Attachment 2:

NIOSH Responses to S. Cohen & Associates Comments: Draft Review of the NIOSH Site Profiel for the Nevada Test Site, SCA–TR-TASK1-0006, dated 12/31/05

Rozner, Kathleen (Reid)

From: Broehm, Jason E. (CDC/OD/CDCW) [zfr4@cdc.gov]
Sent: Monday, July 17, 2006 11:14 AM
To: Schubert, Sandra (Reid); Raborn, Shannon (Reid); Rozner, Kathleen (Reid)
Cc: dot2dot3@earthlink.net
Subject: NTS Site Profile Review - NIOSH response to findings
Attachments: NTS_Response to SCA TBD Comments_to OCAS 2006-07-17.doc

Attached is NIOSH's response to issues raised in SC&A's draft Nevada Test Site site profile review. It is being shared with the Working Group in advance of its meeting next week.

Jason

<<NTS_Response to SCA TBD Comments_to OCAS 2006-07-17.doc>>

Comment 1: Some radionuclide lists are not complete. This is especially important for atmospheric testing and for early re-entry workers. [Finding 1, Issue 5.1]

RADIONUCLIDE LISTS [5.1]

Radionuclide lists are not complete for several aspects of NTS operations [Finding 1].

Comment 1a: Table 1 shows the activation products regarded as important in the study by the National Research Council of the NAS on nuclear testing evaluating exposures of armed forces personnel (NAS 1989).

Table 1: Activation Products Important for External Gamma Dose

Radionuclide	Half-life	Photon energies, principal emissions, KeV
^{239}Np	2.36 days	100, 117, 210, 228, and 278
^{24}Na	15.0 hours	1369 and 2754
^{56}Mn	2.58 hours	847, 1811, and 2113
^{38}Cl	37.2 minutes	1642 and 2168
^{28}Al	2.24 minutes	1779
^{46}Sc	83.8 days	889 and 1121
^{134}Cs	2.07 years	569, 605, and 796
^{60}Co	5.27 years	1173 and 1332

Notes: 1. Photon energies shown are those cited in NAS 1989.
2. Very short half-life activation products are only relevant in case of entry into areas very soon after the test or in case of entrainment in fallout affecting personnel.

Source: NAS 1989, pg. 31

The extent to which a specific radionuclide would result in exposure would depend on the time of entry into the contaminated area and the nature of the test (atmospheric, underground, and within those two broad categories, the details of the detonation arrangements). Since the delay between the shot and the presence of workers at or near the ground zero of atmospheric tests or in tunnels or mined shafts was highly variable, the radionuclides that would be expected to play a significant role in exposure would vary according to the test. For instance, if entry was after a few hours, ^{28}Al would not be relevant. After a few days (~1 week), the main activation products of importance would be ^{239}Np, ^{46}Sc, ^{134}Cs, and ^{60}Co. Note that, in this context, ^{134}Cs is listed as an activation product of stable ^{133}Cs. It is also a fission product. Of these radionuclides, the TBD only lists ^{60}Co as being relevant for tunnel re-entry and mineback operations (TBD Vol. 2, Table 2-2). NIOSH has informed SC&A that Table 2-2 has been revised (see Attachment 2). The radionuclide lists in Section 5D-4 are also not complete. For instance, the lists in Table 5D-10 (NTS TBD Vol. 5, pg. 56) do not include ^{24}Na, ^{46}Sc, or ^{239}Np in the 1-day or 10-day lists. Strontium-90 is not on the 1-day list.

Response 1a: NTS TBD Table 2-2 has been revised and now contains all of the Table 1 radionuclides listed above except ^{38}Cl, ^{28}Al, and ^{46}Sc. NIOSH will add these radionuclides to Table 2-2 along with the areas of concern. Also, other NTS TBD tables that identify radionuclides of concern will be reviewed and revised as appropriate.

Comment 1b: Finally, the radionuclides listed in Table 2-8 in NTS TBD Vol. 2, do not show time-dependence of the radionuclide list. The year for which the inventories were calculated should be stated, in order to account for radionuclide decay (see also discussion below on environmental dose).

Response 1b: Table 2-8 has been removed from the draft revision of the TBD.

Comment 1c: The list of radionuclides for atmospheric testing in Table 2-3 appears to be sound. However, the table starts with 10-day concentrations. Concentrations should be estimated by hour for the first day and by day after that, since entry into areas near ground zero often occurred shortly after the tests on the day of the test.

Response 1c: Because of the pending Special Exposure Cohort (SEC) petition for workers involved in atmospheric testing, NIOSH believes adding additional information to Table 2-3 is not appropriate at this time.

Comment 1d: Further, Table 5D-13 (NTS TBD Vol. 5, pg. 59), which is a brief guide to internal dose during the atmospheric testing period, does not correspond to Table 2-3 and does not show time-dependence. This is especially important for estimating internal dose during the atmospheric testing period, since personal internal monitoring data are lacking for almost all radionuclides during this period (see discussion below on internal dose).

Response 1d: Because of the pending SEC petition, NIOSH believes revising Table 5D-13 is not appropriate at this time.

Comment 2: TBD does not provide adequate guidance for dose estimation to gonads, skin, and gastrointestinal (GI) tract for early reactor test re-entry personnel. Large hot-particle doses to skin and GI tract have not been evaluated. Naval Radiological Defense Laboratory (NRDL) documents and models have not been evaluated, though one document is referenced. [Finding 2, Issue 5.2, 7.1.1]

REACTOR RE-ENTRY PERSONNEL [5.2]

The NTS TBD does not provide adequate guidance for estimating doses associated with reactor propulsion tests, notably those to early re-entry personnel. These doses may be dominated by large particles incorporating short-lived fission products. Doses to the skin, gonads, and gastrointestinal tract appear to be particularly important [Finding 2].

Completeness of Data Sources [7.1.1 Objective 1, excerpt] SC&A also notes that there are other sources that the NTS TBD has not explored that could be critical to dose reconstruction for several groups of workers. Among the most important of these sources are the reports prepared by the NRDL for estimating doses to personnel re-entering reactor test areas soon after the tests. NRDL 1968 was cited by NIOSH, but its dose-related aspects were not presented or analyzed in the NTS TBD. NRDL 1968 also contains several references that have more detailed data regarding hot particles and radiation doses. SC&A suggests intensive study of these and related sources and archives, since they are likely to contain data and analytical

methods that would be of material value in several different aspects of dose reconstruction including:

- ***Doses to re-entry personnel***
- ***Organ dose implications of exposure to hot particles***
- ***Geometry considerations relevant to dose of record relative to organ dose***
- ***Potential long-term skin, gonad, GI-tract, thyroid, and breast radiation dose due to large particles incorporating radionuclides that are relatively long-lived, such as 60Co, that could deliver large local doses***
- ***Far-field hot particle doses***

Comment 2a: Reactor-driven rocket engines were tested at NTS from the late 1950s into the early 1970s. These tests were conducted in the open, releasing fission and activation products that were deposited near the reactor test area to areas more than forty miles downwind. Area 25 was used from 1959 to 1973 "for a series of open-air nuclear reactor, nuclear engine, and nuclear furnace tests and for the High Energy Neutron Reactions Experiment" (NTS TBD Vol. 2, pg. 31). Area 26 was used for the development of a nuclear ramjet engine starting in 1957.

The open-air reactor tests sent fission products into the air that were dispersed by wind and deposited on the ground, with the larger particles being deposited closer to the reactor test site and finer particles being deposited farther afield. The total and differential depositions of the particles of various sizes would, of course, depend on the size of the test (total energy generated), the duration of the test, and meteorological factors. According to the Naval Radiological Defense Laboratory (NRDL), it was "necessary for personnel to re-enter the test site area as soon as possible" after the test (NRDL 1968, pg. ii).

NRDL 1968 is a report that was prepared in the context of a reactor test, called the Phoebus 2A, EP-II test. That test was to have a power output of 5,000 megawatts for 20 minutes. Given the large total energy output, the report used prior reactor test data to estimate expected doses for the purpose of deciding re-entry times and durations. Although the NTS TBD cites this report, it does not contain any guidance based on it for dose reconstruction purposes, or any evaluation of its dose-estimation-related contents. This is surprising, because the data and analysis in the doses for reactor re-entry personnel, but probably also for (1) personnel re-entering test areas after atmospheric tests, (2) drill-back and tunnel re-entry workers who entered within hours or days after underground tests, and (3) evaluation of doses from underground tests with inadvertent releases of radionuclides that exposed many personnel, notably the Baneberry test.

> **Response 2a:** NIOSH agrees that the methods outlined in the NRDL (1968) report in conjunction with test-specific radiological survey reports could be important in dose reconstructions for individuals involved in drillback and tunnel re-entry activities as well as individuals identified as potentially affected by tests that resulted in loss of containment. Therefore, NIOSH will evaluate the dose estimation methods outlined in the NRDL (1968) report, and develop appropriate guidance applicable to NTS dose reconstructions. The TBD will be revised to reflect this guidance, and to identify the NTS work areas and processes applicable to such guidance.

Comment 2b: The projected doses in NRDL 1968 are based on actual data from prior reactor tests. The report discusses doses from fine as well as large particles. These incorporated mainly short-lived fission products. The aim of the report was to estimate doses, with re-entry time and *length of stay as the key safety variables that needed to be decided prior to the Phoebus 2A reactor test.*

Large particles, also called "coarse particles," were defined as "those of diameters greater than 12μ." The dose from these particles would be due to exposure as they fell out and due to resuspension, with the latter assumed to be the only mode after 20 hours (NRDL 1968, pg. 21).[1] Using a resuspension factor of $4*10^{-6}$ m-1, NRDL 1968 found the resuspension doses to be small compared with the early re-entry doses (NRDL 1968, pg. 38).

In this context, lung doses, which are due to inhalation of fine particles, were evaluated to be rather small. Gonad doses from fine particle deposition were not small in several circumstances. Doses were also estimated from large particles to the GI tract and skin, and were found to be large in many cases. For the gonads, the dose would be from beta particles and photons emanating from deposited fine particles, whereas the beta component was expected to dominate skin and GI-tract doses. It is noteworthy that the beta dose to the GI tract was attributed to inhalation of large particles:

> *Inhalation may lead to introduction of particles to the deep lung where they reside for relatively long times or to the gastrointestinal tract where they reside for shorter intervals.* [NRDL 1968, pg. 1]

And,

> *Doses contributed by fine particles to the gastrointestinal tract are negligible with respect to those contributed by coarse particles. Dose estimates in this section will, therefore, be based on coarse particles alone.* [NRDL 1968, pg. 15]

Inadvertent direct ingestion of soil containing radioactive particles and ingestion of contaminated food are not discussed in NRDL 1968. Rather, ingestion of large particles after inhalation (presumably either through the nose or the mouth or both) appears to have been the main consideration. Similarly, skin doses were estimated as being due mainly to large particle deposition.

Table 2 shows skin and GI-tract doses due to large particle exposure, as estimated in NRDL 1968 for the Phoebus 1B, EP-IV reactor test. It should be noted that these doses are estimated using a statistical approach by combining the probability of finding a particle in the GI tract or on the skin (small) and the dose per particle (large). A Poisson distribution was used to combine the two. SC&A has not investigated the details of the calculations or the raw data that went into the estimates, but the approach appears reasonable within the context of the data presented in NRDL 1968. Specifically, SC&A has not evaluated the linear dependence of large particle dose on wind speed assumed in the calculations.

Table 2. Skin and Gastrointestinal-Tract Large Particle Beta Doses to Re-entry Workers, Phoebus 1B, EP-IV Test

Location, deposition density	Time of entry, hours[1]	Skin β dose (rad)[3]	GI-tract β dose (rad)[3]
CP Area, 6 particles/100 ft^2	16.50	418	709
R-MAD, 5 particles/100 ft^2	3.50	1,605	1,334
R-MAD, 120 particles/100 ft^2	12.91	10,625	16,290
R-MAD, 1.5 particles/100 ft^2	23.00[2]	83.7	154
A&E parking lots 1 particle/150 ft^2	6.50	119	133
A&E parking lots, 30 particles/100 ft^2	12.50	2,750	4,140

Source: NRDL 1968, Table B, pg. 49.
Note 1: Converted from data and time to hours after the reactor test, which was at 1430 hours, February 23, 1967.
Note 2: Value at 20 hours used in NRDL 1968, since that was the maximum time for the computer program.
Note 3: Dose estimates in NRDL are proportional to large particle areal density and wind speed. The high doses estimated here are, in part, due to the high wind speed of 15 mph during the reactor test.

