Final Report

NATIONAL INSTITUTE OF OCCUPATIONAL SAFETY AND HEALTH ADVISORY BOARD ON DOSE RECONSTRUCTION

TASK 1 — SITE PROFILE REVIEWS

SUBTASK 1

SITE PROFILE REVIEW PROCEDURES

Contract No. 200-2004-03805

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NATIONAL INSTITUTE OF
OCCUPATIONAL SAFETY AND HEALTH
ADVISORY BOARD ON DOSE RECONSTRUCTION

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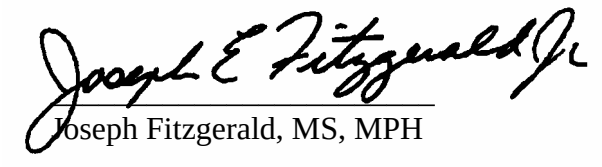
SC&A Standard Operating Procedure
for Performing Site Profile Reviews

Revision 1, May 13, 2004

Task Manager:  5/13/04
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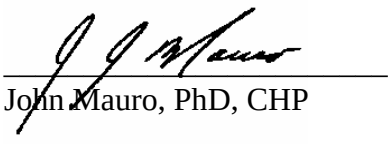
Project Manager:  5/13/04
John Mauro, PhD, CHP Date

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SITE PROFILE REVIEW PROCEDURE

1.0 INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) site profile database is designed to support the conduct of individual dose reconstructions under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA or the Act) by compiling data other than dosimetric information, such as that related to facility operations and processes over time; radiological source term characterization; chemical and physical forms of the radionuclides; and historic workplace conditions and practices. Specific radiological information includes potential types of exposure, types of material, and various details about the dosimetry program [i.e., limits of detection, frequency of badge exchange, multiple badging, types of radiation exposure monitored (or not monitored), medical exposure information, in vitro (bioassay) monitoring, in vivo (whole body counting) monitoring, and action levels]. The Advisory Board will be responsible for the selection of the site profiles for review.

S. Cohen and Associates (SC&A) will evaluate the approach taken in the NIOSH site profiles to gauge the adequacy, completeness, and validity of the information consistent with the methods stipulated in Title 42, Part 82, of the Code of Federal Regulations (42 CFR 82), and in the NIOSH External Dose Reconstruction Implementation Guideline (OCAS-IG-001) and Internal Dose Reconstruction Implementation Guideline (OCAS-IG-002). The review process outlined and the lines of inquiry provided in this procedure are directed at "sampling" site profile analysis and data for validation purposes, not to provide a rigorous quality control process whereby actual analyses or calculations are duplicated or verified. Not all the lines of inquiry presented necessarily would be applicable for a particular site profile, nor would they all be used. The scope and depth of review sampling would be focused on aspects or parameters of the site profile that would be deemed particularly influential in deriving dose reconstructions or bridging uncertainties encountered.

It is apparent from the first 2 years of dose reconstruction under the Act that the role of site profiles has assumed a level of significance even greater than was previously assumed. As it has become clearer that primary sources of occupational dose data at Department of Energy (DOE) sites may be more suspect and less reliable as reviews go further back in time, the profiles have become the critical instrument by which missing dose or operational uncertainties are bridged and older dosimetry data are interpreted. As such, they have become the primary means by which many individual dose reconstructions are derived.

2.0 OBJECTIVES

Given this essential role, it is essential that these documents be reviewed for their completeness, technical accuracy, adequacy of data, consistency among the various sites, and compliance with stated objectives, as defined in 42 CFR Part 82 and other supporting standards and guidelines. The Site Profile Reviews will meet the following objectives:

2.1 Objective 1: Completeness of Data Sources

- To identify the principal sources of data and information that were used to write each of the Site Profiles.

  - Did the Site Profile make use of all available information considered relevant and significant to dose reconstruction?

  - Conversely, are there other sources of available data considered relevant/significant that were not used and should have been used?

2.2 Objective 2: Technical Accuracy

- To critically assess how the sources of data identified in the Site Profile were used in developing technically defensible guidance or instructions as cited in the Site Profile/Technical Basis Document.

  The review procedure for this element should, therefore, address the question(s) of whether proper technical use was made of the available data.

2.3 Objective 3: Adequacy of Data

- To determine whether the resultant data and guidance contained in the Site Profile are sufficiently detailed and complete for use in dose reconstruction, or in instances where no or limited data provide a defensible surrogate approach to dose reconstruction.

2.4 Objective 4: Consistency among Site Profiles

- As the review progresses through Site Profiles/Technical Basis Documents (TBDs), our procedural review will identify key elements common to all Site Profiles and assess the degree of consistency among them, identify areas of inconsistencies, and determine the potential significance of any inconsistency with regard to dose reconstruction.

2.5 Objective 5: Regulatory Compliance

- To determine whether the Site Profile/Technical Basis Documents (TBDs) are consistent and compliant with the following:

  - Stated policy and directives contained in Final Rule and 42 CFR Part 82
  - Guidance and protocols defined in OCAS-IG-001 and OCAS-IG-002

3.0 PROCEDURAL APPROACH

Consistent with the objectives presented in Section 2.0, the elements of this review, as specified in the statement of work for this task, will include the following, *as deemed appropriate*:

- **Interviews with NIOSH, ORAU or ORAU subcontractor personnel** responsible for the development of the site profile.

- **Evaluation of whether NIOSH identified, evaluated, and where appropriate, incorporated, all relevant data sources** (e.g., DOE, AWE, CDC, EML, NRC, EPA, External Health and Safety Regulators, GAO, DNFSB, Congressional Hearing Records, other research programs, research publications, publications regarding the history of the DOE complex, or administrative records) within the site profile.

- **Review of dose estimates** resulting from the site profiles to determine adequacy and validation of the data and assumptions (data adequacy to be reviewed with regard to any parameters affecting dose calculations, e.g., radionuclide(s), chemical form, and particle size), and any parameter needed in the determination of an individual's exposure (e.g., specific process information and job descriptions).

- **Interviews with site "experts"** (those with longstanding knowledge of processes, materials, events, and exposures, etc., such as employees, employee representatives, advocacy organizations, and health and academic researchers).

- **Comparison of different categories of information** to check for consistency and to determine which types of data can be used to complement the basic site and individual dosimetric data being used for dose estimation.

SC&A's procedural approach to this task is three-fold:

(1) **To conduct a broad ("horizontal") review and evaluation of the type and nature of information collected and data used in the site profiles to ascertain its adequacy and completeness as a basis for dose reconstruction:** This will be accomplished by reviewing what information sources are relied upon for each particular site and whether they can be considered "necessary and sufficient" to develop valid site profiles.

(2) **To conduct a sampling ("vertical") probe of key dosimetric parameters, assumptions, and operational issues that are found to be most influential in establishing the site profile dose models from which individual dose reconstructions are derived:** The validity of these analytic benchmarks will be reviewed by a multidisciplinary set of experts who will focus on the respective technical basis documents (e.g., internal dosimetry, external dosimetry, occupational medical dose, occupational environmental dose, etc.) that contribute to an overall site profile.

(3) **To ascertain whether the site profile worst-case estimates "bound" the available data and assumptions that can be made for the site in question, taking into consideration missing dose, suspect dosimetry, uncertain source terms, operational history and actual practice:** If it can be demonstrated that such estimates may not be "claimant-favorable" or that sufficient uncertainty exists, such issues will be highlighted for Board attention by the SC&A review.

Finally, it is recognized that the scope and complexity of site profiles will vary considerably, with those for atomic weapons employer (AWE) sites often being based on limited records and accounts, with large sites such as Savannah River and Hanford having a large spectrum of source terms and a long history of operations and successive contractors. These procedures will be adjusted for each review accordingly to assure that the scope and depth of review is tailored to the site profile being reviewed.

4.0 ROLES, RESPONSIBILITIES, AND DELIVERABLES

4.1 Advisory Board on Radiation and Worker Health

The Board will select all site profiles to be reviewed by SC&A, specifying approximately 10-12 DOE site profile reviews and 2-4 AWE site profile reviews the first year. The Board will review and approve all contractor review procedures. The Board will routinely review progress being achieved in the site profile reviews and address issues it determines to be of significance.

