
Draft

**ADVISORY BOARD ON
RADIATION AND WORKER HEALTH**

National Institute for Occupational Safety and Health

**REVIEW OF THE SUMMARY SITE PROFILE FOR THE
PACIFIC PROVING GROUNDS**

**Contract No. 200-2009-28555
SCA-TR-SP2013-0040, Revision 1**

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S. COHEN & ASSOCIATES: <i>Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program</i>	Document No. SCA-TR-SP2013-0040
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ABBREVIATIONS AND ACRONYMS

Advisory Board or Board	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
A/P	anterior/posterior
AWE	Atomic Weapons Employer
CATI	Computer-Assisted Telephone Interview
CDC	Centers for Disease Control and Prevention
CE	Claims Examiner
cm	centimeter
DEEOICA	Division of Energy Employees Occupational Illness Compensation
DNA	Defense Nuclear Agency
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DTRA	Defense Threat Reduction Agency
EE	Energy Employee
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ft	foot
H&N	Holmes and Narver
hr	hour
in	inch
ISO	isotropic
JTF1	Joint Task Force 1
JTF3	Joint Task Force 3
keV	kiloelectron volt
km	kilometer
kt	kiloton
mm	millimeter
MDA	minimum detectable activity
MDL	Minimum Detection Limit
MPE	Maximum Permissible Exposure

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mR	milliroentgen
Mt	megaton
NIOSH	National Institute for Occupational Safety and Health
NOD	net optical density
NRC	National Research Council
NST-LLC	National Securities Technologies, LLC
NTS	Nevada Test Site
ORAUT	Oak Ridge Associated Universities Team
POC	probability of causation
PPG	Pacific Proving Grounds
R	roentgen
Rem	Roentgen equivalent man
ROT	rotational
SAIC	Science Applications International Corporation
SC&A	S. Cohen and Associates (SC&A, Inc.)
SEC	Special Exposure Cohort
SRDB	Site Research Query Database
TBD	technical basis document
TNT	high explosive
U.S.C.	United States Code
WG	Work Group

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1.0 EXECUTIVE SUMMARY

This draft report presents S. Cohen and Associates' (SC&A, Inc.) evaluation of the Site Profile for the Pacific Proving Ground [ORAUT-TKBS-0052, Rev. 0 (ORAUT 2006)]. This draft report was prepared at the request of the Advisory Board on Radiation and Worker Health (the Board). Authorization for the preparation of this report was issued during a full Board meeting held in Santa Fe, New Mexico, in June 2012.

As part of our evaluation, SC&A also reviewed numerous other documents that were considered relevant and included the following:

- Select documents referenced in the Pacific Proving Grounds (PPG) Site Profile
- Documents contained in the NIOSH Site Research Query Database (SRDB)
- Relevant reference texts and scientific studies cited in the open literature

1.1 TECHNICAL APPROACH AND REVIEW CRITERIA

The approach used by SC&A to perform this review includes, but is not limited to, the procedural protocols described in *Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). Approved by the Advisory Board on March 18, 2004, SC&A's protocol reflects the following review criteria:

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

Deficiencies pertaining to these review criteria are noted as "issues." Our review of the PPG Site Profile identified a total of 10 issues. Nine of the issues are regarded as "findings" and represent deficiencies that may require correction due to their potential adverse impact(s) on dose reconstruction. A single issue designated as an "observation" corresponds to an issue with limited significance for affecting dose reconstruction.

The purpose of this review is to provide the Advisory Board with an independent assessment of issues that surround the PPG Site Profile. Specifically, findings identified in our review are expected to provide the Advisory Board with a **preliminary** overview of potential issues that may impact the feasibility of dose assessment.

SC&A's draft report with its preliminary findings will subsequently undergo a multi-step resolution process. Resolution includes a transparent review and discussion of draft findings with members of the Advisory Board's Work Group and select personnel representing NIOSH/ORAUT. This resolution process is intended to ensure that each finding is evaluated on its technical merit in a fair and impartial manner.

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1.2 SUMMARY OF ISSUES

SC&A's review of ORAUT-TKBS-0052, Rev. 00, principally focused on the following four sections of the PPG Site Profile:

- Section 1.0 – Introduction
- Section 4.0 – Occupational Environmental Dose
- Section 6.0 – Occupational External Dose
- Attachment A

Of the nine preliminary findings identified in this review, one finding questioned the 250-day Special Exposure Cohort (SEC) requirement for PPG participants, one finding pertained to Occupational Environmental Dose, five to Occupational External Dose, and two to Attachment A.

A brief statement for each of the nine findings is presented below. However, the reader is cautioned that nearly all findings are supported by a substantial body of information and data that are provided in the text. A more complete understanding and judgment of merit in behalf of these findings may, therefore, require a full review of this draft report.

- Finding 1: NIOSH needs to update ORAUT-TKBS-0052, Rev. 00, with regard to the 250-workday requirement for SEC Class inclusion. Revision 00 of ORAUT-TKBS-0052, *Summary Site Profile for the Pacific Proving Grounds*, was issued on August 30, 2006. At that time, SEC status for presumptive cancer claimants required employment of at least 250 workdays. The 250-workday requirement for PPG workers was subsequently amended by the Department of Labor (DOL) in EEOICPA Bulletin No. 06-15 issued on September 27, 2006 (DOL 2006), and EEOICPA Bulletin No. 07-05 issued on January 11, 2007 (DOL 2007).
- Finding 2: Section 4.0 "Occupational Environmental Dose" completely ignores occupational environmental doses for PPG locations from fallout. (Note: For PPG locations, occupational external environmental dose is for all practical purposes an integral part of the occupational external [as well as internal] dose and should be assessed as such in Section 6.0 of the PPG Site Profile.)
- Finding 3: Available Department of Energy (DOE) records for a claimant may not only be incomplete/inaccurate, but more importantly may not include unmonitored exposures associated with cohort badging, exposure to fallout, etc.
- Finding 4: ORAUT-TKBS-0052 does not provide a definition for unmonitored dose as it applies to PPG participants or any specific guidance.
- Finding 5: Average photon energies associated with fallout are well above >250 keV. Depending on what exposure geometry is assumed, a default photon energy of 30–250 keV may not be claimant favorable.

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- Finding 6: Since claims involving skin cancer usually specify the location(s) on the body, the critical variable of distance above the source plane defined by Barss and Weitz (2006) should be included in the assignment of beta-to-gamma dose ratios for PPG claimants.
- Finding 7: NIOSH's guidance for the assignment of missed dose is based on assumptions that are not supported by facts and in the face of uncertainty are clearly not claimant favorable.
- Finding 8: Independent of other concerns/limitations that characterize the Defense Nuclear Agency (DNA) dose distribution data (e.g., their accuracy, completeness, etc.), use of the 50th percentile dose as a coworker dose is not justified for PPG participants for Operations up to and inclusive of Operation CASTLE.
- Finding 9: Operation-specific dose distributions defined by DNA must be adjusted to account for the minimum detectable activity (MDA) value of film dosimeters regardless of what percentile value is employed.

1.3 ORGANIZATION OF THE REPORT

This draft report was written and organized as a "stand-alone" document by including summary information/data from various sources used to support our findings in the text of this report. For most of the nine findings, additional information is provided that either represents select portions or the full text of documents considered relevant to our findings.

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2.0 INTRODUCTION AND SCOPE OF AUDIT

Under the Energy Employees Occupational Illness Compensation Program Act of 2000 (EEOICPA), the Advisory Board on Radiation and Worker Health (Board) is mandated to conduct an independent review of the methods and procedures used by NIOSH and its contractors for dose reconstruction. As contractor to the Board, S. Cohen and Associates (SC&A, Inc.) has been charged to support this effort by independently evaluating site profiles as requested by the Board that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

At an Advisory Board meeting held in Santa Fe, New Mexico, in June 2012, SC&A was tasked to review/evaluate the Site Profile for the PPG (ORAUT-TKBS-0052, Revision 00), which was issued on August 30, 2006.

2.1 SCOPE AND OBJECTIVES OF AUDIT

SC&A's past approach to the review of other site profiles closely followed the protocol described in *Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004). For the PPG Site Profile, this standard review process is of limited value, due to the fact that for earlier time periods of operations, PPG workers may not have been monitored for exposure, or available records pertaining to worker monitoring, job duties and work locations, and source-term data were insufficient to perform **complete** dose reconstructions. Hence, NIOSH recommended an SEC class that includes all employees of DOE, DOE contractors, or subcontractors who worked at the PPG from 1946 through 1962, who were monitored or should have been monitored for exposure to ionizing radiation as a result of nuclear weapons testing at the PPG (NIOSH 2005).

SC&A's review of the PPG Site Profile will, therefore, assess and evaluate Sections 1, 4, and 6 and Attachment A of the PPG Site Profile, as well as all claimant-specific and site-specific data that are available and considered appropriate for a partial dose reconstruction in behalf of individuals who do not qualify for inclusion in the SEC.

3.0 RELEVANT BACKGROUND INFORMATION

Between 1946 and 1962, the U.S. Atomic Energy Commission (AEC, the DOE predecessor agency) conducted a total of 105 atmospheric and underwater nuclear weapons tests at several locations in the Pacific that principally included the Bikini Atoll and Enewetak Atoll of the Marshall Islands, Johnston Island, and Christmas Island, as summarized in Table 3-1.

Table 3-1. Summary Statistics of Numbers of U.S. Tests and Explosive Yields at Mid-Pacific Locations

	Bikini Atoll	Enewetak Atoll	Christmas Island Area	Johnson Atoll Area	Other Pacific Locations
Number of test	24 ^a	42	24	12	3
Missing yield values ^b	0	0	0	4	2
YIELD (kt TNT equivalent)					
Minimum ^c	1.7	2.2	2.2	11.3	30.0
Maximum ^c	15000.0	10400.0	7650.0	8300.0	30.0
Mean ^c	3201.6	736.1	968.9	2472.0	30.0
Median ^c	388.5	45.5	310.0	1495.0	30.0
Total ^c	763838.8	31653.4	23253.3	19776.3+	30+

^a Includes shot YUCCA, 100 km W of Bikini

^b Data not released.

^c Based on available data only; not strictly correct for Johnson Atoll and Other Pacific locations because of missing values.

Source: Simon and Robison 1997

Inspection of Table 3.1 shows that the collective explosive yield for the 105 nuclear tests in the PPG was the equivalent of 151.55 megatons of TNT (151.55 Mt); and for the 66 nuclear tests conducted at Bikini Atoll and Enewetak Atoll, a combined yield of 108.5 Mt is estimated. Included among these tests was MIKE, the first thermonuclear (hydrogen) device tested on November 1, 1952, on Enewetak yielding 10.4 Mt, and Shot BRAVO, which at 15 Mt is the largest thermonuclear device ever tested by the U.S. on March 1, 1954, local time.

In order to gain a quantitative perspective about the nature of weapons tested in the PPG, the explosive yields of these tests must be compared to those conducted within the continental U.S. at the Nevada Test Site (NTS), as shown in Table 3-2. Thus, the explosive yield for tests in the PPG is about 113-fold larger than those conducted at NTS, while tests in the Marshall Islands are nearly 80-fold larger.

Table 3-2. Atmospheric Nuclear Tests Conducted by the United States

Location of Test	Number of Weapons Detonated	Total Yield (megatons TNT)
Continental United States	107	1.38
All PPG Tests	105	155.6
Marshall Islands	66	108.5
• Bikini Atoll	23	76.8
• Enewetak Atoll	43	31.6

(Source: DNA 1986)

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Another noteworthy aspect of the PPG weapons testing program is the temporal spacing between successive tests.

As shown by dates in Table 2-1 of the PPG Site Profile, the time intervals between tests at the two atolls of the Marshall Islands during the 12-year period of 1946–1958 varied dramatically. For the first 5 years (from June 30, 1946, to May 24, 1951), there were only 9 tests (2 tests in 1946, 3 in 1948, and 4 in 1951) with a combined yield of 544.5 kt that represents 0.5% of the 108.5 Mt yield for all tests in the Marshall Islands.

Beginning with the IVY test series in October 1952 and continuing with the CASTLE series in 1954, the frequency and size of weapons tested increased dramatically. There were six dates (June 11, 1956; May 11, 1958; May 26, 1958; June 14, 1958; June 27, 1958; and July 22, 1958) on which two nuclear tests were conducted on the same day.

The purpose of presenting the aforementioned statistics is to point out the magnitude and dynamics of the PPG testing program and the demands and limitations it placed on personnel and resources that were further complicated by the remote/isolated locations that characterize the four test sites of the PPG.

Undoubtedly impacted by unexpected events, limited resources, and adverse operating conditions were RadSafe personnel. Their charter was to provide radiological surveillance and personnel monitoring for tens of thousands of personnel assigned to the PPG program.

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4.0 REVIEW OF SECTION 1.0 “INTRODUCTION” OF THE PPG SITE PROFILE

Section 1.0 (ORAUT 2006), *Introduction*, briefly describes the purpose of the PPG Site Profile with the following statements:

*The purpose of this document is to provide guidance for dose reconstruction of **non-SEC cancers and those presumptive cancer claims that have less than 250 days of employment** for EEOICPA claimants who participated in Pacific Proving Ground (PPG) operations.*

*An SEC class established for the PPG includes all employees of DOE, DOE contractors, or subcontractors who worked at the PPG from 1946 through 1962 who were monitored or should have been monitored for exposure to ionizing radiation as a result of nuclear weapons testing at the PPG (NIOSH 2005). **This SEC applies to workers with covered cancers who were employed for a number of workdays, aggregating at least 250 workdays** occurring either solely under this employment or in combination with workdays within the parameters (excluding aggregate workday requirements) established for other classes of employees included in the SEC. [Emphasis added.]*

SC&A Comments

From these statements, NIOSH may exclude a claimant from the SEC class for the following reasons:

1. Exclusion is based on the fact that the cancer is a non-SEC cancer regardless of the number of workdays; and
2. Even for one of the 22 covered cancers, exclusion from the SEC class is based on fewer than 250 workdays.

