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

SC&A's Review of ORAUT-TKBS-0060, Revision 00, "Site Profile for Grand Junction Facilities"

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Abbreviations and Acronyms

ABRWH	Advisory Board on Radiation and Worker Health
D&D	decontamination and decommissioning
DAC	derived air concentration
d_c	calendar day
DOE	U.S. Department of Energy
dose (i)	annual dose in a given year
DR	dose reconstruction
ER	evaluation report
GJF	Grand Junction Facilities (Grand Junction, CO)
GMD	geometric mean dose
GSD	geometric standard deviation
hr	hour
keV	kiloelectron volt
L	liter
LOD	limit of detection
MPC	maximum permissible concentration
m^3	cubic meter
µCi	microcurie
ml	milliliter
n	number of annual doses
NIOSH	National Institute for Occupational Safety and Health
ORAUT	Oak Ridge Associated Universities Team
PA	posterior-anterior
PER	program evaluation report
PFG	photofluorographic
pCi	picocurie
qt	quarter
Ra	radium
REMS	Radiation Exposure Monitoring System
SEC	Special Exposure Cohort
SRDB	Site Research Database

TBD	technical basis document
Th	thorium
WLM	working level month
y	year

1 Introduction and Background

The National Institute for Occupational Safety and Health (NIOSH) issued the technical basis document (TBD), ORAUT-TKBS-0060, revision 00, "Site Profile for Grand Junction Facilities," on May 18, 2018 (NIOSH, 2018; hereafter referred to as the "TBD") for the Grand Junction, CO, U.S. Department of Energy (DOE) facilities (GJF).

As a result of the Subcommittee for Procedure Reviews meeting of February 18, 2021, SC&A was tasked with reviewing the TBD.

The following is a list of documents applicable to this review:

- DCAS-PER-047, revision 0, "Grand Junction Operations Office," March 26, 2014 (NIOSH, 2014)
- "Dose Reconstruction Methodology for the Grand Junction Facilities," September 15, 2015 (NIOSH, 2015b)
- SCA-TR-PR2015-0093, revision 1, "A Review of NIOSH's Program Evaluation Report DCAS-PER-047, 'Grand Junction Operations Office,'" February 10, 2015 (SC&A, 2015)
- Addendum to NIOSH's petition evaluation report (ER) for Special Exposure Cohort (SEC) Petition SEC-00175, March 13, 2015 (NIOSH, 2015a)
- SCA-TR-2016-SEC006, revision 0, "A Focused Review of the NIOSH SEC Evaluation Report for Grand Junction Operations Office, Addendum to Petition SEC-00175," May 17, 2016 (SC&A, 2016)
- "NIOSH Response to SC&A review of Grand Junction Evaluation Report Addendum," July 20, 2016 (NIOSH, 2016)
- SC&A's June 22, 2017, memorandum, "Resolution of Finding 3 under SC&A's Review of DCAS-PER-047 (GJOO)" (SC&A, 2017)

Additionally, NIOSH issued DCAS-PER-090 (NIOSH, 2019) on July 17, 2019, to address dose reconstruction (DR) methods modified by issuing the GJF TBD to replace the previous DR template for GJF. However, SC&A has not been tasked with a review of that document.

The following sections of this report summarize SC&A's review of the GJF TBD.

- Section 2 – site description
- Section 3 – occupational medical dose
- Section 4 – occupational onsite ambient and environmental dose
- Section 5 – occupational internal dose
- Section 6 – occupational external dose
- Section 7 – SC&A's summary and conclusions for the TBD

2 SC&A's Review of the TBD Site Description

SC&A reviewed section 2, "Site Description," of the TBD. The section contains a reasonable amount of information about GJF that provides a useful background for the dose reconstructor. Table 2-1 summarizes the buildings and their usage periods. SC&A had no findings or observations in this section.

