SC&A S. COHEN & ASSOCIATES
AN EMPLOYEE-OWNED COMPANY

July 16, 2006

Mr. David Staudt
Centers for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Subject: Contract No. 200-2004-03805, Task Order 1: Review of the NIOSH Site Profile for the Mound Laboratory Site, SCA-TR-TASK1-0012

Dear Mr. Staudt:

SC&A is pleased to submit to NIOSH and the Advisory Board our draft *Review of the NIOSH Site Profile for the Mound Laboratory Site*, commonly referred to as the Mound Site Profile.

If you have any questions or comments on this report, please contact John Mauro at 732-530-0104. We look forward to discussing this draft report with NIOSH and the Advisory Board.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
Advisory Board Members
L. Wade, PhD, NIOSH
L. Elliott, NIOSH
J. Neton, PhD, NIOSH
S. Hinnefeld, NIOSH
L. Homoki-Titus, NIOSH
A. Brand, NIOSH
J. Broehm, NIOSH
L. Shields, NIOSH
A. Makhijani, PhD, SC&A
H. Behling, SC&A
M. Thorne, SC&A
H. Chmelynski, SC&A
D. Chan, SC&A
J. Fitzgerald, Saliant
J. Lipsztein, SC&A
K. Robertson-DeMers, CHP, Saliant
S. Ostrow, PhD, SC&A
K. Behling. SC&A
Project File (ANIOS/001/12)

1608 SPRING HILL ROAD, SUITE 400 • VIENNA, VIRGINIA • 22182 • 703.893.6600 • FAX 703.821.8236

ACRONYMS AND ABBREVIATIONS

Advisory Board	Advisory Board on Radiation and Worker Health
AP	Anterior-Posterior
AEC	Atomic Energy Commission
AEDE	Annual Effective Dose Equivalents
AMAD	Activity Median Aerodynamic Diameter
BIO	Basis for Interim Operations
Bq	Becquerel
BWXT	BWX Technologies, Inc.
CAM	Continuous Air Monitor
CEDE	Committed Effective Dose Equivalent
CFR	*Code of Federal Regulations*
Ci	Curie
cpm	Counts per minute
D&D	Decontamination and Decommissioning
DAC	Derived air concentration
DCF	Dose correction factor
D_L	Decision Level
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
dpm	Disintegrations per Minute
DR	Dose Reconstructor
DTPA	Diethylenetriaminepentaacetate
EDS	Energy Dispersive X-ray Spectroscopy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
GI	Gastrointestinal
GSD	Geometric Standard Deviation
HHS	Health and Human Services
HPNO	Health Physics Number
HPO	Health Physics Office
HT	Elemental Tritium
HTO	Tritium Oxide or Tritiated Water

ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
keV	Kiloelectron Volt
kVp	kilovolts peak
LANL	Los Alamos National Laboratory
LAT	Lateral
LOD	Limit of Detection
LSC	Liquid Scintillation Counting
μCi	Microcurie
MCW	Mallinckrodt Chemical Works
MDA	Minimum Detectable Activity
MEMP	Miamisburg Environmental Management Project
MeV	Million electron volts
MMCIC	Miamisburg Mound Community Improvement Corporation
mrem	Millirem
nCi	nanocurie
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NTA	Eastman Kodak Nuclear Track Film Type A
NTD	Non-destructive testing
NTS	Nevada Test Site
OBT	Organically bound tritium
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
OSTI	Office of Scientific and Technical Information
OTIB	ORAU Technical Information Bulletin
OW	Open Window
PA	Posterior-Anterior
PAM	Portable alpha meter
pCi	pico curies
PFG	Photofluorography
PIC	Pocket ionization chamber

POC	Probability of Causation
ppm	Parts Per Million
RadCon	Radiological Control
RCCC	Radiological Control Coordinating Committee
RCT	Radiological Control Technician
Rem	Roentgen equivalent man
RFP	Rocky Flats Plant
RTG	Radioisotope Thermoelectric Generator
RWP	Radiation work permit
SC&A	S. Cohen and Associates
SEM	Scanning Electron Microscope
SMT	Stable Metal Tritide
SOP	Standard Operating Procedure
SRS	Savannah River Site
SSD	Skin to Surface Distance
SSN	Social Security Number
STC	Special Tritium Compound
STP	Stable Triated Particulate
SWP	Specific work permit
TA	Technical Area
TBD	Technical Basis Document
TIB	NIOSH Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
WD	Waste disposal
Y-12 Plant	Y-12 National Security Complex

1.0 EXECUTIVE SUMMARY

This report provides the results of an independent audit conducted by S. Cohen and Associates (SC&A, Inc.) of the technical basis documents (TBDs) that make up the site profile developed by NIOSH for the Mound Site. This audit was conducted during the period October 18, 2005–May 30, 2006, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in the latter's statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) to conduct such reviews and advise the Secretary of Health and Human Services (HHS) on the "completeness and adequacy" of the EEOICPA program.

The Mound Laboratory site in Miamisburg, Ohio, played an important role in the U. S. nuclear weapons program and was first established as a pilot operation in Dayton, Ohio, in the summer of 1943. Monsanto accepted the responsibility for the chemistry and metallurgy of polonium at predecessor facilities that were conducted there under the Dayton Project. The Dayton site's primary activity in its early years was to extract Po-210 from radioactive feedstock received from the Hanford Works to fabricate atomic bomb radiological initiators and other weapons components. The Mound Laboratory became the first permanent U.S. Atomic Energy Commission (AEC) facility in May 1948.

The initial role of polonium production expanded to include nuclear weapons component development and production, and such secondary missions as radioactive waste management and recovery, the use of radioactive materials for non-weapons purposes, and the purification of nonradioactive isotopes for scientific and commercial research. A key collateral mission over the years has been the development, engineering, manufacturing, and evaluation of explosive components for the nuclear weapons program.

Starting in the early 1950s, Mound developed radioisotopic thermoelectric generators (RTGs) for primary use as a self-contained power source for spacecraft. Tritium-handling technologies began in the mid-1950s and consisted of both research and production missions, which continued throughout the operational history of the plant. Other missions included the manufacturing of enriched stable isotopes for medical, industrial, and general research; development of chemical heat sources; and development of technologies for radioactive waste management.

Mound Laboratory was managed by four principal operating contractors over its more then 50-year existence, starting with Monsanto from 1946–1988 and EG&G from 1988–1997, during the production era, and Babcock and Wilcox of Ohio (1998–2002) and CH2M Hill Mound (2002–present) managing decontamination and decommissioning (D&D) and site closure activities following cessation of operations. During the D&D phase, BWXTO decontaminated and decommissioned 57 buildings and transferred 127 acres to the Miamisburg Mound Community Improvement Corporation (MMCIC) for future use (BWXT 2006).

The review included two separate weeks of unclassified interviews with over 20 site experts (primarily former Mound workers) by SC&A personnel at the Ohio Field Office center at the Mound closure site and a conference call with additional former workers, as well as extensive non-classified document retrieval at the Dayton Federal Records Center in Dayton, Ohio. A classified document retrieval effort had been planned at Los Alamos National Laboratory (LANL), where it was subsequently learned that the Mound classified records file at LANL had been disposed of the year before (see Secondary Finding 16). Questions were submitted to NIOSH and its technical support contractor, ORAU, during the course of this review, and a conference call was held between the SC&A review team and their ORAU counterparts on June 8, 2006, regarding specific issues surrounding the contents of specific TBDs that make up the Mound Site Profile.

The TBDs were evaluated for their completeness, technical accuracy, adequacy of data, compliance with stated objectives, and consistency with other site profiles, as stipulated in the *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). As "living" documents, TBDs are constantly being revised as new information, experience, or issues arise. A complete list of the Mound TBDs, as well as supporting documents, that were reviewed by SC&A is provided in Attachment 1.

This review found that the site profile characterized the primary radiological exposure sources, but failed to address fully the exposure implications of these and other radiation sources, as well as the potential impact of identified deficiencies in historic dosimetry program implementation. Whereas the early polonium, and later tritium and plutonium exposures and dosimetry are characterized, the implications to dose reconstruction of metal tritides, high-fired Pu-238, and radon are not adequately addressed. Likewise, the "established" radiation dosimetry program is discussed in terms of what limits of detection (LOD), minimum detectable activity (MDA), monitoring frequencies, and badging policies were the policy and site practice at the time, without qualifying this information with past and current information regarding how effectively the dosimetry program was actually carried out. This is particularly critical for a site such as Mound Laboratory, where issues arose in the 1990s regarding deficient management of the bioassay program that were sufficiently serious to warrant a federal court order and Price-Anderson Act civil enforcement actions by DOE (DOE 1999b).

In this context, SC&A found that the site profile did not address the bioassay program deficiencies identified in 1997 nor indicate for dose reconstruction purposes to what extent these program failures would have dose estimation implications for previous years. These issues, as documented in a 1997 DOE report, included failures of workers to submit required bioassay samples, use of outdated (and elevated) MDA values, failures to meet bioassay sampling cycle times, and other procedural violations. The internal dose TBD does not address these deficiencies in the bioassay program in terms of how it may have adversely impacted who received bioassays, how bioassay was carried out, and how dose was actually recorded.

With respect to sources of radiological exposure, the site profile provides dose characterization data for metal tritides, radon, and Pu-238, but does not fully address the uncertainties involved with conducting dose estimation. For example, metal tritides (particularly hafnium tritide) were used more extensively at Mound than at many other DOE sites, and were found to be of very low solubility. Given the lack of recorded doses and without any documented facility characterization for metal tritides until the early 1990s, it is not clear from the TBD how NIOSH would assign dose without knowing where metal tritides were handled, who was exposed, and what quantities may have been available for intake.

Similarly, for radon exposure in the SW and R buildings, NIOSH has based upper-bound dose estimation on a single-spot air sample taken in 1979 in SW-19. Other Mound facility radon dose assumptions are based on a 1989–1990 UNC Geotech building-by-building baseline survey. However, the representiveness of these values is uncertain, given the long time frame of this problem (1950s–1970s) and the likely high radon exhalation rates through foundation cracks in the SW and R buildings, which were constructed over extensive radium-226 contamination located in the abandoned and since buried "old" cave. Likewise, former radiation control technicians interviewed noted that informal experiments were conducted to demonstrate that operation of negative pressure hoods in these facilities led to markedly increased radon exhalation through the building foundations. The demonstrably elevated radon concentrations associated with these sources were a continuing problem for the overlying production facilities, and was not even partially remediated until venting of these subterranean sources was undertaken in 1980. The TBD's assumption that the uncertainty of these measurements (for thoron and actinon, as well as radon) is "a factor of at least 10" is the apparent basis for the choice of a geometric standard deviation (GSD) of 3 to compensate for these uncertainties. However, with little data for radon and no useable data for thoron and actinon, this would not be a sufficient basis for assuming that a technically plausible upper-bound had been determined.

For Pu-238 microspheres, which were fabricated at Mound for many years through an extremely high-temperature fabrication process, the site profile defines their solubility as Type S without addressing the implications of initial biokinetic retention on incident or near-term urinalysis. While the integrity of the Pu-238 particles may be susceptible to physical factors, such as "greater specific gravity and therefore a greater energetic alpha recoil" (ORAUT-TKBS-0016-5), leading to more transfer to body fluids as observed by the site profile, it has been also found from past exposures that this phenomenon takes time to be realized, leading to a delay in urinalysis detection. In the absence of viable in-vivo monitoring, such a delay may lead to missed dose if a worker was not continuously monitored following exposure, e.g., where production workers were reassigned or with support personnel who would not have been bioassayed regularly.

It is not clear from the internal dosimetry TBD (Millard 2004), how dose estimation would be performed for maintenance and support workers who were not classified as radiation workers and who had access to Mound radiological operations. No guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers, such as this category of support personnel whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to radiation workers, and whose access to various Mound buildings may have led to a variety of radionuclide exposures over their job history.

SC&A's external dose issues are primarily directed at how the TBD addressed dose estimation in the early years of Mound operation. The retrospective use of external dose distribution data from the 1949–1959 operating period to Mound's earliest periods (1943–1948) is questionable, given the difference in radiological operations, dose limits, and control practices. Worker exposure to beta radiation sources was prominent in a number of operations, but is not addressed sufficiently in the TBD to enable a dose reconstructor to establish when reliable beta and extremity dose records are available for specific operating periods. The familiar issue of whether "cohort" badging was being implemented in the 1947–1959 time period is not evaluated, so as to establish how workers were selected for badging and whether the "maximally exposed" individuals were among them. Likewise, the dose estimation implications of the energy dependence of neutron track emulsion type A (NTA) film use are not addressed, so that it is clear what correction factors will be assigned for Mound workers exposed to neutron sources with energies less than 1 MeV (and which workers and which work locations would have been affected).

Decontamination and decommissioning (D&D) activities at Mound are not addressed from the standpoint of historic radiation exposure history and dose estimations. While this experience is relatively recent (1993–2005) and founded on contemporary radiation protection standards and technology, it is also clear that a fundamental shift occurred with this transition regarding potential radiation hazards and radiological control philosophy. At least one site expert, a former worker familiar with Mound's radiation dosimetry program before and after this transition, noted that D&D workers were monitored with lapel samplers and derived air concentration (DAC) hour criteria as their primary dosimetry, as opposed to the routine bioassay radiation workers received during production. (According to this same source, this practice was modeled directly after that of Rocky Flats Plant (RFP), which was undergoing D&D at the time and was seen widely as a model within DOE). A former Radiological Control Technician (RCT) indicated that lapel samplers were assigned randomly among a group of D&D workers, and often did not represent the maximally exposed individual. The site profile is essentially silent on any treatment of radiation exposure experience during this period and for dosimetric techniques applied by BXTO and CH2M Hill, the two operating contractors responsible for the bulk of D&D and waste management activities.

Issues presented in this report are sorted into the following categories, in accordance with SC&A's review procedures:

(1) Completeness of data sources
(2) Technical accuracy
(3) Adequacy of data
(4) Consistency among site profiles
(5) Regulatory compliance

Following the introduction and a description of the criteria and methods employed to perform the review, the report discusses the strengths of the TBDs, followed by a description of the major issues identified during our review. The issues were carefully reviewed with respect to the five review criteria. Several of the issues were designated as findings because they represent deficiencies in the TBDs that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions.

1.1 SUMMARY OF FINDINGS

Finding 1: Inadequate bioassay techniques and procedures may have led to under-reporting and missed dose. The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. While many of these issues were documented for the D&D era of the 1990s, they also have clear implications for the operational time period at Mound that preceded them. A 1997 DOE report documented failures of workers to submit required bioassay samples, use of outdated and elevated MDA values, failures to meet bioassay sampling cycle times, and lack of adherence to the established bioassay program, all of which had earlier contributed to a Price-Anderson Act noncompliance civil penalty. The TBD does not evaluate this history as it pertains to deficient program implementation where it may have adversely impacted who received bioassays, how bioassay was carried out, and how dose was actually recorded.

Finding 2: Potential doses from insoluble metal tritides not sufficiently addressed. Insoluble stable metal tritides (SMTs) and stable tritiated particulates (STPs) were used in various applications at Mound during its operational history. It is clear from internal documentation that there was not an adequate means of detecting exposures or even monitoring SMTs and STPs before 1999. Before that time, hafnium tritide and other SMTs were routinely handled in gloveboxes in various process areas of the SW complex with internal dosimetry and monitoring designed not for STPS, but for elemental tritium (HT) and tritium oxide (HTO). A March 26, 1999, Defense Nuclear Facilities Safety Board Staff Report (DNFSB 1999) highlighted this deficiency and noted that during the production era in the SW, R, and T facilities, and during the deactivation and decommissioning phase, workers were not properly monitored for SMTs and STPs, and proper work controls were not in place. The DNFSB staff review went on to note that "past characterization efforts to identify and locate SMT contamination were limited…as of the time of the staff review (DNFSB 1999), a rigorous characterization program had not yet been fully developed…" While ORAUT-TKBS-0016-5 (Millard 2004) states that a lung clearance Class S should be assumed for metal tritides other than lithium, it is not clear from the scientific literature and site expert interviews whether this assumption is valid for higher "Z" SMTs, such as hafnium tritide. It is also not clear where SMT contamination existed at Mound, given that characterization of metal tritides by specific location within a room or building was not initiated at Mound until 1992. With no NCRP- or ICRP-accepted dose model for metal tritides, NIOSH has not provided a sufficient technical basis for its assumed Class S solubility designation.

Finding 3: Chronic unmonitored indoor radon dose to process workers from underlying radium cave and tunnel not adequately addressed. ORAU-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW-19 (due to exhalation into the building area from radium and thorium processing wastes from the "Old Cave"), and relies upon limited air monitoring data from 1979–1980 coupled with a more comprehensive characterization study conducted in 1989 (UNC Geotech 1990), which is summarized in a June 2000 BWXT report (BWXT 2000), for its assumed building-by-building Rn-222 dose reconstruction assignments in

Table 5-14. However, the air-sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW and R building complex, (R building was implicated in former RCT interviews), nor can it be assumed they reflect concentrations that existed in previous years. From former RCT interviews, it was noted that considerable radon exhalation was experienced through foundation cracks in SW (alpha meters would "peg out"); concentrations of radon in such areas would be expected to be elevated over other locations. Furthermore, the rate of radon exhalation and, therefore, the ambient indoor concentration, reportedly increased considerably whenever negative pressure hoods were used in SW and R buildings, which was relatively frequent. The TBD (Millard 2004) does not present substantiated radon characterization data for the SW and R process areas prior to the venting of the underlying cave and tunnel areas in 1980; the limited 1979 spot air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that period. Likewise, the TBD's assumption that the uncertainty of these measurements (for thoron and actinon, as well as radon) is "a factor of at least 10" is the apparent basis for the choice of a GSD of 3 to compensate for these uncertainties. However, with little data for radon and no useable data for thoron and actinon, this would not be a sufficient basis for assuming that a technically plausible upper bound had been determined.

Finding 4: Potential doses from high-fired plutonium-238 and thorium-232 not sufficiently addressed. It has been found that plutonium that has been exposed to extreme temperatures (e.g., in excess of 1,000°C) undergoes metallurgical reactions and upon inhalation, exhibits a very long retention time in the lungs that exceeds the default absorption types specified by the current ICRP lung model. While this so-called "Super S" type of plutonium has already been addressed in ORAUT-OTIB-0049 (OCAS 2006) for Rocky Flats, it is not clear how this empirical approach would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238). These microspheres were formed through high-temperature heating processes and were designed for use in thermal generators. The Occupational Internal Dosimetry TBD (Millard 2004) notes that "in general, Pu-238 compounds are more soluble than Pu-239 due to greater specific gravity and therefore a greater energetic alpha recoil for Pu-238," but does not provide definitive guidance on the projected urine excretion rate for high-fired Pu-238 microspheres, and what adjustment factors would be needed for urinalysis results.

For example, it is unlikely that an exposure to a high-fired Pu-238 oxide will be detected, measured, or noted until some time after the event. This is due to the fact that the highly insoluble high-fired Pu-238 oxide will not be detectable in the urine, and because of the lack of penetrating photons from the Pu-238, it will not be detectable through lung counting with any reasonable MDA sensitivity. Thus, significant unknown exposures may have occurred and remained undetected for months. This becomes an even more significant issue in light of the policy described in Millard's 2004 TBD of discontinued monitoring of workers after they were moved to other projects, and the fact that administrative personnel and support personnel were not monitored routinely.

With respect to high-temperature processing of Th-232 feed material, ORAUT-TKBS-0016-5 observes that "the caustic treatment was likely to have been a high-temperature process that would have resulted in such refactory and highly insoluble thorium compounds as thorium dioxide." However, Attachment 5A of this TBD, which provides the lung clearance class for each compound handled in Mound facilities, lists thorium isotopes from thorium refining as Class "M," as opposed to Type S, or perhaps more appropriately, "Super S." Apart from this seeming contradiction, it is not clear what the implications are of worker exposure to such high-fired thorium compounds.

Finding 5: Use of 1949–1959 dose data for modeling earlier years (1943–1948) is questionable. A modal dose of 50 mrem/week for neutrons and 50 mrem/week for photons (i.e., neutron to photon ratio of 1:1) is cited in ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) for 1949–1959, and recommended for assigning doses for the period 1943–1948 (pages 14 and 22). While these dose assignment criteria are apparently based upon badged worker dose records, no data is provided to substantiate the selection of the 50 mrem/week dose value. 50 mrem/week equates to 2.5 rem/year, which is much less than the allowable limits in 1943–1949 of, first, 26 rem/year, and then, 15 rem/year, as noted on page 15 in ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Therefore, a worker could have received 6–10 times the proposed assigned dose and still have satisfied the guidelines in place at Mound at the time. The facilities, working conditions, dose control policies, accidents/incidents, and knowledge of hazards and exposure controls were sufficiently different between the two eras that the use of 1949–1959 dose data for earlier workers could lead to significant underestimation of exposures. Other methods need to be considered to arrive at claimant-favorable doses.

Finding 6: Historic beta exposures not sufficiently characterized. Beta dose reconstruction is not sufficiently covered in the Occupational External Dosimetry TBD (ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Periods when reliable beta dose and extremity dose records are not available need to be identified. Beta skin doses from contamination and organ and/or extremity doses from handling beta-emitting materials close to the body and hands need to be further addressed. Table 6-23 on page 35 of the TBD provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. While the TBD provides some information concerning beta/low-energy photon dosimetry for this period, it appears scattered and incomplete. Without dose records available for analysis, it is not possible to determine if and when skin doses were recorded, or how LOD, zero, and blank readings were handled. The potential for underestimating beta dose is not sufficiently covered in the present TBD.

Finding 7: Assessment of personnel badging policy during early years needs further review. While ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) indicates that all radiation workers were badged during 1949–1962, it is also apparent that roughly only 15%–20% of total Mound workers were, in fact, badged during 1947–1959. It is important to know who was considered a "radiation worker" and how they were selected for badging, as this has dose consequence. In that era, it was not uncommon to conduct "cohort badging," where supervisors would select "representative" workers to wear dosimeters to record doses for specific operations or buildings. It is also clear that radiation hazards were not well recognized during that time period. This resulted in some workers not being monitored during a period when not all radiation hazards were recognized. The TBD does not clearly address these issues by clarifying the basis for how monitoring was conducted, nor which worker categories were badged (i.e., was everyone inside the plant area—security, crafts, maintenance, janitorial, etc.—considered "radiation workers," or just those routinely handling radioactive materials?). These issues need to be reviewed and substantiation provided that the maximally exposed workers were badged, and that there is a means to estimate radiation dose to unmonitored support workers with access to production areas. Additionally, it is not stated if all post-1949 workers who were badged were monitored for both neutron and photon radiation, or if some were only monitored for photons.

Finding 8: Problems with NTA film Neutron Doses. It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron doses records for **badged** workers are being corrected for the low energy response and fading of NTA film (especially at low neutron energies), for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film's under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficient detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons, with less than 1 MeV of energy, at the numerous facilities at Mound that produced neutron exposures throughout the years. Other issues of internal consistency were noted in the TBD, including inconsistencies in given neutron-to-photon ratios for various operational periods, neutron flux to dose conversion factors used in 1947–1969, and NTA film fading in the 1950s and 1960s.

Finding 9: The decontamination and decommissioning (D&D) era of Mound operations is not sufficiently addressed. Monitoring practices, particularly internal dosimetry, are not specified in the TBD for the D&D period (1992–2003) at Mound. At least one site expert, a former worker familiar with Mound's radiation dosimetry program before and after this transition, noted that D&D workers were monitored with lapel samplers and DAC hour criteria as their primary dosimetry, as opposed to routine bioassay. (This practice was apparently modeled directly after that of the RFP, which was undergoing D&D at the time and was seen widely as a model within DOE). A former RCT indicated that lapel samplers were assigned randomly among a group of D&D workers and often did not represent the maximally exposed individual. The site profile is essentially silent on any treatment of radiation exposure experience during this period and dosimetric techniques applied by BXTO and CH2M Hill, the two operating contractors responsible for the bulk of D&D and waste management activities. For example, while the internal dose TBD indicates "personal BZ air-sampling data should be used in preference to air-sampling data and no other means of estimating dose is possible," no guidance is provided regarding the inherent limitations of BZ air sampling and its conversion to assumed internal dose. It is also not clear to what extent first, second, and third-tier subcontractors were "captured" in the site's dosimetry program and Mound's central records. It is also not clear how a co-worker dose model would be applied for unmonitored workers located adjacent to D&D operations, and whether resuspension of radioactive particulates was an onsite issue during D&D.

Finding 10: Missing internal dose estimation methods for unmonitored workers, e.g., maintenance and support personnel, not provided. It is not clear from the internal dosimetry TBD (Millard 2004), how dose estimation would be performed for maintenance and support workers who were not classified as radiation workers and who had access to Mound radiological operations. For example, in one instance in the TBD's recommended approach for assigning tritium internal dose, it asserts that "doses would not be assigned to any administrative or other non-radiological workers," although tritium use and contamination was common in many Mound buildings. However, no guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers in the category of support personnel, whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to radiation workers, and whose access to various Mound buildings may have led to a variety of radionuclide exposures over their job history. It is also not clear how the designation of "radiological worker" was historically defined at Mound, and how workers were selected on this basis for bioassay for various operations.

Finding 11: Concerns over application of Detection Limit vs. MDA. There are potential missed doses for workers at Mound who were not monitored or recorded and had doses assigned, based on either the detection limits or MDA values, that could have significant impact on determining a claimant's total dose at Mound. In the case of protactinium, the TBD (Millard 2004), Table 5-7, lists "**Detection limit (dpm)"** for protactinium, also noted as the "MDA" in the caption preceding the table**.** The above statement from the TBD thus implies that the action level and reporting limits are the same. If this is the case, then the missed dose (those not resampled and unmonitored administrative personnel) would include all those having urine samples less than 2.2 cpm $24hr^{-1}$, which also equates to 300 mrem wk^{-1} or 15 rem yr^{-1}. This could be a very significant missed dose where no follow-up sampling would have been done for those administrative personnel, maintenance personnel, and those who may have had exposure just prior to discontinuation of work on the project.

1.2 OPPORTUNITIES FOR IMPROVEMENT

(1) The external dose TBD (Proctor and Algutifan 2004) needs to make it clear if the "dose of record" for the workers has been modified with the necessary adjustments or not. These adjustments would include Tantalum shielding of 60 keV gammas; NTA film track fading and low-energy threshold; and TLD signal fading and decreased response at high neutron energies. The TBD provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but none concerning the worker's dose of record and its adjustments for use during dose reconstruction.

(2) The issue of how zero and/or blank entries were made in the dose of records needs to be addressed in the external dose TBD (Proctor and Algutifan 2004). This applies to both monitored workers and the doses used to assign co-worker data to unmonitored workers.

(3) The external dose TBD (Proctor and Algutifan 2004) could be improved by addressing the issue of beta doses and records in a more concise manner. Presently, it is mentioned occasionally in the TBD, but it is not presented in a way that allows the reader a good picture of what, and when, beta doses were of concern. It is also not

made clear how beta doses were monitored, or what will be done during dose reconstruction concerning periods when beta doses were not monitored/recorded.

(4) No information or justification is provided in the TBD (Proctor and Algutifan 2004) for recommending the use of the 1949–1959 external dose data to assign 50 mrem/wk for neutron and photon doses for 1943–1948 workers. The TBD needs to provide some technically sound reasoning and data to support their recommendation.

(5) The external dose TBD (Proctor and Algutifan 2004) does not make it clear who was badged and when. It uses the term "radiation worker" when describing who was badged, but does not state what defined a radiation worker. The TBD needs to investigate who was and was not badged, and the method(s) used to select those who were badged.

