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 BROOKHAVEN NATIONAL LABORATORY

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

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Comparison of SC&A's Blind Dose Reconstruction to NIOSH's Dose Reconstruction of Case #[Redact] from the Brookhaven National Laboratory	Page 2 of 20
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TABLE OF CONTENTS

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
BGRR	Brookhaven Graphite Research Reactor
BNL	Brookhaven National Laboratory
CADW	Chronic Annual Dose Workbook
CATI	Computer-Assisted Telephone Interview
CW	coworker
DCF	dose conversion factor
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
DR	dose reconstruction
EE	energy employee
GSD	geometric standard deviation
HFBR	High Flux Beam Reactor
HHS	(U.S. Department of) Health and Human Services
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
MeV	Million electron volts
NIOSH	National Institute for Occupational Safety and Health
NM	not monitored
NTA	Eastman Kodak Nuclear Track Film Type A
PA	posterior-anterior
PFG	photofluorography
POC	probability of causation
rem	Roentgen equivalent man
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SID	Source to image distance

TBD	technical basis document
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 12, 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 entitled, *SC&A's Dose Reconstruction of Case #*[Redact] *from the Brookhaven National Laboratory* (SC&A 2015b), which provides the assumptions and methodologies used to derived 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 NIOSH's and SC&A'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 nasal cavity cancer diagnosed in behalf of Case #[Redact]. 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 #[Redact]

	SC&A Nasal Cavity Doses (rem)	NIOSH Nasal Cavity Doses (rem)
External Dose:		
▪ **Recorded/Unmonitored Dose**		
- Photons 30–250 keV	5.664	5.350
- Photons >250 keV	11.469	11.421
- Neutrons	1.802	1.386
▪ **Missed Dose**		
- Photons 30–250 keV	1.550	1.338
- Photons >250 keV	3.138	3.165
- Neutrons	11.917	20.467
▪ **Occupational Medical Dose**		
- Photons 30–250 keV	0.157	0.478
Internal Dose:		
<15 keV electrons	0.161	0.159
>15 keV electrons	102.385	101.625
<30 keV Photons	0.096	0.094
>250 keV Photons	4.680	4.571
Alpha	0.971	0.944
Total Cancer Dose	**143.990**	**150.998**
POC	**51.05%**	**52.54%**

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 Brookhaven National Laboratory (BNL) from [redact] through [redact]. Based on DOL records and the CATI, the EE worked as a [redact] and [redact] at the BNL. The EE first worked at the Brookhaven Graphite Research Reactor (BGRR) and then the High Flux Beam Reactor (HFBR). The EE was monitored for external photon exposure during most of the employment period at BNL. The EE was diagnosed with nasal cavity cancer (sinonasal melanomas of the [redact] nasal cavity, ICD-9 Code 160.0) on [redact].

This was a partial DR, because not all internal doses could be assigned, as per the BNL Special Exposure Cohort (SEC). According to ORAUT-TKBS-0048, page 12, the Secretary of the U.S. Department of Health and Human Services (HHS) has designated BNL employees as an addition to the SEC. Based on the findings and recommendations of NIOSH and the Advisory Board on Radiation and Worker Health, the Secretary of the HHS has concurred with the finding that NIOSH does not have access to sufficient personnel or area monitoring data, or sufficient source or source term information, about BNL operations to bound potential internal exposures for the period from January 1, 1947, through December 31, 1993 (other than tritium after December 31, 1964).

The EE was employed at BNL during the SEC period; however, since nasal cavity cancer is considered a non-presumptive cancer, it was not covered under the SEC class. Therefore, a DR was required.

For calculating radiation doses from employment at BNL, both DR methods primarily relied on guidance in the BNL Technical Basis Document (TBD) (ORAUT-TKBS-0048). Using the guidance provided in this document, along with the employee's dosimetry records, SC&A employed a **best-estimate approach** for calculating annual organ external and internal doses, while NIOSH employed a **best-estimate approach** for calculating annual organ external doses and a **minimizing approach** for calculating annual organ internal doses. This resulted in both SC&A and NIOSH deriving 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 or Unmonitored Dose:		
Records/Guidance Documents	DOE records, BNL TBD, and ORAUT-OTIB-0005.	DOE records, BNL TBD, ORAUT-OTIB-0005, and the BNL Dose Calculation Workbook 2.04.
Work Locations	BGRR & HFBR	BGRR & HFBR
Energy Range	25% 30–250 keV 75% >250 keV 100% 0.1–2 MeV neutrons	25% 30–250 keV 75% >250 keV 100% 0.1–2 MeV neutrons
Exposure Organ DCFs	30–250 keV DCF = 1.440 >250 keV DCF = 0.972 0.1–2 MeV neutrons DCF = 1.086	Monte Carlo generated centered on: 30–250 keV DCF = 1.440 >250 keV DCF = 0.972 0.1–2 MeV neutrons DCF = 1.086
ICRP-60 Correction F.	1.91	1.91
Neutron Fading F.	1.81	1.81
Dose Distribution	Normal; 30% uncertainty.	Normal; 30% uncertainty.
External Missed Dose:		
Records/Guidance Documents	DOE records, OCAS-IG-001, PROC-0006, and BNL TBD.	DOE records, OCAS-IG-001, PROC-0006, BNL TBD and the BNL Dose Calculation Workbook 2.04.
No. of zeros	287 photons, 383 neutrons	238 photons, 385.5 neutrons
LOD Value	0.030 rem photon & neutron	0.030 rem photon & neutron
Energy Range	25% 30–250 keV 75% >250 keV 100% 0.1–2 MeV neutrons	25% 30–250 keV 75% >250 keV 100% 0.1–2 MeV neutrons
Exposure Organ DCFs	30–250 keV DCF = 1.440 >250 keV DCF = 0.972 0.1–2 MeV neutrons DCF = 1.086	Monte Carlo generated centered on: 30–250 keV DCF = 1.440 >250 keV DCF = 0.972 0.1–2 MeV neutrons DCF = 1.086
ICRP-60 Correction F.	1.91	1.91
Neutron Fading F.	None	1.81
Dose Distribution	Lognormal with GSD = 1.52	Lognormal with GSD centered around 1.52
Shallow Dose:		
	NA	NA
Coworker Dose:		
Records/Guidance Documents	BNL TBD, Table 6-2	NA
Energy Range	25% 30–250 keV 75% >250 keV	NA
Exposure Organ DCFs	30–250 keV DCF = 1.440 >250 keV DCF = 0.972	NA
Dose Distribution	Normal; 30% uncertainty.	NA
Onsite External Ambient Dose:		
	NA	NA
Occupational Medical Dose:		
Guidance Documents	BNL TBD, ORAUT-OTIB-0006	BNL TBD
Frequency	22 documented x-ray exams	22 documented x-ray exams
Dose Distribution	Normal; GSD = 30%.	Normal; GSD = 30%.

NA = not applicable or not analyzed.

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 records not available	Bioassay records not available
Environmental Internal:		
Records/Guidance Documents	BNL TBD, CADW	BNL TBD, CADW
Dose Determination Approach	Best-estimate methodology	Minimizing methodology
Solubility Type	Site default that max. dose	Site default that max. dose
Dose Distribution	Lognormal, GSD of 3.000	Lognormal, GSD of 3.000

2.1 OCCUPATIONAL EXTERNAL DOSE CALCULATIONS

2.1.1 Recorded/Unmonitored Photon and Neutron Doses

The DOE records show that the EE was monitored at BNL during each year from [redact] through [redact], with some quarterly badge exchanges recorded as not monitored (*NM*). The records indicate that the EE was not monitored (*NM* recorded) for two quarters during the year [redact], and 14 quarters during the period [redact]–[redact]. Because the BGRR did not operate until [redact] (ORAUT-TKBS-0048 page 26), neither SC&A nor NIOSH assigned doses for the two quarters the EE was not monitored during [redact].

<u>[Redact]–[redact] NM Quarters</u>

The quarterly total recorded doses, and zero values, for photon, neutron, and shallow doses in the EE's DOE files were very well organized and legible (shallow dose is not applicable to the nasal cavity). However, both SC&A and NIOSH found that there was one discrepancy in the DOE radiation report for the 2nd quarter of [redact]. This report cited a *Lifetime Total* dose that was 0.440 rem greater than the total dose calculated when summing up the quarterly values through the 2nd quarter of [redact] (14.590 rem vs. 14.150 rem).

