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ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

NEVADA TEST SITE: REVIEW OF SITE PROFILE COMMENT 26

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	Atomic Energy Commission
Am	americium
Be	beryllium
Bq	becquerel
BN	Bechtel Nevada
BREN	Bare Reactor Experiment Nevada
CFR	*Code of Federal Regulations*
Ci	curie
CP	Chemical Processing (complex)
Cs	cesium
CY	calendar year
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOELAP	U.S. Department of Energy Laboratory Accreditation Program
DOE/NV	U.S. Department of Energy/Nevada Operations Office
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
GCD	greater confinement disposal
GFP	gross fission product
GMX	Gadgets, Mechanics, and Explosives (Project)
H	hydrogen
HAZMAT	hazardous material
HE	high explosive
HENRE	High Energy Neutron Reactions Experiment
$H_p(d)$	personal dose equivalent (d = depth in millimeters)
HPRR	Health Physics Research Reactor
HTO	tritiated water
IREP	Interactive RadioEpidemiological Program
JASPER	Joint Actinide Shock Physics Experimental Research (Facility)
keV	kiloelectron volt
LANL	Los Alamos National Laboratory

LLNL	Lawrence Livermore National Laboratory
LLW	low-level radioactive waste
µCi	microcurie
MAD	Maintenance, Assembly, and Disassembly (facility)
mrem	millirem
mR	milirad
MeV	mega-electron volts
MLLW	mixed low-level waste
MTRU	mixed transuranic
NASA	National Aeronautics and Space Administration
NCRP	National Council on Radiation Protection and Measurements
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NFO	Nevada Field Office, U.S. Department of Energy
NRCH	Non-Radiological Classified Hazardous (waste)
NIOSH	National Institute for Occupational Safety and Health
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NRC	non-Radiological Classified (waste)
NRCH	Non-Radiological Classified Hazardous (waste)
NRDS	Nuclear Rocket Development Station
NSO	Nevada Site Office
NSTec	National Security Technologies
NTA	nuclear track emulsion type A (dosimeter)
NTTR	Nellis Test and Training Range
NTS	Nevada Test Site
ORAUT	Oak Ridge Associated Universities Team
PCB	polychlorinated biphenyl
pCi	picocurie
Pu	plutonium
Ra	radium
RAMATROL	Radioactive Material Control
RCRA	Resource Conservation and Recovery Act

REECo	Reynolds Electrical and Engineering Company
RSPC	Radiological Safety Prime Contractor
RTR	real-time radiography
RWMS	radioactive waste management site
RWP	Radiation Work Permit
SEC	Special Exposure Cohort
SMS	Site Monitoring Services
Sr	strontium
SRDB	Site Research Database
Sv	sievert
TBD	technical basis document
TED	track-etch dosimeter; total effective dose
Th	thorium
TLD	thermoluminescent dosimeter
TPCB	TRU Pad Cover Building
TRU	transuranic
TTR	Tonopah Test Range
U	uranium
WEF	Waste Examination Facility
WG	Work Group
WIPP	Waste Isolation Pilot Plant

1.0 INTRODUCTION AND BACKGROUND

The Advisory Board on Radiation and Worker Health (ABRWH) at the January 5, 2017, Nevada Test Site (NTS)[1] Work Group (WG) meeting (NIOSH 2017) directed SC&A to review issues associated with post-1992 waste handling and related items captured in Comment 26 of the *Site Profile Issues Resolution Matrix* (SC&A 2017). SC&A and the NTS WG originally raised these concerns, which pertain to the site profile (consisting of six technical basis documents [TBDs]), while reviewing the National Institute for Occupational Safety and Health's (NIOSH's) evaluation report (NIOSH 2010) of Special Exposure Cohort (SEC) petition SEC-00084, which recommended adding a class of petitioners over the period from January 1, 1963, to December 31, 1992. The December 31, 1992, date represents the end of the year when all nuclear weapons testing ceased at NTS. NIOSH also claimed in its evaluation report that it could adequately perform dose assessments in the post-testing period:

> *Per EEOICPA* [Energy Employees Occupational Illness Compensation Program Act] *and 42 C.F.R. § 83.13(c)(1), NIOSH has established that it has access to sufficient information to: (1) estimate the maximum radiation dose incurred by any member of the class; or (2) estimate radiation doses more precisely than a maximum dose estimate for the period from January 1, 1993 forward. Information available from the Site Profile and additional resources is sufficient to document or estimate the maximum internal and external potential exposure to members of the proposed class under plausible circumstances during this period.*

In the course of preparing this report, SC&A reviewed the NIOSH evaluation report to examine what information is offered for post-1992 activities, but not for the purpose of assessing the merits of NIOSH's assertion that it could adequately perform dose assessments for that time period.

SC&A's initial review of the site profile (SC&A 2005) examined Revision 0 of the NTS TBDs (NIOSH 2004a–f), which were published between February 2, 2004, and September 30, 2004. The SC&A review did not consider the post-1992 period or waste handling operations because the TBDs themselves did not cover these issues. At its June 2012 meeting (NIOSH 2012a), the ABRWH directed SC&A to update the site profile issues resolution matrix (SC&A 2006) following NIOSH's issuing of the SEC-00084 evaluation report (NIOSH 2010) on January 25, 2010, and subsequent discussions. The ensuing matrix (SC&A 2012) added a new comment (Issue 26) "*related to workers handling radioactive waste and to decommissioning…as a place-holder for WG discussion*." SC&A 2012 noted that "*There are some ongoing activities in the post-1992 period that may involve exposure potential including subcritical tests, waste handling and disposal, and decommissioning areas of the site. These activities and the associated exposure potential have not been reviewed by SC&A*," and concluded in the discussion section that a review was not needed for Issue 26 at that time, "*pending WG discussion of this placeholder item*."

NIOSH committed at the December 3, 2014, WG meeting (NIOSH 2014) to investigate the post-1992 issues associated with waste handling activities, as recorded in a May 15, 2015, addition to

[1] Note that the historical Nevada Test Site (NTS) is currently named the Nevada National Security Site (NNSS).

the issues resolution matrix (noted in SC&A 2017). The current version of the matrix (SC&A 2017) contains the following statements about Issue 26:

> *Issue Description: A number of issues in relation to waste handling, decommissioning, and other post-1992 site activities were reviewed by SC&A in SC&A 2005 or during the SEC review.*
>
> *Status: This is a new matrix comment. It has been added to this matrix update as a placeholder for WG discussion.*
>
> *From the 12/3/14 WG Mtg: NIOSH will investigate post-1992 internal and external dose issues associated with waste handling activities to include neutron dose from orphan sources and extremity dose for waste handling.*

The paragraph about the December 2014 Work Group meeting was added to the December 14, 2012, matrix (SC&A 2012) and differs from that appearing in the December 29, 2016, SC&A memo updating the site profile matrix comments, which states: "*SC&A Comment, December 2016: NIOSH to review the SC&A 2005 NTS site profile review and provide responses to the waste handling issues raised there, as per the December 2014 WG transcript*" (SC&A 2016). SC&A does not believe this is a material difference.

NIOSH used the "SC&A Preliminary Conclusions" column (the last column of the matrix) to record its response to the WG's direction from the December 3, 2014, WG meeting. Following the NIOSH material in the last column, SC&A inserted the following statement in SC&A 2017: "*SC&A is tasked to review post-1992 issues involving waste disposal in relation to the pertinent sections of the TBD and other documents as referenced in NIOSH response (above)*."

Section 2 of this report reproduces NIOSH's response regarding the post-1992 waste handling issues and shows corresponding SC&A comments. Section 3 presents comprehensive background information on waste handling to help put the issues into context and to supplement the material that NIOSH presents in the last column of the matrix. Section 4 presents SC&A's evaluation of the adequacy of NIOSH's response as well as some observations and recommendations related to post-1992 dosimetry and other issues.

2.0 ASSESSMENT OF COMMENT RESOLUTION

NIOSH's response to the WG directions appears in the last column (labelled "SC&A Preliminary Conclusions") of the *Site Profile Issues Resolution Matrix* (SC&A 2017) and is reproduced below, section by section, accompanied by SC&A's evaluation and comments. SC&A has included pertinent text from documents referenced by NIOSH in its response (e.g., from the TBDs) to provide a convenient, consolidated waste disposal and handling description to the interested reader. SC&A consulted the current versions of the TBDs, which are listed in the References as NIOSH 2006, 2008, and 2012b–e. Note that the radioactive waste management sites (RWMSs) frequently mentioned are located in Areas 3 and 5. Area 3 radioactive waste storage of bulk and packaged material utilizes seven subsistence craters, and Area 5 storage consists of 22 landfill cells and 13 greater confinement disposal (GCD) boreholes (for disposal of high-specific-activity waste). The Transuranic (TRU) Pad Cover Building (TPCB) and Waste Examination Facility (WEF) are also located in Area 5.

NIOSH Comment in Issues Matrix:

> *The following waste handling information is currently contained within the NTS Technical Basis Document.*
>
> ***ORAUT-TKBS-0009-2, Nevada Test Site – Site Description:*** [NIOSH 2008, also referred to as "TBD-2"]
>
> *Section 2.2.3, Area 3 Nuclear Test Zone and Radioactive Waste Management Site. This section includes crater disposal activities and contaminated waste streams (e.g., scrap steel, soil, etc.).*

SC&A Evaluation and Comments: The following reproduces key passages from Section 2.2.3 of TBD-2:

> *This portion of the Nuclear Test Zone occupies 83 km^2 (32 mi^2) near the center of the Yucca Flat weapons test basin. It was the site of 14 atmospheric tests between 1952 and 1958. There were 252 underground nuclear tests in Area 3 from 1958 to 1992…*
>
> *NTS disposes of bulk low-level waste in seven Area 3 subsidence craters* [created by the collapse of underground cavities formed by below-ground nuclear tests] *that collectively make up the Area 3 Radioactive Waste Management Site (RWMS). This activity began in the mid-1960s with the beginning of removal of scrap tower steel, vehicles, and other large objects subjected to atmospheric testing. From 1979 to 1990, large amounts of contaminated soil and other debris from the NTS were added to the craters.*
>
> *There are four stockpile stewardship emplacement holes in Area 3. Until 1992, Area 3 Camp provided test support for LANL* [Los Alamos National Laboratory] *and consisted of a full complement of craft shops, equipment and material storage*

> *yards, and administrative services. In 1992, construction and maintenance operations were consolidated in Area 6.*

SC&A has reviewed this section of TBD-2 and concurs with NIOSH's characterization of its applicability and contents but notes that quantification of the radioactive material appears elsewhere in TBD-2 (e.g., Tables 2-2 and 2-4).

