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

December 13, 2005

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

Re: Contract No. 200-2004-03805**,** Task Order 1: Draft Review of the *NIOSH Site Profile for the Nevada Test Site*

Dear Mr. Staudt:

S. Cohen & Associates (SC&A) is pleased to submit our draft review of the *NIOSH Site Profile for the Nevada Test Site,* consisting of our evaluation of "Rev. 00" of the six technical basis documents (TBDs) for introduction, site description, and occupational medical, environmental internal, and external dose, respectively. We understand that some or all of these TBDs are under active revision and have reflected that understanding with respect to findings and issues that we have identified to the extent possible.

While this report was completed in October 2005, it was submitted to the Department of Energy on November 3, 2005, for the purpose of confirming that there is no classified or Unclassified Controlled Nuclear Information (UCNI) national security information inadvertently included. DOE returned this draft report with such certification in a December 1, 2005 letter. Attachments 4 and 5 of this report were submitted separately to DOE for review, with similar confirmations received on December 6 and December 13, respectively. SC&A will prepare an issue resolution matrix based on this review and submit it to the Board at least 1 week prior to its January 24-26 meeting.

Sincerely,

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
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Draft

ADVISORY BOARD ON

RADIATION AND WORKER HEALTH

National Institute of Occupational Safety and Health

Review of the NIOSH Site Profile for the Nevada Test Site

Contract No. 200-2004-03805
Task Order No. 1
SCA-TR-TASK1-0006

Prepared by

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December 13, 2005

Disclaimer

S. COHEN & ASSOCIATES: *Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program*	Document No. SCA-TR-TASK1-0006 Effective Date: Draft — December 13, 2005 Revision No. 0 – (Draft)
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Task Manager: _________________________ Date: ___________ Arjun Makhijani	Supersedes: N/A
Project Manager: _________________________ Date: ___________ John Mauro	

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ACRONYMS AND ABBREVIATIONS

ACL	Administrative Control Limit
Advisory Board	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
AFB	Air Force Base
Anti-Cs	Anti-contamination Clothing
AP	Anteroposterior
ASER	Annual Site Environmental Reports
ATM	Atmospheric
BN	Bechtel Nevada
BREN	Bare Reactor Experiment Nuclear
CAT	Computed Axial Tomography
CDC	Centers for Disease Control and Prevention
CFR	*Code of Federal Regulations*
CP	Control Point
DAF	Device Assembly Facility
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
DOECAP	Department of Energy Contractor Assurance Program
DRI	Desert Research Institute
DRP	Dosimetry Research Project
DTPA	Diethylenetriaminepentaacetate
DTRA	Defense Threat Reduction Agency
DU	Depleted Uranium
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
EPA	Environmental Protection Agency
GI	Gastrointestinal
GSA	General Services Administration
HEU	Highly Enriched Uranium
HP	Health Physics or Health Physicist
HRC	Historical Records Center

HTO	Tritiated Water Vapor
ICRP	International Commission on Radiological Protection
IH	Industrial Hygiene
IMBA	Integrated Modules for Bioassay Analysis
INEEL	Idaho National Engineering and Environmental Laboratory
IREP	Interactive RadioEpidemiological Program
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LOD	Limits of Detection
MDA	Minimum Detectable Activity
MDD	Minimum Detectable Dose
NAS	National Academy of Sciences
NCRP	National Council on Radiation Protection and Measurements
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NRDL	Naval Radiological Defense Laboratory
NRDS	Nuclear Rocket Development Station
NSO	Nevada Safety Operations
NTA	Nuclear Test Archive
NTA film	Neutron Track Type A Film
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site
NTS TBD	Nevada Test Site Technical Basis Document
NTSER	Nevada Test Site Environmental Report
OCAS	Office of Compensation Analysis and Support
ORAU	Oak Ridge Associated Universities
PFG	Photofluorography
PIC	Pocket Ionization Chamber
POC	Probability of Causation
PPE	Personnel Protective Equipment
PPG	Pacific Proving Grounds

RDC	Radon Daughter Concentration
REECo	Reynolds Electrical Engineering Company
REMS	Radiation Exposure Monitoring System
RIDP	Radionuclide Inventory and Distribution Program
RIF	Reduction-in-force
RSSU	Radiation Safety Support Unit
RWP	Radiation Work Permit
SAIC	Science Applications International Corporation
SC&A	S. Cohen and Associates
SFCP	Spent Fuel Climax Project
SNL	Sandia National Laboratory
SSN	Social Security Number
TBD	Technical Basis Document
TIB	Technical Information Bulletin
TLD	Thermoluminescent Dosimeter
UG	Underground
WBC	Whole-Body Count
WIPP	Waste Isolation Pilot Plant
WL	Working Level
WLM	Working Level Month

1.0 EXECUTIVE SUMMARY

This report presents the S. Cohen and Associates (SC&A, Inc.) evaluation of the site profile, *Technical Basis Document for the Nevada Test Site* (ORAUT-TKBS-0008), which was published in six volumes numbered ORAUT-TKBS-0008-1 through ORAUT-TKBS-0008-6, inclusive, referred to in this report as the Nevada Test Site (NTS) technical basis document (TBD) Vols. 1 through 6. This review covers all six volumes of the NTS TBD. It includes a review of related NTS records and documented exchanges with the National Institute of Occupational Safety and Health (NIOSH) and Oak Ridge Associated Universities (ORAU) through questions sent by SC&A (Attachment 1), written answers from NIOSH and its contractors (Attachment 2), and a conference call with NIOSH and its contractors (Attachment 3). This review also includes interviews with site experts conducted by SC&A in Nevada (Attachment 4) and by telephone (Attachment 5). This report was prepared at the request of the Advisory Board on Radiation and Worker Health (Advisory Board). SC&A is the technical support contractor of the Advisory Board.

The NTS TBD was evaluated for its completeness, technical accuracy, adequacy of data, compliance with stated objectives, and consistency with other site profiles, as stipulated in the *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). As "living" documents, TBDs are constantly being revised as new information, experience, or issues arise. The results of reviews of other documents by SC&A, including reviews of other TBDs and of NIOSH procedures (SC&A 2005d) have been incorporated into the present report as appropriate.

This report is a review of Rev. 00 of the NTS TBD. The six volumes of Rev. 00 were published between February 2, 2004, and September 30, 2004. They represent the most recent published version of the NTS TBD on NIOSH's web site as of August 30, 2005. From the written response to SC&A questions, sent to SC&A on September 8, 2005 (Attachment 2), and the conference call of September 9, 2005, SC&A learned that NIOSH is close to completing a revision of the NTS TBD (Rev. 01). However, this revision has not yet been published.

Following the introduction and a description of the criteria and methods employed to perform the review, the report discusses the strengths of the TBD, followed by a description of the major issues identified during our review. The issues were carefully reviewed with respect to the following five review criteria specified in the SC&A 2004:

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

Several of the issues were designated as findings, because they represent deficiencies in the NTS TBD that need to be corrected, and which have the potential to substantially impact at least some dose reconstructions. Revision 00 of the NTS TBD mainly covers the period from 1963 onwards —that is, from the time that atmospheric testing was no longer done at NTS. However, there are technical comments and conclusions on the pre-1963 period in the NTS TBD. Furthermore, some of the issues are common to the pre- and post-atmospheric testing period. As a result, SC&A has addressed some of the technical issues relating to the atmospheric testing period, and has discussed its findings for this period. Except for the findings that relate specifically to conclusions or technical statements in the NTS TBD about the atmospheric testing period, the SC&A findings in regard to that period should be viewed as suggestions for incorporation into future revisions of the NTS TBD.

1.1 SUMMARY OF STRENGTHS

The following strengths were noted in the NTS TBD:

- After 1957, everyone was badged. After 1966, there was an integrated film and ID badge. The characteristics of the dosimeters are described in the NTS TBD. The approach to external dose estimation is, overall, technically sound and claimant favorable in those cases where data are available and sound.
- Radionuclide lists are context-specific. This is important, given the variety of radionuclides at NTS, and the differences in radionuclides in different NTS projects and environments.
- A wide variety of methods to assess internal dose were employed as the internal dosimetry program at the NTS matured. The TBD makes good use of these methods for the purpose of reconstructing internal doses to workers.
- Tritium exposures were recognized as requiring monitoring in the late 1950s. The TBD makes reference to and use of this data.

1.2 SUMMARY OF FINDINGS

Finding 1: Radionuclide lists are not complete for several aspects of the NTS operations.

Finding 2: The NTS TBD does not provide adequate guidance for estimating doses associated with reactor propulsion tests, notably doses 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 (GI) tract appear to be particularly important.

Finding 3: The TBD has not adequately considered large particle doses to personnel entering nuclear weapons 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 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 5: Environmental occupational dose during weapons testing is not adequately addressed in the TBD.

Finding 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. The following summarizes the various issues that need to be addressed with respect to worker doses from resuspension:

- 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.
- Survey grid in the "affected areas" may not be adequate to detect hot spots.
- Measurements of soil inventory of radionuclides in areas thought to be relatively unaffected may not be adequate to identify all significant hot spots.
- The resuspension factor used in the TBD is questionable.
- The TBD method to assign resuspension doses to workers where the location is not known may underestimate the exposure.
- The TBD does not evaluate resuspension exposure for monitored workers. Adjustments to radionuclide intake may be necessary for some monitored workers.
- Some solubility assumptions for resuspended radionuclides are not scientifically appropriate.
- A dust loading approach may be more appropriate than using resuspension factors for estimating resuspension intakes.

Finding 7: Occupational environmental dose needs to be re-examined with explicit consideration given to the time period of testing. The following are the issues that need to be examined:

- Representativeness of data for a given area needs to be further evaluated.
- Is it claimant favorable to assign 1967 data for the time period 1963 to 1966?
- Data for 1968 though 1976 are missing. The TBD has not specified an approach to estimating external environmental dose for these years.
- Pre-1963 period external environmental dose estimation procedure is not addressed in the TBD.
- External environmental dose estimation for monitored workers needs to be more comprehensively evaluated.

- Conclusions regarding external environmental dose for unmonitored and monitored workers need to be evaluated further.

Finding 8: Radon exposure in tunnels needs to be more thoroughly evaluated and radon exposure in the Gravel Gerties needs to be evaluated.

Finding 9: Accuracy of HTO (tritiated water vapor) sampling is questionable.

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

Finding 11: The soil ingestion pathway needs to be addressed in the TBD as part of the environmental dose estimation process.

Finding 12: Numerous issues related to the reconstruction of internal dose need to be investigated, including the following:

- Important details as regards interpretation of various kinds of internal dose data are not included in the NTS TBD Vol. 5**.**

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

- Assigning only environmental doses to workers thought not to be at risk of internal exposure may not capture the full extent of radionuclide intake.

- The NTS TBD Vol. 5 has not adequately explored intake of radionuclides via the ingestion pathway.

- The NTS TBD Vol. 5 does not adequately consider the possibility of exposure to different enrichments of uranium.

- 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 accordance 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. Furthermore, any use of ORAUT-OTIB-0002 should be justified by examining radionuclide lists and the reasonableness of using a one-time intake.

Finding 13: 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. These issues include the following:

- Open window dose was not recorded until 1966. As such, 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.

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

- The TBD does not contain complete instructions for converting external dosimetry data into IREP inputs.

- The NTS TBD Vol. 6 does not contain information about extremity dosimetry.

- 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.

- Angular dependence of the individual monitors for ground surface irradiation geometry needs to be taken into consideration.

- 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 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.

Finding 14: The guidance regarding the reconstruction of medical doses needs to address additional medical exposure scenarios, including the use of photofluorography, and additional uncertainties associated with routine chest x-rays.

1.3 OPPORTUNITIES FOR IMPROVEMENT

SC&A understands that NIOSH is preparing to publish a revised NTS TBD (see Attachments 2 and 3). It would be desirable to evaluate the following suggestions for incorporation into the revised TBD:

(1) Radionuclide lists should be more complete, especially for the period to 1967, when internal dose data are either lacking or not plentiful or detailed enough.

(2) NIOSH should fully evaluate the Naval Radiological Defense Laboratory (NRDL) methods for estimating certain aspects of dose—those from large, hot particles—to early re-entry employees in the reactor propulsion test areas. The data and methods appear to be useful, not only for assessing reactor area doses, but also for atmospheric weapon tests, underground tests that vented accidentally, and possibly for post-1970 underground tests.

(3) In addressing the lack of beta dose data prior to 1966, NIOSH should evaluate whether the usual approach of applying beta-gamma ratios is applicable, in view of the fact that the gamma dose at 1 m is determined mainly by fine particle deposition, whereas some doses, notably skin and GI-tract doses, appear to be dominated by large particles for certain groups of workers.

(4) NIOSH should carefully evaluate the issue of external dosimetry data integrity with a view toward determining how widespread the problem of not wearing badges might have been and how long it lasted.

(5) Guidance on some issues of technical detail, such as the effect of heat on film badges and thermoluminescent dosimeters (TLDs) stored in personal vehicles and organ dose geometry relative to recorded dosimeter dose, should be explicitly developed.

(6) NIOSH should make a greater effort to take into account site expert information and investigate worker accounts. The on-site, first-hand experience of site experts enables them to provide original perspectives and information concerning site practices and exposure histories. NIOSH has incorporated a limited amount of worker input into the latest version of the TBD. However, NIOSH's use of experts with vast knowledge, such as Barton Hacker and William Brady, has been minimal or non-existent.

(7) NIOSH should revamp its approach to environmental doses by evaluating the dust loading approach. Air concentration data should be re-evaluated in the light of the Los Alamos study on large particle undercounting at high wind speeds discussed in this review.

(8) NIOSH needs to make a much more complete review of many data sources in order to address the findings in Section 1.2 above.

(9) The National Academy of Sciences (NAS) report titled, *A Review of the Dose Reconstruction Program of the Defense Threat Reduction Agency* (NAS 2003), contains numerous findings and recommendations pertaining to the reconstruction of doses for military personnel exposed at the NTS. Many of these findings and recommendations may also apply to the reconstruction of claimant doses under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) and should be considered in future revisions of the TBD.

(10) The NTS TBD needs to be more compete in its coverage of periods and facilities, including atmospheric testing (which was largely excluded from Rev. 00 and which will be covered in Rev. 01), aspects of waste handling and packaging, bomb assembly (if required in the NTS TBD) and decommissioning, including the facilities mentioned in Section 2.2.31 of the TBD.

More detailed suggestions for improvement are mentioned or discussed as part of the various findings in Section 5 and the discussion in Section 7 of this review.

2.0 SCOPE AND INTRODUCTION

2.1 REVIEW SCOPE

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

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

- ORAUT-TKBS-0008-1, *Technical Basis Document for the Nevada Test Site – Introduction* (Rollins 2004a)
- ORAUT-TKBS-0008-2, *Technical Basis Document for the Nevada Test Site – Site Description* (Rollins 2004b)
- ORAUT-TKBS-0008-3, *Technical Basis Document for the Nevada Test Site – Occupational Medical Dose* (Rollins 2004c)
- ORAUT-TKBS-0008-4, *Technical Basis Document for the Nevada Test Site – Occupational Environmental Dose* (Rollins 2004d)
- ORAUT-TKBS-0008-5, *Technical Basis Document for the Nevada Test Site – Occupational Internal Dose* (Rollins 2004e)
- ORAUT-TKBS-0008-6, *Technical Basis Document for the Nevada Test Site – Occupational External Dosimetry* (Rollins 2004f)

These documents are referred to in this review as NTS TBD Vols. 1 through 6. These six volumes are supplemented by technical information bulletins (TIBs), which provide additional guidance to the dose reconstructor. SC&A, in support of the Advisory Board, has critically evaluated the NTS TBDs and supplementary and supporting documents in order to:

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

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

The review is directed at "sampling" the site profile analyses and data for validation purposes. The review does not provide a rigorous quality control process, whereby actual analyses and calculations are duplicated or verified. The scope and depth of the review are focused on aspects or parameters of the site profile that would be particularly influential in dose reconstructions, bridging uncertainties, or correcting technical inaccuracies. This review does not explicitly address the issue of radiation exposures to cleanup workers and decommissioning workers, as that is not addressed in the TBDs.

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

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

The case of the NTS is, in many ways, unique because of the hundreds of nuclear weapons tests, as well as safety tests with nuclear materials that were conducted there. These tests included both atmospheric tests (until 1963) and underground tests (from 1961 onward). In the latter category, there were tests that vented significant amounts of radioactivity. Safety tests with plutonium have left many areas contaminated. Such activities have left significant amounts of contamination in many parts of the site. Testing of experimental nuclear reactors for possible use to power rocket engines was also done at NTS. Since fission products and neutron activation products were created in large amounts in ways that had the potential to give rise to exposure to short-lived radionuclides, the assessment of exposure potential at NTS is an unusually complex matter. A variety of other activities, such as assembly of test weapons and management of wastes from other sites, add to this complexity.

2.2 REVIEW APPROACH

SC&A's review of the TBDs and supporting documentation concentrated on determining the completeness of data collected by NIOSH, the adequacy of existing NTS personnel and environmental monitoring data, and the evaluation of key dose reconstruction assumptions. Site expert interviews were conducted with current and former NTS workers. Also included were workers who supported testing operations, but worked at either Lawrence Livermore National Laboratory (LLNL) or Los Alamos National Laboratory (LANL).

All review comments apply to the Rev. 00 versions of the NTS TBD cited above, since they are the most recent published versions. SC&A was informed on September 9, 2005, that NIOSH is close to completing and publishing Rev. 01 of the NTS TBD. This revision is expected to cover the atmospheric testing period. Revision 00 mainly covers the period from 1963 onward. However, Rev. 00 has several material guidelines and conclusions about the atmospheric testing period, such as the conclusion that neutron doses from atmospheric testing were not important, or which radioisotopes were "of concern for dose" (NTS TBD Vol. 5, Table 5D-13, pg. 59). This SC&A review includes findings for both periods. Unless explicitly stated, the findings on the atmospheric testing period should not be viewed as deficiencies of Rev. 00, but as suggestions for consideration by dose reconstructors for this period.

On May 6, 2005, SC&A sent questions to NIOSH as part of its evaluation of the TBD. These questions are reproduced in Attachment 1. ORAU sent written responses to the comments on September 8, 2005; they are reproduced in Attachment 2. A conference call was held with NIOSH and contractor personnel, including some of those preparing the TBD and dose reconstructors performing work on NTS individual dose reconstructions. A summary of that conference call is included here as Attachment 3.

Site expert interviews were conducted to help SC&A obtain a comprehensive understanding of the radiation protection program, site operations, and environmental contamination. Attachment 4 provides summaries of the interviews conducted by SC&A by teleconference or in person in Las Vegas during the course of this review. The site experts included current and former staff from radiation control, operations, environmental monitoring, maintenance, and other support organizations. These interviews were conducted during the course of the NTS Site Profile Review. An integrated summary is provided in Attachment 4. The summary is a paraphrase of conversations held with a number of site experts, rather than a verbatim transcript. Their statements have been grouped into categories to provide a linkage with various portions of the NTS Site profile. References to the names of specific site experts have been omitted for privacy reasons. These individuals were given the opportunity to review the interview summary for accuracy. This is an important safeguard against missing key issues or misinterpreting some vital piece of information.

SC&A also held a telephone interview with William J. Brady, who worked at the site from 1952 to 1991, when he retired as Principal Health Physicist. A summary of that interview is reproduced in Attachment 5. Mr. Brady gave permission to SC&A to include his name in the interview summary. While none of the interviews were classified, they were submitted to the DOE along with the summaries in Attachments 4 and 5 for declassification review as a precautionary measure.

2.3 REPORT ORGANIZATION

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

(1) Executive Summary
(2) Scope and Introduction
(3) Assessment Criteria and Method
(4) Site Profile Strengths
(5) Findings
(6) Observations
(7) Completeness, data adequacy, technical accuracy, and regulatory compliance, and comparison of the NTS TBD with other site profiles

Based on the issues raised in each of these sections, SC&A prepared a list of findings, which are provided in the executive summary. Issues are designated as findings if SC&A believes that they represent deficiencies in the TBD that need to be corrected, and which have the potential to have a substantial impact on at least some dose reconstructions. These findings are not meant to be exhaustive, but rather issues of dosimetric significance that SC&A investigated in more detail in order to develop suggestions for improvement of any revisions to the NTS TBD and for use in dose reconstruction, as appropriate. Issues can also be designated as observations if they simply raise questions, which, if addressed, would further improve the TBDs and might possibly reveal deficiencies that would need to be addressed in future revisions of the TBDs.

3.0 ASSESSMENT CRITERIA AND METHODS

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

3.1 OBJECTIVES

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

3.1.1 Objective 1: Completeness of Data Sources

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

3.1.2 Objective 2: Technical Accuracy

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

3.1.3 Objective 3: Adequacy of Data

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

3.1.4 Objective 4: Consistency Among Site Profiles

SC&A reviewed the site profile with respect to Objective 4, which requires SC&A to identify common elements within site profiles completed or reviewed to date, as appropriate. In order to accomplish this objective, the NTS TBDs were compared to some of the other TBDs reviewed to date. This assessment was conducted to identify areas of inconsistencies and determine the potential significance of any inconsistencies with regard to the dose reconstruction process. It is more limited than for some of SC&A's other reviews, because none of the other sites whose profiles have been reviewed so far had many of the activities at NTS.

3.1.5 Objective 5: Regulatory Compliance

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

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

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

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

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

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

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

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

NTS TBD Vol. 1, ORAUT-TKBS-0008-1, *Technical Basis Document for the Nevada Test Site – Introduction*, explains the purpose and the scope of the site profile. It also explains the role of each TBD in support of the dose reconstruction process. During the course of its review, SC&A

was cognizant of the fact that the site profile is not required by the EEOICPA or by 42 CFR Part 82, which implements the statute. Site profiles were developed by NIOSH as a resource to the dose reconstructors for identifying site-specific practices, parameter values, and factors that are relevant to dose reconstruction. Based on information provided by NIOSH personnel, SC&A understands that site profiles are "living" documents, which are revised, refined, and supplemented with TIBs, as required, to help dose reconstructors. Site profiles are not intended to be prescriptive nor necessarily complete in terms of addressing every possible issue that may be relevant to a given dose reconstruction. Hence, the introduction helps in framing the scope of the site profile. NIOSH has informed SC&A that Rev. 01 of the NTS TBD is close to completion, and that considerable additional information will be included in it. SC&A has made comments in this review as to areas of additional information that should be considered for inclusion in the revised TBD.

NTS TBD Vol. 2, ORAUT-TKBS-0008-2, *Technical Basis Document for the Nevada Test Site – Site Description* (Rollins 2004b), is a very important document, because it provides a description of the facilities, underground testing, atmospheric testing, and historical information that serve as the underpinning for subsequent NTS TBDs. Specifically, this document describes the various areas of NTS and the activities that were conducted there. SC&A's review addresses whether the NTS TBD includes dose reconstruction guidelines for all major activities conducted at the site.

NTS TBD Vol. 3, ORAUT-TKBS-0008-3, *Technical Basis Document for the Nevada Test Site – Occupational Medical Dose* (Rollins 2004c), provides a set of procedures for reconstructing the radiation exposures of workers from medical radiographic procedures that were required of employees at the NTS site. SC&A reviewed this section for technical adequacy and consistency with other NIOSH procedures, and compared these with other site profiles.

NTS TBD Vol. 4, ORAUT-TKBS-0008-4, *Technical Basis Document for the Nevada Test Site – Occupational Environmental Dose* (Rollins 2004d), provides background information and guidance to dose reconstructors for reconstructing the doses to unmonitored workers outside of the facilities at the site who may have been exposed to routine and episodic airborne emissions from these facilities. SC&A's review also considers special environmental exposure situations in which doses may not be fully reflected in exposure records. SC&A reviewed this section from the perspective of the source terms and the atmospheric transport, deposition, and resuspension models used to derive the external and internal doses to these workers.

NTS TBD Vol. 5, ORAUT-TKBS-0008-5, *Technical Basis Document for the Nevada Test Site – Occupational Internal Dose* (Rollins 2004e), presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers. This section was reviewed with respect to background information and guidance regarding the types, mixes, and chemical forms of the radionuclides that may have been inhaled or ingested by the workers; the recommended assumptions for use in reconstructing internal doses based on whole-body counts and bioassay data; the methods recommended for use in the reconstruction of missed internal dose; and the methods recommended for characterizing uncertainty in the reconstructed internal doses.

NTS TBD Vol. 6, ORAUT-TKBS-0008-6, *Technical Basis Document for the Nevada Test Site – Occupational External Dose* (Rollins 2004f), presents background information and guidance to dose reconstructors for deriving occupational external doses to workers. This section was reviewed with respect to background information and guidance regarding the different types of external radiation (i.e., gamma, beta, and neutron) and the energy distribution of this radiation to which the workers may have been exposed. SC&A also reviewed the recommendations for converting external dosimetry data to organ-specific doses, the methods recommended for use in the reconstruction of missed external doses, and the methods recommended for characterizing uncertainty in the reconstructed external doses.

It is important to note that SC&A's review of the NTS TBD is not exhaustive. The findings are oriented to in-depth consideration of selected issues that SC&A has concluded have a potentially significant impact on either the scientific soundness of the dose reconstruction process or the claimant favorability of the result of the estimation procedure. In all its reviews, SC&A uses the same general criteria in evaluating adequacy of data or completeness of the data search by NIOSH. These are large, complex documents, and SC&A used its judgment in selecting those issues that we believe are important with respect to dose reconstruction.

There are three levels of review for this report. First, SC&A team members reviewed the report internally. Second, SC&A consultants who had not participated in the preparation of this report were asked to review all or portions of the report, according to their specializations. The third level, referred to as the expanded review cycle, will consist of a review of this draft by the Advisory Board and NIOSH. The first two of these have been completed prior to submittal of this report to the Advisory Board.

The usual procedure, after the Advisory Board and NIOSH have had an opportunity to review the draft report, is a comment resolution process, for which a public record is maintained. The Advisory Board usually initiates this, in order to resolve as many of the issues as possible and for any outstanding differences to be transparent.

4.0 SITE PROFILE STRENGTHS

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

(1) After 1957, everyone was badged, and after 1966, there was an integrated film and ID badge, which ensured that everyone onsite had external dose monitoring. The integrated ID/film badge also made it far more difficult and less likely that employees would remove their badges to ensure their ability to continue to work in forward areas.

(2) The approach to external dose estimation is, overall, technically sound and claimant favorable in those cases where data are available and sound.

(3) Radionuclide lists are context-specific. This is important, given the variety of radionuclides at NTS, and the differences in radionuclides in different NTS projects and environments.

(4) A wide variety of methods to assess internal dose were employed as the internal dosimetry program at the NTS matured. The TBD makes good use of these methods for reconstructing internal doses to workers.

(5) Tritium exposures in the tunnel environments were recognized as requiring bioassay monitoring, which was started in the late 1950s.

(6) The NTS TBD has identified site in situ and aerial survey data as useful sources from which to estimate internal environmental dose. However, as noted in the findings, SC&A has considerable reservations about the details of the use of this data.

5.0 FINDINGS

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

5.1 ISSUE 1: RADIONUCLIDE LISTS

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

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. 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).

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. 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).

The radionuclide list for the reactor testing areas is also not complete (see Finding 2 below).

5.2 ISSUE 2: REACTOR RE-ENTRY PERSONNEL

Finding 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.

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 report and in some of the referenced material appears to be invaluable not only for evaluating 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.

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.

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[1] The analysis in NRDL assumes that particles of 50 microns or more settle out within 2 hours, and that particles of 12 microns take about 20 hours to settle (NRDL 1968, pg. 16). This assumption may be valid for reactor tests, but may not be valid for weapons tests. In the latter case, dust particles could remain suspended in the air for days after the test (see Warren 1945, for instance). Stafford Warren, the test safety director, did not provide particle sizes, and these are not given for the post-Trinity test survey. However, he noted that there was "still a tremendous quantity of radioactive dust-floating in the air" on July 21, 1945, in his memo to General Groves of that date.

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. 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.

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. 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.

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.

5.3 ISSUE 3: LARGE PARTICLE DOSES DURING NUCLEAR WEAPONS TESTS

Finding 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.

The TBD does not discuss problems analogous to the ones discussed in Finding 2 for early re-entry 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.

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 re-evaluate shallow doses and GI-tract doses, in light of the NRDL analysis of large particle exposures associated with the Baneburry test, as well as other underground tests that resulted in accidental ventings.

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.

5.4 ISSUE 4: INGESTION DUE TO ORO-NASAL BREATHING

Finding 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.

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.

5.5 ISSUE 5: ENVIRONMENTAL OCCUPATIONAL DOSE

5.5.1 Overall Environmental Dose Finding

Finding 5: Environmental occupational dose during weapons testing is not adequately addressed in the TBD.

SC&A's review of occupational environmental dose involved consideration mainly of Volume 4 of the NTS TBD, but also of the Introduction to the TBD (Vol. 1) and the Site Description (Vol. 2). SC&A also reviewed some of the associated documentation.

The environmental TBD includes internal doses to unmonitored workers from onsite releases to the air and from resuspension of contaminated soil, external doses from ambient radiation and releases of noble gases, and radon exposure to tunnel workers. Atmospheric testing from 1951–1963 is mentioned and some data are presented in the TBD. However, the focus of the TBD is on underground testing. In view of the data and conclusions that are presented for the atmospheric testing period and the pending revision of the NTS TBD, this SC&A review covers that period, but largely focuses on the methodology for exposures from 1963 onward. However, some comments on the pre-1963 period are included for NIOSH to consider as it addresses the atmospheric testing period. Further, covering the early period is important for non-weapons testing related issues, notably reactor testing. While the TBD addresses environmental dose issues only for unmonitored workers, SC&A has noted some issues that also affected monitored workers who spent significant amounts of time in outdoor contaminated areas. These include large particle doses to workers re-entering reactor and weapons test areas, and possibly large particle resuspension ingestion doses.

5.5.2 Internal Occupational Environmental Dose

Finding 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.

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.

5.5.2.1 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.

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 km^2 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 m^2, 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).

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

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 m^2 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 m^2 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.

5.5.2.3 Measurements of soil inventory of radionuclides in areas thought to be relatively unaffected may not be adequate to identify all significant hot spots

SC&A is in broad agreement with the process described in McArthur 1991 to identify the areas most likely to be contaminated:

> *The portions of the NTS covered by the in situ surveys…. … include all the GZs of above-ground nuclear tests, the GZs of underground nuclear tests where significant amounts of radioactivity reached the surface, safety-shot sites, the rocket test facilities in Area 25, and other places where aerial surveys showed elevated levels of radioactivity. For the most part, those portions of the NTS not covered by in situ surveys were known (from aerial surveys, ground-based monitoring, and the history of NTS operations) to have no contamination from NTS activities.* [McArthur 1991, pp. 4–5]

SC&A has therefore listed this approach as one of the strengths of the NTS TBD. However, SC&A has some concerns regarding the identification of all significant hot spots. Specifically, hot spots in areas some distance from ground zero might be expected from atmospheric testing in a manner that is not easily susceptible to estimation. A similar comment would apply to underground tests that resulted in significant venting.

Moreover, confirmatory sampling in areas designated as unaffected does not appear to have been done in a manner that would be likely to detect previously unidentified hot spots. Specifically, "only a few measurements were made in background areas" (McArthur 1991, pg. 3). Moreover, in areas that had no ground zeros, which would constitute the bulk of the areas designated as unaffected, "measurements were made primarily along roads" (McArthur 1991, pg. 7). The NRC guidelines suggest that unaffected areas should be "uniformly scanned" (NRC 1992, pg. 4.16), and that soil sample locations should be "randomly selected." This procedure does not appear to have been followed in the surveys of the unaffected areas.

The TBD does not discuss any procedure by which the available raw data could be analyzed in order to ensure that the occupational environmental dose estimation procedure based on soil inventory and distribution estimates is scientifically reliable and consistently claimant favorable. In fact, the TBD does not have any analysis of those raw data at all.

5.5.2.4 The resuspension factor used in the TBD is questionable

The resuspension factor was based on the model presented by Anspaugh et al. (2002). The long-term equilibrium value of 1.3 x 10^{-9} m^{-1} was selected "because the vast majority of radionuclides in surface soil were deposited from atmospheric testing that stopped in 1962, and because it is reasonable to assume that unmonitored employees would not be likely to be exposed to freshly deposited radionuclides."

The TBD provides no analysis for the various periods of activities and classes of employees to validate the assumption that "unmonitored employees would not be likely to be exposed to freshly deposited radionuclides." This assumption may not be correct for all periods. Specifically, SC&A has two concerns regarding this assumption. There was no internal dose monitoring until late 1955, and monitoring was scant and selective after that into the 1960s. Since Rad-Safe and other personnel did enter forward areas from the start of the testing program, the assumption that unmonitored employees were not at risk of exposure appears to be too expansive and needs, at least, to be narrowed to specific job types and specific periods. As another example, site expert interviews indicate that "laborers" were used in the initial years of atmospheric testing to perform certain tasks, like equipment retrieval, soon after test shots. They may not even have had external monitoring. For entry into contaminated areas within 100 days of a test shot, the TBD acknowledges that the resuspension factors could have been orders of magnitude higher:

> *As discussed in Anspaugh (2002), the uncertainty suggested in equation 4-3 is plus or minus one order of magnitude. This is a large uncertainty, but it is based on actual measurements that suggest the very complex nature and unpredictability of the resuspension process. In addition, the time-dependence of the resuspension factor suggested by equation 4-3 covers a range of almost four orders of magnitude. Therefore, if an unmonitored employee was exposed to freshly deposited fallout, the intake values in Tables 4.2.2-2 and 4.2.2-3 could represent significant underestimates of the actual intake. However, because of the rapid decrease in the resuspension factor with time, the likelihood of exposure of this type for periods greater than a few days would be very small. In addition, a claimant-favorable factor of 10 has been applied to the resuspension factor to minimize the likelihood that airborne concentrations would be underestimated. In addition, the number of unmonitored employees likely to have been inadvertently exposed to fresh fallout would be small.* [TBD Vol. 4, pp. 34–35]

In fact, Anspaugh 2002 does not recommend the use of resuspension coefficients for estimating intakes at times long after the initial radionuclide deposition. Rather, the dust loading approach is preferred, unless suitable air concentration data are available:

> *The resuspension-factor model has been widely used to predict the concentration of resuspended contaminant at times early after the initial deposition. The mass-loading model has generally been preferred for times long after the deposition. However, at times long after deposition and in situations where there is a real and legitimate concern about resuspension, it is always preferable to rely on*

> *actual measurements that are performed over long time periods.* [Anspaugh 2002, pg. 676.]

In view of the above, reliance on Anspaugh 2002 for estimating a resuspension factor for times long after the deposition is inappropriate, as is the use of such a factor for long-term intake estimation.

The TBD makes no attempt to describe which workers were likely to have entered within a few days. Further, entry for short periods of time, such as a few days within several days of the test, would be likely to produce doses in excess of those that would be estimated using the suggested resuspension factor of 1.3 x 10^{-9} per meter. For instance, accepting the values in Figure 4.2.2-1 of the TBD (Vol. 4, pg. 32) as valid, entry within a month would imply a resuspension factor of ~1 x 10^{-6} per meter, which is about 770 times larger than the mean value assumed in the TBD. Entry within a few days would imply resuspension factors thousands of times larger than those assumed in the TBD.

The approach suggested for entry after long periods is not demonstrably claimant favorable. The TBD states that "a claimant-favorable factor of 10 has been applied to the resuspension factor to minimize the likelihood that airborne concentrations would be underestimated." However, in view of the above and the analysis below, this does not ensure a claimant-favorable procedure in the absence of additional data for validating the claimant favorability of the choice.

It is not clear that the particulate sampling data at NTS can meet the test of suitability for use in determining resuspension factors for the purpose of claimant-favorable dose reconstruction. Specifically, the measurement of respirable particulates in the 5 to 10 micron range may be underestimated to a considerable extent by certain types of air samplers. Extensive wind tunnel research by Los Alamos scientists has shown that some sampler designs have efficiencies of only 20% to 25% for 5 to 10 micron particles at high wind speeds (12.5 m/sec or more), whereas others have efficiencies in the 50% to 100% range (Rodgers et al. 2000). The TBD contains no analysis of the underestimation of the resuspension factor and of the uncertainties in it that may be caused by the type of sampler that was used.

Further, the air sampling data are area measurements. The problem of relating these area measurements to individual worker intake is complex and difficult. While the assumption of a 2,000 hour per year presence in the contaminated areas may be assumed to be generally claimant favorable, it remains to be demonstrated that such an assumption can offset the factors that could contribute to significant underestimation of environmental dose at NTS.

