DRAFT

REPORT TO THE ADVISORY BOARD
ON RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

COMPARISON OF SC&A'S BLIND DOSE RECONSTRUCTION TO NIOSH'S DOSE RECONSTRUCTION OF CASE #[REDACT] FROM THE ROCKY FLATS PLANT

Contract No. 211-2014-58081
SCA-TR-DRC2015-CN[Redact]

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April 2015

S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-DRC2015-CN[Redact] Effective Date: Draft – April 13, 2015
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Project Manager: ________________________ Date: ___________ John Stiver, MS, CHP	Reviewer: Kathleen Behling John Stiver

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	4/13/2015	Initial issued.

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ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
AP	anterior-posterior
CADW	Chronic Annual Dose Workbook
CATI	Computer-Assisted Telephone Interview
CW	coworker
DCF	dose conversion factor
DDE	deep dose equivalent
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
DR	dose reconstruction
EE	energy employee
GM	geometric mean
GSD	geometric standard deviation
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
keV	kilo electron volt; 1,000 electron volts
LAT	lateral
LOD	limit of detection
L-S	lumbar-spine
MeV	Million electron volts
µCi/ml	microcuries per milliliter
mrem or mR	millirem
NCRP	National Council on Radiation Protection and Measurements
NDRP	Neutron Dose Reconstruction Protocol
NIOSH	National Institute for Occupational Safety and Health
n/p	neutron-to-photon ratio
OCAS	Office of Compensation Analysis and Support
PA	posterior-anterior
Pene	penetrating
POC	probability of causation

rem	Roentgen equivalent man
RFP	Rocky Flats Plant
SC&A	S. Cohen and Associates (SC&A, Inc.)
SDE	skin dose equivalent
TBD	technical basis document
TIB	technical information bulletin
WBC	whole-body count
y	year

1.0 RELEVANT BACKGROUND INFORMATION

Under Contract No. 211-2014-58081, SC&A was tasked by the Advisory Board on Radiation and Worker Health (Advisory Board) to perform six blind dose reconstructions (DRs) at the July 2014, DR Subcommittee meeting. SC&A was provided all of the Department of Energy (DOE) dosimetry records; the Department of Labor (DOL) correspondence, forms, and medical records; and the Computer-Assisted Telephone Interview (CATI) Reports that were made available to the National Institute for Occupational Safety and Health (NIOSH) for constructing doses in behalf of these cases. SC&A used an independent approach to reconstruct occupational external and internal doses for the cases using the available dosimetry records and current guidance from NIOSH, including the spreadsheets and other tools developed by NIOSH to calculate the doses.

On February 27, 2015, SC&A submitted to the Advisory Board and NIOSH a memorandum containing the summary results of our blind DR in behalf of Case #[Redact] (SC&A 2015a). The complete DR report titled *SC&A's Dose Reconstruction of Case #*[Redact] *from the Rocky Flats Plant* (SC&A 2015b), which provides the assumptions and methodologies used to derive occupational radiation doses and the resultant probability of causation (POC), is included herein as Addendum A. In this report, SC&A presents a comparison between SC&A's and NIOSH's DR methodologies, doses, and resultant POC values for Case #[Redact]. Table 1-1 summarizes the external and internal occupational doses calculated by SC&A and the NIOSH-assigned doses for the cancers diagnosed in behalf of Case #[Redact]. The dose assignments and Interactive RadioEpidemiological Program (IREP) Input tables were identical for cancers of the [redact] breast. A detailed comparison of the two methodologies used to calculate doses in behalf of this case is presented in Section 2. Section 3 of this report provides Summary Conclusions.

It should be noted that, where appropriate, an explanation is provided regarding the differences in doses and why they occurred; however, SC&A does not make any value judgments regarding which among them may be the more preferred approach. It is our position that further discussions are best addressed by the DR Subcommittee.

Table 1-1. Comparison of SC&A's Blind Dose Reconstruction to NIOSH's Dose Reconstruction for Case #[redacted]

	SC&A – [redacted] Breast [redacted] Dose (rem)	NIOSH – [redacted] Breast [redacted] Dose (rem)
External Dose		
▪ Recorded/Modeled n/p Dose:		
30–250 keV Photons	0.247	0.258
<30 keV Photons	0.027	0.059
Neutrons by n/p	0.457	0.445
▪ Missed/Assigned n/p Dose:		
30–250 keV Photons	0.385	0.330
<30 keV Photons	–	–
Neutrons by NDRP & n/p	1.270	0.999
▪ Coworker Dose:		
30–250 keV Photons	1.505	1.498
<30 keV Photons	0.724	0.709
Neutrons	6.333	6.163
▪ External Environmental Dose:		
30–250 keV Photons	0.016	0.018
▪ Occupational Medical Dose:		
30–250 keV Photons	0.104	0.033
Internal Dose		
CW Pu Alpha	3.218	1.082
CW U-234 Alpha	0.167	–
Total Dose:	**14.453**	**11.593**
Each Cancer POC:	**25.02%**	**24.44%**
Combined POC:	**43.78%**	**42.91%**

2.0 COMPARISON OF METHODOLOGY/DOSES USED BY SC&A AND NIOSH FOR CASE #[REDACT]

Case #[Redact] represents an energy employee (EE) who worked as a [Redact], [Redact], and [Redact] at the Rocky Flats Plant (RFP) during the following periods:

- [Redact]–[Redact]
- [Redact]–[Redact]

The EE was diagnosed with [redact] breast invasive ductal carcinoma in situ (ICD-9 Code 233.0) in [redact].

According to DOL records and the CATI report, the EE worked in the [redact], [redact], and [redact] Areas during the first period of employment, and in the [redact], close to Building 664, during the second period of employment. The EE was monitored for external photon exposure during most of the first employment period, and twice during the second employment period at the RFP.

For calculating radiation dose from employment at RFP, both DR methods primarily relied on guidance in the RFP Technical Basis Document (TBD) (issued as six separate documents numbered ORAUT-TKBS-0011-1, through ORAUT-TKBS-0011-6). Using the guidance provided in these documents, along with the employee's dosimetry records, SC&A and NIOSH employed a best-estimate approach for calculating annual external and internal doses. SC&A and NIOSH both derived a POC of **<50%**.

A summary of the documents, assumptions, and dose parameters used by each DR method is provided in Tables 2-1 and 2-2:

Table 2-1. Comparison of External Dose Data and Assumptions Used by SC&A and NIOSH

Parameters	SC&A	NIOSH
	External Recorded & Coworker Dose:	
Records/Guidance Documents	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, and OTIB-0017.	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, OTIB-0017, and the RFP Dose Calculation Workbook 5.00.
Dose Determination Approach	Best estimate methodology.	Best estimate methodology.
Work Locations	Plutonium buildings.	Plutonium buildings.
Photon Energy Range	100% 30–250 keV	100% 30–250 keV
Photon Organ DCFs	Exposure: 1.266 Deep Dose: 0.894	Exposure: 1.266 Deep Dose: 0.894
Neutron Exposure Organ DCFs	<10 keV: 1.612 10–100 keV: 1.117 0.1–2 MeV: 1.180 2–10 MeV: 1.185	<10 keV: 1.612 10–100 keV: 1.117 0.1–2 MeV: 1.180 2–10 MeV: 1.185

Table 2-1. Comparison of External Dose Data and Assumptions Used by SC&A and NIOSH

Parameters	SC&A	NIOSH
Neutron Deep dose Organ DCFs	<10 keV: 1.411 10–100 keV: 1.111 0.1–2 MeV: 1.145 2–10 MeV: 1.12	<10 keV: 1.411 10–100 keV: 1.111 0.1–2 MeV: 1.145 2–10 MeV: 1.12
Neutron Energy-weighted ICRP-60 Correction F.	<10 keV: 0.0755 10–100 keV: 0.0309 0.1–2 MeV: 1.31 2–10 MeV: 0.345	<10 keV: 0.0755 10–100 keV: 0.0309 0.1–2 MeV: 1.31 2–10 MeV: 0.345
Recorded Photon Dose Distribution	Normal with 30% uncertainty.	Normal with 30% uncertainty, or lognormal with various uncertainties.
Assigned Neutron Dose Distribution	Lognormal with 1.520 GSD.	Lognormal with various uncertainties.
Coworker Photon and Neutron Dose Distribution	Lognormal with 1.520 GSD.	Normal, lognormal, and triangular with various uncertainties.
	External Missed Dose:	
Records/Guidance Documents	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, and OTIB-0017.	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, OTIB-0017, and the RFP Dose Calculation Workbook 5.00.
Dose Determination Approach	Best estimate methodology.	Best estimate methodology.
No. of zeros	Photons: 27 Neutrons: 27	Photons: 21 Neutrons: 25
LOD Value	[redact]–[redact] = 0.020 mR [redact]–[redact] = 0.020 mrem [redact]–[redact] = 0.010 mrem	[redact]–[redact] = 0.020 mR [redact]–[redact] = 0.020 mrem [redact]–[redact] = 0.010 mrem
Photon Energy Range	100% 30–250 keV	100% 30–250 keV
Photon Organ DCFs	Exposure: 1.266 Deep Dose: 0.894	Exposure: 1.266 Deep Dose: 0.894
Neutron Exposure Organ DCFs	<10 keV: 1.612 10–100 keV: 1.117 0.1–2 MeV: 1.180 2–10 MeV: 1.185	<10 keV: 1.612 10–100 keV: 1.117 0.1–2 MeV: 1.180 2–10 MeV: 1.185
Neutron Deep dose Organ DCFs	<10 keV: 1.411 10–100 keV: 1.111 0.1–2 MeV: 1.145 2–10 MeV: 1.12	<10 keV: 1.411 10–100 keV: 1.111 0.1–2 MeV: 1.145 2–10 MeV: 1.12
Neutron Energy-weighted ICRP-60 Correction F.	<10 keV: 0.0755 10–100 keV: 0.0309 0.1–2 MeV: 1.31 2-10 MeV: 0.345	<10 keV: 0.0755 10–100 keV: 0.0309 0.1–2 MeV: 1.31 2-10 MeV: 0.345
Missed Photon Dose Distribution	Lognormal with 1.550 GSD.	Lognormal with GSD centered around 1.52.
Missed Neutron Dose Distribution	Lognormal with 1.520 GSD.	Lognormal with GSD centered around 1.52.
	Shallow Dose:	
Records/Guidance Documents	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, and OTIB-0017.	DOE records, RFP TBD-6, OCAS-IG-001, OTIB-0005, OTIB-0017, and the RFP Dose Calculation Workbook 5.00.
Energy Range	<30 keV photons.	<30 keV photons.

Table 2-1. Comparison of External Dose Data and Assumptions Used by SC&A and NIOSH

Parameters	SC&A	NIOSH
Photon Organ DCFs	Exposure: 0.457 Dose equivalent: 0.761	Exposure: 0.457 Dose equivalent: 0.761
Dose Distribution	Normal with 30% uncertainty.	Normal with 30% uncertainty.
Onsite External Dose:		
Guidance Document	ORAUT-PROC-0060	ORAUT-PROC-0060
Period	[redact]–[redact] & [redact]–[redact]	[redact]–[redact] & [redact]–[redact]
Photon Energy Range	100% 30–250 keV	100% 30–250 keV
Photon Organ DCF	0.587	~0.634
Dose Distribution	Constant with no uncertainty.	Normal & triangular.
Occupational Medical Dose:		
Guidance Document	RFP TBD-3	RFP TBD-3
Frequency	3 documented x-ray exams.	3 documented x-ray exams.
Dose Distribution	Normal with 30% uncertainty.	Normal with 30% uncertainty.