4.2 SC&A

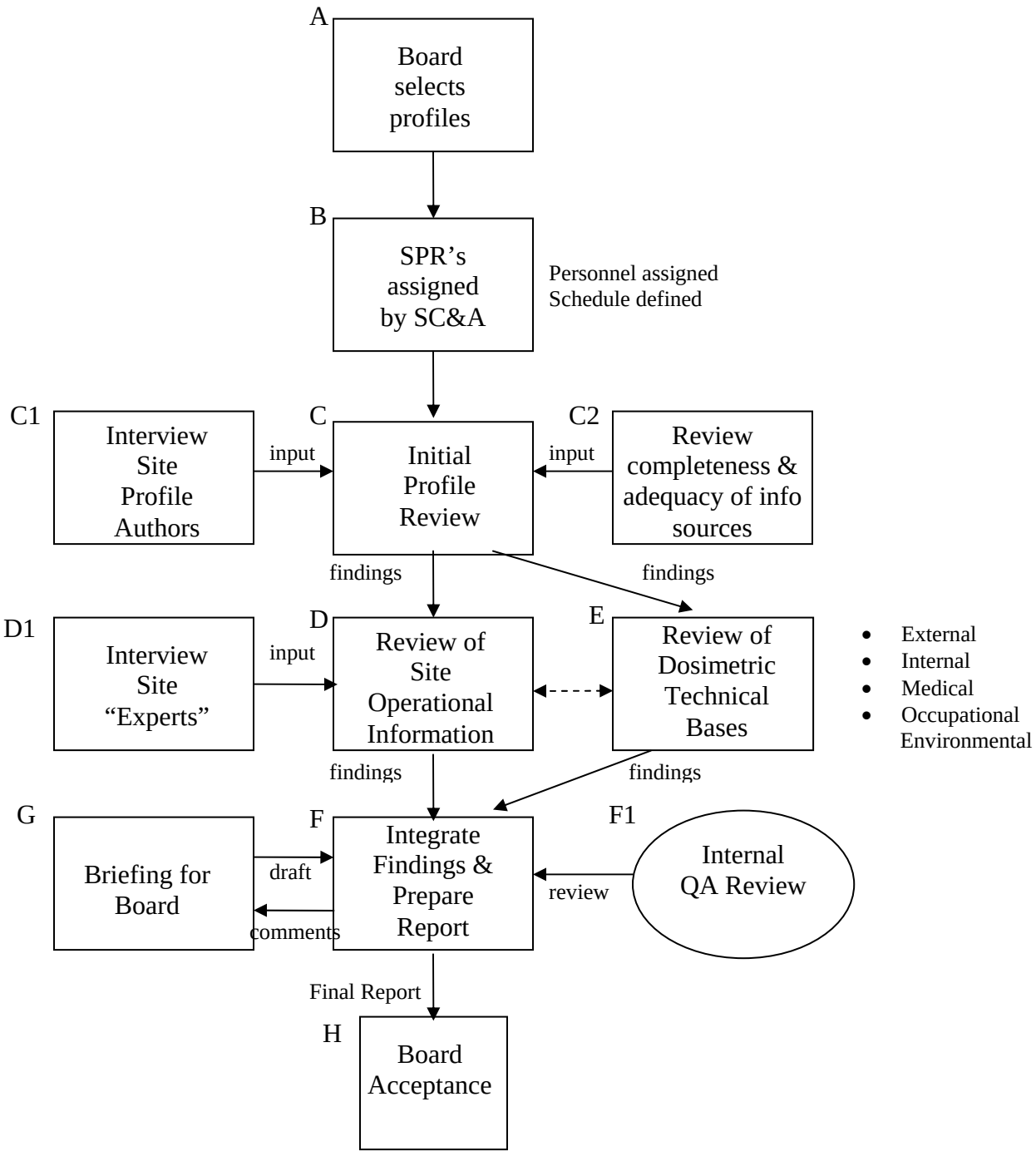
SC&A will develop and maintain this Site Profile Review Procedure, and review all site profiles stipulated by the Board. The contractor will be responsible for the following deliverables to be provided the Board: (1) Site Profile Review Procedure; (2) monthly summary of progress for all site profile procedures; (3) a final report for each site profile review, and (4) a final summary report with aggregate findings. SC&A will identify information or data sources needed to support its site profile review, and submit any requests for such information through its designated POC at NIOSH. SC&A will keep the Board informed of emerging issues from its review and promote active dialogue regarding the significance and implications of findings, and what courses of action may be warranted by the contractor as these reviews proceed.

4.3 National Institute of Occupational Safety and Health and Oak Ridge Associated Universities

NOISH will make available for interview those individuals responsible for the development and approval of site profiles selected by the Board for review. NIOSH will identify and make available information and data sources used or considered for use in the site profiles, including pertinent documentation. In addition, NIOSH will provide an interface with ORAU and DOE regarding requests for information, and DOE site and/or DOE contractor site or personnel access to provide an official basis for such requests and to facilitate responsiveness.

4.4 Procedures

The following sequence of steps will be taken to conduct Site Profile Reviews, as illustrated below and described in subsequent accompanying text (corresponding to lettering indicated below).



A. Selection of Site Profiles for Review

The Advisory Board will select site profiles for review and will provide guidance as to preferred sequence, albeit contractor resources, clearances and other logistical issues will need to be addressed.

B. Assignment of Site Profile Reviewers

The SC&A Site Profile Manager will assemble a team of site profile reviewers with expertise and experience appropriate to the site profile to be reviewed. Reviewers will be drawn from a roster of qualified personnel who have been determined not to have any conflicts of interest. Typical teams will consist of 2-3 health physics and operational experts, led by a designated team leader, supported by specialists, as needed, who will be identified to the Advisory Board in the monthly status report. As a function of personnel availability and qualifications, the contractor may field 2-3 site profile reviews at a time to better pace the complement of profiles assigned for the year.

C. Initial Review of Profile

The site profile reviewers will conduct a detailed review of site profiles, including all associated technical basis documents, and pertinent referenced documentation. The objective of this initial stage of the review is to become familiar with what information sources proved most influential in developing the profile, and what assumptions and analyses were critical to its ultimate findings. Lines of inquiry that will be important at this point include the following:

(1) What sources of data were relied upon; what information was considered "authoritative" and for what reason? For example, how was the validity of air sampling, film badge, TLD, and bioassay data assessed for various periods and across facilities? What acceptance criteria did the profilers use?

(2) What assumptions were made in the formulation of the site profile, why they were necessary, and are they adequately supported? For example, to what extent are the "correction factors" that have been applied to dosimetry over time at various DOE sites been accepted as is, or have they been evaluated to ascertain their validity?

(3) To what extent were unplanned, but relatively common events taken into consideration to assure a claimant-favorable assessment? For example, "blowouts" of uranium metal reduction furnaces were known to have occurred on some frequency in uranium processing plants in the reduction of UF4 to U metal; also, pyrophoric fires involving uranium or plutonium fines were a frequent occurrence in the early years.

(4) What are the worst-case dose-estimate scenarios presented and are they adequately supported by the data presented and assumptions made? For example, where upper or lower bounds of exposure are assigned for specific operations or

cohorts of workers, are these truly bounding or do they miss significant outliers or underestimate potential dose due to lack of dose or monitoring records?

(5) What data "gaps," particularly missed dose, are identified and addressed in the site profiles, and is the proposed treatment of the issue sound? For example, how are short-term contamination incidents addressed? How is badge or dosimeter location on the body addressed?

(6) Is the operational history provided complete and adequate for characterizing sources of occupational dose? Are all productions involving radioactive material accounted for, including potential contaminants or decay products? Are all episodic releases and contamination incidents accounted for and considered?

(7) Is the dosimetry history provided complete and adequate for characterizing measurement technology, standards and practices over time at the facilities in question? For example, how are accidents and spills addressed, and what is known about those workers assigned to cleanup or decontamination with respect to work designations, badging and bioassay monitoring?

(8) Has the site profile assessed all the facilities and processes on the site to identify the (1) radionuclides that were processed, (2) the trace contaminants in the radionuclides that were processed, (3) the solubilities of the radionuclides of interest, and (4) evidence about particle sizes in the workplace. Have all of these items been examined with due regard to the changes over time that may have taken place in each of them?

