Draft

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

SC&A Review of Overall NIOSH Response to SC&A's Supplemental Review of M&C Work Group Issues as of November 2023

Response Paper

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
AWE	Atomic Weapons Employer
AWWA	American Water Works Association
CDC	Centers for Disease Control and Prevention
CED	committed effective dose
CI	cast iron (pipe)
CFR	Code of Federal Regulations
cm	centimeter
cpm	counts per minute
D&D	decontamination and decommissioning
DCAS	Division of Compensation Analysis and Support
DOE	U.S. Department of Energy
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
ER	evaluation report
g/m^3	grams per cubic meter
HFIR	High Flux Isotope Reactor
HHS	U.S. Department of Health and Human Services
IAEA	International Atomic Energy Agency
M&C	Metals and Controls Corporation
$\mu g/m^3$	micrograms per cubic meter
MRWA	Minnesota Rural Water Association
NIOSH	National Institute for Occupational Safety and Health
NRC	U.S. Nuclear Regulatory Commission
ORAU	Oak Ridge Associated Universities
ORAUT	Oak Ridge Associated Universities Team
OSHA	Occupational Safety and Health Administration
pCi/g	picocuries per gram
PVC	polyvinyl chloride
R&M	repair and maintenance
SEC	Special Exposure Cohort
SRDB	Site Research Database
TBD	technical basis document
TI	Texas Instruments, Incorporated
U	uranium
VC	vitreous clay (pipe)
WG	work group

1 Executive Summary

Special Exposure Cohort (SEC) Petition SEC-00236 for the Metals and Controls Corporation (M&C) in Attleboro, Massachusetts, was received on September 1, 2016, and qualified on November 14, 2016. The petition class evaluated by the National Institute for Occupational Safety and Health (NIOSH) was defined as:

> All atomic weapons employees who worked as facilities construction and maintenance workers, including lubricators/oilers, industrial pipefitters, engineering technicians (mechanical, electrical, structural), maintenance supervisors, electricians, plumbers, millwrights, carpenters, instrumentation technicians, chemical handlers, waste treatment operators, and all production workers, including machine operators/helpers and repair & maintenance (commonly called R&M) workers, who worked in Buildings 4, 5, 10 interior areas, and Buildings 5, 10, 11, 12, 17 exterior areas at Metals and Controls Corp. in Attleboro, Massachusetts, from January 1, 1968 through March 21, 1997. [NIOSH, 2017a, p. 3]

SC&A's review commenced in 2017, focusing on NIOSH's evaluation report (ER) for M&C. The original exposure potential was predicated on the more passive scenarios available in ORAUT-OTIB-0070, revision 01 (ORAUT, 2012; "OTIB-0070"), and Battelle-TBD-6000, revision 1 (NIOSH, 2011; "TBD-6000"), uranium process models for Atomic Weapons Employers (AWEs). NIOSH has since added six bounding exposure models to address worker-identified intrusive activities during the residual period. NIOSH and SC&A reached tacit agreement on these bounding models, but the M&C Work Group (WG) did not concur and in 2021 requested further SC&A review. SC&A issued "Supplemental Review of M&C Work Group Issues" in August 2022 (SC&A, 2022), with a NIOSH response in January 2023 (NIOSH, 2023a) and an SC&A response in April 2023 (SC&A, 2023). NIOSH issued a response to SC&A's April 2023 paper on August 22, 2023 (NIOSH, 2023b), including an updated table comparing M&C with other AWEs for intrusive activities.

SC&A reviewed this most recent NIOSH response paper in the context of NIOSH's overall response and reached the following specific conclusions about its key responses to SC&A and WG concerns, which are addressed in more detail in this paper.

Effects of coagulant on source term. The issue is whether the routine discharge of a coagulant oil, used as a lubricant for wiring operations in Building 10, into the drainage system over the duration of activities in that building may have led to consolidation and concentration of uranium- and thorium-contaminated sediments present in excess of the upper bound source term defined by NIOSH from the later 1995 pre-decontamination and decommissioning (D&D) characterization surveys. Given the unknown identity and properties of this coagulant oil, it is uncertain what the degree of consolidation and concentration of these suspended sediments would have been. Likewise, the rate and form of deposition for the consolidated sediment deposited inside the drain pipes is unknown. Notably, the resulting clogs containing these sediments are what M&C maintenance workers were exposed to in cutting and cleaning out these pipes. In its response, NIOSH (2023b) has provided no resolution to this issue. The presence of coagulant oils within the M&C drainage system in Building 10, the regular discharge of which

the workers attributed the clogging of drain pipes, may have led to increased concentrations for uranium- and thorium-contaminated sediments during the pre-1995 residual period, for which upper bound estimates may not be feasible. SC&A concludes that this question constitutes an SEC issue that pertains to the sufficient accuracy of the M&C *Inside Subsurface* source term for the WG to consider.

Aerosolization of drain line interior surface contamination. The issue is whether NIOSH has adequately addressed contaminated scale (in addition to drain pipe sediment) in its inside subsurface exposure model to bound intakes by M&C maintenance workers during the residual period. While activity levels for interior pipe surface contamination were found to be "as high as 1,000,000 dpm/100 cm^2" in a pre-D&D survey (NIOSH, 2021, p. 7), only drainpipe sediment contaminant levels have heretofore been addressed as a source term by NIOSH's exposure model. With only that single elevated measurement cited, supplemented by a few spot samplings of scale in drain pipes, it is not known whether this activity level can represent the highest measurement of scale similar to the 53,000 picocuries per gram (pCi/g) Priority 1 drain pipe sediment measurement from the 1995 sediment survey, which was among the numerous and distributed results from which the 95th percentile inside subsurface bounding value of 6,887 pCi/g was derived. This is compounded by the difficulty and uncertainty of translating direct radiation measurements to interior pipe surface contamination levels, as confirmed by Weston in its pre-D&D surveys (refer to section 4.5).

NIOSH's recent use of U.S. Department of Energy (DOE) parameters and methods from the Bridgeport Brass AWE hazard assessment (DOE, 1996) to calculate a corresponding worker dose based on the million disintegrations per minute per 100 square centimeters (dpm/100 cm^2) survey result raises uncertainties surrounding the lack of M&C-specific data and information to support that calculation. The uncertainty surrounding the lack of systematic and representative M&C survey measurements for scale is compounded by (1) uncertainties surrounding the nature, composition, and formation of scale in the presence of an oil-based coagulant and (2) uncertainties involving the exposure pathway for maintenance workers in terms of inhalation of fumes and volatized material due to power or torch cutting and cleaning of drain pipes. SC&A finds that NIOSH's inside subsurface exposure model does not address this source term adequately, and, therefore, the proposed bounding dose may not be sufficiently accurate. SC&A concludes that this question constitutes an SEC issue for the WG to consider.

Work in confined spaces. SC&A's original finding (SC&A, 2022, finding 2) was that NIOSH's proposed application of Mound project data for deriving the M&C dust loading factor does not satisfy the Advisory Board on Radiation and Worker Health (ABRWH, "Board") surrogate data policy for site and process similarity given disparities between the sites for confined space conditions. The use of the Mound-based dust loading factor as one of the "three legs of the stool"[1] (ABRWH, 2023b, slide 15) for NIOSH's bounding intake approach for M&C may, therefore, not be sufficiently accurate for that purpose. However, with (1) SC&A's acknowledgment that this is essentially a technical basis document (TBD) issue and (2) NIOSH's acceptance that it will need to review "recent suggestions to upgrade its dust loading models, including enhancement factors and confined spaces, and will consider incorporating methods

[1] The other two are source term and occupancy/time.

suggested by SC&A in their supplemental review" (NIOSH, 2023b, p. 24), SC&A recommends that the issue of the dust loading factor for M&C be pended for resolution by the WG awaiting the results of that review.

Additional intrusive activity information for table 1 comparison of AWE sites. SC&A finds that some of the residual period activities noted by NIOSH in its new table 2 for other AWEs bears some resemblance to those at M&C. However, by its action to derive six exposure models for M&C, NIOSH itself acknowledges that these intrusive maintenance activities were sufficiently distinct from the more passive resuspension scenarios in OTIB-0070 and TBD-6000, and differed from experience at these other AWEs, to warrant special treatment from an exposure bounding standpoint.

Data applicability (Work Group concern). A judgment on the question of whether there is sufficient similarity of conditions and processes between the D&D era, during which the 1995 characterization sampling was conducted, and the preceding M&C residual period maintenance activities resides with the Board, as it did for Linde Ceramics on a similar question between Linde's D&D and renovation periods. But it is clear that there are uncertainties related to source terms and exposure pathways for the M&C residual period, in addition to different conditions and processes, that may not be adequately addressed by NIOSH's current inside subsurface bounding model that is founded on pre-D&D sampling.

Application of "extreme conservatism." In its most recent response, NIOSH (2023b, p. 32) claims that "SC&A and the Work Group are misinterpreting NIOSH's use of the phrase 'extreme conservatism' to mean implausibly high" and counters that it is "using conservative assumptions that are appropriate for a bounding scenario." SC&A has cited NIOSH's defined application and scope of "extreme conservatism" precisely as given and in the context that it was given. Given the breadth and depth of unknowns and uncertainties for M&C's residual period inherent in this bounding approach, it will be incumbent on the Board to gauge whether the application of extreme conservatism—and the assumptions inherent in such an approach—represents a plausible means to define an upper bound for past exposures of M&C maintenance workers during the 27 years in question. Likewise, if NIOSH's bounding model cannot account for M&C's "intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a, p. 17) without resorting to extreme conservatism, sufficient accuracy becomes a concern.

Conservatism of 95th percentile soil contamination value.[2] In its 2021 response to WG questions, NIOSH proceeded to "make the case that M&C's area monitoring **assures** that the 95th percentile soil-contamination value is conservative based on routine surveys of Building 10 during the first 14 years of the residual period (1968-1981)" (NIOSH, 2021, pp. 7–8; emphasis added). In response to SC&A's (2022) supplemental review observation 2, NIOSH noted that it "was not using the M&C Safety and Health manual, NRC inspection results, operator training, and other programmatic considerations to *justify* using the 95th percentile" (NIOSH, 2023a, p. 23). In its April 2023 response, SC&A emphasized that "whether using these program

[2] This issue was raised as observation 2 in SC&A's (2022) supplemental review and addressed in subsequent NIOSH and SC&A responses but was not addressed in NIOSH's August 2023 response paper.

documents to justify, or to demonstrate, corroborate, illustrate, or show that such monitoring procedures and oversight 'assures' that the 95th percentile soil contamination value is conservative is a distinction with little difference" (SC&A, 2023, p. 12). In that response, SC&A reaffirmed that it stands by its observation that the program references NIOSH cites "do not necessarily substantiate the conservatism of the 95th percentile soil contamination value being applied" (SC&A, 2023, p. 12).

Overall conclusion. SC&A concludes that NIOSH has a pathway to address the confined space issue, which is acknowledged as a TBD concern, and for which options for revised resuspension factors and a derived dust loading factor have been identified. However, uncertainties remain for source terms related to in-pipe contaminated sediments (due to the presence of coagulants), in-pipe interior surface contamination (scale), and residual contamination in repurposed AWE-era machinery and equipment, respectively, which are not accounted for in the proposed inside subsurface bounding model. Concentrations of in-pipe sediments and scale may have been higher during the 27 years of M&C maintenance activities involving pipe cutting and cleanout that preceded the 1995 survey upon which NIOSH's inside subsurface bounding value is based. This is the basis for SC&A's finding 1 of its supplemental review. As acknowledged by NIOSH, the extreme conservatism of this bounding value is meant to address the inherent unknowns and uncertainties in this back-application of source term, but the Board may not consider such an approach to be a plausible means to do so.

2 Introduction

The remainder of this paper responds to NIOSH's corresponding responses to SC&A's April 2023 review. It follows the same issue organization and format as NIOSH's most recent August 22, 2023, response paper (NIOSH, 2023b). For each issue, NIOSH (2023b) first quoted SC&A's comments, then gave NIOSH's response. In this paper, each issue section begins with the relevant SC&A (2023) and/or M&C WG comments, followed by either a quote from NIOSH's August 22, 2023, response or (where necessary for brevity) a summary of that response, and finally SC&A's response. In a few cases where NIOSH responded more than once to the same issue, SC&A's summary reflects both responses.

3 Effects of Coagulant on Source Term

3.1 SC&A comment: Atomic Weapons Employer (AWE)-related coagulants in drain lines

> The release of nonradioactive coagulant oil to drain lines was done separately from any HFIR operational radioactive releases and may have had a collateral influence on how AWE-related uranium and thorium contamination already in the piping would have concentrated over the years following those original discharges. In fact, in its response, NIOSH supports this interpretation by making the case that "wire operations during the residual period did not process radioactive materials; therefore, most material rinsed into the drains was non-radioactive except for residual contamination that remained in cracks and crevices" (NIOSH [2023a], p. 12). SC&A agrees with NIOSH that the wiring operations did not contribute radioactive materials to the drain lines. It was the coagulant oil itself that may have consolidated the uranium and thorium already entrained in the pipes ("cracks and crevices") that would have impacted the covered AWE material from prior years (the resulting sediment would not have been distinguishable between AWE and HFIR residual contamination). [SC&A, 2023, pp. 6–7]

3.1.1 NIOSH response: AWE-related coagulants in drain lines

There appears to be a misinterpretation of the following NIOSH statement:

> *More specifically, wire operations during the residual period did not process radioactive materials; therefore, most material rinsed into the drains was non-radioactive except for residual contamination that remained in cracks and crevices,* ***as shown in the following figures****.* [NIOSH [2023a], PDF p. 17]

Although it is still possible that there were cracks and crevices within the drain lines as SC&A describes, NIOSH refers to the low-level contamination that remained in the cracks and crevices *under the wire machines*, as shown on the subsequent pages in Figures 1 and 2 of NIOSH [[2023a], PDF pp. 18–19].