It is evident that these doses depend heavily on (1) weather conditions (specifically wind speed), (2) particle size distributions, and (3) assumptions about ingestion of large particles as a result of inhalation in the case of GI-tract doses and particle deposition on skin for skin doses. SC&A notes that NRDL 1968 considers only deposition on 22% of the skin surface and ignores beta dose due to particles deposited on clothing.

The NTS TBD contains essentially no guidance on dose reconstruction for reactor re-entry personnel. Table 5D-20 lists only current radionuclides of concern for the Nuclear Rocket Development Area (Area 25). This short list is inadequate for assessment of doses for personnel associated with reactor testing, and especially so for early re-entry personnel. The TBD is substantially incomplete in this regard. SC&A suggests that NIOSH evaluate the NRDL model and data, and consider the issue of large particle ingestion and skin deposition.

Response 2b: NIOSH agrees that large particle ingestion and skin deposition could be important for individuals involved in early reactor test re-entries. NIOSH will evaluate the NRDL model and data and apply the model, as appropriate, for dose reconstruction of the potentially affected individuals. The TBD will be revised to include: 1) information assessing any potential for large hot-particles in the NTS processes or work areas; and 2) internal and external dose reconstruction guidance appropriate to the TBD that will allow the dose reconstructor to adequately account for NTS doses due to large hot-particles.

Comment 2c: Further, since the GI-tract doses are due to large particle ingestion, urinary analysis for mixed fission products is unlikely to be a satisfactory indicator of the dose. Fecal data that are accompanied by times of sampling and analysis may be helpful in providing some indication of the exposures via this pathway. SC&A has not reviewed claimant files to examine whether adequate data exist to perform such an analysis.

Response 2c: Fecal bioassay data at the NTS have been found to be sparse and mostly limited to individuals involved with clean-up activities where plutonium was the radionuclide of interest. When fecal bioassay data are found in the DOE record for a claimant, the data have been, and will continue to be, considered in dose reconstruction.

Guidance regarding the possible usefulness of available fecal data in the assessment of large hot-particle ingestions at NTS will be included as appropriate in the TBD revision associated with response 2b above.

Comment 2d: NRDL 1968 provides time- and distance-related dose estimates for the gonads ranging from a low of a few millirad to a high of 2.78 rad, assuming that personnel were not allowed into the areas with the highest radiation fields less than 8 hours after the test (NRDL 1968, Table E, pg. 52). These figures indicate that NIOSH should also examine the issue of beta-gamma gonad dose for reactor tests, since the cumulative dose to certain personnel may be considerable. This issue will be of particular importance in the years prior to 1966, when no beta doses were recorded. NIOSH should also consider the dose implications of the above methods for other near-surface organs, notably the breast and thyroid.

Response 2d: NIOSH agrees that the issue of beta-gamma dose to gonads (and possibly prostate) should be evaluated in light of the dose estimating methods outlined in the NRDL (1968) report. Therefore, NIOSH will evaluate the dose estimation methods outlined in the NRDL (1968) report, and develop appropriate guidance applicable to NTS dose reconstructions. The TBD will be revised to reflect this guidance, and to identify the NTS work areas and processes applicable to such guidance.

Comment 2e: Finally, the magnitude of the doses and their dependence on test size and conditions, indicate that NIOSH should conduct a test-by-test estimate of the relevant organ doses, unless estimates that bound all reactor tests are developed and can be reasonably applied.

Response 2e: NIOSH continues to develop efficiency methods to facilitate dose reconstruction and will do so as well when developing methods to envelope potential doses. The NRDL methodology will be reviewed and evaluated by NIOSH in developing these methods. Guidance will be added to the TBD as it becomes available.

Comment 2f: As a final point with regard to this finding, when doses are in the hundreds of rad or more, the harm is expected to extend beyond stochastic risks of cancer to somatic harm. NRDL 68 discusses the Krebs dose to the skin in this context:

> ***Dose rates from particles of different sizes were calculated at two depths in tissue using the NRDL TDD model. The two selected depths are: (1) 100 μ directly underneath the particle, i.e., in the germinal skin layer, and (2) the Krebs' depth. The Krebs' depth is defined as being anywhere along the periphery of a circular field of 4 mm radius 100 μ deep in skin tissue. The center of the field is directly beneath the particle on the skin. Krebs has shown that acute lesions to the skin develop if a dose greater than 1500 rads is accumulated at the Krebs' depth.*** **[NRDL 1968, pg. 21]**

The issue of how localized large doses due to coarse hot particles are to be handled in IREP inputs and estimates of the probability of causation needs to be addressed at least for those organs for which these are relevant, namely the organs near the surface of the skin and the GI tract.

Response 2f: While it is known that large doses from hot particles can cause somatic effects, such effects are not relevant to Subtitle B and, therefore, are not addressed in this

TBD or in other associated project documents. Regarding the translation of large, localized shallow doses to Interactive Radio Epidemiological Program (IREP) inputs for estimating Probability of Causation (POC), this issue is addressed in ORAUT-OTIB-0017, *Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose*. Note that the approach established in ORAUT-OTIB-0017 involves the calculation of dose over the entire skin area (when the specific particle deposition location is unknown), which greatly reduces the calculated doses and POC. Therefore, sufficient project documentation exists to allow a dose reconstructor to translate information in the TBD regarding hot-particle sizes and deposition probabilities into POC. Hot particles have been addressed on a claim-by-claim basis. This is an extremely limited set of circumstances (i.e., indication that the cancer is in the region where the exposure to hot particles occurred). Consultation with the principal external dosimetrist may be conducted as appropriate.

NIOSH agrees that additional investigation into the subject of large particles and ingestion doses is warranted. Information from the referenced document (NRDL) will be reviewed, but it is noted that this document was written prior to International Commission on Radiological Protection (ICRP) 30; models changed dramatically with this publication so the information will need to be evaluated in the context of current models.

Comment 3: Doses from large (non-respirable) particles to GI tract and skin for workers in the early atmospheric test period have not been evaluated. These doses could be high. Hot-particle doses also need to be evaluated for early drillback and other early re-entry workers during underground testing periods. [Finding 3, Issue 5.3]

LARGE PARTICLE DOSES DURING NUCLEAR WEAPONS TESTS [5.3]

The TBD has not adequately considered large particle doses to personnel entering nuclear weapon test areas within hours or days of the test. Reactor test studies indicate that skin and GI-tract doses to early re-entry personnel may far exceed doses estimated via the fine particle inhalation or deposition pathway [Finding 3].

Comment 3a: The TBD does not discuss problems analogous to the ones discussed in Finding 2 for early reentry by personnel into reactor test areas that may affect dose estimates for personnel associated with atmospheric and underground weapons testing. In addition to the above considerations regarding doses from large hot particles incorporating mainly short-lived fission products, airborne large particles during atmospheric testing would be expected to contain short-lived activation products, notably the ones listed in Table 1 above. For instance, large particles with significant amounts of ^{24}Na need to be evaluated. In the case of atmospheric testing, the resuspension of previously deposited large particles may be of considerable importance, in addition to the inhalation doses due to fine particles.

Response 3a: NIOSH agrees that large particle ingestion and skin deposition could be important for individuals involved in underground testing. The TBD will be revised to include: 1) information assessing any potential for large hot-particles in the NTS processes or work areas; and 2) internal and external dose reconstruction guidance appropriate to the TBD that will allow the dose reconstructor to adequately account for NTS doses due to large hot-particles. However, due to the pending SEC petition for workers involved in atmospheric testing, NIOSH does not intend to extend these evaluations for individuals involved with atmospheric testing at this time.

Comment 3b: Large particle doses may also be of considerable importance during accidental ventings of underground tests, notably the Baneberry test, when many personnel were exposed to the fallout cloud. According to the NTS TBD, none of the 86 personnel exposed received an "exposure that exceeded the guideline for radiation workers" (NTS TBD Vol. 5, pg. 69). NIOSH should reevaluate shallow doses and GI-tract doses, in light of the NRDL analysis of large particle exposures associated with the Baneberry test, as well as other underground tests that resulted in accidental ventings.

Response 3b: NIOSH agrees that large particle exposures could be important to shallow and GI-tract doses during accidental ventings. The TBD will be revised to include: 1) information assessing any potential for large hot-particles in the NTS processes or work areas; and 2) internal and external dose reconstruction guidance appropriate to the TBD that will allow the dose reconstructor to adequately account for NTS doses due to large hot-particles. Shallow dose issues are addressed on a project-wide basis in ORAUT-OTIB-17, *Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose*, and any special circumstances will be addressed with the concurrence of the principal external dosimetrist.

Comment 3c: Finally, the large particle issue may also be an issue for early drillback and other re-entry by personnel into underground test areas. SC&A has not evaluated this issue in light of the NRDL analysis, but it deserves screening calculations by NIOSH to determine the relevance and scope of the issue.

Response 3c: NIOSH agrees that large particle ingestion and skin deposition could be important for individuals involved in early drillback and other re-entry activities. Therefore, NIOSH will evaluate the dose estimation methods outlined in the NRDL (1968) report, and develop appropriate guidance applicable to NTS dose reconstructions. The TBD will be revised to reflect this guidance, and to identify the NTS work areas and processes applicable to such guidance.

Comment 4: Ingestion of non-respirable hot particles by reactor testing and nuclear weapons testing workers due to oro-nasal breathing needs to be evaluated. [Finding 4, Issue 5.4]

INGESTION DUE TO ORO-NASAL BREATHING [5.4]

Ingestion of large particles due to oro-nasal breathing may increase GI-tract doses to workers who re-entered weapons and reactor testing areas shortly after the tests [Finding 4].

SC&A has so far raised oro-nasal breathing issues in relation to inhalation doses. However, in the case of the NTS, ingestion of large particles by mouth breathers would be expected to be larger than that due to inhalation of large particles alone. NIOSH should examine the *significance of this issue in light of the above considerations. SC&A emphasizes that the issue here does not relate to heavy or light work as such, but to ingestion of large,* ***non-respirable*** *particles at all levels of activity that may be enhanced due to oro-nasal breathing.*

Response 4: NIOSH agrees that oro-nasal breathing in relation to inhalation is an issue warranting further consideration. There will continue to be discussions between NIOSH and the contractor internal dosimetry staff to assess the appropriate complex-wide guidance regarding the possibility of oro-nasal breathing affecting internal dose reconstruction. The NTS TBD will be revised specifically to reference any applicable complex-wide guidance as it relates to possible intakes of large hot-particles in the NTS work areas.

Comment 5: Resuspension model and resuspension factor are not scientifically defensible or claimant favorable, due to a variety of factors. Doses may be underestimated by an order of magnitude or more. Mass-loading approach would be preferable for internal dose. [Finding 6, Issue 5.5.2]

Internal Occupational Environmental Dose [5.5.2]

Resuspension intake estimates are not scientifically defensible or claimant favorable due to a variety of factors. The doses estimated by using the procedures specified in the TBD may underestimate doses by more than an order of magnitude [Finding 6].

The estimation of intakes and doses from deposited radionuclides is a complex problem, fraught with uncertainties, especially for unmonitored workers, and to a lesser extent, for monitored workers. SC&A has explored several crucial factors and parameters that are discussed in the TBD and that go into estimation of resuspension doses for unmonitored workers. SC&A has also indicated lines of analysis for monitored workers in this section, which are amplified and discussed in more detail in the sections on internal and external dose. The following subsections present the various sub-elements that comprise this finding.