Finally, future revisions of the TBD should consider the comments on resuspension factors pertinent to the NTS presented in *A Review of the Dose Reconstruction program of the Defense Threat Reduction Agency*, prepared by the NAS. Of particular relevance to the reconstruction of internal dose associated with resuspension processes are comment Nos. 6 and 7 on pages 193 and 207 of the NAS report. These comments address the importance of addressing the inhalation doses associated with the resuspension of aged fallout, and the finding that resuspension factors associated with the blast wave could be over 100-fold greater than the default resuspension factors of 10^{-5} per meter employed in the program.

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

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.

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

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.

5.5.2.7 Some solubility assumptions for resuspended radionuclides are not scientifically appropriate

The TBD recommends that Type S solubility be used for all radionuclides deposited in the soil, except for plutonium for which Type M or Type S is recommended because of dispersal of plutonium in safety tests. While the implication of the assumption is that particles in nuclear test fallout are oxides and this is correct, the other implicit assumption that oxides in fallout are all Type S is not correct. For instance, cesium oxide may be assumed to be Type F, since it belongs to the alkali metals group. The ^{137}Cs dose conversion factor for the kidneys for Type F is about 50% larger than that for Type S. There may also be additional considerations in the specific instance of ^{137}Cs released from a high-temperature environment. Studies of this issue in connection with the Chernobyl accident largely confirm Type F behavior, but also indicate that some fraction of ^{137}Cs may be retained for much longer—months or years. NIOSH needs to re-examine the blanket assumption that an assumption of Type S for all resuspended radionuclides except plutonium is scientifically reasonable and claimant favorable.

5.5.2.8 A dust loading approach may be more appropriate than using resuspension factors for estimating resuspension intakes.

Both the dust loading and resuspension factor approaches can be useful for estimating radionuclide concentrations in air arising from the resuspension of ground deposits. However, their contexts of applicability are substantially different. The resuspension factor approach is most applicable to recent deposits arising from atmospheric deposition. In these circumstances, the radionuclide is deposited heterogeneously at or close to the soil surface, and it is difficult to define a meaningful concentration on a mass basis appropriate to the soil particles that are susceptible to resuspension. In these circumstances, an empirically determined resuspension factor may be used. This relates the concentration in air (Bq m^{-3}) to the areal concentration on the ground (Bq m^{-2}). Thus, it has dimensions of $[L]^{-1}$ and typical units of m^{-1}.

The resuspension factor approach has the advantage that it relates directly to the deposit per unit area, so the issue of depth averaging is avoided. However, a consequence of this is that the resuspension factor depends on the time after deposition, due both to the development of a vertical soil profile and (possibly) to a change in the degree to which the deposited radionuclide is associated with different soil fractions. In principle, these changes should depend on factors such as soil type, vegetation cover, and climatic conditions. However, in practice, a single two-component curve is often adopted as a simplification.

The resuspension factor approach has the other characteristic that it implicitly includes the effects of contributions to the air concentration from areas upwind of the point of measurement, i.e., it is not a local measure. This can lead to enhanced values of the resuspension factor when there is a strong gradient of decreasing soil deposition downwind.

The dependence of the resuspension factor with time after deposition is well illustrated by the formula given in Equation 4-3 of ORAUT-TKBS-0008-4. This is:

$$SF = [1*10^{-5}\exp(-0.07t) + 6*10^{-9}\exp(-0.003t) + 1*10^{-9}]\times 10^{\pm 1}\ m^{-1}$$

where *t* is the time after deposition in days.

This formulation permits a time-averaged resuspension factor to be calculated as:

$$\int SF\,dt / \int dt$$

Values of this quantity computed over the interval [0, T] are shown in the following table and graph for different values of T. Note that from Equation 4-3, these values are uncertain by a factor of $10^{\pm 1}$. Thus, for exposure over extended periods after deposition, a resuspension factor in the range $1*10^{-9}$ to $1*10^{-5}$ m^{-1} seems plausible.

Table 3: Time-Averaged Resuspension Coefficients

T (d)	Time-averaged Value (m^{-1})	T (d)	Time-averaged Value (m^{-1})	T (d)	Time-averaged Value (m^{-1})
1	9.67E-06	160	8.99E-07	2000	7.34E-08
3	9.03E-06	180	7.99E-07	3000	4.93E-08
10	7.20E-06	200	7.20E-07	4000	3.72E-08
20	5.39E-06	250	5.77E-07	5000	3.00E-08
30	4.19E-06	300	4.81E-07	6000	2.51E-08
40	3.36E-06	350	4.13E-07	7000	2.17E-08
50	2.78E-06	400	3.62E-07	8000	1.91E-08
60	2.35E-06	450	3.22E-07	9000	1.71E-08
70	2.03E-06	500	2.90E-07	10000	1.55E-08
80	1.79E-06	600	2.42E-07	15000	1.07E-08
90	1.59E-06	700	2.08E-07	20000	8.24E-09
100	1.43E-06	800	1.82E-07	25000	6.79E-09
120	1.20E-06	900	1.62E-07		
140	1.03E-06	1000	1.46E-07		

In the dust loading approach, the radionuclide concentration in air is calculated as the product of the radionuclide concentration in surface soil (expressed on a dry mass basis and averaged over some specified depth), the dust load in air derived from local soil (not necessarily identical to the total dust load in air), and an enhancement factor reflecting the degree to which the resuspended dust is enhanced (or depleted) in the radionuclide of interest relative to the local soil.[2] The enhancement factor depends on the soil texture, as radionuclides tend to be preferentially adsorbed to the smallest soil particles, and these are preferentially resuspended. Thus, the enhancement factor is largest for sandy soils (as these have the smallest fraction of small particles) and smallest for clay soils.

Dust loads in air are very variable, ranging from <0.1 mg m^{-3} up to ~100 mg m^{-3} during disturbance by mechanical action. The soil depth from which resuspension occurs is not well defined, but it is plausible to take it as about 1 mm. As surface soil has a dry bulk density of around 10^3 kg m^{-3}, the total mass of soil available for resuspension is around 1 kg m^{-2}. Applying

[2] See discussion of enhancement factors provided in Algorithm for Calculating an Availability Factor for the Inhalation of Radioactive and Chemical Materials, EGG-2279, prepared by Envirosphere Co., New York, NY for the U.S. Department of Energy under Contract No. DE-ACO7-76IDO1570, February 1984.

a resuspension factor in the range $1*10^{-9}$ to $1*10^{-5}$ m^{-1} (see above), the calculated dust load in air is in the range 0.001 to 10 mg m^{-3}. Thus, there is an overlap in the ranges calculated by the two methods, but the dust loading approach tends to give rather larger values.

Since the dust loading approach is more applicable at long times when a soil profile has developed, is more readily related to physical processes, and typically yields higher concentrations of radionuclides in air (and hence is claimant favorable), it is preferred for assessment purposes. For instance, in a recent international study on long-term impact of contaminant releases from waste disposal, the French nuclear waste agency, ANDRA, noted the following:

> *Particulate resuspension from terrestrial surfaces is caused by wind erosion of soil, vehicle traffic on dusty roads, industrial and agricultural activities and combustion of biomass for fuel or land-clearance. The effects of these processes are poorly understood. Even the science of wind erosion, which has been studied extensively, does not permit prediction of the upwardly directed flux of soil particles resuspended by wind action. Thus, the conventional flux dispersion methodology must be abandoned and resuspension and subsequent deposition of dust or soil onto plants and soil surfaces is generally computed using a mass-loading approach. This approach treats all the particulate resuspension processes simultaneously.* [BIOPROTA 2005, pg. 6]

In summary, SC&A recommends that, in the context of estimating environmental internal occupational exposures at NTS at times more than a few weeks after deposition, that NIOSH use a dust loading approach, with dust values chosen in an appropriately claimant-favorable manner.

5.5.2.9 Conclusions in the TBD regarding resuspension intake estimates and their implications for dose estimates need to be reconsidered.

The TBD recommends that the values in Table 4.2.2-3 be used for resuspension intakes for monitored workers. The values in this table are not claimant favorable and do not represent a full exploration of the uncertainties in intakes of radionuclides by unmonitored workers. The various factors that need to be considered and included in claimant-favorable ways before the estimates of intakes could be considered scientifically defensible and claimant favorable are as follows:

- The radionuclide concentrations at or near ground zero areas are likely to be much higher than the average for affected areas, and some workers who were involved in clean-up work and equipment retrieval would be more likely to go to such areas. The choice of values for areal radionuclide density needs to be made more claimant favorable.

- The general assumption that unmonitored workers were not at risk needs to be re-examined for some job types and time periods.

- Early entry into contaminated areas (less than 100 days after the shot) should be evaluated for some groups of workers, including unmonitored workers. This evaluation should include consideration of the resuspension factor as well as the radionuclide list to be used in assessing intake.

- The raw data from which areal radionuclide densities are estimated need to be analyzed to establish uncertainties created by sampling procedures that use a grid that is either too crude or non-representative. Such an examination may yield insights into how claimant-favorable values for areal radionuclide density can be established in light of relatively sparse survey data, especially in some areas.

- Activation products need to be factored in and their solubilities need to be explicitly considered.

- Large-particle-related doses to re-entry workers and other time-specific issues need to be developed in order to ensure scientifically sound and claimant-favorable dose estimates.

- There are a number of parameters involved in the estimation of mean and 95th percentile values for the resuspension factor that have not been taken into account. These include sampler underestimation of 5 to 10 micron particles at high wind speeds, the likelihood that in some time periods unmonitored workers did enter areas with high contamination soon after test shots (in the early period to 1957), and uncertainties in the time of entry of workers into the contaminated areas.

- The choice of Type S solubility for some radionuclides is neither scientifically defensible nor claimant favorable. The choice of Type F solubility of cesium oxide, for instance, is a reasonable one scientifically, for the most part (see above), and it results in a higher dose to some organs than an assumption of Type S solubility (e.g., kidneys). The more claimant-favorable value should be used.

In summary, the estimates of intakes of radionuclides recommended in the TBD (Vol. 4, Table 4.2.2-3, pg. 33) due to resuspension could be too low by one to several orders of magnitude. In addition, unfavorable solubility assumptions in some cases would lower the doses for any given assumed intake. A considerable amount of scientific, statistical, and analytical work remains to be done before resuspension doses could be said to be scientifically defensible and claimant favorable. SC&A recommends that NIOSH use the dust loading approach for estimating internal intakes, since it is more scientifically defensible and claimant favorable for times more than a few weeks after radionuclide deposition.

5.5.3 External Occupational Environmental Dose

5.5.3.1 Overall Finding Regarding Occupational External Environmental Dose

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

The TBD provides data for ambient external gamma radiation at different NTS areas that are listed in Table 4.3.1-2. The data covers the years 1967 to 2001. However, there are no data for the years 1968 through 1976 (inclusive). If the area is known in which a claimant has worked, the data listed for the area should be used in the dose reconstruction. According to the TBD, if the work area is not known, the maximum value should be selected. For 1963 to 1966, the maximum value reported for 1967 that was measured at Area 3 (318 mrem yr^{-1}) should be assigned. The TBD states on page 40 that to do so is "reasonable and probably claimant favorable" because "it is likely that the elevated ambient radiation peaked in the early 1960s near the end of above-ground testing." The TBD does not specify any approach to reconstructing the external environmental dose for the period 1968 to 1976.

This finding consists of a number of sub-elements that focus on the following issues:

- Are the data in Table 4.3.1-2 representative for a particular area in question?

- Is it claimant favorable to use the Area 3 value for 1967 for the time period 1963 to 1966?

- Can the data in the TBD be used to estimate occupational external environmental dose for the period prior to 1962?

- What are the issues relating to the 1968–1976 period for which there are no data in Table 4.3.1-2?

5.5.3.2 Representativeness of data for a given area needs to be further evaluated.

The external gamma dose rates after the end of above-ground testing vary by area and within a given area. Two contributors to the external dose rate are natural background and global fallout, but their variability from area to area is probably small. The area-to-area variability due to NTS operations can be attributed to deposition from atmospheric testing, venting of underground tests, and other sources of radioactivity deposition (or re-deposition). Figure 3 indicates that the locations of the tests cover a large geographic area. In contrast to this, gamma dose rates were usually monitored at one location in a given area (Figure 4). Figure 5 indicates that the locations of the NTS ionization chambers were not in the most contaminated area. In addition, short-term exposures from cratering events, such as SCHOONER, were unlikely to be covered by the sparse network that the TBD relies on. This is illustrated by the fallout map for test SCHOONER in December of 1968 (Figure 6). The test was detonated in Area 19, but the closest locations with gamma dose rate data are Areas 12 and 18. It does not appear that the monitoring locations were in the fallout path.

The variability of the external dose is large (Figure 7) and is, in part, explained by NTS tests. In addition, the measured external dose is strongly correlated with the beta activity in air, as shown in Figure 8. The variability in soil contamination has resulted in a variability of airborne radioactivity, and probably external gamma dose rates as well. It is, therefore, possible that a person who was present in a given area was exposed to higher external doses than those reported in the TBD on the basis of a single location. Therefore, it has not been demonstrated by ORAU that the sampled location is either representative or claimant favorable.

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

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.

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

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.

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

The TBD does not discuss estimation of external environmental doses during the period of atmospheric testing (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

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

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.

- 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.

- 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.

- 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.

- 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).

5.5.3.7 Conclusions regarding external environmental dose for unmonitored and monitored workers need to be evaluated further.

(1) The TBD has not demonstrated that the reported gamma doses are claimant favorable for a given area in a given year. It is unlikely that it is claimant favorable to assign 1967 data for the time period 1963–1966.

(2) No method has been developed in the TBD to assess environmental external doses for the atmospheric testing period 1951–1962.

(3) The factors relating to external environmental dose geometry for monitored workers have not been considered.

(4) It may be very difficult to make best estimates of external environmental dose for unmonitored workers, given the uncertainties. A set of assumptions that would systematically give claimants the benefit of the doubt for the various sources of uncertainty remains to be developed.

(5) There are some issues regarding external environmental dose estimation for monitored workers that remain to be addressed. Correction factors to resolve issues relating to geometry of exposure and time of entry need to be developed to demonstrate that the dose estimates are claimant favorable for the periods when monitored workers' duties led them to spend a significant proportion of their time in outdoor contaminated areas or some time in such areas shortly after tests. Off-normal practices also need to be taken into account.

5.5.4 Radon Dose

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

The TBD recommends using the data in Table 4.4.1-1 for ^{222}Rn 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.

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.

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).

Finding 9: Accuracy of HTO sampling is questionable.

The TBD summarizes HTO atmospheric concentrations in Table 4.2.1.2.1-1 on page 14. The efficiency of silica gel to capture water at low humidity is poor, as determined at Los Alamos. There, the amount of water collected in the dry season was less than a quarter of the amount expected from measured humidity levels (Eberhardt 1999). Since the environment at NTS is even drier than at Los Alamos, a correction factor needs to be developed for this loss of efficiency in low humidity. Ideally, the correction factor should be dependent on the season. However, in the context of dose reconstruction, NIOSH might consider developing a single year-round, claimant-favorable correction factor.

The NTS site environmental reports do not appear to have corrected for this. If Los Alamos values are used, the reported data may have to be adjusted by a factor of ~4. Given the drier climate, the correction could be higher. SC&A has not done a detailed evaluation of the correction factor that would be suitable for the climate at NTS. SC&A notes that a suitable correction factor may result in HTO dose estimates of up to 8 or 10 mrem yr^{-1}, rather than less than 2 mrem per year estimated in the TBD (Vol. 4, pg. 12).

The TBD does not provide any reference or other scientific basis for the stated ratio of a factor of 2 between the mean and 95th percentile values. As noted above, just one factor that was not considered, humidity, could lead to an error of a factor of 4 or more. Other uncertainties would be on top of this systematic measurement error. Finally, SC&A notes that there are no HTO measurement data before 1977. Since atmospheric tests would be expected to generate the largest amount of tritium, an estimation procedure for environmental dose for this period needs to be developed. An estimation procedure for the pre-measurement period, notably the 1963–1970 period when there were several important inadvertent vents of tests, needs to be developed. It is not clear that the reasoning in the TBD that HTO doses were low for the post-1977 period would apply to the first two decades of NTS operation.

5.5.5 Occupational Iodine-131 Data

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

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.

5.5.6 Soil Ingestion

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

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.

Table 4: Size of NTS Areas Contaminated with Plutonium-239,240 as Determined by Soil Inventory Data

NTS Area Number	NTS Area size (km^2)	Contaminated area used for inventory calculation (km^2)	Percentage of area with $^{239,240}Pu$ contamination
1	70	69	99%
2	52	51	98%
3	83	84	100%
4	41	41	100%
5	246	8	3%
6	212	84	40%
7	52	50	96%
8	34	36	100%
9	52	52	100%
10	54	52	96%
11	67	10	15%
12	104	100	96%
14	67	-	0%
15	96	91	95%
16	73	37	51%
17	80	81	100%
18	231	71	31%
19	388	380	98%
20	259	16	6%
22	83	-	0%
23	13	-	0%
25	578	2	0%
26	57	1	1%
27	130	-	0%
29	161	-	0%
30	150	1	1%
Total	3,433	1,316	38%

Table 5: Ambient Radiation Measurements at NTS Areas

Year	Area with maximum radiation	Maximum radiation (mrem yr^{-1})	Area 3 radiation (mrem yr^{-1})
1967	3	318	318
1968	3	285	285
1978	10	320	200
1979	12	191	190
1980	20	207	199
1981	3	218	218
1982	10	209	188
1983	20	206	181
1984	7	327	162
1985	7	347	78
1986	7	318	150
1987	19	246	184
1988	19	223	207
1989	2	217	205
1990	20	192	187
1991	3	194	194
1992	19	189	173
1993	20	213	200
1994	15	143	62
1995	5	212	150
1996	5	225	151
1997	30	170	131
1998	7	201	137
1999	7	191	135
2000	7	217	161
2001	2	299	151

Source: NTS TBD Vol. 4, Table 4.3.1-2, pp. 38–39.

Table 6. Iodine-131 Releases from Underground and Cratering Tests that Resulted in the Detection of Offsite Radioactivity

Test	Date	^{131}I (kCi)
Yuba	5-Jun-63	0.000022
Eagle	12-Dec-63	0.00228
Oconto	12-Jan-64	0.001
Pike	13-Mar-64	0.36
Alva	19-Aug-64	0.000037
Drill	5-Dec-64	0.0122
Parrot	16-Dec-64	0.0046
Sulky	18-Dec-64	13
Alpaca	12-Feb-65	0.000024
Palanquin	14-Apr-65	910
Tee	7-May-65	0.0016
Diluted Waters	16-Jun-65	0.0177
Red Hot	5-Mar-66	0.2
Fenton	23-Apr-66	N.A.
Pin Stripe	25-Apr-66	0.2
Double Play	15-Jun-66	0.12
Derringer	12-Sep-66	0.00024
Nash	19-Jan-67	0.0138
Midi Mist	26-Jun-67	0.00026
Umber	29-Jun-67	0.00052
Door Mist	31-Aug-67	0.008
Hupmobile	18-Jan-68	0.12
Cabriolet	26-Jan-68	6
Buggy	12-Mar-68	40
Schooner	8-Dec-68	15
Pod	29-Oct-69	0.000078
Scuttle	13-Nov-69	0.000004
Snubber	21-Apr-70	0.0055
Mint Leaf	5-May-70	0.08
Baneberry	18-Dec-70	80
Diagonal Line	24-Nov-71	0.00136
Riola	25-Sep-80	0.00058
Glencoe	22-Mar-86	0.000000009
Mighty Oak	10-Apr-86	0.0024

Source: NCI 1997, Tables 2.2 and 2.3 (pp. 2.8 and 2.9)

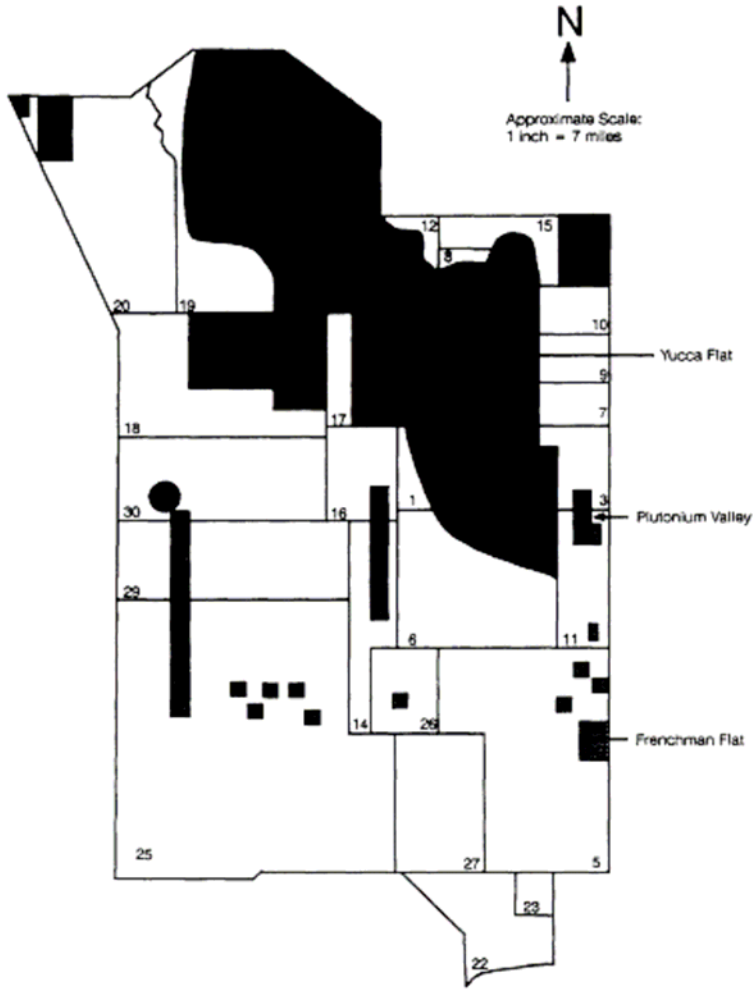


Figure 1: Portions of the NTS Surveyed by the Radionuclide Inventory and Distribution Program
(Source: McArthur 1991)

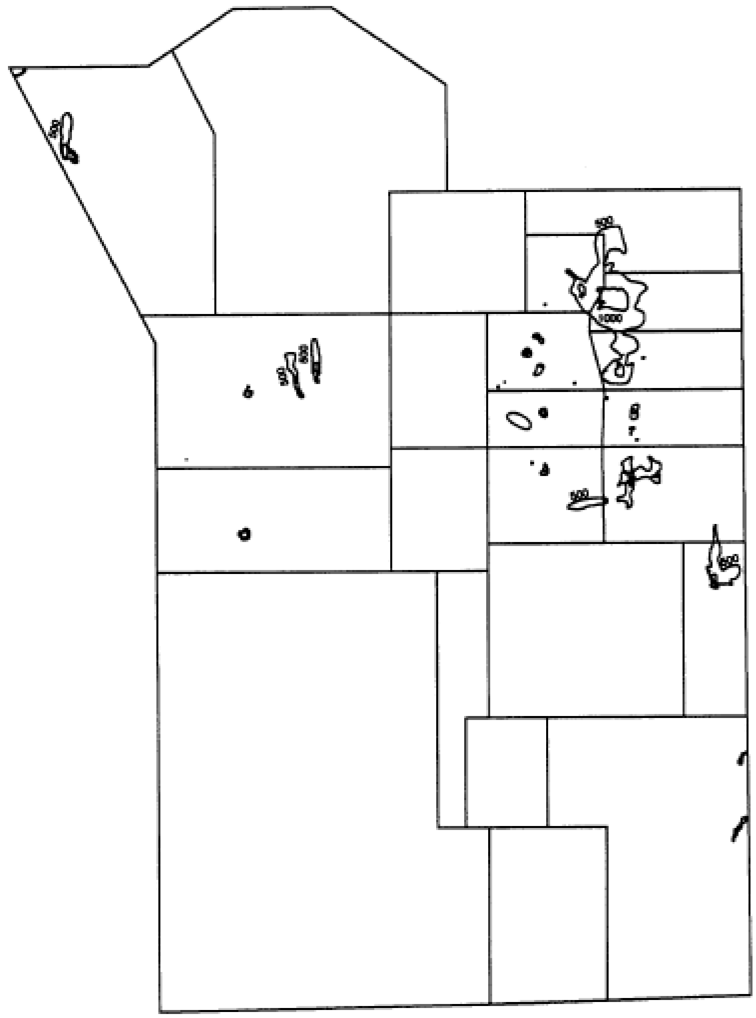


Figure 2: Distribution of Plutonium-239,240 on NTS as of January 1, 1990
Isopleth levels are 500, 1,000, and 10,000 nCi m^{-2} (McArthur 1991)

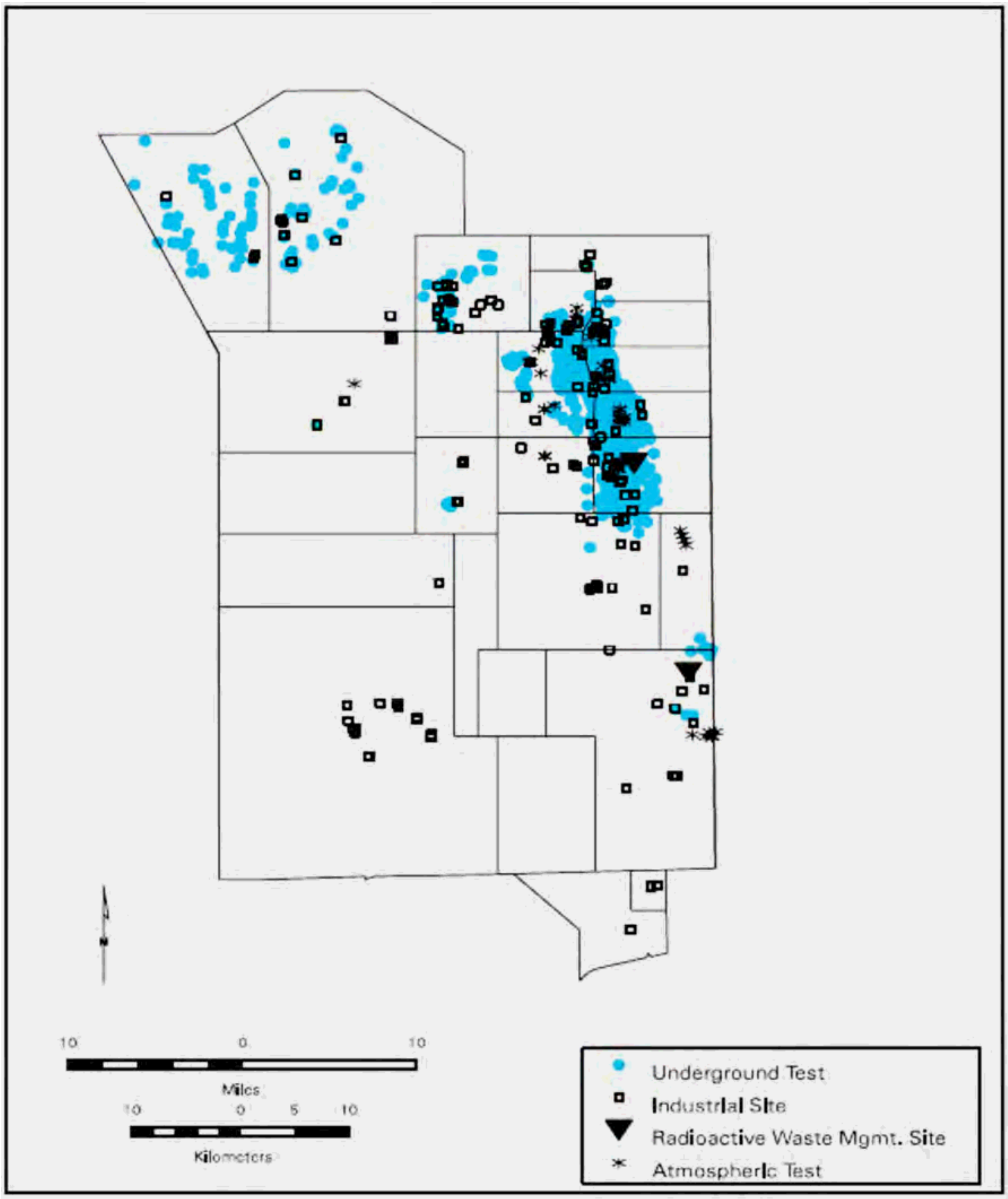


Figure 3: Locations of Atmospheric and Underground Nuclear Tests, Industrial Sites, and Operating Radioactive Waste Management Sites on the Nevada Test Site

(Source: Hechanova and O'Neill 1998)

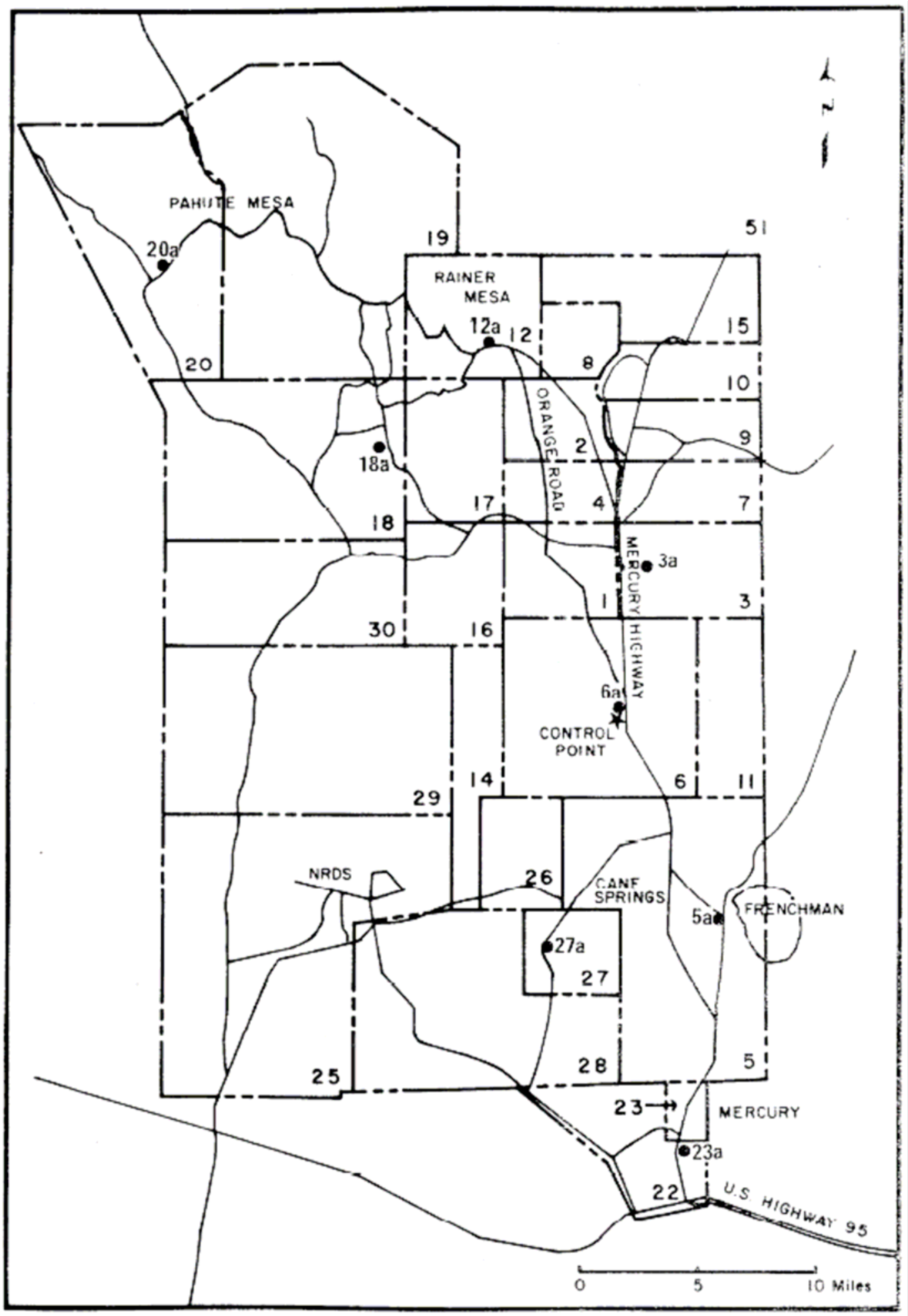


Figure 4: **NTS Ionisation Chamber Sampling Locations at NTS, July 1966 to June 1967, marked 3a, 5a, 6a, 12a, 18a, 20a, 23a, 27a**
(Source: REECo 1968)

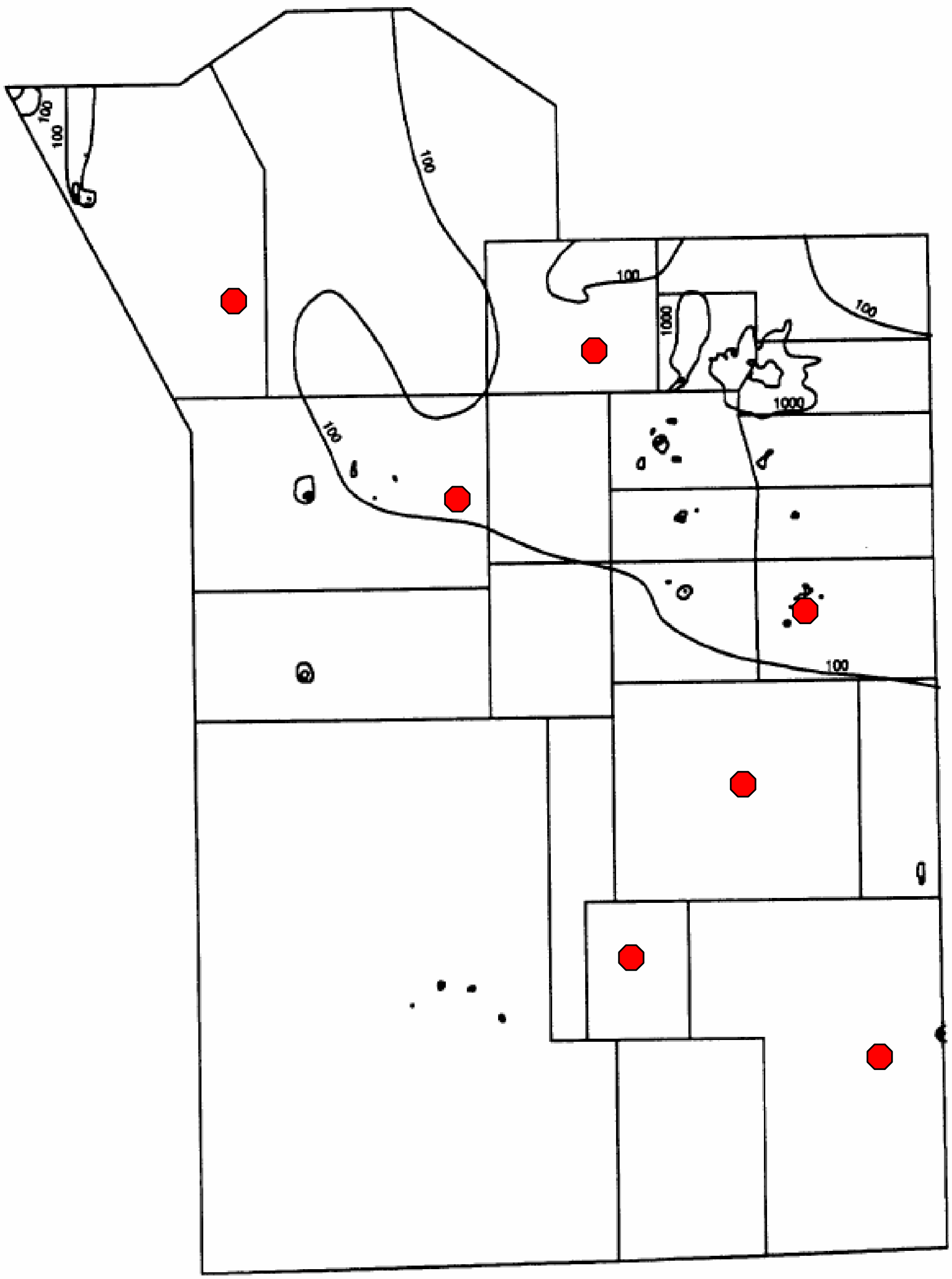
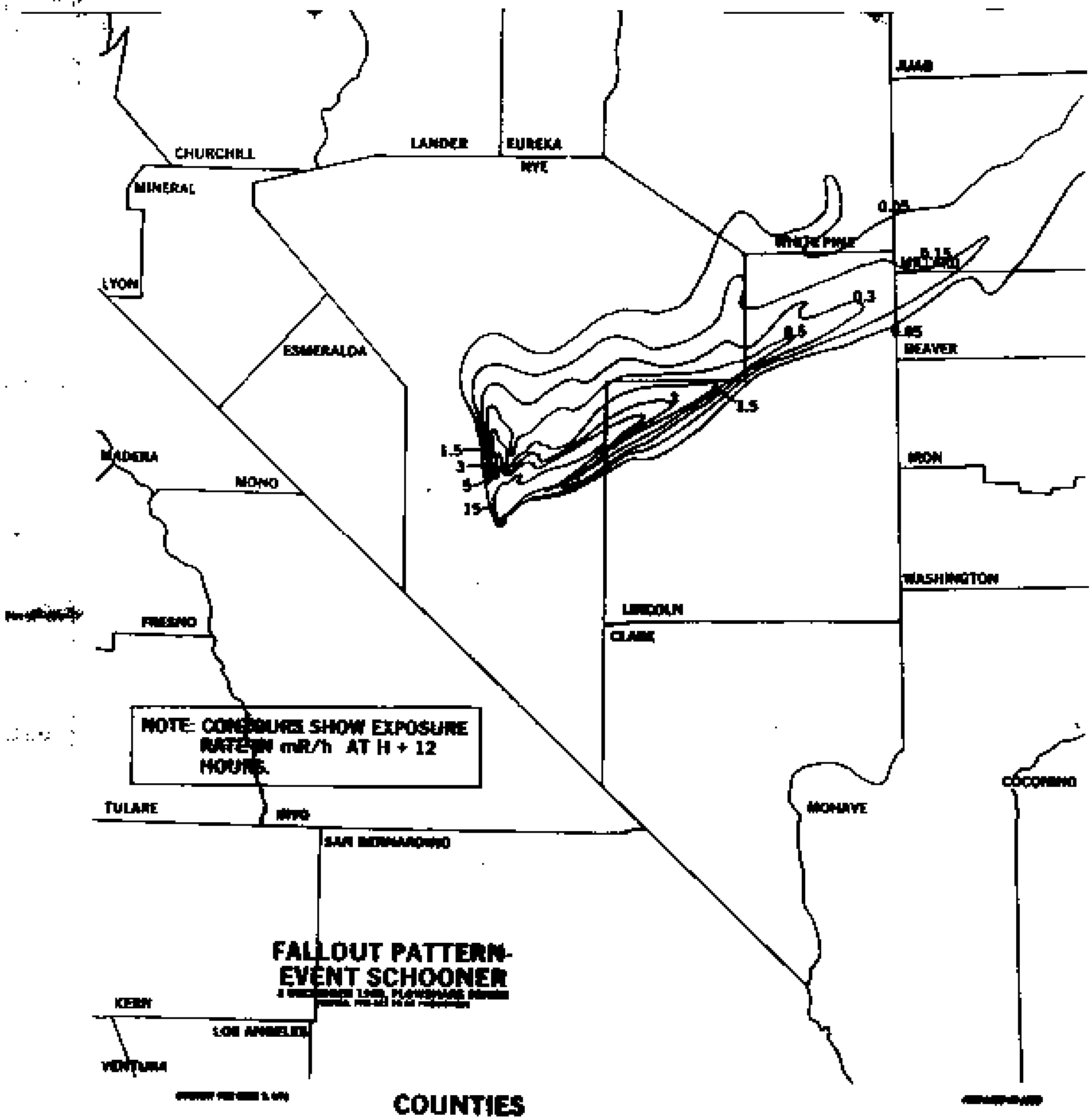


Figure 5: Areas with Cesium-137 Contamination and Approximate Locations of NTS Ionisation Chamber Sampling Locations (hexagons) at NTS, July 1966 to June 1967
(Sources: REECo 1968; McArthur 1991)

Figure UE/16/X. Map of close-in exposure rates, prepared by EG&G for the Department of Energy, related to the test SCHOONER of 8 December 1968.