<u>SC&A's Method for Assigning Dose during NM Periods</u>

The additional 0.440 rem of recorded exposure in the [redact] summary sheet could have occurred any time in the 14 NM periods between [redact] and [redact], and may not have been entered into the quarterly sums, but carried in the Lifetime Total dose records. Therefore, to be claimant favorable, 0.220 rem was assigned to the first potentially missed monthly exchange in [redact], and the remaining 0.220 rem assigned to the second potentially missed monthly exchange in [redact], which occurred during the 3rd quarter. The total 0.440 rem was not assigned during one monthly exchange, because that would exceed the 5-rem per year dose limit applicable at that time; i.e., 5.000 rem/y × (1/12 months/y) = 0.417 rem/month maximum. For all the other potentially missed monthly exchanges during the period [redact]–[redact], which had the *NM* notation in the records (as per ORAUT-TKBS-0048, page 82, recommendations for lost or destroyed badges), a monthly photon prorated coworker (CW) dose was derived from the annual dose values as recommended in ORAUT-TKBS-0048, Table 6-2, page 84. This amounted to approximately 0.026 rem/month. SC&A did not assign CW neutron doses during unmonitored periods, because the POC was >50% without assigning CW neutron dose.

NIOSH's Method for Assigning Dose during NM Periods
NIOSH distributed the additional photon dose (0.440 rem) evenly over the 14 quarters when NM was recorded, starting with the third quarter of 1950; NIOSH did not assign CW dose. NIOSH did not assign additional neutron doses, because the sum of the quarterly neutron doses was slightly greater than the reported total, indicating no neutron dose had been missed in the quarterly records.

Comparison of SC&A's and NIOSH's Methods and Doses for Recorded Photons and Neutrons
Both DR methods assumed the EE worked primarily in reactor areas. Therefore, both SC&A and NIOSH used the DR parameters as recommended in ORAUT-TKBS-0048, which consisted of an energy range of 25% 30–250 keV photons, 75% >250 keV photons (Table 6-3, page 86); and 100 keV–2 MeV neutrons with a neutron ICRP-60 (ICRP 1991) correction factor of 1.91 (Table 6-5, page 87) and a Nuclear Track Film Type A (NTA) dosimeter fading correction factor of 1.81 (page 91). Exposure (as opposed to deep dose) conversion factors (DCFs) were used, as per ORAUT-TKBS-0048, page 90. The thyroid was used as the surrogate organ for the nasal cavity (ORAUT-OTIB-0005, page 15) because of it being in approximately the same physical location. A limit of detection (LOD) value of 0.030 rem for both photons and neutrons with a monthly badge exchange was assumed (ORAUT-TKBS-0048, Table 6-1, page 82). SC&A used the mode DCF values listed in OCAS-IG-001; however, NIOSH used Monte Carlo-generated DCFs based on the triangular distribution of DCF values listed in OCAS-IG-001.

Using the EE's dosimetry records and above-cited parameters, SC&A and NIOSH assigned photon and neutron recorded doses as shown in Table 2-3. The slightly larger photon doses assigned by SC&A reflect the use of CW data for NM periods, as opposed to NIOSH's method of spreading the unaccounted for 0.440 rem dose over the 14 NM periods. NIOSH's lower neutron dose resulted from the use of Monte Carlo DCFs, as opposed to the mode values in OCAS-IG-001, and not including the relatively small recorded neutron doses ≥LOD/2 for the years [redact], [redact], and [redact] in the measured neutron dose assignments.

Table 2-3. Comparison of Recorded/Unmonitored Photon and Neutron Doses

	SC&A (rem)	NIOSH (rem)
Total Recorded/Unmonitored Photon Dose	17.133	16.771
Total Recorded Neutron Dose	1.802	1.386

Both DR methods entered doses into the Interactive RadioEpidemiological Program (IREP) as a normal distribution with 30% uncertainty.

2.1.2 Missed Photon and Neutron Doses

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

SC&A's Missed Photon and Neutron Doses
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), ORAUT-PROC-0006, and a reasonable approach to arrive at a total of **287 zeros** (or <LOD/2 values) for photons, and **383 zeros (**or <LOD/2 values) for neutrons. SC&A used the annual number of zeros, the LOD/2

value, the DR parameters listed above, and the applicable DCF to determine the annual missed photon and neutron doses. SC&A did not apply the neutron film fading factor of 1.81 to missed neutron dose (as was applied to recorded neutron dose), because ORAUT-TKBS-0048, page 91, states:

> *For the period from site startup through 1984, a fading correction factor of 18% per week provides a reasonable overestimate of fading for NTA film dosimeters on an annual basis. For a monthly wear period with 1 week for reading of the dosimeter, an average time for fading would be 3 weeks. This corresponds to a loss of about 55% of the tracks. The recorded neutron doses should be corrected by applying a multiplication factor of 1.81 (inverse of 55%).* [Emphasis added.]

Therefore, SC&A interprets this to mean that the NTS film fading factor should only be applied to recorded neutron dose, and not to missed neutron dose.

SC&A assigned a total missed photon dose of **4.688 rem** and a total missed neutron dose of **11.917 rem**.

NIOSH's Missed Photon and Neutron Doses

As stated in the DR Report, NIOSH calculated missed dose as described below:

> *Based on information provided in the dosimetry records, the total number of dosimeter cycles assigned was* ***238 for photons*** *and* ***385.5 for neutrons****. The number of zero badge readings was based upon the reported zero readings plus the readings that were less than half the dosimeter's limit of detection* [OCAS-IG-001 and ORAUT-TKBS-0048]. *The dosimetry records prior to 1985 were available only as quarterly summaries. For this period, the number of zero badge readings was evaluated as a best estimate based on reported annual doses, dose limits, and the limit of detection* [ORAUT-PROC-0006]. *Missed dose was assigned based on the dosimeter's limit of detection* [OCAS-IG-001 and ORAUT-TKBS-0048]. [Emphasis added.]

NIOSH used the annual number of zeros, the LOD/2 value, the DR parameters listed above, Monte Carlo-generated DCFs, and the 1.81 neutron film fading factor to determine the annual missed photon and neutron missed doses. NIOSH assigned a total missed photon dose of **4.503 rem**, and a total missed neutron dose of **20.467 rem**.

Comparison of SC&A's and NIOSH's Methods and Doses for Missed Photons and Neutrons

Using the EE's dosimetry records and above-cited parameters, SC&A and NIOSH assigned missed photon and neutron doses as shown in Table 2-4. SC&A used the actual counting of zeros and potentially missed badge cycles to determine missed dose, whereas NIOSH used a program that determines the best-estimate number of zeros; therefore, while similar, the number of zeros do not match exactly.

Comparison of Missed Photon Dose
The slightly larger missed photon dose assigned by SC&A was due to the fact that SC&A derived a greater number of zeros for photons; i.e., 287 vs. 238. SC&A investigated the missed photon doses derived by SC&A compared to NIOSH and by back calculations found that the Monte Carlo DCFs used by NIOSH were generally larger than the OCAS-IG-001 DCF values used by SC&A; this decreased the magnitude of the difference in assigned missed photon dose that would have otherwise occurred considering the difference in the number of zeros used.

Comparison of Missed Neutron Dose
The number of missed neutron doses used in this case was similar (SC&A used 383 and NIOSH used 385.5). The larger missed neutron dose assigned by NIOSH was due to fact that NIOSH applied the NTA film fading factor to missed neutron doses, while SC&A did not apply this correction factor based on above-cited guidance in ORAUT-TKBS-0048.

Table 2-4. Comparison of Missed Photon and Neutron Doses

	SC&A (rem)	NIOSH (rem)
Total Missed Photon Dose	4.688	4.503
Total Missed Neutron Dose	11.917	20.467

Both DR methods entered missed photon and neutron doses into IREP as a lognormal distribution with uncertainty centered on 1.520.

2.1.3 Onsite Ambient Doses

As per ORAUT-TKBS-0048, Section 4.2.2, page 59, external ambient dose should not be applied when the EE is assigned recorded (and/or CW) dose. Therefore, neither SC&A nor NIOSH assigned external ambient dose in this case, since the EE was assigned recorded and/or CW doses for all years of employment.

