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

September 16, 2008

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. 200-2004-03805, Task Order 1: Draft Report SCA-TR-TASK1-0027, *Review of the NIOSH Site Profile for the Santa Susana Field Laboratory*

Dear Mr. Staudt:

SC&A is pleased to submit its draft report, *Review of the NIOSH Site Profile for the Santa Susana Field Laboratory*, SCA-TR-TASK1-0027. This report was reviewed for Privacy Act information and edited accordingly. On August 15, the document was forwarded to the U.S. Department of Energy (DOE) for approval. Notification was received from DOE on September 15th that the document had been approved for distribution.

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

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, Board Chairperson
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Draft

ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

Review of the NIOSH Site Profile for the Santa Susana Field Laboratory

Contract No. 200-2004-03805
Task Order No. 1
SCA-TR-TASK1-0027

Prepared by

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August 2008

S. COHEN & ASSOCIATES: ***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program***	Document No. SCA-TR-TASK1-0027 Effective Date: Draft – August 16, 2008 Revision No. 0 – (Draft)
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Task Manager: _________________________ Date: ___________ Gregory P. Beronja	Supersedes: N/A
Project Manager: _________________________ Date: ___________ John Mauro, PhD, CHP	

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ACRONYMS AND ABBREVIATIONS

Advisory Board or ABRWH	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AERD	Atomic Energy Research Department
AETR	Advanced Epithermal Thorium Reactor
AI	Atomics International
AMAD	Activity median aerodynamic diameter
AP	Antero-Posterior
ATR	Advanced Test Reactor
bq	Becquerel
CFR	*Code of Federal Regulations*
Ci	curie
cpm	counts per minute
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
dpm	disintegrations per minute
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
ER	Evaluation Report (part of the Special Exposure Cohort documentation)
ESE	Entrance Skin Exposure
ETEC	Energy Technology Engineering Center
EU	Enriched Uranium
F	fast (solubility type)
ft	foot
g	gram
HEPA	high-efficiency particulate air
hr	hour
HRTM	Human Respiratory Tract Model
ICRP	International Commission on Radiological Protection
IREP	Interactive RadioEpidemiological Program
ISF	Interim Storage Facility
keV	kiloelectron volt
l	liter
LAT	Lateral
LMEC	Liquid Metal Engineering Center
LMFBR	Liquid Metal Fast-Breeder Reactor
LMIC	Liquid Metal Information Center
LMR	Liquid Metal Reactor
LOD	Limits of Detection
M	moderate (solubility type)

MDA	Minimum Detectable Amount
MDL	Minimum Detection Limit
MeV	megaelectron-volt, 1 million electron-volts
MFP	Mixed Fission Product
mL	milliliter
MPBB	maximum possible body burden
mR	millirem
mrem	millirem
NAA	North American Aviation
NIOSH	National Institute for Occupational Safety and Health
NSEC	Nuclear Science and Engineering Corporation
NTA	Neutron Track Analysis
ORAUT	Oak Ridge Associated Universities Team
PA	Posterior-Anterior
pCi	picocurie
POC	Probability of Causation
R&D	Research and Development
REIRS	Radiation Exposure Information Reporting System
rem	Roentgen Equivalent Man
RI	Rockwell International
RMDF	Radioactive Material Disposal Facility
RSRMS	Radiation Safety Records Management System
S	slow (solubility type)
S8ER	SNAP 8 Experimental Reactor
SC&A	S. Cohen & Associates
SEC	Special Exposure Cohort
SNAP	Systems for Nuclear Auxiliary Power
SRE	Sodium Reactor Experiment
SSFL	Santa Susana Field Laboratory
Sv	sievert
TIB	Technical Information Bulletin
TBD	Technical Basis Document
UAlx	Uranium-Aluminum
UCLA	University of California Los Angeles
UF	Uranium fluorometric
UR	Uranium radiometric
W	watt
WB	Whole Body
WBC	Whole Body Count
WBNS	Water Boiler Neutron Source
Y-12	A plant at the Oak Ridge

yr	Year
µm	micrometer
µrem	microrem

1.0 EXECUTIVE SUMMARY

This draft report presents the S. Cohen and Associates (SC&A, Inc.) evaluation of the National Institute for Occupational Safety and Health (NIOSH) Site Profile for the Santa Susana Field Laboratory (SSFL) (ORAUT-TKBS-0038), which was issued as six separate technical basis documents (TBDs) numbered ORAUT-TKBS-0038-1 through ORAUT-TKBS-0038-6. This draft report was prepared at the request of the Advisory Board on Radiation and Worker Health (Advisory Board) and covers all six TBDs identified below.

- ORAUT-TKBS-0038-1, *Technical Basis Document: Atomics International – Introduction*, Rev. 01 (ORAUT 2006a)
- ORAUT-TKBS-0038-2, *Technical Basis Document: Energy Technology Engineering Center – Site Description*, Rev. 00 (ORAUT 2006b)
- ORAUT-TKBS-0038-3, *Technical Basis Document: Atomics International – Occupational Medical Dose*, Vol. 3, Rev. 00 (Atomics International TBD, 2006aORAUT 2006c)
- ORAUT-TKBS-0038-4, *Technical Basis Document: Area IV of the Santa Susana Field Laboratory, the Canoga Avenue Facility (Vanowen Building), the Downey Facility, and the De Soto Avenue Facility (sometimes referred to as the Energy Technology Engineering Center [ETEC] or Atomics International) – Occupational Environmental Dose*, Rev. 01 (ORAUT 2007)
- ORAUT-TKBS-0038-5, *Technical Basis Document: Energy Technology Engineering Center – Occupational Internal Dose,* Rev. 00 (ORAUT 2006d)
- ORAUT-TKBS-0038-6, *Technical Basis Document: Atomics International – Occupational External Dosimetry*, Rev. 01 (ORAUT 2006e)

Throughout this report, individual TBDs are referenced simply by number. For example, ORAUT-TKBS-0038-1 will be identified as TBD-1. As part of our evaluation, SC&A also reviewed other documents that were considered relevant, including the following:

- Select documents that were referenced in the SSFL Site Profile
- Documents contained in the NIOSH Site Research Query Database
- Select documents contained on the SSFL Advisory Panel website

1.1 TECHNICAL APPROACH AND REVIEW CRITERIA

The approach used by SC&A to perform this review follows the protocols described in *Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). Approved by the Advisory Board on March 18, 2004, SC&A's protocol reflects the following review objectives:

(1) Completeness of data sources
(2) Technical accuracy
(3) Adequacy of data

(4) Consistency with other site profiles
(5) Regulatory compliance

Deficiencies pertaining to these review criteria are noted as "findings." It should be noted that these findings vary in degree of severity as to their potential impact on the dose reconstructions. The purpose of this review is to provide the Advisory Board with an independent assessment of issues that surround the SSFL site profile. Findings identified in our review are expected to provide the Advisory Board with a preliminary overview of potential issues that may impact the NIOSH dose assessment methodologies and/or perhaps raise issues pertaining to the feasibility of performing certain SSFL dose reconstructions.

SC&A's draft report will undergo a multi-step issues-resolution process. The issues-resolution process includes a transparent review and discussion of draft findings with members of the Advisory Board and select personnel representing NIOSH/Oak Ridge Associated Universities Team (ORAUT). This resolution process is intended to ensure that each finding is evaluated on its technical merit in a fair and impartial manner.

1.2 SUMMARY OF FINDINGS

A summary of SC&A's findings for the SSFL site profile is presented below. The findings are presented in Section 4 of this report and are organized by TBD. An overview of findings identified in each TBD is presented below.

TBD-1 (Introduction): The Introduction describes the purpose and scope of the SSFL site profile. The findings for this TBD include the following:

(1) The dates of operation for various activities are not consistent

(2) The various names used to reference SSFL, the outlying sites, and the areas within SSFL are not consistent and should be discussed in the introduction and used consistently throughout all of the TBDs

TBD-2 (Site Description): The Site Description TBD provides critical information regarding the historical and current status of facilities, processes, source terms, etc., at SSFL. SC&A's findings for this TBD include the following:

(1) An incomplete presentation of information on the Sodium Reactor Experiment (SRE) coolant failure

(2) A lack of information on the number and type of workers at the facility

(3) The site description lacks sufficient detail; for example, given the unique and highly complex activities that characterize this site, descriptions of individual facilities/processes are too brief and lack information necessary to perform dose reconstructions

(4) An incomplete listing of radionuclides

(5) The operational dates presented in the text and Table 2-1 are inconsistent for different units

(6) The history and relationship of the private entities at SSFL are poorly presented

TBD-3 (Occupational Medical Dose): The Occupational Medical Dose TBD provides guidance for reconstructing doses from diagnostic x-ray procedures required as a condition of employment. The findings for this TBD include the following:

(1) The TBD requires subjective interpretation and makes unreasonable demands on the dose reconstructor

(2) The units in Table 3-2 [i.e., PA chest ESE (mR) and Organ dose (rem)] should be modified to indicate these exposures are "per examination"

TBD-4 (Occupational Environmental Dose): TBD-4 provides data for the reconstruction of doses to unmonitored workers exposed onsite internally and externally from environmental releases. The findings for this TBD include the following:

(1) Surrogate use of the time-integrated average yearly gross alpha/gross beta stack emissions corresponding to years 1971–1999 is likely to underestimate stack emissions for years 1954–1970

(2) Use of average radionuclide-specific stack emission data representing years 1988–1999 as surrogate data is unlikely to be representative of stack emissions for years 1954–1987

(3) The basis for a single reduction factor of 0.01 as a way of converting average air concentrations (at points of release for multiple stacks) to breathing zone air concentrations for all site locations and all years of facility operations is not documented

(4) Estimates of annual external occupational environmental doses prior to 1974 are incomplete and are based on multiple "assumptions" that are neither explained nor properly referenced

(5) The TBD states that potable water is not a source of occupational radiation exposure, which is inconsistent with what is presented in the SEC Evaluation Report (NIOSH 2008) and other information sources

(6) Insufficient information is provided on the potential exposure to the sodium burn pit

TBD-5 (Occupational Internal Dose): This TBD presents information on establishing the internal dose that workers received, either through bioassays or indirect means. SC&A's findings for this TBD include the following:

(1) Monitoring for internal exposure of SSFL workers was incomplete and poorly documented for most years of facility operations

(2) There is insufficient correlation between bioassay data and potential exposures to specific radionuclides

(3) Certain radionuclides are missing from the bioassay data

(4) There is no coworker model

(5) The assumption of chronic intake in evaluating bioassay results may not always be correct

(6) Inconsistencies exist between the minimum detectable amount (MDA) values described in the text and the ones reported in Table 5.4

(7) The MDA for enriched uranium needs to be clarified

(8) There is an inconsistent presentation of dates of operation in Table 5.9 versus what is presented in TBD-2

(9) There is no mention of neptunium and depleted uranium in Table 5.9, even though TBD-2 identifies them in Building 4064 (fuel storage facility)

(10) The recommendation in the TBD to use solubility Type S for the dose reconstructions is not claimant favorable

(11) There is information in TBD-2 related to airborne concentrations and dispersible material that is not included in TBD-5

(12) The TBD interpretation of reported values by the contract laboratory Nuclear Science and Engineering Corp. (NSEC) may not be correct

(13) The information for evaluating uranium bioassay data is not complete

(14) There are unanswered questions regarding the completeness and quality of personnel exposure records

(15) The site survey data/source term should not be regarded as useful surrogate data in dose reconstruction

(16) Potential unmonitored internal exposures associated with radiation incidents are not addressed

TBD-6 (Occupational External Dose): This TBD presents the methodology for determining the external dose workers received at SSFL. SC&A's findings for this TBD include the following:

(1) The document does not address the use of a coworker model for those individuals potentially exposed but not monitored

(2) Workers were unlikely to have been monitored for thermal neutrons

(3) It may not be appropriate to use Y-12 data as a surrogate, due to the level of uncertainty surrounding neutrons at SSFL

(4) Correction factors for the insensitivity of NTA to neutrons at energies below 500 keV should be considered

(5) There is a lack of discussion on issues associated with the response of dosimeters to low-energy photons

(6) There is insufficient supporting information to justify the use of the surrogate time periods in evaluating stack emissions

(7) No consideration has been given to potential exposure in Area I of SSFL, such as potential exposure to the coal gasification process

1.3 REPORT ORGANIZATION

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

(1) Executive Summary
(2) Scope and Introduction
(3) Relevant Background Information
(4) Findings Identified in the SSFL Site Profile
(5) Preliminary SEC Issues

Following this Executive Summary, Section 2.0 identifies the review objectives that were used to evaluate the SSFL TBD.

