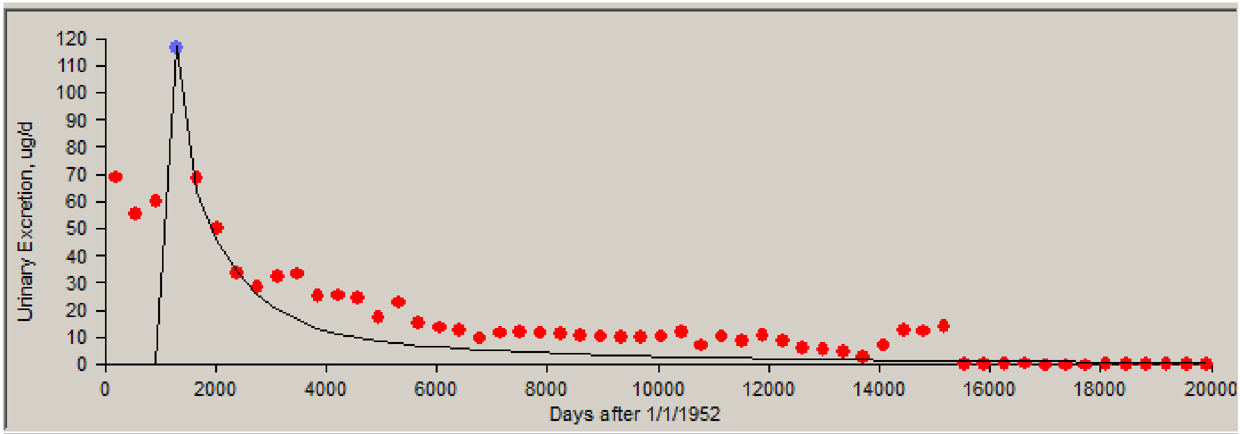

Figure A-18. Predicted values (line) versus measured results (blue dots), 01/01/1955 to 12/31/1955, 84th percentile, type S.

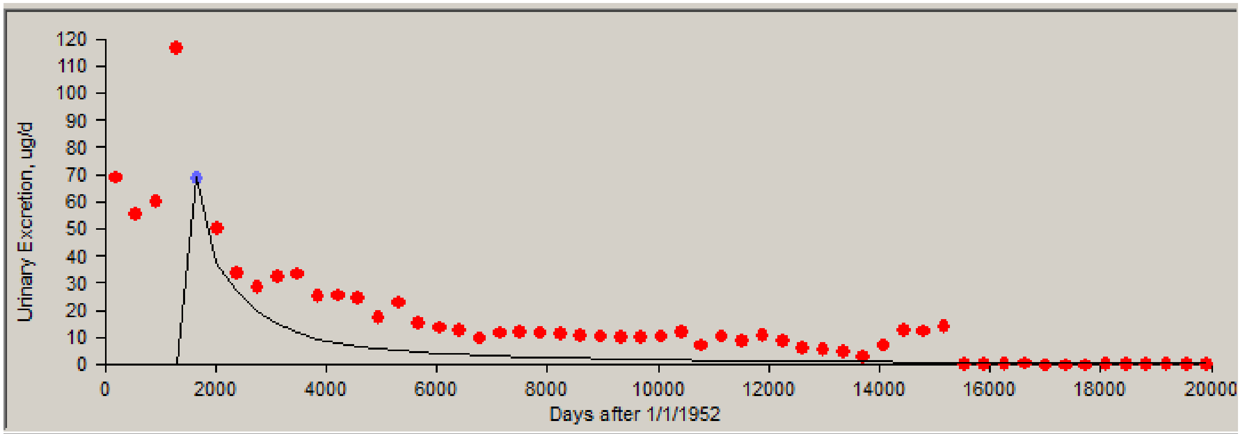

Figure A-19. Predicted values (line) versus measured results (blue dots), 01/01/1956 to 12/31/1956, 84th percentile, type S.

