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November 30, 2021

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U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

Regional Administrator
U.S. Nuclear Regulatory Commission
Region IV
1600 East Lamar Boulevard
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Director, Office of Enforcement
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

RE: Homestake Mining Company of California – Grants Reclamation Project – License No. SUA-1471; Docket 040-08903. HMC Reply to a Notice of Violation, NRC Inspection Report 040-08903/2021-002 and Notice of Violation

Dear Regional Administrator:

Homestake Mining Company of California (HMC) hereby submits to the U.S. Nuclear Regulatory Commission (NRC) this response to the NRC Inspection Report 040-08903/2021-002 and Notice of Violation, dated October 19, 2021 (NRC ADAMS Accession No. ML21286A797). HMC is contesting the two alleged violations cited in this inspection report based on the information and evaluations provided in this response.

Thank you for your time and attention on this matter. If you have any questions, please contact me via e-mail at bbingham@homestakeminingcoca.com or via phone at 505.290.8019.

Respectfully,

Brad R. Bingham

Brad R. Bingham
Closure Manager
Homestake Mining Company of California
Office: 505.287.4456 x35 | Cell: 505.290.8019

Enclosure

ec:

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Reply to Notice of Violation, NRC Inspection Report 040-08903/2021-002

The U.S. Nuclear Regulatory Commission (NRC) staff conducted an unannounced, onsite inspection of the Homestake Mining Company of California's (HMC) Grants Reclamation Project (facility) in Cibola County, New Mexico from August 24-26, 2021. The inspection staff examined HMC activities conducted under radioactive materials license SUA-1471 as related to safety and compliance with the Commission's rules and regulations and with the conditions of HMC's license. Based on the results of the inspection, NRC staff determined that two Severity Level IV violations of NRC requirements occurred. The alleged violations include: (1) failure to use a radiation work permit or standard operating procedure during contractor work with radiologically contaminated materials, in accordance with License Condition 24; and (2) failure to perform surveys to evaluate the magnitude and extent of radiation levels, with two examples, as required by 10 CFR 20.1501.

HMC has carefully reviewed NRC staff's descriptions and explanations of the alleged violations as documented in NRC Inspection Report 040-08903/2021-002 and Notice of Violation (NOV) (ADAMS[1] Accession No. ML21286A797), and has concluded that the staff's stated regulatory bases for the alleged violations are inadequate or inappropriately applied to cited HMC activities or deficiencies under applicable regulations, license conditions, and facility standard operating procedures (SOPs). Therefore, HMC denies that these alleged infractions occurred, and is contesting both cited violations based on the information provided in this response to the NRC Inspection Report.

ALLEGED VIOLATION "A":

The first alleged violation as cited in the Inspection Report (Violation A) is reproduced as follows:

A. *Title 10 to the Code of Federal Regulations (10 CFR) 40.3, states that a person subject to the regulations in this part may not receive title to, own, receive, possess, use, transfer, provide for long-term care, deliver or dispose of byproduct material or residual radioactive material as defined in this part or any source material after removal from its place of deposit in nature, unless authorized in a specific or general license issued by the Commission under the regulations in this part.*

   NRC Materials License SUA-1471, Condition 24, states, in part, that the licensee shall be required to use a Radiation Work Permit for all work or nonroutine maintenance jobs where the potential for significant exposure to radioactive material exists and for which no standard written procedure already exists.

   Contrary to the above, on six occasions from May 6, 2021, through July 23, 2021, the licensee failed to use a Radiation Work Permit for nonroutine maintenance conducted by contractors, for which the potential for significant exposure to radioactive material existed, and for which no written procedure existed. Specifically, nonroutine maintenance performed by contractors on the pond spray evaporators, which were known to be radiologically contaminated, was not conducted using a Radiation Work Permit, and no standard written procedure existed for this work.

HMC Response:

In accordance with 10 CFR 40.3, HMC's radioactive materials license SUA-1471 with the Commission specifically authorizes HMC to possess, use, and dispose of uranium mill tailings and other 11e.(2) byproduct wastes resulting from the licensee's past milling operations. The pond spray evaporators are known to become contaminated during routine operations from contact with pond water and accumulation of evaporative salts (evaporites) on the exterior surfaces of this equipment. Maintenance work on the spray evaporators, along with other facility equipment associated with water treatment operations, is an ongoing

[1] NRC Agencywide Documents Access and Management System (ADAMS).

authorized use of licensed materials under SUA-1471 and 10 CFR 40.3. The subject maintenance work on spray evaporators did not violate 10 CFR 40.3 regulations as alleged by NRC.

With respect to license conditions (LCs), Condition 24 is not the only LC that applies. LCs that apply to spray evaporator maintenance work include Conditions 10, 21, 23, 24, and 32 as follows:

LC 10. "This license authorizes only the possession of residual uranium and byproduct material in the form of uranium waste tailings and other byproduct waste generated by the licensee's past milling operations in accordance with Tables 1 and 3 and the procedures submitted by letter dated September 2, 1993, as modified by letters dated January 9, 1995 (NRC ADAMS Accession No.ML080030053), and March 7, 1996."