Section 3.0 of this report provides a brief summary of relevant background data contained in the SSFL site profile. The site profile specifies relevant background information and methods to be used by NIOSH for the reconstruction of internal and external doses. Included herein are brief summaries of materials and quantities processed, facility descriptions, and radionuclides of concern to dose reconstruction.

As a result of our review of the site profile and other documents, SC&A identified findings which are summarized above and are presented in more detail in Section 4 of this report. The technical basis for each finding is presented. For some findings, support is also provided by one or more documents, which are enclosed as exhibit(s), or are referenced (see the reference list in Section 6.0).

These exhibits frequently contain empirical data and/or personal observations/opinions expressed by key individuals who were involved in SSFL operations and worker/workplace monitoring. Interviews provide vital site expert evidence that SC&A publishes and carefully takes into account, along with other evidence, in the preparation of its TBD review. For this reason, the reader is encouraged to review the enclosed exhibits and independently determine the degree to which they support each of the corresponding findings. For practical reasons, findings are grouped by TBDs in six subsections of Section 4.

SC&A has been asked by the Advisory Board to identify preliminary issues associated with the SEC Petition Evaluation Report that was submitted to NIOSH on February 6, 2008. The preliminary issues we have identified are included in Section 5. SC&A, if requested by the Advisory Board, will prepare a more comprehensive and detailed review of the Evaluation Report, building on the issues in Section 5.

2.0 SCOPE AND INTRODUCTION

2.1 REVIEW SCOPE

Under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA) and federal regulations defined in Title 42, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program*, of the *Code of Federal Regulations* (42 CFR Part 82), the Advisory Board on Radiation and Worker Health (Advisory Board) is mandated to conduct an independent review of the methods and procedures used by 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 the Santa Susana Field Laboratory (SSFL):

- ORAUT-TKBS-0038-1, *Technical Basis Document: Atomics International – Introduction*, Rev. 01 (ORAUT 2006a)
- ORAUT-TKBS-0038-2, *Technical Basis Document: Energy Technology Engineering Center – Site Description*, Rev. 00 (ORAUT 2006b)
- ORAUT-TKBS-0038-3, *Technical Basis Document: Atomics International – Occupational Medical Dose*, Rev. 01 (ORAUT 2006c)
- ORAUT-TKBS-0038-4, *Technical Basis Document: Area IV of the Santa Susana Field Laboratory, the Canoga Avenue Facility (Vanowen Building), the Downey Facility, and the De Soto Avenue Facility (sometimes referred to as the Energy Technology Engineering Center [ETEC] or Atomics International) – Occupational Environmental Dose*, Rev. 01 (ORAUT 2007)
- ORAUT-TKBS-0038-5, *Technical Basis Document: Energy Technology Engineering Center – Occupational Internal Dose*, Rev. 00 (ORAUT 2006d)
- ORAUT-TKBS-0038-6, *Technical Basis Document: Atomics International – Occupational External Dosimetry*, Rev. 01 (ORAUT 2006e)

These documents are referred to in this review as TBDs 1 through 6. SC&A also reviewed other pertinent documents, including those cited on the NIOSH Site Research database. SC&A, in support of the Advisory Board, has critically reviewed the SSFL TBDs, as well as supplementary and supporting documents, against the following three evaluation criteria:

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

SC&A's review of the six TBDs, along with its supporting supplemental documentation, focuses on the quality and completeness of the data that characterized the facility and its operations, and the adequacy 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 dose reconstructions, bridging uncertainties, or correcting technical inaccuracies.

The six volumes of the SSFL site profile are supposed to serve as site-specific guidance documents to be used in support of dose reconstructions. While dose reconstructors use other data, information, and guidance documents in making dose estimates, the purpose of site profiles is to provide dose reconstructors with consistent general information and specifications to support their individual dose reconstructions. This report was prepared by SC&A to provide the Advisory Board with an evaluation of whether and how the TBDs can support the various types of dose reconstruction estimates that NIOSH performs—minimum for compensation only; maximum, with worst-case assumptions to be used for denial only; and "best-case" or "reasonable" dose estimates to be used for both compensation and denial. The criteria for evaluation include whether the TBDs provide a basis for scientifically supportable and claimant-favorable dose reconstructions that systematically resolve uncertainties in favor of the claimant as required by 42 CFR 82, the regulation governing the dose reconstruction process.

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

SC&A's review of the SSFL TBDs was further supplemented by interviews with former and current site personnel, in order to gain a better insight into operational practices and the implementation of radiation protection protocols. Attachment 1 provides a transcript of the interviews, in which statements were paraphrased and names of those interviewed have been omitted for privacy reasons.

2.2 ASSESSMENT CRITERIA AND METHODS

Under Task Order 1, 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 SSFL site profile and supporting technical information bulletins (TIBs). Our review identifies a number of issues, and discusses the degree to which the site profile fulfills the review objectives delineated in SC&A 2004 with the following objectives.

2.2.1 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 are (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.

2.2.2 Objective 2: Technical Accuracy

Objective 2 requires SC&A to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instructions, including evaluating field characterization data, source term data, technical reports, standards and guidance documents, and literature related to processes that occurred at SSFL. The goal of this objective is to analyze the data according to sound scientific principles, and then evaluate this information in the context of dose reconstruction.

2.2.3 Objective 3: Adequacy of Data

Objective 3 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. An important consideration in this aspect of our review of the site profile is the scientific validity and claimant favorability of the data, methods, and assumptions employed in the site profile to fill in data gaps.

2.2.4 Objective 4: Consistency among Site Profiles

Objective 4 requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the SSFL TBDs were compared to other TBDs reviewed to date. This assessment was conducted to identify areas of inconsistencies and determine the potential significance of any inconsistencies with regard to the dose reconstruction process.

2.2.5 Objective 5: Regulatory Compliance

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

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

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%, assuring compensability to the claimant. In some cases, such partial/incomplete dose reconstructions with a POC greater than 50% may 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 [based on limits of detection (LOD)] that results in a POC greater than 50%. For this reason, dose reconstructions in this category may only be marginally affected by incomplete/missing data or uncertainty of the measurements. In fact, regulatory guidelines recommend the use of a partial/incomplete dose reconstruction, the minimization of dose, and the exclusion of uncertainty for reasons of process efficiency, as long as this limited effort produces a POC of equal to or greater than 50%.

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

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

Although simplistic in design, 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 to satisfy this type of a dose reconstruction. Thus, for external exposures, maximum dose rates must be identified in time and space that correspond to a worker's employment period, work locations, and job assignment. Similarly, in order to maximize internal exposures, highest air concentrations and surface contaminations must be identified.

Category 3: The most complex and challenging dose reconstructions consist of claims where the case cannot be dealt with in 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 a "reasonable" or "best-case" estimate, 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.]

SC&A's draft report and preliminary findings will subsequently undergo a multi-step resolution process. Prior to and during the resolution process, the draft report is reviewed by the Department of Energy (DOE) Office of Health, Safety, and Security to confirm that no classified documents or information has been incorporated into the report. Resolution includes a transparent review and discussion of draft findings with members of the Advisory Board Working Group, petitioners, claimants, and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its technical basis in a fair and impartial basis. A final report will then be issued to the full Advisory Board for deliberation and a final recommendation.

3.0 RELEVANT BACKGROUND INFORMATION

This section presents summary information that will provide the reader with an overview of key facility processes, production quantities, and radiological source terms that may have contributed to internal and external exposures.

3.1 PRINCIPAL OPERATIONS

SSFL consists of a total of 2,850 acres and is located in the Simi Hills of Ventura County, approximately 30 miles northwest of downtown Los Angeles, California. Based on ownership and operations, SSFL is divided into four administrative and operational portions—Area I, Area II, Area III, and Area IV. DOE operations are conducted in a 290-acre westernmost administrative and operational portion designated as Area IV.

SSFL was initially established in 1947 by North American Aviation (NAA) to meet the requirements for a field test laboratory to static-fire large rocket engines; however, it also met NAA's need for a nuclear research facility. As a result, Area IV was established in 1953 at SSFL as a nuclear research and development (R&D) facility. Since then, SSFL has housed both nuclear development and rocket development groups, although in distinct and separate locations. Atomic Energy Research Development (AERD) also conducted operations in SSFL-Area IV. In December 1955, the nuclear development and rocket development groups were transformed into separate divisions—Atomics International (AI) and Rocketdyne.

Two distinct AI groups were housed in Area IV and supported by DOE. One focused on development of civilian nuclear power, and the other was a center of excellence for research and testing of non-nuclear components related to liquid metals. These two groups were referred to as AI and Liquid Metal Engineering Center (LMEC), respectively. Nuclear R&D activities in Area IV increased rapidly from 1953 into the late 1960s, and then began to decline. AI was eventually merged into Rocketdyne in 1984 as a result of this decline.

The LMEC was created in 1966 as a government-owned and contractor-operated organization; its purpose was to provide development and non-nuclear testing of Liquid Metal Reactor (LMR) components and to establish the Liquid Metal Information Center (LMIC) for the Atomic Energy Commission's (AEC's) Liquid Metal Fast-Breeder Reactor (LMFBR) program. The LMEC was renamed Energy Technology Engineering Center (ETEC) in 1978 to reflect DOE's desire to broaden its mission beyond the LMFBR program.

Several corporate mergers and organizational changes occurred over the years. In 1967, NAA merged with Rockwell Standard to become North American Rockwell. In 1973, the corporate name changed to Rockwell International (RI). Rockwell International with AI and Rocketdyne continued to exist as independent divisions until 1984, when AI was absorbed by the Rocketdyne division. The Boeing Company purchased RI in 1996, and Rocketdyne is now a division of Boeing.

Before the remaining research activities ended in 1998, three primary types of operations were conducted at Area IV: (1) development and testing of nuclear reactors, (2) nuclear support operations, and (3) non-nuclear energy R&D.

3.2 DEVELOPMENT AND TESTING OF NUCLEAR REACTORS

Between 1953 and 1980, several nuclear reactors were built, tested, and operated in Area IV. These included both nuclear reactors and critical test assemblies. Nuclear reactor programs focused on the development and operation of homogeneous water boiler-type reactors, sodium-cooled graphite-moderated reactors, and uranium-zirconium hydride reactors.

3.2.1 Homogeneous Water Boiler Reactors

The water boiler reactors were operated in Buildings 4073 and 4093. The water boiler reactors used a 93% enriched uranyl sulfate solution held in a critical configuration in a spherical vessel. Rather than actually boil, the neutron and gamma flux caused radiolytic decomposition of water into hydrogen and oxygen in the form of tiny bubbles, which gave the impression of boiling. Area IV contained two water boiler reactors.

3.2.2 Sodium-Cooled Graphite-Moderated Reactors

The Sodium Reactor Experiment (SRE) facility consisted of 12 structures, including the reactor building, office buildings, and support structures. Eight structures were directly involved in operations with radioactive materials:

(1) Reactor Building (Building 4143)
(2) Component Storage Building (Building 4041)
(3) Temporary Hot Waste Storage Building (Building 4686)
(4) Site Service Building (Building 4163)
(5) Cold Trap Vault (Building 4695)
(6) Liquid Radioactive Waste Vault (Building 4653)
(7) Interim Radioactive Waste Storage Area (Area 4654)
(8) Intermediate Contaminated Storage Area (Area 4689)

3.2.3 Systems for Nuclear Auxiliary Power Reactors

The Systems for Nuclear Auxiliary Power (SNAP) program operated from 1956 to 1971 to support the development and testing of small reactors designed to provide power for research missions in space. The SNAP reactors were uranium-zirconium hydride reactors that used fully enriched (93%) uranium dispersed in fuel rods containing zirconium hydride. Seven SNAP reactors were tested and operated in Buildings 4010, 4024, 4028, and 4059.

3.3 CRITICAL TEST FACILITIES

Several programs used critical test facilities (i.e., low-power reactors) in Area IV. Use of these low-power reactors began in 1954, and continued until 1974. The critical test facilities included SNAP development test facilities, which were housed in Buildings 4373, 4012, 4019, and 4024. Critical test facilities supporting the development of civilian nuclear power included Buildings 4009 and 4100.

3.4 NUCLEAR SUPPORT OPERATIONS

Starting in 1956, several operations were conducted in Area IV to support nuclear programs. These included the manufacture, management, and disassembly of fuel for reactor operations, as well as the operation of nuclear waste management facilities for offsite disposal.

3.4.1 Reactor Fuel Manufacturing

As part of the nuclear reactor development work performed for the government, three different reactor fuel manufacturing operations occurred at the SSFL in Buildings 4003, 4055, and 4064. The first operation was the assembly of fuel elements for the SRE, the second was a plutonium fuel manufacturing facility, and the third was a uranium carbide fuel pilot plant. There was also a Fuel Storage Facility, used to store the Special Nuclear Materials (enriched uranium and plutonium) used to make the fuels.