[NIOSH, 2023b, p. 3]

3.1.2 SC&A response

SC&A was responding to NIOSH's contention that "the release of coagulant oil and production materials carried with it did not introduce higher concentrations of *covered* uranium and thorium from AWE operations (1952–1967) to the subsurface" (NIOSH, 2023a, p. 12), but accepts NIOSH's clarification that it was referring to "cracks and crevices" underneath the wiring machines containing residual contamination (NIOSH, 2023b, p. 3). However, this distinction does not change SC&A's finding that coagulant oils could have consolidated and concentrated existing residual contamination in the drainage system, including that in pipe cracks and crevices, thus leading to potentially higher radiological source terms over the early M&C residual years preceding the 1995 pre-D&D characterizations.

3.2 SC&A comment: Coagulant concentrations and maintenance workers

> The AWE sediment was clearly present within the system following the cessation of AWE operations; any later introduction of oil-based coagulant solutions within that system may have collected and concentrated the uranium and thorium already present in that system and led to higher sedimentation to which M&C maintenance workers would have been exposed. This concern represents a new issue that has not been addressed. [SC&A, 2023, p. 7]

3.2.1 NIOSH response: Coagulant concentrations and maintenance workers

NIOSH cites an interview with an M&C maintenance supervisor regarding the wire drawing operation and the "green lube" coagulant oil used in that operation (NIOSH, 2023b, p. 4). NIOSH observes that "although these excerpts do not directly address SC&A's concern, they do reveal that this maintenance supervisor may know additional details worth pursuing" (NIOSH, 2023b, p. 4). NIOSH indicates that when revisions are made to the M&C TBD, NIOSH will (NIOSH, 2023b, p. 4):

- Identify the locations of wire machines in Building 10 and overlay their locations above the drain lines to indicate their distance from Priority 1 drain lines.

- Mark-up the drain lines with flow paths to determine which lines were downstream of the coagulant sources (*i.e.,* wire machines).

NIOSH (2023b, p. 5) also notes several other considerations that it believes are relevant to the issue:

- Weston could have noted and collected coagulant when they characterized the drain lines, as described in the following. "After pipes were opened, a sample of the sediment **or other residue** in the pipe was collected and submitted for isotopic and/or total uranium analyses" [Weston, 1996b, PDF p. 11]. For example, the clay pipe with the highest interior surface contamination (1,000,000 disintegrations per minute [dpm]/100 cm^2) "did not contain a visible accumulation of residue" [Weston 1996b, PDF p. 11].

- The airborne hazard associated with cleaning clogged pipes was minimal because the material was wet, and the presence of coagulants functioned as glue, effectively locking/fixing contamination in place along the pipe's interior surfaces. These conditions significantly reduced the resuspension and respirability of the source term, eliminating the coagulant concern from consideration as a bounding internal dose scenario for NIOSH to incorporate. The fixed contamination could be an external contributor that NIOSH's external dose model will address. NIOSH requests SC&A to supply a technical justification showing that a coagulant can function as both a substance that is sticky enough to clog drains **and** allow resuspension of respirable particles.

- NIOSH's experience with surface contamination indicates it would either travel through and exit the system or become fixed such that an aggressive decontamination technique would be required to move it through the system. NIOSH performed a literature search to confirm SC&A's assertion and studied vegetable/mineral oils to determine their physical properties (e.g., pH) to see if they possessed solvent properties sufficient to mobilize a fixed contaminant and accumulate it downstream. NIOSH did not find any supporting information in the technical literature. If SC&A is aware of such information, NIOSH will consider it.

Finally, NIOSH concludes that it has "determined that it can describe plausibly, and bound exposures associated with unclogging pipes while accounting for the effects of introducing a nonradioactive coagulant to the drain line source term" (NIOSH, 2023b, p. 5).

3.2.2 SC&A response

NIOSH's response regarding the regular presence of coagulant oils within M&C drain lines does not change SC&A's original conclusion about the source term implications of this unknown substance for existing uranium- and thorium-contaminated sediments:

> SC&A agrees with NIOSH that the wiring operations did not contribute radioactive materials to the drain lines. It was the coagulant oil itself that may have consolidated the uranium and thorium already entrained in the pipes . . . that would have impacted the covered AWE material from prior years (the resulting sediment would not have been distinguishable between AWE and HFIR residual contamination). The AWE sediment was clearly present within the system following the cessation of AWE operations; any later introduction of oil-based coagulant solutions within that system may have collected and concentrated the uranium and thorium already present in that system and led to higher sedimentation to which M&C maintenance workers would have been exposed. [SC&A, 2023, p. 7]

Whether or not Weston would have identified and collected coagulant during their characterization work does not comport with the physical and chemical properties of coagulants and how they actually function. Coagulants and the coagulant mechanism can be explained as follows (CDC, 2022):

> Coagulation is often the first step in water treatment. During coagulation, chemicals with a positive charge are added to the water. The positive charge neutralizes the negative charge of dirt and other dissolved particles in the water. When this occurs, the particles bind with the chemicals to form slightly larger particles. Common chemicals used in this step include specific types of salts, aluminum, or iron.

In other words, coagulants are substances that can neutralize the normally repulsive electrical charge of particles in a suspended solution such that the particles will begin to consolidate, or cling together, forming floc that settle out in the form of a binding sediment or sludge-like substrate that in wastewater treatment (for example) enables them to be more readily removed (MRWA, 2020; AWWA, 2011). Once they have done this job, the coagulants themselves have ceased to exist in their original form. Therefore, there are no coagulants, per se, that could have been identified and collected by Weston, only the resulting consolidated and concentrated particles or sediments that were the result of the coagulant effect that had come out of suspension and settled out within the drainage pipe.

In this context, it is not accurate to describe the coagulants as "sticky" or functioning as a "glue" for the drainpipe sediments (NIOSH, 2023b, p. 5). As already described, the properties of coagulants are to neutralize naturally repellant electrical charges of particles or sediments. There is considerable scientific, industry, and government literature available regarding this phenomenon and its long and wide application, particularly for drinking and waste water treatment. The following references from the published scientific literature, government fact sheets, and industry trade journals are particularly relevant.

References for general properties, functions, and experience with coagulants in water treatment:

- Centers for Disease Control and Prevention (CDC, 2022), "Water Treatment"
- Campbell (2022), "What is Coagulation for Water Treatment?"
- Safe Drinking Water Foundation (n.d.), "Conventional Water Treatment: Coagulation and Treatment"
- American Water Works Association (AWWA). (2011). AWWA Manual M37, *Operational Control of Coagulation and Filtration Processes*, third edition
- Minnesota Rural Water Association (MRWA). (2020). *Minnesota Water Works Operations Manual*, Chapter 12, "Coagulation and Flocculation"

While the identity and properties of the oil-based coagulant introduced during the M&C residual period are unknown, there is literature on the use of natural or plant-based coagulants that may be relevant:

- Vijayaraghavan, Sivakumar, and Vimal Kumar (2011), "Application of Plant Based Coagulants for Waste Water Treatment"
- Saleem & Bachmann (2019), "A Contemporary Review on Plant-Based Coagulants for Applications in Water Treatment"

- Alazaiza et al. (2022), "Application of Natural Coagulants for Pharmaceutical Removal from Water and Wastewater: A Review"

Regarding NIOSH's comment on the mobility of pipe contamination, SC&A has already clarified that a key impact of regularly introduced coagulant oil would be to consolidate (bind) and concentrate whatever contaminated sediment, presumably waterborne suspended particulates, was already present within the M&C drainage system, leading to potentially increased concentrations of contaminant deposits within the pipes. Whether the coagulant involved had "solvent" properties to "mobilize a fixed contaminant" (NIOSH, 2023b, p. 5) would be speculative at this point, without knowing the specific coagulant employed (beyond what was remembered as "green lube" (NIOSH, 2023b, p. 4)), its chemical and physical properties, the chemical and physical properties of whatever fixed contamination existed within the M&C drainage pipes, and the properties of the water solution inside the drain during discharges (e.g., pH, volume, speed of passage). However, it is clear that during the M&C residual period, the drainage pipes would have contained both in-solution suspended sediments and fixed sediment contamination of varying degrees, for which the regular introduction of an oil-based coagulant during Building 10 operations was known by M&C workers to consolidate or bind in-pipe sediments such that drain pipes became plugged, requiring cleanout. Again, the chemical and physical form of the actual consolidated sediment making up these clogs is not known beyond the uranium concentrations determined.

4 Aerosolization of Drain Line Contamination (1,000,000 dpm/100 cm^2)

4.1 SC&A comment: Cleaning/cutting drain lines

> Another historical aspect of M&C drain lines is the accumulation of contaminant scale that has plated out inside the piping. This scaling was found in at least one instance at M&C to exceed[3] 1,000,000 dpm/100 cm^2 in a 4-inch mainline drain that was being cut and removed (NIOSH, [2021], p. 7). While such pipe scale has been identified at other AWE sites, M&C maintenance workers frequently cut, repaired, replaced, and cleaned out such piping during the residual years using power tools such as saws, drills, grinders, and powered snakes, as well as cutting torches. [SC&A, 2022, p. 21]

4.1.1 NIOSH response: Cleaning/cutting drain lines

SC&A begins the paragraph above discussing drain lines, which NIOSH and SC&A agree represent the most significant source term.

Regarding the following SC&A excerpt from above:

> *M&C maintenance workers frequently cut, repaired, replaced, and cleaned out such piping during the residual years using power tools such as saws, drills, grinders, and powered snakes, as well as* ***cutting torches****.*

[3] This reference was incorrectly cited by SC&A as "to exceed" rather than "as high as" 1,000,000 dpm/100 cm^2.

> The drain lines of concern were either cast iron or clay and would have been cut with a snap-cutter or saw and not routinely cut with torches. There *were* other services that traversed the subsurface (e.g., airlines, recirculation piping); however, NIOSH does not consider work performed in the subsurface at a distance (>5 ft) from the drain lines to represent the bounding scenario.
>
> [NIOSH, 2023b, p. 6]

4.1.2 SC&A response

As NIOSH observes, SC&A and NIOSH agree that the most significant source terms are those related to cutting and cleaning of drain lines. As cited by NIOSH in its response, SC&A notes that a wide array of intrusive activities, many involving power tools, were used to cut, clean out, and repair these pipes, including saws, drills, grinders, powered snakes, and cutting torches. The specific tools employed would have depended upon the type of pipe (e.g., cast iron versus clay), the size and nature of the clog, and the size and condition of the pipe.

SC&A agrees that while snapcutters and saws would have been more routine than cutting torches, the volatizing and suspension of fine particles or fumes of contaminated scale (or other interior pipe surface contamination) during all of these mechanized activities is the issue—one that was highlighted by DOE in its hazard assessment example involving pipe cutting using a cutting torch. All of this work would have been performed within the 5-feet criterion noted by NIOSH and would have likewise been often performed in a confined space atmosphere that would have had the potential for concentrating generated fumes and particulates in the breathing zone of the worker handling this equipment.

4.2 SC&A comment: Bridgeport Brass hazard assessment

> As noted by DOE in its hazard assessment of the Bridgeport Brass AWE, "the residual uranium could eventually be released . . . through intrusive work activities such as pipe cutting and removal" (DOE, 1996, PDF p. 11), and that "it is possible that under certain conditions (such as cutting through a steel pipe with a cutting torch) surface activity attached to the steel could be released with the steel particles" (DOE, 1996, PDF p. 48). [SC&A, 2022, PDF p. 21]

4.2.1 NIOSH response: Bridgeport Brass hazard assessment (torch cutting)

> The excerpt above shows why the reference provided by SC&A is concerned with the torch cutting of drain lines, and since M&C's drain lines were not steel, NIOSH did not select torch cutting of drain lines as a bounding scenario.
>
> NIOSH reviewed the U.S. Department of Energy (DOE) Bridgeport Brass AWE Hazard Assessment [DOE 1996] referenced by SC&A to determine the types of pipes that were cut with torches and found the following:
>
> > *Many of the drain lines at the GM site are constructed of* ***carbon steel****. It is unlikely that contamination could penetrate uniformly as deep as 1 cm into* ***carbon steel*** *(or even clay tile pipes).* [DOE 1996, PDF p. 47]
>
> [NIOSH, 2023b, pp. 6–7]

4.2.2 SC&A response

As noted in the preceding response, SC&A identified a range of intrusive, mechanized processes by which drain pipes were cut, cleaned out, and repaired, of which torch cutting was identified as one such means. While the Bridgeport Brass AWE hazard assessment focuses on the cutting of steel pipes, torch cutting was among several means by which cast iron (CI) pipes and vitreous clay (VC) pipes were cut at M&C by maintenance workers. Any of the mechanized cutting and repair procedures may have volatized and suspended any contaminated scale that would have been present on the inside of the VC or CI drain pipes being worked on. The Bridgeport Brass AWE cautionary note on torch cutting of pipes by DOE was provided to highlight this concern for a scenario that would have likely provided the upper range of airborne contamination given the added heat and energy involved. However, electric drills, grinders, and powered snakes may have likewise served to release any contaminated scale present on the inside of the piping.