2.1.4 Occupational Medical Doses

Both DR methods:

- 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 files
- Used the thyroid or eye/brain as the surrogate organ for the nasal cavity for all posterior-anterior (PA) and lateral (LAT) view exposures (the doses were identical for the thyroid and eye/brain for all PA and LAT views used in this case, as per ORAUT-TKBS-0048, Table 3-3, page 51)
- Assigned LAT view doses for x-ray exams performed after [redacted], as per ORAUT-TKBS-0048, Table 3-1, page 46
- Used the recommended doses for PA, LAT, and photofluorography (PFG) exams for the thyroid or eye/brain (as a function of time) from ORAUT-TKBS-0048, Table 3-3, page 51

- Assigned doses for 21 PA view, 3 LAT views, and 1 PFG x-ray exams.

Comparison of Medical X-ray Assigned Doses

Both SC&A and NIOSH assigned a total dose of 0.061 rem for the 21 PA view, and 0.024 rem from the 3 LAT view x-ray exams. However, for the [redact] PFG x-ray exam, NIOSH used the thyroid as the surrogate organ and assigned a dose of 0.394 rem, whereas SC&A assigned a dose of 0.073 rem using the eye/brain as the surrogate organ according to the recommendation on page 16 of ORAUT-OTIB-0006:

> *The thyroid DCF is usually selected as the substitute to determine the dose to the eye/brain. However, one important exception to this generality is made for determining eye/brain dose from photofluorography (PFG) examinations of the chest. Because of the shorter SID used in PFG (40 in.) compared with radiographic chests (72 in.), the thyroid is most likely to be in the primary beam for PFG, while the eye/brain is most likely to be outside the primary beam of PFG. A better choice of a substitute DCF for the dose to the eye/brain for PFG is then one where the thyroid (as a substitute for the eye/brain) is just outside the primary beam.* [Emphasis added.]

The wording of the latter part (underlined) of the last sentence in this statement is not clear; however, SC&A interpreted it to mean that for PFG exams, an organ outside the primary beam is to be used instead of the thyroid (which may be in the primary beam) for cancers located at, or near, the eye/brain. Since the nasal cavity is located near the eye/brain, SC&A used the eye/brain dose cited in Table 3-3 of ORAUT-TKBS-0048 for the nasal cavity in this case.

Table 2-5 shows a comparison of the occupational medical doses calculated by the two DR methods. The resulting total doses were identical for the PA and LAT views, but the PFG exam doses differed, as described above.

Table 2-5. Comparison of Occupational Medical Doses

View	SC&A (rem)	NIOSH (rem)
PA	0.061	0.061
LAT	0.024	0.024
PFG	0.073	0.394
Total:	**0.157**	**0.478**

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

2.2 OCCUPATIONAL INTERNAL DOSES

There were no recorded bioassay results for this EE in the DOE records. There was a request for a urine sample for plutonium analysis in [redact] and a whole-body count in [redact]; however, no results were recorded/available. According to the information provided in the site profile for BNL (ORAUT-TKBS-0048, page 12) and the SEC class definitions, internal radiation doses at the BNL from [redact], through [redact], cannot be reconstructed because the data necessary to estimate doses during this time period cannot be readily retrieved. Therefore, because no bioassay data are available for the EE, no estimation techniques can be employed to derive internal dose, except for internal dose from the intake of ambient air activity.

2.2.1 Internal Environmental Dose

Both SC&A and NIOSH used the BNL site default radionuclides and associated intakes (as provided in Table 4-2 of ORAUT-TKBS-0048) for the years of employment in the Chronic Annual Dose Workbook (CADW) to derive the annual doses to the nasal cavity.

SC&A's Best-Estimate Method
SC&A used the best-estimate method by assigning environmental intakes for the full years for [redact]–[redact] (employment termination date of [redact]) and deriving the annual dose through the year the cancer was diagnosed ([redact]).

NIOSH's Minimizing Method
NIOSH used a minimizing method by assigning environmental intakes for the full years for [redact]–[redact] (i.e., NIOSH did not assign intakes for the employment termination year of [redact]), which resulted in an approximately 1/36 decrease in intake and dose. In addition, NIOSH did not assign dose for the year the cancer was diagnosed ([redact]).

Table 2-6 shows a comparison of the internal doses calculated by the two DR methods.

Table 2-5. Comparison of Internal Environmental Doses

	SC&A (rem)	NISOH (rem)
<15 keV electrons	0.161	0.159
>15 keV electrons	102.385	101.625
Gamma <30 keV	0.096	0.094
Gamma 30–250 keV	NA	NA
Gamma >250 keV	4.680	4.571
Alpha	0.971	0.944
Total:	**108.293**	**107.393**

NA = not applicable or <0.001 rem.

Both methods entered annual doses into IREP as a lognormal distribution with geometric standard deviation (GSD) of 3.000.

Comparison of Internal Environmental Dose Methods and Results
SC&A and NIOSH arrived at similar internal dose results. NIOSH's assigned dose values were slightly less than SC&A's, since NIOSH used a minimizing method as opposed to the best-estimate method used by SC&A.

3.0 SUMMARY CONCLUSIONS

Total external and internal doses and resultant POCs calculated by SC&A and NIOSH in behalf of Case #[Redact] 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 for the Nasal Cavity

	SC&A (rem)	NIOSH (rem)
External Doses:	35.697	43.605
Internal Doses:	108.293	107.393
Total Dose:	143.990	150.998
POC:	51.05%	52.54%

As shown in Table 3-1, SC&A's and NIOSH's dose estimates and resulting POCs are in close agreement. The primary difference in assigned external dose was due to NIOSH applying an NTA film fading factor to both recorded and missed neutrons dose, whereas SC&A only applied an NTA film fading factor to recorded neutron dose.

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

- Dose Reconstruction Methodology
  - SC&A employed a best-estimate approach to DR throughout.
  - NIOSH employed a best-estimate approach to external doses, and a minimizing approach to internal DR.

- Dose Conversion Factors
  - SC&A applied the mode DCF values as recommended in OCAS-IG-001.
  - NIOSH applied Monte Carlo-generated DCFs using OCAS-IG-001 data.
  - This difference in methodology resulted in slight differences in the assignment of recorded and missed photon and neutron doses.

- Assignment of Unmonitored Dose
  - SC&A assigned unmonitored photon dose based on 50^{th} percentile CW data for periods where the records showed the EE was not monitored (NM), after assigning the unaccounted recorded dose of 0.440 rem to the first two NM periods.
  - NIOSH prorated the 0.440 rem of unaccounted recorded dose over all the 14 NM periods and did not use CW data.
  - This difference in methodology resulted in SC&A deriving slightly higher doses for unmonitored periods than NIOSH.

- Assignment of Missed External Dose
  - SC&A assigned missed photon and neutron doses based on the actual and projected number of zeros and <LOD/2 values, identified in the EE's DOE records.
  - NIOSH assigned missed photon and neutron doses based on best-estimate methodology.
  - This difference in methodology resulted in SC&A deriving slightly greater missed doses than NIOSH assigned.

- Assignment of Neutron Dose
  - SC&A applied the NTA film fading factor of 1.81 only to the recorded neutron dose, as per SC&A's interpretation of the BNL TBD.
  - NIOSH applied the NTA film fading factor of 1.81 to both the recorded and missed neutron doses.
  - This difference in methodology resulted in NIOSH assigning a larger (by a factor of approximately 1.8) missed neutron dose as compared to SC&A.

- Assignment of Onsite Ambient Dose
  - Neither SC&A nor NIOSH assigned onsite external ambient dose, because the EE was assigned recorded or unmonitored doses for the entire employment period.

- Assignment of Occupational Medical X-ray Dose
  - To derive the x-ray doses, SC&A used the number of x-ray exams recorded in the DOE files and the dose values recommended in the BNL TBD, using the thyroid as the surrogate organ for the nasal cavity for PA and LAT views, and the eye/brain as the surrogate organ for the PFG exam.
  - To derive the x-ray doses, NIOSH used the number of x-ray exams recorded in the DOE files and the dose values recommended in the BNL TBD, using the thyroid as the surrogate organ for the nasal cavity for PA and LAT views, and also the thyroid as the surrogate organ for the PFG exam.
  - This difference methodology resulted in NIOSH assigning a larger PFG x-ray dose than that derived by SC&A.

- Assignment of Internal Dose
  - SC&A used the best-estimate approach to assign environmental intakes/doses.
  - NIOSH used a minimizing approach to assign environmental intakes/doses.
  - This difference in methodology resulted in NIOSH assigning a slightly less total internal dose than SC&A.

4.0 REFERENCES

ICRP (International Commission on Radiological Protection) 1991. *Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Pergamon Press, Oxford, England.