3.4.2 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies

During reactor test operations, it was often necessary to examine reactor fuel assemblies and other test specimens to determine how they were performing. This involved handling and examining highly radioactive items, for which the Hot Lab operated in Building 4020 from 1959 to 1990. The Hot Lab was a 16,000-ft^2 facility with four large hot cells with remote manipulators and cranes, a mock-up area, an operating area, and decontamination areas. Construction was completed in 1959, and the facility was used until 1990.

3.4.3 Fabrication, Use, and Storage of Radioactive Sources

Operations at SSFL required many instruments for detecting and measuring radioactivity, and these instruments were calibrated periodically using known quantities and types of radioactivity called sources, which were sealed containers that contained small measured quantities of radioisotopes. Sources were also used for some forms of radiography, irradiation testing, and other applications. Sources were manufactured in the Hot Lab at SSFL and used in various facilities at SSFL and elsewhere. Approximately 140,000 Ci of radioactive material (primarily Pm-147) were fabricated into sources at the Hot Lab. They were stored in secured locations and used under carefully controlled conditions.

3.4.4 Preparation of Radioactive Material for Disposal

The operation of nuclear reactors generates radioactive waste and other radioactive material that must be disposed of off the site. Other operations at the SSFL (fuel fabrication, reactor and fuel examination, etc.) also generated radioactive waste. Radioactive waste was prepared for disposal at the RMDF with support at the Interim Storage Facility (ISF) in Building 4654.

3.4.5 Research on Reprocessing Used Reactor Fuel

The Hot Cave in the Engineering Test Building supported licensing of nuclear fuel reprocessing. The used fuel assemblies from nuclear reactors contain unused fissionable material, fissionable transuranic products (mainly plutonium), and fission products. Rockwell developed a process to make a partial separation of used fuel, removing part of the fission products so that the material could be used again as reactor fuel. The experiments used up to kilogram quantities of unirradiated uranium and thorium, and up to 100-g quantities of highly irradiated materials.

3.4.6 Operation of Particle Accelerators

Rockwell operated a Van de Graaff generator in Building 4030, bombarding tritium targets with deuterons to produce neutrons. A second Van de Graaff generator was operated for neutron activation of materials.

3.4.7 Research Using Radioisotopes

Some of the research at the SSFL required the use of special radioisotopes. For these tests, small quantities of specially prepared radioisotopes were brought to the SSFL, used in laboratories under carefully controlled conditions, and then either returned to the vendor or stored safely when reuse was required.

3.4.8 Miscellaneous Operations

Two of the facilities at SSFL, the Conservation Yard and the Sodium Disposal Facility (also referred to as sodium burn pit), were not intended for use with radioactive materials, but both were inadvertently contaminated. The site profile states that both areas have been remediated and that no residual contamination has been detected.

3.5 OTHER RELEVANT FACILITIES

There are three other operations that are addressed in the site profile and include the Downey facility, the Canoga Park facility, and the De Soto facility. Each of these facilities is described below.

3.5.1 Downey

The Downey facility, located in Downey, California, included AEC-funded activities performed in a small portion of a large building from 1948–1955. The AEC activities included mainly paper studies, R&D, and engineering studies. The R&D activities involved the use of a 2-MeV Van de Graaff generator, a small-scale radiochemical laboratory, a neutron counting room, and a construction area with a small 0.5-W teaching reactor.

3.5.2 Canoga Park

Activities at the Canoga Park, California, facility occurred in the Vanowen Building from approximately 1954–1960. Activities that had been performed at the Downey facility were moved to the Canoga Park facility at the end of 1955. The primary activities performed at the Vanowen Building included design, development, and operation of small aqueous fuel reactors, fuel development, and radiochemistry, and beryllium machining is believed to have occurred.

3.5.3 De Soto

Radiological operations occurred at the De Soto facility from 1959 to the mid-1990s. Nuclear fuel material and other radioactive materials were used in Buildings 101 and 104 (referred to as 001 and 004, respectively, prior to 1984) from 1959–1983. Building 104 was used at a much-reduced level until the mid-1990s. The nuclear operations conducted in these buildings included the Advanced Test Reactor (ATR) fuel fabrication and supporting activities; a Gamma Radiation Facility; and a mass spectroscopy (Helium Laboratory).

3.6 RADIONUCLIDES OF CONCERN

Workers at SSFL were engaged in many process operations and maintenance activities that had the potential for external and internal exposures to a host of radionuclides shown in Table 2-3 of TBD-2. A credible assessment of worker exposures to these radionuclides is hampered as a result of the following:

- No specific information is available on diagnostic x-ray equipment and techniques used prior to 1971.
- There is a limited amount of internal personnel monitoring data for pre-1959 exposures. This is consistent with the findings that SSFL routine bioassay program was not initiated until August 1958.
- There is a lack of meaningful source term information (such as isotopic and curie content) for the 1955–1958 period.
- No stack effluent concentration data are available for the period prior to 1965.

4.0 FINDINGS IDENTIFIED IN THE SANTA SUSANA SITE PROFILE

This section identifies findings that resulted from our review of the six TBDs that represent the SSFL site profile. Findings are grouped by their corresponding TBD. For some findings, supportive information is provided by one or more exhibits. For ease of tracking, findings and their associated exhibits are numbered in a manner that provides a linkage. For example, all findings associated with internal dose reflect TBD-5 (of ORAUT-TKBS-0038-5) and are discussed in Section 4.5 below. The first finding pertaining to internal dose is, therefore, identified as Finding 4.5-1. An exhibit that would support Finding 4.5-1 would be labeled as Exhibit 4.5-1. If there were more than one exhibit supporting this finding, they would be labeled as Exhibit 4.5-1A, Exhibit 4.5-1B, etc.

Some of the findings included below are not likely to have an impact on the preparation of dose reconstructions, but instead are provided to improve the quality of the site profile. These findings include "(Observation)" following the finding number.

4.1 REVIEW OF TBD-1 (ORAUT-TKBS-0038-1) ATOMICS INTERNATIONAL – INTRODUCTION

The Introduction explains the purpose and the scope of the site profile. This section provides a useful overview of the site profile, and explains the role of each TBD in support of the dose reconstruction process. Hence, the introduction helps in framing the scope of the site profile. The findings for TBD-1 are presented below.

Finding 4.1-1. TBD-1 and subsequent TBDs present inconsistent dates of operation of various activities at the SSFL Site.

The dates presented for various activities are not consistent and should be reviewed and revised to be consistent. For example, the Introduction (TBD-1, p. 1) states, "Area IV of the Santa Susana Field Laboratory (SSFL) established by the U.S. Atomic Energy Commission in 1966…" Page 3 of TBD-2, however, states, "Area IV was established at the SSFL in 1953 as a nuclear research and development facility." Later on this same page, it is stated that "Nuclear R&D activities in Area IV increased rapidly from 1953 into the late 1960s, then declined."

Finding 4.1-2 (Observation). TBD-1 discusses the ways the facility has been referred to over the years. It focuses on the use of Atomics International (AI) to represent the entire site and Area IV [also known by many other names, including Energy Technology Engineering Center (ETEC)] as the primary area of study. TBD-2 uses ETEC in referring to the primary area of study, which is included in the document title. The titles of other TBDs include AI (TBD-3 and TBD-6), Area IV (TBD-4), and ETEC (TBD-6).

While this is not a big issue, the nomenclature should be consistent to avoid confusion. In addition, it appears that the intention of the TBDs is to address Area IV of SSFL and the outlying properties (Downey, De Soto, and Canoga) consistently. However, this is not the case. The TBDs focus more on Area IV and, in some cases, refer to information on Area IV when the item also contains information on the outlying properties (e.g., the title of Table 2-1 is "Site

Information of nuclear research operations conducted at Area IV," yet the table also includes information on the other three sites). Downey, Canoga Park, and DeSoto facilities do not have separate TBDs.

4.2 REVIEW OF TBD-2 (ORAUT-TKBS-0038-2) ENERGY TECHNOLOGY ENGINEERING CENTER – SITE DESCRIPTION

The Site Description is an important document, because it provides a description of the facilities and processes, as well as historical information that serve as the underpinning for subsequent TBDs. Specifically, this document describes the history and current status of key facilities and processes, and the associated source terms that are relevant to dose reconstruction. SC&A's review of this section focused on whether all the potentially important site activities and processes are described, and whether characterization of source terms is complete and sufficient to support dose reconstruction.

It should be noted that much of the relevant background information contained in Section 3.0 of this report was taken from TBD-2. A positive feature of TBD-2 is a series of tables (i.e., Tables 2-1 through 2-6) that provide a comprehensive overview of key facilities and periods of operation, radionuclides of concern and quantities, and description of major incidents.

Finding 4.2-1: Additional information is available and should be presented related to the Sodium Reactor Experiment (SRE) coolant failure.

TBD-2 contains a discussion of the SRE coolant failure in Section 2.2.1.1.2 and in Table 2-6. Section 2.2.1.1.2 provides very little information on the incident, and does not discuss any potential exposure information. Table 2-6 (30 pages later in the document) provides more detail on the incident, but does not provide any worker exposure information. There is information in Table 2-6 about exposure being negligible for nearby residents (a maximum theoretical calculated dose of 0.06 μrem to someone living in Susana Knolls, the nearest residential area at the time), but does not present exposure information for workers. Based on our review of claimant files, it does not appear that all workers who should have been badged were indeed badged. In instances where workers were not badged and may have worked in this area, the lack of exposure information is problematic.

Atomics International prepared two reports on this incident; a report titled *SRE Fuel Element Damage, An Interim Report (NAA-SR-4488)—November 15, 1959* (AI 1959), and a second report titled, *SRE Fuel Element Damage, Final Report (NAA-SR-4488 (suppl)—1961* (AI 1961), that are not referenced in TBD-2.

The dose reconstructions that were reviewed referenced TBD-2 in considering the SRE coolant failure and did not rely on the two AI reports from 1959 and 1961.

The interim report (AI 1959) contains information that would add value to the Site Profile as it relates to this incident. Examples of this information include the following:

- *During this occasion, specifically, in October 1958, the maximum radiation levels in the general area of the moderator coolant pump were reported to be about 50 Mr/hr (October 14). Below shield blocks 1 and 2, the radiation level was about 21 mr/hr (on October 11).* (p. IV-C-9)

- *Radiation levels measured on April 18, 1959 varied from 50 to 420 mr/hr. …Additional measurements made 5 days later (a total of 17 days after shutdown) indicated no significant decay*. (p. IV-C-10) [Table IV-C-6 includes radiation levels in the Gamma Facility on various dates in August, September, and October of 1959. The measured radiation levels peaked on August 12 (2.9 r/hr) and decreased to 0.7 r/hr on October 5.]

- *Cold trapping was started during run 14. However, radiation measurements could not start until August 8 (due to the radiation hazard from the high radiation levels of Na^{24}), at which time the dose rate, extrapolated to near the surface, was about 70 r/hr. It is possible that initial cold-trap dose rates, had they been measured, would have yielded significantly higher values.* (p. IV-C-12) [The radiation rates at the cold trap, shown in Table IV-C-7, range from 63 r/hr on August 8, 1959, to 50 r/hr, with a peak of 81 r/hr on August 13.]

- *Following the termination of run 14, the fuel handling cask was used to inspect the fuel elements in the reactor. … Operations directed towards removal of these slugs resulted in occasional radiation levels as high as 1000 r/hr at 1 ft. from the slugs. However, the maximum total exposure received by operations personnel during these cask operations did not exceed 1 rem in a single week.* (p. IV-C-22). [The basis for this last statement was not provided in the report and the number of personnel exposed was also not presented.]

The final report (AI 1961) also contains information that would be of value to the Site Profile. Examples of this information include:

- *This report discusses the distribution and management of the fission products during the recovery operations. During the recovery effort the objectives were: (1) To limit personnel exposure to an average dosage rate of 1.25 rem/quarter (5 rem/yr).* (p. III-19)

- *Throughout the recovery effort the radiation exposure to each individual was limited to less than 5 rem/yr. It was occasionally necessary to permit the weekly exposure for some key individuals to reach 600 mrem per week, in which case the individual was not exposed to radiation during the following week. Such exposures required a special permit, and only 30 permits were issued. For the 150 persons directly involved in the work, the average exposure was 2 rem/yr.*

Finding 4.2-2. The TBD does not present information on the types of workers at the site. There is reference to "radiation workers," but this term is not defined and there is no information on the number of radiation workers at the site over the years of operation.