(6) The current version of the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), does not adequately address the issues of insoluble SMTs. These insoluble forms were not properly monitored, and recommended methods in the TBD for dose reconstruction are inadequate. More recent publication of studies of these insoluble tritides are not addressed, as discussed in Vertical Issue 5.2. It is suggested that the TBD (Millard 2004) use the approach agreed upon for these tritides in the site profile for the Savannah River Site (SRS).

(7) The ORAUT-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW19, and the TBD relies upon limited air monitoring data from 1979–1980 coupled with a more comprehensive characterization study conducted in 1989. However, the air sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW building complex, nor can it be assumed they reflect concentrations or production conditions that existed in previous years. The characterization provided for the dose reconstruction in the present TBD (Millard 2004) does not provide a technically plausible basis to reconstruct radon dose for the early period prior to 1980s.

(8) The ORAUT-TKBS-0016-5 (Millard 2004) addresses the fact that Pu-238 was produced under high-temperature conditions (plasma torch), which would produce a high-fired oxide form. This material has been shown to react differently in the lungs than the air-oxidized form of Pu-238. This is discussed in a U.S. Transuranium Registry paper (TR 1995) and at Los Alamos in papers by both (Hickman 2003) and (Cheng 2004). There issues, as noted in Vertical Issue 5.4, need to be addressed in the revised Mound Occupational Internal Dosimetry TBD.

(9) The ORAUT-TKBS-0016-5 TBD (Millard 2004) relies heavily on the King report (1995) for identifying radionuclides of concern in buildings. Decontamination and decommissioning characterization reports at the time of D&D lead us to believe that other radionuclides were present in many of these buildings that were not monitored for in the earlier days and are not addressed in the TBD (Millard 2004). The TBD also

does not indicate whether workers were monitored and sampling carried out for these other radionuclides during the time of decontamination and demolition of buildings. The practices of monitoring for the radionuclides, identified by King, as well as other found nuclides needs to be addressed for periods involving D&D activities.

(10) NIOSH apparently has not made full use of the Meyer historical document (Meyer 1992) regarding the recovery efficiency of polonium that could make a significant change in the dose commitment calculation.

(11) The current version of the Occupational Environmental Dose TBD, ORAUT-TKBS-0016-4 (Hysong et al. 2004), was published with asserted data gaps of information before 1971. Future revisions need to include additional information pertaining to new environmental monitoring and effluent data collected, since the original publication of the current TBD. It also should include any applicable information that comes from NIOSH responses to pending SC&A questions.

(12) Section 3 of the Mound Plant Technical Basis Document for Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006), makes reference to occupational dose guidelines in Revision 2 of ORAUT-OTIB-0006 (Kathren 2003) as its basis document for estimating medical dose. Kathren 2003 has since been revised. Revision 3, "Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures" (Kathren and Shockley 2005) provides a more reasonable basis for assumptions regarding estimation of worker medical exposures at Mound. The SC&A review evidences that the Occupational Medical Dose TBD (Algutifan et al. 2006) recognizes the total lack of exposure data and protocols that existed prior to 1980. The TBD (Algutifan et al. 2006), in Table 3.2, details technique factors for x-rays prior to 1980 that are based solely on assumptions taken from Revision 2 of OTIB-0006 (Kathren 2003), not actual measurements.

(13) Specific dose estimations in the Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006), for occupational x-rays are also derived for the period 1980 to 1988, from ICRP Report 34 (ICRP 1982) and NCRP Report 102 (NCRP 1989). This is an important issue, in that estimated medical doses based upon this research are not an actual measurement of dose from the Mound x-ray unit. For the period of 1988 – present, there were measurements made by the State of Ohio.

(14) The Occupational Medical Dose TBD (Algutifan et al. 2006) states there is no physical evidence to show if photofluorography (PFG) to do chest screenings occurred at Mound. In the absence of documentation, the TBD (Algutifan et al. 2006) directs that dose assessors not include the use of PFGs in their dose estimations.

(15) Additionally, the TBD (Algutifan et al. 2006) does state that all medical x-rays administered, in conjunction with routine or special exams, are considered as part of occupational exposure; however, only pre-employment and routine chest exams are mentioned to be used by dose assessors.

2.0 SCOPE AND INTRODUCTION

The review of the Mound Site profile was conducted from October 18, 2005–May 30, 2006.

2.1 REVIEW SCOPE

Under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) and Federal regulations defined in Title 42, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program*, of the *Code of Federal Regulations* (42 CFR Part 82), the Advisory Board on Radiation and Worker Health (Advisory Board) is mandated to conduct an independent review of the methods and procedures used by the National Institute for Occupational Safety and Health (NIOSH) and its contractors for dose reconstruction. As a contractor to the Advisory Board, S. Cohen and Associates (SC&A, Inc.) has been charged under Task 1 to support the Advisory Board in this effort by independently evaluating a select number of site profiles that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

This report provides a review of the following six technical basis documents (TBDs) related to historical occupational exposures at Mound Site:

- ORAUT-TKBS-0016-1, *Technical Basis Document for Mound Site – Introduction, Rev. 00* (Vollmer 2004a)
- ORAUT-TKBS-0016-2, *Technical Basis Document for Mound Site – Site Description, Rev. 00* (Vollmer 2004b)
- ORAUT-TKBS-0016-3, *Technical Basis Document for Mound Site – Occupational Medical Dose, Rev. 01 PC-2* (Algutifan et al. 2006)
- ORAUT-TKBS-0016-4, *Technical Basis Document for Mound Site – Occupational Environmental Dose, Rev. 00* (Hysong et al. 2004)
- ORAUT-TKBS-0016-5, *Technical Basis Document for Mound Site – Occupational Internal Dose, Rev 00* (Millard 2004)
- ORAUT-TKBS-0016-6, *Technical Basis Document for Mound Site – Occupational External Dosimetry, Rev. 00* (Proctor and Algutifan 2004)

These documents are supplemented by technical information bulletins (TIBs), which provide additional guidance to the dose reconstructor. A complete list of these documents is available in Attachment 1.

Implementation guidance is also provided by so-called “workbooks,” which have been developed by NIOSH for selected sites to provide more definitive direction to the dose reconstructors on how to interpret and apply TBDs, as well as other available information.

SC&A, in support of the Advisory Board, has critically evaluated the Mound Site TBDs for the following:

- Determine the completeness of the information gathered by NIOSH in behalf of the site profile, with a view to assessing its adequacy and accuracy in supporting individual dose reconstructions
- Assess the technical merit of the data/information
- Assess NIOSH's use of the data in dose reconstructions

SC&A's review of the six TBDs focuses on the quality and completeness of the data that characterized the facility and its operations, and the use of these data in dose reconstruction. The review was conducted in accordance with *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004), which was approved by the Advisory Board.

The review is directed at "sampling" the site profile analyses and data for validation purposes. The review does not provide a rigorous quality control process, whereby actual analyses and calculations are duplicated or verified. The scope and depth of the review are focused on aspects or parameters of the site profile that would be particularly influential in deriving dose reconstructions, bridging uncertainties, or correcting technical inaccuracies.

The six TBDs serve as site-specific guidance documents used in support of dose reconstructions. These site profiles provide the health physicists who conduct dose reconstructions on behalf of NIOSH with consistent general information and specifications to support their individual dose reconstructions. This report was prepared by SC&A to provide the Advisory Board with an evaluation of whether and how the TBDs can support dose reconstruction decisions. The criteria for evaluation include whether the TBDs provide a basis for scientifically supportable dose reconstruction in a manner that is adequate, complete, efficient, and claimant favorable. Specifically, these criteria were viewed from the lens of whether dose reconstructions based on the TBDs would provide for robust compensation decisions.

The basic principle of dose reconstruction is to characterize the radiation environments to which workers were exposed and determine the level of exposure the worker received in that environment through time. The hierarchy of data used for developing dose reconstruction methodologies is dosimeter readings and bioassay data, co-worker data and workplace monitoring data, and process description information or source-term data.

2.2 REVIEW APPROACH

SC&A's review of the TBDs and supporting documentation concentrated on determining the completeness of data collected by NIOSH, the adequacy of existing Mound personnel and environmental monitoring data, and the evaluation of key dose reconstruction assumptions.

2.3 REPORT ORGANIZATION

In accordance with directions provided by the Advisory Board and with site profile review procedures prepared by SC&A and approved by the Advisory Board, this report is organized into the following sections:

(1) Executive Summary
(2) Scope and Introduction
(3) Assessment Criteria and Method
(4) Site Profile Strengths
(5) Vertical Issues
(6) Overall Adequacy of the Mound Site Profile as a Basis for Dose Reconstruction.

Based on the issues raised in each of these sections, SC&A prepared a list of findings, which are provided in the Executive Summary. Issues are designated as findings if SC&A believes that they represent deficiencies in the TBD that need to be corrected, and which have the potential to have a substantial impact on at least some dose reconstructions. Issues can also be designated as secondary issues if they simply raise questions, which, if addressed, would further improve the TBDs and may possibly reveal deficiencies that will need to be addressed in future revisions of the TBDs.

Many of the issues that surfaced in the report correspond to more than one of the major objectives (i.e., strengths, completeness of data, technical accuracy, consistency among site profiles, and regulatory compliance). Section 6.0 provides in summary form a list of the issues, and to which objective the particular issue applies.

In many ways, the TBDs have done a successful job in addressing a series of technical challenges. In other areas, the TBDs exhibit shortcomings that may influence some dose reconstructions in a substantial manner.

3.0 ASSESSMENT CRITERIA AND METHODS

SC&A is charged with evaluating the approach set forth in the site profiles that is used in the individual dose reconstruction process. These documents are reviewed for their completeness, technical accuracy, adequacy of data, consistency with other site profiles, and compliance with the stated objectives, as defined in *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). This review is specific to the Mound Site Profile, supporting TIBs, and dose reconstruction worksheets; however, items identified in this report may be applied to other facilities, especially facilities with similar source terms and exposure conditions. The review identifies a number of issues, and discusses the degree to which the site profile fulfills the review objectives delineated in SC&A's site profile review procedure.

3.1 OBJECTIVES

SC&A reviewed the site profile with respect to the degree to which technically sound judgments or assumptions are employed. In addition, the review identifies assumptions by NIOSH that give the benefit of the doubt to the claimant.

3.1.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires SC&A to identify principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective include (1) determining if the site profile made use of available data considered relevant and significant to the dose reconstruction, and (2) investigating whether other relevant/significant sources are available, but were not used in the development of the site profile. For example, if data are available in site technical reports or other available site documents for particular processes, and if the TBDs have not taken into consideration these data where it should have, this would constitute a completeness-of-data issue. The Oak Ridge Associated Universities (ORAU) site profile document database, including the referenced sources in the TBDs, was evaluated to determine the relevance of the data collected by NIOSH to the development of the site profile. Additionally, SC&A evaluated records publicly available relating to the Mound site and records provided by site experts.

3.1.2 Objective 2: Technical Accuracy

SC&A reviewed the site profile with respect to Objective 2, which requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instruction, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes that occurred at Mound. The goal of this objective is to first analyze the data according to sound scientific principles, and then to evaluate this information in the context of compensation. If, for example, SC&A found that the technical approach used by NIOSH was not scientifically sound or claimant favorable, this would constitute a technical accuracy issue.

3.1.3 Objective 3: Adequacy of Data

SC&A reviewed the site profile with respect to Objective 3, which requires SC&A to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct dose reconstruction, and whether a defensible approach has been developed in the absence of data. In addition, this objective requires SC&A to assess the credibility of the data used for dose reconstruction. The adequacy of the data identifies gaps in the facility data that may influence the outcome of the dose reconstruction process. For example, if a site did not monitor all workers exposed to neutrons who should have been monitored, this would be considered a gap and, thus, an inadequacy in the data.

3.1.4 Objective 4: Consistency Among Site Profiles

SC&A reviewed the site profile with respect to Objective 4, which requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the Mound TBD was compared with the LANL and the SRS site profiles. In particular, this dealt with how each site handled and is handling dose reconstruction for workers exposed to stable metal tritides and Pu-238 high-fired oxides.

3.1.5 Objective 5: Regulatory Compliance

SC&A reviewed the site profile with respect to Objective 5, which requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR Part 82. In addition, SC&A evaluated the TBD for adherence to general quality assurance policies and procedures utilized for the performance of dose reconstructions.
In order to place the above objectives into the proper context as they pertain to the site profile, it is important to briefly review key elements of the dose reconstruction process, as specified in 42 CFR Part 82. Federal regulations specify that a dose reconstruction can be broadly placed into one of three discrete categories. These three categories differ greatly in terms of their dependence on and the completeness of available dose data, as well as on the accuracy/uncertainty of data.

Category 1: Least challenged by any deficiencies in available dose/monitoring data are dose reconstructions for which even a partial assessment (or minimized dose(s)) corresponds to a probability of causation (POC) value in excess of 50%, and assures compensability to the claimant. Such partial/incomplete dose reconstructions with a POC greater than 50% may, in some cases, involve only a limited amount of external or internal data. In extreme cases, even a total absence of a positive measurement may suffice for an assigned organ dose that results in a POC greater than 50%. For this reason, dose reconstructions in behalf of this category may only be marginally affected by incomplete/missing data or uncertainty of the measurements. In fact, regulatory guidelines recommend the use of a partial/incomplete dose reconstruction, the minimization of dose, and the exclusion of uncertainty for reasons of process efficiency, as long as this limited effort produces a POC of greater than or equal to 50%.

Category 2: A second category of dose reconstruction is defined by Federal guidance, which recommends the use of "worst-case" assumptions. The purpose of worst-case assumptions in dose reconstruction is to derive maximal or highly improbable dose assignments. For example, a worst-case assumption may place a worker at a given work location 24 hours per day and 365 days per year. The use of such maximized (or upper-bound) values, however, is limited to those instances where the resultant maximized doses yield POC values below 50%, which are not compensated. For this second category, the dose reconstructor needs only to ensure that all potential internal and external exposure pathways have been considered.

The obvious benefit of worst-case assumptions and the use of maximized doses in dose reconstruction is efficiency. Efficiency is achieved by the fact that maximized doses avoid the need for precise data and eliminates consideration for the uncertainty of the dose. Lastly, the use of bounding values in dose reconstruction minimizes any controversy regarding the decision not to compensate a claim.

Although simplistic in design, to satisfy this type of a dose reconstruction, the TBD must, at a minimum, provide information and data that clearly identify (1) all potential radionuclides, (2) all potential modes of exposure, and (3) upper limits for each contaminant and mode of exposure. Thus, for external exposures, maximum dose rates must be identified in time and space that correspond to a worker's employment period, work locations, and job assignment. Similarly, in order to maximize internal exposures, highest air concentrations and surface contaminations must be identified.

Category 3: The most complex and challenging dose reconstructions consist of claims where the case cannot be dealt with under one of the two categories above. For instance, when a minimum dose estimate does not result in compensation, a next step is required to make a more complete estimate. Or when a worst-case dose estimate that has assumptions that may be physically implausible results in a POC greater than 50%, a more refined analysis is required. A more refined estimate may be required either to deny or to compensate. In such dose reconstructions, which may be represented as "reasonable," NIOSH has committed to resolve uncertainties in favor of the claimant. According to 42 CFR Part 82, NIOSH interprets "reasonable estimates" of radiation dose to mean the following:

> *. . . estimates calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.* ***Claimants will in no case be harmed by any level of uncertainty involved in their claims, since assumptions applied by NIOSH will consistently give the benefit of the doubt to claimants.*** [Emphasis added.]

In order to achieve the five objectives described above, SC&A reviewed each of the six TBDs, their supplemental attachments, and TIBs, giving due consideration to the three categories of dose reconstructions that the site profile is intended to support. The six Mound TBDs provide well-organized and user-friendly information for the dose reconstructor when adequate data were available to do that comprehensively.

ORAUT-TKBS-0016-1, Rev. 00, *Technical Basis Document for Mound Site – Introduction* (Vollmer 2004a), explains the purpose and the scope of the site profile. SC&A was attentive to this section, because it explains the role of each TBD in support of the dose reconstruction process. During the course of its review, SC&A was cognizant of the fact that the site profile is not required by the EEOICPA or by 42 CFR Part 82, which implements the statute. Site profiles were developed by NIOSH as a resource to the dose reconstructors for identifying site-specific practices, parameter values, and factors that are relevant to dose reconstruction. Based on information provided by NIOSH personnel, SC&A understands that site profiles are living documents, which are revised, refined, and supplemented with TIBs as required to help dose reconstructors. Site profiles are not intended to be prescriptive or necessarily complete in terms of addressing every possible issue that may be relevant to a given dose reconstruction. Hence, the introduction helps in framing the scope of the site profile. As will be discussed later in this report, NIOSH may want to include additional qualifying information in the introduction to this and other site profiles describing the dose reconstruction issues that are not explicitly addressed by a given site profile.

ORAUT-TKBS-0016-2, Rev. 00, *Technical Basis Document for Mound Site – Site Description* (Vollmer 2004b), is an extremely important document, because it provides a description of the facilities, processes, and historical information that serve as the underpinning for subsequent Mound TBDs.

ORAUT-TKBS-0016-3, Rev. 01, PC-2, *Technical Basis Document for Mound Site – Occupational Medical Dose* (Algutifan et al. 2006), provides an overview of the sources, types of exposure, and the frequency of exams that workers potentially received.

ORAUT-TKBS-0016-4, Rev. 00, *Technical Basis Document for Mound Site – Occupational Environmental Dose* (Hysong et al. 2004), provides background information and guidance to dose reconstructors for reconstructing the doses to unmonitored workers outside of the facilities at the site who may have been exposed to routine and episodic airborne emissions from these facilities.

ORAUT-TKBS-0016-5, Rev. 00, *Technical Basis Document for Mound Site – Occupational Internal Dose* (Millard 2004), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers.

ORAUT-TKBS-0016-6, Rev. 00, *Technical Basis Document for Mound Site – Occupational External Dose* (Proctor and Algutifan 2004), presents background information and guidance to dose reconstructors for deriving occupational external doses to workers.

In accordance with SC&A's site profile review procedures, SC&A performed an initial review of the six TBDs and their supporting documentation. SC&A then submitted questions to NIOSH with regard to assumptions and methodologies used in the site profile. These questions are provided in Attachment 3.

NIOSH provided responses to the SC&A questions that can be found in Attachment 4.

A conference call was then conducted with NIOSH, ORAU, and the SC&A team to allow NIOSH to provide clarifications, and to explain the approaches employed in the site profile TBDs. A summary of this conference call with NIOSH, ORAU, and SC&A is provided in Attachment 5.

Attachment 6 provides a summary of the currently recommended dose reconstruction procedures that NIOSH has provided in the Occupational External Dosimetry TBD (Proctor and Algutifan 2004).

Attachment 7 provides a history and chronology of stable metal tritides at Mound Laboratory (Final Draft 2 report).

Information provided in the conference call with NIOSH was evaluated against the preliminary findings to finalize the vertical issues[1] addressed in the audit report. There are three levels of review for this report. First, SC&A team members review the report internally. Second, SC&A engages an outside consultant, who has not participated in the preparation of this document, to review all aspects of this report. The third level, referred to as the expanded review cycle, will consist of a review of this draft by the Advisory Board and NIOSH. The first two of these have been completed.

After the Advisory Board and NIOSH have an opportunity to review this draft, SC&A plans to request a meeting with Advisory Board members and NIOSH representatives to discuss the report. Following this meeting, we will revise this report and deliver the final version to the Advisory Board and to NIOSH. We anticipate that, in accord with the procedures followed during previous site profile reviews, the report will then be published on the NIOSH Web site and discussed at the next Advisory Board meeting. This last step in the review cycle completes SC&A's role in the review process, unless the Advisory Board requests SC&A to participate in additional discussions regarding the closeout of issues, or if NIOSH issues revisions to the TBDs or additional TIBs, and the Advisory Board requests SC&A to review these documents.

Finally, it is important to note that SC&A's review of the six TBDs and their supporting TIBs is not exhaustive. These are large, complex documents, and SC&A used its judgment in selecting those issues that we believe are important with respect to dose reconstruction.

3.2 SITE PROFILE STRENGTHS

In developing a TBD, the assumptions used must be fair, consistent, and scientifically robust, and uncertainties and inadequacies in source data must be explicitly addressed. The development of the TBD must also consider efficiency in the process of analyzing individual exposure histories, so that claims can be processed in a timely manner. With this perspective in mind, we identified a number of strengths in the Mound site TBDs. These strengths are described in the following sections.

---

[1] The term "vertical issues" refers to specific issues identified during our review, which were identified as requiring more in-depth analysis, due to their potential to have a significant impact on dose reconstruction.

(1) NIOSH's use of the Wayne King document on radionuclides by location at Mound (King 1995) has provided a comprehensive baseline of historic radionuclide use at Mound (with the possible exceptions listed below). The Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b), effectively summarized the radionuclides handled and room locations where work was done in HH Building (Table 2-4, pg. 14). Likewise, similar listings are included in the Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b), for PP Building (Table 2-5, pg. 15); R Building (Table 2.6, pp. 16–17); SM Building (Table 2-7, pg. 18); SW Building (Table 2-8, pp. 19 and 20); T Building (Table 2.9, pp. 20–22); T Building (Table 2-9, pg. 23); and WD and WDA Buildings (Table 2-10, pg. 24). Within the text of the Site Description TBD (Vollmer 2004b), radioisotopes used and the rooms where they were used in numerous other Mound buildings were also provided. One interviewee (see Attachment 2) said that in spite of these extensive listings, some room numbers and the isotopes used in these rooms had not made it into these summaries. It is also apparent from worker interviews that D&D characterization studies may have shown the presence of radionuclides in certain facilities not identified as such by the King report.

(2) NIOSH in the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), is to be commended for recognizing and dealing with corrections necessary to take into account recovery problems with metabolized Po-210 prior to 1964 and the poor recoveries of Pu-238,239 prior to 1960, and for making these corrections for the years prior to 1964 and 1960, respectively.

(3) The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), provides a useful Table 5-1, page 9, which lists primary bioassay programs with reported radionuclide action levels in counts per minute for a urine sample, workers who were monitored, and frequency of monitoring.

(4) Section 5.3.1, pages 14–27 of the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), provides an effective summary of the primary radionuclides handled by workers at Mound. In addition Section 5.3.2, pages 27–36 of the TBD (Millard 2004), provides a nice overview of the secondary radionuclides used at Mound. Table 5.20 (page 38) in the TBD (Millard 2004) also provides a useful summary of analytical methods and detection limits (MDAs) that assists in the proper evaluation of bioassay data, as well as a means to assign missed dose.

(5) The TBDs' use of personnel monitoring data and environmental monitoring data to determine dose is consistent with the requirements outlined in 42 CFR Part 82, as follows:

- Where in-vivo and in-vitro analyses are available, this information is provided for use in determination of internal dose.

- Where routine beta/gamma and neutron dosimeters are available and adequate, this information is provided for use in determination of external exposure.

- Where environmental measurements are available, these data are used as the basis for environmental dose.

NIOSH has effectively complied with the hierarchy of data required under 42 CFR Part 82 and its implementation guides for monitored workers.

4.0 VERTICAL ISSUES

SC&A has developed a list of key issues regarding the Mound Site Profile. These issues relate to each of the five objectives defined in SC&A 2004. Some issues are related to a particular objective, while others cover several objectives. Many of the issues raised below are applicable to other DOE and AWE sites and should be considered in the preparation and revision of other site profiles.

4.1 ISSUE 1: INADEQUATE BIOASSAY TECHNIQUES AND PROCEDURES MAY HAVE LED TO UNDER-REPORTING AND MISSED DOSE

The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. While many of these issues were documented for the D&D era of the 1990s, they also have clear implications for the operational time period at Mound that preceded them.

One of the more comprehensive lists of alleged deficiencies was identified by the Union representing Mound workers following a significant concern that arose with urinalysis of actinium-227 samples. The bioassay program issues included the following (OCAW 1998):

- Lack of funding to develop and validate "…a state of the art radiobioassay procedure for urine and fecal matrices…"
- Inadequate radiological contamination detection
- Lack of sufficient hold-up time "…for Actinium 227 bioassay samples to allow an ingrowth factor of at least 0.75 for Thorium 227 before analysis"
- The use of an elevated Minimal Detectable Activity (MDA) to determine positive bioassays; "MDA's were calculated using only square roots of the reagent blank counts for a limited number of samples only," instead of a proper MDA in accordance with ANSI standards
- Failure to perform bioassays, particularly for exposure to Ac-227, which accumulated in improper storage modes and remained unanalyzed for a period of years
- Failure of the contractor bioassay laboratory to establish Energy department accreditation
- Discarding of low recovery bioassays, especially incident samples
- Failure to update standard operating procedures

A previous dose reconstruction performed by MJW at Mound (MFW 2002b) was performed, in part, to address these and other issues that raised doubts regarding the adequacy of Mound bioassay measurements. However, this dose reconstruction apparently only addressed workers with recorded monthly doses above 10 mrem, which leaves uncertainty regarding the balance of workers who received no dose corrections as to the appropriateness of their selection for bioassay, the adequacy of their bioassay, and how MDA was applied.

In 1997, DOE (DOE 1997) made the following finding:

> *…it was determined that approximately 108 workers performing radiological work activities under the auspices of at least 20 different Radiation Work Permits had failed to submit samples for bioassay as required. …These violations occurred because the most current, accurate laboratory data were not used to evaluate worker bioassay sample results. In fact, the Minimum Detectable Activity (MDA) values for some radionuclides, […], had not been updated since 1992. …As a result of these practices, a situation occurred where positive dose for workers would not have been identified, evaluated and recorded. For example, you identified that for [a radionuclide], the most current, accurate laboratory data provided a detection capability that was six times lower than the historical MDA that was in use for dose assessment. By failing to use current, accurate data for calculating worker exposure to [a radionuclide]… individual workers could have received internal doses up to [specified value] which would have been recorded as a zero dose in the workers records.*

These problems persisted. By 1998, DOE (DOE 1998) reported the following violations under its Price-Anderson Act authority:

> *(1) failure to ensure the continuity of bioassay services as required by the Mound Radiobioassay Laboratory Quality Assurance Plan, (2) failure to meet bioassay sample cycle times as required by the Internal Dosimetry – Radiobioassay Laboratory Memorandum of Understanding, (3) failure to provide timely notification to workers of positive bioassay results, (4) failure to adequately implement quality improvement processes for the bioassay program, (5) failure to formally control design interfaces between vendor software and Mound data bases, and (6) failure to adequately assess management processes to ensure that management tools, i.e., internal audits, were adequate to identify and correct bioassay program problems.*

According to DOE (DOE 1998):

> *These problems occurred because of a continuing culture of non-adherence to your established bioassay program requirements by your staff. Additionally, there was a clear lack of communication between the Radiobioassay Laboratory analytical function and the Dose Assessment function as well as failure to understand the implications to the workers when the bioassay program did not fulfill its obligations. DOE is concerned because the violations and deficiencies associated with these issues are not isolated events and reflect a management*

> *failure across several organizations responsible for the safe operation of the site. Further, despite the attention to the Mound bioassay program over the last several years by DOE, including the issuance of civil penalties to the previous contractor, significant deficiencies continued to go uncorrected.*

Moreover, the use of outdated and elevated MDA values was found by the DOE Price-Anderson Enforcement Office to be widespread throughout the Energy department complex (DOE 1999b). In this DOE 1999b memorandum to contractors, DOE stated the following:

> *Contractors should establish and document a clear basis for the prospective determination as part of the contractor's existing internal dosimetry program and/or technical basis documents. Such documents should include the technical rationale used by the contractor for including or excluding populations of radiological workers from monitoring for internal deposition of radioactive materials. Contractors should maintain these documents as part of the contractor's record system… DOE is primarily concerned with the programmatic implications of repetitive and long-term bioassay program problems that have not been corrected by the contractor. DOE expects the contractor to effectively manage and implement their documented bioassay programs including being knowledgeable of the extent of any deficiencies.*

It is not clear if Mound (and other DOE sites) came into compliance with DOE internal dosimetry requirements, leaving the possibility of false-negative and under-reported bioassay readings. The TBD (Millard 2004) needs to address to what extent these reported historic deficiencies in the Mound bioassay program may have adversely impacted who received bioassay, how bioassay was carried out, and how dose was recorded.

