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Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

A Review of NIOSH's Program Evaluation Report DCAS-PER-075, "Battelle Memorial Institute TBD Revision"

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
BCLDP	Battelle Columbus Laboratories Decommissioning Project
BMI	Battelle Memorial Institute
DOE	U.S. Department of Energy
DR	dose reconstruction
HEPA	high efficiency particulate air [filter]
IREP	Interactive RadioEpidemiological Program
MDA	minimum detectable activity
MDL	minimum detection level
MeV	mega-electron volt
mrem	millirem
n/p	neutron-to-photon
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NTA	nuclear track emulsion, type A
ORAUT	Oak Ridge Associated Universities Team
PER	program evaluation report
PFG	photofluorographic
POC	probability of causation
RU	radiometric uranium
SEC	special exposure cohort
SRDB	Site Research Database
TBD	technical basis document

1 Statement of Purpose

To support dose reconstruction (DR), the National Institute for Occupational Safety and Health (NIOSH) and the Oak Ridge Associated Universities Team (ORAUT) assembled a large body of guidance documents, workbooks, computer codes, and tools. In recognition of the fact that all of these supporting elements in DR may be subject to revisions, provisions exist for evaluating the effect of such programmatic revisions on the outcome of previously completed DRs. Such revisions may be prompted by document revisions due to new information, misinterpretation of guidance, changes in policy, and/or programmatic improvements.

A program evaluation report (PER) provides a critical evaluation of the effects that a given issue or programmatic change may have on previously completed DRs. This includes a qualitative and quantitative assessment of potential impacts. Most important in this assessment is the potential impact on the probability of causation (POC) of previously completed DRs with POCs less than 50 percent.

During a teleconference by the Advisory Board on Radiation and Worker Health (Board) Subcommittee for Procedure Reviews on November 16, 2023, the Board tasked SC&A to review DCAS-PER-075, revision 0 (NIOSH, 2017; "PER-075"), which was issued to address the impacts on previously completed claims of issuing ORAUT-TKBS-0058, revision 01 (ORAUT, 2015), the technical basis document (TBD) for Battelle Memorial Institute (BMI). In conducting a PER review, SC&A is committed to perform the following five subtasks, each of which is discussed in this report:

- **Subtask 1:** Assess NIOSH's evaluation and characterization of the issue addressed in the PER and its potential impacts on DR. Our assessment intends to ensure that the issue was fully understood and characterized in the PER.

- **Subtask 2:** Assess NIOSH's specific methods for corrective action. When the PER involves a technical issue that is supported by documents (e.g., white papers, technical information bulletins, procedures) that have not yet been subjected to a formal SC&A review, subtask 2 will include a review of the scientific basis and/or sources of information to ensure the credibility of the corrective action and its consistency with current/consensus science. Conversely, if such technical documentation has been formalized and previously subjected to a review by SC&A, subtask 2 will simply provide a brief summary and conclusion of this review process.

- **Subtask 3:** Evaluate the PER's stated approach for identifying the universe of potentially affected DRs and assess the criteria by which a subset of potentially affected DRs was selected for reevaluation. The second step may have important implications where the universe of previously denied DRs is very large and, for reasons of practicality, NIOSH's reevaluation is confined to a subset of DRs that, based on their scientific judgment, have the potential to be significantly affected by the PER. In behalf of subtask 3, SC&A will also evaluate the timeliness of the completion of the PER.

- **Subtask 4:** Conduct audits of DRs affected by the PER under review. The number of DRs selected for audit for a given PER will vary. (It is assumed that the Board will select the DRs and the total number of DR audits for each PER.)

- **Subtask 5:** Prepare a written report that contains the results of DR audits under subtask 4, along with our review conclusions.

2 Relevant Background Information

The Battelle Memorial Institute (BMI) was located in Columbus, Ohio, and performed atomic energy research and development and beryllium work for the U.S. Department of Energy (DOE) and its predecessor agencies from 1943 to 1986. BMI consisted of two separate locations in Columbus: King Avenue and West Jefferson. The King Avenue location processed and machined enriched, natural, and depleted uranium and thorium; fabricated fuel elements; analyzed radiochemicals; and studied power metallurgy. Beryllium work was conducted from 1943 until at least 1961. The West Jefferson location operated a large hot cell facility and a research reactor. The hot cell facility (JN-1) operated from 1955 through 1986. The research reactor was operated from October 1956 through December 1974, and the reactor was defueled and partially dismantled in 1975.