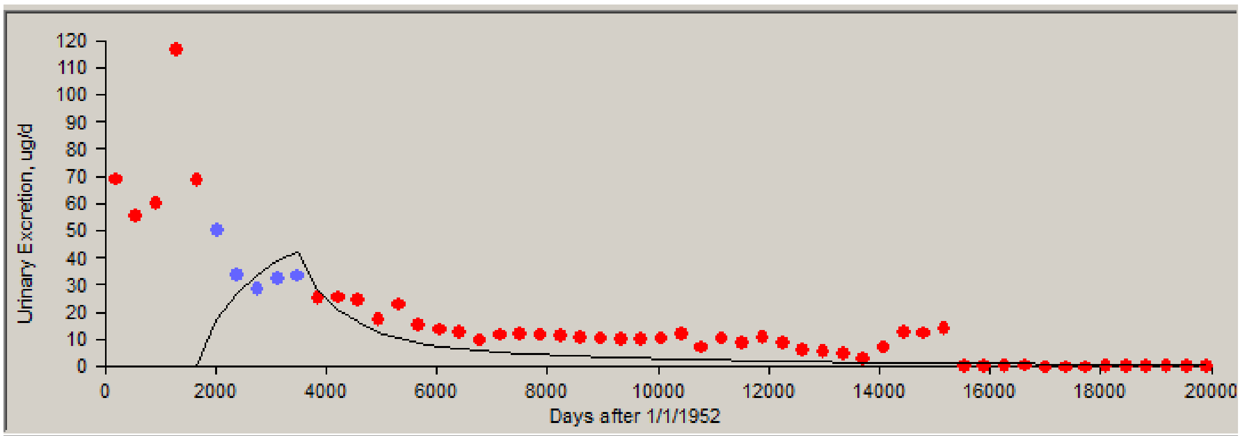

Figure A-20. Predicted values (line) versus measured results (blue dots), 01/01/1957 to 12/31/1961, 84th percentile, type S.

ATTACHMENT A
COWORKER DATA FIGURES
Page 9 of 10

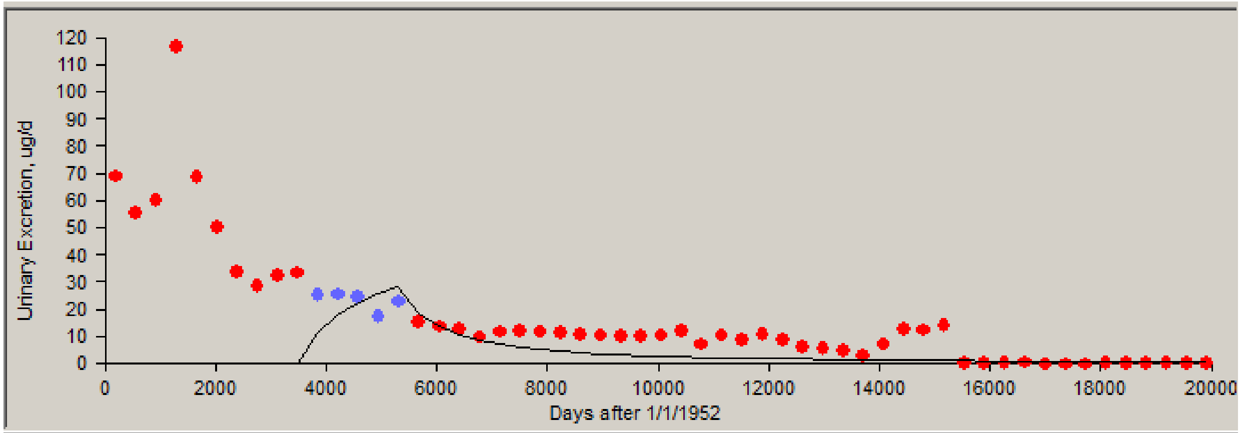

Figure A-21. Predicted values (line) versus measured results (blue dots), 01/01/1962 to 12/31/1966, 84th percentile, type S.