NIOSH Comment in Issues Matrix:

> *Section 2.2.5, Area 5 Radioactive Waste Management Site and Spill Test Zones. This section describes the Area 5 facilities including the RWMS, the Hazardous Waste Storage Unit, the HAZMAT Spill Center, the TRU Pad Cover Building, and the Waste Examination Facility (WEF), and the Gravel Gerties used for safety tests in the 1950s and 1982. The RWMS includes 22 landfill cells and 13 greater confinement disposal boreholes.*
>
> *Table 2-2 provides a listing of radionuclides of concern by activity and location (i.e., Area).*

SC&A Evaluation and Comments: SC&A has reviewed this section of TBD-2 and concurs with NIOSH's characterization of its applicability and contents. The following are relevant portions of TBD-2 Section 2.2.5:

> *This area in the Reserved Zone occupies about 246 km^2 (95 mi^2) in the southeastern portion of the site. It includes the Area 5 RWMS, the Hazardous Waste Storage Unit, the HAZMAT Spill Center, the Transuranic (TRU) Pad Cover Building, and the Waste Examination Facility (WEF). The WEF houses a large multilevel glovebox used to examine legacy and national laboratory waste, to separate and segregate Resource Conservation and Recovery Act (RCRA) material, and to repack TRU waste for shipment to the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. The original and repacked containers are stored in the TRU Pad Cover Building. Operations in WEF have the potential for internal exposure if a breach in the glovebox barrier occurs…*
>
> *Twenty-four experiments occurred between 1954 and 1956 in the Gadgets, Mechanics, and Explosives (GMX) project site in Area 5 in which small quantities of plutonium materials were subjected to HE* [high explosive] *detonations (see Section 2.3.2* [of the TBD]*) for additional information on safety tests). Five underground nuclear weapons tests occurred at Frenchman Flat between 1965 and 1971. However, the presence of a carbonate aquifer makes this area less suitable for underground testing than other locations on the NTS…*
>
> *One of the primary NNSA/NSO missions has been to provide an ongoing waste management program that covers all wastes generated on the NTS as well as wastes from other defense-related facilities. Opened in 1961, the Area 5 RWMS is a 296-hectare (732-acre), low-level radioactive waste storage and disposal facility. The developed area at the RWMS consists of 22 landfill cells (pits and*

trenches) and 13 greater confinement disposal boreholes. DOE [the U.S. Department of Energy] *has disposed of mixed waste, including transuranic mixed waste, at the NTS in the past and currently stores transuranic wastes in Area 5 pending ultimate disposal at WIPP.*

NIOSH Comment in Issues Matrix:

Section 2.3.2, Safety Tests and Contaminated Surface Soils. Includes description of the safety tests conducted in Areas 3 and 5.

SC&A Evaluation and Comments: SC&A has reviewed this section of TBD-2 and concurs with NIOSH's characterization of its contents. The following are excerpts from TDB-2 Section 2.3.2:

Safety tests evaluated the safety of nuclear weapons in accident scenarios. Safety experiments that produced no nuclear explosions but created surface contamination were conducted at locations on the NTTR (Area 13) and TTR (DOUBLE TRACKS and CLEAN SLATE I-III), at Plutonium Valley in Area 11, and at the GMX site in Area 5. Contamination from these sites is limited to surface soils. The depth of contamination could vary among sites, but it is not expected to exceed 1 ft at any site (NDEP 2000)…

Operation Roller Coaster was an experimental series of plutonium dispersal tests that were conducted in 1963 at the TTR. The purpose of these tests was to evaluate storage and transportation issues. The DOUBLE TRACKS site was remediated in 1995 and 1996 and the CLEAN SLATE I corrective actions were performed in 1997. Contaminated soil was transported to the NTS Area 3 RWMS. Corrective actions for CLEAN SLATE II and III are pending an agreement between the State of Nevada and the Federal government on the level of cleanup. A summary of the plutonium dispersal tests is listed below:

- *GMX conducted at NTS Area 5, 1954-1956*
- *PROJECT 56 conducted at NTS Area 11 (Plutonium Valley), 1955 1956*
- *PROJECT 57 conducted at NTTR Area 13 in 1957*
- *DOUBLE TRACKS and CLEAN SLATE I-III (Operation Roller Coaster) conducted at TTR in 1963*

The safety tests used mixtures of plutonium and uranium dispersed by conventional explosives. Concurrent with and after these detonations, extensive studies were conducted to understand the dispersal and transport of these radionuclides in the environment including uptake by plants and animals. These studies were documented in a benchmark series of papers by the Nevada Applied Ecology Group, a panel of scientists chartered to investigate the effects of testing at the NTS. The immediate effects of the tests included the dispersal of plutonium and uranium over wide areas. To determine the area affected by these tests, inventories were conducted and later augmented by extensive sampling efforts in *the field under the Radionuclide Inventory and Distribution Program. These studies resulted in the definition of affected areas. The GMX PROJECT at Area 5 resulted in the contamination of about 240 acres, and the PROJECT 56 tests resulted in the contamination of about 2,200 acres. On the NTTR Complex, two disturbed areas total slightly less than 1,000 acres. On the TTR, almost 670 acres were contaminated.*

At both onsite and offsite locations, the primary radionuclides are plutonium, uranium, and americium, with lesser amounts of cesium, strontium, and europium. These long-lived radionuclides remain in the surface soils in the vicinity of the test areas and are available for transport by wind and uptake by plants and animals. Extensive research into the mobility of the radionuclides has found that wind can transport such contaminants and concentrate them in mounds around desert shrubs, and water can cause plutonium to migrate deeper into the soils with time. At present, the radionuclides are relatively immobile unless the soils are disturbed. Evidence of wind-driven contamination is low. The heat of initial blast, soil bonding and weathering, and the rockiness of native soil prevent deep migration (REECo 1995). DOE (1997b) provides an estimate of the $^{239+240}$*Pu inventory at the studied sites.*

Surface soils in certain areas on and off the NTS were contaminated with one or more of plutonium, americium, and tritium from nuclear device safety, atmospheric, or cratering tests. Vehicular activity is forbidden in these areas. There is no evidence of significant wind dispersal after initial deposition. Rain and runoff have caused migration in some areas. These areas could become sources of exposures to americium and plutonium if the contaminated soils were to be resuspended during windy conditions, surface cleanup, construction, vehicular travel, or similar activities.

Areas 1 to 12 and 15 to 20 on the NTS, Area 13 on NTTR, and the CLEAN SLATE I to III sites on the NTTR at the TTR contain diffuse sources of radionuclide effluents. Due to occasional high winds, some contaminated soil becomes airborne. Results from air samples in these areas indicate the routine detection of ^{241}*Am and* $^{239+240}$*Pu, but only in concentrations slightly above the minimum detectable concentration. The other predominant isotopes found in NTS soil samples are* ^{137}*Cs and* ^{238}*Pu.*

MacArthur [sic] *(1991) contains inventories of americium and plutonium in contaminated surface soils. These areas could become sources of exposure to americium and plutonium if the contaminated soils become resuspended.*

TBD-2 Table 2-4 (reproduced below) provides residual radioactivity at NTS as of January 1996, taken from DOE 1997a, for the waste disposal areas.

Table 2-4. Residual Activity on the NTS, January 1996 **[NIOSH 2008]**

Source of Radioactivity	Type of Area	Environmental Media	Major Known Elements or Waste	Depth Range	Approximate Activity (curies)
Atmospheric Tests[b]	*Aboveground nuclear proving area*	*Surface soils and test structures*	*Americium, cesium, cobalt, plutonium, europium, strontium*	*At surface*	*20*
Safety Tests[b]	*Aboveground experimental area*	*Surface soils*	*Americium, cesium, cobalt, plutonium, strontium*	*Less than 0.9 m (3 ft)*	*35*
Big Explosives Experimental Facility[b]	*Bunkers*	*Underground*	*Depleted uranium*	*N/A*	*N/A*
Deep Underground Tests[b]	*Underground nuclear testing areas*	*Soils, alluvium, and consolidated rock*	*Tritium, fission and activation products*	*Typically less than 640 m (2,100 ft); but may be deeper*	*Greater than 300 million*
Nuclear Reactor Tests[b]	*Nuclear rocket motor, reactor, and furnace testing area*	*Surface soils*	*Cesium, strontium*	*Less than 3 m (10 ft)*	*1*
Shallow Borehole Tests[b]	*Underground nuclear testing area*	*Soils and alluvium*	*Americium, cesium, cobalt, europium, plutonium, strontium*	*Less than 61 m (200 ft)*	*2,000 at land surface; depth unknown*
Shallow land burial of low-level waste[b]	*Waste disposal landfills*	*Soils and alluvium*	*Dry-packed low-level and mixed wastes*	*Less than 9 m (30 ft)*	*500,000 at time of disposal; no decay*
Crater Disposal	*Subsidence crater with sidewalls, cover, and drainage*	*Soils and alluvium*	*Bulk contaminated soils and equipment*	*Less than 30 m (100 ft)*	*1,250 at time of disposal; no decay*
Greater Containment Disposal	*Monitored underground waste disposal borehole*	*Soils and alluvium*	*Tritium, americium*	*Less than 30 m (100 ft)*	*9.3 million at time of disposal; no decay*
U1a Complex[b]	*Mined underground complex*	*Underground*	*Special Nuclear Material (SNM), tritium, depleted uranium*	*To 350 m (1,000 ft)*	*N/A*
Containment Ponds[c]	*Surface*	*Water, air, and soil*	*Tritium*	*N/A*	*130*
Laboratories[c]	*Surface*	*Air and soil*	*Tritium*	*At surface*	*500 µCi*

Source of Radioactivity	Type of Area	Environmental Media	Major Known Elements or Waste	Depth Range	Approximate Activity (curies)
Joint actinide research (JASPER)[c]	*Surface*	*Air and soil*	*SNM, actinides*	*N/A*	*N/A*
Contaminated Surface Soils	*Surface*	*Soil*	*Americium, plutonium*	*0 to 5 cm*	*Assumed to be included in above totals*

a. *N/A = not available*
b. *DOE* ([1996]*)*
c. *DOE (1997a)*

NIOSH Comment in Issues Matrix:

Section 2.3.5, Radioactive Waste management Sites:

2.3.5.1 Crater Disposal – Area 3. Includes description of crater disposal activities. Section 2.3.5.2, Shallow Land Burial – Area 5 Low-Level. Describes low level disposal activities. Section 2.3.5.3, Greater Confinement Disposal – Area 5. Describes greater confinement disposal activities and current inventory in curies.

