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March 24, 2009

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

Re: Contract No. 200-2009-28555, SCA-TR-TASK1-0023: *Review of the NIOSH Site Profile for the Argonne National Laboratory - East*

Dear Mr. Staudt:

SC&A is please to submit to NIOSH and the Advisory Board our report titled, *Review of the NIOSH Site Profile for the Argonne National Laboratory - East*. This report has been reviewed for Privacy Act-restricted information and edited accordingly, and has been cleared by DOE for release to interested members of the public.

Should you have any questions, please contact me at 732-530-0104.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc:
P. Ziemer, Board Chairperson
Advisory Board Members
T. Katz, NIOSH
L. Elliott, NIOSH
J. Neton, NIOSH
S. Hinnefeld, NIOSH
L. Homoki-Titus, NIOSH
A. Brand, NIOSH
J. Broehm, NIOSH
C. Ellison, NIOSH
L. Shields, NIOSH
D. Sundin, NIOSH
L. Breyer, NIOSH
A. Makhijani, SC&A
H. Behling, SC&A
S. Ostrow, SC&A
H. Chmelynski, SC&A
J. Fitzgerald, Saliant
J. Lipsztein, SC&A
K. Robertson-DeMers, Saliant
S. Marschke, SC&A
K. Behling, SC&A
T. Bell, Saliant
D. Farver, SC&A
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ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

Review of the NIOSH Site Profile for the Argonne National Laboratory - East

Contract No. 200-2009-28555
Task Order No. 1
SCA-TR-TASK1-0023

Prepared by

S. Cohen & Associates
1608 Spring Hill Road, Suite 400
Vienna, Virginia 22182

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

March 2009

Disclaimer

S. Cohen & Associates: ***Technical Support for the Advisory Board on Radiation and Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0023 Effective Date: March 11, 2009 Revision No. 0 – Draft
REVIEW OF THE NIOSH SITE PROFILE FOR THE ARGONNE NATIONAL LABORATORY - EAST	Page 1 of 102
Task Manager: _____ Date: _____ Charles Phillips	Supersedes: N/A
Project Manager: _____ Date: _____ John Mauro, PhD, CHP	

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AGHCF	Alpha/Gamma Hot Cell Facility
ALARA	As Low as Reasonably Achievable
Am	Americium
AMAD	Activity Median Aerodynamic Diameter
ANL	Argonne National Laboratory
ANL-E	Argonne National Laboratory – East
A-P	Anterior-Posterior
AWE	Atomic Weapons Employer
APS	Advanced Photon Source
ATLAS	Argonne Tandem Linear Accelerator System
Bq	Becquerel
CFR	*Code of Federal Regulations*
CMR	Chemical Metallurgy Research
CP	Chicago Pile
D&D	Decontamination and Decommissioning
DAC	Derived Air Concentration
DCF	Dose Conversion Factor
DOE	Department of Energy
DOELAP	Department of Energy Laboratory Accreditation Program
DOL	Department of Labor
dpm	Disintegrations per Minute
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ERP	Environmental Research Program
ESE	Entrance Skin Exposure
ES&H	Environmental, Safety, and Health Group
GE	General Electric Corporation
GI	Gastrointestinal
ha	hectare area

HEP	High Energy Physics
HEPA	High Efficiency Particulate Air
HHS	Health and Human Services
HP	Health Physics
HPI	Health Physics Instrumentation
HVL	Half value layer
ICRP	International Commission on Radiological Protection
INEEL	Idaho National Engineering and Environmental Laboratory
INL	Idaho National Laboratory
IPNS	Intense Pulsed Neutron Source
IREP	Interactive RadioEpidemiological Program
keV	kilo electron volt; 1,000 electron volts
kVp	kilovolt potential
kW	kilowatt
LANL	Los Alamos National Laboratory
LAT	Lateral
LINAC	Linear Accelerator
LOD	Limit of Detection
LS	Lumbar Spine
LWR	Light Water Reactor
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration
MDL	Minimum Decision Level
MICU	Mobile Intensive Care Unit
mL	milliliter
mm	millimeter
MeV	Million electron volts
mR	milliroentgen
mrem	Millirem
Mw	megawatt
NBL	New Brunswick Laboratory
NCRP	National Council on Radiation Protection and Measurements

NELAP	National Environmental Laboratory Accreditation Program
NIOSH	National Institute for Occupational Safety and Health
NTA	Eastman Kodak Nuclear Track Film Type A
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
OSTI	Office of Scientific and Technical Information
OTIB	ORAU Technical Information Bulletin
PA	Posterior-Anterior
PAC	Portable Alpha Counter
PCM	Personnel Contamination Monitor
PFG	Photofluorography
PIC	Pocket Ionization Chamber
POC	Probability of Causation
PRM	Pulse Rate Meter
QA	Quality Assurance
R	Roentgen
R&D	Research and Development
RadCon	Radiological Control
rem	Roentgen equivalent man
RM	Radioactive Material
ROUT DOS	Routine Dosimeter
ROV DOS	Rover Dosimeter
SC&A	S. Cohen and Associates
SNM	Special Nuclear Material
SRS	Savannah River Site
Sv	SI derived unit of dose equivalent
TBD	Technical Basis Document
TIB	NIOSH Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
VOC	Volatile Organic Compound
ZGS	Zero Gradient Synchrotron

1.0 EXECUTIVE SUMMARY

This report provides the results of an independent audit of the Argonne National Laboratory – East (ANL-E) technical basis documents (TBDs) conducted by S. Cohen and Associates (SC&A). The TBDs reviewed make up the site profile developed by the National Institute for Occupational Safety and Health (NIOSH) for the ANL-E site. This audit was conducted during the period December 2007–September 2008, in support of the Advisory Board on Radiation and Worker Health (Advisory Board) in its statutory responsibility under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA). This authority includes the conduct of such reviews and advising the Secretary of Health and Human Services (HHS) on the "completeness and adequacy" of the EEOICPA program.

The present site of the ANL-E (Figure 1) is on the central 607 ha (1,500 acres) of a 1,514-ha (3,740-acre) tract in Dupage County, Illinois, about 27 miles southwest of downtown Chicago and 5 miles west of Site A (Wescott and O'Rourke 2001). This site was acquired in 1947 and was called Site D (*D* for Dupage County–see Figure 2). Much of the 907-ha (2,240-acre) Waterfall Glen Forest Preserve around the site was part of ANL-E before being deeded to the Dupage County Forest Preserve District in 1973 (Golchert and Kolzow 2005).

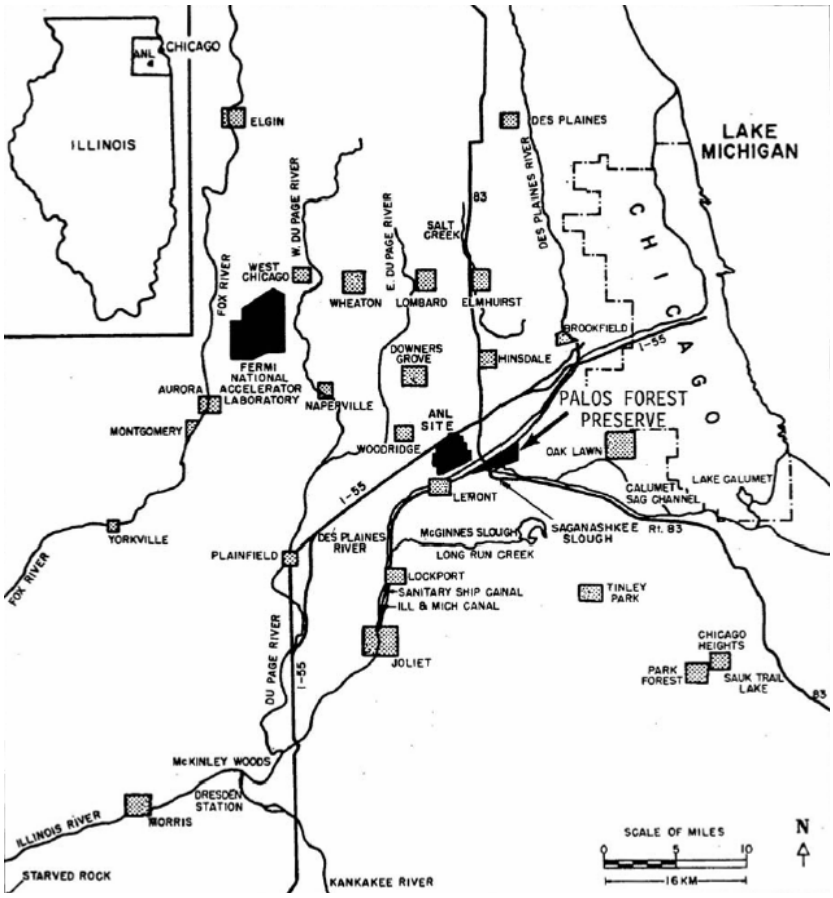

Figure 1. Present Location of Argonne National Laboratory – East

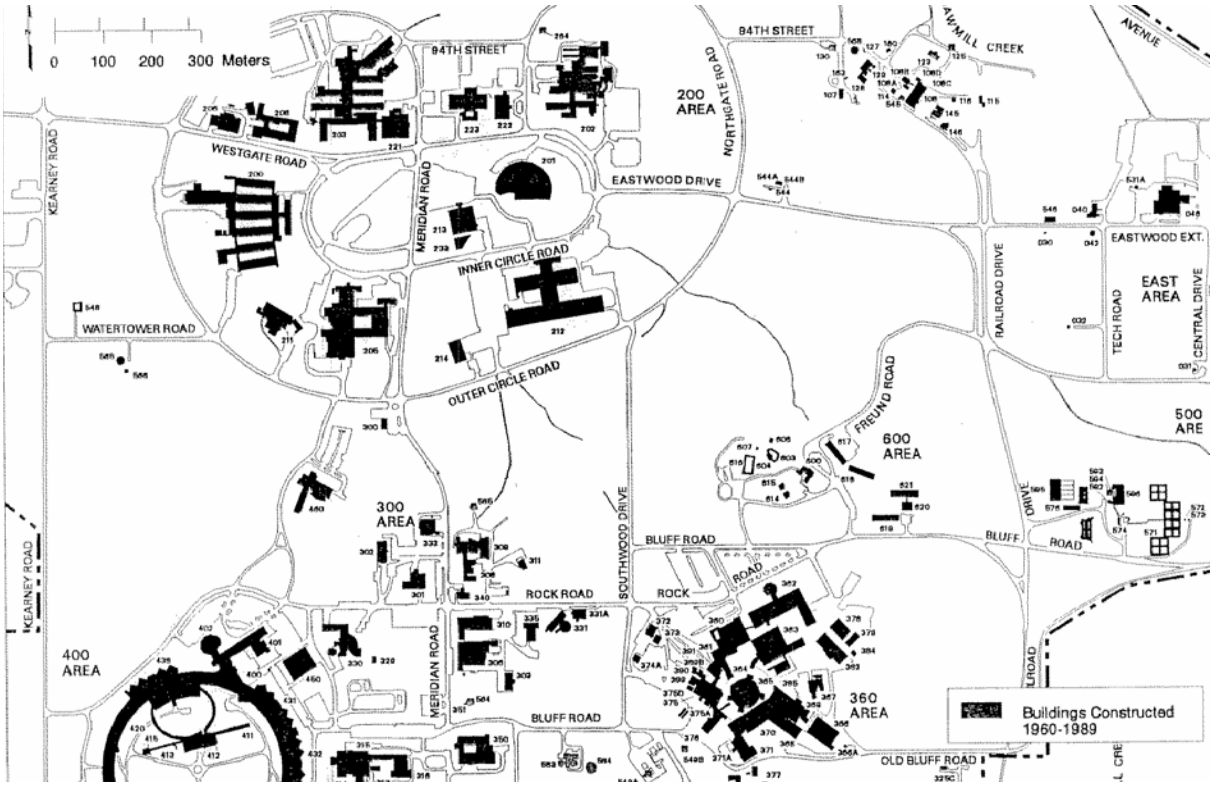

Figure 2. Site D: Argonne National Laboratory – East

ANL-E was established as the first national laboratory on July 1, 1946, as a result of the Atomic Energy Act of 1946, which created the U.S. Atomic Energy Commission (AEC) and the national laboratory system. The University of Chicago has operated ANL-E since its creation. The research that ANL-E carried out in the early years as a national laboratory began under the University's Metallurgical Laboratory, which built the first nuclear reactor, Chicago Pile 1 (CP-1), under the West Stands of the University's Stagg Field. CP-1 successfully achieved the world's first man-made nuclear chain reaction in 1942. Before 1946, the University dismantled CP-1 and rebuilt it as CP-2 at Site A in the Palos Forest Preserve, about 25 miles southwest of Chicago in the Argonne Woods. Although the site profile addresses some of the activities conducted at Site A, it is not clear whether this is appropriate, given that the work at Site A was initiated by an Atomic Weapons Employer (AWE).

Most of the permanent structures at ANL-E were erected in the 1950s and 1960s, although additional support facilities were constructed in the 1970s and 1980s. Over its approximate 62-year history, diverse research was conducted at the laboratory, and the site has hosted several nuclear reactors and particle accelerators, resulting in the storage of significant quantities of radioactivity. Although health and safety was a concern from the inception of the laboratory, health protection and access-control practices have improved over the years.

Questions generated during the review process by SC&A were submitted to NIOSH and its technical support contractor, Oak Ridge Associated Universities (ORAU), and are included as Attachment 3.

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. The complete list of the ANL-E TBDs, as well as supporting documents that were reviewed by SC&A, is provided in Attachment 1.

This review found that the site profile provides an informative overview of ANL-E historical operations and defines the primary radiological exposure sources and conditions. The presentation and analyses of the available data were generally technically sound. The period covered is large, as it is for several of the other DOE sites. However, the TBDs fail to fully address the exposure implications of these and other radiation sources to the degree necessary to allow a comprehensive assignment of historical doses, including missed doses.

ORAUT-TKBS-0036-3 provides a reasonable basis for some assumptions regarding estimation of worker medical exposures at ANL-E. SC&A notes that the TBD recognizes the total lack of exposure data and protocols that existed prior to 1988. Section 3.2 of the Occupational Medical Dose TBD observes that site-specific data for x-rays prior to 1988 are not documented, so the occupational medical doses estimated in this document rely mainly on guidelines specified in ORAUT-OTIB-0006 (ORAUT 2005b), which are derived from ICRP Publication 34 (1982) and NCRP Report 102 (1989).

The Occupational Medical Dose TBD (ORAUT-TKBS-0036-3) does not adequately document the variety of occupational medical exposures. In addition, the TBD suffers from a lack of documentation on the type of x-ray equipment, beam quality, exposure protocols, and maintenance records. Therefore, dose reconstructions following guidance set forth in the TBD will likely not be a conservative and claimant-favorable estimation of dose.

The Occupational Environmental Dose TBD, ORAUT-TKBS-0036-4, indicates that routine monitoring of the external radiation fields at the site consists primarily of thermoluminescent dosimeters (TLDs) placed at strategic locations outdoors beginning about 1972. The site profile indicates that outdoor film badge measurements may have been made before 1972, but these data could not be found.

The site profile states that it is likely that external radiation fields increased as a function of time due to the buildup of radionuclides over time, and concludes that measurements made at later time periods should be bounding as applied to earlier time periods. Although this argument has some merit, we believe that it will be difficult to reconstruct external doses received by unmonitored outdoor workers prior to 1972, especially if some of the radionuclides released during the early years were relatively short-lived and/or there was some cleanup of the site prior to 1972.

A weakness of ORAUT-TKBS-0036-6 is that the entire period is often covered without subdividing it according to the ongoing activities at the time and the level of control technology available. A particular concern is the lack of material describing the operations at Site A prior to cessation of activities at that site, bringing into question the ability to adequately assign

appropriate radiation doses to workers at that site. There is an unusually large degree of uncertainty expressed in many sections of the External Dose TBD. For example, words and phrases such as "probably," "there is some indication," "films were apparently," and "the years given are approximate" are often used. This pervasive use of qualified and vague terms leads to a concern about the degree to which many of the basic components of the external dosimetry program are actually known.

It is not clear from the Internal Dosimetry TBD (ORAUT-TKBS-0036-5) how dose estimation would be performed for workers who were not classified as radiation workers and who had access to ANL-E radiological operations. No guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers, such as support personnel whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to those of radiation workers, and whose access to various ANL-E buildings may have led to a variety of radionuclide exposures over their job histories.

Historic radiological exposure incidents or unusual exposure conditions were frequent at ANL, particularly in the early years; however, the site profile does not fully address the significance of such incidents. The Site Description TBD, ORAUT-TKBS-0036-2 (ORAUT 2006a), provides an overview of 10 incidents occurring from 1952 to 1976, with mention of small fires occurring over a 30-year period. No accidents that occurred before 1952 are listed in the site profile. The TBD indicates that accidents are documented in health physics progress reports, as well as in the personnel dosimetry files, if non-routine dosimetry procedures were instituted. In interviews with ANL-E dosimetry staff, SC&A was informed that the ES&H Coordinator maintains the incident reports for any safety incidents. It is unclear if these incident reports are duplicated in the individual radiation exposure files. While it is clear that judgment needs to be exercised regarding what accidents and incidents need to be reviewed and included in site profile characterization, it is important to identify available information regarding key accidents and incidents and assure their availability and use by dose reconstructors. Equally important, the site profile needs to evaluate this accident history for its implications regarding dosimetry adequacy and completeness of dose reconstruction; in particular, the accidents that occurred prior to 1952 and the implications of the absence of records for this period should be addressed.

Interviews were conducted with 32 ANL-East site experts. Years represented by those interviewed range from 1953 to the present. Interviews were conducted at the Argonne National Laboratory in Argonne, Illinois, February 25–28, 2008, in conjunction with the onsite records review. The purpose of these interviews was to obtain information on past radiological control and personnel monitoring practices, and to better understand how operations were conducted through time. Interviewees were identified by ANL-E based on general recommendations provided by SC&A.

Employees interviewed worked at Site A, Plot M, and Site D (present location) locations of the laboratory, collectively. Facilities represented by the interviewees included 200, 201 (Central Administration Building), 202 (Biology Building), 203 (Physics Building), 205 , 211 (Chemistry), 212, 306 (Decontamination Shop/Waste Management), 317, 331, 335, 350, 370, 375, 376 (Powerhouse), 391, the Zero Gradient Synchrotron (ZGS, 360 series of Buildings), the Intense Pulse Neutron Source (IPNS), Chicago Pile-5 (CP-5, Building 330), the East Area, and the Advanced Photon Source (APS, 400 Area).

Some individuals interviewed worked in all areas of the site, while others worked in a limited number of areas. The categories represented by interviewees include the following:

- Accelerator Health Physics (HP)
- Building Maintenance
- Environmental Engineering
- Environmental Protection Management
- External Dosimetry
- Firefighter/Paramedic
- Internal Dosimetry
- Machinist
- Medical X-ray Technician
- Maintenance (e.g., Mechanics, Painters, Riggers, Electromechnical Technicians, Millwrights, Custodians, etc.)
- Operational Health Physics (Technicians and Area Health Physicists)
- Physician
- Radiological Records
- Reactor Engineering
- Training
- Transportation
- Waste Management

The interviewees were informed that the interviews were being conducted as part of SC&A's review of the ANL-E site profile. Participants were told the interviews were unclassified and not to disclose classified information. Summaries from each interview set were prepared and provided to the interviewees for review. Most of those involved with the interviews responded. It was explained that interview notes with names are made available to the Advisory Board. A consolidated version of all interviews may be redacted for Privacy Act reasons by the Department of Health and Human Services for the publicly released report.

All interviews have been compiled and summarized in Attachment 2. This is not a verbatim discussion, but rather a summary of information from multiple interviews with many individuals. The information provided by the interviewees was based entirely on their personal experience at ANL-E. It is recognized that site expert recollections and statements may need to be further substantiated. However, they stand as critical operational feedback and reality reference checks. These interview summaries are provided in that context. ANL-E site expert input is similarly reflected in the body of the report.

The information the ANL-E workers provided to SC&A has been invaluable in providing us with a better understanding of the ANL-E site operations and, with the preceding qualifications in mind, this summary has contributed to issues raised in the site profile report.

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. These issues were carefully reviewed with respect to the five review criteria. Thirteen of the issues were designated as findings because they represent deficiencies in the TBDs that need to be corrected, and that have the potential to materially impact at least some dose reconstructions. These findings are summarized below.

Finding 1: Lack of Definition of Radionuclide Compositions and Radionuclides Not Addressed in the Site Profile

The source terms associated with ANL-E operations are not adequately described and quantified in sufficient detail in ORAUT-TKBS-0036-5. While Chapter 5 of the site profile (Section 5.2.2) defers to ORAUT-TKBS-0036-2, in neither document is the magnitude of site activity or the assignment of isotopic composition for U, Pu, or Am sufficiently described to allow the dose reconstructor to address all relevant aspects of the site radionuclides. For example, according to Chapter 2, as noted in Figure 5-6, the facility handled natural, enriched, and depleted uranium; however, the degree of enrichment is not indicated.

The dose reconstructor requires the isotopic composition to properly calculate the internal doses. On pages 13 and 14 of Chapter 5, two different isotopic compositions are offered for plutonium. It is not known whether other compositions of plutonium isotopes were used at ANL-E. NIOSH should provide guidance to dose reconstructors on composition assumptions to assure that claimant-favorable determinations are made, particularly for plutonium and enriched uranium.

Both research and development (R&D) and production operations have contributed to the extensive and diverse list of radionuclides historically present at ANL-E. The D-Building and Chemical Metallurgy Research (CMR) facility were both heavily involved in R&D to support the weapons program. Accelerator facilities have been used to produce both stable and radioactive elements for use by the Department of Energy (DOE) complex and commercial vendors. Reactors have been used to irradiate elements. The Biology Building has conducted studies on the metabolism of radionuclides in animals and humans, as well as direct irradiation of animals from a reactor. The long-term operations and R&D activities at ANL provided constant opportunities for workers to come in contact with radionuclides spanning the periodic table.

Accelerator facilities such as IPNS and APS produce activation products which can create a potential exposure. There have been predictive calculations and characterization measurements to identify activated material at IPNS and APS. In general, accelerator beams are activating iron, copper, aluminum, and structural material. As such, these activation products would include Co-60, Co-57, Co-59, Mn-54, Na-22, Na-24, V-48, Fe-55, and some level of tritium. At IPNS, the highest induced activity is at the target and the surrounding shield materials. At APS, septum devices are used to split the beam into multiple beams, and this is where the activation occurs. The major activation products are Na-24 and Co-60, with Mn-54, Co-57, and Fe-55 in smaller quantities.

These potential sources of exposure from secondary and so-called "exotic" radionuclides, such as Pa-231, Po-210, Cf-252, and other transplutonium elements, are based on a limited SC&A review of ANL operational history and available health physics files. Further research by NIOSH into these non-traditional radionuclides should be completed in any revision of the ANL-E site profile to assure that their significance and dose contribution are fully addressed. Bioassay techniques should be evaluated for entire periods of potential exposure for their effectiveness in detecting other radionuclides. Appropriate methods for internal monitoring were not always available for all years of potential exposure.

Finding 2: Potential Missed Dose from the Use of Gross Alpha Counting for Bioassay (1946 to 1972)

The bioassay techniques applied from 1946 to 1972 (Section 5.3.3.1) for all alpha emitters involved gross alpha counting for sample activity determination. A quote from ANL 1949 illustrates the lack of sufficiency of minimum detectable concentrations (MDCs) for alpha-emitting radionuclide bioassay samples:

> *The term Bio-assay essentially refers to the assay of human excreta and other body fluids (i.e., sputum, etc.) for the presence of trace amounts of radioactive materials. The need for a continuous survey of individuals working with often large amounts of radioactive substances is self-evident. Reliable methods adaptable for the detection of very small amounts of radioactive contaminants are present* [sic] *available for only a few isotopes, especially for plutonium.*

The effectiveness of early radiobioassay methods for all alpha-emitting radionuclides is unclear from the TBD. Issues with chemical recovery by radionuclide, the ability to detect radionuclides in urine, interferences from other radionuclides, and chemical solubility should be further substantiated prior to assuming all alpha-emitting radionuclides were detectable with the actinide or gross alpha analysis. The potential missed dose associated with non-specific bioassay techniques should be further investigated to determine the impact on internal dose calculations. The TBD fails to provide guidance to the dose reconstructor on how to deal with mixtures of alpha emitters for bioassay techniques that may analyze for multiple radionuclides.

Finding 3: Assumption of Default Inhalation Pathway May Not Be Claimant Favorable

According to ORAUT-TKBS-0036-5, Section 5.3.1.3, if specific information is not available, the dose reconstructor should assume inhalation as the pathway for internal doses. This

recommendation is not claimant favorable for cancers in the alimentary tract, where ingestion can result in higher doses. Doses from the ingestion pathway, particularly those for the gastrointestinal (GI) tract, should not be ignored. Failure to include these doses for ingestion of plutonium, americium, and uranium compounds represents a missed dose and is not claimant favorable.

Finding 4: Insufficient Information on the Calculation of Minimum Detectable Concentrations and Uncertainties in Bioassay Methodology

The assessment of the missed dose for the monitored workers with bioassay results below the MDC or decision level is an important issue that is inadequately addressed in this site profile. Potential missed dose associated with inadequate bioassay techniques should be further investigated to determine the impact on internal dose calculations.

SC&A also finds the document incomplete in terms of providing information relevant to the calculation of uncertainties for the bioassay techniques that were used at ANL-E. The uncertainty in the values of the minimum decision levels (MDLs) or MDCs for bioassay samples has not been adequately discussed in ORAUT-TKBS-0036-5. This is a major omission, since the uncertainty associated with these parameters may have a significant impact on the estimate of missed dose.