Table 2-2. Comparison of Internal Dose Data and Assumptions Used by SC&A and NIOSH

Parameters	SC&A	NIOSH
Bioassay Internal:		
Records/Guidance Documents	Bioassay assays all background.	Bioassay assays all background.
Assigned Internal:		
Records/Guidance Documents	RFP TBD-5 and CADW	OTIB-0018
Dose Determination Approach	Coworker intake from urinalyses from TBD-5.	Air sampling data from OTIB-0018.
Solubility Type	Used M, S, or SS to maximize dose.	Used M and S to maximize dose.
Dose Distribution	Constant with zero uncertainty.	Lognormal with 3.000 GSD.
Environmental Internal:		
	Not applicable	Not applicable

2.1 OCCUPATIONAL EXTERNAL DOSE CALCULATIONS

2.1.1 Recorded Photon/Shallow Doses

The DOE reports contained quarterly and/or yearly badge readings. The datasheet for [redact] lists the EE's name and the quarterly exchanges, but it contained all blank results, while the recorded readings for the period [redact]–[redact] contained some positive recorded doses, and some zeros. A summary sheet on page 13 of the DOE records contained annual dose summaries for the years [redact]–[redact], plus data for one badge exchange in [redact], and one in [redact] (with zero deep dose and zero neutron dose recorded each year). There was no record of monitoring during the employment period of [redact]–[redact]. The only positive shallow dose readings were recorded during the period [redact]–[redact].

Comparison of SC&A's and NIOSH's Methods and Doses for Recorded/Shallow Photons

Both DR methods assumed the EE worked primarily in the RFP plutonium area. Therefore, the photon energy fraction of 100% 30–250 keV was assumed for deep doses and 100% <30 keV photons for shallow doses, as specified in the RFP ORAUT-TKBS-0011-6, Table 6-9, page 36. Both SC&A and NIOSH selected OCAS-IG-001 DCFs that reflected Exposure (R) to Organ Dose values for the period [redact]–[redact], and Deep Dose Equivalent (rem) to Organ Dose values for the period [redact]–[redact], as previously summarized in Table 2-1. Both exposure and deep dose organ-to-dose conversion factors are generally referred to as dose conversion factors (DCFs).

The yearly DOE records from RFP contain penetrating dose (which include photon and neutron doses), and skin dose (which include non-penetrating, photon, and neutron doses). Table 2-3 summarizes the methods used to derive the various external doses from the recorded dose at the RFP using the information in ORAUT-TKBS-0011-6, Table 6-14, page 29, and the equations on page 38:

Table 2-3. Summary of External Dose Assignment Methods

	Penetrating photons 30–250 keV	**Non-penetrating photons <30 keV**	**Neutrons in four energy ranges**
[redacted]	Pene × [1/(1+n/p)]	(Skin - Pene)/0.65	Pene x [(n/p)/(1+n/p)] or NDRP data
[redacted]	Pene × [1/(1+n/p)]	(Skin - Pene)	Pene × [(n/p)/(1+n/p)]
[redacted]	Penetrating	(Skin - Pene)	n/p = 0.42 or recorded n dose

SC&A and NIOSH used the neutron-to-photon radio (n/p) values from Tables 6-21 and 6-22 of ORAUT-TKBS-0011-6, page 50, to derive the appropriate doses; the tables are reproduced here as Exhibit A.

Exhibit A. Summary of n/p Values

(Source: ORAUT-TKBS-0011-6, page 50)

Table 6-21. RFP lognormal neutron-to-photon ratio values, [redacted] to [redacted]

Year	Neutron-to-photon ratio GM (semimonthly exchange)	GSD	95th percentile	Neutron-to-photon ratio GM (monthly exchange)	GSD	95th percentile
[redacted]	1.61[a]	3.45	12.4	N/A	N/A	N/A
[redacted]	1.61	3.45	12.4	N/A	N/A	N/A
[redacted]	1.32	2.15	4.64	0.8	2.63	3.94
[redacted]	1.32[b]	2.15	4.64	N/A	N/A	N/A
[redacted]	0.68	3.01	4.16	N/A	N/A	N/A
[redacted]	0.67	3.31	4.82	N/A	N/A	N/A
[redacted]	0.95	3.59	7.81	0.78	4.29	8.55

a. Data for [redacted] were not available. This value is the greater of the ratios for [redacted] and [redacted]. The high neutron-to-gamma ratio in [redacted] for Building 771 is reasonable from a process aspect, and extrapolating that ratio back to [redacted] also is reasonable. In the aftermath of the [redacted] plutonium fire in Buildings 776 and 777, the salvaged plutonium oxide had to be converted back to plutonium metal, a process done in Building 771. Building 771 had a huge backlog for relatively pure plutonium (little americium, low gamma) to be reprocessed, which was staged in the 776 to 771 tunnel and any other possible staging area in the vicinity. In addition, PuF_4 (a high neutron source) seemed to be generated faster in Building 771 than it could be reduced to metal, which also caused a staging problem in or near the process areas in Building 771 until the backlog could be reduced.

b. Data for [redacted] were not available. This value is the greater of the ratios for [redacted] and [redacted]

Table 6-22. ORAU Team-developed neutron-to-gamma ratios.

Year	GM	GSD
[redacted]	0.33	3.31
[redacted]	0.57	2.53
[redacted]	0.37	3.31
[redacted]	0.43	2.57
[redacted]	0.51	2.41
[redacted]	0.4	2.4
[redacted]	0.42	3.01

Year	GM	GSD
[redacted]	0.41	3.07
[redacted]	0.42	3.37
[redacted]	0.49	2.93
[redacted]	0.36	3.56
[redacted]	0.6	2.83
[redacted]	0.36	3.5
[redacted]	0.35	3.77

Year	GM	GSD
[redacted]	0.29	2.41
[redacted]	0.4	2.03
[redacted]	0.61	1.93
[redacted]	0.41	2.35
[redacted]	0.35	2.28
[redacted]	0.26	4.1
[redacted]	0.44	2.18

Year	GM	GSD
[redacted]	0.39	3.03
[redacted]	0.45	2.79
[redacted]	0.6	1.8
Overall	0.42	3

Using the EE's dosimetry records and above-cited parameters, SC&A and NIOSH assigned photon and shallow doses as shown in Table 2-4.

Table 2-4. Comparison of Recorded Photon/Shallow Doses

	SC&A (rem)	NIOSH (rem)
Recorded photon dose, 30–250 keV photons	0.247	0.258
Recorded shallow dose, <30 keV photons	0.027	0.059

The difference in recorded photon doses assigned by SC&A and NIOSH reflects the fact that SC&A and NIOSH handled a discrepancy in the DOE records by different methods. The datasheet for [redact] on page 32 of the DOE records appears to contain an error, in that the 3rd quarter skin dose was recorded as *71 mrem* and the penetrating dose was recorded as *98 mrem*. Considering the fact that RFP at that time defined shallow dose as the skin dose minus the penetrating dose (ORAUT-TKBS-0011-6, page 38), the skin dose must be greater than or equal to the penetrating dose (and it was for all the other recorded positive doses).

SC&A's Handling of the 1970 Discrepancy

It appears that the two dose values for the 3rd quarter of [redact] may have been interchanged and the penetrating dose was actually 71 mrem and the skin dose was 98 mrem; SC&A used this assumption, as it is consistent with the other recorded doses for this EE. Another error that SC&A found was in the DOE records on pages 11, 12, and 13, where the summary sheets list the annual *Deep Dose Equivalent* (or *DDE*) and the *Skin Dose Equivalent* (or *SDE*) doses as equal to each other for the years [redact]–[redact]; this is incorrect according to the details provided by the quarterly exchange datasheets and therefore will not be used in the DR.

NIOSH's Handling of the 1970 Discrepancy

NIOSH used the *DDE* dose of *0.146 rem* recorded on page 13 of the DOE file for the 3rd quarter [redact] penetrating 30–250 keV photon dose. NIOSH used the recorded skin dose on page 32 for the non-penetrating <30 keV photon dose (treating the recorded *71* mrem *SKIN* dose as a net non-penetrating dose = [shallow - pene] = 0.071 rem).

This difference in methodology resulted in NIOSH assigning a slighter greater recorded 30–250 keV photon dose and a larger <30 keV photon shallow dose than was assigned by SC&A.

2.1.2 Coworker Photon Dose

Coworker (CW) photon doses were assigned by both SC&A and NIOSH for periods the EE was not monitored.

SC&A's Coworker Penetrating Photon Dose

SC&A used the 50th percentile plutonium CW photon dose values recommended in Table C-3, page 97, and Table C-4, pages 99–100, of ORAUT-TKBS-0011-6 (applying the parameters previously described) to assign photon doses during the periods the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW dose values for Building 71 were used, because the EE could have been at numerous locations and overall Building 71 dose values provided for the most claimant-favorable dose assignments.

SC&A's Coworker Shallow Photon Dose

SC&A used the 50th percentile uranium CW photon dose values (as per ORAUT-TKBS-0011-6, pages 94–95) recommended in Table C-5, pages 100–101 (applying the parameters previously described) to assign shallow photon doses during periods when the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW shallow dose was derived by subtracting the 50th percentile penetrating dose value from the 50th percentile non-penetrating dose value and assigning it as <30 keV photons, as per ORAUT-OTIB-0017.

In this case, SC&A found that a lognormal distribution provided for the greater POC for photon doses; therefore, the CW photon doses were entered into the IREP Input tables using a lognormal distribution with an uncertainty of 1.520.

NIOSH's Coworker Photon Dose

NIOSH used the same methodology as SC&A to assign CW photon and non-penetrating doses, except NIOSH used normal, lognormal, and triangular distributions.

Comparison of SC&A's and NIOSH's Coworker Photon Doses

SC&A and NIOSH assigned nearly identical CW photon doses, as shown in Table 2-5. The small differences in the annual assigned doses resulted mainly from the method used to calculate the prorated work periods; i.e., by using the number of days, fraction of months, or fraction of year to determine the prorated time fraction. Additionally, NIOSH used the triangular distribution for some of the CW photon doses assignments, whereas SC&A used a lognormal distribution of all CW photon dose assignments.

Table 2-5. Comparison of Coworker Photon Doses

	SC&A (rem)	NIOSH (rem)
Total coworker 30–250 keV photon dose	1.505	1.498
Total coworker <30 keV photon dose	0.724	0.709

2.1.3 Missed Photon Dose

Missed photon doses were assigned by both SC&A and NIOSH.

Comparison of SC&A's and NIOSH's Methods Used to Assign Missed Photon Dose

SC&A analyzed the number of actual zeros and potential zeros based on monthly badge exchange cycles using the guidance in OCAS-IG-001, page 16, to arrive at a total of **27 zeros** (or <LOD/2 values) for photons, and no zero (or <LOD/2 values) for non-penetrating <30 keV photons. According to the DR report, NIOSH used **21 zeros** for 30–250 keV photons. SC&A and NIOSH used the annual number of zeros, the DR parameters as previously described, and the applicable DCFs to determine the annual missed photon doses. The limit of detection (LOD) values from ORAUT-TKBS-0011-6, Table 6-12, page 40, were used, and were as follows:

- [Redact]–[redact] = 0.020 mR
- [Redact]–[redact] = 0.020 mrem
- [Redact]–[redact] = 0.010 mrem

SC&A's Missed Photon Dose

SC&A used the following methods to derive missed photon dose:

- DCFs as recommended in OCAS-IG-001.
- Because all the recorded doses were relatively small, each quarterly recorded dose could have occurred within one monthly badge exchange. Therefore, missed dose was assigned for each monthly badge exchange that could have potentially read zero, for a total of 27 zeros.
- Assigned 4 potential missed doses for the last two quarters of [redact].

