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 DANA HEAVY WATER PLANT AND SAVANNAH RIVER SITE

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Comparison of SC&A's Blind Dose Reconstruction to NIOSH's Dose Reconstruction of Case #[Redact] from the Dana Heavy Water Plant and Savannah River Site	Page 2 of 23
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ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
BCC	basal cell carcinoma
CATI	Computer-Assisted Telephone Interview
CF	conversion factor
DCF	dose conversion factor
DHWP	Dana Heavy Water Plant
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
dpm	disintegrations per minute
DR	dose reconstruction
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
FP	fission product
GM	geometric mean
GSD	geometric standard deviation
HHS	Health and Human Services
ICD	International Classification of Diseases
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules of Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
keV	kiloelectron volts
LOD	limit of detection
MDA	minimum detectable activity
MeV	million electron volts
µCi/L	microcuries per liter
NIOSH	National Institute for Occupational Safety and Health
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
OW	open window
PA	posterior/anterior
POC	probability of causation

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rem	Roentgen equivalent man
S	shielded
SC&A	S. Cohen and Associates (SC&A, Inc.)
SD	standard deviation
SEC	Special Exposure Cohort
SRS	Savannah River Site
TBD	technical basis document
TIB	technical information bulletin

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1.0 RELEVANT BACKGROUND INFORMATION

Under Contract No. 200-2009-28555, SC&A was tasked by the Advisory Board on Radiation and Worker Health (Advisory Board) to perform six blind dose reconstructions (DRs) at the May 21, 2013, 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 two independent approaches to reconstruct occupational external and internal doses for the cases. Both approaches used the available dosimetry records and current guidance from NIOSH. The first approach, which is referred to as DR–Method A, used the spreadsheets and other tools developed by NIOSH to calculate the doses, whereas the second approach, referred to as DR–Method B, manually calculated the doses using a deterministic model that is based on central values and first principles.

One of the six draft blind DR reports [*SC&A's Dose Reconstruction of Case #*[**Redact**] *from the Dana Heavy Water Plant and Savannah River Site* (SC&A 2014), was submitted to the Advisory Board and NIOSH on February 26, 2014. In this report, SC&A presents a comparison between SC&A's and NIOSH's DR methodologies, doses, and resultant Probability of Causation (POC) values for Case #[**Redact**]. Table 1-1 summarizes the external and internal occupational doses calculated by SC&A (using two independent methods) and the NIOSH-assigned doses for cancers to the prostate, bladder and colon, and basal cell carcinomas (BCCs) of the right cheek and right lower eyelid diagnosed in behalf of Case #[**Redact**]. As a minimizing DR approach, SC&A's 'Method B' only assigned partial doses to the non-presumptive cancers (i.e., prostate and BCCs). All three DR methods calculated doses that resulted in a POC >50% and would, therefore, be compensable. A detailed comparison of the three 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 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.

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

Dose Elements	NIOSH				SC&A's DR–Method A			SC&A's DR–Method B	
	Prostate Dose (rem)	Bladder Dose (rem)	Colon Dose (rem)	Cheek and Eyelid Dose (rem)	Prostate and Bladder Dose (rem)	Colon Dose (rem)	Cheek and Eyelid Dose (rem)	Prostate Dose (rem)	Cheek and Eyelid Dose (rem)
External Dose (Occupational):									
▪ Recorded Photon Dose									
30–250 keV Photons:	2.516	2.516	2.144	2.023	1.546	1.323	1.771	2.321	1.866
>250 keV Photons:	1.786	1.786	1.707	2.023	1.617	1.548	1.771	2.321	1.866
▪ Missed Dose									
30–250 keV Photons:	3.004	3.004	2.560	2.415	1.418	1.219	4.088	3.751	3.015
>250 keV Photons:	–	–	–		1.482	1.419	–	–	–
▪ Recorded Shallow Dose									
NIOSH, Method A (e^- >15 keV); Method B (e^- <30 keV)				4.810	–	–	4.385	–	3.196
▪ Missed Shallow Dose, e^- >15 keV:	–	–	–	–	–	–	0.125	–	–
▪ Unmonitored Photon Dose (30–250 keV)	–	–	–	–	–	–	–	0.546	0.546
▪ Unmonitored Shallow Dose (<30 keV)	–	–	–	–	–	–	–	–	0.332
▪ Unmonitored Neutron Dose (0.1–2 MeV)	–	–	–	–	–	–	–	5.306	6.665
▪ Unmonitored Neutron Dose (2–20 MeV)	–	–	–	–	–	–	–	3.424	3.099
▪ Occupational Medical Dose									
SRS:	0.051	0.051	0.051	0.026	0.051	0.051	0.026	0.046	0.031
Dana:	0.375	0.375	0.375	0.096	0.375	0.375	0.096	0.375	0.090
▪ Occupational Environmental Dose									
Photon (30–250 keV)	0.306	0.306	0.306	0.306	0.318	0.318	0.318	1.361	1.107
Internal Dose (Occupational):									
Missed Pu (alpha)	0.323	0.537	0.710	0.863	–	–	–	–	–
FP (e^- >15 keV)	0.085	0.086	0.317	0.072	–	–	–	–	–
Eu-154 (e^- >15 keV)	0.012	0.001	0.004	0.001	–	–	–	–	–
Unmonitored H-3 (e^- >15 keV)	0.799	0.799	0.799	0.799	–	–	–	–	–
Environmental (e^- <15 keV)	0.031	0.031	0.031	0.031	1.296	1.296	1.296	–	–
Total	**9.288**	**9.492**	**9.004**	**13.465**	**8.103**	**7.549**	**13.876**	**19.451**	**21.813**
POC	**51.39%**				**51.00%**			**60.84%**	

