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Ionizing Radiation Exposures to Air Force Personnel with Duties in Vicinity of the Nevada Test Site

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AIR FORCE SAFETY CENTER

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14. ABSTRACT Recently, Air Force veterans with assignments to Tonopah Test Range during the 1980’s have expressed concerns over their radiation and toxic materials exposure potential. The Air Force (AF) Safety Center supports the AF Surgeon General in assessments of radiation exposures to veterans. This report provides an assessment of radiation exposure potential for veteran's assigned duties at Tonopah Test Range, Tonopah AFS, NV, Indian Springs AFB, NV, and Groom Lake (on Nevada Test and Training Range) from nuclear and reactor tests at the Nevada Test Site, and from plutonium safety shots under Operation Roller Coaster and Project 57 over the period of 1959 to 1992. Hundreds of documents available to the public were accessed and reviewed in preparation of this report. The data supported the conclusion that radiation exposures from these sources were below 100 mrem in a year, and in most years a very small fraction of natural background. The data in this report will be useful for evaluation of Veteran Administration service-related health claims.

15. SECURITY TERMS ionizing radiation exposure nuclear test Operation Roller Coaster Tonopah Test Range Veterans Administration Groom Lake Nellis Test and Training Range Nevada Test Site plutonium Indian Springs AFB Tonopah AFS reactor test fission products

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List of Acronyms and Abbreviations

α	alpha
AEC	Atomic Energy Commission
AF	Air Force
AFB	Air Force Base
AFS	Air Force Station
AMAD	activity median aerodynamic diameter
ASN	air surveillance network
β	beta
Bq	Becquerel
CAU	Corrective Action Unit
CDC	Centers for Disease Control
CEDE	committed effective dose equivalent
cfm	cubic feet per minute
Ci	Curie
CIA	Central Intelligence Agency
CP1	control point 1
CS	Clean Slate
CDE, H_{50}	committed dose equivalent
DAC	derived air concentration
DASA	Defense Atomic Support Agency
DC	dose coefficient
DCF	dose conversion factors
DE or *H*	dose equivalent
DL	detection limit
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DoW	Department of War
dpm	disintegrations per minute

d/m	disintegrations per minute
DRI	Desert Research Institute
DTRA	Defense Threat Reduction Agency
DU	depleted uranium
EA	environmental assessment
EEOICP	Energy Employees Occupational Illness Compensation Program
EP	experimental plan
EG&G	Edgerton, Germeshausen, and Grier
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration
eV	electron volt
E	effective dose
FIDLER	field instrument for detection of low-energy radiation
FY	fiscal year
γ	gamma
GL	Groom Lake
Gy	Gray
GZ	ground zero
H+1	one hour post detonation
H+12	twelve hours post detonation
HEU	highly enriched uranium
H_T	equivalent dose in a tissue of organ
H_E	effective dose equivalent
ICRP	International Commission on Radiological Protection
keV	kiloelectron volt
kg	kilogram
kT	kiloton
LET	linear energy transfer
LTBT	Limited Test Ban Treaty
LTHMP	Long-Term Hydrological Monitoring Program

MCL	maximum concentration limit
MEC	munitions and explosives of concern
MPC	maximum permissible concentration
mR	milliroentgen
MT	megaton
MeV	megaelectron volt
NAFR	Nellis Air Force Range
NCRP	National Commission on Radiological Protection and Measurements
NNSS	National Nuclear Security Site
NPG	Nevada Proving Ground
NRDS	National Rocket Development Station
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
ORAU	Oak Ridge Associated Universities
OTA	Office of Technology and Assessment [of US Congress]
PHS	Public Health Service
PoC	probability of causation
Q or QF	quality factor
R	roentgen
Rad	radiation absorbed dose
RADEX	radiation exclusion zone
RBE	relative biological effectiveness
rem	roentgen equivalent-man
SDWA	Safe Drinking Water Act
SEC	Special Exposure Cohort
SI	System International
Sv	Sievert
SWRHL	Southwest Radiological Health Laboratory
TEDE	total effective dose equivalent
TLDs	thermoluminescent dosimeters
TTBT	Threshold Test Ban Treaty