The *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004) suggests that the site profile should include the identification of worker groups as each group relates to monitoring practices, and review how the site management dealt with each group. Ideally, the workers should be divided into the following groups:

- Workers who were not monitored for radiation exposure
- Workers who should have been, but were not monitored
- Workers who were monitored inadequately for radiation exposure
- Workers whose monitoring records are incomplete or missing
- Workers who were monitored adequately for radiation exposure

The above comments also apply specifically to decontamination and decommissioning (D&D) workers who were providing support at the facility from the 1960s onwards as reactors were decommissioned. Specific issues that would be helpful to cover include the following:

- Whether D&D workers were monitored for external dose and in what periods
- Whether D&D workers were monitored for internal exposure and how the exposure potential is to be determined

Finding 4.2-3: The Site Description lacks sufficient detail to assess potential exposures to workers.

Given the unique and highly complex activities that characterize this site, descriptions of individual facilities/processes are too brief and may lack information considered relevant to dose reconstruction. For example, there is limited/incomplete data concerning discrete radiological events, as summarized in the text and in Table 2-6. At a minimum, a TBD should provide proper references/auditable documents of any significant radiological incidents. A review of the text and inspection of Table 2-6 of the TBD reveals that no references are cited for these incidents, and no useful data are provided that may be relevant to dose reconstruction. A prime example of this is the SRE incident discussed in Finding 4.2-1.

Finding 4.2-4: Incomplete listing of radionuclides.

Section 2.3 and Table 2-3 identify radionuclides of potential concern by facility and time period.

Potentially significant radionuclides missing from TBD-2 include the following:

- **Na-24:** Large quantities of sodium-24 were likely produced in the SRE reactor and the SNAP8 Experimental Reactor. Moreover, both reactors experienced fuel failure that may have resulted in worker exposure.

- **Radioiodines (I-131, I-133, and I-135):** These volatile and high-yield fission products were likely present at all reactor facilities.
- **Mn-54 (and other activation products):** Significant quantities of magnesium-54, as well as other activation products, would have been produced during reactor operations.
- **U-232 and U-233:** These radionuclides would have been present, since thorium-232 was used as fertile material at the SRE.

Finding 4.2-5: TBD-2 contains discrepancies in the dates of operation provided in the text and in Table 2-1.

Table 2-1 in TBD-2 summarizes the site information of all nuclear research operations conducted at Area IV, to include facility names, descriptions of facilities, periods of operation, and building locations. After reviewing TBD-2, SC&A found several discrepancies in Table 2-1 for the periods of operation of several facilities, as compared to the text descriptions of these facilities in TBD-2. These discrepancies are presented in Exhibit 4.2-5. Although the title refers to operations in Area IV, the table includes the De Soto Plant Building 104. The TBD should include a short discussion of the role of the facilities other than Area IV.

Exhibit 4.2-5: Discrepancies in Site Information of Nuclear Research Operations Conducted at Area IV

(Source: TBD-2)

Section	Name	Description	Period of Operation	Discrepancy in Period of Operation (SC&A Findings)	Facility
2.2.1.2.1	SNAP Critical Test Facility	Second SNAP Critical Test Facility	1962–1968	1961–1967	Building 4012
2.2.2.3	Radiochemistry Laboratories	Hot Radiochemistry Laboratories	1959–1989	1959–1983, reduced work until 1990s	DeSoto Plant Building 104
2.2.1.3.1 (1)	Engineering Test Building	Reactor fuel manufacturing facility to support Sodium Reactor Experiment	1954–1964	Unable to determine the dates of operation based on information provided in TBD-2	Building 4003
2.2.1.3.5 (1)	Hot Cave	Hot cell for reprocessing used reactor fuel	1954–1964	Unable to determine the dates of operation based on information provided in TBD-2	Building 4003
2.2.1.3.1 (3)	Uranium Carbide Fuel Pilot Plant	Uranium Carbide Fuel Manufacturing Pilot Plant	1964–1967	? – 1967 (operations completed in 9 months in 1967)	Building 4005
2.2.1.3.6 (1)	Van de Graaff Accelerator	Particle Accelerator	1960–1964	? – 1962 (removed from building in 1962)	Building 4030
2.2.1.3.2 (1)	Hot Lab	Hot Laboratory for disassembly and examination of used reactor fuel	1957–1988	1959–1990	Building 4020
2.2.1.3.7 (2)	Corrosion Testing Laboratory	Liquid Metals Compound Testing Facility	1962–1986	Unable to determine the dates of operation based on information provided in TBD-2	Building 4023
2.2.1.3.3 (1)	Radioactive Measurement Facility	This facility for storage and use of radioactive sources for calibration of radiation instruments	1959-1974	? –1974	Building 4029

Exhibit 4.2-5: Discrepancies in Site Information of Nuclear Research Operations Conducted at Area IV
(Source: TBD-2)

Section	Name	Description	Period of Operation	Discrepancy in Period of Operation (SC&A Findings)	Facility
2.2.1.3.1 (4) and 2.2.1.3.7	Fuel Storage Facility	Fuel Storage Facility is a vault built to provide storage for fissionable fuel material (EU & PU)	1958-1993	? –1993	Building 4064

Finding 4.2-6 (Observation): The history/relationship of the private entities at SSFL should be presented early in this TBD and other TBDs, so it is clear how these firms are related.

An example of a paragraph that could be included early in each of the TBDs is presented below.

The AEC began work at SSFL in 1948 through a contract with North American Aviation (NAA). The purpose of this contract was to conduct nuclear research operations at Area IV of SSFL and the Downey, Canoga, and De Soto sites. NAA's work was conducted through one of its divisions, AI. Several corporate mergers and organizational changes occurred over the years. In 1967, NAA merged with Rockwell Standard to become North American Rockwell. In 1973, the corporate name changed to Rockwell International (RI). Atomics International and another division, Rocketdyne, operated independently under RI until 1984, when AI was absorbed by the Rocketdyne division. The Boeing Company purchased RI in 1996, with Rocketdyne continuing as a division of Boeing.

The dates of operation for the various activities presented in the NIOSH SEC Petition Evaluation Report (Petition SEC-00093 or "ER") were consistent with the period of operations listed in Table 2-1 of TBD-2 for the following facilities: SNAP Critical Test Facility, Engineering Test Building, Hot Cave, Van de Graff Accelerator, Corrosion Testing Laboratory, Radioactive Measurement Facility, and Fuel Storage Facility. However, SC&A was unable to confirm the periods of operation for the following facilities: Radiochemistry Laboratories, Uranium Carbide Fuel Pilot Plant, and the Hot Lab. The periods of operation need to be reviewed and the document revised accordingly.

4.3 REVIEW OF TBD-3 (ORAUT-TKBS-0038-3) ATOMICS INTERNATIONAL – OCCUPATIONAL MEDICAL DOSE

Existing programmatic documents do not furnish a complete record of the criteria used since 1948 to determine which workers were required to have x-ray examinations or the frequencies of the examinations; nevertheless, some information is available.

> *The review of records suggests that:*
>
> - *About half of the pre-employment examinations included both posterior-anterior (PA) and lateral (LAT) chest views and one or two views (PA and*

LAT) of the lumbar spine. The remainder included only one PA chest view.

- *It was rare for an employee to have annual chest radiographs. Most individuals were never subjected to periodic radiographic reexamination.*
- *Of those who were reexamined, the typical periodic examination frequency was every 3 to 5 years. About half of those reexamined had one PA chest view. Others had a PA chest and some form of lumbar-spine examination.*
- *There was no evidence of collimation on the radiographs.*
- *There was no evidence suggesting the use of photofluorography.*
- *There was no evidence suggesting the use of fluoroscopy.*
- *There was no evidence suggesting the use of stereo chest films (same view on two films, slightly displaced).*
- *All typical views – PA chest, LAT chest, AP lumbar spine, and LAT lumbar spine – commonly found in the records were of the same size: 14 in. by 17 in.*
- *In a few cases, antero-posterior (AP) spot and LAT spot lumbar-spine views were observed, and in these cases a smaller film size, 10 in. by 12 in., was common.*
- *There was no evidence of the use of gonadal shielding in the lumbar-spine views.*

Radiation safety standards from 1966–1972 required "pre-exposure examinations" and termination examinations for radiation workers. Even though some employees were not radiation workers, it is assumed that all employees received a pre-employment examination consisting of a PA chest film, LAT chest film, AP lumbar spine film, and AP lumbar spine spot film. For 1972 through 1997, a similar examination policy was in place. After 1997, pre-employment lumbar-spine and chest radiography were no longer required.

Finding 4.3-1: The TBD requires subjective interpretation and makes unreasonable demands on the dose reconstructor.

Since formal documentation regarding AI policy for administering routine medical examinations prior to 1997 has not been identified, the TBD states the following in Section 3.4.2:

> *… Lacking specific claimant information,* ***assume*** *each radiation worker had a PA and LAT radiographic chest examination* ***every year*** *and one AP lumbar spine with an AP lumbar spine spot film examination every four years.* [Emphasis added.]

In Section 3.7, the TBD provides the following guidance for dose reconstruction:

The records provided by DOE are likely to include adequate information to define the date, type, and count of X-ray examinations that were administered to the claimant as a condition of employment. ***Use the assumptions regarding radiographic exposure frequency only for screening or when specific claimant records are not available****.*

If confusion about the radiographic exposure record exists, consider requesting that the **notes** *on the exterior of the envelope(s) containing the claimant's X-ray films be transcribed and provided. These* **notes** *should give insight to the reason that the exposures were made, for example pre-employment examination, routine surveillance, or diagnosis of injury. . . .* [Emphasis added]

SC&A interprets this guidance to imply that for dose reconstructions defined by "best estimates," the dose reconstructor is to make the following decisions/assumptions:

- Determine whether the **absence** of DOE records reflects the fact that (1) the claimant was **not** subjected to medical radiation exposure, or (2) the claimant may have been subjected to medical exposure, but records have been lost and default values apply.
- Request additional data from the DOE and decipher medical "notes" regarding the reasons for and type of medical exposures.

If our interpretation of stated guidance is correct, SC&A concludes that current guidance not only imposes unreasonable demands on the dose reconstructor, but more importantly may lead to subjective and inconsistent interpretation of records/absence of records.

Finding 4.3-2: Table 3-2 should be revised to show that the exposure units [i.e., PA chest ESE (mR) and Organ dose (rem)] should be modified to indicate these exposures are "per examination."

Table 3-2 should be clarified, so that it is clear that the exposure units (mR and rem) are actually mR/examination and rem/examination. While this may be assumed by some dose reconstructors, it may not be clear to others.

4.4 REVIEW OF TBD-4 (ORAUT-TKBS-0038-4) AREA IV OF THE SANTA SUSANA FIELD LABORATORY, THE CANOGA AVENUE FACILITY (VANOWEN BUILDING), THE DOWNEY FACILITY, AND THE DE SOTO AVENUE FACILITY (SOMETIMES REFERRED TO AS THE ENERGY TECHNOLOGY ENGINEERING CENTER [ETEC] OR ATOMICS INTERNATIONAL) – OCCUPATIONAL ENVIRONMENTAL DOSE

Occupational environmental dose refers to radiation exposures received by workers while onsite but outside the SSFL facilities from facility discharges to the atmosphere, ambient external radiation originating in the facilities, and inadvertent ingestion of site-generated radionuclides. The environmental monitoring program was established at Area IV in May 1954, before construction of the first radiological facility, with emphasis on soil, vegetation, and water sampling.

TBD-4 provides guidance and data for assigning occupational environmental doses for Area IV, and the Downey, Canoga, and De Soto sites that make up SSFL, for all years, starting with 1954 through 1999. Due to insufficient environmental monitoring/data limitations, the TBD relied on the following data and applied the following assumptions in order to provide the dose reconstructor the means to estimate inhalation intakes that are radionuclide-specific and for all years of facility operations.