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

Case #[Redact] represents an energy employee (EE) who worked at the Dana Heavy Water Plant (DHWP) from [redact], [redact], and the Savannah River Site (SRS) from [redact], through [redact]. Based on DOL records and the CATI, the EE worked as a [redact]-[redact]/[redact] during employment at the DHWP. While employed at the SRS, the EE's job title was [redact] and [redact], and the EE worked primarily in the [redact] Areas. The EE was not monitored for external or internal exposure at DHWP; however, the EE was monitored for external radiation exposure and participated in the bioassay monitoring program throughout most of the employment at SRS. The EE was diagnosed with five cancers between [redact] and [redact], as shown in Table 2-1.

Table 2-1. Primary Cancers

Diagnosis Date	Description	ICD-9 Code
[redact]	Adenocarcinoma of Prostate	185
[redact]	Papillary Transitional Cell Carcinoma of Bladder	188.8
[redact]	Adenocarcinoma Sigmoid Colon	154.0
[redact]	BCC of Skin of Right Cheek	173.31
[redact]	BCC of Skin of Right Lower Eyelid	173.11

On February 2, 2012, the Secretary of Health and Human Services (HHS) designated the following class of SRS employees as an addition to the Special Exposure Cohort (SEC) under Petition SEC-00103:

> *All employees of the Department of Energy, its predecessor agencies, and their contractors and subcontractors who worked at the Savannah River Site from January 1, 1953, through September 30, 1972, for a number of work days aggregating at least 250 work days, occurring either solely under this employment or in combination with work days within the parameters established for one or more other classes of employees included in the Special Exposure Cohort.*

With regard to non-presumptive cancers, the SEC designation stated the following (HHS 2012):

- *NIOSH finds it is feasible to reconstruct the doses received from potential exposures to thorium (metal) and its progeny or encapsulated thorium for workers assigned to other areas including the 300 Area, the Savannah River Site R, P, K, L, C reactors (100 area), and F and H Separation Canyons (200 area). There was no exposure to thorium in the heavy water plant (400 area). . . .*

- *NIOSH has determined that it has access to sufficient external monitoring data, and associated medical monitoring data, for all personnel during all time periods at the Savannah River Site facility. NIOSH has identified that it can bound, or reconstruct with sufficient accuracy, the external and occupational medical dose for all Savannah River Site workers. . . .*

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- *Although NIOSH found that it is not possible to completely reconstruct radiation doses for the proposed class, NIOSH intends to use any internal and external monitoring data that may become available for an individual claim (and that can be interpreted using existing NIOSH dose reconstruction processes or procedures) to support a partial dose reconstruction for non-presumptive cancers and/or cases that have less than 250 work days of employment.*

Lastly, the DHWP facility produced heavy water for the nuclear weapons programs from 1943 through 1957, and is listed as a 'covered facility' under the Energy Employee's Occupational Illness Compensation Program Act of 2000 (EEOICPA). However, heavy water is not radioactive, and there is no radioactivity associated with the production of heavy water. Therefore, all three DR methods only estimated occupational medical doses in behalf of the EE for the covered periods of employment that coincide with the production of heavy water at the plant (i.e., 1943 through 1957).

For calculating radiation doses from employment at SRS, all three DR methods primarily relied on guidance in the SRS Technical Basis Document (TBD) (ORAUT-TKBS-0003), *External Dose Reconstruction Implementation Guideline* (OCAS-IG-001), *Interpretation of Dosimetry Data for Assignment of Shallow Dose* (ORAUT-OTIB-0017), and *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-Ray Procedures* (ORAUT-OTIB-0006) . Using the guidance provided in the relevant documents, along with the employee's dosimetry records, NIOSH employed a **best-estimate approach** for calculating annual organ doses, while SC&A's 'Method A' and 'Method B' performed a **partial DR** to calculate doses, since this was sufficient to produce a POC >50%. The SC&A DR methods were considered minimizing, since 'Method A' did not calculate any internal dose, other than environmental tritium doses, and 'Method B' only calculated doses associated with the non-presumptive cancers and did not consider any internal doses.