The regulatory requirement of the 250 workdays is cited in 42 CFR 83, Subpart C §83.13 paragraph (c)(3)(ii), which states:

*(ii) For health endangerment **not established** on the basis of a **discrete incident**, as described under paragraph (c)(3)(i) of this section, NIOSH will specify a minimum duration of employment to satisfy the health endangerment criterion as having been employed for a number of work days aggregating at least 250 work days within the parameters established for the class or in combination with work days within the parameters established for one or more other classes of employees in the Cohort [Emphasis added.]*

Important to note is the fact that ORAUT-TKBS-0052, Rev. 00, was issued on August 30, 2006, and complies with the regulatory requirement of the 250 workdays as cited above in 42 CFR 83, Subpart C § 83.13 paragraph (c)(3)(ii). However, the 250-workday requirement for PPG

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workers was subsequently amended by the DOL in two separate bulletins. Salient excerpts from each of the two documents are cited below (DOL 2006).

From EEOICPA Bulletin No. 06-15 issued September 27, 2006:

*1. This new addition to the SEC affects DOE employees and DOE contractor employees or subcontractor employees employed at the PPG from 1946 through 1962 for a number of work days aggregating at least 250 work days, either solely under this employment or in combination with work days established for other classes of employees included in the SEC. . . . This new SEC designation is established for workers who were “monitored or **should have been monitored**” while employed at the PPG. Using the current standards for monitoring of workers at a nuclear facility site, DOL is interpreting “monitored or **should have been monitored**” as including all employees who worked at the PPG during the period from 1946 to 1962. . . .*

*Please note that for this new SEC class, the **250 work day calculation includes any time spent at any of the islands or atolls that make up the PPG during its SEC time period. This includes time spent working or living at the PPG during the SEC time period.** In addition, employees were evacuated to ships from the PPG prior to nuclear weapons tests being performed. Time spent on ships just prior to a nuclear weapons test is counted toward meeting the 250 work day requirement. **For any 24-hour period that the employee was present (either worked or lived) on the PPG or on ships (evacuated prior to a nuclear weapon testing), the CE would credit the employee with the equivalent of three (8-hour) work days. If there is evidence the employee was present at the PPG or on ships for 24 hours in a day for 83 days, the employee would have the equivalent of 250 work days and would meet the 250 work day requirement.***

*Since continuous time spent at this site is credited toward the calculation of 250 work days, it is important the CE establish any period when the employee was not present at the site and exclude these periods from the 250 work day calculation. **In determining the actual employment period, the CE must have clear and convincing evidence of a beginning date (hire) and end date (termination) of employment at the PPG. Where the evidence is not clear and convincing or consists only of film badge date(s) without a beginning date or end date, the CE must await further policy guidance before proceeding with the verification of covered SEC employment at the site. The National Office of DEEOIC continues to explore methods by which confirmation of employment can occur for workers alleging employment at the PPG. [Emphasis added.]***

SC&A’s Comments Pertaining to EEOICPA Bulletin No. 06-15

Based on statements contained in Bulletin No. 06-15, claimants with presumptive cancers and verifiable employment of at least 83 days at the PPG are eligible for SEC class status if they were monitored or should have been monitored.

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However, Bulletin No. 06-15 further states that “. . . In determining the actual employment period, . . . [and] where the evidence is not clear and convincing or consists only of film badge date(s) without beginning date or end date, the CE must await further policy guidance before proceeding with the verification of covered SEC employment at the site.”

Further policy guidance in dealing with PPG claims for which employment period(s) at the PPG lacks “clear and convincing evidence” was subsequently provided in EEOICPA Bulletin No. 07-05 issued on January 11, 2007. Additional guidance includes the following (DOL 2007):

From Bulletin No. 07-05

1. This bulletin is in addition to the guidance specifically referenced in Item 5 of Bulletin 06-15. . . .

*Absent evidence of hire and end dates of employment, the CE may utilize external film badge (dosimetry) records to establish covered employment at PPG. As confirmed by DEEOIC, employees working at PPG during its SEC period were issued individual film badges to monitor for radiation exposure. These individual film badges were generally issued for **one day, one week or a month depending on potential exposure to the individual**. Typically, film badge records would include the issue date and the end (return) date which can be used to document employment periods at the PPG.*

*As noted for this SEC class in Bulletin 06-15, continuous time spent (including **working or living**) at PPG is credited toward the calculation of 250 work days. If the film badge records include an issue date and end (return) date within the PPG SEC time period, the CE is to credit the employee with the equivalent of three (8-hour) work days **for each date the employee was badged**, inclusive of the issue date and end (return) date. For example, an employee with a film badge with the issue date of 3/27/1954 and the end (return) date of 3/31/1954 would be credited with 15 (8-hour) work days. [Emphasis added.]*

SC&A Comments Pertaining to EEOICPA Bulletin No. 07-05

Use of film badge data may **only** serve as a credible substitute for formal employment records at PPG during the limited number of years when **all** personnel were issued dosimeters from the time of arrival/assignment at the PPG to the time of departure. The practice/policy of badging all personnel “**around-the-clock**” for the entire assignment at the PPG was not implemented until Operation **REDWING**, which represented a 17-detonation test series from May 5, 1956, to July 21, 1956.

During earlier operations, badging was not only restricted to select personnel, but also for restricted time periods as short as **one day** as noted above in Bulletin No. 07-05. This type of badging was defined as **mission badging** with the consequence of failing to badge personnel **who should have been badged**. Other limitations related to the potential use of film badge data relate to the practice of (1) **coworker** badging, (2) the undocumented use of **time** and **dose-rate**

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instrumentation, as a means of restricting exposures to within a daily dose limit of 100 mr, and (3) failure to monitor personnel to fallout during “off-duty” times.

These monitoring practices that to variable degrees persisted until Operation REDWING are discussed extensively in the body of this review and suggest the limited value of **film dosimetry data** as surrogate documentation for employment periods. This is inarguably true for PPG personnel who were **not**, but should have been, monitored.

Finding 1. NIOSH needs to update ORAUT-TKBS-0052, Rev. 00, with regard to the 250-workday requirement for SEC Class inclusion. Revision 00 of ORAUT-TKBS-0052, Summary Site Profile for the Pacific Proving Grounds, was issued on August 30, 2006. At that time, SEC status for presumptive cancer claimants required employment with at least 250 workdays. The 250-workday requirement for PPG workers was subsequently amended by the Department of Labor (DOL) in EEOICPA Bulletin No. 06-15 issued on September 27, 2006, and EEOICPA Bulletin No. 07-05 issued on January 11, 2007.

Additionally, there may be a need for further discussions pertaining to the surrogate use of film badge dosimetry for PPG employment period(s) as recommended in DOL’s EEOICPA Bulletin No. 07-05.

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5.0 REVIEW OF SECTION 3.0 “OCCUPATIONAL MEDICAL DOSE” OF THE PPG SITE PROFILE

In Section 3.0 of the PPG Site Profile, NIOSH provides the following information/guidance:

Multiple organizations based at various sites in the DOE complex sponsored and took part in the various operations. Based on records provided by DOE, the dose reconstructor must, if possible, determine the facility in the complex with which the employee was associated during participation in an oceanic test or operation.

*While these [DOE] sites provided many participants, other sites across the complex also provided participants . . . Other employers might have been associated with only one DOE facility or **none** at all. . . .*

*. . . For other participants that were **hired on location**, the complex-wide documentation should be applied. The approach for applying occupational medical dose is found in **Occupational X-Ray Dose Reconstruction for DOE Sites** ([ORAUT 2004]). [Emphasis added.]*

SC&A Comments

For a participant and claimant who may **not** have had any formal affiliation with a DOE facility (as suggested by reference to “. . . other participants that were hired on location”), Section 3.0 of the PPG Site Profile does not provide clear guidance and raises the following question:

Is the “**non-affiliated**” claimant eligible for occupational medical exposures when:

- (1) There are no records of occupational medical exposure?
- (2) Records of occupational medical exposures are available but were performed at a facility that is not a “covered facility” as defined in ORAUT-OTIB-0079 [ORAUT 2011a]?

Observation #1. There is a need for more definitive guidance pertaining to the assignment of occupational medical dose in behalf of claimants with no formal affiliation with a DOE or AWE facility.

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6.0 REVIEW OF SECTION 4.0 “OCCUPATIONAL ENVIRONMENTAL DOSE” OF THE PPG SITE PROFILE

Although the stated **purpose** in Section 1.1 of ORAUT-TKBS-0052 is to provide “. . . guidance for dose reconstruction . . . for EEOICPA claimants who participated in Pacific Proving (PPG) operations,” Section 4.0 only addresses occupational environmental doses that claimant may have received while assigned to **specific DOE-complex** location(s) identified in ORAUT-OTIB-0006, Rev. 3 PC-1, *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*.

While SC&A agrees that while a PPG participant/claimant may also have had employment periods with radiation exposures at DOE facilities (which may require assessment of site-specific occupational environmental exposures for that DOE site), Section 4.0 of the PPG Site Profile neither makes reference to nor provides guidance for an assessment **of occupational environmental dose that is specific for any PPG locations**.

SC&A Comments

Given the highly unusual radiological conditions created by massive fallout, to which many PPG participants were exposed but **not monitored**, raises the question whether such exposures should even be classified as environmental or should, more appropriately, be labeled as **occupational external dose**. Regardless of how **unmonitored exposure to fallout** among PPG personnel is labeled, neither Section 4.0 “Occupational Environmental Dose,” nor Section 6.0 “Occupational External Dose” of the PPG Site Profile makes reference to or provides guidance for quantifying exposures from fallout received indoors and outdoors at assigned duty stations where personnel worked and lived for extended time periods.

As discussed in Section 7.2 below, for some nuclear-test (n-test) Operations, **unmonitored** exposures to fallout far exceeded recorded exposures to personnel assigned **mission** badges.

Finding 2: Section 4.0 “Occupational Environmental Dose” completely ignores occupational environmental doses for PPG locations from fallout. (Note: For PPG locations, occupational external environmental dose is for all practical purposes an integral part of the occupational external (as well as internal) dose and should be assessed as such in Section 6.0 of the PPG Site Profile.)

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7.0 REVIEW OF SECTION 6.0 “OCCUPATIONAL EXTERNAL DOSE” OF THE PPG SITE PROFILE

In the SEC Petition Evaluation Report, Petition SEC-00020 (NIOSH 2005), NIOSH stated that due to a lack of available data, it is not feasible to estimate with sufficient accuracy radiation doses resulting from **internal** exposures during PPG operations. Thus, for claimants with either non-SEC cancers or with presumptive cancers but less than 250 workdays, dose reconstruction is principally defined by **occupational external** dose. It is for this reason that SC&A’s audit of the PPG Site Profile heavily focused on NIOSH’s assessment of occupational external doses associated with specific n-test **operations** in terms of **accuracy**, **reliability**, and **completeness**.

Discussion and guidance for the assignment of occupational external dose in the PPG Site Profile are limited to less than a single page under Section 6.0 “Occupational External Dose” and Attachment A. Attachment A identifies summary dose distributions of personnel who participated in the nine PPG n-test Operations, as reported by the DNA,¹ and 50th percentile doses for each Operation as derived by NIOSH.

As a convenience to the reader, Section 6.0 of the PPG Site Profile and the first page of Attachment A are reproduced herein as Exhibit 7-1 and Exhibit 7-2, respectively.

Based on statements contained in Section 6.0 and Attachment A of the PPG Site Profile (see Exhibits 7-1 and 7-2), occupational external dose estimates may be based on (1) dosimetry records provided by DOE for a monitored claimant or (2) the derived 50th percentile dose of the appropriate n-test Operation defined in Attachment A for an **unmonitored** claimant.

Key elements contained in these two exhibits are referenced in Section 7.4 in our assessment of the PPG Site Profile for the assignment of occupational external dose with regard to **accuracy**, **completeness**, and **claimant favorability**.

Due to the fact that radiation monitoring practices, issues that impacted the veracity of film badge dosimeters and the availability of resources varied over the 16-year test period, SC&A’s assessment of data and guidance provided in the PPG Site Profile is most appropriately done for specific Operations. While a comprehensive review of all nine Operations is beyond the scope of this audit, SC&A has selected two earlier operations, Operation CROSSROADS and Operation GREENHOUSE, which illustrate the range of issues that potentially impact dose reconstruction for most non-DoD participant claimants who are not included in the SEC class. Issues that impact the integrity of film badge dosimetry at PPG Operations, such as overstated readings that resulted from environmental damage, are discussed in Section 7.3 of this report and are detailed in DTRA/NTPR 2008.

¹ The Defense Nuclear Agency was a predecessor organization to the Defense Threat Reduction Agency (DTRA). DTRA was established in 1998 by consolidating several DoD organizations, including the Defense Special Weapons Agency (successor to the **Defense Nuclear Agency**) and the On-Site Inspection Agency as a result of the 1997 Defense Reform Initiative.

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Summarized in Sections 7.1, 7.2, and 7.3 are data and statements taken from reports issued by the DNA, the Atomic Energy Agency (AEC), and the National Research Council (NRC) that pertain to radiological conditions and personnel monitoring practices for Operation CROSSROADS and Operation GREENHOUSE.

Exhibit 7-1. Section 6.0 (Page 13) from the PPG Site Profile

6.0 OCCUPATIONAL EXTERNAL DOSE

A review of the records provided by DOE and application of the operation-specific parameters listed in Table 2-2 will provide a dose estimate for the employee. The assignment of unmonitored dose to participants who did not receive a dosimeter should be evaluated. NIOSH considers the available data and methods adequate for performing external photon dose reconstruction at the PPG. NIOSH determined in the SEC Petition Evaluation Report (NIOSH 2005) that it lacks sufficient information to adequately reconstruct neutron doses at the PPG. The following specific guidance is provided for external dose reconstruction:

Energy distribution:	Assume an energy distribution of 100% 30-250 keV for photons. This is very favorable to claimants since it is likely that participants present during the events were exposed to photons >250 keV. Beta dose was not evaluated on the film dosimeters used during these operations. Beta-to-gamma ratios would be consistent with the guidance in the NTS TBD where atmospheric testing also occurred.
Missed dose:	Assign missed dose based on the number of exchanges found in the dosimetry records. During these tests there were operation badges that were worn for the entire test sequence or some other established interval of the operation and there were mission badges that were worn for the duration of a specific task. Since both badges were to be worn at the same time, only one zero should be assigned.
Uncertainty and bias:	Assign uncertainty to the measured photon dose. As an assignment that is favorable to claimants, bias has been defaulted to 1.0 for both the missed and measured doses. According to the information in Film Badge Dosimetry in Atmospheric Nuclear Tests, the dose of record was to be divided by the bias, however it is favorable to claimants to assign as discussed above.