As for the penetration of contamination into either CI or VC pipes at M&C, there are no data to support the degree to which surface contamination on the interior of such pipes would have adhered to, penetrated, or deposited within the M&C drainage system. The only data are from the D&D characterization surveys in terms of what was actually measured, in a very limited way, as surface contamination for pipe interiors.

4.3 SC&A comment: Bridgeport Brass hazard assessment (pipe cutting)

> NIOSH fails to address the source of this concern: the U.S. Department of Energy's (DOE's) Bridgeport Brass AWE hazard assessment, where it was warned that pipe cutting involving internal radioactive contamination could lead to airborne releases that may involve worker exposure (DOE, 1996, PDF p. 48). [SC&A, 2023, p. 7]

4.3.1 NIOSH response: Bridgeport Brass hazard assessment (pipe cutting)

"NIOSH reviewed the complete Bridgeport Brass Hazard Assessment [DOE 1996] referenced by SC&A" (NIOSH, 2023b, p. 7) and detailed its findings, including source terms, exposure pathways, and a comparison with M&C regarding maximum source term and annual total effective dose.

4.3.2 SC&A response

The context of SC&A's original comment was to point out the source of its concern regarding pipe cutting involving interior surface radioactive contamination, which was underscored in DOE's hazard assessment for the Bridgeport Brass AWE. NIOSH has now acknowledged its review of this issue, as well as an overall assessment of that report. Regarding NIOSH's comment that the "ratio of assigned dose to source term level using the Bridgeport Brass reference SC&A recommended compares favorably to that proposed for M&C" (NIOSH, 2023b, p. 8), SC&A did not recommend the Bridgeport Brass exposure modeling for direct application to M&C. It was cited to illustrate that in-pipe surface contamination can be a credible source term that also needs to be considered for M&C from an exposure pathway standpoint. The physical characteristics of the piping at Bridgewater Brass, the specific source term involved, and the thickness of in-pipe surface contamination (identified by DOE as the most significant

variable), make a direct comparison with M&C problematic given differences between the two sites and the uncertainties of these parameters for M&C.

4.4 SC&A comment: Systemic or isolated drain line/pipe scale (1,000,000 dpm/100 cm^2)

> NIOSH contends that cutting of drain lines with contaminated scale exceeding 1,000,000 disintegrations per minute per 100 square centimeters (dpm/100 cm^2) would constitute "isolated hot spots," not a systemic condition, and that in any case, it does not believe there is any evidence that even higher activity levels might have existed. [SC&A, 2023, p. 7]

4.4.1 NIOSH response: Systemic or isolated drain line/pipe scale (1,000,000 dpm/100 cm^2)

SC&A's line of inquiry about pipe scale stems from a misinterpretation of one survey indicating a contamination level of 1,000,000 dpm/100 cm^2 found in the Screen Print Room (Area 7). The following is from SC&A's *Supplemental Review of M&C Work Group Issues*:

> *Another historical aspect of M&C drain lines is the accumulation of contaminant **scale** that has plated out inside the piping. This **scaling** was found in at least one instance at M&C **to exceed** 1,000,000 dpm/100 cm^2 in a 4-inch mainline drain that was being cut and removed* (NIOSH, [2021], p. 7). [SC&A 2022, PDF p. 22]

The Weston [1996b] drainage system characterization does not identify any scale found at the location SC&A references [PDF pp. 10–11]. As NIOSH previously noted, this drain line was clay; scale/rust is associated with cast iron drain lines. To further clarify, this pipe had contamination levels **as high as** 1,000,000 dpm/100 cm^2 and was cut and removed by Weston decontamination and decommissioning (D&D) workers, not as part of M&C maintenance work.

[NIOSH, 2023b, p. 8]

4.4.2 SC&A response

To be precise, the one survey result cited by SC&A from NIOSH's 2021 response paper is explained in an excerpt from that response paper, as follows (p. 7):

> *During contaminated concrete removal at the north side of the Screen Print Room (Area 7), the initiation point of a **4-inch vitreous clay (VC) mainline** was encountered. This line exhibited surface contamination levels (on the pipe interior) as high as 1,000,000 dpm/100 cm^2, although did not contain a visible accumulation of residue. Approximately 15 feet of line was removed until surface contamination levels within the pipe were reduced to background levels.*
> [emphasis added]

NIOSH concludes that scale would only be associated with CI pipes but provides no evidence that this was the case at M&C (though specific scale survey results were reported by Weston for

a few CI pipes and rust may obviously also be present with CI pipes). The one million dpm/100 cm^2 measurement was for the initiation point for a VC mainline. The VC lines accepted flows from floor drains, while CI lines accepted flows from the roof of Building 10 (Weston, 1996b, PDF p. 7).[4]

The 1,000,000 dpm/100 cm^2 "surface contamination levels (on the pipe interior)" of the VC mainline pipe "did not contain a visible accumulation of residue," as reported by the Weston survey (Weston, 1996b, PDF pp. 10–11), which correlates with scale readings taking in other locations (e.g., survey locations 2, 3, 4 and 5, cited by NIOSH and summarized in section 4.5). For example, for the scale readings in locations 4 and 5, the Weston survey reported that "sampling and visual observation confirmed that there was little to no accumulation of residue in these lines" (Weston 1996b, PDF p. 17). That Weston did not label this 1,000,000 dpm/100 cm^2 surface contamination as scale is a distinction with little difference as it was found to be a high contamination level on the interior surface of this drain pipe with little visible accumulation of residue sediment associated with it. The apparent interchangeability of such terminology (scale versus interior surface contamination) is further borne out as noted by survey data for Areas 1 and 4 (refer to SC&A's response in section 4.5 of this paper).

Whether the pipe in question was cut and removed by D&D workers versus M&C maintenance workers is beside the point. The presence of contaminated scale and similar in-pipe surface contamination (without associated residue) within the drainage pipe system at M&C during the residual period represents a potential source term for which limited sampling was performed during D&D characterization and for which uncertainties remain.

4.5 SC&A comment: Systemic or isolated drain line/pipe scale (additional survey evidence)

> NIOSH presents no evidence that this contaminated scale would not have been present elsewhere in the piping system, could have involved both metal and clay pipes, or that even higher activity levels may have been present elsewhere in the pipe network. [SC&A, 2023, p. 7]

4.5.1 NIOSH response: Systemic or isolated drain line/pipe scale (additional survey evidence)

NIOSH notes that it "relies on the available source-term survey data because of the comprehensiveness exercised by Weston and Texas Instruments" (NIOSH, 2023b, p. 9) in its M&C assessments and surveys, and the methods employed during those assessments. It also notes that "in addition to the systematic sampling prescribed by NUREG/CR-5849, Weston collected **biased** samples at 'cracks or other locations across the grid exhibiting elevated surface activity measurements' [Weston 1995, PDF p. 6]" (NIOSH, 2023b, p. 9). In terms of "existing

[4] Workers indicated that there had been some "cross routing" between the systems over time (Weston 1996b, PDF p. 7), as corroborated by an interview with an M&C maintenance worker who noted that excess drain water with "green lube" in it had been apparently pumped into a roof drain and turned the pond green (ORAUT, 2017c, PDF pp. 12–13).

scale data" (NIOSH, 2023b, p. 9) from sampling performed by Weston, NIOSH provided the following information in its April 2023 response paper.[5]

Weston January 1996 drainage system characterization survey data (Weston, 1996b):

> Weston reported collecting scale samples at locations 2, 3, 4, and 5 [Weston 1996b, PDF pp. 15, 17] that provide contamination data as high as 507.7 pCi/g [Weston 1996b, PDF p. 18]. In addition, NIOSH has the following information:
>
> - In the Caged Area (Areas 1 and 4 where the fuel rod was found), radiological surveys of this piping typically showed marginal surface contamination on the interiors of the pipes, typically ranging from less than 3000 dpm/100 cm^2 [Weston 1996b, PDF p. 10].
>
> - Locations 4 and 5 accessed lines that had previously supported assay laboratories associated with nuclear material manufacturing activities. Sampling and visual observation confirmed that these lines had little to no residue accumulation. Analytical data for both CI lines showed a total uranium concentration of approximately 500 pCi/g in the thin layer of scale [Weston 1996a, PDF p. 17].
>
> [NIOSH, 2023b, p. 9]

Weston October 1996 remediation of building interiors, Buildings 4, 5, and 10 survey data (Weston 1996a):

> - Areas 3 and 4 were identified as having scale and rust with a total uranium concentration of 1,864 pCi/g [Weston 1996a, PDF p. 174].
>
> [NIOSH, 2023b, p. 9]

Beyond the cited survey data, NIOSH indicates that it "can use Weston [1996b] Table 3, Building 10 Feed Drain Surveys [PDF p. 21], particularly the beta scintillator data as scale activity measurements" (NIOSH 2023b, p. 10). NIOSH also observed that "M&C also developed a method to calculate surface contamination levels on pipe interiors using the thickness of residue lining the pipes and the total uranium concentration in the residue" and that this method and source term data (as outlined in Weston, 1997a, PDF pp. 11, 13, 15) can support "drain calculations with conversions to surface activity where total surface contamination levels prior to decontamination ranged from 53,000 to 95,000 dpm/100 cm^2" (NIOSH, 2023b, p. 10).

NIOSH concludes that:

> In summary, neither SC&A nor the M&C Work Group has provided any evidence explaining why these surveys are not a suitable basis for NIOSH's bounding source term. This issue boils down to a demand that NIOSH prove a negative (*i.e.*,

[5] This is in addition to the 1,000,000 dpm/100 cm^2 survey of the interior surface of a CI mainline pipe in Area 7, which NIOSH noted in the response discussed in section 4.4 of this paper was not labeled as scale by Weston.

> prove something did not exist). NIOSH has cited credible evidence to support its calculations. Assertions that there could have been other higher contamination levels—with no supporting evidence—rely on speculation. NIOSH's model using the pre-D&D survey that included a fuel pin in the pipe is the highest plausible bounding scenario. NIOSH has not received any technical evidence contradicting the use of this survey in a bounding model. [NIOSH, 2023b, p. 10]

4.5.2 SC&A response

The following is in response to the specific survey data highlighted by NIOSH pertaining to interior pipe scale.

NIOSH: "Weston reported collecting scale samples at locations 2, 3, 4, and 5 [Weston 1996b, PDF pp. 15, 17] that provide contamination data as high as 507.7 pCi/g [Weston 1996b, PDF p. 18]" (NIOSH, 2023b, p. 9).

SC&A response: The scope of the cited sampling of scale is very limited for purposes of characterizing the range of activity levels within M&C drain pipes and what may represent the upper bound of that activity. Weston relied upon two primary programs: (1) sampling and analyses of in-pipe residue and (2) radiological measurements within the interiors of arterial and feed piping (Weston, 1996b, PDF p. 11). For the latter, a Ludlum Model 44-1 beta scintillator was used in 8 to 10 feed lines as a means to identify contaminated scale (Weston, 1996b, PDF p. 12). In terms of characterizing in-pipe surface contamination levels, Weston confirmed the difficulty of translating direct radiation measurements to interior pipe surface contamination levels:

> Correlation of direct radiation measurements to interior pipe surface contamination levels is hampered by irregular surfaces in the drain lines, the presence of larger blockages, varying geometries, the presence of radium and other naturally-occurring radioactive material (NORM), and the presence of moisture and liquid resulting from active facility discharges. [Weston, 1997a, PDF p. 11]

These limitations would have also hampered the representative identification and characterization of scale in piping at M&C using direct radiological scanning.

As it stands, the Weston characterization survey of M&C in-pipe scale can only be attributed to *two* drain pipe measurements supporting *one* Building 10 operation (assay laboratories), as noted in the following review of NIOSH's survey results.

NIOSH: "In the Caged Area (Areas 1 and 4 where the fuel rod was found), radiological surveys of this piping typically showed marginal surface contamination on the interiors of the pipes, typically ranging from less than 3000 dpm/100 cm^2 [Weston 1996b, PDF p. 10]" (NIOSH 2023b, p. 9).

SC&A response: These measurements were apparently taken in "near-surface recirculation piping," not drain pipes (Weston, 1996b, p. 10). Regarding such utility piping, NIOSH notes that "there *were* other services that traversed the subsurface (e.g., airlines, recirculation piping);

however, NIOSH does not consider work performed in the subsurface at a distance (>5 ft) from the drain lines to represent the bounding scenario" (NIOSH, 2023b, p. 6). It is also noteworthy that while NIOSH cites all of these survey measurements as "scale data" (NIOSH, 2023b, p. 9), the ones cited by Weston for Areas 1 and 4 are for "surface contamination on the interiors of the pipes" (Weston, 1996b, p. 10), which supports SC&A's contention that the in-pipe scale and surface contamination terminology appears to have been interchangeable.