- A.UE/16.7 -

Figure 6: Offsite Dose Rates Related to Ploughshare Test SCHOONER (from area 19)
(Source: http://www2.nci.nih.gov/I131/intros/BK0.html)

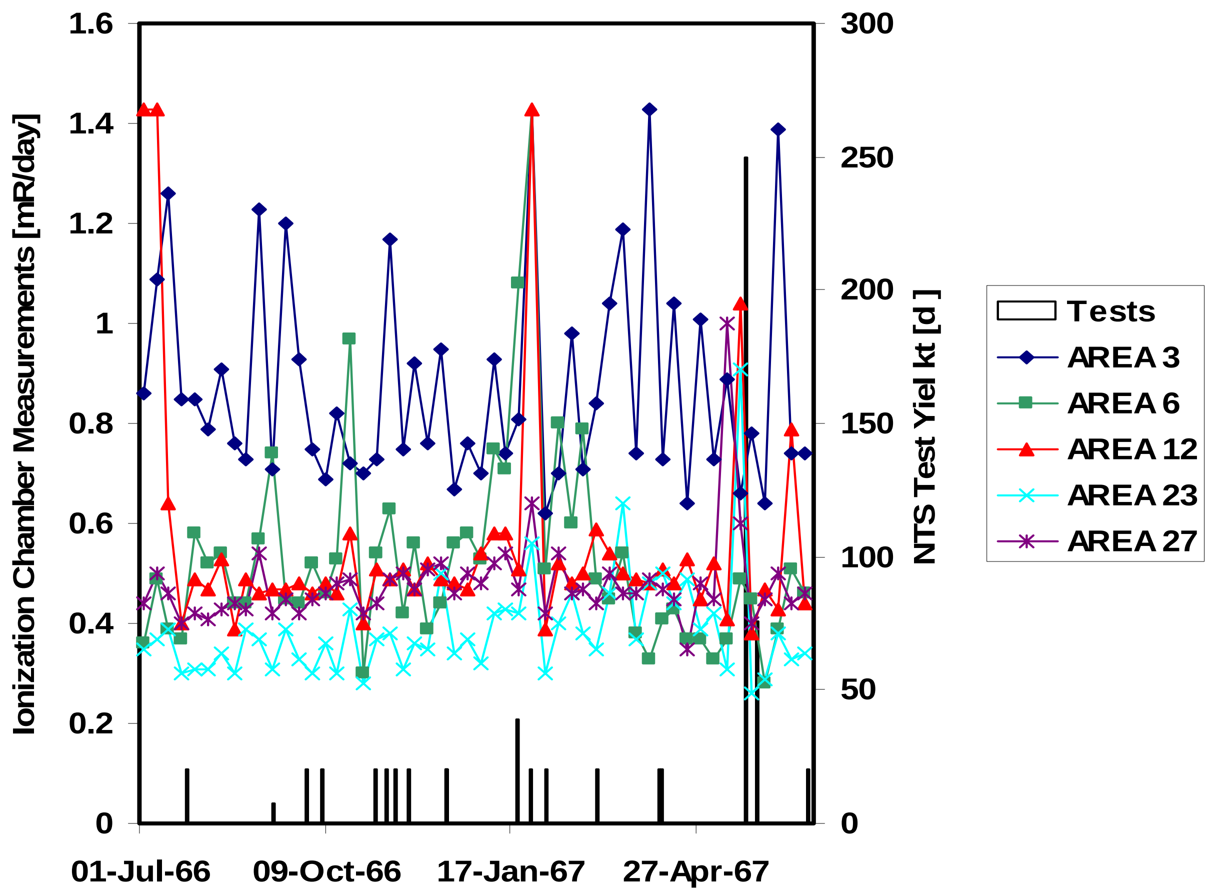


Figure 7: Ambient External Gamma Radiation at Nevada Test Site, July 1966 to June 1967
(Source: REECo 1968)

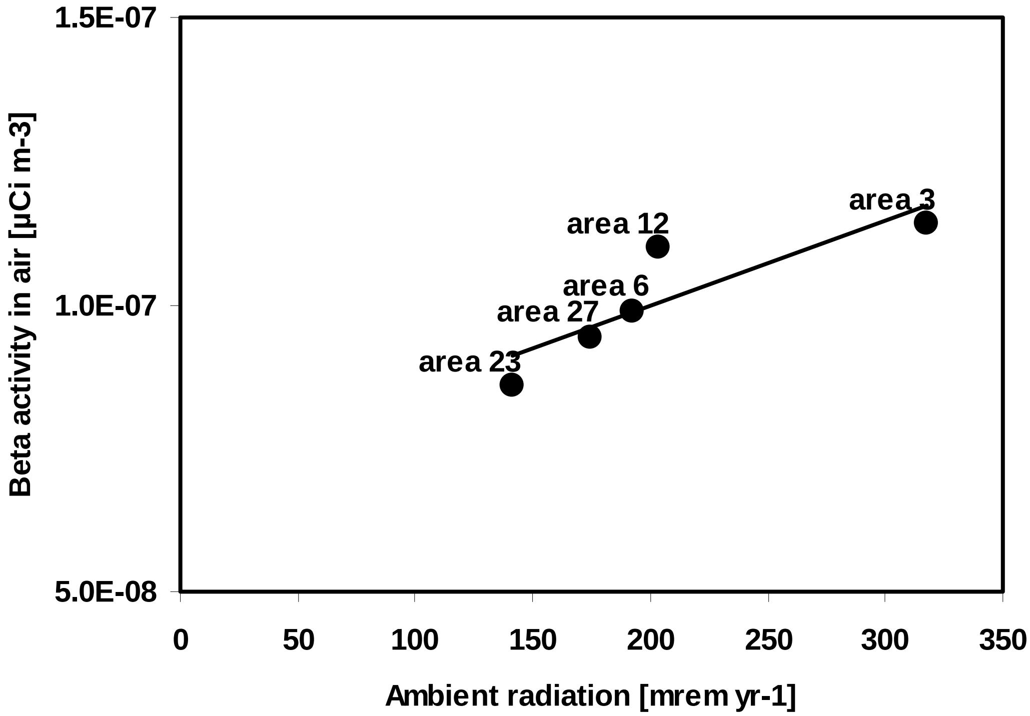


Figure 7: Correlation between Ambient External Gamma Radiation and Beta Activity in Air at the Nevada Test Site, July 1966 to June 1967
(Source: REECo 1968)

5.6 ISSUE 6: INTERNAL DOSE

5.6.1 Overview

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

In this section, a review is provided of the occupational internal dose component of the Technical Basis Document (TBD) for the NTS. The information reviewed is included in Volume 5 of the NTS TBD, ORAUT-TKBS-0008-5, Revision No. 00, September 2004 (herein referred to as NTS TBD Vol. 5.)

A special characteristic of the NTS is that most of the activities are conducted in projects (often of short duration), and that radiological protection activities are tied to those projects (NTS TBD Vol. 5, pages 10 and 11). It is not clear whether this has been the case throughout the operations of the NTS, which is a matter to be clarified, but this seems likely to have been the case. Even if this has not been the case, it is clear that the potential for internal exposure and the mix of radionuclides to which workers could have been exposed will have differed substantially from project to project. Thus, for the purposes of dose reconstruction, it is fundamental that the dose reconstructor should begin by developing a timeline of the work history of the claimant matched to the various projects that occurred at the NTS during the period of employment of the claimant. Though implicit in the text, this needs to be brought out clearly as an overarching principle, as it applies more strongly at NTS than at some other facilities, where similar activities persisted for many years and provided a context in which more limited special campaigns occurred. This finding is divided into a series of sub-elements described in the following sections. Interspersed in these sub-elements are both Findings and Observations.

An overarching suggestion that might be helpful in addressing many issues related to reconstructing internal doses to workers who entered contaminated area shortly following atmospheric tests, but had inadequate internal dosimetry, is to carefully consider the extensive data and dose reconstruction protocols that have been developed by the Defense Treat Reduction Agency for reconstructing internal doses to veterans who supported weapons testing at the NTS.

5.6.2 Important Details as Regards Interpretation of Various Kinds of Internal Dose Data are Not Included in the NTS TBD Vol. 5

The wide range of projects and radionuclides of potential relevance at the NTS meant that a wide variety of bioassay procedures were adopted. It appears that in the early period of site activities, there was an emphasis on screening (NTS TBD Vol. 5, page 10). This seems consistent with the view that external exposures generally dominated, and that significant internal exposures constituted incidents. However, such screening generally provides no more than an indication that significant internal contamination may have occurred. It may be appropriate to insert a caution to the dose reconstructor that such samples should not be interpreted quantitatively. This should be obvious in respect to nasal swabs, but there may be a temptation to treat initial urine samples as having the same status as later samples, whereas they may have been collected under very different circumstances (e.g., spot versus 24-hour samples) and may have been at greater risk of contamination (e.g., from soil or fecal material). NTS TBD Vol. 5 provides useful detail on the methods by which bioassay samples were analyzed, but almost nothing on how they were collected. Knowledge of methods of collection is fundamental to determining how such samples should be interpreted and the weight that should be attached to the results obtained. Although descriptive information is sometimes provided, e.g., ‘24-hour urine sample,’ it is very sparse. For example, no information is provided on when urine samples were given for different projects or under different potential exposure conditions (end of shift, before shift, 24-hour collection). Section 5.2.3 of the NTS TBD Vol. 5 (page 21) does give some information on correcting for urinalysis volume, but the contents of the four bottles are not specified, so the interpretation of an ‘equivalent 24-hour sample’ is obscure. Also, the collection of both 24-hour and spot (single void) urine samples is identified (but not the circumstances under which samples of different types were taken), and a statement is included that normalization was made to total 24-hour excretion. However, it is not clear what basis was used for normalization. This could, for example, have been by volume or by creatinine content. Further to this point, there are confounding relationships between the volume of urine excreted and the biokinetics of radionuclides that should be explicitly recognized. For example, high intakes of fluids (either occurring routinely or encouraged if an intake of tritium was suspected) decrease the half-life of tritium in the body and modify the relationship between concentration in urine and amount excreted per day. In this case, dose calculations are most robustly undertaken by assuming that the tritium concentration in urine is representative of the concentration in body water. However, in the case of uranium, the evidence suggests that the fractional loss in urine per day is approximately independent of fluid intake, so the concentration in urine will vary inversely with the excreted volume, and correction to a standard volume is necessary if the current body burden is to be inferred.

The wide variety of bioassay procedures adopted was selected to determine intakes and body contents of different radionuclides. Although some of the techniques were specifically directed to particular radionuclides (e.g., thyroid counting for radioisotopes of iodine), others were of wider applicability. Specifically, several different techniques, if applied to the same individual, would provide complementary information on intakes of a particular radionuclide. Thus, for example, on page 10 of the NTS TBD Vol. 5, it is recognized that urine and fecal sampling, together with lung and whole-body counting, are useful to detect and assess intakes of actinides. Although this is recognized, the NTS TBD Vol. 5 gives very little indication to the dose reconstructor as to how bioassay measurements either from a single technique or from multiple techniques should be used in dose estimation. It is tempting to restrict the TBD to providing factual information and to leave issues of interpretation to other documents, but this is not possible. A view has to be taken on how the data will be used to determine what information is to be included and what excluded from the summary provided in the TBD. The NTS TBD Vol. 5 needs to be substantially augmented to provide clear guidance on how the bioassay data are to be used to generate reconstructed doses to claimants. This key aspect of the work is scarcely addressed.

In Table 5-1 (NTS TBD Vol. 5, page 12), Minimum Detectable Activities (MDAs) are given for various in-vitro sample analyses. Information is given for fecal samples for all the actinides, except for ^{244}Cm. It is thought that this is an oversight. The information for ^{244}Cm should be obtained and added. In Footnote "a" to this table, a reference is made to adjustments to the minimum detectable amount for larger sample sizes. It is not clear what adjustments were made or how they were justified. The text should be expanded to address these issues.

Section 5.2.2.1 includes a very useful table (Table 5-2) on the relative abundance of various radioisotopes of iodine. However, it is based on calculations undertaken in the late 1950s and early 1960s. It should be confirmed that the nuclear data used in those calculations were fit for purpose, notably in terms of the half-lives used. It is unlikely that there will be significant revisions, but it is a Finding that here, and throughout, historical data should not be accepted at its face value. If possible, such calculations should not simply be reproduced, but should be checked and confirmed. In this case, the calculations should be straightforward. In other cases, the information available may not be sufficient for the calculations to be reproduced. In such cases, it should be explicitly stated that it has not been possible to confirm the original calculations.

In some of the descriptions of early methods for source preparation (e.g., for Americium, as described on page 14 of the NTS TBD Vol. 5), the precipitate produced from the radiochemical procedure is described as being slurried onto a stainless steel plate for counting. Although the original documentation on the methods has not been checked, the terminology used suggests that a thick source of ill-defined geometry could have been produced. For alpha counting, this could imply substantial variations in the relationship between count rate and sample activity from sample to sample. The original procedures and results of counting of standards need to be examined to see whether this was the case.

Also relationships are given between mass of an element and count rate (see Section 5.2.2.3 of NTS TBD Vol. 5). Such relationships can only apply to a particular mix of radioisotopes, but this is not specified. The fundamental quantities determined are count rates and mass concentrations are of little relevance in the current context.

On page 15 of the NTS TBD Vol. 5 and elsewhere, there are references to old compliance criteria that imply particular biokinetic assumptions. Thus, 0.02 pCi of ^{239}Pu in a 24-hr sample of urine is stated to represent less than 5% of a maximum permissible body burden of ^{239}Pu. When analyzing the data, care should be taken to use the underlying observations, e.g., concentrations of ^{239}Pu in urine, and not interpretations of those observations, e.g., body burden, as such interpretations are contingent on the biokinetic model in use at the time. It may be worth inserting a cautionary footnote on this point.

It is assumed that MDA-based calculations will be performed for all radionuclides of relevance, as required. However, the interpretation of MDA-based calculations will be very different, depending on the radionuclide in question. In the case of tritium, monitoring often occurred only quarterly. HTO has a half-life in the body of only 10 days in temperate conditions, and considerably less in the desert conditions in Nevada, where fluid intakes would have been high in normal circumstances (and potentially further enhanced if tritium contamination was known or suspected). Therefore, quantification of intakes that could have occurred as much as 90 days before monitoring would be practically impossible, since the intake would have occurred between 9 and more than 20 biological half-lives earlier, depending on total fluid intake. In contrast, for plutonium, urine monitoring is primarily useful in estimating the accumulated body burden, rather than recent intakes, and daily excretion is less affected by environmental conditions (though the concentration in urine can be affected because of variations in the volume excreted). For uranium, the situation is more complex, as excretion reflects both recent intakes and the accumulated body burden in a way that depends on the previous pattern of intakes. These comments illustrate the general issue that the NTS TBD Vol. 5 is strong on the quantification of MDA values, but weak on how bioassay data (including both positive results and MDA values) are to be used in dose reconstruction. In particular, it would be useful to provide a comprehensive set of MDA values and explicit calculations of how the annual missing doses to be associated with those MDA values should be calculated.

A routine use of MDA values for dose estimates without the analysis suggested above, and without explicit consideration of the issues discussed in the internal dose section, does not appear to be warranted.

5.6.3 Lack of Early Internal Monitoring Data

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.

5.6.4 Assigning Only Environmental Doses to Workers Thought Not to be at Risk of Internal Exposure may Not Capture the Full Extent of Radionuclide Intake

Unlike universal external monitoring after 1966, not all workers were monitored for internal intake. Monitoring and radionuclide coverage were dependent on judgments that workers were at risk of internal exposure, even after the capability to monitor a range of radionuclides was established. The question therefore arises as to how internal doses should be reconstructed for workers that were not subject to bioassay because the contribution from internal dose was perceived, at the time, to be small.

It seems from the NTS TBD Vol. 5 (page 35) that such workers will only be assigned environmental doses. However, if they were involved in particular projects, this may result in underestimation of their doses. A more acceptable approach may be to identify a comparable population of monitored co-workers and to assign doses based on dose reconstructions for those co-workers. The co-worker approach has been applied at other facilities, but is not addressed here. During the conference call with SC&A, NIOSH stated in the context of external dose estimation that co-worker dose could be assigned to unmonitored workers, but that guidance specific to NTS may not be on the calendar for development as yet (Attachment 3).

However, it is noted that Section 5.5.4 of the NTS TBD Vol. 5 (page 36) comments that guidance for monitored workers with few or no bioassay measurements is under development. Once this guidance has been developed, consideration should be given to whether it can be adapted to apply to groups of unmonitored workers that may have had higher levels of internal exposure than would have been typical for unmonitored workers who were not at risk of internal exposure.

SC&A notes that dose reconstructions should not be unduly influenced by contemporary judgments on the relative importance of external and internal exposure. Those judgments were conditioned by the environmental, biokinetic, and dosimetric models available at the time. It is important that internal dose reconstructions should be undertaken using the underlying data and best present-day techniques. Judgments on the relative importance of external and internal exposure should follow from these reconstructions, and should not be imposed *a priori*. It is clear from other site profiles, that NIOSH intends that this principle should be followed, but it is important to state it explicitly here, as there is the potential that dose reconstructors may rely on apparently authoritative statements made at the time that internal exposure was not an issue. Such statements have to be confirmed by quantitative calculations.

Because of the type of operations that occurred at NTS, a wide variety of different radionuclides was of relevance. The specific radionuclides differed from context to context. As noted above, one of the strengths of the NTS TBD is that it identifies the radionuclides of interest in various contexts (though SC&A has also noted that some of these lists are not complete). However, it is a weakness that this is done on a case-by-case basis, so no overview is ever provided to the dose reconstructor of the radionuclides that may need to be taken into account.

It would strongly facilitate auditing of dose reconstructions if a master list of all radionuclides of potential relevance to monitoring or of possible radiological significance was drawn up and displayed early in the NTS TBD Vol. 5. There is a list in NTS TBD Vol. 2 (pg. 37), but it is incomplete and does not indicate that time dependence could be completed and refined for this purpose. The dose reconstructor could then proceed by first screening that list to identify which radionuclides were of relevance to the particular claimant under consideration, and then determining what quantitative information was available on those radionuclides determined to be of relevance. Documentation of the screening aspect would help to ensure that a full audit trail was created of all qualitative and quantitative decisions made in dose reconstruction. Although this is an overarching issue that has relevance to all site profiles, the wide variety of radionuclides and contexts occurring at NTS means that this requirement has first been identified in this context. SC&A notes that ^{134}Cs is omitted from the list of radionuclides of primary dosimetric concern at NTS TBD Vol. 5, page 10. As ^{137}Cs is listed, this omission is surprising.

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

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.

5.6.6 The NTS TBD Vol. 5 does Not Adequately Consider the Possibility of Exposure to Different Enrichments of Uranium

On page 17 of the NTS TBD Vol. 5, it is proposed that the ratio of the radioactivity of ^{238}U to ^{234}U in urine can be used as an indicator of exposure to Depleted Uranium (DU) or Highly Enriched Uranium (HEU). The criteria given are that DU has a ^{238}U:^{234}U in the range of 3 to 10, HEU has a ratio of about 0.1 or smaller, and natural uranium has a ratio of 1 or less. However, the discussion does not address the possibility of workers being subject to exposure to uranium of different degrees of enrichment at different times. As uranium in urine reflects a mix of uranium that has recently entered the systemic circulation and remobilization of older deposits, notably in mineral bone, there are potentially large ambiguities of interpretation in this context. This issue needs to be discussed explicitly.

On page 18 of the NTS TBD Vol. 5, reference is made to a survey of approximately 60 non-occupationally exposed adults residing in the southwestern portion of Nevada who were sampled to determine the natural uranium background. The use of these survey data needs to be better explained. The implications of the text seem to be that a high percentile of the distribution from the non-exposed population would be used to identify occupationally exposed individuals. The text does not address the issue of any background subtraction to be made once the occupationally exposed individuals have been selected, but this may also be intended. Given the variability of natural background concentrations, it is realistic and claimant favorable to assume that such a background subtraction could be negligible in any individual case and, therefore, not to make any correction for background. This should be stated. As to excluding individuals, the main consideration is not whether the concentration could have arisen from natural exposure, but whether the concentration is radiologically significant if it had arisen from NTS exposure. On this basis, it seems more appropriate to treat the total concentration in urine as derived from NTS, if this was consistent with the work history of the individual. In this approach, the survey of non-occupationally exposed individuals would not be used to impose a lower limit on the uranium concentrations in urine considered for dose reconstruction.

Incidentally, in the survey results for non-occupationally exposed, it is odd that the 99.9th percentile is higher for total uranium than it is for the sum of ^{234}U and ^{238}U. The presence of ^{235}U cannot account for this difference. NIOSH should provide an explanation on this point.

5.6.7 Use of ORAUT-OTIB-0002

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.

5.6.8 Miscellaneous Internal Dose Issues

At the bottom of page 23 of the NTS TBD Vol. 5, it is stated that the MDA is directly proportional to the photon intensity (by which yield per decay is meant). This is surely incorrect. The MDA would be expected to scale in inverse proportion to the yield. This material should be checked and amended, as required.

On page 25 of the NTS TBD Vol. 5, it is surprising that the whole-body count sensitivities listed in Table 5-7 were only just adequate to detect the normal ^{40}K content of the body. This seems to indicate an exceptionally low sensitivity system, as ^{40}K is generally very prominent in such systems. The reasons for this low sensitivity should be pursued.

On page 29 of the NTS TBD Vol. 5, there seem to be two errors by a factor of 10 in the CWT-cm column of Table 5-11. 40.3 should be 4.03, and 28.0 should be 2.80. These errors should be corrected.

On page 31 of the NTS TBD Vol. 5, although wound dose is not estimated, presumably the occurrence of a contaminated wound initiated programs of special monitoring, e.g., of urine, that would have provided results that could be used in dose reconstruction. This matter should be discussed. Also on page 31, it is pointed out that air-sampling records were considered as workplace-monitoring records rather than intake monitoring. It is further noted (page 32) that correlation between sample concentrations in given rooms and work locations and a specific person would be difficult. These views are endorsed, as is the conclusion that the use of air-monitoring data should be considered only as a last resort.

On page 34 of the NTS TBD Vol. 5, where contamination external to the lung is mentioned in relation to chest counting, the reader may not understand that this includes internally incorporated radionuclides taken up in the ribs. This should be stated explicitly.

On page 47 of the NTS TBD Vol. 5, entry 042 in Table 5D-3 is ambiguous. Which isotopes of californium are included? This point should be clarified.

On page 50 of the NTS TBD Vol. 5, the MDA for tritium in urine changes from $5*10^6$ pCi/L from 1958 to 1976, to $1*10^3$ pCi/L from 1977 to 1987, $3*10^2$ pCi/L from 1988 to 1999, $1*10^3$ pCi/L from 2000 to 2002, and $5*10^3$ pCi/L from 2003 to present. It is understandable that the MDA should have been high in the early days. However, modern techniques of analysis were in place well before 1977 (liquid scintillation detection was in place by 1966, see page 16), so it is not clear why the MDA did not come down earlier. Furthermore, it is not clear why the MDA has increased by more than an order of magnitude since 1999, bearing in mind that the value was stable from 1988 to 1999. This raises the question of whether the MDA was optimistically estimated over that period, and whether the true value was higher.

Similarly, the MDA for ^{239}Pu in urine changed from 0.9 pCi/24-hr from 1954 to 1957, to 0.0225 pCi/24-hr from 1958 to 1960, 0.00225 pCi/24-hr from 1961 to 1976, 0.05 pCi/L from 1977 to 1987, and 0.01 pCi/L from 1988 to 2000. The reason why the MDA sharply increased from 1976 to 1977 by about a factor of 30 (assuming a 24-hr sample of 1.4 L) remains unexplained.

Other MDAs have not been examined at the same level of detail, but this sequence of values raises some interesting questions. MDA values should be carefully scrutinized for consistency, and the reasons for any anomalies identified and described. The review process would be facilitated if MDA values were converted to common units, as has been done here.

On page 53 of the NTS TBD Vol. 5, it is noted that the MDA for ^{99m}Tc increased between 1967 and 1993 (Table 5D-7). No reason is provided. The issues raised are similar to those outlined in the context of MDA values for tritium and ^{239}Pu.

On page 55 of the NTS TBD Vol. 5, the meaning of the central column in Table 5D-9 is obscure. This meaning should be clarified.

5.7 ISSUE 7: EXTERNAL DOSE

5.7.1 Overview of External Dose

Finding 13: 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.

The external dose volume of the NTS TBD (Vol. 6) is, in many respects, a well-based technical document with detailed descriptions of dosimetry practices and dosimeters that were in use at various periods. The information given in the TBD is useful and important for dose reconstruction and, in some respects, claimant favorable. Specifically, the NTS TBD guidelines are more claimant favorable than the dose reconstruction guidelines specified for the Idaho National Laboratory (see Section 7). The following presents sub-elements of this finding and includes both Findings and Observations.

5.7.2 Early Open Window Dose

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.

5.7.3 Data Integrity

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.

5.7.4 The TBD does Not Contain Complete Instructions for Converting External Dosimetry Data into IREP Inputs

Due to the special and highly varied nature of the activities at NTS, there was potential for exposure to an exceptionally large array of radionuclides from various irradiation geometries. Since these radionuclides have photon emission spectra that cover all three ranges of the inputs required for IREP, which is used to calculate the probability of causation, it appears crucial for the dose reconstructor that the TBD should define the photon energy spectrum and irradiation geometry for each type of work or installation. However, NIOSH did not find it essential that this information should be in the TBD, when this question was raised in the September 9, 2005, conference call between NIOSH and SC&A (Attachment 3):

> *SC&A inquired whether Rev. 01 would contain instructions for converting dosimetry data into inputs for IREP that is covered in other TBDs but which is not available in Rev. 00 of the NTS TBD. NIOSH responded that such information would be provided by dose reconstruction supervisors and that the TBD was not there to provide all details.*
>
> *SC&A pointed out that the details in question were essential, since their absence could result in inconsistent dose reconstruction. Without uniform guidance on the topic, different dose reconstructors would come up with different numerical values for the doses for the same exposure conditions.*

This ad hoc approach to providing information to dose reconstructors regarding photon spectra led to additional comments during the conference call that are worth noting in this context (Attachment 3):

> *…in the present context, the important question [that SC&A was asking] was: Is NIOSH saying that the TBD does not provide instructions for dose reconstruction.*
>
> *NIOSH responded by stating: "That is correct."*

SC&A understands that not all dose reconstruction data and guidelines can be included in a TBD. However, guidelines that are needed to prevent significant inconsistencies between dose reconstructions should be included in the TBD. In this instance, SC&A finds that due to the complexity of the problem and the variety of radionuclides at NTS and exposure geometries, basic guidelines for photon spectra and geometries associated with various jobs and locations should be specified in the TBD, in order to prevent inconsistencies in dose reconstruction. It is SC&A's recommendation that as much explicit guidance as possible be incorporated into the TBDs, and that NIOSH continue to develop workbooks with detailed instruction manuals as a means to ensure that this guidance is implemented in a consistent manner. Based on discussions held at recent meetings of the Advisory Board, it appears that this approach to the preparation of TBDs is being implemented.

5.7.5 Extremity Dosimetry

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.

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

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.

5.7.7 Neutron Doses

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.

5.7.8 Neutron Exposure During Atmospheric Testing

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 un-monitored 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.

5.7.9 Miscellaneous External Dose Issues

On page 10 of the NTS TBD, it states in Table 6.1 that the bias is 1.00 for photons for these years. In the detailed description of the response of the film dosimeter used from 1961 to 1966 (page 38), it is stated that the bias is 1.25 due to the loss of information of low-energy photons. It is suggested that the bias value in Table 6.1 be changed to 1.25.

On page 10 of the NTS TBD, it can be seen in the Table 6-1, column "Description" for the three film badges, that there is no overlap in the low and high dose measurement range. For the DuPont 556 Packet, there is in fact a "gap" between 5 and 10 R. For instance, if the dosimeter were irradiated with a 6 R exposure, the low-range element would show an exposure higher than 5 R, but the high range element would not show anything. It is suggested that the TBD should include a recommendation to the dose reconstructor on how to proceed in such cases.

On page 17 of the NTS TBD, there is the term "above the uncertainty edge of the filter;" the term "uncertainty edge" should be better defined.

On page 20 of the NTS TBD, in the equation $D_c = CF \times (D_i - D_o)$, D_c is defined as the calibration factor, as is CF from the text immediately above the equation. The terms D_o (actual dose) and D_i (indicated dose) are also not clear.

On the page 25 of the NTS TBD, it is stated "at the 90% confidence level." This should be "at the 95% confidence level."

On the page 26 of the NTS TBD, Table 6-4, the entry "0–150" is a typographical error. Also on this page, it is not correct to use the standard deviation of the background TLDs from all the monitored sites (as shown in Table 6.4) to calculate the LLD. The correct method is to determine the standard deviation of a background measurement at one site. The procedure is more or less as follows. Twenty monitors are prepared and left for a month in a low-background area. The monitors are read, and the mean and standard deviation are calculated. This standard deviation is then used to calculate the LLD. As the above standard deviation will likely be less than the 0.057 mrem/day quoted for the deep dose in Table 6-4, the approach used in the TBD is claimant favorable.

On page 31 of the NTS TBD, the legend of Figure 6-6 is not correct. It should read, "Conversion coefficients for personal dose equivalent $Hp(10,0^0)$ per unit Dose equivalent H as a function of neutron energy."

On page 34 of the NTS TBD, Figure 6-9 could be made more informative by extending the line of the graph up to at least 20 MeV. Also the y-axis title is not understandable. It should be Tracks/cm^2 per mrem.

On page 39 of the NTS TBD, there is a typographical error; the footnotes should be numbered (1) and (2).

On page 42, the X axis title should be "MeV." The caption of the figure should say "thickness of moderators."

5.8 ISSUE 8: MEDICAL DOSE

Finding 14: The guidance regarding the reconstruction of medical doses needs to address additional medical exposure scenarios, including the use of photofluorography, and additional uncertainties associated with routine chest x-rays.

The TBD does not provide any positive documentation that photofluorography was not used. In its response to SC&A questions on this issue (Attachment 3, Item #6), ORAU stated that, "[t]here is no documentation or anecdotal information that PFG was used." NIOSH assumes that there was no photofluorography done at NTS. This would not be an issue in cases where it can be established that a worker wore a film badge or TLD during the x-ray procedure. However, where this was not the case, more positive evidence of the type of equipment is needed. This is also true of the period 1957 to 1970 where there are no data at all about the type of equipment that was used and for which period NIOSH guidance indicates the PFG should be assumed in the absence of data.

The uncertainties in medical dose appear to be understated as a generic matter in NIOSH Site Profiles. SC&A has discussed this issue in detail in the review of the Rocky Flats TBD and that discussion is not repeated here.

6.0 OBSERVATIONS

6.1 ENVIRONMENTAL DOSE

6.1.1 Verification is needed of Environmental Monitoring Data Referenced in the TBD

A suitable reference nuclide for inhalation of outdoor air at NTS is $^{239/240}$Pu. The procedure outlined in the TBD suggests taking the bigger of the annual averages of environmental monitoring data and inferred air concentration using soil inventory data and resuspension. If the exact location of an employee is not known, site average values should be used.

The TBD claims in ORAUT-TKBS-0008-4 that the concentrations in Tables 4.2.1.2.2-1 are "typically the average of the maximum concentration for a given area and a given year. In cases where maximum values were not provided, the average of the concentrations was reported." Table 7 shows the results of the comparison for the years 1996, 1999, and 2000 with data in the Nevada Test Site Annual Site Environmental Reports cited in the TBD. Not all values that were entered in Tables 4.2.1.2.2-1 could be verified. In particular, no data were entered for some areas even though data were reported in the Environmental Report (e.g., Area 2 in CY 1996). In some cases, the reported value does not correspond to the average for the site (e.g., Area 4, CY 2000).

SC&A has not performed a detailed check of the data entry in the TBD, but notes this discrepancy as an indication that the QA/QC procedures for data entry in the TBD may need to be improved.

6.1.1.1 There are Gaps in the Soil Data for $^{239/240}$Pu, as well as Other Questions Regarding Adequacy of $^{239/240}$Pu Characterization.

The data for average annual intakes in Table 4.2.2-2 of the TBD are based on TBD Table 2-8. Both tables contain no $^{239/240}$Pu inventory data for Areas 23, 25, 26. However, air monitoring data are available for Areas 23, 24, 25, and 26. It is not reasonable to assume that some areas have no $^{239/240}$Pu inventory at all.

Further, there appear to be some discrepancies in soil inventory of some radionuclides in some areas. For instance, Table 2-5 lists the inventory of $^{239+240}$Pu in surface soil (0 to 5 cm) for Project 56 in Area 11 as 36.00 curies, while Table 2-8 lists the $^{239+240}$Pu for all of Area 11 to be 29 curies. Moreover, since the Table 2-8 is derived from McArthur 1991, the reported inventory should be for the top 15 cm, which accentuates the discrepancy. As another example, Table 2-8 does not mention Area 13, even though Area 13 is discussed in the text in the context of this table (NTS TBD Vol. 2, Section 2.3.13, pg. 34) while Table 2-5 lists the soil inventory of $^{239+240}$Pu as 46 curies.

6.2 INTERNAL DOSE

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.