3 SC&A's Review of the TBD Occupational Medical Dose

SC&A reviewed section 3, "Occupation Medical Dose," of the TBD. For most years, the occupational medical x-ray examinations were conducted off site and do not apply to DR doses. However, there were several periods when x-ray exams may have been performed on site. The following list summarizes the TBD's recommended occupational medical x-ray exam assignments:

- 1943–1946: Preemployment, annual, and postemployment posterior-anterior (PA) chest and anterior-posterior pelvis x-ray exam for *each year*
- 1947–1961: Taken off site, no occupational medical dose to be assigned
- 1962–1969: Preemployment, annual, and postemployment PA chest or photofluorographic (PFG) x-ray exam, whichever is most favorable to the claimant (use ORAUT-OTIB-0006 1943–1962 PFG doses (NIOSH, 2011) if PFG dose is assigned)
- 1970–present: Taken off site, no occupational medical dose to be assigned

SC&A had no findings. SC&A found that the recommended occupational medical x-ray methodology was consistent with other DOE sites. SC&A did have one observation:

Observation 1: The term "each year" needs to be replaced

The recommendations for 1943–1946 contains the term "each year." This could be misleading, because all the x-ray exams would not be assigned for each and every year. This observation was also identified in SC&A's (2015) review of DCAS-PER-047 as observation 2 (SC&A, 2015, p. 16), but does not appear to have been corrected in the recent TBD.

4 SC&A's Review of the TBD Occupational Onsite Ambient and Environmental Dose

SC&A reviewed section 4, "Occupation Onsite Ambient and Environmental Dose," of the TBD. This section recommends that no onsite ambient and environmental dose be assigned because it is accounted for in any co-exposure data assigned to unmonitored workers, and there is no indication that ambient doses were subtracted from the monitored doses.

SC&A concurs with this recommendation and had no findings or observations for this section.

5 SC&A's Review of the TBD Occupational Internal Dose

SC&A reviewed section 5, "Occupational Internal Dose," of the TBD. Per NIOSH's ER for GJF for SEC-00175 (NIOSH, 2015a), internal dose for radon and thoron intakes and resulting doses cannot be reconstructed for the period January 1, 1943, through January 31, 1975, and intakes and resulting doses for thorium, uranium, and their associated long-lived progeny cannot be reconstructed for the period January 1, 1943, through December 31, 1985. Therefore, SC&A's review of the TBD was for the periods February 1, 1975, through the present for radon and thoron intakes and January 1, 1986, through the present for all other internal intakes.

The internal radiological exposure potentials at GJF applicable to the post-1975 period for radon and thoron and the post-1985 period for uranium and thorium were from the following sources:

- Uranium – After 1985, uranium was a source of exposure due to contamination from previous operations and support work for other programs, including remediation of the GJF buildings and grounds. There is little information about any enrichment of uranium at GJF; therefore, because of the large amount of natural uranium handled at GJF, it is assumed that potential uranium intakes consisted of natural uranium.

- Thorium – Thorium-232 (Th-232) was not a major contaminant of concern for the overall GJF site. However, Th-232 was handled as part of the development of the instrument calibration sources or models. This work was performed in the Sample Preparation Laboratory, where the main source of exposure occurred during the crushing and grinding operations. Also, Th-230 was present as a contaminant of the uranium ore.

- Radium – Radium-226 (Ra-226) was present as a contaminant of the uranium ore and assumed to be in equilibrium with uranium-234.

- Radon would have been present in areas and buildings that processed or handled uranium or in buildings built on tailings piles.

- Thoron would have been present in the Sample Preparation Laboratory where thorium was processed and handled.

Tables 5-1 and 5-2 (p. 15) of the TBD provide the alpha intake fractions for each of the radionuclides for uranium ore/tailings and thorium ore, respectively, after 1985. Alpha intake fractions for uranium ore/tailings in table 5-1 were derived from a 1987 study of GJF uranium ore and tailings (DOE, table 6, 1987). In deriving the alpha fractions in table 5-2 for thorium ore, NIOSH assumed equilibrium concentrations. Table 5-3 outlines the use of thorium ore for calibration purposes and surface pads for the period 1986–1988.

There is no comprehensive database of bioassay results for GJF. Therefore, the recommended intakes (as provided in tables 5-4, 5-5, 5-6, and 5-7, p. 21) were based on measured air concentration or a methodology using maximum permissible limits.