NIOSH's Missed Photon Dose

NIOSH used the following methods to derive missed photon dose:

- DCFs as recommended in OCAS-IG-001.
- A best-estimate methodology to determine the number of zeros, for a total of 21 zeros.
- Did not assign missed dose for the last two quarters of [redacted].

Comparison of SC&A's and NIOSH's Missed Photon Doses

SC&A and NIOSH assigned missed photon doses as shown in Table 2-6. The smaller missed photon dose assigned by NIOSH was due to the fact that:

- NIOSH derived a fewer number of zeros using the best-estimate method, as opposed to counting the potential number of zeros, as was done by SC&A.
- NIOSH did not apply any monthly zeros for the last two quarters of [redacted], when the EE's records listed quarterly results.

Table 2-6. Comparison of Missed Photon Doses

	SC&A (rem)	NIOSH (rem)
Total missed photon dose	0.385	0.330

Both DR methods entered the missed photon doses into IREP Input tables as a lognormal distribution.

2.1.4 Recorded Neutron Dose

For the employment period [redacted]–[redacted], the annual DOE records for RFP contained penetrating dose (which include photon and neutron doses) and skin dose (which included non-penetrating, photon, and neutron doses). The RFP records did not contain separate photon and neutron dose records. The DOE records contained Neutron Dose Reconstruction Protocol (NDRP) data for [redacted]. For the employment period [redacted]–[redacted], the annual DOE record showed a deep dose of zero and a neutron dose of zero for each year. There was no record of monitoring during the employment period of [redacted]–[redacted].

SC&A's Neutron Dose Assignment Methodology

The n/p method was used to sort out the respective photon and neutron doses from positive recorded readings. Because the EE's duties required the EE to be present in various operating locations at the RFP (i.e., the EE did not spend the majority of the time in an office building), CW-modeled neutron doses were assigned during periods the EE's records contained no monitoring data. Missed neutron dose was assigned using the n/p method.

[redacted]: There were no doses recorded for this year; therefore, no recorded neutron dose was assigned. Coworker data were used to assign neutron dose during this employment period.

[redacted]: The DOE records contained NDRP data for [redacted], in which there were four recorded badge exchanges with all readings less than the LOD/2 value of 0.060 rem ([redacted] neutron LOD = 120 mrem, as per ORAUT-TKBS-0011-6, Table 6-20, page 47). Therefore, SC&A assigned four neutron missed doses and eight months of CW neutron dose, since the EE was partially monitored for neutrons during [redacted]; no measured or n/p-derived neutron doses were assigned for [redacted].

[redacted]–[redacted]: The n/p method was used to sort out the respective photon and neutron doses from positive recorded readings for this period.

[redacted]–[redacted]: There were no positive doses recorded for this period; therefore, no recorded neutron dose was assigned. Missed dose or CW data were used to assign neutron dose during this employment period.

The previous Table 2-3 summarizes the methods (NDRP data, n/p values, etc.) used to derive the various external doses from the recorded dose at RFP. SC&A used the n/p values from Tables 6-21 and 6-22 of ORAUT-TKBS-0011-6, page 50, to derive the appropriate doses; these tables were reproduced previously in this report as Exhibit A. A summary of the neutron DCFs (OCAS-IG-001, page 66) and energy-weighted ICRP-60 correction factors (ORAUT-TKBS-0011-6, Table 6-17, page 45, and Table 6-18, page 46) is as follows:

- **Neutron Exposure Organ DCFs:**
  <10 keV: 1.612
  10–100 keV: 1.117
  0.1–2 MeV: 1.180
  2–10 MeV: 1.185

- **Neutron Deep dose Organ DCFs:**
  <10 keV: 1.411
  10–100 keV: 1.111
  0.1–2 MeV: 1.145
  2–10 MeV: 1.12

- **Neutron Energy-weighted ICRP-60 Correction Factors**
  <10 keV: 0.0755
  10–100 keV: 0.0309
  0.1–2 MeV: 1.31
  2–10 MeV: 0.345

NIOSH's Neutron Dose Assignment Methodology

SC&A's analysis of the DR report and accompanying files for this case indicate that NIOSH used the same methods and parameters to assign neutron dose in this case as SC&A used (which were described above).

<u>Comparison of SC&A's and NIOSH's Neutron Doses and Methods</u>

Using the EE's dosimetry records and above-cited parameters, SC&A and NIOSH assigned nearly identical neutron doses, as shown in Table 2-7.

Table 2-7. Comparison of Recorded Neutron Doses

	SC&A (rem)	NIOSH (rem)
Recorded neutron dose	0.457	0.445

In analyzing the neutron dose assignment calculation worksheets, SC&A found that the slight difference in recorded neutron dose assigned by SC&A and NIOSH resulted from rounding of the multiple parameters and intermediate values derived in the process of determining the final assigned dose from the original recorded data using the process outlined previously in Table 2-3.

SC&A and NIOSH both assigned recorded neutron dose using a lognormal distribution.

2.1.5 Coworker Neutron Dose

Coworker neutron doses were assigned by both SC&A and NIOSH for periods the EE was not monitored.

<u>SC&A's Coworker Neutron Dose</u>

SC&A used the 50th percentile plutonium CW neutron dose values recommended in Table C-3, page 97, and Table C-4, pages 99–100, of ORAUT-TKBS-0011-6 (applying DCFs and energy-weighted ICRP factors as previously described) to assign neutron doses during periods when the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW dose values for Building 71 were used, because the EE could have been at numerous locations and Building 71 dose values provided for the most claimant-favorable dose assignments.

SC&A used a lognormal distribution, with an uncertainty of 1.520, to assign CW neutron dose.

<u>NIOSH's Coworker Neutron Dose</u>

SC&A's analysis of the DR report and accompanying files for this case indicates that NIOSH used the same methods and parameters to assign CW neutron dose in this case as SC&A (which were described above), except NIOSH used normal, lognormal, and triangular distributions.

<u>Comparison of SC&A's and NIOSH's Coworker Neutron Doses</u>

SC&A and NIOSH assigned CW neutron doses as shown in Table 2-8. The differences in the annual assigned doses resulted from rounding of the multiple parameters and intermediate values derived in the process of determining the final assigned dose from the original recorded data using the process outlined previously in Table 2-3. A slight difference in dose was also introduced based on the method used to calculate the prorated work periods; i.e., whether the number of days, fraction of months, or fraction of year was used to determine the prorated time fraction. Additionally, NIOSH used normal, lognormal, and triangular distributions for CW neutron doses assignments, whereas SC&A used a lognormal distribution for all CW neutron dose assignments.

Table 2-8. Comparison of Coworker Neutron Doses

	SC&A (rem)	NIOSH (rem)
Total coworker neutron dose	6.333	6.163

2.1.6 Missed Neutron Dose

Missed neutron doses were assigned by both SC&A and NIOSH.

<u>Comparison of SC&A's and NIOSH's Methods Used to Assign Missed Neutron Dose</u>

SC&A analyzed the number of actual zeros and potential zeros based on a monthly badge exchange cycle using the guidance in OCAS-IG-001, page 16, to arrive at a total of **27 zeros** (or <LOD/2 values) for neutrons. According to the DR report, NIOSH used **25 zeros** for neutron dose. SC&A and NIOSH used the annual number of zeros, the DR parameters as previously listed, and the applicable DCFs to determine the annual missed neutron doses.

<u>SC&A's Missed Neutron Dose</u>

SC&A used the following information to derive missed neutron dose:

- DCFs, energy-weighted ICRP factors, and n/p values as previously described.
- [Redact]: There were no doses recorded for this year; therefore, no missed neutron dose was assigned. Coworker data were used to assign neutron dose during this employment period.
- [Redact]: The DOE records contained NDRP data for [redact], in which there were four recorded badge exchanges with all readings <LOD/2 value of 0.060 rem ([redact] neutron LOD = 120 mrem as per ORAUT-TKBS-0011-6, Table 6-20, page 47). Therefore, SC&A assigned four neutron missed doses and eight months of CW neutron dose, since the EE was partially monitored for neutrons during [redact].
- [Redact]–[redact]: The n/p method was applied to the missed photon doses during this period.
- [Redact]–[redact]: Missed neutron dose, based on missed photon dose and the n/p method, was assigned during this employment period. There were no positive photon or neutron dose values recorded during this period; therefore, only missed or CW dose was assigned.
- [Redact]–[redact]: There was no record of monitoring during this employment period; therefore, only CW neutron dose was applied.

- Assigned the missed neutron dose with a lognormal distribution and geometric standard deviation (GSD) of 1.520.

NIOSH's Missed Neutron Dose

SC&A's analysis of the DR report and accompanying files for this case indicates that NIOSH used the same methods and parameters to assign missed neutron dose in this case as SC&A (which were described above), except NIOSH used a lognormal distribution with a GSD centered around 1.520.

Comparison of SC&A's and NIOSH's Missed Neutron Doses

SC&A and NIOSH assigned missed neutron doses as shown in Table 2-9. The smaller missed neutron dose assigned by NIOSH appears to be due to the fact that NIOSH used a smaller number of missed doses (SC&A used 27 zeros, and the DR report stated that NIOSH used 25 zeros for assigning neutron dose). Additional small differences in the annual missed neutron doses resulted from rounding of the multiple parameters and intermediate values derived in the process of determining the final assigned dose from the original recorded data using the process as outlined previously in Table 2-3.

Table 2-9. Comparison of Missed Neutron Doses

	SC&A (rem)	NIOSH (rem)
Total missed neutron dose	1.270	0.999

2.1.7 Onsite Ambient Doses

According to ORAUT-PROC-0060, Attachment A, page 14, RFP onsite external ambient dose is to be assigned prior to 1977 and after 1999, even if other doses are assigned during these periods.

SC&A's External Environmental Dose

SC&A used the best-estimate DR value of 0.004 rem/y (as recommended on page 25 of ORAUT-PROC-0060), the appropriate years, and prorated for time worked to assign ambient dose in this case. SC&A used the ambient rotational exposure geometry DCF of 0.587 for the breast (as per page 49 of OCAS-IG-001). SC&A derived a total external environmental dose of 0.016 rem. The doses were entered as a constant with no uncertainty in the IREP Input tables, as per ORAUT-PROC-0060, page 25.

NIOSH's External Environmental Dose

NIOSH used the best-estimate DR value of 0.004 rem/y (as recommended on page 25 of ORAUT-PROC-0060), the appropriate years, and prorated for time worked to assign ambient dose in this case. NIOSH did not state in the DR report or the accompanying files what DCF was used; however, SC&A performed some back calculations and found NIOSH used an average DCF of approximately 0.634 for external ambient dose in this case. NIOSH derived a total external environmental dose of 0.018 rem. The doses were entered with normal or triangular distributions in the IREP Input tables.

<u>Comparison of SC&A's and NIOSH's External Ambient Doses</u>

SC&A's and NIOSH's external ambient doses agree reasonably well. The main difference was the value of the DCFs used and the types of distributions applied.

2.1.8 Occupational Medical Doses

Both SC&A and NIOSH:

- Calculated an occupational medical dose from diagnostic x-ray procedures required as a condition of employment.
- Used the number and type of x-ray exams as provided in the EE's DOE records.
- Assigned doses for 3 posterior-anterior (PA) view and 1 lumbar-spine (L-S) view x-ray exams.
- Used the appropriate breast x-ray dose values as recommended in ORAUT-TKBS-0011-3, Table 3-6, page 13, for the PA views, and Table 3-7, page 14, for the 1968 lumbar-spine lateral (LAT) and anterior-posterior (AP) view.