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

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

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
Recorded Photon Doses			
Records/Guidance Documents	DOE records, SRS TBD, and the SRS Dose Calculation Workbook 2.03.	DOE records, SRS TBD, and the SRS External Dose Calculation Workbook 2.10.	DOE records, SRS TBD, and OCAS-IG-001
Work Locations	[redact] Area	[redact] Area	[redact] Area
Energy Range	50% 30–250 keV 50% >250 keV	50% 30–250 keV 50% >250 keV	50% 30–250 keV 50% >250 keV
Organ DCFs	Prostate/Bladder = 1.244 Colon = 0.883 Skin = 1.0	Prostate/Bladder = 0.873 Colon = 0.747 Skin = 1.0	Prostate = 1.244 Skin = 1.0
Dosimeter Correction Factor	1.119	1.119	1.119
Dose Distribution	Constant; no uncertainty	Constant; no uncertainty	Constant; no uncertainty
Missed Photon Doses			
Records/Guidance Documents	DOE records, SRS TBD, ORAUT-OTIB-0017, and SRS Dose Calculation Workbook 2.03.	DOE records, SRS TBD, ORAUT-OTIB-0017 and IG-001.	DOE records, SRS TBD, OCAS-TIB-006, ORAUT-OTIB-0017, and IG-001.
No. of zeros	93	239	172
LOD Value	0.040 rem	0.040 rem	0.040 rem
Energy Range	100% 30–250 keV	50% 30–250 keV 50% >250 keV	100% 30–250 keV
Organ DCFs	Prostate/Bladder = 1.244 Colon = 0.883 Skin = 1.0	Prostate/Bladder = 0.873 Colon = 0.747 Skin = 1.0	Prostate = 1.244 Skin = 1.0
Dose Distribution	Lognormal with GSD = 1.52	Lognormal with GSD = 1.52	Lognormal with GSD = 1.52
Recorded Shallow Doses			
Records/Guidance Documents	DOE records, SRS TBD, ORAUT-OTIB-0017 guidance, IG-001. Shallow minus Deep dose.	DOE records, SRS TBD, and ORAUT-OTIB-0017 guidance. Shallow minus Deep dose.	DOE records, OCAS-TIB-006, and ORAUT-OTIB-0017 guidance. Shallow minus Deep dose.
Energy Range	100% E>15 keV	100% E>15 keV	100% photons <30 keV
Dosimeter Correction Factors	None	None	0.6 prior to 1971 (OTIB-0006) 1.119 (OTIB-0017)
Organ DCF	DCF = 1.0	DCF = 1.0	DCF = 1.0
Dose Distribution	Constant distribution	Constant distribution	Constant distribution
Missed Shallow Doses			
Records/Guidance Documents	All missed shallow doses assigned as 100% photon 30–250 keV, as described above under missed photon doses.	DOE records, SRS TBD, and ORAUT-OTIB-0017 guidance. Shallow minus Deep dose.	All missed shallow doses assigned as 100% photon 30–250 keV, as described above under missed photon doses.
No. of zeros		6	
LOD Value		0.040 rem	
Energy Range		100% E>15 keV	
Dose Distribution		GM of Lognormal distribution GSD = 1.52	

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

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
Unmonitored Photon/Electron Doses			
Guidance Documents	Not considered.	Not considered.	SRS External Coworker Model (ORAUT-OTIB-0032)
Coworker Percentile	Not considered.	Not considered.	50th percentile
Period of Time Assigned	Not considered.	Not considered.	[redact]–[redact]
Energy Range	Not considered.	Not considered.	100% 30–250 keV
Dose Distribution	Not considered.	Not considered.	Lognormal with GSD of 1.52
Unmonitored Neutron Doses			
Guidance Documents	Not considered.	Not considered.	SRS Neutron Exposure (OCAS-TIB-007), SRS TBD, and IG-001
Methodology	Not considered.	Not considered.	neutron-to-photon ratio for the 221-H, B-Line
Period of Time Assigned	Not considered.	Not considered.	[redact]–[redact], [redact]–[redact]
Energy Range	Not considered.	Not considered.	0.1–2 MeV 2–20 MeV
Organ DCF	Not considered.	Not considered.	Prostate = 0.796 Skin = 1.0
ICRP 60 CF	Not considered.	Not considered.	0.1–2 MeV – CF=1.14 2–20 MeV – CF=0.53
Dose Distribution	Not considered.	Not considered.	Lognormal with GSD of 1.52
Onsite Ambient Dose			
Guidance Document	ORAUT-PROC-0060, SRS TBD	SRS TBD	ORAUT-PROC-0060, SRS TBD
Period to Time Assigned	[redact]–[redact] and 1977	[redact]–[redact] and 1977	[redact]–[redact]
Energy Range	30–250 keV	30–250 keV	Prostate: 100% 30–250 keV Skin: 100% 30–250 (Ambient) 30% e^->15 keV (Ar-41) 70% p >250 keV (Ar-41)
Dose Distribution	Lognormal with GSD of 1.3	Constant	Lognormal with GSD of 1.3
Occupational Medical Doses			
Guidance Documents	DHWP = ORAUT-OTIB-0006, SRS = SRS TBD	DHWP = ORAUT-OTIB-0006, SRS = SRS TBD	DHWP = ORAUT-OTIB-0006, SRS = SRS TBD
Frequency	DHWP = annual ([redact]–[redact]) SRS = 15 documented x-rays	DHWP = annual ([redact]–[redact]) SRS = 16 documented x-rays	DHWP = annual ([redact]–[redact]) SRS = 16 documented x-rays
Dose Distribution	Normal; SD = 30%.	Normal; SD = 30%.	Normal; SD = 30%.
Internal Doses – Plutonium			
Records/Guidance Documents	DOE records, SRS TBD, ORAUT-OTIB-0049, IMBA	Not Considered.	Not Considered.
Dose Determination Approach	All urinalyses results <MDA. Missed dose based on ½ MDA on last Pu urinalysis measurement.	Not Considered.	Not Considered.
Solubility Type	Type SS	Not Considered.	Not Considered.
Dose Distribution	Mode of a triangular distribution	Not Considered.	Not Considered.