NIOSH: "Locations 4 and 5 accessed lines that had previously supported assay laboratories associated with nuclear material manufacturing activities. Sampling and visual observation confirmed that these lines had little to no residue accumulation. Analytical data for both CI lines showed a total uranium concentration of approximately 500 pCi/g[6] in the thin layer of scale [Weston 1996b, PDF p. 17]" (NIOSH, 2023b, p. 9).

SC&A response: It is not clear how representative these spot samples may be, coming from a limited survey of CI lines supporting one specific Building 10 operation, the assay laboratories. This is the source of the "as high as 507.7 pCi/g" cited by NIOSH (2023b, p. 9) for scale measurements. However, being collected from drain pipes servicing only one location, it would not necessarily be representative of a bounding or even high scale concentration for the full scope of Building 10 drain pipes during the residual period.

NIOSH: "Areas 3 and 4 were identified as having scale and rust with a total uranium concentration of 1,864 pCi/g [Weston 1996a, PDF p. 174]" (NIOSH, 2023b, p. 9).

SC&A response: This survey measurement appears to be for total "bulk material," that was removed from the priority 2 drain lines using a "specially designed vacuum" (table 5.2, Weston, 1996a, PDF p. 177). Weston noted that "once the loose material and water were removed from the line, a hydrolaser was used to remove fixed-surface contamination" (Weston, 1996a, PDF p. 177). The cited uranium concentration is for loose debris removed from the Priority 2 drain pipes in the form of combined "sediment, debris, scale, [and] rust," as noted in table 5.2 of Weston (1996a, PDF p. 177). The radiological contribution of scale would not have been distinguishable from the sediment and other "debris removed from the pipes" (Weston, 1996a, PDF p. 177).

The proposed use of beta scintillator data (from table 3, Weston, 1996b, PDF p. 21) to represent scale activity measurements may be of questionable utility as the "geometry of this system is not optimal for detecting large accumulations in or around pipes," but is "adequate for **identifying** [but, presumably, not quantifying] contaminated scale within the line" (Weston, 1996b, PDF p. 12; emphasis added). It was used in "8 to 10 feedlines" (Weston, 1996b, PDF p. 12), specifically for Building 10 locations 23–34 (table 3, Weston, 1996b, PDF p. 21). These measurements are direct reading radiological measurements in counts per minute (cpm) with a background of 60 to 80 cpm, with results ranging from 71 to 491 cpm (Weston, 1996b, PDF p. 21). Such measurements would have suffered from the limitations of direct interior pipe

[6] 507.7 pCi/g of total uranium is cited in table 1 of Weston 1996a (PDF p. 18).

surface contamination measurements cited by Weston (Weston, 1997a, PDF p. 11; refer to previous SC&A response in this section).

Regarding the M&C surface activity calculation method cited in NIOSH's response (NIOSH, 2023b, p. 11), Weston's "SNM License Termination Hypothetical Radiological Dose and Exposure Rate Assessment" of Priority 2 drain lines made clear that this methodology was aimed at "hypothetical scenarios" that would generate a "hypothetical dose and exposure rate" (Weston, 1997a, PDF p. 6). The 1997 Weston's hypothetical radiological dose and exposure rate assessment report notes that its methodology relies on combining estimated pipe volumes and average densities to "determine the total mass of piping which, when crushed, was available for distribution over a surface area thickness of 1 cm (as recommended by NRC)," with the "residual total uranium activity . . . [to be] distributed in a thin layer lining the pipes" (Weston, 1997a, PDF p. 4). The proposed use of the described "method to calculate surface contamination levels on pipe interiors using the thickness of residue lining the pipes and the total uranium concentration in the residue" (NIOSH, 2023b, p. 10), as intended for site release, may not be sufficiently accurate for purposes of estimating the upper bound source term for scale, particularly with the lack of available, representative survey data for interior surface contamination.

SC&A and the WG raise a simple and direct question pertaining to both coagulants and scale that goes to the heart of NIOSH's claims to be able to bound exposures for M&C maintenance workers: Does the inside subsurface bounding exposure model adequately reflect and bound potential exposures by M&C maintenance workers when cutting, cleaning out, and repairing clogged drain pipes at M&C during the entirety of the residual period? The presence of contaminated scale on the inside of drain pipes has been confirmed in pre-D&D surveys cited by NIOSH in its own evaluation. Is that source term adequately addressed by NIOSH given its apparent reliance on high 1995 pre-D&D sediment concentrations to derive a bounding value? SC&A finds that not to be the case: While contaminated scale and sediments both figure in pre-D&D survey results for drain pipes, only the latter was addressed in NIOSH's bounding model. SC&A continues to find the source term issue regarding scale to be credible and substantive.

NIOSH appears to lack sufficient and representative survey data for in-pipe contaminant scale (or interior pipe surface contamination) to provide an adequate basis for an upper bound source term for potential exposure of M&C maintenance workers involved with cutting and cleaning out these pipes. A single reading as high as 1,000,000 dpm/100 cm^2 is supported by only two unequivocal scale concentration measurements; these were taken from the same area servicing the Assay Laboratory and, therefore, may not be a representative sampling of Building 4 and 10 drain lines. This is important because NIOSH bases its selection of the 95th percentile concentration of 6,887.84 pCi/g on a review of a relatively large and representative sampling of uranium sediment measurements taken from the 1995 pre-D&D characterization surveys. Without other survey measurements, how does NIOSH determine that the "as high as" 1,000,000 dpm/100 cm^2 survey measurement represents the highest value for drainline pipe interior surface contamination, including scale, or that higher activity levels would not have existed within the M&C drainage system?

As the WG has made clear, for matters of sufficient accuracy the burden resides with NIOSH to demonstrate that its exposure models are adequate and bounding. This is not a "demand" that

NIOSH prove a "negative" (NIOSH, 2023b, p. 10). On the contrary, NIOSH needs to address substantive source terms and potential exposure pathways that NIOSH itself has identified and heretofore has not chosen to reflect in its exposure model.

4.6 SC&A comment: Bounding exposure pathway

> NIOSH's reliance on "mass-based sample data" and "soil-sampling plans" does not address the simple question raised: Given that an AWE hazard assessment raised this general worker exposure concern, can this [1,000,000 dpm/100 cm^2] potential exposure pathway at M&C be characterized and bounded? This concern represents a new issue that has not been addressed. [SC&A, 2023, p. 7]

4.6.1 NIOSH response: Bounding exposure pathway

> NIOSH used the source term concentration calculation from the Bridgeport Brass AWE Hazard Assessment [DOE 1996], recommended by SC&A, to calculate an inside subsurface dose that incorporates the million dpm survey value that can be used to model cutting through a contaminated pipe. . . .
>
> This calculation shows that adding this one survey result to NIOSH's other subsurface data will increase maintenance worker dose from 71 to 96 mrem committed effective dose (CED).
>
> This adjustment is based on only adding the single value (1,000,000 dpm/100 cm^2) to NIOSH's dataset. According to Weston [1996b], this was the highest surface contamination value, and as shown above, additional data are available. Therefore, adding this single value biases the dataset in a very claimant-favorable way (*i.e.*, it increased the 95th percentile by almost a factor of 2). NIOSH has determined that it has methods for incorporating surface contamination data into a bounding method, eliminating the aerosolization of drain line contamination as an SEC issue.
>
> [NIOSH, 2023b, pp. 10–11]

4.6.2 SC&A response

To clarify, SC&A did not recommend use of any particular source term calculation from, or based on, the Bridgeport Brass AWE hazard assessment for purposes of arriving at an estimated exposure value. SC&A merely pointed out that NIOSH had heretofore failed to address a concern documented in that assessment: "that pipe cutting involving internal [surface] radioactive contamination could lead to airborne releases that may involve worker exposure (DOE, 1996, PDF p. 48)" (SC&A, 2023, p. 7).

SC&A supports NIOSH's recent effort to assess this potential exposure pathway using available methods and source term information. However, questions and uncertainties remain.

For example, NIOSH states that "according to Weston [1996b], this was the highest surface contamination value," and referring to the NIOSH response discussed in section 4.6.1 of this paper, "additional data are available" (NIOSH, 2023b, p. 11). However, Weston (1996b) never claimed that the "as high as 1,000,000 dpm/100 cm^2" (NIOSH, 2023b, p. 8) was the *highest* in-

pipe surface contamination value at M&C; it happened to be the highest one *measured* in its limited survey of interior pipe surface contamination levels. The "additional data are available" (NIOSH, 2023b, p. 10) consideration was addressed in section 4.6.1 of this paper, but these data are few in number, some are not applicable, and, overall, they are not a representative characterization of interior pipe surface contamination of the M&C drain pipe system. Therefore, reliance on a single data point from one portion of a single pipe (Area 7, initiation point of a 4-inch VC mainline) may not be sufficiently accurate for deriving a source term for this exposure pathway.

It should be noted that the source term values for the Bridgeport Brass hazard assessment were based on "actual U-238 surface activity measurements" at that site (DOE, 1996, PDF p. 47), with a uranium (U) dose conversion factor assuming "an activity-weighted average for natural uranium, based on the U-238, U-234, and U-235 natural radioactivity ratio of 1:1:0.046" (DOE, 1996, PDF p. 42). This contrasts with the single cited interior pipe surface activity measurement for M&C that likely contained a higher fraction of U-235, backed by a few spot scale measurements.

In this case, the uncertainty also extends to the derivation of "T," thickness of interior pipe surface activity. As noted in the DOE hazard assessment, the "selection of the thickness of the contamination layer is a significant uncertainty for the hazard assessment," with DOE's selection of T for Bridgeport AWE based on "a conservative estimate developed based on literature values, and information related to the cleanup methods for this site [Bridgeport]" (DOE, 1996, PDF p. 47). In applying DOE's parameter for surface activity thickness in its calculation, it is unclear what M&C-specific information could and should have been applied by NIOSH based on M&C interior surface activity thickness within drain pipes. However, without some basis in actual M&C measurements and experience, any calculation may not be sufficiently accurate for exposure modeling.

First, the fixed surface contamination present at Bridgeport was for carbon steel, with little assumed penetration, and a thin layer of residual surface contamination because those pipes had been "cleaned using high pressure wash systems" (DOE, 1996, PDF p. 47). This differs from the M&C case, where the as high as 1,000,000 dpm/100 cm^2 value was apparently sampled using smears[7] from a PVC pipe containing surface contamination that had not been previously washed and was obviously not fixed contamination.

Second, unlike Bridgewater, the thickness and density of in-pipe surface contamination would have been influenced by the unique physical and chemical characteristics of M&C drainpipe discharge. Of particular note was the regular release of an oil-based coagulant to the drain lines, which may have induced scale and other contaminant buildup on the interior of pipes that would have influenced the thickness and density of surface activity. Surface activity composition,

[7] SC&A did not find a specific reference to the sampling method that resulted in the up to 1,000,000 dpm/100 cm^2 measurement but is relying on NIOSH's statement about it that "it is appropriate to use mass-based sample data (e.g., pCi/g) to characterize the exposure environment," as it permits the development of "models more representative of the subsurface work than do swipes of surface contamination" (NIOSH, 2021, p. 7).

density, and thickness may have been significantly different for M&C than those experienced at Bridgeport or any other AWEs due to the regular presence of this coagulant.

These and other uncertainties are presumably the basis for NIOSH adding additional conservatism—e.g., "increased the 95th percentile by almost a factor of 2" (NIOSH, p. 11)—as part of its "extreme conservatism" approach. However, the sufficient accuracy and, ultimately, plausibility of this approach are questionable.

5 Work in Confined Spaces

5.1 SC&A comment: Routine drain line repair in pits or trenches (6-month occupancy)

> As emphasized in former worker interviews, it was not uncommon to be working in a trench doing routine utility repairs or pipe cleanouts for days and up to a week (NIOSH, 2017b, pp. 1–2). One installation project in Building 10 involved the cutting out of an existing drain line and installation of new equipment, piping, and large tanks, necessitating a trench 100 feet long, with a depth of 8–10 feet in places, that was worked in for 6 months in 1983–1984 ([ORAUT, 2017c], p. 11). [SC&A, 2023, p. 8]

5.1.1 NIOSH response: Routine drain line repair in pits or trenches (6-month occupancy)

> There appears to be some misinterpretation in SC&A's description of work performed in confined spaces that requires clarification. SC&A stated that M&C workers were performing confined space work for six months, presumably to install the Beckett line mentioned in the following interview excerpts. [NIOSH, 2023b, p. 13]

NIOSH proceeds to cite various interviews that indicate that workers were not actually within the confined space for the full 6 months and that their presence in the Beckett line trench actually involved periodic work activities that were, in general, about 200–300 hours per year "inside a hole" (ORAUT, 2017c, PDF p. 19), with the duration of work being about a week at a time. This level of activity also reflected reliance on outside contractors for much of the excavations.

NIOSH summarized that the main points from the worker interview include the following (NIOSH, 2023b, p. 17):

- Maintenance workers using a snake while standing on the undisturbed concrete floor, addressed probably more than 60% of clogged drains (*i.e.*, primary source term).
- "Stage 3" excavations, (*i.e.*, when the snake did not work), happened approximately once a year.
- Contractors, not maintenance personnel, cut the concrete using a wet process and excavated the hole for the Beckett Wire machine with a backhoe.