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Exhibit 7-2. Page 1 of Attachment A from PPG Site Profile

The following information is available in the DNA radiation reports for the various PPG Operations. Using this summary data provided in the reports, the mid-point of each distribution has been determined and then multiplied by the number of non-DOD participants or badges (for the Crossroads data) that hypothetically received that mid-point dose. The midpoint for the last distribution was calculated using the highest dose as an end point. These were summed across all distributions and then divided by the total. This provides a 50% dose for each operation that can be used as co-worker dose, until such time as co-worker data is available.

$$50\% \text{ dose} = \Sigma (A_n * B_n) / C$$

A = midpoint of each distribution

B = total non-DOD participants or badges within the distribution

C = total non-DOD participants or badges

Crossroads – Actual Film Badge Readings (R gamma)

Month	Total Badges	0 (R)	0.001 – 0.1 (R)	0.101 – 1.0 (R)	1.001 – 10 (R)
July totals	3767	2843	689	232	3
% of Badges	100	75	18	6	<0.1
August totals	6664	3947	2139	570	8
% of Badges	100	59	32	9	0.1

Highest dose during Crossroads Operation was to a radiation safety monitor at 3.72 R.

Calculated dose at 50% is 0.118 rem

Sandstone – Film Badge Readings (R gamma) for non-DOD participants (119 participants badged)

April/May	0 (R)	0.001 – 1 (R)	1 – 2 (R)	>2 (R)
Total non-DOD participants	18	83	6	12

Eleven individuals from the Rad Safe group received doses above the imposed standard of 3 R. The highest dose received was 17 R. The average dose for all participants (including DOD) was 0.25 R with 65% receiving a zero recorded exposure.

Calculated dose at 50% is 1.383 rem.

Greenhouse – Film Badge Readings (R gamma) for non-DOD participants (551 participants badged)

April/May	0 (R)	0.001 – 1 (R)	1 – 3 (R)	>3 (R)
Total non-DOD participants	110	325	82	34

The average dose was 0.5 R. The highest dose received was 8.6 R.

Calculated dose at 50% is 0.950 rem.

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7.1 RELEVANT DATA FOR OPERATION CROSSROADS

Operation CROSSROADS was the first of the n-tests conducted at Bikini Atoll and consisted of two tests – ABLE, a 21 kt **air drop** on June 30, 1946, and BAKER, a 21 kt 90-foot **underwater detonation** on July 24, 1946. The series was to test the effects of nuclear weapons and “survival” of 90 naval vessels assembled in Bikini Lagoon as targets.

Background information and data considered salient to this review are presented below as verbatim **excerpts** taken from technical reports issued by the DNA, NRC, and others.

Excerpts from DNA (1984): Operation CROSSROAD

FACT SHEET²

...

*The support fleet of more than 150 ships provided **quarters, experimental stations, and workshops for most of the 42,000 men** (more than 37,000 of who were Navy personnel) of Joint Task Force 1 (JTF1), the organization that conducted tests. **Additional personnel were located on nearby atolls such as Enewetak and Kwajalein.** The islands of the **Bikini Atoll** were used primarily as **recreation and instrumentation sites.***

...

In the ABLE test, the weapon was dropped from a B-29 and burst over the target fleet. In BAKER, the weapon was suspended beneath an auxiliary craft anchored in the midst of the target fleet.

*[For] **ABLE operations** . . . The radioactivity created by the burst had only a transient effect, and within a day nearly all the surviving target ships had been safely reboarded. The ship inspections, instrument recoveries, and remooring necessary for the BAKER test proceeded on schedule. **Five ships were sunk as a result of the test.***

*The crews of the target ships that had been remanned following ABLE were evacuated by BAKER to the support fleet east of the atoll. **BAKER sank eight ships and damaged more ships than ABLE.** The detonation caused most of the target fleet to be **bathed in radioactive water spray and radioactive debris** from the lagoon bottom. With the exception of 12 target vessels anchored in the array and the landing craft beached on Bikini Island, the **target fleet remained too radiologically contaminated for several weeks for more than brief on-board activities.***

² Although the old DNA reports are referenced in the site profile and are therefore the focal point of this review, updated fact sheets with revised information are available at the DTRA website. Example: <http://www.dtra.mil/documents/ntrp/factsheets/Crossroads.pdf>.

The inability to complete inspections on much of the target fleet threatened the success of the operation after BAKER. A program of target vessel decontamination was begun in earnest about 1 August. This involved washing the ships' exteriors using work crews drawn from the target ships' companies under radiological supervision of monitors equipped with radiation detection and measurement devices. . . .

By 10 August, a decision was made to stop work in Bikini and tow the surviving target fleet to Kwajalein Atoll where the work could be done in uncontaminated water.

. . . A major task at Kwajalein was to offload ammunition stored aboard the target ships. This work continued into the fall of 1946. Personnel continued to work on target ships at Kwajalein into 1947.

. . .

The support ships were decontaminated as necessary and received a radiological clearance before they could return to the fleet. . . .

Finally, a formal resurvey of Bikini Atoll was conducted in the summer of 1947 to study long-term effects of the CROSSROADS.

. . .

About 15 percent of the JTF-1 personnel was issued at least one of the 18,875 film-badge dosimeters during CROSSROADS. Approximately 6,596 personnel were on islands or ships that had no potential for radiation exposure. Personnel anticipated to be at greatest radiological risk were badged, and a percentage of each group working in less contaminated areas was badged. . . .

. . . A summary of film badge readings (in roentgens) for July and August, when the largest number of personnel was involved is listed below:

*Actual Film Badge Readings:
(R gamma)*

	<i>Total</i>	<i>0</i>	<i>0.001–0.1</i>	<i>0.101–1.0</i>	<i>1.001–10.0</i>
<i>July</i>	<i>3,767</i>	<i>2,843</i>	<i>689</i>	<i>232</i>	<i>3</i>
<i>%</i>	<i>100</i>	<i>75</i>	<i>18</i>	<i>6</i>	<i>>0.1</i>
<i>August</i>	<i>6,664</i>	<i>3,947</i>	<i>2,139</i>	<i>570</i>	<i>8</i>
<i>%</i>	<i>100</i>	<i>59</i>	<i>32</i>	<i>9</i>	<i>0.1</i>

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From DNA 1984, page 48:

Film Badges

Two types of film badges were used at CROSSROADS. One type, called a personnel or mission badge, had a range from 0 to 2 R. Badges were issued to some of the men about to enter possibly radioactive areas and most badges were collected after the men returned, usually the same day. Some badges were worn for 2 or 3 days, and a few for as long as 9 days have been noted. . . . Each badge was sealed in a tropically weather-proof envelope to protect it against the hot, humid Bikini climate.

The badges were designed to measure both beta and gamma exposure, but the beta readings obtained and recorded are now considered questionable.

[Emphasis added.]

From DNA 1984, pages 50–51:

Unmonitored Personnel Contamination

Personnel working in radioactive areas sometimes picked up radioactive particles on their bodies and their clothing. Procedures were established to minimize the spread of this contamination and potential internal and external exposure from these radioactive sources. . . .

Clothing so contaminated that it read more than 0.10 R/24 hours (gamma) was placed in paper bags, and radiation was allowed to decay for a period of time before the clothing was washed. If the radiation did not decrease to less than 0.10 R/24 hours, the clothing was disposed of at sea. [Emphasis added.]

From DNA 1984, pages 216–218:

FILM BADGE DOSIMETRY PROGRAM

The device used to record individual exposures, the film badge, was used exclusively for personnel involve in missions that had radiation exposure potential. The Operation Plan defined the CROSSROADS personnel who were to wear badges and under what conditions. All radsafe monitors and assistant monitors were to wear them when entering potentially radioactive areas. . . .

In practice, badging for personnel other than the monitors and certain aircrews was more complete for personnel doing tasks with an obviously high potential for exposure, such as test-day surveys, initial boarding of target vessels, recovery of test animals, and early recovery of instruments, than for those engaged in other activities. . . . During early August, before decontamination of ships at Bikini was stopped, an average of about 100 unbadged personnel worked on USS Salt

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Lake City (CA-25) in three 2-hour shifts. Each shift was assigned two monitors who surveyed working areas to provide information concerning the time allowed in each area before a tolerance exposure was accrued.

All personnel not badged on these missions were, however, accompanied in the potential exposure areas by monitors equipped with radiation detection instruments. The monitor's function was to guide the work parties away from radiologically "hot" areas and determine safe stay times in work areas. His pocket dosimeter or film badge recorded a representative exposure for the group he accompanied.

A total of 18,775 badges were issued during CROSSROADS at Bikini and at Kwajalein through 31 December 1946. Almost 11 percent of the badges were issued on ABLE-day and about 7 percent on BAKER-day, or the days immediately following each shot. . . .

Through July and August, 10,431 personnel badges were issued. Most of the remaining 8,344 badges were issued during September and October. Because most badges were issued for only 1 day, some individuals received more than one badge. The number of individuals receiving badges is not presently available, but the Navy Department currently estimates that up to 15 percent of the personnel received at least one badge.

Badge-Recorded Exposures after BAKER

. . . The CROSSROADS bikini badge readings were entered into standard government ledger books, along with certain associated information. The data-recording had several shortcomings. Given names or initials were included with only about half of the last names, and therefore when several entries containing only the same last name are found, it cannot be determined whether they represent the badge reading of one person or several with the same last name. Poor penmanship and spelling on the part of the clerks making the entries further complicates identification. Although a ship's name was usually entered along with a person's name, it is not always clear whether the ship named was the one on which the man lived or the one on which he worked as he wore the badge. However, the target ships with few exceptions were not renamed, so if a target ship is named in the ledger it was the place where the exposure occurred. [Emphasis added.]

Excerpts from NRC 1989:

Personnel badging issues during Operation CROSSROADS were also summarized in a 1989 NRC report, *Film Badge Dosimetry in Atmospheric Nuclear Tests*, which included the following comments (pp. 88–90).

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On Badge Issue and Exchange:

Badges were intended to be issued on a daily basis. That was the typical experience although a few badges were retained for 2 or 3 days and as long as 9 days. Badges were not issued to all personnel working or living in radiation areas. They were typically issued only to one or a few Rad-Safe monitors in a group. The film badge exposure of the Rad-Safe monitor was intended to be representative of the exposure of all members of the group, a concept called cohort badging. During the major ship decontamination effort between August 4 and 10 there were typically two monitors per 100 personnel. All personnel in aircraft that were within 20 miles of the explosions were badged at the time of the test detonations. About 15% of the Navy personnel in the task force were issued at least one badge sometime during the test series. The largest number of badges issued to one person (a Rad-Safe monitor) was 19. [Emphasis added.]

7.2 RELEVANT DATA FOR OPERATION GREENHOUSE

Operation GREENHOUSE was the third test series conducted in the Pacific and involved four detonations on the islands of Enjebi, Eleleron, and Runit on Enewetak Atoll in April and May of 1951 (Table 7-1 and Figure 7-1). Approximately 9,350 people participated in the operation, but film badges were only issued to 2,416 of the participants (DNA 1983b).

Film badges were issued from the RadSafe building that was located on **Parry Island**, Enewetak Atoll. Most badges were issued for **specific missions** of limited duration and were to be returned by the end of the day. Personnel assigned to naval support vessels were monitored by **cohort film badging**. (About 75 film badges for each of the 4 tests were distributed among the 6 participating ships to be worn from the day of the test and 7 days thereafter.) Table 7-2 summarizes the **recorded** film badge exposures for personnel representing the U.S. Army, Navy, Air Force, Marine Corp, and **Non-DOD/civilians**.

Of relevance to this report is the distribution of recorded film badge exposures for the 551 badged civilians out of a total of 2,049 civilians who participated in Operation GREENHOUSE.

Table 7-1. Operation GREENHOUSE Detonations, Enewetak, 1951

Detonation	Date	Time	Island Location in Enewetak	Yield (kt)	Type Burst
DOG	8 April	0634	Runit	81	300-foot (91.4-meter) tower shot
EASY	21 April	0627	Enjebi	47	300-foot (91.4-meter) tower shot
GEORGE	9 May	0930	Eleleron	225	200-foot (61.5-meter) tower shot
ITEM	25 May	0617	Enjebi	45	200-foot (61.5-meter) tower shot

Sources: DNA 1983b; DOE/NV 2000

Table 7-2. Operation GREENHOUSE Badge Exposures (R)

	Total No. of Participants	Number Badged	0	0-1	1-3	3-5	Over 5	High (R)
U.S. Army	1,615	195	6	143	35	10	1	5.430
U.S. Navy	2,951	813	134	458	187	27	7	8.080
U.S. Air Force	2,604	849	86	516	146	64	37	8.475
U.S. Marine Corps	134	8	[redact]	[redact]	[redact]	[redact]	[redact]	[redact]
Non-DOD/Civilians	2,049	551	110	325	82	20	14	8.575
TOTALS	9,371	2416	339	1445	450	123	59	

Source: DNA 1983b

Estimates of radiation exposures to participants of Operation GREENHOUSE, as cited in Table 7.2, are principally dose distributions representing **mission badges**. Presented below are data and excerpts taken from the 1983 DNA (1983b) report and other sources, which properly characterize the limitations and deficiencies of the recorded film dosimeter data.

Limitations and Deficiencies Pertaining to Recorded Film Dosimeter Data

Radiation monitoring by RadSafe personnel of the Joint Task Force-3 (JTF-3) focused on defining radioactive areas after each shot, accompanying re-entry parties to radioactive areas to retrieve experimental data, and issuing film badges to select individuals involved in episodic **missions** that had significant potential for radiation exposure. (The majority of film badges were issued to personnel to record their exposures (1) while on the shot islands to recover data, test animals, and instrumentation; (2) while decontaminating aircrafts, etc.; (3) as members of the boat pool; or (4) as personnel who flew aircraft during/after each shot.)