5.1 Comparison with previous documents

The recommended intake values and time periods in the TBD generally matched those recommended in the GJF DR template (NIOSH, 2015b), except for several changes resulting from modification of the GJF DR process. The following list cross-references the equivalent tables in the TBD and DR template:

- TBD table 5-1, "Alpha intake fraction for each radionuclide for uranium ore and tailings, after 1985" (p. 15), is equivalent to table 7 (p. 13) of the template.
- TBD table 5-2, "Alpha intake fraction for each radionuclide for thorium ore, after 1985" (p. 15), is equivalent to table 8 (p. 13) of the template.
- TBD table 5-3, "Thorium ore use, 1986–1988" (p. 15), is equivalent to table 9 (p. 13) of the template.
- TBD table 5-4, "Sample Plant gross alpha inhalation and ingestion intake rates by job category (pCi/calendar day), 1986 to 1990" (p. 21) is equivalent to table 4 (p. 11) of the template.
- TBD table 5-5, "D&D gross alpha inhalation and ingestion intake rates (pCi/calendar day), 1988 to 1990" (p. 21) is equivalent to table 5 (p. 12) of the template.
- TBD table 5-6, "Gross alpha inhalation and ingestion intake rates (pCi/calendar day), after 1990" (p. 21) is equivalent to table 9 (p. 12) of the template.
- TBD table 5-7, "Radon and thoron exposure rates, February 1975 through 1998" (p. 21) is equivalent to table 10 (p. 14) of the template.

SC&A (2015) had previously evaluated DCAS-PER-047 (NIOSH, 2014). In that evaluation, SC&A performed a detailed evaluation of the internal intake recommendations in the GJF DR template. SC&A identified two findings concerning internal dose during that review, which have since been resolved:

- **Finding 3:** NIOSH provides neither the raw data nor a documented source for the 569 air sample measurements associated with D&D work for years 1989–2006. (SC&A, 2015)

  Resolution: NIOSH provided SC&A with the necessary air sample data and SC&A verified NIOSH's recommended values (SC&A, 2017).

- **Finding 4:** In the derivation of intake rates for Ra-226 and Th-230, NIOSH failed to employ activity fractions cited in table 3 of attachment A. (SC&A, 2015)

  Resolution: This finding involved only the derivation of the recommended uranium, radium, and thorium co-exposure intakes for the period 1975–1984, which are no longer applicable to the TBD because the GJF SEC covers that period.

In addition, SC&A performed a focused review (SC&A, 2016) of the SEC-00175 addendum (NIOSH, 2015a) to assess the appropriate end date for the proposed SEC period (December 31, 1985) and the feasibility of dose reconstruction after that date. SC&A's review produced a single finding and two related concerns with the following resolutions:

- **Finding 1:** Workplace air monitoring data do not support the assumption that unmonitored radiation workers would not have exceeded 200 DAC-hours or that non-radiation workers would not have exceeded 40 DAC-hours in a given year. (SC&A, 2016)

  Resolution: NIOSH produced an initial response to SC&A's finding in July 2016 (NIOSH, 2016), which was the subject of work group discussions in October 2016 (ABRWH, 2016). Based on those discussions, NIOSH initiated two separate interviews with a principal dosimetrist during the period of interest. In addition, NIOSH performed an extensive review of activities during the period 1991–1993, which included any activities related to decontamination and decommissioning (D&D). These additional review activities are documented in a July 27, 2017, NIOSH memorandum (NIOSH, 2017). NIOSH presented this additional research to the Grand Junction Facilities Work Group in August 2017, at which time the work group closed the finding (ABRWH, 2017).

- **Concern 1:** Both interviewees are management-level employees, not operators or laborers who performed the actual work. It would be beneficial to obtain information from the actual workers about work conditions and controls to supplement the current information. (SC&A, 2016)

  Resolution: As described under the resolution for finding 1, NIOSH conducted two separate interviews with a principal dosimetrist at the site who was employed during the period beginning in 1991. The interviewee provided expert testimony as to the state of the internal dosimetry program beginning in 1991, including the use of airborne radioactivity areas to control exposure and determine bioassay program participation requirements for the workforce. A summary of the key findings related to the interview can be found in NIOSH (2017) and was discussed by the GJF work group in August 2017 (ABRWH, 2017).