TON	Tonopah
TTR	Tonopah Test Range
UK	United Kingdom
US	United States
USSR	Union of Soviet Socialist Republics
UXO	unexploded ordnance
VA	Veterans Administration
WGU	weapons grade uranium
WGP	weapons grade plutonium
w_T	tissue weighting factor

Ionizing Radiation Exposures to Air Force Personnel with Duties in Vicinity of the Nevada Test Site

1.0 Introduction.

The United States (US) conducted 1054 nuclear tests from 1945 to 1992, with 28 of these being joint tests with the United Kingdom (UK). A total of 928 tests were conducted at the Nevada Test Site (NTS), of which 100 were atmospheric and 828 underground. From 1950-1951 NTS was named Site Mercury, while it was called the Nevada Proving Ground (NPG) from 1952-1954 and the Nevada National Security Site (NNSS) from 2010 to present. Because most tests were conducted under the NTS designation, this will be used throughout this report. One hundred six tests were conducted in the Pacific, with most among Enewetak and Bikini Atolls (66), 24 at Christmas Island, 12 launched from or near Johnston Atoll, and four in open water areas. Three tests were conducted in the South Atlantic. The remaining 17 were conducted in 10 locations in the US mainland and Alaska. Three of these tests were conducted on the Nevada Test and Training Range (NTTR), while three were on the Tonopah Test Range (TTR). Among the six tests conducted on TTR and NTTR, five were conventional explosives detonations associated with plutonium scatter safety experiments. One of the tests was intended for detonation on NTS, but decades later discovered to have been 300 feet outside the NTS boundary and on NTTR (the 1962 Small Boy test). The NTTR provides a boundary on three sides of the NTS, while three sides of the TTR are also bounded by NTTR. NTTR has also been identified in historical documents as the Nellis Air Force Range (NAFR) and even earlier as the Las Vegas Bombing and Gunnery Range. The summary test data provided above is from Department of Energy Report NV-209, Revision 16 (2015).

In 1977, 15 years after atmospheric testing ceased by the US, the Center for Disease Control (CDC), noted a possible leukemia cluster within the group of soldiers who were assigned to the NTS during the Smoky nuclear test event, within the 1957 Plumbbob series (DNA 1997). Subsequently, Congress passed the Veterans' Dioxin and Radiation Exposure Compensation Standards Act (PL 98-542 1984), which noted most types of leukemia, malignancies of the thyroid, female breast, lung, bone, liver, and skin, and polycythemia vera are associated with exposure to certain levels of ionizing radiation. This law established the requirement for the Veterans Administration (VA) to assess potential causative links between ionizing radiation exposures incurred from service and claimed diseases. Details of this assessment process are currently listed in 38 Code of Federal Regulations (CFR), § 3.311, *Claims Based on Exposure to Ionizing Radiation*.

The Radiation Exposed Veterans Compensation Act of 1988 (PL 100-321 1988) afforded presumptive compensation for 13 specific cancer conditions for those with on-site participation in US atmospheric nuclear tests. Two additional cancer conditions were added for presumptive compensation in a 1992 amendment (PL 102-578 1992) and an additional group in a 2004 Veterans Administration (VA) administrative action. Table A-1 provides a listing of presumptive disease conditions, while Table A-2 lists the on-site participation periods for the series of US atmospheric tests. Specific to the NTS focus of this report, the periods for on-site participation in NTS tests are highlighted in yellow. Details of this assessment process are currently listed in 38 CFR, § 3.309, *Disease Subject to Presumptive Connection*. The Defense Threat Reduction Agency (DTRA) supports the VA in adjudication of health claims related to radiation exposure to veterans with on-site participation. Defense Special Weapons

Agency, Defense Nuclear Agency (DNA), and Defense Atomic Support Agency (DASA) were predecessor organizations to DTRA.