The following review activities will proceed on parallel tracks in support of the above initial review.

C.1 Interviewing Site Profile Authors

As part of the initial detailed review of site profile materials, it may be necessary to interview the authors and contributors responsible for their development. The objective of this activity is to ascertain *why* and *how* specific information was used, analyses were conducted, and assumptions were made in producing the profile materials being reviewed. It is also an opportunity to clarify questions from the site profile reviewers arising from their initial review. The following "general" lines of inquiry will be pertinent in this activity (would also include site-specific questions and issues based on preliminary review of site profile).

(1) What information or data sources represented principal sources and references for the profile? Why was this information relied upon and how was it determined to be comprehensive? What other information was identified, sought, but ultimately could not be included? Why was it not used? What is the significance of the information not included?

(2) Beyond the actual dose records provided by DOE to NIOSH, what secondary sources of information were relied upon? How are worker representative and

other "site expert" interview data used to create a site profile that is more realistic in terms of what assumptions are reasonable for making dose estimates?

(3) How significant were identified gaps in records (e.g., over time, between co-workers, for certain operations, for specific monitoring categories)? How were these gaps bridged in the profile?

(4) Did the site profilers review overall deficiencies that have been identified in DOE's worker exposure records, such as those described by the Tiger Teams between 1989 and 1992?

(5) What individual dose records are largely lacking or unreliable for sites, facilities, or categories of workers? What approach or techniques were employed to approximate a conservative dose range, i.e., a "worst-case dose estimate," and why?

(6) How did the site profilers decide that the information at hand was sufficient for the site profile? How was the decision to evaluate secondary sources of radiological exposure information made? How was the data collection and dose estimate analysis process conducted?

(7) What past radio-epidemiological or health effects research studies were considered to be authoritative for purposes of these profiles and why? Were the principal investigators for these studies interviewed or consulted in the compilation of the profiles?

(8) As these profiles are considered "living" documents, what would the profilers identify as subjects or areas of the profiles that could benefit from additional information which is now available or may be available in the future for incorporation?

Interviews with site profile personnel will be conducted either in conference calls or in person, with the latter option reserved for instances where the efficiency of review requires it.

C.2 Review of Completeness and Adequacy of Information Sources

SC&A will determine whether the NIOSH contractor appropriately identified, evaluated, and incorporated all relevant data sources by comparing the extent to which such information is present in the profile with what can be identified via an independent review of such sources of information. The objective of this activity is to ascertain whether sources of pertinent information for the site profile were identified and obtained in a comprehensive manner. Data sources that will be scanned include the following:

- Department of Energy
  - Field Offices
  - Operating contractors
  - Institutional histories
  - Inspector general files

  - Headquarters and field oversight reports
  - Radiation exposure assessments

- Atomic Weapons Establishment
- Centers for Disease Control
- Nuclear Regulatory Commission
- Environmental Protection Agency
- General Accounting Office
- Defense Nuclear Facilities Safety Board
- Congressional Hearing Records
- State environmental and safety regulatory agencies
- National Academy of Science
- Administrative/court records
- Department of Defense
- Environmental Monitoring Laboratory (formerly HASL)
- Workers compensation records
- Worker and public advocacy groups
- Historic records in private hands

It is anticipated that a baseline of what relevant information is contained in these and other data sources will be established at the onset, facilitating subsequent comparisons with site profile information.

D. Review of Site Operational Information

For many DOE and AWE sites, reliable dosimetry records may be lacking, particularly for workers from the 1940s to 1960s. In these instances, historic operational information that includes the nature of operations, radiological source terms in use, process material concentrations, and location and time periods of worker activities may be the only data available from which dose estimates can be derived. The objective of this activity is to survey information at the DOE site or in AWE records to ascertain whether the site profiles adequately reflect at least the following information, as applicable:

- Operational processes over time, including improvements, upgrades, modifications and terminations *(important because worker exposures are often higher during major process changes)*

- Historic radiological inventory, source terms, and movement through facility ("mass balance") to include feed material, products, and byproduct and waste streams

- Any unplanned events, including radiological over-exposures, contaminations, releases, spills, criticality incidents, and unusual occurrences

- Changes in contractor management and attendant changes in safety policies, procedures and practices *(important because new contractors import new radiation protection programs and operational practices)*

- Applicable standard operating procedures, memorandum, directives, or recorded practices governing onsite management of radioactive materials and processes

- Actual historic operational practices established by first-hand accounts, i.e., by site "experts" *(important because actual DOE contractor facility practices often varied from documented procedures)*

- Historic radiation protection programs in place, including personnel monitoring requirements, protective equipment practices, dosimetric techniques and technologies in use, and procedural enforcement history *(important to determine whether and to what degree the dosimetry program reflected actual potential exposures possible)*

- Worker rosters with identifiers, work assignments and location, as well as summary of work histories sufficient to determine what categories of workers were assigned to what type and locations of radiological work

The foregoing information will be used in a comparative manner to ascertain whether the site profiles are complete in how they characterize, from a historic standpoint at a particular site, what radiological materials were present and in what concentrations and chemical or physical forms, what worker cohorts may have been in proximity with sources of exposure and whether certain activities or unplanned events may have made such exposure likely, and what administrative procedures, operational practices, protective equipment use, and facility conditions may have influenced the likelihood of such exposure.

The following review activity will proceed on parallel tracks in support of the site operations review.

D.1 Interviewing Sources of Site Knowledge

SC&A, as necessary, will conduct one-on-one or group interviews with selected sources including worker representatives, worker advocacy organizations, individuals with site "expertise" due to past employment or familiarity with operational history, and others who can verify the adequacy of site profile information that has been collected for the site profiles. Interviews will be conducted where convenient for these individuals or groups, including near the actual site in question. The objective of this activity is to avail the review of the first-hand experience and recollection of individuals who through their association with the site in question have original perspectives and information regarding site practices and exposure history.

Lines of inquiry would include the following:

(1) How did actual radiation protection practice compare with documented policy and procedures?

(2) Were there instances of obvious "missed dose," e.g., not wearing or improperly wearing dosimeters, non-recording of dose, etc.?

(3) Were there any incidents involving potential radiation exposure, whether reported or unreported?

(4) Were there special work activities or facility modifications that constituted process changes that increased radiation exposure potential?

(5) Were workers concerned about past exposure or radiation protection practices? How did management respond and what, if any, changes occurred in onsite practice?

(6) Did workers wear protective equipment as required?

(7) Was the protective equipment free of radiological contamination?

(8) Were radiological jobs planned for exposure minimization (e.g., ALARA)?

(9) What was the general housekeeping in the facility? Was radiological contamination common during the history of the facility?

(10) Were there special feed materials introduced or contaminants of concern identified for which radiation exposure may figure?

(11) Were there certain work activities at the facility that were considered "hotter" jobs from the standpoint of potential radiation exposure?

(12) Were safety procedures followed literally and did management assure that they were enforced uniformly?

(13) In terms of conduct of operation, were workers permitted to smoke, eat or drink in control areas? Was protective clothing and equipment worn in these areas; was egress monitoring conducted?

(14) Were negative or "zero" doses recorded on periodic dosimetric records despite known exposure to significant radiation sources?

(15) Were zeros entered into the dose record when dosimeters were not turned in or lost?

(16) Were records and other documentation of radiation exposure discarded or retained by management?

(17) Were there cases of over-exposed film and how were they treated?

(18) Are the exchange frequencies of dosimeters reported by workers, their representatives, and other knowledgeable sources consistent with one another and with site procedures?

The information gleaned from these interviews will be used to ascertain the validity and completeness of information collected, assumptions made, and analyses conducted in corresponding site profiles. Discrepancies or issues surfaced in this manner will be pursued through reviews of other information sources, as well as additional interviews for corroboration.

E. Dosimetric Technical Basis: Internal, External, Medical, and Occupational Environmental

In reviewing Technical Basis Documents as part of the site profiles, SC&A will compile both general and site-specific lines of inquiry as a means to "test" the adequacy and completeness of these documents, including underlying validity of assumptions, treatment of uncertainties, reflection of operational history, and conservatism of characterized dose ranges. The following lines of inquiry are illustrative of general questions that can be posed to ascertain whether the profile reflects key considerations germane to characterizing the exposure history at the site. The questions are written in a format that can be used as guidance for site profile reviewers and also site profile preparers.