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

Parameters	NIOSH	SC&A's DR–Method A	SC&A's DR–Method B
Internal Dose - Fission Product			
Records/Guidance Documents	DOE records, SRS TBD, IMBA	Not Considered.	Not Considered.
Dose Determination Approach	All urinalyses results <MDA. Missed dose based on worst-case chronic intake of Ru-106.	Not Considered.	Not Considered.
Solubility Type	Type F	Not Considered.	Not Considered.
Dose Distribution	Constant with no uncertainty	Not Considered.	Not Considered.
Internal Dose - Europium			
Records/Guidance Documents	DOE records, SRS TBD, IMBA	Not Considered.	Not Considered.
Dose Determination Approach	All urinalyses results <MDA. Missed dose based on Eu-152 and Eu-154 comparison, with Eu-154 claimant favorable.	Not Considered.	Not Considered.
Solubility Type	Type M	Not Considered.	Not Considered.
Dose Distribution	Constant with no uncertainty	Not Considered.	Not Considered.
Internal Dose - Environmental			
Guidance Documents	SRS TBD, IMBA	SRS External Dose Calculation Workbook 2.10.	Not Considered.
Dose Determination Approach	Assumed maximum environmental annual intakes for 1966–1977 resulting in assignment of plutonium and unmonitored tritium doses.	Unmonitored tritium dose assigned 1966–1977 based on 1 µCi/L.	Not Considered.
Dose Distribution	Pu = lognormal with GSD 3.0 H-3 = constant	Constant with no uncertainty	Not Considered.

2.1 OCCUPATIONAL EXTERNAL DOSE CALCULATIONS

2.1.1 Recorded Photon Doses

The DOE records show that the EE was monitored at SRS during each year from [**redact**] through [**redact**], except for [**redact**]–[**redact**], and the first 3 months of [**redact**], when no data were present in the records.

All three DR methods assumed the EE worked primarily in the [**redact**] Area. Therefore, the photon energy fraction of 50% 30–250 keV and 50% >250 keV was assumed, as specified in the SRS TBD. All DR methods also applied a TBD-specified dosimeter correction factor (CF) of 1.119 to the recorded doses. NIOSH and SC&A's 'Method B' selected DCF that reflect Exposure (R) to Organ Dose (H_T) values from OCAS-IG-001 for organs other than the skin. SC&A's 'Method A' applied Deep Dose Equivalent [Hp(10)] to Organ Dose (H_T) DCFs for the prostate, bladder and colon. All DR methods applied a DCF of 1.0 to the skin cancers, as specified in ORAUT-OTIB-0017.

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Using the EE's dosimetry records and above-cited parameters, NIOSH, SC&A's 'Method A,' and SC&A's 'Method B' calculated recorded photon doses as shown in Table 2-3. The slightly lower doses calculated by SC&A's 'Method A' reflect the use of the lower Hp(10) DCF value.

Table 2-3. Comparison of Recorded Photon Doses

Cancer Site	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
Prostate Dose	4.302	3.163	4.642
Bladder Dose	4.302	3.163	Not considered.
Colon Dose	3.851	2.871	Not considered.
BCCs [redact]	4.046	3.542	3.732
Total	**16.501**	**12.739**	**8.374**

All three DR methods entered doses into the Interactive RadioEpidemiological Program (IREP) as a constant with no uncertainty.