Two classes of workers were added to the Special Exposure Cohort (SEC) for the BMI King Avenue site. SEC Petition 208 established a class of workers that covered from April 16, 1943, through June 30, 1956. NIOSH determined that it was not feasible to reconstruct internal doses for inadequately monitored radionuclides such as uranium, thorium, and their progeny through June 30, 1956. NIOSH also determined it was not feasible to reconstruct external doses from beta, gamma, and neutron radiation through February 13, 1951. SEC Petition 229 established a class from July 1, 1956, through December 31, 1970. NIOSH determined that due to insufficient personnel and workplace monitoring and source term data, sufficient information was lacking to reconstruct internal exposures to thorium and its progeny. SC&A notes that it has not reviewed the most recent petition for the King Avenue site, whose designated end date was of some concern to the Board during its deliberations in November 2015. However, such reviews are beyond the scope of this report.

3 Subtask 1: Identify the Circumstances that Necessitated DCAS-PER-075

3.1 Chronology of events

NIOSH issued revision 00 of ORAUT-TKBS-0058 on March 26, 2010, for BMI (ORAUT, 2010a). As a result of the SEC reviews, revision 01 of ORAUT-TKBS-0058 was issued on June 27, 2016 (ORAUT, 2016). This revision has the potential to increase dose due to the inclusion of environmental doses and recycled uranium components as well as other modifications to internal and external dose assessment. PER-075 evaluated the effects of using revision 01 of the TBD on all previously completed BMI claims.

3.2 SC&A's comments

Programmatic revisions that may affect the outcome of previously completed DRs and mandate the need for a PER include any revisions to guidance documents that may result in the assignment of a higher dose.

SC&A believes that the issuance of a revision to the TBD, which resulted in the potential for BMI dose estimates to increase due to the inclusion of environmental dose and recycled uranium, is justification for reevaluating worker doses, as defined in PER-075. SC&A concurs with NIOSH's decision to issue PER-075 and has no findings.

4 Subtask 2: Assess NIOSH's Specific Methods for Corrective Action

The principal changes in revision 01 of ORAUT-TKBS-0058 are the incorporation of environmental internal and external doses, recycled uranium components, reference to ORAUT-OTIB-0076, revision 00 (ORAUT, 2014), for thorium intakes, and multiplication factors for assessing beta dose expressed in arbitrary units in dose records. Since SC&A has not previously reviewed ORAUT-TKBS-0058, SC&A's review of PER-075 includes an evaluation of the TBD to assess the scientific basis and sources of information to ensure the credibility of the corrective action.

4.1 Internal dose estimate

BMI required in vitro and in vivo bioassay monitoring. The TBD contains information regarding internal dosimetry practices and assessment of bioassay results at BMI over the years.

Urinalysis: The earliest urinalysis record for BMI is from July 1956. The frequency of urinalysis samples was determined based on a worker's exposure potential. Samples were also collected as a followup to radiological incidents. The BMI TBD includes information regarding the urinalysis minimum detectable activities (MDAs) for various radionuclides over the years (table 4-3). Some urinalysis results from 1976 through 1982 were marked "RU" for "radiometric uranium," where gross radioactivity of the sample was measured, rather than measuring the mass of uranium in the sample by fluoroscopy. NIOSH states these samples may have been used to quantify exposures from enriched uranium. Some urinalysis results may be marked "SPU" for "specific uranium," not plutonium. If the uranium enrichment is not known for a fluorometric result, natural uranium should be assumed. Although it is not well known whether recycled uranium was processed at BMI, the TBD assumes that, after 1952, uranium from refineries was recycled uranium or contained recycled uranium. Therefore, the TBD includes a table with the assumed contaminant activity fractions.

Fecal analysis: NIOSH found records for fecal samples from May 1974 through March 1982. Samples were analyzed for potassium-40, uranium, plutonium, americium, and fission products. Samples were collected as needed following radiological incidents.

Nose swabs/Lapel sampling: Nose swabs were also collected following radiological incidents or when exiting dusty cleanup work in Building JN-4 (main Plutonium Laboratory). Lapel samplers were also used beginning in 1975 in JN-4 as well as any operations with a high exposure potential. Results from both nose swabs and lapel samplers are not used to quantify intakes but served to verify if a worker had a positive intake after an incident.

Whole-body counting: The earliest record of whole-body counting at BMI is August 1970. The BMI TBD lists maximum MDAs to use if the batch MDA is not listed with a whole-body count prior to 1995. After 1995, MDAs were reported with each worker's results. There is no evidence of lung counts at BMI.

Plutonium intakes: The TBD includes information regarding the assumed plutonium isotopic composition to use when calculating internal dose from plutonium intakes, as well as the plutonium absorption types that are applicable for the site.

Fission products: For assessing mixed fission products, the BMI TBD discusses the use of ORAUT-OTIB-0054, revision 04 (ORAUT, 2015), to reconstruct internal doses for workers with bioassay results reported as only gross beta or gamma. It was determined that, if there was adequate ventilation in areas where fission and activation products were handled, the workers in these areas were likely not exposed to radioiodine. The TBD also provides spent fuel cooling times for JN-1, the research reactor, or fuel dissolution to use with ORAUT-OTIB-0054 for determining fission products workers may have been exposed to.