Finding 5: Lack of Guidance for Estimation of Missed Dose for Unmonitored Workers

ORAUT-TKBS-0036-5 provides in-depth information on the in-vivo and in-vitro bioassay program through time. Insufficient guidance is included in the Internal Dose TBD on how to use this information. For example, insufficient guidance is provided on estimating internal doses for unmonitored workers. Even in the case of monitored workers, there is a lack of information on some default assumptions, such as solubility, assignment of dose from trace radionuclides, etc.

> *The routine bioassay monitoring program at ANL-E has historically been conducted for workers (identified by self-reporting, by supervision, and by radiation protection staff) in areas involving possible internal exposure. Most workers at ANL-E were not identified to be at risk and were not monitored.* (ORAUT 2006d, page 29)

This statement needs more support to provide a greater level of assurance that all workers with potential risk were subject to routine or special bioassay monitoring, especially in the early years of operation. ORAUT-TKBS-0036-5 (ORAUT 2006d) also states the following on page 18:

> *The bioassay reports for 1961 and 1962 were more descriptive than for 1953 and 1954 (Pingel 1953, Robinson 1955); however, they included only the results for nonroutine and special analyses. The analyses performed during that period included alpha (plutonium, neptunium, thorium, actinium, americium, and curium), beta activity, iodine, plutonium, polonium, radium, tritium, uranium, and other miscellaneous nuclides (e.g., 99Tc, 65Zn). Gross alpha data were reported in some cases. The reports did not generally specify the type of bioassay but,*

> *because the data were reported as disintegrations per minute per specified volume, it can be assumed that they refer to urine bioassay. Several reports from that period indicated activity in fecal samples and nasal swabs. In one case, a blood sample was indicated with a value of 0 dpm/1,500 mL. Because it is unlikely that a 1,500-mL blood sample was analyzed, this probably was a typographical error in the report. In another case, skin scrapings were analyzed. Because only special and nonroutine sample data were included in the monthly reports, it is unclear whether routine fecal analyses occurred during that period.*

This citation indicates that bioassay data may not be available for certain periods or for some workers. If this is the case, NIOSH should provide guidance within the site profile for the dose reconstructor to estimate doses based on coworker data.

Finding 6: Failure to Adequately Define and Assess Occupational Medical Exposures in the Pre-1988 Years and Potentially Missed Special Employment Exams

The guidelines used in ORAUT-TKBS-0036-3 for the estimates of occupational medical exposures prior to 1988 are reasonable for determining the overall dose estimates for claimants. Unfortunately, the guidelines have not been interpreted by NIOSH in such a way as to be claimant favorable. NIOSH's interpretation of its own guidelines is similar to interpretations at other sites; for example, the Mound Plant, Los Alamos National Laboratory (LANL), and Pinellas. In all cases, dose reconstructors do not include doses due to special and screening medical examinations. Dose reconstructors apply only the dose from chest x-rays that are part of routine physical examinations. However, in more recent documentation [ORAUT-OTIB-0006, Revision 3 (ORAUT 2005b)], it is concluded that other examinations should be included, such as special screening examinations (e.g., respiratory protection, beryllium workers, asbestos workers, etc.) and termination examinations. Although this TBD recognizes these changes from the previous Revision 2 of the OTIB by referencing Revision 3, it does not address or document these necessary changes in ORAUT-TKBS-0036-3.

The TBD (ORAUT 2006b) concludes that chest examinations were often quite limited after 1980. It is suggested that the frequency of chest examinations was every 4 years unless special circumstances existed; however, this policy was not documented. To the contrary, there is ample evidence that chest x-rays were often provided on a voluntary basis to nearly all workers, usually on an annual basis. The majority of workers had routine chest x-rays at DOE sites until the mid-1980s, when federal guidelines that warned against routine screening were first enforced.

SC&A believes that NIOSH'S interpretation of the frequency of occupational medical x-rays used in the TBD is not claimant favorable. We are concerned that for certain workers with "high-risk" jobs, the additional radiation dose associated with medical screenings might not be accounted for in their total occupational dose estimates. Since all radiation exposure results in some risk and is arguably cumulative, a claimant-favorable estimate should include all occupational exposures. SC&A believes that NIOSH should review its interpretation of the guidelines provided in the most recent version of ORAUT-OTIB-0006 (ORAUT 2005b) and how it is being applied in this TBD, and adopt the most claimant-favorable interpretation in ORAUT-TKBS-0036-3.

Finding 7: The Lack of Techniques and Protocols for Medical Examinations Prior to 1988 Increases the Uncertainty of DCFs Listed in ORAUT-TKBS-0036-3

The TBD fails to describe adequately all the information needed to establish beam quality for x-ray units in use from 1940 to 1980. In 1970, the site installed a single-phase GE Model DXD-350 unit; however, there is only limited documentation to verify that the single-phase unit in use from 1970 through 1985 had a half value layer (HVL) of approximately 2.5 mm of Al, as stated in the TBD. In the absence of definitive tube output measurements, the TBD directs the use of default values and dose conversion factors (DCFs) presented in Table 3-3, which are 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) and presented in Table 3-7 of the TBD. SC&A is concerned that the DCFs are derived using a default HVL of 2.5 mm Al for Type 1 units in use from 1946–1980 without sufficient evidence of its appropriateness.

The TBD provides little documentation to support the assumed techniques and protocols used to calculate doses, which are mainly derived from NCRP Report 102. The TBD states that a posterior/anterior (PA) chest x-ray was typically the only view used after 1980, although this assumption is undocumented. SC&A has inquired of NIOSH whether definitive protocols existed to validate that chest exams included PA views and lateral (LAT) views only on a limited basis after 1960. NIOSH has acknowledged in other TBD reviews that the lack of verifiable protocols is 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, as so stated in the TBD.

The TBD also recognizes that little documentation exists to validate any x-ray protocols and/or equipment maintenance and upkeep records prior to 1988, but fails to adequately describe the implications of this paucity of information.

Finding 8: Frequencies and Types of X-ray Exposures are Uncertain

The TBD relies on a very limited review of archived medical records to establish worker x-ray frequency assumptions. The assumption of one chest radiograph (PA) every 4 years after 1980 is not reasonably conservative, in that workers could essentially request an x-ray or be subject to special screening exams that were not in sequence with routine physical examinations. The frequency of screenings and the numbers and types of workers receiving medical x-rays varies from site to site and within worker job classifications.

The TBD in Section 3.3 provides no documentation to support the assumption that only a limited group of workers received x-ray exams more frequently than every 4 years after 1980. To the contrary, up until about 1990, most DOE sites performed chest x-rays almost on a voluntary basis. DOE medical program reviews conducted during the early 1990s showed that many sites still used chest radiography as a general screening examination. Most workers accepted chest x-rays, even though the job did not require them to do so. Also, the assumption that workers in special exposure categories, such as beryllium workers, were given chest x-rays only as part of their routine physical examinations is not well-documented and not consistent with special

screening guidelines. The TBD does not apply conservative assumptions to the existence and frequency of these special job-related physical examinations.

Sections 3.1 and 3.3 of the TBD state that photofluorography (PFG) was not thought to have been used after 1948. However, there is evidence that limited applications of PFG did occur until 1956 and possibly as late as 1958. The undocumented absence of PFG units at ANL-E clearly has significant dose implications for workers who may have received significant doses from PFG units. The PFG unit delivers a higher dose than conventional radiography by a factor of 5–6. SC&A believes that it is not claimant favorable to instruct dose assessors to assume PFG use for chest radiography only until 1956 without a higher level of assurance. It would be more claimant favorable to assume PFG use for chest radiographs and assess an annual occupational medical dose of 3 rem per year until at least 1958, in accordance with guidelines set forth in ORAUT-OTIB-0006 (ORAUT 2005b).

Finding 9: Uncertainty and Undocumented Aspects of the Film Dosimetry Needs Re-examination

The technology or service provider for the dosimetry program changed at least 12 times during the period that film emulsion was used as the beta-gamma detection medium. Table 6.2 of ORAUT-TKBS-0036-6 exhibits most of these changes. For several of the time periods under review, there are no specifications or information regarding the dosimeter, including the emulsion, wrapper, holder, or algorithm. Indeed, for some periods, the site profile recommends the use of information from the Idaho National Environmental Engineering Laboratory (INEEL) [now known as the Idaho National Laboratory (INL)], program, since nothing is available for ANL-E. For example, due to the lack of data on the covering material on early dosimeters, the site profile utilizes an INEEL analysis for beta under response because the "dosimeters used at the two sites were similar" (Section 6.8.3.1).

The concern with this approach is that while the badges are said to be similar, no reference or documentation to support this conclusion is offered. For beta absorption in a wrapper, very small changes in thickness would have large impacts on transmission. (Beta transmission is a commonly used feedback control mechanism for paper, coatings, and plastic film manufacture.) The numerous changes in the program prior to the conversion to TLDs in 1988 create great uncertainty and variability in a number of factors that could have a significant effect on the response to, or interpretation of, the results of the exposure of a dosimeter. Some of these factors are discussed in the site profile. They are broken down by timeframe in some cases. However, given the unusually large number of changes in the dosimetry program over the years, it would be difficult for a dose reconstructor to conduct all the required evaluations, such as missed dose, under-reported dose, etc. A master matrix would help identify the gaps in knowledge and enable the dose reconstructor to determine whether a dose reconstruction is limited by any of these factors.

Specifically, there are errors in the assumptions made regarding the film cover and the correction factors provided in Table 6-19 of the TBD. A number of vendors supplied the film over the 1945–1988 timeframe; yet only two cover thicknesses are considered, and these data were taken from an INEEL analysis, since nothing was available for ANL-E.

In summary, it is difficult to make assessments over the entire timeframe covered by film use due to the large number of variables and unknowns. A matrix is needed that lays out the numerous parameters for the approximately 12 different film technology periods. Once a more comprehensive definition of the history of the dosimetry employed at ANL-E is offered, the technical basis should be re-examined for each of the technologies and periods in question.

Finding 10: Neutron Dosimetry is inadequately addressed

Thermal neutrons in the beta gamma film badge holder were monitored with a cadmium filter starting in 1967. It is unclear from the site profile how this information was used and whether all holders included cadmium. No indication is given in the TBD as to how the decision was made to assign thermal neutron badges following the commencement of thermal neutron monitoring. It is also not clear in the TBD how missed thermal neutron dose is to be assigned prior to or post-1967.

The site profile discusses the various dates when dosimetry was initiated for thermal, intermediate, and fast neutrons. Based on this discussion, it appears that fast neutron Nuclear Track Film Type A (NTA) film was introduced by 1953, and a thermal film program by either 1967 or 1971. Prior to this time, boron-lined pocket ionization chambers (PICs) "were reported at other facilities." This implies that there was limited or no neutron monitoring for the first 7 years of operation and certainly no record of the program. The TBD fails to provide guidance to the dose reconstructor for the period from 1946–1953, when there was apparently no neutron monitoring program in place. Presumably standard techniques for inserting missed or unmonitored doses would be used, although there is no discussion provided on the merits of this approach.

The site profile addresses missed dose in the expected fashion with LOD/2 being applied for all zero doses on NTA film. (See example in Section 6.7.6.2 of ORAUT-TKBS-0036-6). For NTA, a limit of detection (LOD) of 50 mrem is assumed, which seems reasonable based on the approach defined in OCAS-IG-001, Rev. 1 (NIOSH 2002). However, Section 6.7.3.3 of the site profile states:

> *Before 1960, neutron films were apparently only read if the gamma dose was 100 mrem or more. This correction should be accounted for by adding missed dose for each zero reading where there is an indication that neutron monitoring occurred.*

A concern arises that the statistical approach called for in NIOSH 2002 assumes a lognormal distribution of missed doses below the LOD. In the case of NTA prior to 1960, the missed dose may well be higher than the LOD, depending on the ratio of gamma to neutron in the given situation and depending on the accuracy of the gamma dose measurement. There is no justification to support using the standard missed dose approach in this widespread situation. Given this concern, it is recommended that NIOSH revisit this issue and develop a more claimant-favorable approach for assigning missed dose during this time period.

Section 6.7.3.2 of the site profile discusses the energy response limitations of NTA and recognizes that the response drops off sharply below 800 keV. Table 6-16 provides correction factors to account for this under-response in various facilities. Correction factors ranging from 1.25 to 4 are estimated, "…based on experience," but no rationale beyond this statement is provided for the selection of these values.

Given that the response of NTA is zero at energies around 100 keV, assumptions regarding the spectral mix are needed for a range of timeframes, work areas, experiments, etc. The implication from this table is that at least 25% of the neutron dose contribution was due to energies above 800 keV in all situations where exposure might have occurred. Yet Section 6.7.3.2 describes one facility where the factor would apparently need to be 20 or more, not 4 (maximum value in Table 6-16):

> *A 1966 investigation pointed out that the majority of neutrons in areas occupied by personnel at the 4.5-MeV and 2-MeV Van de Graaff accelerators had energies between 100 keV and 1 MeV. NTA film measurements in the facilities showed dose equivalents of less than 5% of the values from instrument measurements (Till 1966)….*

Additional references and guidance are needed to enable a determination of the suitability of these values. In addition, the large inconsistency between "experience" and measurements (Till 1966) needs to be discussed in light of Table 6-16.

Section 6.7.4 of the TBD states the following:

> *A 1965 study of neutron field characteristics at the 50-MeV proton injector of the ZGS indicated that NTA film response decreased from 84% of the calculated dose equivalent when the film was perpendicular to the source to 57% when the film was at 90°. The effective energy of the neutrons was 1.18 MeV and the dose equivalent rates were high (174 rem/hr). The contribution of scattered neutrons to the dose equivalent at the point of measurement was determined to be 24% with an effective energy of 0.49 MeV (Steele 1965). The location of these measurements was not in an area occupied by personnel during operation of the accelerator.* ***Due to multi-scattering, NTA film response in the normally occupied areas is likely to be less angular dependent****. Therefore, with the possible exception of accidental exposures in high-dose areas,* ***no correction for angular dependence is deemed necessary****.* (Emphasis added.)

It is unclear what is being asserted in this paragraph. However, it would seem likely that in a multi-scattering environment, the average neutron angle of incidence would be something approximating 45° to the Anterior-Posterior. If so, then a correction would indeed seem warranted, unless a site-specific calibration had been performed. In addition, as NTA response drops below approximately 1 MeV, it is likely that the angular response drops further; but the TBD fails to address this dependence. Thus, the claim that no correction for angular dependence is required should be substantiated.

Finding 11: Quantification of External Exposures to Unmonitored Workers Outdoors is Inadequately Justified

For time periods prior to 1972, there are virtually no data characterizing the external radiation fields outdoors. The site profile states that since radionuclides build up outdoors over time, external exposures to unmonitored outdoor workers post-1972 were likely greater than pre-1972 exposures. Hence, the site profile states that post-1972 data can be used to bound pre-1972 exposures. Given the complexity of the site and how operations changed over time, it does not appear plausible to reconstruct pre-1972 outdoor external exposures to unmonitored workers using post-1972 data. Is NIOSH simply going to assume that no outside workers and unmonitored workers experienced external exposures in excess of 100 mrem/year? The site profile would benefit from a more thorough discussion of how such exposures will be reconstructed.

Sections 2.3 and 4.3 of the site profile provide overviews of the potential for airborne contaminants within buildings at the site and in the airborne effluents from the various facilities. Section 2.3 of the site profile states that, "…no estimates of the quantity of effluents release are available for 1946 to 1972." Hence, as with external outdoor exposure, it is important to distinguish between pre- and post-1972 exposures. Notwithstanding the limitations in the pre-1972 effluent monitoring data, Section 4.3 cites historical records indicating that, from the very beginning of operations in 1946, the Health Physics Division of ANL-E was very concerned about the potential for chronic and acute exposure to airborne radionuclides in the work environment at all facilities and instituted routine indoor surveys of the airborne radionuclide concentrations. The implications are that, by having an awareness of the airborne radionuclide concentrations indoors, there was a degree of control and an understanding of the potential airborne emissions and outdoor exposures at the site from the time of its initial operation. In addition, Section 4.3 of the site profile cites 52 outdoor air particulate samples collected in 1949. However, NIOSH was unable to find these data.

The site profile also cites numerous reports characterizing radioactive material in the outdoor environment prior to the more formal effluent monitoring initiated in 1974, including comprehensive studies related to characterizing global fallout at the site. Those reports reveal that most of the elevated radionuclide concentrations found outdoors during the 1960s were from global fallout and not ANL-E effluents. However, the site profile cites some measurements revealing that there were detectable outdoor radionuclide concentrations associated with ANL-E operations. The measurements of Ar-41 in the air near building CP-5 is given as an example in Table 4-2 of the site profile.

Table 4-5 of the site profile presents a summary of the annual atmospheric releases of seven radionuclides from ANL-E from 1974 through 2003. The values were taken from annual environmental reports published by ANL-E. A more complete list of the annual releases of 11 radionuclides to the atmosphere from 1973 to 2004 is provided in Section 2-4 of the site profile.

Table 4-6 of the site profile presents estimates of the annual release of Ar-41, tritium, and C-11 from the CP-5 reactor for 1946 to 1973. These are based on several reports issued in the 1970s stating that these represent the major airborne radioactivity releases from the laboratory. It

appears that the atmospheric releases from CP-5 during the early years are based on averaging the measured releases for the later years and assuming that those average releases apply to the early years. Some discussion is needed about why such an assumption is appropriate and claimant favorable.

Based on this review, it appears that estimates of the routine annual radionuclide releases from all facilities at ANL-E are available beginning in 1973 as a result of effluent monitoring programs required to evaluate potential offsite doses for the annual environmental reports. It does not appear that the data were gathered for the purpose of characterizing potential exposures to workers outdoors onsite. We have a number of concerns with the data and their use in onsite dose reconstruction.

We are concerned that airborne effluent data collected prior to 1974 are extremely limited. Given the highly complex and time-varying nature of the operations at the facility, and the numerous incidents that occurred there, as cited in Section 2.4 of the site profile, it does not appear to be appropriate to use post-1974 effluent data as a basis for estimating pre-1974 releases. Nevertheless, this approach was used in Table 4-6 of the site profile for estimating the release of Ar-41, tritium, and C-11. In particular, it appears that the atmospheric releases from CP-5 during the early years are based on averaging the measured releases for the later years and assuming that those average releases apply to the early years. Some discussion is needed about why such an assumption is appropriate and claimant favorable.

As described in Section 2.2.2 of the site profile, Site A was established as the first national laboratory on July 1, 1946. It was the site of the CP-2 and CP-3 reactors, which were fueled with natural uranium and used a graphite moderator (in 1953, the natural uranium in CP-3 was replaced with enriched uranium). In addition, a low-level radioactive waste burial facility was established in 1943 at Site A and operated until 1949. In the mid-1950s, the reactors and waste disposal facilities underwent decontamination and decommissioning.

Based on our review of the site profile, no data are available characterizing external exposures, effluent releases, or airborne radionuclide concentrations outdoors. It is our understanding that exposures to unmonitored workers outdoors at Site A will be reconstructed by extrapolation from data acquired from Site D in the later years, or by assuming that the doses outdoors at Site D place an upper bound on the doses at Site A. This might be a correct assumption, but additional justification seems to be warranted.

Finding 12: Outdoor Inhalation Exposures Associated with Waste Disposal Operations in Area A and from Particulates Released during Accidents are Not Adequately Addressed

Section 4.4 describes the approach that is recommended for use in reconstructing internal exposures to workers outdoors. It appears that only exposure to tritium and Rn-220 were considered. Attachment A to Chapter 4 of the site profile provides the rationale for not explicitly addressing other (particulate) radionuclides. A review of Attachment A indicates that indirect methods were used to come to this conclusion. Specifically, measurements of uranium and plutonium in soil and plant samples collected in the 1970s in Area A revealed relatively little contamination. (As described in Section 2.2, Site A housed the CP-2 and CP-3 reactors, which

operated until 1954 and is also the location of low-level radioactive waste disposal.) Also, aerial surveys and analyses of soil samples in the 1970s revealed only low levels of Cs-137 and other radionuclides that might have been due to site operations. On the basis of these data, the site profile concludes that the potential for inhalation exposures to particulates outdoors in Site A up to 1954 were negligible. Our review reveals that NIOSH's conclusions regarding this matter are reasonable. However, some additional discussion is needed regarding the potential for short-term, but possibly large, inhalation exposures associated with the waste disposal operations in Area A, and whether exposures to particulates that might have been released during accidents could have contributed significantly to the outdoor inhalation dose.

As described in Section 4.3.2, the Environmental Protection Agency's (EPA's) atmospheric computer code CAP-88 was used to reconstruct outdoor inhalation exposures using the atmospheric radionuclide emissions identified in Table 2-4 of the site profile. Apparently, NIOSH was able to determine the emissions from individual buildings, and then determine the airborne radionuclide concentrations as a function of distance and direction from each building. Reasonable assumptions were made regarding release height and effluent exit velocity. However, discussion is needed regarding possible exposure to some workers as a result of accidents where large amounts of radionuclides might have been released to the atmosphere over short periods of time when average annual atmospheric dispersion factors could substantially underestimate or overestimate the doses.

Finding 13: Lack of Consideration of Occupational Radiological Exposure at Site A and Plot M

Although ANL-E received its official designation as a national laboratory on July 1, 1946, the laboratory was operated prior to this time at the University of Chicago and at the Palos Park Site A in the Argonne woods. Operations at the University of Chicago location (i.e., new Chemistry Laboratory and Annex, West Stands, Ryerson Physical Laboratory, Eckhart Hall, Kent Chemical Laboratory, Jones Chemical Laboratory, and Ricketts Laboratory) are considered a part of the Metallurgical Laboratory, which is listed as a separate facility from ANL-E. The EEOICPA coverage for ANL-E includes the years from 1946 to the present. The operations at Palos Park Site A and Plot M from 1943 through June 30, 1946, are not adequately considered in the ANL-E site profile. The Site Description TBD provides some discussion on Site A and Plot M, but the scope is specifically defined as beginning on July 1, 1946:

> *Argonne National Laboratory was established on July 1, 1946, and this TBD is intended to cover the time period beginning on that date.* (ORAUT 2006a, pg. 8)

Furthermore, the Internal Dose TBD indicates internal dose was considered starting in 1946:

> *The purpose of this TBD is to provide information to assist in the evaluation of occupational internal radiation dose associated with operations at Argonne National Laboratory – East (ANL-E) from 1946 to the present.* (ORAUT 2006d, pg. 7)

Chicago Pile-2, a reconstruction of CP-1 assembled at Site A, went into operation in March of 1943. Chicago Pile-3, the first heavy-water-moderated reactor, began operation at Site A on May 15, 1944 (Holl 1997). Other work conducted at Site A included fission product separation, reactor physics studies, tritium recovery from irradiated lithium, and radionuclide metabolism studies in laboratory animals. Radiological work continued at this location until 1956. Plot M was used for radioactive waste burial from 1943 through 1949. Both sites underwent remediation, which was completed in 1956 (Golchert and Sedlet 1977, ANL 1979).

The ANL-E TBD does not adequately consider dose from radiological operations, which potentially exposed workers to uranium, tritium, fission products, and other radionuclides in the initial years of operation at Site A and Plot M. Exposures during the 1940s were particularly likely, considering the less-effective radiological controls in place at the time.

In addition to the 13 findings above, SC&A identified 7 other concerns that did not rise to the level of the 13 findings. These are listed as "Secondary Issues" in Section 4.0, below.

2.0 INTRODUCTION AND SCOPE

2.1 INTRODUCTION

In 1941, the first nuclear reactor, the CP-1, was constructed and operated by the metallurgical laboratory of the University of Chicago under the West Stands of the University's Stagg Field. In 1943, CP-1 was moved to Site A in the Palos Forest Preserve, about 25 miles southwest of Chicago, and renamed CP-2. In 1944, CP-3 began operation at Site A. Unlike CP-2, which was fueled with natural uranium and moderated by graphite, CP-3 was moderated by heavy water. In 1953, the natural uranium in CP-3 was replaced with enriched uranium and the reactor was renamed CP-3 Prime. CP-2 and CP-3 Prime operated until 1954, when they were dismantled and the lease on Site A was terminated.

The site profile states that ANL, the nation's first national laboratory, was established in 1946. Although some of the activities at Site A continued beyond 1946, those activities were initiated by an AWE. Therefore, it is not clear whether it is appropriate to incorporate them in this site profile for a national laboratory. Moreover, the site profile is often unclear as to whether the activities ongoing at Site A after 1946 are considered to be a part of the ANL-E site profile.

The present site of ANL is about 3 miles northwest of Site A and grew out of Site D, on which several temporary structures were erected in 1947 and 1948, and additional permanent buildings were constructed in the 1950s and 1960s. The location of all of these structures, which have since been demolished, became known as the 800 Area of ANL-E. Research facilities were initially built in the late 1940s and 1950s, with Quonset huts in the East Area and supporting utility facilities in Areas 100 and 500. The 600 area was constructed to house visiting scientists. More permanent buildings housing the chemistry, chemical engineering, physics, reactor engineering, and biology divisions were constructed in the 1950s and 1960s in the 200 and 300 Areas, including several reactors and accelerators. Additional support facilities were constructed in the 200 and 300 Areas during the 1970s and 1980s. The 400 Area, which houses the Advanced Photon Source facility, was added in 1990.

Over its approximate 62-year history, the ANL-E site has hosted production, power, and research reactors ranging from 0 power to 5 Mw. A number of particle accelerators, including a cyclotron, a Van de Graff generator, a linear accelerator, a zero-gradient synchrotron, an intense pulsed neutron source, and an advanced photon source, were also constructed and operated on the site. While these facilities were being designed, constructed, and operated, diverse research projects were also ongoing at ANL. These included research into radioactive waste management and treatment, processing of nuclear fuels, radiochemistry, irradiation of foods, radiation chemistry, materials science, and basic nuclear physics. These varied projects resulted in the storage on the site of significant quantities of radioactive materials, including depleted, natural, and enriched uranium; thorium; fission products; tritium; transuranics; and activation products. Moreover, decontamination and decommissioning (D&D) of facilities at ANL-E have been ongoing since the 1950s, and environmental restoration of inactive waste sites under DOE's Environmental Restoration and Waste Management Program began in 1990.