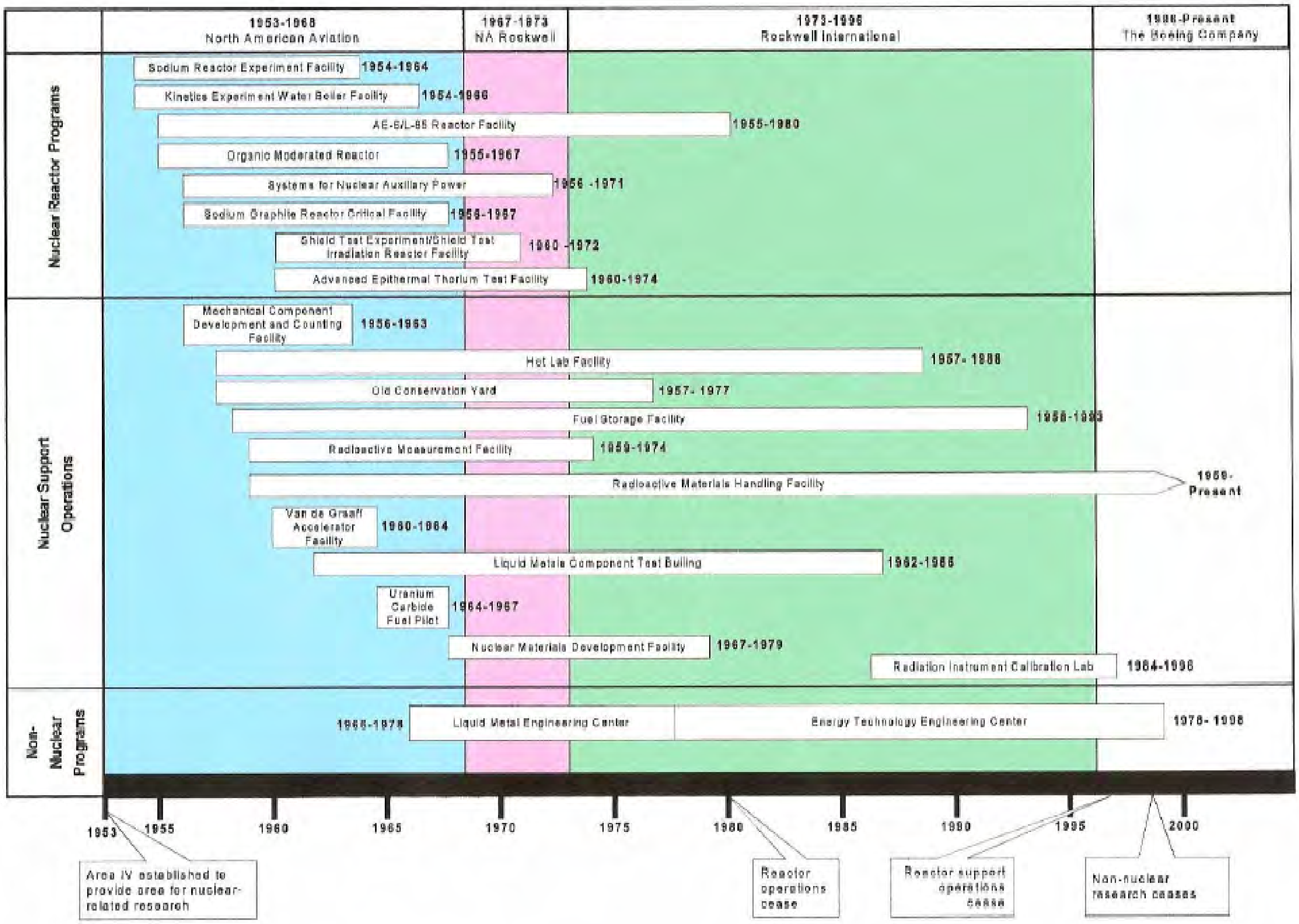
> *Average annual gross alpha/gross beta concentrations in facility stack emissions were the basis for estimating potential worker environmental* ***inhalation*** *intakes. Most of the available SSFL* ***stack*** *emission data include annual average gross alpha and gross beta concentrations at the* ***stack point of release****. Years with data vary by facility, but gross alpha/gross beta concentration information is available for* ***most*** *years between* ***1971*** *and* ***1999****. …*
>
> *…Identification of* ***specific radionuclides*** *released from various facilities in stack emissions are available … from* ***1988*** *to* ***1999*** *and were used to characterize radionuclide emissions for* ***all*** *years. …*
>
> *…In years where data were not available, stack concentrations were assumed to be the* ***average yearly*** *gross alpha and gross beta concentrations in stack effluents from years* ***1971*** *to* ***1999,*** *for which data were available.*
>
> *…Furthermore, the average percentage that each identified radionuclide contributed to the gross alpha or gross beta concentration determined from* ***1988*** *to* ***1999*** *data was applied to each of these years to make radionuclide-specific stack concentration estimates….*
>
> *…Because the stack effluent concentrations were at the point of release, a further* ***reduction factor*** *of* ***0.01*** *was taken to account for the lessened overall intake due to contribution from multiple, widely spaced facilities; atmospheric dispersion of stack effluent over the course of a year's exposure; and building wake effects.* [Emphasis added.]

The approach for the reconstruction of environmental occupational exposures, as briefly summarized above, was evaluated against data presented in TBD-2, which includes Figure 2-3 (enclosed here in Exhibit 4.4). The findings associated with this TBD are presented below.

Finding 4.4-1: Surrogate use of the time-integrated average yearly gross alpha/gross beta stack emission corresponding to years 1971 to 1999 (when stack measurements were taken) is likely to underestimate stack emissions for years 1954 through 1970.

SC&A's conclusion is supported by the steady reduction in facility operations over time, as illustrated in Exhibit 4.4. For example, nuclear reactor programs were essentially phased out in the early 1970s.

EXHIBIT 4.4



1953-1966
North American Aviation
1967-1973
NA Rockwell
1973-1996
Rockwell International
1996-Present
The Boeing Company
Nuclear Reactor Programs
Sodium Reactor Experiment Facility
1954-1964
Kinetics Experiment Water Boiler Facility
1954-1966
AE-6/L-85 Reactor Facility
1955-1980
Organic Moderated Reactor
1955-1967
Systems for Nuclear Auxiliary Power
1956 -1971
Sodium Graphite Reactor Critical Facility
1956-1967
Shield Test Experiment/Shield Test Irradiation Reactor Facility
1960 -1972
Advanced Epithermal Thorium Test Facility
1960-1974
Nuclear Support Operations
Mechanical Component Development and Counting Facility
1956-1963
Hot Lab Facility
1957- 1988
Old Conservation Yard
1957- 1977
Fuel Storage Facility
1958-1993
Radioactive Measurement Facility
1959-1974
Radioactive Materials Handling Facility
1959-Present
Van de Graaff Accelerator Facility
1960-1964
Liquid Metals Component Test Builing
1962-1986
Uranium Carbide Fuel Pilot
1964-1967
Nuclear Materials Development Facility
1967-1979
Radiation Instrument Calibration Lab
1984-1996
Non-Nuclear Programs
1966-1978
Liquid Metal Engineering Center
Energy Technology Engineering Center
1978- 1996
1953
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Area IV established to provide area for nuclear-related research
Reactor operations cease
Reactor support operations cease
Non-nuclear research ceases

Finding 4.4-2: Use of average radionuclide-specific stack emission data representing years 1988 through 1999 as surrogate data is unlikely to be representative of stack emissions for years 1954 through 1987.

Use of radionuclide-specific data obtained only after 1988 as surrogate data for all prior years that go back to 1954 is inappropriate, due to major shifts in facility operations and processes (see Exhibit 4.4). For example, in Section 5.3.1.5 of TBD-5 (Occupational Internal Dose) of the SSFL site profile, the following statement appears:

> *By **1989, all R&D** activities had ended. All work with radioactive materials has been in conjunction with ongoing decontamination and decommissioning activities. …* [Emphasis added]

Finding 4.4-3: The basis for a single "reduction factor of 0.01 as a way of converting average air concentrations (at points of release for multiple stacks) to breathing zone air concentrations for all site locations and all years of facility operations is not supported.

Furthermore, the 0.01 reduction factor for deriving breathing zone air concentrations is solely linked to stack emissions. Not addressed in estimates of inhalation doses is the resuspension of ground surface contaminants that build up over time.

Finding 4.4-4: Estimates of annual external occupational environmental doses prior to 1974 are incomplete and are based on multiple "assumptions" that are neither explained nor properly referenced.

Sections 4.6.4, 4.6.5, and 4.6.6 of TBD-4 acknowledge the lack of external dose rate monitoring data prior to 1974, and provide unsupported/unreferenced assumptions that were used to derive annual external dose estimates for a **restricted** number of facilities, as given in Table 4-4 of the TBD.

Finding 4.4-5: The TBD states that potable water is not a source of occupational radiation exposure, which is inconsistent with what is presented in the SEC Evaluation Report and other information sources.

Under the ingestion pathway in Section 4.7 of the TBD, it states "Potable water is not a source of occupational radioactive material at SSFL because the SSFL facilities used either bottled water from an off-site vendor (Moore, Fisher, and Rowe 1962) or the city water supply." However the SEC ER (p. 50) states "Available data indicate that onsite water supply wells were the primary water source from 1949 to 1964." In addition, other references (Winzer 1980; Winzer 1981; and Curphey 1983) indicate that well water was a source of drinking water into the 1980s.

Although the ER stated that the drinking water supply wells did not have elevated levels of tritium (>1,000 pCi/l) (concern with tritium given current tritium plume on site), the SEC ER has tried to bound any contamination that may have existed when the onsite supply wells were the source of drinking water with a resulting value of 30,000 pCi/l. More recent Boeing reports (Boeing 2003; Boeing 2004; Boeing 2005; and Boeing 2006) have documented tritium concentrations as high as 117,000 pCi/L in the monitoring wells (not the drinking water wells). The TBD should be revised to include this information and discuss this pathway.

Finding 4.4-6: Additional information should be sought and provided on exposures to the sodium burn pit and other contaminated areas.

The sodium burn pit was built to clean nonradioactive metallic sodium and NaK from various scrap test components. Contamination was identified in the sodium burn pit in 1978, at which time monitoring of the area began and continued until 1983. Prior to 1978, no radioactivity was expected in this area, thus raising questions whether individuals involved in these activities would be considered for internal monitoring. It is unclear when the radioactive contamination was introduced to the burn pit or how far back in time the potential exposure to radiation exists. Given the violent nature of the operation, it would be expected that this operation would have generated an airborne hazard. Since the sodium burn pit was not expected to result in radiation exposures, there was no routine monitoring. But this does not mean that routine exposure can be ruled out. In one of the dose reconstructions presented to support the SEC ER, the claimant (a fireman) was assigned to the sodium burn pit. Five out of 10 of the fireman's bioassays were above the method detection limit (MDL). In addition, there are no radionuclide-specific bioassay data available for the fireman. The site profile should contain additional information on this unit and the potential exposures to workers, given information that is available.

The TBD also does not consider exposure to contaminated soil that has resulted from spills and other incidental releases. For example, a review by an EPA official in 1989 (Dempsey 1989) identified Building 064, the Special Nuclear Materials Storage Area, that had been contaminated as a result of a spill. This EPA official also had concerns about the validity of some, if not all, of their environmental data:

> *In the Rocketdyne procedure, soils are heated in a muffle furnace for 8 hours at 500 C. Several problems were identified: first, this temperature is sufficient to volatilize most man-made radionuclides of concern, including cesium-137 and strontium-90. Second, from the Rocketdyne procedure, soil is sieved through a coors crucible to obtain uniform particle size…. This procedure is a screening method at best and is not an accurate quantitative procedure.*

4.5 REVIEW OF TBD-5 (ORAUT-TKBS-0038-5), ENERGY TECHNOLOGY ENGINEERING CENTER – OCCUPATIONAL INTERNAL DOSE

TBD-5 describes the internal dosimetry (bioassay) program at SSFL, with key excerpts from this section presented below. Entry into the bioassay program was based on job assignment. By 1959, routine urine samples were requested weekly, mainly on Fridays. By the early 1960s, the bioassay program "normally" consisted of urinalysis for personnel whose work assignments involved "potential exposure to radioactive materials." The frequency of sampling varied from one to four per year, depending on the nature of the employee's work, past exposure history, etc.

In 1970, standards for bioassay sampling were published (Staszesky 1970). Work in areas where unencapsulated radioactive material was present required baseline and termination urine samples. A new baseline could be required for a change in job assignment. For new operations, a "pilot" bioassay program consisting of weekly urine samples could be required until a pattern was established. Regular work in these areas required a quarterly routine urine sample, but monthly samples could be required in a case of high exposure potential. Periodic fecal samples and in vivo counts could also be required. Employees who performed work in these areas only periodically were subject to semiannual urine samples. Personnel such as project engineers, industrial engineers, etc., who frequently entered these areas but did not perform hands-on work provided annual routine urine samples.

By the mid-1970s, the definition of who was included in the routine bioassay monitoring program had changed to "personnel whose work assignments potentially expose them to respirable-sized radioactive aerosols" (Hart 1979). By the late 1980s, the criterion was "personnel whose work assignments potentially expose them to radioactive aerosols" (Tuttle 1989). Quarterly urine sampling was the norm through the 1980s (Hart 1979; 1980a,b,c; Eggleston 1983, 1984; Tuttle 1985, 1986a,b,c, 1988a,b, 1989).