In accordance with SEC Petitions 208 and 229, NIOSH believes it is infeasible to estimate internal dose from thorium from the beginning of operations through December 31, 1970. NIOSH has not identified any data after this date that indicates a significant potential for thorium exposure.

4.1.1 SC&A's comments

SC&A reviewed the internal dosimetry information in the BMI TBD. Our assessment identified three observations as discussed in sections 4.1.1.1 and 4.1.1.3.

4.1.1.1 Urinalysis

SC&A agrees with NIOSH's assumption that recycled uranium was potentially processed at BMI and that recycled uranium contaminants should be applied to uranium intakes. The recycled uranium contaminant activity fractions in table 4-6 of the BMI TBD (ORAUT, 2016) were found to match those included in table 3.2 of Battelle-TBD-6000, revision 1 (NIOSH, 2011a).

With regard to other urinalysis information provided in the TBD, SC&A had two observations.

Observation 1: SC&A is unable to verify detection limits listed in TBD table 4-3

Table 4-3 of the BMI TBD includes detection limits for various radionuclides over time via urinalysis. Upon review of documented communication from Eberline Services (Eberline, 2007), SC&A was able to verify the detection limits for mixed fission products after 1993 and for isotopic uranium and isotopic plutonium after 1992. Based on the review of the records listed below containing urinalysis information and data for BMI, SC&A was unable to confirm the remaining detection limits listed in the table 4-3. The BMI TBD states that the detection limits in table 4-3 were derived from stated less-than values in worker records. SC&A's limited review of urinalysis records noted that some records did not list a "less-than" value, or the less-than value was smaller than what is listed in BMI TBD table 4-3 (ORAUT, 2016). SC&A requests clarification for how the values in BMI TBD table 4-3 were selected. The records reviewed were as follows:

- Battelle Memorial Institute (1956; Site Research Database (SRDB) 95541)
- Battelle Memorial Institute (1958; SRDB 34412)
- Eberline Instrument Corporation (1963; SRDB 34416)
- Eberline Instrument Corporation (1964a; SRDB 34417)
- Eberline Instrument Corporation (1964b; SRDB 34418)
- Eberline Instrument Corporation (1965; SRDB 34420)

Observation 2: Unclear how radiometric uranium urinalysis results should be interpreted for dose reconstructions

The TBD indicates that some uranium urinalysis results from 1976 through 1982 were designated as "RU" for "radiometric uranium," and that detection limits for this method of sample analysis are unknown; however, the TBD provides no guidance on how to assess "RU" results. SC&A requests additional information on how the "RU" urinalysis results should be used in dose reconstructions if the detection limits are unknown.

4.1.1.2 Fecal samples, nose swabs, and lapel sampling

The BMI TBD discusses fecal sampling, nose swabs, and lapel samplers that were also used for internal monitoring. The TBD does not include information for the minimum detection levels of nose swabs and lapel samplers but does state that nose swabs and lapel sample data should only be used in a DR to verify a potential positive intake. SC&A agrees with this approach.

4.1.1.3 Fission products

The TBD discusses the use of ORAUT-OTIB-0054 (ORAUT, 2015) to assess internal dose from mixed fission products to workers who may have worked in the hot cell facility, as most of the work performed there involved examination of irradiated fuel. The TBD clarifies that some work was done to specifically study fission gases, such as iodine-131, but this work would not be covered by ORAUT-OTIB-0054. Additionally, the TBD implies that urinalyses for iodine-131 were performed and are considered to be a part of the fission gas work. NIOSH then describes the ventilation capabilities of the areas where materials containing fission and activation products were handled. These areas appeared to have adequate ventilation, including exhausts above the pool-type reactor, individual exhausts for the hot cells as well as a building exhaust for the hot cell facility, and gloveboxes and hoods with exhausts and high efficiency particulate air (HEPA) filters. SC&A agrees with NIOSH's determination that adequate ventilation existed when handling materials with fission and activation products in these areas, and therefore radioiodine intakes from ORAUT-OTIB-0054 do not need to be considered for employees who worked in those areas.

SC&A also reviewed the TBD attachments and had the following concern.

Observation 3: Information needed for x-ray diffraction sample preparation methodology

SC&A reviewed attachments C and D of the BMI TBD, which discuss the operational history of the site by building and the types and quantities of material used at the site, respectively. Footnote a of table C-1 indicates that x-ray diffraction was performed for most samples, and footnote d of tables C-1 and C-2 and footnote a of tables D-1, D-2, and D-3 indicate that x-ray diffraction used powder samples, and that small amounts of the sample material should be assumed to have been ground into a powder (ORAUT, 2016). Also, based on table B-1 of attachment B, "Buildings and Other Facilities," it appears that grinding may have taken place in Building 5 (Machine Shop) of the King Avenue location. SC&A requests additional information on how samples were ground into a powder, and what monitoring may have been conducted of the workers performing the grinding.