SC&A Evaluation and Comments: SC&A has reviewed this section of TBD-2 and concurs with NIOSH's characterization of its applicability and contents. The following are excerpts from TBD-2 Section 2.3.5:

2.3.5.1 Crater Disposal – Area 3

DOE disposes of bulk low-level waste in seven selected Area 3 subsidence craters that collectively make up the Area 3 RWMS. This activity began in the mid-1960s when DOE began removing scrap tower steel, vehicles, and other large objects that had been subjected to atmospheric testing. From 1979 to 1990, large amounts of contaminated soil and other NTS debris were added to the craters (DOE [1996]*).*

Today, Area 3 is used for the disposal of bulk and packaged low-level waste from on- and offsite DOE-approved generators. Waste disposal cells at the Area 3 RWMS consisted of four subsidence craters (U-3ax, U-3bl, U-3ah, and U-3at) with areas between U-3ax and U-3bl and between U-3ah and U-3at excavated to make two oval landfill units. Conventional landfill methods are used to dispose of waste in each cell; each layer of waste is covered with 1 m (3 ft) of fill before additional waste materials are added. The inactive U-3ax/bl disposal cell contains low-level mixed waste. The U-3ah/at cell is used for low-level waste disposal; mixed waste is not accepted. Three additional subsidence craters (U-3bh, U-3bg, and U-3az) have been reserved for use as low-level waste cells.

As of 1996, approximately 1,250 Ci had been disposed of in the Area 3 subsidence craters (DOE [1996]*).*

Because the low-level Area 3 RWMS is in a location where the surrounding surface soil has been contaminated by past nuclear tests, the resuspension of this soil by wind or vehicular activity results in the detection of above-background levels of plutonium in air samples collected inside and outside the perimeter fence (DOE 2002a).

Personnel working inside the RWMS wear whole-body TLDs [thermoluminescent dosimeters] *and pocket dosimetry. Extremity monitoring and multiple dosimetry are required for some waste-handling work (REECo 1995).*

2.3.5.2 Shallow Land Burial – Area 5 Low-Level

The Area 5 RWMS uses pits and trenches for shallow land burial of standard packaged low-level waste. The category of low-level waste includes material that is classified because of its physical shape or specific composition. Classification creates a need for the use of separate disposal units controlled with additional security measures.

In 1961, the Area 5 RWMS was established for the disposal of low-level waste, low-level mixed waste, and classified low-level waste from both on- and offsite generators. The waste area at the Area 5 site consists of 23 landfill cells (pits and trenches), 13 greater confinement disposal boreholes, as discussed below, and the transuranic waste storage pad (DOE 2002b). Approximately 500,000 Ci of low-level waste had been disposed of in Area 5 pits and trenches by 1996. High-specific-activity wastes were disposed of in the greater confinement disposal units.

The Area 5 RWMS is a diffuse source of radiological effluents. However, the only emission detected by the various types of samplers surrounding the site in 2001 and attributed to site operations was HTO [tritiated water] *in atmospheric moisture. Table 2-6 lists the estimated number of curies emitted from the source for 2001 (DOE 2002a). Personnel working inside the site wear whole-body TLDs, track-etch dosimeters (TEDs), and pocket dosimeters. Extremity monitoring is required for some waste-handling work (REECo 1995).*

Table 2-6. Estimated curies emitted from the source for 2001[a] **[NOSH 2008]**

Event	*Estimated Ci*
RWMS No 4	*6.5*
SEDAN Crater	*13*
E Tunnel Pond	*11*
SCHOONER Crater	*400*

a. Source: DOE (2002a)

2.3.5.3 __Greater Confinement Disposal – Area 5__

NTS adopted greater confinement burial [21 to 40 m (70 to 120 ft) deep] for wastes that are not appropriate for near-surface disposal due to their radioactive exposure levels. Material was disposed of from 1984 to 1989. The specific types of waste include certain high-specific-activity, low-level waste (for example, fuel rod claddings and sealed sources), TRU waste, and some classified material. The developed waste area in the Area 5 RWMS includes 13 greater confinement disposal boreholes.

As of 1996, approximately 9.3 x 10^6 Ci of high-specific-activity waste, primarily tritium, had been disposed of in greater confinement disposal units in Area 5 (DOE [1996]*).*

__NIOSH Comment in Issues Matrix__:

ORAUT-TKBS-0009-6, Nevada Test Site – Occupational External Dose: [NIOSH 2012d, also "TBD-6"]

Section 6.3.2.3, Extremity Monitoring. This section describes the types of extremity dosimeters used at the NTS and the dose limits for extremity exposure. Section 6.3.5.3, Neutron Fields. This section describes the neutron fields encountered at the NTS by source, date and location, including Area 5 TRU waste. Section 6.3.5.3.2, Isotopic Neutron Sources. Discussed neutron sources used for calibrating neutron instrumentation at the NTS. Table 6-13 provides neutron energy fractions for waste activities in Areas 3 and 5. Table 6-14 provides fractional energy bands for various neutron sources. Table 6-15 provides neutron field characteristics associated with NTS operational areas including the Low-Level waste site TRU waste. Table 6-16 provides neutron to photon dose ratios for isotopic sources at the NTS.

__SC&A Evaluation and Comments__: SC&A has reviewed this section of TBD-6 and concurs with NIOSH's characterization of its applicability and contents. The following are excerpts from TBD-6 Section 6.3, "Dose Reconstruction Parameters":

6.3.2.3 Extremity Monitoring

Extremity dosimetry has been used at NTS to assess exposure to the finger, hand, forearms, and even the head (on rare occasions) that might have occurred during operations near or involving the manual manipulation of radioactive material and radiation-emitting objects. Extremity monitoring might be required, for example, if radiation technicians were involved in handling post-test core samples.

The dosimeter (film or TLD) was worn in a position that was intended to represent the highest exposure to the extremity, usually on the inside of the wrist in the case of film, or on the finger near the tip. The extremity being monitored is normally identified in the dose record using the codes listed in ORAUT-TKBS-

0008-5, Nevada Test Site – Occupational Internal Dose (ORAUT 2010b, Table A-2). [NIOSH 2012b in this report]

In 1957, extremity limits were set at 1,500 mrem/wk (Griffith 2007). The film pack used at that time was the Film badge-DuPont 559 film packet (Table 6-1). This continued until July 1960 when the use of DuPont film packet Type 301-4 (also called DuPont Type 556) was adopted (Table 6-1). In 1964, the limit for extremities was set at 75 rem per quarter (Griffith 2007). TLD finger rings for extremity monitoring were used beginning in July 1967 (Griffith 2007).

Although the regular use of TLD finger rings was documented in 1967 (Griffith 2007), extremity monitoring with film and, later, TLD occurred on rare occasions before that time (DeMarre [2006]*). ConRad ^{7}LiF and Teflon discs, 1.3 cm in diameter by 0.4 mm thick were used for measuring finger and hand exposures when personnel handled radioactive material in certain operations (REECo 1968). The ^{7}LiF and Teflon disks were protected from the light by inserting them in black plastic pouches. The pouches were affixed to the adhesive portion of "band-aids", which were attached to the fingers of the personnel being monitored. Extremity dose determined by the TLDs was not included in the routine dose reports. Rather, they were included with the bioassay data, and a card file of extremity doses was maintained.*

The current extremity monitoring dosimeter is the single-element Panasonic UD-807 TLD shown in Figure 6-5 [not included here]. *The Panasonic UD-807 TLD is similar to a single $CaSO_4$:Tm element in the Panasonic UD-802 TLD. A single UD-807 TLD is sealed in a small, transparent, circular envelope embossed with the TLD serial number. Except when removed for placement in an envelope-type holder, the TLD is kept in a processing holder. The holder has a serial number identical to the number embossed on the TLD element encapsulation. All personnel monitoring, exposure checks, and calibrations are performed with the TLD in the envelope-type holder, while all processing is performed with the TLD in the Panasonic holder…*

6.3.5.3 Neutron Fields

Table 6-9 lists areas and operations where neutron exposure could have occurred at NTS. From 1961 to 1986, fast neutron monitoring was conducted using NTA film. Personnel who did not work in the areas listed in Table 6-9 or were not directly involved in operations during the periods indicated were not issued personal neutron dosimeters. However, there was a thermal-neutron-sensitive component in every NTS film badge to record any indication of neutron exposure.

Table 6-9, which is not reproduced here, includes the Area 5 low-level waste site and notes that it has been operating from 1974 to the present, and that its source of neutrons is TRU waste. The table is from Allen and Schoengold 1995, and the Area 5 data are from Norton 2006.

6.3.5.3.2 Isotopic Neutron Sources

A more significant potential source of neutron exposure was from isotopic neutron sources such as ^{238}PuBe or ^{252}Cf. These sources were used in specific activities such as instrument calibration and well logging. Only a few highly trained and specialized individuals, however, had access to such sources [26]…

6.4.1.4 IREP Input Photon Radiation Energy Fractions

Attachment A of ORAUT-TKBS-0008-5, Nevada Test Site – Occupational Internal Dose *(*[NIOSH 2012b]*) presents an inventory of the radionuclides at NTS by area and operation. This information is a basis for estimating the IREP input fraction of the dose in each of the three energy groups – less than 30 keV, 30 to 250 keV, and greater than 250 keV. Default values are 100% 30 to 250 keV for efficiently processing a claim or 25% 30 to 250 keV and 75% greater than 250 keV. The results are listed in Table 6-13.*

Table 6-13. NTS work area and operation-dependent photon fractions.[a] **[NIOSH 2012d]**

Operation	*Area*	*Assigned Fraction*		
		<30 keV	*30-250 keV*	*>250 keV*
Drillback operations	*1–10 and 18-20*	*0.03*	*0.50*	*0.47*
Reentry and mineback operations	*1, 12, 15, and 16*	*0.04*	*0.38*	*0.58*
Routine tunnel operations	*1, 12, 15, and*	*0.00*	*0.22*	*0.78*
Decontamination facility	*6*	*0.14*	*0.43*	*0.44*
Treatability test facility	*25*	*0.12*	*0.46*	*0.42*
Atmospheric safety test areas	*5 and 11*	*None indicated*		
Atmospheric weapons test areas	*1–5, 7–11, and 18*	*0.10*	*0.45*	*0.45*
Low-level waste site	*3*	*0.31*	*0.40*	*0.29*
Low-level waste site	*5*	*0.20*	*0.45*	*0.34*
Radiation instrument calibration	*6 and 23*	*0.36*	*0.40*	*0.24*
Radiograph operations	*23*	*0.00*	*0.23*	*0.76*
Well logging operations	*1–10 and 18–20*	*0.32*	*0.38*	*0.30*
Nuclear explosive/device assembly	*6 and 27*	*0.57*	*0.43*	*0.00*
Nuclear rocket development	*25 and 26*	*0.02*	*0.43*	*0.55*
Radioactive source storage	*6 and 23*	*0.26*	*0.41*	*0.33*
Radiochemistry and counting laboratories	*6 and 23*	*0.09*	*0.40*	*0.51*

a. See Attachment B for derivation of partition fraction

Areas 3 and 5 are the low-level waste sites, but it is not clear if the fractional values have changed over the years from 1992 to the present because of waste handling, receiving, and shipping operations.