Review of External Dose Reconstruction

- Assumptions

  (1) List Major Assumptions made in each profile – for each, are they valid and or claimant-favorable?

  (2) Develop a list of claimant-favorable assumptions/practices/dose reconstruction methods used at each facility, type of workplace, or for each individual with significant potential for exposure. Are they reflected in the site profile?

- Worker Exposure Categories, Exposure Potential, and Recorded Dose

  (1) Identify Worker Groups as to monitoring practices and review how the site management dealt with each group. Was the approach valid? If not, what additional steps and information are required to correct the insufficiency?

  The workers are 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

  (2) What types of potential exposure were present, i.e., photon, neutron, electron, etc.?

(3) What energy ranges were personnel exposed to?
- Photons E<30 keV, 30-250 keV and >250 keV
- Neutrons E<10 keV, 10-100 keV, 100-2000 keV, 2-20 MeV and >20 MeV
- Electrons E>14 keV

(4) When was neutron monitoring implemented at the site?

(5) Have neutron doses been adequately determined, especially during the early periods when tissue equivalent proportional counters, moderated boron tri-fluoride (BF_3) detectors or NTA film was used? When did the site convert to TLD dosimeters?

(6) Was there a significant potential for skin contamination that could cause a shallow dose due to electrons that should be included in the dose reconstruction for claimants who have skin cancer? What skin monitoring and decontamination facilities did the site management provide?

(7) What is the site's radiological inventory, and for each worker group, which radionuclides were common in the work place and should be considered in determining the dose?

- Types of Dosimeters

(1) When did the site convert from NTA film to TLD?

(2) When did the facility begin using multi-shielded film badges or multi-element TLDs? Did they keep up in a timely fashion with upgrades in dosimeter technology.

(3) How did the site deal with the over-response of early film badges to low-energy photons? Were scientific studies conducted to determine exposure geometry and energy distribution?

(4) What did the site report as the uncertainty for each type of dosimeter used? At very low doses, how did the site deal with potential increase of dosimeter uncertainty at low doses?

(5) Did the site take into account the fading of the film badge dosimeter especially in high temperature environments (resulting in a slight decrease in measured dose) and the spurious luminescence in the annealing process in TLD dose determination (resulting in an overestimation of true dose)?

(6) What were the minimum and maximum detection levels of each dosimeter and was each MDL consistent with current practice at the time? To which energy range did this MDL apply?

(7) What were the capabilities of the dosimetry system, such as the response to different types and energies of radiation, particularly in mixed fields?

(8) How did the site calibrate the respective monitoring systems? What were the similarities of methods of calibration to sources of exposure in the workplace?

- Missed or Unmonitored Dose

(1) Did the site profilers evaluate the statistical procedures used by the site for determining missed dose?

(2) What statistical procedures did the site profilers use to make their own missed dose estimates, and how did they validate these procedures?

(3) What dosimetry recording practices, especially in the 1940s to 1960s, led to "missed dose?" What did management do about this? Is the reconstruction of "missed dose" valid or does more work need to be done to properly document "missed dose?"
  – Were dosimetry readings below the limit of detection discarded?
  – Did the dosimetrist not record the open window dose in the official records?

(4) If the evaluated dose was less than the LOD, did the site use the Half-Limit of Detection (LOD/2) – registering the dose as being half of the LOD resulting in a slightly positive bias/overestimate as recommended by the National Research Council) as a claimant-friendly practice or was the dose in this case registered as zero?

(5) Was a "recording level" adopted for registering the doses, or were all doses above zero recorded? Was this "recording level" equal to the Limit of Detection?

(6) Did the site profilers use a log normal distribution (that dominates in the low-dose region) to determine "missed dose?"

(7) Did the site profilers use LOD times the number of zero measurements to get the upper 95% dose?

(8) How did the site profilers determine "missed dose" when multiple monitoring badges were worn during a particular monitoring period? In using the LOD/2 method, was the number of zero measurements based on the number of routine monitoring intervals in a given year?

(9) Do zeros in the dose record indicate dose below LOD or a missed dose because of procedural or estimation problems?

(10) Have the site profilers documented and reported the potential for significant "missed dose" among workers at the plutonium finishing facilities and the neutron source production areas?

(11) How are short-term, high-contamination episodes being handled? What is the approach for missing data on such episodes?

(12) What are the assumptions regarding doses for workers who were not monitored for some or the entire period of their employment? Is it reasonable, given process data, fluctuations in job assignments, process upsets, accidents, lack of data on when these process upsets happened to assign group doses to these workers based on general air sampling or breathing zone (BZ) sampling?

(13) What assumptions were used for missed dose in the case of workers who lost their dosimeters and subsequently entered workplaces without them?

- Photon Dose (Questions marked with an asterisk are also relevant to missing dose as applied to photons and neutrons.)

(1) Did the site dosimetrist interpolate correctly between two periods for which monitoring data is available before and after an incomplete or missing period of monitoring?*

(2) Was the potential under-reporting of dose due to some workers being issued multiple dosimeters taken into account? If so, what estimation procedure was used to ensure that the estimate would be systematically claimant-favorable?*

(3) If incomplete data is either before or after monitoring data, did the dosimetrist accurately extrapolate from adjacent (near-by) time periods to get a dose estimate? Was this a reasonable procedure in the specific circumstances to which it was applied?*

(4) When no personal monitoring data is available, did the site dosimetrist rely on the appropriate hierarchy of data in the following order: co-worker data, radiation survey data, and then source term data? When co-worker data was used, was the claimant-favorable approach used to find the maximum reasonable worker dose with the group?*

(5) When determining potential dose to a worker when only survey data is available, did the dosimetrist take into account that such exposure would likely be for 8 hours/day, 5 days a week and 50 weeks per year. If exposure was known, was the dose determined using the actual exposure period?*

(6) If reconstruction of a dose is necessary from source term, did the site conduct an investigation to determine if the process is sufficiently similar

to other operations at the monitored facility such that other worker data or survey data could be used to estimate workplace exposure levels? Was a program such as Microshield used to facilitate the computation from source term information?

(7) Whatever program was used, does the computation seem valid and are the input parameters valid?*

(8) If dose reconstruction had to be done only based on administrative or radiological monitoring controls (least desirable method resulting in gross overestimation of dose), was the dose determined from the threshold for required monitoring, the radiation posted limits, or the annual radiation dose limits? Did the application of one of these limits seem to be valid?*

(9) In computation of uncertainty associated with dose determination, did the site use the midpoint of the dose range as the most likely estimate and determine the maximum dose using the upper 95% of a lognormal distribution?*

(10) How were the relative positions of the organ, dosimeter, and the source of radiation taken into account in determining organ dose?

(11) Was there any kind of individual shielding used at the workplace, such as lead apron? Was the photon dosimeter used over or under the apron, or were two dosimeters worn?

- Neutron Dose

(1) Did the site use the appropriate radiation weighting factors for dose reconstruction and reporting of dose?

(2) During the early periods when boron-lined pocket ionization chambers were used to measure slow or thermal neutrons, did the site take into account the high degree of uncertainty when using these dosimeters to assess exposure to fast neutrons?

(3) Did the site take into account that NTA film was unable to accurately measure neutrons below about 500 keV?

(4) Did the uncertainty the site found associated with neutron monitoring follow a normal distribution and was the uncertainly about 10% to 25% (based on a comprehensive review of neutron dosimeter response uncertainty at 12 DOE sites)?

(5) Was the dose from intermediate energy neutrons treated as a missed dose since dose due to neutrons between thermal energies (0.025 eV) and the NTA threshold of 500 keV was not measured and therefore not reported?

(6) If accurate stay times are available at the site for workplace neutron exposures and if numerous neutron dose rate measurements exist, did the site develop a reasonable estimate of dose derived from recorded exposures below the limit of detection?

(7) Did the site take into account that the reported limit of detection/reporting limit for the neutron dosimeter in the early 1950s was 90 mrem and therefore a dose under the reporting limit may represent a "missed dose?"

(8) Did the site take into account that there are two components of neutron – "missed dose," i.e., the "missed dose" due to the high value of the lower detection limit, and also the restricted energy range for neutron monitoring using film badges?