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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 BROOKHAVEN NATIONAL LABORATORY

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

Prepared by

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February 27, 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 BROOKHAVEN NATIONAL LABORATORY	Page 2 of 26
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.

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

Advisory Board	Advisory Board on Radiation and Worker Health
AP	anterior-posterior
[Redact]	[Redact]
BNL	Brookhaven National Laboratory
CADW	Chronic Annual Dose Workbook
CATI	Computer-Assisted Telephone Interview
CW	coworker
DCF	dose conversion factor
DOE	(U.S.) Department of Energy
DOL	(U.S.) Department of Labor
DR	dose reconstruction
EE	energy employee
[Redact]	[Redact]
HHS	(U.S. Department of) 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	kilo electron volt; 1,000 electron volts
LAT	lateral
LOD	limit of detection
MeV	Million electron volts
µCi/l	microcuries per liter
NIOSH	National Institute for Occupational Safety and Health
NM	not monitored
NTA	Eastman Kodak Nuclear Track Film Type A
ORAUT	Oak Ridge Associated Universities Team
PA	posterior-anterior
PFG	photofluorography
POC	probability of causation
qt	quarter

rem	Roentgen equivalent man
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SID	Source to image distance
TBD	technical basis document
TIB	technical information bulletin
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 [redacted] at the Brookhaven National Laboratory (BNL) from [redacted] through [redacted]. This was a partial DR, because not all internal doses could be assigned, as per the BNL Special Exposure Cohort (SEC).

The EE was diagnosed with **nasal cavity cancer** (sinonasal melanomas of the [redacted] nasal cavity, ICD-9 Code 160.0) on [redacted].

According to ORAUT-TKBS-0048, page 12, the Secretary of the U.S. Department of Health and Human Services (HHS) has designated BNL employees as an addition to the SEC. Based on the findings and recommendations of the National Institute for Occupational Safety and Health (NIOSH) and the Advisory Board on Radiation and Worker Health (Advisory Board), the Secretary of HHS has concurred with the finding that NIOSH does not have access to sufficient personnel or area monitoring data, or sufficient source or source term information, about BNL operations to bound potential internal exposures for the period from January 1, 1947, through December 31, 1993 (other than tritium after December 31, 1964).

The EE was employed at BNL during the SEC period; however, since nasal cavity cancer is considered a non-presumptive cancer, it was not covered under the SEC class; therefore, a DR was required.

According to the Department of Labor (DOL) files and the Computer-Assisted Telephone Interview (CATI) report, the EE was a [redacted] and [redacted] at BNL. The EE was monitored for external photon exposure during most of the employment period at BNL. The EE first worked at the [redacted], and then the [redacted] during the remainder of the EE's employment at the BNL.

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 NIOSH procedures relevant to this case, which included the Technical Basis Document (TBD) for the BNL (ORAUT-TKBS-0048), ORAUT-OTIB-0005 for surrogate organs, OCAS-IG-001 for dose conversion factors (DCFs), and ORAUT-OTIB-0006 for occupational x-ray 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 the nasal cavity. Table 1 provides a summary of the total doses assigned to the cancer site. Appendix A provides a list of SC&A's assigned annual organ doses 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 **51.05%**.

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

	Nasal cavity IREP entry	Dose (rem)
External Dose (Occupational)		
▪ Recorded/CW Dose:		
30–250 keV Photons	1–35	5.664
>250 keV Photons	36–70	11.469
0.1–2 MeV Neutrons	71–77	1.802
▪ Missed Dose:		
30–250 keV Photons	78–114	1.550
>250 keV Photons	115–151	3.138
0.1–2 MeV Neutrons	152–188	11.917
▪ Occupational Medical Dose:		
30–250 keV Photons	189–213	0.157
Internal Dose, Environmental:		
<15 keV Electrons	214–262	0.161
>15 keV Electrons	263–321	102.385
<30 keV Photons	322–370	0.096
>250 keV Photons	371–429	4.680
Alpha	430–488	0.971
Total		**143.990**

2.0 EXTERNAL DOSES

To perform this DR, SC&A analyzed the DOE files containing the quarterly totals of the badge readings (individual badge cycle data were not available), and one DOE file spreadsheet that provided a summary of doses received by this EE as of the 2nd quarter of [redacted].

SC&A used the DR parameters as recommended in ORAUT-TKBS-0048, which consisted of an energy range of 25% 30–250 keV photons, 75% >250 keV photons (Table 6-3, page 86); and 100 keV–2 MeV neutrons with a neutron ICRP-60 (ICRP 1991) correction factor of 1.91 (Table 6-5, page 87) and a Nuclear Track Film Type A (NTA) dosimeter fading correction factor of 1.81 (page 91); and a limit of detection (LOD) value of 0.030 rem for both photons and neutrons with a monthly badge exchange (Table 6-1, page 82). Exposure (as opposed to deep dose) conversion factors (DCFs) were used, as per ORAUT-TKBS-0048, page 90. The thyroid was used as the surrogate organ for the nasal cavity (ORAUT-OTIB-0005, page 15) because of it being in approximately the same physical location. In some cases, the *Remainder* organs DCF may be used; however, these organs are not located near the nasal cavity and would not be as applicable for external radiation to the nasal cavity as the thyroid. As recommended in OCAS-IG-001, for anterior-posterior (AP) geometry, a 30–250 keV photon DCF of 1.440 (page 61), a >250 keV photon DCF of 0.972 (page 61), and a 0.1–2 MeV neutron DCF of 1.086 (page 76) were used.

The quarterly total recorded doses and zero values for photon, neutron, and shallow doses in the EE's DOE files were very well organized and legible (shallow dose is not applicable to the nasal cavity). However, there was one discrepancy, in that one of the DOE file radiation reports listed a summary of dose received by this EE as of the 2nd quarter of [redacted] that indicated a *Lifetime Total* dose received while working at BNL that was 0.440 rem greater than the total of the doses received when summing up the quarterly values through the 2nd quarter of [redacted] (14.590 rem vs. 14.150 rem). There were 16 quarters when a notation of not monitored (*NM*) was entered into the EE's records during the period [redacted]–[redacted]. Because the [redacted] did not operate until [redacted] (ORAUT-TKBS-0048, page 26), no additional doses were added for the two NM periods during [redacted]. The extra 0.440 rem of recorded exposure in the summary sheet could have occurred any time during the remaining 14 NM periods, and may not have been entered into the quarterly sums, but carried on the Lifetime Total dose. Therefore, to be claimant favorable, 0.220 rem was assigned to the first potentially missed monthly exchange in [redacted] and the remaining 0.220 rem to the second potentially missed monthly exchange in [redacted], which occurred during the 3rd quarter. The total 0.440 rem was not assigned during one monthly exchange, because that would exceed the 5 rem per year dose limit applicable at that time; i.e., 5.000 rem/y × (1/12 months/y) = 0.417 rem/month maximum. For all the other potentially missed monthly exchanges during the period [redacted]–[redacted], which had the *NM* notation in the records, (as per ORAUT-TKBS-0048, page 82, recommendations for lost or destroyed badges) a monthly prorated coworker (CW) dose from the annual dose values, as recommended in ORAUT-TKBS-0048, Table 6-2, page 84, was applied as was appropriate for each year (this amounted to approximately 0.026 rem/month).

2.1 RECORDED/CW PHOTON DOSES

SC&A used the recorded photon dose values that were >LOD/2 of 0.015 rem, plus the extra 0.440 rem, and CW doses for the *NM* periods to assign photon doses using the parameters previously described.

Example of [redacted] recorded photon dose calculations – SC&A calculated the recorded [redacted] photon dose to the nasal cavity as follows:

> Records show that for the four quarters of [redacted], the EE received a deep dose of 0.160 rem + 0.410 rem + 0 + *NM*. This total of 0.570 rem recorded plus 0.079 rem CW (0.317 rem/y × (1y/4 qt)) dose = 0.649 rem for [redacted]. The photon dose was assumed to be 25% 30–250 keV and 75% >250 keV. DCFs of 1.440 for 30–250 keV photons and 0.972 for >250 keV photons were applied.
>
> 30–250 keV photon dose = D.D. × DCF × Energy f.
> = 0.649 × 1.440 × 0.25
> = 0.234 rem
>
> >250 keV photon dose = D.D. × DCF × Energy f.
> = 0.649 × 0.972 × 0.75
> = 0.473 rem

SC&A's calculated [redacted] 30–250 keV and >250 keV doses are shown in entries #10 and #45, respectively, of Appendix A.