4.2 External dose estimate

The BMI TBD details information regarding external dosimetry practices at BMI over the years, including the various dosimetry processing services, the various types of dosimeters used, dosimeter exchange frequencies, and the various minimum detection levels. According to the evaluation report for SEC Petition 208 (NIOSH, 2012), NIOSH has not located any external exposure records before February 13, 1951, and, therefore, determined that it is not feasible to reconstruct external beta, gamma, and neutron doses through February 13, 1951. NIOSH also stated that for some individuals, dose records may be missing for short periods of time, and that this may be due to actual missing records, or the worker had little exposure potential and was not monitored for this time.

Beta dose: From 1956 through 1961, NIOSH states that beta exposures may have been reported as "other" or "arbitrary units." These doses were converted to millirep using factors based on an assumed beta energy, and the BMI records may include notes indicating either the assumed beta energy, the multiplication factor to apply, or both. The multiplication factor for "old" fission products greater than 6 months old with an assumed energy of less than 0.7 mega-electron volts (MeV) is 5.3. The multiplication factor for "new" fission products less than 6 months old with an assumed energy of less than 1.4 MeV is 2.2. For work with uranium, a multiplication factor of 1.6 should be used. If a claimant's dose records do not indicate an assumed beta energy or multiplication factor, dose reconstructors should use a factor of 5.3 as a claimant-favorable assumption.

Photon dose: The BMI TBD also includes photon energy range parameters for various materials to which workers could have been exposed, including natural or depleted uranium, enriched uranium, natural thorium, mixed fission products, and plutonium. The TBD states that, if the specific materials a worker was exposed to cannot be determined, assume 100 percent 30–250 kiloelectron volt photons. NIOSH also states that workers at the West Jefferson site might have worked with gloveboxes.

Neutron dose: Neutron exposures were monitored via nuclear track emulsion, type A (NTA) film dosimeters at the West Jefferson location for a portion of the operational period. To account for the underresponse of NTA film dosimeters, NIOSH calculated neutron-to-photon (n/p) ratios derived from paired workplace measurements from BMI survey records. Attachment F of the BMI TBD contains the analyses NIOSH performed to develop the n/p ratios for buildings JN-1, JN-2, JN-3, and JN-4 at the West Jefferson location. Prior to 1970, neutron surveys were reported in terms of thermal and fast neutron flux. NIOSH used an equation to calculate the resulting dose using guidance from National Council on Radiation Protection and Measurements (NCRP) Report 38 (NRCP, 1971). Table 5-6 of the BMI TBD (ORAUT, 2016) lists the buildings, time periods, n/p ratios, geometric means, geometric standard deviations, 95th percentile n/p ratios, and the number of measurements NIOSH used to calculate the n/p ratios.

Environmental dose: Measurements of onsite external dose began at the West Jefferson site in 1978 and continued through 2005 except for 1999, for which no report was found. Environmental monitoring was also performed at the King Avenue site from 1993 through 1998. Since the King Avenue measurements were less than those from the West Jefferson site, NIOSH applied the West Jefferson environmental measurements as bounding doses for both sites. The

doses were prorated for an assumed worker exposure of 2,000 hours per year. For years prior to 1978 without environmental monitoring data, the highest annual dose from 1978 to 2005 should be applied.

4.2.1 SC&A's comments

SC&A reviewed the external dosimetry information in the BMI TBD. SC&A also reviewed a sample of film badge dosimetry results from 1956 through 2008 (BMI, 1956–2008; "SRDB 52924"), which contains a sample of BMI dosimetry records, and confirmed the various dosimetry processing services used at BMI listed in TBD table 5-1. SC&A was able to verify most of the minimum detection levels (MDLs) listed in TBD table 5-2 from the dosimetry records, except for the periods discussed in observation 4. SC&A agrees with NIOSH's determination that it is unlikely neutron detection sensitivity would have decreased over time and that an assumed neutron dosimeter MDL of 50 millirem (mrem) for the period of 1961 through 1996 is appropriate.

Observation 4: SC&A is unable to verify several MDLs listed in TBD table 5-2

- **Photon MDL:** Table 5-2 in the BMI TBD lists a dosimeter MDL of 50 mrem for photons for the period March 1951 through March 1956. SC&A was unable to verify the 50 mrem photon MDL stated by NIOSH. In the 1951 and 1952 personnel monitoring records for a BMI employee (BMI, 1951), doses of 30 mrem were listed. SC&A requests documentation or further explanation for NIOSH's assumed photon MDL of 50 mrem for March 1951 through March 1956.