2.1.2 Missed Photon Doses

Missed photon dose was assigned by all DR methods. Determining the number of missed dose cycles was complicated, since not all badge cycles were recorded, and the recording method changed in mid-1963. This resulted in each DR method estimating a significantly different number of zeros or < ½ LOD values, as discussed below.

NIOSH. As stated in their DR Report, NIOSH calculated missed photon dose as described below:

> *. . . a zero dosimeter result was applied for each listed cycle which was blank for all monitored years. Dosimetry results were reported as bi-weekly from* [redact] *through* [redact], *monthly for year* [redact], [redact], *and* [redact], *and* ***quarterly*** *from* [redact] *through* [redact].
>
> *. . . In an effort to* ***minimize the total missed dose****, only the actual cycle entries recorded in the dose records were evaluated.* [Emphasis added.]

For missed skin dose, any badge cycle with a combination of zero results in any of the non-penetrating and penetrating doses, a single missed dose for each cycle is assigned in accordance with ORAUT-OTIB-0017.

This resulted in NIOSH counting 93 missed photon doses and calculating doses assuming ½ the limit of detection (LOD) value of 0.040 rem for shielded (S) readings and 0.050 rem for open window (OW) readings. NIOSH used the same organ dose conversion factor (DCF) values as for recorded photon doses and entered the annual doses into IREP as geometric mean (GM) of a lognormal distribution, with a geometric standard deviation (GSD) of 1.52.

SC&A's 'Method A'. 'Method A' assessed missed photon dose by using the NIOSH-supplied "External Dosimetry Data" file, which did not agree with the data in the DOE files, primarily because it did not account for recorded values <LOD/2. SC&A's 'Method A' corrected these

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data values and entered the "External Dosimetry Data" file in the "SRS Calculation Workbook 2.10," which calculated a total of 239 zeros, or <LOD/2, values. Annual missed photon doses were entered into IREP as 50% 30–250 keV and 50% >250 keV as a lognormal distribution with a GSD of 1.52 for the prostate, bladder, and colon. Missed skin doses were assigned as 100% 30–250 keV.

SC&A's 'Method B'. It was assumed by SC&A's 'Method B' that for years [redact] through [redact], the EE was monitored on a monthly basis, which is consistent with Table 5.5.1-1 of ORAUT-TKBS-0003, even though DOE records only included quarterly results. 'Method B' made the claimant-favorable assumption that all reported quarterly doses were recorded during 1 month and the remaining 2 months of the quarter were assumed to be zero doses.

For missed skin dose, 'Method B' followed guidance in ORAUT-OTIB-0017 and assigned a single missed dose for any badge cycle with a combination of zero results in any of the non-penetrating and penetrating doses.

Based on these assumptions, a total of 172 monitoring cycles were assigned a missed photon dose. Doses were calculated assuming ½ the LOD value of 0.040 rem for S readings and 0.050 rem for OW readings. The same organ DCF values as for recorded photon doses were applied, and annual doses entered into IREP as a GM of a lognormal distribution, with a GSD of 1.52.

Table 2.4 compares the missed photon doses for the three DR methods.

Table 2-4. Comparison of Missed Photon Doses

Cancer Site	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
Prostate Dose	3.004	2.836	3.751
Bladder Dose	3.004	2.836	Not considered.
Colon Dose	2.560	2.638	Not considered.
BCCs [redact]	2.415	4.088	3.015
Total	**10.983**	**12.398**	**6.766**

2.1.3 Recorded Shallow Doses

Electron dose was assigned by each of the three DR methods to only the two skin cancers. The electron dose was calculated by subtracting the OW reading from the S deep dose reading. All methods applied a DCF value of 1.0. Only SC&A's 'Method B' applied a dosimeter correction factor of 0.6 prior to 1971, in accordance with OCAS-TIB-006, and 1.119, as specified in the SRS TBD and ORAUT-OTIB-0017. NIOSH and SC&A's 'Method A' entered the electron doses into IREP as 100% >15 keV. SC&A's 'Method B' entered the doses into IREP as 100% <30 keV.

Table 2-5 shows a comparison of total assigned recorded electron doses.

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Table 2-5. Comparison of Recorded Electron Doses

Cancer Site	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
BCCs [redact]	4.810	4.385	3.196

All DR methods assumed a constant dose distribution with no uncertainty.

2.1.4 Missed Shallow Doses

Only SC&A's 'Method A' assigned a missed electron dose. This dose was calculated based on ORAUT-OTIB-0017, page 21, which provides recommendations for the assignment of missed dose to the skin; if only the OW (shallow) reading was reported as zero (and the deep dose was positive), the missed dose assigned should be the appropriate OW LOD (divided by 2, treated as lognormal) and considered >15 keV electrons. Therefore, 'Method A' analyzed the number of electron dose zeros using this guidance and a best-estimate reasonable approach in estimating the number of potential zeros in this case, and compared them to those provided by the SRS Workbook 2.10, which arrived at a total of 6 zeros, or <LOD/2, values for electrons. SC&A used the annual zero values provided by the workbook and calculated a missed electron dose of 0.125 rem.