The health protection and access control practices at ANL evolved over the years. Personnel monitoring with dosimeters and pocket ion chambers was used since the inception, bioassays were used to an unspecified extent, and air monitoring and neutron dosimetry were under development. As these dosimetry measures were improved and implemented, health and safety procedures were refined and access control was improved.

2.2 REVIEW APPROACH

Under the 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 82), the Advisory Board is mandated to conduct an independent review of the methods and procedures used by NIOSH and its contractors for dose reconstruction. As a contractor to the Advisory Board, SC&A 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 ANL-E:

- ORAUT-TKBS-0036-1, *Argonne National Laboratory - East – Introduction, Rev. 00*
- ORAUT-TKBS-0036-2, *Argonne National Laboratory - East – Site Description, Rev. 00 PC-1*
- ORAUT-TKBS-0036-3, *Argonne National Laboratory - East – Occupational Medical Dose, Rev. 01 PC-1*
- ORAUT-TKBS-0036-4, *Argonne National Laboratory - East – Occupational Environmental Dose, Rev. 00*
- ORAUT-TKBS-0036-5, *Argonne National Laboratory - East – Occupational Internal Dose, Rev. 00*
- ORAUT-TKBS-0036-6, *Argonne National Laboratory - East – Occupational External Dosimetry, Rev. 00*

A complete list of documents reviewed for this audit, including the above, is provided in Attachment 1.

SC&A, in support of the Advisory Board, has critically evaluated the ANL-E TBDs with the following objectives:

- Determine the completeness of the information gathered by NIOSH on behalf of the site profile, with a view to assessing its adequacy and accuracy in supporting individual dose reconstructions
- Evaluate the adequacy of NIOSH's presentation of existing information in the TBDs
- 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 characterize 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 the degree to which the TBDs can support dose reconstruction decisions. The criteria for evaluation include whether the TBDs provide a basis for scientifically supportable dose reconstructions in a manner that is adequate, complete, efficient, and claimant favorable. Specifically, these criteria were viewed from the position 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 a worker received in that environment through time. The hierarchy of data used for developing dose reconstruction methodologies is dosimeter readings and bioassay data, coworker data and workplace monitoring data, and process description information or source term data.

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) Introduction and Scope
(3) Assessment Criteria and Method
(4) Site Profile Strengths
(5) Vertical Issues
(6) Overall Adequacy of the ANL-E 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 is found in the Executive Summary and, in more detail, in Section 4.0. 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 material 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 possibly reveal deficiencies that will need to be addressed in future revisions of the TBDs. Seven secondary issues were identified in the ANL-E site profile and are discussed in Section 4.0.

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

In many ways, the TBDs were successful in addressing a series of technical challenges. In other areas, the TBDs exhibit shortcomings that could potentially 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 ANL-E Site Profile, supporting technical information bulletins (TIBs), and dose reconstruction workbooks; 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 when they should have done so, 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 publicly available records relating to ANL-E 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 ANL-E. 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 ANL-E TBD was compared with the Mound and Pinellas Plant site profiles. In particular, this comparison dealt with how each site handled and is handling dose reconstruction for workers exposed to a wide range of radionuclides.

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 82. In addition, SC&A evaluated the TBD for adherence to general quality assurance (QA) 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 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 this category may be only 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 a day and 365 days a 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 eliminate consideration of the uncertainty of the dose. Finally, 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 assignments. Similarly, in order to maximize internal exposures, the 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 by 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 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 and their supplemental attachments, giving due consideration to the three categories of dose reconstructions that the site profiles are intended to support. The six ANL-E TBDs generally provide well-organized and user-friendly information for the dose reconstructor when adequate data are available to do that comprehensively. Exceptions are noted in the findings in Section 4.0. The six TBDs are briefly described below.

ORAUT-TKBS-0036-1, *Argonne National Laboratory - East – Introduction, Rev. 00* (ORAUT 2005a), 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 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 that 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-0036-2, *Argonne National Laboratory – East – Site Description, Rev. 00 PC-1* (ORAUT 2006a), is an extremely important document, because it provides a description of the facilities, processes, and historical information that serve as the underpinning for subsequent ANL-E TBDs.

ORAUT-TKBS-0036-3, *Argonne National Laboratory – East – Occupational Medical Dose, Rev. 01 PC-1* (ORAUT 2006b), provides an overview of the sources, types of exposure, and the frequency of exams that workers potentially received.

ORAUT-TKBS-0036-4, *Argonne National Laboratory – East – Occupational Environmental Dose, Rev. 00* (ORAUT 2006c), 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-0036-5, *Argonne National Laboratory – East – Occupational Internal Dose, Rev 00* (ORAUT 2006d), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers.

ORAUT-TKBS-0036-6, *Argonne National Laboratory – East – Occupational External Dosimetry, Rev. 00* (ORAUT 2006e), 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.

After the Advisory Board and NIOSH have an opportunity to review this draft, SC&A plans to meet with representatives of the Advisory Board and NIOSH to discuss our findings. Following these meetings, the draft may be revised, depending on direction we receive from the Advisory Board. We anticipate that, in accordance with the procedures followed during previous site profile reviews, the draft report and any subsequent revisions will be published on the NIOSH

Web site. 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 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 ANL-E TBDs. These strengths are described in the following sections.

(1) The Site Description TBD, ORAUT-TKBS-0036-2 (ORAUT 2006a), effectively summarizes the history and activities at the site and the exposure sources.

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

- Where 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.

(3) There is a very good sequence in ORAUT-TKBS-0036-2 (ORAUT 2006a) of the site profile chronicling the construction history on the main Argonne site (D). There is widespread acknowledgment of the large degree of uncertainty in the data and information available throughout the early years, as evidenced by the use of conditional and tentative language throughout.

(4) In general, the TBDs describe in sufficient detail the historical site operations, sources of radiation dose, potential missing and unmonitored dose, and dose reconstruction guidance. The level of information provided appears to be consistent with the supporting documents reviewed and the magnitude of the potential doses associated with plant operations. There are omissions from each of the six TBDs and additional information and considerations that should be included in revisions of the documents. These shortcomings are detailed in Section 4.0.

4.0 VERTICAL ISSUES

SC&A has developed a list of key issues regarding the ANL-E 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 Department of Energy (DOE) and Atomic Weapons Employer (AWE) sites, and should be considered in the preparation and revision of other site profiles.

4.1 FINDING 1: POTENTIAL MISSED DOSE FROM LACK OF DEFINITION OF RADIONUCLIDE COMPOSITIONS AND RADIONUCLIDES NOT ADDRESSED IN SITE PROFILE

The source terms associated with ANL-E operations are not adequately described and quantified in sufficient detail in ORAUT-TKBS-0036-5. While Chapter 5 of the site profile (Section 5.2.2) defers to ORAUT-TKBS-0036-2, in neither document is the magnitude of site activity or the assignment of isotopic composition for U, Pu, or Am sufficiently described to allow the dose reconstructor to address all relevant aspects of the site radionuclides. For example, according to Chapter 2, as noted in Figure 5-6, the facility handled natural, enriched, and depleted uranium; however, the degree of enrichment is not indicated.

The dose reconstructor requires the isotopic composition to properly calculate the internal doses. On pages 13 and 14 of Chapter 5, two different isotopic compositions are offered for plutonium:

> *The ANL "Draft Environmental Impact Statement" (ANL 1979) presents the isotopic compositions of two plutonium mixtures. For the scenario of a glovebox explosion in the New Brunswick Laboratory, the isotopic composition considered to be "representative of the most hazardous material expected to be received (i.e., from LWR recycle) and is not typical of present operations" was 2% ^{238}Pu, 58% ^{239}Pu, 23% ^{240}Pu, 12% ^{241}Pu, and 5% ^{242}Pu by mass fractions. For the scenario of a plutonium fire in one of the Building 350 vaults, the plutonium isotopic considered to "bound all similar risks at ANL" was 0.1% ^{238}Pu, 70.9% ^{239}Pu, 24% ^{240}Pu, 4% ^{241}Pu, and 1% ^{242}Pu by mass factions. Values for the ^{241}Am component were not given.*

It is not known whether other compositions of plutonium isotopes were used at ANL-E. NIOSH should provide dose reconstructors with guidance on composition assumptions to assure that claimant-favorable determinations are made, particularly for plutonium and enriched uranium.

Both R&D and production operations have contributed to the extensive and diverse list of radionuclides historically present at ANL-E. The D-Building and Chemical Metallurgy Research (CMR) facility were both heavily involved in R&D to support the weapons program. Accelerator facilities have been used to produce both stable and radioactive elements for use by the DOE complex and commercial vendors. Reactors have been used to irradiate elements. The Biology Building has conducted studies on the metabolism of radionuclides in animals and humans, as well as direct irradiation of animals from a reactor. The long-term operations and R&D activities at ANL provided constant opportunities for workers to come in contact with

radionuclides spanning the periodic table. Some of the activities resulting in potential exposure to "secondary" radionuclides are listed below (Steurenberg and Burris 2000):

- Pyrometallurgical Research
- Early uranium and plutonium separations process development
- Advanced fuel recovery operations
- Fission product separations
- Recovery and separation of Mo-99
- Fluoride processing
- Production of radionuclides by accelerator and reactor operations
- Biological effects of radiation research
- Waste treatment development

Accelerator facilities such as IPNS and APS produce activation products that can create a potential exposure. There have been predictive calculations and characterization measurements to identify activated material at IPNS and APS. In general, accelerator beams are activating iron, copper, aluminum, and structural material. As such, activation products would include Co-60, Co-57, Co-59, Mn-54, Na-22, Na-24, V-48, Fe-55, and some level of tritium. At IPNS, the highest induced activity is at the target and its surrounding shield materials. At APS, septum devices are used to split the beam into multiple beams, and this is where the activation occurs. The major activation products are Na-24 and Co-60, with Mn-54, Co-57, and Fe-55 present in smaller quantities. This is due to photoneutron activation which occurs with constituents of the steel, aluminum, copper, and epoxy (Refer to interview summary).

These potential sources of exposure from secondary and so-called "exotic" radionuclides, such as Pa-231, Po-210, Cf-252, and other transplutonium elements, are based on a limited SC&A review of ANL operational history and available health physics files. Further research by NIOSH into these nontraditional radionuclides should be completed in any revision of the ANL site profile to assure their significance and dose contribution are fully addressed. Bioassay techniques should be evaluated for entire periods of potential exposure for the effectiveness in detecting other radionuclides. Appropriate methods for internal monitoring were not always available for all years of potential exposure.

4.2 FINDING 2: POTENTIAL MISSED DOSE FROM THE USE OF GROSS ALPHA COUNTING FOR BIOASSAY (1946 TO 1972)

The bioassay techniques applied from 1946–1972 (Section 5.3.3.1) for all alpha emitters involved gross alpha counting for sample activity determination. A quote from ANL 1949 illustrates the lack of sufficiency of MDCs for alpha emitting radionuclide bioassay samples:

> *The term Bio-assay essentially refers to the assay of human excreta and other body fluids (i.e., sputum, etc.) for the presence of trace amounts of radioactive materials. The need for a continuous survey of individuals working with often large amounts of radioactive substances is self-evident. Reliable methods adaptable for the detection of very small amounts of radioactive contaminants are*

> *present [sic] available for only a few isotopes, especially for plutonium.* (ANL 1949).

The effectiveness of early radiobioassay methods for all alpha emitting radionuclides is unclear from the TBD. Issues with chemical recovery by radionuclide, the ability to detect radionuclides in urine, interferences from other radionuclides, and chemical solubility should be further substantiated prior to assuming all alpha emitting radionuclides were detectable with the actinide or gross alpha analysis. The potential missed dose associated with non-specific bioassay techniques should be further investigated to determine the impact on internal dose calculations. The TBD fails to provide guidance to the dose reconstructor on how to deal with mixtures of alpha emitters for bioassay techniques that may analyze for multiple radionuclides.

4.3 FINDING 3: ASSUMPTION OF DEFAULT INHALATION PATHWAY MAY NOT BE CLAIMANT FAVORABLE

According to ORAUT-TKBS-0036-5, Section 5.3.1.3, if specific information is not available, the dose reconstructor should assume inhalation as the pathway for internal doses. This recommendation is not claimant favorable for cancers in the alimentary tract, where ingestion can result in higher doses. The potential significance of this decision is illustrated in the following discussion.

Example for Plutonium:

For some organs, the intake of plutonium from ingestion is more significant than for inhalation in terms of dose delivered per Bq excreted and measured in bioassay samples. For example, if a worker's exposure lasted 1 year, the 1-year committed equivalent doses to the different organs, per Bq of Pu-239 excreted in a 24 hr working-day urine sample at the end of the working year, is illustrated in Table 1. As shown in Table 1, the doses due to ingestion are higher than those due to inhalation except for the organs related to the respiratory tract. For further emphasis, Figures 3 and 4 graphically represent the information provided in Table 1.

Table 1. One-Year Pu-239 Committed Equivalent Doses per Bq Pu-239 Present in 24-hr Working Day Urine Sample, Collected at the End of 1 Year Exposure

	Inhalation Type M	Inhalation Type S	Ingestion f1=0.0005	Ingestion f1=0.0001	Ingestion f1=0.00001
Organs	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**	**Sv/Bq excreted**
Adrenals	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Bladder Wall	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.19E-03
Bone Surface	1.48E+00	1.13E+00	1.73E+00	1.73E+00	1.73E+00
Brain	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Breasts	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Esophagus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
St Wall	3.65E-03	5.72E-03	2.03E-02	8.49E-02	8.12E-01
SI Wall	3.74E-03	1.01E-02	4.45E-02	2.06E-01	2.02E+00
ULI Wall	4.55E-03	4.73E-02	2.48E-01	1.23E+00	1.22E+01
LLI Wall	6.42E-03	1.33E-01	7.18E-01	3.56E+00	3.56E+01
Colon	5.33E-03	8.43E-02	4.50E-01	2.23E+00	2.23E+01
Kidneys	3.72E-02	2.95E-02	4.24E-02	4.24E-02	4.24E-02
Liver	2.44E-01	1.86E-01	2.86E-01	2.86E-01	2.86E-01
Muscle	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.19E-03
Ovaries	1.47E-02	1.12E-02	1.72E-02	1.73E-02	1.79E-02
Pancreas	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Red Marrow	1.50E-01	1.14E-01	1.76E-01	1.76E-01	1.76E-01
ET Airways	9.96E-01	7.65E+01	4.17E-03	4.17E-03	4.17E-03
Lungs	2.10E+00	1.21E+02	4.17E-03	4.17E-03	4.17E-03
Skin	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Spleen	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Testes	1.49E-02	1.14E-02	1.76E-02	1.76E-02	1.76E-02
Thymus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Thyroid	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.17E-03
Uterus	3.59E-03	2.77E-03	4.17E-03	4.17E-03	4.22E-03

Years of Exposure to Pu-239: 1 year
Collection of 24hr working day urine sample: last month of the 1st year
Equivalent Doses calculated for the 1st year after the beginning of work
Excretion of Pu-239 in urine entirely due to inhalation exposure of Type M – 5μm AMAD
Excretion of Pu-239 in urine entirely due to inhalation exposure of Type S – 5μm AMAD
Excretion of Pu-239 in urine entirely due to ingestion exposure ($f1 = 5 \times 10^{-4}$)
Excretion of Pu-239 in urine entirely due to ingestion exposure ($f1 = 1 \times 10^{-4}$)
Excretion of Pu-239 in urine entirely due to ingestion exposure ($f1 = 1 \times 10^{-5}$)

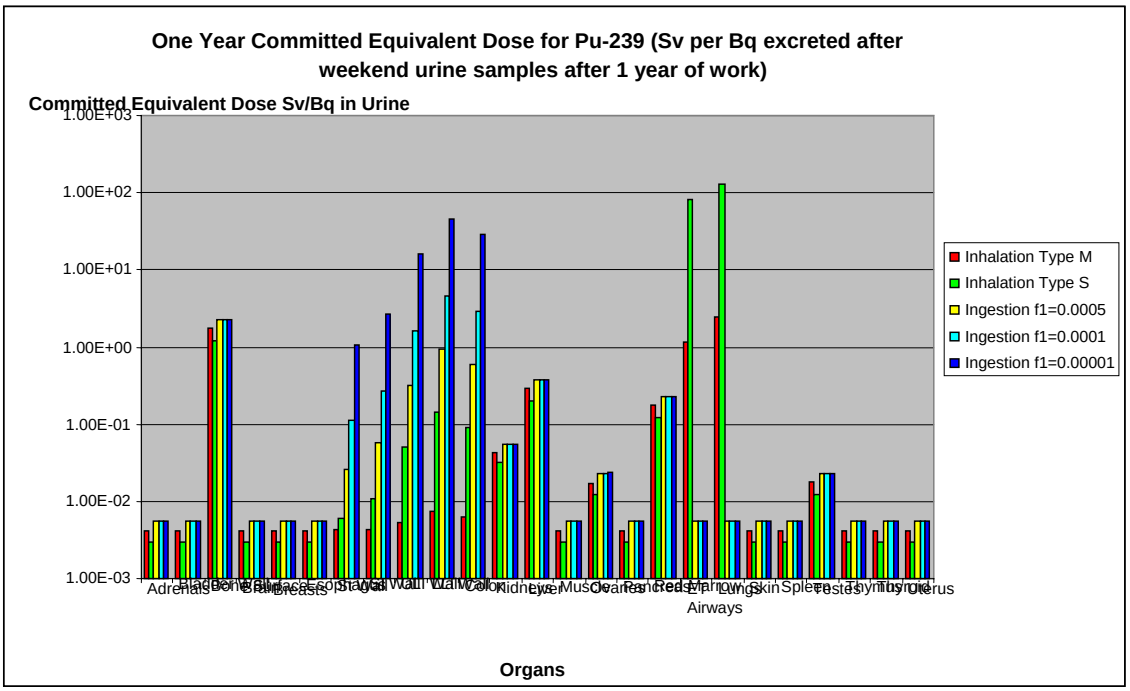

Figure 3: 1-Year Committed Equivalent Dose for Organs due to 1-Year Chronic Intake of Pu-239, in Sv/Bq Excreted in 24-Hr Working Day Urine Samples after 1 Year of Work

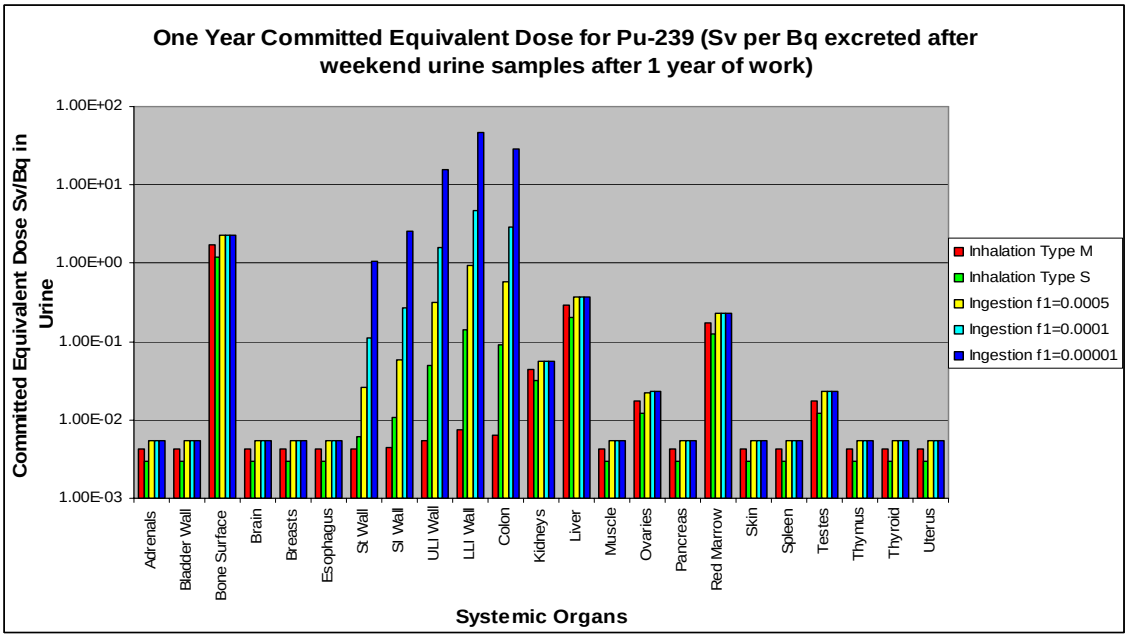

Figure 4: 1-Year Committed Equivalent Dose for Systemic Organs due to 1-Year Chronic Intake of Pu-239, in Sv/Bq Excreted in 24-Hr Working Day Urine Samples after 1 Year of Work

As illustrated above, doses from the ingestion pathway, particularly those for the GI tract, should not be ignored. Failure to include these doses for ingestion of plutonium, americium, and uranium compounds represents a missed dose and is not claimant favorable.

4.4 FINDING 4: INSUFFICIENT INFORMATION ON THE CALCULATION OF MINIMUM DETECTABLE CONCENTRATIONS AND UNCERTAINTIES IN BIOASSAY METHODOLOGY

The assessment of the missed dose for the monitored workers with bioassay results below the MDC or decision level is an important issue that is inadequately addressed in this TKBS. To demonstrate the potential significance of this issue, Table 2 provides an example of the assessment of missed dose considering 10 years of chronic intake of ^{239}Pu, Type S, AMAD = 5 μm. The missed doses for the first 10 consecutive years of exposure was estimated, based on the decision level value of urinalysis (0.4 dpm/1500 mL) given in this TKBS, Table 5-11, page 25. The daily intake and total intake for the years of exposure are also shown in Table 2. The values were calculated assuming that the sample was collected on the last day of the year and the result was 0.4 dpm (0.008 Bq). As demonstrated in Table 2, only total intakes higher than 10^4 Bq would be detected in the earlier times of ANL-E, given the assigned decision level for plutonium bioassay samples. The estimated missed equivalent doses based on this total intake are shown in Table 3.

Table 2 – Estimated Intake due to 10 years Chronic Inhalation of ^{239}Pu (Type S, AMAD 5μm) Based on the Decision Level Value of Urinalysis (0.4 dpm/day or 0.008 Bq/day) Given in Table 5-11 (TKBS-0036-5)

Time (years)	Daily intake (Bq)	Total Intake (Bq)
1	1.23E+02	4.49E+04
2	6.20E+01	4.53E+04
3	4.15E+01	4.54E+04
4	3.11E+01	4.54E+04
5	2.52E+01	4.61E+04
6	2.13E+01	4.67E+04
7	1.86E+01	4.76E+04
8	1.67E+01	4.87E+04
9	1.51E+01	4.97E+04
10	1.39E+01	5.07E+04

Table 3 - Missed Doses for the Organs due to Chronic Inhalation of ^{239}Pu (AMAD = 5μm), Based on the Decision Level Value of Urinalysis (0.008 Bq/day) Given in Table 5-11 (TKBS-0036-5)

	Missed equivalent dose (Sv) x Time of exposure (years)									
Organs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Adrenals	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Bladder Wall	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Bone Surface	9.29E-03	2.70E-02	5.00E-02	7.78E-02	1.10E-01	1.44E-01	1.90E-01	2.35E-01	2.73E-01	3.26E-01
Brain	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Breasts	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Esophagus	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
St Wall	4.67E-05	8.62E-05	1.34E-04	1.89E-04	2.50E-04	3.15E-04	3.99E-04	4.76E-04	5.43E-04	6.34E-04
SI Wall	8.25E-05	1.23E-04	1.70E-04	2.27E-04	2.88E-04	3.53E-04	4.39E-04	5.19E-04	5.84E-04	6.78E-04
ULI Wall	3.84E-04	4.31E-04	4.80E-04	5.39E-04	6.05E-04	6.72E-04	7.79E-04	8.65E-04	9.30E-04	1.04E-03
LLI Wall	1.08E-03	1.14E-03	1.19E-03	1.26E-03	1.34E-03	1.42E-03	1.56E-03	1.67E-03	1.73E-03	1.88E-03
Colon	6.83E-04	7.38E-04	7.83E-04	8.49E-04	9.20E-04	9.91E-04	1.12E-03	1.21E-03	1.27E-03	1.39E-03
Kidneys	2.41E-04	5.51E-04	8.77E-04	1.22E-03	1.58E-03	1.92E-03	2.36E-03	2.74E-03	3.05E-03	3.46E-03
Liver	1.53E-03	4.55E-03	8.61E-03	1.38E-02	1.97E-02	2.65E-02	3.53E-02	4.42E-02	5.24E-02	6.33E-02
Muscle	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Ovaries	9.24E-05	2.73E-04	5.13E-04	8.18E-04	1.17E-03	1.57E-03	2.09E-03	2.62E-03	3.11E-03	3.75E-03
Pancreas	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Red Marrow	9.41E-04	2.72E-03	5.00E-03	7.69E-03	1.06E-02	1.37E-02	1.78E-02	2.16E-02	2.48E-02	2.91E-02
ET Airways	6.26E-01	1.12E+00	1.49E+00	1.80E+00	2.05E+00	2.27E+00	2.55E+00	2.75E+00	2.85E+00	3.05E+00
Lungs	9.80E-01	1.14E+00	1.23E+00	1.32E+00	1.39E+00	1.46E+00	1.59E+00	1.66E+00	1.68E+00	1.78E+00
Skin	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Spleen	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Testes	9.41E-05	2.77E-04	5.25E-04	8.34E-04	1.19E-03	1.60E-03	2.13E-03	2.67E-03	3.17E-03	3.82E-03
Thymus	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Thyroid	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04
Uterus	2.29E-05	6.16E-05	1.09E-04	1.65E-04	2.25E-04	2.90E-04	3.72E-04	4.49E-04	5.15E-04	6.06E-04

NIOSH needs to provide guidance in TKBS-0036-5 for dose reconstructors to assess this potential missed dose, especially for the insoluble compounds, given that plutonium urine concentrations near the MDC may represent a significant intake and dose. This also applies to other alpha emitters, including uranium and americium.