On page 19 of the NTS TBD Vol. 5, the first paragraph of Section 5.2.2.9 provides a very brief discussion of the deposition of various elements in human tissues. This material is valid, but does not provide a sufficient basis for dose reconstruction. It would be better to provide references here and elsewhere to the specific tools to be used in dose reconstruction, e.g., IMBA.

Although, in general, the descriptions of analytical techniques are adequate, the description under Section 5.2.2.10 of the NTS TBD Vol. 5 (page 21) is not sufficient. Gamma spectrometry is an inadequate description. There is a need to know whether it was NaI- or HPGe-based. The 1993 method is adequately described, but the 1961 technique is not. It seems likely that a NaI system was used at that date, but nothing is said about the crystal size or geometry. A history of the changes in equipment used from 1961 to 1993 would be helpful. This presumably could be synthesized from REECo (1993b) and related source documents.

Under in-vivo counting on page 22 of the NTS TBD Vol. 5, it seems odd to have to assume that chest counting at the new facility used Phoswitch detectors. The facility opened in 1981, so it is difficult to believe that there is not a full record available of the equipment installed and used. A record should be identified and used to augment this account.

On page 22 of the NTS TBD Vol. 5, it is also noted that the background subtraction for the whole-body and chest counting was not the standard channel-by-channel approach, but was an activity-based subtraction. It is not clear why this approach was used, as it seems to sacrifice some detail in the data. A comment on this point would be helpful.

6.3 EXTERNAL DOSE

In regard to external dose, the TBD should examine multiple badging and its relevance for estimating organ dose for groups of workers and periods when such data are not available. In addition, the matter of the recording practices of doses from each badge worn needs clarification.

Table 7. Atmospheric Concentrations of Plutonium-239,240 (pCi m^{-3}) for the Nevada Test Site

Area	Size (m^2) [a]	CY 1996		CY 1999		CY 2000		Inferred soil resuspension [c]
		TBD [b)]	Env Rep [d] (avg of max)	TBD [b]	Env Rep [e] (avg of avg)b	TBD [b]	Env Rep [f] (avg of max)	
1	6.90E+07	7.5E-04	7.5E-04		4.8E-05	8.5E-05	8.5E-05	4.6E-04
2	5.10E+07		3.5E-05		1.8E-05		4.3E-05	5.6E-04
3	8.40E+07	3.0E-04	3.4E-04		1.1E-04	2.7E-04	2.8E-04	5.6E-04
4	4.10E+07		8.1E-05	5.9E-05	5.9E-05	5.9E-05	1.0E-04	1.3E-03
5	7.50E+06	1.6E-05	2.2E-05		8.5E-06	2.1E-05	2.1E-05	8.4E-04
6	8.40E+07	4.6E-05	4.6E-05		2.1E-05	4.1E-04	4.1E-04	1.3E-04
7	5.00E+07	4.5E-04	4.5E-04		1.4E-05	3.4E-05	3.4E-05	4.2E-04
8	3.60E+07							3.9E-03
9	5.20E+07	6.1E-04	6.1E-04		1.3E-03	2.8E-03	2.8E-03	2.2E-03
10	5.20E+07	5.8E-05	5.8E-05		4.5E-05		1.1E-04	2.8E-03
11	1.00E+07	1.9E-05	1.9E-05					3.5E-03
12	1.00E+08	3.7E-06	3.7E-06					4.9E-04
15	9.10E+07	2.4E-04	2.4E-04	1.1E-05	1.1E-05	2.6E-04	2.6E-04	8.8E-04
16	3.70E+07	1.8E-06	1.8E-06					1.3E-04
17	8.10E+07							2.9E-04
18	7.10E+07	3.5E-06	3.5E-06	1.1E-05	8.9E-06	1.0E-05	1.0E-05	1.8E-03
19	3.80E+08							4.6E-04
20	1.60E+07	4.5E-06	4.0E-06	2.0E-05	7.3E-06	6.6E-06	6.6E-06	3.3E-03
23		6.3E-06	6.3E-06					
25	2.30E+06	4.2E-06	4.2E-06	6.2E-06	6.2E-06	1.1E-05	1.1E-05	
26	5.20E+05							
27		2.6E-06	2.6E-06					
28								
30	7.80E+05							2.4E-02
Average of data		1.6E-04	1.5E-04	2.1E-05	1.3E-04	3.6E-04	3.2E-04	2.5E-03
Weighted average			2.0E-04		1.3E-04		3.7E-04	8.9E-04

(a) Source: TBD, Table 4.2.2-1
(b) Source: TBD, Table 4.2.1.2.2.-1
(c) Calculated by multiplying TBD, Table 2-8 values with resuspension factor of 1.3×10^{-9} m^{-1}
(d) Nevada Test Site Annual Site Environmental Report for Calendar Year 1996, DOE/NV11718-137, October 1997, page 5-29
(e) Nevada Test Site Annual Site Environmental Report for Calendar Year 1999, DOE/NV11718-463, page 4-25
(f) Nevada Test Site Annual Site Environmental Report for Calendar Year 2000, October 2001, DOE/NV11718-605, page 5-35

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

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

7.1 THE FIVE OBJECTIVES

The SC&A review procedures, as approved by the Advisory Board, require that each site profile be evaluated against five measures of adequacy: completeness of data sources, technical accuracy, adequacy of data, site profile consistency, and regulatory compliance. Each of these is discussed below.

7.1.1 Objective 1: Completeness of Data Sources

For the period after NTS bioassay capability was established, the NTS TBD Vol. 5 is strong on information on analysis techniques, but weak on sampling techniques in respect of bioassay materials. Also, normalization techniques were applied to results obtained from the analyses, but the details of those normalizations are not given. Attachment 5D provides a good account of the codes used in bioassay records and should allow the original records to be readily scrutinized. Some information on in-vivo counting procedures is given there, but this is mainly referenced to other documents (e.g., REECo 1993a), which have only been briefly reviewed at this time.

In regard to external dose, the NTS TBD has carefully documented the characteristics of the dosimeters in use in various periods and their detection limits. The external dose volume of the TBD provides a solid account of the practices as they evolved and as reported in the supporting documentation.

The TBD is particularly strong in regard to the technical basis of recent external and internal dose procedures, since it is based on guidance and evaluations that have been prepared and periodically updated since the 1990s.

As is evident from the reference lists at the ends of the six volumes of the NTS TBD, NIOSH has made an extensive data capture effort and used a considerable amount of this literature in the preparation of the NTS TBD. Further, NIOSH has also been in frequent contact with site experts. The list of contacts was provided by NIOSH to SC&A, and is reproduced in Annex A to Attachment 3 of this report. NIOSH has especially been in frequent contact with the health physics and record keeping staff at NTS.

Yet, NIOSH's literature search and site expert contacts are incomplete in crucial ways. In regard to literature, NIOSH makes no mention of the official history of nuclear test radiation safety between 1947 and 1974, written by Barton C. Hacker, entitled *Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing 1947–1974*. This book contains nearly 200 pages of notes to the text, including a large number of references to primary sources on radiation safety. It also contains an excellent bibliography. While the book is about much more than employee radiological safety at NTS, omission of any reference to it in the NTS TBD is surprising. The book and associated materials could provide valuable insights into conditions prevailing during the tests, as well as the operational practices in regard to radiological safety.

For instance, Dr. Hacker's book makes clear that there were conflicts between personnel safety and the policies of compensation for employees, and that the problems emerged early. Here is how he describes the 1952–1953 period leading up to the Upshot-Knothole test series in 1953:

> *Problems persisted, however, raising concerns in Washington about the fate of workers. AEC Chairman Dean, in particular, wondered just what standards and safeguards applied. Santa Fe Operations reported matters well under control. Areas reading 100 milliroentgens per hour or more were posted; work parties in such areas required a monitor present. Personnel film badges were read and recorded daily, after each shift for workers in areas regarded as contaminated. The accepted national standard of 0.3 roentgen per week was strictly enforced but integrated over a longer time. Santa Fe Operations set the limit for Tumbler-Snapper roll-up as 3 roentgens, gamma only, in ten weeks; the Division of Biology and Medicine concurred but only after changing the limit to 3.9 roentgens per quarter. **Nearing that total barred a worker from contaminated areas; exceeding that total meant transfer or layoff**.*
> [Hacker 1994, pg. 90, emphasis added]

Since work in forward areas was paid more than work in other places, approaching the quarterly limit was clearly associated with a significant economic penalty for employees; the penalty for exceeding it could be as severe as a layoff. Hence, the compensation and employment system created systematic incentives for employees to compromise radiation safety in favor of pay and job security. Dr. Hacker's book provides extensive references to primary documentation for the policies and controversies discussed in this paragraph (Hacker 1994, Note 52, pg. 327) that would be a very useful guide to the pressures that led to what appears to have been a significant compromise of the integrity of the external dose record in the early period.

There were also tensions between weapons testing and safety, at least in the early period:

> *Immediate questions about worker safety merged into larger questions about the wisdom of further testing in Nevada. The request from Washington for a report on workers also asked for an "early study of the operational future for Nevada Proving Ground." …Overseeing the study General Fields, the director of military application, stressed three questions: "A. What steps can be taken to minimize contamination both in the immediate test area and off site? B. What steps can be*

> *taken to improve documentation procedures? C. What steps can be taken to eliminate or minimize existing and anticipated health and public relations problems?* [Hacker 1994, pg. 90]

How this tension between safety and continued testing was resolved and what aspects of the resolution led to more safety and which ones to better public relations is a material issue that needs to be investigated as NIOSH prepares Rev. 01 of the NTS TBD. This is especially relevant since *Elements of Controversy* documents the "discontent" of the armed forces with AEC radiation exposure limits, which was the context in which the AEC relaxed its rules and allowed armed forces personnel to be present closer to the tests than previously allowed (Hacker 1994, pg. 92). Rad-Safe personnel would also have been present at the same locations as the armed forces personnel. Rad-Safe personnel generally preceded armed forces personnel into areas near ground zero. Both factors would tend to increase external and internal exposure. Stationing personnel closer to ground zero also raises questions about the extent of neutron exposure during atmospheric testing that bear close examination and analysis. As discussed above, NIOSH's conclusion that personnel were not exposed to neutrons during nuclear weapons tests is premature at best. Study and analysis of primary documentation, including possibly still classified documentation about the tests, may be especially useful. Specifically, the possibility that troops (and hence Rad-Safe personnel) were stationed closer than permitted distances appears to be an important item of investigation.

SC&A recognizes that NIOSH plans to cover atmospheric testing in Rev. 01 of the NTS TBD. However, there are important conclusions about dose estimates and radiological testing during this period in Rev. 00 of the NTS TBD. As discussed above, the TBD contains a conclusion that neutrons were not an important source of radiation exposure during the atmospheric testing period. Furthermore, the Barton Hacker work extends well into the period of underground testing.

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

[3] Mr. Brady recalled being briefly contacted by Mr. Griffith, but does not recall any substantive conversation on dose reconstruction or radiation safety issues. He also said that Mr. Griffith did not identify himself as a consultant to NIOSH or NIOSH contractors, or that the contact was part of information gathering pursuant to the implementation of compensation decisions pursuant to EEOICPA. SC&A has reproduced NIOSH's entire summary of the interchange as Annex A to Attachment 3.

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.

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

SC&A suggests that NIOSH make a careful assessment of Barton Hacker's history and the sources that are cited in it insofar as they concern on-site radiation safety practices. SC&A also suggests that NIOSH should (1) interview William Brady in depth on a far greater range of topics than it appears to have done, and (2) follow up on suggestions regarding documentation not yet considered, but which may be relevant to the dose reconstruction program.

The TBD did not rely on classified documents in its production. Interviews with Mr. Brady, as well as Dr. Hacker, as to the utility of the classified documentation for NTS dose reconstruction would provide a useful guide. Dr. Hacker, who had access to the classified record, did not find that it added much to the unclassified and declassified record for the purposes of historical analysis; however, the conclusion may well be different for dose reconstruction since source terms for individual tests and other classified information would appear to be relevant, especially for the periods when internal dose monitoring data are not available or incomplete in important ways, and for the period for which there are questions as to the integrity of external dose records for certain groups of workers.

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 ^{60}Co, that could deliver large local doses
- Far-field hot particle doses

Such archival and analytical reviews would also likely be useful for other sites, notably Hanford, where large hot particles may have caused doses of a kind that may be analyzed by similar methods.

Finally, the NTS TBD has not made adequate use of Congressional hearings and the 2003 NAS National Research Council study. The latter has not been reviewed in the NTS TBD for relevance and importance. An assessment of such sources is needed, especially for the period of about the first two decades, when there are various issues of data and analysis that are complex, and where SC&A has greater concerns about the data and analysis in the NTS TBD.

NIOSH has acknowledged the need for a more complete investigation of sources in one area: bomb assembly workers. It is unclear at the present time where the relevant dose information for these workers is located and in what TBD it should be covered (Attachment 6).

7.1.2 Objective 2: Technical Accuracy

The NTS TBD does not provide adequate analysis to sustain technically accurate, "best estimate" doses in several areas, including:

- Issues of geometry of exposure relative to badge locations and external DCFs need to be addressed in the specific context of the NTS TBD to ensure that estimated doses are scientifically defensible and claimant favorable. The SC&A review of individual dose reconstructions for NTS indicates that these factors may not be as important for minimum and maximum dose reconstruction; however, they are likely to be significant for "best estimate" doses. NIOSH has acknowledged that these issues need to be addressed and they are under discussion on a generic basis at the Advisory Board Working Group level as of this writing (mid-October 2005).

- The technical accuracy of internal beta doses from hot particles has not been evaluated. This is likely to particularly affect skin, gonad, and GI-tract doses for workers entering reactor and weapons testing areas.

- The technical accuracy of the environmental dose estimation procedure is questionable for periods long after the test.

- The NTS TBD does not set forth a procedure for making defensible or, in some cases, any internal or external dose estimates for re-entry into weapon and reactor test areas at times soon after the tests.

- The NTS TBD does not provide adequate guidance for dose reconstruction in regard to specific waste handling and repacking activities.

- The TBD does not provide guidance about a procedure to take into account the effect of heat on film badges and TLDs stored in personal vehicles.

Accuracy of dose reconstruction will be affected by the issue relating to the integrity of external dose data discussed in this review.

7.1.3 Objective 3: Adequacy of Data

The data and analysis presented in the NTS TBD are incomplete and inadequate for the purpose of reconstructing doses to many classes of employees, at least into the 1960s and possibly into the 1970s for weapons testing and extending into the 1970s for reactor testing and possibly other areas as well. In reference to early re-entry employees, data that exist have not been used. It is unclear whether they would be adequate, since they have not been fully evaluated.

External dose data, except for neutron doses, for the period after 1966 may be adequate, provided that the data integrity issues can be determined to be minimal after the time that the integrated ID-dosimeter badge was introduced. Open window doses were also recorded after that time, enabling beta and low-energy photon dose estimation. The caveat in this context is that the dose of record needs to be supplemented by multiple-badging data, as well as analysis of exposure geometry (noted above).

External and internal dose data adequacy is questionable in the following specific ways:

- There are no open window external dose data prior to 1966. There is no analysis of this issue in the TBD. Therefore SC&A cannot arrive at any conclusions regarding whether the existing data, in the form of source terms, size and nature of the tests, etc., would be adequate to reconstruct shallow dose, which is important for skin, breast, testes, and thyroid cancers.

- The integrity of the external dose record up to the mid-1960s and possibly into the 1970s, is open to question for some groups of workers, as discussed above. It would appear therefore that the adequacy of that dataset at it stands currently, that is without some adjustments and other data sets to complement it, for dose reconstruction is open to question, at best. A careful analysis of the entire problem of external exposure, the extent and nature of off-normal practices, and working conditions during this period is needed before conclusions can be made about the adequacy of the entire set of available information for external dose reconstruction in the early period. SC&A suggests careful research on instances of workers taking off badges, and employment practices such as transferring or laying off workers who reached or approached quarterly radiation limits. This should include both site expert interviews and archival research. Reference to the archives of key experts such as Barton Hacker, William J. Brady, and Floyd Wilcox may be especially useful to address this crucial issue.

- Internal dose data for the early period are non-existent (to late 1955). Tritium data are non-existent to the late 1950s, and detailed radionuclide analytical data only began in 1967. It is noted that French and Skrable found that the bioassay data from E-Tunnel workers were limited in both the quantity and quality needed for making reasonably accurate estimates of their intakes and doses (NTS TBD Vol. 5, page 69). Hence internal dose data until well into the 1960s are sparse at best. The TBD has not developed any procedures based on available data, such as testing source terms and short-term deposition of radionuclides to allow an assessment of the adequacy of the early data for internal dose reconstruction. Based on the conference call with NIOSH, SC&A expects that these issues will be addressed in Rev. 01 of the NTS TBD (see Attachment 3).

The NTS TBD does not provide adequate data or analysis for dose reconstruction for early re-entry workers in reactor test areas, notably due to exposure to large hot particles incorporating mixed fission products. The NTS TBD also does not provide adequate data in this regard for atmospheric testing, for underground tests that vented, including Baneberry, and possibly for underground test early re-entry employees.

Data that would enable dose reconstruction for workers re-entering reactor and weapon test areas within hours or days after the test appear to be available, at least to some extent. These data affect the entire reactor testing period from the late 1950s to 1973, and are also relevant for the entire atmospheric testing period. In regard to the underground testing period, an evaluation of the adequacy of the data for reconstruction of doses in re-entry and drillback operations is needed with specific reference to the kinds of issues raised by the NRDL in assessing doses to re-entry personnel (NRDL 1968).

7.1.4 Objective 4: Consistency Among Site Profiles

It is important to recognize that the NTS differs substantially from other facilities in the DOE Complex, because it has not hosted ongoing production of materials. Rather, the NTS was, and is, mainly an outdoor testing and research facility. In that context, many of the considerations that apply to the control and monitoring of permanent buildings are not relevant. Although this relaxes some requirements for consistency with other site profiles, SC&A notes that there is still a need to ensure that information is provided to a similar level of detail in various TBDs.

7.1.4.1 Consistency – Internal Dose

The NTS TBD notes here, however, that NTS compares unfavorably with other sites on internal dose monitoring until well into the 1960s. DOE sites and even AWE sites have some internal bioassay data going back to the late 1940s. NTS had none until late 1955. Even after that time, data are limited to plutonium, until the introduction of tritium monitoring a few years later. This lack of internal dose data was due to the erroneous general assumption in the early years that only external dose was of significance in weapons testing. Despite the deficiency of the internal dose data well into the 1960s, the NTS TBD does not address the issue in detail. This is unlike some other TBDs, where considerable attention to the quantity of data, going back to the early 1950s is often presented.

7.1.4.2 Consistency – External Dose

The INEEL site and the NTS site had many work activities in common. The main source of photons for both sites was fission and activation products. Both sites worked with prototype reactors. Some of the projects at INEEL involved the controlled destruction of reactors that resulted in similar surface contamination scenarios as seen at NTS. The external individual dosimetry used in the two sites followed very similar time-lines and techniques. Therefore, the two sites should have similar dose-reconstructor guidelines.

This is not the case, however. Whereas the NTS guidelines are, on the whole, claimant favorable, the INEEL guidelines are not. Tables 8, 9, and 10 below summarize the differences between the guidelines for the two sites, and also include guidelines taken from the Savannah River Site TBD for comparison.

Table 8. Comparison of Photon Dosimetry

Parameter	NTS	INEEL	SRS
Minimum detection limit for film dosimetry – DuPont type 508 emulsion	40 mrem	10 mrem	40 mrem[1]
Compensation for loss of information of dose due to low energy (E < 100 keV) photons. This loss is due to the use of the lead filter only to measure Hp(10).	Multiply the Hp(10) by 1.25	No compensation	Add the open window dose to Hp(10)
Energy spectrum for reactor work	30 to 250 = 100%	30 to 250 = 25% E > 250 = 75%	30 to 250 = 50% E > 250 = 50%
Energy spectrum for fuel processing	30 to 250 = 100%[2]	30 to 250 = 25% E > 250 = 75%	30 to 250 = 50% E > 250 = 50%
Energy spectrum for waste processing	30 to 250 = 100%[3]	30 to 250 = 25% E > 250 = 75%	30 to 250 = 50% E > 250 = 50%
Energy spectrum for calibration	30 to 250 = 100%[3]	30 to 250 = 25% E > 250 = 75%	30 to 250 = 50% E > 250 = 50%
Irradiation geometry	AP[3]	Not given	Mainly AP

1) DuPont 552 and 558 emulsions
2) For NTS, exposure to fission and activation products
3) Not explicitly stated in the TKBS

Table 9. Comparison of Neutron Dosimetry

Parameter	NTS	INEEL	SRS
Minimum detection limit for NTA film dosimetry	250 mrem	14 or 20 mrem	30 or 40 mrem
Bias for loss of information due to NTA film dosimetry (low energy neutrons)	Multiply the Hp(10) by 2.5 for all workers	Multiply the Hp(10) by 3 for MTR workers only	Use photon to neutron ratio
Energy spectrum for reactor work	0.1 to 2 MeV = 100%	E < 10 keV = 20% 10 to 100 keV = 5% 0.1 to 2 MeV = 50% 2 to 20 MeV = 25%	10 to 100 = 15% 0.1 to 2 MeV= 85%
Energy spectrum for processing	0.1 to 2 MeV = 100%	-	0.1 to 2 MeV = 100%
Energy spectrum for waste processing	0.1 to 2 MeV = 100%	0.1 to 2 MeV = 5% 2 to 20 MeV = 95%	-
Energy spectrum for calibration	0.1 to 2 MeV = 100%	0.1 to 2 MeV = 20% 2 to 20 MeV = 80%	0.1 to 2 MeV =83% 2 to 20 MeV = 17%
Irradiation geometry	AP[3]	Not given	Mainly AP

Table 10. Comparison of Beta Dosimetry

Parameter	NTS	INEEL	SRS
Two window film dosimeter	No beta dosimetry[1]	Beta dosimetry with MDL = 10 mrem	Beta dosimetry with MDL = 40 mrem
Multi window film dosimeter	Beta dosimetry with MDL = 40 mrem	Beta dosimetry with MDL = 10 mrem	Beta dosimetry with MDL = 40 mrem

1) From NTS: “reliable beta dosimetry was not possible until the introduction of the multi-element badge.” As discussed in Section 5, there are no personal beta dose data until 1966.

It can be seen from the above tables that, in terms of claimant favorability, the NTS external TBD is the most favorable, followed by the SRS TBD. The INEEL external TBD is the least claimant favorable. Overall, it is possible to say that, with respect to the indicated parameters, the NTS and SRS TBD parameters are claimant favorable, and the INEEL TBD parameters are not.

External dose data integrity issues are not discussed in the TBD. This is similar to the lack of discussion of that issue in the Rocky Flats TBD.

7.1.4.3 Consistency – Guidelines

It has been SC&A's observation that some TBDs, such as those for Hanford and Savannah River, and those for AWEs, in addition to providing comprehensive background information, provide considerable explicit guidance for dose reconstructors. It is appears that a consistent philosophy regarding the purpose of the TBDs needs to be defined and communicated to the authors of the TBDs. In this respect, the NTS TBD does not contain comparable detail, such as in the matter of internal dose estimation discussed above or estimation of missing beta dose to 1966. SC&A acknowledges here that NIOSH may include more detail in the forthcoming revision of the TBD.

7.1.5 Objective 5: Regulatory Compliance

SC&A noted no issues regarding regulatory compliance in the post-1970 period (i.e., 1971 and after). There are a number of potential issues for the early period related to technical accuracy and to data adequacy. Since the NTS TBD is incomplete in several essential respects, and since they may be addressed in Rev. 01 of the NTS TBD, SC&A is not providing an analysis of the regulatory issues associated with the first two decades of NTS operation at this time.

8.0 REFERENCES

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

Anspaugh, L. R., 2002. "Movement of Radionuclides in Terrestrial Ecosystems by Physical Processes," *Health Physics*, volume 85, number 5, pp. 669–679, Lippincott Williams and Williams, Hagerstown, Maryland.

BIOPROTA 2005. *Modeling the Inhalation Exposure Pathway. A report prepared within the international collaborative project BIOPROTA: Key Issues in Biosphere Aspects of Assessment of the Long-term Impact of Contaminant Releases Associated with Radioactive Waste Management*. Main Contributors: M. Wasiolek (Task Leader), A. Agüero, A. Albrecht, U. Bergström, H. Grogan, G.M. Smith, M.C. Thorne, M. Willans and H. Yoshida. Published on behalf of the BIOPROTA Steering Committee by BNFL (Nexia Solutions Ltd), United Kingdom.

Eberhardt C.F. 1999. Using Absolute Humidity and Radiochemical Analyses of Water Vapor Samples to Correct Underestimated Atmospheric Tritium Concentrations (June 1999): LA-UR-99-1107.

Favor, D. N., 1987. *Survey of Radon and Radon Daughter Concentrations in Selected Rainier Mesa Tunnels*, DOE/NV/10327-31, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

Hacker, Baron C., 1994. Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing 1947–1974. Berkeley, California: University of California Press, 1994.

A.E. Hechanova, A.E and L.J. O'Neill, 1998. *Description of the Nevada Test Site and Nellis Air Force Range Complex Activities in Nevada*, May 1998, http://nstg.nevada.edu/web_pubs/ntsdesc.pdf

LANL 2002. *Environmental Surveillance at Los Alamos during 2002*, LA-14085-ENV, Los Alamos National Laboratory, Los Alamos, New Mexico, 2002.

McArthur, Richard D., 1991. *Radionuclides in Surface Soil at the Nevada Test Site*, DOE-NV/10845-02, Desert Research Institute, University of Nevada System, Las Vegas, Nevada, August 1991.

NAS 1989. Committee on Film Badge Dosimetry in Atmospheric Nuclear Tests, Film *Badge Dosimetry in Atmospheric Nuclear Tests*. Washington, DC: National Academy Press, 1989.

NAS 2003. Committee to Review the Dose Reconstruction Program of the Defense Threat Reduction Agency, *A Review of the Dose Reconstruction Program of the Defense Threat Reduction Agency*. Washington, DC: National Academy Press.

NCI 1997. *Estimated Exposures and Thyroid Doses Received by the American People from Iodine-131 in Fallout Following Nevada Atmospheric Nuclear Bomb Tests*, National Cancer Institute.

NCRP 1999. *Recommended Screening Limits for Contaminated Surface Soil and Review of Factors Relevant to Site-Specific Studies,* National Council on Radiation Protection and Measurements, Publication 129, ISBN 0-929600-61-4.

NRC 1992. J.D. Berger, *Manual for Conducting Radiological Surveys in Support of License Termination*, Draft Report for Comment, prepared by Oak Ridge Associated Universities for the Nuclear Regulatory Commission, Oak Ridge, Tennessee, 1992. (No final report was located).

NRDL 1968. *Hazards to Personnel Entering the Nevada Test Site Following Nuclear Reactor Tests*, NRDL-TR-68-49, Naval Radiological Defense Laboratory, San Francisco, California, December 19, 1968.

NTS 1997. Black, S.C., and Y.E. Townsend, 1997, *Nevada Test Site Annual Site Environmental Report for Calendar Year 1996*, DOE/NV11718-137, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

NTS 1999. Black, S.C., and Y.E. Townsend, 2000, *Nevada Test Site Annual Site Environmental Report for Calendar Year 1999*, DOE/NV11718-463, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

NTS 2001. Townsend, S.E. and R.F. Grossman, 2001, *Nevada Test Site Annual Site Environmental Report for Calendar Year 2000, October 2001*, DOE/NV11718-605, U.S. Department of Energy, Nevada Operations Office, Las Vegas, Nevada.

ORAUT-OTIB-0002. *Technical Information Bulletin – Maximum Internal Dose Estimates for Certain DOE Complex Claims*, ORAUT-OTIB-0002, July 5, 2004.

Reynolds Electrical Engineering Company (REECo) 1968. *Environmental Radioactivity at the Nevada Test Site – July 1966 through June 1967*, NVO-410-15, May 1968.

REECo 1993a. *Technical Basis for Internal Dosimetry at the Nevada Test Site*, Reynolds Electrical Engineering Company, 1993.

REECo 1993b. Documents for the ORAU "O Drive" entitled "NTS General Information 1953–1973" containing list by year of instruments, dosimetry (mostly external), rad levels, exposure criteria, respiratory protection, internal contamination, and calibration information.

Rodgers, J., P. Wasiolek, J. Whicker, C. Eberhart, K. Saxton, and D. Chandler, 2000. *Performance Evaluation of LANL Environmental Radiological Air Monitoring Inlets At High Wind Velocities Associated with Resuspension, Los Alamos National Laboratory*, Los Alamos, LA-UR-00-3091, 2000.

Rollins 2004a. NTS TBD Vol. 1, *Technical Basis Document for the Nevada Test Site – Introduction*, ORAUT-TKBS-0008-1, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, February 4, 2004.

Rollins 2004b. NTS TBD Vol. 2, *Technical Basis Document for the Nevada Test Site – Site Description*, ORAUT-TKBS-0008-2, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, February 2, 2004

Rollins 2004c. NTS TBD Vol. 3, *Technical Basis Document for the Nevada Test Site – Occupational Medical Dose*, ORAUT-TKBS-0008-3, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, June 9, 2004

Rollins 2004d. NTS TBD Vol. 4, *Technical Basis Document for the Nevada Test Site – Occupational Environmental Dose,* ORAUT-TKBS-0008-4, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, April 20, 2004

Rollins 2004e. NTS TBD Vol. 5, *Technical Basis Document for the Nevada Test Site – Occupational Internal Dose,* ORAUT-TKBS-0008-5, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, September 30, 2004.

Rollins 2004f. NTS TBD Vol. 6, *Technical Basis Document for the Nevada Test Site – Occupational External Dose,* ORAUT-TKBS-0008-6, Subject Expert Eugene M. Rollins, National Institute for Occupational Safety and Health, September 21, 2004.

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

SC&A 2005a. *Second Supplemental Review of the Mallinckrodt Site Profile Revision 1(Effective Date March 10, 2005),* Second Supplement to SCA-TR-TASK1-0002, July 1, 2005.

SC&A 2005b. *Review of NIOSH Site Profile for the Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP) Final Integrated Version,* SCA-TR-TASK1-0009c, June 2005.

SC&A 2005c. *Third Supplemental Review of the Mallinckrodt Site Profile Revision 1(Effective Date March 10, 2005)*, Third Supplement to SCA-TR-TASK1-0002. August 16, 2005.

SC&A 2005d. *Review of NIOSH/ORAUT Procedures and Methods Used for Dose Reconstruction*. SCA-TR-Task3, January 2005.

Sherrill, R. D.; Sumerlin, N. G.; Beck, J. N., Kuroda, P. K., 1975. "Variation of the Ratio of Cesium-137 to Strontium-90 in the Atmosphere," *Health Physics*. Vol. 28, April 1975, pp. 335–340.

Warren 1945, Stafford L. Warren, memorandum to Gen. Groves, “Subject: Report on Test II at Trinity, 16 July 1945,” July 21, 1945.

ATTACHMENT 1: SC&A QUESTIONS TO NIOSH

INITIAL SC&A QUESTIONS FOR NIOSH/ORAU REGARDING NTS SITE PROFILE May 6, 2005

General

1) Has NIOSH done worker and site expert interviews? If so, could NIOSH provide the minutes and notes of these interviews to SC&A as soon as possible?

2) The TBD seems to emphasize the underground tests that occurred at NTS, while spending little time on the period of atmospheric testing. Does the statement in the introduction (TBD Vol. 1, pg. 7) that NIOSH is researching how to estimate dose from volatile radionuclides cover pathways of exposure?

3) Specifically in relation to atmospheric testing, is NIOSH considering internal dose pathways from activities, such as recovery of equipment, cleanup of debris, and other work assignments that may have occasioned entry into contaminated zones shortly after tests? Has NIOSH considered external and internal doses due to fallout from presence of workers outdoors during some atmospheric tests? Is NIOSH investigating the doses to health physics monitors who may have gone into the test areas for monitoring purposes shortly after the tests? In Vol. 2 (pg. 28), NIOSH notes that workers did re-enter test areas after the tests, and that this "had the potential to cause significant external and internal radiation exposures." It is not clear from the context whether NIOSH is considering this in detail both for the atmospheric and underground testing periods. Would NIOSH clarify this? What is the state of the research in characterizing this exposure potential other than the resuspension estimation? Vol. 6 (pg. 38) on external dose, for instance, cites three references for external dose for re-entry personnel, but two refer to general articles for fission product spectra and one is a personal communication. Are there sit- specific data for the statements regarding the claimant-favorable approach to dose estimation discussed in the paragraph just above Section 6.3.4.2?

4) What areas of NTS are associated with AEC/DOE operations alone? How has NIOSH segregated exposure between DOE and DOD operations, or have they assumed all radioactive exposure was a result of AEC/DOE activities? Specifically, has NIOSH investigated whether any AEC, or AEC contractor or subcontractor personnel participated with armed forces personnel in the exercises at NTS?

5) Table 2-2 in the site description lists no radionuclides of concern for Areas 3 & 11, the Nuclear Explosive Assembly Area (Area 27), and the Device Assembly Area (Area 6). Is this an oversight on the part of the TBD author or is NIOSH/ORAU indicating that there were no radiation exposures in these areas? Are there any area or personnel exposure records for these areas?

Occupational Medical Exposure

1) Who performed diagnostic x-ray inspections at NTS? Was the State of Nevada involved in this? Why was NIOSH not able to determine the machine type and factors used in diagnostic x-rays after 1957 and even as late as 2002 (Table 3-4, Vol. 3, of the TBD)? By contrast, NIOSH has all the details for the machine in the 1951–1957 period in the same table. Is there a contemporaneous reference that NIOSH used to determine the characteristics of the 1951–1957 machine? Is NIOSH certain that no photofluorography was done at NTS during the 1950s?

2) NIOSH states that the SSD is smaller than the SID. The SSD was set at 183 cm, which corresponds to the SID in other TBDs. What is the justification for this variance?

Occupational Environmental Exposure

1) NIOSH has indicated that REECo established an environmental surveillance program in 1964 designed to measure radiological conditions throughout the site without regard to nuclear tests. Has NIOSH/ORAU identified similar environmental monitoring programs prior to 1964? If so, where is this documented? (pg. 8)

2) NIOSH has concluded that "unmonitored employees would not be likely to be exposed to freshly deposited radionuclides" (pg. 7). What is the basis for this assumption? Is there documentation that unmonitored employees did not enter radiologically sensitive areas shortly after tests? Has NIOSH verified this assumption by site expert and worker interviews?

3) Were the glass fiber filters and later Whatman filters analyzed using wet or dry chemistry prior to 1971? (pg. 9)

4) What is NIOSH/ORAU's justification that those employees who were onsite continuously for weeks spent their nonworking hours indoors? (pg. 36)

5) How is a dose reconstructor to assign environmental dose prior to the earliest years provided in environmental summary tables? Specifically, the table does not contain any entries prior to 1964. Some tables start in 1966; others start even later.

6) How were the averages in Tables 4.2.1.2.2-1 calculated? Why were no data entered for some areas even though data were reported in the Environmental Report (e.g. Area 2 in CY 1996)?

7) The TBD concluded that the bigger of the annual averages of environmental monitoring data and inferred air concentration using soil inventory data and resuspension should be used for inhalation dose assessment. In order to compare the two approaches, did NIOSH review the location of the air sampling stations with respect to the location of contaminated areas?

8) The TBD states that the spatial variability of soil data is not a relevant issue because "radiological control practices would have prevented unmonitored employees from being inadvertently exposed in the more highly contaminated areas" (pg. 35). Where is this practice documented?

9) The TBD recommends the use of an average for unmonitored workers where locations are not known (pg. 33). While area weighting was used, an alternative would be to assume equal presence at all areas. Why was area weighting assumed? Was area weighting based on area sizes that were sampled for the inventory estimates rather than based on the total size of the areas?

10) Did NIOSH review the sampling efficiency of particulate samplers at high wind velocities with respect to the reliability of air monitoring and resuspension factors?

11) Did NIOSH review the accuracy of HTO sampling at low humidity levels at NTS?

12) Did NIOSH provide an analysis of I-131 releases from NTS after 1962 since internal I-131 exposures of non-monitored workers are not accounted for?

13) The TBD states that it is "reasonable and probably claimant-favorable to assign maximum annual environmental doses for the years 1963 through 1966 equal to the maximum value reported for 1967 (i.e., 318 mrem yr-1)." Given other airborne releases from NTS in 1962 and 1965, can NIOSH provide measurements from NTS itself that corroborate this claim?

14) NIOSH did not address inadvertent ingestion of soil as a pathway. Why was this excluded?

15) The TBD states on page 35 "Although there were many radiation measurements completed between 1951 and 1967, most of these were to characterize the effects of weapons tests and were therefore not appropriate for use in estimating external environmental dose for unmonitored employees." Which measurements were reviewed and where are they referenced?