Not recorded by mission film dosimeters were exposures during unmonitored periods that included exposure to **fallout** on islands where personnel were housed and lived for extended periods of time as described below.

From DNA (1983b), p. 31:

In late 1948 H&N [Homes and Narver] was charged with complete rehabilitation of the operational islands of Enewetak Atoll. . . . Construction included barracks for 708 men on Parry [Island], mess halls, laboratories, medical areas, theaters, barber shops, chapels, experimental structures, and many other facilities to support a semipermanent workforce. . . .

. . . Japtan [Island], just north of Parry [Island] . . . had a good stand of coconut trees and other vegetation . . . and was used for recreation.

. . . Temporary camps were constructed on three islands in the shot area in preparation for GREENHOUSE. A tent camp capable of billeting 610 was constructed in Enjebi [Island]. Similar camps for 320 men on Bijire [Island] and 240 on Runit [Island] were also constructed . . . [Emphasis added.]

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The locations of these islands relative to the locations of the four nuclear tests of Operation GREENHOUSE are shown in Figure 7-1 along with aerial photos of Enewetak, Parry, Japtan, and Enjebi Islands (Figures 7-2, 7-3, 7-4, and 7-5, respectively).

Significant levels of fallout resulted from three of the four shots of Operation GREENHOUSE: DOG shot, ITEM shot, and GEORGE shot. Details of these three events are described in Cooney (1951) and summarized later in DNA (1983b). The following statements and data are taken from DNA (1983b).

From pp. 232–239:

*. . . Three shots of the series deposited fallout over the **base islands** at Enewetak [Atoll] and six nearby ships, exposing personnel to radiation.*

*. . . Only a portion of the personnel in areas where exposure was **not** expected were badged. Radiation from the **unexpected** fallout, therefore, was unrecorded for the **large majority of GREENHOUSE participants**. Fallout radiation, however, was recorded by instruments used to monitor background radiation, on film badges staked outside of buildings on Parry Island, as well as by sample badges issued to select personnel working in the areas affected by fallout.*

These basic background measurements and sample badges were used by radsafe personnel at the time of GREENHOUSE to estimate the maximum possible exposures resulting from fallout. Estimates were made for personnel staying on the base islands – Enewetak, Parry, and Japtan – as well as the ships.

Figure 7-6 shows the cumulative gamma exposure for Parry Island for the period April 8, 1951, through May 14, 1951, from fallout radiation associated with shots DOG and EASY. Figure 7-7 shows the cumulative outdoor gamma exposure on Parry Island for the 5-day period of May 25 to May 30 for shot ITEM. These and other data were used in a 1981 analysis that produced a matrix of the estimated doses in rem for the whole GREENHOUSE test period for Parry, Enewetak, and Japtan Islands included herein as Figures 7-8, 7-9, and 7-10, respectively. Values shown in the figures reflect an assumed shielding adjustment of 0.7, which corresponds to a dose that would have been recorded by a properly worn film badge.

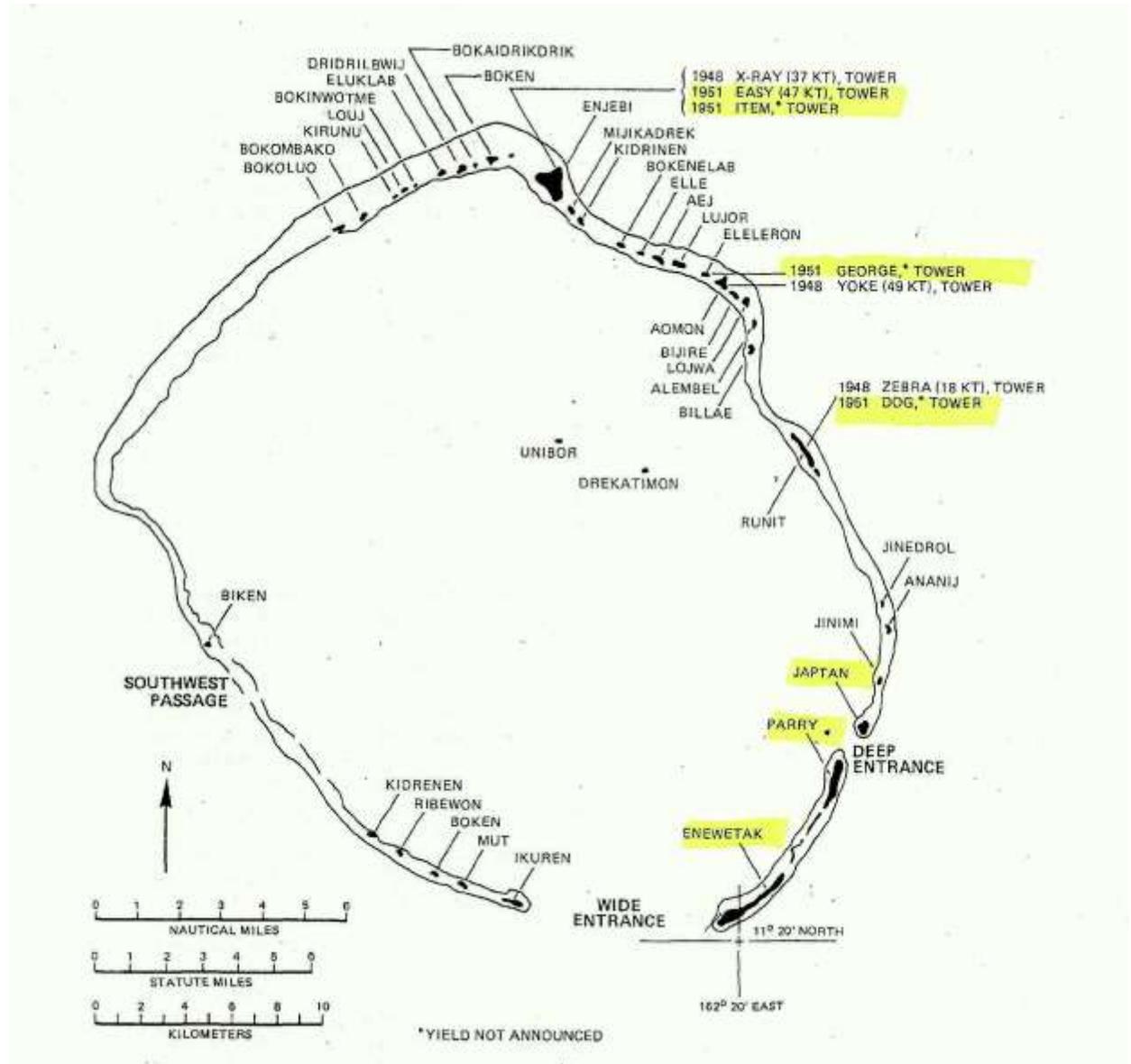
Inspection of Figures 7-8, 7-9, and 7-10 shows that for personnel present at Parry, Enewetak, or Japtan Islands for the full duration, a maximum dose of about **4 rem from fallout** would have been received at each of the three assessed islands. (Note: This “unmonitored/undocumented photon dose” of up to 4 R from fallout at locations where personnel lived/worked must be compared to the 50th percentile dose for Operation GREENHOUSE cited in Exhibit 7-2 above.)

The Report (DNA 1983b) concluded with the following statements:

*The recent analysis does confirm that **all personnel** living on these three islands of Enewetak Atoll through the entire series probably exceeded the task force’s*

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*maximum permissible exposure (MPE) due to fallout alone. Any additional exposures on **missions** would add to this **overexposure**. [Emphasis added.]*



Source: DNA 1983b

Figure 7-1. Enewetak Atoll showing GREENHOUSE and SANDSTONE Detonation Sites and Islands Where Support Personnel Worked and Lived

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Source: Pevec 1999

Figure 7-2. Center of Enewetak (Fred) Island



Source: Pevec 1999

Figure 7-3. Medren (Elmre) Island (formerly Parry Island)

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Source: Pevec 1999

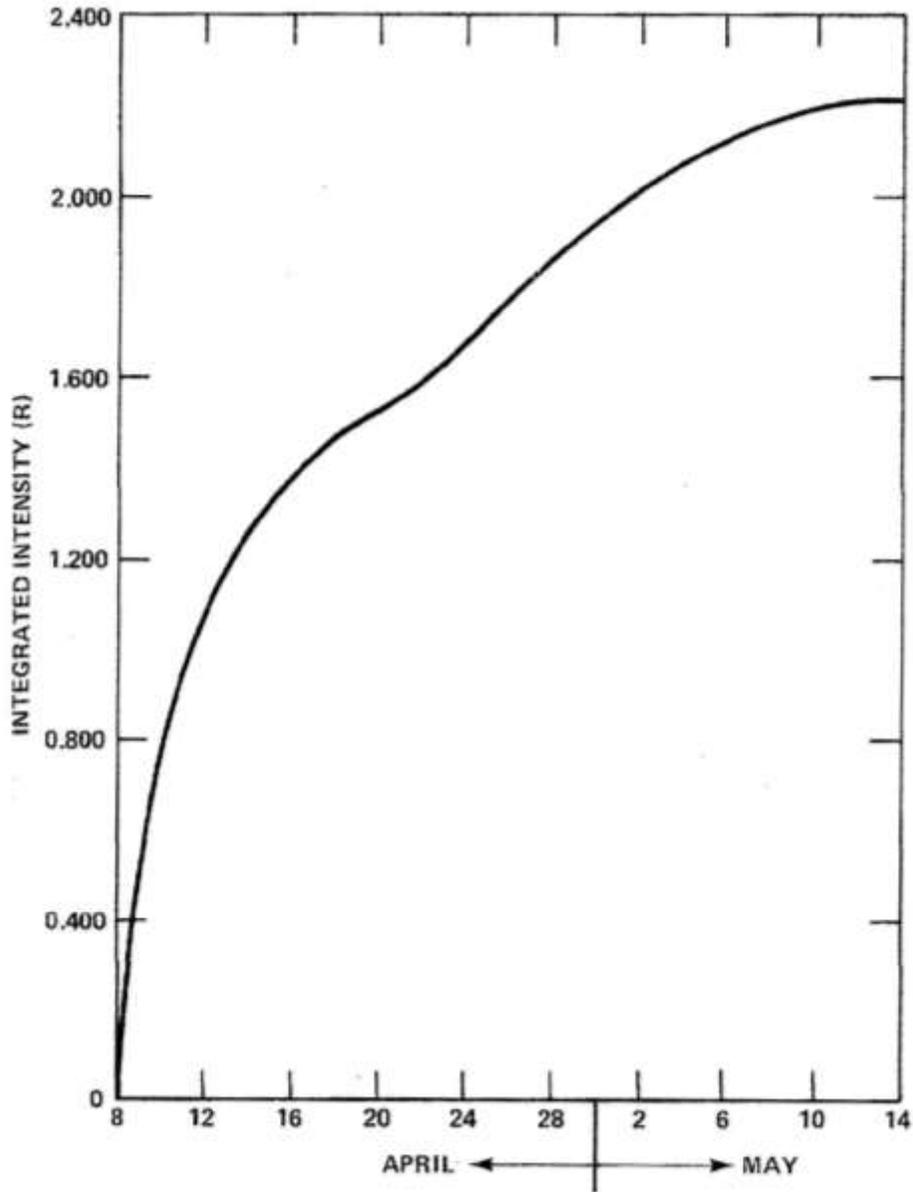
Figure 7-4. Japtan Before Cleanup



Source: DNA1983b

Figure 7-5. Enjebi Camp, GREENHOUSE

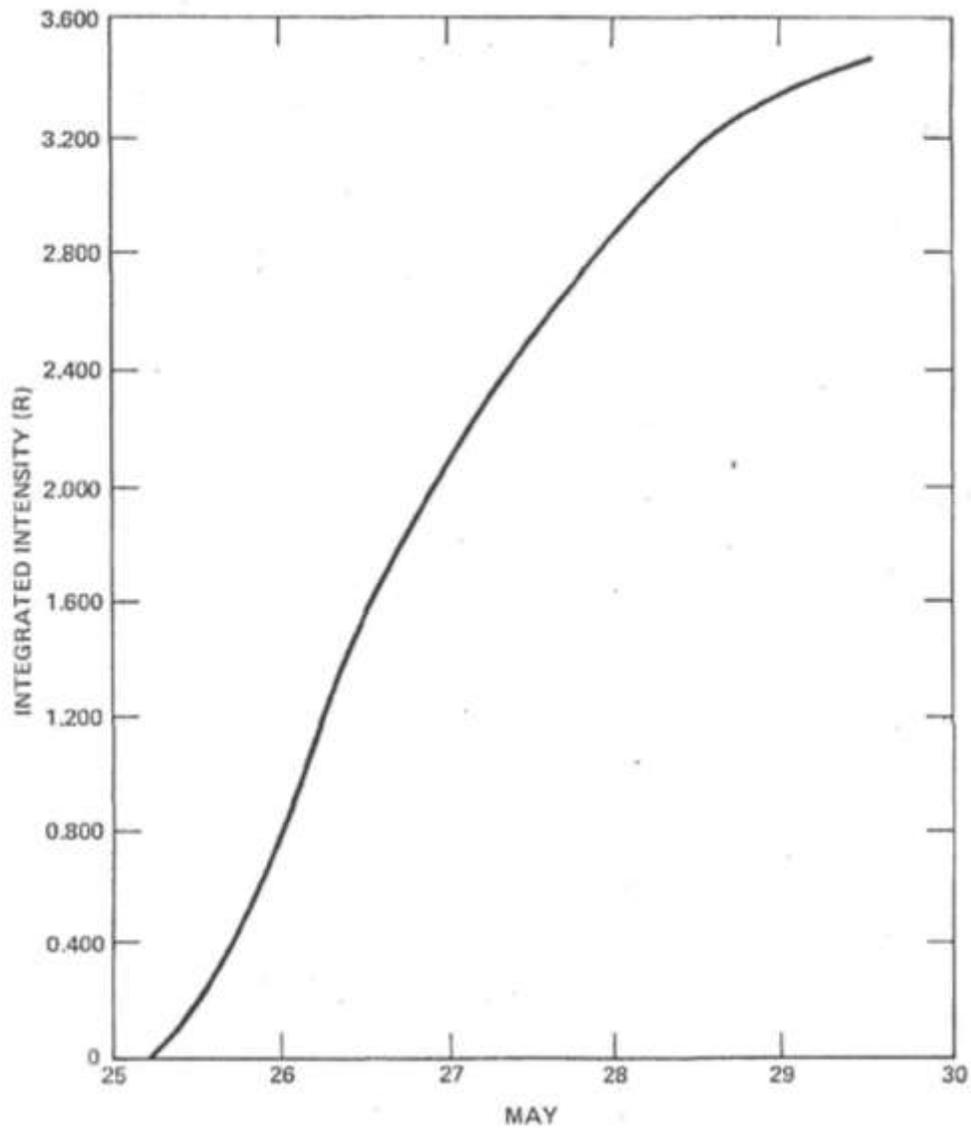
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Source: DNA 1983b