- A pump was needed to remove the water from the wet subsurface environment.
- Once excavated, the contractors lined the hole with clean dirt, and M&C workers installed the equipment on top of the clean fill.
- Of the various M&C groups, Facilities personnel spent the most time performing subsurface work, which amounted to less than two months per year.

5.1.2 SC&A response

SC&A did not misinterpret the available information regarding the Beckett line work. This was an SC&A comment based on a worker interview conducted by NIOSH (ORAUT, 2017c, p. 12) that there had been one installation that "involved cutting out an existing drain line and installing new equipment, piping, and large tanks, necessitating a trench 100 feet long, with a depth of 8–10 feet in places, that was worked in for 6 months in 1983–1984" (SC&A, 2022, p. 32). This worker citation (ORAUT, 2017c) was included in the supplemental review to illustrate that not all subsurface excavation work at M&C during the residual period was small, short-duration utility replacement or repair work. NIOSH infers that SC&A interprets that M&C workers would have been present continuously within the Beckett line trench during the entire 6 months of excavation and installation, but that was not SC&A's interpretation. Given the nature and history of M&C maintenance work, that would not make sense nor does that comport with SC&A's citations in the supplemental review that noted that "the work involved considerable time, usually days, but sometimes a week at a time ([NIOSH, 2017b], p. 2) and up to 6 months for one project ([ORAUT, 2017c], p. 11)" (SC&A 2022, p. 12). The work was intermittent and task related and would have been performed as such for the duration of the 6-month subsurface project.

5.2 SC&A comment: Confined spaces standard

SC&A previously supplied a confined space definition:

> OSHA defines confined spaces and cites examples including pits, tanks, silos, maintenance holes, sewers, enclosed drains, and manholes . . . . OSHA notes that pits, although typically open on top, can be completely underground or below grade and can still be a confined space (OSHA, 2015). Supporting industry literature following promulgation of the Subpart AA standard noted that confined spaces "include tight work areas with reduced air flow" where work such as "welding, cutting, grinding, sanding or any high-energy activity can create . . . respirable particles and/or toxic aerosols (Chase, 2019)." [SC&A, 2022, p. 32]

5.2.1 NIOSH response: Confined spaces standard

> Although there were confined spaces at M&C, the concern within the EEOICPA program is only for those with a radiological hazard. The source term of primary concern at M&C was the drain lines in the subsurface of Building 10. The Weston [1996b] drainage system characterization describes that system as follows:

> *Buildings 4 and 10 drainage systems consist of 4-inch vitreous clay (VC) and 4, 5, and 6-inch cast-iron (CI) lines (referred to as "arterial lines")* ***located 2 to 3 feet below facility Grade****.* [PDF p. 7]

Considering the Weston [1996b] statement above, NIOSH does not consider a Facilities worker spending two months during a particular year working on a drain line in such a shallow hole to have performed that work in a confined space.

For the remaining 40% of the time when the snake would not work, workers had to dig ~3 feet to access the clogged pipe. A safety professional would not control this work as a confined space entry, especially in an industrial facility with active ventilation. The hole is too shallow to "include tight work areas with reduced air flow" as the reference SC&A provided above states. Furthermore, as pointed out in the *SNM License Termination Radiological Dose Assessment*, "Scenario assumptions for ventilation and work times understate the true dilution effects of ventilation" [Weston 1997b, PDF p. 14]. M&C had two exhaust fans that ventilated and removed air from Building 10. One ventilation stack equipped with a high-efficiency filter exhausted air from the press room at a rate of 616 ft^3 per minute (cfm), and another stack exhausted air from the furnace area at a rate of 500 cfm [Texas Instruments 1979, PDF p. 20].

Within the OSHA confined space standard, there are no strict definitions as to the exact depth required to designate, which allows room for professional judgment. However, standard practice indicates that safety professionals would not control a 3.5-foot-deep trench dug to service a drain line as a confined space. In general, work on the drainage system, identified as the worst-case exposure scenario for maintenance workers, would not have been performed within a confined space work environment.

[NIOSH, 2023b, pp. 17–18]

5.2.2 SC&A response

The reason SC&A raised this issue is that confined spaces restrict the movement of air in work spaces such that fumes and particulates released into those spaces can concentrate and pose increased inhalation exposure concerns—and notably increased airborne concentrations—for workers within those spaces. The ergonomics of the work matters. If workers must crouch and bend over to conduct their work within a trench of even 3.5-foot depth, as would M&C maintenance workers cutting, cleaning, and replacing drain pipes, the breathing zone of those workers would have been closer to the bottom of the trench (adjacent to the pipes) and affected by confined space atmospheres in terms of the concentration of particulates and fumes. While there would have been building ventilation in Building 10, it is unlikely to have made much difference within the work trenches involved, whether the 3.5-foot drainline trenches or the 8–10-foot Becket line installation trench.

To address these circumstances, a revised resuspension factor (and dust loading factor) is needed as indicated in SC&A's supplemental review (SC&A, 2022, p. 32):

> To illustrate, while NIOSH applies a standard 10^{-6} m^{-1} resuspension factor in its OTIB-0070 evaluation, the International Atomic Energy Agency (IAEA) guidelines for "Radiological Aspects of Non-fixed Contamination of Packages and Conveyances" recommends a resuspension factor of 4×10^{-5} m^{-1} for dusty operations in confined spaces (IAEA, 2005, p. 11).[24] [[24] IAEA-TECDOC-1449 references the Fairbairn model, which applies other parameters for modeling airborne contaminants. It is unclear how these parameters relate to similar OTIB-0070 considerations, although it does appear more conservative regarding confined spaces.] The U.S. Department of Energy (DOE) "User's Manual for RESRAD-BUILD Version 3" gives a resuspension factor of 4.3×10^{-5} m^{-1} for "active work in confined, unventilated space" (Argonne National Laboratory, 2003, p. J-33).

These considerations also reinforce finding 2 of SC&A's supplemental review, that "the application of surrogate data from the Mound project to provide a dust-loading factor for M&C subsurface activities does not satisfy the Board's surrogate data policy" (SC&A, 2022, p. 33). The Mound project data do not reflect any consideration of reduced ventilation within trenches, pits, and vaults within which intrusive maintenance activities were conducted. The air monitoring data collected for that study were taken at a distance from the excavation (15–20 feet away) (NIOSH, 2020c, p. 6) and are, therefore, not equivalent to the more confined spaces within which M&C workers conducted their pipe cutting, cleanouts, and replacement.

5.3 SC&A comment: Confined spaces and work not associated with drain line cleaning

> While the 1995 drain line sediment reading is a high concentration level, can it be applied as a bounding exposure for unrelated inside subsurface work (i.e., non-drain line cleaning) for which little, if any, information is available and for which confined space atmospheres were involved? [SC&A, 2022, p. 21]

5.3.1 NIOSH response: Confined spaces and work not associated with drain line cleaning

The following is SC&A's summary of the NIOSH (2023b) response on pages 19–25, which included figure 1, "Building 10 – Affected Areas," and figure 2, "Building 10 Pipe Grouping for Uranium-235 Inventory Development." According to NIOSH (2023b, pp. 18–19):

> NIOSH acknowledges there were confined spaces at M&C. However, the key consideration is whether there were **contaminated** confined spaces associated with the Building 10 subsurface where M&C workers incurred exposures that represent a plausible scenario for which NIOSH cannot bound doses. NIOSH finds:
>
> - The pathway for contaminants to get to the subsurface was through the floor drains, and to a lesser extent, through cracks in the concrete when the floor flooded, and contaminants got washed into the subsurface.

- The subsurface is well described and shows that after contaminants flowed to the subsurface, they generally stayed within 5 feet of the drainage system network of pipes, which were approximately 3-feet deep.

> Interviewees described subsurface work that included some confined space work; however, their recollections included work in other buildings and areas not associated with the source term. When workers **did** describe work in Building 10, they referred to the entire building and did not differentiate whether their work was in the part of the building that contained the source term of primary concern: Priority 1 drain lines. This is an important distinction because nuclear manufacturing operations were primarily performed in the northern third of Building 10, and support activities, including transportation and storage, were performed in the balance [Weston 1996a, PDF p. 10].

NIOSH elaborates that "the area of Building 10 with the Priority 1 drain lines is small compared to the rest of the building," as illustrated by two diagrams of "Building 10 – Affected Areas" and "Building 10 Pipe Grouping for Uranium-235 Inventory Development" (NIOSH, 2023b, p. 19).

NIOSH (2023b, pp. 23–24) summarized that:

> M&C evaluated exposures to maintenance workers using pre-D&D survey data, developed a bounding scenario for all work activities except those associated with Priority 1 drain lines, and calculated a dose of <1 mrem. Conservatively, NIOSH applies **its** model to **all** subsurface work at M&C, including work in most of Building 10 that was not associated with the Priority 1 drains.
>
> Regarding SC&A's concern about other types of work, when M&C did perform other work, such as replacing large pieces of machinery, they (or contractors) dug deeper holes. There is some potential that contaminants migrated into some of those soils, especially if they were close to a drain line. However, NIOSH does not consider that work extensive enough to be selected as the plausible bounding scenario.

5.3.2 SC&A response

The context of SC&A's comment (and its original finding 2 from the supplemental review) relates to the use of the Mound project data as a basis for the dust loading factor for M&C-wide exposure modeling, and the concern that it does not reflect the effect of confined spaces on the resuspension and concentration of airborne particulates and fumes. NIOSH has responded that it is committed to reviewing recent suggestions to upgrade its dust loading models, including enhancement factors and confined spaces, and will consider incorporating methods suggested by SC&A in their supplemental review. While the issues raised by NIOSH (e.g., proportion of operating buildings affected by confined spaces, proximity to radiological sources, and degree of contamination) are mitigating considerations, they would not change the overriding finding by SC&A that the proposed sitewide dust loading factor for M&C, as based on the Mound excavation project data, does not meet the Board's surrogate data policy in terms of equivalent site conditions.

Regarding the issue of other types of work (i.e., "non-drain line cleaning" (SC&A 2022, p. 21)), specifically the repurposing of large pieces of equipment, we address NIOSH's response in section 7.4 as part of our response to the WG's concern about AWE equipment.

5.4 SC&A/Work Group comment: Applying Mound surrogate data to dust loading factor

SC&A commented:

> NIOSH does not respond to the central question posed: In applying the Mound surrogate data to derive a dust loading factor, did they address confined space considerations? From a larger perspective, did they consider the impact of confined spaces on their modeled airborne resuspension of uranium and thorium? The answer appears to be "no" in both cases. Confined spaces represent a new issue that has not been addressed. [SC&A, 2023, pp. 8–9]

At the July 13, 2023, WG meeting, a Board member presentation stated (ABRWH, 2023a, slide 19):

- . . . M&C maintenance workers doing subsurface work routinely had to snake out and repair (cut, saw, grind, weld) underground pipes.
- These routine components of M&C operations also created additional sources of radioactive dusts and particulates, beyond those from the (Mound-based) dust-loading.
- The current NIOSH bounding model does not appear to account for these and should.

As the Board member explained (ABRWH, 2023a, slides 16–17):

> **The Mound database: Collected under different conditions than the M&C subsurface trenching**
>
> - The Mound project trenching data were collected outdoors on a country lane, whereas the M&C maintenance subsurface exposures, of course, took place indoors in Building 10.
> - As such, using the Mound data as surrogates for M&C violates one of the Criteria for the Use of Surrogate Data, adopted by the Board in 2014. . . .
>
> **The Mound database seems a poor fit for M&C**
>
> Because of the major differences in work environments between Mound and M&C – an outdoor, relatively placid country lane vs. an indoor, dirty, often muddy industrial worksite, respectively – this WG member believes the Mound database is a poor fit for M&C surrogacy.

5.4.1 NIOSH response: Applying Mound surrogate data to dust loading factor

> The hazards associated with working in confined spaces are not new to the field of industrial hygiene and were also recognized by M&C personnel. NIOSH is committed to reviewing recent suggestions to upgrade its dust loading models, including enhancement factors and confined spaces, and will consider incorporating methods suggested by SC&A in their supplemental review. In addition, as discussed by SC&A in *SC&A Commentary on NIOSH's Approach to Quantifying Outdoor and Indoor Airborne Dust Loadings*, airborne contamination levels can be modeled (i.e., bounded) up to a choking level [SC&A 2021, PDF p. 22], making the confined space effect on dust loading factors a TBD issue and not an SEC issue. This addresses SC&A's remaining issue with applying the Mound surrogate data to derive a dust loading factor. [NIOSH, 2023b, p. 24]

5.4.2 SC&A response

SC&A stands by its original finding 2 (SC&A, 2022) that NIOSH's proposed application of Mound project data for deriving the M&C dust loading factor does not satisfy the Board's surrogate data policy for site and process similarity given disparities between the sites for confined space conditions. The use of the Mound-based dust loading factor, as one of the three "legs of the stool" (ABRWH, 2023b, slide 15) for NIOSH's bounding intake approach for M&C may not be sufficiently accurate for that reason.