Special bioassay sampling, consisting of more frequent urine testing, was in place very early (1960), and in the mid-1970s, fecal sampling was also used, but "only when gross internal contamination" was suspected (Hart 1979). Using the concept of a Maximum Possible Body Burden (MPBB), an excretion rate was determined by radionuclide that would indicate that one MPBB had been received. For several years prior to 1968, the policy was to restrict employees from work in potential airborne areas until their body burden was less than 25% of the MPBB (Alexander 1968a). Starting in January 1968, ETEC imposed a restriction from work in areas with potential airborne exposure (or in some cases, from all radiation areas) if the bioassay results indicated the receipt of 50% or more of the MPBB. The restriction remained in place until two consecutive bioassay samples indicated that the remaining deposition was less than 25% of the MPBB (Staszesky 1970).

SC&A's findings for TBD-5 are presented below.

Finding 4.5-1: Monitoring for internal exposure of SSFL workers was incomplete and poorly documented for most years of facility operation.

In Section 5.2 (page 10) of the TBD, the evaluation of the SSFL internal monitoring program is prefaced with the following statement:

> *Early 1960s AI documents describe **all** the elements of a **comprehensive** radiation safety program, including a laboratory with bioassay capability.* … [Emphasis added]

This statement, however, was tempered by numerous admissions in subsequent sections of the TBD. A sampling of statements suggesting serious deficiencies and data limitations include the following:

Page 13:

> *Specific radionuclides **could** be determined "where required" (Lang 1960). **Some** detail has been found on early urinalysis methods. In addition to the in-house laboratory capability, bioassay services were contracted to the following vendors:* [Eight vendors are listed.]
>
> *…Information on the periods during which ETEC used these laboratories was **not** found.* [Emphasis added.]

In addition to the eight contract laboratories, ETEC had its own **in-house** laboratory, which analyzed urine for uranium content by fluorometric method. Exposure to uranium may have existed in various states of enrichment up to 93%.

Page 14:

> *Due to its higher specific activity, EU activity **could** be determined by counting….*
>
> *No specific information on sensitivities for the **in-house** laboratory was obtained….* [Emphasis added.]

Page 15 (Regarding Thorium):

> *No details of early thorium analyses were recovered…*

Page 15 (Urinalyses for period 1967–1974):

> ***Partial** documentation on bioassay methods from 1967 through 1974 was found. …These documents are **believed** to refer to services offered by UST* [one of the eight contract laboratories].

Page 17 (Urinalysis for period 1975–1988):

> *The following analytical methods were taken from a series of annual reports…. The measurement "type" in parentheses appears in many personnel bioassay records. The detection limits should have improved over the years. However, a listing was **not** found.* … [Emphasis added.]

Page 18 (On the method for analyzing mixed fission products):

> *Mixed fission products were precipitated from a **basic** oxalate media. … Alkali metals such as ^{137}Cs did **not** precipitate. In addition, **volatile** fission products such as 1-131 were **lost**.* … [Emphasis added.]

Page 19 (On in vitro methods for individual radionuclides):

> *Although fecal sampling was mentioned as both a routine and a special bioassay method in site documents,* ***little*** *detail has been found about the analytical methods used. …* [Emphasis added.]

Page 20 (On the use of whole-body counting for monitoring workers):

> *… whole-body counting for fission or activation products was apparently* ***not*** *part of the routine bioassay program at ETEC. Between 1975 and 1988, only 25 counts on 25 individuals were summarized in annual reports. …All WBCs were reported positive for* ^{137}Cs*. Ten counts were performed in 1977 and 15 were performed in 1979.* [Emphasis added.]

Page 20/21 (On the use of chest counting):

> *In 1967, the first chest (lung) counts for uranium using a medical system were performed at UCLA. The 186-keV gamma ray from the decay of* ^{235}U *was used to quantify the amount of EU in the lung … Calibration of this system was* ***crude****;…*
>
> *Starting in 1968, Helgeson Nuclear Services provided lung counting services. … The results were reported in milligrams of* $^{235}U \pm 2$ *sigma…*
>
> *By 1977, two 5-in.-diameter, thin-window phoswich detectors were used, …* [to detect U-235]
>
> (SC&A notes that all chest measurements only quantified the amount or the activity of U-235. Without a firm understanding of the level of enrichment, the more important contribution of U-234 to total alpha activity cannot be determined.)

Page 25 (On solubility type, fraction activity, and particle size per facility):

> *In the absence of any measurements or studies, NIOSH guidance requires the use of default* ***solubility classes*** *and particle size values from the International Commission on Radiological Protection. … With one exception, facility-specific solubility and particle size data for ETEC has* ***not*** *been found. Activity fractions were* ***not*** *available with the exception of those for limited fuel fabrication operations. … Table 5-9 lists* [recommended/default] *this information.* [Our review of Table 5-9 indicates that to date, (1) a solubility class has not been assigned to all radionuclides, (2) activity fractions are lacking for several facilities, (3) activity fractions are based on inappropriate data, and (4) activity fractions fail to identify select radionuclides (e.g., Na-24, radioiodines)].

Finding 4.5-2: Insufficient correlation between bioassay data and potential exposures to specific radionuclides.

Two sources in the site profile (NIOSH 2008, ORAUT 2006e) state that there is sufficient bioassay and other supporting data available for 1959 and beyond to establish an upper bound for uranium, mixed fission products (MFPs), Po-210, plutonium, SR-90, tritium, and thorium. SC&A does not believe that these sources have clearly demonstrated a correlation between the bioassay data available and the potential exposures to specific radionuclides. They have not clearly defined for which workers each of the procedures were conducted, including gross alpha and gross beta. From a brief review of claimant files, it appears that monitoring was not routine for all workers handling radioactive material. Furthermore, detection limits for 1975–1988 are unavailable, and Table 5-9 containing solubility type and fraction of activity is incomplete in many cases.

Finding 4.5-3: Missing radionuclides in bioassay data.

The site profile indicates that bioassay data were available for gross alpha, gross beta, uranium, fission products, plutonium, thorium, Po-210, Sr-90, H-3, P-32, S-35, C-14, Pm-147, americium, and curium. Potential exposure to radionuclides such as U-233 and U-234 could have occurred during these operations.

Finding 4.5-4: No coworker model.

The site profile has not cited an internal coworker model as necessary, and the document does not address the use of a coworker model for those individuals potentially exposed, but not monitored. A review of some of the claimant files indicates that some workers, who it appears should have been monitored, were not monitored, and those workers who were monitored were not monitored on a routine basis. In many cases, the dose reconstruction reports rely on guidance that has been developed for internal dose determinations based on other site information, rather than relying on site information. A coworker model would allow for more precise determinations of the doses the SSFL workers received.

Finding 4.5-5: Assumption of chronic intake in evaluating bioassay results.

TBD-5 states on page 11, "By 1959, routine samples were requested on Fridays and each employee was required to submit the first voiding on Monday morning (following the absence from work of 48 hours or more)." This is an important statement and it requires some guidance for the dose reconstructor. The Site Profile recommends that exposure be considered as chronic intake for situations of routine exposure. However, since the samples were taken at least 48 hours after last intake, if a chronic intake is assumed instead of the real scenario (5 days of work/week and samples taken 2 days after exposure), the estimated intake will be almost 3 times lower compared to the real scenario. Exhibit 4.5-5A presents the daily excretion rates (Bq/Bq intake) for the scenarios of chronic intake and chronic intake simulating the working days (8 hours per day, 5 days per week) for a case of inhalation of uranium Type S, AMAD=5μm. The excretion rate expected 48 hours after the last intake is about 3 times lower compared to the rate assuming chronic intake. This difference will be reflected in the estimated intake. Exhibit 4.5-5B presents the intake values calculated assuming the two scenarios described above. The simulation assumes a quarterly frequency of monitoring and the result of urinalysis equal to 1 Bq/day of U. Based on this assumption, if the intake is estimated assuming chronic intake simulating the real scenario, it will be 1,900 Bq. However, if the intake is estimated assuming chronic intake, it will be 690 Bq for that interval of monitoring. The respective 50-year committed doses for bone surface will be 4.54 Sv and 2.31 Sv. The site profile should provide guidance on how to address samples collected on the weekends. The assumption of 24-hours chronic intake used in the site profile is not claimant favorable.

Exhibit 4.5-5A – Daily urinary excretion for uranium simulating chronic inhalation of Type S, AMAD=5 µm

Chronic intake for 24 hours and chronic intake during 8 hours/day, 5 days/week

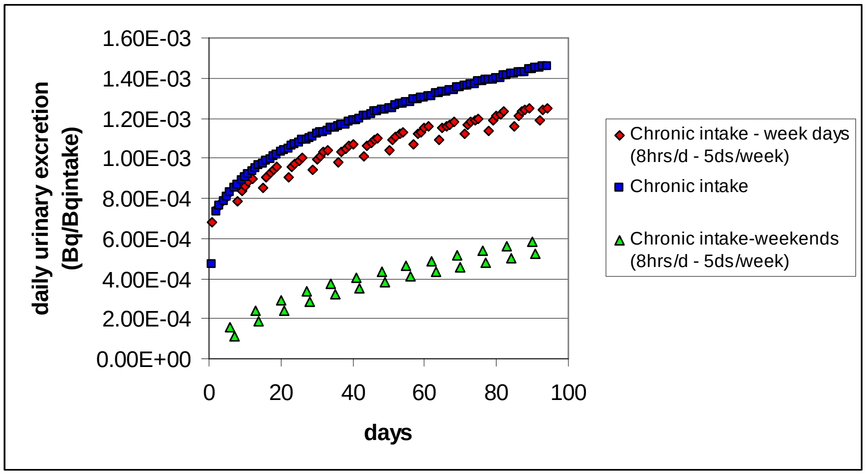


Exhibit 4.5-5B – Intakes derived for each day of the week assuming a chronic intake of uranium Type F (AMAD=5 um), urinary excretion equal to 1Bq/d

Chronic intake – simulating working days (8 hrs/day – 5 days/week)				Chronic intake – 24hours		
Days of exposure		**Urinary excretion rate (Bq/d)**	**Intake (Bq/day)**	**Days of exposure**	**Urinary excretion rate (Bq/d)**	**Intake (Bq/day)**
85	Monday	1.16E-03		85	1.42E-03	
86	Tuesday	1.21E-03		86	1.43E-03	
87	Wednesday	1.23E-03		87	1.43E-03	
88	Thursday	1.24E-03		88	1.43E-03	
89	Friday	1.25E-03		89	1.44E-03	
90	Saturday	5.81E-04		90	1.44E-03	
91	Sunday	5.25E-04	**1.90E+03**	91	1.45E-03	**6.90E+02**

Finding 4.5-6: There are some inconsistencies between the MDA values described in the text and the ones reported in Table 5.4 of the TBD.

Examples of these inconsistencies include the following:

- The methodology for determination of Ca-45 and radium are not described in the text, but the minimum detectable amount (MDA) values are reported in Table 5.4.
- Phosphorus, sulfur, carbon, americium, and curium are not included in Table 5.4.
- Neptunium and depleted uranium should be part of the source term, but they are not mentioned in the text or Table 5.4.
- On page 15, the sensitivity for Po-210 analysis was shown as 0.001 dpm/mL; however, the MDA in Table 5.3 is 0.01 dpm/mL.
- It is noted on page 15 that autoradiography started around October 1966, although the methodology applied for Pu measurements before 1966 was not noted. If it was gross alpha counting, a discussion is needed on how to distinguish plutonium from enriched uranium and other alpha emitters.
- The MDA values for uranium measured through fluorimetric methods (Procedures A and B) in the text are 0.5 μg/L for Procedure A and 0.05 μg/L for Procedure B and are not in agreement with Table 5.4, where the values are shown as 3 μg/L and 0.2 μg/L. In Table 5.4, the MDA for Procedure A is not distinguished from Procedure B.
- The MDA value in the text for uranium measured through radiometric methods (urine) (p. 16) is 0.5dpm/sample (standard sample volume per day was 1,500 mL), which is not in agreement with Table 5.4, where it is shown as 6 dpm/L. The MDA values for uranium analysis in feces are reported in Table 5.4, but the methodology is not mentioned in the text.
- Plutonium Procedure A and Procedure B (p. 16) describe the methodology to determine Pu in urine samples, but in Table 5.4, the MDA values are for feces samples.
- The MDA value for polonium in the text (p. 16) is 0.5 dpm/sample and in Table 5.4, it is 0.01 dpm/mL.
- The MDA value for strontium in the text (p. 16) is 4 dpm/sample, and in Table 5.4, it is 0.02 dpm/mL.
- The MDA value for promethium in the text (p. 17) is 5 dpm/sample and in Table 5.4, it is 0.05 dpm/sample.