- **Post-2002 MDLs:** From review of PDF pages 18–20 of SRDB 52924, SC&A is unable to verify the photon, beta, and neutron MDLs listed in table 5-2 of the BMI TBD for the period of 2003 and after, when Global Dosimetry Services was the dosimetry provider. SC&A requests additional information from NIOSH for how those MDLs were determined.

Other concerns that SC&A had regarding various aspects of external dose assignments are discussed in observations 5 through 10.

Observation 5: Clarification needed for workplace radiation fields

NIOSH cited the external dose TBDs for Y-12 (ORAUT, 2009), Lawrence Livermore National Laboratory (ORAUT, 2010b), Idaho National Laboratory (ORAUT, 2011a), and Los Alamos National Laboratory (ORAUT, 2013) for the workplace radiation fields photon energy range in table 5-4 of the BMI TBD (ORAUT, 2016). SC&A reviewed these TBDs and found potential inconsistencies in the assumed photon energy range percentages for natural uranium, depleted uranium, enriched uranium, and plutonium. Therefore, SC&A requests additional information on how NIOSH determined the energy range percentages assumed for BMI.

To assess the beta energy multiplication factors used to determine doses reported as "other" or "arbitrary units," SC&A reviewed the cited references: "Conversion Factors for 'Other' Readings on Film Badge Reports" (Landauer, 1951) and "The Response of Sensitive 552 Dupont Film to Beta Radiation" (Storm, 1951). Based on this review, SC&A was able to confirm the

NIOSH multiplication factors for the assumed beta energies. SC&A finds NIOSH's guidance to use a multiplication factor of 5.3 for these reported doses when the dose record does not include a multiplication factor or beta energy to be claimant favorable and reasonable. SC&A did, however, have one observation about interpreting various dosimetry records, as discussed in observation 6.

Observation 6: Unclear if doses reported as "arbitrary units" would be reported on various dose records

SC&A reviewed dose records from September 1956 that were reported on two different dosimetry forms. Page 48 of SRDB 102296 is a Landauer film badge dose report that contains a column labeled as 'other' (Landauer, 1956). Page 7 of SRDB 108188 is a DOE-provided film badge exposure report that does not contain a column labeled "other" (BMI, 1956). Based on this inconsistency in dosimetry records, it is unclear how the dose reconstructor would interpret the beta dose. It is also unclear if any notes about the assumed beta energy or multiplication factor would appear on these forms.

For assessing the TBD n/p ratios for the West Jefferson site, SC&A reviewed attachment F, "Analysis of Measured Neutron and Photon Dose Radiation Survey Data." Using data in NCRP Report 38 (NCRP, 1971), SC&A verified the equation NIOSH used to convert thermal and fast neutron flux to dose. NIOSH did not include references for the surveys used to determine the n/p ratio for JN-1 but did include references for the data used in the calculations for the n/p ratios for JN-2, JN-3, and JN-4. NIOSH also provided SC&A with spreadsheets containing the data and calculations used. Based on this review, SC&A has the following concerns regarding the calculated n/p ratios.

Observation 7: More information needed on what records were selected for n/p ratio calculations

NIOSH stated that, for the JN-1 n/p ratio and the JN-4 n/p ratio, only a sampling of available records was used in the calculations. The JN-1 n/p ratio used a total of 49 measurements, and the JN-4 n/p ratio used a total of 41 measurements. SC&A requests additional information on how the records that were used were selected from the available data. Additionally, it is unclear why NIOSH limited the data used for these calculations when over 2,000 measurements were used in the calculation for the JN-3 n/p ratio.

SC&A agrees with NIOSH's determination that the presence of extremity dosimetry is an indicator for glovebox work. However, NIOSH's guidance regarding assessment of dose to glovebox workers is not clear.

Observation 8: TBD lacks guidance about glovebox workers in JN-1 and JN-3

The last paragraph of TBD section 5.5 (page 35), states that guidance in DCAS-TIB-0010, revision 04, "Best Estimate External Dose Reconstruction for Glovebox Workers" (NIOSH, 2011c), applies to glovebox workers handling plutonium in JN-2 and JN-4. SC&A asks if DCAS-TIB-0010 also applies to glovebox workers in JN-1 and JN-3.

SC&A reviewed NIOSH's methodology for determining annual ambient external doses using the yearly site environmental reports. SC&A believes that assigning the higher average dose from the security perimeter measurements for 1985 through 2004 rather than the lower doses from the recreation area and property boundary measurements is reasonable and claimant favorable. SC&A also agrees that applying the higher doses from the West Jefferson site for the King Avenue site is reasonable and claimant favorable. However, SC&A does have two observations about how these doses are applied.