- **Concern 2:** SC&A was not tasked to perform a comprehensive data review. As such, it is not clear how the "thousands of pages" of health and survey data will be used by the dose reconstructors or what guidance will be provided to assess the unmonitored internal dose to a D&D worker with no bioassay data.

  Resolution: NIOSH provided the summary data in spreadsheet form to SC&A in February 2017. SC&A provided its review of the dataset in a June 22, 2017, memorandum (SC&A, 2017). This issue was also discussed during the teleconference meeting of the GJF work group in August 2017 (ABRWH, 2017), and the work group concurred that DR was feasible. NIOSH has included its assessment of the relevant air monitoring data in the GJF TBD with a calculated intake for D&D activities occurring from 1988 through 1990 (NIOSH, 2018).

5.2 SC&A's evaluation of TBD intakes

SC&A had previously evaluated the recommended intake values in DCAS-PER-047 (SC&A, 2015) and concurred with them. In the present review, SC&A verified the current recommended values in the TBD tables that will be used for DR. The following subsections summarize SC&A's verification.

5.2.1 SC&A review of TBD table 5-4

After 1985, the air sample data available for the Sample Plant indicated that the air concentration did not exceed the GJF quarterly limit of 520 maximum permissible concentration hours (MPC-hr), as described in section 5.3.2 of the TBD. Therefore, the intake rate of 13.68 picocurie per calendar day (pCi/d_c) for the Operator/Laborer was derived using a limiting MPC for Th-230 of 2.00E-12 microcurie per milliliter (µCi/ml) as follows:

Intake rate = 2.00E-12 µCi/ml per MPC × 1.0E06 ml/m^3 × 1.2 m^3/hr × 1.0E06 pCi/µCi × 520 MPC-hr/qt × 4 qt/y × 1 y/365 d_c
= 13.68 pCi/d_c

where:

m^3 = cubic meter
hr = hour
µCi = microcurie
qt = quarter
y = year
d_c = calendar day

5.2.2 SC&A review of TBD table 5-5

During the D&D phase, air samples were routinely taken, which NIOSH used to derive the co-exposure intakes for 1988–1990. The intake rate of 17.5 pCi/d_c for the Operator/Laborer was derived using the 95th percentile air concentration of 2.66E-12 µCi/ml. This was verified by SC&A's analysis of the air concentration data (SC&A, 2017, pp. 3 and 5) as follows:

Intake rate = 2.66E-12 µCi/ml × 1.0E06 ml/m^3 × 1.2 m^3/hr × 1.0E06 pCi/µCi × 2000 hr/y × 1 y/365 d_c
= 17.5 pCi/d_c

5.2.3 SC&A review of TBD table 5-6

For this period, GJF implemented DOE Order 5480.11 requiring workers to be bioassayed if the potentially exposure was greater than 10 percent of the limiting derived air concentration (DAC). The most limiting DAC was for Th-230 at 3.00E-12 µCi/ml. NIOSH derived the intake rate of 1.97 pCi/d_c for the Operator/Laborer using a DAC for Th-230 of 3.00E-12 µCi/ml as follows:

Intake rate = 3.00E-12 µCi/ml per DAC × 1.0E06 ml/m^3 × 1.2 m^3/hr × 1.0E06 pCi/µCi × 0.1 DAC × 2000 hr/y × 1 y/365 d_c
= 1.97 pCi/d_c

Observation 2: Apparent inconsistency in DAC values

In section 5.3.4 of the TBD (p. 19), NIOSH used a Th-230 DAC value of 3.00×10^{-12} μCi/ml to derive intake values for table 5-6 for co-exposure intakes after 1990. However, NIOSH's (2017) memorandum (p. 5) indicated that a DAC value of 7×10^{-12} μCi/ml was being used at the site (NIOSH, 2017). There appears to be an inconsistency in the DAC values used that needs clarification.