16) The TBD states on page 36 for external dose that the claimant-favorable maximum site value should be used if the area in which the employee worked is not known. In case of resuspension doses, the area-weighted average was used if the area in which the employee worked is not known. Why do the procedures differ in the two cases?

17) With respect to the occupational dose to tunnel workers for radon, there is uncertainty with respect to the skin dose relative to a given lung tissue dose (see e.g., G.M. Kendall and T.J. Smith, "Doses to organs and tissues from radon and its decay products", J. Radiol. Prot. **22** (2002) 389–406). How is uncertainty accounted for?

Occupational Internal Exposure

1) NIOSH indicated in the NTS TBD that several ingestion intakes occurred during cleanup activities at CLEANSLATE and DOUBLE TRACK. Where are the details of these ingestions documented?

2) For what years was LANL responsible for the bioassay program at NTS? Which aspects of the program did LANL oversee?

3) Are the radionuclides outlined in Table 3.1.1-2 of TIB-0002 used to determine the internal dose for nonmetabolic cancers? Why did NIOSH/ORAU not use the area or facility-specific radionuclides of concern, given the variability of radioactive constituents?

4) It is unclear from the TBD what values were used for particle size, length of exposure, and breathing rate for internal dose calculation. Where is this information found?

5) The TBD cites a reference to the effect that internal exposure data for E-Tunnel workers "were limited in both the quality and quantity needed for making reasonable accurate estimates of the intakes and doses." (Vol. 5, pg. 69). How is NIOSH approaching this problem of E-Tunnel worker internal dose estimation?

6) NIOSH has cited examples of ingestion dose (Vol. 2, pg. 21 and Vol. 5, pg. 69), but the TBD contains no model for estimating ingestion exposure. Does NIOSH consider that internal dose monitoring was sufficient to cover ingestion as well as inhalation? How is NIOSH partitioning between ingestion and inhalation in going back from bioassay data to intakes of radionuclides?

Occupational External Exposure

1) What type of beta/gamma dosimeter was used before 1961? Where is this information documented?

2) What type of neutron dosimeter was used before 1966? Where is this information documented?

3) NIOSH/ORAU has applied the Pantex neutron-to-photon ratios for NTS assembly workers. What is the basis for choosing the Pantex neutron-to-photon ratio? Were the weapons being assembled at the two facilities identical?

4) The TBD is unclear regarding the direction provided to the dose reconstructor on assignment of external dose. Explain the process to be used by the dose reconstructor to calculate the dose under the following conditions:

    - Individual has measured photon dose
    - Individual has measured beta dose

- Individual has measured neutron dose
- Individual has no beta/gamma monitoring data
- Individual has no neutron monitoring data
- Individual has values below the detection limit of the particular dosimeter

Please include comments on the adjustment factors, when missed doses are assigned, and the IREP input parameters (i.e., default radiation type and energy, and statistical methodology).

5) Has NIOSH investigated dose from contact with contaminated water in the tunnels?

6) Was there multiple badging of workers at NTS to allow for organ dose determination? If so, how is NIOSH using these data for estimating doses for workers with only one badge? If not, has NIOSH considered the problem of exposure geometry versus badge location in specific areas, such as hot spots, and specific jobs, such as re-entry workers (atmospheric and tunnel)? This issue turned out to be significant at IAAP, for instance, where NIOSH estimated that external pelvic area dose was 2.5 times the value recorded on the badge.

7) The TBD states on page 17 that "background films" were used to zero the densitometer prior to reading a badge. What was the variability of the background film data and the densitometer reading itself? Is that uncertainty reflected in the bias factors and GSD for film badge data?

8) The TBD states on page 12 that data from pocket ionization chambers (PIC) be used in case film badge results were not available. It is claimed that because of "typical overresponse characteristic", use of PIC results is claimant favorable if no film badge data are available. Can NIOSH provide a comparison of PIC and film badge data?

9) The TBD indicates the detection threshold for neutron energies for NTA film to be "about" 0.8 MeV, for TEDs "about" 100 keV. What is the uncertainty in the detection threshold, and how would a different detection threshold affect the bias factors?

10) Section 6.3.2.2 (and subsections) contain statements that in other than neutron generator areas, "[n]eutron doses, for the most part, were low" (pg. 28). The TBD also states that neutron doses for unmonitored workers can be ignored because exposures were "unlikely" (pg. 28). There is little or no documentation cited as the technical basis for these judgments. Would NIOSH provide the references that are the basis for these conclusions? Has NIOSH interviewed site experts and workers in this regard?

ATTACHMENT 2: ORAU WRITTEN RESPONSES TO SC&A QUESTIONS

RK: As a general comment, SCA seems to be especially concerned with respect to ingestion and resuspension, and with contamination on the skin (e.g., their comment 35). These may be of concern because of the experience of SCA with respect to the Marshall Islands, where they were the experts supporting the plaintiffs in litigation there, and in calculating the doses to the Marshallese who were contaminated with fallout (as from BRAVO) and who lived on the contaminated atoll for a time. Thus, resuspension may be of interest because of their concerns about skin dose considerations from resuspended material settling back down on the skin, or from a dose from a contaminated field, which were concerns from fallout in the Marshall Islands (cf. Bravo shot). Similarly they are concerned about ingestion of soil because the Marshall Islanders were living in a contaminated area. The reviewers may not be particularly knowledgeable about operations at NTS as compared with the early days of testing in the Pacific.

CS: Some of these comments are Task 5 responsibilities, not Task 3.

Resolutions provided by:

GR = Gene Rollins
RK = Ron Kathren
VS = Vern Shockley
LA = Lori Arent
CS = Cheryl Smith
RG = Richard Griffith (Griff is due back next week, 9/12 I believe)

#	Assigned to	Comment	Resolution
General Comments			
1	Lori Gene	Has NIOSH done worker and site expert interviews? If so, could NIOSH provide the minutes and notes of these interviews to SC&A as soon as possible?	LA: NTS worker and site expert interviews have been conducted. The TBD includes references to personal communications and e-mail correspondence as necessary. Formal minutes were not prepared. GR: A list of site experts and former workers that were contacted can be provided upon request.

2	Cheryl Lori	The TBD seems to emphasize the underground tests that occurred at NTS, while spending little time on the period of atmospheric testing. Does the statement in the introduction (TBD Vol. 1, pg. 7) that NIOSH is researching how to estimate dose from volatile radionuclides cover pathways of exposure?	LA: The original direction was to prepare the NTS TBD, Rev. 00 for post-atmospheric testing. NTS TBD, Rev. 01 provides more details for the atmospheric testing era. CS: Pathways of exposure will be evaluated for importance to EE dose by the dose reconstructor guidance in the process of being developed.
3a	Cheryl Lori	Specifically in relation to atmospheric testing, is NIOSH considering internal dose pathways from activities, such as recovery of equipment, cleanup of debris, and other work assignments that may have occasioned entry into contaminated zones shortly after tests? Has NIOSH considered external and internal doses due to fallout from presence of workers outdoors during some atmospheric tests? Is NIOSH investigating the doses to health physics monitors who may have gone into the test areas for monitoring purposes shortly after the tests?	LA: Dose reconstructors consider post-test activities in the EE evaluation depending on job title and area of assignment. CS: The contractor acknowledged that anyone on site had potential to receive external exposure from testing. Those who directly participated in the test were monitored as stated in the safety report specific to the operation. Internal monitoring was limited at NTS. It is possible to assign missed internal dose using LANL MDA values since LANL was responsible for the NTS bioassay program and performed the analyses until 1958. Co-worker data may also be develped if it is cost effective to do so for the period before all EEs were assigned a dosimeter.
3b	Cheryl Lori	In Vol. 2 (pg. 28), NIOSH notes that workers did re-enter test areas after the tests, and that this "had the potential to cause significant external and internal radiation exposures." It is not clear from the context whether NIOSH is considering this in detail both for the atmospheric and underground testing periods. Would NIOSH clarify this?	LA: Dose reconstructors consider all testing periods in the dose evaluation. NTS TBD, Rev. 01 provides more details for the atmospheric testing era. CS: This statement applies to deep underground testing. According to records that have been reviewed to this point, anyone involved in these re-entries would have external and possibly internal dose reports (if an intake was suspected). This information is found in the access records and in the internal and external dose reports which are provided by DOE. These records are evaluated during the dose reconstruction. For atmospheric testing, the individual safety reports include specific information on re-entry which is available to the dose reconstructor.
3c	Gene	What is the state of the research in characterizing this exposure potential other than the resuspension estimation? Vol. 6 (pg. 38) on external dose, for instance, cites three references for external dose for re-entry personnel, but two refer to general articles for fission product spectra and one is a personal communication. Are there site-specific data for the statements regarding the claimant-favorable approach to dose estimation discussed in the paragraph just above Section 6.3.4.2?	GR: The best source of site-specific information regarding the spectrum of radionuclides in fallout at various times after detonation is a series of papers written by Harry G. Hicks of the Lawrence Livermore Laboratory between about 1961 to 1981. These papers were reviewed in detail and can be provided upon request. CS: The revision to the TBD external section includes an evaluation of the energy ranges based on the radionuclides present at NTS.
4	Lori Cheryl	What areas of NTS are associated with AEC/DOE operations alone? How has NIOSH segregated exposure between DOE and DOD operations, or have they assumed all radioactive exposure was a result of AEC/DOE activities? Specifically, has NIOSH investigated whether any AEC, or AEC contractor or subcontractor personnel participated with armed forces personnel in the exercises at NTS?	LA: DOD atmospheric and underground nuclear tests were sponsored by one of the laboratories (i.e., SNL, LLNL, LASL) in multiple NTS areas. NIOSH assumed radioactive exposure was a result of AEC/DOE activities. AEC and their contractor personnel provided support (e.g., air sampling) to armed forces at NTS. CS: Any identified activity w/i the EE's confirmed employment that was not expressly omitted is evaluated in the dose of record.

5	Lori	Table 2-2 in the site description lists no radionuclides of concern for Areas 3 & 11, the Nuclear Explosive Assembly Area (Area 27), and the Device Assembly Area (Area 6). Is this an oversight on the part of the TBD author or is NIOSH/ORAU indicating that there were no radiation exposures in these areas? Are there any area or personnel exposure records for these areas?	LA: Table 2-2 has been revised to include radionuclides of concern for the listed areas. There are personal and area exposure records for these locations.
Occupational Medical Comments			
6	Vern Ron	Who performed diagnostic x-ray inspections at NTS? Was the State of Nevada involved in this? Why was NIOSH not able to determine the machine type and factors used in diagnostic x-rays after 1957 and even as late as 2002 (Table 3-4, Vol. 3, of the TBD)? By contrast, NIOSH has all the details for the machine in the 1951─1957 period in the same table. Is there a contemporaneous reference that NIOSH used to determine the characteristics of the 1951─1957 machine? Is NIOSH certain that no photofluorography was done at NTS during the 1950s?	VS/RK: Diagnostic x-ray beam measurements were made by NTS personnel, as indicated by the references. Documentation on the type of machine and factors used subsequent to 1957 have not been located; however, these data are irrelevant inasmuch as measurement of the ESE is available. There is no documentation or anecdotal information that suggests that PFG was carried out in the 1950s.
7	Vern Ron	NIOSH states that the SSD is smaller than the SID. The SSD was set at 183 cm, which corresponds to the SID in other TBDs. What is the justification for this variance?	VS/RK: The text is correct as written. Section 3.2.3 states that the SID is 72 inches (= 183 cm) and that the SSD was "somewhat smaller." There is discussion of chest thickness later in the section, as well as in much more detail in OTIB-0006. Further, the variation in SSD is discussed in the section on uncertainty, and both SID and SSD are defined in the glossary. The comment apparently refers to Table 3.4, which gives the Source to Skin Distance as 72." In that table, SSD is incorrect and should be SID (Source to Image Distance).
Environmental Comments			
8	Gene	NIOSH has indicated that REECo established an environmental surveillance program in 1964 designed to measure radiological conditions throughout the site without regard to nuclear tests. Has NIOSH/ORAU identified similar environmental monitoring programs prior to 1964? If so, where is this documented? (pg. 8)	GR: Numerous Safety reports prior to 1964 were reviewed and the data contained consisted primarily of radiation readings at various distances from ground zero. These data did not include any onsite information that could be construed to be in unaffected areas (i.e., background). To date, no baseline for unaffected areas onsite have been identified prior to 1964. VS: The offsite environmental monitoring program at the NTS was conducted by the USPHS in Las Vegas. This data on the offsite environmental exposure should have been documented in their Las Vegas facility and will contain the data from the start of their program. REECo also conducted environmental monitoring.

9	Gene Ron	NIOSH has concluded that "unmonitored employees would not be likely to be exposed to freshly deposited radionuclides" (pg. 7). What is the basis for this assumption? Is there documentation that unmonitored employees did not enter radiologically sensitive areas shortly after tests? Has NIOSH verified this assumption by site expert and worker interviews?	GR: An extensive review of the radiological safety regulations at the NTS revealed detailed instructions related to posting and entry requirements for areas contaminated after detonations. These regulations required posting and positive entry controls through manned checkpoints for areas with radiation exposures in excess of 10 mR/hr. Entry into these areas was controlled through entry and exit logs and all individuals entering these areas were monitored with film badges and pocket ionization dosimeters. Upon exit from these areas, these individuals were also monitored for contamination. With these regulations in place, it would seem unlikely that an unmonitored employee would be allowed to enter a posted contamination area. With regard to documentation, it would be unlikely that documentation would exist that proved that something did not happen. Site experts have been contacted to verify that the radiological control regulations were implemented and complied with. VS/RK: Unmonitored employees -- i.e., employees without personnel dosimeters -- did not have access to radiation areas, or even to the site itself. Security considerations limited access to unbadged people. Access to the site required a security badge and a dosimeter, plus training as a rad-worker if they had access to radiologically controlled areas.
10	Gene Ron	Were the glass fiber filters and later Whatman filters analyzed using wet or dry chemistry prior to 1971? (pg. 9)	GR: Prior to 1971, particulate air samples were analyzed for gross alpha and beta by gas proportional counting. During this same period, gross gamma analysis was performed using Na(TI) detectors. All of these analyses would have involved direct counting of dry filter papers. Records indicate that wet chemistry did not start until 1971 when radiochemical analysis for plutonium was instituted. VS/RK: Standard practice was to count the filters dry and not perform wet chemistry especially on fiber glass filters.
11	Gene Ron	What is NIOSH/ORAU's justification that those employees who were onsite continuously for weeks spent their nonworking hours indoors? (pg. 36)	GR: It is well documented through interviews with workers and information gained through the CATI interviews that NTS employees typically worked more than 8 hours per shift (typical shifts were 10–12 hours). In addition, when off duty, it is presumed that they did not have their meals served outside (~2 hours/day) nor did they sleep outdoors (~ 8 hours per day). Accounting for these activities leaves only a couple of hours when they could have possibly been outdoors during nonworking hours. VS/RK: Most nonwork activities -- e.g., Sleeping, eating, recreation (movies, etc.) were indoors. Other activities, softball, volleyball, etc. played in very low background areas. These areas were monitored by area badges and could be used for dose determination, if not registered on their film badges that they were probably wearing.

12	Gene Cheryl	How is a dose reconstructor to assign environmental dose prior to the earliest years provided in environmental summary tables? Specifically, the table does not contain any entries prior to 1964. Some tables start in 1966; others start even later.	GR: The assignment of environmental external dose for unmonitored workers during the atmospheric testing phase at the NTS has not yet been decided. CS: This determination will be made based on how the background/control dosimeters were handled during this period. Dose reconstructors are applying the 1966 data back to 1963 based on project guidance.
13	Gene	How were the averages in Tables 4.2.1.2.2-1 calculated? Why were no data entered for some areas even though data were reported in the Environmental Report (e.g. Area 2 in CY 1996)?	GR: These values represent arithmetic averages of the sample results within each of the areas. It is agreed that data was provided for 1996 and it was not included in the table. A review for missing data will be performed prior to the next revision to assure that all available data is included in the table.
14	Gene	The TBD concluded that the bigger of the annual averages of environmental monitoring data and inferred air concentration using soil inventory data and resuspension should be used for inhalation dose assessment. In order to compare the two approaches, did NIOSH review the location of the air sampling stations with respect to the location of contaminated areas?	GR: As stated in the TBD, the resuspension model (Anspaugh 2002) used to predict atmospheric concentrations of plutonium was based on a databank of empirical measurements made at the NTS starting as early as 1957. These data consisted of comparisons of soil concentrations to measured atmospheric concentrations. The relative agreement (usually within a factor of 10) between the measured data (i.e., Tables 4.2.1.2.2-1 and 4.2.1.2.2-2) and the derived data (Table 4.2.2-2) verifies the applicability of the model. In addition, the claimant-favorable assumptions used with the resuspension model assure, in most cases, that the derived intakes will exceed the intakes derived from the measured data. In an instance where this is not the case (e.g., Area 9, 1993), the TBD requires documentation that the EE spent the majority of their time in that area in the outdoor environment before the higher measured value may be used.
15	Gene	The TBD states that the spatial variability of soil data is not a relevant issue because "radiological control practices would have prevented unmonitored employees from being inadvertently exposed in the more highly contaminated areas." (pg. 35) Where is this practice documented?	GR: Please see response to comment 9 above. VS/RK: A personnel monitor and a security badge were required for access to contaminated areas. Entry was controlled by site security as they would not allow non-badged personnel the NTS controlled area.
16	Gene	The TBD recommends the use of an average for unmonitored workers where locations are not known (pg. 33). While area weighting was used, an alternative would be to assume equal presence at all areas. Why was area weighting assumed? Was area weighting based on area sizes that were sampled for the inventory estimates rather than based on the total size of the areas?	GR: Using the site average values is the same as assuming equal presence in all areas. The extensive soil surveys that were conducted in the 1980s (McArthur 1983, 1985, 1987, 1988, 1989, 1991) consisted of thousands of in-situ measurements taken from many locations within the contaminated areas. These data were used to estimate total inventories (by Area) of the most important radionuclides. The values provided in Table 4.2.2-1 are simply the total Area inventory divided by the total Area size.
17	Gene	Did NIOSH review the sampling efficiency of particulate samplers at high wind velocities with respect to the reliability of air monitoring and resuspension factors?	GR: No. The relative agreement of the predicted values and the measured values, along with the claimant-favorable assumptions used in the resuspension model provide reasonable assurance that the predicted intake will not underestimate the actual intakes.
18	Gene	Did NIOSH review the accuracy of HTO sampling at low humidity levels at NTS?	GR: No. The samplers contained a catalytic converter to convert elemental tritium to tritium oxide which was then trapped in a column of distilled water.

19	Gene Cheryl	Did NIOSH provide an analysis of I-131 releases from NTS after 1962 since internal I-131 exposures of non-monitored workers are not accounted for?	GR: There were 10 underground tests that resulted in loss of containment and unanticipated significant atmospheric releases after August of 1963. These are documented in Chapter 2 and in the limitations that precede Chapter 6, Rev. 00. To date, no analysis of radioiodine releases that occurred after 1962 has been performed. CS: This will be done on an as-needed basis by the dose reconstructor based on the infomation provided in Chapter 5. Additional detail for iodine characterization has been included in Rev. 01 of Chapter 5.
20	Gene	The TBD states that it is "reasonable and probably claimant-favorable to assign maximum annual environmental doses for the years 1963 through 1966 equal to the maximum value reported for 1967 (i.e., 318 mrem yr-1)." Given other airborne releases from NTS in 1962 and 1965, can NIOSH provide measurements from NTS itself that corroborate this claim?	The value of 318 mrem was based on the maximum ambient dose measured within any area in 1967. As stated in the TBD, this value was 50% higher than any other measure reported for the entire site for that year. Therefore, although not known with certainty, it seemed appropriate to use this value to bound exposures for the period from 1963 through 1966 because, in reality, employees would not likely be located 100% of the time at the location of highest radiation exposure. This value could be increased if deemed appropriate.
21	Gene	NIOSH did not address inadvertent ingestion of soil as a pathway. Why was this excluded?	GR: Inadvertent ingestion of soil has typically not been shown to be a significant pathway for exposure when compared to direct exposure and inhalation pathways. An evaluation was performed that showed ingestion of the most contaminated soil at the NTS (i.e., 100,000 Bq/m^2 over a 10 cm depth, Table 4.2.2-1) at the EPA accepted ingestion rate for workers of 50 mg/day (RAGS 1989) would result in an annual dose to any organ from any radionuclide of much less than 1 mrem per year. Doses of this magnitude are typically not included in the IREP analysis. Therefore, the inclusion of annual dose resulting from ingestion of soil is not deemed to be important for purposes of dose reconstruction.
22	Gene	The TBD states on page 35 "Although there were many radiation measurements completed between 1951 and 1967, most of these were to characterize the effects of weapons tests and were therefore not appropriate for use in estimating external environmental dose for unmonitored employees." Which measurements were reviewed and where are they referenced?	GR: These data are summarized in a series of 19 Radiological Safety reports that were produced from 1951 through 1966. These reports typically included radiological data for all tests conducted in a given year. These data were gathered on a daily basis after each test and used to determine the 10 mR/hr and 1 R/hr lines where control points were set up to control access. Data were also gathered at "downwind" locations including many offsite locations. However, it is not possible to determine with any certainty which of the many measurements may have represented radiation levels essentially unaffected by the test. These Radiological Safety reports have not been cited in the TBD because the data from them was not used. However, the citations can be added if deemed necessary.
23	Gene	The TBD states on page 36 for external dose that the claimant-favorable maximum site value should be used if the area in which the employee worked is not known. In case of resuspension doses, the area-weighted average was used if the area in which the employee worked is not known. Why do the procedures differ in the two cases?	GR: In each case, the recommendation favors the claimant. As explained in the response to Comment 10 above, the claimant-favorable assumptions used in the resuspension will result in intakes that are, with few exceptions, greater than those derived from the measured data. Likewise, using the site maximum ambient dose rate will always result in the highest dose assignment to the claimant.

24	Gene	With respect to the occupational dose to tunnel workers for radon, there is uncertainty with respect to the skin dose relative to a given lung tissue dose (see e.g. GM Kendall and T J Smith, "Doses to organs and tissues from radon and its decay products", J. Radiol. Prot. 22 (2002) 389–406). How is uncertainty accounted for?	GR: To date, NIOSH has limited dose reconstruction from exposure to radon to the lung and ET1 and ET2 regions. Therefore, contribution (and uncertainty) to skin dose from exposure to radon has not been considered. VS/RK: Generally, workers in tunnels were provided with respiratory protection, and also work protective clothing. These workers were continually monitored by the REECo RadSafe Monitors. They also wore their PIC, film badge and usually if airborne radioactivity was suspected continous air sampling was performed.
		Internal Comments	
25	Lori	NIOSH indicated in the NTS TBD that several ingestion intakes occurred during cleanup activities at CLEANSLATE and DOUBLE TRACK. Where are the details of these ingestions documented?	LA: The summary report that includes the Double Tracks intake (one worker, ^{239}Pu, June 1995) prepared by an independent investigation team is cited in the NTS TBD (French & Scrable, 1995). The site contractor documented the details of the occurrences in internal reports.
26	Lori	For what years was LANL responsible for the bioassay program at NTS? Which aspects of the program did LANL oversee?	LA: LANL was responsible for the program and performed bioassay for NTS from 1955 to 1958 when the REECo radioanalytical laboratory came online.
27	Cheryl	Are the radionuclides outlined in Table 3.1.1-2 of TIB-0002 used to determine the internal dose for nonmetabolic cancers? Why did NIOSH/ORAU not use the area or facility specific radionuclides of concern, given the variability of radioactive constituents?	CS: Several techniques have been developed for assigning internal dose. Project specific guidance has not been developed for the atmospheric testing era to date. Dose reconstructors are permitted to use ORAUT (Oak Ridge Associated Universities Team) guidance (i.e., ORAUT-OTIB-2, ORAUT-OTIB-14, and ORAUT-OTIB-18 within their stated limitations) for NTS.
28	Lori	It is unclear from the TBD what values were used for particle size, length of exposure, and breathing rate for internal dose calculation. Where is this information found?	LA/CS: The default values for particle size and breathing rate used for internal dose reconstruction are from the Internal Implementation Guide, OCAS-IG-002. The length of exposure is determined by the Dose Reconstructor consistent with the description of the NTS bioassay program in Chapter 5.
29	Lori	The TBD cites a reference to the effect that internal exposure data for E-Tunnel workers "were limited in both the quality and quantity needed for making reasonable accurate estimates of the intakes and doses." (Vol. 5, pg. 69). How is NIOSH approaching this problem of E-Tunnel worker internal dose estimation?	LA: The summary report that includes the E Tunnel intakes (24 workers, ^{239}Pu, June to August 1994) prepared by an independent investigation team is cited in the NTS TBD (French & Scrable, 1995). The site contractor documented the details of the occurrences in internal reports.

30	Cheryl	NIOSH has cited examples of ingestion dose (Vol. 2, pg. 21 and Vol. 5, pg. 69), but the TBD contains no model for estimating ingestion exposure. Does NIOSH consider that internal dose monitoring was sufficient to cover ingestion as well as inhalation? How is NIOSH partitioning between ingestion and inhalation in going back from bioassay data to intakes of radionuclides?	CS: For those workers where the dose reconstructor determines that a chronic environmental dose can be applied, ingestion is included in the evaluation. When performing internal dose evaluations, inhalation has been found to be the dominant factor and is the pathway evaluated when using IMBA. If project guidance from #ORAUT-OTIB-0018, Internal Dose Overestimates for Facilities with Air Sampling Programs, Rev 01, August 9, 2005 can be applied, ingestion/resuspension is included in this model. VS: I don't know why there is so much emphasis on injestion? While I was working there, we were very careful that we did not enter highly contaminated areas without adequate protection, full Anti-Cs and respiratory protection. Also, during high winds we did not enter these areas. Weather was key to much of our activities in the flats. All testing was controlled by the weather and forecasts.
		External Comments	
31	Griff Ron Cheryl	What type of beta/gamma dosimeter was used before 1961? Where is this information documented?	RK: The NTS film badge was changed to a multi-element holder in 1966; the badge used prior to 1966 is described in both the text and in Table 6.3.1-1. CS: Chapter 6, Rev. 01 will include dosimetry information back to 1951.
32	Griff Ron	What type of neutron dosimeter was used before 1966? Where is this information documented?	RK: As indicated in both text and table, neutron dosimeters were not used prior to 1966.
33	Griff Ron	NIOSH/ORAU has applied the Pantex neutron-to-photon ratios for NTS assembly workers. What is the basis for choosing the Pantex neutron-to-photon ratio? Were the weapons being assembled at the two facilities identical?	RK: Given the basic design and materials involved, as well as the operations, it is reasonable to assume that the Pantex ratios are appropriate. There are classified reports of studies of neturon and gamma doses from weapons. CS: Pantex TBD is in draft. LA Chapter 6, Rev. 01 states: "For exposures after 1960, if neutron dose information is not specifically available for those involved with final assembly and arming operations, photon exposure records, together with neutron-to-photon dose ratios can be used. The neutron-to-photon ratios can be derived from the experience at Pantex where weapons assembly operations were conducted. Analysis of dose records for each Pantex worker with a positive neutron dose greater than 50 mrem for the period 1993 to 2003 yields a geometric mean of 0.81 and GSD of 1.51. An upper 95th-percentile value of 1.6 should be used for the neutron-to-photon dose ratio (ORAU 2004b Iowa Army Ammunitions Plant TBD).

34	Cheryl	The TBD is unclear regarding the direction provided to the dose reconstructor on assignment of external dose. Explain the process to be used by the dose reconstructor to calculate the dose under the following conditions: • Individual has measured photon dose • Individual has measured beta dose • Individual has measured neutron dose • Individual has no beta/gamma monitoring data • Individual has no neutron monitoring data • Individual has values below the detection limit of the particular dosimeter. Please include comments on the adjustment factors, when missed doses are assigned, and the IREP input parameters (i.e., default radiation type and energy, and statistical methodology).	CS: General project guidance for assigning dose is found in • NIOSH, (2002) External Dose Reconstruction Implementation Guideline, Rev 1, OCAS-IG-001, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio. • ORAUT (Oak Ridge Associated Universities Team), ORAUT-PROC-0006, External Dose Reconstruction, Rev 00 PC-2, December 11, 2003. This covers photon, electron and neutron radiation types. Beta dose is evaluated consistent with • ORAUT (Oak Ridge Associated Universities Team), ORAUT-OTIB-0017, Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose, Rev 00, January 19, 2005. After 4/1/57, all EEs entering the site were assigned dosimeters. While these dosimeters were not read for the beta/electron component, this has been identified and other means of estimating beta/electron dose are being investigated.

34		Continued	For an individual with no neutron bioassay, ORAUT (Oak Ridge Associated Universities Team), ORAUT-OTIB-0023, Technical Information Bulletin: Assignment of Missed Neutron Doses Based on Dosimeter Records, Rev 00, March 7, 2005; Chapter 6, Section 6.3.2.2; and the records provided by DOE for the EE would be reviewed to determine the appropriateness of applying neutrons. For values below the detection limit of the particular dosimeter the LOD/2 would be applied as missed dose. This is consistent with • NIOSH, (2002) External Dose Reconstruction Implementation Guideline, Rev 1, OCAS-IG-001, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio and • ORAUT (Oak Ridge Associated Universities Team), ORAUT-PROC-0006, External Dose Reconstruction, Rev 00 PC-2, December 11, 2003. Uncertainty factor of 1.3 has been applied to doses as maximizing based on the information in Section 6.3. This is consistent with the methods used at other sites for uncertainty. Table 6-8 provides further information that is used for neutrons. Currently maximizing photon dose is 100% 30–250 keV. Entry post-event is 25% 30–250 keV and 75% >250keV. Further discrimination regarding photon energy ranges is included in the Rev. 1 of Chapter 6 of the TBD. Statistical methodology is contained in project guidance including several of the above cited documents and additionally • ORAUT (Oak Ridge Associated Universities Team), ORAUT-OTIB-0012, Technical Information Bulletin: Monte Carlo Methods for Dose Uncertainty Calculations, Rev 00, February 14, 2005; • ORAUT (Oak Ridge Associated Universities Team), ORAUT-OTIB-0020, Technical Information Bulletin: Use of Coworker Dosimetry Data for External Dose Assignment, Rev 00, December 29, 2004 VS: Co-worker procedures should cover this area and they can be used as default values that are claimant favorable.
35	Griff	Has NIOSH investigated dose from contact with contaminated water in the tunnels?	CS: In 1961, there was a tritium exposure incident in B-Tunnel (Area 12) that is reported in Chapter 5.
36	Griff Ron	Was there multiple badging of workers at NTS to allow for organ dose determination? If so, how is NIOSH using these data for estimating doses for workers with only one badge? If not, has NIOSH considered the problem of exposure geometry versus badge location in specific areas, such as hot spots, and specific jobs, such as re-entry workers (atmospheric and tunnel)? This issue turned out to be significant at IAAP, for instance, where NIOSH estimated that external pelvic area dose was 2.5 times the value recorded on the badge.	RK/CS: Multiple organ badging was typically not done and indeed was not standard industry practice. Organ doses can be derived from a badge measurement using standard techniques. In the absence of documentation indicative of unusual exposure geometry, the badge data should prove adequate. Unusual exposure geometries require specific individual evaluations; however, in most cases project guidance will be applied.

37	Griff Ron	The TBD states on page 17 that "background films" were used to zero the densitometer prior to reading a badge. What was the variability of the background film data and the densitometer reading itself? Is that uncertainty reflected in the bias factors and GSD for film badge data?	RK: The practice at NTS was consistent with standard photodosimetry practice. The variability of background data within a film lot or batch is virtually nil, and variation from batch to batch is likewise small. Typically, film from a single lot or batch was issued. Any effect of background fog on bias and GSD is trivial and would have no effect on dose estimation.
38	Griff Ron	The TBD states on page 12 that data from pocket ionization chambers (PIC) be used in case film badge results were not available. It is claimed that because of "typical overresponse characteristic", use of PIC results is claimant favorable if no film badge data are available. Can NIOSH provide a comparison of PIC and film badge data?	RK: The energy dependence of the film badge was characterized in the text; under the Pb filter, energy response was essentially flat above 80 keV. As was well known at the time, and published in numerous studies and indeed obvious from the construction of the PICs which had a high Z wall relative to the Z of tissue or air, PICs were notoriously energy dependent for photon energies below about 200 keV, showing a large overresponse relative to tissue (cf. for example, Price, *Nuclear Radiation Detection,* McGraw-Hill, 1958, pg. 91; HW-31781; LA-1835, 3rd ed., pp. 89–90, App. O and LA-2679). There is no known comparison of PIC and film badge data at NTS.
39	Griff Ron	The TBD indicates the detection threshold for neutron energies for NTA film to be "about" 0.8 MeV, for TEDs "about" 100 keV. What is the uncertainty in the detection threshold, and how would a different detection threshold affect the bias factors?	RK: The first sentence in this question is not understood; what is meant by "TEDs "about" 100 keV"? Certainly a shift in the neutron energy detection threshold could affect the calibration (i.e., bias) factor of the NTA film for a specific neutron spectrum. However, far more significant from the standpoint of uncertainty is the neutron spectrum itself which is highly variable, the angle of incidence of the neutrons as a function of energy, and latent image fading.
40	Griff Vern	Section 6.3.2.2 (and subsections) contain statements that in other than neutron generator areas, "[n]eutron doses, for the most part, were low" (pg. 28). The TBD also states that neutron doses for unmonitored workers can be ignored because exposures were "unlikely" (pg. 28). There is little or no documentation cited as the technical basis for these judgments. Would NIOSH provide the references that are the basis for these conclusions? Has NIOSH interviewed site experts and workers in this regard?	CS: ORAUT-OTIB-23 provides guidance on assigning missed neutron dose. EE records reviewed to date have included limited positive recorded doses for neutrons. VS: NTS site experts and workers have been interviewed. The neutron generators were in high security areas and controlled. Unmonitored workers would not have access to these areas as they were under security's control. There seems to be a misunderstanding of how neutron generators were used. Note: This is a security sensitive area. There is more than 20 years of site experience for persons developing these TBDs. Some of the authors worked with the workers using this equipment.

ATTACHMENT 3: SUMMARY OF CONFERENCE CALL ON SEPTEMBER 9, 2005

Summary of September 9, 2005, Conference Call Regarding SC&A Questions Sent to NIOSH on May 6, 2005. The questions sent by SC&A to NIOSH are in Attachment 1. Written ORAU Responses are in Attachment 2. This summary of the conference call complements the written responses in Attachment 2.

Present on the September 9, 2005 call:

NIOSH: Mark Rolfes
ORAU and ORAU subcontractors: Judson Kenoyer, Gene Rollins, Cheryl Smith,
SC&A: John Mauro, Hans Behling, Arjun Makhijani, John Hunt, Tom Bell

In the following summary the term "NIOSH" refers to NIOSH, ORAU, or ORAU subcontractors.

NIOSH stated that Richard Griffith, Ron Kathren, and Vern Shockley could not be on the call due to other commitments, but they are all valuable resources for questions in their areas of expertise.

NIOSH Worker and Site Expert Interviews

NOISH had extensive interchanges with site experts by telephone, e-mail, and numerous site visits. The closest communication was with Martha DeMarre, Manager, Nuclear Testing Archive, Coordination and Information Center. Phone communication with her and external and internal dosimetrists was pretty much on a daily basis during the preparation of the TBD. NIOSH also talked to retired workers. There are informal notes of communications as well as e-mails. The e-mails and notes that were used in the site profile were cited as references and are available. They are listed as personal communications and were documented. They are in the CD that was sent to the documents section to be archived. They can be retrieved and sent to SC&A. The referenced communications are on the O drive [which is the main NIOSH document database]. There is a CD of references for every chapter of the TBD. [A list of contacts made by NIOSH with NTS personnel is shown in Annex A to this Attachment.]

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

It was not clear during the call whether NIOSH had interviewed William J. Brady, who worked at NTS from 1952 to 1991, when he retired as Principal Health Physicist. [Post-call clarification: Richard Griffith, NIOSH contractor, interviewed Mr. Brady on February 27, 2004, regarding neutron exposure and on April 15, 2004, regarding photon exposure. A summary of the contacts is shown in Annex B of this Attachment.] [SC&A's interview with Mr. Brady is in Attachment 5.]

There were no declassification delays in the interview process. A declassification officer was involved in the review of the various sections of the TBD. Although she only attended one of our meetings for the day, she reviewed all of the TBD chapters prior to dissemination.

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.

SC&A requested the notes of interviews, the notes of the interview with William Brady if it was done, other records interviews, and e-mails, whether or not these notes and e-mails were used in the preparation of the TBD, by 22 September 2005. The deadline for final completion of SC&A review was a few days after that.