Response 5: NIOSH agrees that a dust loading model could be more appropriate for estimating atmospheric concentrations of resuspended particles for times long after initial deposition and will evaluate such a model for use in estimating potential long term intakes. NIOSH also agrees that the averaging techniques used in the TBD to estimate long-term intakes may not be claimant favorable for certain individuals preferentially located in areas of higher contamination. However, the results of a plethora of empirical data related to measured concentrations of ^{238,239}Pu and summarized in the TBD Tables 4.2.1.2.2-1 and 4.2.1.2.2-3 do not support the suggestion that long-term intakes for the majority of individuals could have been underestimated by factors of hundreds or thousands. [Reference for the preferred method to predict concentrations of resuspended contaminants: Anspaugh, L. R., 2002. "Movement of Radionuclides in Terrestrial Ecosystems by Physical Processes," *Health Physics*, Vol. 85, No. 5, pp. 669–679, Lippincott Williams and Williams, Hagerstown, Maryland.] In fact, a comparison of site average intakes derived from measured data versus intakes derived from the resuspension model (see Table 1 below) indicates that the resuspension model average intakes using a resuspension factor of 1.3 E-09 (Table 4.2.2-3) overestimate the site average intakes based on air sampling data (Tables 4.2.1.2.2-2 and 4.2.1.2-4) by factors of about 5 and 17 for ^{239}Pu and ^{238}Pu, respectively. These factors seem to indicate that, on average, the resuspension model would provide a reasonably claimant favorable intake for most individuals. Further, for cases where the exact location where individuals worked, the maximum intakes in Table 4.2.2-3 indicate that use of Area-specific data in Table 4.2-2 could increase the average intakes by factors of as much as 260 and 480 for ^{239}Pu and ^{238}Pu, respectively, depending on location. It should also be noted that the maximum intakes of ^{239}Pu provided in Table 4.2.2-3, if received chronically over long periods, would have been detected by routine *in vitro* bioassay and chest counts.

Also, NIOSH developed a simplified mass loading model to investigate the relative differences between this model and the resuspension model used in the TBD. The mass loading model used the Area-specific radionuclide inventories and the associated contaminated areas provided by McArthur (McArthur, S. W., 1991, *Radionuclides in Surface Soil at the Nevada Test Site*, DOE/NV/10845-02, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada, Table 5, p. 11) and made the assumption that all of the contamination was contained in the top three centimeters of the soil (Anspaugh 2002, p. 677). Using a dust loading factor for an active environment in the Yucca Mountain Region (Amargosa Valley) of 0.005 gm/m^3, the site average intakes agree very well with the resuspension model intakes when a resuspension factor of 1.3 E-09 m^{-1} was used. [Reference for dust loading factor: Office of Civilian Radioactive Waste Management, *Inhalation Exposure Input Parameters for the Biosphere Model*, ANL-MGR-MD-000001 RREV 2 ICN 0, Yucca Mountain Project Office, Las Vegas, Nevada, June, 2003.] It should be noted that the average values presented in Table 4.2.2-3 were derived using a resuspension factor of 1.3 E-08 m^{-1} and, for this reason, could be assumed to be an underestimate. However, average intakes from Table 4.2.2-3 will not result in annual doses to any organ greater than 0.001 rem and therefore need not be evaluated (see Table 2 below with supporting data).

Of greater interest is the comparison of the maximum intakes derived from the resuspension and the mass loading models because these intakes could result in substantial doses to certain organs. The maximum values provided in Table 4.2.2-3 were derived using the NTS Area with the highest radionuclide-specific areal deposition (Ci/m^2) and a resuspension factor of 1.3 E-08 m^{-1}. It should be noted that for every radionuclide, Area 30 provided the highest areal deposition. Area 30 is relatively small (150 km^2), inaccessible, and is located on the Western edge of the NTS. It has rugged terrain and includes the northern reaches of Fortymile Canyon. In 1968, it was the site of Project BUGGY, the first nuclear row-charge experiment in the PLOWSHARE Program. As a result of the test, a trench 255 meters long, 77 meters wide, and 206 meters deep was created. The test resulted in large quantities of vitrified glass. It should be noted that although the resuspension and mass loading intakes provided in Table 1 below include contributions from Area 30, the intakes of $^{238,239}Pu$ derived from air sampling data do not because air sampling data for Area 30 was not provided in the annual environmental reports.

In summary, NIOSH believes that, after review of the measured air sampling data, the average intakes provided in Table 4.2.2-3 derived using the resuspension model are in general agreement even if corrections are made for collection inefficiencies of the air samplers. Collection efficiencies of the air samplers were reported as possibly low by a factor of 5 [Reference: Shinn. Joseph H., *Protocols of Radiocontaminant Air Monitoring for Inhalation Exposure Estimates*, UCRL-ID-122254, Health and Environmental Assessment Lawrence Livermore National Laboratory (LLNL), September, 1995]. Also, Table 2 below indicates that doses resulting from long-term average intakes would, in most cases, not result in annual doses to any organ in excess of 0.001 rem and therefore, need not be considered for probability of causation evaluations. Further, the possibilities of long-term maximum intakes derived from the simplified mass loading model are not supported because intakes of plutonium at these levels would be readily identified by routine *in vitro* bioassay sampling which has not been shown.

NIOSH also believes that each dose reconstruction involving ambient internal dose at the NTS must be considered on a case-by-case with special emphasis as to job location and classification. The dose reconstructors must evaluate the potential for undetected, elevated, intakes resulting from resuspended contaminates based on information available in the dosimetry records and professional judgment. For the reasons given above, NIOSH believes that the average intakes provided in Table 4.2.2-3 represent a reasonable underestimate which is appropriate for use with compensable cases and that the maximum values provided in Table 4.2.2-3 represent a reasonable overestimate for use with noncompensable cases. For cases where compensability is affected by the maximum intakes, the dose reconstructor must make every effort to obtain work locations and apply intakes for those locations provided in Table 4.2.2-2. For these cases where work location is not obtainable, the maximum values must be applied to assure claimant favorability. The assignment of ambient external dose will be consistent with ORAUT-PROC-0060, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*. The TBD will be revised to reflect this guidance.

Table 1. Annual intakes, Bq, for soil contaminants important to dose derived from resuspension and mass loading models.

	Resuspension Model[1]	Mass Loading Model[2]	Mass Loading Model[3]	Air Sampling Data[4]					
	Annual	Annual	Annual	Average of All Areas and All Years			Highest Area and Highest year		
	Maximum Annual Intake, Bq	Maximum Annual Intake, Bq	Maximum Annual Intake, Bq	Average Annual Intake, Bq	Minimum Annual Intake, Bq	Maximum Annual Intake, Bq	Average Annual Intake, Bq	Minimum Annual Intake, Bq	Maximum Annual Intake, Bq
Pu-239 Type S	20.80	205.1	34.78	0.0151	0.001	0.0678	0.0967	0.0026	0.3813
Pu-238 Type S	6.690	65.92	21.27	0.00079	0.0017	0.000081	0.0032	0.011	0.00029
Am-241 Type S	4.750	46.88	16.3						
Co-60 Type S	1.190	11.72	5.6						
Cs-137 Type F	2.230	21.97	18.47						
Eu-152 Type M	1.540	15.15	15.15						
Eu-154 Type M	0.149	1.46	1.13						
Eu-155 Type M	0.345	3.4	3.4						
Sr-90 Type F	1.930	19.04	12.09						
Sr-90 Type S	1.930	19.04	12.09						

1. Maximum intakes from Table 4.2.2-3 derived from site area with highest contamination deposition (i.e., Area 30).
2. Maximum intakes derived from site area with highest contamination deposition (i.e., Area 30).
3. Maximum intakes derived from site area with highest contamination deposition excluding Area 30.
4. Average, minimum, and maximum values derived from arithmetic averages for years from 1971 through 2001.

Table 2. 30-Year organ doses, rem, resulting from 10-year intakes of maximum intakes provided by Table 4.2.2-3 of the NTS TBD.

	Pu-239 Type S	Pu-238 Type S	Am-241 Type S	Co-60 Type S	Cs-137 Type F	Eu-152 Type M	Eu-154 Type M	Eu-155 Type M	Sr-90 Type F	Sr-90 Type S
Adrenals	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Urinary Bladder	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brain	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Breast	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gall Bladder	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Heart Wall	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kidneys	0.005	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Liver	0.206	0.063	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ovaries	0.013	0.004	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pancreas	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Testes	0.013	0.004	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thyroid	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RBM	0.057	0.018	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bone Surface	0.938	0.288	0.263	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Stomach	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SI	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ULI	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LLI	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skin	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spleen	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thymus	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Uterus	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ET	1.659	0.541	0.390	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lung	0.944	0.334	0.241	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Colon	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ET1	0.032	0.201	0.135	0.002	0.004	0.002	0.000	0.000	0.004	0.004
ET2	1.660	0.542	0.391	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LN(ET)	2.051	0.638	0.488	0.000	0.000	0.000	0.000	0.000	0.002	0.002
LN(TH)	6.111	1.885	1.453	0.000	0.000	0.000	0.000	0.000	0.002	0.002
Esophagus	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 3. 30-Year organ doses, rem, resulting from 10-year intakes of maximum intakes provided by Table 4.2.2-3 of the NTS TBD increased by a factor of 10.

	Pu-239 Type S	Pu-238 Type S	Am-241 Type S	Co-60 Type S	Cs-137 Type F	Eu-152 Type M	Eu-154 Type M	Eu-155 Type M	Sr-90 Type F	Sr-90 Type S
Adrenals	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Urinary Bladder	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Brain	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Breast	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Gall Bladder	0.015	0.005	0.003	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Heart Wall	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Kidneys	0.052	0.016	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Liver	2.060	0.631	0.229	0.000	0.000	0.003	0.000	0.000	0.000	0.000
Ovaries	0.125	0.038	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pancreas	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Testes	0.128	0.039	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thyroid	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RBM	0.574	0.179	0.120	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Bone Surface	9.378	2.880	2.628	0.000	0.000	0.002	0.000	0.000	0.000	0.000
Stomach	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SI	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ULI	0.017	0.005	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LLI	0.020	0.006	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Skin	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Spleen	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thymus	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Uterus	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ET	16.590	5.414	3.904	0.001	0.000	0.000	0.000	0.000	0.002	0.002
Lung	9.443	3.341	2.406	0.001	0.000	0.001	0.000	0.000	0.012	0.012
Colon	0.018	0.006	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ET1	0.317	2.012	1.352	0.016	0.043	0.017	0.004	0.002	0.042	0.042
ET2	16.603	5.416	3.906	0.001	0.000	0.000	0.000	0.000	0.002	0.002
LN(ET)	20.509	6.380	4.885	0.001	0.000	0.000	0.000	0.000	0.016	0.016
LN(TH)	61.113	18.851	14.528	0.001	0.000	0.000	0.000	0.000	0.023	0.023
Esophagus	0.015	0.005	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Comment 6: The use of the site average air concentration values when worker location is not known is not claimant favorable. Largest value consistent with job-type data should be used in such cases. [Finding 6, Issue 5.5.2.5]

Resuspension intake estimates are not scientifically defensible or claimant favorable due to a variety of factors. The doses estimated by using the procedures specified in the TBD may underestimate doses by more than an order of magnitude [Finding 6].

The TBD method to assign resuspension doses to workers where the location is not known may underestimate the exposure [5.5.2.5].

In cases where the exact location is not known, the TBD recommends the use of site average values (NTS TBD Vol. 4, pg. 33). This may underestimate the exposure by a considerable amount, given the differences between locations and the differences between the average and maximum intakes (NTS TBD Vol. 4, Tables 4.2.2-2 and 4.2.2-3). For example, if a claimant was working in Area 11, but this was not properly recorded, the use of site average data for that site would result in a resuspension dose that is a factor of 4 lower than in the case where records exist. The differences between areas are even larger. The overall underestimation could be an order of magnitude or even much more. Since the lack of proper records should not result in a disadvantage for the claimant, it would be more appropriate to use the values for the area with the maximum inferred air concentration. If the area number is not known, the largest value should be used, consistent with other employee job-type data.

Response 6: NIOSH believes that each dose reconstruction involving ambient internal dose at the NTS must be considered on a case-by-case with special emphasis as to job location and classification. The dose reconstructors must evaluate the potential for undetected, elevated intakes resulting from resuspended contaminates based on information available in the dosimetry records and professional judgment. For the reasons given in Response 5, NIOSH believes that the average intakes provided in Table 4.2.2-3 represent a reasonable underestimate which is appropriate for use with compensable cases and that the maximum values provided in Table 4.2.2-3 represent a reasonable overestimate for use with noncompensable cases. For cases where compensability is affected by the maximum intakes, the dose reconstructor must make every effort to obtain work locations and apply intakes for those locations provided in Table 4.2.2-2. For these cases where work location is not obtainable, the maximum values must be applied to assure claimant favorability. The assignment of ambient external dose will be consistent with ORAUT-PROC-0060, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*. The TBD will be revised to reflect this guidance.