4.2 ISSUE 2: POTENTIAL DOSES FROM INSOLUBLE METAL TRITIDES ARE NOT SUFFICIENTLY ADDRESSED

Insoluble stable metal tritides (SMTs) and tritiated particulates (STPs) were used in various applications at Mound during its operational history. It is clear from internal documentation that there was not an adequate means of detecting exposures or even monitoring SMTs and STPs before 1999. Before that time, hafnium tritide and other SMTs were routinely handled in gloveboxes in various process areas of the SW complex, with internal dosimetry and monitoring designed not for STPS, but for elemental tritium (HT) and tritium oxide (HTO). A March 26, 1999, Defense Nuclear Facilities Safety Board Staff Report (DNFSB 1999) highlighted this deficiency and noted that during the production era in the SW, R, and T facilities, and during the deactivation and decommissioning phase, workers were not properly monitored for SMTs and STPs, and proper work controls were not in place. The DNFSB staff review went on to note that "past characterization efforts to identify and locate SMT contamination were limited…as of the time of the staff review (DNFSB 1999), a rigorous characterization program had not yet been fully developed…" While ORAUT-TKBS-0016-5 (Millard 2004) states that a lung clearance Class S should be assumed for metal tritides other than lithium, it is not clear from the scientific literature and site expert interviews whether this assumption is valid for SMTs such as hafnium tritide. It is also not clear where SMT contamination existed at Mound, given that characterization of metal tritides by specific location within a room or building was not initiated at Mound until 1992. With no NCRP- or ICRP-accepted dose model for metal tritides, NIOSH has not provided a sufficient technical basis for its assumed Class S solubility designation.

Dose reconstruction for SMTs and STPs are complex, problematic, and contain major uncertainties, due in part to the rapidly evolving state of scientific understanding regarding their internal dosimetry. Because tritides may leach out in the lung fluids, and then be incorporated into body water, they may also produce organically bound tritium from contact with lung tissue. This further complicates the metabolic process.

Particle size is also a critical factor for dose reconstruction. Given the numerous activities at Mound over the years involving production, handling, and the residual collection of tritides in the workplace, it appears unlikely that particle size distribution can be assigned to specific tasks, particularly in the absence of air concentration and bioassay data until recent years. As noted by the DOE:

> *Deposition fractions affect clearance rates of particulates from the lung to the gastrointestinal (GI) tract. Since urine excretion of tritium dissolved from tritiated particulate over time is a function of those particles that have not cleared from the lung, interpretation of urine excretion curves can extract particle size information. This requires extended monitoring without additional tritium intakes. When tritiated materials and sizes are likely to range broadly, it will be difficult to provide material identification and size characterizations in the workplace. Moreover, although dissolution rate data are available for several materials, these data do not include all the possible combinations of materials and particle sizes that might be encountered.* (DOE 2004a, pg. 36)

Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble tritides for workers with job assignments and in work areas that had the potential for higher exposures.

> [Note: According to a draft literature review conducted in January 2006 by the International Commission on Radiological Protection (ICRP 2006) the following compounds were tentatively identified with following lung clearance categories:
>
> - Titanium tritide – Class Moderate
> - Zirconium tritide –Class Moderate
> - Carbon tritide – Class Slow
> - Hafnium Tritide – Class Slow]

The DOE Handbook 1184-2004, *Radiological Control Programs for Special Tritium Compounds* (DOE 2004), mentions the Special Tritium Compound (STC) forms of tritides. The DOE handbook (DOE 2004a) assigns an S lung clearance class for purposes of dose calculations for organic [(CH2)n], rust [~FeO(OH)], and titanium, zirconium, and hafnium tritide compounds. The Handbook explains the assumptions of tritium dissociation that the ICRP Publication 71 (ICRP 1996) uses. However, they only provide absorption into the bloodstream for tritiated water vapor (HTO) and organically bound tritium (OBT), which are much more soluble than hafnium tritide. This does not provide much guidance for the highly insoluble forms of tritides.

However, studies of hafnium tritide reported by Cheng et al. 2002, not referenced in the DOE handbook, point out that for particles in simulated lung fluids, less than 1% of the tritium was dissolved after 215 days, and the long-term dissolution half time was 4.28×10^5 days. This data raises a strong argument that the use of Type S for the ICRP 66 and 71 Model, as shown in Figure 5 of their report, does not come close to the measured dissolution rate of the hafnium tritide. Cheng et al. 2002 noted the following:

> *The current understanding of metal tritide and its radiation Dosimetry for internal exposure is limited, and ICRP publications do not provide the tritium Dosimetry for hafnium tritide.*

Strom et al. 2002 states the following:

> *For cells less than about 7 µm away from the surface of a metal tritide, the primary dose component is due to electrons. However, bremsstrahlung radiation may deposit some energy tens, hundreds, or even thousands of micrometers away from the surface of a tritide particle.*

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) states in Section 5.3.1.1, page 16, that, "Limited information is available on the metal tritides to which workers could have been exposed." In interviews conducted by SC&A staff of health physicists from the facility, concerns were expressed for tritium and tritide exposures, especially concern for potentially high exposures in the early years. It was stated that exposures occurred while workers were passing things in and out of the gloveboxes or fume hoods. They stated that hafnium tritides were relatively insoluble, and that tritides were considered "bad characters." One of the health physicists commented that he didn't have any good answers on whether these tritides were being monitored or not, and if they are insoluble just can't be detected. This problem has been addressed by SC&A in the reviews of a couple of other Site Profile reviews, in particular those of RFP and LANL, and is exacerbated in the case of Mound by the potential risks to significant portions of the worker population to insoluble tritide exposures within numerous areas of the facilities.

Further documentation on this issue at Mound comes from the 1990s, in particular in a 1999 *Draft Mound Technical Basis Document for Stable Tritiated Particulate and Organically Bound Tritium* (this Mound STP TBD was not found during the SC&A review). A Babcock and Wilcox of Ohio (BWO) memorandum dated June 17, 1999 (BWO 1999), with its attachment dated April 30, 1999, entitled: "Final Draft 2," reports on the stable metal tritides history and chronology at Mound (see Attachment 7)**,** and is indicative of even more concern over the potential exposures of workers to SMTs and STPs without adequate means of detecting exposures or even monitoring for them properly in the times before 1999. The "Final Draft 2" (BWO 1999) points out the use of hafnium tritide and SMT in gloveboxes in SW-10, SW-13, SW-142, SW-150, SW-219, SW-8, SW-9, and R-108, and recirculating systems in SW-12, SW-231, SW-150, SW-152, and SW-240. Many of these gloveboxes and systems were removed in the 1970s and 1980s, and it appears that much of the monitoring that was done was the same as that for HT and HTO, which cannot be applied to SMTs.

Technological shortfalls were identified in 1999 in the DNFSB March 26, 1999, Staff Report (DNFSB 1999). This DNFSB Staff Report pointed out that workers during the days of production in SW, R, and T Buildings, and during the deactivation and decommissioning activities of these areas, were not properly monitored, and proper work controls were not in place to protect the workers (DNFSB 1999). There were various DNFSB and DOE comments and reviews in 1999 that pointed out weaknesses in the Draft STP TBD that would still leave remaining facilities not properly covered, even after the problems of SMTs/STPs were recognized. Many incidents of exposure and potentials for exposure are noted throughout the review of site documents.

The Babcock and Wilcox memorandum of June 17, 1999, with its attached Final Draft 2 dated April 30, 1999 (BWO 1999), provided the following conclusion about stable metal tritides at Mound (see Attachment 7):

> *Hafnium tritide and to a lesser extent other SMTs are potential contaminants in gloveboxes in SW-13 (Struers Box), SW-150/152/240, SW-8 (old recovery box only), R-108 and SW-9. The glovebox recirculation systems in SW-231 and R-108 and any piping that remains of the glovebox purification system in SW-12 have the potential for SMT contamination. Inaccessible surfaces in SW-13 and to a lesser extent SW-150 may have SMT contamination due to the 1972 glovebox breach and 1993 tracking event. Ventilation exhaust in SW-13 and to a lesser extent SW-150 may also be SMT contaminated. Iron oxide tritoxide may be found in the carbon steel TD-column feed tanks in SW-8 and to a lesser extent in the ICI fixed tube trailer and the ERS and TERF surge tanks.*

The DNFSB review of Mound in 1999 (DNFSB 1999) found the following regarding the Miamisburg Environmental Management Project (MEMP):

> *Deactivation and decommissioning activities at MEMP are expected to involve work in areas suspected of being contaminated with stable metal tritides (SMTs)… The dose resulting from a given intake of a particular type of SMT may be many times greater than that for tritium oxide (HTO). Therefore, a radiation protection approach somewhat different from that traditionally used for elemental tritium (HT) and HTO is needed for work with SMTs.*

The DNFSB listed the following shortfalls in the Mound monitoring programs (DNFSB 1999, pg. 2):

- *Past characterization efforts to identify and locate SMT contamination were limited. As of the time of the staff review, a rigorous characterization program had not yet been fully developed; however, it was indicated to the staff that efforts are being made to improve the program.*

- *The Basis for Interim Operations (BIO) does not address deactivation and decommissioning activities in a detailed manner. The BIO also does not adequately address SMTs.*

- *The technical bases for radiation program measures associated with SMTs were under development or incomplete. In some cases, the technical bases communicated during the review were excessively qualitative.*

- *Development of an integrated radiation protection program addressing SMTs had not been completed.*

Section 5.3.1.1, Metal Tritides, of the TBD (Millard 2004) states that a lung clearance class of S should be assumed for all metal tritides other than lithium. Interviews by SC&A with site experts found that former workers considered these metal tritides, especially hafnium tritides, to be very insoluble. It was also noted in these interviews that many small accidents with exposures to tritium occurred **all the time**, with an example of 3 cases occurring in one weekend and that tritium was ubiquitous in a number of operations and existed in many areas of the plant. It was also noted that tritium sampling was performed regularly and usually confirmed low levels of tritium present. Thus, if an individual worked at Mound for any length of time in tritium areas, they would likely have had recorded low levels of chronic tritium exposure without any credit for potential metal tritide exposure.

A paper by G. T. McConville and C. M. Woods in 1995 (McConville and Woods 1995) discussed the following concerns about metal tritides:

> *Tritium in the form of metal tritides particles presents a peculiar problem for the calculation of internal dose. Standard calculations indicate that just a few 3 to 5 micron sized particles appears to lead to a very large dose. There are very few data on which calculations can be based.*

A BWX Technologies, Inc., letter of July 13, 1998, includes an Attachment 1 dated July 9, 1998, which is a white paper on metal tritides at Mound (BWXT 1998, Attachment 1, pp. 1–3) that further describes technological shortfalls that existed in 1998 regarding worker health protection and management. These are summarized below:

- Air monitoring techniques used flow-through ionization chambers as the major monitoring technique for identifying tritium in air. These instruments can measure tritium in its elemental form (HT), oxide form (HTO) or any other gaseous compound form (tritiated methane, ammonia, etc.). However, these same instruments cannot be used to measure a particulate, because filters and electronic precipitators have been purposely incorporated into the system design.

- It may not be possible to accurately monitor for surface and skin contamination when dealing with stable metal tritides.

  Liquid scintillation counting (LSC), the primary method used to measure tritium from a surface (floor, skin, etc.), provides a determination of the number of pulses of light emitted from the beta particle produced when the tritium atoms decay and strike a liquid medium containing phosphors. In forms of tritium that rapidly disassociate, the quantity of light pulses is directly proportional to the quantity of tritium present. Stable metal tritides present a unique challenge when attempting to monitor for surface and skin contamination. Since these materials are in particulate form, many of the tritium atoms associated with the particle are interior to the surface of the particle. As a result, the counting technique will show a tritium activity that is too low since the beta particle from tritium within the metal tritide particle cannot escape the particle.

- Characterization of metal tritides by specific location within a room or building was not initiated until 1992. The project was initiated to systematically identify specific locations where tritides were handled. A "sticking" wipe survey was used to grab the particles that were then analyzed in an Energy Dispersive X-ray Spectroscopy (EDS) analyzer and a Scanning Electron Microscope (SEM) as the analysis tools for evaluation. Prior to this, no such detailed location analysis had been done.

- Characterization of particle size and solubility was also needed, and was useful in determining a conversion from liquid scintillation counting to actual quantity of material present. Particle size also determines the respirable fraction of the stable metal tritide and the extent to which the stable metal tritide is trapped in the lung. Even in 1998, a detailed facility characterization and determination of particle sizing and solubility had not been completed.

- When performing urine bioassay for stable metal tritides, it is not possible from a single urine sample to determine if the exposure was to metal tritides or to gaseous forms of tritium.

- In 1998, there was no National Council on Radiological Protection and Measurements (NCRP)- or International Council on Radiological Protection (ICRP)-accepted dose model for metal tritides, due to inadequate biological and solubility information.

Mound workers, prior to the realization of their significant potential for uptakes of metal tritides in the mid to late 1990s were not adequately monitored for metal tritide exposure. The means of detecting and doing bioassays for metal tritides, as noted above, were still evolving in the 1999 timeframe. NIOSH should, therefore, develop a methodology to estimate metal tritide dose for workers in locations noted in the quote above (BWO 1999) and paragraph 3 of this issue.

With these concerns in mind, SC&A does not feel the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) does an adequate job of addressing potential doses from uptakes of these insoluble tritides or from high-fired oxides. This TBD (Millard 2004) acknowledges that on page 16 that:

> *Limited information is available on the metal tritides to which workers could have been exposed…. Halfnium tritides were also used at Mound primarily in SW, R and T buildings. A lung clearance class of S should be assumed for metal tritides other than lithium. A lung clearance class of S should be assumed for halfnium tritides.*

The tritium recommendations provided in the TBD Occupational Internal Dosimetry (Millard 2004) on page 17, do not appear sufficient for many cases that most likely involved significant doses to SMTs and STPs, and do not acknowledge worker exposures to SMTs and STPs during the D&D operations from 1995 to present. The TBD (Millard 2004) recommends the following:

> *The corrected upper 95 percentile dose of 340 mrem should be assumed in assigning annual doses to unmonitored workers from 1947 to 1956. When the Mound records from 1957 to 1995 only include dose without any concentrations, equations 5-4 should be used to correct reported Mound doses to ICRP 68 doses. Tritium doses reported as blanks from 1957 to 1995 should be reconstructed by assuming a 6 μCi per liter urine concentration reporting limit. Otherwise, all actual recorded bioassay results should be used. Doses reported at or below detection or as zeros should be corrected using the applicable MDAs given in Table 5-4. Doses should not be assigned to any administrative or other non-radiological workers.*
>
> *Dose reconstructions should assume that tritium source term was constant because reliable air data was not available from 1947 to 1957 and effluent records starting in 1959, which precluded any evaluation of tritium source terms during the period of missing urinalysis.*

There does not appear to be documentation of personnel monitoring or adequate area monitoring for SMTs that would make it possible to be able to do dose reconstruction for claimants exposed to metal tritides. This is borne out in the reviews and comments in BWXT 1999 and DOE 1999a, and the comments provided by the DNFSB (1999), regarding the *Draft Mound Technical Basis Document for Stable Tritiated Particulate and Organically Bound Tritium*. The guidance provided by NIOSH in OCAS-TIB-002 (OCAS 2003) does not adequately address these specific problems with SMTs and STPs.

SC&A has concern with the NIOSH-suggested use of the default exposure values in the absence of measured SMTs. These default exposure values have been demonstrated by Cheng, et al. 1997 to be inadequate for metal tritides, because they are so insoluble and have a very slow dissolution, particularly with regard to hafnium tritides.

The use of Type S for dose calculation may not represent the degree of insolubility that hafnium tritides exhibit. However, research published by Zhou and Cheng (Zhou and Chen 2004) suggests the use of Type S. The ICRP 66-corrected deposition fraction (ICRP 1994) did give similar CED values taken from animal studies. The DOE Radiological Control Coordinating Committee (RCCC) also looked at the tritides issue and in their November 2000 meeting (RCCC 2000) made reference to the upcoming DOE Handbook (DOE 2004), which was referenced earlier in this issue. The RCCC also noted that RESRAD calculations appear to give very little dose consequence when levels of 10,000 dpm/100 cm^2 contamination were used in the calculation. The relatively low dose consequence from SMT contamination is supported by the recent statement by SC&A (SC&A 2006) that intake of metal tritides will typically produce annual dose to most organs of a few mrem, and about 10 mrem to the lung. SC&A recommends that NIOSH use an approach similar to that used at the SRS. In the SRS approach, the surface contamination limit for tritium in accessible spaces is used with a conservative resuspension factor (50%) to derive an daily intake value of particulate tritium. This can be used to assign a claimant-favorable absorption type (either S or M) to bound the maximum potential exposures that a worker may have received over the years from the very insoluble metal tritides. This is particularly that of hafnium tritides, while recognizing that the overall doses to workers may not be increased greatly by the contribution from metal tritides (SC&A 2006).

4.3 ISSUE 3: INTERNAL DOSE TO WORKERS FROM RADON EXPOSURES MAY NOT HAVE BEEN RECORDED

ORAU-TKBS-0016-5 (Millard 2004) acknowledges radon as an internal dose concern in SW-19 (due to exhalation into the building area from radium and thorium processing wastes from the “Old Cave”), and relies upon limited air-monitoring data from 1979–1980, coupled with a more comprehensive characterization study conducted in 1989 (UNC Geotech 1990), which is summarized in a June 2000 BWXT report (BWXT 2000) for its assumed building-by-building Rn-222 dose reconstruction assignments in Table 5-14. However, the air-sampling measurements from 1979–1980 were limited in location, and do not necessarily reflect potential radon air concentrations in various parts of the SW Building complex, nor can it be assumed they reflect concentrations that existed in previous years when radon exhalation was potentially much higher. From interviews with former RCTs, it was understood that considerable radon exhalation was experienced through foundation cracks in the SW buildings (they indicated that alpha meters would “peg out”); concentrations of radon in such areas would be expected to be elevated over other locations. Furthermore, the rate of radon exhalation into buildings, and therefore, the ambient indoor concentration, would increase considerably whenever negative pressure hoods were used in SW Building, which was relatively frequent. The TBD (Millard 2004) does not present substantiated radon characterization data for the SW process areas prior to the venting of the underlying cave and tunnel areas in 1980; the limited 1979 spot-air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that earlier period. It is likewise not clear how the stated GSD of 3 is considered sufficient to offset the uncertainty regarding radon concentrations prior to 1980.

The TBD (Millard 2004) points out the measurements in building SW-19 of Rn-222 near an employee's desk ranged from 67 to 160 pCi L^{-1} in 1979, and concentrations in the tunnel were measured at 88,000 pCi L^{-1} Rn-222, 28,000 pCi L^{-1} Rn-220, and 640,000 pCi L^{-1} Rn-219. Table 5-14 provides Rn-222 levels to be used in dose reconstruction for all the buildings on site. This may be reasonable for the Rn-222 exposures to site personnel, however, there appears to be variability of exposure potential within areas, and this was borne out in interviews with site experts. These interviewees pointed out that radon was pulled out of basement floor cracks by negative pressure draw, when negative pressure hoods were used in SW Building (See Attachment 2). A 1980 Monsanto Research Corporation memorandum (Monsanto 1980) discussed elevated radon levels in SW-19, and pointed out the following regarding the June 1979 to May 1980 timeframe:

> *When the problem in SW-19 was discovered, the Radon Group was just getting established and did not have adequate equipment or techniques established to do a first rate job of quantifying the levels… Our efforts then turned to identifying the source of the radon, which we now believe is the tunnel under that area of SW. At the same time, the hole in the floor of SW-19 and cracks along the baseboards were sealed. This reduced the radon concentrations in the room somewhat.*

A 1982 Monsanto Research Corporation memorandum (Jenkins 1982) also pointed out that when sealing the base of the east wall of SW-19, the base of the partition that had not been sealed had the following air-sampling levels:

> a. *The air near the base of the partition continues to have a concentration of Rn-219 decay products roughly 10 times greater than the concentration at the normal breathing rate.*
>
> b. *Only trace quantities of Rn-222 decay products were observed in the samples. This is due to normal background.*

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004, pg. 29) mentions a DOE radon study conducted from December 12–15, 1989, and provides the following summary:

> *A DOE study was conducted from December 12 to 15, 1989, to measure radon in various Mound buildings (UNC Geotech 1990). The majority of the buildings had radon concentrations below 1.0 pCi/L^{-1} ^{222}Rn, except SW and Old SD Buildings. In June 2000 a radon study summary report was issued based on 1990 and 1999 measurements (BWXT 2000). Mound site radon background was reported to be 0.5 pCi/l^{-1} with a range of 0.1 to 2.1 L^{-1}. SW-19 was the only building at Mound identified as an area of potential occupational exposure to ^{222}Rn and ^{220}Rn.*

The Occupational Internal Dosimetry TBD also provides the results of various radon surveys done at Mound (Millard 2004, Table 5.13, pg. 28).

In 1991, however, a DOE Indoor Radon Study (UNC Geotech 1991, pp. 70–75) showed that even though most building readings at Mound were now in the range of 0.4 to 1.3 pCi/l, there were still areas were radon levels exceeded this average range:

Building	Radon pCi/l		Room	Comment
Bldg 21	161.1	125.8	Above Air Sampler	Wet – Old thorium storage
Bldg 21	115.7		Above Air Sampler	Wet – Old thorium storage
SW	4.8		19 Mid East Wall	History of Elevated Levels
48	3.2		114 B Closet On Sprinkler Pipe	
19	2.6		Room 1	
Old SD Bldg	2.4		Basement Right Cabinet	
55	2.1		1 Below thermostat on E. wall	
57	1.9		Room 1	
87	1.5		143	
998 Fire Station	1.4		Room 002 Equipment Room with SUM	

There is also the fact that other isotopes were involved throughout the operations that are not addressed, such as thoron and actinon. Review of reports, documents, and site expert interviews with regard to radon exposures to workers are rather extensive, with the worst conditions existing in SW Building and entrances in and around the “Cave” area.

Attachment 5D.7 of the Occupational Internal Dosimetry TBD (Millard 2004) states the following:

> *Information on the location and use of radioactive gases was primarily only available for ^{222}Rn (radon) from 1979 to the present. Very limited information was available for ^{220}Rn (thoron) and ^{219}Rn (actinon), and the measurements were questionable due to excessive decay times before analysis.*

The Occupational Internal Dosimetry TBD further states the following (Millard 2004, Attachment 5D.7):

> *The lack of data for the presence of thoron and actinon inside buildings at Mound could cause a large degree of uncertainty in actual worker exposures. Radon, thoron, and actinon in particular could have caused substantial worker exposure inside buildings before implementation of proper ventilation controls in 1980. Lung dose commitments from actinon could have been significant due to a very short actinon half-life of 4.0 s and direct deposition of actinon daughters on respiratory tract tissues.*” The following statement is made without support, “*Uncertainty from lack of radioactive gas information could underestimate*

> *worker doses by a factor of at least 10. However use of an assumed GSD of 3 compensated for this uncertainty.*

SC&A does not believe this position is sufficiently supported to provide claimant-favorable doses from the unmonitored gaseous radionuclides, such as thoron, actinon, and radon. SC&A is concerned that NIOSH is recommending the use of characterization data from the 1980s–1990s be used to define exposures for workers in earlier plant operations. SC&A questions whether the spot-sampled areas were representative of in-plant radon concentrations, particularly in the SW Building complex, as well as periods of operation involving negative pressure ventilation.

4.4 ISSUE 4: POTENTIAL DOSES FROM HIGH-FIRED PU-238 AND TH-232 ARE NOT SUFFICIENTLY ADDRESSED

It has been found that plutonium that has been exposed to extreme temperatures (e.g., in excess of 1000°C) undergoes metallurgical reactions, and upon inhalation, exhibits a very long retention time in the lungs that exceeds the default absorption types specified by the current ICRP lung model. While this so-called "Super S" type of plutonium already has been addressed in ORAUT-OTIB-0049 (OCAS 2006) for RFP, it is not clear how this empirical model would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238). These microspheres were formed through high-temperature plasma heating processes, and were designed for use in thermal generators. The Occupational Internal Dosimetry TBD (Millard 2004) notes that "in general, Pu-238 compounds are more soluble than Pu-239 due to greater specific gravity and therefore a greater energetic alpha recoil for Pu-238," but does not substantiate this claim, or provide a definitive solubility range for high-fired Pu-238, including the likely insoluble microspheres. The TBD (Millard 2004) assumes a solubility class "S," based on a 1995 King report, without addressing the implications of plutonium high-firing on this assumption.

[Note: The potential for exposure to high-fired oxides was present in several processes: According to the Energy Department:

> *In the microsphere process, the powder was fed through a plasma torch, producing microspheres of uniform size that went directly to the hot press facility. In the shard process, the powder was sieved for size and placed in a controlled atmosphere furnace at an atmosphere of oxygen-16. The material was heated to 1,600°C for 2 to 4 hours. This step produced a sintered plutonium-238/oxygen-16. The sintered oxide was then transferred to the hot press facility where a sphere was fabricated. The die body was sprayed with colloidal graphite and then charged with plutonium dioxide particles. The die was loaded into the press, and the hot press chamber was evacuated. With a force of 2,500 pounds per inch and a temperature of 1,480°C, a sphere of plutonium dioxide was formed. The plutonium dioxide sphere was removed from the die, weighed, and gauged. The sphere was placed in a controlled atmosphere furnace and treated with oxygen-16 at 700°C for 1 hour. Next, the sphere was placed in a vacuum furnace and was allowed to outgas for 30 minutes at a temperature of 1,200°C and a vacuum of*

> *1×10^{-5}. The sphere at this point underwent calorimetry for specification testing. Now ready for encapsulation, the sphere was transferred to the R Building. Encapsulation involved welding a machined metal cover over the sphere. Encapsulation materials included iridium, graphite, tantalum, titanium, and hastelloy (an alloy of cobalt, molybdenum, chrome, tungsten, and iron).*
> (DOE Undated)

The TBD (Millard 2004, Section 5.3.1.4, pg. 24) states that the plasma torch process was used primarily in SM-39, resulting in PuO_2; the use of plasma torch plutonium has been demonstrated to produce the high-fired oxide of plutonium.

Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble high-fired oxides for workers with job assignments and in work areas that had the potential for higher exposures.

An analysis discussed in the SC&A *Rocky Flats Plant Site Profile Review* (SC&A 2005) showed that the incidental acute intake of insoluble plutonium compound in the first 20 years may be difficult to identify because of several factors, including the relatively high MDA (0.01 Bq), the low fraction of activity intake excreted through the urine (10^{-6} Bq), and historic delay in or lack of performing post-incident urinalysis or fecal analysis. It was found that the contribution of chronic intake in urinary activity increases over the time of exposure, obviating the detection of incidental intakes, unless the activity is extremely high or the chronic exposure is very low or undetectable. This analysis took into account chronic inhalation of Type S plutonium compound at 15 Bq/day and 100 Bq/day with acute intake of high fired-oxide, both with annual and quarterly urinalysis sampling respectively, and chronic inhalation of Type S plutonium at 100 Bq/day, plus acute intake with urinalysis sampling on day after acute intake.