6.4.3.1 Energy Dependence of Dosimetric Quantities

The neutron spectra at NTS have been generally unmoderated and rich in fast neutrons, so much so that doses from thermal neutrons were most certainly *trivial. However, in some operational situations, considerable scattering could have occurred, resulting in some softening of the spectra. Attachment A, Section A.5 presents more detail on neutron spectral characteristics. Figure A-10 and Table A-4 indicate that the* $H_p(10, 0°)$ *contribution from neutrons with energies less than 10 keV can be ignored for NTS dose reconstruction. The primary* $H_p(10)$ *contributions fall in the energy ranges 100 keV to 2 MeV and 2 to 20 MeV. This information is summarized by energy band for a variety of spectra in Table 6-14 and NTS operational areas in Table 6-15.*

Table 6-14. Fraction of $H_p(10,0°)$ ***by energy band for selected spectra*** **[NIOSH 2012d]**

Spectral description	*Neutron energy bands*		
	<100 keV	*100 keV–2 MeV*	*2 MeV–20 MeV*
Cf-252	*0.003*	*0.659*	*0.338*
Cf-252 with room scatter	*0.017*	*0.691*	*0.292*
Cf-252, 15 cm D_2O	*0.089*	*0.579*	*0.332*
Cf-252, D_2O *with room scatter*	*0.106*	*0.669*	*0.225*
AmBe-241	*0.001*	*0.261*	*0.738*
AmBe with room scatter	*0.010*	*0.366*	*0.624*
PuBe at 1m	*0.005*	*0.368*	*0.627*
TRU Plant, Pu Repro. Plant, heavily shielded	*0.080*	*0.734*	*0.186*
Pu-238 O_2 *at 100 cm*	*0.021*	*0.821*	*0.158*
Operation BREN HPRR[a]	*0.15*	*0.62*	*0.23*
Operation HENRE linear accelerator[b]	*N/A*	*0.05*	*0.95*
Super Kukla reactor[c]	*0.10*	*0.86*	*0.04*
Godiva spectrum	*0.008*	*0.773*	*0.219*

a. *These data are representative for the HPRR at an angle of incidence of zero. For other configurations, refer to Sims and Ragan (1987).*
b. *These data are representative for the linear accelerator at an angle of incidence of zero. For other configurations, refer to Burson (1971).*
c. *Source: Wimett (1965).*

It is not clear which data in Table 6-14 are applicable to the post-1992 environment.

*The last column of Table 6-15 lists factors to make the conversion from dose equivalent (*H *as given in NCRP Report 38; NCRP 1971) to personal dose equivalent* $H_p(10,0°)$ *for each of the four neutron energy groups for dose reconstruction at NTS (none of the neutron-producing facilities generated a significant number of neutrons above 20 MeV). If the neutron spectra are not known, dose reconstructors should treat the exposure as having come from neutrons in the 0.1- to 2-MeV range, and should use a factor of 2 to convert from NCRP (1971)-based values to* $H_p(10)$. *If the spectral characteristics of the operational neutron field are known, dose reconstructors can use Table 6-17 in Section 6.5.2 to assign neutron dose fractions to the primary energy bands – 10 to 100 keV, 100 keV to 2 MeV and 2 to 20 MeV. In the absence of such information, however, it is recommended that dose reconstructors make the assumption, which is favorable to claimants, that neutron dose is entirely due to neutrons in the 100-keV to 2-MeV energy band.*

6.4.3.2 Neutron-Photon Dose Ratios

The use of NTA film at NTS began in 1961 (REECo 1961). Before that time, an estimation of neutron doses to workers <u>*known*</u> *to have worked with neutron-emitting sources or in operations where neutrons were present (Table 6-15) could be made from the recorded photon dose, together with an appropriate neutron-photon dose ratio. The nominal neutron-photon dose ratios for isotopic neutron sources are listed in Table 6-16. These are based on literature values for sources free in air. However, these values are not appropriate for estimation of the neutron dose from recorded photon dose because the photon usually includes a large fractional contribution from other photon sources that are not accompanied by neutrons. Therefore, if the neutron exposure is associated with the use of isotopic sources, use of a neutron-photon dose ratio of 5 is recommended. These operations include neutron instrument calibration and down-hole well logging.*

***Table 6-15. Neutron field characteristics associated with NTS operational areas.[a]* [NIOSH 2012d]**

Area	Operation	Neutron sources	Neutron energy fractional distribution	
			Neutron energy (MeV)	Fraction
4	Operation BREN, 1962	Fission neutrons (HPRR[b])	<10 keV 10–100 keV 0.1–2.0 2.0–20	0.10 0.05 0.62 0.23
5	Low-level waste site (TRU waste) (1970–present)	TRU waste	0.1–2.0	1.00
6	Nuclear device assembly (1951–1992)	Fission neutrons	0.1–2.0	1.00
25	NRDS (1959–1973)	Fission neutrons and neutron sources Cf-252, PuBe, AmBe	0.1–2.0	1.00
	Operation HENRE (1966–1968)	Fission neutrons (linear accelerator[c])	0.1–2.0 2.0–20	0.05 0.95
26	PLUTO Reactor (nuclear-powered ramjet engine) (1960–1964)	Fission neutrons and neutron sources Cf-252, PuBe, AmBe	0.1–2.0	1.00
27	Nuclear explosive assembly using Special Nuclear Material (1958–1975)	Fission neutrons & neutron sources Cf-252, PuBe, AmBe	0.1–2.0	1.00
	Super Kukla (1964–1979)	Fission neutrons (Super Kukla reactor[d])	10–100 keV 0.1–2.0 2–20	0.10 0.86 0.04
Various	Down-hole well logging (1951–present)	PuBe-238 isotopic sources	0.1–2.0 2.0–20	0.50 0.50
Various	Down-hole well logging (1951–present)	Cf-252 isotopic sources	0.1–2.0 2.0–20	0.75 0.25
Various	Neutron detection instrument calibration facilities (1955– present)	PuBe-238 isotopic sources	0.1–2.0 2.0–20	0.50 0.50
Various	Neutron detection instrument calibration facilities (1955–present)	Cf-252 isotopic sources	0.1–2.0 2.0–20	0.75 0.25

a. Neutron field characteristics are applicable to certain timeframes as indicated in Table 6-9.
b. These data are representative for the HPRR at an angle of incidence of zero. For other configurations, refer to Sims and Ragan (1987).
c. These data are representative for the linear accelerator at an angle of incidence of zero. For other configurations, refer to Burson (1971).
d. Source: Wimett (1965).

Only the data on the Area 5 line of the above table pertain to waste storage, but it is not clear which of all the data presented pertain to the post-1992 period. Well logging and neutron detection instrument calibration facilities information are also pertinent post 1992.

> *Of the other neutron-related operations listed in Table 6-15, only the nuclear device assembly in Area 6 and nuclear explosive assembly using Special Nuclear*

Material were carried out before the introduction of personal dosimetry in 1961 (Allen and Schoengold 1995). Specific information on the neutron-photon dose equivalent ratios is not readily available for these operations at NTS. However, similar operations were carried out at the Pantex Plant. Based on analysis of dosimetry records at Pantex, as well as at the Hanford and Savannah River Sites, where similar materials were handled, this resulted in a recommendation in ORAUT-TKBS-0013-6, Pantex Plant – Occupational External Dose ([NIOSH] *2007) that a neutron-photon dose equivalent ratio of 1.7 be adopted for Pantex workers.*

Table 6-16. Neutron-photon Dose Ratios for Isotopic Sources **[NIOSH 2012d]**

Neutron Sources	*Neutron-photon dose equivalent rate ratio*
Bare Cf-252[a]	*20*
Cf-252 moderated by 15 cm D_2O[a]	*5.6*
PuBe-238	*29*[b]
AmBe-241	*>5*[c]

a. Used for neutron dosimeter calibration starting in the early 1980s.
b. Mayer, Otto, and Golnik (2004).
c. ISO (2001).

<u>NIOSH Comment in Issues Matrix</u>:

Guidance related to the issuance of extremity badges and dose limits for the extremities is found in the Radiation Control Manual [sic] (DOE/NV/25946-801), dated October 2009 [DOE 2009]. *Specifically the following:*

512 Technical Requirements for External Dosimetry

1. *The RSPC* [Radiological Safety Prime Contractor] *shall maintain an external monitoring program that is adequate to demonstrate compliance with Subpart C of 10 CFR 835 and that is accredited in accordance with DOELAP* [DOE Laboratory Accreditation Program].

2. *The Technical Basis document should address dosimeters monitoring radiation outside the scope of DOELAP, such as dosimetry associated with high-energy accelerators and extremity dosimeters. The External Dosimetry Technical Basis Document shall be maintained by the RSPC.*

3. *Multiple dosimeters should be issued to individuals to assess effective dose in non-uniform radiation fields. Non-uniform radiation fields exist when the dose to a portion of the whole body will exceed the dose to the primary dosimeter by more than 50 percent and the anticipated whole body dose is greater than 100 mrem. When the radiation field is well characterized and the worker's orientation is known, relocation of the primary dosimeter is permitted in lieu of issuance of multiple dosimeters. Under such*

conditions, the individual's dosimeter should be relocated to the portion of the whole body likely to receive the highest dose. Dosimeter relocation should be conducted in conformance with facility procedures or specific work authorizations, such as RWPs [Radiation Work Permits]. *The RSPC program documentation should describe the methodology used in determining the dose of record when multiple dosimeters are used.*

4. *Extremity dosimetry should be used for work in a radiation field where the beta-plus-gamma dose rate in contact with the source of radiation is 10 times greater than the beta-plus-gamma dose rate at 30 cm from the source and the contact exposure rate is ≥ 50 mR/hr.*

5. *A dose assessment shall be performed for each instance of a lost, damaged, or contaminated personnel dosimeter, if required.*

213 Radiological Worker Dose Limits

1. *Except for emergency exposures authorized according to 10 CFR 835.1302, the occupational dose received by general employees shall be controlled such that the following limits are not exceeded in a year:*

    a. *A TED of 5 rem (0.05 Sv)*

    b. *The sum of the equivalent dose to the whole body for external exposures and the committed equivalent dose to any organ or tissue other than the skin or the lens of the eye of 50 rem (0.5 Sv)*

    c. *An equivalent dose to the lens of the eye of 15 rem (0.15 Sv)*

    d. *The sum of the equivalent dose to the skin or to any extremity for external exposures and the committed equivalent dose to the skin or to any extremity of 50 rem (0.5 Sv)*

347 Controls for Bench-Top Work, Laboratory Fume Hoods, Sample Stations, and Glove Boxes

3. *The following controls apply to glove-box operations:*

    a. *Glove boxes should be inspected for integrity and operability before use.*

    b. *Glove boxes should be posted to identify whole-body and extremity dose rates.*

511 Requirements

1. *Individual dosimetry shall be required for the following:*

a. *Radiological workers who under typical conditions are likely to receive from external sources an effective dose of 100 mrem or more in a year, an equivalent dose to the skin or to any extremity of 5 rem or more in a year, or an equivalent dose to the lens of the eye of 1.5 rem or more in a year or greater than 10 percent of the corresponding limits specified in Table 2-1*

SC&A Evaluation and Comments: SC&A has reviewed the *Nevada Test Site Radiological Control Manual* (DOE 2009) and concurs with NIOSH's characterization of its applicability and contents.