Comment 7: Resuspension doses to monitored workers, especially early re-entry workers, may be underestimated, due to the presence of short-lived radionuclides and higher resuspension expected in the days and months after a test (including safety tests). TBD does not specify procedures for estimating environmental internal doses in such cases. [Finding 6, Issue 5.5.2.6]

Resuspension intake estimates are not scientifically defensible or claimant favorable due to a variety of factors. The doses estimated by using the procedures specified in the TBD may underestimate doses by more than an order of magnitude [Finding 6].

The TBD does not evaluate resuspension exposure for monitored workers. Adjustments to radionuclide intake may be necessary for some monitored workers [5.5.2.6].

Available evidence indicates that after 1957, entry into contaminated areas was restricted to workers who were monitored (Attachment 4). However several factors, discussed in more detail elsewhere in this review, indicate that an explicit evaluation of working conditions is necessary to ensure that dose estimates due to resuspended radionuclides are claimant favorable. The following factors need to be taken into account:

- *Bioassay done every few months would not detect the presence of relatively short-lived radionuclides, such as ^{24}Na and ^{239}Np. Workers entering contaminated areas within days of a detonation of an atmospheric test or a test that vented may have been exposed to a variety of short-lived radionuclides (see Finding 3 above). The TBD does not specify a procedure for evaluating exposures to such radionuclides for monitored workers.*
- *Time of entry after the test and the specific type of test are both important in assessing the radionuclide list, as well as the potential for large, hot particle ingestion or shallow dose. The TBD does not specify procedures for best estimate doses or maximizing procedures in such cases.*
- *Resuspension of plutonium in safety test areas due to atmospheric weapon testing needs to be evaluated for its importance, especially to early re-entry workers.*

Response 7: Due to the pending SEC petition for individuals involved with atmospheric testing, NIOSH does not intend to evaluate potential intakes of short-lived radionuclides such as ^{24}Na and ^{239}Np or ingestion from large particles resulting from atmospheric testing. With regard to resuspension of plutonium from safety tests, the only test that occurred post 1962 was DOUBLE TRACKS in 1963 on the Tonopah Test Range (TTR). Results from air samples in this area indicate routine detection of $^{239+242}Pu$ and ^{241}Am, but in concentrations only slightly above minimum detectable concentrations. Therefore, NIOSH believes that application of intakes provided in Table 4.2.2-3 would adequately envelope both compensable and noncompensable cases. For case involving individuals potentially exposed on the TTR where compensability is affected by the maximum intakes provided in Table 4.2.2-3, the dose reconstructor will evaluate TTR air sampling data to determine best estimate intakes. The TBD will be revised to include these instructions.

Comment 8: Use of 1967 external dose data for 1963–1966 is not claimant favorable. There was no test in 1967 with measurable offsite fallout. Relatively short-lived radionuclides, which were likely present in 1963–1966, would have substantially decayed away by 1967. [Finding 7, Issue 5.5.3.3]

Occupational external ambient radiation doses need to be re-examined with explicit consideration given to the time period of testing [Finding 7].

It is unlikely that assigning 1967 data for the time period 1963–1966 is claimant favorable [5.5.3.3].

The lack of external gamma dose data at NTS prior to 1967 is puzzling. It is unlikely that the reported dose for Area 3 in 1967 is claimant favorable for the following reasons:

- *There were no underground tests in 1967 that resulted in measurable offsite fallout. In contrast to this, underground test PIN STRIPE on April 25, 1966, resulted in measurable offsite fallout (http://www2.nci.nih.gov/I131/intros/BK0.html).*
- *The dose measured for Area 3 is unlikely to have been the largest onsite dose at NTS, given the sparse network and the lack of representative sampling.*
- *Shorter-lived radionuclides like ^{134}Cs, ^{141}Ce, and ^{144}Ce would have decayed substantially or nearly completely between 1963 and 1967, so that earlier external doses can be expected to be higher.*

Response 8: As stated in Section 6.3.2.1.5.3.1 of the NTS TBD, unexposed control films and thermoluminescent dosimeters (TLDs) were processed with personnel dosimeters and the readings from these control dosimeters were subtracted from the personnel dosimeter readings to obtain a net reading for determining exposure. Beginning on April 1, 1957, all employees entering the NTS were required to wear dosimeters while inside the NTS. Because the control dosimeters were maintained in environmentally controlled, low background areas (e.g., Building 111 in Mercury), exposure resulting from elevated ambient environmental levels from testing activities in other areas of the site would have been included in the individual exposure records. For these reasons, NIOSH believes that for best estimate dose reconstructions and compensable cases, ambient environmental exposures should not be included. To assure claimant favorability, ambient environmental exposures may be included for noncompensable cases. The assignment of ambient external dose will be consistent with ORAUT-PROC-0060, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*. The TBD will be revised to provide this additional guidance. With regard to additional analysis, NIOSH does not believe that a test-specific analysis is required to assure that ambient environmental dose has not been underestimated for noncompensable cases and would also be of little values for best estimate and compensable cases.

Comment 9: Lack of environmental external dose data for 1968–1976 is puzzling. TBD has not specified an approach to estimating external environmental dose for this period. Venting in the 1968–1970 period likely made external dose in that period (and possibly beyond) higher than 1967. [Finding 7, Issue 5.5.3.4]

Occupational external ambient radiation doses need to be re-examined with explicit consideration given to the time period of testing [Finding 7].

Data for 1968 through 1976 are missing. The TBD has not specified an approach to estimating external environmental dose for these years [5.5.3.4].

The NTS TBD states that no external environmental measurements were reported between 1968 and 1976 (NTS TBD Vol. 4, pg. 35). It is proposed that maximum 1967 data be used for the years 1968–1976. However, it is not clear that this is claimant favorable, as claimed in the NTS TBD (Vol. 4, pp. 36–40). SC&A notes that there were no unplanned large venting events in 1967, but *that was not the case for the period 1968–1970. The Baneberry test in December 1970 was the last large unplanned venting. The TBD has not specified any approach to estimating external environmental dose during those years. Significant deposition of radionuclides from ventings in the 1968–1970 period may have caused external environmental doses during that time, and possibly for a couple of years after that, to be higher than the measured values in 1967. A test-specific analysis should be carried out to develop claimant-favorable assumptions for the period of missing data. From the description in the introduction to Section 4.3 (pg. 35) and associated tables on pages 37 to 39 in Vol. 4 of the NTS TBD, it appears that NIOSH has not looked beyond the annual environmental reports to locate the missing data, but just filled in the gap as noted above.*

Response 9: For the reasons presented in Response 8, NIOSH believes that for best estimate dose reconstructions and compensable cases, ambient environmental exposures should not be included. To assure claimant favorability, ambient environmental exposures may be included for noncompensable cases consistent with the guidance in ORAUT-PROC-0060, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites.*

Comment 10: The TBD does not provide any guidance for pre-1963 external environmental dose. Issues relating to unmonitored workers, as well as time of entry into contaminated areas, could be important. [Finding 7, Issue 5.5.3.5]

Occupational external ambient radiation doses need to be re-examined with explicit consideration given to the time period of testing [Finding 7].

Pre-1963 period external environmental dose estimation procedure is not addressed in the TBD [5.5.3.5].

The TBD does not discuss estimation of external environmental doses during the period of atmospheric testing (i.e., 1951–1962). There are several issues to be considered in this context for unmonitored workers:

- *Entry of unmonitored workers into contaminated areas, notably in the period up to and including 1957*
- *Time of entry of workers into contaminated areas*
- *Activation products in the soil with high external radiation potential—and the times at which these are important*

Response 10: All personnel entering the NTS were badged after April 1, 1957. Because the control dosimeters were maintained in environmentally controlled, low background areas (e.g., Building 111 in Mercury), exposure resulting from elevated ambient environmental levels from testing activities in other areas of the site would have been included in the individual exposure records after this date. Environmental external dose will be considered, as appropriate, for workers prior to this date. NIOSH agrees that guidance for pre-1957 external environmental dose is needed for unmonitored workers with cancers that are not covered in the SEC petition. Guidance will be included in the TBD revision.

Comment 11: Correction factors for external environmental dose due to geometry of organ

relative to badge, and angular dependence of the dose conversion factor need to be developed. [Finding 7, 13; Issue 5.5.3.6, 5.7.6]

Occupational external ambient radiation doses need to be re-examined with explicit consideration given to the time period of testing [Finding 7].

External environmental dose estimations for monitored workers need to be more comprehensively evaluated [5.5.3.6].

The TBD does not discuss factors affecting external environmental dose for monitored workers. This omission rests on the implicit assumption that the dose recorded on the film badge was the dose experienced by the organ for which the dose reconstruction is being done, and that the data from the monitoring and radionuclide lists in the TBD are sufficient for splitting the recorded external dose into the three energy ranges that IREP requires for estimation of probability of causation. SC&A has several concerns about these assumptions. The following factors need to be addressed and correction factors developed, as necessary, so that the recorded external dose can be modified in a suitable way that is both scientifically defensible and claimant favorable for the purpose of estimating organ dose.

Comment 11a: The organ for which doses are being estimated relative to the position of the external radiation source—that is organs closer to the ground will tend to get a larger dose than those farther away—needs to be determined, so that an organ-specific external dose estimation procedure can be developed. SC&A notes that NIOSH developed correction factors for recorded dose for lower torso organs as part of its consideration of issues related to development of dose reconstruction for workers at the Mallinckrodt site in St. Louis (SC&A 2005b). Similar considerations apply in the case of external environmental dose at NTS, since the source of the radiation is located on the ground, but the film badge or TLD is normally worn on the pocket or collar.

Response 11a: NIOSH agrees that correction factors should be developed for lower torso organs for situations where the majority of the organ dose results from ground contamination. Therefore, NIOSH will evaluate to determine when this situation is likely to exist and will develop correction factors for lower torso organs, as appropriate. This information will be added to the TBD.

Comment 11b: Two other correction factors for external dose are also necessary; (1) angle of incidence of the gamma radiation onto the film badge when it is not normal to the badge, and (2) the dose conversion factor. Both these factors are discussed in SC&A 2005a, SC&A 2005c, and SC&A's Task 3 report, SC&A 2005d.

Response 11b: NIOSH agrees to develop external dose correction factors for: (1) angle of incidence of the gamma radiation onto the film badge when it is not normal to the badge; and (2) the dose conversion. These correction factors will be established to be consistent with guidance from the principle external dosimetrist. The TBD will be revised to reflect these correction factors and the relevant guidance to the dose reconstructors.

Comment 11c: The time of entry into the contaminated zone is important, because the radionuclides present, and therefore, the photon energy spectrum that characterizes residual radiation, are time dependent.

> **Response 11c**: NIOSH agrees that that the time dependence of the photon energy spectrum may be important for certain cohort groups involved in early re-entry activities. Therefore, NIOSH will evaluate the time dependence of the photon energy spectrum for these groups. However, NIOSH does not believe that development of time dependence of the photon energy spectrum for individuals not included in these cohort groups would be of value. Therefore, the claimant favorable assumption is made that the photon energy range is 100 percent 30 to 250 keV in non-compensable cases. When minimizing or providing a best estimate dose, the photon energy range assumption is 25 percent 30 to 250 keV and 75 percent >250 keV. This information will be included in the TBD.

Comment 11d: The TBD needs to investigate the possibility that workers sometimes did not wear their badges when the quarterly dose was near the 3-rem limit or above it, because they were sent to lower paying jobs or were laid off from their jobs for the rest of the quarter (see Section 7 below).

> **Response 11d:** At this time, NIOSH sees no way of retrieving missing data when this practice may have occurred because: 1) it cannot be definitively established that the claimant actually failed to use the badge; and 2) cohort dosimetry is probably not available because the entire cohort is likely to have adopted the same practice at the same time. The project principals will evaluate this situation for the NTS as well as for other sites within the DOE complex where similar claims have been made.

Protocols for reconstructing external dose during testing need to be further developed and the guidance for reconstructing doses to workers subsequent to testing needs to explore and address a number of issues [Finding 13].

Angular Dependence of the Individual Monitors for Ground Surface Irradiation Geometry Needs to be Taken into Consideration [5.7.6]

Comment 11e: The NTS TBD states "the effect (of angular dependence)...is generally minimal...for angles of incidence ranging from about 30 to 150 degrees." The TBD also states: "...for angles approaching parallelism (i.e., 0 degrees) with the plane of the film, the effect [lower response] can be pronounced, and can lead to significant underestimates in dose. The problem should be minimal for exposures at NTS, because these were typically...at angles close to normal with the plane of the film" (NTS TBD Vol. 6, pg. 16).