In support of its finding, SC&A provided examples of resuspension factors developed by national and international standards bodies based on experience with the effects of confined space atmospheres in working environments. In doing so, SC&A clearly acknowledges that this issue, by past practice and experience, is a TBD issue for which there are obviously means and information by which a more accurate dust loading factor can be derived. NIOSH does not directly accept or acknowledge that the Mound data should not be applied, as currently derived, but does accept that it will need to review "recent suggestions to upgrade its dust loading models, including enhancement factors and confined spaces, and will consider incorporating methods suggested by SC&A in their supplemental review" (NIOSH, 2023b, p. 24).

In its response to the WG on this issue (NIOSH, 2023b, pp. 33–35), NIOSH cites the contributions of Dr. Lynn Anspaugh to the "SC&A Commentary on NIOSH's Approach to Quantifying Outdoor and Indoor Airborne Dust Loadings" (SC&A, 2021) regarding the use of the Mound surrogate data at M&C. In that review, SC&A concluded that "the renovation indoor dust loading of 10^{-4} g/m^3 (100 µg/m^3) might include excavation and would seem to independently support NIOSH's use of 212 µg/m^3 as a reasonable estimate when applied to the M&C subsurface indoor excavation scenario and also to indoor excavation dust loading in general" (SC&A, 2021, p. 18).

As noted in SC&A's supplemental review and later responses, SC&A does not dispute the scientific validity of Dr. Anspaugh's work in support of SC&A's past review of the Mound dust loading factor, just that the Mound Study air monitoring was performed 15–20 feet away from the actual trench excavation and its air sampling results would not have been representative of the increased particulate resuspension expected within the trench due to confined space effects. This was the basis for SC&A's finding that the Mound study data would not satisfy the Board's

surrogate data policy because such monitoring information was not obtained in an equivalent manner as that of trenches and other confined space circumstances at M&C.

With SC&A's acknowledgment that this is essentially a TBD issue and NIOSH's acceptance that it will need to review SC&A's suggested options to revise its dust loading models for M&C, SC&A recommends that the issue of the dust loading factor for M&C be pended for resolution by the WG awaiting the results of that review.

6 Additional Intrusive Activity Information for Table 1, Comparison of AWE Sites

6.1 NIOSH summary of SC&A table 1 and response (table 2 of NIOSH, 2023b)

> In the *Supplemental Review of M&C Work Group Issues* [SC&A 2022], SC&A provided a table with the following five column headings: (1) AWE site, (2) source of exposure potential, (3) intrusive work activity (covered), (4) SEC class designated, (5) and reference. During the May 12, 2023, M&C Work Group meeting, NIOSH indicated it would provide information that could serve to update Table 1 with additional detail concerning intrusive activities and dose potential. [NIOSH, 2023b, p. 24]

NIOSH provided table 2, "Additional Information to Augment SC&A's *Comparison of AWE Sites* Table 1" (NIOSH, 2023b, pp. 25–29).

6.1.1 SC&A response

While SC&A has no reason to dispute the additional information provided by NIOSH to illustrate some of the additional intrusive activities that took place at other AWEs, it is unclear what NIOSH's purpose is for providing it at this time. An earlier AWE-by-AWE assessment in response to a WG question elicited a similar NIOSH response (NIOSH, 2020a, p. 13):

> NIOSH Conclusion: M&C operations were similar to operations at these other sites. Uranium was machined at most of these sites; thorium is documented to have been at over half of them. Residual-period tasks performed by workers at these other sites, including contaminated soil excavation and welding and torch-cutting in contaminated areas, have been evaluated. The pathways leading to internal exposures from alpha-emitting radionuclides such as uranium and thorium are identical for workers at all of these sites: the inhalation and ingestion of resuspended, contaminated dust.
>
> The methods proposed for M&C by NIOSH and SC&A are similar and consistent with those previously approved by the Board to bound worker exposures during residual periods, including developing ratios between materials with known concentration data and materials with historically unmeasured concentrations.
>
> The types of radioactivity, the crafts personnel who worked with it, and the tasks performed are found across all of the AWE sites. The worker radiation exposures

> and the applicability of the bounding methods during the M&C residual period do not stand out as unusual amongst AWE sites.
>
> Although the procedures used by NIOSH [ORAUT 2012] appear to be designed for routine exposures, NIOSH and the Board have adapted and relied upon them to bound non-routine exposures, such as those that occurred during M&C maintenance, or at other AWEs with foundries and steel mills.

The intent of SC&A's supplemental review table 1 was to take exception to this broad characterization by contrasting the pronounced and protracted level of intrusive activities by M&C maintenance workers during the residual period to those of workers at other AWEs. SC&A's disagrees with NIOSH's conclusion in its 2020 response that "the pathways leading to internal exposures from alpha-emitting radionuclides such as uranium and thorium are identical for workers at all of these sites: the inhalation and ingestion of resuspended, contaminated dust" (NIOSH, 2020a, p. 13). It is clear to SC&A, as highlighted in its supplemental review and subsequent papers, that M&C's maintenance activities more closely resembled the renovation activities highlighted in NUREG/CR-5512 rather than the passive exposure scenarios based on contaminant resuspension derived from OTIB-0070 and TBD-6000 for these other sites. As noted by SC&A in its April 2023 response paper:

> While the question of how intrusive work activities may have been at M&C is obviously a subjective one, SC&A believes there is clear evidence that maintenance activities during the M&C residual period were unique in terms of their level of intrusiveness (excavations, pipe cleaning, pipe cutting), work environments (confined spaces), and uncertain or unknown source terms (contaminated pipe sediments, presence of coagulants, contaminated scale, confined space concentration of airborne particulates). While other AWE sites, such as Carborundum and Dow Madison had residual work activities (e.g., welding, torch-cutting, soil excavation) similar to those of M&C maintenance workers, the difference is the aforementioned level of intrusiveness and uncertain or unknown source terms. Ultimately, NIOSH acknowledges the "high exposure conditions" and "unknown contamination sources" that may have been associated with such M&C intrusive activities (NIOSH, [2023a], p. 17) in developing its bounding models. [SC&A, 2023, p. 11)]

The fact that workers at other AWEs performed, for example, general machine shop maintenance, periodic lathe grinding, routine steel plant maintenance, periodic excavations, and soil removals, and handled heavy equipment, as outlined in NIOSH's table 2 (NIOSH, 2023b, pp. 25–29), is not surprising, but these activities do not rise, in SC&A's judgment, to the level, nature, and frequency of intrusive activity that typified M&C maintenance activities.

SC&A's judgment appears to be supported by the basis for NIOSH's original decision to consider specific exposure models to address worker-identified exposure pathways at M&C that were sufficiently intrusive as to be inconsistent with assumptions based on OTIB-0070 and TBD-6000 resuspension methods (NIOSH, 2018, p. 2):

> From October 24 through October 26, 2017, NIOSH, Oak Ridge Associated Universities (ORAU), and Sanford Cohen & Associates (SC&A) personnel interviewed 12 former M&C workers and individuals knowledgeable about maintenance work. Interviewers asked questions regarding the frequency and duration of work, including HVAC, utility and drain line maintenance, and new equipment installations. During the interviews it became apparent that Building 10 experienced recurring issues with water drainage (ORAUT [2017a], PDF p. 6; [2017b], PDF p. 5; [2017c], PDF p. 8; [2017d], PDF p.7; [2017e], PDF, p. 5) and underwent multiple equipment change-outs that necessitated subsurface and overhead work. **Although this work was sporadic and sometimes emergent in nature, it exposed workers in a manner that did not agree with the method described in the SEC-00236 ER (i.e., surface contamination resuspension).** [Emphasis added.]

While all of these AWEs (for their residual periods, with the exception of Norton, Linde, and Vitro) did not necessitate special bounding models for any of the intrusive activities mentioned in table 2 (NIOSH, 2023b, pp. 25–29), M&C required no less than six such models to address intrusive activities that could not be readily bound by the more passive resuspension and exposure assumptions available in OTIB-0070 and TBD-6000. SC&A does not question NIOSH's ability to adapt such methods designed for more passive exposure scenarios to what are clearly unique and substantial intrusive activities at M&C but does disagree with the generalization that M&C's maintenance activities were little different than those found during the residual periods for these other AWEs.

SC&A finds that *some* of the residual period activities noted by NIOSH for these other AWEs bear *some* resemblance to those at M&C. However, by its action to derive six exposure models for M&C, NIOSH itself acknowledges that these intrusive maintenance activities were sufficiently distinct from the assumed passive scenarios of OTIB-0070 and TBD-6000, and differed from experience at other AWEs, to warrant special treatment from an exposure bounding standpoint.

7 M&C Work Group Concerns

NIOSH selected specific concerns to address based on WG concerns expressed during its recent deliberations and presentations. SC&A addressed those that have been raised previously in its reviews and responses in support of the WG. This paper addresses issues such as worker protection, claimant-favorable assumptions (i.e., extreme conservatism), and confined spaces in the sections centered on those topics. Sections 7.1–7.6 address the balance of issues raised by NIOSH as WG concerns, for which SC&A has previously provided comments, and for which Board review and judgement would be rendered.

7.1 Work Group concern: Data applicability

The following excerpts show data applicability concerns that have been presented at recent Advisory Board and M&C WG meetings.

The M&C WG Chairperson's presentation at the August 16, 2023, Advisory Board meeting:

- NIOSH applies 1995 D&D survey data as basis for an upper bound for residual period exposure. For radiological data from one time period to be considered informative about exposures during another time period, there should be sufficient similarity of conditions and processes between the two periods. [ABRWH, 2023b, slide 19]

A Board member's presentation at the July 13, 2023, M&C WG meeting:

- M&C maintenance workers were given no radiological health and safety (H&S) information or training during the residual period, and only occasionally received personal protective equipment (PPE). Also, after 1983, following the NRC's removal of radiation work restrictions for Building10, they believed they were not working under hazardous radiological conditions.

- Thus, certainly after 1983, M&C maintenance workers could not be expected to have followed the ordinary, common-sense precautions that any intelligent person would follow when working on and near the piping in a potentially hazardous radiation environment.

- **The Result:** The M&C maintenance workers would be expected to experience greater doses of radiation than assessed in the NIOSH bounding model. [ABRWH, 2023a, slide 10]

7.1.1 NIOSH response: Data applicability

If NIOSH identified **air** monitoring during an operation (e.g., grinding) in one time period and tried to apply that data to a different time period and operation (e.g., welding), then the Work Group's concern could be valid. Similarly, if NIOSH used Priority 3 drain line data to bound exposures during work with the Priority 1 **source term**, then again, the Work Group would have a valid data applicability argument. On the contrary, NIOSH validated a bounding source term (pre-D&D to the extent a fuel pin was still present) and applied appropriate resuspension/dust loads for the various operations described by interviewees.

Furthermore, one of the primary reasons the Weston [1996b] drainage system characterization (the report where NIOSH obtained the subsurface data) was performed before D&D in 1995, was to quantify the risk to ongoing drain line maintenance workers as documented in the following excerpt:

> *The drainage system investigation was performed immediately after the Pilot-Scale Interiors Remediation Project and prior to the Full-Scale Interiors Remediation Project. An aggressive investigation schedule was implemented in support of Nuclear Regulatory Commission (NRC) license termination and* ***to assess the potential for inadvertent exposures to non-radiological workers performing routine drainage system maintenance****.* [Weston 1996b, PDF p. 7]

> The excerpt above confirms that drain line maintenance was still being performed at the time of the 1995 survey. In fact, after these data were obtained, and because of the results, M&C implemented controls on future drain line maintenance using three levels of priority designation [Weston 1996b, PDF p. 29].
>
> Although the frequency of clogged drains may have increased over time as the building aged, the techniques employed to unclog drains did not change throughout the residual period (*i.e.*, snake technology did not change significantly from 1968 to 1995).
>
> [NIOSH 2023b, pp. 30–31]

7.1.2 SC&A response

A central thesis of SC&A's supplemental review for M&C is founded on the Board's deliberations during the Linde Ceramics SEC review:

> The use of a high exposure or concentration value based on a set of specific workplace [pre-D&D sediment] data to bound or represent that of other workers in a facility or on a site, particularly over a lengthy time period, would not be appropriate if their exposure potential could be higher, conditions were different, or if there is a lack of information upon which to make that judgment. [SC&A, 2022, p. 36]

In testing this thesis, SC&A made several key findings that highlighted conditions or processes that would have potentially affected the source term for M&C maintenance worker exposure during the residual period that were not considered in the application of the 1995 pre-D&D data in NIOSH's exposure modeling.

SC&A found that coagulant oil could have introduced higher concentrations of covered uranium and thorium from AWE operations into the drains, specifically during Wire Department operations in Building 10 up through 1981. NIOSH initially disputed this finding but now has "determined that it can describe plausibly, and bound exposures associated with unclogging pipes while accounting for the effects of introducing a nonradioactive coagulant to the drain line source term" (NIOSH, 2023b, p. 5). This conclusion is premised on a series of explanations and assumptions that SC&A has not accepted as valid (refer to the preceding discussion regarding coagulants in section 3). As SC&A emphasized in its supplemental review and subsequent responses, the regular discharge of a known coagulant into the M&C drainage system during Building 10 operations that led to the cited clogging of pipes represents a condition and process that would have potentially consolidated and concentrated existing uranium and thorium within the drainage system in the earlier M&C residual period, which may have led to an elevated source term not addressed by NIOSH's inside subsurface exposure model.