Figure 7-6. Cumulative Gamma Exposure – Parry Island, Maximum Possible GREENHOUSE, DOG, and EASY

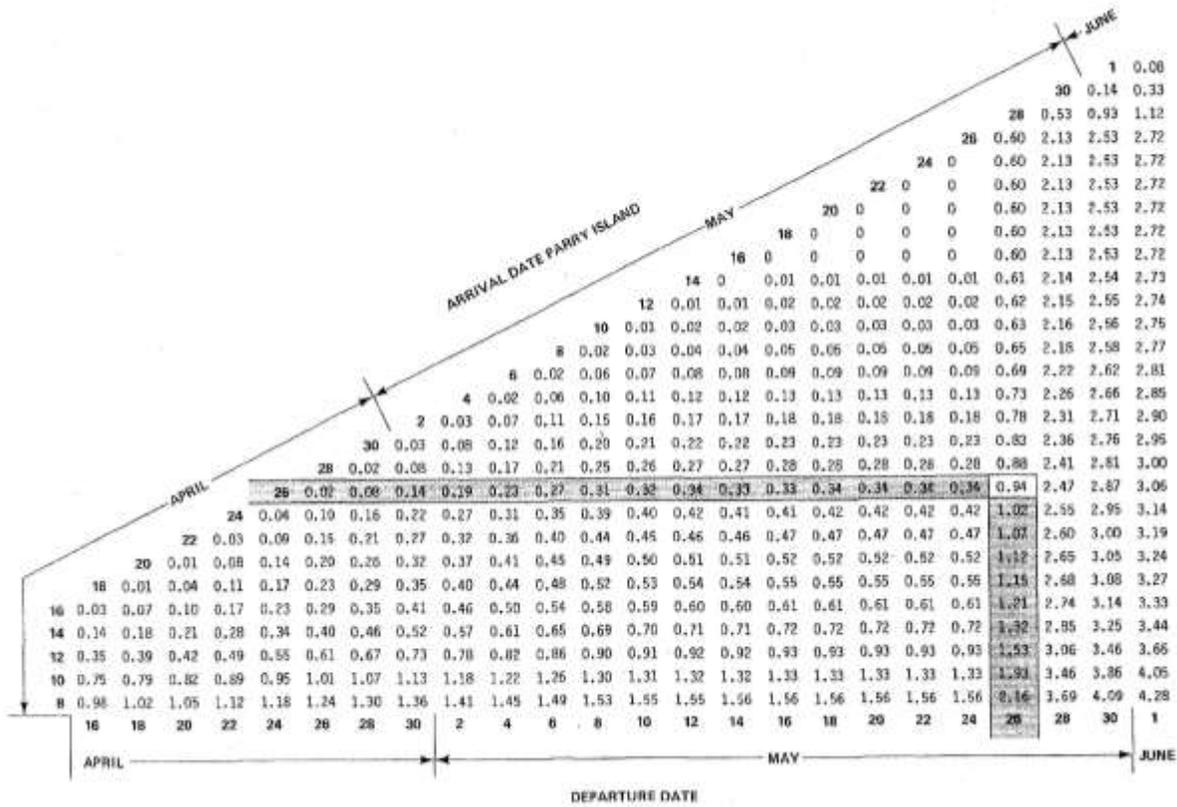
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Source: DNA 1983b

Figure 7-7. Cumulative Gamma Exposure – Parry Island, Maximum Possible GREENHOUSE, ITEM

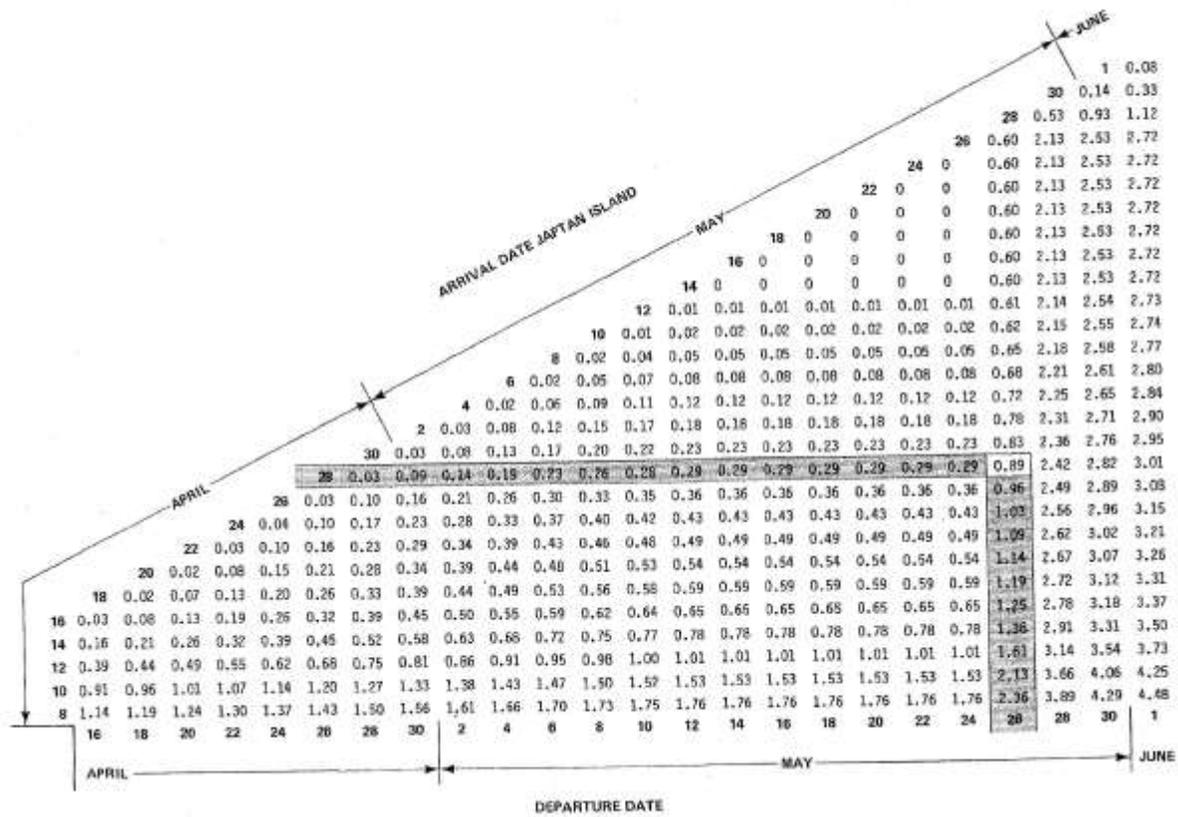
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Source: DNA 1983b

Figure 7-8. Cumulative Dose (rem) for Personnel on Parry Island due to GREENHOUSE Fallout

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Source: DNA 1983b

Figure 7-10. Cumulative Dose (rem) for Personnel on Japtan Island due to GREENHOUSE Fallout

7.3 OTHER LIMITATIONS OF RECORDED FILM BADGE DATA

Beyond the **incompleteness** of recorded personnel monitoring data that were limited to (1) discrete time periods/missions of select personnel and/or (2) the use of cohort badges for which individual members of the cohort were frequently not identified (i.e., no doses were assigned), their use in dose reconstruction must further be assessed in terms of their accuracy and reliability. For each of the PPG operations, reports by the DNA (i.e., DNA 1981, 1982a, 1982b, 1982c, 1982d, 1982e, 1983a, 1983b, 1983c, and 1984) provided critical assessment of the type and design of the badge; calibration and processing of badges; and dosimeter responses. A comprehensive review of these film badge data was reported by the NRC report, *Film Badge Dosimetry in Atmospheric Nuclear Test* (NRC 1989).

Perhaps the single most important deficiency associated with the various film dosimeters used over the 16-year period was the inability to accurately monitor the beta dose. Starting with operation CROSSROADS, NRC (1989) stated:

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. . . When a film badge with only a lead filter and an open area is exposed to unknown mixtures of beta and photon energies, it is not possible to determine contributions from each component to NOD [net optical density] in the film open area.

*. . . It is likely that the NOD of some films attributed to beta exposure was in fact caused entirely by photon exposure. **For these reasons, beta exposure results determined with film badges at Operation CROSSROADS are unreliable.***
[Emphasis added.]

Several subsequent attempts to modify film dosimeters in order to monitor beta dose proved to be unsuccessful and the NRC (1989) concluded that, “. . . Thus, beta particle monitoring with personnel film badges was not successful during **atmospheric nuclear testing series.**”
[Emphasis added.]

Other problems included (1) environmental impacts associated with high ambient temperatures, high humidity, and exposure to sea water/mist; and (2) inconsistencies in the calibration, processing, and interpretation of the film responses, as given in the following example statements from NRC 1989:

. . . Film badges were subject to the high temperature and humidity of the Pacific test site and were not free of environmental damage in spite of the plastic “tropical” envelope.

*. . . Calibration films were not processed with each batch of films that was developed. Calibrations were **assumed** to be valid **over a series** of successive development batches.*

. . .

*. . . Often films were exposed at a **nonperpendicular** angle to the radiation beam . . .*

And

*. . . Unspecified measures were taken to compensate for or to remove the contribution from fallout to the film badge readings . . . **The existence of a problem was revealed in Cooney’s report (1951) where little confidence was placed on film readings less than 0.4 R.*** [Emphasis added.]

The above-stated NRC reference to the “1951 Cooney Report” refers to the following statements cited on page 29 of Cooney 1951 at the time of the shot DOG, which was the first of the four n-tests of Operation GREENHOUSE:

*A series of test was conducted to determine the **accuracy**, with fission product exposure, of **film badge data** compared with readings of quartz fiber pocket dosimeters. A Victoreen thimble ionization chamber, known to be reasonably*

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energy independent, was used as a standard comparison. It was found that a film badge reading of 100 to 200 mr has a low significance, owing primarily to the variable exposures received by all unused film badges during the Dog day fall-out. Readings above 400 mr agreed with the standard chamber within about 10 percent and were considered to be reliable for doses equal to or greater than 400 mr. [Emphasis added.]

In an attempt to gain a better understanding of protocols that may have existed at the time of Operation GREENHOUSE, the NRC provided the following information and conclusion (NRC 1989, pg. 103):

During review of the data from the Operation [GREENHOUSE], some films were retrieved and analyzed in an attempt to deduce the method used to adjust film readings for fallout. Calibration and unexposed control films as well as all density data no longer exist. Comparisons of the reported exposure and new density measurement did not reveal consistent patterns. A film reported with an exposure of 0.04 R on April 9, 1951, had a gross density of 0.87. A film reported with 0.4 R three days later had a density over 3.0. The densities are too high for the reported exposures unless a large control density for background and fallout was subtracted during the original analysis. [Emphasis added]

Other PPG Operations. Personnel monitoring deficiencies, as discussed above, were not limited to Operation CROSSROADS and Operation GREENHOUSE, but by variable degrees persisted throughout the entire 16-year testing period, including Operation CASTLE in 1954. CASTLE series consisted of 6 tests and a collective yield of 48,200 kt (or 48.2 MT). With a yield of 15 MT, shot BRAVO, the first of the test series and largest device ever tested by the U.S., posed significant challenges to RadSafe personnel as a result of **unexpected fallout** (DNA 1982a). Pages 101 to 107 of the DNA (1982a) report discuss many of the film dosimetry and recordkeeping program challenges with the test series, including shot BRAVO:

The initial plan was to badge all personnel expected to receive a significant amount of radiation . . . [and] . . . a representative 10% of other personnel. . . . Shot BRAVO “contaminated some of the ships to the point that it would have been most desirable to issue film badges to all personnel on them . . . [because] . . . many people with no film badges received significant radiation. . . . Sufficient badges were not available, however, and furthermore TU 7 lacked the personnel to process a larger number of badges. Even so, the TU 7 technicians attempted to estimate the doses of those without badges based on film badges of similarly exposed personnel, but it was impossible to do this accurately in many cases. After BRAVO, more badges became available, with assignment priorities given to “people expected to receive significant radiation and people who had already received a relatively large amount of radiation. [Emphasis added.]

The availability of more film badges in subsequent test series, however, did not resolve all problems, as noted by the DNA during the 1956 test series Operation REDWING (DNA 1982, p. 109):

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*All film processing and record posting were done manually. As a result, as many as 40 individuals were assigned to the Dosimetry and Records Section. **Manual reading and posting operations were tedious and subject to many errors.***
[Emphasis added.]

As noted earlier in this report, most permanent badges at Operation REDWING suffered from environmental damage that rendered the readings unsuitable for assessing exposure. These films exhibited positive readings for a period of coverage with no known potential for exposure or that greatly exceed the reconstructed dose from known exposure pathways.

Most of the damage seen in film badges worn by REDWING participants resulted from the combined effects of heat and humidity that caused breaches in the casing that sealed the film package from the exterior environment. The most common effect was that moisture penetrated the film badge casing and damaged the film packet within. Water-damaged films can usually be identified visually by an irregularly shaped, often mottled, unevenly darkened image.