Recently, Air Force (AF) veterans with assignments to TTR during the 1980's have expressed concerns over their radiation and toxic materials exposure potential (CBS Chicago 2024). Public interest stimulated questions to the DoD from Nevada congressional members regarding exposure potential. The primary concerns for radiation exposure are related to three plutonium scatter safety experiments conducted in 1963 under the Project Roller Coaster, a joint US-UK safety experiments effort. Also, there were statements by veterans regarding nuclear detonations on the TTR. The latter claims are not true. The Department of Energy (DOE) or its predecessor, the Atomic Energy Commission (AEC), never conducted a test involving a nuclear detonation on the TTR. The three Clean Slate tests conducted under Roller Coaster only involved the detonation of conventional explosives.

The Air Force Surgeon General's office addresses radiation exposure claims for veterans with radiation exposure potential to support the VA adjudication process. Since the mid-1990's, the Air Force Safety Center, Weapons Safety Division (AFSEC/SEW), has provided technical assistance on those claims related to nuclear weapons-related exposures. In relation to NTS nuclear tests, veterans with assignments to locations in the vicinity of the NTS, yet with unrelated duties, have often expressed concerns for potential exposures to radiation in claims submitted to the VA. These are common to veterans with assignment to Tonopah Air Force Station (AFS), TTR, the Groom Lake (GL) area on NTTR, Indian Springs Air Force Base (AFB), Nellis AFB NV, Stead AFB NV, and Boron AFS CA. Winnemucca and Fallon AFSs are also in northern Nevada, though claims for exposure have not been received for AF veterans assigned to these stations. Indian Springs AFB has since been renamed Creech AFB.

This report provides a summary and review of historical information that is useful for assessment of exposures to veterans with assignments in the vicinity of the NTS, yet without duties on NTS in support of nuclear tests. The primary focus period of this report is from 1961 to 1992, when almost all nuclear tests conducted on NTS were underground. The primary locations of interest for exposure reviews and summaries are Groom Lake, TTR, Tonopah, and Indian Spring AFB. It will be apparent, however, radiation exposure potential to personnel at Stead AFB, Nellis AFB, Winnemucca AFS, Fallon AFS, and Boron AFB was significantly lower than the former due to much greater distance from points of radiation release from NTS and unfavorable meteorological conditions for transport of airborne radioactivity to these locations. Most data summarized and referenced is from Public Health Service (PHS) radiological monitoring reports, with later reports by the Environmental Protection Agency (EPA), created in 1970 and subsequently absorbed the PHS mission.

This report will also provide a summary of dosimetry data for DoD personnel assigned duties on NTS during the underground testing period. This is provided primarily for informational purposes and provides context on radiation exposures to personnel supporting underground tests. In addition, the Nuclear Rocket Development Station (NRDS) was located within the boundary of NTS on Jackass Flats (Area 25). Reactor tests conducted at this Station also had the potential for detectable off-site radiological releases. While radiological monitoring was conducted in a similar manner to nuclear tests, the emissions were not commonly incorporated into some documents summarizing those from nuclear tests, as many reports had a primary focus of evaluating adherence to the Limited Test Ban Treaty

(LTBT) signed on 5 August 1963. The LTBT specified restrictions on off-site emissions from underground nuclear tests.

In development of this report, extensive historical monitoring data for locations surrounding the NTS were evaluated. For personnel located at Groom Lake, TTR, Tonopah, and Indian Spring AFB over the period of 1961 to 1992, exposures were low in comparison to standards established for the tests, background sources or radiation in the environment, and below current recommended standards for members of the public. Over the period covered in this report, the highest levels of off-site radiological impact were observed between 1962 and 1970, and attributed primarily to a few Plowshare tests and underground containment failures. Post 1970, radiological impacts to off-site areas of NTS were negligible in comparison. This is especially pertinent to military members with assignments to TTR. The Air Force did not have dedicated mission use of TTR until the mid-1970s.