5.2.4 SC&A review of TBD table 5-7

The recommended intake value of 5.7 pCi per liter (pCi/L) in table 5-7 was the largest radon survey results from a 1990 study of the radon in occupied buildings at the GJF (DOE, 1990, p. 19), which should be applied to all GJF workers during the period 1975 through 1998 (NIOSH, 2018, p. 20). This was discussed in SC&A's 2015 review of DCAS-PER-047, and SC&A concurred with this intake recommendation (SC&A, 2015, pp. 19 and 20). The buildings with radon levels above the action level of 4 pCi/L were remediated; after 1998, the radon levels were less than 1.6 pCi/L, which is considered background or less for that area. Therefore, no additional radon intake assignment is recommended after 1998.

Observation 3: Potential radon calibration chamber exposure

The TBD states (p. 20):

> Any exposure from radon while working around the radon calibration chamber were calculated as WLM and should be provided in a workers exposure file.

Did NIOSH examine the claimant files and find that workers who entered the chamber had such working level month (WLM) dose records in some claim files? The radon calibration chamber could be a source term that may not be appropriately bounded by the 5.7 pCi/L found in Building 30B.

5.2.5 Summary of TBD intake review

SC&A verified the prorated intake values for the Supervisor and Administrative personnel in the TBD intake tables. SC&A verified the ingestion intake values in the tables based on OCAS-TIB-009, revision 0 (NIOSH, 2004, p. 4). The amount of activity ingested daily can be estimated by assuming it to be 0.2 times the activity per cubic meter of air, which is approximated by multiplying the inhalation intake by 0.02.

SC&A concurs with the recommendations in this section and has no findings.

6 SC&A's Review of the TBD Occupational External Dose

SC&A reviewed section 6, "Occupational External Dose," of the TBD. According to the GJF SEC, unmonitored external dose cannot be reconstructed prior to 1960. Therefore, this section is applicable to the period 1960 through the present. SC&A reviewed the references given in the TBD for the limit of detection (LOD) values and exchange frequencies in table 6-1 for photons (p. 25), table 6-2 for betas (p. 25), and table 6-3 (p. 26) for neutrons and found them correct. Assignment of 100 percent 30–250 kiloelectron volt (keV) photons, 100 percent >15 keV betas, and 0.1–2 mega-electron volt neutrons as recommended in the TBD is consistent with the

potential radiation exposures at GJF (mainly uranium and decay products). SC&A analyzed the co-exposure methods for photons, betas, and neutrons presented in the TBD. The results of SC&A's analysis are provided in the following subsections.

6.1 Photon co-exposure data

Table 6-4 of the TBD (pp. 26–27) lists the recommended gamma co-exposure dose values for the years 1960–present according to the following categories:

- **Operator/Laborer** – The TBD recommends the maximum recorded annual dose value through 1980. The maximum recorded annual dose value for the adjacent year (1980) is recommended for 1981–1984. The 95th percentile dose value from the Radiation Exposure Monitoring System (REMS) database is recommended for 1985–present. The recommended dose values are adjusted for potentially missed dose by adding the appropriate LOD/2 value for the number of exchanges (per table 6-1) for that year minus one exchange cycle that the positive dose could have occurred.

- **Supervisor** – The TBD recommends 50 percent of the Operator/Laborer dose, or missed dose for all exchange cycles, whichever is greater.

- **Administrative** – The TBD recommends 10 percent of the Supervisor dose, or missed dose for all exchange cycles, whichever is greater.

Table 6-4 encompasses 50 years of exposure data. To quality check each year would involve considerable resources; therefore, SC&A selected one year of data (1985) to analyze. SC&A (2015) had performed a similar analysis for 1985 photon co-exposure doses in exhibit B-3 (pp. 40–54) using the previous LOD values appropriate at the time. SC&A reanalyzed the 1985 dose data using the appropriate LOD and exchange values as summarized in table 6-1 (p. 25) of the TBD. The results of the current analysis are as follows:

$$\begin{aligned}
\text{Geometric Mean Dose (GMD)} &= \exp[((\text{sum of 1 to n of (ln dose(i))))/n] \\
\text{GMD} &= \exp[-1738/528] \\
\text{GMD} &= 0.0372 \text{ rem} \\
\text{Geometric Standard Deviation (GSD)} &= \exp[(\text{sum of 1 to n of (ln dose (i)/GMD)}^2)/n)]^{1/2} \\
\text{GSD} &= \exp[111.79/528]^{1/2} \\
\text{GSD} &= 1.5843 \\
\text{95th percentile dose} &= \text{GSD}^{1.645} \times \text{GMD} \\
\text{95th percentile dose} &= (1.5843)^{1.645} \times 0.0372 \text{ rem} \\
\text{95th percentile dose} &= 0.0793 \text{ rem}
\end{aligned}$$

Where dose (i) is the annual dose in a given year and n is the number of annual doses used (n = 528 in this case).