<u>SC&A's Method for Assigning Medical X-ray Dose</u>

The DOE records show that the EE received a pre-hire x-ray exam in [redact], a termination x-ray exam in [redact], and a routine x-ray exam in [redact]. SC&A noted that the summary sheet on page 8 of the DOE file lists two x-ray exams in [redact], but the detailed original data sheets for [redact], pages 6 and 7, list only one x-ray exam on [redact]. Therefore, SC&A assumed that the EE had one x-ray exam in [redact]. According to ORAUT-TKBS-0011-3, page 8, the frequency of x-ray exams at RFP varied widely; therefore, since there were x-ray exam records available for this EE, no additional x-ray exam doses will be assigned. SC&A assumed a PA and L-S LAT and AP view as listed in Table 3-7, page 14, of ORAUT-TKBS-0011-3, because the original x-ray exam record was not available. However, for [redact], the original x-ray exam record (DOE record, pdf. 5) was available and it does not indicate that an L-S exam was performed. Therefore, SC&A did not include an L-S exam for [redact].

<u>NIOSH's Method for Assigning Medical X-ray Dose</u>

SC&A's analysis of the DR report and accompanying files for this case indicates that NIOSH used the same methods and parameters to assign medical x-ray dose in this case as SC&A (which were described above), except for the [redact] L-S LAT and AP dose values.

<u>Comparison of SC&A's and NIOSH's Medical X-ray Doses</u>

SC&A's and NIOSH's medical x-ray doses match, except for the [redact] L-S LAT and AP dose values. Table 3-7, page 14 of ORAUT-TKBS-0011-3, recommends an L-S LAT dose value of

4.75E-2 rem, and an L-S AP dose value of 3.6E-2 rem (these dose values appear in entries #148 and #149, respectively, of SC&A's IREP Input tables). However, NIOSH's entry #150 in the IREP Input tables contains a dose of 7.58E-3 rem for the L-S LAT view, and entry #151 contains a dose of 4.78E-3 for the L-S AP view. SC&A's investigation of the RFP Workbook 5.00 reveals that the *Xray Data* tab contains the L-S AP dose value of <u>4.78E-3 rem</u> in Column D, Row 201, and the L-S LAT dose value of <u>7.58E-3 rem</u> in Column D, Row 286. These values do not match those provided in ORAUT-TKBS-0011-3, Table 3-7, page 14, for the [redact] L-S LAT and AP view.

Table 2-10 shows a comparison of the occupational medical doses calculated by the two DR methods.

Table 2-10. Comparison of Occupational Medical Doses

	SC&A (rem)	NIOSH (rem)
Total medical x-ray dose	0.104	0.033

Both methods entered annual doses into IREP as a normal distribution with an uncertainty of 30%.

2.2 OCCUPATIONAL INTERNAL DOSES

There were a total of three whole body counts (WBCs) performed in [redact], [redact], and [redact] for this EE. All results were recorded as background.

2.2.1 Internal Dose Assignment

SC&A assigned internal intakes and resulting doses based on coworker urinalyses data recommended in ORAUT-TKBS-0011-5, September 2014. NIOSH assigned internal intakes and resulting doses using *Internal Dose Overestimates for Facilities with Air Sampling Programs*, ORAUT-OTIB-0018, August 2005.

<u>SC&A's Internal Dose Assignment</u>

SC&A selected CW intake data to assign internal dose in this case, because the EE was monitored or assigned CW dose for all external dose assignments, and the EE had received some WBCs. SC&A used the CW intake data from Table D-4, page 150 (uranium Types F, M, and S); Table D-5 plutonium, page 150 (Type M); and Table D-6, page 151 (plutonium Type S *Systemic intake rates*) in the RFP Chronic Annual Dose Workbook (CADW) (located in the DR Tools folder) for the years [redact]–[redact] and [redact]–[redact]. Coworker intakes were selected for all the periods of employment, with full-year intakes applied to the years of partial employment. All potential solubility types were analyzed and the type that produced the greater dose was selected. This resulted in the selection of Type S U-234 and Type S plutonium (which consisted of Pu-238, Pu-239, Pu-241, and Am-241), which are all alpha emitters.

The total resulting dose was 0.167 rem from U-234 and 0.818 rem from the Type S plutonium components. However, the doses from the plutonium components were adjusted for systemic organs according to ORAUT-OTIB-0049, Table 4-8, page 17, for urine bioassays (as noted in footnote *a.* of Table D-6 of ORAUT-TKBS-0011-5, page 151). The CW intake period ending date in Table D-6 was used as the date of the last bioassay for each intake period in this case (as per the last paragraph on page 150 of ORAUT-TKBS-0011-5). The plutonium Type SS dose was 3.218 rem, and the U-234 Type S dose was 0.167 rem; the total adjusted plutonium plus uranium alpha dose was 3.385 rem. The plutonium and uranium annual doses were entered separately into the IREP Input tables with a constant distribution and an uncertainty of zero, since the coworker intake values were at the 95th percentile level (and per ORAUT-TKBS-0011-5, page 51).

<u>NIOSH's Internal Dose Assignment</u>

NIOSH assigned internal intakes and resulting doses using, *Internal Dose Overestimates for Facilities with Air Sampling Programs*, ORAUT-OTIB-0018, August 2005. SC&A analyzed the DR report and accompanying files and found that NIOSH derived internal doses using the *Rocky Flats alpha-emitting radionuclides in Pu chemistry operations or default for the site, 1953–1994* air concentration value of 4E-12 µCi/ml from Table 4-1, page 10, of OTIB-0018 in the CADW for the period [redact]–[redact] and [redact]–[redact]. NIOSH derived both the inhaled and ingested doses (ingestion was included because air concentrations were used). NIOSH derived a total inhaled plus ingested dose of 1.082 rem from all alpha-emitting radionuclides.

The total uranium plus plutonium annual doses were entered into the IREP Input tables with a lognormal distribution and a GSD of 3.000.

<u>Comparison of Internal Dose Assignments</u>

Table 2-11 shows a comparison of the internal doses assigned by the SC&A and NIOSH.

Table 2-11. Comparison of Internal Doses

	SC&A (rem)	NIOSH (rem)
Plutonium plus uranium dose	3.385	1.082

The difference in the internal dose assignments resulted from SC&A using the CW intake data from ORAUT-TKBS-0011-5, as opposed to NIOSH using the air concentration data from ORAUT-OTIB-0018.

SC&A's investigation of this difference indicates that the derived internal doses before consideration of Type SS plutonium were very similar; i.e., SC&A derived a total internal dose of 0.985 rem compared to NIOSH's assigned value of 1.082 rem. However, SC&A's doses from the plutonium components were adjusted for systemic organs according to ORAUT-OTIB-0049, Table 4-8, page 17, for urine bioassays (as noted in footnote *a.* of Table D-6 of ORAUT-TKBS-0011-5, page 151). NIOSH's internal doses assigned from using ORAUT-OTIB-0018 were derived from using air concentration data; and according to ORAUT-OTIB-0049, Table 4-8, page 17, the doses would not be adjusted for Type SS plutonium. SC&A used CW data from ORAUT-TKBS-0011-5, which was issued in 2014; whereas, NIOSH used data from ORAUT-

OTIB-0018, which was issued in 2005, before any versions of ORAUT-OTIB-0049 were issued, and before Type SS plutonium adjustments were made.

3.0 SUMMARY CONCLUSIONS

Total external and internal doses and resultant POCs calculated by SC&A and NIOSH in behalf of Case #038531 are presented in Table 3-1 for comparison.

Table 3-1. Comparison of SC&A's and NIOSH's Total External and Internal Dose Estimates

	SC&A [Redact] breast	NIOSH [Redact] breast	SC&A [Redact] breast	NIOSH [Redact] breast
External Dose	11.068	10.511	11.068	10.511
Internal Dose	3.385	1.082	3.385	1.082
Total Dose	14.453	11.593	14.453	11.593
Cancer POC	25.02%	24.44%	25.02%	24.44%
Combined POC	**-**	**-**	**43.78%**	**42.91%**

As shown in Table 3-1, SC&A's and NIOSH's dose estimates and resulting POCs are in close agreement. The key difference is reflected in internal dose assignments, where SC&A applied CW urinalyses data from ORAUT-TKBS-0011-5, and NIOSH used air concentration data from ORAUT-OTIB-0018.

A more detailed discussion of variables that contributed to key differences in dose assignments is presented below.

- <u>Handling of the 1970 External Dose Record Discrepancy</u>
  - – SC&A considered that the deep dose and the shallow dose entries may have been reversed.
  - –NIOSH added additional dose as a possible overestimate approach.
  - –This difference in methodology resulted in NIOSH assigning a slighter greater recorded 30–250 keV photon dose and a larger <30 keV photon shallow dose than SC&A assigned.

- <u>Dose Distribution</u>
  - – SC&A used the following dose distributions:
    - Recorded photon and shallow dose; Normal distribution with 30% uncertainty
    - Assigned neutron dose; Lognormal distribution with 1.52 GSD
    - Coworker photon and neutron dose; Lognormal distribution with 1.52 GSD
    - Missed photon dose; Lognormal distribution with 1.55 GSD
    - Missed neutron dose; Lognormal distribution with 1.52 GSD
    - Environmental external dose; Constant with no uncertainty
    - Medical x-ray dose; Normal distribution with 30% uncertainty
    - Internal environmental dose; Constant with no uncertainty.

– NIOSH used the following dose distributions:
  - Recorded photon and shallow dose; Normal and lognormal distributions with various uncertainties
  - Assigned neutron dose; Lognormal distribution with various uncertainties
  - Coworker photon and neutron dose; Normal, lognormal, and triangular distributions with various uncertainties
  - Missed photon dose; Lognormal distribution with uncertainty centered on 1.52
  - Missed neutron dose; Lognormal distribution with uncertainty centered on 1.52
  - Environmental external dose; Normal and triangular distributions with various uncertainties
  - Medical x-ray dose; Normal distribution with 30% uncertainty
  - Internal environmental dose; Lognormal with 3.000 GSD

– The difference in distributions accounted for some difference in the assigned doses, especially when NIOSH used a triangular distribution; e.g., coworker and environmental external doses.

- <u>Assignment of Missed External Dose</u>

  – SC&A assigned missed dose for each potential monthly badge exchange that could have read zero, for a total of 27 photon and 27 neutron zeros; this included 4 potential missed doses for the last two quarters of [redacted].

  – NIOSH used a best-estimate methodology to determine the number of zeros, for a total of 21 photons and 25 neutron zeros. NIOSH did not assign missed dose for the last two quarters of [redacted].

  – This resulted in NIOSH assigning slightly less missed photon and neutron doses compared to SC&A.

- <u>Assignment of Onsite Ambient Dose</u>

  – SC&A assigned external ambient dose for the period [redacted]–[redacted] and [redacted]–[redacted] with a constant distribution and no uncertainty.

  – NIOSH assigned external ambient dose for the period [redacted]–[redacted] and [redacted]–[redacted] with normal and triangular distributions.

  – This resulted in SC&A assigning a slightly less ambient dose than NIOSH.

- <u>Assignment of Occupational Medical X-ray Dose</u>

  – Both SC&A and NIOSH used the number and view of recorded exams in the DOE records for this EE to assign medical x-ray doses.

  – SC&A used the dose tables in RFP ORAUT-TKBS-0011-3 to assign doses.

  – NIOSH used the dose values in the RFP calculation workbook.

- SC&A's and NIOSH's medical x-ray doses match, except for the [redact] L-S LAT and AP dose values. The L-S LAT dose assigned by NIOSH was lower than those listed in ORAUT-TKBS-0011-3, Table 3-7, page 14, for the [redact] L-S LAT and AP view.