2.0 Background.

2.1 US Nuclear Tests from 1961 to 1992 and Reactor Experiments at NRDS.

Table B-1 contains a complete listing of continental US and Alaska nuclear tests from 1961 to 1992 and reactor experiments conducted on NTS, while Table 2-1 provides a brief summary. The list contains a total of 890 individual entries among nuclear tests and reactor experiments. The list of reactor experiments is limited to those with expectation for important radiological emissions requiring monitoring, based on review of Department of Energy (DOE) report NV-401 (1995). The list of nuclear tests is based on NV-209, Revision 16 (2015). Prior to December 1993, 204 nuclear tests conducted at the NTS between 1963 and 1990 remained classified, NV-296 (1995). Revision 16 of NV-209 contains a list of all NTS tests. From Table B-1, some individual tests (by row entry) contain the detonation of multiple test devices. In these cases, the yield for each individual test is listed along with the depth for each individual device. All nuclear detonation yield and depth of burial information is provided in units of kilotons (kT) and feet, respectively. All nuclear tests were conducted at depth in soil, with the following exceptions: Little Feller I and II, and Small Boy conducted under Dominic II within the Test Series Storax 1, and four plutonium dispersal (scatter) safety tests conducted in 1963 under Storax IV. Three dispersal tests were the Clean Slate series: 1, 2, and 3 on TTR, with Double Tracks being conducted on NTTR, outside the western TTR boundary. The plutonium dispersal tests were conducted at ground-level. Another plutonium dispersal test germane to this report, but not listed in Table B-1 was Project 57 on NTTR in April 1957. For many nuclear tests, yield information is provided, though for others yield remain classified. In these cases, yield information is provided by a range, e.g., < 20, 20 – 200, low. For the plutonium dispersal safety tests and two other tests, the yield is listed as zero, as there was no nuclear contribution. The highest listed yield among the tests was 1,300 kT, Test Boxcar on NTS, though the DOE currently lists the Cannikin test on Amchitka, AK as < 5,000 kT. Twenty-two nuclear tests with yield were conducted jointly by the US and UK, and additionally four involving plutonium dispersal safety tests.

Table B-1 also has a list of references used for specific tests. DOE/NV-317 (1995) contains a summary of radiological releases from nuclear tests during the underground testing era. Key information from this report is the detection of an off-site release. Reactor tests are covered in DOE/NV-401 (1995). Tests with significant DoD involvement have a DNA report reference. Key reports with extensive radiological monitoring data are in the last column, primarily PHS reports.

Twenty-seven nuclear tests supported the Plowshare program, with 23 conducted on the NTS, as listed in Table 2-1. Three of the tests conducted outside of NTS were gas stimulation experiments designed to improve permeability of underground gas flow. Among the tests conducted on NTS, most experiments were conducted to study the use of nuclear explosives for earth excavation purposes, while four were experiments to study heavy element creation. The AEC also conducted several tests under Plowshare that involved conventional explosives only. Those are not discussed or listed in this report. Table 2-2 lists the five Plowshare tests that were planned as cratering events. These five experiments had no expectation for containment, and did have detection of contamination off NTS boundaries.

Table B-1 lists the group of reactor tests conducted at the NRDS with the expectation for important radiological emissions requiring monitoring. Among the seven reactors used, testing spanned the period of 1959 to 1972. The Kiwi and NRX reactors had the highest number of tests at 15 and 16.

TABLE 2-1. Summary of US Nuclear Test Events and Reactor Experiments from 1959 to 1992 at NTS.