The recorded photon doses were entered into the IREP as a normal distribution with a 30% uncertainty (ORAUT-TKBS-0048, page 95, was the best guidance available). SC&A assigned a total of 17.133 rem recorded/CW dose in entries #1–#70 of the IREP Input table, as summarized in Table 1 and detailed in Appendix A.

2.2 MISSED PHOTON DOSES

SC&A analyzed the number of physical zeros and potential zeros based on a monthly badge exchange cycle using the guidance in OCAS-IG-001, page 16, and a best-estimate reasonable approach to arrive at a total of 287 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 DCF to determine the annual missed photon dose.

Example of [redacted] missed photon dose calculations – SC&A calculated the missed [redacted] photon dose to the nasal cavity as follows:

> Records show that for the four quarters of [redacted], the EE had received a deep dose of 0.160 rem + 0.410 rem + 0 + *NM*. This results in a potential for seven zeros in [redacted]. The photon dose was assumed to be 25% 30–250 keV and 75% >250 keV. DCFs of 1.440 for 30–250 keV photons and 0.972 for >250 keV photons were applied.

$$\text{Missed Photon Dose (30–250 keV)} = (\text{\# zeros} \times \text{LOD}/2) \times \text{DCF} \times \text{Energy f.}$$
$$= (7 \times 0.015 \text{ rem}) \times 1.440 \times 0.25$$
$$= 0.038 \text{ rem}$$

$$\text{Missed Photon Dose (>250 keV)} = (\text{\# zeros} \times \text{LOD}/2) \times \text{DCF} \times \text{Energy f.}$$
$$= (7 \times 0.015 \text{ rem}) \times 0.972 \times 0.75$$
$$= 0.077 \text{ rem}$$

SC&A's calculated 30–250 keV missed photon dose of 0.038 rem is shown in entry #88, and the >250 keV missed photon dose of 0.077 is shown in entry #125 of Appendix A.

The missed photon doses were entered into IREP as a lognormal distribution with an uncertainty of 1.520. The total missed photon dose of 4.688 rem was assigned in entries #78–#151 of the IREP Input tables, as summarized in Table 1 and detailed in Appendix A.

2.3 RECORDED NEUTRON DOSES

SC&A used the recorded neutron dose values that were >LOD/2 of 0.015 rem to assign neutron doses using the DR parameters previously described. During periods when the EE was not monitored (*NM* in the records), additional neutron dose was not assigned because the POC exceeded 50% with the current dose assignments.

Example of [redacted] recorded neutron dose calculations – SC&A calculated the recorded [redacted] neutron dose to the nasal cavity as follows:

> Records show that for the four quarters of [redacted], the EE received a neutron dose of 0.030 rem + 0.040 rem + 0.010 + *NM*. This resulted in a total of 0.070 rem, because the 0.010 rem was less than the LOD/2 value of 0.015 rem. The neutron energy range was assumed to be 100% 0.1–2 MeV. A DCF of 1.086, a fading factor of 1.81, and an ICRP-60 correction factor of 1.91 was used, as previously described.

$$\text{0.1–2 MeV neutron dose} = \text{Neutron dose} \times \text{Fading f.} \times \text{ICRP f.} \times \text{DCF} \times \text{Energy f.}$$
$$= 0.070 \times 1.81 \times 1.91 \times 1.086 \times 1.00$$
$$= 0.263 \text{ rem}$$

This dose is shown in entry #74 of Appendix A.

The recorded neutron doses were entered into the IREP as a normal distribution with an uncertainty of 30%. SC&A assigned a total of 1.802 rem in entries #71–#77 of the IREP Input table, as summarized in Table 1 and detailed in Appendix A.

2.4 MISSED NEUTRON DOSES

SC&A analyzed the number of physical zeros and potential zeros based on a monthly badge exchange cycle using the guidance in OCAS-IG-001, page 16, and a best-estimate reasonable approach to arrive at a total 383 zeros, or <LOD/2 values, for neutrons. SC&A used the annual

number of zeros, the LOD/2 value, the DR parameters listed above, and the applicable DCF to determine the annual missed neutron dose.

<u>Example of [redacted] missed neutron dose calculations</u> – SC&A calculated the missed [redacted] neutron dose to the nasal cavity as follows:

> Records show that for the four quarters of [redacted], the EE had received a dose of 0.030 rem + 0.040 rem + 0.010 + *NM*. This resulted in a potential total of 7 zeros (2 months/qt × 3 quarters plus one from the recorded 0.010 rem that was less than the LOD/2 value of 0.015 rem). The neutron energy range was assumed to be 100% 0.1–2 MeV. A DCF of 1.086, and an ICRP-60 correction factor of 1.91 were used, as previously described. [Note that a fading factor of 1.81 was not applied to the <u>missed</u> neutron dose in this case, because ORAUT-TKBS-0048, page 91, states, "The <u>recorded</u> neutron doses should be corrected by applying a multiplication factor of 1.81 (inverse of 55%);" it does not state to apply it to missed neutron dose.]

$$\begin{aligned}\text{0.1–2 MeV neutron dose} &= (\text{\#zeros} \times 0.015 \text{ rem}) \times \text{ICRP f.} \times \text{DCF} \times \text{Energy f.}\\ &= (7 \times 0.015 \text{ rem}) \times 1.91 \times 1.086 \times 1.00\\ &= 0.218 \text{ rem}\end{aligned}$$

This dose is shown in entry #162 of Appendix A.

The missed neutron doses were entered into IREP as a lognormal distribution with an uncertainty of 1.520. The total missed neutron dose of 11.917 rem was assigned in entries #152–#188 of the IREP Input table, as summarized in Table 1 and detailed in Appendix A.

2.3 OCCUPATIONAL MEDICAL DOSE

<u>Records</u>
The DOE records show that the EE received one photofluorography (PFG) x-ray exam in [redacted] and 21 occupational medical x-ray exams (which were not for injuries, etc.) during the period [redacted]–[redacted]. Posterior-anterior (PA) views were assumed for all 22 exams, plus lateral (LAT) views for those taken after [redacted], as per ORAUT-TKBS-0048, Table 3-1, page 46.

<u>Surrogate Organ</u>
SC&A selected the occupational medical x-ray surrogate organ for the nasal cavity using the following recommendations:

ORAUT-OTIB-0005, page 6, states:

> *This TIB does not address the appropriate organ to use with medical X-ray procedures due to different potential exposure geometries of those procedures. The organs to be used for dose reconstruction from medical X-ray procedures can be found in ORAUT-OTIB-0006, Dose Reconstruction from Occupationally*

Related Diagnostic X-Ray Procedures (ORAUT 2005), or the site-specific technical basis documents and site profiles.

ORAUT-OTIB-0006, page 16 states:

> *The thyroid DCF is usually selected as the substitute to determine the dose to the eye/brain. However, one important exception to this generality is made for determining eye/brain dose from photofluorography (PFG) examinations of the chest. Because of the shorter SID used in PFG (40 in.) compared with radiographic chests (72 in.), the thyroid is most likely to be in the primary beam for PFG, while the eye/brain is most likely to be outside the primary beam of PFG. A better choice of a substitute DCF for the dose to the eye/brain for PFG is then one where the thyroid (as a substitute for the eye/brain) is just outside the primary beam.*

Therefore, SC&A used the eye/brain as the surrogate organ for the nasal cavity for the [redacted] PFG exam, and the thyroid for the PA and LAT views for the [redacted]–[redacted] exams.

Using the appropriate organ dose values recommended in Table 3-3, page 51, of ORAUT-TKBS-0048 as a function of the year the exam was performed, SC&A assigned a dose of 0.073 rem for the PFG exam in entry #189 of the IREP Input table, a total dose of 0.061 rem for the PA views (entries #190–#210), and 0.024 rem for the LAT views (entries #211–#213), for a total occupational medical x-ray dose of 0.157 rem. These doses are summarized in Table 1 and detailed 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.

2.4 ONSITE AMBIENT DOSE

As per ORAUT-TKBS-0048, Section 4.2.2, page 59, external ambient dose should not be applied when the EE is assigned recorded (and/or CW) dose. Therefore, no external ambient dose as assigned in this case, since the EE was assigned recorded and/or CW doses for all years of employment.