LC 21. "The site Radiation Protection Administrator (RPA), who is responsible for conducting the site radiation safety program, shall possess the minimum qualifications as specified in Section 2.4.1 of Regulatory Guide 8.31, Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Mills will be As Low As is Reasonably Achievable."

LC 23. Standard procedures shall be established for all activities involving radioactive materials that are handled, processed, or stored. Procedures shall enumerate pertinent radiation safety practices to be followed. Additionally, written procedures shall be established for environmental monitoring, bioassay analyses, and instrument calibrations. An up-to-date copy of each written procedure shall be kept in the area to which it applies.

LC 24. "The licensee shall be required to use a Radiation Work Permit (RWP) for all work or nonroutine maintenance jobs where the potential for significant exposure to radioactive material exists and for which no standard written procedure already exists. The RWP shall be approved by the RPA or his designee, qualified by way of specialized radiation protection training, and shall at least describe the following:

A. The scope of work to be performed.
B. Any precautions necessary to reduce exposure to uranium and its daughters.
C. The supplemental radiological monitoring and sampling necessary prior to, during, and following completion of the work."

LC 32. "The licensee shall follow the guidance set forth in U.S. Nuclear Regulatory Commission Regulatory Guides 8.22, "Bioassay at Uranium Mills" (as revised), and 8.30, "Health Physics Surveys in Uranium Recovery Facilities" (as revised), or NRC-approved equivalent."

The licensee shall follow the guidance set forth in U.S. Nuclear Regulatory Commission Regulatory Guide 8.31, "Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable" (as revised), or NRC approved equivalent, with the following exception:

The licensee may temporarily assign qualified designee(s) to perform daily inspections in the absence of the Radiation Safety Officer (RSO) and Radiation Safety Technician (RST). Qualified designee(s) may perform daily inspections on weekends, holidays, or anytime the RSO and RST must otherwise be absent during Site operations, subject to the training requirements and limitations specified in Attachment 1 of the May 5, 2020, license amendment request (NRC Agencywide Documents Access and Management System (ADAMS) Accession No. ML20133J904)."

In addition to the above LCs, there are a number of facility SOPs that apply to spray evaporator maintenance work, including:

- **SOP 2** – Procedure for Conducting a Field Level Risk Assessment (FLRA)

- **SOP 5** – General Work and Maintenance Procedure
- **SOP 9** – Lock-Out Tag-Out Procedure
- **SOP 18** – Procedure for Implementing a Radiation Work Permit (HP-16)
- **SOP 23** – Collection and Evaporation Pond Operations & Tailings Inspections

The approved occupational Radiation Protection Program (RPP) under SUA-1471 is defined in LC 10 by reference to the 1995 version of Table 3 (Figure 1). Table 3 explicitly indicates that radiological contamination surveys and occupational monitoring of worker exposures are required only when specified under a Radiation Work Order (RWO), which is equivalent to a Radiation Work Permit (RWP) as described in SOP-18. Based on the LC 32 requirement to follow NRC Regulatory Guide 8.31 specifications, SOP-18 is clear that decisions on issuance of an RWP reside with the Radiation Safety Officer (RSO), which is equivalent to the Radiation Protection Administrator (RPA) specified in LC 21. License Condition 21 requires that the RSO meet the qualification requirements specified in U.S. NRC Regulatory Guide 8.31, and because HMC's RSO meets these requirements, HMC's RSO is both authorized and required under LCs 10, 24, and 32 to make decisions on issuance of RWPs. LC 24 is explicit that RWPs are issued for "all work or nonroutine maintenance jobs where the potential for significant exposure to radioactive material exists and for which no standard written procedure already exists", and that the RPA (RSO) is responsible for approving all RWPs. This means that the decision to issue an RWP is determined by the RSO based on the potential for significant radiological exposures, and when an SOP does not exist for the work in question.

In accordance with SOP-2, the RSO evaluated the description of maintenance work involving the APEX spray evaporators on the FLRA form for each project, discussed the work and potential exposures with the RST, and determined in accordance with LC 10, LC 24, LC 32, and SOP-18 that an RWP was not warranted for the work as the project would not involve significant potential for radiological exposures to workers. However, the RSO recognized that trace contamination was possible for this work, and issued an FLRA requirement for contamination surveys of all personnel and equipment in contact with potentially contaminated material. This information is documented on the FLRA forms signed by the RSO. Again, the requirement in LC 24 for issuance of an RWP is that 1) the potential for a significant exposure must exist, and 2) there is no SOP covering the work in question.

In this case, maintenance of spray evaporators is specifically mentioned in SOP-23 (Pond Operations) with reference to actions that may be conducted in accordance with SOP-2 (FLRAs), SOP-5 (General Work and Maintenance Procedure), SOP-9 (Lock-Out Tag-Out), SOP-18 (RWPs) and/or SOP-21 (Spill Reporting and Response Procedure), depending on the nature of the maintenance work to be performed. In other words, there are multiple SOPs that are used as needed to cover this specific task (maintenance of spray evaporators), and the NRC staff's allegation that there was no SOP in place to cover this work is incorrect.