2.1.5 Unmonitored Photon/Electron Doses

Only SC&A's 'Method B' considered assigning unmonitored photon and electron doses for the 3-year gap in external monitoring (i.e., years [redact]–[redact]). Assignment of these doses was based on (1) the EE's job function, which did not change throughout employment, (2) the EE's statement in the CATI that the EE was routinely monitored, and (3) OCAS-TIB-006, which states that ". . . when an entire year is missing from the SLHP3 form, this also should not be interpreted as meaning that an individual worker was not monitored."

Using guidance in *External Coworker Dosimetry Data for the Savannah River Site* (ORAUT-OTIB-0032, Table 2), gamma doses at the 50th percentile were assigned for [redact], [redact], and [redact]. This resulted in a total photon dose of 0.546 rem to the prostate and the two skin cancers. Annual doses were entered into IREP as a lognormal distribution with a GSD of 1.52.

In addition, an unmonitored non-penetrating dose at the 50th percentile was also assigned to the skin cancers for years [redact]–[redact]. Values cited in Table 2 of ORAUT-OTIB-0032 resulted in the assignment of a total unmonitored skin dose of 0.332 rem. The annual doses were entered into IREP as photons <30 keV and considered lognormally distributed with a GSD of 1.52.

2.1.6 Unmonitored Neutron Doses

Although DOE records do not indicate that the EE was monitored for neutron doses during employment, SC&A's 'Method B' determined that this worker did have the potential for neutron exposures, since the EE worked primarily in the [redact] Areas. This is supported by information provided in *Neutron Exposures at the Savannah River Site* (OCAS-TIB-007).

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Using guidance in the SRS TBD and assuming the GM neutron-to-photon ratios for the 221-H, B-Line cited in Table 5.5.2-2, Method B assigned a neutron dose for all years of employment prior to [redact] and [redact]–[redact]. The photon doses were multiplied by the appropriate International Commission on Radiological Protection (ICRP) DCF and organ DCF values (ICRP 1991). The neutron doses were assumed to be associated with energy ranges 10–100 keV and 0.1–2.0 MeV neutrons, based on the EE's work location in the 221-H, B-Line. This resulted in the assignment of 8.730 rem to the prostate and 9.764 rem to the two BCCs.

2.1.7 Onsite Ambient Doses

All three DR methods calculated onsite ambient doses as described below.

NIOSH. Since the EE was not monitored for ionizing radiation in [redact], [redact], [redact], and [redact], NIOSH assigned onsite ambient doses for these years. It was assumed that the EE worked primarily worked in Area [redact]. Using guidance in *Occupational On-Site Ambient Dose Reconstruction for DOE Sites* (ORAUT-PROC-0060), and best-estimate dose values cited in Table C-19 of ORAUT-TKBS-0003 and assuming a 50-hour work week, NIOSH calculated a total onsite ambient dose of 0.306 rem for each of the cancer sites. Annual dose values were entered into IREP as a mean of a normal distribution with standard deviation (SD) of 1.3.

SC&A's 'Method A.' 'Method A' also assigned onsite ambient doses for only those years when the EE was not monitored (i.e., [redact]–[redact], [redact]). The assignment of environmental external ambient photon doses during these unmonitored years was based on 2,000 hours/year dose values provided in Table C-19 of ORAUT-TKBS-0003, adjusting for 2,500 hours/year, and prorated for partial employment in [redact]. This resulted in a total dose of 0.318 rem for all cancer sites. Annual doses were entered into IREP as a constant value with no uncertainty.

SC&A's 'Method B.' SC&A's 'Method B' assigned onsite ambient doses in accordance with guidance in ORAUT-PROC-0060, Attachment A. This Attachment states that monitored SRS employees should be assigned onsite ambient doses through 1979. Therefore, in accordance with best-estimate guidance in Section 3.4.1 of the SRS TBD, 'Method B' assigned prostate and skin doses using ambient radiation levels associated with Area F from Table C-19 for years [redact] through [redact]. Onsite ambient doses were not included for the partial years of employment in [redact] and [redact]. Skin doses from exposure to Ar-41 at Area F were also assigned, as specified in Table C-20 of the SRS TBD.

Applying an organ DCF of 1.244 for the prostate and DCF of 1.0 for each of the two skin cancers resulted in a total onsite ambient dose of 1.361 rem and 1.107 rem, respectively. Annual onsite ambient radiation doses were entered into IREP with a photon energy range of 30–250 keV as GM values with a GSD of 1.3, in accordance with SRS TBD best-estimate guidance. Skin doses associated with submersion in Ar-41 were entered into IREP as 30% electrons >15 keV and 70% photons >250 keV.