SC&A also finds the document incomplete in terms of providing information relevant to the calculation of uncertainties for the bioassay techniques that were used at ANL-E.

The uncertainty in the values of the minimum decision levels or minimum detectable concentrations (MDC) for bioassay samples has not been adequately discussed in the ORAUT-TKBS-0036-5. This is a major omission, since the uncertainty associated with these parameters may have a significant impact on the estimate of missed dose. It is stated on page 22 of the TKBS:

> *There has been no evidence found that MDAs were assessed or recorded before 1995. Instead, 10% of maximum permissible excretion levels, action (repeat sampling) levels, and reporting levels have been used. These levels, if found or*

> *discerned, are reported in previous sections. The information is significantly incomplete for certain periods and radionuclides.*

The uncertainty in in-vitro bioassay can be large, especially for concentrations close to the MDC. The MDC is influenced by several factors, including the chemical recovery and several other factors related to the analysis of each sample. These factors include the degree of digestion of organic material in the sample, composition of the samples, purity of reagents, and proficiency in the preparation of the sample. Based on these factors, the specific sample MDC may be higher than some of the tabulated values. NIOSH should provide an uncertainty analysis for the minimum detectable activity (MDA) or decision levels.

Potential missed dose associated with inadequate bioassay techniques should be further investigated to determine the impact on internal dose calculations.

4.5 FINDING 5: LACK OF GUIDANCE FOR ESTIMATION OF MISSED DOSE FOR UNMONITORED WORKERS

ORAUT-TKBS-0036-5 provides in-depth information on the in vivo and in vitro bioassay program through time. Insufficient guidance is provided in the internal TBD on how to use this information. For example, there is insufficient guidance on estimating internal doses for unmonitored workers. Even in the case of monitored workers, there is a lack of information on some default assumptions such as solubility, assignment of dose from trace radionuclides, etc.

It is stated on page 29 of the TKBS:

> *The routine bioassay monitoring program at ANL-E has historically been conducted for workers (identified by self-reporting, by supervision, and by radiation protection staff) in areas involving possible internal exposure. Most workers at ANL-E were not identified to be at risk and were not monitored.*

This statement needs more support to provide a greater level of assurance that all workers with potential risk were subject to routine or special bioassay monitoring, especially in early times of operation.

It is also stated on page 18 of ORAUT-TKBS-0036-5:

> *The bioassay reports for 1961 and 1962 were more descriptive than for 1953 and 1954 (Pingel 1953, Robinson 1955); however, they included only the results for nonroutine and special analyses. The analyses performed during that period included alpha (plutonium, neptunium, thorium, actinium, americium, and curium), beta activity, iodine, plutonium, polonium, radium, tritium, uranium, and other miscellaneous nuclides (e.g., 99Tc, 65Zn). Gross alpha data were reported in some cases. The reports did not generally specify the type of bioassay but, because the data were reported as disintegrations per minute per specified volume, it can be assumed that they refer to urine bioassay. Several reports from that period indicated activity in fecal samples and nasal swabs. In one case, a*

blood sample was indicated with a value of 0 dpm/1,500 mL. Because it is unlikely that a 1,500-mL blood sample was analyzed, this probably was a typographical error in the report. In another case, skin scrapings were analyzed. Because only special and nonroutine sample data were included in the monthly reports, it is unclear whether routine fecal analyses occurred during that period.

This citation indicates that bioassay data may not be available for certain periods or for some workers. If this is the case, NIOSH should provide guidance within the site profile for the dose reconstructor to estimate doses based on coworker data.

4.6 FINDING 6: FAILURE TO ADEQUATELY DEFINE AND ASSESS OCCUPATIONAL MEDICAL EXPOSURES IN THE PRE-1988 YEARS AND POTENTIALLY MISSES SPECIAL EMPLOYMENT EXAMS.

The guidelines used in ORAUT-TKBS-0036-3 for the estimates of occupational medical exposures prior to 1988 are reasonable for determining the overall dose estimates for claimants. Unfortunately, the guidelines have not been interpreted by NIOSH in such a way as to be claimant favorable. NIOSH's interpretation of the guidelines is similar to its actions at other sites (the Mound Plant, LANL, and Pinellas), in that there are no special or screening medical examinations included—but only chest x-rays that are part of routine physical examinations. In more recent documentation, ORAUT-OTIB-0006, Revision 3 (ORAUT 2005b), it is concluded that other examinations should be included, such as special screening examinations (e.g., respiratory protection, beryllium workers, asbestos workers, etc.) and termination examinations. Although this TBD recognizes these changes from the previous Revision 2 of the OTIB by referencing Revision 3, it does not address or document these changes in ORAUT-TKBS-0036-3.

The TBD (ORAUT 2006b) concludes that chest examinations were often quite limited after 1980. It is suggested that the frequency of chest examinations was every four years unless special circumstances existed; however, this policy was not documented. To the contrary, there is ample evidence that chest x-rays were often provided on a voluntary basis to nearly all workers, usually on an annual basis. The majority of workers had routine chest x-rays at DOE sites until the mid-1980s, when federal guidelines that warned against routine screening were first enforced.

SC&A believes that NIOSH'S interpretation of the frequency of occupational medical x-rays used in the TBD is not claimant favorable. We are concerned that for certain "high-risk" workers, the additional radiation dose associated with medical screenings associated with these higher risk jobs might not be accounted for in their total occupational dose estimates. Since all radiation exposure results in some risk, and is arguably cumulative, a claimant-favorable estimate should include all occupational exposures. SC&A believes that NIOSH should review its interpretation of the guidelines provided in the most recent version of ORAUT-OTIB-0006 (ORAUT 2005b), and adopt the most claimant-favorable interpretation in ORAUT-TKBS-0036-3.

4.7 FINDING 7: LACKING TECHNIQUES AND PROTOCOLS FOR MEDICAL EXAMINATIONS PRIOR TO 1988 INCREASES THE UNCERTAINTY OF DCFS LISTED IN ORAUT-TKBS-0036-3.

The TBD fails to describe adequately all the information needed to establish beam quality for x-ray units in use from 1940 to 1980. In 1970, the site installed a single phase GE Model DXD-350 unit; however, there is only limited documentation to verify that the single phase unit in use from 1970 through 1985 had an HVL of approximately 2.5 mm of Al, as stated in the TBD. In the absence of definitive tube output measurements, the TBD directs the use of default values and DCFs presented in Table 3-3, which are 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) and presented in Table 3-7 of the TBD. SC&A is concerned that the DCFs are derived using a default HVL of 2.5 mm Al for Type 1 units in use from 1946–1980 without sufficient evidence of its appropriateness.

The TBD provides little documentation to support the assumed techniques and protocols applied to calculate doses, which are mainly derived from NCRP Report 102. The TBD states that a PA chest x-ray was typically the only view used after 1980, although this assumption is undocumented. SC&A has inquired of NIOSH whether definitive protocols existed to validate that chest exams included PA views and LAT views only on a limited basis after 1960. NIOSH has acknowledged in other TBD reviews that the lack of verifiable protocols is 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, as so stated in the TBD.

The TBD also recognizes that little documentation exists to validate any x-ray protocols, equipment maintenance, and upkeep records prior to 1988, but fails to adequately describe the implications of this paucity of information.

4.8 FINDING 8: FREQUENCIES AND TYPES OF X-RAY EXPOSURES ARE UNCERTAIN

The TBD relies on a very limited review of archived medical records to establish worker x-ray frequency assumptions. The assumption of one chest radiograph (PA) every four years after 1980 is not reasonably conservative, in that workers could essentially request an x-ray or be subject to special screening exams which were not in sequence with routine physical examinations. The frequency of screenings and the numbers and types of workers receiving medical x-rays varies from site to site and within worker job classifications.

The TBD in Section 3.3 provides no documentation to support the assumption that only a limited group of workers received x-ray exams more frequently than every four years after 1980. To the contrary, up until about 1990, most DOE sites performed chest x-rays almost on a voluntary basis. DOE medical program reviews conducted during the early 1990s showed that many sites still used chest radiography as a general screening examination. Most workers accepted chest x-rays, even though the job did not require them to do so. Also, the assumption that workers in special exposure categories, such as beryllium workers, were given chest x-rays only as part of their routine physical examinations is not well-documented and not consistent with special

screening guidelines. The TBD does not apply conservative assumptions to the existence and frequency of these special job-related physical examinations.

Sections 3.1 and 3.3 of the TBD state that photofluorography (PFG) was not thought to have been used after 1948. However, there is evidence that limited applications of PFG did occur until 1956, and possibly as late as 1958. The undocumented absence of PFG units at ANL-E clearly has significant dose implications for workers who may have received significant doses from PFG units. The PFG unit delivers a higher dose than conventional radiography by a factor of 5–6. SC&A believes that it is not claimant beneficial to instruct dose assessors to assume PFG use for chest radiography only until 1956, without a higher level of assurance. It would be more claimant favorable to assume PFG use for chest radiographs and assess an annual occupational medical dose of 3 rem per year until at least 1958, in accordance with guidelines set forth in ORAUT-OTIB-0006 (ORAUT 2005b).

4.9 FINDING 9: UNCERTAINTY AND UNDOCUMENTED ASPECTS OF THE FILM DOSIMETRY NEED RE-EXAMINATION

The technology or service provider for the dosimetry program changed at least 12 times during the period that film emulsion was used as the beta-gamma detection medium. Table 6.2 of the site profile exhibits most of these changes. For several of the time periods under review, there are no specifications or information regarding the dosimeter, including the emulsion, wrapper, holder, or algorithm. Indeed, for some periods the site profile recommends the use of information from the INEEL program, since nothing is available for ANL-E. For example, due to the lack of data on the covering material on early dosimeters, the site profile utilizes an INEEL analysis for beta under-response (ORAUT 2006e, pg. 36):

> *6.8.3.1 Under Reporting of Shallow Dose Equivalent*
> *Due to the thickness of the covering material and the thickness of early beta detectors, early beta monitoring systems under-reported the dose for a depth of 7 mg/cm2. A general analysis of the under-response of beta dosimeters was done for INEEL* (ORAUT 2004). ***Since the dosimeters used at the two sites were similar and few details are available for ANL-E, the INEEL analysis is used in part here****. Table 6-19 provides the fraction of beta dose recorded for the various dosimeters. To determine the corrected beta dose, the dose reconstructor should divide the non-penetrating results by the values in the last column of Table 6-19. This result will probably be an overestimate since the beta calibration involved but undoubtedly did not consider a similar correction. This value is used directly for the shallow dose equivalent [Hp(0.07)].* (Emphasis added.)

The concern with this approach is that the badges are said to be similar, but no references or documentation to support this conclusion are offered. For beta absorption in a wrapper, very small changes in thickness would have large impacts on transmission. (Beta transmission is a commonly used feedback control mechanism for paper, coatings, and plastic film manufacture.) The numerous changes in the program prior to the conversion to TLDs in 1988 create great uncertainty and variability in a number of factors, including:

- Holder and filter design specifications
- Film wrapper thickness and impact on beta and x-ray response
- Algorithm
- Correct usage of the film emulsion log density curve when subtracting background, applying an algorithm and performing a calibration. (See NRC 1989)
- Calibration
- Minimum dose detectable (x, beta, and gamma)
- Maximum dose detectable (x, beta, and gamma)
- Uncertainty
- Angular response
- Over-response to low energy x-rays
- Fade and other emulsion based artifacts
- Wear period
- Processing only badges thought to be exposed
- Suitability for use of a beta: gamma or neutron: gamma ratio
- QA program
- Control dosimeter use and background subtraction practices (For example; was the control in a suitably low background or was "too much" background subtracted from personnel dosimeters?)
- Badge storage location
- Position of badge worn on the body. (Different styles are likely to have had different attachment mechanisms or pouching methods.)

Some of the above factors are discussed in the site profile. They are broken down by time-frame in some cases. However, given the unusually large number of changes, it would be difficult for a dose reconstructor to conduct all of the required evaluations, i.e., missed dose, under-reported dose, etc. A master matrix would help identify the holes in knowledge and enable the dose reconstructor to determine whether a dose reconstruction is limited by any of these factors.

Specifically, there are errors in the assumptions made regarding the film cover and the correction factors provided in Table 6-19 of the site profile. A number of vendors supplied the film over the 1945–1988 timeframe, yet only two cover thicknesses are considered. The data were taken from an INEEL analysis, since nothing was available for ANL-E.

In summary, it is difficult to make assessments over the entire timeframe covered by film use owing to the large number of variables and unknowns. A matrix laying out the numerous parameters is needed for the approximately 12 different film technology periods. Once a more

comprehensive definition of history of the dosimetry employed at ANL-E is offered, the technical basis should be re-examined for each of the technologies and periods in question.

4.10 FINDING 10: NEUTRON DOSIMETRY IS INADEQUATELY ADDRESSED

Thermal neutrons were monitored with a cadmium filter in the beta gamma film badge holder starting in 1967. It is unclear from the site profile how this information was used and whether all holders included cadmium. No indication is given in the TBD as to how the decision was made to assign thermal neutron badges following the commencement of thermal neutron monitoring. It is also not clear in the TBD how missed thermal neutron dose is to be assigned prior to or post-1967.

The site profile discusses the various dates when dosimetry was begun for thermal, intermediate, and fast neutrons. Based on this discussion, it appears that fast neutron NTA film was introduced by 1953, and a thermal film program by either 1967 or 1971. Prior to this time boron-lined PICs "were reported at other facilities." This implies that there was limited or no neutron monitoring for the first seven years of operation and certainly no record of the program. The TBD fails to provide guidance to the dose reconstructor for the period from 1946–1953, when there was apparently no neutron monitoring program in place. Presumably, standard techniques for inserting missed or unmonitored doses would be used, although there is no discussion provided on the merits of this approach.

The site profile addresses missed dose in the expected fashion with LOD/2 being applied for all zero doses on NTA film. (See example in Section 6.7.6.2 of ORAUT-TKBS-0036-6). For NTA, an LOD of 50 mrem is assumed, which seems reasonable based on the approach defined in OCAS-IG-001, Rev. 1 (NIOSH 2002). However, Section 6.7.3.3 of the site profile states:

> *Before 1960, neutron films were apparently only read if the gamma dose was 100 mrem or more. This correction should be accounted for by adding missed dose for each zero reading where there is an indication that neutron monitoring occurred.*

A concern arises that the statistical approach called for in NIOSH 2002 assumes a lognormal distribution of missed doses below the LOD. In the case of NTA prior to 1960, the missed dose may well be higher than the LOD, depending on the ratio of gamma to neutron in the given situation and depending on the accuracy of the gamma dose measurement. There is no justification to support using the standard missed dose approach in this widespread situation. Given this concern, it is recommended that NIOSH revisit this issue and develop a more claimant-favorable approach for assigning missed dose for this time period.

Section 6.7.3.2 of the site profile discusses the energy response limitations of NTA and recognizes that the response drops off sharply below 800 keV. Table 6-16 provides correction factors to account for this under-response in various facilities. Correction factors ranging from 1.25 to 4 are estimated, "…*based on experience*," with no rationale beyond this statement provided for the selection of these values.

Given that the response of NTA is zero at energies around 100 keV, assumptions regarding the spectral mix are needed for a range of timeframes, work areas, experiments, etc. The implication from this table is that at least 25% of the neutron dose was from energies above 800 keV in all situations where exposure might have occurred. Yet Section 6.7.3.2 describes one facility where the factor would apparently need to be 20 or more, not 4 (maximum value in Table 6-16):

> *A 1966 investigation pointed out that the majority of neutrons in areas occupied by personnel at the 4.5-MeV and 2-MeV Van de Graaff accelerators had energies between 100 keV and 1 MeV. NTA film measurements in the facilities showed dose equivalents of less than 5% of the values from instrument measurements (Till 1966)….*

Additional references and guidance are needed to enable a determination to be made of the suitability of these values. In addition, the large inconsistency between "experience" and measurements (Till 1966) needs to be discussed in light of Table 6-16.

Section 6.7.4 of the TBD states the following:

> *A 1965 study of neutron field characteristics at the 50-MeV proton injector of the ZGS indicated that NTA film response decreased from 84% of the calculated dose equivalent when the film was perpendicular to the source to 57% when the film was at 90°. The effective energy of the neutrons was 1.18 MeV and the dose equivalent rates were high (174 rem/hr). The contribution of scattered neutrons to the dose equivalent at the point of measurement was determined to be 24% with an effective energy of 0.49 MeV (Steele 1965). The location of these measurements was not in an area occupied by personnel during operation of the accelerator. D**ue to multi-scattering, NTA film response in the normally occupied areas is likely to be less angular dependent**. Therefore, with the possible exception of accidental exposures in high-dose areas, **no correction for angular dependence is deemed necessar**y. [Emphasis added.]*

It is unclear what is being asserted in this paragraph. However, it would seem likely that in a multi-scattering environment, the average neutron angle of incidence would be something approximating 45° to A-P. If so, then a correction would indeed seem warranted, unless a site-specific calibration had been performed. In addition, as NTA response drops below approximately 1 MeV, it is likely that the angular response drops further, but the TBD fails to address this dependence. Thus, the claim that no correction for angular dependence is required should be substantiated.

4.11 FINDING 11: QUANTIFICATION OF EXTERNAL EXPOSURES TO UNMONITORED WORKERS OUTDOORS IS INADEQUATELY JUSTIFIED

For time periods prior to 1972, there are virtually no data characterizing the external radiation fields outdoors. The site profile states that since radionuclides build up outdoors over time, external exposures to unmonitored outdoor workers post-1972 were likely greater than pre-1972 exposures. Hence, the site profile states that post-1972 data can be used to bound pre-1972

exposures. Given the complexity of the site and how operations changed over time, it does not appear plausible to reconstruct pre-1972 outdoor external exposures to unmonitored workers using post-1972 data. Is NIOSH simply going to assume that no outside workers and unmonitored workers experienced external exposures in excess of 100 mrem/year? The site profile would benefit from a more thorough discussion of how such exposures will be reconstructed.

Sections 2.3 and 4.3 of the site profile provide overviews of the potential for airborne contaminants within buildings at the site and in the airborne effluents from the various facilities. Section 2.3 of the site profile states that "no estimates of the quantity of effluents release are available for 1946 to 1972." Hence, as with external outdoor exposure, it is important to distinguish between pre- and post-1972 exposures.

Notwithstanding the limitations in the effluent monitoring data pre-1972, Section 4.3 cites historical records indicating that, from the very beginning of operations in 1946, the Health Physics Division of ANL-E was very concerned with the potential for chronic and acute exposure to airborne radionuclides in the work environment at all facilities and instituted routine indoor surveys of the airborne radionuclide concentrations. The implications are that, by having an awareness of the airborne radionuclide concentrations indoors, there was a degree of control and an understanding of the potential airborne emissions and outdoor exposures at the site from the time of its initial operation. In addition, Section 4.3 of the site profile cites 52 outdoor air particulate samples collected in 1949. However, NIOSH was unable to find these data.

The site profile also cites numerous reports characterizing radioactive material in the outdoor environment prior to the more formal effluent monitoring initiated in 1974, including comprehensive studies related to characterizing global fallout at the site. Those reports reveal that most of the elevated radionuclide concentrations found outdoors during the 1960s were from global fallout and not ANL-E effluents. However, the site profile cites some measurements revealing that there were detectable outdoor radionuclide concentrations associated with ANL-E operations. The measurements of Ar-41 in the air near building CP-5 is given as an example in Table 4-2 of the site profile.

Table 4-5 of the site profile presents a summary of the annual atmospheric releases of seven radionuclides from ANL-E from 1974 through 2003. The values were taken from annual environmental reports published by ANL-E. A more complete list of the annual releases of 11 radionuclides to the atmosphere from 1973–2004 is provided in Section 2-4 of the site profile.

Table 4-6 of the site profile presents estimates of the annual release of Ar-41, tritium, and C-11 from the CP-5 reactor for 1946–1973. These are based on several reports issued in the 1970s, which state that these represent the major airborne radioactivity releases from the laboratory. It appears that the atmospheric releases from CP-5 during the early years are based on averaging the measured releases for the later years and assuming that those average releases apply to the early years. Some discussion is needed about why such an assumption is appropriate and claimant favorable.

Based on this review, it appears that estimates of the routine annual radionuclide releases from all facilities at ANL-E are available beginning in 1973, as a result of effluent monitoring programs required to evaluate potential offsite doses, as required for annual environmental reports. It does not appear that the data were gathered for the purpose of characterizing potential exposures to workers outdoors onsite. We have a number of concerns with the data and their use in onsite dose reconstruction.

We are concerned that airborne effluent data collected prior to 1974 are extremely limited. Given the highly complex and time-varying nature of the operations at the facility, and the numerous incidents that occurred at the facility, as cited in Section 2.4 of the site profile, it does not appear to be appropriate to use post-1974 effluent data as a basis for estimating pre-1974 releases. Nevertheless, this approach was used in Table 4-6 of the site profile for estimating the release of Ar-41, tritium, and C-11. In particular, it appears that the atmospheric releases from CP-5 during the early years are based on averaging the measured releases for the later years and assuming that those average releases apply to the early years. Some discussion is needed about why such an assumption is appropriate and claimant favorable.

As described in Section 2.2.2 of the site profile, Site A was established as the first national laboratory on July 1, 1946. It was the site of the CP-2 and CP-3 reactors, which were fueled with natural uranium and used a graphite moderator (in 1953, the natural uranium in CP-3 was replaced with enriched uranium) . In addition, in 1943, a low-level radioactive waste burial facility was established at Site A, which operated until 1949. In the mid-1950s, the reactors and waste disposal facilities underwent D&D.

Based on our review of the site profile, no data are available characterizing external exposures, effluent releases, or airborne radionuclide concentrations outdoors. It is our understanding that exposures to unmonitored workers outdoors at Site A will be reconstructed by extrapolation from data acquired from Site D in the later years, or by assuming that the doses outdoors at Site D place an upper bound on the doses at Site A. This might be a correct assumption, but additional justification seems to be warranted.

4.12 FINDING 12: OUTDOOR INHALATION EXPOSURES ASSOCIATED WITH WASTE DISPOSAL OPERATIONS IN AREA A AND FROM PARTICULATES RELEASED DURING ACCIDENTS ARE NOT ADEQUATELY ADDRESSED

Section 4.4 describes the approach that is recommended for use in reconstructing internal exposures to workers outdoors. It appears that only exposure to tritium and Rn-220 were considered. Attachment A to Chapter 4 of the site profile provides the rationale for not explicitly addressing other (particulate) radionuclides. A review of Attachment A indicates that indirect methods were used to come to this conclusion. Specifically, measurements of uranium and plutonium in soil and plant samples collected in the 1970s in Area A revealed relatively little contamination. (As described in Section 2.2, Site A housed the CP-2 and CP-3 reactors, which operated until 1954, and is also the location of low-level radioactive waste disposal.) Also, aerial surveys and analyses of soil samples in the 1970s revealed only low levels of Cs-137 and other radionuclides that might have been due to site operations. On the basis of these data, the site profile concludes that the potential for inhalation exposures to particulates outdoors in Site A up

to 1954 was negligible. Our review reveals that NIOSH's conclusions regarding this matter are reasonable. However, some additional discussion is needed regarding the potential for short-term, but possibly large, inhalation exposures associated with the waste disposal operations in Area A and whether exposures to particulates that might have been released during accidents could have contributed significantly to the outdoor inhalation dose.

As described in Section 4.3.2, the Environmental Protection Agency's atmospheric computer code, CAP-88, was used to reconstruct outdoor inhalation exposures using the atmospheric radionuclide emissions identified in Table 2-4 of the site profile. Apparently, NIOSH was able to determine the emissions from individual buildings and then determine the airborne radionuclide concentrations as a function of distance and direction from each building. Reasonable assumptions were made regarding release height and effluent exit velocity. However, some discussion is needed regarding the exposures some workers might have experienced during accidents where large amounts of radionuclides might have been released to the atmosphere over short periods of time and time periods during which average annual atmospheric dispersion factors could substantially underestimate or overestimate the doses.

4.13 FINDING 13: LACK OF CONSIDERATION OF OCCUPATIONAL RADIOLOGICAL EXPOSURE AT SITE A AND PLOT M

Although ANL-E received its official designation as a national laboratory on July 1, 1946, the laboratory was operated prior to this time at the University of Chicago and at the Palos Park Site A in the Argonne woods. Operations at the University of Chicago location (i.e., new Chemistry Laboratory and Annex, West Stands, Ryerson Physical Laboratory, Eckhart Hall, Kent Chemical Laboratory, Jones Chemical Laboratory, and Ricketts Laboratory) are considered a part of the Metallurgical Laboratory, which is listed as a separate facility than ANL-E. The EEOICPA coverage for ANL-E includes the years from 1946 to the present. The operations at Palos Park Site A and Plot M from 1943 through June 30, 1946, are not adequately considered in the ANL-E site profile. The site description TBD provides some discussion on Site A and Plot M, but the scope is specifically defined as beginning on July 1, 1946:

> *Argonne National Laboratory was established on July 1, 1946, and this TBD is intended to cover the time period beginning on that date.* (ORAUT 2006a, pg. 8)

Furthermore, the internal TBD indicates internal dose was considered starting in 1946:

> *The purpose of this TBD is to provide information to assist in the evaluation of occupational internal radiation dose associated with operations at Argonne National Laboratory – East (ANL-E) from 1946 to the present.* (ORAUT 2006d, pg. 7)

Chicago Pile-2, a reconstruction of CP-1 that was assembled at Site A, went into operation in March 1943. Chicago Pile-3, the first heavy-water-moderated reactor, began operation at Site A on May 15, 1944 (Holl 1997). Other work conducted at Site A included fission product separation, reactor physics studies, tritium recovery from irradiated lithium, and radionuclide metabolism studies in laboratory animals. Radiological work continued at this location until

1956. Plot M was used for radioactive waste burial from 1943 through 1949. Both sites underwent remediation which was completed in 1956 (Golchert and Sedlet 1977, ANL 1979).