The report "Film badge dosimetry in atmospheric nuclear tests," NAS 1989, page 77, states, "The irradiation geometry for a worker standing on a contaminated field may be considered to be best approximated by the rotational geometry. The worker immersed in a hemi-spherical cloud of radionuclides may be considered to be also in the rotational geometry." For workers that entered extended contaminated areas after, for example, an air test, the worker may be considered to be standing on a plane whose surface is uniformly contaminated. The best approximation to this exposure geometry is the rotation geometry.

For individual dosimetry made for ground contamination, there will be loss of response of the dosimeter due to:
(a) The angular dependence
(b) The absorption of photons going through the worker
(c) The fact that the dosimeter is placed higher than the main ICRP 60 organs of interest

These losses have been partially compensated for by assuming in the TBD an AP exposure geometry for the irradiation. The adoption of the AP factors for this exposure case is claimant favorable —for photon energies above 250 keV, a positive bias of around 20% will be seen with respect to the rotational geometry. However, for "best case" dose estimates, NIOSH still has to correct the general dose conversion factors published in its procedures. This is a matter that is generic and being resolved on that basis in technical discussions between NIOSH, SC&A, and the Advisory Board.

SC&A notes here that issues of geometry may especially affect certain job types, such as tunnel re-entry and drillbacks in the test areas, waste repackaging, maintenance on rocket engine test reactors, and so on. NIOSH, in responding to SC&A comments on this issue in the specific instance of the Mallinckrodt Chemical Works, developed an approach for assessing the correction factors that would be needed for organ dose compared to badge location on a job specific basis. NIOSH used the ATTILA model, as well as facility-specific job-type information to perform the calculations (SC&A 2005a, Attachment 4, pp. 64–70). NIOSH should perform an assessment of job types at NTS in various periods, as well as the situations involving external environmental dose, to determine which ones need correction factors to make external dose estimates scientifically sound and claimant favorable. Multiple-badging data, available at NTS, may be helpful in the implementation of this suggestion.

> **Response 11e:** NIOSH agrees that an assessment of job types may be necessary to determine which ones need correction factors for angular dependence and geometry considerations. Therefore, NIOSH will evaluate the various job types using available data to determine which jobs and locations require the application of correction factors. This information will be added to the TBD as it becomes available.

Comment 12: Radon doses in G-tunnel are not claimant favorable. Gravel Gertie radon doses are not discussed, and could be substantial. (Site status of Gravel Gertie workers needs clarification.) [Finding 8, Issue 5.5.4]

Radon Dose [5.5.4]

Radon exposure in tunnels needs to be more thoroughly evaluated [Finding 8].

Comment 12a: The TBD recommends using the data in Table 4.4.1-1 for 222Rn exposures for miners and tunnel workers. For example, for pre-1984 exposure in the G-Tunnel, the radon daughter concentration (RDC) for alternating ventilation is calculated to be 0.13 WL, based on data reported by Favor 1987. Table 3 of the referenced document contains the results of measurements that were actually taken in July 1984. The calculations in the TBD are based on the results of radon daughter grab samples, rather than on integrated samples. The comparison *of the data indicates that in two out of three measurements, the integrated sample concentrations were a factor of 1.5 and 1.6 larger than the grab sample (see Table 5).*

The TBD methodology for P-Tunnel and N-Tunnel measurements was to determine the average of the maximum values for sampled locations, whereby non-detected values are ignored. SC&A suggests that NIOSH should apply the same method to the G-Tunnel as well. The resulting RDC concentration for alternating ventilation would be 0.16 WL, or 1.92 WLM per year (based on 170 hours of exposure per month for 12 months).

Further, the above calculations are based on the assumption that the G-Tunnel ventilation was equivalent to the one during sampling, i.e., one of two fans turned off on alternate evenings. There were no records available to verify this assumption. NIOSH should investigate the issue of tunnel ventilation further.

Response 12a: NIOSH agrees that to assure claimant favorability, the higher integrated results should be used for dose reconstruction and that non-detected values be ignored. Therefore the TBD will be revised to reflect a revised value of 0.16 working level (WL) for G-Tunnel and the instructions will be revised to reflect that this value should be used for periods prior to 1985.

Comment 12b: Another issue is the assignment of radon exposures in cases where the underground work location is not known. The TBD recommends using a level of 0.05 WL for all time periods, a value that actually represents the maximum level for 1984 onwards. It would be more appropriate and claimant favorable to assign the G-Tunnel value of 0.16 WL for exposures prior to 1984, if the underground work location is not known.

Response 12b: NIOSH agrees with the recommendation. The TBD will be revised to instruct dose reconstructors, for cases where location of underground work is not known, to use the G-Tunnel value of 0.16 WL prior to 1985 and the value of 0.05 WL from 1985 forward.

Comment 12c: The TBD does not discuss radon doses experienced by workers in the Gravel Gerties. In view of the possibility of significant respiratory tract radon doses, NIOSH should explicitly consider this issue in the NTS TBD or another appropriate TBD (depending on where the workers in these facilities came from).

Response 12c: NIOSH agrees that radon exposures should be evaluated for individuals identified as working in the Gravel Gerties. Exposure data available from other sites with Gravel Gerties will be reviewed for relevance to NTS activities. This information will be added to the TBD.

Comment 13: Environmental doses due to I-131 venting need to be taken into account for non-monitored workers. [Finding 10, Issue 5.5.5]

Occupational I-131 Data [5.5.5]

The lack of occupational environmental ^{131}I data for non-monitored workers needs to be addressed in the TBD [Finding 10].

Exposures specifically considered in the Occupational Environmental Dose TBD are applied to non-monitored workers (ORAUT-TKBS-0008-5, page 35). Consequently, internal ^{131}I exposures of non-monitored workers are currently not accounted for in the TBD.

From 1963 onwards there were many cratering and underground tests that resulted in the release of ^{131}I. The total estimated source term is 1,065 kCi (Table 5). The dominant event was test PALANQUIN on April 14, 1965. These releases have resulted in exposures of non-monitored workers and need to be accounted for.

> **Response 13:** NIOSH agrees that current guidance in the TBD may not be adequate to account for potential ^{131}I exposures for monitored and unmonitored workers. Therefore, NIOSH will develop guidance to be used for workers that will envelope potential organ doses from ^{131}I exposures. The TBD will be revised to reflect this guidance.

Comment 14: There are no internal monitoring data until late 1955 or 1956; some Pu from then on; some tritium from 1958; Pu, tritium, and mixed fission products from 1961; and full radionuclide coverage established in about 1967. The TBD does not provide significant guidance for estimating internal dose for the pre-1967 periods for many radionuclides. [Finding 12, Issue 5.6.3]

Numerous issues related to the reconstruction of internal dose need to be investigated [Finding 12].

Lack of Early Internal Monitoring Data [5.6.3]

There are no internal monitoring data until late 1955, or possibly 1956. After that, bioassay data are sparse in terms of radionuclide coverage until the 1960s. Furthermore, the integrity of external dose data for some groups of workers in this same period is open to question. Therefore, internal dose estimation in this context is likely to be complex and difficult, at best, for this period for most radionuclides.

In the early years of testing at NTS, intakes of radionuclides were thought to be unimportant relative to external dose. As a result, there exist important gaps in internal dosimetry data. Specifically, no personal internal dosimetry data of any kind exist for the period from the start of testing in January 1951 to late-1955 or 1956. At that time, Los Alamos began analyzing some NTS bioassay samples for plutonium. Selective tritium monitoring data exist from 1958 (NTS TBD Vol. 5, pg. 16). By 1961, NTS had a greater capability for internal monitoring, which included plutonium, tritium, and gross fission products (NTS TBD Vol. 5, pg. 8). However, fuller capability of internal monitoring was not established until 1967, when whole-body counting equipment was set up.

As has been noted, the NTS TBD covers some aspects of dose reconstruction for the atmospheric testing period, including some radionuclide lists. However, the overall topic is to be covered in Rev. 01 of the NTS TBD (see NIOSH statements in Attachments 2 and 3). SC&A is making some *preliminary observations regarding some issues regarding internal dose estimation during the atmospheric testing, since this is a topic that has been extensively discussed and analyzed in the context of dose reconstruction for atomic veterans.*

The 2003 review by the NAS National Research Council of the dose reconstruction program for atomic veterans being conducted by the DTRA throws some important light on the complexities of the scientific issues associated with internal dose estimation in the absence of bioassay or other personal monitoring data. Since there are no personal data that would enable estimation of internal dose, DTRA reconstructs internal doses using ratios of surface contamination to photon radiation, coupled with assumptions about resuspension and direct intake of fallout by armed forces personnel.

Apart from the question of large particle beta dose discussed earlier in this review, the use of this indirect approach depends crucially on two factors:

(1) The integrity of the external dose record

(2) The ability to make scientifically defensible and claimant-favorable assumptions regarding intake due to resuspension in view of the varying and complicated patterns of fractionation of radionuclides

The NAS review describes a variety of ways in which resuspension approaches to internal dose reconstruction can be made claimant favorable in the period immediately following nuclear atmospheric radionuclide releases from nuclear tests (NAS 2003, pp. 166–182). It also provides an analysis that points to significant factors that could lead to considerable underestimation of internal dose. Specifically radionuclides that are not photon emitters or weak photon emitters, like ^{90}Sr and ^{239}Pu, deposit in disproportionately large amounts in areas close to ground zero due to their lower volatility relative to radionuclides like ^{137}Cs and ^{131}I. The differential deposition (fractionation) is also highly variable from one test to another, a factor that can lead to large differences in deposition. Further, resuspension from effects due to the blast wave of radionuclides deposited in prior tests would greatly increase resuspension in a manner that needs to be taken into account. Finally, NIOSH should also review the specific issue of ^{137}Cs to ^{90}Sr ratios in fallout. Sherrill et al. (1975) concluded that "extreme values of the $^{137}Cs/^{90}Sr$ ratio in large and small [offsite] fallout particles [can be] expected to be observed in rain may range from about 0.2 to several times the production ratio." The importance of this conclusion for onsite deposition and doses needs to be evaluated:

> *Participants who engaged in activities in forward areas within a few hours after a shot almost certainly were exposed to previously deposited fallout that was resuspended to a large extent by the blast wave produced by the detonation. However, effects of a blast wave have been ignored in all dose reconstructions, so the upper bound of the resuspension factor probably has been underestimated by more than a factor of 100 in scenarios in which resuspension is assumed to be caused by walking or other light activities. In addition, plutonium was probably the most important inhalation hazard in previously deposited fallout, and, as noted above, concentrations of plutonium in fallout at the NTS are underestimated by a factor of about 3 or more because of neglect of fractionation. Furthermore, fallout that occurred more than a few months before a shot of concern has generally been*

> *ignored, but many prior shots contributed to fallout at the NTS toward the end of the period of aboveground testing. Therefore, unless concentrations of plutonium in fallout are overestimated by the NTPR [Nuclear Test Personnel Review] program by substantially more than a factor of 100 – which seems highly unlikely considering the interest in measuring plutonium in cloud samples – biases in other assumptions that tend to result in overestimates of inhalation radiation dose almost certainly are not sufficient to compensate for the neglect of blast-wave effects in all dose reconstructions at NTS. Furthermore... upper bounds of organ equivalent doses in this scenario could be substantially above 1 rem in some cases. [NAS 2003, pg. 213]*

These observations for armed forces personnel in forward areas during atmospheric testing would also apply to AEC and contractor personnel in forward areas during that period. They may also apply in some circumstances to personnel exposed to unplanned ventings during the underground testing program. A factor that NIOSH might take into consideration is that plutonium and several other metal oxides may be in a high-fired form, given the extremely high temperatures associated with nuclear explosions. Hence certain organ doses, such as those associated with the respiratory tract, may be considerably higher than would be estimated by a normally conservative assumption of Type S for dose estimation. The chemical evolution of high-fired metal oxides in the environment should also be considered as a factor in long-term environmental dose.