In addition, many of the dosimeter films from badges worn by DOMINIC I personnel have water damage similar to that seen in Operation REDWING. DOMINIC I films, in addition to water damage, have a higher incidence of damage due to light leaks from breaches in the plastic covering of the badge. Such light damage occurred in film badges that had long periods of coverage, which appears to correlate with a higher frequency of emulsion and/or process damage. Films with long periods of coverage are also more likely to exhibit spurious “filter images” due to background radiation exposure (without appropriate controls) and/or pressure from the lead filter strip (NRC 1989; SAIC and NST-LLC 1989–2006; Perkins and Hammond 1980).

A key point for DOMINIC I films returned after November 1, 1962, is that they were processed at the NTS, often without the correct set of control films. Compounding the issue is that film reading was automated. Automated film reading without critical review allowed gradients in darkening or damaged areas to be assessed as legitimate density readings. The lack of appropriate background subtraction and the inadequate screening of results are the principal reasons why doses were assigned to these individuals when no exposures had occurred. Despite the potential for exposure at tests at the NTS during the period of testing, doses of one to several rem were not systematically reviewed (NRC 1989).

Failure to Monitor Skin/Clothing Contamination to Fallout/Large Particles

As in other Operations in which participants were exposed to high levels of contamination that resulted in skin/clothing contamination, exposure to fallout during Operation GREENHOUSE raised special concerns due to the large particle size and high activity levels in fallout (Cooney 1951).

Fallout from Dog Shot

About 1 hr 40 min after the shot, the recording instruments in the radiological safety center indicated that a radioactive fall-out was occurring . . .

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The occurrence of fallout at such a short time after zero hour was a cause of considerable concern from a health standpoint . . .

*Within a very short time, substantial evidence was brought forth that **most of the activity was carried on large particles**. . . . The rate of fall of the particles must have exceeded 10,000 ft/hr, and by using Stoke's law, the size was computed to be **100 microns or greater**. . .*

*Some of the very largest particles found were from the island of Rigili. **One of these** measured between 1 and 2 mm. It was crushed . . . and divided into roughly three portions. **Each portion carried part of the activity which indicated more or less thorough mixing when the particle was made**. [Emphasis added.]*

Fallout from Item Shot

*. . . at H+30 min., MajGeneral M. McDonnel, Dr. Howard, L. Andrews, and Gen. Cooney flew to **Engebi** [Island] by helicopter and landed near Building 69. Upon arrival, the radiation intensity was about 400 mr/hr outside Building 69. . . . Another radiological survey was then made around Building 69, and it was found that the intensity had risen to 1.2 r/hr. It was evident that a **large-particle** fall-out was in progress. As a matter of fact, the falling particles **could be felt on the face and hands**. [Emphasis added.]*

7.4 COMMENTS AND FINDINGS PERTAINING TO THE ADEQUACY OF THE PPG SITE PROFILE FOR THE ASSIGNMENT OF OCCUPATIONAL EXTERNAL DOSE

SC&A's evaluation of ORAUT-TKBS-0052, Section 6.0 and Attachment A, is largely based on comparison of the guidance provided in ORAUT-TKBS-0052 with available data/information. (This includes the PPG Operation-specific DNA reports **referenced** in ORAUT-TKBS-0052.)

7.4.1 Limitations and Deficiencies of Personnel Monitoring During PPG Operations

Based on data/information summarized in Sections 7.1, 7.2, and 7.3 above, the following **limitations/deficiencies** must be considered relevant to the reconstruction of occupational external dose for participants of Operation CROSSROADS and Operation GREENHOUSE:

- The majority of film badges that define gamma exposures in Attachment A of the PPG Site Profile were issued as **mission** badges. These badges were worn for **select tasks** and for restrictive time periods.
- Mission badges were issued only to a small fraction of participants in these Operations and were generally collected at the end of a task for processing.

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- For most participants, “monitoring” was based on **cohort badging**. Film badge exposure to the RadSafe monitor was intended to be “representative” of the exposure to all members of a group as large as 50 personnel who had not been issued a dosimeter.
- The principal objective of the **cohort badging** was to provide some measure of oversight that would limit exposures of “**unbadged**” personnel to levels **below Routine Maximum Permissible Exposures (MPE)** as defined in Table 2-2 of the PPG Site Profile.
- Recording of film dosimeters experienced multiple shortcomings of which the most serious one was the inability to identify the assigned person/RadSafe monitor. For cohort badging, this implies the loss of assigned dose to the entire cohort.
- Film dosimeters were known to be improperly calibrated, processed, and interpreted. As noted in NRC 1989, little is known about the method and values used to **subtract** “background” radiation that was not considered relevant to the dose associated with a particular **mission**.
- Film dosimeters proved incapable of measuring beta exposures that dominated skin exposures.
- Personnel assigned to specific tasks (e.g., re-entry on Shot-islands for retrieval of instruments, survey measurements, etc.; decontamination of aircrafts, and target ships from ABLE-Shot and Baker-Shot) routinely experienced skin and clothing contamination that were not quantitatively assessed/recorded.
- Personnel living/working on islands that were subjected to fallout were not monitored. For Operation GREENHOUSE, **unmonitored/unrecorded gamma** exposures of about 4 rem from fallout have been estimated for the islands of Enewetak, Parry, and Japtan. In addition, orders of magnitude higher beta doses may have resulted from fallout particles that ranged in the hundreds of microns.

7.4.2 An Assessment of Guidance Provided in the PPG Site Profile

Guidance in Section 6.0 and Attachment A of the PPG Site Profile can be summarized with the following statements (see Exhibits 7-1 and 7-2 above):

Statement #1 from Section 6.0 of the PPG Site Profile

*A review of the **records** provided by DOE and application of the operation-specific parameters listed in Table 2-2 [of ORAUT-TKBS-0052] will provide a dose estimate for the employee. [Emphasis added.]*

SC&A’s Response/Finding to Statement #1

Reconstruction of a claimant’s external dose by means of **DOE records** may suffer from the following deficiencies:

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- (1) The claimant was **not** issued mission badge(s), but was “monitored” as a member of a cohort for which records are not available.
- (2) The claimant was issued mission badges but, due to **recording errors**, dosimeter readings were not filed/assigned to the claimant.
- (3) Recorded **mission dosimeters** experienced processing deficiencies and were subjected to “background subtraction” from fallout that during Operations GREENHOUSE may have involved values as high as 400 mR.
- (4) Exposure to **fallout** on islands where personnel lived/worked was not recorded. For example, during Operation GREENHOUSE, personnel on the Islands of Enewetak, Parry, and Japtan may have received as much as 4 R of unmonitored gamma exposure from fallout.

Finding #3: Available DOE records for a claimant may not only be incomplete/inaccurate, but more importantly may not include unmonitored exposures associated with cohort badging, exposure to fallout, etc.

Statement #2 from Section 6.0 of the PPG Site Profile

The assignment of unmonitored dose to participants who did not receive a dosimeter should be evaluated.

SC&A’s Response/Finding to Statement #2

Beyond the “recommendation” that unmonitored dose should be evaluated, NIOSH provides no additional guidance. Additionally, for PPG participants, the term “unmonitored” differs from conventional energy employees/claimants at DOE facilities. For PPG participants, the term “unmonitored” may involve a member of a cohort who was “monitored” by badged RadSafe members, but the doses were not assigned to members of the cohort.

Finding #4: ORAUT-TKBS-0052 does not provide a definition for unmonitored dose as it applies to PPG participants or any specific guidance.

Statement #3 from Section 6.0 of the PPG Site Profile

*Assume an energy distribution of 100% 30–250 keV for photons. This is **very favorable** to claimants since it is **likely** that participants present during the events were exposed to photons >250 keV. [Emphasis added.]*

SC&A’s Response/Finding to Statement #3

PPG participants whose dose reconstruction may be defined by ORAUT-TKBS-0052 include (1) persons with non-SEC cancers and (2) persons with any cancer inclusive of the 22 SEC cancers, but with less than the required 250 days of employment. The statement that an assumed energy distribution of 30–250 keV is “very favorable to claimants” may not be correct and depends on the cancer site and the assumed exposure geometry:

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- For an **assumed** exposure geometry of anterior/posterior (AP), a higher dose is obtained for photon energy >250 keV for bone marrow and esophagus cancers.
- For a more **realistic** exposure geometry defined by large-scale surface contamination from fallout in the PPG, higher doses are derived for >250 keV photons for **all cancers** (including skin cancers) under isotropic (ISO) or rotational (ROT) exposure geometries.

Finding #5: Average photon energies associated with fallout are well above >250 keV. Depending on what exposure geometry is assumed, a default photon energy of 30–250 keV may not be claimant favorable.

Statement #4 from Section 6.0 of the PPG Site Profile

Beta dose was not evaluated on the film dosimeters used during these operations. Beta-to-gamma ratios would be consistent with the guidance in the NTS TBD where atmospheric testing also occurred.

SC&A’s Response/Finding to Statement #4

In the absence of shallow dose/skin dose measurements associated with beta radiation from fallout, NIOSH recommends beta-to-gamma ratios defined in Table 6-14 of Section 6.4.2.2 as well as in Attachment C of the NTS Site Profile ORAUT-TKBS-0008-6 (ORAUT 2012). As a convenience to the reader, Table 6-14 is reproduced below as Table 7-3.

Table 7-3. Beta-Photon Ratios for Exposure from Surface Contamination

Elapsed Time Following the Production Event	Beta/photon Sv/Sv
0 to 50 d	10
50 to 365 d	25
1 to 5 yr	60
>5 yr	25

Source: ORAUT 2012, Table 6-14

SC&A assumes that beta-to-gamma ratios cited by NIOSH in Table 7-3 represent a distance from a source plane (i.e., contaminated ground surface) of about 120 to 140 cm, which corresponds to the position of a film dosimeter worn on the chest area.

Due to the limited range of beta particles, the beta-to-photon dose ratios differ significantly as a function of distance from a source plane. The critical variable of height above the source plane was defined for Pacific test sites by N.M. Barss and R.L. Weitz (2006). Reproduced herein as Table 7-4 are beta-to-gamma dose ratios for bare skin exposures for distances of 1 cm to 200 cm from a contaminated ground surface.

Table 7-4. Beta-to-gamma Dose Ratios for Bare Skin Exposures to Mixed Fission Products at Pacific Test Sites

Time after Detonation	Distance from Source Plane (cm)							
	1	20	40	80	100	120	160	200
0.5 h	36.4	24.2	17.7	11.9	10.4	9.1	7.0	5.4
1 h	32.5	21.4	15.5	10.3	8.9	7.8	5.9	4.5
2 h	32.0	20.8	15.0	9.9	8.5	7.4	5.5	4.2
4 h	40.3	25.9	18.5	12.0	10.3	8.9	6.7	5.0
6 h	51.1	32.6	23.1	14.9	12.7	11.0	8.2	6.2
12 h	65.6	41.0	28.6	17.8	15.0	12.8	9.3	6.8
1 d	65.1	38.7	25.8	14.9	12.2	10.0	6.8	4.7
2 d	64.4	35.2	22.1	11.8	9.3	7.4	4.7	2.9
3 d	62.8	32.2	19.3	9.8	7.6	6.0	3.6	2.1
1 wk	62.3	29.0	16.3	7.7	5.8	4.5	2.5	1.4
2 wk	65.5	30.5	17.1	8.1	6.2	4.7	2.7	1.6
1 mo	72.4	34.7	19.9	9.8	7.6	6.0	3.7	2.2
2 mo	85.7	39.8	22.8	11.8	9.5	7.8	5.1	3.3
4 mo	90.7	40.4	23.0	12.5	10.5	9.0	6.4	4.4
6 mo	94.6	42.5	24.5	13.9	11.9	10.4	7.7	5.5
9 mo	116.7	54.5	32.5	19.6	15.4	15.4	11.8	8.8
1 y	166.1	81.2	50.3	31.7	25.6	25.6	20.1	15.2
2 y	494.2	251.9	160.5	104.2	85.3	85.3	68.0	52.3

Source: Barrs and Weitz 2006

Inspection of Table 7-4 indicates that for a skin cancer claim involving areas of the lower leg (i.e., 20 to 40 cm above ground), the beta-to-gamma dose ratios are 3 to 5 times higher than at chest level (or values cited in Table 7-3 above).

Finding #6: Since claims involving skin cancer usually specify the location(s) on the body, the critical variable of distance above the source plane defined by Barss and Weitz (2006) should be included in the assignment of beta-to-gamma dose ratios for PPG claimants.

Statement #5 from Section 6.0 of the PPG Site Profile

Assign missed dose based on the number of exchanges found in the dosimetry records. During these tests there were operation badges that were worn for the entire test sequence . . . and there were mission badges that were worn for the duration of a specific task. Since both badges were to be worn at the same time only one zero should be assigned. [Emphasis added.]

SC&A Response/Finding to Statement #5

A review of DNA reports shows that these statements are incorrect for PPG tests conducted between June 1946 and May 1954, which included Operations CROSSROADS, SANDSTONE, GREENHOUSE, IVY, and CASTLE. For Operation CASTLE, NRC (1989) stated the following:

The initial plan for badging personnel expected to receive significant amounts of radiation exposure and a representative 10% of other Personnel (Martin 1982).

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Although there was a need to badge all personnel immediately after the first shot, BRAVO, because of the extensive contamination due to fallout, there were not enough badges available to do this. Additionally, the staffing level of Task Unit 7.1.7, which provided radiological safety support, was insufficient to process a larger number of badges than were available.

*For shots subsequent to BRAVO, there were more badges available and there was a greater emphasis on personnel monitoring. **Nevertheless, all personnel involved in the series were not monitored with individual personnel dosimeter.***
[Emphasis added.]

An assessment of missed dose requires a firm understanding of **badge issue** and **exchange frequency** for a given Operation. The assignment of missed dose for Operations up to and inclusive of CASTLE are made difficult by (1) the restrictive use/assignment of **mission** badges, (2) undocumented use of cohort badging, and (3) the unspecified subtraction of “exposures to fallout.”

Finding #7: NIOSH’s guidance for the assignment of missed dose is based on assumptions that are not supported by facts and in the face of uncertainty are clearly not claimant favorable.