Finally, the NRC staff's allegation that "the potential for significant exposure to radioactive material existed" for the spray evaporator maintenance work is not based on any evidence, survey or sampling data, or technical evaluations provided by the staff. In accordance with LC 24, the potential for significant exposures during this work was determined by the RSO to be insufficient to warrant an RWP based on FLRA descriptions of the work (per SOP-2), and a previous dose assessment for potential worker exposures to radioactive materials associated with the evaporation ponds based on analytical sampling data for evaporites, pond water, and pond sediments/sludge (ERG, 2017)[2]. That dose assessment (provided in Attachment 1 to this response), was reviewed by NRC staff and verbally discussed with the RSO during the fall 2017 site inspection.

In conclusion, the RSO's decision not to issue an RWP for this work was determined in accordance with the requirements of LCs 10, 21, 23, 24, and 32, and that decision was based on relevant analytical data and a

[2] Environmental Restoration Group, Inc. (ERG). 2017. Occupational dose assessment for potential radiological exposures at surface pond facilities. Internal Technical Memorandum dated August 18, 2017.

formal radiological dose assessment conducted by the RSO in 2017 (Attachment 1). The staff has not provided any technical basis that contradicts the RSO's assessment that the spray evaporator maintenance work would not involve "potential for ***significant exposure*** to radioactive material" (emphasis added) and did not warrant issuance of an RWP. Furthermore, spray evaporator maintenance is an ongoing authorized use of licensed materials under SUA-1471 and 10 CFR 40.3 requirements, and the work was conducted under facility SOPs 2, 5, 9, and 23. Therefore, HMC denies that the maintenance work on the spray evaporators represents an infraction of any regulation or non-compliance with any license conditions or SOP specifications, and is contesting this alleged violation.

Table 3 Homestake Occupational Monitoring Program (1-95)

Type of Sample	Number	Locations	Method	Frequency	Analytical Parameters
Lapel Personal Air Sample	As required by RWO	As required by RWO (2 L/min or eq.)	HP-1	As required by RWO	Alpha, U-nat
Lapel Personal Air Sampler Calibration	As required by RWO	na	HP-1	As required by RWO	Flow rate
Release of Equip.	As required by RWO	Potentially Contam. Equipment and Materials	HP-4	As required by RWO	Alpha, beta gamma
ALARA	na	As required by RPA	HP-6	na	As required by RPA
Respiratory Protection	As required by RWO	As required by RWO	HP-7	na	na
Bioassay	As required by RWO	As required by RWO	HP-8	Baseline, termination and semi-annually	U-nat in urine
Instrument Calibration	Variable	Radiation Detection Instruments in use	HP-10	6 months or less	na
Personnel Gamma (TLD)	Variable	Personnel	HP-11	Quarterly	Gamma
Personnel Contam.	As required by RWO	As required by RWO	HP-12	As required by RWO	alpha
Radiation Protection Training	As required	Mill Site	HP-14 Taught by RPA (certified individual) subjects as per Reg Guide 8.31	Initial & annual refresher for people working with groundwater or physical work with tailings sand/ slimes	Training Class & Written Test

Figure 1: Approved occupational radiation monitoring program under LC 10 (January 9, 1995 version of Table 3).

ALLEGED VIOLATION NO. "B":

The second alleged infraction as cited in the Inspection Report (Violation B) is reproduced as follows:

B. *10 CFR 20.1501 states, in part, that each licensee shall conduct surveys that are reasonable under the circumstances to evaluate the magnitude and extent of radiation levels, and the potential radiological hazards of the radiation levels and residual radioactivity detected.*

Contrary to the above, the licensee failed to conduct surveys that were reasonable under the circumstances to evaluate the magnitude and extent of radiation levels and the potential radiological hazards of the radiation levels and residual radioactivity detected, with two examples. Specifically, the licensee failed to conduct surveys to evaluate the extent of radiological contamination during the daily sampling of the reverse osmosis unit, which is known to contain radioactive contamination. In addition, the licensee had not conducted surveys of personnel during groundwater sampling of radiologically impacted wells, to evaluate the extent of radiological contamination levels.

HMC Response:

The regulation cited for this second NOV states the following specifications:

"§ 20.1501 General.

(a) Each licensee shall make or cause to be made, surveys of areas, including the subsurface, that -

(1) May be necessary for the licensee to comply with the regulations in this part; and

(2) Are reasonable under the circumstances to evaluate—

(i) The magnitude and extent of radiation levels; and

(ii) Concentrations or quantities of residual radioactivity; and

(iii) The potential radiological hazards of the radiation levels and residual radioactivity detected."