Particle size also plays an important role in the potential for higher dose from Pu-238 high-fired oxides. The Mound Occupational Internal Dosimetry TBD (Millard 2004, pg. 12) states the following:]

> *…much of the reported particle size distribution information from the site was qualitative in nature and could not be verified by evaluation of quantitative particle size study results. In addition, it is not clear whether actual breathing zone particle sizes were based on reported estimates of process particle size distributions.*
>
> *Due to the limitations, the default particle size distribution AMAD from ICRP Publication 66 (ICRP 1994) of 5 μm should be used for all processes, as indicated in Table 5A-1. The default AMAD of 5 μm should be used to estimate intake and dose with an associated geometric standard deviation of 2.5 or the default value given in IMBA.*

Based on direction provided by 42 CFR Part 82, a default 5 μm AMAD particle size is only applicable in cases where there is no information on particle sizes available. SC&A recommends that the particle sizes should be reviewed, and the probability of exposure to particle sizes smaller or larger than 5 μm should be calculated before adopting the default parameter of 5 μm.

It is important to note that unless workplace indicators alert the staff of an exposure condition, it is very unlikely that an exposure to a high-fired Pu-238 oxide will be detected, measured, or noted until quite some time after the event. This is due to the fact that the highly insoluble high-fired Pu-238 oxide will not be detectable in the urine, and because of the lack of penetrating photons from the Pu-238, it will not be detectable through lung counting with any reasonable MDA sensitivity. Thus, very significant unknown exposures may have occurred and remained undetected for months. This becomes an even more significant issue in light of the policy described in the TBD (Millard 2004) of discontinued monitoring of workers after they were moved to other projects, and the fact that administrative personnel and support personnel were not monitored routinely.

The TBD (Millard 2004) does adequately address potential high doses from uptakes of these insoluble high-fired oxides. It is a fact that many of these insoluble radionuclides cannot be seen, and the uptakes quantified through urinary excretion and accurate assessments by *in-vivo* techniques, such as lung counting for transuranics, which has poor sensitivity and a high uncertainty associated with the measurements, particularly in the first year or so. The TBD points out that the reported MDAs in 1990 ranged from 69.6 to 73.7 nCi for plutonium and 0.18 nCi for americium (Millard 2004, Section 5.4.2, pg. 39). These values are fairly typical for most facilities, therefore leading to a potentially high missed dose and uncertainty in the estimated uptake.

In 1996, one Mound radiation safety staff member alerted Mound management in a memorandum (Robertson-DeMers 1996) that there were high-fired oxides present in some locations at Mound R Building that could lead to considerable contamination problems, and that effective bioassay and other detection techniques were not yet in place to adequately quantify dose:

> *….. I have considerable concerns about the D&D of R-140. After having several conversations with the production technicians who worked in the room and studying the process history, I have discovered that this room contains high-fired plutonium oxide. The glovebox removal could potentially lead to considerable contamination problems. This is evident by the contamination levels resulting from glovebox leaks and glove failures. In addition, I have also recorded contamination of the same isotopes as seen in R-140 in neighboring R-142 on the window behind Glovebox #2.*
>
> *My primary concern has been that current bioassay methods used at Mound are not sufficient to detect high-fired oxide. The reason for this is that the high-fired oxide does not go into solution adequately both in the body and in the radiochemical process for analysis of urine for plutonium. The bioassay and dosimetric difficulties of analyzing for high-feed oxide have been documented by both Hanford and Rocky Flats. In my discussions with experts on high-fired oxide, I have been told*

> *that the most effective way of determining intake of high-fired oxide is a lung count for identification of Am-241. In addition, there are improved urinalysis techniques for detection of this material including Fission Track Analysis and Mass Spectroscopy. I encourage you to develop an appropriate method of bioassay prior to additional work in R-140 and other areas identified as having high-fired oxide.*

In the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5, the statement is made, "In general, Pu-238 compounds are more soluble than Pu-239 due to greater specific activity, and therefore, a greater energetic alpha recoil for Pu-238 (Millard 2004, Section 5.3.1.4, pg. 23)." It appears this statement is based on observation of two human exposures; (1) at the SRS, "…in which a Pu-238-oxide inhalation case appeared to exhibit biokinetic behavior more characteristic of a class D material" (Carbaugh 2003), and (2) at LANL, in which "There was… considerably less activity in the respiratory tract than would be expected on the basis of current models…" (USTUR 1995). However, this may be insufficient substantiating evidence upon which to reduce the margin of conservatism necessary for dose reconstruction involving high-fired Pu-238 oxide particles. By contrast, the Energy department does not accept the position stated in the TBD (Millard 2004), and has adopted Type S lung absorption for high-fired oxides of plutonium isotopes, as part of its dose reconstruction guidance (DOE 2004b).

In this context**,** the assumption in the TBD (Millard 2004) must be viewed very carefully, because while the Pu-238 high-fired oxide may be slightly more soluble than the Pu-239 high-fired oxide, the former can be considered still highly insoluble. High-fired Pu-238 oxides in microsphere forms were generated as products of production, in addition to the plasma torch operations and other operations that could have produced some of these high-fired oxide forms of Pu-238. It appears that high-fired Pu-238 oxides were present in numerous areas throughout the processes at Mound. Studies at LANL demonstrated the initial extreme insolubility of Pu-238 microspheres in lungs (James 2003). This was followed months later by a slightly more rapid dissolution of the Pu-238 high-fired oxide than seen with Pu-239 high-fired oxide. The TBD (Millard 2004) needs to address the Super Type S form of Pu-238 high-fired oxide and any modifications to modeling that might be required by the dose reconstructors.

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004, Section 5.3.1.4, pg. 24) states the that plasma torch process was used primarily in SM-39, resulting in PuO_2, the use of plasma torch around plutonium has been demonstrated to produce the high-fired oxide of plutonium.

Given these uncertainties, NIOSH/ORAU should use the more claimant-favorable approach for high-fired Pu-238 oxides, as adopted by the DOE in its dose reconstruction guidance. NIOSH-ORAU should also reconsider their approach to dose reconstruction considering the non-detectability of exposures to high-fired forms of Pu-238 below 70–75 nCi or more in the lungs and only detectable in urine months after an event, if monitoring was done at that time.

With respect to high-temperature processing of Th-232 feed material, ORAUT-TKBS-0016-5 observes that "the caustic treatment was likely to have been a high-temperature process that would have resulted in such refactory and highly insoluble thorium compounds as thorium dioxide." However, Attachment 5A of this TBD, which provides the lung clearance class for each compound handled in the Mound facilities, lists thorium isotopes from thorium refining as Class "M," as opposed to Type S, or perhaps more appropriately, "Super S." Apart from this seeming contradiction, it is not clear what the implications are of worker exposure to such high-fired thorium compounds.

4.5 ISSUE 5: USE OF 1949–1959 DOSE DATA FOR MODELING EARLIER YEARS (1943–1948) IS QUESTIONABLE.

The Site Description TBD (ORAUT-TKBS-0016-2), the Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004), and other documents illustrate how the Dayton/Mound sites in the early years were rapidly changing and exploring new, unknown technologies, especially in the area of radioisotopes. The first era was during 1943–1948, when research and development (R&D) and limited production was conducted at several make-shift sites. The second era was around 1949–1959, when a new facility was used to start production and further R&D. The physical facilities, working conditions, and radiation exposures of the two eras were necessarily different. Additionally, information gathered during the first era (at Dayton and other institutions) could start to be used to control radiation exposures during the second era. Therefore, the doses to the workers during 1949–1959 would decrease, compared to the workers of 1943–1948.

However, the second era was not, itself, without health physics (HP) problems. Page 9 of the Occupational External Dosimetry TBD (Proctor and Algutifan 2004) mentions that Mound never had a well-documented quantitative study of its external dosimetry programs, and on page 10, it states that the record on historical dose limit standards is ambiguous and a great deal must be inferred. A modal dose of 50 mrem/wk for neutrons and 50 mrem/wk (n/p = 1:1) for photons from 1949–1959 is recommended on pages 14, 22, 50, and 51 of the TBD (Proctor and Algutifan 2004) for dose assignment for workers during 1943–1948. There is no data provided to support the 50 mrem/wk dose value. The 50 mrem/wk equates to 2.5 rem/year. This is comparable to today's standards, but is much less than the allowable limits of 26 rem/year, and later 15 rem/year, as allowed in 1943–1949 (Proctor and Algutifan 2004, Table 6-3, pg. 11). Therefore, a worker could have received 6–10 times the proposed assigned dose and still have satisfied the guidelines.

The current Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) does not address some important issues that could lead to an underestimate of doses to workers when using the modal dose from 1949–1959 to assign doses to the 1943–1948 workers. Some of these issues are as follows:

- Different facilities: Many of the older facilities were not intended for use with radioactive material (surface decontamination, controlled areas, ventilations, etc).

- Different working conditions: Earlier workers did not benefit from established production operations and infrastructure as later workers did.

- Accidents/incidents: For example, the two that occurred in 1944 (as described in an article by L.B. Silverman (Silverman 1962)) are not captured by assigning later cohort doses.

- The later years had the benefit of experience from the earlier years; therefore, a lower modal dose would be expected during the later period.

- Early era dose limits were based on staying below regulatory limits, not necessarily on individual accumulative doses. Using modal doses from a period that controlled individual exposure does not correctly reflect the doses received by earlier workers where such controls did not exist.

Considering the differences between the two eras, it does not appear to be technically sound or claimant favorable to use the 1949–1959 modal recorded doses to back-establish doses for workers from the first era of Mound operations. Other methods are needed to address this issue.

4.6 ISSUE 6: HISTORIC BETA EXPOSURES ARE NOT SUFFICIENTLY CHARACTERIZED

Beta dose reconstruction is not sufficiently covered in the Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004). Periods when reliable beta dose and extremity dose records are not available need to be identified. Beta skin doses from contamination and organ and/or extremity doses from handling beta-emitting materials close to the body and hands need to be further addressed. Table 6-23 on page 35 of the TBD (Proctor and Algutifan 2004) provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. While the TBD (Proctor and Algutifan 2004) provides some information concerning beta/low-energy photon dosimetry for this period, it appears scattered and incomplete. Without dose records available for analysis, it is not possible to determine if and when skin doses were recorded, or how LOD, zero, and blank readings were handled. The potential for underestimating beta dose is not sufficiently covered in the present TBD (Proctor and Algutifan 2004).

As early as 1944, it was known that the beta fields were intense around the irradiated material, because workers had to use lead gloves and tongs to handle them, and in 1956, beta activity in 1 lambda of water saturated the beta counter. In 1957, a bismuth shipment contained beta-contaminated water. The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) and other documents also state that many beta-decay radioisotopes accompanied the bismuth/polonium irradiation, separation, and handling process, and Table 6-23 on page 35 provides a list of numerous beta-emitting isotopes that presented external dose hazards at the Dayton/Mound facilities from 1943 to 2000. The TBD (Proctor and Algutifan 2004) outlines some historic information concerning beta/low-energy photons dosimetry; such as on page 25:

- *1946–1952: No low-energy photon doses measured.*

- *1953–1977: Skin dose – Started reading OW in 1953 per pg. 25, but 1960 per pg. 23).*
- *1972: Began routine extremity dosimetry.*
- *1979: First beta calibration of dosimetry.*
- *1978–2006: Skin dose = skin gamma + neutron + beta (if measured).*
- *1995: Limit of detection (LOD) for beta was 53 mrem/qtr (pg. 36).*

Without a clear delineation of in-plant practices and for what periods of time reliable records exist of beta exposure, there is insufficient guidance for the dose reconstructor from the characterization information provided in the TBD (Proctor and Algutifan 2004) to ensure claimant-favorable dose reconstruction. Areas that need to be addressed are as follows:

- Periods when reliable beta dose and extremity dose records are not available need to be identified.

- Methods are needed to assign beta doses for periods when dose records are not available.

- Beta doses to organs and/or extremities from handling beta-emitting materials close to the body and hands need more investigation.

- The magnitude of beta skin doses from contamination needs to be determined.

- It needs to be determined how zeros, blanks, and LOD values were handled in recording the beta dose values, and how they will be handled during dose reconstruction.

In summary, the subject of beta exposure has not been sufficiently developed in the present TBD to ensure that workers will be assigned claimant-favorable beta doses.

4.7 ISSUE 7: ASSESSMENT OF PERSONNEL BADGING DURING THE EARLY YEARS NEEDS FURTHER REVIEW

Pages 11 and 15 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) indicate that all *radiation* workers were badged during 1949–1962. However, according to a report of January 1961 (Mathew 1961), roughly only 15%–20% of the employees were badged during 1947–1959. This could have resulted in some workers not being monitored during a period when all the radiation hazards were not recognized and, therefore, those workers were not considered radiation workers at the time. The TBD (Proctor and Algutifan 2004) is not clear concerning who was monitored and when. The term “radiation worker” has not been defined, and it is not certain how this was used at Mound Laboratory at the time to assign badges. Table 6-4, page 11 (Proctor and Algutifan 2004), lists some information on who was badged in the ‘Comments’ column. From this information, it is not clear for what time periods certain workers were badged; i.e., was everyone inside the plant area (security, crafts, maintenance, janitorial, etc.) considered “radiation workers,” or just those who routinely handled radioactive materials? There are some concerns that not all workers who needed to be monitored were monitored when they needed to be, as supported by statements made in the Occupational External Dosimetry TBD (Proctor and Algutifan 2004), as follows:

- ***Maintenance and engineering staff –*** Table 6-2, page 10, states that night maintenance staff in Building P started to be routinely monitored for neutrons in 1963, and that some hourly engineering staff members were starting to be routinely monitored for neutrons in 1966.

- ***Maintenance staff*** – Page 23 instructs the dose reconstructor to assign maintenance staff 38 mrem/2-wk periods or 1 rem/yr for unmonitored periods before March 22, 1966 [Maintenance workers often performed many different functions at different locations and under different situations, and are being assigned much lower doses than are listed on pages 50 and 51 (Proctor and Algutifan 2004) for base and missed (neutron plus gamma) doses of 2 to 7 rem/y.]

- ***Other workers –*** It appears that other workers (such as those involved in decontamination and decommissioning activities, roving workers, janitorial staff, etc.), who may have had the potential to be exposed to higher than average radiation doses, may not have been considered for monitoring, especially during post-1990 when operations stopped and D&D was performed. For example, Building 59 (Proctor and Algutifan 2004, pg. 34) could present radionuclides of concern, such as U-235 and Fe-59, in the form of rust during building demolition.

It is not apparent from the TBDs if incidents and accidents were recorded for unbadged workers, and if these will be used for individual dose reconstruction.

NIOSH needs to address the following:

- Determine how Mound Laboratory defined “radiation workers” during 1949–1962.

- Determine if these radiation workers were badged for neutron and beta, as well as photon, radiation, and if all doses were recorded.

- Examine the Mound badging policy and dose records to determine what criteria was used to assign badges; for example:

  - Were all workers who were expected to receive above a certain exposure badged?
  - Were supervisors allowed to select the workers who were badged?
  - Was badging random within a selected group of workers to be badged?
  - Were the maximum exposed workers continuously badged; if so, how can it be ascertained that they were the maximum exposed?

Much of this information can be derived from a detailed review of annual dose records. The answers to these concerns are important in order to determine whether workers who were potentially exposed to radiation were adequately monitored, and which workers need doses assigned based on co-worker radiation exposures. Workers who were unbadged, or whose individual doses were not recorded, cannot be assigned missed doses based on LOD values and still be ensured that the doses are technically sound. This issue needs further investigation and clarification.

4.8 ISSUE 8: PROBLEMS WITH NTA FILM NEUTRON DOSES

It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron dose records for **badged** workers are being corrected for the low-energy response and fading of NTA film (especially at low neutron energies), and for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficient detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years. Other issues of internal consistency were noted in the TBD (Proctor and Algutifan 2004), including inconsistencies in given neutron-to-photon ratios for various operational periods, neutron flux to DCFs used in 1947–1969, and NTA film fading in the 1950s and 1960s.

The use of NTA film to monitor neutron doses at Mound Laboratory raises several areas of concern as outlined below.

NTA film neutron energy threshold – As at other nuclear facilities, Mound became aware of the problem of the under-response of NTA film to neutrons of less than around 0.8–1.0 MeV in the 1960s. It is stated on page 17 of the TBD (Proctor and Algutifan 2004) that in 1963, the average energy of the neutrons measured in SM Building was 0.75 MeV, and again in 1969, an average neutron energy close to 0.75 MeV was measured; but that Mound dosimetrists thought it conservative to assume the higher energy of 1.3 MeV. The real danger in assuming a higher energy neutron field than that to which the worker is really exposed is that the NTA film practical threshold is around 1 MeV and, therefore, lower energy neutrons could go undetected. This was mentioned on page 19 of the TBD (Proctor and Algutifan 2004), but not sufficiently addressed. An adjustment to missed or under-reported doses is recommended on pg. 30 of the TBD (Proctor and Algutifan 2004), Table 6-17, in footnote (d), which recommends using a 14% correction factor obtained from the SRS for neutrons in the range of 0.1 to 2 MeV.

Correction factors for poor low-energy response depend to a large extent on the facilities' operating conditions, and should be determined for each site and location within a given site. Neutron sources in hydrogenous shielding and process streams quickly degrade to lower-energy neutrons. A missed dose of 14% for all neutrons that fall below the 1-MeV threshold of NTA film, considering the varied missions at the Mound Site, appears to be very small and could result in missed dose. In general, NTA film misses around 1/4 to 1/2 of the neutron dose around moderated neutrons. A multiplication factor of 2 (i.e., 1/2 go undetected) is stated for 1970–1976 on page 21 of the TBD (Proctor and Algutifan 2004).

It is not obvious from the current TBD (Proctor and Algutifan 2004) that the dose reconstructor has sufficiently and consistently detailed correction factors and instructions available to correct for unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy. The following areas need to be investigated to ensure complete neutron dose assignment:

- Determine in what buildings and time periods lower-energy (PoLi, PoF, PuO_2, PuF_4, etc.) or heavily moderated higher-energy (PoBe or PuBe) neutrons sources were present.

- Determine what neutron source(s) were used for NTA film calibration during these time periods.

- Determine if all exposed workers' neutron dose records were appropriately corrected for NTA film lower-energy response for each year (such as multiplying by a factor of 2, as stated on page 21 for 1970–1976) for the exposure and calibration conditions that existed.

[The above information is also useful for correcting for track fading, especially at lower-neutron energies.]

- Resolve the apparent conflicting concept of multiplying dose records by a factor of 2, as stated on page 21 for 1970–1976, as opposed to using a correction factor of 1.14, as stated in footnote (d) of Table 6-17 on page 30 to correct for missed dose because of poor low-energy response.

Neutron/photon ratios are not consistent – The Occupational External Dosimetry TBD (Proctor and Algutifan 2004, Section 6.6.3.4, pg. 37) states that the neutron-to-photon ratio at Mound was 2:1. However, Tables 6A-1 and 6A-2 both list the ***same*** imputed base dose for neutrons and photons of 2,600 mrem/y for the years 1943–1949 (i.e., n/p = 1.0). The first paragraph on page 50 (Proctor and Algutifan 2004) lists the base annual dose for 1947–1977 as the cohort dose **or** the modal dose for 1949–1959 of 2,600 mrem/yr for neutrons and 1,040 mrem/yr for photons (i.e., n/p = 2.50). A modal dose of 50 mrem/wk neutron and 50 mrem/wk photon is stated for 1949–1959, and recommended for dose reconstruction during 1943–1948; this is a n/p = 1.0.

Variation in neutron QF – Page 16 of Occupational External Dosimetry TBD (Proctor and Algutifan 2004) lists possible reasons why the neutron flux required to equal 300 mrem/wk varied between 30 and 150 n^o/cm^2-s in the period of 1947–1969. However, the two reasons suggested (longer than a 40-hr work week or decreased energy of the neutron sources) would not account for these drastic changes. Even a 60-hr work week would only decrease it by 33%. Changing back and forth between 5 MeV and 1 MeV neutrons would only change it by a factor of 2 (ICRP 1991; Proctor and Algutifan 2004, pg. 17). No feasible explanation was provided for the changes in the conversion factors.

NTA film fading – Page 20 of Occupational External Dosimetry TBD (Proctor and Algutifan 2004) discusses NTA film track fading, and states that it became important in 1968 and corrections were made from that time forward. It also states that Meyer (Meyer 1951) noted film fading as early as 1951; but he must have not considered it important, and no corrections were apparently made until July 15, 1968. If fading resulted in under-recorded doses in 1968, it also could be a problem back to 1949, when NTA film was first used at Mound. This is of concern especially when lower-energy neutrons from (alpha, n) reactions are present, such as those from PuO_2, PoF, PuF_4, or PoLi, etc, because of the more pronounced fading of lower energy tracks in NTA film.

Some aspects of neutron dose reconstruction for **missed** dose is provided on page 30 of the TBD (Proctor and Algutifan 2004), but it is not clear from the present TBD if the neutron dose records for **badged** workers are being consistently and appropriately corrected for the low-energy response and fading of NTA film (especially at low-neutron energies), and if and how the n/p values are being used in neutron dose reconstruction.

4.9 ISSUE 9: THE DECONTAMINATION AND DECOMMISSION (D&D) ERA OF MOUND OPERATIONS IS NOT SUFFICIENTLY ADDRESSED

Monitoring practices, particularly internal dosimetry, are not specified in the TBD for the D&D period (1992–2003) at Mound. Other contemporaneous sites undergoing D&D, such as RFP, conducted urinalysis on D&D workers, including subcontractors who entered radiological control areas and had Rad Worker II training. They also reportedly employed lapel samplers among other air samplers as a means to trigger special bioassays, as needed. One site expert indicated that Mound sent a team of workers to RFP in the early 1990s to study and emulate the RFP approach to radiation monitoring of D&D workers. However, according to this worker, the resulting D&D monitoring program applied lapel samplers and DAC-hour analysis as the primary, not secondary, dosimetry, as reported for RFP. (This assertion was also made by an RFP former D&D worker and is currently under review.) There are also concerns related to the adequacy of bioassay during the D&D period at Mound for specific radionuclides, as noted in Issue 1 (Section 4.1) of this report.

A number of questions present themselves that are not addressed by the existing Mound Site Profile. What specific external and internal monitoring program was established for D&D operations, and how effectively was it implemented? With the use of first-, second-, and third-tier subcontractors, to what extent were these workers “captured” in the site’s dosimetry program, and are their records maintained in the Mound database? How would the co-worker dose model be applied for unmonitored workers located adjacent to D&D operations; was resuspension of radioactive particulates an onsite issue during D&D?

There is a lack of sufficient environmental monitoring data to fully characterize source terms to which workers were exposed during waste disposal and D&D demolition procedures, particularly as production began to cease in the early 1990s. Many of the radionuclides that researchers were working with were often unknown to radiation safety personnel. Buildings at Mound were engineered during their construction to provide ventilation systems, fumehoods, and gloveboxes to help minimize inhalation uptakes by workers. As demolition workers began to remove walls and dividers, and to remove these contaminated fumehoods, gloveboxes, and ventilation systems, these engineering controls were breached and no longer became effective in minimizing inhalation uptakes. Contamination within the ventilation ductwork would have been an additional source of uptakes. Not always being aware of the mix of radionuclides present in specific demolition areas and/or researcher-handling areas made it difficult to adequately prevent, monitor, and detect uptakes of these radionuclides.

Over the years, occasional D&D at Mound Laboratory was a part of normal operations. However, there were two main eras when most of the D&D occurred at the overall Dayton Project facilities. The first was around 1948, when the older units were removed, such as Units I-IV, Site Description TBD (Vollmer 2004b, pg. 10), and the second in the 1990s, when the Mound facilities (Unit V) underwent D&D. The more recent D&D operations (1974–2001) at Mound are mentioned briefly in the Site Description TBD (Vollmer 2004b, pp. 9, 18, 19, 26, and 31) in the contents of building numbers and dates, but not with specific operations or dose details. The only reference to dose was on page 22 of the Site Description TBD (Vollmer 2004b), where it refers to Meyer as stating that the highest neutron doses were in D&D operations in Building PP, where the neutron doses were about 30 mrem/2 weeks. This was in the context of the fading of the thermoluminescent dosimeter (TLD) signal and not to workers' doses, in particular. The Site Description TBD (Vollmer 2004b, pg. 6) states that it was DOE's plan to close the Mound facility in 2006; and on page 34, it mentions that Building 59 could present radionuclides of concern, such as U-235 and Fe-59, in the form of rust during building demolition. The end of the table on page 9 (Vollmer 2004b) refers to some cleanups, and it states on page 31 that Building 123 was deconstructed in 2001, although no potential worker exposures or dose details are provided. In summary, this is the full extent to which this final era of radiological operations is mentioned in the various TBDs of the Mound Site Profile.

One of the Mound RCTs did address D&D activities during his SC&A interview, and his radiation exposure experience is provided in Attachment 2. As he pointed out, particular dose reconstruction attention should be considered for the open-processing areas of SM Building and PP Building (also known as Building 38), particularly in the late 1980s and early 1990s when the critical clean-up evolutions were underway. There was also some uranium work done in SM Building, whereas PP Building was primarily Pu-238 with potential for high-fired oxide exposures. Later in PP Building, there were many orphan sources handled. Some were encapsulated, but even these became leaky. As T Building was being torn down, all walls and cubicles were gutted, and there was only one cavernous area with many untested changes in the engineering controls. There were some very different and uncommon radioisotopes used in A-line operations. There was also significant potential for exposure to neutrons from Pu-238 operations. In most cases, Pu-238 contamination was effectively quantified and controlled, but there were instances when contamination leaked out of the D&D tents unexpectantly, and personnel may have had uptakes, since respirators were not always required for such work.

> *One Mound interviewee indicated that a small breathing zone (BZ) air monitoring program was implemented in 1989 (See Attachment 2). Once a month, workers were selected in certain production areas to wear lapel air samplers for measuring breathing zone (BZ) air concentrations. One worker remarked that it seemed to him that the BZ sampler was always given to the "cleanest" worker, i.e., the one with the least likelihood of high airborne readings, because elevated*

> *levels above certain criteria could shut a particular job down. According to the worker, a full-fledged breathing zone program was implemented in 1998.*

In most D&D activities, workers have to cut or otherwise breach the system during the removal process. This lends itself to multiple radionuclides used by researchers at Mound, but is a particular concern when such environmental exposures involve SMTs and STPs. In the BWX Technologies, Inc., letter providing responses on a draft TBD for STPs, BWX responded to questions regarding SMTs by stating the following (BWXT 1999):

> *Pre-job characterization surveys will be performed, but the tritium results will not be analyzed to differentiate forms of tritium. Further characterization is not necessary, since we are assuming that all tritiated materials on a survey or lapel sample are Stable Tritiated Particulates (STPs). Using the Dose Conversion Factors (DCFs) for observed counts has shown to be fairly independent on particle type and size, therefore reducing the impact that additional characterization data would have.*

According to a BWO response (BWO 1991), Mound attempted to monitor STPs:

> ….[by taking] *more accurate air monitoring results, which are used to assign dose… Urine bioassay is no longer considered to be a usable approach to assign dose. To the best of our knowledge the methodology for STP fecal bioassay analysis is not currently available; therefore the shortfall associated with the final methodology cannot be discussed. In a recent teleconference with DOE Headquarters regarding the TBD, they indicated that they intend to pursue development of a fecal bioassay methodology for STPs; however no timeline has as yet been established. Nonetheless, worker protection can be effectively achieved without a fecal bioassay process.*

In the same BWX Technologies, Inc., document (BWXT 1999), a question was raised about the potential use of the results of the individual lapel air sampling in assigning individual doses, what the sample validation process would be, and whether a sample validation process was referenced in Mound's existing procedures. It was also asked if Mound used lapel sampling results for assigning doses in the past. BWX responding by stating the following:

> *The following process will be used to validate lapel air sampling analysis background and a check source count will be run with each set of lapel samples as an indication that the instrumentation is functioning properly. In addition, the instrument is verified operational on a daily basis through the use of control charts using a predetermined background and a tritium check source. These processes are documented in MD-I 03 79, Health Physics Counting Laboratory Manual. A review of the lapel sample data will be performed by Count Lab health physicists before it is submitted to Internal Dosimetry for use in assigning individual doses. To the best of our knowledge, Mound has not used lapel sampling results for assigning doses in the past.*

Decontamination and decommissioning is not addressed in any detail in the documents reviewed to date on the "O" drive concerning external doses. In revisions to the TBDs, NIOSH should devote a section to D&D operations, and find ways to quantify dose for workers involved in D&D and demolition operations that produced dust levels with potentially high internal uptakes, and with worker exposure to radioactive debris that might have resulted in a significant potential for external dose. It is not apparent from the TBDs if recent D&D was performed on any large scale and, if it was completed, what specific operations were conducted. The TBDs should provide information by building decontaminated or demolished, and if not yet demolished, at what stage of D&D key facilities stand. This should include information that describes if the building was just decontaminated or completely removed, and if all the contaminated soil and material was removed. Health physics procedures needed for these D&D operations were also not addressed in the TBDs. No external dose monitoring, precautions, unusual conditions, or incident tracking during D&D is mentioned. All D&D workers in the radioactive areas should have been badged for ***photons, beta, and neutrons.*** It is not clear if this was done or if workers always wore respiratory protection during such evolutions. Buildings and materials could contain radioactive materials that emit neutrons from (alpha, neutron) reactions, such as PuBe contamination. This could present external and internal neutron exposures that are not normally encountered in D&D operations. Additionally, high concentrations of beta emitters (hot particles) could present unusual skin and internal exposures, if present.