Descriptor	Number	Category	Notes
Nuclear Test Events	822	All	
	22	Joint US-UK	Nuclear test events with a nuclear yield
	660	Weapons Related	
	63	Weapons Effects	DoD primary interest.
	4	Plutonium Dispersal	Joint DoD & UK, 3 on TTR, one on NTTR; not deemed nuclear detonation, as there was no nuclear contribution (e.g., a yield)
	29	Safety Experiments	
	8	Weapons-related and Safety Experiment	
	27	Plowshare	Five were cratering tests, with the expectation for some atmospheric release. Two in CO and MS, remainer at NTS.
	7	Vela Uniform	Seismic detection methods research/development
	2	Seismic Calibration	One in central Nevada and other Amchitka, AK
Reactor Tests	67	All	Conducted on NRDS
	15	Kiwi	1959 – 1965
	6	Tory	1961 - 1964
	16	NRX	1964 – 1967
	10	Phoebus	1965 - 1968
	2	Peewee	1968
	11	XE Prime	1968 - 1969
	7	Nuclear Furnace	1972

TABLE 2-2. Plowshare Nuclear Tests with Cratering.

Name	Date	Yield (kT)	Depth (ft)	NTS Area	Notes
Sedan	6 Jul 62	104	635	10	Off-site contamination
Palanquin	14 Apr 65	4.3	280	20	Off-site contamination
Cabriolet	26 Jan 68	2.3	170	20	Off-site contamination
Buggy	12 Mar 68	5 @ 1.08 ea	135	30	Off-site contamination
Schooner	8 Dec 68	30	365	20	Off-site contamination

2.2 NTS and Surrounding Areas.

Figure 2-1 contains a relief map of NTS with annotation of the individual test areas. The NRDS is located in Area 25, within a geologic area referred to as "Jackass Flats." Figure 2-2 provides a map of NTS with some details on facilities and roads. This map shows the primary access point to NTS at Mercury, Area 23, on the southeast corner of NTS. As noted, Las Vegas in 65 miles from NTS on US Hwy 95. The primary road through NTS is Mercury Hwy that traverses north to south. The Headquarters for operations were at CP1 (e.g., control point 1), on this highway, along with a nearby