HMC's objections to this NOV are based on the "*reasonable*" provision of 10 CFR 20.1501 along with actual data that demonstrate no personnel contamination. HMC's radiation protection staff has extensive experience with personnel contamination surveys for various types of sources and activities at the site, an extensive database of analytical results from all water sources at the site, and years of data for activities with greater potential for measurable contamination. For example, an extensive well plugging and abandonment project on top of the Large Tailings Pile (LTP) was recently conducted under an RWP. This project, conducted over many months, had significant potential for contamination of personnel and equipment due to contact with tailings-contaminated well water and possibly, direct contact with tailings. Other recent projects with high contamination potential, each conducted under an RWP, included cleanout of a large volume of sludge/sediments from the West Collection Pond, annual scale cleaning of the clarifiers and flash mix tank, and replacement of highly contaminated RO membranes. For all of these projects, some with significantly more potential radiological hazards, contamination survey data did not show contamination on personnel in excess of daily action levels set at the upper range of background levels (in accordance with SOP 12 specifications).

The licensee's knowledge of various sources, activities, and contamination potential informs the RSO's determination of what surveys are "*reasonable under the circumstances*" as described in 10 CFR 20.1501(a)(2). This approach is consistent with the objective of 10 CFR 20.1501(a)(1), which is to ensure compliance with the "*regulations in this part*" (Part 20). In addition, HMC considers the requirements of applicable license conditions (e.g. LCs 10, 23, and 24) and facility procedures (e.g. SOPs 2, 4, 17, and 18) in determining what surveys are reasonable or necessary to perform under the license. In summary, HMC has a long history of relevant personnel contamination survey data to support expectations that groundwater sampling and other types of water sampling activities at the site are unlikely to result in contamination of personnel in excess of any established limits.

At the inspection closeout meeting, the lead NRC inspector expressed concerns about a lack of contamination survey requirements for personnel performing water sampling activities for groundwater wells and RO clarifier water but did not cite this as a violation. The inspector directed HMC to provide an evaluation of the need for personnel contamination surveys for these water sampling activities, and required an email response by August 30, 2001. Accordingly, on August 30, 2021 an email from the site Closure Manager was sent to the lead NRC inspector proposing that HMC conduct a two-week evaluation where HMC employees completing the sampling activities will perform and document personnel exit surveys prior to entering any other areas or leaving the site. The lead inspector agreed that the proposed evaluation was appropriate in an email on August 31, 2021.

Based on this documented agreement for the proposed study, HMC proceeded in good faith with implementation (discussed further below), but on September 16, 2021, before HMC had completed the study and data evaluation, NRC staff contacted the facility's Closure Manager to inform him that HMC would be receiving a second NOV for failure to conduct surveys to evaluate radiological contamination during routine sampling of groundwater or RO clarifier influent water.

In spite of the NOV issuance HMC completed the agreed upon study and, as expected, the study results (Table 1) were consistently below the action levels. In addition, HMC performed an experiment to test a bounding (worst case) contamination event, where disposable cloth rags were completely saturated in either clarifier water or groundwater from one of the most radiologically impacted wells at the site (well B44). The intentionally contaminated rags were allowed to dry for radiological measurements to determine the maximum contamination levels that could realistically be encountered by personnel during these water sampling activities (Table 2). The results shown in Table 2 indicated that the maximum activity level displayed was approximately 1/10th of the release limit for personnel surveys per NRC Regulatory guide 8.30. Results of both study experiments verify HMC expectations that personnel contamination surveys are not warranted for these water sampling activities, and there is no justification for modifying respective SOPs.

In conclusion, HMC's lack of contamination survey requirements for water sampling personnel is justified and does not constitute a violation of 10 CFR 20.1501. Surveys as described in 10 CFR 20.1501(a)(2) are not necessary for personnel conducting water sampling activities to maintain compliance with Part 20 requirements, and respective revisions to applicable SOPs are not necessary to ensure consistency with the objective of 10 CFR 20.1501(a)(1). This conclusion is supported by HMC's extensive experience with such surveys for a wide variety of applications at the site, along with actual survey data for these specific water sampling activities based on the study described herein. Furthermore, the staff cannot cite any actual data contradicting HMC's technical justifications or a valid regulatory basis for issuing a violation on this matter. Therefore, HMC is formally contesting this alleged violation.

Table 1: Results of contamination surveys for water sampling personnel.