Finding 4.5-7: Clarification of MDA related to testing methodology.

The site profile states that most uranium samples were apparently analyzed by using both uranium radiometric and fluorimetric methods (UR, UF) (p.17). The site profile should present the MDA for enriched uranium in cases of samples analyzed just by fluorometric methodology, which can be very important for the estimate of missed dose.

Finding 4.5-8: Inconsistent presentation of dates of operation.

The dates of operation shown in Table 5.9 of TBD-5 should be revised once the dates in Table 2.1 of TBD-2 are corrected (see Finding 4.2-5).

Finding 4.5-9: Neptunium and depleted uranium not included in Table 5.9.

TBD-2 identifies neptunium and depleted uranium activities in Building 4064 (fuel storage facility). However, there is no mention of neptunium and depleted uranium in Table 5.9 of TBD-5.

Finding 4.5-10: Inappropriate solubility type.

TBD-5 recommends solubility Type S to be applied for the dose reconstruction for workers in the powder room. This recommendation is not claimant favorable. There are data available (Leggett et al. 2005) that recommend specific lung retention parameters for workers exposed to airborne uranium aluminide. The data analyzed in this paper seem to be related to the workers in the powder room at ETEC. The author shows that several months after the start of the UAlx fuel fabrication program, it became evident from monitoring data that the behavior of inhaled UAlx differed from that of other forms of uranium that had been handled at this facility, and that intake and lung retention were being underestimated from standard models and assumptions. In addition, the urinary excretion rate has a different behavior compared to the behavior from standard International Commission on Radiological Protection (ICRP) solubility types. It appears that UAlx particles initially dissolved extremely slowly in the lungs, but began to break apart or otherwise change form after a few months, resulting in an increase over time in the rate of absorption of U to blood. This inferred behavior differs markedly from the monotonically decreasing dissolution and absorption rates derived from each of the three absorption types defined in the Human Respiratory Tract Model (HRTM) of the ICRP (ICRP 1994 and 2002), as shown in Figure 4.5-10A. The author recommends specific lung retention parameters for UAlx. As shown in Figure 4.5-10B, the urinary excretion rate differs from ICRP Type S and Type M solubilities.

This information should be taken into consideration. Applying specific lung retention parameters for UAlx (Leggett et al. 2005), the systemic doses are about 40% higher compared to Type S solubility, as recommended in Table 5.9 (TBD-5).

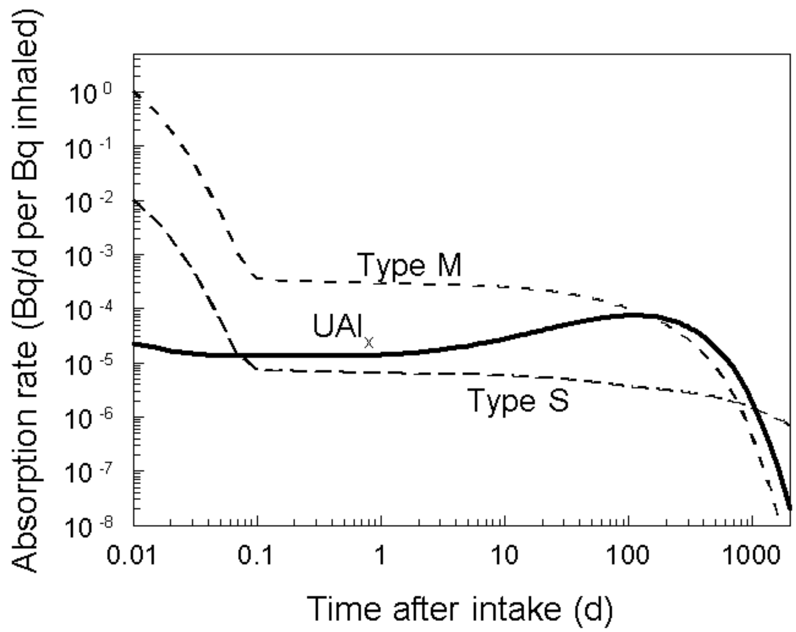


Figure 4.5-10A. For acute inhalation of U, change with time in the rate of absorption of U from the respiratory tract to blood as predicted by the model for UAl*x* described in Leggett's paper and the ICRP default models for relatively insoluble material (Type S, AMAD = 5 µm) and moderately soluble material (Type M, AMAD = 5 µm) (Leggett et al. 2005).

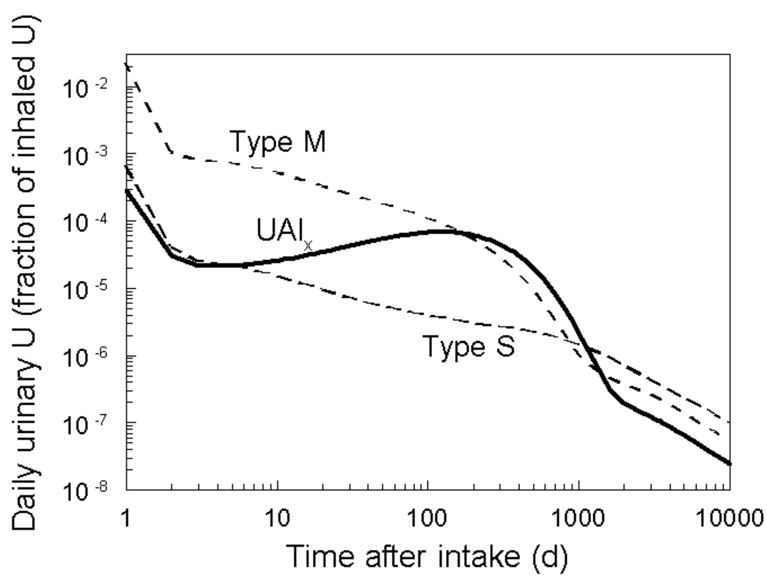


Figure 4.5-10B. Daily urinary U following acute inhalation, as predicted by the UAl*x* model in Leggett's paper and ICRP default models for relatively insoluble material (Type S, AMAD = 5 µm) and moderately soluble material (Type M, AMAD = 5 µm). The ICRP's systemic biokinetic model for U (ICRP 1995) was applied in all cases (Leggett et al., 2005).

Finding 4.5-11. Elements presented in TBD-2 are not addressed in TBD-5.

TBD-5 states the following:

> *Without bioassay or air sample data, the last resort is determination of airborne concentrations using source term evaluations (NIOSH 2002, p. 19). Data on the amount of dispersible material available does not appear to be available for ETEC.*

There are some elements described in TBD-2 that are not included in TBD-5.

Finding 4.5-12: NIOSH's interpretation of reported values by the contract laboratory Nuclear Science and Engineering Corp. (NSEC) may not be correct.

Section 5.3.1.2 (page 14) of TBD-5 attempts to clarify data reported by NSEC related to urinalyses for gross alpha, gross beta, and MFPs:

> ***Gross Alpha***
> *Shepard (1959) gave a minimum measurable concentration of 7.5 dpm/L for gross alpha counting. NSEC gave its minimum measurable concentration as 0.2 cpm/mL (NSEC 1957). It is* ***assumed*** *that this is a* ***typographical error*** *and 0.2* ***dpm****/mL was* ***intended****.* [Emphasis added.]
>
> ***Gross Beta***
> *Shepard (1959) gave a minimum measurable concentration of 75 dpm/L for gross beta counting. NSEC gave its minimum measurable concentration as 1.0 cpm/mL (NSEC 1957). It is* ***assumed*** *that this is a* ***typographical error*** *and 1.0 dpm/mL was intended.* [Emphasis added.]
>
> ***Mixed Fission Products***
> *… for beta activity with an approximate minimum detectable amount (MDA) of 60 dpm/****sample*** [is assumed] *(ORAU 2004, p. 27) … NSEC gave its minimum measurable concentration as 2.0* ***cpm****/mL (NSEC 1957). It is* ***assumed*** *that this is a* ***typographical error*** *and 2.0 dpm/mL was intended.* [Emphasis added.]

The unsupported assumption that in all three cases a "typographical error" was in fact made may not be correct, given the discrepancies between the values reported by NSEC relative to those of Shepard:

	Shepard 1959	NSEC
Gross alpha	7.5 dpm/l	0.2 cpm/ml or **200 cpm/l**
Gross beta	75 dpm/l	1 cpm/ml or **1000 cpm/l**
MFP	60 dpm/l	2 cpm/ml or **2000 cpm/l**

If, in fact, the NSEC data were correctly reported in the units of cpm/ml, and adjusted for yield(s) and counting efficiencies, MDA values (redefined in dpm/l) are likely to more than double. Such large differences are hard to explain and raise questions about the credibility of bioassay data provided by contract laboratories as a whole.

Finding 4.5-13: Potential difficulties associated with uranium bioassay data.

Uranium at SSFL, to which workers may have been exposed, existed in various degrees of enrichment (i.e., 2% to 93%). Section 5.3 of TBD-5 discusses the two independent methods used to assess uranium in urine; the fluorometric method only identifies uranium concentrations in µg/ml, while the radiometric method assesses the gross alpha activity in dpm/l. Given the potentially wide range of specific activities of uranium defined by fluorometric urine data, all fluorometrically analyzed urine would also require a **concurrent** radiometric evaluation of that sample in order for these data to be useful to dose reconstruction.

From information contained in Section 5.3 of the TBD, it is unclear whether urine samples were consistently analyzed by both fluorometric **and** radiometric methods. It is **not** unreasonable to assume that for the early years, concern for the chemical toxicity of uranium may have limited urine bioassay to the fluorometric method. If this assumption is true, the absence of concurrent radiometric analysis of urine samples would severely limit the value of early fluorometric data.

Thus, in the event that a fluorometric urine bioassay cannot be matched with a concurrent radiometric analysis, a claimant-favorable default value should be used that defines the enrichment level of uranium.

Finding 4.5-14: There are unanswered questions regarding the completeness and quality of personnel exposure records.

In Section 5.2 of the TBD, the following statements appear:

Page 10:

> *…AI established health and safety files on each employee that contained radiation exposure records, injury records, and other "pertinent" data (Lang undated, 1960). Today, personnel radiation exposure records are in the Radiation Safety Records Management System (RSRMS), which encompasses about **170 file cabinets***. [Emphasis added.]

Page 12:

> *The bioassay records in the individual files generally consist of:*
>
> - *Individual Personnel Keysort Cards (Figure B-2, Attachment B), which were used to track the type, frequency, and week of sample collection. … The forms can be **difficult to read due to the quality of the copies**, and dose reconstructors should refer to the forms listed below for urine and fecal data. This form **might** be the **only** place **in vivo*** [?] *data are listed.* [Emphasis added.]

Section 5.7 (page 23):

> *The bioassay results from ETEC and its predecessor organizations are **apparently not** available in a computerized format. The units used to report the results are **generally** included in the hard-copy reports. …* [Emphasis added.]

Section 5.8 (page 23):

> ***No codes** have been found* [for excreta samples]. …

These statements suggest that (1) all personnel records currently exist in hardcopy form only, and (2) records may be of poor quality, difficult to interpret, and incomplete.

SC&A concludes that the use of these records for dose reconstruction will require a comprehensive assessment regarding the quality and completeness of records contained in the 170 file cabinets and provide necessary guidance to dose reconstructors for their interpretation/use.

Finding 4.5-15: Use of SSFL site survey data/source term cannot be regarded as useful surrogate data for bioassay data in dose reconstruction.

In the absence of an individual's in vitro/in vivo bioassay data, the TBD provides the following information and guidance to dose reconstructors:

Section 5.11 (page 26):

> *If bioassay data are **not** adequate to evaluate an individual's internal doses, dose reconstructors can use workplace monitoring data (NIOSH 2002). The following types of workplace data **might** be available for ETEC: breathing zone air samples, general area air samples, and surface contamination surveys. However, **these data are not likely to be in individual exposure records**. Data on respirator use are **not** likely to be available … resuspension factors are **not** likely to be available.* [Emphasis added.]

Section 5.12 (page 30):

> *Without bioassay or air sample data, the last resort is determination of airborne concentrations using **source term** evaluations (NIOSH 2002, p. 19). Data on the amount of dispersible material available does **not** appear to be available for ETEC.* [Emphasis added.]

This "guidance" is deficient and places an unrealistic responsibility on the dose reconstructor.

Finding 4.5-16: Potential unmonitored internal exposures associated with radiation incidents are not addressed.