- <u>Assignment of Internal Dose</u>
  - SC&A assigned internal intakes and resulting doses based on CW urinalyses data recommended in ORAUT-TKBS-0011-5, September 2014.
  - NIOSH assigned internal intakes and resulting doses using *Internal Dose Overestimates for Facilities with Air Sampling Programs*, ORAUT-OTIB-0018, August 2005.
  - This difference in methodology resulted in a lower internal dose being assigned by NIOSH compared to SC&A's internal dose assignment, mainly because the air concentration data did not need to be adjusted for Type SS plutonium, but CW urinalyses data did, as recommended in ORAUT-OTIB-0049.

4.0 REFERENCES

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ADDENDUM A: SC&A'S BLIND DOSE RECONSTRUCTION REPORT OF CASE #[REDACT]

DRAFT

REPORT TO THE ADVISORY BOARD ON RADIATION AND WORKER HEALTH

National Institute of Occupational Safety and Health

BLIND DOSE RECONSTRUCTION OF CASE #[REDACT] FROM THE ROCKY FLATS PLANT

Contract No. 211-2014-58081
SCA-TR-BDR2015-CN[Redact]

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February 2015

S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-BDR2015-CN[Redact] Effective Date: Draft – February 27, 2015 Revision No. 0 (Draft)
BLIND DOSE RECONSTRUCTION OF CASE #[REDACT] FROM THE ROCKY FLATS PLANT	Page 2 of 24
Task Manager: _________________________ Date: _________ Douglas Farver, MS	Supersedes: N/A
Project Manager: _________________________ Date: _________ John Stiver, CHP	Reviewers: Douglas Farver Rose Gogliotti Kathy Behling John Stiver

Record of Revisions

Revision Number	Effective Date	Description of Revision
0 (Draft)	02/27/2015	Initial issued.

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ABBREVIATIONS AND ACRONYMS

AP	anterior-posterior
CADW	Chronic Annual Dose Workbook
CATI	Computer-Assisted Telephone Interview
CW	coworker
DCF	dose conversion factor
DDE	Deep dose equivalent
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
DR	dose reconstruction
EE	Energy Employee
GM	geometric mean
GSD	geometric standard deviation
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volts
L-S	lumbar-spine
LAT	lateral
LOD	limit of detection
MeV	megaelectron-volt, 1 million electron-volts
mrem	millirem
NCRP	National Council on Radiation Protection and Measurements
NDRP	Neutron Dose Reconstruction Project
NIOSH	National Institute for Occupational Safety and Health
NP	non-penetrating
n/p	neutron-to-photon dose ratio
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
PA	posterior-anterior
Pene	penetrating
POC	probability of causation

rem	Roentgen equivalent man
RFP	Rocky Flats Plant
SC&A	S. Cohen and Associates (SC&A, Inc.)
SDE SK	Shallow dose equivalent – skin
TBD	technical basis document
TIB	technical information bulletin
WBC	whole-body count
y	year

1.0 SUMMARY BACKGROUND INFORMATION

This report presents the results of an independent blind dose reconstruction (DR) performed by S. Cohen & Associates (SC&A, Inc.) for an energy employee (EE) who worked as a [Redact], [Redact], and [Redact] at the Rocky Flats Plant (RFP) during the following periods:

- [Redact]–[redact]
- [Redact]–[redact]

The EE was diagnosed with [redact] breast invasive ductal carcinoma in situ (ICD-9 Code 233.0) in [redact].

According to Department of Labor (DOL) files and the Computer-Assisted Telephone Interview (CATI) report, the EE worked in the [redact], [redact], and [redact] Areas during the first period of employment, and in [redact], close to Building [redact], during the second period of employment. The EE was monitored for external photon exposure during most of the first employment period, and twice during the second employment period at the RFP.

1.1 SC&A BLIND DR APPROACH

SC&A reviewed all of the Department of Energy (DOE) records provided on behalf of this employee and the National Institute for Occupational Safety and Health (NIOSH) procedures relevant to this case, which included the Technical Basis Document (TBD) for the RFP (issued as six separate document numbered ORAUT-TKBS-0011-1 through ORAUT-TKBS-0011-6), ORAUT-OTIB-0005 for surrogate organs, OCAS-IG-001 for dose conversion factors (DCFs), and ORAUT-OTIB-0017 for shallow doses. Using the guidance provided in these documents, along with the employee's dosimetry records, SC&A calculated reasonable, claimant-favorable annual organ doses for each of the two cancer sites. Table 1 provides a summary of the total doses assigned to the cancer sites. Appendix A provides a list of SC&A's assigned annual organ dose and also includes the Interactive RadioEpidemiological Program (IREP) input parameters, such as energy range, distribution type, and uncertainty for each year.

SC&A determined the probability of causation (POC) for this case using the annual doses as input into the POC program; the total doses shown in Table 1 produced a POC of **43.78%**.

Table 1. Summary of SC&A-Derived External/Internal Dose Estimates

	[Redact] Breast [Redact] Entry No.	Dose (rem)
External Dose –		
▪ Recorded/Modeled n/p Dose:		
30–250 keV Photons	1–4	0.247
<30 keV Photons	5–7	0.027
Neutrons by n/p	8–19	0.457
▪ Missed/Assigned n/p Dose:		
30–250 keV Photons	20–25	0.385
<30 keV Photons	NA	-
Neutrons by NDRP & n/p	26–49	1.270
▪ Coworker Dose:		
30–250 keV Photons	50–64	1.505
<30 keV Photons	65–79	0.724
Neutrons	80–139	6.333
▪ External Environmental Dose:		
30–250 keV Photons	140–147	0.016
▪ Occupational Medical Dose:		
30–250 keV Photons	148–152	0.104
Internal Dose –		
CW Pu Alpha	153–195	3.218
CW U-234 Alpha	196–238	0.167
Total		**14.453**

2.0 EXTERNAL DOSES

To perform this DR, SC&A analyzed the DOE files containing the quarterly and annual summaries. The datasheet for [redact] lists the EE's name and the quarterly exchanges, but it contained all blank results; while the recorded readings for the period [redact]–[redact] contained some positive recorded doses and some zeros. A summary sheet on page 13 of the DOE files contained annual summaries for the years [redact]–[redact], plus data for one badge exchange in [redact] and one in [redact] (with zero doses recorded). The datasheet for [redact] on page 32 of the DOE files appears to contain an error, in that the 3rd quarter skin dose was recorded as *71 mrem* and the penetrating dose was recorded as *98 mrem*. Considering the fact that at this time at the RFP, the shallow dose was defined as the skin dose minus the penetrating dose (ORAUT-TKBS-0011-6, page 38), the skin dose must be greater than or equal to the penetrating dose (and it was for all the other recorded positive doses). Therefore, it appears that the two values may have been interchanged and the penetrating dose was actually 71 mrem and the skin dose was 98 mrem; SC&A will use this assumption, as it is consistent with the other recorded doses for this EE. Another error that SC&A found was in the DOE files on pages 11, 12, and 13, where the summary sheets list the annual *Deep* (or *DDE*) and the *Skin* (or *SDE SK*) doses as equal to each other for the years [redact]–[redact]; this is incorrect according to the details provided by the quarterly exchange datasheets and, therefore, will not be used in the DR.

SC&A used the DR parameters as recommended in ORAUT-TKBS-0011-6 and ORAUT-OTIB-0017. Because the EE's tasks involved work in various locations at the RFP, a default energy range of 100% 30–250 keV photons for fresh plutonium (ORAUT-TKBS-0011-6, Table 6-9, page 36) and 100% <30 keV photon for non-penetrating dose (ORAUT-OTIB-0017, page 6) was used. A photon limit of detection (LOD) value of 0.020 rem was used for all years of monitored data (ORAUT-TKBS-0011-6, Table 6-12, page 40). Exposure DCFs were used for the period [redact]–[redact], and deep DCFs for the period [redact]–[redact], as per ORAUT-TKBS-0011-6, Table 6-11, page 39.

SC&A used 30–250 keV photon DCFs, as recommended in OCAS-IG-001 (for AP geometry), which consisted of a breast photon exposure DCF of 1.266, and a deep DCF of 0.894. For <30 keV photons from plutonium, SC&A used DCFs as recommended in OCAS-IG-001 (for AP geometry), which consisted of a <30 keV photon breast exposure DCF of 0.457, and a deep DCF of 0.761. No further adjustment of the dose to the breast is recommended, as per ORAUT-OTIB-0017, page 6.

ORAUT-TKBS-0011-6, page 38, recommends that the following methods be used to determine penetrating and non-penetrating doses from recorded dose data:

Table 2. Summary of External Dose Assignment Methods

	Penetrating Photons 30–250 keV	Non-penetrating Photons < 30 keV	Neutron Four Energy Ranges
[redacted]	Pene × [1/(1+n/p)]	(Skin - Pene)/0.65	Pene x [(n/p)/(1+n/p)] or NDRP data
[redacted]	Pene × [1/(1+n/p)]	(Skin - Pene)	Pene × [(n/p)/(1+n/p)]
[redacted]	Penetrating	(Skin – Pene)	n/p=0.42 or recorded n dose

In this case, the DOE files contained Neutron Dose Reconstruction Project (NDRP) data for [redact], in which there were four recorded badge exchanges with all readings <LOD/2 value of 0.060 rem (1970 neutron LOD = 120 mrem as per ORAUT-TKBS-0011-6, Table 6-20, page 47). Therefore, SC&A assigned 4 neutron missed doses, and 8 months of coworker (CW) neutron dose, since the EE was partially monitored for neutrons during [redact]. When applicable, the neutron-to-photon (n/p) ratio method was used for measured and missed neutron doses; the n/p values used in this DR were obtained from Tables 6-21 and 6-22, page 50, of ORAUT-TKBS-0011-6. Because the EE's duties required the EE to be present in various operating locations at the RFP (i.e., the EE did not spend the majority of the time in an office building), CW modeled photon and neutron doses were assigned during periods the EE's records contained no monitoring data.

2.1 RECORDED PHOTON DOSE

SC&A used the [redact]–[redact] recorded photon dose values to assign measured photon doses using the parameters previously described.

Example of [redact] recorded photon dose calculations – SC&A calculated the [redact] photon dose to the breast as follows:

> Analyzing the DOE records, SC&A found that the EE received a total penetrating dose of 0.119 rem and skin dose of 0.146 rem (with recording errors corrected as previously discussed) for [redact]. The photon dose was calculated as follows:

$$\text{Photon dose} = \text{Pene} \times 1/(1+n/p) = 0.119 \text{ rem} \times 1/(1+1.61) = 0.046 \text{ rem}$$

$$\begin{aligned}\text{30–250 keV photon dose} &= \text{Photon dose} \times \text{DCF} \times \text{Energy f.}\\ &= 0.046 \text{ rem} \times 1.266 \times 1.00\\ &= 0.058 \text{ rem (entry \#1 of the IREP table)}\end{aligned}$$

$$\begin{aligned}\text{<30 keV photon dose} &= (\text{Skin-Pene})/0.65 \times \text{DCF} \times \text{Energy f.}\\ &= (0.146 - 0.119)/0.65 \text{ rem} \times 0.457 \times 1.00\\ &= 0.019 \text{ rem (entry \#5 of the IREP table)}\end{aligned}$$

SC&A's calculated total 30–250 keV dose (0.247 rem) and <30 keV photon dose (0.027 rem) are summarized in Table 1, and the details are listed in the IREP Input table in entries #1–#4 and #5–#7, respectively, of Appendix A.

As per ORAUT-OTIB-0017, page 10, dose to organs such as the breast can be assigned with a normal or constant distribution, whichever is most claimant favorable. In this case, SC&A found that a normal distribution provided for the greater POC; therefore, the recorded photon doses were entered into the IREP Input table using a normal distribution with a 30% uncertainty.