Date	Water Sampling Activity	Alpha ALARA Action Level (CPM)	Maximum Count Rate (CPM)
9/15/2021	Groundwater Wells	16.5	1
9/20/2021	Groundwater Wells	8	7
9/21/2021	Groundwater Wells	10.5	3
9/21/2021	Groundwater Wells	7.5	2
9/22/2021	Groundwater Wells	16.5	7
9/23/2021	RO Clarifier Water	13.5	8
9/24/2021	RO Clarifier Water	15	2
9/24/2021	RO Clarifier Water	15	1
9/27/2021	Groundwater Wells	18	2
9/27/2021	RO Clarifier Water	9	3
9/28/2021	Groundwater Wells	16.5	9
9/28/2021	Groundwater Wells	7.5	5
9/28/2021	RO Clarifier Water	16.5	4
9/29/2021	RO Clarifier Water	13.5	6
9/29/2021	Groundwater Wells	13.5	2
9/30/2021	Groundwater Wells	12	3
9/30/2021	RO Clarifier Water	12	4
10/1/2021	RO Clarifier Water	15	2
10/2/2021	RO Clarifier Water	9	2
10/3/2021	RO Clarifier Water	7.5	1
10/4/2021	RO Clarifier Water	16.5	5
10/5/2021	RO Clarifier Water	12	6
10/6/2021	RO Clarifier Water	12	2
10/6/2021	Groundwater Wells	12	4
10/7/2021	RO Clarifier Water	13.5	7
10/8/2021	RO Clarifier Water	15	8
10/9/2021	RO Clarifier Water	12	2
10/10/2021	RO Clarifier Water	12	7
10/11/2021	RO Clarifier Water	9	8
10/12/2021	RO Clarifier Water	7.5	8

Table 2: Experimental testing of maximum contamination potential for water sampling activities.

Date	Contaminated Water Source	Scanned Test Items	Measured Total Activity on Dried Rags (dpm/100 cm^2)*
9/7/2021	Clarifier Water	Rags soaked in impacted water and allowed to dry	113
9/7/2021	Well 44 Water	Rags soaked in impacted water and allowed to dry	63
9/9/2021	Clarifier Water	Rags soaked in impacted water and allowed to dry	50
9/9/2021	Well 44 Water	Rags soaked in impacted water and allowed to dry	25

*Release limit for personnel surveys per NRC Regulatory Guide 8.30 = 1,000 dpm/100 cm^2

ATTACHMENT 1

2017 Occupational dose assessment for potential radiological exposures at surface pond facilities

Environmental Restoration Group, Inc.
8809 Washington St NE, Suite 150
Albuquerque, NM 87113
ph: (505) 298-4224
www.ERGoffice.com

TECHNICAL MEMORANDUM	
To: Tom Wohlford (HMC)	**Date**: August 18, 2017
From: Randy Whicker (ERG)	**Project**: HMC Grants Reclamation Project
Direct: 970-556-1174	**Task(s)**: Radiation Protection Administrator
Cc: Toby Wright (WES); Chuck Farr (ERG)	
Subject: Occupational dose assessment for potential radiological exposures at surface pond facilities	

Dear Mr. Wohlford,

Per my recent request to have salt crust samples from Evaporation Pond 1 (EP1) analyzed for U-nat, Th-230 and Ra-226, this Technical Memorandum provides conservative radiological dose assessments for workers that could potentially be occupationally exposed to radionuclides when working on or near any of the surface pond facilities at the Homestake Mining Company of California (HMC) Grants Reclamation Project. The intent of this information is to support a determination of whether occupational air monitoring or other radiation safety measures may be prudent to consider under future Radiation Work Permits (RWPs) for projects involving potential exposures to pond process water, sludge, or evaporative salts at the HMC Grants Reclamation Project site.

Please let me know if you have questions or need more information.

Thanks,

Randy Whicker, CHP
RPA, HMC Grants Reclamation Project

Environmental Restoration Group, Inc.
8809 Washington St. NE, Suite 150
Albuquerque, NM 87113
Email: RandyWhicker@ergoffice.com

Occupational Dose Assessment for Surface Pond Facilities

1. Introduction

This Technical Memorandum provides conservative radiation dose assessments for workers at the Homestake Mining Company of California (HMC) Grants Reclamation Project (Site) whom may be occupationally exposed to 11.e(2) byproduct material radionuclides when working on or near collection or evaporation ponds. The intent of this information is to support a determination of whether occupational air monitoring or other radiation safety measures may be prudent to consider under future Radiation Work Permits (RWPs) for projects involving potential exposures to process water, sludge, or evaporative salts at the HMC Grants Reclamation Project site.

2. Potential Exposure Scenarios

Based on observation of operational procedures involving the process water collection or evaporation ponds, HMC's Radiation Protection Administrator (RPA) has identified the following potential pathways for potential occupational exposure to radiation from 11.e(2) byproduct radionuclides:

1) Accidental ingestion of dissolved radionuclides in process water contained in the collection or evaporation ponds.
2) Inhalation of radionuclides in airborne particulates released from dried evaporative salts or exposed sludge from the ponds.
3) Inhalation of radionuclides in airborne liquid aerosols released by turbo misters.
4) Exposure to external gamma radiation from sludge contained in the collection or evaporation ponds or near-surface tailings below the liner of the small tailings pile (STP).