(9) When no personal monitoring data is available, did the site dosimetrist rely on the appropriate hierarchy of data in the following order: co-worker data, workplace radiation survey data, and then source term data? When co-worker data was used, was the claimant-favorable approach used to find the maximum reasonable worker dose within the group?

(10) If the workplace involved working with critical assemblies or reactors, were neutron dose rate measurements conducted to verify adequate shielding of the reactor so as to more accurately evaluate estimated exposures?

(11) Did the site use instrumentation that reported dose rate or fluence? Fluence allows for easy conversion to organ dose if used (as long as the neutron energy spectrum is known).

(12) Did the site review and document sources of uncertainty i.e., duration of exposure, distance from the source, variations in shielding thickness and the uncertainty of the initial neutron fluence? Did they use the most reasonable value for each parameter to determine the central estimate? Did they use claimant-favorable assumptions to estimate the upper bound of the distribution?

- Electron Dose

(1) Are high-energy (E>1.0 MeV) electrons encountered in workplaces at the site. If so, they can be significant for breast and testicular cancers. Were such exposures adequately documented and doses reported?

(2) If the average beta energy is below 500 keV (as in most cases), has the dose been measured and such exposures documented so that this information is available for individuals with skin cancer?

(3) Were doses measured as a shallow dose ($H_p(10)$) at a depth of 0.07 mm in tissue using a tissue-equivalent TLD?

(4) Did the site dosimetrist have information about where the dosimeter was worn (inside or outside clothing), electron energy spectra, and response of film dosimeter?

(5) Was the program VARSKIN used to estimate skin dose? If not, is the other method of estimation as valid in determining skin dose?

(6) Did the dosimetrist take into account while conducting dose reconstruction for skin cancer, the following multiple parameters: average area of measurement probe and average area of actual contamination.

(7) When no personal monitoring data is available, did the site dosimetrist rely on the appropriate hierarchy of data in the following order: co-worker data, workplace radiation survey data, and then source term data? When co-worker data was used, was the claimant-favorable approach used to find the maximum reasonable worker dose with the group?

- Site or Facility Dose Reconstruction Parameters

(1) What were the administrative practices adopted by the site and/or facilities on the site to calculate and record personnel dose based on technical, administrative, and statutory compliance considerations?

(2) Were there workplace radiation fields that included mixed types of radiation, variations in exposure geometries, and environmental conditions?

(3) What was the nature of the radiation workplace-monitoring program and was it adequate? Did the site use portable radiation instruments, make contamination surveys, and establish area controls? Were personal dosimeters, area monitors, air monitors, etc., used, and in each case, were they state-of-the-art at the time, and when portable instruments were used, were they properly calibrated?

(4) What were the weekly, monthly or annual dose control limits in use at the time of dose recording or estimation? How did they change over time? What are the current dose control limits? In the early days, did higher dose control limits result in more significant "missed dose?"

(5) Were special intercomparisons made between dosimeter evaluations to evaluate the dosimeter's energy response for lower energy (i.e., E<100keV) photons that are significant at plutonium facilities?

(6) In effecting the calibration of a dosimetry system used at a site, did the site evaluate the dosimetry system's response characteristics to each radiation

type, energy, and angle of incidence, the methodology used to calibrate the dosimetry system, and the similarity between the radiation fields used for calibration and those present in the workplace?

(7) Did the site properly evaluate the workplace radiation fields? Are there significant complex beta, photon and neutron fields in, for example, reactor areas, irradiation fuel processing, plutonium handling, neutron source production, and radioactive waste facilities? If so, have they been evaluated accurately?

(8) Was the fraction of the total dose in each neutron energy group determined by dividing the neutron spectra into the four lower neutron energy groups? Does the site have neutron exposures in the highest neutron energy range (E>20 MeV) and if so, what special facility enhancements such as shielding were made to minimize personal exposures?

(9) Is high scatter of neutrons from shielding in plutonium storage facilities (shown by a increasing neutron to photon ratio) a problem at a site, and if so, what radiation controls were put in place to minimize personnel exposure?

(10) What assumptions were made about Pu-240 content of plutonium and proximity of workers to sources containing Pu-240?

(11) If neutron radiation is present in routine work areas during reactor operations, does the site use the most claimant-favorable neutron to photon ratio? Based on review of 100 workers at Hanford from 1959-1961, the most favorable neutron to photon ratios ranged from 0.13 to 0.73 with a weighted average of 0.26.

(12) Were adjustment factors used to arrive at the estimate of dose? If so, how were they derived? How do adjustment factors affect the quality of dose data and the process for making claimant-favorable assumptions?

(13) Were extremity exposures estimated from whole body dose? How sound was this practice? How was non-uniform exposure to skin estimated?

(14) Did the site use a claimant-favorable standard uncertainty estimate of 50% for neutron dosimetry between 1971 and 1985? Starting in 1985, did the site use a standard uncertainty of 15% in neutron-recorded doses?

(15) Is the correct NCRP 38 neutron quality factor used for the four typical neutron energy groups? What are the average quality factors used at the site? Were the ICRP 60 neutron-weighting factors used correctly?

Review of Internal Dose Reconstruction

- Assumptions

  (1) List Major Assumptions; for each, are they valid and/or claimant-favorable?

  (2) Develop a list of claimant-favorable assumptions/practices/dose reconstruction methods used at each facility, type of workplace, or for each individual with significant potential for exposure.

  (3) The following questions should be reviewed in the site TBDs for internal dose reconstruction:
  - Were the radiation environments characterized in the best way possible?
  - Were the worker exposures in each radiation environment well defined, or in the most plausible claimant-friendly way?
  - Was the time the worker spent in the radiation environment well defined, or in the most plausible claimant-friendly way?
  - Are individual monitoring data and workplace monitoring data available to evaluate the worker's dose?

- Facility Data: Characterization of the radiation environments to which workers were exposed

  – Evaluate how dose reconstruction data is organized and handled with respect to:

    (1) Characterization of the different working environments in the facility, description of the installation, engineering controls.

    (2) Characterization of the source term.

    (3) Stage of activities in the installation: construction, operation, decommissioning.

    (4) Modifications to the source or to the installation.

    (5) Description of the work done in each location, description of all processes for each work location.

    (6) Extent of encapsulation and containment of sources.

    (7) Potential for exposures of the workers in each working environment, considering all possible actions involving the sources, the way workers operate with or near the sources.

(8) Radioprotection practices in each working environment, changes in the protection practices, potential impact of radioprotection practices for workers exposure. Acceptable limits of exposure and changes.

(9) Operational, maintenance, and administrative procedures, including accountability of the radioactive sources, occupational protection and safety measures local rules, and restriction of access. Modifications introduced to these procedures.

(10) Information about accidents, failures, and other events that could have lead to exposures.

(11) Showering and washing facilities and storage of personal clothes.

(12) Organizational structure, distribution of work among different groups of workers and distribution of individual tasks within different groups of workers.

- Characterization of source term in each working environment: Evaluate adequacy of information collected in relation to the following items:

(1) What are the primary radionuclides at each facility/work site? Have the radiological impurities present been accounted for in determination of dose (normally minimal)?

(2) In evaluation of source term data, can published values for resuspension factors be used in lieu of adequate source term data?

(3) Has the site profile addressed the dispersible quantity of material available and the fraction of this quantity that actually produces airborne contamination in the individual's breathing zone?

(4) Are particle size distribution studies available for each working environment? Are particle size distribution studies for similar facilities and processing of radioactive material available? Was the ICRP default AMAD 5μm used because there was no other data available that could lead to a better estimation of the AMAD?

(5) Were the chemical compounds known? Were the appropriate absorption types chosen for the radionuclide compounds with potential for inhalation?

(6) Were radionuclides present that could have been classified as gases or vapors, as recommended by the ICRP? How were they treated? For radionuclides that could be present as particulates or in the gas/vapor form, which form was assumed or which mixture was assumed and why?

- Workers exposure in each radiation environment: Evaluate adequacy of information collected and analyzed with respect to the following items:

  (1) Which specific tasks were assigned to the worker? Which locations was the worker able to enter? How did his tasks change with time? Why did his task change?

  (2) How was the distribution of work among different groups of workers? How was the distribution of individual tasks within different groups of workers? Did workers occasionally substitute in other jobs?