SC&A found that that cutting of drain lines with contaminant scale found to be as high as 1,000,000 dpm/100 cm^2 may be a systemic issue for M&C exposure potential, a concern exemplified by DOE in its hazard assessment for the Bridgeport Brass AWE. NIOSH disputes that this is a systemic issue at M&C but has provided only that single high measurement and a few spot samples of scale contaminant measurements to back its claim.

The cutting, cleaning out, and repair of piping with such interior surface contamination levels would have led to the likely volatization and airborne suspension of such contaminants into the breathing zone of maintenance workers performing these intrusive activities. This condition and exposure pathway are not addressed by NIOSH in its existing inside subsurface exposure model based on resuspension of contaminated sediment as the bounding source term (though NIOSH has now performed a cursory exposure analysis based on parameters from DOE's Bridgeport Brass hazard analysis).

Regarding confined spaces, SC&A stands by its original finding 2 (SC&A, 2022) that NIOSH's proposed application of Mound project data for deriving the M&C dust loading factor does not satisfy the Board's surrogate data policy for site and process similarity given disparities between the sites for confined space conditions. Therefore, the use of the Mound-based dust loading factor as one of the three "legs of the stool"[8] (ABRWH, 2023b, slide 15) for NIOSH's bounding intake approach for M&C may not be sufficiently accurate for that purpose. While not a data back-application issue, it raises a similar data applicability concern. While NIOSH continues to dispute the significance of this issue for its dust loading model, it has agreed to review "recent suggestions to upgrade its dust loading models, including enhancement factors and confined spaces, and will consider incorporating methods suggested by SC&A in their supplemental review" (NIOSH, 2023b, p. 24).

NIOSH questions the distinction SC&A draws between how the exposure potential of D&D workers would have been less than M&C maintenance workers when performing pipe cutting and removals. However, its January 2023 response paper (NIOSH, 2023a) references a worker account that supports the interpretation that the latter's job was also to clean the pipe prior to repair (versus removal for D&D), and that, therefore, there would have been a difference in physical proximity and source term. It is clear to SC&A that M&C workers performed more intrusive work with more proximity of exposure, without the radiological controls that would have mitigated that exposure.

The preceding forms a key basis for SC&A's finding 1 that "the back application of a high 1995 sediment survey result to bound inside subsurface activities is not adequately supported by information for M&C worker activities from the earlier residual time period" (SC&A, 2022, p. 36). NIOSH's interpretation of data applicability, specifically the conditions and processes in place during the 27-year M&C residual period versus those in 1995 (when the pre-D&D sediment samples were obtained), is in question here. While these 1995 source term concentrations, at the 95th percentile, were deemed by NIOSH as the upper bound for all workers conducting maintenance work inside M&C buildings, SC&A has taken issue with whether facility conditions and processes during the residual period may have been sufficiently different than those in 1995 to compromise this back-application of radiological source term.

7.1.2.1 Linde Ceramics precedent

The precedent for this concern can be found with the Linde Ceramic SEC Board recommendation and U.S. Department of Health and Human Services (HHS) designation of the

[8] The other two are source term and occupancy/time.

SEC class for Linde's renovation period. As with M&C, NIOSH believed it had sufficient and representative D&D-era data to apply to the prior residual period (HHS, 2011, p. 4):

> Based on available Linde decontamination and decommissioning (D&D) survey data and residual radiation surveys conducted in association with FUSRAP activities, NIOSH believed it had the necessary data to support bounding internal exposures for uranium, uranium progeny, and radon during the residual period. Radioactive operations terminated at the end of the operational period and source-term materials were removed from the site. NIOSH's position was that the application of these survey data would result in overestimates of doses during general activities, as well as during the highest potential exposure conditions for the period evaluated in the ER (January 1, 1954 through July 31, 2006).

As with M&C's residual period, NIOSH had proposed to apply D&D-era survey data as the basis for developing an upper bound source term for Linde's renovation period (HHS, 2011, p. 4):

> NIOSH has determined, and the Board concurred, that there was the potential for exposure to significant dose levels during the renovation period from 1954 through 1969. To account for this potential of exposure, NIOSH proposed using survey data taken during the decontamination activities (which took place during the operational period) as the basis for developing an upper bound for the exposure. **In order for radiological data from one time period to be considered informative about exposures during another time period, there should be some similarity of conditions and processes between the two periods.** The NIOSH ER regarded the decontamination activities at the end of the operational period to be sufficiently similar to renovation activities during the residual period. Therefore, NIOSH believed that radiological data from the former were informative about exposures during the latter. Although NIOSH has proposed claimant-favorable dose reconstruction methods in its ER for workers at the Linde site during the renovation period, **the uncertainty (as discussed by the Board) concerning what activities actually took place during renovation and the impact such activities might have had on the resulting dose levels suggests that the dose reconstruction methods may not account for all exposure scenarios during building renovation**. [Emphasis added.]

The pipe cutting and cleaning *activities* may have been similar over time, but the *conditions and processes* would have varied due to potentially different source terms and exposure pathways during the pre-1995 M&C residual period. These include the regular presence of coagulant in the drainage system; the presence of radioactive scale; the movement, maintenance, and repurposing of equipment; and presence of confined spaces within which maintenance work on subsurface drain pipes and utilities may have been conducted. Furthermore, to illustrate a distinction relevant to M&C, HHS found the following for Linde Ceramics (HHS, 2011, pp. 4–5):

> Specifically, some Board members noted that the decontamination activities were conducted with the knowledge that workers were exposed to a radiological environment. Consequently, radiological control measures appropriate for the time were likely utilized during decontamination activities. On the other hand,

> renovation activities during the residual contamination period were conducted in what was expected to be a non-radiological environment, so no radiological control measures would be adopted. Additionally, worker accounts describe removal of heavy equipment and other activities during the renovation period that would be expected to reveal contaminated surfaces that would not have been decontaminated during the decontamination efforts at the end of the operational period. Therefore, the Board was not convinced that radiological data from the decontamination efforts during the operational period were sufficiently informative about exposures in the renovation period. Based upon this concern, the Board determined that such data could not be used in dose reconstructions for the renovation period.

Finally, HHS concluded the following for Linde Ceramics (HHS, 2011, p. 5):

> There is insufficient support for NIOSH's position that the decontamination activities at the end of the operational period were sufficiently similar to renovation activities during the renovation period. Because of the proposed differences between the two periods, NIOSH cannot be certain that the radiological data from the decontamination efforts during the operational period sufficiently account for exposures during the renovation period. Therefore, it is not feasible to reconstruct radiation doses with sufficient accuracy for the renovation period.

A judgment on the question of whether there is sufficient similarity of conditions and processes between the D&D-era during which the 1995 characterization sample were completed and the preceding M&C residual period maintenance activities resides with the Board, as it did for Linde Ceramics. But it is clear that there are uncertainties related to source terms and exposure pathways for the M&C residual period that may not be addressed with sufficient accuracy by NIOSH's current inside subsurface bounding model.

7.2 Work Group concern: Worker protection

An August 16, 2023, M&C WG presentation stated that "maintenance workers were unaware of radioactive contamination and operated without radiological controls and health physics oversight" (ABRWH, 2023b, slide 7).

7.2.1 NIOSH response: Worker protection

Work practices such as those specified in the WG's concern do not affect the source term of *any* of the "three legs of the stool" that form NIOSH's bounding method because the M&C model does not assume any worker training or the use of engineering and administrative controls (NIOSH, 2023b, p. 31).

7.2.2 SC&A response

As explained in section 7.1, citing the Linde Ceramics SEC precedent, this comment is directed at the overall uncertainties of comparing the processes and conditions of one time period to another at a site:

> In order for radiological data from one time period to be considered informative about exposures during another time period, there should be some similarity of conditions and processes between the two periods. [HHS, 2011, p. 4]

The distinct differences among how workers conducted their work, the conditions and processes of that work, and the radiological controls under which they performed their activities lead to greater uncertainty over a comparison between the D&D-era exposure potentials and those of the pre-1995 residual period. To paraphrase a key basis for the SEC designation for Linde Ceramics, the corollary question for M&C that the Board would address is whether the radiological data from the 1995 pre-decontamination surveys were "sufficiently informative" (HHS, 2011, p. 5) about exposures in the preceding 27 years of the residual period.

7.3 Work Group concern: Claimant-favorable assumptions

An August 16, 2023, presentation states (ABRWH, 2023b):

> **How does M&C compare with other AWEs?**
>
> . . .
>
> - SC&A finds M&C to be comparable to facilities with more intrusive activities, e.g., those related to renovation as defined by NRC and found at Linde Ceramics (SEC class designee).
>
> - Why is this important?
>
> - Standard models from OTIB-0070 and TBD-6000 assume more passive worker activities related to occupancy, like other non-SEC AWEs. [slide 9]
>
> . . .
>
> - NIOSH use of "extreme conservatism" to account for M&C's "intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a) results in a high bounding value – but is it plausible? [slide 12]

7.3.1 NIOSH response: Claimant-favorable assumptions

The information presented at the August 16, 2023, Advisory Board meeting is inaccurate, especially regarding OTIB-0070. It could be argued that TBD-6000 allows default assumptions which may be considered more passive, but OTIB-0070 makes no such assumptions and requires the user to make a thoughtful selection. It is a document that provides options to select models that are as aggressive or passive as appropriate.

SC&A and the Work Group are misinterpreting NIOSH's use of the phrase "extreme conservatism" to mean implausibly high. NIOSH is using conservative assumptions that are appropriate for a bounding scenario. The maximum predicted committed effective dose equivalent is still only 71 mrem which is not

> implausibly high and is on par with normal background radiation levels every American experiences. [NIOSH, 2023b, p. 32]

7.3.2 SC&A response

The context of the Board's comment regarding OTIB-0070 and TBD-6000 is the application of these modeling guides in practice, specifically for M&C. As noted earlier, SC&A questions the application of such standard modeling approaches for the unique circumstances at M&C during the residual period, where more intrusive activities, or unique conditions or processes, make the "thoughtful selection" (NIOSH, 2023b, p. 32) of appropriate resuspension and dust loading factors important.

NIOSH itself noted that OTIB-0070 had not been adapted in the ER to adequately consider the more intrusive activities described by M&C workers:

> During the first day of interviews, NIOSH interviewed [redacted for privacy] and a knowledgeable health physicist. The information indicated that the workers at M&C conducted more intrusive work into subsurface areas than previously considered in the ER. The ER models resuspension (OTIB-0070) and does not specifically address potential exposures from digging, snaking/replacing clogged drain lines, or repurposing M&C equipment (e.g., removing and replacing mill units). [NIOSH, 2017b, PDF p. 2]

This subsequently led to NIOSH adding its six bounding models for such exposures.

Similarly, SC&A expressed reservations in its 2021 review regarding the use of a generic dust loading value, 212 ug/m^3, from OTIB-0070 for outdoor and indoor excavations at various facilities and sites, noting that such assumptions should be uniquely evaluated at each site of proposed use (SC&A, 2021, p. 12). NIOSH agreed with SC&A that "one size will not fit all," and indicated that it "will address this further during the next ORAUT-OTIB-0070 revision" (NIOSH, 2022, p. 5).

SC&A's response to NIOSH's response on the application of extreme conservatism in support of its exposure modeling is incorporated in section 8.1 of this paper.

7.4 Work Group concern: AWE equipment

An August 16, 2023, Board meeting presentation states (ABRWH, 2023b, slide 10):

> **What were typical intrusive activities and exposure pathways during M&C residual period?**
>
> . . .
>
> - Maintenance, movement, and replacement of repurposed AWE equipment

7.4.1 NIOSH response: AWE equipment

> NIOSH has previously responded to this concern. Texas Instruments reported to the NRC that the AWE operations (Buildings 3, 4, and 10) were decontaminated and decommissioned and that all radioactive materials were removed during the

> period from 1955 to 1968; the largest Building 10 cleanup effort occurred at the end of 1958. "…contaminated noncombustible scrap material and machinery were collected in 55-gallon steel drums and disposed of through authorized agencies or buried on-site in compliance with 10CFR20.304" [Sowell 1985, PDF p. 12]. [NIOSH, 2023b, p. 32]

7.4.2 SC&A response

NIOSH's response does not address the potential exposure pathway posed to M&C maintenance workers from the repurposing, movement, and subsequent maintenance of AWE-era equipment during the residual period. As detailed by SC&A's footnote 7 in the supplemental review (SC&A, 2022, p. 14, n. 7):

> Routine maintenance on equipment is cited by former workers ([ORAUT, 2017e], p. 5; [ORAUT, 2017f], p. 3; [ORAUT, 2017g], p. 4), and was performed by the M&C Repair and Maintenance group. It was also identified by NIOSH as not being addressed by the ER resuspension models (OTIB-0070) and involved "repurposing M&C equipment (e.g., removing and replacing mill units)" ([NIOSH, 2017b], p. 1). A former worker noted that relocating equipment in Building 10 was a regular activity that typically took place on weekends ([ORAUT, 2017e], p. 12). The status of equipment carried over from the pre-1968 AWE operational period is not addressed explicitly in the ER. It should be assumed that any equipment used in the operational period, prior to D&D, may have had internal contamination, as well as contamination under it, to which maintenance workers would have been later exposed when servicing [or repurposing] that equipment or moving it. This issue was raised during Board discussions about the Linde SEC by a Board member with firsthand experience, who found that when workers "were actually moving, removing production processes . . . we always found the most contamination was in the footprint of these processes" (ABRWH, 2011, pp. 267–268). For M&C, it is reported that compressed air was typically used to clean mechanical equipment (Elliott & Lorenzen, 2017), which could have resuspended internal contaminants. The concentration of this contamination may be higher than that of surface contamination surveys conducted in 1967–1968 and could have included uranium and thorium particulates.