The period from the end of operations to complete closure of the site appears to be missing from the TBDs reviewed to date. It is not possible to evaluate the external dose issues during this period without additional information on the D&D operations, health physics and monitoring procedures, and dose data results.

4.10 ISSUE 10: OCCUPATIONAL MEDICAL EXPOSURE IS NOT ADEQUATELY DEFINED AND ASSESSED

The current guidelines, as presented in Kathren and Shockley (2005), go a long way in ensuring that all occupational medical exposures are reasonably included in determining the overall dose estimations for claimants. Unfortunately, the interpretation of these guidelines, to date, by the contractor (ORAU) has not been applied conservatively to be claimant favorable. The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) assumes an interpretation of what constitutes an occupational medical x-ray examination, which also has been considered and applied at other sites, such as the RFP and LANL. To this extent, the assumption that medical procedures are limited to only one pre-employment chest x-ray and chest x-rays which are part of routine physical exams may substantially underestimate worker medical exposure when evaluating occupational medical exposure.

In the current guidelines document, ORAUT-OTIB-0006, Revision 3 (Kathren and Shockley 2005), it is concluded that other examinations should be included, such as special job exams (e.g., respiratory protection, beryllium workers, asbestos workers, etc.) and termination exams. The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) does not recognize this change from the previous Revision 2 of OTIB-0006 (Kathren and Shockley 2005), and also assumes that special chest radiography for respirator certification, beryllium and asbestos workers, and food handlers are accomplished as part of the annual physical, if these jobs are defined as "at-risk" workers. This is not documented in the TBD (Algutifan et al. 2006). Another factor not discussed in the TBD (Algutifan et al. 2006) is the potential for and impact of x-ray procedures utilized by medical authorities to do special screenings.

The TBD (Algutifan et al. 2006) makes the conclusion that one chest examination of a PA view per year should be limited to a small group of "high-risk" workers after 1980 and smokers after 1989, as documented in Table 3.1 of the Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006). The only differential noted is that women who underwent breast augmentation surgery after 1988 also had a chest LAT x-ray performed. To the contrary, there is ample evidence that chest x-rays were often provided on a voluntary basis to nearly all workers. The majority of workers had chest x-rays as a routine at DOE sites until the mid-1980s, when Federal guidelines warning against routine screening were first being enforced.

After discussion with NIOSH personnel, it became clear that it was their decision to limit occupational medical exposure to those chest exams described above, and to conclude all other exposure should be part of worker background. SC&A believes such an interpretation is not claimant favorable to those most at risk. Our concern is that specified "high-risk" workers, i.e., those most likely exposed to radiation and beryllium, would be at risk of having an incomplete dose assessment, if not all radiation associated to medical diagnoses for job-related activities were included. Since, all radiation provides some risk, and arguably, is cumulative, workers warrant consideration of all forms of work-related x-ray exposure to be claimant favorable. SC&A believes NIOSH should review its interpretation of included medical exposure, and should reasonably adopt a broader interpretation of occupational medical dose, as provided in the most recent version of OTIB-0006 (Kathren and Shockley 2005).

4.11 ISSUE 11: POTENTIAL MISSED DOSE

SC&A has concern with the TBD (Millard 2004) as it presently reads regarding the potential for large missed dose in the early days. Section 5.1.3, page 10, 2nd paragraph of the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) states the following:

> *Individuals identified as being involved in an internal exposure incident or had urinalysis results in excess of the* ***reporting limits listed in Table 5-7*** *were required to submit additional urine 24-hr samples for analysis. Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed.*

In the case of protactinium, Table 5-7 of the TBD (Millard 2004) lists "**Detection limit (dpm)"** for protactinium, also noted as the "MDA" in the caption preceding the table**.** The above statement from the TBD thus implies that the action level and reporting limits are the same. If this is the case, then the missed dose (those not resampled and unmonitored administrative personnel) would include all those having urine samples less than 2.2 cpm $24hr^{-1}$, which also equates to 300 mrem wk^{-1} or 15 rem yr^{-1}. This could be a very significant missed dose, where no follow-up sampling would have been done for those administrative personnel, maintenance personnel, and for those who may have had exposure just prior to discontinuation of work on the project.

This is further exacerbated by the statements in the Occupational Internal Dosimetry TBD (Millard 2004), Attachment 5D.0 on Uncertainty Assessment, which states the following:

> *Uncertainties in estimating worker dose commitments from bioassay data result from uncertainty in monitoring measurements and assessment of intake (ICRP 1998). Uncertainties for the bioassay measurements were not stated in the records.*

SC&A has concern with the TBD (Millard 2004) as it presently reads regarding the potential for large missed dose in the early days. When monitoring for Pa-231, it is stated that monitoring was done for, "…only those workers conducting research to separate and purify protactinium," and "…Individuals identified as being involved in an internal exposure incident or had urinalysis in excess of the reporting limits listed in Table 5-1."

These limits were based on the 300 mrem wk^{-1} MPC to the target organ at that time. This would indicate that any value less than the dose limit, equivalent to15 rem per year, may be missed.

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004) goes on to point out that the practice was that, "Administrative personnel were not monitored and monitoring was discontinued for operational personnel if their work on specific projects was no longer needed."

This, likewise, would lead to potentially significant missed doses, as described above for these workers.

There is also the issue of contamination reported in several documents for "T" Building in the early 1950s. Report MLM-MU-51-69-0024, September 15, 1951 (Mound 1951), addresses *T Building Contamination Problem in the Process and Electrolysis Lines*. The report mentions "levels of activity in the high risk corridors," and that "one of the greatest sources of contamination comes during trash collection." It is pointed out that about 300,000 counts per minute are contributed to the total weekly air count of a high-risk corridor during collection of trash. This level was significant and produced potential internal exposure risk to all workers in "T" Building using these corridors. Individuals using these corridors may not have been on any monitoring program for the contaminants that may have been present; the site profile TBDs are unclear on this.

In the early years, much was unknown about the potential exposure to other radionuclides, as pointed out by the Mound Phase II Final Report, Appendix C (MJW 2002a, pg. 7):

> *Many difficulties were encountered in attempting to interpret the available bioassay records and reports of the other radionuclides. Some of the results were*

> *not associated with a name, social security number (SSN), or health physics number (HPNO). Oftentimes, there were no units associated with a result. In many cases, there were results for an element such as radium or thorium, but it was unclear which isotope was intended. There was no information on the age, solubility, or chemical form of the elements. Also, there was no information concerning incidents, known intakes, or details concerning the work activities of any of the workers for whom there are results.*
>
> *The intake and dose assessments for the "other" radionuclides done during this project are based on limited, and on occasion conflicting, information. In some cases, it appears that the same bioassay results were repeatedly reported for two, or sometimes three, different radionuclides. For example, a person may have identical results for protactinium and thorium-232. In other cases, urine samples may have been analyzed for radium/actinium/thorium by differential decay analysis of the radium fraction. The same urine sample may have also been analyzed for Th-232 by doing a Ra-Th separation. The results of the differential decay analysis appeared to conflict with the Th-232 analysis in that the dominant radium isotope is Ra-223 whereas Ra-224 would be expected. This would seem to indicate that the thorium results should have been interpreted as Th-227.*
>
> *Because there is very little information available, it was necessary to take a holistic and somewhat flexible approach to each individual's assessment, rather than design a "one-size-fits-all" procedure. Also, the interpretation that would yield the most conservative estimate of dose was used. A set of default assumptions based on fundamentals of the Mound Internal Dosimetry Program were used primarily to limit the number of decisions that had to be made, the basis of which may be tenuous at best.*

The state of the art of the Mound internal dosimetry program did not reach a much improved status until about the early 1990s. A draft internal dosimetry upgrade summary plan in June 1990 (Mound 1990) had this to say about the Mound internal dosimetry program prior to 1990:

> *The lack of a consolidated, comprehensive Internal Dosimetry Program at Mound has led to the present situation involving many areas of noncompliance with internal dosimetry monitoring specified in DOE Order 5480.11. Mound has no unified, technically based performance requirements for bioassay and in vivo monitoring and action levels for prompt dose assessment and remedial actions. The new DOE Order 5480.11 and the draft DOELAP Accreditation Program for Internal Dosimetry provides the incentive for developing a new Mound Internal Dosimetry Program Manual which establishes the technically based performance criteria for all internal radiation exposure monitoring requirements…Presently, supervisors are responsible for assuring that their employees, visitors, or contractors receive the appropriate personnel dosimetry monitoring for the areas which they will encounter while at Mound. Although guidance in the form of policy and recommendations is available in several manuals and procedures,*

> *information and technical assistance is not consolidated or readily available. Supervisors are not provided with a single point of contact for obtaining technical or administrative guidance to fulfill their responsibilities associated with personnel dosimetry. An especially confounding problem is knowing whether construction contractors are provided with adequate personnel monitoring services to comply with internal dosimetry requirements.*

Beyond the compliance issues, it is clear that even as late as the early-1990s, Mound did not have a coherent dosimetry program, apparently relied upon supervisors for monitoring decisions, and was initially struggling with assuring adequate bioassays for D&D construction workers.

4.12 SECONDARY ISSUES

4.12.1 Secondary Issue 1: Lack of Available Dose Data Details

The Occupational External Dosimetry TBD, ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) recommends using cohort dose data to assign doses to unmonitored workers. Some statistical analysis needs to be provided concerning the cohort data. For example, how many workers were badged during each year for neutrons and for photons, and what was the dose range and number of zeros in each dose set? What is the justification for applying this dose data to unmonitored workers? Will dose reconstruction be performed on a building or job title basis, or will the one dose be used for all workers, as is recommended for the 1943–1949 groups? Column 2 of Tables 6A-1 and 6A-2 recommends using the cohort dose; will this be on a yearly basis, or averaged over the time period listed in Column 1? Additionally, it is not clear from the TBD if adjustments (for fading, thresholds, etc.) to the recorded doses have been made in the past or if these adjustments will be made to the worker's dose during the dose reconstruction process. In view of the lack of complete dose records for all workers, it is certainly necessary to explore in some detail the data that is available and its applicability to unmonitored workers.

Some of the previously stated external dosimetry issues stem from the lack of available dose data details in Occupational External Dosimetry TBD, ORAUT-TKBS-0016-6. More details are needed concerning the 1949–1959 dose data and the appropriateness of using the modal dose of 50 mrem/wk neutron and 50 mrem/wk photon for dose reconstruction, especially in view of Section 6.6.3.4, page 37 of the TBD that states that the n:p ratio was 2:1. The TBD needs to provide a technically sound basis for using 50 mrem/wk modal doses and the applicability of the use of cohort data as suggested in Tables 6A-1 and 6A-2. Some tabular information is needed concerning the individual workers' dose data to include: year, ID number, job tile and/or department number and/or building number, neutron penetrating dose, photon penetrating dose, total penetrating dose, skin or non-penetrating dose.

Some statistical analysis needs to be provided. For example, how many workers were badged during each year for neutrons and for photons, and what was the dose range and number of zeros in each dose set? What is the justification for applying this dose data to unmonitored workers?

Will dose reconstruction be performed on a building or job title basis, or will the one dose be used for all workers, as is recommended for the 1943–1948 group?

Column 2 of Tables 6A-1 and 6A-2 recommends using the cohort dose; will this be on a yearly basis, or averaged over the time period listed in Column 1?

The Occupational External Dosimetry TBD does not make it clear if the "dose of record" for the workers has been modified with the necessary adjustments or not. These adjustments would include tantalum shielding of 60 keV gammas; NTA film track fading and low-energy threshold; TLD signal fading; and decreased response at high-neutron energies. The TBD provides a lot of information concerning adjustments to the "Missed" dose calculations based on LOD, but very little information concerning the worker's dose of record and its adjustments for use during dose reconstruction. In view of the lack of complete dose records for all workers, it is certainly necessary to explore in some detail the data that is available and its applicability to unmonitored workers.

4.12.2 Secondary Issue 2: Discrepancies in Definitional Terms

There is confusion throughout the Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004) in the use of and definitions of MDA, Reporting Level, Decision Level, Decision Limit, and Action Level. This is illustrated on pages 10, 11, and 22 of the TBD (Millard 2004). It would appear that the terms "decision level" and "decision limit," and "MDA" are used by the author interchangeably. On pages 10 and 11, the equations 5-1 and 5-2 approximately define decision level (D_L) and minimum detectable activity (MDA).

Confusion is further added in the TBD (Millard 2004) on page 22, where it states, "Table 5-7 lists reported background count rates given in Section 4, Bigler's Annual Monitoring Reports by time period and **MDAs** derived using Currie's equation 5-2 (Meyer and Reeder 1992)." This is followed by Table 5-7 that lists the last column as **Detection limit.** Is this column D_L or MDA, as stated in the sentence preceding the Table 5-7?

It is SC&A's view that NIOSH needs to review this section for technical accuracy.

4.12.3 Secondary Issue 3: Problems with Recovery of Po-210 and Pu-238,239 Could Affect Dose

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), goes into detail describing the problems discovered in the 1980s and 1990s, and discussed at length by Meyer (1992) *History of Mound Bioassay Programs*, regarding the recovery problems with metabolized Po-210 prior to 1964 and the poor recoveries of Pu-238,239 prior to 1960. In the Meyer (1992) report he states:

> *If we were to do dose commitment calculations today, we would consider the recovery efficiency of polonium from all past urinalyses to be just 10%. This would make a very significant change in the dose commitment calculations that*

> *we have done on a limited basis in the past and will do for a comprehensive study in the future.*

NIOSH in the TBD (Millard 2004) is to be commended for recognizing and dealing with these corrections for years prior to 1964. However, SC&A is not sure the full content of the Meyer report, quoted above, has been applied or considered. Meyer states that this recovery efficiency of polonium from **all past urinalyses be just 10%** and would make a significant change in the dose commitment calculation done on a limited basis in the past and will be done in the future. NIOSH is suggesting in Section 5.3.1.2, page 21, that this correction be applied to the data **prior to 1964. Data reported after 1963 should be normalized to 86% and corrected for a 63% chemical recovery** based on analysis by (Fellman 1989), a study done 3 years prior to the Meyer historical documentation. The difference is explained by NIOSH in the TBD (Millard 2004) on page 19 as being due to 10% recovery from the presence of metabolized polonium in raw undigested or unoxidized urine and from 1964 to 1973 a 63% correction factor based on ashed sample results duplicating methods used previously at Mound with a 2-hr spontaneous plating time conducted at room temperature.

4.12.4 Secondary Issue 4: Revised Body Burdens and Resultant Organ Doses May Need Further Evaluation

Kenneth R. Heid at the U.S. Transuranium Registry reported the results of a Pu assessment study done in 1983. Mr. Heid's April 11, 1984, letter to Mr. W. A. Bigler at Monsanto Research Corporation (Heid 1984) provided the results for the six participating laboratories who took part in a coordinated laboratory intercomparison study for bioassay of Pu-238. In that letter (Heid 1984), he pointed out the following:

> *The results reported showed good agreement between the participating laboratories. Results are shown in Table 1 and Figure 1. For most of the cases in the study the difference between the highest and lowest estimates reported was a factor of two or three. For two cases the difference was nearly a factor of ten with an average slightly over four for all 17 cases. This may not be too different from what might be expected if one laboratory had made all the assessments using a different person to make the assessment each time.*

The estimated systemic burdens (nCi plutonium) for Mound Laboratory, Lab C in Table 1 (Heid 1984), showed that the estimated body burdens that Mound results study were lower by almost one-half when compared to the other five DOE laboratories. Thus, the recorded Pu-238 estimated systemic burden data at Mound needed a correction factor to make up for the missed dose. It appears from Lab C results, shown on a different page (Heid 1984), that Mound was given an opportunity to redo their samples and provided revised nCi plutonium systemic burden estimates for 17 cases. NIOSH needs to ensure that previous Pu-238 systemic burden estimates were multiplied by about two and corrected in individual worker dose reconstruction files for Pu-238 doses recorded prior to April 1984.

On May 10, 1985, Dr. Ken Scrable from Lowell University did an internal dosimetry review of Mound's Health Physics Office (HPO) internal dose evaluation program, air sampling methods for plutonium, the HPO training program, and other aspects of the HPO operations. In a memorandum from Meyer, H. E. to Neff, R. A. dated May 16, 1985 (Meyer 1985), this review was discussed. Bob Robison revised the methodology used at Mound in past years to calculate the internal systemic burden of Mound employees to Pu-238. It is noted that Bob Robison found some errors in the Mound program, and that there would be significant ramifications in revising upward the body burden estimates for Mound employees. At a review closeout meeting on May 10, Dr. Scrable agreed with Bob Robinson's calculations that an upward revision of Mound employee systemic burdens was appropriate. In this memorandum (Meyer 1985), Dr. Scrable recommended that Mound go beyond the mere revision of the Mound body burden estimates to one of calculating radiation dose to specific organs, such as lung, liver, and bone. NIOSH needs to ensure that Mound did such calculations, and that the revised body burdens and resultant internal dose was entered into personnel files or, if not, that NIOSH has included such a provision in its Mound site-specific dose reconstruction guidance.

A Status Review Visit to EG&G Mound, July 8–10, 1991 (Runkle 1991), provides a status of the plutonium reconstruction project, the polonium reconstruction project, the Mound DOELAP program, the upgrade of the lung counting lab, and an addendum to the Blush Incident Report. Mound was required to ensure that all urinalysis results were in pCi for each Mound worker by October 20, 1991. The Polonium Reconstruction Committee was required to reach a consensus on the parameters to be used for dose calculations. The Mound Dosimetry Coordinator was required to ascertain that all personnel working in areas where internal exposures were possible were included in the urinalysis (in-vitro) bioassay program. NIOSH needs to ensure that workers who received doses prior to this 1991 review visit had necessary adjustments made to their dosimetry records to reflect any possible increase in dose for recommended adjustments in dose from these dose reconstruction projects, and that improvements in detection capabilities resulted in more accurate recorded or reconstructed dose.

A report prepared by Herbert Meyer and Dianne Reeder (Meyer and Reeder 1992) provided further information on the need to use raw data to rebuild the personal files of Mound's plutonium workers by stating the following:

> *Of primary concern was Mound's historical dosimetry program. One activity in this program, involving some 59,000 urinalysis records, yielded estimates of individual plutonium <u>body burdens</u>. The new standards require recording and reporting committed doses. Also, it was found that Mound's bioassay records misidentified a number of employee's urine samples in early years of operations because health physics identification numbers of terminated employees had been assigned to subsequently hired employees. The development of reliable records would require a complete reconstruction of plutonium bioassay results using only original records of raw data to rebuild the personal files of Mound's plutonium workers.*

The Phase II Final Report prepared by MJW Corporation describes what was done on behalf of Mound workers (MJW 2002b, Executive Summary):

> *Due to concerns raised by workers at Mound in 1996, the Department of Energy committed to make several improvements to the Mound Radiological Safety Program. One of those commitments was to perform internal dose assessments for all individuals who were estimated to have received equal to or greater than 20.0 rem Committed Effective Dose Equivalent (CEDE) from intakes of radioactive material received prior to 1989.*
>
> *The contract to perform the work was awarded to the MJW Corporation on April 23, 1997 and was broken down into two distinct phases. In Phase I, data in all formats (paper and electronic) was gathered and entered into an electronic database using a detailed QA process and screened for the potential to exceed 20.0 rem internal exposure prior to 1989 using very conservative assumptions. The screening resulted in data for 1553 individuals (approximately 500,000 data points) being screened for inclusion in the Phase II portion of the project. Thirty-one of the Phase II candidates were not assessed due to various problems with their data.*
>
> *In Phase II, the data for individuals who met the Phase I screening criteria of 20.0 rem were assessed and assigned dose using standardized processes and procedures describing, in detail, the method, software and assumptions used for each radioisotopic case. The Phase II process resulted in assessment of 2327 radioisotopic intakes for 1522 individuals. This information was then entered into the Mound MESH database for formal documentation of the dose received.*

On page 1 of 6 of the Phase II Final Report (MJW 2002b), the following summary is provided on the dose assessment work that was done for plutonium (non-DTPA) workers:

> *A total of 850 non-DTPA plutonium assessments were completed as part of the Phase II work. The isotope Pu-238 was involved in 788 of the assessments, while Pu-239 was involved in 210 of the assessments. Both isotopes were assessed for 148 assessments… A total of 40 original plutonium assessments were reworked due to the discovery of raw data in the files that in some significant way changed the original assessment.*

Page 2 of 6 of the same document (MJW 2002b) reported the following findings on plutonium workers who received DTPA therapy:

> *Mound employees who received or who were believed to have received significant intakes of plutonium were administered the chelation agent DTPA in an attempt to bind and eliminate the plutonium taken into the body and thereby reduce the dose received. A total of 63 individuals were on record as receiving DTPA therapy. After careful review of all bioassay records for these individuals, it was*

> *determined that one of the individuals fell outside the scope of the Pre-1989 Dose Assessment Project in that he had been chelated after December 31, 1988. Therefore, no plutonium dose assessment was performed for this individual.*

All plutonium dose assessments were performed by MJW and were based on information in a plutonium position paper, Section 6, Appendix (La Bone 1994). Polonium dose assessment for Mound workers was also completed. The Phase II Final Report (MJW 2002b) on page 3 of 6 states the following:

> *Once all of the above tasks were complete, polonium dose assessment work was initiated in October of 1999. A total of 1147 polonium assessments were performed as part of the Phase II work. As in the case of plutonium, a polonium position paper has been prepared to detail the thought processes used to accomplish this work.*

In regards to Mound workers dose assessment for "Other" radionuclides, the Phase II Final Report, Appendix C (MJW 2002a), states the following on page 3 of 6:

> *The "other" radionuclides consisted of all of the nuclides used for various experiments at the Mound other than plutonium and polonium. The nuclides used to varying degrees consisted of actinium-227, protactinium-231, radium-226 and 228, thorium-228, 230 and 232 and uranium-233, 234, 235 and 238… and were broken down by nuclide as follows: actinium (82), protactinium (17), radium (44), Th-228 (81), Th-230 (57), Th-232 (60) and uranium (28).*

The Occupational Internal Dosimetry TBD, ORAUT-TKBS-0016-5 (Millard 2004), spends little time addressing this plutonium assessment effort. It is unclear if current NIOSH dose reconstruction processes go beyond the mere revision of the Mound body burden estimates to one of calculating radiation dose to specific organs, such as lung, liver and bone. NIOSH should clarify how the plutonium reassessment doses are being used and what the procedures are for determining organ doses. This should be addressed in the revisions to the next Mound Occupational Internal Dosimetry TBD. If this has not been done, it could result in plutonium doses that are not claimant favorable.

4.12.5 Secondary Issue 5: Lack of Environmental Monitoring and Survey Data Limits Accurate Dose Estimation at the Dayton Facility

The Occupational Environmental Dose TBD ORAUT-TKBS-0016-4 (Hysong et al. 2004) states that the principal contaminant at the Dayton facilities, which contributed to environmental dose, was Po-210. Dayton facilities involving the use of radioactive materials included Units I, III, and IV, which operated from late 1943 through late 1948, at which time operations shifted to the Mound facility in Miamisburg, Ohio. Most activities involving the release of Po-210 occurred at Units III and IV from October 1943 through 1948.

The TBD indicates that environmental monitoring data is very limited in the form of progress reports in 1945, monthly health reports in 1947, and additional monthly health reports in 1948. No environmental data was found for 1943, 1944, and 1946. Based upon the data available, the TBD suggests that Unit I contributed little to the dose, and Units III and IV contributed most to the environmental dose and had similar effluent levels. SC&A agrees that the operational records show negligible contribution to the dose results from Unit I; however, the data viewed on Units III and IV is too limited to suggest they are equivalent within reasonable certainty. In fact, a 3-year period is not adequate to suggest comparability.

The conclusion in the TBD is that, since the weekly outdoor perimeter data for Unit III in December 1947 was the highest they noted, it could be applied to both Units III and IV for the entire 3-year period. SC&A notes that this approach cannot be considered statistically sound, as no evidence exists of other comparisons. For example, the TBD does not address whether a cross-comparison to operational and production schedules was performed to further test that the assumption of highest effluents occurring in December 1947 could be validated.

4.12.6 Secondary Issue 6: Atmospheric Dispersion Models are not Correlated to Offsite Data

Atmospheric dispersion models based upon effluent (Stack) data are used to determine onsite airborne concentrations. NIOSH has not attempted to correlate these onsite airborne concentrations to the results from offsite monitoring data.

The Occupational Environmental Dose TBD, ORAUT-TKBS-0016-4 (Hysong et al. 2004), in the absence of onsite monitoring results prior to 1971, uses stack samples and dispersion analyses to determine and estimate onsite airborne concentrations. The TBD recognizes that the stack results are limited, and are not available for some operational periods and episodic events. There is no documentation of metrological data to test or validate the dispersion calculations. Contrary to what occurred at the Dayton facilities, there was significant offsite environmental airborne monitoring at Mound during the late 1940s, 1950s, and 1960s. The TBD indicates the author chose not to use the offsite monitoring results to estimate airborne concentrations, due to gaps in data and monitoring stations frequently being moved, as some monitoring was performed using mobile truck-based samplers. SC&A believes that when offsite locations are known and comparable stack effluents exist, a back calculation using the offsite monitoring data could reasonably test the validity of the dispersion calculation.

4.12.7 Secondary Issue 7: Missing Dose within Annual Dose Records for 1947–1977

The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004, pg. 50) states that only annual dose records are available for 1947–1977, because the weekly, monthly, or quarterly records were lost. If a complete year of dose information is not available, some form of dose assignment may be appropriate. But the dose reconstructor does not know if a given year in a worker's dose record includes monitoring for the complete year. Perhaps, the dose record only contains information for a part of a year. Given the fact that Mound did not have any type of policy for recording dose due to lost or damaged dosimeters, the

TBD effectively compounds this problem. A worker's dose record may appear complete for a given year, but in reality it lacks dose information for the amount of time that the worker's dose was not monitored or recorded. It appears that this would go uncorrected if the dose reconstructor follows the current recommended procedure. Assigning a missed dose based on LOD is not acceptable for unbadged workers or for lost, damaged, or unreturned badges, because it may not reflect the actual dose received. Assignment of dose based on adjacent readings is possible, if there are no incidents/accidents (such as fires) during the unmonitored periods to create abnormal exposures. A method for ensuring that the entire year of exposure is accounted for is needed for each worker for each year employed.