Table 2-6 shows a comparison of total assigned onsite ambient doses. The NIOSH and SC&A 'Method A' values are nearly identical. SC&A's 'Method B' is 4 times higher due to assigning

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doses for 17 years, while NIOSH and 'Method A' only assigned doses for 4 years of employment.

Table 2-6. Comparison of Onsite Ambient Doses

Cancer Site	NIOSH (rem)	SC&A's 'Method A' (rem)	SC&A's 'Method B' (rem)
Prostate, Bladder, Colon	0.306	0.318	1.361 (prostate only)
BCCs of cheek and eyelid	0.306	0.318	1.107

2.1.8 Occupational Medical Doses

All three DR methods calculated an occupational medical dose from diagnostic x-ray procedures required as a condition of employment at both the DHWP and SRS. NIOSH and SC&A's 'Method A' assumed an annual posterior/anterior (PA) chest x-ray for each year of covered employment at DHWP and assigned doses based on ORAUT-OTIB-0006. This resulted in both DR methods calculating a total of 0.375 rem for the prostate/bladder/colon and 0.096 rem to each of the skin cancers.

For calculating occupational medical doses for employment at SRS, NIOSH and SC&A's 'Method A' identified 16 documented PA x-ray exams in the EE's records. Using values cited Table 3-10 of ORAUT-TKBS-0003-3, both DR methods calculated a dose of 0.051 rem to the prostate, bladder, and colon, and 0.026 rem to the skin cancers.

SC&A's DR 'Method B' also assigned an annual PA chest x-ray for each year of employment at the DHWP (i.e., [redact]–[redact]). Using ORAUT-OTIB-0006, an annual prostate dose of 0.025 rem (based on Table A-7) and an annual skin dose of 0.0064 rem (based on Tables A-1 and A-7 for the eye/brain) were assign for the period of [redact] through [redact].

For the EE's employment at SRS, 'Method B' assigned an occupational medical dose for 15 documented PA chest x-ray exams performed between [redact] and [redact]. DOE records indicate that 9 of these x-ray exams were taken with Type I equipment and the remaining 6 were taken with Type II equipment. Using the SRS Occupational Medical Dose guidance (ORAUT-TKBS-003-3, Table 3-10), the Type I annual dose of 0.00504 rem and Type II annual dose of 0.000141 rem were assigned to the prostate (using the bladder as the surrogate organ). An annual Type I dose of 0.00096 rem and Type II dose of 0.00273 rem was assigned to each of the two skin cancers on the face (using the eye/brain as a surrogate organ).

Table 2-7 shows a comparison of the occupational medical doses calculated by the three DR methods, which resulted in identical/nearly identical dose values.

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Table 2-7. Comparison of Occupational Medical Doses

Facility	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
DHWP: Prostate/bladder/colon	0.375	0.375	0.375 (prostate only)
BCCs	0.096	0.096	0.090
SRS: Prostate/bladder/colon	0.051	0.051	0.046 (prostate only)
BCCs	0.026	0.026	0.031

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

2.2 OCCUPATIONAL INTERNAL DOSES

DOE records show that the EE had *in vitro* (urinalysis) bioassay monitoring for plutonium, fission and activation products, and europium during employment at SRS. All bioassay results were below the minimum detectable activity (MDA) for the given radionuclides and bioassay method. Only NIOSH calculated missed internal doses based on the bioassay monitoring. Details associated with their calculation of internal doses are provided below.

2.2.1 NIOSH Plutonium Intakes

The EE submitted 6 samples for plutonium urinalysis between [redact] and [redact]. All results were reported below the MDA level. Therefore, to assessed potential internal dose from exposure to plutonium, NIOSH assumed exposure to ½ the MDA level of 0.1 dpm/sample of the last urinalysis measurement. They also assumed a 10-year aged, 12% fuel-grade Pu-240 material was chronically inhaled from the beginning of employment until August [redact]. Solubility Types M, S, and SS were compared, with SS producing the highest dose.

2.2.2 NIOSH Fission Product Intakes

The EE submitted nine urinalysis samples for fission/activation products between [redact] and [redact]. To assess potential fission/activation product doses, NIOSH assumed a worst-case, chronic intake based on ruthenium-106, Type F absorption at ½ the MDA value from the beginning of employment until the last fission product bioassay on [redact].

2.2.3 NIOSH Europium Intakes

The EE submitted five samples between [redact] and [redact] for europium urinalysis. All results were reported at below the MDA. NIOSH assessed dose from potential exposure to europium by comparing europium-152 and europium-154 at levels below the detection limits. A chronic intake from inhalation for the period [redact] (beginning of employment), through [redact] (last europium bioassay sample), was assessed. It was determined that europium-154, Type M, resulted in the most claimant-favorable dose.

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2.2.4 NIOSH Internal Environmental Dose

For years [redact] through [redact], when the EE has no records for bioassay monitoring, NIOSH assigned internal dose based on maximum annual intakes of environmental airborne radionuclides cited in the SRS TBD. This assessment assumed a constant exposure to iodine and uranium.