For the ingestion pathway, it was conservatively assumed for this dose assessment that a worker could fall into one of the ponds and accidentally ingest as much as 1 liter of water containing elevated levels of dissolved radionuclides. For the inhalation pathway, it was conservatively assumed that a worker could be intermittently exposed to airborne particulate matter from dried evaporative salts or sludge, or to aerosols of process water that are released into the air by turbo misters. Elevated levels of gamma radiation and the external exposure pathway is primarily limited to areas near the edges of Evaporation Pond 1 (EP1), and since routine dosimetry monitoring of workers over the years has not shown significant external doses in the past, this pathway is not evaluated in this Technical Memorandum.

3. Source Term

The source terms used for assessment of potential internal doses from occupational exposure scenarios 1-3 as identified in the previous Section, were based on analytical results for samples of process water, sludge and evaporative salts collected from the ponds. Specifically, the radiological data in Table 1 were compiled for this dose assessment.

Table 1: Relevant media concentration data.

Sample	Location	Sample Date	U-nat (pCi/g)	Th-230 (pCi/g)	Ra-226 (pCi/g)	Ra-228 (pCi/g)
Salt Crust	EP1	6/14/2017	161	16.6	20.1	-
Sludge	W Coll Pond	9/24/2015	2566	0.5	-	-
Sludge	EP1	9/24/2015	-	-	32.5	-

Sample	Location	Sample Date	U-nat (mg/L)	Th-230 (pCi/L)	Ra-226 (pCi/L)	Ra-228 (pCi/L)
Water	E Coll Pond	8/5/2015	14.4	3.8	10	3.7
Water	EP1	8/17/2010	538	792	138	4.7
Water	EP2	8/17/2010	68	45	76	1.6
Water	EP3A	8/16/2011	362	893	84	11.9
Water	EP3B	8/7/2012	575	826	82	73.9
Water	W Coll Pond	8/4/2014	20	0.09	1.4	0.8

For water samples, additional data are available, but samples with among the highest reported concentrations were selectively included in the table above. The concentration values actually used as the source term for the dose assessment were the maximum values in the above table for each type of media (water, sludge and salt crust), and these values are shown in Table 2.

Table 2: Assumed source term concentrations.

Media	Conc. Units	U-nat	Th-230	Ra-226	Ra-228
Evaporative Salts	pCi/g	161	16.6	20.1	-
Pond Sludge	pCi/g	2566	0.5	32.5	-
Process Water	mg/L	575	-	-	-
Process Water	pCi/L	-	893	138	73.9

4. Intakes

INGESTION

For the process water ingestion pathway, the activity intake for the i^{th} radionuclide (in µCi) from accidental ingestion of 1 liter of process water was calculated as follows:

U-nat:

$$Ingestion\ Intake\ (\mu Ci) = \left(Conc_i \frac{mg}{L}\right)\left(SA \frac{\mu Ci}{mg}\right)(1\ L)$$

Where:

$Conc_i$ = source term concentration of U-nat (from Table 2)

SA = specific activity of U-nat [0.000691 µCi/mg (ORISE, 2017)]

Th-230, Ra-226 and Ra-228:

$$Ingestion\ Intake\ (\mu Ci) = \left(Conc_i \frac{pCi}{L}\right)\left(\frac{\mu Ci}{1 \times 10^6\ pCi}\right)(1\ L)$$

Where:

Conc$_i$ = source term concentration of Th-230, Ra-226 or Ra-228 (from Table 2)

The resulting intake for each radionuclide is shown in Table 3.

Table 3: Assumed intake of each radionuclide from ingestion of 1 liter of process water.

U-nat			Th-230		Ra-226		Ra-228	
Process Water (mg/L)	Spec. Activity (µCi/mg)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)	Process Water (pCi/L)	Intake from 1 L (µCi)
575	6.91E-04	0.397	893	8.9E-04	138	1.4E-04	73.9	7.4E-05

INHALATION

For the inhalation pathway, mass-based and activity-based source term concentrations from Table 2 were converted into airborne activity concentrations using the applicable equation below. The assumed source-to-air mass loading for inhalation was 0.0001 g/m^3 for releases of dry sludge to air [this is the default value for releases from soil to air as given in the RESRAD-OFFSITE computer code (ANL, 2013)]. For releases of evaporative salts to air, or process water to airborne aerosols via the turbo mister, the mass loading was assumed to be an order of magnitude higher (0.001 g/m^3) based on opacity criteria described in Table 4.

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{mg}{kg}\right)\left(\frac{kg}{1000\ g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{g}{1000\ mg}\right)\left(SA \frac{\mu Ci}{g}\right)\left(\frac{m^3}{10^6\ mL}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{pCi}{g}\right)\left(\frac{\mu Ci}{10^6\ pCi}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{mg}{L}\right)\left(\frac{L}{1000\ cm^3}\right)\left(\rho \frac{cm^3}{g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)\left(SA \frac{\mu Ci}{mg}\right)$$

$$Airborne\ Conc.\left(\frac{\mu Ci}{mL}\right) = \left(Conc_i \frac{pCi}{L}\right)\left(\frac{L}{1000\ cm^3}\right)\left(\rho \frac{cm^3}{g}\right)\left(ML \frac{g}{m^3}\right)\left(\frac{m^3}{10^6\ mL}\right)\left(\frac{\mu Ci}{10^6\ pCi}\right)$$

Where:

Conc$_i$ = source term concentration (from Table 2)

ML = mass loading (g/m^3)

SA = specific activity of U-nat [0.691 µCi/g (ORISE, 2017)]

Table 4: Mass loading assumption criteria.