4.12.8 Secondary Issue 8: Assumed Techniques and Protocols used in the TBD could increase Uncertainty of DCFs

The assumed techniques and protocols used in the TBD could increase the uncertainty of dose correction factors (DCFs) that are listed in the Occupational Medical Dose TBD, ORAUT-TKBS-0016-3 (Algutifan et al. 2006). Sections 3.2 and 3.3 of the TBD fail to adequately describe information upon which to adequately establish beam quality for x-ray units in use from 1946 to 1980. In 1980, the site installed a single phase Eureka unit. There is documentation to show that the TWX-235/Eureka 125, in use from 1980 through 2003, had 3.3 mm Al of added filtration, as first measured by the State of Ohio after 1988. However, in the absence of definitive tube output measurements prior to 1980, the TBD directs the use of default values and DCFs derived from ICRP Report No. 34 (ICRP 1982). These values are then applied to determine organ doses using Tables A.2 through A.8 of ICRP Report No. 34 (ICRP 1982). An issue of concern is that the DCFs are derived using a default HVL of 2.5 mm Al for Type 1 units, in use from 1946–1980. The TBD does not document the measure of any HVL for units in use prior to 1980. Another issue is that the unit, in use from 1980–2003, had added filtration of 3.3 mm Al, which is different from the default value from NCRP Report 102 (NCRP 1989).

The TBD likewise provides little documentation to support the use of assumed techniques and protocols applied to calculate the dose, which is also mainly derived from NCRP Report 102. NIOSH has acknowledged that the lack of verifiable protocols and beam measurements are a generic problem at many sites, has planned to search all available records, and will include pertinent records and references in any future revision of this section of the TBD.

4.12.9 Secondary Issue 9: The Frequency and Type of X-ray Exposure is Uncertain

The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) relies on a very limited historical review (Mound 2002) to establish x-ray frequency assumptions. The assumption of one chest radiograph (PA) per year is not reasonably conservative, in that workers could essentially request an x-ray, or be subject to special screening exams. The frequency of screenings, and number and type of workers receiving x-rays does vary from site to site.

The TBD, in Section 3.2, provides no documentation or references to support the assumption that only a limited group of workers received annual x-ray exams after 1959. To the contrary, up until about 1985, most DOE sites performed chest x-rays almost on a voluntary basis. DOE medical program reviews documented during the early 1990s showed many sites still used chest radiography as a general screening exam. Most workers accepted chest x-rays, even though the job did not require it. Also, the assumption that workers in special exposure categories, such as beryllium workers, were given chest x-rays only as part of their annual physical is not well-documented. The TBD applies no conservative assumption to cover specialty screening exams.

The TBD, in Sections 3.2, states that photofluorography (PFG) units, although generally available up to the late 1950s at most DOE sites, were not used at Mound. The undocumented absence of PFG units at Mound clearly has significant dose implications to workers who may have been given much higher doses from PFG units. The PFG unit provides a dose to the worker greater by a factor of 5–6, more than that delivered by conventional radiography. The TBD fails to document the type of equipment in use at Mound prior to 1980. SC&A believes it is not claimant favorable to instruct dose assessors to use kerma (dose) values of 200 mrem and 100 mrem for chest radiography, prior to 1970 and 1970–1979, respectively. To be fully claimant favorable, it would be appropriate to instruct dose assessors to use an annual dose of 3.0 rem per year for chest radiographs, in accordance with guidelines set forth in OTIB-0006 (Kathren and Shockley 2005).

4.12.10 Secondary Issue 10: The Use of Medium of Onsite Monitoring Results from the Period 1971–2003 May Not be Claimant Favorable

The Occupational Environmental Dose TBD (Hysong et al. 2004) states that to calculate environmental doses, it used a median value of onsite monitoring results for the isotopes that would most contribute to environmental dose. SC&A is concerned that, depending on where the air monitoring stations are located relative to worker occupancy determinations, the use of "median" value may not be claimant favorable. In the absence of accurately being able to estimate worker occupancy and frequency rates for the higher known concentration locations, it may be more appropriate to use the "mean" value, plus two standard deviations, to assure that estimations of environmental dose are claimant favorable.

4.12.11 Secondary Issue 11: Environmental Gamma Measurements at Mound do Not Correlate to Prior Dayton Estimates

There is no correlation between aerial direct gamma measurements at Mound when compared to control badge measurements at Dayton. The Occupational Environmental Dose TBD (Hysong et al. 2004) documents that an aerial survey performed at Mound in 1976 reported gamma estimates that ranged from 20.5 to 23.5 µR/h. If this were the case, the annual estimated environmental direct gamma dose at Mound would be approximately 40–50 mrem. When compared to the 1,800 mrem for 2,000 hours ambient dose rate mentioned in the TBD on page 15, the estimates of occupational exposure in the µR/h range do not seem claimant favorable. In the TBD (Hysong et al. 2004, pg. 15), the µR/h estimates were apparently calculated by assuming that the control badge was representative of the ambient dose outside the Dayton facilities. This draws attention to the possibility that Dayton environmental dose estimates are probably in error. The production rates and source terms at Mound always exceeded those at Dayton. Residual materials and waste products at Mound exceeded Dayton by several orders of magnitude. There are no known sources at either site during the years of Mound operations to cause elevated levels of gamma, beyond a few tens of mrem per year. NIOSH may want to revisit Dayton estimates as being unreasonably high.

4.12.12 Secondary Issue 12: Other Potential Medical Exposures have Not been Identified

The Occupational Medical Dose TBD ORAUT-TKBS-0016-3 (Algutifan et al. 2006) does not address the potential use of other forms of x-ray exposure other than routine chest x-rays. Workers were exposed to other x-ray examinations to support medical injury diagnoses. This may have involved the use of isotopes, sealed sources, etc.

The Occupational Medical Dose TBD does not discuss the use of portable radiography to perform screenings. Interviews with past medical staff do suggest that portable x-ray units were not used. This is potentially an issue relatively to the potential use of a PFG unit, which was often van-mounted at other sites. Additionally, the TBD fails to document that available x-ray units were not operated at greater than 80–90 kVp. To the contrary, Table 3-3 of the TBD indicates that the kVp after 1988 was set at 110 kVp when performing LAT chest exams.

The conclusion is that the TBD does little to reasonably document the variety of medical occupational exposures, and the lack of documentation on the type of equipment and the maintenance records does little to assure that a conservative and claimant-favorable estimation of dose is possible. This circumstance would suggest the need to reconsider a worst-case approach to establishing dose. NIOSH should revisit and update Sections 3.2 and 3.3 of the TBD, as needed.

4.12.13 Secondary Issue 13: There are Other Additional Factors that May Contribute to the Uncertainties of Medical Occupational Dose

The Occupational Medical Dose TBD (Algutifan et al. 2006) does not consider dose impacts due to less than optimal use of technology, such as using screens, grids, or bucky systems, nor does it consider these elements as potential contributions to uncertainty.

The TBD does consider the potential contribution to dose that may have resulted in less than optimal use of collimation at least prior to 1980, as stated in Section 3.2 of the TBD, and offers substitute DCFs for use by Dose Reconstructors (DRs) for selected exams, as presented in Tables 3-4 and 3-5.

Uncertainty is defined in the TBD as being due to measurement error and variations in kilovoltage, tube current, timers, and the skin-to-surface distance (SSD). This approach is quite similar to the uncertainty analyses documented in other DOE site profiles. The conclusion in the TBD, and others, is that an uncertainty factor of +30% should be used by dose reconstructors.

SC&A agrees that the TBD conservatively estimates these essential aspects of an uncertainty review. Unresolved is the contribution to uncertainty in dose, due to other errors introduced by lack of quality controls in processing equipment and lack of adherence to established standard operating procedures (SOPs). A reasonable estimate of these contributions to uncertainty would be an evaluation of retake rates, per examination type. NIOSH should revisit the potential for significant retake rates and evaluate its potential effect on dose as part of future revisions of the TBD.

4.12.14 Secondary Issue 14: Mound Classified Document Shipments

An activity of Non-nuclear Reconfiguration (FY1991–FY1993) included the shipment of 458 boxes (1 box equals 1 cubic ft) of Mound classified documents to LANL. These boxes represented the entire Mound Inactive (meaning they were no longer routinely used and were boxed and sent for storage) classified records. Due to the storage location (T-Bldg.), radiological surveys were required before the boxes could be removed from the building. These surveys produced positive results, which caused the collection to be shipped as a classified, contaminated collection. The boxes were never formally inventoried at the folder or document level, but a brief description of the box contents was provided to LANL at the time of the shipment. Generally speaking, this collection contained classified research and development records, and classified financial and programs records, and bioassay records. During the SC&A, NIOSH, and ORAU conference call (see Attachment 4), it was learned that MJW conducted a classified review in the late 1990s of the Mound classified records in this contaminated collection, and did retrieve the logbooks containing the bioassay data. The researcher’s lab notebooks were primarily filled in during the 1950s and 1960s. These boxes were shipped to the LANL at the direction of the DOE Albuquerque Weapons Quality Division, where they were to be imaged and the originals destroyed as contaminated, classified waste. Subsequently, approximately 40 boxes of the contaminated, classified laboratory notebooks were returned to Mound to be scanned and made part of the final shipment of Mound classified document shipments that were sent in May 2003 to the National Nuclear Security Administration (NNSA) Classified Records Service Center, Sandia National Laboratory in Albuquerque, New Mexico, and to the DOE Office of Scientific and Technical Information (OSTI) center at Oak Ridge, Tennessee.

Our review identified an unclassified records file at the Dayton Federal records center and a classified file being maintained at LANL. The classified records being held at LANL were considered particularly important to address a number of site profile issues, e.g., metal tritides, Pu-238, etc., for which data was found to be lacking in the unclassified files in Dayton. Arrangements were made to meet with the LANL records manager to arrange access, wherein he notified us that all of these records had been disposed of the previous year (2005) at the direction of LANL management. He also indicated that “notifications” had been sent to pertinent parties to determine any objections to this disposal. He indicated that an inventory had been taken of the disposed records, which he would make available to SC&A. This inventory will be transmitted in the near future, but at the time of release of this report, the inventory is being delayed awaiting final review and approval.

The provision by DOE and LANL of an inventory of the buried records will help determine what original records are not now available for site characterization and dose reconstruction, and what implications that may have. It is also clear that MJW in its 1990s dose reconstruction for Mound workers had reviewed these records and has apparently retrieved considerable information. This retrieved data should be compared with the inventory when it is available to ascertain whether the relevant and important radiological information is accessible through this alternate source. It should also be ascertained whether this MJW-retrieved data and the Mound dose reconstruction data, in general, is readily available in the public domain for use by the Advisory Board and its support contractor. Finally, given the implications of the destruction of such a large amount of potentially relevant worker radiological information, it will be important to determine how the disposal of these historic records occurred.

Non-nuclear Reconfiguration of specific DOE sites in the United States was a Presidential mandate and affected weapons production facilities such as RFP, Pinellas, Mound, and Fernald. LANL was to image the classified, contaminated collection so that it could be electronically available, with the intent to ensure these Mound records were transferred from the contaminated record block onto contamination-free electronic records. LANL apparently never received the funding from DOE to image the collection. In approximately 2004, the DOE Ohio Field Office Chief General Counsel received a request from LANL for approval to destroy the collection. Discussions between SC&A team members who went to LANL for a classified record review in April 2006 and the LANL Records Manager verified that this block of Mound Inactive contaminated classified records were disposed of at an undisclosed burial site in 2005.

As a separate effort, the Mound Classification Office was responsible for the managing of the Active classified records. In 1999, a large-scale effort was intiated to consolidate numerous classified safes and repositories located all over the site, which resulted in >73,000 documents coming to a centralized location. This collection included additional individual lab books that were issued to Mound researchers to keep their personal notes of the research they were conducting. There were also financial data, technical reports, research papers, Safety Analysis Reports (SARs), Final Safety Analysis Reports (FSARs), litigation records, classified drawings, and other documents.

Several projects were performed simultaneously involving the now-consolidated Active classified collection. First, a records inventory was performed to separate records from non-records. All non-records were destroyed with approval of the DOE Ohio Field Office. Second, an imaging project was initiated to convert the records (paper) collection into electronic format, thus further reducing the security area footage. Third, DOE required that DOE facilities and laboratories provide a copy to the Office of Scientific and Technical Information (OSTI) of any formal report released. A part of the 73,000 documents included formal reports that had not been provided to OSTI, per the DOE Order. In the 2001 timeframe, DOE required that Mound conduct a review of all classified formal reports and forward to OSTI any formal reports that had not been previously submitted. OSTI provided an inventory listing of all formal reports they already had and Mound compared that list to the current holdings. Any Mound formal documents that had not already been sent to OSTI were sent at this point. OSTI received 28 boxes of hardcopy documents, 7 boxes of microfiche, and 7 boxes of microfilm that are purported to include all of the Mound formal document collection.

Once the imaging project was complete, Mound contacted DOE Albuquerque about taking the newly imaged classified collection. DOE Albuquerque agreed to accept the classified collection.

On April 8, 2003, Mound shipped by Medlar Trucking to the Sandia's National Nuclear Security Administration (NNSA) Service Center, Albuquerque, New Mexico, all of the remaining Mound classified documents. Mound has a DOE F 5635.3 record receipt form signed by a representative of the Sandia NNSA Service Center on April 15, 2003, that verified receipt of the classified shipment.

Mound believes that all exposure records needed for dose reconstruction are included in the Mound Radiological Laboratory records. Mound Radiological Lab records are unclassified and include the individual radiation personal file; personal incident reports filed by incident number and by incident itself by year by date; and in Mound incidence and accident reports. The personal incident file can be accessed by HP number or name or incident number. Sometimes this data was put into an individual's medical record, but when done represented a duplicate of what was included in the incident file. According to Mound Records personnel, this duplication was not always done.

4.12.15 Secondary Issue 15: Occupational Medical Exposure is Not Adequately Defined and Assessed

The current guidelines, as presented in the *Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* (ORAUT-OTIB-0006, Kathren and Shockley 2005), go a long way in ensuring that all occupational medical exposures are reasonably included in determining the overall dose estimations for claimants. Unfortunately, the interpretation of the guidelines to date by the contractor (ORAU) has not been applied conservatively enough to be claimant favorable. The interpretation in the TBD (ORAUT-TKBS-0016-3, Algutifan et al. 2006), wherein medical procedures are assumed to be limited to only one pre-employment chest x-ray and other chest x-rays that are part of routine physical exams, may substantially underestimate worker medical exposure when evaluating occupational medical exposure. This overly restrictive interpretation also has been considered for and applied at other sites, such as RFP and LANL.

5.0 OVERALL ADEQUACY OF THE SITE PROFILE AS A BASIS FOR DOSE RECONSTRUCTION

The SC&A procedures call for both a "vertical" assessment of a site profile for purposes of evaluation of specific issues of adequacy and completeness, as well as a "horizontal" assessment pertaining to how the profile satisfies its intended purpose and scope. This section addresses the latter objective in a summary manner by evaluation of (1) how, and to what extent, the site profile satisfies the five objectives defined by the Advisory Board for ascertaining adequacy; (2) the usability of the site profile for its intended purpose, i.e., to provide a generalized technical resource for the dose reconstructor when individual dose records are unavailable; and (3) generic technical or policy issues that transcend any single site profile that need to be addressed by the Advisory Board and NIOSH.

5.1 SATISFYING THE FIVE OBJECTIVES

The SC&A review procedures, as approved by the Advisory Board, require that each site profile be evaluated against five measures of adequacy—completeness of data sources, technical accuracy, adequacy of data, site profile consistency, and regulatory compliance. The SC&A review found that the NIOSH site profile (and its constituent TBDs) for Mound represents an adequate accounting of the "core" polonium and Pu-238 handling operations, and dosimetry history of the Mound site, but falls short in fully characterizing a number of key underlying issues that are fundamental to guiding dose reconstruction. In some cases, these issues may impact other site profiles. Many of the issues involve lack of sufficient conservatism in key assumptions or estimation approaches, or incomplete site data or incomplete analyses of these data. Section 6.0 summarizes the key issues. Detailed evaluation of these issues is provided elsewhere in the report.

5.1.1 Objective 1: Completeness of Data Sources

The breadth of data sources used as a basis for the Mound site profile is evident in the 411 reports for Mound Laboratory and 30 reports for Monsanto Chemical Company, Dayton, Ohio, available in the Site Profile Research Database. Three hundred and fifty-two (352) of these reports were cited in the site profile references, while others served to provide confirmatory information. The ORAU team included health physics personnel with long histories at Mound, who have extensive knowledge of key dosimetry historical processes and personnel monitoring data.

There are additional sources of data, however, that have not been fully reviewed, and it is unclear to what depth the classified records have been reviewed. There is significant concern related to the content of the Mound classified, contaminated records disposed of at LANL. These records dated from the early days up through 1993 (see Secondary Issue 15). Although MJW did capture much of this important bioassay data from bioassay logbooks during their review of Mound classified documents at LANL in the late 1990s, there were still many additional classified documents for potential additional review that have been lost. When notified of the burial of these records during the conference call, MJW staff involved in the LANL data captures expressed concern regarding the disposal of these records and their importance to dose reconstruction efforts. LANL has located the inventories pertaining to these records and is in the process of reviewing the information for security purposes. Upon completion of this review, the inventory will be released to SC&A. That inventory will provide some insight into what kind of records have been lost. Additional classified records sent to Sandia National Laboratory have not been reviewed to evaluate their usefulness in dose reconstruction. Many boxes of Mound MLM reports are still sitting in boxes at the Mound Museum that have not been inventoried and applied to addressing missed dose and gaps in radiological monitoring that could be useful in doing claimant-favorable dose reconstructions. The daughter of a claimant has recently scanned many of these documents, and has 4 drawers containing about 1,300 documents (Jerison 2006). There are 135 boxes of documents at the Mound Museum that have not been previously reviewed. SC&A recommends that NIOSH should review this new source of Mound data to ensure these boxes of records do not contain important dose-related information for Mound workers.

The Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004, pg. 50) states that only annual dose records are available for 1947–1977, because the weekly, monthly, or quarterly records were lost, and recommends that the model dose be used for missed dose information. Occupational external dosimetry data is very limited in the 1943–1948 time period. This first era of research and development was conducted at several makeshift sites. This was a period when Dayton/Mound were exploring new, unknown technologies using many multiple, and not very adequately characterized, radioisotopes. The TBD's (Proctor and Algutifan 2004) use of 1949–1959 external radiation exposure data is questionable. It is unlikely that doses during 1949–1959, when radiation monitoring coverage was improved, adequately characterizes the external dose to workers in the 1943 to 1948 early period. Even in the later period of 1949–1959, Mound never had a well-documented quantitative study of its external dosimetry programs. Only 15%–20% of the employees were badged during 1947–1949 (Matthew 1961). It is not even clear for what time periods certain workers were badged; i.e., was everyone inside the plant area (security, crafts, maintenance, janitorial, etc.) considered "radiation workers," or just those who routinely handled radioactive materials? If a complete year of dose information is missing, some form of dose assignment may be appropriate. But the dose reconstructor does not know if a given year in a worker's dose record includes monitoring for the complete year.

There is a lack of sufficient environmental monitoring data to fully characterize source terms to which workers were exposed during waste disposal and D&D demolition procedures, particularly as production began to cease in the early 1990s. Many of the radionuclides that researchers were working with were often unknown to radiation safety personnel. Buildings at Mound were engineered during their construction to provide ventilation systems, fumehoods, and gloveboxes to help minimize inhalation uptakes by workers. As demolition workers began to remove walls and dividers, and to remove these contaminated fumehoods, gloveboxes, and ventilation systems, these engineering controls were breached and no longer became effective in minimizing inhalation uptakes. Contamination within the ventilation ductwork would have been an additional source of uptakes. Not always being aware of the mix of radionuclides present in specific demolition areas and/or researcher handling areas made it difficult to adequately prevent, monitor, and detect uptakes of these radionuclides.

5.1.2 Objective 2: Technical Accuracy

NIOSH, in the Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004), is to be commended in recognizing and dealing with corrections necessary to take into account recovery problems with metabolized Po-210 prior to 1964, and the poor recoveries of Pu-238,239 prior to 1960, and for making these corrections for years prior to 1964 and 1960, respectively.

It is not clear from the present TBD (Proctor and Algutifan 2004) if or when the neutron dose records for **badged** workers are being corrected for the low-energy response and fading of NTA film (especially at low-neutron energies) and for what years, and if and how the neutron-photon values are being used in neutron dose reconstruction. As at other nuclear facilities, Mound became aware of the NTA film under-response to neutrons below 0.8–1.0 MeV in the 1960s. However, it is not obvious that the dose reconstructor has sufficiently detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years.

The radionuclide-specific application of detection limits and minimal detectable activities criteria as cited in ORAUT-TKBS-0016-5, Occupational Internal Dosimetry TBD (Millard 2004), do not include treatment of historic issues related to inadequate bioassay techniques and procedures that may have led to significant under-reporting and missed dose at Mound. This is particularly true for the pre-1990s, before these were more adequately addressed and documented during the D&D era of the 1990s. A more comprehensive list of these deficiencies in provided in Vertical Issue 5.1.

The Occupational Internal Dosimetry TBD (Millard 2004, pg. 16) indicates, "Limited information is available on the metal tritides to which workers could have been exposed." The TBD (Millard 2004, pg. 16–17) does provide some guidance on tritides when it states the following:

> *Halfnium tritides were also used at Mound primarily in SW, R. and T buildings. A lung clearance class of S should be assumed for all metal tritides other than lithium. A lung clearance class of S should be assumed for halfnium tritides… Intake of lithium tritides should be estimated by assuming exposure to HTO. Exposure to all other tritides including halfnium should assume class S clearance.*

In the TBD (Millard 2004, pp. 47–48), Table 5A-1 does provide recommended lung clearance types for the site process activities for the buildings noted above. In addition, Table 5B-1 (pp. 51, 53, 54, 55, 59, and 60) does provide specific comments on tritide use in specific buildings and rooms, and comments on the activities ongoing there. These are only mentioned, however, as secondary to other radionuclides (pg. 51 – Ac-227; pg. 53 – Ra-223, Ra-224, and

Ra-226; pg. 54 – Rn-226 and Rn and progeny; pg. 55 – Th-228, Th-229, Th-230 and Rn and progeny; and pp. 59 and 60 – U-235, U-238, and U-239). This aspect is more complete that any other site profile where tritide exposure is an issue. However, the TBD (Millard 2004) does not probe deep enough into the impact of specific operations and activities that are known to have the potential for significant radiation exposure and address recommendations to the dose reconstructor on how these should be handled to develop a claimant-favorable tritide dose. Dose reconstruction guidelines need to be more specific and have more instructions and backup materials to enable claimant-favorable estimates of high doses from insoluble tritides for workers with job assignments and in work areas that had the potential for higher exposures. The TBD needs to address more up-to-date information on tritides by Cheng et al. (1997) and incorporate these considerations into the dose reconstruction instructions; the use of type S may not be adequate for hafnium tritides.

Dose reconstruction parameters and a generic dose assignment of a corrected 95th percentile dose of 340 mrem of workers exposed SMTs and STPs from 1947 to 1956 was provided in Section 5.3.1.1 of the TBD (Millard 2004). In SC&A's opinion, these procedures fall short in dealing with many significant exposures to SMTs and STPs at Mound that likely far exceeded these generic guidelines.

In regard to dose reconstruction for Pu-238 high-fired oxides, the TBD (Millard 2004) does not probe deep enough into the correct models to use to do claimant-favorable dose reconstructions. These Pu-238 high-fired oxides have a much longer retention time in the lungs that exceeds the default adsorption types specified by the current ICRP lung model. NIOSH has tried to address the so-called "Super S" type of plutonium in ORAUT-OTIB-0049 (OCAS 2006) for RFP. It is not clear, however, how this empirical model would apply to Pu-238 microspheres at Mound (there is no current ICRP treatment of the biokinetics of Pu-238 for these Mound operations). It is important to note that unless workplace indicators alert the staff of an exposure condition, it is very unlikely that an exposure to Pu-238 high-fired oxide would have been detected, measured, or noted until quite some time after the event. The TBD (Millard 2004) needs to address some of the literature available on highly insoluble (high-fired ceramic particles) Pu-238 by James et al. (2003), Guilmette et al. (1994), Cheng e. al. (2004), and Hickman et al. (2003). There is a difference in the way the body appears to handle and excrete Pu-238 from that of Pu-239.

The TBD (Millard 2004) does not go far enough in addressing the potentially high radon doses in SW Building. Air-sampling measurements from 1979–1980 were limited in location and do not necessarily reflect potential radon air concentrations in various parts of the SW Building complex, nor can it be assumed they reflect concentrations that existed in previous years when radon inhalation was potentially much higher. The TBD (Millard 2004) does not present substantiated radon characterization for the SW process areas prior to the venting of the underlying case and tunnel areas in 1980; the limited 1979 spot-air measurements and much later site-wide characterization do not provide a technically plausible basis to reconstruct radon dose for that earlier period. Likewise, it is not clear how the stated GSD of 3 is considered sufficient to offset this uncertainty regarding radon concentrations prior to 1980.

5.1.3 Objective 3: Adequacy of Data

The Occupational Internal Dose TBD ORAUT-TKBS-0016-5 (Millard 2004) does not adequately cover the dose potential from D&D activities that have been ongoing since the end of the weapons component production period in 1995. The Occupational Internal Dose TBD (Millard 2004) provides limited direction to dose reconstructors on the process and assumptions that should be used to calculate internal dose for the D&D activities. The TBD (Millard 2004) provides limited guidance for the assessment of missed dose for unmonitored workers.

NIOSH/ORAU have made extensive use of the Wayne King report on radioisotopes by location (King 1995), which provides credibility to the tables provided in the Site Description TBD, ORAUT-TKBS-0016-2 (Vollmer 2004b) that in most cases nicely covers what workers would have been exposed to in each building and room at Mound Laboratories.

The Occupational Internal Dosimetry TBD ORAUT-TKBS-0016-5 (Millard 2004) provides a very useful Table 5-1 on page 9, which lists primary bioassay programs with reported radionuclide action levels in counts per minute for a urine sample, workers who were monitored, and frequency of monitoring.

Section 5.3.1, pages 14–27 of the TBD (Millard 2004), provides an effective summary of the primary radionuclides handled by workers at Mound. In addition, Section 5.3.2, pages 27–36 of the TBD (Millard 2004), provides a nice overview of the secondary radionuclides used at Mound. Table 5.20 (page 38) in the TBD (Millard 2004) also provides a most useful summary of analytical methods and detection limits (MDAs) that assists in the proper evaluation of bioassay data, as well as a means to assign missed dose.

5.1.4 Objective 4: Consistency Among Site Profiles

An extensive comparison was performed by SC&A to compare and contrast the methodologies used in the Mound and other site profiles reviewed to date to determine external, internal, medical, and environmental dose. These comparisons focus on the methodologies and assumptions associated with dose assessments and the derivation of values used to obtain a POC for individual claimants.