Statement #6 from Attachment A of the PPG Site Profile

*The following information is available in the DNA radiation reports for the various PPG Operations. Using this summary data . . . **a 50% dose for each operation can be used as co-worker dose**, until such time as co-worker data is [sic] available. [Emphasis added.]*

SC&A’s Response/Findings to Statement #6/Attachment A

Operation-specific dose distribution data cited in Attachment A of the PPG Site Profile (see Exhibit 7-2 above) is dominated by mission film dosimeters, which represent exposures associated with specific tasks conducted by select personnel. As explained above, mission badge exposures represent only a portion of exposures received by PPG participants. Furthermore, the accuracy of recorded film badge data is uncertain due to issues of (1) dosimeter calibration, (2) errors in recordkeeping, and (3) subtraction of unspecified exposures registered on “control badges” that had been exposed to elevated ambient levels of fallout radiation.

Lastly, SC&A questions NIOSH’s interpretation and use of these Operation-specific dose distribution data cited in DNA reports for the following reasons:

- (1) Use of a derived **50% dose** as the coworker dose
- (2) Misuse of DNA data for defining the 50% dose

Misuse of the 50% Dose. Coworker dose models have been used extensively by NIOSH for assigning external as well as internal doses to workers at DOE and AWE facilities. Guidance for

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the assignment of a coworker dose is provided in ORAUT-OTIB-0020 (ORAUT 2011b). Section 3.0 of OTIB-0020 provides the following guidance.

*The general approach to applying coworker data for cases with little or no individual external monitoring data is to assign either 50th- or 95th-percentile doses with the intent that the assigned doses **represent, but do not underestimate**, the doses that would be assigned had the employee been monitored. . . .*

*. . . In general, the 50th-percentile dose may be used as a best estimate of a worker's dose when professional judgment indicates the worker was likely exposed to **intermittent** low levels of external radiation. The 50th-percentile dose should **not** be used for workers who were **routinely exposed**. For **routinely exposed** workers (i.e., workers who were **expected** to have been monitored), the 95th-percentile dose should be applied. [Emphasis added.]*

The restrictive badging policy for Operations up to and inclusive of Operation CASTLE was dictated not on the basis of need, but rather by the limited availability of dosimeters and human resources for their calibration, processing, and recording. Under less restrictive conditions, **all** participants should/would have been badged. Notwithstanding that permanent badges were issued to all participants beginning with Operation REDWING in 1956, the veracity of readings from those dosimeters is highly questionable for at least two Operations; REDWING and DOMINIC I.

Finding #8: Independent of other concerns/limitations that characterize the DNA dose distribution data (e.g., their accuracy, completeness, etc.), use of the 50th percentile dose as a coworker dose is not justified for PPG participants for Operations up to and inclusive of Operation CASTLE and for the subsequent Operations where dosimeter damage was an issue.

Misuse of DNA Data for Deriving 50% Dose. Inspection of Attachment A (see Exhibit 7-2 above) identifies an equation that is applied to each Operation-specific dose distribution, which consists of the following four dose ranges:

0	0.001–1 R	1–3 R	>3 R
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These dose distributions not only suffer from various deficiencies, including subtraction of unspecified ambient fallout doses recorded by “control badges” and overstated readings from environmental damage, but are reduced further by NIOSH’s failure to modify these dose distributions by acknowledging the 40 mR MDA value of film dosimeters used at the time. Thus, the first and second dose ranges should have been modified to account for the dosimeters MDA of 0.04 R as follows:

0.0–0.04 R and 0.04–1 R

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Finding #9: Operation-specific dose distributions defined by DNA must be adjusted to account for the MDA value of film dosimeters regardless of what percentile value is employed.

8.0 AN ASSESSMENT OF THE PPG SITE PROFILE FOR ADEQUACY IN PERFORMING A DOSE RECONSTRUCTION

A practical way to assess the adequacy of guidance provided in ORAUT-TKBS-0052 for the reconstruction of external dose for PPG claimants is to review a representative claim. SC&A searched its own records of PPG dose reconstructions that had previously been audited by SC&A. In October 2010, SC&A issued its draft audit of Case # [Redacted], which involved an energy employee (EE) who worked as a [Redacted] for the [Redacted] at various locations/islands that are part of Enewetak Atoll of the Marshall Islands. The following data summarize key elements of the EE's dose reconstruction:

- Employment Periods
 - (1) [Redacted]–[Redacted]
 - (2) [Redacted]–[Redacted]
- Cancer: The EE was diagnosed with [Redacted] on the [Redacted] in [Redacted].
- The dose reconstruction performed by NIOSH in April 2009 employed a partial dose reconstruction that assigned the following exposures shown in Table 8-1.

Table 8-1. Summary of NIOSH-Derived External Dose Estimates

	Dose (rem)			
	[Redacted]	[Redacted]	[Redacted]	Total
External Dose (Occ.):				
▪ Recorded/Modeled Dose:		0.225	0.131	0.356
- Photons 30–250 keV		0.225	0.131	0.356
- Electrons >15 keV				
▪ Missed Dose Dose			0.025	0.025
- Photons 30–250 keV				
- Electrons >15 keV				
▪ Assigned Coworker Dose				
- Photons 30–250 keV	0.250			0.250
- Electrons >15 keV	0.250			0.250
▪ Occupational Medical Dose				
- Photons 30–250 keV	1.229		1.229	2.458
Total				3.695

It should be noted that the **dose reconstructor** for Case # [Redacted] is also a **co-author** of the PPG Site Profile ORAUT-TKBS-0052 (ORAUT 2012). Discussed in Sections 8.1 through 8.4 is a detailed assessment of the EE's assigned doses and their deficiencies.

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8.1 RECORDED/MODELED DOSE

8.1.1 Recorded/Modeled Dose for [Redacted]

Table 8-1 shows a photon and electron dose of 0.225 mR, which reflects the recorded gamma dose of two mission badges issued on two consecutive days of [redacted], and [redacted], with readings of 50 mR and 70 mR, respectively.

In addition, there was an “assigned” dose of 60 mR for fallout for a total gamma dose of 180 mR (see Exhibit 8-1). The recorded and assessed gamma dose of 180 mR was multiplied by a correction factor of 1.25 (used at the NTS site) for the assigned gamma dose of 0.225 mR.

For assigning a corresponding beta dose, the dose reconstruction stated:

*... A beta-to-gamma ratio of **one-to-one** was applied to the measured and unmonitored dose assigned, consistent with presence immediately after a test.⁹*
[Emphasis added.] [Ref. 9 above refers to the NTS Site Profile.]

SC&A’s Comments. Assigned gamma and beta doses for the year [redacted] are underestimated for the following reasons:

- (1) NIOSH’s “assumed” beta-to-photon ratio of 1 is incorrect and inconsistent with recommended value of ~10 defined in Table 7.3 above.
- (2) Based on statements provided by the EE and DNA’s formal dose assessment with Operation GREENHOUSE fallout (DNA 1983b), there are sound reasons to question the photon dose of 60 mR as “assessed” on [redacted], for the EE on the day of the EE’s departure.

Statements provided by the EE on [redacted], 2008, and recorded on page 10 of the Computer-Assisted Telephone Interview (CATI):

[Statements made by the EE during the interview have been redacted in full for Privacy Act concerns.]

The EE’s presence on Enewetak Atoll from [redacted], to [redacted], coincided with the [redacted]. The EE’s two mission badges issued on [redacted] and [redacted] can reasonably be assumed to represent [redacted]. Thus, unmonitored exposure to fallout occurred on the test island of [redacted] and other support islands that included Japtan (see Figures 7.1 through 7.9 above).

Based on time-integrated fallout exposures for Japtan Island (see Figure 7-10 above), a reasonable gamma dose for the [redacted], would be 1.75 rem, and 17.5 rem for the beta dose.

Exhibit 8-1. [Redacted] Dosimetry Records for Case #[Redacted]

Date	Badge No.	Reading mR	Acc. Dose r	Date	Dosimeter No.	Reading mR	Acc. Dose r
[Redacted]	[Redacted]	50	50				
[Redacted]	[Redacted]	70	120				
		50	120				

70-10-00
11/21-11/22

Name: [Redacted] Org.:

*Fo = 60 mrem (assessed)
Film Badges = 120 mrem
180 mrem*

8.1.2 Recorded/Modeled Dose for [Redacted]

For the year [redacted], DOE records identify three dosimeter assignments (see Exhibit 8-2). The first two badges (#[redacted] and #[redacted]) yielded “responses” that were recorded as 50 mrem and 55 mrem, respectively. The third badge (#[redacted]) was recorded as zero dose. NIOSH again employed a “correction factor” of 1.25 and a **beta-to-photon ratio of 1** for the two dosimeters, yielding a total gamma and beta dose of 0.131 rem each.

SC&A Comments

Exposure recorded on film badges #[redacted] and #[redacted] predate [redacted] and must, therefore, reflect fallout from the [redacted]. For fallout that has aged for about 2 years, the **beta-to-gamma ratio of about 60** is recommended in Table 6-14 and Appendix C of the NTS Site Profile (ORAUT 2012).

Therefore, for [redacted], the recorded photon dose of 0.131 rem translates to a **beta dose of about 7.86 rem.**

Additionally, SC&A questions the accuracy of the two film dosimeters (i.e., badge #**[redacted]**) identified in Exhibit 8-2 for reasons that had been noted in NRC (1989) and discussed in Section 7.3 of this report. The concern centers on the **undocumented** method used by RadSafe dosimeter processing personnel for the **background subtraction of control film badges** from issued film badges.

Original processing information of badge #**[redacted]** and badge #**[redacted]**, as shown in Exhibit 8-3, supports this concern:

- Badge #**[redacted]** with a “recorded” dose of **50 mR** had a **Net Optical Density (NOD)** of 0.00
- Badge #**[redacted]** with a recorded dose of **55 mR** had a **NOD** of 0.02

These data suggest that the background subtraction of control badges may have been subjected to variable and significant amounts of fallout radiation. Exposures to and responses by control dosimeters to ambient fallout were likely shared by dosimeters **issued** to personnel and should, therefore, **not** be subtracted. (Note: Prior to nuclear testing in the PPG, natural background radiation from **terrestrial** and cosmic radiation was minimal.) SC&A, therefore, concludes that the practice of subtracting the optical densities of control badges exposed to fallout from assigned badges results in an NOD that wrongly reduces the recorded dose of assigned film dosimeters.

Exhibit 8-2. **[Redacted] Dosimetry Records for Case #**[Redacted]****

OFFICIAL USE ONLY

Individual External Dosimetry Records

SSN: **[redacted]**

Film Badge No.	Issue Date	Deep Dose (Gamma) (mrem)	Comment	Org Name	
[redacted]	[redacted]	50	First Quarter 1958	H&N	
[redacted]	[redacted]	55	First Quarter 1958	H&N	
[redacted]	[redacted]	0	Operation Hardback-I	H&N	TG 7.5, TU-1, ORG-12
Pacific Proving Grounds					
[redacted]	TOTAL:	105			

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Exhibit 8-3. Original Processing Information of Badge # [Redacted] and Badge # [Redacted] Inclusive of Recorded NOD Values

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[Redacted]	[Redacted]	ENGINEERS — CONSTRUCTORS	
Badge #	Date Issued	BADGE ISSUE RECORD	
[Redacted]	[Redacted]	0-00	55
Organization	Date Returned	NOD	nr Gamma
[Redacted]	[Redacted]		
ID Number	Date Developed	Remarks	
NAME: [Redacted]		*88-1 BIKINI	
18-100	Other Information	Signature	

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[Redacted]	[Redacted]	ENGINEERS — CONSTRUCTORS	
Badge #	Date Issued	BADGE ISSUE RECORD	
[Redacted]	[Redacted]	0-02	50
Organization	Date Returned	NOD	nr Gamma 7h
[Redacted]	[Redacted]		
ID Number	Date Developed	Remarks	
NAME: [Redacted]		*88-1 BIKINI	
18-100	Other Information	Signature	

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8.2 ASSIGNED MISSED DOSE

For both employment periods, NIOSH assigned but a single missed dose of 0.025 rem for the year [redacted] along with the following explanation:

A missed dose represents the dose that could have been received but may not have been recorded due to dosimeter detection limits or site reporting practices. Based on information provided in the Summary Site Profile of the Pacific Proving Ground, the number of dosimeter cycles assigned was 1 for photons. This number was based on the actual number of annual dosimeter exchanges found in the records provided by DOE. . . . a limit of detection (LOD) for each Operation is found in Table 2-2 of the Summary Site Profile of the Pacific Proving Ground, and was used in this dose reconstruction. [Emphasis added.]

SC&A's Comments

Statements regarding **annual dosimeter exchange** and the assignment of missed doses, as stated above, are **incorrect/unsupported**. As previously cited in DNA reports, for **all** Operations up to and inclusive of Operation CASTLE, the majority of assigned film dosimeters were **mission badges** that were usually limited to a specific task and returned for processing at **end-of-day**. Exhibit 8-1 identifies two **separate** mission badges dated [redacted] and [redacted], that coincided with [redacted]. For the EE's second employment in 1958, Exhibit 8-2 and Exhibit 8-3 identify two film dosimeters (badges #[redacted] and #[redacted]) with recorded exposures of 50 mR and 55 mR, respectively, and a third dosimeter (badge #[redacted]) with a dose of zero.

A deficiency associated with the assigned missed photon dose of 0.025 rem for [redacted] include the fact that the missed **photon** dose would **also** have had a **beta** component along with an appropriate beta-to-photon adjustment factor. For the missed photon dose of 0.025 rem and a beta-to-photon ratio of 10, a **beta dose** of 0.25 rem should have been assigned.

8.3 ASSIGNED COWORKER DOSE

For [redacted], the DOE stated that there were no dosimetry records for the EE. NIOSH, therefore, assigned an "unmonitored" dose for this year with the following explanation:

*Based on summaries of external dose measurements, a 50% dose has been calculated in accordance with **Attachment A** of the Summary Site Profile for the Pacific Proving Ground. . . . For the year that [the EE] was unmonitored no tests occurred. To be claimant favorable, the 50% dose from the previous test (Sandstone, 1948 [DNA 1983c]) was assigned as **both photon and electron**. [Emphasis added.]*

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SC&A Comments

Under Operation [redacted], three tests ([redacted], [redacted], and [redacted]) were conducted over a 30-day period in [redacted] on [redacted] ([redacted]).