Status of Revision 1 of the TBD

Through the written response provided to the questions (see Attachment 2) on September 8, 2005, SC&A learned that NIOSH was preparing Revision 1 of the TBD.

In response to the SC&A question about the status of Rev. 01 during the conference call, NIOSH stated that it is still working through the approach document for internal dose during atmospheric testing. The issues on this point are not resolved yet and are at the contractor level still. NIOSH is aware of the problem and is exploring various options for assigning internal dose during the atmospheric testing era. Revisions of other chapters are essentially complete and could be released. They have been edited and formatted. NIOSH is close to issuing revisions to all chapters except Chapter 1. [The person responsible for Chapter 1 could not be on the call.] Chapter 1 will be revised, as necessary, to reflect the content of most recent revisions of the other chapters of the TBD. The actual timing of the release of Rev. 01 will depend on the time required to resolve outstanding issues with OCAS.

SC&A noted that its review was of Rev. 00, while NIOSH was ready to issue Rev. 01 at about the same time as the SC&A review of the prior document. NIOSH stated that Rev. 00 was to provide guidance for dose reconstruction from 1963 onward. SC&A stated that it would acknowledge that Rev. 01 is in the works in its introduction, and specifically note that Rev. 01 would contain dose reconstruction information on the atmospheric testing period. SC&A noted that its review will contain some evaluation of issues relating to the atmospheric testing period that emerged as part of its overall review of NTS dose reconstruction questions.

Contractors and Subcontractors

SC&A noted that Mr. Brady had estimated in his interview that there were 800 subcontractors at NTS over the years and asked how many had been identified.

NIOSH stated that the total of 800 included all kinds of contractors small and big, including those who did tasks like mixing cement [which Mr. Brady had also said in his interview – see Attachment 5]. For instance there was someone on site for 34 days and he had 33 badges. He is a claimant. NIOSH wanted job titles and NTS has put that list together along with a short list of prime contractors. Martha DeMarre has identified the main contractors. The job title and major contractor list is included in NTS TBD Chapter 2, Rev. 01.

The integrated ID and film badge was introduced in 1966. There is a clear record of access to the site along with film badge records after that. The film was replaced by the TLD in 1987. Details of dosimeter history are in Table 6.1 of the TBD.

In regard to whether doses were received by NTS personnel when they went to other sites, such as for the New Mexico plowshares test, NIOSH stated that the records of all workers employed at NTS (primarily by REECo) are complete. The issue is rather the other way, as to whether there is double counting of doses for people who came to NTS from Los Alamos or Livermore. There will be a section on this issue in Chapter 6 of Rev. 01 of the NTS TBD. SC&A noted that there may be a period for which the records of Sandia personnel at NTS are not complete in the NTS archive. This is not expected to affect NTS employees' dose reconstruction.

Some Atmospheric Testing Issues

There was apparently no internal dosimetry until 1955 or 1956 when Los Alamos did some plutonium bioassay. NIOSH has not seen any internal data prior to this time in doing its NTS dose reconstructions. There does not appear to be a list of people who were monitored for internal dose at the time; Martha DeMarre has said that the most likely people were the people from Wackenhut, but there are no positive bioassay results. To date the records reviewed during dose reconstruction for this group (security guards) have provided no positive bioassay. SC&A raised questions about the quality and quantity of data – i.e., frequency of sampling, cross contamination, etc. Many workers were not exposed to situations with potential for intakes of radionuclides. Other workers went in and scraped the glassy radioactive matrices formed due to the tests. NIOSH proposes to assign Los Alamos minimum detectable amounts to workers in this period. Also for external dose, NTS TBD Table 6-1 has been expanded to include the specific LODs for the various operations prior to 1963. There are still outstanding issues.

One opinion put forth by NIOSH was that external dose monitoring was not required until 1957, and is not complete in the period up to that time. One of the dose reconstructors stated that badges were provided to everyone after the April 1, 1957. There were no NTS tests from January 18, 1956 (Project 56, NTS Area 11), to April 24, 1957 (Project 57, Pu dispersal tests), conducted on the Nellis Air Force Range, which is contiguous to NTS and which used the same population of workers. The first NTS Test in 1957 was May 28, 1957 (NTS, Area 7, tower test, BOLTZMANN, Operation Plumbbob). From then on the external dose record was pretty good. Prior to that time there are some numbers, but they are of people involved in the test. Others like those at Camp 12, housekeepers who changed beds, etc., were not badged before 1957.

SC&A raised the question of the relative exposure potential during the atmospheric testing period compared to the underground testing period. NIOSH stated that exposures during the atmospheric testing period for workers may not be higher than during the underground testing period because the wind carried away most material after atmospheric tests, while it remained underground after underground tests. In that light, people offsite may have received higher doses than onsite personnel during the atmospheric testing period.

SC&A raised the question of determining the time of entry into ground zero after the test. NIOSH stated that that was a difficult question for the early period. There are operations records for events that could be matched with the personnel records to determine when people were signed in and out of the barricaded areas. There are isopleths of radiation levels in the early time frame, but they are not very helpful in determining dose. During the atmospheric testing period, Rad Safe personnel entered ahead of the marines to monitor radiation levels. Laborers and other crafts entering the area after an atmospheric test occurred were provided radiological support.

SC&A noted that there are a lot of data for armed forces personnel that SAIC has and that they may be a useful source for dose reconstruction for civilian personnel. ORAU personnel responded that ORAU had approached SAIC, but that access to the data was denied, apparently for the reason that the data were generated for a specific client (presumably the Department of Defense), and therefore that it was not appropriate to share it with another client. SC&A noted that some records might be public and even be available on the DTRA [Defense Threat Reduction Agency] web site. NIOSH states that some of those records are in its archive on its "O drive."

As regards access time after underground tests, it could vary from a day to a couple of weeks. That is documented in the access records. For reactor tests, access was as close as they could access the site after shutdown of the reactor test, depending on the purpose of the test. Recently Task 5 [the ORAU Dose Reconstruction task] was looking for re-entry information on a specific reactor test. We were informed that NTS did not have the reports that might contain that information. The responsible site (LLNL in this case) would need to be contacted.

Occupational Medical Exposure

There was a general discussion of how to deal with the issue of PFG when there was no evidence of its use. In the case of NTS, NIOSH has found no evidence of PFG. In response to an SC&A question about the size of the x-ray plates, NIOSH stated that only a record of the list of x-rays that was done was provided. X-ray information is not included in all DOE files. When provided the record, in most cases only the name of the person and the type of x-ray that was done were given [in terms of the medical aspects, not the type of machine that was used].

SC&A noted that the issue of PFG in the early period (up to 1970) was a recurring theme in reviews. According to NIOSH's general procedure, specified in a technical information bulletin (ORAUT-OTIB-0006), one of the default assumptions is an annual exposure from PFG, to be applied when there is no positive indication of equipment that was used. The application of this seems to be inconsistent. Sometimes when there is no evidence, the TBD advises use of PFG; in other cases it does not. In the case of NTS, there is no information on equipment even after 1957, though NIOSH has done an extensive search of the records for this. But the TBD does not recommend assumption of PFGs through 1970. Rather it assumes use of x-ray film throughout. SC&A noted that this could make a big difference because PFG doses are ~3 rem per procedure. SC&A also pointed out that the dose assumptions for PFG procedures are not consistent between

TBDs, which do not always use 3 rem as the default dose. NIOSH stated that the question could not be addressed on the call since the person who has investigated those issues, Ron Kathren, was not on the call.

SC&A has looked at the issue of dose per PFG procedure and concluded that 3 rem is very claimant favorable for an average value. So the issue is not the average value, but the uncertainty. The factor of 1.3 for uncertainty is a one-sigma value and so does not represent a 95th percentile value for the dose. SC&A recognizes that this is a generic issue, but it does affect specific sites and dose reconstructions and so should be taken into account.

Occupational Environmental Exposure

SC&A noted that the average contamination levels may not reflect working conditions for individuals. It seems that in-situ surveys only covered about 10% of the affected area. A review of the isopleths in the McArthur report indicates that area-wide average values may have underestimated soil concentrations, especially when testing areas were close together or tests were done in the same area within a short time of one another.

NIOSH responded that the dose calculation assumed an exposure time of 2,600 hours. Since workers would not spend all their time in highly contaminated areas, this approach was appropriate since NIOSH would not be significantly underestimating the intake. Further, all personnel were badged after 1957. NIOSH also assumes an extra factor of ten for resuspension above the average value when estimating internal environmental doses.

SC&A raised the issue of why NIOSH had chosen to use a resuspension approach, rather than a mass loading, for times long after the tests. NIOSH responded that the resuspension model overestimates dose when compared with on site measurements.

SC&A raised two points in response to this question. First, the main reference cited in the TBD for the resuspension factors, Anspaugh 2002, states that the mass-loading approach is preferred over the resuspension model for times long after deposition, but that actual air concentration measurements are always preferred (Anspaugh et al. 2002, pg. 676). Also Anspaugh 2002 does not contain a good definition of near-field resuspension. Hence, reliance on this reference for resuspension factors at times long after the initial deposition did not seem appropriate. The mass-loading approach gives a different set of numbers.

In regard to the intake estimates derived from resuspension being larger than air concentration measurements, SC&A raised the question of how valid such area air concentration measurements were for estimating individual resuspension dose, especially since a Los Alamos study had area monitoring known to underestimate 5 to 10 micron particle resuspension. Since these particles would dominate the radioactivity content, the use of air concentration measurements as a comparison point seemed to be questionable.

NIOSH and contractor personnel on the call were not familiar with the study. SC&A said it would provide the reference. It is:

John Rodgers, Piotr Wasiolek, Jeff Whicker, Craig Eberhart, Keith Saxton, David Chandler, *Performance Evaluation of LANL Environmental Radiological Air Monitoring Inlets At High Wind Velocities Associated with Resuspension*, LA-UR-00-3091, 2000.

It is downloadable from the web at
http://www.airquality.lanl.gov/pdf/AQReports/LA-UR-00-3091.pdf

SC&A questioned the TBD assumption that it was "reasonable and probably claimant-favorable to assign maximum annual environmental doses for the years 1963 through 1966 equal to the maximum value reported for 1967 (i.e., 318 mrem yr^{-1})." This was because there were airborne releases in the earlier period, but no inadvertent airborne releases in 1967. Also since the TBD assumed that resuspension decreased significantly after the first 100 days, this back-extrapolation raised issues about using 1967 data for the 1963–1966 period.

NIOSH stated that it had not come up with a better method for this than back-extrapolation. With regard to venting — once the venting was identified, they tried to keep people out of the downwind plume.

SC&A said that the question did not refer to a plume due to venting, but to dose from deposition many weeks or longer after the test. Further the 318 mrem was an area monitor and not a personnel dose measurement. SC&A also asked whether the external area radiation measurements indicated a decrease proportional to $t^{-1.2}$ [where t is time after the test].

NIOSH pointed out that 318 mrem per year was the highest ambient dose rate anywhere on NTS. From 1966 onward, the numbers were very stable. The idea was to use the 318 mrem per year after atmospheric testing had stopped, and the dose contribution was limited to ventings.

External Dose – Photon and Beta Components

There was a discussion of correction factors for external dose in light of the NIOSH correction factors estimated for Mallinckrodt. SC&A noted that the correction factor in regard to the relative location of the organ compared to the badge would not be as large for NTS as with the point-source (or close to point-source) geometry that was typical of Mallinckrodt, since NTS would be more akin to an infinite plane geometry. While the effect would not be more subtle at NTS, it needed to be estimated. Further, the angular dependence issue was important, and possibly, far more important at NTS, and the beta component issue may also be different.

SC&A noted that TLDs and film are calibrated with normal incidence geometry. Angles different from normal will introduce an uncertainty into dose measurement, and would result in underestimates of dose. The degree of underestimation will depend on angular dependence of the film or the TLD, which would have to be calculated using a Monte Carlo or some other approach. For instance, exposure would be isotropic when people went into tunnels. SC&A has not estimated how big a difference this factor would make for NTS. SC&A also noted that a related aspect of the problem was the dose conversion factor issue for external dose that it has identified as a separate issue.

NIOSH contractors stated that they would defer to NIOSH and get more information to SC&A after the call. This would be on the agenda for the planned October 6, 2005, meeting.

SC&A noted that this issue has been unresolved for some time. SC&A asked what dose reconstructors were doing currently in regard to exposure geometry when it was not AP. What are the current instructions about this? Ninety or 95 percent of the information is spread out throughout TBD. It would be nice for it to be summarized in a table. For instance, it is not clear from TBD whether dose reconstruction should use AP or rotational geometry. If AP is to be used, this should be mentioned in the document.

NIOSH stated that AP geometry is used as a default, along with a default energy range of 30 to 250 KeV for photons. Hence, DCFs were not currently an issue in the minimum-maximum type of dose reconstructions that are currently being done. DCFs that are more than 1 (e.g., bladder) are used as they are; those that are less than 1 are rounded up to 1. The DCFs in OCAS guidance were designed to be used in best estimates, rather than maximum estimates. Only the low-hanging fruit – minimum and maximum doses – are being done.

SC&A inquired whether Rev. 01 would contain instructions for converting dosimetry data into inputs for IREP that other TBDs have, but which is not now in Rev. 00 of the NTS TBD. NIOSH responded that that information would be provided by dose reconstruction supervisors and that the TBD was not there to provide all details.

SC&A pointed out that the detail in question was essential, since its absence could result in inconsistent dose reconstruction. Without a uniform guidance on the topic, different dose reconstructors would come up with different numbers.

NIOSH responded that the instruction is provided, but not in the TBD. SC&A inquired whether there was a Workbook on the topic. NIOSH responded that that was a whole different side of the picture apart from the TBD.

SC&A noted that it was working with the Advisory Board in order to develop a comprehensive review process that included the workbooks. But in the present context, the important question was: Is NIOSH saying that the TBD does not provide instructions for dose reconstruction.

NIOSH responded by stating: “That is correct.”

SC&A noted that the TBD has included a number of claimant-favorable assumptions on external dose, but inquired about extremity dose monitoring and data since this was not discussed in the TBD.

NIOSH responded that it had not come across any cases for bomb assembly workers for whom this topic was most relevant. This may be information that was classified. At present NIOSH has not looked into it.

SC&A inquired whether bomb assembly was pending as a part of the TBD, in a manner similar to atmospheric testing. NIOSH responded that it was not pending. SC&A then asked how extremity doses for bomb assembly were being handled. NIOSH responded that Dick Griffith would get back to SC&A about that.

Referring to Table 6.3 on page 25, Vol. 6 of the TBD, SC&A asked whether the conversion factor, millirem per mR [there is a typo in the table, it should be millirem per mR, not millirem per R] that starts out at 0.45 is for 30 KeV photons. Another question about this table was whether these values were for backscatter. NIOSH responded that this question should go to Dick Griffith.

In regard to the dosimeter specifications in Table 6.1 of the TBD, SC&A noted that sometimes the high and low sensitive emulsions seem to leave a gap in the middle. One dosimeter read up to 5 R and the other started at 10R. What about the problems in the gap between the two emulsions, for instance, in case of the DuPont 556 package? SC&A inquired whether NIOSH would assume 10 R exposure if there was a reading of 5 R.

NIOSH responded that it would not affect significant number of people, since not many got over 5 R per dose period.

As regards beta dose, SC&A stated that the open window dose was not recorded before 1966. Therefore, the issue of beta dose before that time appears to be unresolved. How was skin dose being defined prior to 1966? NIOSH stated that it was aware of the issue. NIOSH had come up with a solution for estimating that component of the dose for that period prior to 1966 and it would appear as an attachment to Rev. 01 of the TBD.

SC&A raised the appropriateness of using PIC data for dose reconstruction. It was certainly inappropriate for beta doses and PIC would not pick up low energy gamma (less than 30 KeV photons.

NIOSH states that it did not believe that PIC data are being used for NTS dose reconstruction at present. The use of PIC data may be considered for the time before universal badging if NIOSH finds any PIC results in the records provided. In most cases with the re-entry records, the estimated doses are contained in the dose record for the year. There may be some variation, but so far the two records have been consistent.

SC&A stated that it was not aware of any way to make PIC readings claimant favorable. NIOSH stated that PIC data would only be used if no dosimeter data were available.

In response to an SC&A comment that there was a wide range of information in the TBD that seemed hard to sift for use in dose reconstruction, NIOSH responded that there is an “approach document” in the dose reconstruction part of the program that specified how dose reconstruction was to be done for NTS. The details on this were provided in the written responses to SC&A, under comment 34. [See Attachment 2, Comment 34 and response to Comment 34.] The informal approach document is currently under development by Task 5 and is being reviewed internally.

NIOSH stated that the approach has been very claimant favorable for use for compensable minimum dose estimation.

SC&A stated that its concern was not so much about minimum and maximum dose estimates, because procedures appeared to be robust for them, but about best estimate doses.

NIOSH responded that some of the guidance documents specify for which category of dose the particular approach was to be used. For maximum dose, a generic approach is often used, based on a Technical Information Bulletin. If there is something particular to the site that is not in the OTIB or TIB and needs to be, it will be put there. The sign off procedure for OTIBs and TIBs, generally, is Dick Toohey and then Jim Neton.

SC&A stated that putting new information generated from maximum dose reconstruction at specific sites into OTIB or TIBs sounded like a good idea. But some things like neutron-to-photon ratios may be location specific and difficult to put into an OTIB or TIB. NIOSH agreed that this was a valid point and noted that Dick Griffith [not on the call] could elaborate on this more.

SC&A stated that it was a general concern that there was not a good roadmap for dose reconstruction. Dose reconstructors need a document that helps them develop a dose and put it in the individual's record. NIOSH agreed and stated that the "road map" for dose reconstruction will be contained in the approach document, which will be updated as necessary when guidance needs to be revised.

Neutron Doses

SC&A had several questions about the basis for neutron dose conclusions. Section 6.3.2.2 and subsections contain statements that in other than neutron generator areas, "[n]eutron doses, for the most part, were low" (TBD Vol. 6, pg. 28). The TBD also states that neutron doses for unmonitored workers can be ignored because exposures were "unlikely" (TBD Vol. 6, pg. 28). There is little or no documentation cited as the technical basis for these judgments. Would NIOSH provide the references that are the basis for these conclusions? Has NIOSH interviewed site experts and workers in this regard? After the conference call NIOSH clarified the position as follows:

> *Current wording developed for the NTS report in this regard is as follows:*
>
> *There was a thermal neutron component in the NTS film badge packet from 1966 through 1986 to record neutron dose. Since as every film badge packet issued on site had this component regardless of potential for exposure, monitoring data is not necessarily an indicator of exposure to thermal neutrons during routine activities. Most of the neutron exposure at NTS in this time frame occurred in Area 25 (test reactor area or NRDS). Low level exposure to neutrons in Area 12 would only intermittently have occurred and only involved workers who directly handled the fissile materials used for testing. During this activity, fast neutron monitoring was conducted using NTA film and thermal neutrons were monitored*

using the standard NTS film badge. Since Mr. <XXX>'s responsibilities involved <laying conduit in preparation for the tests and subsequent recovery of equipment> and <he/she> was not monitored for fast neutrons, it is unlikely that <he/she> was involved in the placement of the fissile materials; therefore, neutron exposures were not considered for this dose reconstruction.[4]

This is used in the report unless the EE worked at NRDS or one of the other areas listed in Table 6-7.

SC&A noted that the analysis of neutron doses needed to be enlarged. Pantex data for weapon assembly are okay, but what about other neutrons doses? The TBD states that the neutron dose during atmospheric tests was not significant. But the problem of blast and distance in relation to neutron dose needed to be specifically analyzed and elaborated upon. Currently there is no analysis in the TBD for the conclusion regarding insignificant neutron doses for personnel during atmospheric testing. If some personnel wore dosimeters, the results would be useful. [Post conference call clarification from NIOSH: "To date, we have no evidence that neutron dosimeter measurements were performed during atmospheric testing."]

NIOSH stated that this was a good point and that the problem of neutron doses should be analyzed in more detail. NIOSH has seen cases of laborers monitored for neutron doses but that was from the late-sixties onwards. Currently this is an outstanding question. However, a generic claimant-favorable approach could be developed for use in individual dose reconstruction.

The issue of neutron doses 1963 and 1966 has been set aside. The people involved would need to be identified. The people working on the reactors with neutron exposure potential would have been badged from the late 1970s, so Table 6.1 could be used. Records exist for neutron measurements in the late seventies and Table 6.1 is applicable for this time period.

NIOSH has looked at the possibility of alpha –n reactions in the atmosphere. The estimated dose resulting from such reactions is less than 1 mrem per year; so it can be disregarded.

Unmonitored Employees

SC&A asked for the basis of NIOSH's conclusion that "unmonitored employees would not be likely to be exposed to freshly deposited radionuclides." NIOSH responded that there was a lot of effort into controlling entry into areas around ground zero. They had checkpoints and posting. Laborers entering controlled areas would be badged as well. This was not well established before 1956. If there were a case of a laborer who said in an interview that he went into a controlled area but there was no corresponding film badge data, then a co-worker dose would be assigned if and when co-worker data is made available.

SC&A asked how NIOSH was assigning co-worker doses at present. Was cohort badging part of the records? Is there a co-worker study for NTS?

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[4] NIOSH explained that the phrases in triangular brackets would typically have to change to fit a specific case.

NIOSH responded that it had not come across records of cohort badging so far. There is guidance for co-worker doses for other sites in Technical Information Bulletins 20, 21, 29, and 31. Those are the co-worker studies that have been finished. They are on internal web site ["O" drive]. There is no co-worker study for NTS at this time; such a study may not even currently be in the timetable.

SC&A noted that the posting limit of 10 mR per hour at a checkpoint could still result in dose rates of between 1 and 10 mR per hour. This would mean doses on the order of 1 rem per year, so that the problem of missed dose for unmonitored workers could be important. The dose rates at places like the guard shacks might therefore be significant.

NIOSH responded that this could be important and that people may have been exposed to between 1 and 10 mR per hour. The dose rates were measured in order to put down markers. However, the rates shown on the isopleths are not chronic dose rates. They drop off rapidly with time and became insignificant.

Tritium

SC&A asked whether NIOSH had reviewed the accuracy of HTO sampling using silica gel at low humidity levels at NTS. This had been experienced as a problem at Los Alamos. The problem at NTS might be greater due to drier climate. NIOSH has not reviewed this issue.

In response to an SC&A question about high tritium doses in certain periods in tunnels, like Tunnels E and B, NIOSH stated it was not currently aware of any E-Tunnel tritium exposure, but that it would ask Martha DeMarre about such an exposure. The E-Tunnel exposures in the Rev. 00 NTS TBD are ^{239}Pu in 1994. NIOSH has information on the Tunnel B tritium exposure incident in Section 5D4.2 of the TBD and also a list of incidents in Table 5D-20 of the TBD. The dose data exist for this incident. There is a communication about this incident. SC&A requested a copy and NIOSH said that it would be provided. There are no claims for this as yet.

NIOSH stated that it was aware that B- and E-Tunnel exposures were high but that it has not yet seen any claims. The list of significant events provides one guidepost. There is some response in regard to the E-Tunnel in the written responses to the questions [Comment 29]. A lot of the issues relating to incidents in 1963–1966 period have been set aside. This is a small pool of claimants. It would be someone that you can identify as being directly involved in the events. B-Tunnel exposures were in 1961 (tritium) and 1963 (iodines). E-Tunnel ^{239}Pu exposures were in 1994. Prior to 1961, that was the atmospheric testing period.

Iodine

SC&A inquired about isotopes of iodine other than ^{131}I. NIOSH responded that there are adjustments for that in Volume 5 of the TBD and that there will be more analysis of this issue in Rev. 01 of the TBD.

Ingestion

SC&A asked about the process of estimating ingestion doses.

NIOSH responded that people did eat on site ("they did not go back to Mercury for lunch"), but that it had not asked whether people ate outdoors. There was a lunchroom underground. NIOSH has estimated intakes by assuming a 50 mg soil intake from the most contaminated location. The estimated dose is less than 1 mrem per year, so it does not seem to be a significant issue.

SC&A noted that the NCRP 129 suggested maximum intake value was 100 mg per day. SC&A asked whether it was reasonable to use the average concentration of radionuclides in soil in the top 10 cm for fresh fallout. Another SC&A suggestion was that NIOSH should do a scoping calculation for ingestion dose for the GI tract. NIOSH stated that it would look into the issue.

Annex A to Attachment 3: List of NIOSH Contacts with NTS Personnel

Week of	Number of Contacts/Requests with DOE POCs or Site Technical Staff	Details
6/13/2003	N/A	• TBD Team assembled
6/20/2003	0	
7/3/2003	0	
9/12/2003	2	• Team meeting in Las Vegas • Met with Martha DeMarre and Tom Hayes (REECo RadSafe circa 1960–1980) on 9/9/03 in Las Vegas
9/19/2003	4	• Completed successful team meeting and site visit to NTS
10/2/2003	3	• Contacted Martha DeMarre (3 times) and obtained more documentation on incidents
2/27/2004	1	• Contacted Jay Brady (details in separate e-mail)
4/16/2004	4	• Contacted Jay Brady (4/15/04 via fax)
4/23/2004	2	
4/29/2004	1	
5/7/2004	0	
5/14/2004	0	
5/21/2004	0	
5/28/2004	0	
6/4/2004	0	
6/11/2004	0	• Contacted Al Ogurek [Bechtel Nevada Health Physics Manager in the late 1990s to 2004] on 6/11/04 regarding internal dosimetry
6/18/2004	0	
6/25/2004	0	
7/2/2004	2	
7/9/2004	2	
7/16/2004	3	
7/22/2004	5	• Completed data capture TBD team trip to Las Vegas
7/30/2004	0	
8/6/2004	0	• Contacted Jay Brady on 8/4/04 (details in separate e-mail)
8/13/2004	0	
8/20/2004	0	
8/27/2004	0	
9/3/2004	0	
9/10/2004	0	
9/17/2004	0	
9/24/2004	0	
10/1/2004	0	
10/8/2004	2	• Contacted Martha DeMarre to clarify NTS Dosimetry records for LLNL employees • Contacted Martha DeMarre to determine if NTS has specific information on bioassay collection days per Ed Scalsky/Liz Brackett’s request

Annex A to Attachment 3: List of NIOSH Contacts with NTS Personnel

Week of	Number of Contacts/Requests with DOE POCs or Site Technical Staff	Details
10/15/2004	0	
10/22/2004	1	• Contacted Martha DeMarre to clarify a film badge dosimetry discrepancy and request documents
10/29/2004	10	• Continued to work with Martha DeMarre to clarify film badge dosimetry discrepancies
11/5/2004	8	• Continued to work with Martha DeMarre to resolve NTS data questions
11/12/2004	5	• Contacted Martha DeMarre to resolve NTS data questions
11/19/2004	8	• Travelled to LLNL to obtain references and for discussions with Ike Eichhorn regarding NTS dosimetry practices and PLUTO operations, and Charles Meier regarding PLUTO operations • Contacted Martha DeMarre to resolve NTS data questions
11/26/2004	3	• Contacted Martha DeMarre to resolve NTS data questions
12/3/2004	3	
12/10/2004	3	
12/17/2004	3	
12/24/2004	3	
12/31/2004	3	
1/7/2005	8	• Contacted Martha DeMarre at NTS on PLUTO Test run dates
1/14/2005	5	
1/21/2005	7	• Visited LLNL discussed NRDS activities (PLUTO, etc.) with Chuck Meier and Jim Hadley who were formerly active in the PLUTO program • Contacted Martha DeMarre on dates and areas where at NTS test we conducted • Contacted Michael Terrance Moran retired LLNL on postshot drilling and cable gas blocking • Contacted Roger Staley on gas blocking
1/27/2005	2	Contacted Martha DeMarre at NTS on PLUTO Test run dates
2/4/2005	5	
2/11/2005	5	
2/18/2005	8	
2/25/2005	7	• Contacted Cathy Teasdale (formerly with REECo, NTS) at LLNL regarding the NTS Whole-Body Counter
3/4/2005	5	
3/11/2005	5	• Traveled to LLNL for discussions with Ike Eichorn regarding the Drillback and the Nuclear Rocket drafts and to meet with Gary Mansfield regarding uranium isotopic ratio questions • Contacted Cliff Penwell regarding ROVER/PLUTO
3/18/2005	8	

Annex A to Attachment 3: List of NIOSH Contacts with NTS Personnel

Week of	Number of Contacts/Requests with DOE POCs or Site Technical Staff	Details
3/25/2005	3	• Contacted Roger Staley LRL/LLL/LLNL & DOE retiree and Michael T. Moran LRL/LLL/LANL retired in 1993 to discuss Postshot Drilling for LLL and LASL plus other operational activities (crater re-entry and specific events related to neutron and gamma exposures
4/1/2005	4	• Contacted Joanne Norton, NVOO regarding exposures from TRU waste, Area 5.
4/8/2005	3	
4/15/2005	3	• Contacted Ike Eichkorn at LLNL for NRDS information
4/22/2005	5	
4/29/2005	0	
5/6/2005	0	
5/13/2005	2	• Contacted Clifford Penwell NTS REECo retired on Area 401 (NRDS) Rad Safe activities
5/20/2005	4	
5/27/2005	2	• Contacted Bernie Ubank NTS REECo retired on Area 401 Rad Safe activities and verified that the Hotbox experiment was carried out in Area 401
6/3/2005	4	
6/10/2005	2	
6/17/2005	0	
6/24/2005	0	
7/1/2005	3	• Contacted Larry L. White LRL September 1961 to 1966 Retired, Harry L. Krikham REECo Retired, and Earl C. (Bud) Forry, REECo retired
7/8/2005	0	
7/15/2005	0	
7/22/2005	0	
7/29/2005	0	
8/5/2005	0	
8/12/2005	0	
8/19/2005	0	
8/26/2005	0	
9/2/2005	0	
9/9/2005	0	
9/16/2005	0	
TOTAL	**181**	

Annex B to Attachment 3: Summary of NIOSH Contact with William J. Brady

Resolution of Question Regarding Quantities Used for Reporting the Measurement of Personal Exposures to Photons at the NTS, 1962 to 1987

Richard V. Griffith
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August 4, 2004

There had been confusion about the quantities that was used to report personal photon exposures for the period up to 1987 when the personal dose equivalent was formally introduced at the NTS. The individual monitoring calibration information indicated that calibrations had carried out in terms of *exposure* with units of roentgens. However, the records were presented in units of rem (Personal dose equivalent implied).

To clarify this question, on 15 April I sent a Fax to J.W. Brady who had been in charge of dosimetry activities at the NTS since the early 1950s, and had served on the National Research Council committee that had reviewed film dosimetry at the NTS and the Veterans dose reconstruction efforts. In a subsequent telephone conversion, he told me that during this period, exposure and dose equivalent for photons had been considered equivalent since the quality factor for photons was one. To paraphrase, "An R is a Rad is a Rem." Therefore, *exposure* is used in this TBD up to 1987.

ATTACHMENT 4: MASTER SUMMARY OF SITE EXPERT INTERVIEWS

Interviews were conducted with 15 former and current Nevada Test Site (NTS) production, laboratory support, environmental monitoring, medical, and health physics personnel. Personnel represent experience at the test site ranging from 1961 to the present. The interviews were conducted by Tom Bell and Kathryn Robertson-DeMers during the course of the NTS site profile review. The purpose of these interviews was to receive first-hand accounts of past radiological control and personnel monitoring practices at NTS and to better understand how operations were conducted. Interviewees were selected based upon their historical knowledge of both underground and atmospheric tests, as well as their knowledge of the relationship between NTS and the laboratories. Workers were briefed on the purpose of the interviews, and background on the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) dose reconstruction program and site profiles, and asked to provide their names in case there were follow-up questions. Interviewees were offered the opportunity to comment on their particular interview summary to verify S. Cohen and Associates (SC&A) had accurately captured what was said.

The information the workers provided to SC&A has been invaluable in providing us with a working knowledge of the radiation protection program, atmospheric testing, underground testing, tunnel re-entry, and safety tests. Below is a summary of worker input. This information provided is not a verbatim discussion but is a summary of information from several interviews. Individuals have provided this information based on their personal experience.

General

There were several agencies involved in testing at NTS, including the Defense Nuclear Agency (DNA), Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Sandia National Laboratory (SNL), Reynolds Electrical Engineering Company (REECo) the site contractor, and other supporting subcontractors. The weapons were primarily designed and provided by LLNL and LANL. REECo was responsible for drilling the holes and digging tunnels. They employed miners and drillers to perform these operations. EG&G was responsible for fabricating the diagnostic equipment used in testing. This equipment was placed in massive canisters. The weapons were shipped to the test site by the laboratories, along with engineers and scientists who later evaluated the results of the testing. Experimental physicists were responsible for evaluating the technical aspects of the event. If in fact, LLNL had a jet called “Amy” which was used to transport laboratory personnel back and forth to the test site. Laboratory personnel could be stationed at the test site for weeks, depending on the particular test.

Atmospheric Testing

A majority of the United States nuclear testing occurred at the NTS. During the late 1950s and early 1960s over 100 atmospheric tests were detonated for which there was no containment effort. These tests were conducted at Frenchman Flats and Yucca Flats. NTS areas associated with atmospheric testing included Areas 2, 3, 4, 5, 7, 9, and 10. Tests focused on evaluating new weapons designs. Detonation occurred by various methods, including use of numerous towers built for the atmospheric tests in the 1950s and early 1960s. The Nuclear Test Ban Treaty ended atmospheric testing at NTS in 1962.

Laboratory Testing

The device was constructed as a design model at the laboratories. Some of the final assembly work had to be coordinated with other laboratories. At times, parts would be transported to Nevada and assembly of the device would be completed. The design of the diagnostics canister was done by the responsible national laboratory and it was assembled at the site by contractors such as EG&G in Las Vegas. Some of the canisters were built at the EG&G facility and transported out to the test site.

To install the canister, a circular hole was drilled into the ground. The canister was lowered into the hole. Different layers of backfill (different materials) were added. Attached to the canisters were the diagnostic cables used to record performance of the device. These diagnostic cables came up through the ground and went to trailers, which were at an adequate distance from the ground zero. Recording was conducted without the presence of employees in the trailers. When the subsidence crater occurred, the cables could be pulled away from the trailers.

The shots were fired from a Control Point (CP) where test support staff was located. The CP overlooks the Yucca Flats where the tests were done. All of the pre-shot evaluations were done there. Containment physicists reviewed the design of the containment with the Site Director. There were early morning briefings on the weather conditions to discuss the stability of the weather. The shot were not performed during bad weather. The Site Manager gave the okay. The device was then detonated. The diagnostics were collected and recorded during the shot by the remote equipment.

Typically personnel gained access to the area. Post-detonation, the health physics personnel entered the area to determine whether radiation leakage had occurred. When the all clear was given, scientists went into the area to retrieve the information recorded by the remote system in the trailer.

There was a radionuclide characterization of the gas. At one end of the pipe was a nuclear device, and 400 feet away there were optical diagnostics to observe the prompt radiation in the pipe. In between, there were four alcoves with diagnostics to track the progress of the shot. Slifers were placed in the wall to monitor the propagation of the shot. They compared the experimental data with the calculation theory. They were looking for good agreement. During the “Marvel” event, they tried to collect gas samples that made it to the end of the pipe. After the event, the collection system was pulled up. They wanted to know whether the radiation debris came from the device itself.

Defense Nuclear Agency Testing

The DNA conducted tests with weapons of known design. Underground testing was primarily conducted at Rainer Mesa (i.e., Area 12 and Area 16). They were used by DNA for tunnel and transient radiation effects research.

Tunnels were dug into portions of Rainer Mesa facing Yucca Flats to support DNA operations. The weapon was placed at one end of the tunnel and the rest of the tunnel was used to place open pipes for transient radiation effects studies. It is important to note that different tests may have been performed in the same general areas. The bomb was detonated. As gases from the explosion cooled, the overburden collapsed above the nuclear device. The ground had to be stable prior to re-entry, and the area had to be cleared for health purposes.

Tunnel Re-entry

Tunnel re-entries were done to evaluate the infrastructure and help to decide whether it was safe to go back in or not. The tunnels were well constructed and had containment doors which sealed and prevented gas and debris from getting into the tunnel. In almost all cases, these containment doors worked well. If there were leaks, these usually occurred from leaks through fissures and cracks in the surrounding rock, backfill, or drillbacks. During one of the first tunnel tests the containment systems failed, and there was a fireball that came out of the mouth of the tunnel and vented into Area 12.