TBD-5 does not specifically address radiological incidents that may have resulted in workers' internal exposures that were unmonitored. However, TBD-2 identified six major radiological incidents that are further summarized in Table 2-6. Included among major incidents were the following, which involved (1) the Water Boiler Neutron Source (WBNS in Building 4093), (2) Sodium Reactor Experiment (SRE in Building 4143), and (3) SNAP 8 Experimental Reactor (S8ER in Building 4010).

The first two incidents occurred in 1959 and the third occurred in the early 1960s. Based on information provided in TBD-5, it is unclear (1) whether workers exposed during these early incidents were adequately monitored for internal exposure, and (2) if workers were, in fact, monitored, whether their exposure records exist. A particular concern involves the potential exposures associated with the SRE, which resulted in the partial melt of 13 fuel assemblies and the loss of Na coolant. Worker exposures may have included a complex mixture of highly enriched uranium, actinides, MFPs, and various activation products, including large amounts of Na-24.

4.6 REVIEW OF TBD-6 (ORAUT-TKBS-0038-6) ATOMICS INTERNATIONAL – OCCUPATIONAL EXTERNAL DOSE

This TBD contains supporting documentation to assist in the evaluation of occupational external doses from processes that occurred at AI. An objective of this document is to provide supporting technical data to evaluate, with assumptions favorable to claimants, occupational external doses that can be reasonably associated with worker radiation exposures. This document addresses the evaluation of unmonitored and monitored worker exposure, missed dose, and the bias and uncertainty associated with the monitoring of external dose.

Finding 4.6-1: No coworker model.

TBD-6 has not cited an external coworker model approach as necessary, and the document does not address the use of a coworker model for those individuals potentially exposed, but not monitored. It appears that individuals may have been unknowingly exposed. An October 22, 1962, memorandum from F.H. Badger[1] to the Health and Safety File regarding "Health and Safety Observations at RMDF" states that "Routine smear surveys have repeatedly revealed significant contamination or radiation dose rates in areas usually thought to be free of radioactive material." One of the examples provided was a 4 Rad/hr capsule lying in an area thought to be uncontaminated.

SC&A performed a cursory review of more than 30 dose reconstructions related to the badging of radiation workers. Several observations were made in this review. First, it does not appear any of the claimants, including those that were likely defined as radiation workers, were badged for their full employment period. Other employees who did not work in areas likely to contain

[1] F.H. Badger was employed by Atomics International. His title was Analyst, Health Physics, Senior Health and Safety Operations.

radioactive materials (e.g., administrative staff and staff that were involved with the rocket testing) were not badged. Some employees, who may or may not have worked in areas containing radioactive material, were not badged and therefore were assumed not to have worked in areas containing radioactive materials.

In addition, in an April 1991 Tiger Team Assessment, the DOE noted several issues with the external radiation dosimetry program. The report, as an example, noted, "In 1989 and 1990, extremity doses were not added in to exposure records or reported to the Radiation Exposure Information Reporting System (REIRS)."

Based on the poor track record of badging employees appropriately, the conclusion of no monitoring being equal to no work in a radiation area does not seem to be justified. The dose reconstructor should be able to look at a job title and determine potential exposure, and then be linked to a coworker model.

Finding 4.6-2: Workers were unlikely to have been monitored for thermal neutrons.

As stated in Section 6.2, "…Both fast and **thermal** neutrons were **measured** and **recorded** as whole-body (WB) dose in rem." This statement is contradicted in Section 6.4, where it states, "…It is assumed that the dose recorded was the result of **fast** neutron exposure."

The second statement is likely to be correct, since the common practice at DOE facilities was to assess NTA film for tracks produced by proton recoil. It is unlikely that NTA dosimeters were modified and calibrated for tract analysis of **thermal** neutrons. [Tracks in emulsions exposed to thermal neutrons may be produced by nitrogen in the gelatin that captures a thermal neutron and releases a 0.58 MeV proton – N^{14}(n, p) C^{14}.]

Finding 4.6-3: Due to the level of uncertainty surrounding neutrons at SSFL, it may not be appropriate to use Y-12 data as a surrogate.

In the absence of empirical data involving neutron spectra for reactors and Pu fuel storage facilities, the lack of dosimeter calibration methods, and the relative insensitivity of NTA film to neutrons with less than 500 keV (or as much as 1 MeV), there remains an undefined level of uncertainty for recorded neutron doses. Therefore, the use of Y-12 data as surrogate values may not be appropriate.

Finding 4.6-4: NTA film applicability to neutrons at energies below 500 keV.

This TBD assumes that the NTA film effectively measured all neutron exposure received at AI, and does not consider correction factors for the insensitivity of NTA to neutrons at energies below 500 keV. Actual neutron energy spectrum data is limited to a few facilities (i.e., SRE). There is no discussion of neutron-to-photon ratios in the site profile; however, it is mentioned as an option for calculating thermal neutron exposure in the ER report.

Finding 4.6-5: Dosimeter response to low energy photons.

TBD-6 does not discuss issues associated with the response of dosimeters to low-energy photons. There are statements to the effect that the dosimeter was similar in design to the Hanford dosimeter. The Hanford dosimeter applied a correction factor for exposure of plutonium facility workers to compensate for badge shortcomings. The ER indicates there are source term data available to bound low-energy photon dose; however, no specific information on source term is provided. Furthermore, there is no consideration for dose from skin contamination incidents.

Finding 4.6-6: No justification for use of surrogate time periods in considering releases from the stack.

The TBD states the following regarding stack emissions:

> *No data was available for the 1959 to 1970 time period. Because operations and activities during this period took place in many of the facilities addressed in later years, the average yearly gross alpha and gross beta concentrations in stack emissions for 1971 to 1999 were assumed for each of these years.*

In addition, the TBD states, "No data are available prior to 1958. Fission product releases from 1954 to 1958 are assumed to be the same as those in 1959 to 1964. The alpha-emitting radionuclides are assumed to be 10% of the alpha-emitting radionuclide releases from 1959 to 1964. Releases at the Downey and Canoga Park facilities are assumed to be the same as the 1954 Area IV releases."

There is insufficient supporting information to justify the use of the surrogate time periods.

Finding 4.6-7: Inadequate consideration of Area I in the TBD.

The DOE had operations and facilities in Area I, as well as Area IV of the SSFL facility. However, no consideration has been given to potential exposure in Area I of SSFL, such as potential exposure for the coal gasification process.

5.0 PRELIMINARY SEC ISSUES

SC&A was tasked by the Advisory Board to perform a preliminary review of the SEC Petition and Evaluation Report for the Santa Susana Field Laboratory to determine if there are any significant issues associated with the conclusions reached by the Evaluation Report.

Petition SEC-00093, qualified on October 19, 2007, requested that NIOSH consider the following class: "All employees who worked in all areas of Santa Susana Field Laboratory—Area IV during the time period from 1955 to the present (which incorporated the post-1987 remediation period)." The petitioner mentioned that there was inadequate information associated with the sodium burn pit and internal monitoring; inadequate air monitoring; and referenced the Tiger Team report (DOE 1991) that mentioned inadequate radiation badges and faulty HEPA filters. The original petition was revised on November 16, 2007.

Based on its preliminary research, NIOSH reduced the petitioner-requested class to a class that included the time period from January 1, 1955, through December 31, 1965. NIOSH evaluated the following class: "All employees of the Department of Energy (DOE), its predecessor agencies, and DOE contractors and subcontractors who worked at Area IV of the Santa Susana Field Laboratory from January 1, 1955, through December 31, 1965."

Based on its full research, NIOSH modified the petitioner-requested class to define a single class of employees for which NIOSH cannot estimate radiation doses with sufficient accuracy. The NIOSH proposed class includes "all employees of the Department of Energy (DOE), its predecessor agencies, and DOE contractors and subcontractors who were monitored while working in any area of Area IV of the Santa Susana Field Laboratory for a number of work days aggregating at least 250 work days from January 1, 1955, through December 31, 1958, or in combination with work days within the parameters established for one or more other classes of employees in the SEC."

The basis for modification of the class was that NIOSH stated that they could not estimate internal exposures with sufficient accuracy during the period from 1955 through 1958 (which they stated as a period with limited internal monitoring data). January 1, 1955, was used as the initial date for consideration, since NIOSH did not believe radiological activities occurred at Area IV before this time. December 31, 1958, was used as the end date, since NIOSH believed there was sufficient internal monitoring available after this date to determine the dose to an individual based on a routine in vitro bioassay program that was established in August 1958 (Kellehar 1966).

Issue #1: The language for the proposed class includes employees "who were monitored." The ER expands on the meaning of "who were monitored" (p. 11) by stating that the proposed class includes all employees who were monitored, or should have been monitored, for internal radiological exposures while working in all areas of Area IV. At a minimum, the language for the proposed class should be modified to include employees who should have been monitored. The ER has no further guidance on who should have been monitored. TBD-4 indicates that the definition of the types of workers that were to be monitored changed on several occasions (TBD-4, pp. 11–12). Early entry into the bioassay program was apparently based on job assignment. By the early 1960s, the bioassay program "normally" consisted of urinalysis for personnel whose work assignments involved "potential exposure to radioactive materials." By the mid-1970s, the definition of who was included in the routine bioassay monitoring program had changed to "personnel whose work assignments potentially expose them to respirable-sized radioactive aerosols." By the late 1980s, the criterion was "personnel whose work assignments potentially expose them to radioactive aerosols." Given the evolution of who should have been monitored at SSFL, it is recommended that additional guidance be provided in the ER on which workers should have been monitored.

Issue #2: Additional research needs to be performed related to when radiological activities began at Area IV. The SEC ER uses the date of January 1, 1955, as the initiation of radiological activities at Area IV. However, TBD-2 (p. 3) states, "Area IV was established at the SSFL in 1953 as a nuclear research and development facility." Later on this same page, it is stated that "Nuclear R&D activities in Area IV increased rapidly from 1953 into the late 1960s, then declined."

Issue #3: The original SEC petition requested that both the De Soto and Area IV locations be considered in the class of workers. When the petition was revised, the locations relevant to the petition were described as "Santa Susana Field Lab" and "Area IV—All Areas." There is no explanation in the ER on why Area IV was the only location considered. The site profile addresses the Downey, Canoga Park, and De Soto facilities in addition to Area IV.

Issue #4: The Evaluation Report restricts the time period evaluated to January 1, 1955, to December 31, 1965, but does present the basis for the end date of December 31, 1965.

Issue #5: NIOSH has proposed December 31, 1958, as the end date for the period to be considered for this class of workers. The basis for this date was that sufficient internal monitoring data were available after this time to determine the dose to an individual. Many of the findings in Section 4.5 of this report present concerns about the adequacy of the bioassay program after 1958. For example, it appears that plutonium bioassays were not performed until 1966, which is well after 1959, when adequate internal dose was stated as being available in the ER. Furthermore, it is not clear (from Lee 1963) if Pu and Sr analysis started in 1963, or if there were extensive troubles encountered in taking the measurements.

In addition, there are concerns about the adequacy of the data to assess external doses and doses resulting from environmental exposures, as discussed in Sections 4.6 and 4.4, respectively. For example, NIOSH presents four sample dose reconstructions on the O drive (AB document review SSFL subdirectory). Example #2 involves a fireman whose duties included removal ("burning") of sodium from reactor components at the sodium burn pit. No external dose data are available for this fireman until many years after the fireman started work.

Issue #6: Page 4 of the Evaluation Report Summary, in the section on "Health Endangerment Determination," states the following:

> *NIOSH did not identify any evidence supplied by the petitioner or from other resources that would establish that members of the proposed worker class were*

> *exposed to radiation during a discrete incident likely to have involved levels of exposure similarly high to those occurring during nuclear criticality incidents. However, evidence indicates that **some** workers in the proposed class may have accumulated **substantial** chronic exposures through episodic intakes of radionuclides, combined with external exposures to gamma, beta, and neutron radiation.* [Emphasis added.]

The focus of this comment is on the last sentence of this quote and involves two issues. First, there is no basis presented in the Evaluation Report for concluding that there were substantial chronic exposures at the facility. This information should be presented to justify the proposed class to be added to the SEC. The second point is that assuming there is information that justifies accumulated substantial exposures, NIOSH should add a discussion on what changed after 1958 that would have eliminated or reduced these chronic exposures, particularly for those workers who were not monitored, but should have been monitored. In fact, many of the Area IV programs and operations did not begin until after 1958 (see Exhibit 4.4), and would have been additional sources of exposure.

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ATTACHMENT 1: SUMMARY OF SITE EXPERT INTERVIEWS

This attachment will be provided at a later date.