Finally, while there are technical issues associated with the interpretation of the external dose records of armed forces personnel (NAS 1989), the essential integrity of those records in terms of whether badges were systematically left off due to economic and employment considerations (see below) has not arisen. Given that the integrity of the external dose record is open to question until the mid-1960s and possibly into the 1970s for some groups of workers, the applicability of the internal dose reconstruction approach used by DTRA would be doubtful unless a procedure is developed to compensate for the problems in the external dose dataset.

Response 14: NIOSH is cognizant of the difficulties associated with dose reconstruction for individuals involved in atmospheric testing as outlined in the SC&A finding. As stated in the pending SEC petition for workers involved in atmospheric testing, because of the lack of early internal monitoring data, *inter alia*, NIOSH is unable to estimate with sufficient accuracy the internal exposures and resulting doses for workers onsite from January 27, 1951, through December 31, 1962. NIOSH also believes that future studies would be unlikely to increase the accuracy of dose reconstruction for individuals involved in atmospheric testing to levels sufficient under Energy Employees Occupational Illness Compensation Program Act (EEOICPA) and Title 42 Code of Federal Regulations Part 83. Therefore, NIOSH does not intend to conduct investigations related to the lack of internal monitoring data during the early years of atmospheric testing at this time.

Comment 15: Resuspension of radionuclides by the blast wave, fractionation of relatively non-volatile radionuclides, and the variability of Cs-137 to Sr-90 ratios need to be taken into account in internal dose estimation. [Finding 12, Issue 5.6.3]

Numerous issues related to the reconstruction of internal dose need to be investigated [Finding 12].

Lack of Early Internal Monitoring Data [5.6.3] - See Comment 14 for narrative.

Response 15: As stated in the pending SEC petition for workers involved in atmospheric testing, because of the lack of early internal monitoring data, *inter alia*, NIOSH is unable to estimate with sufficient accuracy the internal exposures and resulting doses for workers onsite from January 27, 1951, through December 31, 1962.

Comment 16: Use of photon dose, as done by DTRA, as the basis for estimating internal dose during periods when there are no data or scattered internal monitoring data has significant uncertainties. These uncertainties are compounded by the data integrity issue associated with NTS (see comment 20 below). [Finding 12, Issue 5.6.3]

Numerous issues related to the reconstruction of internal dose need to be investigated [Finding 12].

Lack of Early Internal Monitoring Data [5.6.3] - See Comment 14 for narrative.

Response 16: NIOSH is aware of the difficulties of estimating internal dose based on measured photon dose. As stated in the pending SEC petition, in the absence of adequate bioassay data and sufficient air monitoring data, NIOSH investigated site-specific monitoring and source term information to establish a credible upper-bound estimate of potential internal exposures resulting from NTS above-ground testing. NIOSH determined that sufficient data regarding the nuclear devices and the behavior of the radionuclides in the fallout (e.g., dispersion, fractionation, and conditions of re-suspension) is lacking to estimate the concentration of fission products and nuclides present after each detonation. NIOSH has no clear, defensible method of determining the concentrations of radionuclides present, or enough exposure scenario information to credibly determine an upper-bound estimate of internal exposure for participants or observers based on source term information.

NIOSH further attempted to determine the magnitude of potential internal doses by relating them to measurements of recorded NTS external doses. NIOSH found this approach to be insufficient for adequate determination of internal doses due to the lack of actual measurement data sufficient to verify the results of the proposed modeling, and the inability to adequately account for particulate re-suspension due to the blast waves from repeated tests in a relatively short period of time. NIOSH cannot at this time develop a direct correlation between recorded external exposure and intake that would generally apply to NTS workers.

Comment 17: Ingestion doses need to be better evaluated. [Finding 11, 12; Issue 5.5.6, 5.6.5]

Soil Ingestion [5.5.6]

Soil ingestion pathway needs to be addressed in the TBD [Finding 11].

Given the large area of NTS, it is reasonable to assume that unmonitored outdoor workers inadvertently ingested contaminated soil. The occupational environmental dose portion of the TBD (Vol. 4) does not address the problem of dose due to ingestion of radionuclides, which would be in addition to the intakes due to inhalation for unmonitored workers.

Ingestion and inhalation intakes should be addressed by running calculations for intakes by both routes and summing them in different proportions. Ingestion will be adventitious and is likely to be in amounts of no more than a few tens of milligrams of soil per day with a claimant-favorable guidance value of ~100 mg/day. For instance, if we assume a soil loading in air of 0.1 mg m^{-3} and a breathing rate of 1.2 m^3 h^{-1} for 8 hours, we get a soil intake rate by inhalation of around 1 mg per day. Thus, if there is no exposure to the initial atmospheric plume, consideration of adventitious ingestion relative to inhalation following resuspension suggests that ingestion could be of greater importance than inhalation, if the bioavailability of radionuclides is comparable for the two routes of exposure. Set against this, for the higher actinides, the fractional GI absorption is likely to be $<1*10^{-3}$, whereas uptake from the respiratory system to the systemic circulation is likely to be ~0.1. Thus, in this case, there is a ratio of 100 in bioavailability, so inhalation is likely to dominate ingestion. The fact that there is a crossover in dominant route depending on details of assumptions on amounts ingested and inhaled, and relative bioavailability, indicates that this issue needs to be explored in detail on a case-by-case basis for workers who spent a significant amount of time outdoors.

Numerous issues related to the reconstruction of internal dose need to be investigated [Finding 12].

The NTS TBD Vol. 5 has not Adequately Explored Intake of Radionuclides via the Ingestion Pathway [5.6.5]

On a related point, it appears that the bioassay data are to be interpreted as if the intakes were by inhalation only (direct plume inhalation and resuspension). However, intakes by ingestion would also have occurred. For example, site experts have indicated that eating was allowed along the major highway that went through the test site, including right over old test sites (Attachment 4).

The relative importance of ingestion versus inhalation can only be addressed by running calculations for intakes by both routes, and summing them in different proportions. Ingestion will be adventitious and is likely to be in amounts of no more than a few tens of milligrams of soil per day (see NCRP 1999). If it is assumed for illustration that the soil loading in air is 0.1 mg m^{-3} and a breathing rate of 1.2 m^3 h^{-1} for 8 hours, the soil intake rate by inhalation is around 1 mg. Thus, if there is no exposure to the initial atmospheric plume, consideration of adventitious ingestion relative to inhalation following resuspension suggests that ingestion could be of greater importance than inhalation, if the bioavailability of radionuclides is comparable for the two routes of exposure. Set against this, for the higher actinides, the fractional GI absorption is likely to be $<1*10^{-3}$, whereas uptake from the respiratory system to the systemic circulation is likely to be ~0.1. Thus, in this case, there is a ratio of 100 in bioavailability, so inhalation is likely to dominate ingestion. The fact that there is crossover in dominant route depending on details of *assumptions on amounts ingested and inhaled, and relative bioavailability, indicates that this issue needs to be explored in detail on a case-by-case basis. An analysis of the importance of addressing both ingestion and inhalation in interpreting bioassay data needs to be included in the NTS TBD Vol. 5.*

Response 17: The simplified mass loading model assumed a mean dust loading factor of 5 mg per m^{-3} and the Environmental Protection Agency (EPA) recommends 50 mg d^{-1} as the value appropriate for incidental ingestion of soil (EPA, 1989, *Exposure Factors Handbook,* Office of Health and Environmental Assessment, EPA/600/8-89/043). Use of these values would derive inhalation and ingestion rates to be about the same (i.e., 50 mg d^{-1}). In addition, the long-term inhalation intake scenario included the maximum annual intakes provided in Table 4.2.2-3 and the resultant 30-year organ doses provided in Table 2 of Response 5. These doses indicate that, with the exception of the liver and bone surfaces, sterile organs and organs of the GI tract would not be expected to receive annual doses greater than 0.001 rem from these long-term inhalation intakes. If the assumption is made that the bioavailability factor would further reduce the Table 2 doses by another factor of 100, it is also unlikely that annual doses to the bone surfaces and liver would exceed 0.001 rem. For this reason, NIOSH does not agree that the soil ingestion pathway for fine particles requires further research. However, However, NIOSH will assess the potential for large hot-particles in the NTS work areas and provide internal and external dose reconstruction guidance appropriate to the TBD that will allow the dose reconstructor to adequately account for NTS doses due to large hot-particles.

Comment 18: Recommended use of ORAUT-OTIB-0002 for post-1971 tunnel re-entry workers is contrary to guidance in that document, and its scientific validity has not been established. Its use may not be satisfactory even with restrictions, for instance for reactor testing early re-entry workers. [Finding 12, Issue 5.6.7]

Numerous issues related to the reconstruction of internal dose need to be investigated [Finding 12].

*Use of **ORAUT-OTIB-0002** [5.6.7]*

The recommendation in the NTS TBD (Vol. 5, pg. 35) that the initial evaluation of internal dose to non-metabolic organs be done using ORAUT-OTIB-0002 is not in accord with the restrictions for the use of this guidance document. ORAUT-OTIB-0002 is restricted to post-1971 workers who did not re-enter tunnels. Further, any use of ORAUT-OTIB-0002 should be justified by examining radionuclide lists and the reasonableness of using a one-time intake.

ORAUT-OTIB-0002 (pg. 8) restricts the use of the intakes for NTS to the period after 1971 for workers who did not re-enter tunnels. By contrast, the NTS TBD suggests that ORAUT-OTIB-0002 be used for a general initial screening test for maximum dose calculation for non-metabolic organs (Vol. 5, pg. 35), without specifying any other restrictions. At a minimum, the restrictions in ORAUT-OTIB-0002, including the one restricting it to post-1971, non-tunnel re-entry workers, should be made explicit in the NTS TBD, in order to prevent incorrect and inconsistent use of ORAUT-OTIB-0002.

Further, it is not clear that ORAUT-OTIB-0002 can be used as a screening maximum dose approach, even with the explicit restriction to post-1971 workers who did not re-enter tunnels. For instance, the radionuclide list for reactor testing re-entry workers is likely to be larger. They may have been exposed repeatedly to gross fission products internally and externally (see above). Just the internal GI-tract dose considerations discussed in Finding 2 above would appear to invalidate the use of ORAUT-OTIB-0002 for these workers. SC&A suggests that any use of ORAUT-OTIB-0002 for post-1971 workers be accompanied by an explicit analysis showing that the doses would be bounding, and by a further exclusion of reactor re-entry workers.

Response 18: NIOSH agrees that the use of ORAUT-OTIB-0002, *Technical Information Bulletin – Maximum Internal Dose Estimates for Certain DOE Complex Claims*, may not be appropriate for tunnel re-entry, reactor testing, and early re-entry workers. Revised direction to the dose reconstructor is under development and will be included in the TBD. The revised language will direct the dose reconstructor to observe the limitations of the approach contained in ORAUT-OTIB-0002.

Comment 19: There are no beta dose data until 1966; the TBD does not specify a procedure for estimating pre-1966 beta dose. When the approach is developed, the large, hot-particle issue will need to be taken into account. [Finding 13, Issue 5.7.2]

Protocols for reconstructing external dose during testing need to be further developed and the guidance for reconstruction [Finding 13]

Early Open Window Dose [5.7.2]

Open window dose was not recorded until 1966, so there is the issue of how beta dose is to be estimated up to that time. NIOSH has said it will address this question in Rev. 01.

The potential for beta exposure would be expected to vary greatly from one area to the next and from one period to the next at NTS. For instance, the beta exposures during atmospheric testing would be expected to vary from one test to another, and also to be quite different from those during tunnel re-entry. These exposures, in turn, would be different from the reactor testing or waste-handling exposures. NIOSH's development of methods to estimate beta exposures during the period up to 1966 will presumably take these differences into account, especially if ratios of beta to photon exposures are used. SC&A notes that as NIOSH develops methods to fill the data gap, adequate account should be taken of the problem of large particle beta dose for re-entry workers, and the limitations that this would impose on the beta-gamma ratio approach.

Response 19: Time-dependent beta-gamma ratios are being developed and will be added to the TBD. In addition, a proposed method to evaluate the beta dose by re-reading the original films has been developed. The revised TBD will describe this method. However, the method involves a significant amount of effort, and would have to be well justified on a case-by-case basis.

The presence of hot particles is task/work area related. Text will be developed that will provide guidance by work area on the potential for hot particle exposure in accordance with ORAUT-OTIB-0017, *Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose*. Summary guidance will be included in the TBD.