  (3) What was the most plausible mode of intake? Inhalation? What was the potential for ingestion? What were the hygienic habits rules for cigarette smoking or eating and drinking in the radiation area or radiation adjacent areas? What was the potential for placing contaminated hands or glove contaminated covered hands in the mouth? Was there potential for absorption through skin?

  (4) How much physical effort was necessary to perform the work? Should the ICRP default ventilation workers parameter for light work be used or should the heavy worker parameters be used?

  (5) Is there evidence of adequate respiratory protection breathing apparatus being worn in areas of airborne contamination? Has this been adequately addressed in determining individual, group or workplace area dose?

  (6) Did the site or facility use HEPA filtered respirators and if so were the associated inhalation doses adjusted by the appropriate respiratory protection factors?

  (7) Did the site profilers take into account how respirators were stored, so as to determine the potential for contamination of the respirators?

  (8) Is there particular recorded documentation of acute or accidental exposure to an individual or group? If so, is there good environmental data to document the extent of the exposure? Do workers interviewed understand how, when, and where they were exposed?

  (9) How was exposure to radon handled?

- Exposure time periods: Evaluate how much information was collected and analyzed with respect to the following:

  (1) What was the most plausible time pattern for the worker's exposure?

  (2) If specific periods of inhalation and or ingestion are not known, was it assumed that a constant chronic exposure existed for the entire period of employment?

  (3) If a chronic exposure is the most plausible pattern of exposure, were working schedules, weekends, and vacation periods taken into consideration?

  (4) If it was necessary to assume a scenario, was it based on producing the highest committed dose to the organ of interest from exposure to the date of diagnosis of the cancer? Is each scenario a credible one?

- Bioassay Data: Evaluate the adequacy of information collected and analyzed for the following:

  (1) Are there bioassay data available for periods of potential inhalation, ingestion, injection or absorption? How did the site profilers establish the validity of this data?

  (2) What type of bioassay measurements are available, i.e., urinalysis, fecal samples, in vivo measurements, breath radon and/or thoron results, nasal smears? Is the sampling screen capable of detecting each radionuclide of interest?

  (3) Which limitations in technology existed in each period of time? For each time period of exposure, which radionuclides or which isotopes were not detected because of this limitation in technology?

  (4) How was the bioassay-monitoring program conducted? What was the frequency of the monitoring program? What criteria were used to assign a bioassay-monitoring program to a worker?

  (5) What were the criteria for initiating a special bioassay in the installation? Which results or assumptions triggered the initiation of a bioassay program?

  (6) What was the minimal detectable dose for bioassay monitoring?

  (7) What was the potential for undetected doses for workers included in the bioassay program? What was the potential for undetected doses for workers not included in the bioassay program?

(8) How was the schedule of the bioassay program in relation to vacation and weekends?

(9) If more than one bioassay method was used, how were they scheduled? Can data from two bioassay methods be used to complement each other?

(10) If different bioassay methods were used to monitor different groups of workers, which criteria were used?

(11) How were the bioassay data recorded? Which data were recorded? Were they specified by site? Is the dose record complete for all the exposure time of the worker? Is the dose record usable for dose reconstruction?

(12) What were the reporting levels, MDA/reporting levels for bioassay, and decision levels used in the early days of weapons production, and how did they change with time? Have these been adequately taken into account in determining the 95% confidence level?

(13) Are there bioassay data that record intake? Was it assumed that the acute inhalation occurred on the first day of exposure (conservative assumption - unless time or exposure is specifically known), or was it assumed that the exposure occurred midway between the two samples dates (the standard approach – can provide a means of estimating the intake date)?

(14) Did site procedures account for possible periods of small multiple intakes that eventually could lead to a detectable bioassay result?

(15) Have calculated bioassay values been based on the higher of the MDA or the actual result plus two standard deviations?

(16) Are there any anomalous bioassay result(s), and were they evaluated for possible removal from the data set?

(17) Were gaps in internal dosimetry data (bioassay data) filled by interpolating between existing bioassay data, air sampling, etc., or use of co-worker data?

(18) Have the detection limits, minimum detectable levels, and/or action levels been adequately documented and properly utilized, especially in determining “missed dose” from recorded zero exposures?

(19) What types of bioassay measurements are available, i.e., urinalysis, fecal samples, in vivo measurements, breath radon and/or thoron results? Is the sampling screen capable of detecting each radionuclide of interest?

(20) Were the laboratories where the samples were analyzed certified by EML as having passed then-prevailing quality standards?

(21) Are there bioassay data that record intake? Was it assumed that the acute inhalation occurred on the first day of exposure (conservative assumption - unless time or exposure is specifically known) or was it assumed that the exposure occurred midway between the two samples dates (the standard approach – can provide a means of estimating the intake date)?

(22) Has the appropriate biokinetic model been used to determine the actual intake or uptake?

(23) Have calculated bioassay values been based on the higher of the MDA or the actual result plus two standard deviations?

(24) Are there anomalous bioassay results, and were they evaluated for possible removal from the data set?

- Whole Body Counting

(1) How does the site's WBC capability compare with typical current minimum detectable levels (MDAs) shown below? How did they vary in the early days, and is this a source of overestimation or underestimation of dose determined from WBC? (SRS ORAUT TKBS-003 Table 4.2.1-2, page 74 of 232)

Radionuclide	MDA (nCi)
M-54	3.4
Co-60	2.9
Zn-65	6.1
Ru-106	36
Sb-125	14
Cs-134	3.8
Cs-137	4.1
Ce-144	69
Eu-152	18
Eu-154	8.4
U-235	14
Np-237	14

(2) How does site chest counting capability compare with typical current minimum detectable levels (MDAs) shown below assuming 2.5 cm chest wall thickness? How did they vary in the early days, and is this a source of overestimation or underestimation of dose determined by chest counting? (SRS ORAUT TKBS-003 Table 4.2.2-1, page 76 of 232)

Radionuclide	MDA (nCi)	Radionuclide	MDA (nCi)
Ce-144	0.31	Pu-238	58
Eu-152	0.056	Pu-239	130
Th-228	3.2	Pu-240	47
Th-232	3.1	3% Pu	110
DU	1.2	6% Pu	96
RU	8.31	2%Pu	70
HEU	5.2	Am-241	0.10
U-234	30	Am-243	0.12
U-235	0.10	Cm-242	28
U-236	89	Cm-244	37
U-238	1.1	Cf-252	32
Np-237	0.31		

(3) How were the MDAs calculated? How did they change with time?

(4) Which methods of in vivo detection were used? Which kinds of detectors were used along the time?

(5) Which geometry was used for the detectors?

(6) What were the measurement procedures? Were routinely monitored workers measured before entering contaminated areas? Were they required to change their clothes? Were they required to wash before monitoring? Which procedures were followed in cases of accidents or suspected exposures?

(7) How was the counting position determined? How far were the detectors from the body?

(8) How reproducible were in vivo results?

(9) How long was the counting time?

(10) How was background radiation accounted for?

(11) How was radiation from natural sources or fallout present in the individual body accounted for?

(12) How was calibration for each nuclide done?

(13) What quality assurance procedures were followed along the time?

(14) What procedures were used to determine a body burden from in vivo results?

(15) How was the body burden (BB) of a nuclide determined from the measurement of daughter nuclides (U, Th)? How was a BB determined from the counting of an associated nuclide (Pu-Am)?

(16) Were workers measured after chelation treatment for contamination? How were these data treated?

(17) Are there reports of interferences from radiopharmaceuticals given to the workers because of diagnosis or treatment?

In Vitro Bioassay Analysis

- Urinalysis

(1) Which methods for urine bioassay were used? How were they changed along the time?

(2) What was the MDA for each method? How were they calculated? How did they change with time?

(3) When were isotopic differentiating methods begun to be used?

(4) Which criteria were used to assign workers to a urine bioassay program?

(5) Which nuclides were the in vitro urinalysis programs aimed to detect? Did the program take into account the solubility of the compound?

(6) How were nuclides not detected in urinalysis accounted for? How were results from detected radionuclides used to assign the exposures of undetected radionuclides?