Observation 9: SC&A requests additional information regarding the applicability of post-operational environmental monitoring data for pre-1978

The TBD states that for years prior to 1978, the highest annual dose from 1978 to 2005 should be applied. However, the available environmental data are from the residual period and remediation period. SC&A requests additional information for how NIOSH determined these data were representative of environmental data for pre-1978 operations.

Observation 10: Ambient external dose does not account for potential overtime

In its calculations for the yearly ambient external doses, NIOSH states that the assumed worker occupancy is 2,000 hours per year. SC&A reviewed the energy employee interview from an audited BMI dose reconstruction (Tab 589), which stated they worked up to 16 hours of overtime a week. SC&A suggests that if workers may have routinely worked in excess of 40 hours per week, it would be appropriate to adjust the assumed worker occupancy and external ambient dose estimate calculations accordingly. This observation also applies to the environmental internal dose.

4.3 Internal dose from onsite atmospheric radionuclides

Air sampling data do not exist for either the King Avenue or West Jefferson locations before 1973. Stack sampling at the King Avenue location took place from 1973 to 1975. In June 1975, BMI placed stack sampling at King Avenue on standby, as the reduced quantity of radioactive materials handled at this site did not warrant continued sampling. Stack sampling at the West Jefferson location took place from 1973 through 2005. Because environmental monitoring was conducted at the site boundary approximately 500 meters from the West Jefferson location, NIOSH used NCRP Report 123 (NCRP, 1996) methodology to estimate an onsite atmospheric dispersion factor to calculate onsite atmospheric concentrations.

Annual inhalation intakes of environmental radionuclides were calculated using the onsite atmospheric dispersion factor, a breathing rate of 1.2 cubic meters per hour, and an exposure of 2,000 hours per year. NIOSH calculated the annual intakes at King Avenue, resulting in organ doses of less than 1 mrem/year that therefore do not need to be assigned. NIOSH calculated annual intakes at the West Jefferson location for alpha-emitting radionuclides from 1973 through 2005 and mixed fission products from 1975 through 2005, based on available air sampling data. The TBD states that prior to 1973, the highest reported intakes for alpha-emitting radionuclides from 1993 can be assigned. Similarly, for the years prior to 1975, the highest reported intakes for mixed fission products from 1977 can be assigned. The TBD states that, if a BMI worker may have traveled between the King Avenue and West Jefferson locations, the West Jefferson intakes should be applied.

4.3.1 SC&A's comments

SC&A reviewed attachment G and NIOSH's calculations for the onsite atmospheric dispersion factor. SC&A believes the assumptions in the calculations are conservative and reasonable. SC&A also calculated an onsite atmospheric dispersion factor of 0.004 seconds per cubic meter and finds this dispersion factor to be reasonably conservative for both sites. In addition, SC&A reviewed the site environmental report for 1997 (BCLDP, 1998) and used the sum of the atmospheric release data for all stacks to calculate intake rates of alpha-emitting radionuclides and mixed fission and activation products at the West Jefferson site for 1997. SC&A was able to closely match NIOSH's calculated intakes shown in tables G-1 and G-2.

As mentioned in observation 10, SC&A believes the intake estimates may need to be adjusted to account for workers' potential overtime at BMI. SC&A also had two additional concerns about the assessment of environmental dose as expressed in observations 11 and 12.

Observation 11: Inconsistency in the application of external and internal environmental dose

Both the external and internal environmental dose estimates are based on environmental data that BMI began to collect several years after the start of operations at each location. For the external environmental dose, NIOSH stated that the dose estimated from the West Jefferson data may also be applied to the King Avenue site, as the West Jefferson data were usually higher than the King Avenue data. However, NIOSH states that the internal intakes calculated using the West Jefferson site data should be applied to King Avenue workers who might have traveled between the two sites, rather than applying the West Jefferson estimates to all workers, as was done for the environmental external dose estimates.

Observation 12: Clarification needed on years with highest alpha-emitter and mixed fission and activation product environmental intake

Section 6.2 of the TBD states that the alpha-emitter intake for the years 1971 and 1972 can be conservatively represented by the highest reported intake values from 1993 in table G-1 (ORAUT, 2016). It appears that NIOSH chose the years 1993 and 1977 based on the highest sum of inhaled radionuclides for a given year, as shown in figures 6-1 and 6-2. If the ratio of the activity of the radionuclides remains fairly constant, then using the results of the year with the highest results would seem claimant favorable and reasonable. However, this does not appear to hold true, in this case, for either the alphas or mixed fission and activation products. Table G-1 for 1993 show that uranium-238 is the driver, but plutonium-239 and americium-241 decreased from 1992 to 1993. The same applies to the mixed fission and activation products in table G-2 where cobalt-60 is the driver, but many other radionuclides that vary by year as shown in figure 6-2. Therefore, it would depend on the target organ which of the radionuclides are dominate. SC&A believes that more analysis may be warranted for NIOSH to demonstrate their recommendation is indeed claimant favorable.