SC&A Observation 1: NIOSH presents data in several tables discussed above, but SC&A frequently does not find it evident whether the data and accompanying discussions are applicable to the post-1992 period or whether they might have changed with time in that period; e.g., radioactive waste-related data likely changed over time as waste was brought into the waste storage areas, stored, and some of it later shipped off site.

3.0 SC&A ASSESSMENT AND OBSERVATIONS

This section examines the completeness of NIOSH's efforts to provide (or reference) available information characterizing radioactive waste handling operations and practices useful to calculating radiation exposures to personnel post-1992 after nuclear weapons testing ceased. Section 3.1 describes additional information identified by SC&A, and Section 3.2 presents SC&A's observations about some perceived shortcomings of the available information, ambiguities in applicable dosimetry practices, and recommendations for material to include in the next revision of the site profile.

3.1 ADDITIONAL INFORMATION IDENTIFIED BY SC&A

This section presents available information identified and reviewed by SC&A on radioactive waste handling operations and practices post-1992 in addition to that enumerated and referenced by NIOSH in the last column of the issues resolution matrix (SC&A 2017) and excerpted in Section 2.0. SC&A did not conduct an exhaustive search of all sources of information that might reside in the Site Research Database (SRDB) or in external databases or locations. The combination of the material in these two sections of this report gives a good overview of the data and methods available and applicable to post-1992 operations. In many cases, this additional information provides a fuller picture than given by NIOSH in the issues resolution matrix or the site profile.

Current aerial photos of the Areas 3 and 5 Radioactive Waste Management Complexes appear in Figures 1 and 2.

Figure 1. Area 3 Radioactive Waste Management Complex (reproduced from DOE 2016)

Figure 2. Area 5 Radioactive Waste Management Complex (reproduced from DOE 2016)

3.1.1 Site Profile

<u>Introduction TBD</u>

ORAUT-TKBS-0008-1, Revision 00 PC-1, *Technical Basis for the Nevada Test Site – Introduction* (NIOSH 2006, also "TBD-1"), briefly summarizes how NTS manages radioactive waste; fuller descriptions appear elsewhere in the site profile. Section 1.2, "Site Description," of TBD-1 states:

> *The NTS manages radioactive waste. DOE disposes of bulk low-level waste in seven selected Area 3 subsidence craters that collectively comprise the Area 3 Radioactive Waste Management Site. The activity began in the mid-1960s when DOE began removing scrap tower steel, vehicles, and other large objects that been subjected to atmospheric testing. From 1979 to 1990, large amounts of contaminated soil and other NTS debris were added to the craters. The Area 5 waste management site uses pits and trenches for shallow land burial of low-level waste in standardized packaging.*
>
> *In addition, DOE adopted greater confinement burial (21 to 40 m [70 to 120 ft] deep) for wastes that are not appropriate for near-surface disposal due to their*

> *radioactive exposure levels. Material was disposed from 1984 to 1989. The specific waste types included certain high-specific-activity, low-level waste (for example, fuel rod claddings and sealed sources, transuranic waste, and some classified material).*

<u>Site Description TBD</u>

ORAUT-TKBS-0008-2, Revision 01 PC-1, *Nevada Test Site – Site Description* (NIOSH 2008), contains the following additional material relevant to waste handling operations and practices. Section 2.2.6, "Area 6 Nuclear Test Zone," of TBD-2 states:

> *The elements of the Yucca Lake facilities include a variety of equipment storage facilities, a heavy-duty maintenance and equipment repair facility, and decontamination (decon) facilities. Facilities for laundering radiologically contaminated clothing were operated here. At the Decon Facility, large pieces of equipment were decontaminated. Contaminated liquid waste from decontamination operations was discharged through floor drains to large tanks. The yard below these facilities could be contaminated. Contaminated radioactive waste was also stored in a tent structure adjacent to the Decon Facility. A 3,353-m (11,000-ft) airstrip and nearby weather station are on the dry Yucca Lake bed.*

SC&A Observation 2: The penultimate sentence of the above quotation from Section 2.2.6 of the TBD-2 asserts that "*Contaminated radioactive waste was also stored in a tent structure adjacent to the* [Area 6] *Decon Facility*." SC&A did not find mention in the site profile or elsewhere of the disposition of this waste or the status of this tent. If it remained in place, then it represents a post-1992 radioactive waste storage area in addition to Areas 3 and 5. NIOSH should clarify.

Section 2.2.25, "Area 25 Yucca Mountain Project, Reserved, and Research and Experiment Zones," of TBD-2 states:

> *In the early 1960s, the AEC and the National Aeronautics and Space Administration (NASA) negotiated an interagency agreement to establish and manage a test area at the NTS called the Nuclear Rocket Development Station (NRDS). It consists of three widely separated reactor test cells or stands, two Maintenance, Assembly, and Disassembly (MAD) facility buildings, a CP complex, an Administrative Area complex, and a radioactive materials storage area. A standard-gauge railroad system connects the test stands and the MAD buildings. The railroad transported nuclear reactors and engine systems back and forth from the rocket and engine assembly buildings to the test cells and engine test stand. The NRDS operated two shallow-land burial radioactive waste disposal units. An equipment decontamination facility was operated near the MAD facility. Attachment B contains additional information about the NRDS.*

SC&A Observation 3: Section 2.2.25 of TBD-2 states that "*The NRDS operated two shallow-land burial radioactive waste disposal units* [in Area 25]." SC&A was not able to verify whether these waste disposal units remained in place after 1992, or, if not, what became of their waste. If they remained in place post-1992, then these waste disposal units represent a post-1992 radioactive waste storage area in addition to Areas 3 and 5. NIOSH should clarify.

Occupational Environmental Dose TBD

ORAUT-TKBS-0008-4, Revision 03, Nevada Test Site – Occupational Environmental Dose (NIOSH 2012c; also "TBD-4"), contains additional information related to waste handling and storage.

> ***Section 4.2.1.1.7 Radioactive Waste Management Sites***
>
> *Areas 3 and 5 contain sites for the disposal of low-level radioactive waste, and Area 5 contains sites for storage of transuranic and mixed transuranic wastes, as well as the Greater Confinement Disposal Test Unit and 12 accompanying boreholes (only a few contain waste). Disposal occurs in pits and trenches; concrete pads provide temporary storage of certain wastes. Area 5 is for packaged waste disposal only. The Waste Examination Facility houses a glovebox with high-efficiency particulate air filtration that is used to examine and repack transuranic (TRU) waste drums. No contamination has been released from glovebox operations to the environment. The drums, which have been sent to NTS from Lawrence Livermore National Laboratory (LLNL) in past years, are stored in the TRU Pad Cover Building. Repacked drums will be sent to the Waste Isolation Pilot Plant. The facility is a diffuse source of radiological effluents. The only radioactive effluent that has been detected by the various samplers around the site is HTO in atmospheric moisture. The Area 3 low-level waste site is in a location where surface soil has been contaminated by deposited plutonium, and resuspension of this soil by wind and vehicular activity has resulted in detection of above-background levels of plutonium in nearby air samples.*

SC&A Observation 4: Section 4.2.1.1.7 of TBD-4 states that "*The drums* [containing TRU], *which have been sent to NTS from Lawrence Livermore National Laboratory (LLNL) in past years, are stored in the TRU Pad Cover Building. Repacked drums will be sent to the Waste Isolation Pilot Plant*." SC&A was not able to determine the disposition of those drums: whether they remained on site post-1992 or whether some or all of them have been sent to the WIPP and how they were handled. NIOSH should clarify.

Tables 4-1 through 4-6 of TBD-4 provide environmental radioactivity information for different areas throughout the NTS site, including Areas 3 and 5; the contents of those tables are summarized below:

- Table 4-1: HTO atmospheric concentrations by year and area with estimated maximum and average annual organ dose through 2001
- Table 4-2: Atmospheric concentrations of ^{239}Pu for sampled areas (pCi/m^3) through 2001

- Table 4-3: Annual inhalation intakes from ^{239}Pu for sampled areas (Bq) through 2001
- Table 4-4: Inventory of contaminated soil (Ci) (1991)
- Table 4-5: Radionuclide areal soil deposition decay, corrected to 1963 (Bq/m^2)
- Table 4-6: Abundance of radionuclides in NTS soils in relation to ^{239}Pu decay, corrected to 1963

Occupational Internal Dose TBD

Several sections in ORAUT-TKBS-0008-5, Revision 03, Nevada Test Site – Occupational Internal Dose (NIOSH 2012b; also "TBD-5"), contain information relevant to post-1992 waste handling and storage operations. Attachment A in particular presents information about "occupational internal dose for monitored workers":

> ***A.3.1.8 Low-Level Waste Site (Area 3)***
>
> *Table A-16 lists radionuclides for identification of a problem and dose concern. In addition to these radionuclides, BN (2000) lists ^{235}U as a radionuclide of concern for this facility. Routine bioassay was to collect quarterly urine samples and conduct annual whole-body counts. Urine samples were gamma analyzed for GFP* [gross fission product]*, plutonium, and americium.*

Table A-16. Low-level waste site (Area 3), isotopes for identification and of concern for dose. **[NIOSH 2012b]**

Mn-54	***Ru-103***	***Ce-144***	***U-233***	***Pu-240***
Co-60	*Ru-106*	*Ac-227*	*U-234*	*Pu-241*
Sr-85	*Cs-134*	*Th-228*	*U-238*	*Pu-242*
Sr-90	*Cs-137*	*Th-230*	*Pu-238*	*Am-241*
Zr-95	*Ba-140*	*Th-232*	*Pu-239*	*Am-243*
Nb-95	*Ce-141*			