While NIOSH further clarified that "a few substantial pieces of equipment were left in place with residual contamination in inaccessible locations" (NIOSH, 2023a, p. 7), SC&A (2023) responded further:

> SC&A's question, here, regards the repurposing of M&C equipment, which does not appear to be addressed in terms of covered exposure to M&C workers performing later maintenance on that equipment during the residual period. While the SEC-00236 ER does cite the contamination surveys performed and that a few substantial pieces of equipment were left in place with residual contamination in inaccessible locations, NIOSH does not address whether later repurposing of M&C equipment may have led to exposures to the workers performing the

> repurposing and whether later maintenance on such equipment would have been a potential exposure pathway. [SC&A, 2023, p. 10]

In its August 2023 response, NIOSH continues to contend that given the D&D activities and surveys conducted, "all radioactive materials were removed during the period from 1955 to 1968," and that contaminated equipment was disposed of as waste (NIOSH, 2023b, p. 33):

> NIOSH has previously responded to this concern. Texas Instruments reported to the NRC that the AWE operations (Buildings 3, 4, and 10) were decontaminated and decommissioned and that all radioactive materials were removed during the period from 1955 to 1968; the largest Building 10 cleanup effort occurred at the end of 1958. "…contaminated noncombustible scrap material and machinery were collected in 55-gallon steel drums and disposed of through authorized agencies or buried on-site in compliance with 10CFR20.304" [Sowell 1985, PDF p. 12].

However, such D&D activities would not have addressed residual contamination under and within AWE-era machinery and equipment that remained, which may have been later moved and repurposed by M&C workers.

SC&A finds that a significant source of exposure to M&C maintenance workers may have been residual contamination under and within AWE-era machinery and equipment that was not decontaminated and decommissioned. The application of a bounding intake without consideration of such identified source terms and potential exposure pathways needs to be reviewed by the WG from the standpoint of completeness, sufficient accuracy, and plausibility.

7.5 Work Group concern: Burial area

An August 16, 2023, presentation states (ABRWH, 2023b, slide 10):

> **What were typical intrusive activities and exposure pathways during M&C residual period?**
>
> . . .
>
> - Excavating contaminated soils, including those near or within radioactive waste burial sites

7.5.1 NIOSH response: Burial area

> NIOSH developed a model to bound exposure during subsurface work in areas outside of Building 10 including the burial ground. However, during Work Group discussions NIOSH agreed to assign doses from the Building 10 subsurface model to all workers since workers constantly moved about the site and because those doses were more claimant favorable. In addition, at the July 13, 2023, M&C Work Group meeting, the Work Group conceded other exposures including those from the burial ground with the following statement: (NIOSH 2023b, pp. 33-34)
>
> > *Attention to subsurface exposures in Building 10. NOTE: The Work Group (WG) and staff generally agreed that the greatest exposures to the M&C maintenance workers came from the subsurface work in Building 10.*

> *Since the NIOSH bounding model is applied to all claimants, further discussion during this presentation focuses solely on such subsurface work and whether or not it is bounded.* [ABRWH 2023a, PDF p. 8]

If the Work Group is aware of new technical information related to the burial ground, NIOSH requests a copy so we may consider it.

[NIOSH, 2023b, pp. 32–33]

7.5.2 SC&A response

The WG may want to add its considerations in response to this issue, but SC&A finds no concern, on its part, in the presentation material cited by NIOSH. The excavation of subsurface soil within the burial ground area represents an intrusive activity that may have had exposure potential to those workers conducting the excavation. However, the question of whether NIOSH's bounding approach for such potential exposures using a blended source term has been addressed by SC&A and the WG based on NIOSH's response paper and subsequent WG discussions. SC&A has no new technical information to add related to the burial ground.

7.6 Work Group concern: Confined spaces and applying Mound surrogate data

SC&A's comment and NIOSH's response have been addressed in section 5 of this paper, with a more specific treatment in section 5.4.

8 Other Issues of Significance

In its supplemental review and followup responses, SC&A raised several additional issues relevant to sufficient accuracy and plausibility as they pertain to NIOSH's proposed bounding models for M&C being reviewed by the WG. These were not addressed fully in NIOSH's August 2023 response.

These include NIOSH's stated application of extreme conservatism in its bounding models and reference to assumed programmatic performance to substantiate the conservatism of the 95th percentile soil contamination value being used. Sections 8.1 and 8.2 summarize these two issues, respectively.

8.1 Application of extreme conservatism

NIOSH refers to the "extreme conservatism in its modeling to account for intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a, p. 17), but this NIOSH approach employs a maximized value to compensate for the lack of any source term and monitoring data for inside subsurface potential exposures for the entirety of the residual period up to 1995. SC&A addressed the plausibility of this approach in its Line of Inquiry 3 from its supplemental review:

> Are the available source term, survey data, and other information applied by NIOSH to support its dose bounding methods sufficiently accurate and plausibly applied? [SC&A, 2022, p. 7]

SC&A's assessment of this question can be found in its April 2023 response (SC&A, 2023, pp. 15–16):

> A guiding principle that NIOSH follows for addressing the "uncertainty around the work performed" or the "complete understanding of the work performed" is that it is "NOT an issue when the bounding doses are very low, and specifically, during AWE residual periods such as at M&C" (NIOSH, [2020b], slide 14). However, as pointed out by SC&A's supplemental review, the question of determining a bounding dose in the absence of sampling data during the AWE residual period and applying sufficient conservatism to it is not without precedent and carries with it the question of plausibility. As pointed out during the Board's Linde review, if "carried to an extreme, we could take any site . . . and we could come up with what we think is the highest possible exposure at that site that would occur, and that would be bounding, and apply that to everybody that ever worked at the site" (ABRWH, 2011, p. 129). However, the essential questions, as the former Board Chair put it, are "is that a plausible bound? And then, who are we trying to characterize?" (ABRWH, 2011, p. 129).
>
> NIOSH's response, that it has "incorporated extreme conservatism in its modeling to account for intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a, p. 17) at M&C for the residual period, raises the very concern raised by Dr. Melius during the Linde AWE proceedings that contributed to the Board's decision on that SEC evaluation. In the absence of source term and monitoring data for the facility time period in question, is it plausible to incorporate what NIOSH terms "extreme conservatism" in its bounding value for inside subsurface exposures based on information from a much later time frame (27 years), from a different operation (pre-D&D), and with different work conditions when attempting to address what NIOSH terms "intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources"? (NIOSH, [2023a], p. 17)?
>
> While NIOSH notes that M&C dose estimates are relatively low and it has "a more complete data set to characterize M&C and a better understanding of M&C maintenance work than we had with Linde" (NIOSH, [2023a], p. 24), it has not addressed the increased exposure potential posed by confined space atmospheres, nor does it similarly consider the implications of coagulant oil discharges and airborne contaminant scale releases to its exposure pathway analyses. NIOSH may claim that the extreme conservatism of its modeling would bound even these exposure pathways, but in the absence of validating information, such a claim may be considered by the work group to be unfounded and implausible.

In its August 2023 response to a WG concern, NIOSH responded on this issue (NIOSH, 2023b, p. 32):

> SC&A and the Work Group are misinterpreting NIOSH's use of the phrase "extreme conservatism" to mean implausibly high. NIOSH is using conservative assumptions that are appropriate for a bounding scenario. The maximum

> predicted committed effective dose equivalent is still only 71 mrem which is not implausibly high and is on par with normal background radiation levels every American experiences.

SC&A citation of NIOSH's explanation for its use of extreme conservatism was literally taken from its response to a key SC&A's question: "The sediment readings taken in 1995 from a Priority-1 pipe obviously had a high uranium concentration, but is it the bounding case for all inside subsurface activities for the previous 27 years of the residual period?" (SC&A, 2022, p. 23).

NIOSH responded that it "is not back-applying conservative D&D measurements" (NIOSH, 2023a, p. 16). Instead, "NIOSH is back-applying measurements taken by M&C and NRC Contractors before D&D that they used to characterize the area to determine the maintenance and subsequent D&D work controls," and "in addition, NIOSH incorporated extreme conservatism in its modeling to account for intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a, pp. 16–17).

Given the breadth and depth of unknowns and uncertainties imbedded in this bounding approach, it will be incumbent on the Board to gauge whether this represents a plausible means to define an upper bound for past exposures of M&C maintenance workers during the 27 years in question. Likewise, if NIOSH's bounding model cannot account for M&C's "intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" (NIOSH, 2023a, p. 17) without resorting to extreme conservatism, the question of sufficient accuracy becomes important.

8.2 Conservatism of 95th percentile soil contamination value

SC&A provided observation 2 in its supplemental review: "References to the M&C safety and health manual, NRC inspection results, operator training, and other programmatic considerations do not necessarily substantiate the conservatism of the 95th percentile soil contamination value being applied" (SC&A, 2022, p. 35).

NIOSH observed in an earlier response to WG comments that, "although comprehensive sample data used to characterize earlier periods did not become available until 1983–1995, NIOSH is aware of the safety program that was in place during the residual period" (NIOSH, 2020a, p. 17). NIOSH proceeded in that response and others to "make the case that M&C's area monitoring **assures that the 95th percentile soil-contamination value is conservative** based on routine surveys of Building 10 during the first 14 years of the residual period (1968-1981)" (NIOSH, 2021, pp. 7–8; emphasis added).

In response to SC&A's observation 2, NIOSH noted that it "was not using the M&C Safety and Health manual, NRC inspection results, operator training, and other programmatic considerations to ***justify*** **using the 95th percentile**" (NIOSH, 2023a, p. 23; emphasis added).

In its April 2023 response, SC&A emphasized that "whether using these program documents to justify, or to demonstrate, corroborate, illustrate, or show that such monitoring procedures and oversight 'assures' that the 95th percentile soil contamination value is conservative is a distinction with little difference" (SC&A, 2023, p. 12). SC&A reaffirmed that it stands by its

observation that the program references NIOSH cites "do not necessarily substantiate the conservatism of the 95th percentile soil contamination value being applied" (SC&A, 2022, p. 37).

9 Conclusion

In its presentation to the full Advisory Board on August 16, 2023, the M&C WG summarized its unresolved concerns for the M&C Petition 00236 evaluation (ABRWH, 2023b, slide 19):

- Intrusive work activities by maintenance workers at M&C during the residual period led to potential exposures for which there are no available monitoring data.

- NIOSH applies 1995 D&D survey data as basis for an upper bound for residual period exposure. For radiological data from one time period to be considered informative about exposures during another time period, there should be sufficient similarity of conditions and processes between the two periods.

- Although NIOSH has proposed a claimant-favorable "inside subsurface" bounding concentration (6,887 pCi/g), there remains uncertainty about source terms and exposure pathways during the residual period [prior to pre-D&D characterization], 1968–1997.[9]

- There is insufficient information available to account for the exposure contribution of confined spaces, pipe scale releases, and released coagulants in a workplace not controlled as a radiation environment, unlike that of the later D&D era at M&C from which NIOSH draws its data.

- The application of "extreme conservatism" in formulating the proposed upper bound concentration to account for "intrusive activities, high exposure conditions, uncertain facility activities, or unknown contamination sources" may not be a plausible approach to compensate for inadequate or insufficient information.

The WG's proposed conclusion is (ABRWH, 2023c, slide 15):

> Because of the identified differences between the two periods (residual vs. D&D era), there is insufficient basis to conclude that radiological data from D&D efforts (including pre-D&D surveys) are sufficiently informative about exposures arising during the entirety of the M&C residual period to be applied in the manner proposed by NIOSH.

[9] The residual period prior to pre-D&D characterization, as noted, is actually 1968–1995.

SC&A's review of NIOSH's August 22, 2023, response paper did not identify information or analyses that materially affect the WG's concerns and proposed conclusion.

SC&A concludes NIOSH has a path forward to address the confined space issue: (1) it is acknowledged as a TBD issue, and (2) SC&A's supplemental review identified options for revised resuspension factors (and accordingly a derived dust loading factor). However, uncertainties remain for source terms related to in-pipe contaminated sediments (due to the presence of coagulants) and in-pipe interior surface contamination (scale) during the pre-1995 M&C residual period. These source terms are not accounted for in the proposed inside subsurface bounding model, and application of the compensatory "extreme conservatism" measures defined by NIOSH may not be considered sufficiently accurate and plausible by the Board. These source term uncertainties are compounded by likely disparities in the exposure potential between M&C maintenance workers and D&D workers, undetermined worker exposure due to repurposing and maintenance of AWE-era machinery and equipment, and the acknowledged intrusiveness of M&C maintenance worker activities compared with other AWEs.

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