The ANL-E TBD does not adequately consider dose from radiological operations which potentially exposed workers to uranium, tritium, fission products, and other radionuclides in the initial years of operation at Site A and Plot M. Exposures during the 1940s were particularly likely with the less effective radiological controls in place at the time.

4.14 SECONDARY ISSUES

Secondary Issue 1: Potential Missed Dose from Skin and Clothing Contamination

Given the nature of the work in the early years, it is possible that skin and clothing were contaminated with beta emitters. This issue is fully recognized in Section 6.8 of the site profile:

> *The earliest maximum permissible exposure limits published at ANL-E recognized the potential hazards of beta exposures of the skin (Nickson 1946). The pioneering work done there fabricating uranium fuel elements and processing irradiated fuel could have resulted in significant beta exposures. Work since the early days has involved a wide range of activities with different natural and man-made isotopes. Beta exposures, including exposures to high-energy (more than 1 MeV) betas, cannot be ruled out….*

NIOSH claims its approach to determining the dose from documented contamination events to be reasonable and claimant favorable. The contamination is assumed to have been undetected on skin for four hours. This would imply that contamination occurs at the start of a shift and is detected at lunch or at the end of the shift. On the surface this seems optimistic. While it might be possible with modern whole-body hand and shoe monitors available, it is quite likely, with handheld analog equipment, that workers could have missed localized contamination during one or more exits of the work area.

It is obviously impossible to estimate with any certainty how long contamination resided on the workers' skin prior to detection. One approach would be to review incidents that have occurred at other facilities where contamination was undetected for a period of time. It does not seem claimant favorable to assume that contamination is detected the first time a worker leaves the area. The assumptions made in this scenario need to be made with consideration of the equipment and procedures that were in place for the earlier operating periods at ANL-E.

Consideration should also be given to adding a component of dose for missed skin contamination in the early years, based on the action levels called out in Nickson 1946 and other contemporaneous action levels in existence throughout the history of the site.

Secondary Issue 2: Other Potential Medical Exposures Have Not Been Identified.

The TBD does not address the potential use of sources of medical exposure, other than x-ray units, to support medical diagnosis, e.g., the use of isotopes and sealed sources. The less than average performance at ANL-E of routine and preventative maintenance during the 1946–1988 timeframe also suggests that routine maintenance of x-ray units was not likely, unless performed by an unknown outside contractor. Unfortunately, since no documentation exists regarding maintenance, calibrations, etc., the lack of defined protocols and the basis for approval of radiography procedures suggests that the use of radiography was not closely controlled. The TBD also does not discuss the use of portable radiography to perform screenings and the potential for exposure of medical personnel or unmonitored workers. This is also potentially an issue relating to the use of a PFG unit, which was often van-mounted, at other sites. Additionally, the TBD fails to mention that available x-ray units were not operated at greater than 80–90 kVp prior to 1988.

SC&A concludes that the TBD incompletely documents the variety of medical occupational exposures. In addition, the lack of documentation on the type of equipment and the maintenance records does not provide confidence that a claimant-favorable estimate of dose is possible. For these reasons, NIOSH might consider the need for a worst-case approach for estimating medical occupational exposure. NIOSH should revisit and update, as needed, Sections 3.2 through 3.6 of the TBD.

Secondary Issue 3: Additional Factors Contribute to Medical Dose Uncertainties.

The occupational medical TBD does not consider dose impacts due to less than optimal use of technology, such as using screens, grids, or bucky systems. The TBD does not consider these elements as potential contributions to uncertainty.

The TBD does consider the potential contribution to dose that may have resulted from less than optimal use of collimation, at least prior to 1970, as stated in Section 3.4 of the TBD. Unresolved is the concern that the DCFs are derived from ICRP (1982), and therefore are not comparable in terms of beam quality, which varies from unit to unit. These factors can contribute significantly to the dose to the chest and other organs, for the x-ray units in operation prior to 1988, as little or no documentation exists that defines the operating parameters. NIOSH has indicated in other TBDs that it will continue to search for available records in order to better define equipment use and beam quality, and will include, as appropriate, this information in an updated version of the TBD. SC&A suggests that NIOSH include this assurance in the ANL-E TBD.

Uncertainty is defined in the TBD as attributable to measurement error and variations in voltage, tube current, timers, and the source-to-skin distance. This approach is similar to the uncertainty analyses documented in other DOE site profiles. The conclusion in this TBD, and others, is that an uncertainty of approximately 30% should be used by dose reconstructors for exposures prior to 1990. SC&A believes an uncertainty correction factor of 2.0, which is applied at other sites, is more appropriate.

Although NIOSH conservatively evaluated the factors it considered in its examination of uncertainty, it did not consider other factors, such as errors introduced by lack of quality controls and lack of adherence to established standard operating procedures. A reasonable estimate of these contributions to uncertainty could be made by evaluating retake rates for each examination type. NIOSH should take retake rates into consideration as a part of future revisions of the TBD, especially as they relate to years prior to 1988.

The TBD does not demonstrate that ANL-E applied dose minimization principles to reduce medical exposures prior to 1988. Moreover, the document does not assess or consider the likely exposure to workers who were referred to off-site medical facilities for follow-up examinations. Little documentation is presented on the number of x-ray examinations provided to the average worker, including those provided for special exposure needs.

Secondary Issue 4: Internal Dose to Workers from Radon Exposures is Not Considered

ANL-E handled Ra-226, Ac-227, and Th-230 as part of R&D and other activities. SC&A is concerned about the lack of consideration of doses from the unmonitored gaseous radionuclides such as thoron, actinon, and radon. The site description indicates Ra-226 was used in Building 203 and 211 as a part of the accelerator program. In Building 200, Rn-220 was produced (ORAUT 2005a, pp. 21–22). Thorium was handled in the East Area and Building 211. Actinium-227 was handled in Building 200 by the Chemistry Division. Considerable research was conducted by the Biology Division concerning Ra-226 and its potential effects on biological systems. In fact, ANL-E was tasked with follow-up of the Radium Dial Painters.

In addition to routine exposures, on June 13, 1952, in Building 203, a sealed capsule containing radium sulfate powder was breached. The radium entered the duct work and spread throughout the building. They tried to decontaminate the area, but there is still residual loose radium contamination found in inaccessible areas (e.g., ducts, electrical boxes, etc.) in this building today. Although the field monitored for loose radium activity, it is uncertain whether monitoring was done specifically for radon and daughters at the time of the accident. The individual directly involved with the incident was monitored; however, residual Ra-226 existed even after the clean-up. This generated a source of radon exposure in this area. Dosimetry indicated radon monitoring was not a part of the routine monitoring program.

Given the use of radium, actinium, and thorium at ANL-E, some consideration should be given to the potential occupational exposures to radon, and possibly thoron and actinon.

Secondary Issue 5: Lack of Treatment Provided to the Monitoring of Contractors, Transferees, and Visitors.

Although “Rover Dosimeters” are mentioned, there is scant mention in the site profile of the monitoring of visitors, transferees, and contractors. Of particular concern, is the absence of information on the treatment of contract workers during the numerous D&D activities known to have been conducted at ANL-E. Since this issue has been a concern at other sites, it should be addressed in greater depth here.

Secondary Issue 6: Human Radiation Experiments Not Addressed

ANL-E and its predecessor, the Metallurgical Laboratory, participated in human radiation experiments, including some involving employees. For example, six Metallurgical Laboratory employees volunteered to drink a solution with small amounts of plutonium. This was done to measure the gastrointestinal absorption and fecal excretion rates for ingested plutonium (DOE 1995). At ANL-E, tracer quantities of radionuclides were administered to human volunteers and measurements collected on the in vivo counter early in its development (ORAUT 2005a, pg. 21). Information on the exposures of ANL employees from participation in human radiation experiments may not be stored with individual radiation and medical files. NIOSH/ORAUT should identify workers participating in human radiation experiments and verify that all relevant data is provided by the site for evaluation in the dose reconstruction. Any files containing additional information on radiation exposures should be requested by NIOSH.

Secondary Issue 7: Incidents and Accidents Need to be Reexamined

Exposure conditions that may present themselves during an incident or occurrence have not been addressed in the TBD. Although individuals involved in incidents are usually monitored, the incident itself may pose special exposure conditions that need to be considered in the dose reconstruction (e.g., injection versus inhalation; partial body exposure to an external beam; cleanup of a spill involving nontraditional radionuclides). Historic radiological exposure incidents or unusual exposure conditions were frequent at ANL, particularly in the early years. However, the site profile does not fully address the significance of such incidents. In the site description TBD, ORAUT-TKBS-0036-2 (ORAUT 2006a) provides an overview of ten incidents occurring from 1952–1976, with mention of small fires occurring over a 30-year period. No accidents that occurred before 1952 are listed in the site profile. The TBD indicates that accidents are documented in health physics progress reports, as well as in the personnel dosimetry files, if nonroutine dosimetry procedures were instituted. In interviews with ANL-E dosimetry staff, SC&A was informed that the ES&H Coordinator maintains the incident reports for any safety incidents. It is unclear if these incident reports are duplicated in the individual radiation exposure files. Medical files contain information related to incidents requiring medical treatment which may not be provided as a part of the claimant data, since ANL-E was not explicitly given direction to provide this information. While it is clear that judgment needs to be exercised regarding those accidents and incidents that need to be reviewed and included in site profile characterization, it is important to identify available information regarding key accidents and incidents and assure their availability and use by dose reconstructors. In addition, the site profile needs to evaluate this accident history for its implications to dosimetry adequacy and completeness of dose reconstruction, particularly the accidents that occurred prior to 1952, or the implications of the absence of records for this period should be addressed.

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

The SC&A procedures call for 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 evaluating (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 ANL-E represent an adequate accounting of the highly varied operations, environmental dose, and dosimetry history, but fall short in fully characterizing a number of key underlying issues that are fundamental to guiding dose reconstruction. Section 6.0 summarizes the key issues. Detailed evaluation of these issues is found in Section 4.0, Vertical Issues, of the report.

5.1.1 Objective 1: Completeness of Data Sources

The breadth of data sources used as a basis for the ANL-E Site Profile is evident in the number of reports available in the Site Profile Research Database, as well as in the number of reports cited in the site profile references. The ORAU team's use of the available sources indicates an understanding of site operations, radionuclide usage, and personnel monitoring data. However, as at most of the DOE sites, there is a lack of data for the early years of operation. In particular, there is little information in the site profile related to operations at Site A.

The TBD fails to describe adequately all the information needed to establish beam quality for x-ray units in use from 1940 to 1980. The TBD also recognizes that little documentation exists to validate any x-ray protocols, equipment maintenance, and upkeep records prior to 1988, but fails to adequately describe the implications of this paucity of information. Likewise, the TBD relies on a very limited review of archived medical records to establish worker x-ray frequency assumptions.

For time periods prior to 1972, there are virtually no data characterizing the external radiation fields outdoors. Hence, the site profile states that post-1972 data can be used to bound pre-1972 exposures. Given the complexity of the site and how operations changed over time, it does not appear plausible to reconstruct pre-1972 outdoor external exposures to unmonitored workers using post-1972 data.

5.1.2 Objective 2: Technical Accuracy

In general, the TBDs for ANL-E favorably reflect the depth of knowledge and technical understanding of the various authors and experts who developed the documents. The analyses and recommendations are generally consistent with NIOSH guidance and the available data from the site. Some exceptions are noted below.

According to ORAUT-TKBS-0036-5, Section 5.3.1.3, if specific information is not available, the dose reconstructor should assume inhalation as the pathway for internal doses. This recommendation is not claimant favorable for cancers in the alimentary tract, where ingestion can result in higher doses.

The uncertainty in the values of the minimum decision levels or minimum detectable concentrations (MDC) for bioassay samples has not been adequately discussed in the ORAUT-TKBS-0036-5. This is a major concern, since the uncertainty associated with these parameters may have a significant impact on the estimate of missed dose.

5.1.3 Objective 3: Adequacy of Data

On the whole, the TBDs address the data necessary for assignment of occupational dose, including missed and unmonitored dose, for ANL-E. The data critical for dose reconstructors are not always presented in a succinct and easily understandable manner.

5.1.4 Objective 4: Consistency among Site Profiles

SC&A compared and contrasted the methodologies to determine external, internal, medical, and environmental dose used in the ANL-E Site Profile with other site profiles reviewed to date. These comparisons focused on the methodologies and assumptions associated with dose assessments and the derivation of values used to obtain a POC for individual claimants. Specifically, we compared the ANL-E Site Profile to those for Mound and the Pinellas Plant. SC&A found a consistent application of NIOSH guidance and claimant-favorable assumptions at the sites compared.

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 82. In addition, SC&A evaluated the TBDs for adherence to general QA policies and procedures utilized for the performance of dose reconstructions. Section 6 addresses this topic.

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 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 defensible. SC&A used the following seven objectives to guide its review of the ANL-E 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

It is not clear from the Internal Dosimetry TBD (ORAUT-TKBS-0036-5) how dose estimation would be performed for workers who were not classified as radiation workers and who had access to ANL radiological operations. No guidance is provided in this TBD with respect to missed dose calculations for unmonitored workers, such as support personnel whose actual jobs (contamination spill cleanup, equipment maintenance, janitorial functions) could have led to exposures comparable to those of radiation workers, and whose access to various ANL-E buildings may have led to a variety of radionuclide exposures over their job history.

6.2 INCONSISTENCIES AND EDITORIAL ERRORS IN THE SITE PROFILES

- Figure 2-1 of the site profile (ORAUT 2005a) contains a map that purports to show Sites A and D, but fails to label the location of Site A. Figure 2-3 (ORAUT 2005a) shows a map of the current Argonne site. The body of the document references the 800 area, although this area is not shown on the map. Better materials than those provided are readily available on the Office of Scientific and Technical Information (OSTI) site that show the locations of Site A and Area 800.

- There is a significant error in Table 6-13 of the site profile. The IREP energy interval multiplier of "2" in the "No information available" column is in the incorrect row. It should be placed in the ">0.1–2.0 MeV" row.

6.3 UNRESOLVED POLICY OR GENERIC TECHNICAL ISSUES

A number of issues were identified that are common in the ANL-E 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, 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 has indicated that it may develop separate TIBs in order to address these more generic issues. The following represent those issues identified in the ANL-E 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) Resolution is required on the availability of early records, particularly from Site A.

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

(3) The method for dose assignment for alpha emitting radionuclides, when only gross alpha analyses were performed on bioassay samples, requires definition.

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

(5) The significance of various exposure pathways and the assumptions made that influence dose contributions need to be considered (most notably) for solubility 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 contract D&D workers should be assessed. Many facilities have large-scale D&D operations that extend back many years. Decontamination and decommissioning

operations often require working in unknown situations, which may provide unique exposure situations.

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

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ATTACHMENT 1: TECHNICAL DOCUMENTS CONSIDERED DURING THE REVIEW

Technical Basis Documents

ORAUT-TKBS-0036-1, *Argonne National Laboratory - East – Introduction, Rev. 00*

ORAUT-TKBS-0036-2, *Argonne National Laboratory - East – Site Description, Rev. 00 PC-1*

ORAUT-TKBS-0036-3, *Argonne National Laboratory - East – Occupational Medical Dose, Rev. 01 PC-1*

ORAUT-TKBS-0036-4, *Argonne National Laboratory - East – Occupational Environmental Dose, Rev. 00*

ORAUT-TKBS-0036-5, *Argonne National Laboratory - East – Occupational Internal Dose, Rev. 00*

ORAUT-TKBS-0036-6, *Argonne National Laboratory - East – Occupational External Dosimetry, Rev. 00*

Technical Support Documents

OCAS-PER-017. *Evaluation of Incomplete Internal Dosimetry Records from Idaho, Argonne – East and Argonne – West National Laboratories*, Office of Compensation Analysis and Support, September 2007.

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

ORAUT-OTIB-0006, Rev. 3. *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, Oak Ridge Associated Universities, Oak Ridge, Tennessee. December 21, 2005.

ATTACHMENT 2: SITE EXPERT INTERVIEW SUMMARY

Interviews were conducted with 32 Argonne National Laboratory–East (ANL-E) site experts. The employment years represented by those interviewed range from 1953 to the present. Interviews were conducted at the Argonne National Laboratory by Charles Phillips and Kathryn Robertson-DeMers in Argonne, Illinois, February 25–28, 2008, in conjunction with the onsite records review. Wanda Munn of the Advisory Board on Radiation and Worker Health (Advisory Board) also attended to observe the interviews. The purpose of these interviews was to obtain information on past radiological control and personnel monitoring practices and to gain a better understanding of operations conducted through the operating period. Interviewees were identified by ANL-E based on general recommendations provided by SC&A.

Employees interviewed worked at the Site A, Plot M, and Site D (present location) locations of the laboratory, collectively. Facilities represented by the interviewees included 200, 201 (Central Administration Building), 202 (Biology Building), 203 (Physics Building), 205 , 211 (Chemistry), 212, 306 (Decontamination Shop/Waste Management), 317, 331, 335, 350, 370, 375, 376 (Powerhouse), 391, the Zero Gradient Synchrotron (ZGS, 360 series of Buildings), the Intense Pulse Neutron Source (IPNS), Chicago Pile-5 (CP-5, Building 330), the East Area, and the Advanced Photon Source (APS, 400 Area).

Some individuals interviewed worked in all areas of the site while others worked in a limited number of areas. The categories represented by interviewees were:

- Accelerator Health Physics (HP)
- Building Maintenance
- Environmental Engineering
- Environmental Protection Management
- External Dosimetry
- Firefighter/Paramedic
- Internal Dosimetry
- Machinist
- Medical X-ray Technician
- Maintenance (e.g., Mechanics, Painters, Riggers, Electromechnical Technician, Millwright, Custodian, etc.)
- Operational Health Physics (Technicians, and Area Health Physicists)
- Physician
- Radiological Records
- Reactor Engineering
- Training

- Transportation
- Waste Management

The interviewees were informed that the interviews were being performed as part of SC&A's review of the ANL-E site profile as part of its technical support to the Advisory Board. Participants were told the interviews were unclassified and not to disclose classified information. Summaries from each interview set were prepared and provided to the interviewees for review, and most of those involved with the interviews responded. It was explained that interview notes with interviewees identified are made available to the Advisory Board. A consolidated version of all interviews may be redacted for Privacy Act reasons by the Department of Health and Human Services for the publicly released report.

The information the ANL-E workers provided to SC&A has been invaluable in providing us with a better understanding of the ANL-E site operations. This summary is not a verbatim discussion, but is an overview of information from the multiple interviews. The information provided by the interviewees was based entirely on their personal experience at ANL-E, and it is recognized that site expert recollections and statements may need to be further substantiated. However, they stand as critical operational feedback and reality reference checks. These interview summaries are provided in that context. ANL-E site expert input is similarly reflected in the body of the report. With the preceding qualifications in mind, this summary has contributed to issues raised in the site profile report.

The summary is based entirely on statements made by the persons interviewed and those statements are included in the summary with no attempt to verify the accuracy of those statements.

Site Operations

The present site with 3,740 acres of property was acquired in 1947. Prior to this, the Manhattan Engineering District operated at a different location. The reactor component of the operation was relocated to this site based on a number of recommendations to retain the structure that were contained in the Atomic Energy Act. The first buildings (Quonset huts) at the current location were completed in 1948 in the East Area of the laboratory. The first wave of buildings included Buildings 49 and 50 (now 200/300), and Building 316, which were used for reactor studies and a hot cell facility.

Site A and Plot M are three miles southeast of the current site location. Site A operated from 1943 to about 1956 when the decontamination and decommissioning was completed. Individuals left Site A as buildings became available at the current laboratory location. Chicago Pile-2 was operated at Site A in 1954 or 1955.

Site A property was never owned by the government. There was an informal understanding that monitoring at Site A would continue, and it did so until 1976. There is now biennial monitoring of this area. Plot M is the waste burial ground and is still in existence. Hazardous and radioactive waste was buried at this location, and there was an informal sampling program for the area. Uranium was found in some surface samples collected. A picnic well sampled at the

Red Gate Woods picnic area indicated the presence of tritium. Samples have been identified back to 1954.

Radiological hazards vary by the division conducting nuclear related work, as indicated below:

- The Chemistry Division worked with a couple of cobalt sources at one time in the back wing of the building. Most of the areas in this building conduct studies with low levels of radioactive material.
- Work in Building 212 was primarily with plutonium in glove boxes. There was also some work with fuel rods in hot cells. Building 212 was decommissioned in the 1990s.
- Building 200 M-Wing housed work with all kinds of transuranics such as curium, californium, and neptunium.
- Building 202 (Biology Division) was utilized for work with P-32, S-35, H-3 and C-14. The Janus Reactor in Building 202 was well contained and posed no real radiological hazards.
- Building 330 housed the CP-5 reactor which was used for irradiation of materials down in the reactor. This created radionuclides with extremely short half-lives. Building 330 was contaminated with tritium. There was also an old accelerator in this building that has been removed.
- Buildings 205 and 212 have plutonium work areas.
- Building 317 was used for underground radioactive material storage.
- The high-level waste is currently stored in the 331 shell.

The East Area at Argonne operated in the early years, but has undergone significant demolition and decommissioning. The East Area included Buildings 2, 14, 19, 20, 37, and 40. Building 37 housed the QA program where radiography of metals was conducted with sources (Ir-192, Co-60) and x-ray units. Building 40 housed the old Plutonium Facility where materials were handled in glove boxes which have been removed from the area. One of the labs housed a Cf-252 source that was used for calibrating dosimeters. Building 17 was the location of the Old Hot Shop. Buildings 14, 19, and 20 housed the Environmental Safety and Health (ES&H) organization, Industrial Hygiene, and Security, respectively. In Building 24 of the East Area there was a laboratory that conducted radiological experiments with animals (e.g., injecting mice with radioactive material.) This organization was separate from the Biology Division and was used to train students and give them an opportunity to practice. The experiments involved mainly P-32, and the area was surveyed on a routine basis. Building 40 is the only building remaining in the East Area, and plutonium is detectable in the floor grates of this building.

During D&D of building structures in the East Area, Argonne had to remove pipes and material that had leached out of the piping, sometimes digging to a depth of 20 feet. The original Quonset huts were supposed to be used for 10 years but were used for much longer. The decontamination

and decommissioning of the area in the early 1980s was completed by site personnel; however, ANL brought in an outside contractor for verification.

The New Brunswick Laboratory (NBL) was moved to Building 350 at the ANL site. NBL was considered a separate facility and had independent HP services, but used maintenance and other services from Argonne. Entry into this area required a clearance and an escort.

Argonne has been heavily involved in accelerator operations over its history. Accelerators have never all been operated under a single accelerator division. ANL is run by a university in a university style with loose associations among the different divisions at ANL and with little centralization, unlike most DOE production facilities.

Among the accelerators at ANL-E are the following:

- Argonne Tandem-Linear Accelerator System (Bldg 203)
- Tandem Van De Graaff (Owned by the Division of Education Program)
- Intense Pulse Neutron Source (Bldgs. 375 and 391 with an office complex at 360)
- Advanced Photon Source (400 Area including support buildings)
- Electron Linear Accelerator (Bldg. 211) (Chemistry Division)
- 3 MeV Van de Graaff (Bldg 211) (Chemistry Division)
- Argonne Wakefield Accelerator (Bldg. 366) – This accelerator is experimental technology and is itself the experiment.

Building 211 housed the cyclotron that was used to irradiate items that were then sent to Building 200 for further work. This unit has been dismantled and removed.

The IPNS Division operates the Intense Pulse Neutron Source accelerator. The Advanced Photon Source (APS, 400 Area) is Argonne's largest accelerator facility and was operated by three separate divisions. The Argonne Tandem-Linac Accelerator System (ATLAS) facility is operated by the Physics Division.

Each accelerator was designed for a different purpose, as described below:

a) Tandem Van de Graaff Accelerator – This accelerator is a demonstration tool for students, teachers, etc., and is a small accelerator facility. The accelerator uses electrons to hit a target. The unit runs about two weeks per year and involves one physicist and one operator.

b) Intense Pulse Neutron Source – IPNS creates beams of neutrons which allow scientists to see nuclear structures by bouncing neutrons off the nuclei of elements.

c) Argonne Tandem-Linac Accelerator System (ATLAS) – ATLAS Scientists are using ATLAS to study nuclear physics, and structural behaviors of nuclei, and the system runs throughout the year. Heavy ions are accelerated at a target to form new radionuclides, and radiation detectors are used to verify and evaluate their existence.

d) Advanced Photon Source – The APS is an electron synchrotron that provides bright beams of x-rays that can be used for all types of experiments that allow scientists to see molecular structures. The APS does not have a target area to generate other particles, as at IPNS. The process facility produces x-rays that exit the storage ring and are directed to experiment enclosures. The x-ray beam energy can be finely tuned through use of magnets. It is like a super microscope that allows researchers to see at the atomic or compound level. It has been used to study viruses and perform pharmacology and geology related work.

The Van de Graaff Accelerator in Bldg 208 is not currently operational but was used historically staring in 1956. The Linear Electron Accelerator Facility in Building 211 is an electron linear accelerator (LINAC). The ZGS unit began operation in the 1960s and shut down in the 1980s. These accelerators were not used to produce isotopes such as medical isotopes.

At the IPNS there is a potential for induced activation of components, structural material, and the air. Personnel are required to wait at least 30 minutes after the shutdown of the beam prior to entry into the area. In the case of corrective maintenance in the beam area of the accelerator, a cooldown period of four days is required. There is a process under which Health Physics performs a comprehensive survey with measurements at 30 cm and at contract. In the past, levels up to 1,300 mR/hr on activated components have been seen. The general radiation level on components inside the IPNS rapid cycling synchrotron tunnel ranges from 10 to 700 mR/hr at 30 cm from the source.