> ***A.3.1.9 Low-Level Waste Site (Area 5)***
>
> *Table A-17 lists radionuclides for identification of a problem and dose concern. Routine bioassay was to collect quarterly urine samples and conduct annual WBCs. Urine samples were analyzed for gamma emitters, sampled for ^{3}H, and analyzed for GFPs, plutonium, and americium.*

Table A-17. Low-level waste site (Area-5), isotopes for identification and of concern for dose. [NIOSH 2012b]

H-3	*Mo-99*	*Ce-141*	*AC-227*	*U-238*
Na-22	*Ru-103*	*Ce-144*	*Th-228*	*Pu-238*
Mn-54	*Ru-106*	*Eu-152*	*Th-230*	*Pu-239*
Co-57	*Sb-124*	*Eu-154*	*Th-232*	*Pu-240*
Co-60	*Sb-125*	*Eu-155*	*U-233*	*Pu-241*
Sr-85	*Ba-133*	*Yb-169*	*U-234*	*Am-241*
Sr-90	*Cs-134*	*Ta-182*	*U-235*	*Pu-242*
Zr-95	*Cs-137*	*Ir-192*	*Np-237*	*Am-243*
Nb-95	*Ba-140*	*Ra-226*		

…

A.3.1.17 Other Facilities Identified After 1992 (the End of Testing)

McMahan and Ogurek (2003) included some facilities and radionuclides of concern that Allen et al. (1993) did not describe. The following paragraphs discuss these newer facilities and Site Monitoring Services (SMS)/Radioactive Material Control (RAMATROL):…

- *Waste Examination Facility (Area 5) – The WEF processes TRU waste drums in preparation for shipment to the Waste Isolation Pilot Plant. The drums are primarily from LLNL, but a small number are from LANL and Rocky Flats. The TRU waste is in 55-gal drums and processed in a glovebox. There is a storage area for the drums called the TRU Pad. The potential for internal exposure can come from a failure of glovebox integrity. Nuclides of concern at WEF are ^{233}U, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Am, ^{243}Am, ^{244}Cm, and ^{252}Cf. Plutonium radionuclides and ^{241}Am have been identified as the predominant nuclides of concern.*

Table A-22, "Current nuclides of concern for NTS locations," lists the following nuclides for Low-Level Waste Sites, Areas 3 and 5:

- Waste Site Area 3: Sr-90, Cs-137, Th-232, Pu-239, Am-241, U-234, U-235, and U-238

- Waste Site Area 5: H-3, Sr-90, Cs-137, Th-232, U-234, U-235, U-238, Pu-239, Am-241, Ra-226, and Pu-238

Note: The TBD-5 Table A-22 entries for Waste Site Area 5 are somewhat garbled (i.e., there are repeated entries for some radionuclides), which should be rectified in the next revision of the TBD.

SC&A Observation 5: Tables presenting radioactive isotopes of concern for internal dose in TBD-5 (NIOSH 2012b) appear inconsistent. Table A-16 lists 27 isotopes for RWMS Area 3, while Table A-22 lists 8 isotopes. Table A-17 lists 42 isotopes for RWMS Area 5, while Table A-22 lists 11 isotopes.

Occupational External Dose TBD

Additional information relevant to radioactive waste, beyond that NIOSH cited in its site profile issue resolution matrix response to Issue 26, is found in Table B-1 of TBD-6, which presents photon fractions by energy group for different NTS areas, including the two waste sites:

Table B-1. Work Area and operation-dependent photon fractions. **[NIOSH 2012b]**

Operation	*Areas*	*Photon fraction*			*Adjusted photon fraction*[a]		
		<30 keV	*30–250 keV*	*>250 keV*	*<30 keV*	*30–250 keV*	*>250 keV*
Drillback operations	*1–10 and 18–20*	*0.06*	*0.36*	*0.58*	*0.03*	*0.50*	*0.47*
Reentry and mineback operations	*1, 12, 15, and 16*	*0.08*	*0.22*	*0.70*	*0.04*	*0.38*	*0.58*
Routine tunnel operations	*1, 12, 15, and 16*	*0.00*	*0.03*	*0.97*	*0.00*	*0.22*	*0.78*
Decontamination facility	*6*	*0.24*	*0.28*	*0.48*	*0.14*	*0.43*	*0.44*
Treatability test facility	*25*	*0.22*	*0.32*	*0.47*	*0.12*	*0.46*	*0.42*
Atmospheric safety test areas	*5 and 11*	*None indicated*			*None indicated*		
Atmospheric weapons test areas	*1–5, 7–11, and 18*	*0.18*	*0.31*	*0.51*	*0.10*	*0.45*	*0.45*
Low-level waste site	*3*	*0.47*	*0.25*	*0.28*	*0.31*	*0.40*	*0.29*
Low-level waste site	*5*	*0.34*	*0.31*	*0.36*	*0.20*	*0.45*	*0.34*
Radiation instrument calibration	*6 and 23*	*0.54*	*0.25*	*0.22*	*0.36*	*0.40*	*0.24*
Radiograph operations	*23*	*0.01*	*0.04*	*0.96*	*0.00*	*0.23*	*0.76*
Well logging operations	*1–10 and 18–20*	*0.49*	*0.23*	*0.29*	*0.32*	*0.38*	*0.30*
Nuclear explosive/device assembly	*6 and 27*	*0.73*	*0.27*	*0.00*	*0.57*	*0.43*	*0.00*
Nuclear rocket development	*25 and 26*	*0.04*	*0.29*	*0.67*	*0.02*	*0.43*	*0.55*
Radioactive source storage	*6 and 23*	*0.40*	*0.25*	*0.32*	*0.26*	*0.41*	*0.33*
Radiochemistry and counting laboratories	*6 and 23*	*0.16*	*0.25*	*0.59*	*0.09*	*0.40*	*0.51*

a. Adjustment factors:
<30-keV contribution = 50% of relative photon contribution to account for attenuation of low-energy photons.
30 to 250 KeV = photon contribution in that energy range +20% of >250-keV contribution to account for scatter of high-energy photon contribution to account for loss due to scatter.

3.1.2 DOE NESHAPS 2001

DOE's National Emission Standards for Hazardous Air Pollutants (NESHAPS) NTS report for 2001 (DOE 2002b), which is a post-1992 report, has several sections that discuss the low-level waste storage areas. Although the report focuses on emissions, it also provides some additional information about the two RWMSs. The following quotation from the report indicates that the Area 5 RWMS is a potential source of offsite radiation exposure. While SC&A recognizes that offsite exposures are not of concern for EEOICPA, the same sources could be expected to result in onsite exposures as well. Therefore, descriptions and information are included in this report.

> *Processing of radioactive materials is limited to laboratory analyses, and handling is restricted to transport, storage, and assembly of nuclear explosive devices and operation of radioactive waste management sites (RWMSs) for low-level radioactive and mixed waste (DOE* [1996]*). Monitoring and evaluation of the various activities conducted onsite indicate that the potential sources of offsite radiation exposure in CY* [calendar year] *2001 were releases from (1) evaporation*

> *of tritiated water (HTO) from containment ponds that receive drainage water from E Tunnel in Area 12 and from discharges of two wells (Well U-3cn PS#2 and Well ER-20-5 #3) into lined ponds, (2) onsite radioanalytical laboratories, (3) the Area 5 RWMS (RWMS-5) facility, and (4) diffuse sources of tritium and re-suspension of plutonium and americium.* [DOE 2002b, p. 1]

A later section in the DOE report discusses the types of waste stored in the two radioactive waste management sites.

> *The RWMSs in Area 3 (RWMS-3) and in Area 5 (RWMS-5) are used for the disposal of low-level radioactive waste (LLW). The RWMS-5 is also used for accumulation of mixed waste and storage of transuranic (TRU) and mixed TRU wastes. Disposal is accomplished by the use of pits and trenches. Concrete pads are used for temporary storage of certain wastes. At RWMS-5, only packaged, dry wastes are accepted for disposal. The facility is considered a diffuse source of radiological effluents. The only radioactive emission detected by the various types of samplers surrounding the site and attributed to site operations was HTO in atmospheric moisture. The calculation of the HTO source term for these emissions is explained in Appendix D. Since the RWMS-3 LLW site is in a location where the surrounding surface soil has been contaminated by past nuclear tests, the re-suspension of this soil by wind or vehicular activity results in above background levels of plutonium being detected in air samples collected inside and outside the perimeter fence.* [DOE 2002b, pp. 2–3]

The report section on the Federal Facilities Agreement and Consent Order between the NTS and the State of Nevada provides radionuclide inventories of wastes sent to RWMS Area 3 from two nuclear tests. The report states:

> *The clean up of DOUBLE TRACKS (DOE 1997a) and CLEAN SLATE I (DOE 1997b) areas resulted in the removal of 5.12 Ci and 5.65 Ci of $^{239+240}$Pu, respectively, based upon radiation measurements of the soil as it was bagged for transporting to burial in the RWMS-3. The amounts removed are within the 95 percent confidence interval of the 1.7 to 6.0 Ci estimated for each of these two locations.* [DOE 2002b, p. 3]

3.1.3 2005 NTS Waste Management Monitoring Report

DOE's National Security Administration issues annual waste management monitoring reports for NTS. The 2005 report (DOE 2006), for example, which is a post-1992 report, details the status of the waste storage areas within RWMS Area 3 and RWMS Area 5.