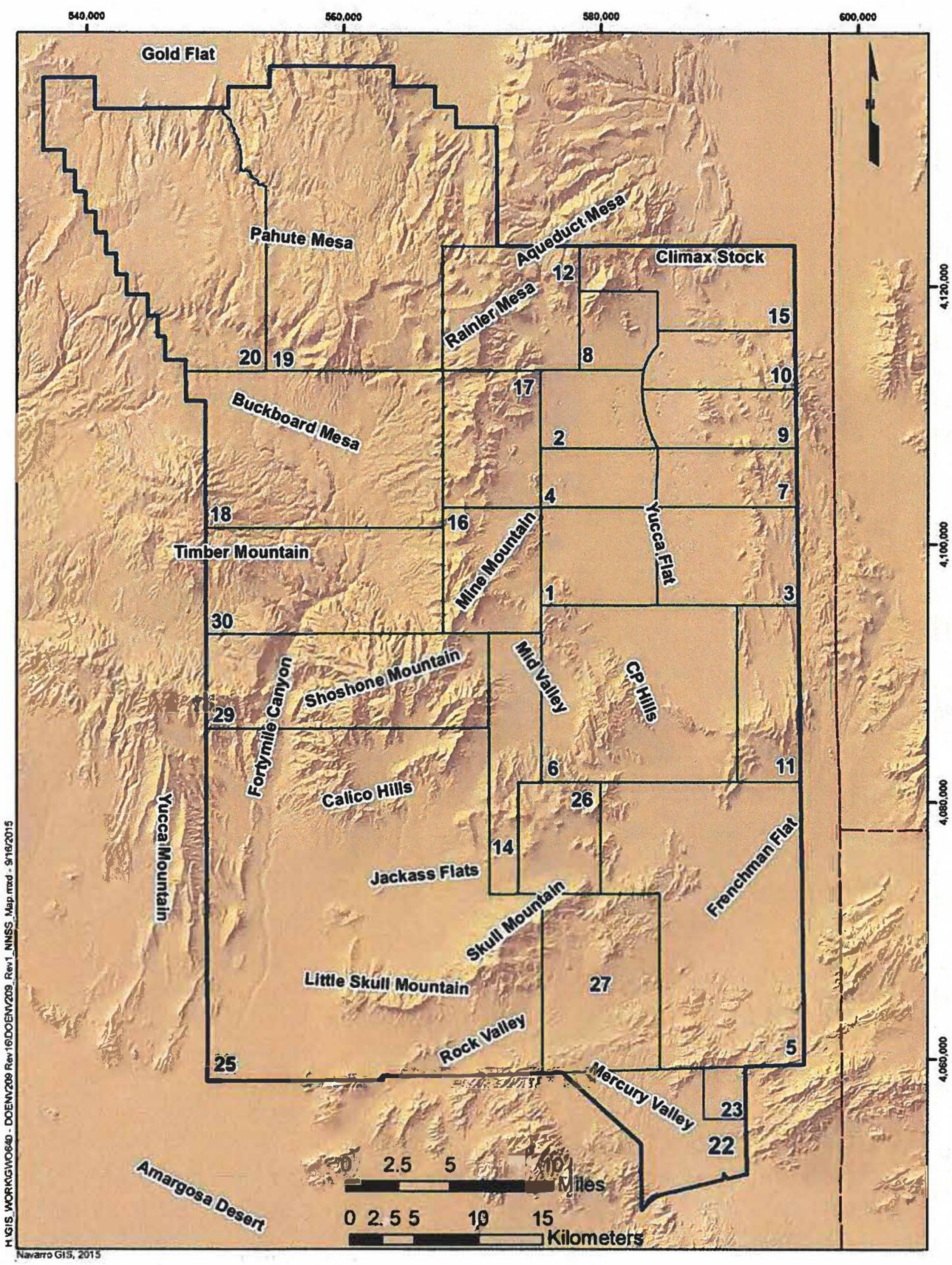


Figure 2-1. NTS Relief Map, Figure 4 of NV-209 (2015).