Airborne mass loading (g/m^3)	Visibility (miles)	Comment
0.00001	50	Very clear
0.00002	25	NM Average
0.0001	5	Hazy; RESRAD default
0.00015	3	24-hr PM-10 standard
0.001	0.5	Smoke from nearby fire

The resulting activity concentrations in air were assumed as shown in Table 5. Intakes via inhalation were based on a breathing rate of 20 L/minute and an exposure occupancy time of 200 hours per year (10% occupational occupancy) as shown in the dose calculations presented in Section 5.

Table 5: Calculated airborne concentrations for the inhalation dose pathway.

Media	Mass Loading (g/m3)	U-nat (µCi/mL)	Th-230 (µCi/mL)	Ra-226 (µCi/mL)	Ra-228 (µCi/mL)
Evaporative Salts	0.001	1.6E-13	1.7E-14	2.0E-14	-
Pond Sludge	0.0001	2.6E-13	5.0E-17	3.3E-15	-
Water	0.001	4.0E-13	8.9E-16	1.4E-16	7.4E-17

5. Radiological Dose

The calculated dose for each source term radionuclide and occupational exposure pathway scenario were based on the Annual Limit on Intake (ALI) values or Derived Air Concentration (DAC) for each radionuclide as given in 10 CFR 20 Appendix B (Table 6). Both non-stochastic ALIs (NALI) for the committed dose equivalent (CDE) to organs or tissues, and stochastic ALIs (SALI) for the effective committed dose equivalent (CEDE) to the whole body, were considered. DAC values for the radionuclides considered are given in 10 CFR 20 Appendix B in terms of the CEDE only.

Table 6: Relevant occupational intake limits from 10 CFR 20 Appendix B.

	U-nat (µCi)	Th-230 (µCi)	Ra-226 (µCi)	Ra-228 (µCi)
$NALI_{ingest\ (d)}$	10	4	2	2
$SALI_{ingest\ (d)}$	20	9	5	4
$NALI_{inhal\ (d)}$	1	0.006	-	-
$SALI_{inhal\ (d)}$	2	0.02	0.6	1
	U-nat (µCi/mL)	**Th-230 (µCi/mL)**	**Ra-226 (µCi/mL)**	**Ra-228 (µCi/mL)**
DAC (day)	5E-10	-	-	-
DAC (week)	3E-10	3E-12	3E-10	5E-10
DAC (year)	2E-11	6E-12	-	-

INGESTION PATHWAY

The applicable occupational dose limits for CDE to organs/tissues and CEDE for the whole body are 50 rem/yr and 5 rem/yr respectively (10 CFR 20.1201). The ALI and DAC values given in Table 6 equate to these annual dose limits. For the ingestion pathway, the CDE (critical organ = bone) and CEDE values for each radionuclide based on the calculated intake assumptions (Table 3) and ALI values (Table 6), were individually calculated and summed to estimate total internal dose from ingestion as follows:

$$CDE = \sum_{n=1}^{i} (Intake_i \ \mu Ci) \left(NALI_i \frac{rem}{\mu Ci} \right) \left(\frac{1000 \ mrem}{rem} \right)$$

$$CEDE = \sum_{n=1}^{i} (Intake_i \ \mu Ci) \left(SALI_i \frac{rem}{\mu Ci} \right) \left(\frac{1000 \ mrem}{rem} \right)$$

Where:
Intake$_i$ = intake (in µCi) of the ith radionuclide (from Table 3)
NALI$_i$ = Non-stochastic ALI for ith radionuclide (from Table 6)
SALI$_i$ = Stochastic ALI for ith radionuclide (from Table 6)

The resulting individual and total internal doses by radionuclide and dose quantity are given in Table 7.

Table 7: Estimated internal occupational dose from accidental ingestion of 1 L of process water.

Internal Dose Quantity	U-nat Dose (mrem)	Th-230 Dose (mrem)	Ra-226 Dose (mrem)	Ra-228 Dose (mrem)	Total Dose (mrem)
CDE (bone)	1987	11	3	2	2003
CEDE	99	0	0	0	100

The conservatively estimated internal doses expected from accidental ingestion of 1 liter of process water are a small fraction of the annual non-stochastic CDE limit (50,000 mrem) or stochastic CEDE limit (5,000 mrem/yr) for workers as specified in 10 CFR 20.1201. These doses are unlikely to ever occur as even if a worker fell into a pond, it is unlikely that the worker would ingest a full liter of process water. These results can be scaled according to actual intake, if known, though the source term may differ from the maximal values used for this assessment. For example, if only 1 mL of process water with concentrations equivalent to those assumed in this assessment were accidentally ingested, the resulting CDE and CEDE values would be on the order of 2 mrem and 0.1 mrem respectively.