> ***Area 3 RWMS***
>
> *Waste disposal cells within the Area 3 RWMS are subsidence craters resulting from underground nuclear testing. The seven craters within the Area 3 RWMS ranged from 122 to 177 m (400 to 580 ft) in diameter and from 14 to 32 m (46 to 105 ft) in depth at the time of formation (Plannerer, 1996). Disposal in the U-3ax*

> *crater began in the late 1960s. Disposal began in U-3bl in 1984. Waste forms consisted primarily of contaminated soil and scrap metal, with some construction debris, equipment, and containerized waste. Craters U-3ax and U-3bl were combined to form the U-3ax/bl disposal unit (Corrective Action Unit [CAU] 110), which is now covered with a vegetated, native alluvium closure cover that is at least 2.4 m (8 ft) thick. For details of the final closure plan of CAU 110, refer to BN (2001a). Disposal in the combined unit U-3ah/at began in 1988. Disposal cell U-3ah/at has been used for disposal of bulk LLW from the NTS and approved off-site generators. Crater U-3bh was originally used for disposal of contaminated soils from the Tonopah Test Range in 1997 and has been used for waste disposal from other approved generators. The remaining two craters are not in use (Figure 3). For a detailed description of the facilities at the Area 3 RWMS, refer to Shott et al. (1997).*
>
> ***Area 5 RWMS***
>
> *Waste disposal has occurred at the Area 5 RWMS since the early 1960s. The Area 5 RWMS consists of 32 landfill cells (pits and trenches) and 13 greater confinement disposal (GCD) boreholes (Figure 4). Some previous documents list fewer landfill cells, but new cells continue to be constructed and Trench 4 was separated into T04C and T04C-1 (BN, 2005). Pits and trenches range in depth from 4.6 to 15 m (15 to 48 ft). The unlined disposal units receive sealed waste containers. Containers are stacked to approximately 1.2 m (4 ft) below original grade and soil backfill is pushed over the containers in a single layer to approximately 2.4 m (8 ft) thick. For a detailed description of the facilities at the Area 5 RWMS, refer to Shott et al. (1998). For further descriptions of pits, trenches, and GCD boreholes, refer to BN (2005) and Cochran et al. (2001).*
>
> *There are currently eight pits receiving waste at the Area 5 RWMS. The open pits include P03U, P06U, P09U, P12C, P13U, P14U, P15U, and P16C. Construction of P16C was completed and P03U was graded in 2005. The only active mixed waste disposal cell is P03U. All other active units contain LLW except P06U, which contains asbestiform LLW. Landfill cells that have been closed to date include all 16 trenches and eight pits. The eight closed pits are P01U, P02U, P04U, P05U, P07U, P08U, P10C, and P11U.* [p. 5]

SC&A Observation 6: The DOE 2005 waste management monitoring report states: "*The Area 5 RWMS consists of 32 landfill cells (pits and trenches) and 13 greater confinement disposal (GCD) boreholes (Figure 4). Some previous documents list fewer landfill cells, but new cells continue to be constructed*." This points up the inconsistency in several places in the site profile about how many landfill cells existed and their characteristics during various time periods, in particular the post-1992 period, as they apparently changed over time.

3.1.4 NTS Environmental Report – 2015

DOE's National Security Administration issues annual environmental reports for NTS (now called the Nevada National Security Site (NNSS)), which are concerned with ensuring that potential radiation exposures to the public do not exceed regulatory limits. The latest is the 2015 report (DOE 2016), which includes current information on RWMS Area 3 and RWMS Area 5. The following excerpts are relevant to this report.

Area 3 (p. 6-9):

> *Between 1952 and 1972, 60 nuclear weapons tests were conducted in Yucca Flat within 400 m (1,312 ft) of the current Area 3 RWMS boundary. Fourteen of these tests were atmospheric tests that left radionuclide-contaminated surface soil and, therefore, elevated radiation exposures across the area. Waste pits in the Area 3 RWMS are subsidence craters from seven subsurface tests, which have been filled with LLW and then covered with clean soil. As a result, exposures inside the Area 3 RWMS are low when compared with those at or outside the fence line.*
>
> *Annual exposures measured inside the Area 3 RWMS and three of four locations at the boundary were within the range of NNSS background exposures in 2015 (Figure 6-4). The boundary location A3 RWMS South has an estimated exposure above the range of NNSS background; it is 160m (525 ft) from the site of two atmospheric nuclear weapons tests. The three E2 TLD locations outside the RWMS that are also above the range of NNSS background (Figure 6-4* [not copied here]*) are a similar distance from the same atmospheric tests, but on the other side, farther from the RWMS boundary. Based on these measurements, it does not appear that waste buried at the Area 3 RWMS would have contributed external exposure to a hypothetical person residing at its boundary during 2015.*

Area 5 (p. 6-10):

> *The Area 5 RWMS is located in the northern portion of Frenchman Flat. Between 1951 and 1971, 25 nuclear weapons tests were conducted within 6.3 kilometers (km) (3.9 mi) of the Area 5 RWMS. Fifteen of these were atmospheric tests and, of the remaining ten, nine released radioactivity to the surface, which contributes to exposures in the area. No nuclear weapons testing occurred within the boundaries of the Area 5 RWMS.*
>
> *During 2015, estimated annual exposures at Area 5 RWMS TLD locations were within the range of exposures measured at NNSS background locations (Figure 6-5* [not copied here]*). The one location outside the Area 5 RWMS that has an estimated exposure above background levels (the Frenchman Lake TLD station) is within 0.5 km (0.3 mi) of six atmospheric tests in the Frenchman Lake Playa.*

The measurements support the following conclusion (p. 6-10):

> *Based on these results, the potential external dose to a member of the public from operations at the Area 3 and Area 5 RWMSs does not exceed the 25 mrem/yr (0.25 mSv/yr) dose limit to members of the public, specified in DOE M 435.1-1*

> [DOE 2001]. *See Section 9.1.2 of this report for a summary of the potential dose to the public from the RWMSs from all exposure pathways.*

Chapter 10, on waste management, is a particularly rich source of information to supplement what currently appears in the NTS site profile; a portion will be excerpted here. The chapter articulates waste management goals, some of which follow:

> *Manage and safely dispose of* ***low-level waste (LLW)****,* ***mixed low-level waste (MLLW)****…, and non-radioactive classified waste/matter, which are generated by NNSA/NFO, other U.S. Department of Energy (DOE) approved generators, or selected U.S. Department of Defense (DoD) operations.*
>
> *Manage and safely store* ***transuranic (TRU)****…and mixed transuranic (MTRU) wastes generated on site for eventual shipment to the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.*
>
> *Manage, safely store, and ship hazardous wastes generated on the NNSS to approved offsite treatment/storage/disposal facilities, and treat by open detonation explosive ordnance wastes generated on the NNSS.*
>
> *Ensure that wastes received for disposal meet NNSS waste acceptance criteria.*
>
> *Evaluate, design, construct, maintain, and monitor closure covers for radioactive waste disposal units at the Area 3 and Area 5 Radioactive Waste Management Sites (RWMSs).*
>
> *Manage radiation doses from the Area 3 RWMS and the Area 5 Radioactive Waste Management Complex (RWMC) to the levels specified in DOE Manual DOE M 435.1-1, "Radioactive Waste Management Manual."* [DOE 2001]

The NNSS Radioactive Waste Management facilities include the Areas 3 and 5 RWMCs, the WEF, and the Hazardous Waste Storage Unit.

Area 3 RWMC

The description of the Area 3 RWMC states that the site was placed in inactive status on July 1, 2006 (DOE 2016, p. 10-3):

> *Disposal operations at the Area 3 RWMS…began in the late 1960s. The Area 3 RWMS consists of seven subsidence craters configured into five disposal cells. Each subsidence crater was created by an underground weapons test. Until July 1, 2006, when the site was placed into inactive status, the site was used for disposal of bulk LLW, such as soils or debris, and waste in large cargo containers. The site consists of the following seven craters:*

2 Disposal Cells (Inactive Status):	*1 Closed Cell:*	*2 Undeveloped Cells:*
U-3ah/at	*U-3ax/bl*	*U-3az*
U-3bh	*(Corrective Action Unit 110)*	*U-3bg*

<u>Area 5 RWMS</u>

The following description (DOE 2016, pp. 10-1, 10-3) of Area 5 RWMS shows that a portion of it (the "92-Acre Area") was closed and filled in 2011, while other portions remain open and are receiving, storing, and shipping waste.

> *The Area 5 RWMS is a DOE-owned radioactive waste disposal facility. It encompasses approximately 740 acres (ac), including 200 ac of historical and active disposal cells used for burial of LLW, MLLW, Non-Radiological Classified (NRC) waste, and Non-Radiological Classified Hazardous (NRCH) waste, and 540 ac of land available for future radioactive disposal cells. Waste disposal at the Area 5 RWMS occurred in a 92-ac portion of the site starting in the early 1960s. This "92-Acre Area" (Figure 10-1* [not copied here]*) consists of 31 disposal cells and 13 Greater Confinement Disposal (GCD) boreholes and was used for disposal of waste in drums, soft-sided containers, large cargo containers, and boxes. The 92-Acre Area was filled and permanently closed in 2011. Closure covers for the 92-Acre Area were seeded in the fall of 2011 and continue to be monitored and reseeded as necessary to aid the establishment of a successful vegetative cover (see Section 15.4). Seven cells, developed immediately north and west of the 92-Acre Area, have been receiving wastes since 2010. They include six LLW cells (Cells 19, 20, 21, 22, 27, and 28) and a MLLW cell (Cell 18). All active Area 5 RWMS cells can accept radioactive waste contaminated with non-regulated polychlorinated biphenyl (PCB) bulk product waste, but only Cell 18 can accept waste contaminated with regulated PCB remediation waste as well as asbestos-contaminated MLLW. Cells 18, 19, 20, 21, 22, 27, and 28 can accept asbestos-contaminated LLW. All disposal cells that were active in 2015 are shown in Table 10-1. MLLW disposal services are expected to continue at the Area 5 RWMS until the remaining needs of the DOE complex are met.*
>
> *Disposal Cell 18 is operated under a Resource Conservation and Recovery Act (RCRA) Part B Permit (NEV HW0101), which authorizes the disposal of up to 25,485 cubic meters (m^3) (899,994 cubic feet [ft^3]) of MLLW and NRCH. The volume and weight of wastes that Cell 18 received in 2015 are shown in Table 10-1. A cumulative total of 11,413 m^3 (403,022 ft^3) of MLLW/NRCH has been disposed in Cell 18 through the end of 2015. Quarterly reports were submitted to the State of Nevada in 2015 to document the weight in tons of MLLW/NRCH disposed each quarter in Cell 18. In 2015, the Area 5 RWMS received shipments containing a total of 37,780 m^3 (1,334,186 ft^3) of radioactive waste for disposal (Table 10-1), which included both NRC and NRCH waste. The majority of waste disposed was received from offsite generators. The total number of waste shipments during fiscal year (FY) 2015…were reported in an annual transportation report (NSTec* [2016]*). In 2015, all offsite waste generators delivering MLLW for disposal in Cell 18 that contained regulated quantities of PCBs were issued Certificates of Disposal, as required under the Toxic Substances Control Act.*

***Table 10-1. Total waste volumes received and disposed at the Area 5 RWMS in calendar year 2015* [DOE 2016]**

Waste Type	*Disposal Cell(s)*	*Volume Received and Disposed in m^3 (ft^3)*
LLW and NRC	*Cells 19, 20, 21, 22, 27, and 28*	*35,062 (1,238,210)*
MLLW and NRCH (includes regulated PCB-contaminated LLW)	*Cell 18*	*2,718 (95,975); 1,379 tons[(a)]*
	Total	*37,780 (1,334,186)*

(a) Fees paid to the state for hazardous waste generated at the NNSS and MLLW wastes received for disposal are based on weight

Waste Examination Facility

Radioactive waste is also handled at the WEF.