Radiation from gas sampling and debris was analyzed with a gas chromatograph and with gamma monitors to determine when it was safe to go back in. This was usually within one or two days, but sometimes sooner. If all seals held, they were able to go back in quickly. These re-entries posed the greatest potential for internal and external exposure at the site. Entry into tunnels had to be preplanned in order to reduce exposures. A few months after tunnel tests, radiation levels still were around 1 R/hr. To help to reduce personnel dose potential to radiation and chemicals, health physics (HP) and industrial hygiene (IH) personnel employed use of multiple crews and time limitations. The establishment of multiple crews meant that each crew only worked in the tunnels every other week. HP and IH entered the tunnels initially to characterize the exposure conditions. There were detectors on the wall to assist in monitoring levels of radiation. If individuals approached the Administrative Control Limit (ACL), they were told to discontinue work and exit the area.

Radiation safety re-entry personnel went into the tunnels wearing anti-contamination clothing (Anti-Cs) and full-face respirators. Initial teams went into tunnels with Scott air packs. HP and IH considerations were determined simultaneously.

There were some tritium exposures documented in the tunnels. The tunnels at NTS became closed atmospheres only when the air exhaust system was turned off and the portal was sealed. Otherwise, tunnels had air exchanges via the drawing of air from the area of the drift face, and they routinely experienced a phenomenon called “pumping” as temperatures changed over a 24-hour period. Where there was water in the tunnels, tritium was sometimes detected. For example, B-Tunnel had tritium-contaminated water. When tritium was detected, they may have sealed off the tunnel and not used it for future tests, depending on the amount of tritium detected.

In regards to internal dose, underground test safety test personnel did wear respirators upon re-entry. Los Alamos National Laboratory was concerned about the dust levels and the potential for inhalation. LANL did a study, took nose swabs, and wrote a report on the condition hazards. They also did an analysis of the decontamination process.

Under the current management of operations, workers wore double Anti-C clothing, a full respirator, and a personal air sampler known as the "giraffe sampler." In the past for the same situation, personnel wore booties, coveralls, and gloves because nothing was moving or being resuspended.

High-Yield Nuclear Test

The Jorum Event in 1969 was a high yield test that was felt miles away in Las Vegas. To prepare for the test, a 12-foot diameter hole was drilled into the ground. The initial placement design was at 3,400 feet. Since this area was previously used as a well, the test placement was moved to approximately 4,000 feet underground into the ground below a water well. The area around ground zero was vaporized and melted rock was found at farther distances away. For example, a one megaton shot vaporized rock up to 20 meters in radius and melted rock as far away as 40 meters in radius.

Dynamic Studies of Gas Flow

The dynamic gas flow studies were conducted over a wide range of exotic high-energy pipe flows. For example, Project Plowshare's Mock 500 piping ("Marvel" event) was used close to the nuclear event. The exposure potential resulted from the exposure in the area due to previous tests that had been done.

Spent Fuel Climax Project

Tunnels used for the Spent Fuel Climax Project (SFCP) were left over from the "Piledriver" experiment. During this project, they excavated a large area of tunnels in the granite rock. Tunnels that went back to the area where the explosives were set off were closed up. The elevator was located at the top of the surface where the excavated material was hauled out. They added a large room, which was used as an assembly area. The elevator was used to carry materials down to this room. This room should not have been affected by the explosions. For the SFCP, gauges and other equipment had to be installed in the wall that was near the spent fuel sites. Spent fuel rods from a reactor were loaded into storage areas underground in the room. Placed in the rock in the immediate area were the diagnostics to analyze the effects on the granite. Operations were done remotely. A report was issued on the setup of the SFCP. This work lasted approximately 5–10 years.

Other Projects and Tests

Area 11 is commonly referred to as Plutonium Valley. Mock-up devices containing weapons grade plutonium were tested in this area. As a result of these safety experiments, the plutonium did not burn up and was dispersed throughout the area. It is expected that most devices tested at the NTS had sufficient plutonium to fission. When dispersed, this plutonium had the potential for inhalation doses over relatively large areas. For some events, such as the "Small Boy" site in Area 5, the device yield was small enough that there was plutonium dispersed with the fission products produced during the detonation. In some areas, safety tests were conducted over the top of old atmospheric test areas. This made it difficult to assess the plutonium contamination with high exposure rate levels at the same location.

At "Gnome", the experiment was to try to use an underground test as a steam generator for electricity. Water was pumped into a previous test underground cavity and the water was super heated by a nuclear detonation producing steam.

The "Smoky" event was conducted on August 31, 1957, in Area 8. Three safety tests were conducted in the vicinity of the "Smoky" site leading to plutonium dispersal. The highest level of ^{241}Am and ^{239,240}Pu identified in soil samples to date were those samples taken after these three safety tests. These events were conducted within eight days of one another. The number of personnel who may have entered these locations between each event is not known, nor is there information on what dosimetry and personal protective equipment (PPE) requirements were in place.

Bechtel Nevada (BN) currently has a contract with other facilities to ship waste to the NTS for burial. For a number of years the NTS agreed to receive shipments of legacy waste from these facilities. LLNL began storing this legacy waste in the early 1970s. It remained stored at LLNL for a number of years before finally being shipped to NTS where it was also in storage for many years. NTS waste handlers still find liquid in some of the drums and they have to dewater them. NTS waste handlers also found mixed waste, (i.e., beryllium pieces) inside, which caused industrial hygiene problems in handling these materials. They found things in the drums that surprised them. The objective was to segregate the transuranic waste, repackage all the non-transuranics back into the drums, and then take the drums back for burial in Area 5. When they found beryllium, the drums had to be unpacked and re-packaged again, ensuring that the beryllium was segregated off by itself. The transuranic waste went to the Waste Isolation Pilot Plant (WIPP) for final disposal. They are getting close to finishing the legacy waste from LLNL. This should be done by the end of 2005.

Radiological Control

Contractor Environmental Safety and Health personnel had minimal presence during the set-up of a testing location. Most of their support was provided pre- and post-event. The pre-event support consisted of exposure rate surveys of the expected entry route and at the ground zero area before the event was conducted. Post-event support consisted of exposure rate surveys after the device was detonated and during experiment recovery. This work scope included most above-ground and underground events.

There were a variety of radiological hazards associated with weapons testing. During the atmospheric testing there was prompt radiation. For underground and atmospheric testing, there was radioactive fallout. The fallout was disbursed by the wind. As a result of testing, the entire site was/is contaminated to some extent. With the 40–45 years that have passed since atmospheric testing, there has been radioactive decay of some radionuclides. Individuals working in the earlier years were exposed to more radioactive material than those that are there currently.

The radionuclides of concern were generally mixed fission and activation products such as ^{60}Co, ^{90}Sr/Y, ^{106}Rh-Ru, ^{131}I, ^{134}Cs and ^{137}Cs. There is also ^{152}Eu, ^{154}Eu and ^{63}Ni found onsite or in the waste stream. Plutomium-239,240, ^{238}Pu, and ^{241}Am were dispersed when mock-ups of different weapon designs were tested to determine the potential of accidental fission from storage or transportation accidents. Weapon's grade plutonium was dispersed over numerous ground zero areas of the NTS. There were special events at the test site that involved ^{233}U. Thorium and polonium were not an issue during weapons testing and post-detonation operations. The highest radon levels were observed in G-Tunnel which was due to the geology and less ventilated areas within the tunnel. Yucca Mountain has similar geology to G-Tunnel, and has some posted radon areas deep down. Those who read the regulations closely want to approach radon as an occupational dose. Strontium-90 and ^{137}Cs are the more prominent radionuclides at NTS. Depleted Uranium was used in artillery round experiments done by the Department of Defense (DOD).

Over the history of the NTS, numerous support camps have been established in the forward areas in support of the testing programs. These support camps were near above-ground and underground ground zeros in many instances. If an event deposited contamination on a camp or major roads, decontamination efforts were utilized to quickly reopen access to these roads and facilities. Once an area was declared "clean", eating was allowed in these facilities and on the major highway that went through the test site. For most of the forward areas, all personnel wore dosimetry and permanent air sampling stations were used to document the success of decontamination efforts near active facilities.

Most of ground zero areas were accessed by road. Many of these roads were used routinely between events and after the locations became inactive. Many are still used with the appropriate warning signs and fencing is maintained to prevent unplanned access.

Posting and fencing of residually contaminated areas was initiated in the late 1960s and early 1970s once the above-ground ground zero areas were on a permanent inactive status. This was especially true of plutonium areas. Prior to this, there was no posting or fencing of above-ground ground zero areas because they were used numerous times, and the fencing would have been destroyed by subsequent events or by post-event clean-ups to prepare the areas for the next event.

Posting and fencing did limit access to areas, but these areas were not policed. Many of the sites and their access roads are relatively remote. It was assumed that the training and briefings received by personnel who entered the NTS would prevent entries into these areas without

Radiological Control support. Compliance was generally good, but there were numerous instances where signs or fences had been knocked down or they were ignored.

There are numerous radioactive sources onsite for various projects. Some of the sources formerly or currently onsite include:

- Eighty-eight one curie ^{137}Cs sources that were placed around the underground shaft at "Sedan" and blown out by the detonation. LLNL found two of these sources in 1989 performing surveys with gamma spectrometers.

- LANL receives all orphan sources like AmBe and PuBe that are sent to NTS from other DOE facilities for storage and that are eventually sent onto the WIPP.

- Both Areas 3 and 5 receive some waste from other facilities including sources. For example, the University of Hawaii sent an old 1,200 Ci Cs source to the NTS for burial in the spring of 2004. They had to get the source into a special shielded container that is now buried out in Area 5 in a trench. Area 5 is one area where waste handling people either currently or in the past, worked around the glove box operations during waste separation.

- Livermore had a ^{252}Cf source in a water well they used for operations onsite.

The deployment personnel, which are part of the nuclear emergency search team and the personnel working at the remote sensing lab at Nellis Air Force Base (AFB) and Andrews AFB, were the groups of people who worked with mobile sources. They use these sources to do response checks on their instruments and they get small doses. The dose is small, but they routinely get dose because of the small check sources, which are in front of them.

Los Alamos National Laboratory (LANL) and Lawrence Livermore National Laboratories (LLNL) personnel currently work with the orphan source recovery program, and they handle the drums coming into the NTS from other DOE facilities and the placement of these drums into the storage bunkers in Area 6. The number of neutron sources is increasing in this area. LLNL people are getting 30–40 mrem/quarter. The top exposure is 60 mrem/quarter in Area 6.

With implementation of the Radiological Control Manual, the site went to the use of Radiation Work Permits (RWPs). Now all work is laid out in the RWPs. There is less Radiological Control Technician (RCT) coverage needed as a result. Up until the implementation of the Radiological Control Manual, radiological safety personnel did not use RWPs. With the more strict regulatory emphasis, the RWPs made the process better, reduced the dose to personnel, and brought better procedures.

Prior to RWPs, the health physicist had the flexibility to make local decisions. Now operations have to follow a prescribed process that may need to be amended but cannot be done so without significant effort. Work performed today is based on regulatory requirements rather than personal experience.

Samples were taken from the puddle at the bottom of the test cavity at an appropriate time after detonation. These samples were like “Trinity” glass. They then punched out some of this core material and placed it into a bottle. The potential for dose was in the multiple R range. They used tongs to do the job, but sampling personnel still got dose. Chemists liked to play with the “Trinity” glass-like material found at the bottom of the cavity, but Radiological Control personnel kept their contact time to a minimum, and exposures were kept down in spite of potential for high dose.

Due to the low potential for neutron exposure onsite, there is a limited inventory of neutron survey instruments. There are shipments received onsite which require neutron survey. For example, when the subcontractors come in with moisture density gauges (Trauxler gauges with AmBe sources in them) neutron surveys are performed. Neutron survey instruments are sent off periodically for calibration to a vendor that has met the DOE contractor assurance program (DOECAP). The vendor is periodically audited. If you have multiple DOE facilities using the same kind of neutron monitoring equipment to be calibrated, these multiple DOE facilities join together to do one group audit rather than every individual customer auditing Thermos’ neutron calibration process. Neutron surveys are completed in areas were neutrons are expected to be an issue.

Internal doses were a problem in 1967 at the Henre Facility (High Energy Neutron Reactor Experiment) facility. It was necessary to change out the target for the accelerator which had a 2000 Ci ^{3}H source. During this change out, a degassing process happened. Personnel went into the area in bubble suits, but they still got doses in the µCi/cc range.

Current instrumentation in use at NTS includes Geiger Mueller counters with pancake probes and Pocket Ionization Chambers (PICs). During the days when REECo was doing operational calibration, the instruments were calibrated according to the specification at that time. Now there are calibration procedures that are approved by the Radiological Health instrumentation personnel.

External Monitoring

External dose was the dose of most importance at NTS. Internal dose was only a fraction of the external dose in most situations. In terms of collective rem/year, the NTS was always lower than any of the other DOE facilities. The site depended on film badges and later thermoluminescent dosimeters (TLDs) to determine external dose.

Prior to 1956, badges were primarily issued by the First Radiation Safety Support Unit (RSSU) operated by the U. S. Army. During the atmospheric nuclear testing era, a film badge was issued to any individual or group of military personnel who were to enter a controlled area (known as a RADEX area.) REECo took over the Radiation Safety functions at the test site in March of 1956. Prior to that period of time, people entering a controlled area were issued dosimetry by the military. From March 1956 through 1965, a person passing through the checkpoint entering the test site was required to wear a separate film badge and a separate security badge, both issued by REECo. In 1966, the film badge was combined with the security badge. In more recent times this design was replaced by two separate badges that are in use today. From 1957 to 1992, during the underground testing era, everyone who entered the test site was assigned a badge. Security guards ensured that the film badge was issued and they collected the film badge for processing. The contractor provided dosimeters to all individuals onsite including Atomic Energy Commission (AEC), DOE, LLNL, LANL personnel, and other support organizations or visitors to the site. The process of assigning doses to subcontractors and visitors was as thorough as badging for regular onsite workers. Visitors, government employees, and subcontractors were monitored according to the same criteria as employees. For visiting laboratory personnel, badges were maintained at NTS on a badge rack. In almost all cases, anyone coming through the gate was badged, including infants brought into Mercury to see a ball game. Therefore, there were children and infants monitored. In such cases or if a visitor to the NTS did not have a social security number (SSN), you would see a birth date for identification purposes.

Temporary badges were issued if the person forgot to bring their badge that day. These badges were issued with a particular identifier for the individual and the computer would add all badge readings together automatically, so all dose was recorded. There were test cases run to ensure that such data was not neglected. Therefore, the system would accept as many dosimetry issues on the person as actually happened.

Cohort badging was not a common procedure at NTS after March 1956. Since March 1956, NTS personnel were badged with their own badge. Although individual badging was used primarily by the military, the military did make more use of cohort badging. There was only one exception. Sometimes film badges were not used for certain tour groups where it was planned that they would not get off the bus or would not go into a radiological area. In such instances, visitors were not all badged but relied on the dosimeter of the tour guide.

The underground nuclear test era ended in 1992. By late 1992, a new film badge policy was being considered and was implemented in 1994. From 1994 and later, it was no longer required that non-radiological workers wear film badges. This policy was not readily accepted by LLNL and they continued to monitor all their personnel. The statistics of doses at the test site shows that 99% of personnel received a zero rem dose. Zero doses for almost all workers at NTS might be anticipated since, unlike other DOE facilities, NTS workers were not dealing with hands-on processes. Instead, they received acute event exposure, if anything at all. Therefore, there were not the usual long-term chronic doses often seen in other DOE facilities. At the test site, there was no production of uranium or plutonium. Nothing was being made at the test site. Large exposures are the exception at the test site and are very few and far between. Any overexposure resulted in a large-scale investigation and a positive dose report, since they were so uncommon. Positive dose reports were prepared and distributed on a daily basis. The positive dose report for any non-NTS, laboratory, or military person was forwarded either to the military, the laboratories, or the individual's parent agency.

For visiting laboratory personnel, badges were maintained onsite in a badge rack at NTS. LLNL policy was to have their personnel use NTS dosimeters while working on the test site. LLNL personnel that came to NTS were instructed not to bring their LLNL badge. NTS made sure the local dosimetry results were sent to LLNL including zero readings.

The supervisor was responsible for telling individuals when they were close to the ACL. PICs were worn in the controlled areas. If the PIC was positive, the badge was pulled for immediate processing. The supervisor had the latest film badge results plus any subsequent PIC results. These were added to evaluate whether individuals were within the limit. The dose was zeroed out on January 1st of each year. During the period from September to December 1961, some miners in the B-Tunnel did approach the administrative limit of 3 rem per quarter. A request was made to the AEC asking that such workers be allowed to exceed the three rem per quarter administrative limit, allowing them to use their full 5 rem/year allowance in that one quarter. AEC made the decision that such workers should not be allowed to exceed the 3 rem/quarter limit.

Bechtel Nevada (BN) has developed a summary analysis of the statistics of badging individuals during the period of underground testing that covers the period from 1961 to 1997. These statistics document the decline of badging after the moratorium on underground testing became effective in 1992. In the 2 or 3 years prior to the end of underground nuclear testing, the Nevada Test Site was badging 28,000 to 29,000 people with dosimeters. In 1993, about 26,000 people were badged, by 1995 only about 15,000 people were badged and by 1998 it was down to 3,000 people badged. Since then, the number of people badged has been going back up. It's hard to imagine, with those kinds of quantities being monitored and the fact that the dosimeter was part of the security badge assembly, that there would be much of any opportunity for someone to get through the entry checkpoints without a dosimeter.

Beta/Gamma

In the external dosimetry technical basis document, a description of the program is carried forward through the revisions. There is information that can be useful that is in all the different revision levels of the technical basis documents. Information goes back to 1951 at the beginning of the testing at the NTS. The documents give description of the dosimeters used at various times over the years right on up to the present. It has some information of the general useful ranges of the dosimeters. It does not talk about how they kept track of dose information in dose records; it does talk about the dosimeter itself. The external dosimetry program is accredited on a 2-year basis, so the technical basis documents were/are updated at the same time.

Film badges were usually exchanged on a monthly basis. TLDs were exchanged on a quarterly, semi-annual, or annual basis. The dosimeter had filters to distinguish between gamma, x-ray, and beta dose as they developed through time. Determination of density of the film badges was done by recording several areas on the film badge if it looked like the badge density was not uniform. Sometimes it was very evident that there was heat or aging damage. In regard to open window exposure, the algorithm backed out any penetrating radiation of low enough energy that could be confused with the actual beta exposure. There were also calculations of exposure to the lens of the eye. The dosimetry form included a lot of information on types of film, frequency of film badge changes, and problems with film in the report.

Controls and standards were processed with each film batch during processing each day. DuPont film was used in film badges and in 1970 they switched to Kodak film. The response of the two types of film was different. They had to put a binary label on each Kodak film, unlike DuPont film which was prenumbered.

If a zero dose was seen, historically it was recorded as zero. Doses of 30 mrem or greater were recorded as the dose of record. There were routinely 15 mrem badges and they would be recorded as zero because of the potential error in a true exposure. The minimum detectable dose (MDD) for current TLDs is 10 mrem for gamma and 10–15 mrem for beta.

For the "Buster Jangle" test series, LANL did the dosimetry and recorded the dose. The MDD was either 50 or 60 mrem. Dose less than these values was recorded with a code indicating that the doses are less than values.

Once workers were allowed to take their dosimeter home, there was a problem with unreturned badges. Workers would simply forget to bring dosimeters back. Badge delinquency was significant in laboratory personnel (LLNL and LANL) and contractor personnel. Delinquency was fairly high even in the early 1980s, but has improved significantly during the 1990s to the present. Fading, heat, and age affected the film badge. People would come in after a 6–8 month absence and turn in their badge. They were issued a new badge and the old one was processed. These film badges had to be processed separately in order to account for the aging component. The older they were, the harder it became to make the needed corrections. If the film in the film badge was over 2-years old, they just recorded a dose based on what they had done with other coworkers since they couldn't get any meaningful density reading off the film. This was also a problem with TLDs and track-etch dosimeters.

NTS badges were processed by NTS. At times, laboratory workers turned their laboratory dosimeter into NTS. These had to be returned to the appropriate laboratory for processing. Although laboratory personnel may have traveled with their laboratory dosimeter, they were not allowed to use their laboratory film badge for work onsite at NTS.

Although all national laboratory personnel were given NTS dosimeters for use in monitoring their potential NTS exposures, some are known to have worn their lab dosimeters "to check on the NTS dosimeter program." This practice was discouraged by both their employer and NTS personnel, but it is known to have happened on an infrequent basis. Thus, any NTS exposure would have also been recorded on their lab dosimeter.

When dosimeters were lost or damaged, or highly exposed, a dose investigation was completed. Damaged film badges were evaluated by reading the film and making a notation of this damage on the log sheet. There were some conditions where the badge could not be read. For example, some guards' badges had the plastic in their film badge warped so badly by heat that the film in the film badge could not be read. The final dose assignment was based on an interview with the person, field data, and coworker data. Because such a small population had a positive exposure during the year, normally the readings were zero. If the individual belonged to a group which did receive exposure, a more detailed analysis of the job tasks was completed. This made it more complicated to reconstruct a dose. If it became too difficult to come up with a hard number, a worst case dose was assigned. Estimated doses are flagged in the dosimetry records.

Much of the time, unexpected readings on dosimeters were the result of the dosimeter being worn during medical x-rays. The individual having nuclear medicine tests and/or treatments, or the dosimeter being run through screening equipment at the airport, are examples of these kinds of unexpected readings. One security employee's film badge is an example of what is known as a "suitcase dose." The x-ray screening of the individual and his personal effects at the NTS security gates does not add any dose to their dosimeter. But when individuals leave their dosimeter in their luggage at the time of checking in for an aircraft flight, the dosimeter goes through a Computed Axial Tomography (CAT) scan and the dosimeter can get a dose of 300 mrem or more. There is, however, a very significant signature pattern under the four elements of the film badges' filters, so that it is easily recognized. An investigation was completed and it was verified that the badge was checked in with luggage at the airport. This happened several times a quarter. These occurrences are well documented in the dose record.

Orientation of Exposure and Multiple Badging

There were situations where partial body exposure to the skin, gonads, or lens of the eyes occurred. Under these conditions, multiple or extremity dosimetry was used. Originally they used impregnated Teflon TLD disks. They could not be reused. As a result of this, there was a switch to TLD chips for extremity use in 1977. TLDs gave lower detection levels as well as being reusable. There were a lot of advantages to making that change. When NTS evaluated the brand new Harshaw models, Harshaw let the site take them for several months to do studies. This benefited Harshaw, because they wanted field testing data on their system.

Multiple badges on several areas of the body were sometimes used when non-uniform radiation fields were present. These multiple film badge locations were usually obvious. For example, multiple dosimeters were to be used while opening drums to remove the waste or during different burial purposes. Coveralls were designed to facilitate multiple dosimetry with little pockets on the sleeve and thigh where you can insert additional dosimeters and they stay there. The site had an established procedure for when extremity and multiple dosimetry was used. The official film badge or TLD of record was worn on the chest. They may have had TLDs taped on their body to see if there was any difference. More often than not, when an incident occurred there was no dose other than the whole body. This kind of data was all put on microfilm that is now in the Nuclear Testing Archive (NTA).

There was a 125 Ci Cs source that NTS was disposing of. It had been stored down in a well and they were going to retrieve it from the well and send it off to burial. They did surveys as it was brought up. Once it was brought up high enough, they wanted to leak test the source. It was maintained in a water-cooled system. Because they were leaning over the well, there was an obvious shielding effect and parts of the body would be exposed and parts of the body would not be exposed. They used 3 multiple dosimeters on each of the people working on the task. There was no meaningful dose. The practices were coordinated well enough that the highest dose was about 30 mrem. With doses that small, it is hard to measure the gradients (i.e. how different is it on the right arm versus the top of the head versus the chest location etc.) There are not jobs at NTS where the dose rates are high enough to get a meaningfully different dose from one part of the body to another. In regard to dose on the back of the body versus the front of the body, with the work being done out here now, NTS hasn't encountered that. One of the questions being asked for the homeland security facility that is being designed right now involves the location of sources in relation to people working in the facility. It will be important to know what the dose will be when a worker is working with one device and another source may be behind him.

At nuclear power plants, dose rates can be variable and dosimeters are needed to determine doses to different parts of the body. At NTS, where the dose at the chest is 20 mrem and the head is 30 mrem, a difference of 10 mrem does not justify doing all the extra work to quantify the difference, as this is within the uncertainty of the film badge reading.

Neutron

There are not many areas at NTS where neutron radiation is an issue. Some neutron exposure is associated with the reactor at Area 27, also known as Area 410, related to the Nuclear Rocket Development Station (NRDS) for tests like "Super Kukla." Neutron exposure was also a possibility from the nuclear propulsion engines in Area 25, also known as Area 400. This involved such tests as "Rover", "Kiwi", and "Rhoades." In Area 26, there were tests which resulted in some neutron exposure. In regard to neutron dose at the atmospheric tests, the only possible source of neutron dose would be from prompt radiation from the nuclear detonation. However, personnel were not permitted close enough to receive such neutron exposure.

The Area 5 waste handling area deals with potential neutron exposure, as does the orphan source recovery program at LANL in Area 6. LANL is collecting sources as part of their orphan source recovery program. Their mission at NTS with respect to orphan sources concentrates on neutron emitting sources. LANL has bunkers full of neutron emitters.

Neutron Track Type A film was used until the mid-1970s and had been used for almost a quarter century. It was realized that the NTA film was not capable of monitoring low energy neutrons, and the NTA film was not valid for accurately determining neutron dose. Neutron film was reported to have an energy threshold of 600 KeV. The biggest issue with neutrons was getting a handle on neutron energy to do an accurate job of estimating neutron dose when it was seen on the dosimeter. The minimum detectable dose (MDD) for NTA film was 30 mrem for neutrons.

With the inadequacies in NTA film, NTS started to consider other options. The only technology which made sense was the use of the LiF-6 and LiF-7. In 1978 or 1979, the new TLD Albedo dosimeter, which used lithium six and lithium seven chips, was developed. This dosimeter was capable of monitoring much lower energies of neutron and was a better dosimeter for recording neutron exposure. The MDD for TLDs was from 10 – 15 mrem.

There were no significant differences in badge response between the calibration source and what was actually seen in the field. The calibration process was working and any differences in source term were accounted for. During the switch from NTA film to TLDs, the spectrum was graphically represented and a calculation of the response was determined to give the true dose. The TLDs worked, but the NTA film did not. They did not go back to apply any correction factors for the NTA film. When they used NTA film, they never got a positive reading because they were never dealing with neutron spectrums of high enough energy to leave any tracks that are associated with neutron exposure.

NTS used an in-house Hankins CR-39 track-etch neutron dosimeter from 1987–2001. The actual MDD for the dosimeter was higher than the reporting threshold, resulting in a few false positives. Doses were reported down to 25 mrem. Some of these doses were probably random variations in the natural background in the detector systems that might get reported as occupational dose. In a case where the MDD is lower than your reporting threshold, then there is a possibility of some small occupational dose that wouldn't be recorded. In our cases it is just the opposite, it would have reported a few doses as occupational that were just variations in natural background, because the MDD was higher than the 25 mrem used as the reporting threshold.

Internal Dosimetry

NTS relied upon in-vitro bioassay and whole-body counting (WBC) to evaluate internal dose. The air sampling data was not typically used, but would be more conservative if it were to be used. There were opportunities for percutaneous, oral ingestion, and inhalation intakes when coming in contact with fallout and with re-entries into tunnel complexes. This was true even years after the test. During atmospheric testing, when troops and support personnel rushed in, there was a potential for internal dose and this may not have been assessed.

There was both a routine and event-based bioassay program. Health Physics personnel at NTS decided who would need bioassay based on who had the likelihood of internal exposure. Submittal of routine bioassay samples was either quarterly or annually. In the case of tritium, samples were submitted within a day or two of exposure. Event-based bioassay was used if it was believed there had been a potential for internal dose. The site provided 1 liter bottles for collecting bioassay samples. Positive bioassay results from events were rare.

Bechtel Nevada has a subcontract to do bioassay, which has been in effect since the year 2000 when BN implemented this new subcontract. Prior to 2000, BN and REECo earlier analyzed bioassay samples at the Camp Mercury analytical laboratory. The onsite lab had a large capacity for processing samples. Outsourcing caused a loss of some on site capabilities for sample analysis. NTS Radiological Health is now trying to reestablish alpha and gamma spectrometry capabilities. There is still some onsite capability for processing environmental air samples.

The first whole-body counter was set up at the NRDS in Area 25, which was owned by Pan Am. When Pan Am went defunct, the WBC was transferred to Mercury. In the mid-1960s they also brought in a WBC trailer and did baselines on personnel. If personnel were on a bioassay program, they also had a WBC each year. WBC and bioassays were usually low.

The original whole-body counters were sodium iodide (NaI) detectors. When they became available, the site switched to germanium detectors. There were no technology shortfalls with the program as they always had the best equipment. Money was not an issue at NTS.

Particle size analyses were not done. They just assumed that the particles were of reparable size and would get into the lungs. The solubility class was based on *Report of Committee 2 on Permissible Dose for Internal Radiation,* ICRP 2, followed by *Limits for Intake of Radionuclides* *by Workers*, ICRP 30. If the particles got into the alveoli, that would be a problem with internal dose.

Tritium was a concern during certain operations at the site. NTS dosimetry used metabolic models and bioassay to develop an infinity curve for tritium uptakes assuming tritiated water. This resulted in an overestimate of the dose. The methodology resulted in calculated doses that were greater than those determined by using ICRP 2 or ICRP 30.

The uranium study completed in 2003 involved getting samples of urine from people who had lived for a period of time in communities in Nevada and Utah that were within several hundreds of miles of the test site. A number of communities were involved in this study. Participants included those on city water systems as well as on wells. This study was the basis for determining natural background uranium level in urine. Navarro was responsible for conducting the study and issued a report on their findings.

Relationship with Outside Organizations

There is a good working relationship between NTS and the State of Nevada personnel. Nevada State personnel come out and take co-samples at the very same time and at the same locations where NTS personnel collect their samples.

There has been a strong EPA and earlier Public Health Service (PHS) presence at the test site. As federal regulations evolved, National Emission Standards for Hazardous Air Pollutants (NESHAPS), the Safe Drinking Water Act, and the Clean Air Act (air pollutants), all became drivers that affected how sampling was done at the test site. There have also been "work smart" standards that were developed by REECo, then BN, and now by the National Nuclear Security Administration (NNSA). Contractual directives and agreements have also been drivers.

Nevada Operations has also done a public outreach program in communities surrounding the test site to explain the residual radiation levels and possible health effect or lack of health effects in cases where doses are low. The "Simon" test produced fallout over the Riverside and the Bunkerville area, which had very small populations. They had to establish a roadblock and ensure cars were washed. The "Harry" test also required roadblocks as the fallout from this test passed over St. George, Utah. St. George, Utah, is the most controversial in terms of offsite fallout. After "Harry," they had to tell the local population to stay inside. After these tests, they evaluated the testing conditions and meteorology in order to prevent similar occurrences. The Public Health Service started offsite surveys in 1953.

Environmental Monitoring

There are onsite monitoring stations scattered over the site, including environmental dosimeters and air sampling units. The air samplers pulled in 1000 m^3 of air and could see 10^{-17} uCi/cc of plutonium. It can be seen in almost any of the samples in the Plutonium Valley area, but the levels are usually quite low. The site performs ambient monitoring with TLDs which they posted and picked up quarterly. Calcium sulfate dosimeters were used in environmental monitoring. These were more prone to rapid fading from ambient heating, i.e., the heat would anneal the accumulated dose right out of them. The lithium fluoride dosimeter, in terms of fade, was not as sensitive and produced less fading characteristics from ambient heating. Although there are currently some effluents at the test site, they are not very common. If they are present, then they are closely monitored. NTS historically had both particulate and gaseous releases.

Historically, offsite monitoring was completed by the contractor in support of operations at NTS. EPA and the Public Health Service also conducted and still conduct their own monitoring. Data has been published covering offsite air sampling results.

NTS used NaI and germanium detectors to count samples in a well-shielded area with an approved method of sample analysis for analyzing samples from air, water bone, soil and vegetation.

Currently, the NTS environmental monitoring program has the responsibility of characterizing the various areas of the test site for residuals of contamination to ensure that DOE and Nevada Operations Office are in compliance with DOE orders, and EPA and Nevada State regulations. Their review is focused on small changes in radiological levels in water, soil, biota, and NTS little critters that live on the test site. Trends are evaluated in residual levels in well water and soil to evaluate small changes in activity; where the contamination is located, and where it is migrating. Both measurements and calculation methods are used to do this tracking.

A major concern of environmental monitoring programs at the test site is that contamination of the water aquifers might occur. These aquifers often run quite deep and can only be monitored by taking samples from deep wells. The NTS environmental monitoring program, however, has never detected contamination moving offsite in the groundwater. The NTS environmental monitoring program samples the springs at Ash Meadows and Beatty area, which are near the California-Nevada border. To date there is no evidence of test site contamination reaching this area, but regulations demand that DOE and Bechtel Nevada continue to monitor this area thoroughly for any possible change in this status.

There was an annual requirement to monitor for ^{226}Ra and ^{228}Ra to make sure they were below the drinking water standards. There did not seem to be an issue.

There are some hot wells on the test site that still have levels above the drinking water standard of 20,000 pCi/l. These wells may also contain other residual contaminates related to the testing era. However, those who monitor the test site know where they are and have seen little if any migration. More recently, environmental monitoring is no longer done on a regular basis, but is accomplished only once in a while to confirm that any residual test site contaminants have not migrated.

There was a tritium issue in Area 5, but at very low levels. The environmental group did some air samples and analysis to determine airborne concentrations. Radiological Health was seeing tritium bioassay results on people that were indicative of E-08 or E-10 µCi/ml. Environmental sampling indicated a level of E-09 µCi/ml. It dovetailed very nicely with the bioassay data and the models for interpreting the bioassay data.

Dose from soil or other material resuspension is not a problem. Plutonium Valley is an excellent example. When the issue of what was happening with plutonium came up at the NTS, it was looked at closely. What remains after testing are large particles. Radioactive material gets bound up in the soil. There isn't fine dust out there to disturb and therefore no fine dust erosion. NTS doesn't have sufficient rain to wash the plutonium into the soil. The plutonium stays in the very top layer of dirt. Even with wildland fires that occurred in Areas 20 and 30, plutonium does not seem to get disturbed. It is not in a form that can be resuspended quickly. Some plutonium was removed in cleanup activities.

Aerial surveys are available for the test site starting in the late 1970s. The beta/gamma signatures are more extensive on the site; however, there are areas with beta, gamma, and alpha contamination. Americium is used to identify the existence of plutonium in the aerial surveys. These surveys have a minimum detectable level of about 50 pCi/gram. Readings seen at the test site can range from below detection up to tens of thousands of pCi/gram right after a detonation.

Beta and gamma residuals around the site of atmospheric tests are still detectable today. Area 18 has a relatively small gamma signature for example. It may not be recognized that plutonium contamination is the primary hazard at these sites, and some workers might have been allowed into these areas with proper monitoring. "Trinity" glass is still present at the major above-ground ground zeros. "Trinity" glass can be a gamma and especially a beta hazard.

Nuclear Reactor Rocket Program in Area 25 was responsible for running a reactor above ground. There were numerous failures of rockets which led to dispersal of fuel fragments and metal debris. These reactor rocket tests did leave a gamma signature on buildings, on flat surfaces of concrete, and on piping. But it is mainly on flat surfaces and soil areas that gamma signatures can still be found. DOE's primary goal with this area is to stabilize it and put it under legacy management.

The Desert Research Institute has conducted soil sampling and in-situ measurements at the test site also. The data from both analyses are being compared to evaluate the coordination between aerial surveys and soil sampling.

It is important to note that although access to ground zero from one test may have been limited, many tests were detonated in areas with almost the same coordinates. In review of the test dates for particular areas, it is noted that detonations could be as close as one day apart. This meant that set up for subsequent tests was taking place within days of the previous event. For example, at the T-7 site, "Baker" was set off on October 28, 1951, "Charlie" was set off on October 30, 1951, and "Easy" was set off on November 5, 1951. In total, 30 events were conducted at this location from 1951 thru 1958. These tests were done in close proximity of one another. Thus, the potential for exposure to previous test(s)' residual radiation or contamination was often possible.

Contractor personnel would work at these sites to install experiments, build towers, or balloon supports before the detonation. They could be tasked to remove debris and reinstall structures for the next test very soon after the previous event. Radiation safety personnel were responsible for taking pre- and post-detonation exposure rate surveys. Limited access to these historical records show that pre-event dose rates could be several mR/hour as a result of multiple tests being conducted in the same area. This work posed a potential for external dose from contaminated soil, as well as internal dose from inhalation of resuspended soil.

There have been animal studies evaluating internal and external dose at NTS. Data indicated that for atmospheric tests, for close-in fallout, that the external dose was 2 to 3 magnitudes higher than the internal dose. Thus for onsite doses in this era, if you controlled the external dose, you controlled the internal dose.