At IPNS, the highest induced activity is at the target and its surrounding shield materials. The target at IPNS is composed of depleted uranium. To change the target, a remotely handled crane pulls it from the chute and puts it into a shield. The shield is moved with a crane and placed on the floor over a storage tube. The target is then lowered into the storage tube, where it can decay until it is ready to be disposed to a radioactive waste facility. IPNS has three targets which have a set life span (on the order of a few years) and must be changed out at the end of their lifetime. There have been predictive calculations and characterization measurements to identify activated material at IPNS. In general, activation is of iron, copper, aluminum, and structural material. Radionuclides such as Co-60, Co-57, Co-59, Mn-54, Na-22, Na-24, and V-48 and lower levels of Fe-55 and tritium are expected. There is some airborne Be-7, but having removable contamination in the facility is unusual. Smears are taken on components and storage tubes and full protective clothing with a Power Air Breathing Respirator is used when opening up a vacuum, water, or target system.

Technicians measured gamma dose rates at 2–3 times background when they were trying to conduct release surveys on clean equipment and materials about 30-50 feet outside the IPNS Building. This areas is not typically occupied, but is posted.

APS has three scheduled shutdowns per year. There is an entry survey prior to allowing individuals to enter the beam area. At APS, the activation occurs at septum devices used to split the central beam into multiple beams. The major activation products are Na-24 and Co-60 with Mn-54, Co-57, and Fe-55 in smaller quantities, resulting from photoneutron activation that occurs with constituents of steel, aluminum, copper, and epoxy.

ATLAS is a low intensity accelerator, and personnel can stand next to it when it runs. There are continuous gamma and neutron monitors in the area to monitor radiation levels, and daily radiation surveys are conducted at this facility. When light ions (i.e. mass less than C-12) are accelerated, ATLAS has a greater capability to generate neutron radiation. When it is running, there are special radiation surveys and access to the area is secured. The authorized user is responsible for assuring that the area is secure. There is a system that monitors integrated dose and when it reaches 10 mrem over an 8-hour period, the individual must exit the area or the beam shuts off automatically. Periodic maintenance is performed on the accelerator.

There are no residual contamination areas at APS or ATLAS. The ATLAS facility had a situation where they discovered that radiation was periodically produced when a dipole magnet was turned off, and the beam hit a quartz window on the end of a vacuum line. Measurements were made with an area monitor to determine the radiation loss point. An area dosimeter put in place for about three months, placed at eye level, indicated a positive gamma exposure, likely from Bremstrahlung radiation. It is not known how long this condition may have been present.

As a part of the Radiological Assistance Program team, technicians work with Cf-252 and AmBe sources. Other neutron generating sources have included a RaBe source in Dynamitron area (Bldg. 203) which they disposed of. The source gave off more gamma than neutron (1.2 R gamma and 40 mrem neutron).

Support Services

There were five satellite shops and one main shop onsite. The current “hot shop” is located in Building 212, and there were also hot shops in Buildings 16 and 17 in the East Area. There were glove boxes built around the machines except the saw for machining plutonium and depleted uranium. Saws were used to cut depleted uranium into pucks to be used as targets at IPNS. The pucks were put into buckets by the HPs and carried to the needed location. There was machining of beryllium, thorium, and likely sodium in this area. The shops were equipped with lathes, mills, grinders, wire Electrical Discharge Machines, and other equipment. The inspection department used an x-ray machine in the East Area in the late 1970s/early 1980s. There were hoods for machining beryllium, and beryllium machining was always separate from uranium. When they shutdown Building 17, they removed the machines and buried them. Some facilities such as APS had multiple shifts or on-call maintenance personnel.

The maintenance individuals (e.g., Maintenance Mechanics) in some areas did their own welding. Large jobs were sent to the Central shops. Only certified welders could verify welds, which was done at the machine shop. There were also outside contractors who performed welding.

Maintenance personnel have entered pits, caves, air handlers, cleaning towers, etc. Some of these areas are posted radiological areas and/or confined spaces. Maintenance personnel also service laboratory and sanitary drain lines. Jobs associated with higher external or internal radiation exposure were crane repairs or Building 212 cell repairs. For cell entries, HP required personnel to suit up. There is HP coverage at these jobs, but such coverage is not required for all maintenance jobs.

One of the duties of riggers at ANL was to operate the cranes used to move shielding blocks, targets, magnets, etc. One individual had to be up in the cab of the crane and another down on the floor or at the shielding blocks to attach the object to the crane. There were many crane operations done in the past, with most of the work taking place during scheduled shutdowns. Other shutdown work included adjusting magnets, moving concrete shielding, and maintaining power supplies. There was some work conducted during operation of the ZGS. Crane operations resulted in riggers receiving some exposure.

Transportation personnel serve as escorts for drivers moving Special Nuclear Material (SNM), and there were times in the past when security escorted movements of SNM. Small amounts of material were transported in 5 gallon cans. Drivers were responsible for moving larger quantities of SNM which could not be hand carried. The riggers were responsible for loading and unloading the truck, and the drivers secured and transported the load.

Maintenance Mechanics performed maintenance and repair on air handlers, pumps, repairing chillers, and other equipment, and provided maintenance support to the infrastructure of the facilities. They also conducted water testing, changed oil on pumps, and cleaned out grease pumps. Some personnel, such as personnel in the Elevators and Cranes group, held jobs that took them all over the ANL-E site.

Among the responsibilities of painters was painting contaminated areas using yellow and magenta paint. This work was hands-on and led to contamination in some cases.

Work orders were generated for maintenance jobs. If a job required work with radiation or other hazards, some kind of paperwork was generated. For example, job safety analysis reports have been done for maintenance jobs, and some records go back to initiation of the facility. These documents were kept in the foreman's office. At some point, the job safety analysis documents were archived. There were also confined space and hot permits, in addition to Radiation Work Permits.

The primary responsibility of Firefighters/Paramedics is to respond to emergency situations, and they have access to every building onsite. The Fire Inspection Division is responsible for inspecting fire extinguishers, as well as the valves and stand pipes on the fire systems. These individuals entered radiological control areas, as needed, using the required precautions for the area. The firefighters had to know the locations and layout of buildings but the Battalion Chief kept/keeps an eye on what his staff is exposed to, because the staff themselves may not know all hazards in each building.

Radiological Control

At one time, the Radiological Control (RadCon) group was centralized, but Health Physicists could be assigned to a particular building. Health Physics Technicians reported to the area Health Physicist, who in turn reported to the Department Director for Health Physics. New technicians were rotated throughout all the areas onsite so they would be familiar with the radiation hazards at various facilities. With a change in RadCon manager, the Health Physics staff was "matrixed" to a particular division with a Central Group under the Chemical Technology Division. Currently, Health Physics is under the Environment, Safety and Health/Quality Assurance Division, although this is scheduled to change.

There has been a general improvement in radiation protection programs over the years. The checks and balances for radiation safety and the procedures have tightened up. The whole safety culture has changed over the last 10–20 years at Argonne, particularly after the Tiger Team audit. There is more training and awareness of hazards and new equipment has improved the monitoring capability. Personnel Contamination Monitors (PCMs) arrived about 1991 or slightly after. There has been good HP coverage, and (according to the interviewees) ANL-E has one of the better programs among the Department of Energy (DOE) facilities.

ANL has reduced the annual exposure limits over the time of operation of ANL-E. In 1976, the annual limit was 5 Rem per year with a lifetime limit of 5 (N-18). The DOE issued a directive in the mid-1990s stating that the DOE annual limit would be 2.0 rem per year. Argonne chose to set this level at 1.0 Rem per year for most areas of the laboratory and 1.5 rem per year for Alpha-Gamma hot jobs.

The workers receive more safety training as a result of the improvements made in the health physics program. Radiation worker training (i.e., Radiation Worker I or Radiation Worker II) is required for entry in radiological areas, with retraining every two years. Facility-specific radiological safety courses are required for those individuals who access the tunnel at the APS. The training courses for APS are ESH738 or ESH700, and ESH707.

In 1976 the technicians were using an Eberline® Portable Alpha Counter (PAC) -3G alpha/beta detector with a 61 cm^2 probe which ran on propane, and a Geiger Mueller counter. They later implemented the PAC-4G with gas-sealed probes and the Pulse Rate Meter (PRM)-5-3 with the PG-2 Probe (sodium iodide detector). This detector was set up to look for the 17 keV, 60 keV, and 185 keV photons from plutonium, americium, and uranium, respectively. At one point, they used it to try to find a lost plutonium source; however, it did not have the required detection capability to be successful. The ASP2E Detector used in the pulse-height analysis mode and the gross count mode was also used for detection of low-energy photons. Gamma dose-rate instruments used were the Juno (historically), RadOwl, and Panoramic 770.

At one time the HP Instruments (HPI)-1010 and HPI-1030 were used to look at gamma-to-neutron ratios. One instrument was used to determine the total and a Juno was used to determine the photon dose. The difference was determined to be the neutron contribution. There were areas where they had to be concerned about pulsed fields. There are Mini-Radiacs on the fire equipment in case firefighters have to use them in an emergency. The survey results are periodically sent to archives.

There are high-volume air samplers, referred to as High-Q's, that operate at up to 200 liters per minute, and low-volume samplers that run at up to 40 liters/minute. Air samplers are positioned near the breathing zone. In 1976, the air sampler used was a Filter Queen (made from a vacuum cleaner). An HV-70 2.5" × 12" asbestos filter was used as an air sample filter. This material was also used for smears. These units were operated whenever and wherever necessary. For example, three per day would be operated for 8 hours in Building 203 for all the radiological areas. Certain areas such as Buildings 205 and 212 operated continuous air monitors. The unit determined the alpha-to-beta ratio to distinguish between radon and other alpha. The filters were changed on a weekly basis; and unless the continuous monitor indicated, the filters were not sent to the lab for analysis. Air flow studies were conducted for the placement of air samplers in the Building 212 load area and at the Alpha/Gamma Facility.

There has been some lapel air sampling during D & D operations (e.g., grinding concrete). The samplers were used primarily for verification sampling because of the low volumes of air collected. There is an area on the Air Sample Sheet (ESH-38) to list Derived Air Concentration (DAC) values, but person DAC-hour tracking wasn't done. Currently, lapel samplers are used for industrial hygiene sampling.

There are varying levels of As Low As Reasonably Achievable (ALARA) evaluations based on several criteria. An ALARA review must be conducted in advance of operations where the dose rate is greater than 1 R/hr at 30 cm. At 10 R/hour an ALARA Committee review is required.

Contamination control was done primarily with the use of engineering control, followed by administrative controls. Engineering control systems such as ventilation systems with High Efficiency Particulate Air (HEPA) filters and shielding have been implemented to reduce personnel exposure. ANL-E does testing of these systems and changes the filters when necessary. Eating, drinking and smoking have never been allowed in radiological areas. Some areas have hand and foot monitors or personal contamination monitors at exits to controlled areas. When these monitors are not employed, a Health Physics Technician is available for a manual contamination survey.

Entry into systems in controlled areas requires that a survey be conducted for loose or residual contamination prior to performing work. In the past, residual contamination was found during invasive work on non-radiological areas in Building 369. As a result, Health Physics implemented pre-job surveys in non-radiological areas prior to work on internals of systems. When contamination is found, it is cleaned up.

In the plutonium areas, personnel wore Tyvex suits, shoe covers, gloves, hoods, a respirator, and a dosimeter. Workers indicated that all openings in protective clothing were taped shut, and the personnel protective equipment is/was consistent among workers doing the same job. There was an increased use of shoe covers in all areas after the Tiger Team visit.

Several types of special radiological controls are implemented at the accelerator facilities to accommodate the differences in the facilities. The APS and IPNS have interlocked entry systems, and accelerator operators must perform a "search and secure" or "sweep" procedure for each area where the beam may be sent. The interlock system forces the operators to walk through each beam line and activate a series of switches that are mounted throughout that area in

a specific sequence to prevent occupancy when the beam is activated. As operators exit the enclosure following the "search and secure," an alarm or warning will sound inside that area. If individuals have been missed, this alarm will indicate the approaching activation of the beam. To be in the area with the beam on would require someone to intentionally ignore the safety rules and alarms.

Some of the smaller accelerator units operate with an authorized user who controls access to the facility. For example, to enter the Building 375 experimental hall, an individual must have card key access and be current on training.

Another element of the radiation monitoring program is the use of "area monitor" dosimeters that are similar or identical to the personnel dosimeters. These dosimeters are placed in specific locations where elevated radiation levels are possible, or where people may spend significant time. The dosimeters enable health physicists to monitor very small changes in the radiation levels over long time periods. Also, Area Operators who are responsible for maintenance of the accelerators check systems and record the information (operating or not operating).

A comprehensive design validation study was completed for the APS. Health Physics selected specific locations where the particle beam could be deliberately misaligned to strike the vacuum pipe and generate a worst-case radiation source. During this process, the radiation levels were measured outside the shielding in order to verify the shielding integrity. Staff went through a validation process to determine whether the shielding worked and the design was adequate. The goal was to maintain dose less than 200 mrem in a year. The beam was deliberately misaligned to test the shielding in various areas. This is also done when new hutches (experimental enclosures) are brought online to check the seams, shielding, etc. Most of the measurements took place after 4:00 p.m. when a majority of workers had left. The validation used the full beam, which is not done during routine operations. The results were reviewed each morning to determine if additional shielding was needed. Measurements were conducted along the entire storage ring. Health Physics worked very closely with the accelerator physicist. The physicists were responsible for design, doing the modeling, and tuning the beam. In order to direct the beam, they determine specific settings for the magnets and other components. At the beginning when physicists were operating the beam, there was tweaking that had to be done. During the validation, Health Physics told the physicists what they wanted to do and the physicists figured out how to do it. The results of the measurements were transmitted to the management in a memo and the survey data are kept at APS.

The most serious radiological problems or challenges at ANL occur at the Alpha/Gamma Hot Cell Facility (AGHCF). The fuel undergoes examination in a hot cell where it is remotely manipulated. The AGHCF is used to store spent fuel in the hot cells, causing a dose rate in the middle of the corridor of 0.5 mR/hr. The hot cells are kept under a nitrogen atmosphere. There was a pay phone in a location outside the facility where the dose rate was 0.5 mR/hour. When this was discovered, the pay phone was moved. The laboratory director shut down the Alpha/Gamma Facility. The area now has active effluent monitoring.

There were certain activities and practices of which the technicians were aware. For example, a metallurgist working with uranium smoked in his work location. Some individuals wanted to get their work done at all costs and would shortcut the safety requirements. (For example, a few

individuals, to prevent excessive exposure recording, would put their dosimeter in a shielded location because they were working with really hot stuff.)

External Dosimetry

The dosimetry and bioassay requirements are determined by the Area Health Physicist based on an employee's potential for exposure. The frequency of dosimeter exchange was job dependent. Health Physics Technicians, Firefighters/Paramedics, and maintenance and craft interviewees reported they were on a quarterly thermoluminescent dosimeter (TLD) badge exchange. Individuals with a higher potential for exposure are put on a monthly or biweekly exchange.

Dosimetry with neutron capability is used at IPNS and ATLAS. The IPNS is the only current accelerator facility with significant radiation exposure. It is the only location where site neutron exposures are found, except during waste management activities.

Until last year APS also used neutron dosimetry; however, since there were no positive neutron results for individuals working there, the program was discontinued. Previously, Health Physics looked at 60,000 dosimeters worn by APS personnel since startup. Since the first evaluation, they have looked at 6,000 additional dosimeter results. Sixteen individuals who wore dosimeters from April 1 to September 30, 2005, had positive dosimeter results ranging from 10–32 mrem. These individuals wore their dosimeters for a period of six months, which is longer than the typical 3-month wear period; thus, the dosimeters had twice as long to accumulate radiation exposure that added up to more than the 10 mrem threshold.

The ANL-E albedo dosimetry is currently accredited (accreditation effective November 2006) by the Department of Energy Laboratory Accreditation Program (DOELAP). The current dosimetry staff does not have access to complete files on the past accreditation. However, copies of certificates for albedo dosimetry dated August 2001 and March 2003 are available.

Employees were given an alarming dosimeter to tell them when they reached a preset level. Prior to the existence of alarming dosimeters, ANL used the Shonka Pocket Ionization Chamber (range 0–200 mrem) and/or chirpers. Workers reported using pencil dosimeters for work in areas of Buildings 200, 205, 212, 331A, and 350 (plutonium/uranium corridor). Residence time in areas was not routinely recorded. There were times when individuals in Building 212 were told not to take any longer than they needed to.

Riggers at ZGS were always working around the beam lines. They routinely came in and out of the building, including going into the target area. Targets were concealed by concrete, and there were interlock doors on these areas. Experimenters in certain areas who were working with the target had magenta lights. There were Radiation Area Monitors located in the areas that sometimes sounded when the beam went out of alignment. Riggers were assigned pocket ionization chambers (PICs) [pencil dosimeters] along with their regular dosimeter. A log was kept of PIC data. Radiation Protection set daily, monthly, and semi-annual limits for riggers, and if an individual exceeded this limit, he/she was pulled from the area and assigned to a different area for six months. Individuals were routinely rotated into and out of certain areas (e.g., 369, 370, 375, 376 (Powerhouse), 371).

Extremity dosimeters are assigned as needed, such as when conducting hands-on work at IPNS. In the case of machinists, fingers rings were available, but could not be worn while machining to avoid the rings getting caught in the machinery.

Some interviewees indicated they were initially on beta/gamma dosimeters, but at a later date were switched to TLDs with neutron measurement capabilities. They indicated they had beta/gamma and neutron monitoring. The interviewees indicated they were formally assigned a beta/gamma dosimeter, but when working at the IPNS changing targets, neutron monitoring was added to their badges.

Neutron dosimetry was definitely initiated by the time ANL started CP-5. There has been little neutron exposure in Building 203 since the startup of the ATLAS accelerator (which probably occurred in or near the 1960s). Historically, neutron film was not read unless the individual received at least 100 mrem gamma dose.

Neutron doses were possible at IPNS, CP-5 (Research Reactor 59-79), CP-2 (Site A) and CP-3 (Site A). Neutron doses from IPNS are reported differently than at other locations because of the difference in the neutron spectrum at that facility. Neutron dosimeters are calibrated using a Cf-252 source which is not identical to the neutron field at IPNS. Correction factors for selected locations have been applied to areas with very high neutron energies in the last few years, based on studies conducted with a rem meter and neutron badges. These results were used to develop a correction factor which has been applied for about the last year. For the IPNS occupied areas, a 0.7 correction factor is applied to the neutron dosimeter results based on Department of Energy DOELAP requirements. There is no compensation for low-energy neutrons. One source of neutron exposure other than IPNS was the calibration facility, which had an AmBe source and APS, but only in unoccupied areas. Workers were directed to wear their badges face out between the neck and the waist. Many wore their badges clipped to their shirt. Film badges actually had filters on both sides of the film. Neutron dosimetry has always been incorporated into the beta/gamma badge as one unit. Badges were stored onsite when workers left for the day.

In the last few years, correction factors for selected locations have been applied to areas with very high neutron energies. There were studies conducted with a Rem meter and neutron badges. A comparison of the two was done at the Intense Pulse Neutron Source to determine the relative responses. The results were used to develop a correction factor, which has been applied for about the last year. For the IPNS-occupied areas, a 0.7 correction factor is applied to the neutron dosimeter results based on Department of Energy Laboratory Accreditation Program (DOELAP) requirements. These dosimeters are calibrated using a Cf-252 source, which is not identical to the neutron field at IPNS. There is no compensation for low-energy neutrons.

The CR-39 was used for supplemental monitoring, but was not used as the dose of record unless the exposures were significantly high. Although they have not been evaluated, there were records stored at Building 202, which may contain information on neutron dosimetry.

DOE always frowned on assigning multiple badges to an individual during the same cycle. This practice was also discouraged by ANL, but in some cases individuals could have more than one badge at a time. In general, the PIC result was not considered a valid dose of record if the person also wore a TLD or film badge. If individuals went to a building other than their primary work

location, they could pick up a PIC to monitor radiation dose while visiting the building. If an individual wore only a PIC, this dose would be added to the whole-body dose from the TLD or film badge. If an individual wore both a PIC and a TLD or film badge, however, only the results from the TLD or film badge were used. Visitors to a radiological facility also used PICs and results of these PICs were added to the whole body dose of record. Subcontractors were badged according to the same criteria as employees.

There were times when TLD readings had to be investigated and doses estimated. If there is a high dose on a badge, an investigation is initiated, and eventually a coworker dose is assigned. Investigation reports are currently conducted on badge results above preset levels (> 100 mrem), when badges are lost, or when there is an occurrence in the field. In the 1950s, workers were allowed 300 mrem/week. If an individual exceeded 300 mrem, an investigation was conducted. During that period, the limits were 15 rem per year whole-body dose. Later, this was changed to 12 rem per year and no more than 3 rem per quarter. Investigations for lost badges go back at least 20–30 years and investigation reports provide the names of workers.

As a result of the visit by the Tiger Team, an annual dosimetry report is now provided to workers. In some cases, workers are told more frequently about their exposure. Most interviewees indicated to SC&A that they received zero doses. A few workers indicated they were not informed of the results of the bioassay samples.

Internal Dosimetry

Radiation Protection is responsible for determining the bioassay requirements. These determinations are arrived at on a case-by-case basis from characterization information provided. A combination of urine and fecal sampling is done at ANL-E. Interviewees reported submitting urine samples when working in Building 205 (Chemical Materials Technology Building), G-wing, and K-wing specifically. A baseline bioassay sample is collected when an individual is hired, upon termination, and when incidents occur. Bioassay-900 Forms that specify routine bioassay requirements are submitted to the Bioassay Group by the scientists in each area to identify radioactive material with which individuals are working. There has been a decrease in collection of bioassay samples over time. Interviewees have reported being changed from a quarterly to an annual bioassay frequency for long-lived radionuclides, such as actinides. Now ANL-E is collecting pre- and post-job samples for individuals entering controlled areas only periodically.

Early bioassay included collection of bioassay during the Proof of Breeding Program. Twenty-four-hour bioassay samples could be routine or special. For fecal sampling, the worker collected 24 hours of fecal elimination and for urine sampling the employee collected one liter. Instructions for collecting bioassay samples were provided in the sample kit and sample containers were taken home for collection.

Currently, air sampling data are used as a trigger for special bioassay (urine and fecal) sampling. When there is an indication of positive exposure or a problem on the badge, Health Physics will ask for a bioassay sample. Workers are rarely restricted from work as a result of a positive/high bioassay result. Work restrictions by the responsible line organization can be enforced for those who have positive fecal samples by altering the employees' pass to enter particular areas.

The Environmental Sample and Bioassay Laboratory was and is responsible for urine, fecal, and in vivo bioassay measurements and is separate from Dosimetry group who performs dose calculations. Bioassay samples from the mid-1960s were analyzed for gross alpha, beta, and gamma. Liquid scintillation counting is performed on some urine samples with results obtained for high, medium, and low beta energies. The lowest energy window is assumed to be tritium. Uranium bioassay (U-234, U-235, U-238) has always been a part of the bioassay program, and americium bioassay has been around for a long time. Curium-244 bioassay has been added to the general curium bioassay in the last couple of years. There has also been was also a program for Pu-238 and Pu-239.

Interviewees indicated they did not receive routine *in vivo* counts. In one case, an interviewee had a single bioassay during the middle of his career. He received a body count as a result of this bioassay sample coming back positive. He was counted at the Iron Cave (2–3 years ago) which they had to reactivate at the time. The body count results were negative.

The in-vivo counter is located below grade in Building 203 to reduce the background. The in-vivo counter was calibrated to assign quantitative values for radionuclides evaluated. In-vivo counts were discontinued some time ago.

There is no routine monitoring for occupational radon exposure. At one time, Radon Breath Analysis was used on employees as a study. Following the radium vial breakage during the D & D of the cyclotron in Building 211, individuals involved were sent to the body counter. The radon from this incident went out the stack. Environmental Monitoring hooked up a special radon monitor on the exhaust stack supporting L-wing (which building) to monitor for radon releases.

Environmental Monitoring and Waste Management

Initially, Environmental Monitoring and Waste Management were under the ES&H Division. They were later moved to a separate division, and are now under the ES&H Division again. Fairly early in the 1950s, Environmental Monitoring was separated from the HP program. Pre-operational samples (i.e., soil, animals, plants, water, etc.) were collected from the area in 1947, but the analytical results from this study are unavailable. The formal monitoring program was started in 1948 or 1949; however, the real semblance of an environmental monitoring program was not seen until the 1950s. From its birth through the late-1980s, employees in this group were responsible for collecting and analyzing samples and preparing environmental reports. Sampling and analysis for radionuclides were performed on air, surface water, sediment, soil, plants, animals, and milk. Groundwater monitoring started formally in the late 1980s, primarily for non-radioactive materials. In the 1980s, environmental laws were passed that resulted in an expansion in the sampling. All analytical activities for industrial hygiene, health physics and environmental monitoring were under one organization (the Analytical Laboratory). Sampling for both radioactive and non-radioactive materials came into the monitoring program. Originally the monitoring group was known as the Background Group. The group is currently called the Monitoring and Surveillance Group.

There has been extensive characterization for remediation at the ANL Main Site. The basis for the characterization changed in the 1980s from purely radiological in nature to permit-related.

The initial list of Solid Waste Management Units included 800 areas needing remediation, but it was later reduced to 56. During the historical site assessment, there were interviews with former employees to identify trouble areas. Geophysical surveys were also conducted to identify areas. Other areas were identified through word of mouth (e.g., burn pits) or through monitoring data. Two of these 56 sites are radiological sites and the remaining 54 are chemical sites. The long-term stewardship program is focused on organics in the groundwater.