2.2.5 NIOSH Unmonitored Tritium Dose

NIOSH also calculated an unmonitored tritium dose for the years [redact] through [redact]. This dose was calculated using the minimum tritium urine concentration of 1 µCi/L. This resulted in an annual assignment of 0.071 rem.

2.2.6 SC&A's 'Method A' Environmental Tritium Dose

SC&A's 'Method A' calculated the intake of environmental tritium for the entire employment period, since this calculation is incorporated in the SRS Dose Calculation Workbook 2.10, and included when deriving the external dose assignments. The workbook also uses the minimum tritium urine concentration of 1 µCi/L, which resulted in the assignment of 0.071 rem per year.

A summary of the total internal dose assigned by NIOSH and SC&A's 'Method A' is shown in Table 2-8. SC&A's 'Method B' partial DR did not consider any dose from potential internal exposures.

Table 2-8. Comparison of NIOSH and SC&A's 'Method A' Total Internal Doses

Cancer Site	NIOSH (rem)						SC&A Method A (rem)
	Plutonium	Fission Products	Europium	Environmental	Tritium	Total	Tritium
Prostate	0.323	0.085	0.012	0.031	0.799	9.288	1.296
Bladder	0.537	0.086	0.001	0.031	0.799	9.492	1.296
Colon	0.710	0.317	0.004	0.031	0.799	9.004	1.296
BCC, [redact]	0.863	0.074	0.001	0.031	0.799	13.465	1.296
BC, [redact]	0.863	0.074	0.001	0.031	0.799	13.465	1.296

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3.0 SUMMARY CONCLUSIONS

Total external and internal doses and resultant POCs calculated by NIOSH, SC&A 'Method A,' SC&A 'Method B' in behalf of Case #037013 are presented in Table 3-1 for comparison.

Table 3-1. Comparison of Total External and Internal Doses Estimated for the Five Cancers

Total Doses	NIOSH (rem)	SC&A-Method A (rem)	SC&A-Method B (rem)
External Doses:			
- Prostate	8.038	6.807	19.451
- Bladder	8.038	6.807	–
- Colon	7.143	6.253	–
- BCC, [redact]	11.699	12.580	21.813
- SCC, [redact]	11.699	12.580	21.813
Internal Skin Doses:			
- Prostate	1.250	1.296	–
- Bladder	1.454	1296	–
- Colon	1.861	1.296	–
- BCC, [redact]	1.766	1.296	–
- SCC, [redact]	1.766	1.296	–
Total Skin Dose			
- Prostate	9.288	8.103	19.451
- Bladder	9.492	8.103	–
- Colon	9.004	7.549	–
- BCC, [redact]	13.465	13.876	21.813
- SCC, [redact]	13.465	13.876	21.813
POC	38.12%	39.33%	48.27%

As shown in Table 3-1, even though NIOSH performed a best-estimate DR and SC&A's 'Method A' performed a partial DR, the doses are in very close agreement. The higher doses estimated by SC&A's 'Method B' were the result of calculating an unmonitored photon dose for a 3-year period and a 15-year unmonitored neutron dose for the three non-presumptive cancers (i.e., prostate, two BCCs). A more detailed discussion of variables that contributed to key differences in dose assignments is presented below.

- Dose Reconstruction Methodology
  - – NIOSH employed a best-estimate approach to dose reconstruction.
  - – SC&A's 'Method A' and SC&A's 'Method B' employed a minimizing (partial) approach to reconstructing doses.
- Assignment of Unmonitored Dose
  - – Only SC&A's 'Method B' calculated unmonitored photon dose based on the 50th percentile coworker data for years [redact], [redact], and [redact].
  - – Only SC&A's 'Method B' calculated unmonitored neutron dose based on a GM neutron-to-photon ratio for years [redact]–[redact] and [redact]–[redact].

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- Assignment of Onsite Ambient Dose
  - NIOSH and SC&A's 'Method A' assigned onsite ambient doses for years [**redact**]–[**redact**] and [**redact**], when the EE was not monitored.
  - SC&A's 'Method B' assigned onsite ambient doses for years [**redact**]–[**redact**] and assigned a skin dose from exposure to Ar-41 for the same period.

- Assignment of Internal Doses
  - NIOSH assigned internal doses from monitored bioassays, which were all <MDA, based on missed dose approach (i.e., ½ MDA value of urinalysis data for plutonium, fission/activation products, europium, environmental, and unmonitored tritium. Internal environmental doses and unmonitored tritium were only assigned for years [**redact**]–[**redact**].
  - SC&A's 'Method A' assigned an environmental tritium dose using the SRS Dose Calculation Workbook for the EE's entire employment period ([**redact**]–[**redact**]).

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4.0 REFERENCES

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