2.2 MISSED PHOTON DOSE

SC&A analyzed the number of potential zeros based on a monthly badge exchange cycle and arrived at a total of **27** zeros, or <LOD/2 values, for photons. SC&A used the annual number of zeros, the LOD/2 value, the DR parameters as listed above, and the applicable DCFs to determine the annual missed photon and shallow doses. Missed dose to the breast was assigned as 30–250 keV photons, as per ORAUT-OTIB-0017, page 18.

<u>Example of [redact] missed photon dose calculations</u> – SC&A calculated the missed [redact] photon dose to the breast as follows:

> Records show that for the four quarters of [redact], the EE had received a penetrating dose of 0, 0, 71 mrem, and 48 mrem (with recording errors corrected as previously discussed). However, the zero entries for the first and second quarters may be suspect, because they may have been entered without monitoring, as per ORAUT-TKBS-0011-6, page 35. Therefore, CW dose was assigned for the first two quarters of [redact], and recorded dose and four potential missed doses assigned for the last two quarters of [redact]. The photon LOD was 0.020 rem.

$$\begin{aligned}\text{Missed 30–250 keV photon dose} &= (\text{\# zeros} \times \text{LOD}/2) \times \text{DCF} \times \text{Energy f.}\\ &= (4 \times 0.010 \text{ rem}) \times 1.266 \times 1.00\\ &= 0.051 \text{ rem (entry \#20 of the IREP table)}\end{aligned}$$

The photon missed doses were entered into IREP as a lognormal distribution (as recommended in ORAUT-OTIB-0017, page 10, and ORAUT-TKBS-0011-6, page 40) with an uncertainty of 1.520. The photon missed dose (0.385 rem) is summarized in Table 1, and assigned in the IREP Input table in entries #20–#25, as shown in Appendix A.

2.3 COWORKER PHOTON DOSE

<u>Coworker Penetrating Photon Dose</u>

SC&A used the 50th percentile plutonium CW photon dose values recommended in Table C-3, page 97, and Table C-4, pages 99–100, of ORAUT-TKBS-0011-6 (applying the parameters previously described) to assign photon doses during the periods the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW dose values for Building 71 were used, because the EE could have been at numerous locations and overall Building 71 dose values provided for the most claimant-favorable dose assignments.

<u>Example of [redact] coworker 30–250 keV photon dose calculations</u> – SC&A calculated the [redact] CW photon dose to the breast as follows:

> According to Table C-3, page 97, the 50th percentile coworker photon dose for [redact] was 0.120 rem. This was prorated for 6 months for the 1st and 2nd quarters when the EE may not have been monitored. The photon dose was calculated as follows:

30–250 keV photon dose = CW Photon dose × Time f. × DCF × Energy f.
= 0.120 rem × 6/12 x 1.266 × 1.00
= 0.076 rem (entry #51 of the IREP table)

SC&A's calculated total penetrating photon dose (1.505 rem) is summarized in Table 1, and the details are listed in the IREP Input table in entries #50–#64, as shown in Appendix A.

<u>Coworker Shallow Photon Dose</u>
SC&A used the 50th percentile uranium CW photon dose values (as per ORAUT-TKBS-0011-6, pages 94–95) recommended in Table C-5, pages 100–101 (applying the parameters previously described) to assign shallow photon doses during periods when the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW shallow dose was derived by subtracting the 50th percentile penetrating dose value from the 50th percentile non-penetrating dose value and assigning it as <30 keV photons, as per ORAUT-OTIB-0017. Additionally, the shallow dose was adjusted by the correction factor of 0.65 for the years [redact] and [redact], as per ORAUT-TKBS-0011-6, page 38.

<u>Example of [redact] coworker <30 keV photon shallow dose calculations</u> – SC&A calculated the [redact] CW shallow photon dose to the breast as follows:

> According to Table C-5, page 100, the 50th percentile non-penetrating (NP) CW photon dose for [redact] was 0.651 rem and the penetrating (Pene dose was 0.531 rem. This was prorated for 6 months for the 1st and 2nd quarters when the EE may not have been monitored. The shallow photon dose was calculated as follows:

<30 keV photon dose = (NP-PEN)/0.65 × Time f. × DCF × Energy f.
= (0.651 rem – 0.531 rem)/0.65 × 6/12 × 0.457 × 1.00
= 0.042 rem (entry #66 of the IREP table)

SC&A's calculated total shallow photon dose (0.724 rem) is summarized in Table 1, and the details are listed in the IREP Input table in entries #65–#79, as shown in Appendix A.

In this case, SC&A found that a lognormal distribution provided for the greater POC for photon doses; therefore, the CW photon doses were entered into the IREP Input table using a lognormal distribution with an uncertainty of 1.520.

2.4 ASSIGNED NEUTRON DOSE

The DOE records show that the EE may have been monitored for neutrons along with the photon monitoring, with all results recorded as zero, except for [redact] when the NDRP data list four recorded neutron doses less than the LOD/2 value of 0.060 rem. Therefore, the n/p method was used to assign neutron dose for the periods the EE was monitored for photon exposures (when either positive photon results or zeros were recorded), except LOD data for neutrons were used for missed dose for the four badge exchanges in [redact] where NDRP data were available. RFP CW neutron dose data will be used for the periods the EE was not monitored, because the EE may have been exposed in the plutonium work areas.

The neutron energy distribution and adjustment factors as listed in Table 6-17, page 45, of ORAUT-TKBS-0011-6 was applied in deriving the neutron doses; the table is reproduced here as Exhibit A.

Exhibit A. Summary of Neutron Adjustment Factors
(From ORAUT-TKBS-0011-6, page 45)

Table 6-17. Default neutron energy distribution.

Neutron energy intervals	Fraction of dose (NCRP 38)	Dose multiplier (ICRP 60)	Dose multiplier[a]
<10 keV	0.035	2.13	0.0755
10–100 keV	0.017	1.86	0.0309
0.1–2 MeV	0.687	1.91	1.31
2.0–20 MeV	0.261	1.32	0.345
>20 MeV	0	None	None

a. Multiply the reported dose by these factors to determine the ICRP 60 neutron dose for each neutron energy interval.

SC&A used the recorded photon dose values that were ≥LOD/2 of 0.010 rem to assign neutron doses using the n/p values from Tables 6-21 and 6-22 of ORAUT-TKBS-0011-6, page 50; the tables are reproduced here as Exhibit B.

Exhibit B. Summary n/p Values
(From ORAUT-TKBS-0011-6, page 50)

Table 6-21. RFP lognormal neutron-to-photon ratio values, [redacted] to [redacted].

Year	Neutron-to-photon ratio GM (semimonthly exchange)	GSD	95th percentile	Neutron-to-photon ratio GM (monthly exchange)	GSD	95th percentile
[redacted]	1.61[a]	3.45	12.4	N/A	N/A	N/A
[redacted]	1.61	3.45	12.4	N/A	N/A	N/A
[redacted]	1.32	2.15	4.64	0.8	2.63	3.94
[redacted]	1.32[b]	2.15	4.64	N/A	N/A	N/A
[redacted]	0.68	3.01	4.16	N/A	N/A	N/A
[redacted]	0.67	3.31	4.82	N/A	N/A	N/A
[redacted]	0.95	3.59	7.81	0.78	4.29	8.55

a. Data for [redacted] were not available. This value is the greater of the ratios for [redacted] and [redacted]. The high neutron-to-gamma ratio in [redacted] for Building 771 is reasonable from a process aspect, and extrapolating that ratio back to [redacted] also is reasonable. In the aftermath of the [redacted] plutonium fire in Buildings 776 and 777, the salvaged plutonium oxide had to be converted back to plutonium metal, a process done in Building 771. Building 771 had a huge backlog for relatively pure plutonium (little americium, low gamma) to be reprocessed, which was staged in the 776 to 771 tunnel and any other possible staging area in the vicinity. In addition, PuF_4 (a high neutron source) seemed to be generated faster in Building 771 than it could be reduced to metal, which also caused a staging problem in or near the process areas in Building 771 until the backlog could be reduced.

b. Data for [redacted] were not available. This value is the greater of the ratios for [redacted] and [redacted].

Table 6-22. ORAU Team-developed neutron-to-gamma ratios.

Year	GM	GSD
[redacted]	0.33	3.31
[redacted]	0.57	2.53
[redacted]	0.37	3.31
[redacted]	0.43	2.57
[redacted]	0.51	2.41
[redacted]	0.4	2.4
[redacted]	0.42	3.01

Year	GM	GSD
[redacted]	0.41	3.07
[redacted]	0.42	3.37
[redacted]	0.49	2.93
[redacted]	0.36	3.56
[redacted]	0.6	2.83
[redacted]	0.36	3.5
[redacted]	0.35	3.77

Year	GM	GSD
[redacted]	0.29	2.41
[redacted]	0.4	2.03
[redacted]	0.61	1.93
[redacted]	0.41	2.35
[redacted]	0.35	2.28
[redacted]	0.26	4.1
[redacted]	0.44	2.18

Year	GM	GSD
[redacted]	0.39	3.03
[redacted]	0.45	2.79
[redacted]	0.6	1.8
Overall	0.42	3

<u>Example of [redact] assigned neutron dose calculations</u> – SC&A calculated the [redact] assigned neutron dose to the breast as follows:

Analyzing the DOE records, it appears that for [redact], the EE received a total penetrating dose of 0.176 rem. The assigned 0.1–2 MeV neutron dose was calculated as follows:

$$
\begin{aligned}
\text{0.1–2 MeV neutron dose} &= \text{Pene} \times [(n/p)/(1+n/p)] \times DCF_{eff} \\
&= 0.176 \text{ rem} \times [1.61/(1+1.61)] \times 1.546 \\
&= 0.168 \text{ rem (entry \#14 of the IREP Input table)}
\end{aligned}
$$

The dose values for the other three neutron energy bands were derived in a similar manner.

The assigned neutron doses were entered into the IREP as a lognormal distribution (as per ORAUT-TKBS-0011-6, page 93) with an uncertainty of 1.520. SC&A assigned a total of 0.457 rem in entries #8–#19 of the IREP Input table, as summarized in Table 1 and detailed in Appendix A.

2.5 MISSED NEUTRON DOSES

SC&A used the number of photon zeros and <LOD/2 values as previously described to assign missed neutron dose, since all neutron doses were recorded as zero (except for the [redact] NDRP data when four badge exchanges were recorded with values <LOD/2). The total number of missed neutron doses was 27 (i.e., 27 photon – 4 photon 1970 + 4 neutron NDRP 1970 = **27**.

<u>Example of [redact] missed neutron dose calculations based on NDRP data</u> – SC&A calculated the missed [redact] neutron dose based on the NDRP data as follows:

Records show that for the four badge exchanges in [redact], 10 mrem, 0 mrem, 12 mrem, and 13 mrem of neutron dose were recorded, all below the neutron LOD/2 value of 60 mrem, as per ORAUT-TKBS-0011-6, Table 6-20, page 47. The derived 0.1–2 MeV missed neutron dose was calculated as follows:

$$
\begin{aligned}
\text{0.1–2 MeV neutron dose} &= (\text{\#neutron zeros} \times \text{LOD/2 rem}) \times DCF_{eff} \\
&= (4 \times 0.060 \text{ rem}) \times 1.546 \\
&= 0.371 \text{ rem (entry \#38 of the IREP Input table)}
\end{aligned}
$$

The dose values for the other three neutron energy ranges were derived in a similar manner.