(7) Which procedures were used for urine collection? Were samples collected at the workplace? Were samples collected at home? Which measures, if any, were taken to prevent external contamination? Were 24-hour samples collected? Were samples collected in a different time protocol (e.g., two 12-hour samples, morning samples, after vacation samples, after weekend samples, weekend samples, etc)? Were the samples collected in relation to a standard or minimum volume, independent of the time? Were the samples collected in a standard or minimum volume in assigned time protocol?

(8) How were results reported: By volume? By 24-hour excretion? By x number of hours to excretion? Were results normalized? Was the normalization based on sampling information? Was normalization based on standard volume excreted in 24 hours? What standard volume was used? Were other normalization methods used?

(9) Which analytical procedures were used? How was recovery in the analytical procedure measured (chemical yield)? Were the samples analyzed in total? Was only an aliquot analyzed? What were the potentials for not accounted losses in the analytical procedure or from sedimentation on the walls of the sampling containers? What was the length of sample storage? How were samples preserved?

(10) Which procedures were used for counting calibration?

(11) How were tracer interferences accounted for?

(12) Which procedures gave results in mass concentration? How were they translated into activity concentration?

(13) What quality assurance procedures were followed along the time?

(14) Were uncertainties reported? How were they calculated?

(15) How were normal excretions of natural radionuclides accounted for?

(16) Were urine samples measured after chelation treatment for contamination? How were these data treated?

(17) Are there reports of interferences from radiopharmaceuticals given to the workers because of diagnosis or treatment?

(18) How was the tritium urinalysis program conducted?

(19) In doing in vitro analysis for tritium, did the site initially use 1 uCi/L as the reported MDA, and have they been able to attain the currently acceptable MDA of 0.02 uCi/L? Did the site in the early days only evaluate tritium bioassay results greater than 5 uCi/L and, if so, is there a potential for "missed dose?"

(20) In doing in vitro analysis for uranium, did the site apply the upper limit at the 99% confidence level for analytical noise and set this at 0.15 dpm/1.5L. Was this applied to all historical samples?

(21) In doing in vitro analysis for radiostrontium, did the site use the claimant-friendly approach that the results are all from Sr-90 even though negligible levels of Y-91 were also grown in from Sr-90; and that the reporting level is assumed to be the same as for the beta component of the fission product analysis.

- Fecal Analysis

(1) Which methods for feces bioassay were used? How were they changed along the time?

(2) What was the MDA for each method? How were they calculated? How did they change with time?

(3) When were isotopic differentiating methods begun to be used?

(4) Which criteria were used to assign workers to a feces bioassay program?

(5) Which nuclides were the in vitro feces analysis aimed to detect? Did the program take into account the solubility of the compound?

(6) How were nuclides not detected in feces analysis accounted for? How were results from detected radionuclides used to assign the exposures of undetected radionuclides?

(7) Which procedures were used for feces collection? Were samples collected at the workplace? Were samples collected at home? Which measures, if any, were taken to prevent external contamination? Were 24-hour samples collected? Were samples collected in a different time protocol (e.g. after vacation samples, after weekend samples, weekend samples, etc)?

(8) How were results reported: By mass? By 24-hour excretion? By grams of feces ash? Were results normalized? Was the normalization based on sampling information? Was normalization based on standard mass excreted in 24 hours? What standard mass was used? Were other normalization methods used?

(9) Which analytical procedures were used? How was recovery in the analytical procedure measured (chemical yield)? Were the samples analyzed in total? Was only an aliquot analyzed? What were the potentials for not accounted losses in the analytical procedure or from sedimentation on the walls of the sampling containers? What was the length of sample storage? How were samples preserved?

(10) Which procedures were used for counting calibration?

(11) How were tracer interferences accounted for?

(12) Which procedures gave results in mass concentration? How were they translated into activity concentration?

(13) What quality assurance procedures were followed along the time?

(14) Were uncertainties reported? How were they calculated?

(15) How were normal excretions of natural radionuclides accounted for?

(16) Were feces samples measured after chelation treatment for contamination? How were these data treated?

(17) Are there reports of interferences from radiopharmaceuticals given to the workers because of diagnosis or treatment?

(18) In doing fecal sample analysis since the 1950s, did sites use typical MDAs of 7 pCi (Am-241), 300 pCi (Pu-238) and 600 pCi (weapons grade plutonium)? If not, what is the basis for not using these typical MDAs?

- Other Bioassay Methods

(1) Are other bioassay results reported (e.g., nasal smears, blood samples, tissue samples from wound, breath)? How were they analyzed? How were they interpreted?

(2) Are there reports of skin contamination measurements? How were they interpreted?

- Physical Samples — Air Sampling

(1) Was an air-sampling program routinely conducted? When was it conducted?

(2) Which kind of air sampling program was conducted? Were static samplers used? How many were used for area characterization? In which locations were they fixed in relation to the sources and in relation to the workers? At what height?

(3) Was particulate air sampling (PAS) used?

(4) What were the characteristics of the samplers? What was the sampling rate of the samplers? How did they change with time?

(5) For which kind of results was the air-sampling program designed? For which nuclides were the air-sampling programs designed?

(6) Which methods were used to measure the concentration of particles present in the environment? What were the MDAs? What method was used to calculate the MDAs? How did they change with time?

(7) Was there a maximum detectable activity?

(8) Was there any information of particle sizes available from air sampling (inhalable fractions or respirable fractions)?

(9) Was the sampling designed to provide information on particle size distribution?

(10) When did isotopic differentiating methods start to be used?

(11) How were nuclides not detected in air samples accounted for? How were results from detected radionuclides used to assign the exposures of undetected radionuclides?

(12) How were results reported: By concentration in air volume? By concentration in y hours sampling? Were results normalized? Was the normalization based on standard volume intake in working hours? What standard volume was used? Were other normalization methods used?

(13) Which analytical procedures were used?

(14) Which procedures gave results in mass concentration? How were they translated into activity concentration?

(15) What quality assurance procedures were followed along the time?

(16) Were uncertainties reported? How were they calculated?

(17) How were natural radionuclides (especially radon progeny) present in air accounted for?

- Surface Sampling

(1) Were surface samples taken routinely? What was the frequency?
(2) What was the purpose of the surface sampling program?
(3) How were surface samples obtained?
(4) How were the results interpreted?

- Record keeping

(1) What was the record keeping practice in the facility? Which documentation was required to be kept? Which results from the monitoring program were recorded? How did record requirements change with time?

(2) How detailed are the records? Which information on individual monitoring programs did they contain?

(3) Which recording levels were used? How did they change with time?

(4) Did records contain dose assessments? Were the processes used for computing the dose registered? Can dose records be used to reestimate organ doses using current ICRP methodologies?

Occupational Medical Exposure

The purpose of this procedure is to evaluate the occupational medical technical basis document, where compiled, to ascertain whether the profile is representative, adequate, and complete, given the available information and data.

The following lines of inquiry are illustrative of the general questions that can be used:

- Medical Exposure From Medical Exams

  (1) Are cited medical records complete with respect to the type, number, and dates of all required occupational x-rays? How was this verified by site profilers? If gaps exist, what assumptions were made?

  (2) Are all possible x-ray exams and retakes received accounted for so as to be claimant-favorable?

  (3) Is it clear from the profile what type of x-ray equipment was used for PA and lateral chest films? What type of x-ray film was used?

  (4) Does the profile clarify whether photofluorography was used for PA chest views? How reliable is the information obtained on photofluorographic use as to when, where, and how any such exams were performed?

  (5) Does the profile address what is known about the x-ray performance characteristics for required occupational chest x-rays which influence exposure potential to a claimant? What information was provided on such parameters as half value layer, mA, timer, geometry, kVp, collimation, film type, focal spot, and rectification of x-ray machines in use over time?

  (6) What was the x-ray output of such x-ray equipment? If measurements are available, how were they evaluated in the profile to ascertain measurement accuracy, precision, limits of detection, etc?

  (7) If information on x-ray characteristics and outputs are inadequate or unknown, what other sources of information were used to provide data that is claimant-favorable?

  (8) How much reliance was placed on NCRP 102 with respect to “use” tables to estimate x-ray output based on characteristics of kVp, HVL, mA and x-ray time? If the site reviewer did not use these or similar reference standards, what assurances can be given that x-ray output was not underestimated?