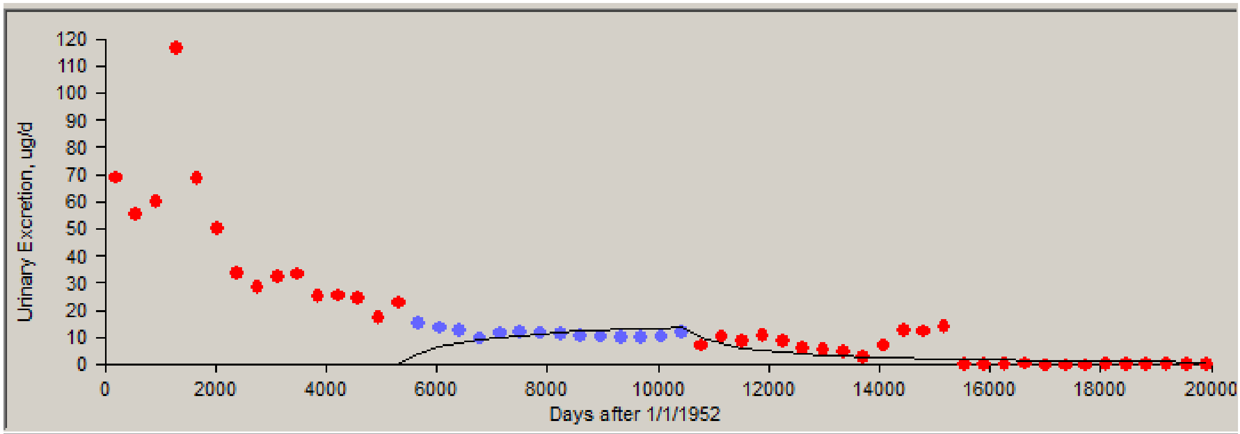

Figure A-22. Predicted values (line) versus measured results (blue dots), 01/01/1967 to 12/31/1980, 84th percentile, type S.

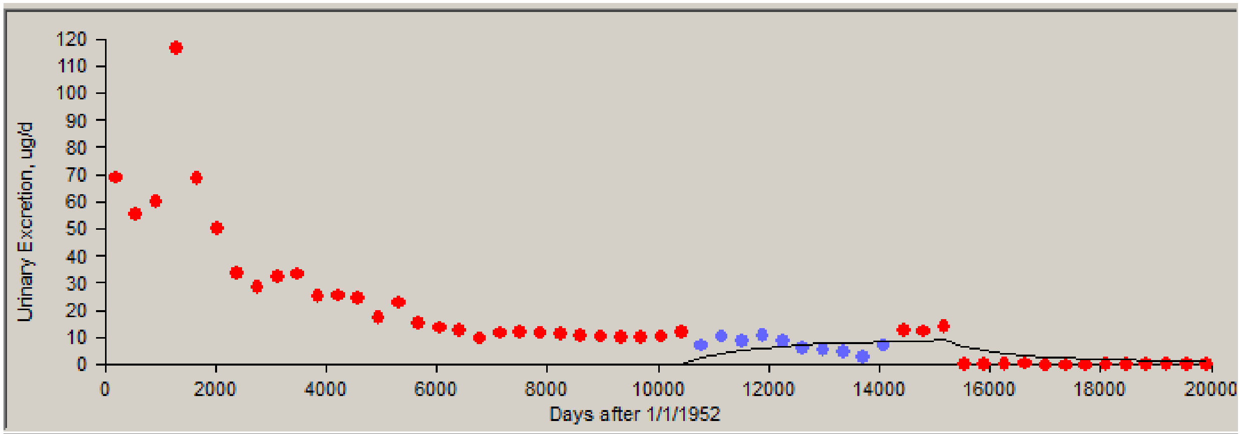

Figure A-23. Predicted values (line) versus measured results (blue dots), 01/01/1981 to 12/31/1993, 84th percentile, type S.