4.4 Residual period exposure

NIOSH states that the West Jefferson site had the potential for residual contamination from 1976 to 1985, and that the King Avenue site had the potential for residual contamination from 2001 through the present. NIOSH claims that workers at both sites were monitored for internal and

external exposure during the residual periods, and that no additional dose assessment is needed to complete DRs for these periods.

4.4.1 SC&A's comments

SC&A reviewed the report on residual radioactive and beryllium contamination at Atomic Weapons Employer facilities (NIOSH, 2011b) cited by NIOSH and confirmed that it states the West Jefferson and King Avenue sites might have residual contamination from 1976 through 1985 and 2001 through the present, respectively. Based on information in the external dosimetry section of the TBD, SC&A confirmed that BMI had the capability to conduct external monitoring for photons, betas, and neutrons for both residual periods. SC&A also reviewed the TBD for BMI internal monitoring capabilities during the residual contamination periods and identified the following observation.

Observation 13: It is unclear what internal exposure monitoring capabilities existed for BMI after 1998

It was not clear from SC&A's review of the internal dosimetry section of the BMI TBD what internal dosimetry methods were available for BMI after 1998. For example, tables 4-1 and 4-3 indicate urinalyses ended in 1998, and section 4.2 of the TBD states that the latest in vivo analysis record was also from 1998.

4.5 Occupational medical dose estimate

BMI implemented an occupational medical program in 1949, which initially only included beryllium workers. The program included a preplacement, annual, and termination exam. X-rays were done off site at a university hospital and are not eligible for inclusion in DRs. In the 1950s, some x-rays of BMI workers were performed at a private physician's office and included chest fluoroscopy. These examinations were also conducted off site and are not eligible for inclusion in DRs. Chest fluoroscopy for BMI employees likely ended in 1956. Between 1957 and 1968, x-rays may have been performed on site or off site at a private physician's office. NIOSH instructs dose reconstructors to assume onsite chest x-rays beginning in 1957, unless the claimant has offsite x-ray records during that time.

Medical x-ray equipment existed at BMI starting in 1968, with the installation of a machine described as being radiographic and fluoroscopic. NIOSH indicated that there is no evidence of chest fluoroscopy after 1956, and to assume that only the radiographic mode was used.

Dose from onsite chest x-rays should be assigned starting in 1957 and include a posterior-anterior chest x-ray for preemployment, annual, and termination physicals. Records also indicate that an annual lateral chest x-ray was performed in addition to the annual posterior-anterior x-ray from 1975 through 1980. Occupational medical doses are not reconstructed for the residual periods of 1976 through 1985 at West Jefferson or 2001 through March 1, 2011, at King Avenue. Revision 01 of the TBD refers to ORAUT-OTIB-0006, revision 04 (ORAUT, 2011b), for assigning organ doses.

4.5.1 SC&A's comments

SC&A concurs with NIOSH that offsite x-rays are not eligible for inclusion in DRs. SC&A also concurs with NIOSH's assumed x-ray frequency and the use of revision 04 of ORAUT-OTIB-0006 for assigning organ doses (ORAUT, 2011b). SC&A does have one observation regarding the potential for photofluorography examinations.

Observation 14: Evidence of photofluorographic examinations at BMI

As part of the 29th set of DR reviews, SC&A reviewed Tab 589, which involved a former BMI employee. As part of the Tab 589 dose reconstruction, NIOSH assigned dose from a total of four photofluorographic (PFG) examinations, two in 1960 and two in 1961. The energy employee was employed at BMI during this time. There is no mention of the use of PFG examinations at BMI in the TBD. SC&A requests more information regarding the potential use of PFG examinations for BMI workers and believes the TBD would benefit from additional discussions regarding these exams.

4.6 SC&A general comment

SC&A had one additional observation regarding the overarching DR methodology for the BMI site.

Observation 15: Inadequate dose reconstruction guidance for workers with potentially missing dose records

Section 5.4 of the TBD acknowledges that external monitoring records may be missing from a monitored worker's dosimetry files. Specifically, the TBD states:

> It should be noted that dose monitoring records appear to be missing for short intervals in some individual records. This could be due to actual missing records or due to the fact that Battelle based the level of monitoring on the exposure potential of the worker and task, so that individuals with little or no potential exposure were not monitored (i.e., the lack of monitoring was intentional based on low dose potential). The dose reconstructor must evaluate available records and determine whether apparent gaps in monitoring require the assessment of unmonitored dose for those periods. Battelle records appear to be adequate to support interpolation methods outlined in OCAS-IG-001 . . . to determine doses for gaps in records that are deemed to be due to missing reports (rather than to the intentional nonmonitoring of workers with low potential for exposure). More significant gaps in monitoring data must be evaluated on a case-by-case basis to determine if additional requests for dosimetry records should be made. [ORAUT, 2016, pp. 33–34]

By extension, SC&A assumes that all types of dosimetry records (e.g., internal bioassay monitoring) might be similarly incomplete in some cases. For potential "gaps" in external dosimetry records, NIOSH recommends an interpolative approach if the gap is relatively small; if the gap is more significant, then alternate methods should be utilized. No further guidance is provided as to what those methods would entail, and the potential for workers with missing internal monitoring records does not appear to be addressed.