  (9) What were the procedures for estimating doses to the workers who operated chest and other x-ray equipment?

- Dose conversion

    (1) In converting x-ray exposure to organ dose, how was the x-ray output in roentgens at a certain distance converted to skin entrance kerma in rads or cGys? Was ICRP 74 used for air kerma conversion? Were inverse square calculations performed for converting air kerma dose to the distance the patient is from the x-ray machine?

    (2) Is the site profiler using the current ICRP methods to calculate organ dose so that older ICRP or NCRP publications may not underestimate the organ dose to the claimant?

    (3) Did the site profiler account for the PA geometry of the chest x-ray (entrance exposure at the back) and not the AP geometry (front) common for radiation badge dosimetry? The same question applies to the lateral view.

Occupational Environmental Dose

Site Profiles are expected to address unmonitored exposures, which include internal and external exposures that might have been received by a claimant who was an onsite non-radiation/unmonitored worker. Potential claimants of this type would be heavily represented by construction, maintenance, administrative, and security personnel, most of whom would have been employed onsite during regular working hours of 8:00 a.m. to 5:00 p.m., Monday through Friday.

In the absence of monitoring data, site profiles will need to address the procedure for estimating doses for these classes of personnel. Among the decisions that would need to be made would be whether it is appropriate to use source terms estimated for offsite exposures, such as those found in site studies commissioned by the CDC, for estimating onsite doses, and if so, for which set(s) of unmonitored personnel such source terms might be used.

Site profile reviews will examine whether and how such an assessment was made. Specifically, the following considerations will be taken into account in evaluating technical basis documents:

(1) Do the source terms whose purpose was for estimating offsite exposure cover all the principal routes and situations of exposure of unmonitored workers? For instance, did the sites burn wastes containing radionuclides that may not have had significant offsite impacts, but may have had considerable onsite impact?

(2) Were significant local radiation fields that would not be part of an offsite study encountered by some groups of workers? Have these situations been assessed in terms of their dose potential relative to doses derived from offsite emissions?

(3) Offsite doses from operating facilities are typically dominated by the air pathway (and pathways deriving from the air pathway). How were the doses from onsite liquid discharges, such as those into holding ponds or seepage basins factored into potential source terms for unmonitored workers?

(4) How was exposure to resuspended radionuclides handled for unmonitored workers?

(5) Was the study assessed for accuracy and completeness in terms of its suitability for use in onsite dose reconstruction?

(6) Were the estimates of source terms peer-reviewed?

(7) Are onsite air, soil, and vegetation monitoring data compatible with those derived from stack source terms used for dose reconstruction? If not, how are the discrepancies to be resolved?

Once the above issues are addressed and a decision is made to use source terms derived for offsite estimation for worker doses, the modeling should include the following considerations:

(1) Identification and characterization of dominant source terms. What is the identity of radionuclides that were released? At what elevation (e.g., at ground level versus elevated release height)?

(2) How were building wake effects and other local factors incorporated into estimating onsite doses?

(3) What were the total curies released in a given year and/or source term release rates (i.e., Ci/sec released)? How did continuous releases compare in importance to episodic releases?

(4) Were meteorological factors evaluated in order to ensure a reliable prediction of contaminant dispersion or air concentration at discrete onsite locations where workers were exposed. How were administrative workers, who may have been mostly in well-defined locations, distinguished from workers who typically moved from one location to another on the site? How were episodic exposures handled for this latter group of workers?

(5) What assumptions were used regarding the time of day, frequency, or duration of airborne releases. What approach was used for modeling episodic releases and accidents.

(6) What data was used to model these exposures and determine their applicability or appropriateness in deriving unmonitored doses?

(7) Has time of release been considered with respect to time of exposure? Were the releases <u>continuous</u> and <u>chronic</u>? Or were releases episodic and/or occurred predominantly during select working hours of the day (i.e., between 9:00 am, and 5:00 p.m./Monday through Friday), when most of the site maintenance and construction workers would have been onsite?

(8) What sources of data were used to estimate internal dose to workers outside the facilities? Did the site profiles incorporate dose from sources such as air concentrations resulting from the individual facility releases, from ground releases, and from resuspension of radioactive materials in the soil?

(9) Did the site profiles consider exposure to unmonitored workers from external exposure to ambient radiation and releases of noble gases to the air?

(10) What atmosphere dispersion models were used at the site, and are they currently used models or best available at the time of dose reconstruction?

(11) Were average and maximum annual intakes developed for radionuclides potentially important for internal dose reconstruction for occupational environmental dose?

(12) Did unmonitored workers spend significant time or minimal time in areas of potential radionuclide intake? If the unmonitored worker worked in multiple areas, did the site profile address potential dose to workers in each of these areas?

- Development of Probability Distribution For the Dose and Overall Uncertainty Analysis

  (1) How was dose reconstruction uncertainty assessed? Is this uncertainty assessment conservative, reasonable, and efficient?

  (2) How are the probability distributions for the various parameters, such as air concentrations particle sizes, and external and internal dose measurements determined for the purpose of developing a joint probability distribution for each year for which dose is estimated? How are site and individual dose parameters combined to yield the probability distribution for each year of dose estimation? [Note: characterization of the probability distribution of the dose is required for each year of the dose estimate under 42 CFR 82.19. Without this distribution, a 99% IREP calculation cannot be done.]

- Secondary Sources of Occupational Exposure Data

  It is clear from 42 CFR Part 82 that secondary sources of radiological exposure data are to be reviewed where uncertainties become significant enough or where clear gaps in the record exist, i.e., “missing dose.” The judgment to evaluate secondary sources is a subjective one, based on professional judgment regarding the reliability of primary sources of information (i.e., recorded individual dose), and the availability and applicability of secondary sources. At most sites, this is not a mere academic exercise given that the reliability of recorded dose often diminishes as a function of how far back in time dose measurements were made and recorded. Site profile reviews need to examine how this judgment — to seek secondary sources of dose data — was reached by site profilers, for what workers at what locations and at what time periods, and to what extent and in what manner

secondary sources of radiological data were evaluated. Finally, to what extent do the secondary sources of data envelope the individual recorded dose?

Secondary sources of occupational dose data would include, but not necessarily be limited to, the following:

- Air sampling data (area and breathing zone)
- Contamination survey records
- Environmental monitoring documentation
- Incident/Accident reports
- Area monitoring and survey data
- Filter activity readings
- Radiation "field" measurements and estimates

F. Integrate Findings and Prepare Report for Advisory Board

Integrate information and findings from each element of site profile review, evaluate overall adequacy and completeness using the following acceptance criteria, and provide conclusions in the form of a draft report to the Advisory Board.

Acceptance criteria:

(1) Are all pertinent and significant sources of information identified, included and accurately represented in the site profile?

(2) Are the assumptions made in analyses and dose estimations contained in the site profile sufficiently supported, valid and claimant-favorable?

(3) Are "missing dose" and other uncertainties associated with site dose estimations provided in site profiles addressed adequately?

(4) Are postulated "worst-case" dose estimate scenarios truly reflective of supporting operational and dosimetric data?

(5) Is the body of information in the site profile sufficient upon which to base individual dose reconstructions?

Conclusions on the foregoing criteria, as well as supporting information, will be provided to the Board in a final draft report following completion of internal SC&A quality assurance review. The report may contain recommendations for further information gathering or evaluation, as appropriate.

G. Briefing for Advisory Board; Provision of Board Comments/Questions

The site profile review leader will provide a briefing on the submitted draft report permitting at least 30 days for review following receipt. The Board (or a designated subpanel) will provide the contractor any observations, comments and questions regarding the site profile review during the briefing, and subsequent to the briefing, convey a formal set of comments and questions for

followup and reflection in the final evaluation report. The Board may request that the contractor extend or expand its review to address specific issues or questions; it may also request additional supporting information from either NIOSH or the contractor. Upon receipt of the Board's feedback, the contractor will project time and resources necessary to respond to the Board and provide same to the Board as soon as possible.

H. Submission of Final Site Profile Review Report

Upon acceptance of a submitted draft report by the Board (or a designated subpanel), the contractor will submit a final report to the Board completing obligations for that particular site profile review. At the Board's discretion, it may reopen a site profile evaluation at any time upon notification of the contractor.