Comment 20: There appears to have been intentional non-use of badges in some circumstances to avoid approaching or exceeding operational dose limits. The practice may have occurred until the mid-1960s or even extended into the 1970s. NIOSH has not investigated this problem, which raises questions on the integrity of the external dose record possibly into the 1970s, which need to be explicitly addressed. [Finding 13, Issue 5.7.3, 7.1.1]

Protocols for reconstructing external dose during testing need to be further developed and the guidance for reconstructing doses to workers subsequent to testing needs to explore and address a number of issues [Finding 13].

Data Integrity [5.7.3]

Completeness of Data Sources [7.1.1 Objective 1, excerpt] ***As one important example of the need for more complete documentation of interviews, the point that the off-normal practice that employees sometimes took off their badges in forward areas during the early period (which may extend well into the 1960s) emerged consistently in SC&A interviews with HP personnel, including those interviewed by NIOSH. The relationship of higher pay in those areas to the off-normal practice appears to be apparent, an inference that can also be made from the safety description in Elements of Controversy quoted above. Yet the NTS TBD does not address this problem, which is crucial to a judgment about the adequacy of external dose data until the mid-1960s and possibly into the 1970s. As a result, it also contains no analysis as to the following:***

- ***Which groups of workers were affected by the conflict between the compensation and safety policies***
- ***Whether scientifically defensible adjustments to the data are possible and, if so, what the procedures should be to make those adjustments***
- ***Whether co-worker data can be reliably constructed, given the data integrity issues that are unresolved***

Data integrity questions exist, at least for some job types regarding the external dose record, due to a reported off-normal practice of the intentional non-use of individual monitors during work in radiation areas. The problems may extend to the mid-1960s or possibly even into the 1970s.

Potentially the most important problem identified with external dose records concerns data integrity in the early period. Site experts have noted that personnel working in radiation areas with a high potential for external dose, notably forward areas in the nuclear testing program, took off their badges from time to time in order to keep quarterly recorded dose below the 3 rem limit. The NTS radiation protection procedure established that a person who received a dose of more than 3 rem in a quarter was not allowed to enter a radiation area. This procedure would imply the possible loss of overtime pay and extra forward-area compensation. Site experts have independently and consistently stated that this practice did occur (Attachments 4 and 5). It is *unclear how long this continued, but it may have gone on to some extent until well into the underground testing program. One possible time when the practice may have decreased is about 1966, when the integrated film and ID badge was introduced. Since an ID badge was essential to demonstrate legitimate presence at NTS, the practice of taking off the film badges thereby became more difficult, and appears to have been essentially eliminated at this time. However, other site experts indicated that the problems with personnel deliberately removing their badges in radiological areas may have extended into the 1970s (Attachment 4). These questions about data integrity are reinforced by clear historical documentation about compensation and employment policies at NTS (see Section 7.1.1 on completeness of data, and Hacker 2004, pg. 90).*

Given that most of the personal dosimeters at NTS were returned with zero recorded dose, the resolution of the data integrity issue is crucial to the integrity of external dose estimates. Zero readings are normally interpreted as representing a dose below the limit of detection. This is a reasonable and defensible assumption only if it is established that the dosimeter was consistently worn in radiological areas. If, as appears possible, a significant number of workers in certain radiological areas did not do so, then the problem of external dose estimation may become acute not only because the individual data would be open to question, but the co-worker data may also be similarly open to question. During his interview with SC&A, Mr. Brady, a senior health physics official, stated that he himself had put his badge between 2-inch thick lead bricks and also had done the same for the badge of the monitor with him. Other site expert interviews done by SC&A indicate that some workers put their dosimeters between rocks, which were more easily available and less obvious in terms of the effort to avoid the recording of doses.

These considerations regarding data integrity need to be investigated for all forward areas. Besides nuclear weapon test areas (atmospheric and underground), reactor test areas would also likely have been affected, given the potential for significant dose due to early re-entry (see above). Waste-handling areas and bomb assembly facilities should also be considered.

Response 20: As stated in Response 11d, NIOSH sees no way of retrieving missing data when this practice was employed because 1) it cannot be known if the claimant actually failed to use the badge, and 2) cohort dosimetry is probably not available because the entire cohort is likely to have adopted the same practice at the same time. The project principals will evaluate this situation for the NTS as well as for other sites within the DOE complex.

Comment 21: The TBD does not contain information about extremity dosimetry. Site status of bomb assembly workers is unclear. [Finding 13, Issue 5.7.5]

Protocols for reconstructing external dose during testing need to be further developed and the guidance for reconstructing doses to workers subsequent to testing needs to explore and address a number of issues [Finding 13].

Extremity Dosimetry [5.7.5]

The NTS TBD Vol. 6, does not contain information about extremity dosimetry. Further, the status of NTS bomb assembly workers and their exposure records appears to be unclear so far as the NIOSH set of TBDs is concerned.

Extremity doses could be far higher than whole-body exposure under some circumstances at NTS, as for instance during weapon assembly or decontamination activities. Such doses could also have been significantly higher for workers handling waste drums, opening them, and performing other activities such as dewatering and repackaging wastes. Site expert interviews (Attachment 4) indicate that multiple badging to measure doses to various parts of the body was practiced in later years, but that the dose of record was from the main badge. Extremity badging appears to have been used from sometime in the 1970s. The TBD does not contain information on extremity dose monitoring or on how the dose of record might need to be supplemented for certain groups of workers if the results of multiple badging are not in the dose record.

SC&A raised this issue generally during the conference call of September 9, 2005. NIOSH's response was restricted to bomb assembly workers:

> *NIOSH responded that it had not come across any cases for bomb assembly workers for whom this topic was most relevant. It is possible that this information is classified. Up to the present moment, NIOSH has not looked into it.*
> (Attachment 3)

In a later communication (Attachment 6), NIOSH stated that it appeared that bomb assembly had been done by Los Alamos and Livermore personnel, but that no reference to that has been located:

> *Response: Bomb assembly was undoubtedly performed by a small cohort. It would have been done by weapons lab (LANL, LLNL, etc.) people and not by REECo staff. Weapons lab dosimetry people should have addressed this issue, and it should be in their TBDs. I have been unable to find reference to it in the LANL TBD on external dosimetry. I have a call in to the author of that section. The LLNL external dosimetry section has not yet been approved. In view of the nature of these exposures, there are undoubtedly classification issues that would require an adequate clearance to address. It would seem appropriate, therefore, to formulate a special task involving one or more specialists with the appropriate clearance and experience to develop an unclassified Complex wide guidance document on this issue.*
> (Attachment 6)

SC&A agrees with NIOSH that investigating this issue is of considerable importance to this group of workers, not only for extremity doses, but generally regarding the status of the bomb assembly group of workers and their dose records. Finally, the issue of extremity doses is far broader than bomb assembly workers. The revised TBD should assess the extent to which workers holding certain types of jobs, such as decontamination and decommissioning, or waste handling and repackaging, may have had extremity exposures that were significantly higher than the dose of record. The existence of multiple-badging for at least some groups of workers may shed light on this issue, as well as on the more general question of geometry of organ dose relative to the dose of record.

Response 21: NIOSH has developed guidance for extremity dosimetry and has incorporated the information in the TBD revision. NIOSH notes that few if any of the NTS contractor personnel fell into the category of *bomb assembly worker* since these operations were primarily conducted by Laboratory employees. If it is found that NTS contractor personnel were involved, guidance developed for Laboratory employees will be applied as appropriate.

Comment 22: There are no neutron dose data until 1966, and partial data until 1979. TBD assertion that neutron doses during atmospheric testing were negligible has not been substantiated and may be in error for some workers. [Finding 13, Issue 5.7.7, 5.7.8]

Protocols for reconstructing external dose during testing need to be further developed and the guidance for reconstructing doses to workers subsequent to testing needs to explore and address a number of issues [Finding 13].

Neutron Doses [5.7.7]

Neutron dose data are lacking until 1966 and are partial until 1979. The TBD does not provide a basis for estimating some neutron doses.

The NTS TBD states that neutron tracking Type A film (NTA film) badges were part of the integrated dosimeter-ID card introduced in 1966. In Table 6-1, and elsewhere in the NTS TBD, NIOSH recognizes and quantifies the problem of low or no response of this type of neutron dosimeter to low neutron energies (the threshold is variously described as 800 keV or 500 to 800 keV, pg. 10 and pg. 32). SC&A is in general agreement with the limitation of NTA film as to its lack of sensitivity to low neutron energies, and that such film is suitable only for neutron energies above 1 MeV (NTS TBD Vol. 6, pg. 32, see especially Figure 6-7). However, on page 13 of the same volume, the NTS TBD claims that the integrated badge introduced in 1966 was capable of measuring all types of radiation, including "thermal neutrons." This error should be corrected.

The NTS TBD discussion regarding the correction factors to be used for the neutron exposure situations cited in Section 6.3.4.3 (Vol. 6, pp. 41–45) is generally claimant favorable and appropriate.

The NTS TBD also discusses the use of neutron-to-photon ratios from the Pantex plant for the purpose of estimating neutron exposures for bomb assembly personnel. SC&A has found, in the context of its review of the TBD for the Iowa Army Ammunition Plant, that that ratio is likely to be claimant favorable, but also cautioned that it is preferable to use site-specific data whenever possible (SC&A 2005b, Finding 8, pp. 29–31). In response to a question posed by SC&A, NIOSH has indicated that there are considerable gaps in the information relating to who did the bomb assembly and where their dosimetry data might be. NIOSH indicated that LANL and Livermore personnel may have done the assembly, but also that those TBDs do not appear to have the relevant information (Attachment 6). It appears, therefore, that some archival research remains to be done to address the questions, and NIOSH has indicated that it seems appropriate to pursue that research (Attachment 6). SC&A concurs that this should be done.

However, the TBD does not discuss the estimation of neutron doses in the pre-1966 period or in cases where low-energy neutrons might be a significant part of the dose, notably for some personnel involved in atmospheric testing (see below) and handling of plutonium-contaminated wastes, where the neutrons would be moderated by the non-nuclear waste material *that dominates the weight and volume of low-level waste contaminated with plutonium. It is not clear that the Pantex neutron-to-photon ratio would be claimant favorable in this context. For all areas with neutron exposure potential other than the Gravel Gerties, a scientifically sound approach to neutron dose estimation needs to be developed.*

Neutron Exposure during Atmospheric Testing [5.7.8]

The assumption that neutron exposure during atmospheric testing "was practically non-existent" is not based on an analysis of the problem, and may not be correct for some groups of workers.

Page 29 of the NTS TBD Vol. 6, states that neutron exposure from nuclear explosions "was practically non-existent." There were a number of tower and air detonations at the NTS and prompt high-energy neutrons can travel a long way in air. It is assumed that the minimum distance considerations for personnel at atmospheric tests were determined based on heat and blast effects. It is possible that such considerations precluded neutron doses in practice. However, neutron dosimetry as a function of distance from atmospheric tests has been extensively studied and published in the open literature (Hacker 1994, pp. 92–95). NIOSH should analyze this literature, as well as the actual practices of the AEC and DOD during atmospheric testing, to evaluate whether there was a possibility of neutron exposure during some tests. This appears to be especially desirable in view of pressures from DOD on the AEC to allow for reduced distances for stationing of troops, which would also probably have meant reduced distances for AEC and contractor monitoring and possibly other personnel. There were tensions between the AEC and the DOD on this and other radiological safety issues (Hacker 1994).