5 Subtask 3: Evaluate the PER's Stated Approach for Identifying the Number of DRs Requiring Reevaluation of Dose

5.1 NIOSH's selection criteria

Section 3.0 of DCAS-PER-075 (NIOSH, 2017) described the following criteria NIOSH used to identify previously completed claims requiring reevaluation using revision 01 of ORAUT-TKBS-0058 (ORAUT, 2016). NIOSH identified all previously completed claims with verified employment at BMI, which was 91 claims. NIOSH then eliminated 27 claims that had a POC of greater than 50 percent. Twenty claims had already been completed using revision 01 of the site profile, were awaiting a DR, or were pulled from DR and were removed from further evaluation because the U.S. Department of Labor no longer needed a DR to determine whether the claim was compensable. This left 44 claims to evaluate.

NIOSH also searched DR reports for the word "Battelle" and identified 3,126 claims. Seventy-two of these claims were previously identified. NIOSH removed 3,050 claims from further evaluation because they had no connection to BMI. The remaining 4 claims were added to the initial search for a total of 48 claims. Twelve of these claims were members of an SEC and were removed from further evaluation, leaving 36 claims to be evaluated further.

NIOSH reevaluated the remaining 36 claims to determine if any changes in revision 01 of the TBD affected the assigned dose. NIOSH determined that 31 claims were unaffected by the TBD changes in revision 01. The 5 remaining claims were reevaluated using revision 01 of the TBD, as well as the current revisions of any other applicable documents. Four of the claims had a POC less than 45 percent, and one claim had a POC between 45 and 50 percent. NIOSH ran the Interactive RadioEpidemiological Program (IREP) 30 times at 10,000 iterations for this claim, and the resulting POC was less than 50 percent.

5.2 SC&A's comments

SC&A finds NIOSH's selection criteria for defining the 36 claims requiring reevaluation of dose to be sufficient to identify all impacted claims. Additionally, SC&A believes the PER was conducted in a timely manner, as revision 01 of the TBD (ORAUT, 2016) was issued in June 2016, and DCAS-PER-075 was issued in December 2017 (NIOSH, 2017). There are no findings associated with subtask 3, but SC&A has two observations.

Observation 16: Details needed on how four claims from the second search were not identified in the first search

It is unclear from NIOSH's description of the selection criteria how the four claims from the second search were not found during the initial search of claims with BMI employment. If these claims only involved visits to BMI, SC&A asks if other PERs include a step of searching all DR reports for mentions of a given site name.

Observation 17: Information requested regarding NIOSH's determination that 31 claims were unaffected by BMI TBD changes in revision 01

SC&A believes that updates to the BMI TBD in revision 01, which included the addition of environmental internal and external doses, recycled uranium components, reference to ORAUT-

OTIB-0076 for thorium intakes, and a multiplication factor for beta dose expressed in arbitrary units, have the potential to affect more than 5 out of the 36 reevaluated claims. As mentioned in section 5.4 of the TBD, some workers may have had gaps in monitoring during employment, possibly due to a lack of exposure potential, that may have required the assignment of environmental internal and/or external dose. Additionally, since uranium was processed at the site, and urinalyses were analyzed for uranium 1957–1998, SC&A believes the potential for workers to have been exposed to uranium and therefore recycled uranium components could have affected more than 5 out of 36 claims, and requests information for how NIOSH determined claims were not exposed to recycled uranium components.

6 Subtask 4: Conduct Audits of a Sample Set of Reevaluated DRs Mandated by DCAS-PER-075

Previous sections of this report described the issuance of revision 01 of ORAUT-TKBS-0058 (ORAUT, 2016), the TBD for BMI. The TBD revised numerous exposure pathways that resulted in an increase in dose and have a potential to impact previously adjudicated claims.

For SC&A to satisfy its commitment under subtask 4, SC&A suggests that our case reviews include the rework of the appropriate number of cases necessary to assess all changes introduced in ORAUT-TKBS-0058, revision 01, as follows:

- assignment of environmental internal dose
- assignment of environmental external dose
- assignment of recycled uranium components
- assessment of thorium intakes
- assessment of beta dose for records expressed in arbitrary units

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