The East Area was torn down in the late 1980s. During the 1940s and 1950s, there was a fair amount of radioactive material used here. Areas such as the 317 and 319 French Drains were contaminated with Volatile Organic Compounds (VOCs) and tritium. These drains were used to discard liquid wastes and underwent remediation. ANL brought in remediation and drilling subcontractors who used large mixers and agitated the soil down to 30 ft. and added metallic iron to remove the organics. In conjunction with this effort, the lab remediated internally contaminated buildings. There is routine permit monitoring and ongoing remediation for areas left in place.

A waste management area was established in the 317/319 Area where containers of material were brought, packaged, and shipped off site. There were six underground storage structures for remotely handled waste, of which one remains; it is currently unused. One method used for VOC decomposition and tritium remediation is pytoremediation.

Sampling went on at Site A and Plot M until 1976. Plot M is the waste burial ground and is still in existence. Hazardous waste was buried at this location, and there was an informal sampling program for the area that identified uranium in some surface samples collected. In addition there was a picnic well at the Red Gate Woods picnic area that was sampled, and results indicated the presence of tritium. Samples results for this program have been identified back to 1954, and there is now biennial monitoring of this area. The Illinois Department of Nuclear Safety was taking samples at Site A/Plot M and found a hockey puck piece of uranium oxide in 1990, which led to another characterization of the area.

Stack monitoring has always been the responsibility of the individual facility. During the proof of breeding project (200 M-wing), Rn-220 was the major source of releases. Upon completion of this project, IPNS became the major source of emissions onsite. The laboratory has met the requirements for National Emission Standards for Hazardous Air Pollutants since 1990.

The first environmental report released by ANL-E covered the years 1948 through 1952. Generation of environmental reports was voluntary up to 1972, and environmental reports for Site A are available on the ANL public website.

Most of the environmental sampling stations are onsite. The air monitoring network consists of 11 samplers around the perimeter and four offsite sampling locations. This allows for comparison of onsite and offsite concentrations. There was a significant upgrade in the air monitoring network in the 1990s. Meteorologists were used to determine the best locations for the stations, and new equipment was installed. Air samplers are run continuously at a high volume.

Environmental sample analysis included determination of gross alpha and gross beta activity. As the technology improved, there was a transition to isotopic results. At the present time they are analyzed for transuranics, uranium, and fission products. Tritium analysis was done by Liquid Scintillation Counting starting in the 1960s. There was an ongoing dialogue with HP to characterize the environmental monitoring samples. For the last 25 years, no radioactivity above background has been detected in soil and vegetation just outside the fence.

The laboratory has a dual waste water treatment system. The sanitary sewer system is kept separate from potentially contaminated water. Discharges from the various labs onsite go into a retention basin, and if the material is less than a preset value it is discharged. Any building with the potential for handling radioactive material has a retention tank and HEPA filters. The Dolomite Well water is monitored on a quarterly basis. The laboratory continues to monitor the original set of wells. There is no indication of movement of radioactive material, which is aided by the fact that the soil is made up of very dense clay.

Burn pits were used in the 1950 time frame. ANL had an incinerator; however, it was not intentionally used to burn radioactive waste. There was a combustion facility in Building 206 used to clean up contaminated sodium. There is a burn pit behind the fire stations where they burn flammable liquids to train personnel how to use fire extinguishers. Building 26 served as a training facility where they would burn pallets and other materials to practice firefighting. This is scheduled for D & D.

The Environmental Research Program is a separate organization from Environmental Monitoring and is responsible for conducting environmental studies, writing environmental impact statements, and providing support for offsite environmental activities. The Environmental Research Program is more the programmatic side of the house, while Environmental Monitoring is on the support side of the house. There have been studies to evaluate the behavior of radionuclides in the environment, such as burying fuel waste from Three Mile Island to study leaching.

There are several environmental assessments available. DOE's Assistant Secretary initiated a study to determine environmental vulnerabilities across the DOE complex in the 1980s. In 1987, teams similar to the Tiger Team were formed to assess the environmental issues at DOE sites, and the Tiger Team visited ANL in 1990s.

Incidents and Unusual Occurrences

When a contamination incident with injury occurs, the paramedics receive a call. The individual informs the paramedics as to whether they are getting high instrument readings for alpha/beta. A precursory survey is completed with a Ludlum 3 and Health Physics is contacted. The injured individual is primarily decontaminated in the field by the Fire Department personnel with the assistance of Health Physics, who performs a more comprehensive survey. If there is an injury, significant exposure or a break in the skin, the individual is taken to Medical by the paramedics, accompanied by Health Physics. The wound is counted with a wound monitor by Health Physics. The wound is rinsed either into a container or into the retention tank beneath the Medical Department. Shampoo or baby wipes may be effectively used as decontamination agents without creating excessive radioactive waste. Rinsing and cleaning of the wound

continues until the count is at background. Medical completes a form on the incident which is shared with Health Physics and the Medical Division, as well as with Environment, Safety and Health/Quality Assurance. Each time a call is received by the Fire Department, a Response Report and an Incident Report are generated by the Fire Department. The official Medical Report (Mobile Intensive Care Unit Report) is sent offsite to Loyola. In the earlier days, the MICU was not always filed.

Several incidents were mentioned during the course of interviews.

- In the 1950s, there was a Ra-226 source used for calibration in the G-Wing of Building 203. A pneumatic-tube was used to pull the source up, and on this occasion the source ruptured as it was brought up. The radium entered the duct work and spread throughout the building. They were going to shut down the building but decided it was too expensive, so an attempt was made to decontaminate the area. However, there is still residual loose radium contamination found in inaccessible areas (e.g., ducts, electrical boxes, etc.) in this building today. Although they monitored for loose radium activity, it is uncertain whether monitoring was done specifically for radon and daughters at the time of the accident.

- In the 1980s, there was a spill of Pm-147 when a guard rolled over on his gun and broke the sight. Individuals walked through the contamination, and it was spread to other buildings, hotels, and cars. Many individuals were contaminated with Pm-147, including offsite officers participating in the exercise. After this incident, they converted to tritium sights on their guns.

- In Building 202 on the service floor, there was a polyvinyl chloride pipe that had corroded and a spill occurred. This pipe serviced the laboratories radioactive drain line, which led to a retention basin. Every time the drains were used, water would spill out of the pipe, and individuals tracked through the water. The water was later analyzed, and two radioactive materials were identified. The firefighters who responded were wearing personal protective equipment at the time and were accompanied by HP personnel. They were scanned out of the area, but no special bioassays were collected from first responders.

- In 1996 or 1997, Health Physics personnel did a characterization of the beam and conducted time-motion studies to determine an upper and lower limit of dose individuals may have received during an incident. As a result of the incident, the facility shut down.

- There was a shipment of depleted uranium which came in years ago. The material was off-loaded from the truck at Building 316. Those involved came up with contamination on their hands and straps/sling. They were taken to the decontamination room to decontaminate their hands and following decon, the contamination level was determined and they were released.

- There was once a spent storage area in Building 330 where fuel rods were stored in a pool. Workers were moving fuel rods from Building 202 to Building 330, and while transferring the fuel to the T2 cask those involved became contaminated.

- There was an incident in about 1980 or 1981 involving work on a reciprocating horizontal saw and cutting on the lathe at the same time. The routine practice was to flood the machined object with coolant to prevent fires. The machine ran out of coolant; sparks fell down into the chip pan and ignited the turnings, starting a small fire. The fire was put out with a CO_2 extinguisher. Sand was supposed be used to extinguish the fire. Health Physics was not contacted at the time. There were no urine samples, fecal samples, or nasal smears collected after the incident. No whole body or chest count was received. The area had a hand and foot monitor for use when exiting the area.

There were a few significant episodic releases from ANL facilities. There was a criticality in 1952, and in 1972 there was an explosion in a plutonium glove box. Twice there were heat exchanger failures at CP-5 which resulted in release of tritium from the reactor. A few iodine releases have occurred. Equipment was disposed of at the 319 area landfill, which was an undocumented landfill. The internals of the equipment were not surveyed for contamination prior to disposal. The laboratory found tritium in the ground water and soil when they were closing the area.

Occupational Medical Exposure

The medical department was formally established at ANL in the 1940s. The department was called the Health Division at one point. Eventually it was moved under the Human Resources Division, but was never a part of the Environmental Safety and Health Division. The Medical Department documented the number of physical exams and chest x-rays done annually. Since ANL was billed for reading films, Medical kept track of the number of films sent out.

Annual physicals were mandatory at ANL and included x-rays done onsite. From the 1950s–1990s, employees received annual x-rays. In the 1990s, Medical went to what was referred to as long and short physicals. During a long physical, chest x-rays were conducted; however, during short physicals they were not. The types of physicals alternate between years, with a posterior-anterior x-ray taken about every two years. Workers were given stereoscopic chest x-rays in the 1950s. They received a baseline chest x-ray (14 × 17” film) when they first became employed and still do. There were some spinal x-rays taken in the 1950s. The staff is not clear when this practiced stopped (possibly 1960). Additional x-rays were taken if there was a change identified in the x-ray indicating a medical condition. X-rays have also been taken as a result of injuries on the job. For example, one interviewee received a neck and shoulder x-ray and another received a left ankle x-ray as a result of a break and a back x-ray as a result of a back injury. At least one individual recalls receiving a retake of a chest x-ray. Access to the x-ray room was limited to the worker and the technician while x-raying. Reading services were/are provided by offsite doctors. The current staff is not aware of the application of photofluorography at ANL-E.

A more recent requirement is that a Job Hazard Questionnaire must be filled out by employees annually. All union personnel are required to complete these. This is probably also done for non-union employees. Copies of this report are provided to Medical and Industrial Hygiene. Based on answers on this questionnaire, individuals' physical and training requirements are determined. When the form was instituted, the frequency of x-rays decreased and became dependent on exposure conditions and age. It was noted that the Fire Department staff receive more extensive physical exams upon hire and annually thereafter.

The x-ray technician has the primary responsibility for taking x-rays. Until recently the nurse served as a back-up to the x-ray technician when chest x-rays needed to be taken and the x-ray technician was not available. This practice was discontinued based on regulatory requirements. There has always been an x-ray technician.

There have been three x-ray units at ANL. The latest General Electric (GE) unit located in Building 201 was acquired in about 1990 and replaced a GE unit. The earlier GE unit was located in other buildings before it was moved to Building 201. There was one unit prior to the earlier GE unit that was located in the East Area of the site. X-rays are taken at 110 kilovolt potential (kVp). The current x-ray unit uses photo-timing.

At the present time, ANL uses an independent health physicist to come in and do inspections of the x-ray unit on an annual basis. Calibration of the unit is done by General Electric. Source One does processor preventive maintenance every other month.

Chest x-ray doses are available since 1988. Up until a few years ago, the Food and Drug Administration did the inspections on medical x-ray equipment, and inspection reports are available back to 1988. There were also internal laboratory inspections which stopped a few years ago when the employee that performed them died. Before 1988, there wasn't effective quality assurance and record keeping. The laboratory has only the x-rays that have not held up well over time.

There are no teletherapy units or radiation generating devices in the medical department except the x-ray units. There has been no administration of radioactive material for diagnostic or therapeutic reasons. Based on the current staff recollection, there have been no chelations at ANL-E.

Historically, Medical and Health Physics worked in parallel and were minimally connected to one another. Medical records do not include bioassay and dosimeter information. Occasionally an employee's previous radiation exposure history arrives at Medical from an outside source. It is then copied and the original is forwarded to Health Physics.

Records

Internal and external dosimetry records, including old files, are located in Building 202. The dosimetry badge records go back to 1941, and are filed according to name, in alphabetical order. In about 1952 they were filed by payroll numbers, sequentially. Eventually ANL went to four-digit and later to five-digit payroll numbers. The External Dosimetry group has used six-digit numbers for some badges. The ES&H Coordinator maintains the incident reports for any safety incident. Dosimetry provided NIOSH with anything in the archived file for each employee. At one time data was on paper copies, but for the last few years data has been stored in a database.

Upon request, the medical file is retrieved from storage and a copy is made for the Department of Labor (Part E). For NIOSH, a list of the chest x-rays is provided for the employee. The Medical Department who provides the x-ray information has been under the impression that only chest x-rays were to be provided to NIOSH, and this is what has been provided. Other x-rays, such as spinal x-rays, were not provided in the information submitted. NIOSH did not clearly define the

exact information wanted from the medical files. The medical files also contain records of injuries, which are also not being provided.

Comments by Interviewees on the NIOSH Site Profile Documents

Note: ANL external dosimetry personnel reviewed sections of the external dosimetry TBD prepared by NIOSH and provided comments. The page number from the TBD is provided along with the statement about which the comment is made.

Pg. 9, *By the mid-1950s some film badge rings provided by a contractor were in use on at least a trial basis to supplement wrist monitoring.*

Comment: Staff do not recall use of rings in the 1950s. It may have been done for a small group of individuals independent of the dosimetry group.

Pg. 9, *Due to the labor needed to read NTA film, it appears that films were developed but not routinely read before 1960. Films were apparently not evaluated unless there had been a gamma dose measured for the same period (Dolecek 1981).*

Comment: Staff indicated neutron films were not read until the gamma exposure reached 100 mR. The "oil immersion" system of reading neutron dose was used from about 1954 to 1965 and then for a short period thereafter.

Pg. 10, *A new whole-body film badge design was put in place in 1962.*

Comment: Staff indicated use of the new whole body film badge started after the 1957–1965 [dosimetry] contracting period ended.

Pg 10, *This badge design was used for whole-body dosimetry until being replaced by thermoluminescent dosimeters (TLDs) in 1988 to 1989.*

Comment: Some film use continued for a "couple more years" for visitors and special assignments and area monitoring.

Pg. 10, *At least initially, NTA film was still added to the beta-gamma badges. The record is unclear exactly when NTA film was finally discontinued.*

Comment: Film use was fully discontinued after 1988.

Pg. 12, *In reference to Table 6-2*

Comment: The solid state track recorder was used only for about 25–30 people in 316.

Pg. 13, *Each card covers 1 wk.*

Comment: Each entry [row] on the card covers one week.

Pg. 14, *Routine dosimeter (ROUT DOS), rover dosimeter (ROV DOS), and film (BETA, GAMMA, and NEUT) results are shown. Each of these results is totaled for the year.*

Comment: ROUT DOS was a supplemental pocket dosimeter used when the film badge was worn. The ROUT DOS dose was not added to the film badge dose. The ROV DOS was worn when the user did not wear a film badge. The ROV DOS was added to the film badge dose to get total exposure.

Pg. 14, *Zeros in the section code column may indicate that the individual did not have a badge for that period.*

Comment: Blanks were used when there was no badge data.

Pg. 19, *Refer to Table 6-3*

Comment: Approximately 600 people stayed on biweekly exchange beyond 1973.

Pg. 19, *No workplace-specific calibration factors have been found.*

Comment: There were workplace-specific neutron calibration factors. IPNS had a different factor from other locations.

Pg. 20, *It appears that ANL-E did generally use different exchange frequencies based on job categories or being in a rack which had higher dose users, so assumption of a single frequency by time period is not reasonable. For example, some workers at the CP-5 reactor or in waste management or who were cyclotron operators received larger doses than most other employees. Every user of racks used by these higher-dose users kept a biweekly exchange frequency when the general exchange frequency went to monthly.*

Comment: ANL-E staff disagree with this statement. See earlier comment about Table 6-3.

Pg. 21, *If the dosimetry history contains a missing entry, this probably indicates that the individual missed the dosimeter exchange and that the next dosimeter includes the dose for both exchange periods.*

Comment: This was never done. An individual was always given a new badge for a new exchange period independent of whether he returned the old badge.

ANL-E environmental monitoring staff indicated the NIOSH environmental TBD was a well written document and that information contained appeared to be correct and comprehensive.

Miscellaneous

- The general scope of work at ANL-E has decreased over time as facilities such as the ZGS and IPNS shut down. This eliminated the source of exposure and the dose went down.

- Argonne has been involved in the Work for Others program providing support to other DOE sites. They provided support to anyone who would pay for their services. For example, the High Energy Physics (HEP) Division has built detectors for use in physics experiments at other laboratories. In the 1980s, HEP would calibrate Zeus Detector

Modules in a beamline at Fermilab. Argonne and Fermilab personnel have participated in safety assessments of the other lab's facilities. Offsite remediation activities have involved ANL employees from Waste Management and Health Physics.

- Overtime has varied on a seasonal basis but could range from 4–20 hours per week on average for some workers. Firefighters/Paramedics work a 56-hour work week.

- Subcontractor hiring is done now and was also done historically. The subcontractors were usually individuals from the construction trades.

- The Paducah Resource Center run by the Department of Labor held a Town Hall Meeting. Some of the issues brought up were eye opening. For example, in 1980 they were conducting beagle studies at ANL. The cages were located around the Janus reactor. One of our people made parts for this reactor. The cages were supposed to be free of radioactivity. NIOSH also organized a meeting with the union.

- There were historical issues with exposure to beryllium and asbestos. Machinists handled many chemicals (e.g., perchloroethylene, trichloroethylene, benzene). The machinists used half-face respirators for machining in the early days. Recently, there was a chemical exposure at the Building 202 that caused an acute response. In addition to exposed workers, it was reported that medical individuals handling those involved also developed symptoms. No respiratory protection was worn.

- Quite a few people have died from cancers, including some never heard of outside industry. About 50% of the shop personnel (hot and cold) have died of cancer.

- Chicago Pile-4 is the Experimental Breeder Reactor I located in Idaho. Chicago Pile-6 is one of the Savannah River Site production reactors.

References

Dolecek, E.H., 1981. *Response to "Dosimetry Records and Radiation Hazards Questionnaire," for the Department of Energy's Health and Mortality Study*, Oak Ridge Associated Universities, Argonne, Illinois.

ATTACHMENT 3: KEY QUESTIONS FOR NIOSH/ORAU REGARDING SITE PROFILE DOCUMENTS

Questions for NIOSH on Site Description (ORAUT-TKBS-0036-2)

(1) ORAUT-TKBS-0036-2 states:

Argonne National Laboratory was established on July 1, 1946, and this TBD is intended to cover the time period beginning on that date. The work was a continuation of that done by the Metallurgical Laboratory of the University of Chicago beginning in 1941 which is an Atomic Weapons Employer under EEOICPA.

How does NIOSH propose to deal with the period from 1941 to July 1, 1946?

(2) How does NIOSH propose to address potential exposures at Site A and Plot M prior to July 1, 1946?

(3) The New Brunswick Laboratory (NBL) moved to Building 350 at ANL. NBL was considered a separate facility with independent health physics services. How does NIOSH propose to address potential exposure to ANL support workers (e.g., maintenance, security, fire protection, etc.) who were on loan to this facility after its arrival at ANL?

(4) How does NIOSH propose to evaluate doses for those ANL individuals conducting offsite decommissioning activities under the auspices of DOE?

Questions for NIOSH on Occupational Medical Dose (ORAUT-TKBS-0036-3)

(1) The current version of the TBD (Rev. 01 PC-1, dated March 27, 2006) references ORAUT-OTIB-0006, Rev. 03 (ORAUT 2005b) as the substantial basis upon which it defines occupational medical doses. NIOSH should consider the need to substantially update Section 3.1 (Introduction) to further reflect that non-routine and out-of-sequence diagnostic screening x-ray exams also contribute significantly to medical doses, as shown in other site profiles. This TBD does the best to date to address this issue, but the message needs to be stronger to guard against missed doses.

(2) The TBD states that little if any early information was found regarding equipment manufacturers, models, examination techniques, and exposure rates prior to 1988. The TBD states that assumptions derived from ORAUT 2003 [a reference to the Savannah River Plant (SRS) TBD] are used as being claimant favorable. Operating parameters for the early G-E Unit are available in *Radiological Survey of the Health Division Diagnostic X-ray Facility* by Januska and Smith (Januska and Smith 1961). Why has the TBD excluded this site-specific information from the occupational medical x-ray exposure evaluation in favor of data from SRS?

(3) Sections 3.1 and 3.3 in the TBD state that limited evidence of use of photofluorography (PFG) was found after 1948. To the contrary, OTIB-0006, Rev. 3, as well as other guidelines, would seem to suggest that without documentation, one should always assume the use of the PFG for dose estimation in order to be claimant favorable. Furthermore, the early G-E unit had fluoroscopic capabilities at least as late as December 1958 (Januska and Smith 1961). The dose reconstructor should use a value of 3 Rem per year at least up through 1958. NIOSH should clarify the intent of this guideline and establish whether the premise of limited PFG use at ANL-E is justified.

(4) The TBD does not document any type of x-ray equipment in use prior to 1970. After 1970, two units are documented; however, little if any physical measurements on beam quality and exposure rates were made prior to 1989. Can NIOSH provide the physical measurement data from surveys prior to 1989? Can NIOSH provide the survey results after 1989 to substantiate the ESE values applied in the TBD?

(5) Section 3.5 of the TBD indicates that all organ dose estimates presented for use by dose reconstructors are based only on a chest x-ray for physicals. Prior to 1970, default doses taken from ORAUT 2005b were to be used. Without evidence of any beam exposure measurements prior to 1989, and more specifically before 1970, how can NIOSH substantiate that the tables and estimated organ doses are claimant favorable?

(6) The TBD does address whether lumbar spine (LS) x-rays may have occurred as a pre-employment exam up to 1960. Can NIOSH document that no LS x-rays were taken after 1960? Can NIOSH document any knowledge of the unit and techniques used to do pre-employment exams up to 1970? Were all pre-employment and annual exams always taken at on-site medical facilities, or were some applicants sent to the University of Chicago? Is there any documentation in medical records that any off-site x-rays were prescribed as a requirement of employment?

(7) The TBD states that uncertainty as described in ORAUT 2003 should be applied as a positive 30% when estimating doses to ANL-E workers. ORAUT 2003 does not discuss other factors in detail that may contribute to dose, such as poor techniques, retakes, faulty processing equipment, etc. Has NIOSH attempted to determine the additional contribution those factors may add?

Questions for NIOSH on Occupational Environmental Dose (ORAUT-TKBS-0036-4)

(1) ORAUT-TKBS-0036 provides a detailed description of environmental monitoring since 1972. Under Section 4.2, External Dose, the following statement is found:

At ANL-E, these doses could have been recorded by film badges before 1970, but references containing these data have not been found.

Has NIOSH attempted to compare operations at ANL-E prior to 1972 to those after this date to estimate perimeter doses from ANL-E operations?

(2) How has NIOSH taken into consideration activities conducted by the Environmental Research Program that evaluated the behavior of radionuclides in the environment by intentionally contaminating areas?

(3) Under Section 4.2, External Dose, page 10, the following statement is found:

In general, the highest TLD doses tabulated correspond to areas in which irradiated hardware is temporarily stored (i.e., 9H for the 300 Area). Personnel around or adjacent to these locations would normally wear badges, as did all personnel who entered areas or buildings where RM was used.

What indications does NIOSH have that what would "normally' happen did in fact happen?

Questions for NIOSH on Occupational Internal Dose (ORAUT-TKBS-0036-5)

(1) ORAUT-TKBS-0036-5 refers to ORAUT-TKBS-0036-2 in regard to radionuclides used on site. ORAUT-TKBS-0036-2 admittedly provides a limited description of the types and amounts of radioactive material used at ANL-E. What will be NIOSH guidance to dose reconstructors relative to:

1.a - Isotopic composition for U and Pu, Am etc., and also the magnitude of site activity.

1.b - The specific activity for uranium (enriched, natural, etc.)

.

According to ORAUT-TKBS-0036-5, if specific information is not available, the dose reconstructor should assume inhalation as a pathway of intake. This recommendation is not claimant favorable. Doses coming from the ingestion pathway should not be ignored, especially in the case of cancer to the GI tract.

(2) Actinides (i.e., Pu, Np, Am, Cm, Th, and Ac) in urine underwent radiochemical processing, followed by a gross alpha count. Workers could be exposed to a mixture of alpha emitters. How does the dosimetrist assign dose in cases where different alpha emitters may occur in the same sample?

(3) How is the dose reconstructor to differentiate between multiple beta emitters in samples evaluated for only gross beta? What default assumptions will be made in cases where it is not known what radionuclide an individual worked with?

(4) How does NIOSH propose to calculate dose from exposure to radon, actinon, and thoron in areas where radium, actinium, and thorium were handled?

(5) What direction is provided for the assessment of dose from exotic radionuclides, such as Pa-231, Po-210, Cf-252, and other transplutonium elements?

(6) The uncertainty in in-vitro and in-vivo bioassay can be large, especially for activities close to minimum detectable concentrations (MDC). In order to evaluate missed doses, what information can NIOSH provide on MDCs for various bioassay techniques?

(7) It is important, especially for the early years when the MDA for the bioassay techniques were high (both in vivo and in vitro), to provide guidance on missed dose for samples below the MDA. What guidance is to be provided for missed dose calculations when the bioassay is below the decision level?

(8) There is no guidance for missed dose calculation when bioassay data are not available. However, there are statements that routine bioassay results were not reported for some periods of operation (page 18 of 42). NIOSH should provide guidance for the dose reconstructor to estimate doses based on coworker data.

Questions for NIOSH on ORAUT-TKBS-0036-6 – Occupational External Dose

(1) Is NIOSH confident that it can assign photon, beta, and neutron doses at Site A and Plot M going all the way back to 1946?

(2) Neutron studies have been completed at IPNS comparing Rem meter measurements with neutron badge measurements. Has this been considered in the evaluation of neutron dose?

(3) What direction is provided to the dose reconstructor during the era when neutron badges were not read with a gamma dose less than 100 mrem, and the neutron-to-photon ratio was greater than 1.0?

(4) How will NIOSH determine neutron doses for the period prior to 1956 (or 1958)?

(5) How will NIOSH assure that incident reports in personnel files are comprehensive in the early years? Does the frequency and depth of the reports suggest that all significant events were documented?

(6) What evaluations have been performed to assess the possibility of additional criticality events beyond the documented one? This question is intended to address both recognized events and possible unknown ones, similar to those identified at other sites.