ORAUT-TKBS-0016-5 (Millard 2004) describes the default assumptions for occupational internal dose at Mound. The assumptions were derived from historical records relating to the in-vivo and in-vitro monitoring programs. The procedures used for assignment of missed internal dose is derived from ORAUT-OTIB-0002, *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims* (Rollins 2004), and ORAUT-OTIB-0018, *Internal Dose Overestimates for Facilities with Air Sampling Programs* (Brackett and Bihl 2005), as indicated in a conference call with NIOSH/ORAU (see Attachment 5). These procedures are similar to those used for other site profile dose reconstructions.

Mound, SRS, and LANL each had operations that involved exposure to SMTs and STPs. The Mound TBD (Millard 2005) and the LANL Occupational Internal Dose TBD ORAUT-TKBS-

0010-5 (Argall 2004) have identified operations involving metal tritides. The Mound TBD has gone one step further by providing solubility classes. The SRS TBD (Scalsky 2005) acknowledges the existence of special tritium compounds; however, it neglects any potential dose from these compounds. All three TBDs fall short in providing specific guidance to the dose reconstructors on how best to do claimant-favorable dose reconstructions for metal tritides. NIOSH has yet to develop a consistent approach for handling of stable metal tritide dose reconstructions.

5.1.5 Objective 5: Regulatory Compliance

SC&A reviewed the site profile with respect to Objective 5, which requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR Part 82. In addition, SC&A evaluated the TBDs for adherence to general quality assurance policies and procedures utilized for the performance of dose reconstructions.

In order to place the above objectives into the proper context as they pertain to the site profile, it is important to briefly review key elements of the dose reconstruction process, as specified in 42 CFR Part 82. Federal regulations specify that a dose reconstruction can be broadly placed into one of three discrete categories. These three categories differ greatly in terms of their dependence on and the completeness of available dose data, as well as on the accuracy/uncertainty of data.

6.0 USABILITY OF SITE PROFILE FOR INTENDED PURPOSE

SC&A has identified seven criteria that reflect the intent of the EEOICPA and the regulatory requirements of 42 CFR Part 82 for dose reconstruction. Because the purpose of a site profile is to support the dose reconstruction process, it is critical that the site profile assumptions, analytic approaches, and procedural directions be clear, accurate, complete, and auditable (i.e., sufficiently documented). SC&A used the following seven objectives to guide its review of the Mound Site Profile TBDs to determine whether they meet these criteria:

Objective 1 – Determine the degree to which procedures support a process that is expeditious and timely for dose reconstruction.

Objective 2 – Determine whether procedures provide adequate guidance to be efficient in select instances where a more detailed approach to dose reconstruction would not affect the outcome.

Objective 3 – Assess the extent to which procedures account for all potential exposures, and ensure that resultant doses are complete and are based on adequate data.

Objective 4 – Assess procedures for providing a consistent approach to dose reconstruction, regardless of claimants' exposures by time and employment locations.

Objective 5 – Evaluate procedures with regard to fairness and the extent to which the claimant is given the benefit of the doubt when there are unknowns and uncertainties concerning radiation exposures.

Objective 6 – Evaluate procedures for their approach to quantifying the uncertainty distribution of annual dose estimates that is consistent with and supports a DOL POC estimate at the upper 99% confidence level.

Objective 7 – Assess the scientific and technical quality of methods and guidance contained in procedures to ensure that they reflect the proper balance between current/consensus scientific methods and dose reconstruction efficiency.

6.1 AMBIGUOUS DOSE RECONSTRUCTION DIRECTION

Page 10 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) points out that the record of historical dose limit standards is ambiguous and a great deal must be inferred.

From the current Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004), it is not obvious that the dose reconstructor has sufficiently detailed correction factors and instructions available to correct for the unmonitored neutron doses resulting from neutrons with less than 1 MeV of energy at the numerous facilities at Mound that produced neutron exposures throughout the years, or the necessary information and dose records for beta-dose and extremity-dose assessments.

6.2 INCONSISTENCIES AND EDITORIAL ERRORS IN THE SITE PROFILES

Page 16 of Occupational External Dosimetry TBD ORAUT-TKBS-0016-6 (Proctor and Algutifan 2004) should read $n^o/cm^2\text{-}s$; not $n^o/s/cm^2$.

6.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues were identified that are common in the Mound and other site profiles reviewed to date and, in some cases, represent potential generic policy issues that transcend any individual site profile. These issues may involve the interpretation of existing standards (e.g., oro-nasal breathing), how certain critical worker populations should be profiled for historic radiation exposure (e.g., construction workers and early workers), and how exposure itself should be analyzed (e.g., treatment of incidents and statistical treatment of dose distributions). NIOSH indicates that it may develop separate TIBs in order to address these more generic issues. The following represents those issues identified in the Mound and previous site profile reviews that in SC&A's view represent transcendent issues that need to be considered by NIOSH as unresolved policy or generic technical issues.

(1) Direction on the applicability of the TBD and/or TIBs to individual dose reconstructions is absent.

(2) Mobility of work force between different areas of the site should be addressed. Site expert testimony that many workers moved from one plant to the next is a complicating factor. Establishment of an accurate worker history is crucial in such cases. This will be especially difficult for family member claimants.

(3) Statistical techniques used in the application of the data to individual workers should be further considered and substantiated.

(4) Dose from impurities and/or daughter products in radioactive material received and processed at sites should be assessed as a contributory exposure source.

(5) The significance of various exposure pathways and the assumptions made that influence dose contributions need to be considered (most notably) for solubility, oro-nasal breathing, and ingestion.

(6) Analysis needs to be performed regarding how "frequent or routine incidents" should be addressed, given the possibility that such "spike" exposures may often be missed by routine monitoring as a function of how often and in what manner it was conducted.

(7) Availability of monitoring records for "transient or outside workers," e.g., subcontractors, construction workers, and visitors who may have potential exposure while working on or visiting a facility should be ascertained.

(8) Dose to D&D workers should be assessed. Many facilities have large-scale D&D operations, which extend back many years. Decontamination and decommissioning operations often require working in unknown situations, which may provide unique exposure situations.

(9) A consistent methodology for assessing exposure to metal tritides should be developed and applied to all sites where these chemical forms are identified.

Dose reconstruction for occupational medical exposures remains incomplete. NIOSH needs to reconsider the definition to include all forms of radiation medical exposure, to ensure its considerations are claimant favorable.

7.0 REFERENCES

42 CFR Part 82, Title 42, *Public Health*, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program Act of 2000, Code of Federal Regulations*, May 2, 2002.

Algutifan, F., Shockley, V. E. and Kathren, R. L., 2006, *Technical Basis Document for the Mound Site – Occupational Medical Dose*, ORAUT-TKBS-0016-3, Rev. 01 PC-2, Oak Ridge Associated Universities, Oak Ridge, Tennessee, March 31, 2006.

Argall, R. S., 2004, *Technical Basis Document for Los Alamos National Laboratory – Occupational Internal Dose*, ORAUT-RKBS-0010-5, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, December 21, 2004.

Brackett, E.M., and Bihl, D.E., 2005, *Internal Dose Overestimates for Facilities with Air Sampling Programs*, ORAUT-OTIB-0018, Revision 01, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 9, 2005.

Burbage, J.J., Director, 10 July 1952, Memorandum to Roberson, J.J., Area Manger USAEC, "*Actinium Handling at Mound*" (Doc. # 240001422, scanned 8/12/04).

BWO 1999, *Stable Metal Tritide History/Chronology*, Babcock and Wilcox of Ohio memorandum from P. J. Burns to Sandy Baker, June 17, 1999 with an attachment entitled *Final Draft 2*, April 30, 1999.

BWXT (BWX Technologies, Inc.) 1998, *Contract No. DE-AC24-97OH20044, Information Regarding The Health and Safety of Metal Tritides*, Letter from Powers, J. R. to Director Miamisburg Environmental Project, July 13, 1998 with an Attachment 1 entitled *Metal Tritides* dated July 9, 1998.

BWXT (BWX Technologies, Inc.) 1999, *Responses to Comments on Draft Technical Basis Document for Stable Tritiated Particulates (STPs)*, Letter from Trent, L. K. to Mr. Provencher, October 7, 1999.

BWXT (BWX Technologies, Inc.) 2000, *Radon Study Summary Report*, Letter transmittal from Kevin Doody to Ronald Daily, Radiological Instrumentation Lab Team Leader, BWXT of Ohio, June 15, 2000.

BWXT (BWX Technologies, Inc.) 2006, Powering Tranformation at the Miamisburg Closure Project, General Overview, BWXT Fact Sheet, 2006 http://www.bwxt.com/operations/bwxto.html

Carbaugh, E. H., 2003, *Methods and Models of the Hanford Internal Dosimetry Program, Chapter 8.0, Plutonium*, PNNL-MA-860, January 31, 2003, http://www.pnl.gov/eshs/pub/pnnl860/chapter8.pdf

Cheng, Y.S., Dahl, A. R., and Jow, H. N., 1997, *Dissolution of Metal Tritides in a Simulated Lung Fluid*, Health Physics, October 1997, Vol. 73, No. 4: 663–638.

Cheng, Y.S., Zhou, Y., Wang, Y.S., Inkret, W. C, and Werner, J. R., 2002, *Dose Estimate of Inhaled Hafnium Tritide Using the ICRP 66 Lund Model*, Health Physics, June 2002, Vol. 82, No. 6: 817–824.

Cheng, Y. S., Guilmette, R. A., Zhou, Y., Gao, J, LaBone, R., Wicker, J. J., Hover, M. D., 2004, *Characterization of Plutonium Aerosol Collected During An Accident*, Health Physics, Vol. 87, No. 6, December, 2004.

Defense Nuclear Facilities Safety Board (DNFSB) 1999, *Deactivation and Decommissioning of Tritium Facilities at Miamisburg Environmental Management Project*, DNFSB Staff Report, Troan J.W., to G. W. Cunningham, March 26, 1999.

DOE (U.S. Department of Energy) 1997, *Preliminary Notice of Violation and Proposed Imposition of Civil Penalty – $112,500 (NTS-OH-MB-EGGM-EGGMAT0401997-0001)(NTS-OH-MB-EGGM-EGGMAT04-1997-0002)*, Letter to: Phillip Ayers, EG&G Inc. From: Peter. N. Brush, Acting Assistant Secretary, Office of Environment, Safety and Health, October 21, 1997.

DOE (U.S. Department of Energy) 1998, *Preliminary Notice of Violation and Proposed Imposition of Civil Penalty – $165,000 (NTS-OH-MB-BWO-BWO04-1998-0001, NTS-(NTS-OH-MB-BWO-BWO04-1998-0002, and (NTS-OH-MB-BWO-BWO06-1998-0001)*, Letter to: Peyton S. Baker, Babcock and Wilcox, Ohio, From: Peter. N. Brush, Acting Assistant Secretary, Office of Environment, Safety and Health, November 16, 1998.

DOE (U.S. Department of Energy) 1999a, *DOE HQ Comments on Mound Technical Basis Document for Stable Tritiated Particulate and Organically Bound Tritium, Draft*, October 8, 1999.

DOE (U.S. Department of Energy) 1999b, *Enforcement Guideline Supplement 99-02: DOE Enforcement Activities of Internal Dosimetry Program Requirements*, Memorandum for DOE PAAA Coordinators Contractor PAA Coordinators, From: R. Keith Christopher, Director, Office of Enforcement and Investigation, Subject: Enforcement Guidance Supplement 99-02: DOE Enforcement Activities of Internal Dosimetry Program Requirements, July 16, 1999.

DOE (U.S. Department of Energy) Undated, *Processes and Characteristics of Major Isotopes Handled at Mound*, Office of Environmental Management, Ohio Field Office, Miamisburg, Ohio, http://www.ohio.doe.gov/oh_seb/docs/isotopes.pdf

DOE (U.S. Department of Energy) 2004a, *Radiological Control Programs For Special Tritium Compounds*, U.S. Department of Energy Handbook 1184-2004, September, 2004.

DOE (U.S. Department of Energy) 2004b, *MACCS Computer Code Application Guidance for Documented Safety Analysis, Final Report*, DOE-EH-4.2.1.4-MACCS2-Code Guidance, June 2004.

DOE (U.S. Department of Energy) 2006, *Radiological Control Programs for Special Tritium Compounds*, DOE-HDBK-1184-2004, June, 2006.

Fellman, A., Ralston, L., Hickman, D., Ayers, L., Cohen, N., Spitz, H., and Robinson, B., 1989, *The Importance of Acid Digestion of Urine Prior to Spontaneous Deposition of ^{210}Po,* Health Physics, Volume 57, No. 4, pp. 615–621, October, 1989.

Guilmette, R. A., Griffith, W. C., Hickman, A. W., 1994, *Intake Assessment for Workers who have inhaled Pu-238 Aerosols*, Radiation Protection Dosimetry, 53: 127–131, 1994.

Heid, K. R., 1984, *United States Transuranium Registry Letter from K.R. Heid to W. A. Bigler, Estimation of Plutonium System Burdens in Workers Based on Urine Excretion Data*, April, 11, 1984

Hickman, A. W., Griffith, W. C., Roessler, G. S., Guilmette, R. A., 2003, *Application of Canine ^{238}Pu Biokinetic/Dosimetry Model to Human Bioassay Data*, Health Physics, Vol. 84, No. 1, January 2003.

Hysong, R., Orthen, R., Mucha, A., and Lombardo, A., 2004, *Technical Basis Document for the Mound Site – Occupational Environmental Dose*, ORAUT-TKBS-0016-4, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, October 6, 2004.

ICRP (International Commission for Radiiological Protection) 1979, *Limits for Intakes of Radionuclides by Workers*, Publication 30, Pergamon Press, Oxford, England.

ICRP (International Commission on Radiological Protection) 1982, *Protection of the Patient in Diagnostic Radiology*, ICRP Publication 34, Pergamon Press, New York, New York

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

ICRP (International Commission on Radiological Protection) 1994, *Human Respiratory Tract Model for Radiological Protection*, ICRP Publication 66, Pergamon Press, Oxford, England.

ICRP (International Commission for Radiiological Protection) 1996, *Age-Dependent Dose to Members of the Public from Intake of Radionuclides, Part 4: Inhalation Dose Coefficients*, Publication 71, Pergamon Press, Oxford, England.

ICRP (International Commission for Radiological Protection) 1998, *Individual Monitoring for Internal Exposure of Workers*, ICRP Publication 78, Pergamon Press, Oxford, England.

ICRP (International Commission for Radiological Protection) 2006, *Hydrogen (Z=1), OIR-1*, International Commission on Radiological Protection, for ICRP Use, Draft, 16 January 16, 2006, http://www.icrp.org/docs/Informal_web_consultation/1-Hydrogen%2816Jan%29.doc

James, R. E., Filpy, J. J., Russell, J. J., McInroy, J. F., 2003, *USTUR Case 0529 Whole Body Donation: A Comprehensive Test of the Current ICRP Models for the Behavior of Inhaled* ^{238}*Pu Oxide Ceramic Particles*, Health Physics, Vol. 84, No. 1: 2-33, January 2003.

Jenkins, P. H., 1982, *Radon-219 Leaks in SW-19*, Monsanto Research Corporation Memorandum from P. H. Jenkins to Emil Mershad, May 13, 1982.

Jerison, D., 2006, *List of Scanned Documents from the Mound Museum Collection*, Jersion Inc., Dayton, Ohio, June 19, 2006.

Kathren, R.L., 2003, *Technical Information Bulletin: Dose Reconstruction from Occupational Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006, Revision 02, Oak Ridge Associated Universities, Oak Ridge, Tennessee, December 29, 2003.

Kathren, R. and Shockley, V. E., 2005, *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006, Rev. 03, Oak Ridge Associated Universities, Oak Ridge, Tennessee. December 21, 2005.

King, W., 1995, *Mound Site Radionuclides by Location*, MD, 22153, EG&G Mound Applied Technologies, Miamisburg, Ohio.

La Bone, T. R., 1994, *Evaluation of Intakes of Transuranics Influenced by Chelation Therapy*, Internal Radiation Dosimetry, 1994, Health Physics Society 1994 Summer School, Medical Physics Publishing, Madison Wisconsin, Chapter 20.

Mathew, E.R., Chairman, 18 January 1961, Memorandum to Creamer, E.B., Area Manager, "*Committee Report: Review of Mound Operations and Procedures (January 1961)* (Doc #010001634 scanned 9/16/03).

McConville, G. T., and Woods, C. M., 1995, *Calculation of Tritium Dose From Insoluble Particulates*, Fusion Technology, Vol. 28, October 1995.

Meyer, H.E., 1951, "*Experiment for Fading of Latent Image on Type NTA Film Emulsions,*" September 13, in Meyer (1994, Volume Viii, p.1).

Meyer, H. E., 1985, *Internal Dosimetry Review – Dr. Ken Scrable*, Memorandum from H. E. Meyer to R. A. Neff, May 16, 1985.

Meyer, H. E., 1992, *History of Mound Bioassay Programs*, MLM-MU-93-93-0003, EG&G Mound Applied Technologies, Miamisburg, Ohio.

Meyer, H. E. and Reeder, D. L., 1992, *Plutonium Historical Dose Reconstruction Program*, June 30, 1992.

Meyer, H. E. 1995, Letter from H. E. Meyer at Mound Laboratory, *Internal Dosimetry Review – Dr. Ken Scrable,* May 16, 1985.

Millard, J., 2004, *Technical Basis Document for the Mound Site – Occupational Internal Dosimetry*, ORAUT-TKBS-0016-5, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, September 9, 2004.

MJW, 2001, *Plutonium Position Paper on Dose Assessments Performed for the Mound Pre-1989 Dose Assessment Project, Phase II Final Report, Appendix A,* Prepared for BWXT of Ohio Inc., Williamsville, N.Y., December 14, 2001.

MJW, 2002a, *Other Radionuclides Position Paper on Dose Assessment Performed for the Pre-1989 Dose Assessment Project*, Phase II Final Report, Appendix C, Prepared for BWXT of Ohio Inc., Williamsville, N.Y. by MJW Corporation, August 12, 2002.

MJW, 2002b, *Phase II Final Report 99-217.223, June 2002*, Prepared for BWXT of Ohio, Inc., Williamsville, NY by MJW Corporation, August 12, 2002.

Monsanto Research Corporation 1980, *Elevated Radon Levels in SW-19*, Monsanto Research Corporation memorandum from Radon Program, T-233 to R. T. Brashear, October 24, 1980.

Mound (Mound Laboratory) 1951, *T Building Contamination Problem in the Process and Electrolysis Lines,* MLM-MU-51-69-0024, September 15, 1951.

Mound (Mound Laboratory) 1990, *Internal Dosimetry Program Upgrades Summary Plan*, Draft Report (Author Unknown), Mound Laboratory, Miamisburg, Ohio, June 15, 1990.

Mound (Mound Laboratory) 2002, *Mound X-ray History*, ORAU Cincinnati Operations Center Terminal Server, O:\DOE Site Images\Mound\Mound X-Ray History, downloaded September 9, 2003 [Mound X-Ray History PDG].

NBS (National Bureau of Standards) 1957, *Protection Against Neutron Radiation Up To 30 Million Electron Volts*, Handbook 63, U. S. Government Printing Office, Washington DC.

NCRP 1989, (National Council on Radiation Protection and Measurements) 1989, *Medical X-ray, Electron Beam, and Gamma-Ray Protection for Energies Up to 50 MeV (Equipment Design, Performance, and Use)*, Report No. 102, NCRP, Bethesda, Maryland.

OCAS (Office of Compensation Analysis and Support) 2002a, *External Dose Reconstruction Implementation Guidelines*, Revision 1, OCAS-IG-001, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, Washington, DC.

OCAS (Office of Compensation Analysis and Support) 2002b, *Internal Dose Reconstruction Implementation Guide,* OCAS-IG-002, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

OCAS (Office of Compensation Analysis and Support) 2003, *Tritium Calculations with IMBA*, OCAS-TIB-002, Rev. 00, National Institutes of Occupational Safety and Health, Cincinnati, Ohio, April 22, 2003.

OCAS (Office of Compensation Analysis and Support) 2006, *Estimating Lung Doses for Plutonium Strongly Retained in the Lung,* Draft ORAUT-OTIB-0049, Rev. 00-D, National Institutes of Occupational Safety and Health, Cincinnati, Ohio, February 2006.

Oil Chemical and Atomic Workers (OCAW) 1998, Local 07-4200, *Opinion on the Root Cause of the Mound Contractor Using Elevated Minimal Detectable Amount Values*, 1998.

Proctor, C. W., and Algutifan, F., 2004, *Technical Basis Document for the Mound Site – Occupational External Dosimetry*, ORAUT-TKBS-0016-6, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 11, 2004.

RCCC (Radiological Control Coordinating Committee) 2000, *Meeting Minutes, November 1–2, 2000, and Meeting Minutes, June 28, 2000, Denver, Co.*.

Robertson-DeMers, K., 1996, *Decontamination and Decommissioning (D&D) of R Building 140 (R-140),* Memorandum to Ray Weaver and Ernie Stonmann, September 30, 1996.

Rollins, 2004, *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims*, ORAUT, OTIB-0002, Rev. 01, PC-2, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 7, 2004.

Runkle, G. E., 1991, *Status Review Visit to EG&G Mound, July 8–10, 1991,* Memorandum to File, July13, 1991.

Scalsky, E. D., 2005, Dose *Reconstruction Project for NIOSH – Savannah River Site,* ORAUT-TKBS-0003, Rev. 03, Oak Ridge Associated Universities, Oak Ridge, Tennessee, April 5, 2005.

SC&A 2004, *SC&A Standard Operating Procedure for Performing Site Profile Reviews*, Rev. 0, March 18, 2004.

SC&A 2005, *Rocky Flats Plant Site Profile Review*, SC&A-TR-Task1-0008 RFP, Draft Report, December 8, 2005.

SC&A 2006, Task1: *Draft Issue Resolution Matrix (Vertical Issues) Based on the SC&A Review of the NIOSH Site Profile for Savannah River Site with Attachment B, Comment 8, pg. 22*, June 5, 2006.

Silverman, L.B., 10 April 1962, letter to Warren, S.L., MD, "*A short History of the Health and Safety Program at the Dayton Polonium Project of Manhattan Engineering District During World War II*" (Doc #030000248 scanned 5/3/04).

Stone, R. S., 1948, Health Protection Activities of the Manhattan Project, Proceedings of the American Philosophy Society," Vol. 90, No. 1, January 1948.

Strome, D. S., Steward, R. D., and McDonald, J. C., 2002, *Spectral Emissions and Dosimetry of Metal Tritide Particulates*, Radiation Protection Dosimetry, Vol. 98, No 4: 389-400, 2002.

UNC Geotech 1990, *DOE Indoor Radon Study*, Office of Projects and Facilities Management, UNC Geotech, Grand Junction, Colorado, April 12, 1990.

UNC Geotech 1991, *Results of the DOE Indoor Radon Study*, Office of Projects and Facilities Management, UNC Geotech, Grand Junction, August 22, 1990.

TR (U.S. Transuranium Registry) 1995, *1995 Annual Report, Executive Summary*, Washington State University, Pullman, Washington, http://www.ustur.wsu.edu/annualreport/Executive%20Summary%2095.htm

Vollmer J. S., 2004a, *Technical Basis Document for the Mound Site – Introduction*, ORAUT-TKBS-0016-1, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, September 9, 2004.

Vollmer J. S., 2004b, *Technical Basis Document for the Mound Site – Site Description*, ORAUT-TKBS-0016-2, Rev. 00, Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 20, 2004.

Zhou, Y, and Cheng, Y. S., 2004: *Dosimetry of Metal Tritide Particles As Evaluated By the ICRP 66 Model and a Biokinetic Model from Laboratory Rats*, Health Physics, February 2004, Vol. 86 No. 2: 155-160.

ATTACHMENT 1: TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW

Technical Basis Documents

ORAUT-TKBS-0016-1, *Technical Basis Document for Mound Site – Introduction, Rev. 00* (Vollmer 2004a).

ORAUT-TKBS-0016-2, *Technical Basis Document for Mound Site – Site Description, Rev. 00* (Vollmer 2004b).

ORAUT-TKBS-0016-3, *Technical Basis Document for Mound Site – Occupational Medical Dose, Rev. 01 PC-2* (Algutifan et al. 2006).

ORAUT-TKBS-0016-4, *Technical Basis Document for Mound Site – Occupational Environmental Dose, Rev. 00* (Hysong et al. 2004).

ORAUT-TKBS-0016-5, *Technical Basis Document for Mound Site – Occupational Internal Dose, Rev 00* (Millard 2004).

ORAUT-TKBS-0016-6, *Technical Basis Document for Mound Site – Occupational External Dosimetry, Rev. 00* (Proctor and Algutifan 2004).

Technical Support Documents

ORAUT-OTIB-0002, Rev. 01 PC-2, (2004), *Technical Information Bulletin, Maximum Internal Dose Estimates for Certain DOE Complex Claims*, , Oak Ridge Associated Universities, Oak Ridge, Tennessee, May 7, 2004 (Rollins 2004).

ORAUT-OTIB-0006, (2005), *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures* , Rev. 03, Oak Ridge Associated Universities, Oak Ridge, Tennessee. December 21, 2005. (Kathren and Shockley 2005).

ORAUT-OTIB-0018, Rev. 01, (2005), *Internal Dose Overestimates for Facilities with Air Sampling Programs*, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August 9, 2005, (Brackett and Bihl 2005).

OCAS-TIB-002, Rev 00 (2003), Tritium Calculations with IMBA, OCAS (Office of Compensation Analysis and Support, National Institutes of Occupational Safety and Health, Cincinnati, Ohio, April 22, 2003.

ORAUT-OTIB-0049, Rev. 00-D (Draft), 2006, *Estimating Lung Doses for Plutonium Strongly Retained in the Lung*, Office of Compensation Analysis and Support), National Institutes of Occupational Safety and Health, Cincinnati, Ohio, February 2006.

ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

Interviews were conducted with 17 operations, RCTs, radiological control (RadCon) and, internal dosimetrists, crafts and maintenance, and radiation waste and decontamination and decommissioning (D&D) personnel. Current workers represented about one-third of the interviewees, with the remainder being retirees who had previously worked at Mound. An attempt was made with the retirees to interview previous workers who had been employed at Mound for at least 20 years. Joseph Fitzgerald and R. Thomas Bell conducted the interviews jointly. "Q"-clearance was not required, since all Mound's classified documents had been sent in May 2003 to Sandia, National Nuclear Security Administration (NNSA) Service Center, Albuquerque, NM and the Office of Scientific and Technical Information (OSTI), Oak Ridge, Tennessee. An older block of Mound classified records (458 boxes) was residually contaminated and was sent to LANL in 1993. In 2005, that collection of Mound classified documents could not, reportedly because of cost, be copied to non-radioactive media and was buried as radioactive waste. This is discussed in more detail in Secondary Issue 6, Section 1.3 of this report. Therefore, there were no classified documents on the Mound site or at the Dayton Ohio Federal Records Center.

The purpose of these interviews was to receive first-hand accounts of past radiological control and personnel monitoring practices at Mound and better understand how operations were conducted. Health physics and radiological control personnel were interviewed on February 15, 2006. Production operations interviews were conducted individually on February 15 and 16, 2006. The interviews with retired Mound Laboratory internal dosimetrists were conducted individually on February 16, 2006. Radiological technicians currently working at Mound Laboratory were interviewed in groups of 2–3 on both February 15 and 16, 2006. Interviews with maintenance and crafts workers were conducted on February 15 and 16, 2006. Interviews with those workers knowledgeable about radiation waste and D&D work were conducted on February 16 and 17, 2006. Interviewees were selected so as to represent a reasonable cross-section of production areas and job categories. Time was also spent reviewing unclassified health physics records and reports, conversing with records staff, and reviewing documents at the Dayton Ohio Federal Record Center.