> *The operational units of the WEF include the TRU Pad, TRU Pad Cover Building (TPCB), TRU Loading Operations Area, WEF Yard, WEF Drum Holding Pad, Sprung Instant Structure, and the Visual Examination and Repackaging Building. The WEF was used for the staging, characterization, repackaging, and offsite shipment of legacy TRU wastes that had been stored for many years at the NNSS. This activity was completed in 2009.*
>
> *Currently, The TRU Pad and TPCB are authorized for the safe storage of radioactive mixed waste under the current RCRA Permit (NEV HW0101). The TPCB accepts TRU/MTRU waste from NNSS generators including the Joint Actinide Shock Physics Experimental Research (JASPER) facility. The TPCB stores the waste until it is characterized for disposal at the WIPP in Carlsbad, New Mexico. In 2015, the TRU waste remaining in storage at the TPCB consisted of two experimental spheres from Lawrence Livermore National Laboratory and 29 standard waste boxes from JASPER.* [DOE 2016, p. 10-3]

The 2015 annual environmental report states: "*All generators of waste streams must demonstrate eligibility for waste to be disposed at the NNSS, submit profiles characterizing specific waste streams, meet the NNSS Waste Acceptance Criteria, and receive programmatic approval from NNSA/NFO for their site waste certification programs*" (DOE 2016, p. 10-4). Following receipt of waste, characterizations are verified before acceptance:

> *Waste verification is an inspection process that confirms the waste stream data supplied by approved waste generators before MLLW or non-radioactive classified hazardous waste is accepted for disposal at the NNSS. Verification may involve visual inspection, Real-Time Radiography (RTR), and/or chemical screening on a designated percentage of MLLW or non-radioactive classified hazardous matter. The objectives of waste verification include verifying that hazardous waste treatment objectives are met, confirming that waste containers do not contain free liquids, and ensuring that waste containers are at least 90% full, per RCRA and State of Nevada requirements. Offsite-generated waste is verified either when the waste is received at the NNSS or when it is still at a*

generator facility or a designated treatment, storage, or disposal facility. The first choice for the method of verification is visual inspection at the site of generation.

In 2015, offsite visual inspections were completed on 66 MLLW packages from 15 separate waste streams, on one radioactive classified hazardous matter package from one matter stream, and on three non-radioactive classified hazardous matter packages from two separate matter streams. No RTR or chemical screening was required in 2015. No onsite visual inspection was conducted in 2015. No MLLW or non-radioactive classified hazardous matter packages were rejected during 2015. [DOE 2016, p. 10-5]

SC&A Observation 7: The annual DOE environmental reports (the latest is DOE 2016) provide information on the post-1992 status of the RWMSs and radioactive waste handling at NTS. This includes material on the activities conducted in various areas and facilities. SC&A recommends that NIOSH supplement material in the TBDs with that information, as well with information drawn from other post-1992 reports.

3.2 ADDITIONAL SC&A OBSERVATIONS AND COMMENTS

SC&A finds that, although NIOSH is generally responsive to the WG concerns in its comments added to the last column of the site profile issues resolution matrix (SC&A 2017) about waste storage and handling practices and operations, there is a dearth of information provided about, or identified as specifically applicable to, post-1992 conditions. It is not clear to SC&A what has occurred post-1992 up to the present; for example, what waste types and what quantities have been brought in and what have been shipped out. An exception is Section A.3.1.17, "Other Facilities Identified After 1992 (the End of Testing)," of Appendix A to TBD-5 (NIOSH 2012b), which discusses the WEF of Area 5.

SC&A Observation 8: This report has pointed to several potential sources of additional data in its observations and recommends that NIOSH include more explicitly pertinent post-1992 information drawn from these potential sources and other sources (documents and interviews) that might be available, and that NIOSH gather such information in dedicated sections in the TBDs, because 1992 is an important date separating the nuclear testing and SEC period from the post-testing, post-SEC period. For example, TBD-5 and TBD-6 (NIOSH 2012b and 2012d respectively) have few dedicated sections for post-1992 (SC&A identified Section A.3.1.17 of TBD-5 as one such section). Such information should include descriptions of the pertinent facilities and operations; the types, volumes, radioactive inventories, and dispositions of the wastes; the job categories and numbers of personnel involved; the duration of their potential exposures; and the associated radiation fields, as well as address the completeness and adequacy of the monitoring records. Although this report focuses on radioactive waste operations post-1992, a similar concern extends to the lack of specific information about other site activities post-1992.

In addition to looking at the description of post-1992 facilities and activities, SC&A also examined dose reconstruction methods and available supporting data for that period associated with waste handling and disposal as well as other activities at the site. Section 5.6.3 of the TBD-5 (NIOSH 2012b) states: "*NIOSH believes that the cessation of all nuclear testing, coupled* *with the implementation of the 1993 NTS internal technical basis document that demonstrates NTS compliance with 10 CFR Part 835, supports NIOSH's ability to bound internal dose for the evaluated class starting in 1993*." Section 5.6.4 goes on to say: "*After 1992, for individuals with job classifications where environmental internal dose assignment is not appropriate, the efficiency approach based on air sampling limits may be used to overestimate cases (*[NIOSH 2005]*) with employment after 1992*." The referenced NIOSH document, ORAUT-OTIB-0018, provides guidance for *Internal Dose Overestimates for Facilities with Air Sampling Programs*.

SC&A Observation 9: SC&A has two concerns related to an efficiency approach using air sampling limits to overestimate internal doses post-1992, as expressed in TBD-5, Section 5.6.4: (1) Overestimates are usually used to deny compensation. In such cases, how does NIOSH establish that the air sampling data actually yield overestimates? (2) It does not appear that the TBD specifies what method NIOSH uses for "best estimates," presuming that it does not use air sampling estimates for all cases, compensated and denied.

SC&A also has questions about the list of assumed radionuclides of concern by area and time period.

SC&A Observation 10: Attachment A, "Occupational Internal Dose for Monitored Workers," to TBD-5 (NIOSH 2012b) contains Tables A-21 and A-22, which list, respectively, radionuclides of concern overall at NTS and by area. The lists seem rather limited, given the wide variety of wastes that are handled. SC&A suggests that NIOSH list all the radionuclides in the waste and justify the shorter lists of the tables as relevant to dose reconstruction or expand the current lists as appropriate. (See also Observation 5 pertaining to lists of isotopes of concern.)

SC&A examined how the TBDs treat potential neutron exposures in the post-1992 period. Table 6-9 (TBD-6, Section 6.3.5.3) lists areas and operations where neutron exposures were and are possible. The ones applicable post-1992 are (1) the Area 5 LLW site from TRU sources and (2) various areas for down-hole well logging or neutron detection instrument calibration facilities from ^{238}PuBe or ^{252}Cf sources. Section 6.3.5.3.2 states:

> *A more significant* [than weapons-test-related sources] *potential source of neutron exposure was from isotopic neutron sources such as ^{238}PuBe or ^{252}Cf. These sources were used in specific activities such as instrument calibration and well logging. Only a few highly trained and specialized individuals, however, had access to such sources.*

SC&A Observation 11: It is not clear how those "*few highly trained and specialized individuals*" (TBD-6, Section 6.3.5.3.2) with access to well-logging and calibration neutron sources are identified and how it is ensured that they have proper monitoring.

SC&A Observation 12: Section 6.4.3 of TBD-6 (NIOSH 2012d) discusses potential neutron radiation exposure from sources such as downhole well-logging instruments and calibration sources. SC&A assumes that the potential for neutron exposures persists post-1992 to the present as shown in Table 6-9. However, the TBD does not appear to discuss specifically the post-1992 badging protocol and how it is ensured that workers, who could be exposed to neutron radiation, have the appropriate dosimeters.

Another dosimetry program concern for SC&A is the characterization of the division between nonradiation workers and radiation workers.

SC&A Observation 13: Table 6-12 of TBD-6 (NIOSH 2012d) presents the number of measured doses per year, from 1945 through 1993, falling in different dose ranges. Footnote *e*, which is attached to the 1993 row, states: "*With the ending of testing, universal badging ended in 1992. Dosimetry was not required for any nonradiation worker; however, a nonradiation worker requesting a dosimeter could have one assigned*." A similar statement is also made in Section 6.5.1: "*At NTS after 1992, only persons identified as having the potential for exposure were issued dosimeters; however, any person who requested a dosimeter would be assigned one*." It is not apparent from the TBD how "nonradiation worker" is defined (is it a judgement call or was there a well-defined protocol and, if so, was it universally followed?) and whether there were any changes in status between radiation and nonradiation workers. If there were such changes, is it documented that a newly designated radiation worker was badged?

Footnote *e* of Table 6-12 (NIOSH 2012d) echoes Allen and Schoengold 1995 (a Reynolds Electrical and Engineering Company [REECo] report on external dosimetry at NTS, often referenced in the TBD), which states:

> *beginning in April 1995, REECo ceased issuing TLDs to all personnel entering the NTS. That change in practice resulted from a change in the policies and procedures for the implementation of DOE/NV directives detailed in the revised DOE/NV Order 5480.11, "Radiation Protection for Occupational Workers," dated September 28, 1994.* [p. 18]

The REECo report also states:

> *Dosimeters are required to be worn by all personnel at the NTS who enter radiologically controlled areas or work with radiation sources or radioactive materials with the potential for external radiation exposure. Dosimeters are also issued to employees and visitors to facilities in Las Vegas who have a potential for exposure to external radiation.* [p. 69]

It should be noted that Sections 2.3.5.1 and 2.3.5.2 of TBD-2 (NIOSH 2008) state that personnel are required to wear various personal dosimeters while working in the two RWMS areas, Areas 3 and 5 respectively.

The 2009 DOE *Nevada Test Site Radiological Control Manual* (DOE 2009) presents criteria in Section 511 for requiring external dosimetry. Subsection 1.a states:

> *1. Individual dosimetry shall be required for the following:*
>
> *a. Radiological workers who under typical conditions are likely to receive from external sources an effective dose of 100 mrem or more in a year, an equivalent dose to the skin or to any extremity of 5 rem or more in a year, or an equivalent dose to the lens of the eye of 1.5 rem or more in a year or greater than 10 percent of the corresponding limits specified in Table 2-1.*

This practice is like that described in SC&A Observation 13. It is not clear to SC&A what constitutes "typical conditions" and how possible changes in conditions are monitored so that badging protocols can be changed appropriately. Also, it seems to be somewhat of a judgement call to forecast whether a worker might exceed the specific specified dose limits, such as 100 mrem in a year. Finally, 5 rem equivalent dose to the skin seems high with respect to skin cancer. If a worker received 4 rem/year for many years, could the skin cancer probability of causation rise above 50%? How would skin dose assignments be made for workers who handled radioactive materials but were never badged?

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