3.0 INTERNAL DOSES

The DOE files for the EE provided little useful information concerning bioassay data. There was some indication that the EE was to have a plutonium urinalysis in [redacted], but no results are available. The EE may have had a whole-body count in [redacted], but no results are available. There is one bioassay for tritium performed in [redacted], with results recorded as <0.02 µCi/l. Therefore, considering this information and the BNL SEC concerning the lack of internal dose data, it is claimant favorable in this case to assign internal environmental dose. Coupled with the external dose assignments, this results in a POC of >50%; therefore, additional internal dose is not necessary in this case.

3.1 INTERNAL ENVIRONMENTAL INTAKE/DOSE

SC&A used the Chronic Annual Dose Workbook (CADW), which uses the inhalation values cited in Table 4-2 of ORAUT-TKBS-0048 for BNL to derive the environmental intakes and resulting doses to the nasal cavity [using *ET1* as the Integrated Modules of Bioassay Analysis (IMBA) program organ and *Other Respiratory* as the IREP model organ, as per ORAUT-OTIB-0005, page 15] for the years [**redacted**]–[**redacted**]. This resulted in a tritium dose of 0.161 rem, a >15 keV electron dose of 102.385 rem, a <30 keV photon dose of 0.096 rem, a >250 keV photon dose of 4.680 rem, and an alpha dose of 0.971 rem, as listed in Table 1. The total internal dose assigned was 108.293 rem, as listed in entries #214–#488 of the IREP Input table and detailed in Appendix A. The annual dose values were entered into the IREP with a lognormal distribution and an uncertainty value of 3.000.

4.0 CATI REPORT AND RADIOLOGICAL INCIDENTS

SC&A reviewed the EE's DOE records and CATI report to determine if the EE was involved in any radiological incidents. SCA& did not find any documentation of radiological incidents that would impact the radiation doses assigned in this case.

5.0 SUMMARY CONCLUSIONS

This partial DR used best-estimate methods to obtain reasonable external and internal dose assignments. The derived total doses resulted in a POC >50%; therefore, the reconstruction of additional doses was not necessary.

The total POC for the nasal cavity cancer was calculated using the IREP (v.5.7.1) and was determined to be **51.05%**.

REFERENCES

ICRP 1991. *1990 Recommendations of the International Commission on Radiological Protection*, International Commission on Radiological Protection Publication 60, Pergamon Press, Oxford, England.

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APPENDIX A: IREP INPUT – NASAL CAVITY

CLAIMANT CANCER DIAGNOSES						
	Primary Cancer #1	Primary Cancer #2	Primary Cancer #3	Secondary Cancer #1	Secondary Cancer #2	Secondary Cancer #3
Cancer Type	Sinonasal melanoma of the [redacted] nasal cavity	N/A	N/A	N/A	N/A	N/A
Date of Diagnosis	[redacted]	N/A	N/A	N/A	N/A	N/A