Workers were briefed on the purpose of the interviews, and background on the EEOICPA dose reconstruction program and site profiles, and asked to provide their names in case there were follow-up questions. Participants were reminded that participation was strictly voluntary and that all interviewer notes would be reviewed for classification following the interview even though the interviews were to be done as unclassified interviews. Interviewees were cautioned not to discuss any topic that they might feel could be classified.

Mound Laboratory facilities represented included by the site experts interviewed included Buildings B, G. T, SW, WD, WD Annex, R, R (Tritium Recovery Laboratory), R (Plutonium Processing), DP, SM, PP, Fire Department, A6 Assembly Building, BS, SD, SW-19 (Old Cave) and SW-22 (New Cave). The job categories represented included:

- H-3 Recovery
- Pu Heat Sources
- Pu Solubility Studies
- Maintenance and Testing of Cylinders
- H-3 Contamination Control in Air Conditioning Systems
- Ultrasonics
- Radiometric Calorimetry
- Research Related Work
- Decontamination
- Radiation Waste Disposal
- Building Demolition
- D&D
- Analytical Chemistry
- Waste Characterization
- Environmental and Waste Management
- Po-210 Trigger Fabrication
- Pu-213 Encapsulation and Assembly Fabrication
- Cotter Concentrate Handling
- Carpenter/Demolition Work
- Health Physics
- Internal Dosimetry
- Bioassay
- Computer Analysis
- Statistical Analysis
- Experimental Design
- Separation and Purification of Po-210
- Separation and Purification of Pu-238

Individuals interviewed were given the opportunity to review the documented interview for accuracy and completeness. This is an important safeguard against missing key issues or misinterpreting some vital piece of information.

All interviews have been documented and summarized below. The information provided is not a verbatim discussion, but is a summary of information from multiple interviews with multiple individuals. Individuals have provided this information based on their personal experience. It is recognized that these former worker recollections and statements may need to be further substantiated before adoption into the six Mound technical basis documents (TBDs). However, they stand as critical operational feedback. These interview notes are provided in that context; former worker input is similarly reflected in our discussion and, with the preceding qualifications in mind, has contributed to our findings and secondary issues.

[NOTE: The following represents a summary of former worker recollections of Mound operations and radiological issues that have not been necessarily substantiated for factual accuracy in the course of this site profile review].

Production/Operations

In the early days, things were not as well understood. There was a high frequency of minor incidents in T Building. Spills of Po-210 were frequent. There was no environmental program in the beginning. A Union representative who did not have much training for what they were doing did the early environmental study program. One interviewee drove around in a truck and run his air sampler to take his air samples at each location. As the environmental program matured, Mound radiation monitoring personnel started looking for radionuclides in the river and took soil samples off site. Even when environmental monitoring was fully in operation, there were never any major releases, nor was anything appreciable found on roofs of buildings. Even when trying to find an air sampler with the highest reading, the contamination found was still below discharge limits and clean air guidelines.

In the beginning years at Mound, Po-210 was the major isotope handled. It had a short half-life, as well as a short shelf life. It was used initially in the fabrication of nuclear triggers. Because of the short half-life, Mound started looking for a substitute to polonium and settled on Pu-238. Most of the early operational work was done in R Building.

Initial production of nuclear triggers involved the use of Po-210. Polonium-210 was produced from bismuth slugs. This bismuth slugs were taken out of a pool and put into a small loading container. Then it was put into long glass tubes. The bismuth slugs were in aluminum containers or aluminum jackets, as they called them. The bismuth in its aluminum jacket was dissolved in acid. The resulting fluid was emptied into casks. As it was processed, it was not pure, but had all kinds of fission products. Cobalt-60 was leached out of the aluminum during the process. Monitoring was crude in the early 1960s. Workers did have pocket dosimeters and the radiation safety personnel were observing the operations. Everyone who needed monitoring received such monitoring with the best radiation safety equipment technology at that time. The workers used special 2-piece clothing, but did not wear respirators. The health physics staff was only worried about gamma dose and nothing was done to determine if they had any uptakes. One good thing about Po-210 was that it had a very short half-life and it was eliminated very quickly.

Protactinium-231 was handled at Mound as early as 1956. At one time, 99% of the work in R Building did involve Pa-231, but over the years the R building was involved in many projects, and many isotopes. Building WD and WD Annex (WDA) were not as hot. When they tapped into the filter banks in WD Annex, they found high levels of contamination. There was a potential for an alpha/beta soup of isotopes. Waste management in the early years had less engineering controls in place. One worker pointed out that Mound had the largest batch of Pa-231 in the world at that time. There was continued interest in collecting the Pa-231, which was used in general research.

By 1960–1962, work with Pu-238 was begun. They extracted or milked U-234 out of the Pu-238. Mound sent the extracted U-234 to the isotope pool at Oak Ridge.

When Pu-238 processing started up in the early 1960s, and they were processing Pu-238 in PP Building and SM Building, large amounts had a gamma component. Some workers had to be pulled from work due to their burnout mainly due to the gamma exposure. Substitute workers were then sent in to replace those workers that had to stop work because of burnout. The burned out worker would then be allowed to go back to work in the next quarter, since they were complying with quarterly dose limits. This happened mostly in the production area. The bulk of the people were very conscientious about complying with the quarterly limits. Burnout with neutrons also occurred in some work areas. The neutron source in this case was the milking of U-234 from the aged U-238. Some neutrons were triggered and leached out of light materials, which created some alpha/neutron reactions.

In the process of fabricating the assemblies, Pu was encapsulated and then assembled in glove boxes or hoods. In R-149, workers were building heat sources. They would encapsulate the Pu-238 in a cylinder with a sealed bottom and then would weld the top in place. This was done in a hood. When the encapsulation was complete, the radiation safety personnel would decontaminate the hood. The hoods got highly contaminated during the process, and the air vents from the hoods were all tied into a HEPA filter bank in the penthouse, thus precluding the release of contamination into the environment.

Many workers chose to work an 8-hour workday or one shift in R Building. In PP Building and SM Building, work was done on a two-shift basis. More recently Mound went on a 4 day, 10-hours/day work schedule. Operational and maintenance personnel were often badged similarly. The type of work they were doing dictated whether they needed extremity dosimeters and had the need to get a WBC done. One HP was asked to compare the 1960s with the 1990s and he indicated that air monitoring did not improve that much, particularly since the continuous air monitor (CAMs) and instrument got older over time. When one health physicist was asked what he would do differently if he could change something that had caused the greatest problem, he said he would have made sure that Pu and alpha emitters were reported in dpm from the start, instead of the early use of cpm.

A lot of special processing was done in T Building in the early years. There were a number of Po-210 issues that needed to be evaluated. There were even some deaths caused by the acid vapors. Many procedures were developed on a trial by error basis. Another RCT, however, never heard of any such associated deaths on the Mound site.

When you look back, there were certain isotopes that couldn’t be seen. You had to often wait for documentation of a worker exposure to a specific radionuclide before radiation safety could develop techniques and methods to document such exposure effectively. This often hinged on the radiation monitoring equipment at the time and its sensitivity and effectiveness in recording cpm, dpm, or mr/hr. During some periods in the 1970s, cpm was recorded, when it would have been far better to record meter response in dpm. There were gross alpha counters that were effective in monitoring for Pu-238, Am-240 and Th-230. Workers at Mound were instructed to provide nose wipes in any situation when intakes were suspected. However, if a worker was a mouth breather, nose wipes could easily miss a significant uptake.

Mound was generally a safe site in most cases. There were a lot of burnouts in SM building though. When handling the fuel cells and the SNAP-27 heat sources, workers would have to rotate them periodically every 2-½ degrees. This involved a lot of handwork to do this, with resultant extremity and whole body dose.

In the early days of the cold war in the 1940s, Mound supervisors had a paranoia that Russia was going to nuke the site. AEC decided to buy a piece of land in Marion Ohio and built a genuine duplicate of T Building (i.e., a redundant facility in case of emergency) in case the main plant in Miamisburg was ever bombed and they needed to shift to a secondary backup plant. Mound never used chemicals or radionuclides at the Marion Ohio site, but they would have one person go over to the site each week to check the site. The local residents thought that the plant facility was real. Many years later, a cancer cluster was detected at Marion Ohio. There is public concern, to this day, that the mock T Building played a role in their development of cancer.

Mound kept pretty much up to date on their radiological monitoring instrumentation. They used the old snowball with the moderator on top for neutrons, and the cutie pie for alpha counting. Pocket ionization chambers (PICs) were used routinely up until 1966, but continued to be used for some applications after that timeframe. The only problem with PICs is that, if you drop them, they go back to zero and any dose on the PIC is lost. Before the mid-1960s, the bioassay process at Mound was a bit shaky. The T-289s were considered a good instrument. The T-290s were not as good. Mound felt they had a very good monitoring capability especially when they compared themselves with other sites. Argonne National Laboratory, in particular, had a much less effective program.

High-fired oxide microspheres using plutonium and uranium were produced in R-140. Higher exposures were possible from the vaporization of the compounds. An argon torch was used in rooms R-145 and R-147. Workers would put the Pu, along with cladding material from around the heat source, in a ceramic crucible to determine how soluble it was with heating. It was then put into jars of water in the analytical laboratory to see how much was going into solution.

In PP-13 Building in the 1980s, they never had a situation that involved a positive high-fired oxide nose wipe. These operations in PP-13 were buttoned up around 1975. Things, however, were scary in the early years. There was need for a lot of scrubbing down. In Building SM, the hoods had Plexiglas, which was installed to reduce exposure mostly from Pu-238 neutrons.

Super high-fired Pu oxides were produced when Pu was heated above about 850°C. You get a very insoluble form of high-fired oxides when the Pu is heated from 1,200° to 1,600°C. During this process, oxygen is given off which will brittle up the cladding. You get an orange glow during the process. After a long period of time, a person’s urine counts will tell you something about the solubilities of the plutonium compounds inhaled.

There were quite a few Pu-238 heat sources in T Building, which delivered a lot of direct radiation to workers if they got too close. These heat sources were generally locked up to prevent this.

Mound also had concrete retention ponds, much like the big sanitary sewage concrete ponds. Workers would precipitate out the alpha emitters and the sludge was then placed in drums and shipped to the Nevada Test Site (NTS) for burial. Also, beta emitters (basically H-3) were mixed with concrete and placed in a small burial drum. That small drum was then placed inside another larger drum. These were also sent to NTS.

The old x-ray machines used for autoradiographs had a tube type that generated 18 to 200 keV. There were also Co-60 isotopic sources used. In R building, there was a 267 Ci Co-60 source. T Building has medical x-ray units and Co-60 was used for industrial autoradiography. The non-destructive testing (NDT) equipment was a Co-60 source with a 1.2 MeV range. An Ir-192 source was also used; it had a half-life of 75 days and put out 440 keV. There were four ranges in the spectrum. Mound had x-ray machines that generated 18 keV and 300 keV. Mound also had a Neutron Facility with a neutron generator. It had a californium CFX multiplier with U-235 plates that kept it at the subcritical level.

The Mound accelerator had an 18 keV tube.

Mound made calibration sources for the nuclear submarines. Neutron sources had a bad name, since their handling them could result in significant dose to workers. The RadCon staff had to watch folks carefully when they were handling tritium sources. A rule of thumb, used at Mound, was that every 4 fast neutrons were equivalent to about 1 mrem of dose potential.

Radiological Control (RadCon) and Health Physics Aspects

In this early period, workers didn't get routine Pa-231 bioassay; workers were, however, monitored. Urine samples (24-hour) were analyzed by collecting a phosphate carrier precipitate. This procedure collected most of the heavy alpha emitters. At first, the counting was gross alpha counts; later alpha pulse height counting was done. One time they attempted to try to monitor for Pa-231 by urinalysis, but this turned out to be an exercise in futility. The solubility was so low that it could not be seen in the urine. They sent these urinalysis samples out to a contractor, but they really should have been taking and analyzing fecal samples. It appears that urinalysis for Pa-231 stated in 1955. By 1959, they were able to detect Pa-231. There was a gut feeling that actinium might be around, but cases did not readily show up. It may only be a problem for less than 6 people. If Pa-231 bioassay was done, it would have been done by sending samples out to contractors for analysis. Protactinium-231 and Th-230 were components in Cotter Concentrate, which was a byproduct of uranium milling of Belgium Congo ore. "Monazite sand" (thorium ore) was very low in Th-230, and 40–60 drums were the stored outside on the hillside. These thorium ore drums had a history of leaking and required periodic redrumming. "Cotter Concentrate" was different and was always stored inside at Mound.

At one point, there was a flap about actinium. Workers were doing some digging in a corridor and Ac-227 contamination was found. It appeared that previously radium had been irradiated and had produced actinium. Actinium is also a predecessor of Pu. Actinium is a “bad actor.” Some 25 to 50 grams of Ra-226 came in when they were ready to make Ac-227. Sometimes Ac-227 sat around in refrigerators for a couple of years before it was realized that it was there.

Actinium is a weak beta emitter; it is hard to detect, and even harder to separate. If you weren’t in an area where actinium was handled, you were not monitored. The only areas in SW Building where actinium monitoring might have been done were in the old radium caves and the new radium caves (SW-19, Old Cave) and (SW-22, New Cave). Some areas of R Building also had similar actinium exposure potential (R corridor – Room 111). Sometimes the only way it was determined that workers were being exposed to actinium was from environmental samples that detected it. It was routine to have contamination surveys show the presence of actinium.

When alpha pulse height analysis was first started, the techniques were not much different that they have been over the past 10 years or so. However, today, the recoveries are up and the backgrounds are down. There has never been a problem with determining solubilities. There was never anything out of the ordinary regarding capturing the source term, determining the activity, or the radioisotope being analyzed.

In R Building, there were large amounts of primarily Pu-238 contamination. There was also some Pu-239 contamination in R-140. In the early days, workers wore respirators on their hip. At some points, workers went in without their respirators. Later, workers had full face respirators donned when they entered any area when loose surface contamination was known or suspected. If a CAM went off, the workers would put on their respirators. If it was needed, HP could determine exposure from real time air samplers. If static air samplers were around, this helped. The CAMS, for the most part, worked quite well. The CAM would go off within 2 seconds, if there were a lot of contamination around. Sometimes the sensitivity of the CAMS was too sensitive, and they would alarm repetitively even in low contamination areas. It this case, the sensitivity was adjusted slightly upward so as to alarm at a more significant contamination level.

There were several processes that produced Bi-210 slugs in production reactors, including Bi-210, itself. The slugs were shipped to Mound for the extraction of polonium. The beta activity of 1 lambda of water from each cask was reported to be too high to count. Because of the quantity of bismuth processed, there are a number of contaminating isotopes that provided the potential for beta dose at Mound through the decommissioning and cleanup of polonium operations in 1971. One HP advised that they used gamma doses to develop ratios of what beta exposure might be expected. The issue of a high mysterious beta problem was discussed, but the HP thought that this was probably not work related, but instead was the result of natural uranium in the well water or other naturally occurring radionuclides.

A lot of radon gas was found in SW Building in the 1970–1980 timeframe especially when working in SW and adjacent areas. Radon was discovered in SW-140 when a high alpha sample was found. This area of SW-140 had been expanded to include an area for the handling of Cotter

Concentrate. Rad Safety set up grab samplers, pulled 10–15 ml air samples, and put the filter in a gross alpha counter. The health physics staff was amazed to find how much radon was there. Remedial actions were taken by drilling down into the concrete floor and putting a tube that was vented to a stack. Later, it was common to leave a spot sample once a month for analysis. In the labs, spot samples were taken twice a day, once in the morning and once later in the afternoon.

Radon and tritium exposure in the 1970s became a problem when it was thought that the Power Plant in the valley was sending up air that was carried by the wind to the Mound site area. Health physics personnel thought this was the cause. Later it was realized that the old radium cave was the origin of the radon exposure. The Old Cave had been used for some Ra-226 work.

Exposure to high-fired oxides was an issue of concern to the HP staff. It is hard to get these high-fired oxides into solution. Counting was done in an attempt to calculate the quantity, in pCi, that would be encountered in several of the operations where this might be a problem. Analysts would look at the records, noted the trends, and try to come up with body burden estimates. Since high-fired oxides have such low insolubility, they stay in the lungs and do not come out into the urine in high enough concentrations to be detected. If workers were in the area when the Pu oxides were heated to high degrees, then they had a potential for inhalation.

High-fired oxides were recognized as a problem as far back at the early 1960s at the time that Pu-238 was beginning to be handled and processed. In dealing with high-fired oxides, it is important to know the minimum detectable levels (MDAs) since different forms of high-fired oxides may have different MDAs. If exact MDAs were not known, it complicated being able to determine dose from high-fired oxides. With the advent of more powerful computers in the 1990s, the MDAs could be calculated. But in the early days, lack of knowledge of the backgrounds could mess up the determination of the MDA. There were rules on how high a background could be tolerated. When asked about problems with spikes with Pu high-fired oxides, one HP indicated that they tended not to worry much about it in the early bioassay program. If an incident was suspected, they would do more frequent sampling and health physics personnel would decide who should be followed, and if fecal sampling needed to be done. If fecal samples were taken, the analytical staff would be warned that fecal planchets were in the batches provided.

Plutonium high-fired oxides were handled in R Building, Room R-142. Workers were required to leave fecal samples when they started working in the area as a baseline and when they completed work and did not plan to return to that area. In high-fired oxide areas, routine fecal sampling was done at least twice a year. For special high-fired jobs, it was required to provide a fecal before and after the specific job. Some of this was still occurring as late as 3–4 years ago during recent D&D operations. A-line in Building 38 in Room 5A, which was in the basement, had some workers that had to be removed from work based on the specific tasks they had been doing. Some of the tasks that involved uptakes was removing ductwork and taking down the old conveyers. These parts had to be taken down and taped up in plastic bags. Workers were in full plastic suites and full-face respirators. One RCT remembered finding tools that had been left on top of the duct, which were covered with a lot of dust and when swiped, were found to be heavily contaminated.

One RCT didn't recall seeing any of his doses from Pu high-fired oxides until late in the 1990s. He had looked at 1989 dose data and found that it did not include dose from Pu high-fired oxides. Lung counts would have shown it, but they couldn't help in quantifying high-fired oxide dose. A dosimetrist from Fernald (previously a Mound worker who did the lung counting) ran the lung counter and he could see the signature but couldn't quantify it. It wasn't until the advent of the germanium detectors in the late 1990s that quantification of high-fired oxides was possible. Health physics personnel at Mound felt there was a population of Mound workers who were exposed to high-fired oxides. The ones most likely to receive dose to high-fired oxides were those in the Pu-238 programs. This was also true for workers who cleaned up facilities during the D&D phase. Monitoring regimens for high-fired oxides did not really come fully into being until the mid 1990s.

Large hard cover urinalysis logbooks were used to record urinalysis results. They were maintained by the HP Staff. Later, these data were entered on a computer mainframe. Then it became possible to choose samples, sum then up, and calculate means and high exposures for radioisotopes sampled. With this old system, it was necessary to type in the parameters to set up the computation, and put data into the appropriate bins. All along, there was concern that the data was being captured properly. About 1955, the computer system became old and the DOE people worried about the computer system crashing. It wasn't until 1993, that an interim computer system was put in place when money was made available for a brand new system. With the new system, it was then possible to calculate sigmas. Now it is possible to keep track of the last 20 background counts and the last 20 spikes and do an analysis with the package that came with the computer system.

In regard to reporting zero dose, when one HP was asked about whether it was common practice to record a dose just below MDA as zero or MDA or non detectable, he stated they usually recorded the exact count. If below MDA, they still used the exact count. When it was possible with more modern computers to do calculations on multiple samples, someone else would determine the MDA. It was easier to do this with long-lived radioisotopes. It was not as easy with Po-210, since it has a 138-day half-life. Most of this was picked up when counting environmental samples. Their requirements were not as low and would usually be run on chambers with higher backgrounds.

Fixed air samples were taken in front of the glove boxes and these air samples were picked up daily. The filters in R Building were changed daily. Starting in 1966, and continuing until 1975, workers worked in controlled areas, and health physics surveys were conducted in these controlled areas.

Field Radiological Control

Early on, the air monitoring program was not real effective. RCTs tried to determine the direction of air flow in the Building spaces and made an attempt to place the CAMs along a route that was believed to be most effective to spot elevated airborne contamination levels. Sometimes walls would be torn out to more favorably allow for exit of air so as to minimize personnel exposure. This continues to be a problem for the site even today, as buildings are gutted and demolished. This kind of problem has occurred for virtually every building in the complex increasing worker potential exposure.

In any lab where production work was ongoing, Mound workers were monitored by some means. This was particularly true for workers in the Pu-238 production areas. However, in the early days, no formal radiation work permit (RWP) process was in place. The health physics staff and line supervisors monitored the areas with significant exposure potential and instituted procedures to minimize dose when it was found to be needed. If a worker worked in an area where uptakes were possible, the routine urine bioassay was enforced. Building SW had its own independent radiation safety program where it was important to utilize procedures for tritium analysis. If they did run into Pu, then a different bioassay process was used.

Prior to the 1996 timeframe, there really was no formal work planning. Starting in 1996, both Job Specific Work Permits (SWPs) and Routine Radiation Work Permits (RWPs) were put into use. The Radiological Records Organization had a collection of permits that extend a number of years in the past. The farther you go back, the less complete the set of permits is.

Radiation Work Permits were written by a combination of the Radiological Engineer and the RCT Supervisor. The field radiation operations supervisors determined the personnel monitoring requirements and personnel protective equipment. During the 1994 to 1996 timeframe, the Internal Dosimetry Technical Basis Document was under development, so it was not available for reference by the field. The PPE was tied to the postings of the area and the type of activity. For example, you could enter a contamination area with shoe covers, gloves, and a lab coat if you were going in a room to change air samples. For repacking drums, a bubble suit was required. I suspect the field supervisors were using personal experience and the Wayne King (King 1995) document. There were sign-in sheets associated with RWPs.

The gamma spectroscopy lab processed mainly soil from remediation activities. Occasionally, the Radiological Control Organization would send smears, air samples, and other items for isotopic characterization by the lab. For example, large area smears were taken in the hood in R-140 and sent it to the laboratory for isotopic analysis. There have been gamma spectroscopy capabilities for quite some time. It was pointed out that this is a good source of information on soil concentrations during remediation for verification of isotopic characterizations and ratios. There was a separate environmental monitoring section. These samples actually went through radiochemistry.

Radiological Engineering included, in their standard procedures, the use of glove boxes, hoods, and negative pressure. When there was no ventilation in a building, maintenance personnel would build tents and use portable ventilation systems to get negative pressure in the tent. There were two failures in the engineering controls during 1994–1996. There was a glove box in R-140 that contained a furnace. In the adjacent room there was a window where the carbon arc equipment shot a beam through the window into the glove box in R-140. Contamination was found around the window, indicating leakage from the back of the R-140 glove box.

The second situation involved a tent constructed to open drums, and recover material from the drums. The tent was based on a three-zone concept, and had ventilation, which exhausted out the window of the building. There was a tritium sniffer that was used to measure tritium off gassing when drums were opened. Workers were required to wear bubble suits due to the tritium airborne potential. The radionuclides of concern in these drums were not limited to tritium. There were situations were tritium leaked through the walls of the tent. In addition, the Radiological Control Organization identified tritium outside the building under the area where the tent was being exhausted. This project also resulted in a contamination incident in R-Building while transporting smears to the R-Building count room. The hallway became contaminated with tritium. The smears had very high levels of tritium on them.

Egress monitoring was improved as a result of the union lawsuit sometime after 1996. While working in the field, workers were required to do their own self-survey out of areas, with a portable alpha meter (PAM). In the case of WD Building, there should also have been a self-survey for beta/gamma.

There was a difference of opinion on what constituted a “high contamination area” verses a “contamination area” between some Field Radiological Control Staff. Some of the Radiological Control staff assumed that you could apply an average contamination level over the room to determine which posting was necessary. Others felt that, if there was an uncontained location in a room greater than 2,000 dpm/cm^2, it should be posted as a high contamination area until it was decontaminated. The level of posting influenced the amount of personal protective equipment (PPE) and the kind of respiratory protection that was worn by each individual that entered into an area.

During the mid-1990s, a significant effort was underway to evaluate the air sampling program of the time. This included an air sampling needs analysis based on radionuclide inventory, and containment in particular rooms. In addition, airflow studies were completed to verify the positioning of both continuous air monitors, tritium monitors, and fixed air sample heads. This documentation, if located, would give a contemporary idea of radionuclides present during the mid-1990s.

There was a feeling among the workers that some workers would sometimes bypass radiation safety protocols. Also, Mound radiation safety personnel sometimes did not tell you that you were being exposed or what the results of the monitoring showed. Radiation safety personnel in general did make sure that individuals were so advised. Some bioassays and fecal samples were taken and then never analyzed. Technicians would sometimes not record the needed radiation monitoring data. This happened a lot until about 1995. The 1970s was the worst time for these problems.

Radon was a concern at Mound. They worked with Ra-226 in the Cave. During early operations, they used to perform Radon Breath Analysis. Radon was often a bad actor for inhalation dose. If thoron daughter products were around, they often would go gaseous and then back to particulates. When they took pipes out of the ground around RW Building, this caused resuspension of particulates. But doses were usually less than 10 mrem/month for workers.

They did study dose especially if it dealt with Ac-227. Dave Abbott was involved in these studies. By 1994–1995, workers in SW Building did begin to wear respirators. They were told that this was because of the potential for radon inhalation.

Internal Dosimetry

Radon dose was considered by workers to be "the joker in the deck" at Mound. In Building R and SW, radon exposure trumped all other dose contributions. It was pointed out that, if you took samples of the soil under R Building, you would really get a good idea of the extent of the radon exposure problem by the amount of Ra-226 you would find. Mound did have health physics personnel supervising the taking of core samples to monitor the radon problem, and these personnel were often in bubble suits.

A number of strange types of radionuclides were used at Mound. Some of these unusual radionuclides were: Sb-128, Sb-121, Bi-210, Ac-227, Pa-231, Th-232. Thorium-232 was a huge problem in legacy waste stored at Mound, especially when it came to leaking drums. These radionuclides were ubiquitous and moved all over the site and you would find them in the most unexpected places.

Mound had to do a lot of bioassays since the greatest exposure potential was internal dose. To ensure that Mound had the best techniques to do this, it was reported that Mound borrowed their procedures from Oak Ridge where these techniques were first developed and refined. One RCT felt that Mound perfected the techniques and adapted them to suit the bioassay needs at Mound.

If the Pu-238 got into your lungs, it was hard to detect since the high-fired oxides were very insoluble, and could not be detected in the urine or by using the lung counter. Lung counting for high-fired Pu-238 oxide, however, was no different than doing normal lung counts for Pu-238 at Mound. The lung counter could not differentiate between routine samples containing Pu-238 and samples containing high-fired Pu-238 oxide. During the 1980s, if positive readings were detected on the lung counter, it usually meant that a worker had received a dose of at least 40 rem or so. This detection level improved greatly with the introduction of more sensitive lung counters in the 1990s.

Plutonium was hard to detect in the early days, when it was used most. It was easy, however, to detect H-3. The old scintillation counters were sensitive enough to detect tritium. With Pu-238 on the lung counters, there was not as good a signature. All you could do is detect if it was present, but you could not quantify it.

Solubilities were all over the place. Once radionuclides got into the lung, you could see many of them by using the alpha spectrometers and chest counters. High-fired oxides, on the other hand, were so insoluble, that they could not be detected after an uptake. Dosimetry personnel were able to pick up the weak 40 kVp x-ray. There was a lot of work in the 1960s and 1970s to take current measurements, and try to infer what the update might have been in the early days. They worked with phantoms, and the chest counters, to attempt to get the data needed for back extrapolation. Dosimetry personnel tried to correct for the person's geometry, i.e., whether the