<u>Example of [redact] assigned missed neutron dose calculations based on photon data and n/p</u> – SC&A calculated the [redact] assigned missed neutron dose based on the missed photon dose data and the n/p method as follows:

Records show that for [redact], the EE had one badge exchange with a recorded result of zero. The assigned 0.1–2 MeV missed neutron dose was calculated as follows:

$$
\begin{aligned}
\text{0.1–2 MeV neutron dose} &= (\text{\#photon zeros} \times \text{LOD/2 rem}) \times n/p \times DCF_{eff} \\
&= (1 \times 0.010 \text{ rem}) \times 0.42 \times 1.500 \\
&= 0.006 \text{ rem (entry \#42 of the IREP Input table)}
\end{aligned}
$$

The dose values for the other three neutron energy bands were derived in a similar manner.

The missed neutron doses were entered into the IREP as a lognormal distribution (as recommended in ORAUT-OTIB-0017, page 10, and ORAUT-TKBS-0011-6, page 40) with an uncertainty of 1.520. SC&A assigned a total of 1.270 rem in entries #26–#49 of the IREP Input tables, as summarized in Table 1 and shown in Appendix A.

2.6 COWORKER NEUTRON DOSE

SC&A used the 50th percentile plutonium CW neutron dose values recommended in Table C-3, page 97, and Table C-4, pages 99–100, of ORAUT-TKBS-0011-6 (applying the parameters previously described) to assign neutron doses during periods when the EE was not continuously monitored ([redact], [redact], and [redact]–[redact]), prorating the appropriate time periods. The CW dose values for Building 71 were used, because the EE could have been at numerous locations and Building 71 dose values provided for the most claimant-favorable dose assignments.

<u>Example of [redact] coworker neutron dose calculations</u> – SC&A calculated the [redact] CW neutron dose to the breast as follows:

> Four badge exchanges for [redact] were accounted for in the NDRP data (and assigned as missed dose because they were <LOD/2); therefore, 8 months of CW neutron data were assigned for [redact]. According to Table C-3, page 97, the 50th percentile coworker neutron dose for [redact] was 1.675 rem. This was prorated for 8 months for [redact] when the EE may not have been monitored for neutrons. The 0.1–2 MeV neutron dose was calculated as follows:

$$\begin{aligned} \text{0.1–2 MeV neutron dose} &= \text{CW Neutron dose} \times \text{Time f.} \times DCF_{eff} \\ &= 1.675 \text{ rem} \times 8/12 \times 1.546 \\ &= 1.726 \text{ rem (entry \#111 of the IREP table)} \end{aligned}$$

The dose values for the other three neutron energy bands were derived in a similar manner.

SC&A's calculated CW neutron dose (6.333 rem) is summarized in Table 1, and the details are listed in the IREP Input table in entries #80–#139, as shown in Appendix A.

In this case, SC&A found that a lognormal distribution provided for the greater POC; therefore, the CW neutron doses were entered into the IREP Input table using a lognormal distribution with an uncertainty of 1.520.

2.7 ONSITE EXTERNAL AMBIENT DOSE

According to ORAUT-PROC-0060, Attachment A, page 14, RFP onsite external ambient dose is to be assigned prior to 1977 and after 1999, even if other doses are assigned during these periods. SC&A used the best-estimate DR value of 0.004 rem/y (as recommended on page 25 of ORAUT-PROC-0060), the appropriate years, and prorated for time worked to assign ambient dose in this case. SC&A used an ambient rotational exposure geometry DCF of 0.587 for the breast (as per page 49 of OCAS-IG-001). SC&A derived a total external environmental dose of 0.016 rem, which was assigned in entries #140–#147 of the IREP Input table, as summarized in Table 1, with details shown in Appendix A. The doses were entered as a constant with no uncertainty in the IREP Input table, as per ORAUT-PROC-0060, page 25.

2.8 OCCUPATIONAL MEDICAL DOSE

Records

The DOE records show that the EE received a pre-hire x-ray exam in [redact], a termination x-ray exam in [redact], and a routine x-ray exam in [redact]. SC&A noted that the summary sheet on page 8 of the DOE file lists two x-ray exams in [redact], but the detailed original datasheets for [redact], pages 6 and 7, list only one x-ray exam on [redact]. Therefore, SC&A will assume that the EE had one x-ray exam in [redact]. According to ORAUT-TKBS-0011-3, page 8, the frequency of x-ray exams at the RFP varied widely; therefore, since there were x-ray exam records available for this EE, no additional x-ray exam doses will be assigned. SC&A assumed a posterior/anterior (PA) and lumbar-spine (L-S) lateral (LAT) and anterior-posterior (AP) view as listed in Table 3-7, page 14, of ORAUT-TKBS-0011-3, because the original x-ray exam record was not available. However, for [redact], the original x-ray exam record (DOE file, pdf. 5) was available and it does not indicate that an L-S exam was performed. Therefore, SC&A did not include an L-S exam for [redact].

SC&A used the appropriate breast x-ray dose values as recommended in ORAUT-TKBS-0011-3, Table 3-6, page 13, for the PA view, and Table 3-7, page 14, for the 1968 L-S LAT and AP view to assign x-ray doses in this case. Table 3 summarizes these assigned doses.

Table 3. Summary of Occupational Medical Doses

(From TKBS-0011-3, Tables 3-6, 3-7, p.13 & 14)

	Dose (rem)	View
[redact]	9.80E-03	PA
[redact]	4.90E-03	PA
[redact]	5.80E-03	PA
[redact]	4.75E-02	L-S LAT
[redact]	3.60E-02	L-S AP
Total:	**0.104**	

The 0.104 rem dose assigned is summarized in Table 1 and detailed in the IREP Input table in entries #148–#152, as shown in Appendix A. The annual occupational medical dose values were entered into the IREP as a normal distribution with 30% uncertainty and a photon energy range of 30–250 keV, as per ORAUT-TKBS-0011-3, pages 7 and 16.

3.0 INTERNAL DOSES

There were three whole-body counts (WBCs) performed in [redacted], [redacted], and [redacted] for this EE. All results were recorded as background. Therefore, in view of the external monitoring records, the EE's documented work areas (as opposed to office buildings) of the RFP, and the use of external CW data, SC&A used CW intake data to derive internal dose assignments in this case.

<u>Coworker Intakes</u>
SC&A used the CW intake data from Table D-4 (uranium Types F, M, and S), Table D-5 (plutonium Type M), and Table D-6, (plutonium Type S) in the Chronic Annual Dose Workbook (CADW) for the RFP in the DR Tools folder for the years [redacted]–[redacted] and [redacted]–[redacted]. Coworker intakes were selected for the entire periods of employment, with full-year intakes applied to those years of partial employment. All potential solubility types were analyzed and the type that produced the greater dose was selected. This resulted in the selection of Type S U-234 and Type S plutonium (which consisted of Pu-239, Pu-238, Pu-241, and Am-241), all alpha emitters. The total resulting dose was 0.167 rem from U-234 and 0.818 rem from the Type S plutonium components. However, the doses from the plutonium components were adjusted for systemic organs according to ORAUT-OTIB-0049, Table 4-8, page 17, and for urine bioassays (as noted in footnote *a.* of Table D-6 of ORAUT-TKBS-0011-5, page 151). The CW intake period ending date in Table D-6 was used as the date of the last bioassay for each intake period in this case (as per the last paragraph on page 150 of ORAUT-TKBS-0011-5). The total uranium and adjusted plutonium alpha dose was 3.385 rem. The plutonium Type SS dose (3.218 rem) was entered into the IREP Input table in entries #153–#195, and the U-234 Type S dose (0.167 rem) in entries #196–#238, both with a constant distribution and an uncertainty of zero, since the CW intake values were at the 95th percentile level (per ORAUT-TKBS-0011-5, page 51).

4.0 CATI REPORT AND RADIOLOGICAL INCIDENTS

SC&A reviewed the EE's DOE records and CATI report (which was provided by the EE) to determine if the EE was involved in any radiological incidents. The EE indicated that the EE had to go through the production areas to get to other areas of the plant, and may have been exposed. Coworker and/or recorded dosimetry data were used to assign dose in this case; therefore, these DR methods would adequately assign doses to cover these exposures.

SC&A did not find any further documentation of radiological incidents that would impact the radiation doses assigned in this case.

5.0 SUMMARY CONCLUSIONS

This DR used best-estimate methods to obtain reasonable external (11.068 rem) and internal dose (3.385 rem) assignments, for a total dose assignment of **14.453 rem**.

The total combined POC for the two cancers was calculated using the IREP (v.5.7.1) and determined to be **43.78%.**

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APPENDIX A: IREP INPUT – [REDACT] [REDACT] BREAST

CLAIMANT CANCER DIAGNOSES	Primary Cancer #1	Primary Cancer #2	Primary Cancer #3	Secondary Cancer #1	Secondary Cancer #2	Secondary Cancer #3
Cancer Type	Breast invasive ductal carcinoma in situ	N/A	N/A	N/A	N/A	N/A
Date of Diagnosis	[redact]	N/A	N/A	N/A	N/A	N/A

EXPOSURE INFORMATION							
Number of exposures							
238							
Exp. #	**Exposure Year**	**Exposure Rate**	**Radiation Type**	**Dose Distribution Type**	**Parameter 1**	**Parameter 2**	**Parameter 3**
1	[redact]	acute	photons E=30–250 keV	Normal	0.058	0.017	0.000
2	[redact]	acute	photons E=30–250 keV	Normal	0.085	0.026	0.000
3	[redact]	acute	photons E=30–250 keV	Normal	0.064	0.019	0.000
4	[redact]	acute	photons E=30–250 keV	Normal	0.040	0.012	0.000
5	[redact]	acute	photons E<30 keV	Normal	0.019	0.006	0.000
6	[redact]	acute	photons E<30 keV	Normal	0.004	0.001	0.000
7	[redact]	acute	photons E<30 keV	Normal	0.004	0.001	0.000
8	[redact]	chronic	neutrons E<10 keV	Lognormal	0.013	1.520	0.000
9	[redact]	chronic	neutrons E<10 keV	Lognormal	0.008	1.520	0.000
10	[redact]	chronic	neutrons E<10 keV	Lognormal	0.005	1.520	0.000
11	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.004	1.520	0.000
12	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.002	1.520	0.000
13	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
14	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.168	1.520	0.000
15	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.103	1.520	0.000
16	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.064	1.520	0.000
17	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.044	1.520	0.000
18	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.027	1.520	0.000
19	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.017	1.520	0.000
20	[redact]	chronic	photons E=30–250 keV	Lognormal	0.051	1.550	0.000
21	[redact]	chronic	photons E=30–250 keV	Lognormal	0.101	1.550	0.000
22	[redact]	chronic	photons E=30–250 keV	Lognormal	0.101	1.550	0.000
23	[redact]	chronic	photons E=30–250 keV	Lognormal	0.114	1.550	0.000
24	[redact]	chronic	photons E=30–250 keV	Lognormal	0.009	1.550	0.000
25	[redact]	chronic	photons E=30–250 keV	Lognormal	0.009	1.550	0.000
26	[redact]	chronic	neutrons E<10 keV	Lognormal	0.029	1.520	0.000
27	[redact]	chronic	neutrons E<10 keV	Lognormal	0.016	1.520	0.000
28	[redact]	chronic	neutrons E<10 keV	Lognormal	0.013	1.520	0.000
29	[redact]	chronic	neutrons E<10 keV	Lognormal	0.014	1.520	0.000
an30	[redact]	chronic	neutrons E<10 keV	Lognormal	0.000	1.520	0.000
31	[redact]	chronic	neutrons E<10 keV	Lognormal	0.000	1.520	0.000
32	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.008	1.520	0.000
33	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.004	1.520	0.000
34	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.004	1.520	0.000
35	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.004	1.520	0.000
36	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.000	1.520	0.000
37	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.000	1.520	0.000
38	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.371	1.520	0.000
39	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.199	1.520	0.000
40	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.163	1.520	0.000