Incidents

In 1963, at the underground test, "Yuba", a tunnel test was conducted and re-entry personnel did receive dose from the iodine exposure. The recovery was initially conducted during the day shift and personnel did the recovery in self-contained breathing apparatus. However, during the graveyard shift, radiation safety monitors found the iodine contamination by using radiation monitors known as "friskers." Personnel involved received whole-body counts following the event. This resulted in a Type B investigation.

In January 1956, Los Alamos did a series of one-point detonation safety tests called Project 56. The fourth safety test conducted for Project 56 went slightly critical and the event was considered a major incident. Plutonium was dispersed over the area. There are some claimants associated with this test.

In Area 12, they had a fire where there was concern of potential resuspension of fallout, but there was no measurable resuspension. It burned out through one of the muck piles outside U12G-Tunnel. U12G experienced a couple of blowouts. An extensive set of measurements and samples were brought back for analysis and the analysis showed that there was measurable resuspension. Tunnel blowouts may have resulted in some internal dose. There was also a fire in Area 30 during 2005. It was stopped before it developed into a blowout.

There was an accident during the change-out of a 1,000 Ci Cs calibration source in the facility in CP-50. The source was shielded in 30 feet of water in its operational configuration. During the change-out of the source, it was dropped while the crane was lowering the source into the shipping cask, and the outer container separated into two pieces. The source was contained within a stainless steel capsule within an aluminum shell around the capsule. A worker thought the source was in the lower container when, in fact, it had gotten up into the upper lid cap. When the cap came off, and the Cs source fell, the area became a high radiation area. He held the cesium source for 2.8 seconds and received a dose of 1200 rem to his hand and a nine rem whole-body dose. Blood samples were sent to Oak Ridge for cytogenetic studies. The Oak Ridge estimated dose of less than 13 rem agreed favorably with the NTS estimates of 9.1 rem. Surprisingly there was no reddening or hair loss.

There was an outdoor process underway on the BREN (Bare Reactor Experiment Nuclear). An incident occurred at the time that the BREN Tower was being moved from Area 2 of the NTS to the NRDS. An experimental space research reactor blew up at the NRDS site and created a potential for high internal doses. Parts of the core spewed out all over the experimental area.

Exposure in air was over 1000 R per hour. The exposure levels were monitored with a teledetector. Fortunately, no personnel received any appreciable dose from this event, since those present were behind shields when they began to search for the pieces of the core.

Baneberry Test

On December 18, 1970, the "Baneberry" test resulted in a large venting to the atmosphere. Fissures in the rocks around the vertical shaft let water and gases escape from the cavity. Gases went around the ground zero casing device. With previous tests, they had evacuated the Area 12 Camp; however, they decided not to during the Baneberry Test. The thermal blast heated up the mountain face and the winds that were sucked up circulated back around to Area 12 Camp. Some 200 test site, laboratory, and maintenance personnel were involved.

Only the HP personnel who were going to be closer to the test site were wearing Anti-Cs. They tried to warn the Control Point that there would be a radioactive cloud coming toward the Area 12 Camp. Control point personnel didn't, however, believe that there could be a cloud coming that way and did not sound the alarm. The Area 12 personnel were still in camp as the cloud passed by. It took an hour to evacuate about 200 people as soon as they realized that personnel were receiving a submersion dose.

They took all the Area 12 Camp personnel to a decontamination pad where they had decontamination showers located. When going thru decontamination showers, the HP personnel found that the areas of greatest contamination were on the hair on the back of their heads, on their hands and their moustaches. Most contamination was the result of noble gases. They used rubber gloves over their hands to induce sweating and draw contamination out of the pores of their skin.

Personnel were instructed to provide urine samples. Thyroid checks for ^{131}I were performed soon after the accident. Personnel were then taken downtown to the University of Nevada at Las Vegas where they each received a whole-body count. Doses to the Area 12 Camp personnel ranged from zero to 700 mrem. Personnel inside trailers at the time received the lowest doses.

Security guards surrounded the Area 12 camp to ensure personnel did not re-enter the area. Some of the guards and health physics staff were in the area for the entire day during and after the fallout cloud passed over Area 12.

A class action suite followed this event which had the security guards and others as part of the class. The Department of Justice came out to help and these lawsuits went on for years. There was a split decision on the jury. They felt DOE was at fault, but could not prove that the illnesses or deaths claimed by the plaintiffs were related to the event. It was later appealed. The class action suit started with several hundred class action claimants, but it was later reduced to about 6 claimants.

As a result of this occurrence, testing was discontinued for six months while they reviewed the geology and issues associated with the venting. There was approximately 6,000 curies of radioactive material that vented to the atmosphere. In general, the earlier tests were more problematic than later tests. As time progressed and more knowledge about testing was obtained, the frequency of exposure events decreased. Investigations of venting incidents helped perfect the containment system and prevent venting through cracks or fissures.

Records

There was a considerable effort to consolidate all NTS and the Pacific Proving Grounds (PPG) dosimetry records in what was originally called the Dosimetry Research Project (DRP), now known as the Nuclear Testing Archive, operated by Bechtel Nevada for the NNSA. The records are under the control of the U. S. Department of Energy and were sent to a GSA-leased NNSA responsible space in a Desert Research Institute building. In addition to site records, records were retrieved from LANL and various archives when it became evident that data was missing.

Hardcopy radiation exposure records and actual film from dosimeters are available for NTS workers. In 1957 electronic data files were developed to store dose information. There was a change in databases in 1980. Although exposure histories are fairly complete, there are some gaps. For example, Sandia maintains records generated for the Tonopah test. Tonopah dosimetry, however, is not part of the NTS dosimetry database system.

BN has rosters of all the dose records for individual NTS workers and military personnel who received dosimeters. BN went through the REECo Radiological Safety Field records on microfilm and created a database that indicates the names and the microfilm location of information for a particular person. This is known as the Historical Records Center (HRC) data. This also contains information on test individuals who may have been associated with the NTS tests. This system allows BN to find the data very quickly. Records for LANL, LLNL, and the military are available through the Nuclear Test Archive (NTA) (i.e., those from test series “Ranger”, “Tumbler-Snapper”, and “Upshot-Knothole”).

These dose records are important sources for the doses to AEC and laboratory personnel as well. Additional information about AEC and laboratory personnel can be found in the DNA NTPR reports for the NTS tests. Another good source of the radionuclides at each NTS test is in the growth and the decay of these radionuclides found in the publications and more formal reports.

The BN Nuclear Testing Archive has a list of all NTS incident reports. They are well documented and since there was no Privacy Act at that time (prior to 1974), the information usually made it into the press. There is also documentation in the open literature about incidents at the NTS. In the case of occurrence reports or significant incidents, information in incident reports is extremely detailed. There are photographs, blood tests, source information, and film badge and/or TLD data for each person involved. Incidents occurring prior to the time REECo took over may be at LANL or LLNL. Many reports from the laboratories are available through NTA.

By 1961, the test site implemented the use of a Form AEC 190, for external dose and a Form AEC 191 for internal dose. A summary report of the data from these forms was submitted to the AEC annually. All DOE sites provided the information to DOE Headquarters and its processors. The internal dose form was not supplied when there were no internal exposures. The report breaks people down by company and exposure categories. Information similar to the recorded exposure data on the Forms AEC 190 and 191 were later used in the development of the current DOE Radiation Exposure Monitoring System (REMS). The DOE REMS dosimetry system information was published as annual dosimetry reports starting in the early 1970s. These reports have now all been converted electronically into the REMS electronic dosimetry system.

Some of the doses were only available in operations logs but not in dosimetry records. Operations logs are located at LLNL but these operations logs have not been found. They are likely held in the Defense and Nuclear Technology Directorate and/or the Engineering Directorate. These logs might also be available through the Archive Group at LLNL. NIOSH should review this. Access may be a problem due to classified material and need-to-know. Many of these operations logs would likely require a Sigma 14 and 15 clearance for areas where they might be stored.

One more gap for potential missed dose occurred in the mid-1950s. One site expert has some original records. Archives do not have them. These records have the actual dose people got and include both film badge and extremity dose. Some of these early dosimetry records are pre-REECo for early contractors like American Federated Services. NTS at Mercury would like to transfer these original records through the University of California to LLNL for permanent archiving. However the process has been found to be cumbersome and attempts to do this have not succeeded. LLNL won't allow transfer of these records from the possession of the NTS Mercury site. These are original sheets that should have been sent to LLNL for the period from 1956–1959.

There are event reports that cover the experimental information on detonations which include operational air sampling. Each test has a safety report associated with it. These should be available through NTS or the National laboratories. These reports should contain exposure rate survey information for the pre-event and post-event operations conducted. There may be some dose information in these reports. This information may be useful to determine the dose rates and contamination levels at locations for those workers supporting pre-event construction activities and subsequent post-event clean-up and construction activities for the next event.

Other data that is pertinent to AEC and laboratory personnel is air sampler data and cascade impactors data, which was useful in determining particle size. Fallout trays, sticky paper, and gummed film were also used for collecting particles for analysis.

The U. S. Department of Energy, Nevada Operations Office, produces two major reports annually documenting environmental monitoring at the Nevada Test Site. These two annual reports are the Nevada Test Site Environmental Report (NTSER) and the NTS NESHAP Report. The requirements for annual site environmental reports (ASERs) go back to about the mid-1970s. There have been many environmental studies and reports that extend back to the beginning of testing at the NTS. The EPA Las Vegas office (Public Health Service) and the Desert Research Institute (DRI) have also been involved in monitoring and publishing reports on the NTS.

The NESHAP report sent to EPA annually is provided to document compliance with 40 CFR 61, Subpart H. The compliance dose limit is 10 mrem/year, with monitoring required if the expected dose might exceed 1 % or 0.1 mrem. Dose monitoring is performed using EPA CAP-88-PC to estimate offsite dose. This is a straight line Gaussian model for particles (not meant for gasses such as tritium). EPA is in the process of approving an updated gaseous model soon. EPA approved a Nevada Safety Operations (NSO) plan for boundary receptor air monitoring in place of offsite air monitoring for compliance. EPA, now associated with DRI, conducts oversight "stakeholder" air monitoring offsite with support from public volunteers at community stations (Community Environmental Monitoring Program). NTS environmental monitoring personnel work with DRI at the community locations and assist in public "outreach" meetings to answer question concerning NTS and its current environmental monitoring program.

The Weapons Test (WT) 1488 report done by the University of California at Los Angeles has information about fallout doses over time. This includes particle size versus distance, as well as fractionation that occurred as you got farther away from the test. There is also environmental data for the Tonapah tests done offsite.

In 1954, the AEC did a major review of NTS Test Operations and published a classified review of the operational future of NTS. This review described the operational future of what type of tests would be conducted at a continental test site. It reviewed the type of test, acceptable weather, and conditions that would be considered appropriate for future tests at the test site. There have been several periodic major reviews of the test site by the laboratories.

Unauthorized Practices

Early supervisors (1950s and 1960s) indicated that some personnel got concerned about exceeding the AEC guidelines and would sometimes not wear their badges. If workers exceeded the 3 rem per quarter, they were moved to another work location or reduced-in-force (RIF) if not needed for the rest of the quarter. Workers looked at this as an employment problem and they would not wear their badge when they got close to the administrative limit. There were numerous incidents where Radiation Control Technicians had to tell individuals to retrieve their dosimeter when they showed up without it. Some personnel may not have worn their badges in the early days of testing, since it was up to the individual to wear the badge. This ceased when things tightened up starting in the later 1970s. It was hard to verify whether individuals wore their badges because they were worn under Anti-Cs.

There were reports of individuals purposely taking off their film badge and shielding it while in a contaminated area. One person was reported to have put his badge in between two lead bricks with a hollowed out section in the bricks and keeping it in his vehicle so there would be no exposure whatsoever. Even rocks in the back of the truck were reportedly used to shield the dosimeter and this was an easier way to do the same thing. This practice has not been reported in the last 40+ years. If an employee was caught doing this, he would be punished up to termination and it would be documented in their personnel file.

People did not try to purposely abuse their film badges. But, if they left their film badge on the windshield and they later used it, radiation safety personnel were quick to detect the pattern of a heat damage and they would determine the individual's dose based on the exposure levels encountered by his co-workers.

Medical Exams and X-rays

At one time in the 1980s and maybe early 1990s, REECo offered annual physicals to all employees who wanted one in addition to the "required" physicals for many employees. Sometime in the early 1990s, this was changed to 1–3 years (or maybe 1–5) depending on the employee's age. In the past, from medical chart review, most of the physicals included hearing evaluation, physical evaluation, and any age-related testing (i.e., EKG, etc.), and it appears that lab tests and x-rays were also done. NTS requires physicals for those in positions that require participation in a surveillance program or have specific job requirements (e.g., respiratory protection, asbestos, etc.). These physicals include hearing, EKG (age-dependent), vitals, a physical exam, lift assessment, vision, labs, and x-rays. The testing is dependent on the specific job requirements. Pre-placement physicals are done only one time at the beginning of employment. X-rays may also be done at the opinion of the provider. Not all NTS personnel currently receive physicals.

Medical exams for laboratory personnel are done by the individual groups currently. It is presumed that they would have the records. Current staff does not know the practices of the past.

In the past, x-rays were done at the site. Currently, the services of Insight Mountain Diagnostics in Las Vegas are used. It is unclear whether photofluorography was conducted at the site. Current medical staff indicated 4" x 5" films were not used. Data on the exact make and model of historic x-ray equipment is not readily available. General Electric may have manufactured older x-ray equipment. An outside vendor is responsible for x-ray inspections.

Based on the knowledge of the present medical staff, Diethylenetriaminepentaacetate (DTPA), Prussian Blue, and Potassium Iodide have not been administered to NTS staff to prevent the uptake of radionuclides in the body. If these procedures did occur, the information would be documented in the medical record.

Miscellaneous

Since the inception of the EEOICPA, NTS has been involved in pulling records that would be useful in supporting claimants. NIOSH requests claimant information and technical reports from the BN NTA. Requested data is compiled and provided to NIOSH for use in dose reconstruction. NTS has a complete list of all claimants for which they have provided information.

The BN NTA has provided NIOSH with the following reports to date.

- DNA Nuclear Test Personnel Review (NTPR) Reports
- Test Series Radiological Safety Reports and Reactor Radiological Safety Reports
- Annual Environmental Reports.

- Laboratory & Field Procedures
- Relevant Animal Studies
- Historical Summaries
- Harry Hicks Reports (in growth and decay of fission products over time)
- HRC Collection Indices
- NESHAP Data
- Technical Basis Documents (internal & external)

The first claim associated with the "Yuba" incident was recently processed and the information associated with the "Yuba" event and its investigation was provided to NIOSH as part of this individual's response package.

Although the BN NTA has a list of all NTS incident reports, NIOSH has not shown interest in incident reports compiled. If a report is needed for an individual claimant, they may request the report. There are also valuable Science Applications International Corporation (SAIC) NTPR-related reports applicable to atmospheric nuclear testing era that have not been requested.

To determine AEC and laboratory personnel exposure, it is important to understand the appropriate job title. The job title of being a laborer is different in atmospheric testing than it was during the underground tests. The atmospheric test laborers were used in recovery and did receive dose in 1952, 1953, 1955, and 1957. In the underground testing program, the laborers were usually not used in the recovery. A job title in the tunnel test era called the "bull gang" and "miners", however, could be used in tunnel recoveries. But the job title "laborer" by itself would usually be a person who was not involved in recoveries for the underground tests. When using the old NTA film, it was also important to know the individual's job. It is often necessary to use other data to determine the dose.

Family members of scientists were invited in the past to visit the Nevada Test Site. They were shown the "Sedan" crater, which resulted from a 100 kiloton nuclear shot. They were only able to stand on the platform for a limited amount of time (~10 minutes) due to the dose rates in the area.

ATTACHMENT 5: SUMMARY OF INTERVIEW WITH WILLIAM J. BRADY, PRINCIPAL HEALTH PHYSICIST (RETIRED)

A draft summary of this interview was sent to Mr. Brady for editing two times, once by fax and the second time by FedEx. Mr. Brady returned it with approval of content by fax the first time and FedEx the second time, with approval of content. He also gave his permission to publish his name with the interview. The interview was conducted by Arjun Makhijani of SC&A.

Arjun Makhijani provided an overview of SC&A's role, which was to provide technical support to the Advisory Board on Radiation and Worker Health regarding issues relating to EEOICPA, and informed Mr. Brady that this interview was part of SC&A's review of the NTS Site Profile. He also informed Mr. Brady that this is an unclassified interview. He asked Mr. Brady if he had been contacted or interviewed by NIOSH or its contractors in regard to dose reconstruction issues associated with the Energy Employees Occupational Illness Compensation Program Act. He said he had not.[5]

Background

Mr. Brady worked at NTS from January 1952 – that is almost since the beginning of AEC testing operations at NTS – and he retired in July 1991. He later was on three National Academy of Sciences committees regarding dose reconstruction, film badges in atmospheric testing, and evaluation of the U.S. Army TLD. He participated in 89 atmospheric tests and hundreds of underground nuclear tests and is very familiar with radiation safety programs at NTS since the time he started work there, both as a representative to the military services and to the AEC and contractor side. He held various positions at NTS over the years, including security operations officer responsible for clearing areas of personnel before each atmospheric test in 1953 and 1955, and retired as Principal Health Physicist. Because of his extensive experience, he was assigned to the Defense Nuclear Agency at the request of Vice-Admiral Monroe, then-Director of the Defense Nuclear Agency, assisting DNA contractors in writing 40 volumes of nuclear test histories and providing much information on DOD participation in atmospheric testing. He attended all monthly and other Nuclear Test Personnel Review (NTPR) meetings, except one, over a period of almost 15 years.

Mr. Brady was also involved as director of the REECo Rad Safe reactor program. He worked for Reynolds Electrical Engineering Company (REECo), Inc., for some 35 years at NTS and in Las Vegas. (REECo was bought out by EG&G Inc., and disappeared as a DOE/NV contractor.) Next he was director of the Rad Safe Lab. Then he was senior HP and technical advisor of the Department responsible for Environmental Sciences. Then he was principal HP in the Division, including seven departments. In all that time he also did special assignments. He said he was assigned to the tough ones because they needed someone who really knew what was going on. He helped Dr. Barton C. Hacker with the official history of the Rad-Safe Program, published as a government award-winning book entitled *Elements of Controversy*, and another, *The Dragon's*

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[5] According to NIOSH, a consultant to its contractor, Richard Griffith, contacted Mr. Brady by fax and phone (Attachment 3). Mr. Brady recollects a call from a Richard Griffith but does not recall that he said he was with NIOSH or NIOSH contractors or any details of the conversation that referred to NTS.

Tail. Dr. Hacker did two interviews with Mr. Brady for his book, *Elements of Controversy*. The interviews included discussion of health and environmental issues at NTS and offsite.

Overview

NTS was a very complex site and many things went on there. There are many stories to tell and much detail that needs to be related. Mr. Brady felt that this interview only scratched the surface. There are about 800 contractors and subcontractors, from large contractors to companies that contracted to do sheet metal work and pour the concrete.

From 1952 onwards, the test organization and the Signal Corps were responsible for radiation safety in the initial years. They used Los Alamos film badges. Not everyone was film-badged. It was after the TEAPOT series that REECo took over the Rad Safety program and got more orderly. All personnel were required to have film badges from 1957 on at NTS and from [Operation] Redwing on in the Pacific. Mr. Brady designed the integrated ID-and film badge that was worn at NTS for 26 years. The film badge report was dated 1967, but the film holder was worn from about 1963 on. Since all workers had to have an ID, they also all had film badges whenever they entered the site. From 1957 on, everyone who entered the test site was monitored for external dose by wearing color-coded monthly film badges that security officers checked before entry was allowed at the main gate to NTS.

The film badge program was sound. Bill Horn was very thorough. The members of the NAS committee that I was on were amazed at what Bill Horn had done from 1956. Mr. Brady compiled a list of dosimetry and calibration procedures during atmospheric tests for the committee. A copy can be made available. (Mr. Brady has one.)

Early Days: Atmospheric Testing Program

REECo Rad Safe personnel went toward ground zero in pickup trucks after each atmospheric shot was fired. They preceded the armed forces personnel, so that they could ensure that soldiers avoided highly contaminated areas as much as possible. The problem was that the military maneuver troops stayed in the contaminated areas too long.

The Marines walked to ground zero. The Rad Safe monitors had their own pickup trucks, but many times they got stuck in deep sand. Laborers and people who picked up equipment, electricians, and contractor people, would go in too. They would stop where the road was impassable and walk the rest of the way, the last several hundred feet. They were pretty close to ground zero because they sometimes had to winch out the cable attached to the experiments. They may have had to cut the cable and get the equipment out any way they could (dash in, grab the experiment, and run out).

The initial fireball of the tests was not the problem in terms of large radiation exposures. It was the shock waves after that—one, two, even three—that brought highly contaminated dust with them. The shock waves raised a tremendous amount of radioactive dust, as high as 100 meters. The contaminated dust from previous tests could hang in the air for a day or two as respirable size particles. That was a problem. This occurred in many atmospheric tests.

For example, after a nominal (10 to 100 kT) shot, the shock-wave wind reached 180 miles an hour at one mile. AEC employees and their contractors who went in after the shot any time within a day or two were subject to the same conditions. The problem of internal dose has been neglected. So, the initial assumption that internal doses from the tests were not high was not correct.

The immediate gamma exposures when personnel walked in were from sodium-24 and manganese-56, which are short-lived neutron-activation products, but there is also exposure from resuspended fission products from prior tests. The resuspension of fission products and unfissioned material, including plutonium and other fissionable materials, deposited from prior tests was created by the dust resuspended by the current test. How much was resuspended depended on the type of device tested. So we are talking about strontium-90 and a few other long half-life radionuclides.

In the fall of 1955, there were four safety shots at NTS, called "Operation 56," in which kilograms of plutonium were spread all over the place. Personnel entered the areas in 1956, mined the plutonium, and put it in 55-gallon drums for recovery at Oak Ridge. There was a truck accident on the way, which presented contamination problems.

There was no bioassay capability at NTS and no bioassay in the early days. Los Alamos did a few samples for plutonium in 1956, but very few. They were finding positive results. What the results meant, he was not sure. The personnel were dressed in rubber suits and had supplied air; even so they were getting contaminated. LANL was getting positive bioassay results, but I am not sure whether they were contaminated or not. There was a problem of cross contamination of samples.

Conditions varied from one test to another a great deal. It was complicated. When Floyd W. Wilcox, deceased in 2004, took over as Superintendent of the Rad Safe Division, he made Mr. Brady head of the training branch and historian in late 1956.

Monitors had to respond to laborers and scientists alike; so they had to be special people. Mr. Wilcox's books and papers referring to these problems and some of Mr. Brady's papers are at the atomic museum in Las Vegas, and some of them speak to the early requirements for hired radiation monitors.

The number of Rad Safe people in some tests was large; in others it was not. For operation Plumbbob, there were 130 Rad Safe people from the AEC and contractors and a similar number from the military. Thus, there were over 200 employees and military types involved with the Rad Safe program for Plumbbob. There were over 2,000 Marines on maneuvers plus other military personnel. The Rad Safe people went in front of the marines so they could keep the marines out of the really hot areas. But there were only 39 people in Rad Safe during Hardtack II and everything was hurried up. As one result our monitors could not say in long and get "burned out."

Rad Safe personnel did many different kinds of work. There were Rad Safe people on all flights after atmospheric tests except the flights whose mission was cloud sampling. Mr. Brady once flew through the cloud after an excavation shot whose mission was to seed it with condensation nuclei to induce rain. They did induce rain but could not eliminate the cloud fully.

In regard to decontamination of the aircraft, Mr. Brady said that it was the Rad Safe monitors who did it at NTS and the rest of the aircraft went to Indian Spring Air Force Base, and the military decontaminated them there. Mr. Brady's Rad Safe people from the lab were down there at Indian Spring to decon the air crews. Air Force personnel used an inch-and-a-half fire hose. The engines would get very hot [radioactive] and they were hard to clean. They would run the engines up and put high pressure water through them. The engines were 50 to 100 R per hour initially. They would get them down to 4 to 5 R/hr. Then they would park them to let the short-lived radionuclides decay.

Internal Dose: Tritium

In the early years, the focus was mainly on external dose. There was not much internal monitoring until the fall of 1955, when LASL did some plutonium urine analysis. Then there were some plutonium bioassays. In 1958 there was some tritium monitoring. At one point there were big exposures of tritium. In one 1961 shot, there was a steam explosion and it blew up the E-Tunnel complex. There were to be multiple tests there. It was ready to go when it got contaminated. We did decontaminate it. In the meantime, the workers were used in B-Tunnel. E-Tunnel was vacuumed out. NTS Rad Safe personnel did not know where the tritium was coming from. It was vented to the atmosphere after we found out which shot sites the tritium was coming from and we drilled holes from the top of the mesa to vent the tritium from the top of the mesa. The original tritium sniffer instruments would go off-scale at the tunnel portals because of the radioactive noble gases. After the exposures in E- and B-Tunnels, Mr. Brady developed a more reliable method of tritium monitoring using anhydrous barium sulfate to absorb some of the water from the tunnel air for analysis.

E-Tunnel was first vacuumed, and then washed down with a 60-foot 2-inch pipe. A berm was built and the water pumped into Haynes Lake. That is how the Haynes Lakes were formed. There were two Haynes Lakes, containing a lot of tritium.

Mr. Brady said that there was tritium in B-Tunnel and that they had burned out the decontamination personnel in E-Tunnel. The tritium exposures in this incident were big, from 5, 10, to 20 rem primarily to Rad Safe personnel. In the fall of 1961, 108 miners were also exposed in E-Tunnel and then B-Tunnel. The documentation of the doses is in the records. The NTS Rad Safe laboratory compiled a list of the exposed personnel every week and was having a difficult time. Finally AEC-Washington sent an Ivy-League type to investigate why NTS was having these overexposures. His name was George John Keto, an assistant to General Betz, who was responsible for testing at NTS.

The venting of tritium took place in the fall of 1961 and the spring of 1962. There was other stuff there too. If you fire a shot—an underground shot—and it does not go well, that is worse than if you have a good yield. In a poor shot, you don't get the molten rock. In a good shot, you have the molten rock to hold the radioactivity to some extent.

In one case, a candle caused an explosion in B-Tunnel. Personnel were blown back a considerable distance toward the black door. There were eight of them. Mr. Brady decontaminated them.

The real big tritium exposures occurred in 1958 at NTS. In 1959 Eric Geiger was trying to reconstruct them. There were microfilmed records. Mr. Brady provided each NTPR team with four boxes with 44 microfilms – one for each branch of the service and one for CAN/Field Command, Albuquerque.

Mr. Brady thought that any values of 355 mrem per year for tritium were very low. He said he had written many memos and documents that referred to tritium. Project Gnome, the first PLOWSHARES test, 30 miles from Carlsbad, NM, had NTS Rad Safe personnel, including Mr. Brady. He called the test a disaster. There were water seeps in the shaft and there was also bound water in the salt rumored to be as much as 6%. This bound water and the seep water flashed into steam, rolled along 1,100 feet of drift into the Station Room after passing through the blast door, proceeded up 1,200 feet of shaft, including a blowout preventer, and geysered 300 feet in the air. Mr. Brady said he spent two 10-day trips down there to fix it. Water was leaking into the shaft. There was tritium in the atmosphere. There was a huge amount of tritium. There were water seeps and springs at various places in the drift. Mr. Brady designed a refrigeration system, with anhydrous calcium sulfate which effectively trapped the tritiated water vapor. Then an AEC representative reversed the airflow and dumped much more tritium to the atmosphere.

Internal Dose: Other Radionuclides

The minters were pretty heavily exposed at NTS. Wes Wilcox used at LASL to calibrate the counters and check the biological half-life of ^{137}Cs by measuring his body burden. After the "candle" incident, eight miners and Rad Safe personnel were heavily exposed.

NTS did not really have a handle on the other radionuclides for internal dose until late in the program. Mr. Brady said he started the bioassay program when he was lab director, but it was never fully implemented and they did not care. Is a monitor going to tell you he got an overexposure? They don't get any overtime that way. In addition, you got an extra hour's pay if you went to a forward area.

Eventually NTS got big analyzers, 4,000 channels, to replace the single channel analyzers and the new lab was built. Mr. Brady said that he designed most of the lab, and that NTS had the best plutonium lab in the world. There were two big bell jars with 32 positions, each of which were used to count the samples for up to two weeks. It was all computerized.

The new lab became operational some time in the 1960s.

Off-Normal Practices

If workers got "burned out" they could not go to work in the forward areas. Monitors put film badges into lead boxes or between 2"-thick lead bricks – that was common. At Hardtack II, there were 39 people in Rad Safe. They were told, "Don't get overexposed; we don't have anyone to replace you." Mr. Brady said he himself told them "don't get overexposed." Some guys would take two lead bricks and put them in their truck glove compartment with their film badges in between. The whole point was not to get overexposed in 1958. Different operations had different problems. For NIOSH or anyone else to estimate now as to how much people got exposed at the test site is kind of ridiculous because there were no general rules until 1957. Even then they put their film badges in lead boxes. Mr. Brady had his film badge and his accompanying monitor's badge in between lead bricks in one initial survey. It read 800 mR when processed. We had gone through a fallout area close to ground zero in excess of 50 R/h gamma.

The jobs in the forward areas paid more and so in a funny way employees were working against the clock and telling people that they never got exposed.

In response to the question as to how long the problem of hiding badges in lead boxes and the like went on, Mr. Brady said that it was minimized in the late 1960s.

Mr. Brady said that there are some stories beyond description. He cited the example of a person at the commercial Beatty low-level radioactive waste facility who was giving away hot material. He gave away a hot cement mixer and everything they mixed at Beatty [using that mixer] was hot. Perhaps some items were sold. That was in the early 1960s; 1962, 1963, 1964.

The guy at Beatty had been in charge of decontamination at the rocket facility (Project 400) and he was used to hundreds of R per hour; he did not care about internal dose things. Once a scale that had been used to measure ^{90}Sr at Livermore was then discarded as waste, sent to Beatty and then wound up in someone's home. It was located on a lady's kitchen counter. NTS Rad Safe and EPA personnel had to monitor and clean up the town of Beatty, including homes, tearing up carpets, concrete floors, etc., and our laboratory at Mercury, NM, where "hot" samples were brought for processing.[6]

[6] In reviewing an interview draft Mr. Brady put in a note regarding personnel who were formerly at NTS who then went to the company that operated the Beatty facility that have been omitted here for privacy reasons.

ATTACHMENT 6: NIOSH RESPONSE TO POST-SEPTEMBER 9, 2005, CONFERENCE CALL QUESTIONS

NIOSH sent the following responses to SC&A questions (which NIOSH also reproduced) that SC&A sent NIOSH as a follow-up to the conference call of September 9, 2005 (Attachment 3).

"SC&A inquired whether bomb assembly was pending as a part of the TBD, in a manner similar to atmospheric testing. NIOSH responded that it was not pending. SC&A then asked how extremity doses for bomb assembly were being handled. NIOSH responded that Dick Griffith would get back to SC&A about that."

Status: SC&A has not received the information or heard from Mr. Griffith.

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.

"Referring to Table 6.3 on page 25, Vol. 6 of the TBD, SC&A asked whether the conversion factor, millirem per mR [there is a typo in the table, it should be millirem per mR, not millirem per R] that starts out at 0.45 is for 30 KeV photons. Another question about this table was whether these values were for backscatter. NIOSH responded that this question should go to Dick Griffith."

Status: SC&A has not received the information.

Response: The table in question has been moved to Appendix A in the draft Revision. In fact, this table was taken directly from REECo (Reynolds Electrical and Engineering Company), 1995b, *External Dosimetry Technical Basis Manual for the Nevada Test Site and Other Designated Locations*, Report (548)-6.4.1, Las Vegas, Nevada, December – Table 5-2, Page 39. There is indeed a typo. It should be rem per R, as in the original table.

The conversion factors specified in the table are prescribed in the DOELAP standard for the National Institute of Standards and Technology (NIST) reference radiations: *NIST Special Publication 250-58, NIST MEASUREMENT SERVICES: Calibration of X-ray and Gamma-Ray Measuring Instruments*, April 2001.

The conversion factors specify the relationship of shallow and deep dose equivalent (using a phantom) to exposure (free in air). These factors have been weighted for each of the reference radiation photon spectra. The definition of personal dose equivalent includes the effects of body interaction, scatter, absorption, etc., while exposure, of course is free-in-air. Backscatter is part of the dosimeter response, and varies with dosimeter design and calibration conditions (e.g., angle of incidence). However, the conversion factors shown in this table only provide a basis for converting from one dosimetric quantity to another. Dosimeter backscatter response comes at the time of calibration.

ATTACHMENT 7: NIOSH NOTES ON CONVERSATIONS WITH MARTHA DEMARRE SENT TO SC&A[7]

TO: File

FROM: Lori Arent and Cheryl Smith, NIOSH Dose Reconstruction Team, Task 3

SUBJECT: Nevada Test Site (NTS) Technical Basis Document (TBD), Chapter 5, Occupational Internal Dosimetry - Record of Interview with Ms. Martha DeMarre, Bechtel Nevada

DATE: August 18, 2004

The NIOSH Dose Reconstruction Team members conducted interviews with Ms. Martha DeMarre, the Bechtel Nevada Coordination and Information Center Manager, during September 2003 and July 2004. The interviews were conducted in Las Vegas to support the drafting of the NTS TBD Internal Dosimetry chapter.

During the week of September 8, 2003, Ms. DeMarre provided the following information which was incorporated into Chapter 5 of the NTS TBD:

- *The 1993 Technical Basis for Internal Dosimetry at the NTS* (REECo 1993) reflects radiological protection practices from about 1970 through the end of nuclear weapons testing in 1992, and is the best available source of internal dosimetry information for the nuclear weapons testing era.

- Radionuclides that have resulted in recorded doses above established limits at NTS are ^{3}H, ^{131}I, ^{239}Pu, and ^{241}Am.

During the week of July 5, 2004, Ms. DeMarre provided the following information, which was incorporated into Chapter 5 of the NTS TBD:

- Tritium monitoring started in 1958 with an MDA of 5 μCi/L used for urine samples.

- Individuals who were involved in tunnel work with job classifications of miner, mucker (muck machine operator), "bull gang" (underground laborer), shifter, tunnel walker, dinky locomotive operator and who held a Q-level clearance should be assigned tritium dose. No worker whose employment history is intermittent (employment intervals $\leq$ 5 months) could have obtained a Q clearance and, therefore, would not have been involved in tunnel re-entry or emplacement of devices during events. Having a Q-level clearance and working in Area 1 or 12 is an indication of the possibility of tritium exposure. All other workers should not be assigned tritium dose.

[7] SC&A notes that more extensive notes on NIOSH's contacts with NTS site experts are available on its database that is used by dose reconstructors (as well as the Board and SC&A).

- NTS collected plutonium samples for 24 hours. In effect, the collection procedure normalized them to 24-hour samples. Screenings for all other radionuclides were normalized to 24-hour samples in the bioassay records.

- For iodine air sampling, bioassay records indicate if the air samples were collected with a charcoal canister or a filter.

- The main concerns at the NTS were tritium, iodines, and plutonium. If iodine was present, it was easily identified. In the case of the YUBA test (1963), even the G-M survey meter detected iodine present in workers leaving the controlled area. Because NTS did not have a Whole-Body Counter (WBS) at this time, these individuals were sent to Donner Laboratory (California) for a full workup (whole body and urine). The iodine was easily detectable in urine and in the whole body.

- Due to security concerns, the word "tritium" was not used. The terms "ACTIVITY or "ACT," "MINT," "EVERGREEN," and "T" were code words for tritium. "PRODUCT" was a code word for ^{239}Pu. "LT" or "-" in the bioassay records means less than the detection limit. The code "-99" means not detected.

- NTS maintains a record set called the "dead bioassay database." There are no codes in this database that include information from 1955 to 1963. In the microfiche copy of the bioassay data, the years are listed as two digits, (e.g., 56, 57, etc.). The main purpose of the dead bioassay file/microfiche is to point to the raw data (note, reel, and frame citations). If an individual has a "deadbio" record, the microfiche page is followed by a copy of the original data forms for the data cited.

- Tunnel air sampling began in 1957 in locations with the potential for airborne exposure. Air samplers operated continuously. Radiological Control Technicians checked and exchanged the filters each shift. Bioassay was done only if there was an indication of an effluent release (e.g., positive air sample).

- The original source of tritium in the 1961 B-Tunnel exposures was from 1958 activities.

- The REECo employees that had whole-body counts after the YUBA Event, June 5, 1963, were sent to Donner Laboratory for monitoring. The information was supplied back to REECo and the AEC at the time regarding the data and data analysis (iodine exposures). Nine REECo personnel received thyroid doses in excess of 30 rads during YUBA.