(7) Can NIOSH develop a matrix that is broken down into each period of dosimetry technology and vendor that lists all the required limits and correction factors, such as LOD, missed dose, etc., for all radiation types? If this cannot be done, can NIOSH make some simplifying assumptions and take a worst case approach for these various factors? The current approach is very difficult for a dose reconstructor to follow.

(8) Has NIOSH fully considered the culture and its impact on assumptions regarding a "significant" dose or event in the early period? For example, in 1946, a 100 mrem/day

dose was in use. This would presumably impact a range of decisions, including, but not limited to, the need to badge, wear protective clothing, or record an event.

REFERENCES

Januska, A.G., and W.H. Smith, 1961. *Radiological Survey of the Health Division Diagnostic X-ray Facility*, ANL-6367, Argonne National Laboratory, Argonne, Illinois.

ORAUT 2003. *Technical Basis Document for the Savannah River Site*, ORAUT-TKBS-0003, Oak Ridge Associated Universities Team, Oak Ridge, Tennessee.

ORAUT 2005b. *Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X-ray Procedures*, ORAUT-OTIB-0006, Rev. 03, Oak Ridge Associated Universities Team, Oak Ridge, Tennessee, April 19.

ATTACHMENT 4: NIOSH RESPONSES TO SC&A KEY QUESTIONS

September 18, 2008

Questions on Site Description (ORAUT-TKBS-0036-2):

(1) ORAUT-TKBS-0036-2 states:

Argonne National Laboratory was established on July 1, 1946, and this TBD is intended to cover the time period beginning on that date. The work was a continuation of that done by the Metallurgical Laboratory of the University of Chicago beginning in 1941 which is an Atomic Weapons Employer under EEOICPA.

How does NIOSH propose to deal with the period from 1941 to July 1, 1946?

ORAUT Answer: The Metallurgical Laboratory of the University of Chicago is a separate and distinct facility which will be addressed outside of the ANL-E site profile documents.

SC&A Response: Although the site profile defines that period of coverage of the ANL TBD as July 1, 1946 to present, portions of the TBD address time periods and potential exposures prior to this time. The first location referred to as Argonne Laboratory is the Argonne Forest Preserve, Site A. Are Site A and Plot M to be included as a part of the Metallurgical Laboratory TBD? NIOSH should clearly define which activities are to be included under the ANL TBD and the Metallurgical Laboratory TBD.

(2) How does NIOSH propose to address potential exposures at Site A and Plot M prior to July 1, 1946?

ORAUT Answer: This is outside the scope of the ANL-E TBD.

SC&A Response: See response to (1).

(3) The New Brunswick Laboratory (NBL) moved to Building 350 at ANL. NBL was considered a separate facility with independent health physics services. How does NIOSH propose to address potential exposure to ANL support workers (e.g., maintenance, security, fire protection, etc.) who were on loan to this facility after its arrival at ANL?

ORAUT Answer: ANL staff working around NBL would have been monitored in keeping with general ANL policies and procedures.

SC&A Response: NBL workers could have been exposed to sources which may or may not have been considered in an individual's personnel monitoring plan. NIOSH should

demonstrate that with individuals exposed to hazards in this facility, the ANL policies and procedures were implemented to provide adequate monitoring coverage.

(4) How does NIOSH propose to evaluate doses for those ANL individuals conducting offsite decommissioning activities under the auspices of DOE?

ORAUT Answer: ANL staff members conducting characterization or verification studies at potential D&D sites would have been monitored in keeping with general ANL policies and procedures.

SC&A Response: Offsite work exposed ANL workers to variable sources which may or may not have been considered in an individual's personnel monitoring plan. NIOSH should demonstrate that with individuals exposed to hazards during this work, the ANL policies and procedures were implemented to provide adequate monitoring coverage. Some consideration should also be given to potential monitoring performed by facilities visited by these ANL workers.

Questions on Occupational Medical Dose (ORAUT-TKBS-0036-3):

(1) The current version of the TBD (Rev. 01 PC-1, dated March 27, 2006) references ORAUT-OTIB-0006, Rev. 03 (ORAUT 2005) as the substantial basis upon which it defines occupational medical doses. NIOSH should consider the need to substantially update Section 3.1 (Introduction) to further reflect that non-routine and out-of-sequence diagnostic screening x-ray exams also contribute significantly to medical doses, as shown in other site profiles. This TBD does the best to date to address this issue, but the message needs to be stronger to guard against missed doses.

ORAUT Answer: X-rays administered as part of occupational health screening programs are the basis of inclusion of medical x-ray dose in dose reconstruction. The ORAUT will examine the language in this section and consider strengthening it; however, it is not incorrect as written.

SC&A Response: SC&A accepts the ORAUT response and trusts that upon review NIOSH will choose to instruct that an edit of Section 3.1 is warranted to improve clarity and ensure that claimant doses are considered fully.

(2) The TBD states that little if any early information was found regarding equipment manufacturers, models, examination techniques, and exposure rates prior to 1988. The TBD states that assumptions derived from ORAUT 2003 [a reference to the Savannah River Plant (SRS) TBD] are used as being claimant favorable. Operating parameters for the early G-E Unit is available in *Radiological Survey of the Health Division Diagnostic X-ray Facility* by Januska and Smith (Januska and Smith 1961). Why has the TBD excluded this site-specific information from the occupational medical x-ray exposure evaluation in favor of data from SRS?

ORAUT Answer: The article referred to was not included in the body of data used to produce the TBD. It will be reviewed. Please note that SRS data were not used in the TBD; the reference was provided only in the uncertainty section regarding uncertainty estimates in the dose reconstruction. The ORAUT-OTIB-0006 formed the basis of default estimates, including the estimate of uncertainty.

SC&A Response: SC&A accepts the ORAUT response.

(3) Sections 3.1 and 3.3 in the TBD state that limited evidence of use of photofluorography (PFG) was found after 1948. To the contrary, OTIB-0006, Rev. 3, as well as other guidelines, would seem to suggest without documentation, one should always assume the use of the PFG for dose estimation in order to be claimant favorable. Furthermore, the early G-E unit had fluoroscopic capabilities at least as late as December 1958 (Januska and Smith 1961). The dose reconstructor should use a value of 3 Rem per year at least up through 1958. NIOSH should clarify the intent of this guideline and establish whether the premise of limited PFG use at ANL-E is justified.

ORAUT Answer: The Januska and Smith reference has not yet been reviewed. The review of x-ray records in claimant files showed that PFG was rarely found after 1948, and was found only in conjunction with medical examinations that were performed at the University of Chicago. PFG examinations were only found through 1956 in a review of claimant files. The x-ray information in the ANL-E claim file records constitute a body of evidence that should be used in the TBD. ORAUT-OTIB-0006 should be used in the absence of such evidence.

SC&A Response: SC&A believes that the ORAUT answer nor the TBD demonstrate that all records and x-rays have been located. Therefore, to be claimant beneficial the guidance in OTIB -0006 Rev. 3 should be followed.

(4) The TBD does not document any type of x-ray equipment in use prior to 1970. After 1970, two units are documented; however, little if any physical measurements on beam quality and exposure rates were made prior to 1989. Can NIOSH provide the physical measurement data from surveys prior to 1989? Can NIOSH provide the survey results after 1989 to substantiate the ESE values applied in the TBD?

ORAUT Answer: It is unlikely that any other x-ray inspection results exist. The ANL-E medical staff provided all that was known to them to exist. It is not unusual for site-specific physical measurement data from early years to be lacking. The default exposure values and related organ doses from ORAUT-OTIB-0006 are based on contemporaneous medical literature are to be used when site-specific measurements are not available.

SC&A Response: SC&A is aware of the paucity of such records at most sites. However, the ORAUT response does not demonstrate that an exhaustive search was performed. The ORAUT response seems to be inconsistent to their search and findings in question #3 above where it is suggested that all records pertaining to medical exposures were recovered.

(5) Section 3.5 of the TBD indicates that all organ dose estimates presented for use by dose reconstructors are based only on a chest x-ray for physicals. Prior to 1970, default doses taken from ORAUT 2005 were to be used. Without evidence of any beam exposure measurements prior to 1989, and more specifically before 1970, how can NIOSH substantiate that the tables and estimated organ doses are claimant favorable?

ORAUT Answer: The ORAUT-OTIB-0006 (ORAUT 2005) estimates are conservatively based on contemporaneous medical literature. SC&A has already reviewed ORAUT-OTIB-0006, and found the values to be claimant favorable.

SC&A Response: SC&A believes that ORAUT has missed the point of the question. SC&A agrees that the guidance in OTIB-0006 is conservative for exposures after 1980, however, prior to 1980 and especially prior to 1970, as the question indicates, this guidance may not be conservative since there is no x-ray equipment output information to consider.

(6) The TBD does address whether lumbar spine x-rays may have occurred as a pre-employment exam up to 1960. Can NIOSH document that no lumbar spine x-rays were taken after 1960? Can NIOSH document any knowledge of the unit and techniques used to do pre-employment exams up to 1970? Were all pre-employment and annual exams always taken at on-site medical facilities, or were some applicants sent to the University of Chicago? Is there any documentation in medical records that any off-site x-rays were prescribed as a requirement of employment?

ORAUT Answer: The review of x-ray records in claim files does not substantiate any other exams than those listed for the post-1960 time period. ANL-E has, since 1949, had its own medical clinic and would have had no need to outsource employee physical examinations. Prior to 1949, medical examinations could have been performed at University of Chicago, as noted in the TBD. Some employees may have continued to receive physical examinations at the University of Chicago through 1956, as noted in the TBD.

SC&A Response: SC&A believes the ORAUT response is incomplete. The lumbar spine x-ray issue is not addressed directly and the response only suggests that offsite exposures are unlikely but does not point to any policy or document to substantiate they didn't occur.

(7) The TBD states that uncertainty as described in ORAUT 2003 should be applied as a positive 30% when estimating doses to ANL-E workers. ORAUT 2003 does not discuss other factors in detail that may contribute to dose, such as poor techniques, retakes, faulty processing equipment, etc. Has NIOSH attempted to determine the additional contribution those factors may add?

ORAUT Answer: The TBD relies on uncertainty estimates from ORAUT-OTIB-0006 (ORAUT 2005) which happens to be the same as those in ORAUT 2003. The additional factors referenced are discussed in ORAUT-OTIB-0006 and the default

estimates provided acceptably accommodate the factors that can influence dose received from occupational screening x-rays. As mentioned previously, SC&A has already reviewed ORAUT-OTIB-0006.

SC&A Response: SC&A believes that the ORAUT response is inadequate. Even though OTIB-0006 does mention some of the issues, they are not included in the 30% positive factor being applied in the TBD. Please note that the ORAUT response only suggests it accommodates those factors which can influence dose but they are not the factors referenced in this question.

Questions on Occupational Environmental Dose (ORAUT-TKBS-0036-4):

(1) ORAUT-TKBS-0036 provides a detailed description of environmental monitoring since 1972. Under Section 4.2, External Dose, the following statement is found:

At ANL-E, these doses could have been recorded by film badges before 1970, but references containing these data have not been found.

Has NIOSH attempted to compare operations at ANL-E prior to 1972 to those after this date to estimate perimeter doses from ANL-E operations?

ORAUT Answer: Not at this time. Doing so might not even be possible, given the large number of different kinds of research projects being conducted at ANL.

SC&A Response: Does NIOSH intend to evaluate this possibility?

(2) How has NIOSH taken into consideration activities conducted by the Environmental Research Program that evaluated the behavior of radionuclides in the environment by intentionally contaminating areas?

ORAUT Answer: This question seems to presume that activities of the ERP might be helpful in estimating possible environmental exposures at the ANL-E site. This would seem unlikely since ERP projects were more often focused on performing environmental studies at distant experimental areas.

SC&A Response: The Environmental Research Program (ERP) is relevant to environmental dose since they intentionally introduced radionuclide material into the environment. The exact scope and location of these programs requires further consideration.

(3) Under Section 4.2, External Dose, page 10, the following statement is found:

In general, the highest TLD doses tabulated correspond to areas in which irradiated hardware is temporarily stored (i.e., 9H for the 300 Area). Personnel around or adjacent to these locations would normally wear badges, as did all personnel who entered areas or buildings where RM was used

What indications does NIOSH have that what would "normally' happen did, in fact happen?

ORAUT Answer: As stated in section 6.4.1 of ORAUT-TKBS-0036-06:

> ***Information developed in a 1982 survey for a DOE health and mortality study (Strom 1982) indicates that early on everyone was badged. By 1965, nearly all employees were still badged. By the early 1970s, the site health physicists assigned badges based on the exposure potential. By 1982 it was noted that approximately one-third of the workers were badged.***

SC&A Response: The earliest data presented in Table 4-1, of ORAUT-TKBS-0036-06, is for 1972; therefore, most, if not all, of the data in this table are from a time when all of the employees were not badged. How can NIOSH be sure that, "Personnel around or adjacent to these locations would normally wear badges…"?

Questions on Occupational Internal Dose (ORAUT-TKBS-0036-05):

(1) ORAUT-TKBS-0036-05 refers to ORAUT-TKBS-0036-02 in regard to radionuclides used on site. ORAUT-TKBS-0036-02 admittedly provides a limited description of the types and amounts of radioactive material used and ANL-E. What will be NIOSH guidance to dose reconstructors relative to:

1.a - Isotopic composition for U and Pu, Am, etc., and also the magnitude of site activity.

1.b - The specific activity for uranium (enriched, natural, etc.)

ORAUT Answer: Isotopic ratios for plutonium and assumptions for Am-241 in plutonium mixtures are described in Section 5.3.2.2.6 of ORAUT-TKBS-0036-05. There is currently no estimate of the magnitude of activity present on the site.

The isotopic composition and the enrichment of uranium were very project-and installation-specific. There was insufficient information regarding specific projects in various buildings to enable a definition of isotopic composition. Hence, no blanket statement can be made because of the variety of projects that occurred through time.

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SC&A Response: Given this uncertainty, what guidance will NIOSH give to dose reconstructors for uranium and plutonium composition?

According to ORAUT-TKBS-0036-5, if specific information is not available, the dose reconstructor should assume inhalation as a pathway of intake. This recommendation is not claimant favorable. Doses coming from the ingestion pathway should not be ignored, especially in the case of cancer to the GI tract.

ORAUT Answer: The Internal Dose Reconstruction Implementation Guideline, OCAS-IG-002 (OCAS, 2002) states that "inhalation is perhaps the most common route of internal exposure to radionuclides." It further states that: "Exposure by ingestion is generally not a significant route of entry" and that "ingestion generally does not need to be considered during a dose reconstruction unless there is some evidence of an unusual event." Such unusual events would be noted in the claimant's file and would be taken into account in determining the route of entry. Therefore, the statement in ORAUT-TKBS-0036-5 is consistent with the guidance provided in OCAS-IG-002.

SC&A Response: As stated in OCAS-IG-002 (OCAS 2002) "inhalation is perhaps the most common route of internal exposure to radionuclides." However, ingestion can occur in the workplace; in cases of GI tract cancer, it needs to be considered in order to be claimant favorable.

(2) Actinides (i.e., Pu, Np, Am, Cm, Th, and Ac) in urine underwent radiochemical processing, followed by a gross alpha count. Workers could be exposed to a mixture of alpha emitters. How does the dosimetrist assign dose in cases where different alpha emitters may occur in the same sample?

ORAUT Answer: Bioassay analyses were conducted for specific radionuclides based on process knowledge as early as 1968 when an intake of a single material was suspected. An example from 1987 is shown in Fig 5-6 of ORAUT-TKBS-0036-5. For potential exposures prior to that, the dosimetrist should assume that reported concentrations are for the worst-case radionuclide on a case-by-case basis.

SC&A Response: According to the ORAUT-TKBS-0036-5, alpha spectrometry started in 1973. In the earlier times it would be difficult to determine intakes of mixtures of alpha emitters from gross alpha data. In addition, gross alpha analysis was used as a screening method for determining whether specific radionuclide analysis was necessary. The effectiveness of early gross alpha procedures should be further investigated to insure the processes were effective for all relevant radionuclides and consideration should be given to potential interferences in the screening methods.

It should be stated in the ORAUT-TKBS-0036-5 that the dosimetrist should assume that reported concentrations are for the worst-case radionuclide on a case-by-case basis and how NIOSH will implement the worst-case radionuclide policy.

(3) How is the dose reconstructor to differentiate between multiple beta emitters in samples evaluated for only gross beta? What default assumptions will be made in cases where it is not known what radionuclide an individual worked with?

ORAUT Answer: Where the bioassay data do not specify the beta emitter, the dosimetrist should assume that the reported concentrations are for the worst-case radionuclide among the beta emitters potentially present at the specific facility. OTIB-0054 is available to evaluate gross beta bioassay data.

SC&A Response: How will NIOSH implement the worst case radionuclide policy given the wide range of beta emitters found at ANL-E?

(4) How does NIOSH propose to calculate doses from exposure to radon, actinon, and thoron in areas were radium, actinium, and thorium were handled?

ORAUT Answer: The doses from isotopes of radon can be calculated only through environmental measurements. There is no indication in the records reviewed that such measurements were made. Radon-219 (actinon) is a decay product of ^{223}Ra which arises from the decay of ^{227}Ac. There is no indication in the ANL-E records that ^{227}Ac was used at the site. While the parent of the decay chain, ^{235}U, was present at the site in enriched uranium, the immediate parent of ^{227}Ac is ^{231}Pa with a half-life of nearly 33,000 years. Therefore, no significant ^{227}Ac activity would build in even with enriched uranium; thus it is unlikely that significant ^{219}Rn would have been present. Radon-220 (thoron), a member of the ^{232}Th decay series, has a very short half-life (55.6 seconds) and would not have been likely to accumulate in buildings where small amounts of natural thorium were present. Radon-222 is a decay product in the ^{238}U decay series and is ubiquitous in the environment. As noted above, we found no data to indicate that ^{222}Rn concentrations in ANL-E buildings were routinely measured. OCAS-IG-002 (OCAS, 2002) provides a detailed description of the problems with differentiating the ^{222}Rn concentrations attributable to work at facilities such as ANL-E from background ^{222}Rn concentrations.

SC&A Response: As indicated in Secondary Issue 4, there were opportunities for exposure to ^{226}Ra, ^{227}Ac, and thorium. In fact the ANL-E TBD acknowledges that the site used ^{226}Ra in Buildings 203 and 211 as a part of the accelerator program. In Building 200, ^{220}Rn was produced (ORAUT-TKBS-0036-5, Table 2-2). Furthermore, there was a substantial incident involving rupture of a ^{226}Ra source which generated radon issues through time. Thorium was machined in the East Area and handled in R & D. ^{227}Ac was also handled in R & D (Manning 1950). Given the use of radium, actinium, and thorium at ANL-E, further investigation into potential occupational exposures to radon and possibly thoron and actinon are necessary.

(5) What direction is provided for the assessment of dose from exotic radionuclides, such as Pa-231, Po-210, Cf-252, and other transplutonium elements?

ORAUT Answer: Bioassays would have been conducted for the specific radionuclide which the worker was using. The dosimetrist would use the appropriate data from the worker's file.

SC&A Response: Refer to Item (2) under Internal Dosimetry questions, above.

(6) The uncertainty in in-vitro and in-vivo bioassay can be large, especially for activities close to minimum detectable concentrations (MDC). In order to evaluate missed doses, what information can NIOSH provide on MDCs for various bioassay techniques?

ORAUT Answer: All available information on uncertainties for ANL-E techniques is included in ORAUT-TKBS-0036-5.

SC&A Response: SC&A accepts the ORAUT response.

(7) It is important, especially for the early years when the MDA for the bioassay techniques were high (both in vivo and in vitro), to provide guidance on missed dose for samples below the MDA. What guidance is to be provided for missed dose calculations when the bioassay is below the decision level?

ORAUT Answer: ORAUT-OTIB-0060 provides a detailed procedure for calculating missed dose due to samples below the MDA.

SC&A Response: ORAUT-OTIB-0060 should be referenced in the TKBS.

(8) There is no guidance for missed dose calculation when bioassay data are not available. However, there are statements that routine bioassay results were not reported for some periods of operation (page 18 of 42). NIOSH should provide guidance for the dose reconstructor to estimate doses based on coworker data.

ORAUT Answer: The bioassay monthly reports summarize the bioassay data. The reports for certain periods of time did not include the routine data. However, the records for the individual workers do include routine bioassay results. These are the data that would be used for dose reconstruction.

SC&A Response: SC&A accepts the ORAUT response.

Questions on ORAUT-TKBS-0036-06 -Occupational External Dose (ORAUT-TKBS-0036-6):

(1) Is NIOSH confident that it can assign photon, beta, and neutron doses at Site A and Plot M going all the way back to 1946?

ORAUT Answer: Based on experience in processing claims and site information concerning radiological records, individual worker nonpenetrating and penetrating doses are available from 1946 (see example as noted in the TBD in Attachment A, p. 4 of 17). The TBD describes how this information may be used to assign the organ dose. The TBD currently describes the application of correction factors to the recorded neutron dose depending on workplace and time period to arrive at a realistic estimate of the neutron dose. It is possible to develop a neutron-to-photon dose ratio distribution from which the 95th percentile could be applied to the assigned photon dose (adjusted for missed dose) to arrive at an estimated upper bound of the neutron dose. Question (4) also addresses the topic of neutron dose assignment.

SC&A Response: This issue is addressed in the SC&A site profile review.

(2) Neutron studies have been completed at IPNS comparing Rem meter measurements with neutron badge measurements. Has this been considered in the evaluation of neutron dose?

ORAUT Answer: Perhaps not. If SC&A can provide the SRDB Ref ID, it will be determined if this was considered and the information could then also be used in any future TBD revisions. There was one IPNS study cited in Section 6.7.1.1 which indicates only low neutron dose equivalent rates in occupied areas.

SC&A Response: This information comes from a site expert interview (see SC&A Site ANL-E Profile Review, page 76 of 92).

(3) What direction is provided to the dose reconstructor during the era when neutron badges were not read with a gamma dose less than 100 mrem, and the neutron-to-photon ratio was greater than 1.0?

ORAUT Answer: This question is apparently in reference to Section 6.7.3.3, which states, "A 1982 survey (Strom 1982) indicated that, similar to Rocky Flats, not all neutron films that were developed were read. Before 1960, neutron films were apparently only read if the gamma dose was 100 mrem or more. The dose reconstructor would normally assign a missed neutron dose for each monitoring period for which a zero or dose less-than one-half of the LOD reading was recorded or in the dose reconstructor's opinion an expectation that neutron monitoring should have occurred. It should be noted that for the early reactors, high-energy gamma fields would likely have accompanied any significant neutron exposure.

SC&A Response: This issue is addressed in the SC&A site profile review.

(4) How will NIOSH determine neutron doses for the period prior to 1956 (or 1958)?

ORAUT Answer: Assuming there is evidence of significant unrecorded neutron dose, a feasible option would be to apply a neutron-to-photon dose ratio since the photon dose is available for all years of operation.

SC&A Response: Can NIOSH give an example of what evidence it will consider to determine that there was significant neutron dose when there was no neutron monitoring?

(5) How will NIOSH assure that incident reports in personnel files are comprehensive in the early years? Does the frequency and depth of the reports suggest that all significant events were documented?

ORAUT Answer: DOE is required to submit relevant incident evaluations along with internal dose, external dose, and medical x-ray documentation for each energy employee to DOL. Typically, any significant dose from incidents is incorporated

into the occupational dose record for each worker. It is typical for dose reconstructors to consider all of the site-provided documentation in developing the dose reconstruction. As currently written, the External Dosimetry section of the ANL-E TBD only addresses skin contamination incidents in conjunction with electron dose reconstruction (Section 6.8). A study has not been done of the broader issue of considering if worker exposure described in all incident reports has been evaluated.

SC&A Response: As indicated in site expert interviews, incident information in the medical files was not being routinely provided for Part B claims. Furthermore, it is unclear whether all incidents were duplicated in the individual radiation exposure file. If an incident report is inadvertently omitted from a claimant file, it is unclear that it could be identified and corrected.

(6) What evaluations have been performed to assess the possibility of additional criticality events beyond the documented one? This question is intended to address both recognized events and possible unknown ones, similar to those identified at other sites.

ORAUT Answer: No evidence of undocumented criticality accidents was located during the research for this section.

SC&A Response: Does NIOSH believe that it has sufficient information on Site A to exclude the possibility of undocumented criticality accidents?

(7) Can NIOSH develop a matrix that is broken down into each period of dosimetry technology and vendor that lists all the required limits and correction factors, such as LOD, missed dose, etc., for all radiation types? If this cannot be done, can NIOSH make some simplifying assumptions and take a worst case approach for these various factors? The current approach is very difficult for a dose reconstructor to follow.

ORAUT Answer: Yes, certainly some simplification is possible for consideration in a future revision.

SC&A Response: SC&A accepts the ORAUT response.

(8) Has NIOSH fully considered the culture and its impact on assumptions regarding a "significant" dose or event in the early period? For example, in 1946, a 100 mrem/day dose was in use. This would presumably impact a range of decisions, including, but not limited to, the need to badge, wear protective clothing, or record an event.

ORAUT Answer: The early radiation protection standards in the 1940s and 1950s based on a tolerance dose concept (i.e., no detriment at dose levels less than the limits) allowed site to reasonably elect to not monitor workers with doses significantly less-than radiation protection limits (i.e., to not monitor workers with expected doses less-than 10% of the allowed dose limit). Once the lifetime occupational dose limit concept [i.e., 5 * (N-18) rem, where N is the age of the person

in years] was adopted in the latter 1950s, there were reasons to monitor greater numbers of lower-dosed workers. However, it should be noted that often badging requirements for all workers were based on ingress into a radiologically controlled area. A reason to prepare the TBD is to evaluate site-specific practices. The term "significant dose" appears only twice in ORAUT-TKBS-0036-6, both in conjunction with the ZPR reactors (Section 6.7.1.1), after dosimetry was well established.

SC&A Response: SC&A accepts the ORAUT response.

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