ATTACHMENT A
COWORKER DATA FIGURES

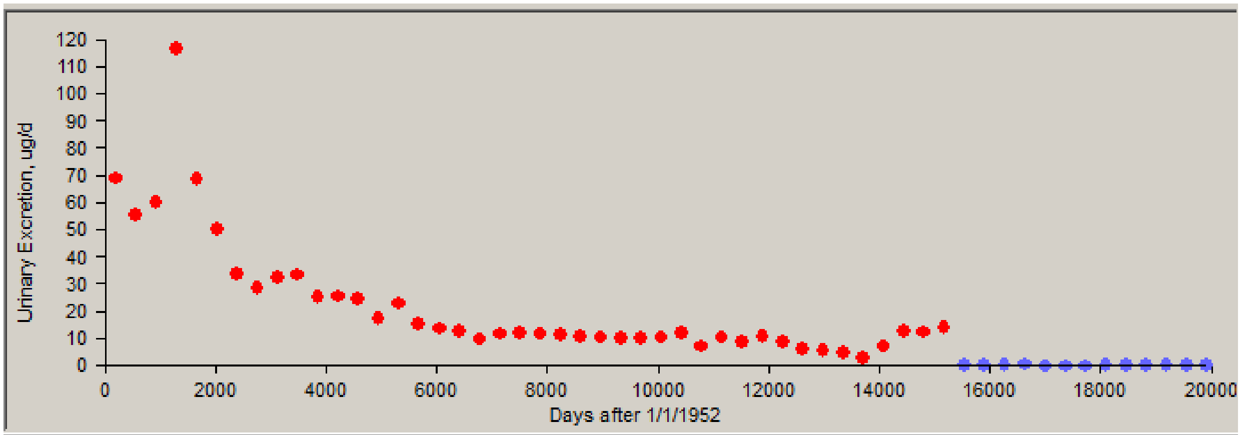

Figure A-24. Predicted values (line) versus measured results (blue dots), 01/01/1994 to 12/31/2006, 84th percentile, type S.

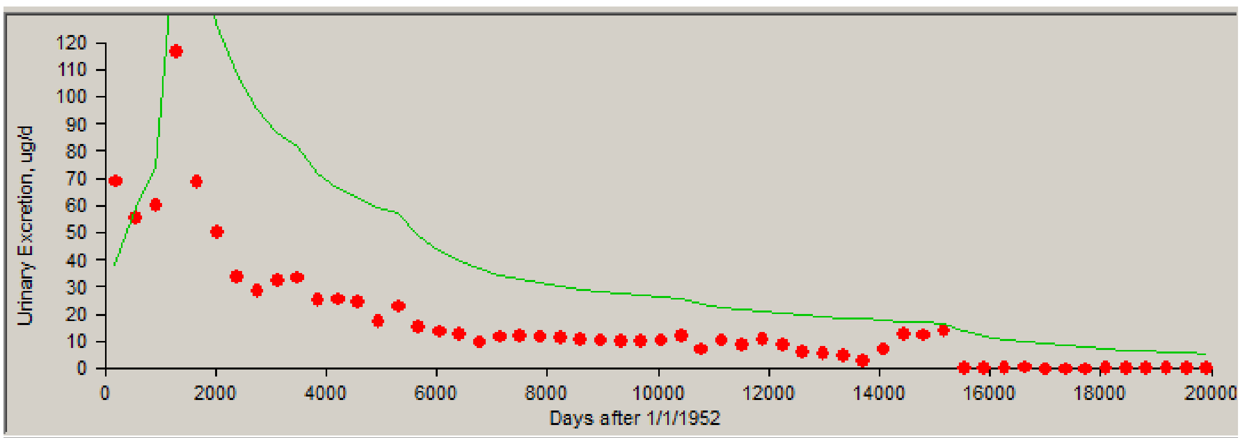

Figure A-25. Summarized results of the predicted values (line) versus the excluded results (red dots), 01/01/1952 to 12/31/2006, 84th percentile, type S.