EXPOSURE INFORMATION

Number of exposures

488

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
1	[redacted]	acute	photons E=30–250 keV	Normal	0.168	0.050	0.000
2	[redacted]	acute	photons E=30–250 keV	Normal	0.056	0.017	0.000
3	[redacted]	acute	photons E=30–250 keV	Normal	0.056	0.017	0.000
4	[redacted]	acute	photons E=30–250 keV	Normal	0.128	0.038	0.000
5	[redacted]	acute	photons E=30–250 keV	Normal	0.074	0.022	0.000
6	[redacted]	acute	photons E=30–250 keV	Normal	0.092	0.028	0.000
7	[redacted]	acute	photons E=30–250 keV	Normal	0.108	0.032	0.000
8	[redacted]	acute	photons E=30–250 keV	Normal	0.036	0.011	0.000
9	[redacted]	acute	photons E=30–250 keV	Normal	0.065	0.019	0.000
10	[redacted]	acute	photons E=30–250 keV	Normal	0.234	0.070	0.000
11	[redacted]	acute	photons E=30–250 keV	Normal	0.273	0.082	0.000
12	[redacted]	acute	photons E=30–250 keV	Normal	0.036	0.011	0.000
13	[redacted]	acute	photons E=30–250 keV	Normal	0.288	0.086	0.000
14	[redacted]	acute	photons E=30–250 keV	Normal	0.504	0.151	0.000
15	[redacted]	acute	photons E=30–250 keV	Normal	0.281	0.084	0.000
16	[redacted]	acute	photons E=30–250 keV	Normal	0.410	0.123	0.000
17	[redacted]	acute	photons E=30–250 keV	Normal	0.194	0.058	0.000
18	[redacted]	acute	photons E=30–250 keV	Normal	0.050	0.015	0.000
19	[redacted]	acute	photons E=30–250 keV	Normal	0.094	0.028	0.000
20	[redacted]	acute	photons E=30–250 keV	Normal	0.076	0.023	0.000
21	[redacted]	acute	photons E=30–250 keV	Normal	0.065	0.019	0.000
22	[redacted]	acute	photons E=30–250 keV	Normal	0.086	0.026	0.000
23	[redacted]	acute	photons E=30–250 keV	Normal	0.133	0.040	0.000
24	[redacted]	acute	photons E=30–250 keV	Normal	0.277	0.083	0.000
25	[redacted]	acute	photons E=30–250 keV	Normal	0.173	0.052	0.000
26	[redacted]	acute	photons E=30–250 keV	Normal	0.198	0.059	0.000
27	[redacted]	acute	photons E=30–250 keV	Normal	0.151	0.045	0.000
28	[redacted]	acute	photons E=30–250 keV	Normal	0.212	0.064	0.000
29	[redacted]	acute	photons E=30–250 keV	Normal	0.389	0.117	0.000
30	[redacted]	acute	photons E=30–250 keV	Normal	0.097	0.029	0.000
31	[redacted]	acute	photons E=30–250 keV	Normal	0.166	0.050	0.000
32	[redacted]	acute	photons E=30–250 keV	Normal	0.158	0.048	0.000
33	[redacted]	acute	photons E=30–250 keV	Normal	0.104	0.031	0.000
34	[redacted]	acute	photons E=30–250 keV	Normal	0.130	0.039	0.000
35	[redacted]	acute	photons E=30–250 keV	Normal	0.101	0.030	0.000
36	[redacted]	acute	photons E>250 keV	Normal	0.340	0.102	0.000
37	[redacted]	acute	photons E>250 keV	Normal	0.114	0.034	0.000
38	[redacted]	acute	photons E>250 keV	Normal	0.114	0.034	0.000
39	[redacted]	acute	photons E>250 keV	Normal	0.260	0.078	0.000
40	[redacted]	acute	photons E>250 keV	Normal	0.150	0.045	0.000
41	[redacted]	acute	photons E>250 keV	Normal	0.187	0.056	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
42	[redacted]	acute	photons E>250 keV	Normal	0.219	0.066	0.000
43	[redacted]	acute	photons E>250 keV	Normal	0.073	0.022	0.000
44	[redacted]	acute	photons E>250 keV	Normal	0.131	0.039	0.000
45	[redacted]	acute	photons E>250 keV	Normal	0.473	0.142	0.000
46	[redacted]	acute	photons E>250 keV	Normal	0.553	0.166	0.000
47	[redacted]	acute	photons E>250 keV	Normal	0.073	0.022	0.000
48	[redacted]	acute	photons E>250 keV	Normal	0.583	0.175	0.000
49	[redacted]	acute	photons E>250 keV	Normal	1.021	0.306	0.000
50	[redacted]	acute	photons E>250 keV	Normal	0.569	0.171	0.000
51	[redacted]	acute	photons E>250 keV	Normal	0.831	0.249	0.000
52	[redacted]	acute	photons E>250 keV	Normal	0.394	0.118	0.000
53	[redacted]	acute	photons E>250 keV	Normal	0.102	0.031	0.000
54	[redacted]	acute	photons E>250 keV	Normal	0.190	0.057	0.000
55	[redacted]	acute	photons E>250 keV	Normal	0.153	0.046	0.000
56	[redacted]	acute	photons E>250 keV	Normal	0.131	0.039	0.000
57	[redacted]	acute	photons E>250 keV	Normal	0.175	0.052	0.000
58	[redacted]	acute	photons E>250 keV	Normal	0.270	0.081	0.000
59	[redacted]	acute	photons E>250 keV	Normal	0.561	0.168	0.000
60	[redacted]	acute	photons E>250 keV	Normal	0.350	0.105	0.000
61	[redacted]	acute	photons E>250 keV	Normal	0.401	0.120	0.000
62	[redacted]	acute	photons E>250 keV	Normal	0.306	0.092	0.000
63	[redacted]	acute	photons E>250 keV	Normal	0.430	0.129	0.000
64	[redacted]	acute	photons E>250 keV	Normal	0.787	0.236	0.000
65	[redacted]	acute	photons E>250 keV	Normal	0.197	0.059	0.000
66	[redacted]	acute	photons E>250 keV	Normal	0.335	0.101	0.000
67	[redacted]	acute	photons E>250 keV	Normal	0.321	0.096	0.000
68	[redacted]	acute	photons E>250 keV	Normal	0.211	0.063	0.000
69	[redacted]	acute	photons E>250 keV	Normal	0.262	0.079	0.000
70	[redacted]	acute	photons E>250 keV	Normal	0.204	0.061	0.000
71	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.150	0.045	0.000
72	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.713	0.214	0.000
73	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.375	0.113	0.000
74	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.263	0.079	0.000
75	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.150	0.045	0.000
76	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.075	0.023	0.000
77	[redacted]	chronic	neutrons E=100 keV–2 MeV	Normal	0.075	0.023	0.000
78	[redacted]	acute	photons E=30–250 keV	Lognormal	0.027	1.520	0.000
79	[redacted]	acute	photons E=30–250 keV	Lognormal	0.049	1.520	0.000
80	[redacted]	acute	photons E=30–250 keV	Lognormal	0.032	1.520	0.000
81	[redacted]	acute	photons E=30–250 keV	Lognormal	0.032	1.520	0.000
82	[redacted]	acute	photons E=30–250 keV	Lognormal	0.022	1.520	0.000
83	[redacted]	acute	photons E=30–250 keV	Lognormal	0.027	1.520	0.000
84	[redacted]	acute	photons E=30–250 keV	Lognormal	0.027	1.520	0.000
85	[redacted]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
86	[redacted]	acute	photons E=30–250 keV	Lognormal	0.059	1.520	0.000
87	[redacted]	acute	photons E=30–250 keV	Lognormal	0.049	1.520	0.000
88	[redacted]	acute	photons E=30–250 keV	Lognormal	0.038	1.520	0.000
89	[redacted]	acute	photons E=30–250 keV	Lognormal	0.022	1.520	0.000
90	[redacted]	acute	photons E=30–250 keV	Lognormal	0.059	1.520	0.000
91	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
92	[redacted]	acute	photons E=30–250 keV	Lognormal	0.032	1.520	0.000
93	[redacted]	acute	photons E=30–250 keV	Lognormal	0.038	1.520	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
94	[redacted]	acute	photons E=30–250 keV	Lognormal	0.032	1.520	0.000
95	[redacted]	acute	photons E=30–250 keV	Lognormal	0.049	1.520	0.000
96	[redacted]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
97	[redacted]	acute	photons E=30–250 keV	Lognormal	0.049	1.520	0.000
98	[redacted]	acute	photons E=30–250 keV	Lognormal	0.065	1.520	0.000
99	[redacted]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
100	[redacted]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
101	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
102	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
103	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
104	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
105	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
106	[redacted]	acute	photons E=30–250 keV	Lognormal	0.054	1.520	0.000
107	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
108	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
109	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
110	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
111	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
112	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
113	[redacted]	acute	photons E=30–250 keV	Lognormal	0.043	1.520	0.000
114	[redacted]	acute	photons E=30–250 keV	Lognormal	0.011	1.520	0.000
115	[redacted]	acute	photons E>250 keV	Lognormal	0.055	1.520	0.000
116	[redacted]	acute	photons E>250 keV	Lognormal	0.098	1.520	0.000
117	[redacted]	acute	photons E>250 keV	Lognormal	0.066	1.520	0.000
118	[redacted]	acute	photons E>250 keV	Lognormal	0.066	1.520	0.000
119	[redacted]	acute	photons E>250 keV	Lognormal	0.044	1.520	0.000
120	[redacted]	acute	photons E>250 keV	Lognormal	0.055	1.520	0.000
121	[redacted]	acute	photons E>250 keV	Lognormal	0.055	1.520	0.000
122	[redacted]	acute	photons E>250 keV	Lognormal	0.109	1.520	0.000
123	[redacted]	acute	photons E>250 keV	Lognormal	0.120	1.520	0.000
124	[redacted]	acute	photons E>250 keV	Lognormal	0.098	1.520	0.000
125	[redacted]	acute	photons E>250 keV	Lognormal	0.077	1.520	0.000
126	[redacted]	acute	photons E>250 keV	Lognormal	0.044	1.520	0.000
127	[redacted]	acute	photons E>250 keV	Lognormal	0.120	1.520	0.000
128	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
129	[redacted]	acute	photons E>250 keV	Lognormal	0.066	1.520	0.000
130	[redacted]	acute	photons E>250 keV	Lognormal	0.077	1.520	0.000
131	[redacted]	acute	photons E>250 keV	Lognormal	0.066	1.520	0.000
132	[redacted]	acute	photons E>250 keV	Lognormal	0.098	1.520	0.000
133	[redacted]	acute	photons E>250 keV	Lognormal	0.109	1.520	0.000
134	[redacted]	acute	photons E>250 keV	Lognormal	0.098	1.520	0.000
135	[redacted]	acute	photons E>250 keV	Lognormal	0.131	1.520	0.000
136	[redacted]	acute	photons E>250 keV	Lognormal	0.109	1.520	0.000
137	[redacted]	acute	photons E>250 keV	Lognormal	0.109	1.520	0.000
138	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
139	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
140	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
141	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
142	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
143	[redacted]	acute	photons E>250 keV	Lognormal	0.109	1.520	0.000
144	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
145	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
146	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
147	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
148	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
149	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
150	[redacted]	acute	photons E>250 keV	Lognormal	0.087	1.520	0.000
151	[redacted]	acute	photons E>250 keV	Lognormal	0.022	1.520	0.000
152	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.156	1.520	0.000
153	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.280	1.520	0.000
154	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.156	1.520	0.000
155	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.187	1.520	0.000
156	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.187	1.520	0.000
157	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.124	1.520	0.000
158	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.156	1.520	0.000
159	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
160	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
161	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
162	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.218	1.520	0.000
163	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.187	1.520	0.000
164	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
165	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
166	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
167	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.311	1.520	0.000
168	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
169	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
170	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
171	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.342	1.520	0.000
172	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
173	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
174	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.342	1.520	0.000
175	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
176	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
177	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
178	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
179	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
180	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
181	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
182	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
183	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
184	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
185	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
186	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
187	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.373	1.520	0.000
188	[redacted]	chronic	neutrons E=100 keV–2 MeV	Lognormal	0.311	1.520	0.000
189	[redacted]	acute	photons E=30–250 keV	Normal	7.250E-02	0.022	0.000
190	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
191	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
192	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
193	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
194	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
195	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
196	[redacted]	acute	photons E=30–250 keV	Normal	7.26E-03	0.002	0.000
197	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
198	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
199	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
200	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
201	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
202	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
203	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
204	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
205	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
206	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
207	[redacted]	acute	photons E=30–250 keV	Normal	5.06E-04	0.000	0.000
208	[redacted]	acute	photons E=30–250 keV	Normal	1.38E-03	0.000	0.000
209	[redacted]	acute	photons E=30–250 keV	Normal	1.38E-03	0.000	0.000
210	[redacted]	acute	photons E=30–250 keV	Normal	1.38E-03	0.000	0.000
211	[redacted]	acute	photons E=30–250 keV	Normal	7.98E-03	0.002	0.000
212	[redacted]	acute	photons E=30–250 keV	Normal	7.98E-03	0.002	0.000
213	[redacted]	acute	photons E=30–250 keV	Normal	7.98E-03	0.002	0.000
214	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
215	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
216	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
217	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
218	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
219	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
220	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
221	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
222	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
223	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
224	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
225	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
226	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
227	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
228	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
229	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
230	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
231	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
232	[redacted]	chronic	electrons E<15 keV	Lognormal	0.003	3.000	0.000
233	[redacted]	chronic	electrons E<15 keV	Lognormal	0.003	3.000	0.000
234	[redacted]	chronic	electrons E<15 keV	Lognormal	0.007	3.000	0.000
235	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
236	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
237	[redacted]	chronic	electrons E<15 keV	Lognormal	0.006	3.000	0.000
238	[redacted]	chronic	electrons E<15 keV	Lognormal	0.008	3.000	0.000
239	[redacted]	chronic	electrons E<15 keV	Lognormal	0.006	3.000	0.000