NIOSH's assigned dose of **0.250 rem for both photons and electrons** as the **50% dose for Operation [redacted]** is incorrect for the following two reasons:

- (1) Attachment A of the PPG Site Profile identifies the **calculated 50% gamma dose for Operation [redacted] as 1.383 rem** (not 0.250 rem) (see Exhibit 7-2 above).
- (2) For the assigned **electron** dose of 0.250 rem, the beta-to-gamma ratio of 1:1 was assumed by NIOSH. Given the approximate 2-year time lapse between Operation [redacted] and the unmonitored year [redacted], a **beta-to-gamma ratio of ~50** should have been applied based on values shown in Table C-1 of the NTS Site Profile (ORAUT 2012). This would correspond to a beta dose of about **69 rem**.

Additional exposures that were either not **monitored** or **recorded** may be assumed based on information provided by the EE. Unmonitored exposures associated with the first employment period during Operation [redacted] may have involved substantial (but difficult to quantify) skin doses associated with **direct deposition of fallout onto skin/clothing**. The EE's recall of having "... [redacted] ..." is consistent with observations and fallout data provided by Cooney (1951) and referenced in Section 7.3 above.

The potential for "unrecorded" exposures must equally be assumed during the EE's first employment period. DOE records indicate that for the entire period of [redacted] (which includes the [redacted]), the EE was assigned only 2 mission film dosimeters, as described in Section 8.1. The "intermittent" assignment of film dosimeters was acknowledged by the EE during the CATI along with the EE's recall of also having been monitored by **cohort badging**, a common practice during Operation [redacted] (see Table 2-2 of the PPG Site Profile). There is no evidence of cohort badging in DOE records and no reference is made to cohort badging in the EE's dose reconstruction report.

8.4 OCCUPATIONAL MEDICAL DOSE

For each of the years [redacted] and [redacted], NIOSH assigned 1.229 rem for a total of 2.458 rem in spite of the fact that (1) DOE had no records of occupational medical exposure, and (2) the EE had no recall of any medical exposures as an employee of the [redacted].

SC&A's Comments

Based on more recent guidelines defined in ORAUT-OTIB-0079 (ORAUT 2011a), the assigned dose of 2.458 rem for occupational medical dose may not be justified.

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8.5 OTHER DEFICIENCIES

The following information was entered into the CATI by the EE on [redacted], 2008:

[The EE] said [the EE] had [redacted] and provided the information already to the DOL. [The EE] said [the EE] will phone [the EE's] attorney and AR [name], and get him involved to contact the DOL. I provided [the EE] with the toll free number to the Seattle DOL Office. [Emphasis added.]

Reference to the CATI report in the dose reconstruction for Case #[Redacted] is limited to the following statements:

*The record of the telephone interview was evaluated **carefully** by the dose reconstructor. According to the telephone interview, [the EE] was **not** involved in any radiation exposure or contamination incidents. The information in the telephone interview is also supported by the dosimetry records provided by the DOE. Therefore, **no additional modifications** to this dose reconstruction were made. [Emphasis added.]*

There was **no acknowledgment** in the DR report (dated April 7, 2009) regarding the EE's alleged claim of v and there was **no follow-up** by NIOSH to verify the EE's claim.

Independent of errors identified by SC&A in Section 8.0 herein and our formal audit of Case #[Redacted], a potential confirmation of three additional melanomas would clearly have affected the probability of causation (POC).

A review of the Department of Labor's (DOL's) **Notice of Final Decision** dated October 9, 2009, identified the following:

- (1) The EE died on [redacted].
- (2) On May 28, 2009, the EE's wife filed a Form EE-2 (for survivor Benefits).
- (3) The claim for [redacted] under Part B of the Act was limited to the [redacted] diagnosed on the [redacted] on [redacted].
- (4) The NIOSH-IREP indicated a 36.94% probability that the employee's cancer was caused by radiation exposure at the PPG.
- (5) On July 29, 2009, the claim was denied.

In summary, our review of the DOL's **Notice of Final Decision** shows that there was **no mention** of [redacted] alleged by the EE. Enclosed herein as Appendix 1 is a redacted copy of the Notice of Final Decision for Case #[Redacted].

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9.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

Unlike all other DOE/AWE facilities, the PPG is not a “facility,” but represents a **remote** cluster of Pacific atolls/islands with limited infrastructure that, nevertheless, served as test sites for nuclear weapons considered too large/dangerous to be tested in the continental U.S.

Given the immense scope of the PPG program and complexity of radiological environments to which PPG participants were exposed, it is not surprising that there were numerous deficiencies in radiological protection and personnel monitoring that **varied over time among successive PPG test Operations**.

As noted in in this report, during earlier Operations, the principal focus on radiological protection was to limit external gamma exposures to less than 0.1 R/day. This objective was mostly achieved by the restrictive/selective use of mission badges, **cohort badging**, (which, however, were **not** consistently assigned/recorded for members of the cohort) and by **dose-rate** measurements and restricted **stay-times** (which may also not have been properly recorded). Lastly, exposures **not** associated with **specific tasks/missions** were unmonitored. Unmonitored exposures principally included external exposure to ambient fallout on islands where personnel worked/lived and to skin/clothing contamination resulting from direct deposition of fallout or contact with contaminated surfaces.

SC&A assessed the PPG Site Profile (ORAUT 2006) in context with operation-specific information and data reported by the DNA and NRC. Based on our review, SC&A concludes the following:

- For the reconstruction of occupational external dose, the PPG Site Profile is lacking in both **guidance** and **data/information** commonly included in a site profile. SC&A’s concerns for the Site Profile’s limited guidance and inappropriate use of data for its coworker model were further supported by our review of a previously SC&A-audited dose reconstruction discussed in Section 8.0.
- Due to evolving changes in radiological protection practices and policies that were introduced over the 16-year period of the PPG program, relevant information provided in DNA reports should be incorporated into the PPG Site Profile for each test Operation.
- For PPG test Operations that **predate** the issuance of **permanent film dosimeters to all test participants**, use of DOE records for individual dose reconstructions will likely result in dose estimates that significantly underestimate actual doses, even when such dose records are assumed “complete.”
- Operation-specific information should, therefore, include **newer data** (such as external unmonitored gamma dose data from fallout during Operation GREENHOUSE) as well as acknowledged **limitations** pertaining to selective dosimeter assignments, deficiencies in film processing and background subtraction, and incomplete dosimeter records.

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- For cancers involving the skin and other surficial tissues, guidance should be provided that address **unmonitored** exposures involving skin/clothing contamination due to fallout.
- Attachment A of the PPG Site Profile should be critically evaluated for its use as a **coworker model** for unmonitored workers. This is particularly true for PPG Operations in which dosimeter data are dominated by mission badges/coworker badges.

One potential alternative to a dose reconstruction involving incomplete records and/or the use of a coworker model is the assignment of the MPE at 0.1 R/day. Support for this option is given by the following statements:

From DNA (1984): Factsheet

*All CROSSROADS operations were undertaken under radiological **supervision intended** to keep personnel from being exposed to more than **0.1 roentgen (R) per day**. At the time, this was considered to be an amount of radiation that could be tolerated for **long periods** without harmful effects on health. [Emphasis added.]*

And from DNA 1983(b) Chapter 10

*The recent analysis does **confirm** that all personnel living on these three islands of Enewetak Atoll through the entire series [of Operation GREENHOUSE] probably **exceeded** the task force's **maximum permissible exposure (MPE)** due to **fallout alone**. Any additional exposures on **missions** would add to this **overexposure**. [Emphasis added.]*

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**APPENDIX 1: DOL'S NOTICE OF FINAL DECISION FOR
CASE [REDACTED]**

U.S. DEPARTMENT OF LABOR

EMPLOYMENT STANDARDS ADMINISTRATION
OFFICE OF WORKERS' COMPENSATION PROGRAMS
DIVISION OF ENERGY EMPLOYEES OCCUPATIONAL
ILLNESS COMPENSATION
FINAL ADJUDICATION BRANCH



EMPLOYEE: [REDACTED]
CLAIMANT: [REDACTED]
FILE NUMBER: [REDACTED]
DOCKET NUMBER: [REDACTED]
DECISION DATE: OCT 09 2009

10-15-09 P01:15 IN

NOTICE OF FINAL DECISION

This is the decision of the Final Adjudication Branch (FAB) concerning your claim for compensation under the Energy Employees Occupational Illness Compensation Program Act of 2000, as amended (EEOICPA or the Act). See 42 U.S.C. § 7384 *et seq.*

For the reasons set forth below, your claim for melanoma under Part B of the Act is denied.

Your claim for melanoma and chronic obstructive pulmonary disease (COPD) under Part E is deferred pending further development.

STATEMENT OF THE CASE

On April 17, 2008, [REDACTED] filed a Form EE-1 (Claim for Benefits Under the EEOICPA) for [REDACTED] and [REDACTED] problems ([REDACTED]).

[REDACTED] filed a Form EE-3 (Employment History for a Claim under the EEOICPA) indicating that he worked as a [REDACTED]

The Department of Energy (DOE) verified that [REDACTED] was employed [REDACTED] [REDACTED] a DOE contractor, at the PPG, a DOE facility, as a [REDACTED]

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Appendix 1: DOL's Notice of Final Decision for Case [Redacted] (continued)



Your attorney submitted medical records, including an operative report by [Redacted], M.D., who diagnosed [Redacted] on [Redacted] and an operative report by Dr. [Redacted] dated [Redacted] which stated that the employee was first diagnosed with [Redacted] in [Redacted]. The district office accepted that the employee was diagnosed with [Redacted] on [Redacted].

The employee died on [Redacted] and his claim was administratively closed.

On May 28, 2009, you filed a Form EE-2 (Claim for Survivor Benefits Under the EEOICPA) for [Redacted] and [Redacted] problems ([Redacted]).

You submitted a copy of your marriage certificate showing that you and the employee were married on [Redacted] and a copy of the employee's death certificate which establishes that you were married to him at the time of his death on [Redacted].

To determine the probability of whether the employee sustained cancer in the performance of duty, the Seattle district office referred your claim to the National Institute for Occupational Safety and Health (NIOSH) for radiation dose reconstruction. On July 6, 2009, you signed Form OCAS-1 agreeing that you are not in possession of any additional information that has not already been provided to NIOSH for completing a dose reconstruction to estimate the radiation doses incurred by the employee.

The district office received the NIOSH Report of Dose Reconstruction dated April 23, 2009. Using the information provided in this report, the district office utilized the Interactive RadioEpidemiological Program (NIOSH-IREP) to determine the probability of causation of the employee's cancer and reported in its recommended decision that there was a 36.94% probability that the cancer was caused by his radiation exposure at the PPG.

On July 29, 2009, the Seattle district office recommended denial of your claim for survivor benefits under Part B, concluding that the dose reconstruction estimates and the probability of causation were completed in accordance with the Act; that the employee's cancers were not "at least as likely as not" (a 50% or greater probability) caused by radiation doses incurred while employed at the PPG; that the employee does not qualify as a "covered employee with cancer" under the Act; and that you are not entitled to compensation under Part B. The district office also recommended deferral of your claim under Part E for [Redacted].

After considering the written record of the claim forwarded by the district office, the FAB makes the following:

¹ See DOE's Office of Health, Safety & Security facility list on the agency website at: <http://www.hss.energy.gov/healthsafety/FWSP/advocacy/facilist/showfacility.cfm>. (retrieved October 9, 2009)

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Appendix 1: DOL's Notice of Final Decision for Case [Redacted] (continued)

FINDINGS OF FACT

1. On April 17, 2008, [Redacted] filed a claim under the Act.
2. [Redacted] was employed [Redacted] a DOE facility, as a [Redacted]
3. The employee was diagnosed with [Redacted] on [Redacted]
4. The employee died on [Redacted].
5. On May 28, 2009, you filed a claim under the Act.
6. You are the surviving spouse of the employee.
7. The NIOSH-IREP indicated a 36.94% probability that the employee's cancer was caused by radiation exposure at the PPG.

Based on the above noted findings of fact, the FAB makes the following:

CONCLUSIONS OF LAW

You have not objected to the recommended decision under section 30.316(a) of the regulations, and the sixty-day period for filing an objection under section 30.310(a) has expired. *See* 20 C.F.R. §§ 30.316(a) (2009) and 30.310(a) (2009).

To qualify for benefits as a survivor of a "covered employee with cancer" under Part B, you must show that you are a survivor of the employee; that the employee was either a DOE employee, or a DOE contractor employee, or an employee of an Atomic Weapons Employer (AWE); who contracted cancer in the performance of duty; after beginning employment at a DOE facility or an AWE facility. *See* 42 U.S.C. §§ 7384l(9), 7384n(b), 7384s(5) and 20 C.F.R. § 30.210(b) (2009).

Using the information provided in the NIOSH Report of Dose Reconstruction, the FAB utilized the NIOSH-IREP to confirm a 36.94% probability that the employee's cancer was caused by radiation exposure while employed at the PPG. *See* 42 C.F.R. § 81.20 (2009) *et seq.*

Although the evidence of record shows that you are the survivor of [Redacted] that he worked at the PPG; and that he was diagnosed with [Redacted] after beginning employment at the PPG; your claim under Part B must be denied because the evidence does not establish that he was a "covered employee with cancer" under the EEOICPA, as his cancer was not determined to be "at least as likely as not" (a 50% or greater probability) related to radiation doses incurred in the performance of duty at the PPG. *See* 42 U.S.C. §§ 7384l(1)(B) and (9)(B); 20 C.F.R. § 30.213(b) (2009); and 42 C.F.R. § 81.2 (2009).

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Appendix 1: DOL's Notice of Final Decision for Case [Redacted] (continued)

For the reasons set forth above, your claim for [Redacted] under Part B of the Act is denied. See 42 U.S.C. § 7384.

Seattle, Washington

[Redacted] [Redacted]
Hearing Representative
Final Adjudication Branch
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