Appendix A: IREP Input – [Redact] [Redact] Breast (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
41	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.184	1.520	0.000
42	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.006	1.520	0.000
43	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.006	1.520	0.000
44	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.098	1.520	0.000
45	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.053	1.520	0.000
46	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.043	1.520	0.000
47	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.049	1.520	0.000
48	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.002	1.520	0.000
49	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.002	1.520	0.000
50	[redact]	acute	photons E=30–250 keV	Lognormal	0.737	1.520	0.000
51	[redact]	acute	photons E=30–250 keV	Lognormal	0.076	1.520	0.000
52	[redact]	acute	photons E=30–250 keV	Lognormal	0.068	1.520	0.000
53	[redact]	acute	photons E=30–250 keV	Lognormal	0.081	1.520	0.000
54	[redact]	acute	photons E=30–250 keV	Lognormal	0.094	1.520	0.000
55	[redact]	acute	photons E=30–250 keV	Lognormal	0.050	1.520	0.000
56	[redact]	acute	photons E=30–250 keV	Lognormal	0.053	1.520	0.000
57	[redact]	acute	photons E=30–250 keV	Lognormal	0.050	1.520	0.000
58	[redact]	acute	photons E=30–250 keV	Lognormal	0.066	1.520	0.000
59	[redact]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
60	[redact]	acute	photons E=30–250 keV	Lognormal	0.046	1.520	0.000
61	[redact]	acute	photons E=30–250 keV	Lognormal	0.045	1.520	0.000
62	[redact]	acute	photons E=30–250 keV	Lognormal	0.038	1.520	0.000
63	[redact]	acute	photons E=30–250 keV	Lognormal	0.038	1.520	0.000
64	[redact]	acute	photons E=30–250 keV	Lognormal	0.011	1.520	0.000
65	[redact]	acute	photons E<30 keV	Lognormal	0.100	1.520	0.000
66	[redact]	acute	photons E<30 keV	Lognormal	0.042	1.520	0.000
67	[redact]	acute	photons E<30 keV	Lognormal	0.045	1.520	0.000
68	[redact]	acute	photons E<30 keV	Lognormal	0.047	1.520	0.000
69	[redact]	acute	photons E<30 keV	Lognormal	0.065	1.520	0.000
70	[redact]	acute	photons E<30 keV	Lognormal	0.053	1.520	0.000
71	[redact]	acute	photons E<30 keV	Lognormal	0.044	1.520	0.000
72	[redact]	acute	photons E<30 keV	Lognormal	0.043	1.520	0.000
73	[redact]	acute	photons E<30 keV	Lognormal	0.048	1.520	0.000
74	[redact]	acute	photons E<30 keV	Lognormal	0.046	1.520	0.000
75	[redact]	acute	photons E<30 keV	Lognormal	0.043	1.520	0.000
76	[redact]	acute	photons E<30 keV	Lognormal	0.042	1.520	0.000
77	[redact]	acute	photons E<30 keV	Lognormal	0.046	1.520	0.000
78	[redact]	acute	photons E<30 keV	Lognormal	0.046	1.520	0.000
79	[redact]	acute	photons E<30 keV	Lognormal	0.014	1.520	0.000
80	[redact]	chronic	neutrons E<10 keV	Lognormal	0.191	1.520	0.000
81	[redact]	chronic	neutrons E<10 keV	Lognormal	0.136	1.520	0.000
82	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
83	[redact]	chronic	neutrons E<10 keV	Lognormal	0.004	1.520	0.000
84	[redact]	chronic	neutrons E<10 keV	Lognormal	0.005	1.520	0.000
85	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
86	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
87	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
88	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
89	[redact]	chronic	neutrons E<10 keV	Lognormal	0.003	1.520	0.000
90	[redact]	chronic	neutrons E<10 keV	Lognormal	0.002	1.520	0.000
91	[redact]	chronic	neutrons E<10 keV	Lognormal	0.002	1.520	0.000
92	[redact]	chronic	neutrons E<10 keV	Lognormal	0.002	1.520	0.000

Appendix A: IREP Input – [Redact] [Redact] Breast (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
93	[redact]	chronic	neutrons E<10 keV	Lognormal	0.002	1.520	0.000
94	[redact]	chronic	neutrons E<10 keV	Lognormal	0.001	1.520	0.000
95	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.054	1.520	0.000
96	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.039	1.520	0.000
97	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
98	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
99	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.002	1.520	0.000
100	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
101	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
102	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
103	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
104	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
105	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
106	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
107	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
108	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.001	1.520	0.000
109	[redact]	chronic	neutrons E=10–100 keV	Lognormal	0.000	1.520	0.000
110	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	2.425	1.520	0.000
111	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	1.726	1.520	0.000
112	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.048	1.520	0.000
113	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.057	1.520	0.000
114	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.066	1.520	0.000
115	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.036	1.520	0.000
116	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.038	1.520	0.000
117	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.036	1.520	0.000
118	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.047	1.520	0.000
119	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.038	1.520	0.000
120	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.033	1.520	0.000
121	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.032	1.520	0.000
122	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.027	1.520	0.000
123	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.027	1.520	0.000
124	[redact]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.008	1.520	0.000
125	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.642	1.520	0.000
126	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.457	1.520	0.000
127	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.012	1.520	0.000
128	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.015	1.520	0.000
129	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.017	1.520	0.000
130	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.009	1.520	0.000
131	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.010	1.520	0.000
132	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.009	1.520	0.000
133	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.012	1.520	0.000
134	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.010	1.520	0.000
135	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.009	1.520	0.000
136	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.008	1.520	0.000
137	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.007	1.520	0.000
138	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.007	1.520	0.000
139	[redact]	chronic	neutrons E=2–20 MeV	Lognormal	0.002	1.520	0.000
140	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
141	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
142	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
143	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
144	[redact]	chronic	photons E=30–250 keV	Constant	0.001	0.000	0.000

Appendix A: IREP Input – [Redact] [Redact] Breast (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
145	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
146	[redact]	chronic	photons E=30–250 keV	Constant	0.002	0.000	0.000
147	[redact]	chronic	photons E=30–250 keV	Constant	0.001	0.000	0.000
148	[redact]	acute	photons E=30–250 keV	Normal	4.75E-02	0.014	0.000
149	[redact]	acute	photons E=30–250 keV	Normal	3.60E-02	0.011	0.000
150	[redact]	acute	photons E=30–250 keV	Normal	9.80E-03	0.003	0.000
151	[redact]	acute	photons E=30–250 keV	Normal	4.90E-03	0.001	0.000
152	[redact]	acute	photons E=30–250 keV	Normal	5.80E-03	0.002	0.000
153	[redact]	chronic	alpha	Constant	0.001	0.000	0.000
154	[redact]	chronic	alpha	Constant	0.015	0.000	0.000
155	[redact]	chronic	alpha	Constant	0.023	0.000	0.000
156	[redact]	chronic	alpha	Constant	0.028	0.000	0.000
157	[redact]	chronic	alpha	Constant	0.032	0.000	0.000
158	[redact]	chronic	alpha	Constant	0.057	0.000	0.000
159	[redact]	chronic	alpha	Constant	0.061	0.000	0.000
160	[redact]	chronic	alpha	Constant	0.064	0.000	0.000
161	[redact]	chronic	alpha	Constant	0.065	0.000	0.000
162	[redact]	chronic	alpha	Constant	0.065	0.000	0.000
163	[redact]	chronic	alpha	Constant	0.066	0.000	0.000
164	[redact]	chronic	alpha	Constant	0.066	0.000	0.000
165	[redact]	chronic	alpha	Constant	0.066	0.000	0.000
166	[redact]	chronic	alpha	Constant	0.067	0.000	0.000
167	[redact]	chronic	alpha	Constant	0.067	0.000	0.000
168	[redact]	chronic	alpha	Constant	0.068	0.000	0.000
169	[redact]	chronic	alpha	Constant	0.069	0.000	0.000
170	[redact]	chronic	alpha	Constant	0.070	0.000	0.000
171	[redact]	chronic	alpha	Constant	0.071	0.000	0.000
172	[redact]	chronic	alpha	Constant	0.071	0.000	0.000
173	[redact]	chronic	alpha	Constant	0.072	0.000	0.000
174	[redact]	chronic	alpha	Constant	0.073	0.000	0.000
175	[redact]	chronic	alpha	Constant	0.075	0.000	0.000
176	[redact]	chronic	alpha	Constant	0.076	0.000	0.000
177	[redact]	chronic	alpha	Constant	0.078	0.000	0.000
178	[redact]	chronic	alpha	Constant	0.087	0.000	0.000
179	[redact]	chronic	alpha	Constant	0.089	0.000	0.000
180	[redact]	chronic	alpha	Constant	0.091	0.000	0.000
181	[redact]	chronic	alpha	Constant	0.092	0.000	0.000
182	[redact]	chronic	alpha	Constant	0.093	0.000	0.000
183	[redact]	chronic	alpha	Constant	0.094	0.000	0.000
184	[redact]	chronic	alpha	Constant	0.095	0.000	0.000
185	[redact]	chronic	alpha	Constant	0.096	0.000	0.000
186	[redact]	chronic	alpha	Constant	0.096	0.000	0.000
187	[redact]	chronic	alpha	Constant	0.099	0.000	0.000
188	[redact]	chronic	alpha	Constant	0.100	0.000	0.000
189	[redact]	chronic	alpha	Constant	0.101	0.000	0.000
190	[redact]	chronic	alpha	Constant	0.101	0.000	0.000
191	[redact]	chronic	alpha	Constant	0.102	0.000	0.000
192	[redact]	chronic	alpha	Constant	0.103	0.000	0.000
193	[redact]	chronic	alpha	Constant	0.104	0.000	0.000
194	[redact]	chronic	alpha	Constant	0.104	0.000	0.000
195	[redact]	chronic	alpha	Constant	0.105	0.000	0.000
196	[redact]	chronic	alpha	Constant	0.001	0.000	0.000

Appendix A: IREP Input – [Redact] [Redact] Breast (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
197	[redact]	chronic	alpha	Constant	0.001	0.000	0.000
198	[redact]	chronic	alpha	Constant	0.002	0.000	0.000
199	[redact]	chronic	alpha	Constant	0.002	0.000	0.000
200	[redact]	chronic	alpha	Constant	0.003	0.000	0.000
201	[redact]	chronic	alpha	Constant	0.003	0.000	0.000
202	[redact]	chronic	alpha	Constant	0.003	0.000	0.000
203	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
204	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
205	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
206	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
207	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
208	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
209	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
210	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
211	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
212	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
213	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
214	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
215	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
216	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
217	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
218	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
219	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
220	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
221	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
222	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
223	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
224	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
225	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
226	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
227	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
228	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
229	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
230	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
231	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
232	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
233	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
234	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
235	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
236	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
237	[redact]	chronic	alpha	Constant	0.004	0.000	0.000
238	[redact]	chronic	alpha	Constant	0.004	0.000	0.000

OTHER ADVANCED FEATURES			
Sample Size	Random Seed		
2000	99		
User Defined Uncertainty Distribution			
Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
Lognormal	1.000	1.000	0.000

SKIN CANCER INPUTS	Not used for cancer selected: Breast
Ethnic Origin : [redact]	

NOTICE: This report has been reviewed for Privacy Act information and has been cleared for distribution. However, this report is pre-decisional and has not been reviewed by the Advisory Board on Radiation and Worker Health for factual accuracy or applicability within the requirements of 42 CFR 82.