240	[redacted]	chronic	electrons E<15 keV	Lognormal	0.007	3.000	0.000
241	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
242	[redacted]	chronic	electrons E<15 keV	Lognormal	0.001	3.000	0.000
243	[redacted]	chronic	electrons E<15 keV	Lognormal	0.002	3.000	0.000
244	[redacted]	chronic	electrons E<15 keV	Lognormal	0.004	3.000	0.000
245	[redacted]	chronic	electrons E<15 keV	Lognormal	0.023	3.000	0.000
246	[redacted]	chronic	electrons E<15 keV	Lognormal	0.037	3.000	0.000
247	[redacted]	chronic	electrons E<15 keV	Lognormal	0.035	3.000	0.000
248	[redacted]	chronic	electrons E<15 keV	Lognormal	0.014	3.000	0.000
249	[redacted]	chronic	electrons E<15 keV	Lognormal	0.002	3.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
250	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
251	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
252	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
253	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
254	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
255	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
256	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
257	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
258	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
259	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
260	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
261	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
262	[redacted]	chronic	electrons E<15 keV	Lognormal	0.000	3.000	0.000
263	[redacted]	chronic	electrons E>15 keV	Lognormal	1.775	3.000	0.000
264	[redacted]	chronic	electrons E>15 keV	Lognormal	1.780	3.000	0.000
265	[redacted]	chronic	electrons E>15 keV	Lognormal	1.780	3.000	0.000
266	[redacted]	chronic	electrons E>15 keV	Lognormal	1.781	3.000	0.000
267	[redacted]	chronic	electrons E>15 keV	Lognormal	1.781	3.000	0.000
268	[redacted]	chronic	electrons E>15 keV	Lognormal	1.781	3.000	0.000
269	[redacted]	chronic	electrons E>15 keV	Lognormal	1.781	3.000	0.000
270	[redacted]	chronic	electrons E>15 keV	Lognormal	1.780	3.000	0.000
271	[redacted]	chronic	electrons E>15 keV	Lognormal	1.807	3.000	0.000
272	[redacted]	chronic	electrons E>15 keV	Lognormal	1.807	3.000	0.000
273	[redacted]	chronic	electrons E>15 keV	Lognormal	1.807	3.000	0.000
274	[redacted]	chronic	electrons E>15 keV	Lognormal	1.807	3.000	0.000
275	[redacted]	chronic	electrons E>15 keV	Lognormal	1.811	3.000	0.000
276	[redacted]	chronic	electrons E>15 keV	Lognormal	1.923	3.000	0.000
277	[redacted]	chronic	electrons E>15 keV	Lognormal	1.752	3.000	0.000
278	[redacted]	chronic	electrons E>15 keV	Lognormal	1.757	3.000	0.000
279	[redacted]	chronic	electrons E>15 keV	Lognormal	1.759	3.000	0.000
280	[redacted]	chronic	electrons E>15 keV	Lognormal	1.736	3.000	0.000
281	[redacted]	chronic	electrons E>15 keV	Lognormal	37.293	3.000	0.000
282	[redacted]	chronic	electrons E>15 keV	Lognormal	1.739	3.000	0.000
283	[redacted]	chronic	electrons E>15 keV	Lognormal	1.705	3.000	0.000
284	[redacted]	chronic	electrons E>15 keV	Lognormal	1.704	3.000	0.000
285	[redacted]	chronic	electrons E>15 keV	Lognormal	1.703	3.000	0.000
286	[redacted]	chronic	electrons E>15 keV	Lognormal	1.703	3.000	0.000
287	[redacted]	chronic	electrons E>15 keV	Lognormal	1.704	3.000	0.000
288	[redacted]	chronic	electrons E>15 keV	Lognormal	1.704	3.000	0.000
289	[redacted]	chronic	electrons E>15 keV	Lognormal	2.119	3.000	0.000
290	[redacted]	chronic	electrons E>15 keV	Lognormal	2.119	3.000	0.000
291	[redacted]	chronic	electrons E>15 keV	Lognormal	2.119	3.000	0.000
292	[redacted]	chronic	electrons E>15 keV	Lognormal	2.120	3.000	0.000
293	[redacted]	chronic	electrons E>15 keV	Lognormal	2.119	3.000	0.000
294	[redacted]	chronic	electrons E>15 keV	Lognormal	3.040	3.000	0.000
295	[redacted]	chronic	electrons E>15 keV	Lognormal	2.022	3.000	0.000
296	[redacted]	chronic	electrons E>15 keV	Lognormal	2.018	3.000	0.000
297	[redacted]	chronic	electrons E>15 keV	Lognormal	2.486	3.000	0.000
298	[redacted]	chronic	electrons E>15 keV	Lognormal	0.762	3.000	0.000
299	[redacted]	chronic	electrons E>15 keV	Lognormal	0.001	3.000	0.000
300	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
301	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
302	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
303	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
304	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
305	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
306	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
307	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
308	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
309	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
310	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
311	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
312	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
313	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
314	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
315	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
316	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
317	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
318	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
319	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
320	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
321	[redacted]	chronic	electrons E>15 keV	Lognormal	0.000	3.000	0.000
322	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
323	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
324	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
325	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
326	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
327	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
328	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
329	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
330	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
331	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
332	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
333	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
334	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
335	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
336	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
337	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
338	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
339	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
340	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
341	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
342	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
343	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
344	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
345	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
346	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
347	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
348	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
349	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
350	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
351	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
352	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
353	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
354	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
355	[redacted]	chronic	photons E<30 keV	Lognormal	0.004	3.000	0.000
356	[redacted]	chronic	photons E<30 keV	Lognormal	0.003	3.000	0.000
357	[redacted]	chronic	photons E<30 keV	Lognormal	0.002	3.000	0.000
358	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
359	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
360	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
361	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
362	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
363	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
364	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
365	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
366	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
367	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
368	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
369	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
370	[redacted]	chronic	photons E<30 keV	Lognormal	0.000	3.000	0.000
371	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
372	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
373	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
374	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
375	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
376	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
377	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
378	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
379	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
380	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
381	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
382	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
383	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
384	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
385	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
386	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
387	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
388	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
389	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
390	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
391	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
392	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
393	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
394	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
395	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
396	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
397	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
398	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
399	[redacted]	chronic	photons E>250 keV	Lognormal	0.109	3.000	0.000
400	[redacted]	chronic	photons E>250 keV	Lognormal	0.228	3.000	0.000
401	[redacted]	chronic	photons E>250 keV	Lognormal	0.232	3.000	0.000
402	[redacted]	chronic	photons E>250 keV	Lognormal	0.233	3.000	0.000
403	[redacted]	chronic	photons E>250 keV	Lognormal	0.233	3.000	0.000
404	[redacted]	chronic	photons E>250 keV	Lognormal	0.233	3.000	0.000
405	[redacted]	chronic	photons E>250 keV	Lognormal	0.233	3.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
406	[redacted]	chronic	photons E>250 keV	Lognormal	0.114	3.000	0.000
407	[redacted]	chronic	photons E>250 keV	Lognormal	0.001	3.000	0.000
408	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
409	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
410	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
411	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
412	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
413	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
414	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
415	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
416	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
417	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
418	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
419	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
420	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
421	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
422	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
423	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
424	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
425	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
426	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
427	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
428	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
429	[redacted]	chronic	photons E>250 keV	Lognormal	0.000	3.000	0.000
430	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
431	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
432	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
433	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
434	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
435	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
436	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
437	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
438	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
439	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
440	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
441	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
442	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
443	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
444	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
445	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
446	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
447	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
448	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
449	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
450	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
451	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
452	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
453	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
454	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
455	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
456	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
457	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000

Appendix A: IREP Input – Nasal Cavity (continued)

Exp. #	Exposure Year	Exposure Rate	Radiation Type	Dose Distribution Type	Parameter 1	Parameter 2	Parameter 3
458	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
459	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
460	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
461	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
462	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
463	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
464	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
465	[redacted]	chronic	alpha	Lognormal	0.027	3.000	0.000
466	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
467	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
468	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
469	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
470	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
471	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
472	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
473	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
474	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
475	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
476	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
477	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
478	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
479	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
480	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
481	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
482	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
483	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
484	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
485	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
486	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
487	[redacted]	chronic	alpha	Lognormal	0.000	3.000	0.000
488	[redacted]	chronic	alpha	Lognormal	0.000	3.000	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

Ethnic Origin	Not used for cancer selected: Other respiratory
[redacted]	