The effect on the monitors and laborers of the DOD and AEC policies and actual practices during troop training exercises needs to be evaluated for each test, and especially for those tests where neutron doses might play a role. DOD estimates of neutron doses for its personnel indicate that these doses were highly variable from one test to another (NAS 2003, pg. 74). Furthermore, while these neutron dose estimates indicate low-neutron exposures relative to photon doses, NIOSH should carefully evaluate the DOD dose reconstruction practices on both counts before coming to the conclusion that neutron doses were "practically non-existent" during atmospheric testing. This is especially important, since there are no neutron dose measurements from the atmospheric testing period, and since the NAS review of the DOD estimates has concluded that neutron exposures to some armed forces personnel could be significant:

> *Most test participants were not exposed to neutrons, except for observers in trenches at NTS tests and a few cloud sampling personnel. For most participants who were exposed to neutrons, the doses were very low. However, a small number of volunteer observers in trenches very close to ground zero did receive substantial neutron (and gamma) doses during some NTS tests (Goetz et al. 1981). (NAS 2003, pg. 158)*

Since AEC and REECo Rad-Safe monitors responsible for test safety were in the same areas as armed forces personnel and generally preceded them into areas near ground zero for the purpose of doing surveys, it is quite possible and even likely that small groups of them also got high exposures. Moreover, in at least one instance, a Rad-Safe monitor was on a *mission accompanying armed forces personnel in aircraft (Attachment 5). It appears, therefore, that the assumption regarding neutron doses during atmospheric testing in the TBD needs to be revisited and carefully analyzed in relation to actual practices for specific groups of employees.*

There are also some other issues regarding neutron exposures in other areas. Page 28 of the NTS TBD (Vol. 6) states: "no single individual had access to areas in which there was potential for neutron exposure." This is taken to mean: "Staff worked in pairs in areas in which there was potential for neutron exposure." This was probably correct for weapon assembly, but not for well-logging or neutron calibration facilities. Page 28 also states that "...if workers were unmonitored for neutrons...then it is highly unlikely that a neutron exposure occurred." This is not consistent with page 29 of the same document: "if neutron dose information is not available for those involved with final assembly and arming operations, ...neutron-photon ratios may be used." The TBD should adopt clearer guidelines for the dose reconstructor as to the possibility of neutron dose.

Response 22: NIOSH agrees that neutron-photon ratios need to be established and used for workers known to have had some neutron involvement. Such data are available in this and other TBDs (e.g., Pantex). The TBD will be revised to include instruction on the use of neutron-to-photon ratios at NTS.

The TBD has been revised to include a detailed discussion of neutron doses from atmospheric nuclear tests and states that neutron doses at distance beyond 6 km from an atmospheric test would have been < 1 mrem. (The closest workers were at CP-2 [later CP-1] in Area 6). These distances are clearly much greater than 6 km (3.6 miles) from the test points. The one exception would have been the aircrews, but even in that case, the separation distance would have been sufficient.

Comment 23: Adequacy of soil data for estimating resuspension doses needs to be evaluated, for instance in relation to hot spot detection and Pu soil data. [Issue 5.5.2.1, 5.5.2.2, 6.1]

NTS soil contamination data and the TBD's analysis of the data to derive air concentrations are inadequate. As a result, resuspension doses may be significantly underestimated [5.5.2.1].

Comment 23a: The TBD relies on McArthur 1991 as the basic reference for soil contamination at NTS, so far as long-lived radionuclides are concerned. These data are summarized in Table 2-8 (TBD Vol. 2, pg. 45).

The contaminated areas that are listed in Table 2-8 represent only part of the entire NTS area. The total of column 2 is 1,300 km2 compared to the size of the entire NTS of 3,500 km^2. According to Figure 1 and Table 3 (at the end of this section), the contaminated areas represent just 38% of the entire NTS area. Figure 2 shows that a contaminated part of a given NTS area is not uniformly contaminated. In contrast, it is characterized by areas with hot spots of high soil activity. The purpose of the radionuclide inventory reports that are the source of the TBD calculations was to determine an overall inventory and its distribution. McArthur 1991, where the inventory and distribution data are summarized, states the following:

> *The objective of the RIDP [Radionuclide Inventory and Distribution Program] was to estimate the distribution and total inventory of the important manmade radionuclides of NTS origin in the surface soil of NTS. [pg. 2]*

The TBD has not made a claimant-favorable evaluation of the available inventory and distribution data. Specifically, the TBD has used the total estimated inventory over an entire area for each listed radionuclide and divided by the area to determine the surface contamination to be used for estimating resuspension. This approach does not take the large variability of soil contamination levels into account. Consider Area 10 as an example. The average concentration of ^{137}Cs indicated in Table A-2 of McArthur 1991 is about 1,930 nCi per m2, whereas there is an isopleth of 10,000 nCi per m^2, or about 5 times the average, for the same radionuclide documented in Figure 6 (pg. 17) of the same publication. The interior area of the 10,000 nCi per m^2 isopleth is rather large. Hence, it is possible and even likely that considerably higher concentrations would be found in the form of hot spots of significant size within that isopleth. SC&A has not investigated the raw data, since the published summary in McArthur 1991 is clearly sufficient to show that the use of average data for area contamination is not claimant favorable, bearing in mind that there could be reasons for claimants to be preferentially located in the areas of higher contamination.

Besides issues relating to the interpretation of the available data in the TBD, there are also deficiencies in the underlying data for soil contamination that are the basis for estimating resuspension dose. These issues are distinct from the choice of resuspension factors (also discussed below).

> **Response 23a:** NIOSH believes that each dose reconstruction involving ambient internal dose at the NTS must be considered on a case-by-case with special emphasis as to job location and classification. The dose reconstructors must evaluate the potential for undetected, elevated, intakes resulting from resuspended contaminates based on information available in the dosimetry records and professional judgment. For the reasons given in Response 5, NIOSH believes that the average intakes provided in Table 4.2.2-3 represent a reasonable underestimate which is appropriate for use with compensable cases and that the maximum values provided in Table 4.2.2-3 represent a reasonable overestimate for use with noncompensable cases. For cases where compensability is affected by the maximum intakes, the dose reconstructor must make every effort to obtain work locations and apply intakes for those locations provided in Table 4.2.2-2. For these cases where work location is not obtainable, the maximum values must be applied to assure claimant favorability. The assignment of ambient external dose will be consistent with ORAUT-PROC-0060, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*. The TBD will be revised to reflect this guidance.

Survey grid in the "affected areas" may not be adequate to detect hot spots [5.5.2.2].

Comment 23b: Most of the areas designated as "affected areas" had a ground zero within them for at least one test. These areas were surveyed as follows:

> *The basic arrangement of measurement locations was a grid of points 400 or 500 feet apart. In the early surveys, an irregular pattern of grid points was measured that reflected the isopleths of exposure rates derived from the aerial survey results. In later*

> *surveys, complete rectangular grids were measured to simplify the data analysis, though the grid spacing was often increased in areas of relatively low concentration. [McArthur 1991, pg. 7]*

Hence, the grid, when regular, consisted of squares, each of which had an area of about 200,000 square feet, or almost 20,000 square meters. Many surveys used a grid that was even more crude. For comparison, in its 1992 decommissioning guidelines (NUREG/CR-5849), the Nuclear Regulatory Commission suggested a grid consisting of 10 x 10 meter squares, or about 100 m2 each for outdoor contaminated areas defined as "affected areas" (NRC 1992, pg. 4-12). Such a grid is about 200 times more refined than the one used for the NTS surveys of the affected areas. SC&A recognizes, of course, that the area to be surveyed at NTS is very large, and that the guidance document cited above was prepared for decommissioning surveys. By the same token, such guidance can serve as an approximate guide to the accuracy of the data for purposes of dose reconstruction. The NRC recommends that surveys should provide 100% coverage of affected areas. The area surveyed by the in-situ measurements was likely to have been a small fraction of this guideline. One might expect that a high-purity germanium detector would effectively 'see' contamination in the top few centimeters out to a radius of around 50 feet, depending on the shielding arrangements employed. This means that an area of ~700 m2 would have been surveyed, which is only about 3.5% of area of a grid square. The coverage would be lower for larger grid spacing.

SC&A recognizes that the aerial coverage could have been better than that covered by the in-situ measurements. However, these surveys were carried out with a NaI detector with a relatively low sensitivity. This is unlikely to have picked up hot spots that might have been missed by the in-situ surveys. NIOSH should examine both the aerial and in-situ raw data in order to make a more refined assessment of the issue of hot spots. Such an assessment is needed for a dose reconstruction approach that is demonstrably claimant favorable.

The use of survey data with a crude grid for dose reconstruction at NTS may be particularly problematic due to the possibility of unrecognized hot spots created during the atmospheric testing period.

> **Response 23b:** NIOSH does not believe the review of raw data that required five years to obtain over a decade and has undergone three years of analysis (not including the re-analysis completed in McArthur 1991) is practicable in the context of the EEOICPA dose reconstruction project. NIOSH also believes that any additional information obtained from such an analysis would be of limited value in making decisions related to compensability in light of the limited information available as to the exact location of workers during various employment periods, the time interval the worker may have been located at the "hot spot," and the relative insensitivity of organ dose and compensability related to the environmental internal dose pathway (see Response 5). However, NIOSH will assess the potential for large hot-particles in the NTS work areas and provide internal and external dose reconstruction guidance appropriate to the TBD that will allow the dose reconstructor to adequately account for NTS doses due to large hot-particles.

Comment 24: The presence of high-fired oxides resulting from atmospheric weapons testing and reactor testing needs to be investigated. [Issue 6.2]

INTERNAL DOSE [6.2]

The NTS TBD does not evaluate the issue of high-fired plutonium oxide, or other high-fired oxides of actinides such as uranium and americium, or of certain fission products like strontium and cerium isotopes. The existence of a certain proportion of high-fired oxides in fallout from weapons tests and rocket engine tests should be investigated. For some radionuclides, solubility considerations appear to be rather restricted. For instance, only Type M is listed for americium and cerium isotopes. NIOSH should justify the use of these solubilities in light of the specific conditions under which the oxides would have been created either during weapons tests or the reactor testing program.

> **Response 24:** NIOSH has revised Table 5D-24 to include a range of solubilities for most radionuclides of concern. To assure that organ doses are not underestimated, dose reconstructors are instructed to use the most claimant favorable solubility type possible for the given exposure situation when the actual type is not known. High-fired plutonium oxides are known to be less soluble than other oxides, and are therefore retained for longer periods in the lungs than more soluble forms. NIOSH is currently developing a Technical Information Bulletin to address doses due to intakes of extremely insoluble materials such as high-fired plutonium oxides. The TBD will be revised to reflect this additional guidance and to identify the NTS work areas and processes to which the guidance applies.

Comment 25: NIOSH documentation of site expert interviews is inadequate, and crucial site expert interviews have not been performed or performed in an incomplete manner, notably Barton Hacker and William J. Brady. Potentially critical archives and documents have not been reviewed, including the Naval Radiological Defense Laboratory and Barton Hacker primary reference materials. [Issue 7.1.1]

Completeness of Data Sources [7.1.1 Objective 1, excerpt] *One of the most important issues in regard to completeness of data sources is the lack of a detailed interview (and associated follow-up) with William J. Brady who worked in security and radiation safety at the NTS for nearly the entire period of atmospheric and underground testing, from January 1952 to July 1991, when he retired as Principal Health Physicist. Mr. Brady has also been on National Research Council committees that have investigated radiation doses to atomic veterans and dosimetry and dose estimation practices in that context.*

Only a very modest contact with Mr. Brady appears to have been made regarding the use of R, rad and rem (See Attachment 3, including Annex B to Attachment 3).3 His vast knowledge of NTS rad safety programs, incidents, off-normal practices, such as putting film badges between two-inch thick lead bricks to prevent the recorded dose from reaching the quarterly limit, appears not to have been used. Exceeding the 3-rem quarterly limit would result in a worker being prohibited from forward areas, and thereby loss of the additional pay accorded workers in those areas. Mr. Brady is also very knowledgeable about the literature and is one of the few people knowledgeable about radiation safety and NTS going back almost all the way to the start of operations there. SC&A's interview with him is summarized in Attachment 5. It is of some interest and relevance to note here that the official history, Elements of Controversy, relied a good deal on Mr. Brady's knowledge and expertise.

NIOSH practices in regard to the documentation and use of the site expert interviews it conducts also raise some questions. During the conference call with SC&A (Attachment 3), NIOSH stated that it does not attempt to make summaries of substantive interviews, but rather makes notes only on those topics that it considers significant:

Not all points made during the exchanges were documented or summarized. NIOSH only documented points that it considered useful.

...

...

The notes of the site-expert and retired-worker communications are scattered. It would take some time to pull them out. There is no organized summary of the interchanges. Notes of site expert interviews that were used in Volume 2 and Volume 4 of the TBD are immediately available.

These practices are questionable from the point of view of completeness of use of the available information. The significance of some comments may emerge only as time goes on. Omitting substantive comments also raises questions about how the selection of the points that are "considered useful" is made.

Response 25: NIOSH has documented almost 5 hours of discussion with Mr. Brady in early 2004. Mr. Hacker has not been interviewed by NIOSH, but other site experts have been interviewed including

NIOSH may conduct additional interviews with site experts to address specific issues as they arise.