From an As Low As Reasonably Achievable (ALARA) perspective, analysis of routine samples of process water in each pond should include U-nat, Th-230, Ra-226 and Ra-228 on at least a semiannual basis in order to have recent radiological concentration data available should a worker accidentally ingest any of this water at the Site. In the event of an accidental ingestion of process water, a urine bioassay sample should be collected about 36 hours after the intake and analyzed for uranium. The analytical result should be evaluated relative to the 10 mg/week limit to protect against toxicity effects for soluble uranium as indicated in 10 CFR 20.1201(e). Where possible, any additional protocols that would minimize the potential for workers to fall into a pond would be consistent with ALARA principles, and should be included in the relevant standard operating procedures (SOP) or radiation work permit (RWP) for any work to be performed on or near the collection or evaporation ponds.

INHALATION PATHWAY

It would be unrealistic to assume that any worker could be continuously exposed to the calculated airborne radionuclide concentrations assumed in Table 5 (Section 4) while working near the collection or evaporation ponds. It was instead conservatively assumed that on an annual basis, a worker is exposed to these airborne concentrations 10% of the time (200 hours out of a total of 2,000 work hours per year). Based on this assumption, the annual CEDE from inhalation of soluble and insoluble forms of these radionuclides (where applicable) based on the calculated airborne concentration assumptions (Table 5) and DAC values (Table 6), were individually calculated and summed to estimate total internal dose from inhalation as follows:

$$CEDE = \sum_{n=1}^{i} \left(AC_i \, \frac{\mu Ci}{mL}\right) \left(\frac{DAC_i}{\mu Ci/_{mL}}\right) (200\ hrs) \left(\frac{2.5\ mrem}{DAC - hr}\right)$$

Where:
AC_i = Airborne concentration for the i^th radionuclide (from Table 4)
DAC_i = Derived air concentration for i^th radionuclide (from Table 6)

The resulting individual and total internal doses by radionuclide source and solubility class are given in Table 8.

Table 8: Estimated internal occupational dose from inhalation of airborne radionuclides from the ponds.

SOLUBLE INHALATION DOSE

Media	CEDE U-nat (mrem)	CEDE Th-230 (mrem)	CEDE Ra-226 (mrem)	CEDE Ra-228 (mrem)	CEDE Total (mrem)
Evaporative Salts	0.3	2.8	0.03	-	3.1
Pond Sludge	0.4	0.01	0.01	-	0.4
Water	0.7	0.1	0.0002	0.0001	0.8

INSOLUBLE INHALATION DOSE

Media	CEDE U-nat (mrem)	CEDE Th-230 (mrem)	CEDE Ra-226 (mrem)	CEDE Ra-228 (mrem)	CEDE Total (mrem)
Evaporative Salts	4.0	1.4	-	-	5.4
Pond Sludge	6.4	0.004	-	-	6.4
Water	9.9	0.1	-	-	10.0

The conservatively estimated internal doses from incidental inhalation of airborne radionuclides by solubility class from each potential source (evaporative salts, sludge and liquid aerosols from the turbo misters) and are a very small fraction of the stochastic CEDE limit (5,000 mrem/yr) for workers as specified in 10 CFR 20.1201. These dose estimates are conservative (erring in favor of higher doses) as it is unlikely that workers would consistently be exposed to such airborne concentrations for 200 hours per year.

From an ALARA perspective, analysis of routine samples of process water in each pond should include U-nat, Th-230, Ra-226 and Ra-228 on at least a semiannual basis in order to have recent radiological concentration data available for use in future dose assessments in the event that conditions change. Although these estimated doses are low and do not warrant routine air monitoring, non-routine air monitoring could be warranted under a RWP for non-routine activities at the discretion of the Radiation Safety Officer (RSO) (e.g. replacing a pond liner, cleaning out dried sludge from collection ponds, etc.).

6. Conclusions

The results of this dose assessment indicate that potential occupational exposures to radionuclides from working on or near the collection or evaporation ponds are unlikely to result in significant radiological doses from accidental ingestion or inhalation exposure pathways. The conservatively calculated dose estimate for each exposure scenario is well below 10% of applicable regulatory dose limits. The concentrations of U-nat, Th-230, Ra-226 and Ra-228 in process water should be analyzed on a semiannual basis to maintain recent data for future dose assessments as needed to ensure that exposures and doses will be kept ALARA. While routine air monitoring for work performed near collection or evaporation ponds is not warranted based on this dose assessment, non-routine work activities involving potential for ingestion or inhalation intakes of evaporative salts, sludge or process water may be warranted under a RWP at the discretion of the RSO.

7. References

Oak Ridge Institute for Science and Education (ORISE). 2017. Radiological and Chemical Properties of Uranium. USNRC ADAMS Accession No. ML11227A233.
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