The dose value of 0.0793 was entered into co-exposure table 6-4 as 0.080 rem for 1985. This quality check indicated the correct values are recommended in table 6-4, and SC&A has no finding concerning co-exposure photon dose data.

6.2 Beta co-exposure data

The TBD (p. 27) recommends the use of a beta-to-photon dose ratio of 1.5 derived from the REMS database. SC&A (2015, p. 14) reviewed the REMS data and concurred with using the beta-to-photon dose ratio of 1.5. Since NIOSH recommends using the same ratio value of 1.5 in the TBD, SC&A has no finding concerning co-exposure beta dose.

6.3 Neutron co-exposure data

Table 6-5 (pp. 27–28) of the TBD lists the recommended neutron co-exposure dose values for the years prior to 1981 and 1981–1985 derived from the REMS database using neutron dose data from the years 1985–2009 according to the following categories:

- **Geologist** – 95th percentile dose derived from the REMS database for the years 1985–2009
- **All others** – 50th percentile dose derived from the REMS database for the years 1985–2009

Table 6-5 neutron dose recommendations are separated into two periods (before 1981 and 1981–1985) because the neutron dosimeter LOD values and exchange frequencies changed in 1981, as shown in TBD table 6-3 (p. 26).

The annual dose values used in compiling the recommended co-exposure neutron doses were adjusted for potentially missed dose by adding the appropriate LOD/2 value for the number of exchanges (per table 6-3) to the annual dose minus one exchange cycle during which the positive dose could have occurred. SC&A (2015, p. 57) had previously performed a similar analysis of the 1986 neutron dose data from the REMS database in exhibit B-6 and derived a 50th percentile value of 0.0315 rem and a 95th percentile dose value of 0.123 rem. These dose values match the recommended measured neutron dose values in column 3 of table 6-5. SC&A reanalyzed the 1986 missed dose data using the appropriate LOD and exchange values as summarized in table 6-3 of the TBD and derived a missed dose of 0.275 rem for the years prior to 1981 and 0.0225 rem for the period 1981–1985. SC&A derived the same total neutron co-exposure doses as recommended in column 5 of table 6-5 in the TBD.

SC&A has no findings concerning co-exposure neutron dose data but did have two observations concerning the assigning of co-exposure neutron doses.

Observation 4: Assigning 95th percentile neutron doses to geologist only

Workers besides those with the job title of geologist may have handled sources of neutrons in performing work and could have been in the 95th percentile exposure category. Geologists themselves may not have handled the tools as much as laborers and other workers.

Observation 5: Need substantiation for not assigning co-exposure neutron dose after 1985

The TBD states (p. 28):

> After 1985, based on a review of GJF records, neutron dosimetry records are assumed to be complete. Therefore, no unmonitored dose should be assigned after 1985.

SC&A could not locate information in the TBD that supports this assumption. A summary of NIOSH's review of the GJF records and the resulting assumption that monitoring for neutron exposure was complete would be appropriate to include in the TBD.

7 Summary and Conclusions

SC&A reviewed the GJF TBD concerning occupational medical, environmental, internal, and external doses and correlated the present TBD with the previous GJF DR template and previous SC&A reviews. SC&A found the TBD to provide reasonable and technically based recommendations, which were consistent with other DOE site profiles and the previous GJF DR template. SC&A had no findings in this review but did have five observations concerned with (1) the wording of text in the occupational medical section, (2) DAC values used, (3) radon calibration chamber exposure, (4) neutron dose assignments, and (5) support of neutron dose recommendations in the external dose section.

8 References

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