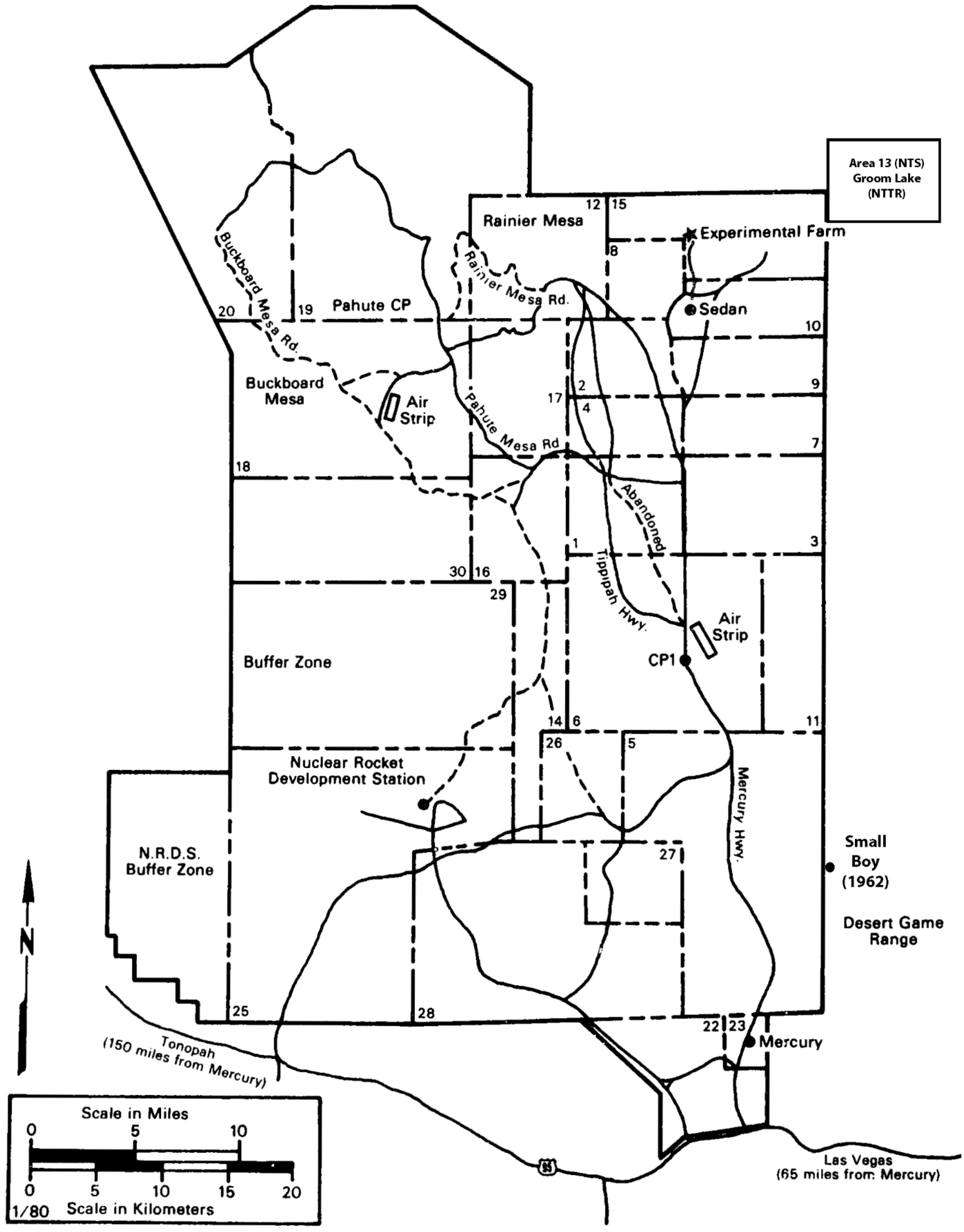


Figure 2-2. NTS Roads and Facilities, Adapted from Figure 2, EMSL-LV-539-36 (1979).

airstrip. Along this highway to the north in Area 10 is the location of the Sedan Test crater (1962 Plowshare experiment). Further along the Mercury Hwy to the north within Area 15 is road access to Groom Lake on NTTR, a dry lake bed. The Groom Lake test area (on NTTR) is abutted to the northeast corner of NTS, with current management by the Air Force. The AEC incorporated this area into its land withdrawal from the Bureau of Land Management in 1955, with numerous other references: Area 13, Watertown, and Paradise Ranch. The Central Intelligence Agency (CIA) requested use of this area for flight testing of the U-2, based on remote access to the site. Figure 2-2 shows the approximate boundaries of this area. Project 57, conducted in the vicinity of Groom Lake on 24 April 1957, was a plutonium dispersal safety test with similar characteristics to the Double Tracks and Clean Slate tests conducted in 1963. The Project 57 test was conducted nearly north of the northeast boundary of NTS Area 15 and about six miles northwest of Groom Lake, as shown in Figure C-1. Some historical maps of NTS show Area 13, while many do not. While Table B-1 does not contain the NTS area detail for each nuclear test, Table E-3 does for those tests with off-site radiological detections. In addition, the NRDS Buffer Zone shown on Figure 2-2 was a common feature of some maps, while other maps include this area as part of NTTR. The location of the Small Boy nuclear test conducted in 1962, is shown on Figure 2-2, just outside the eastern NTS boundary (Area 5) and within the NTTR and Desert Game Range (currently the Desert National Wildlife Refuge). Figure 2-3 shows the location of the current NNSS, TTR, and NTTR in relation to cities, towns, and keys roads. An important annotation on this map is TTR. Some historical maps include this detail, while others include this within the greater NTTR boundary. The TTR was established in 1957 by the AEC to test ballistics and non-nuclear features of atomic weapons (DOE 2022). Figure C-2 shows the location of the three Clean Slate plutonium dispersal sites on TTR in relation to the Range Operations Center, housing area, and main gate. Some historical documents refer to TTR as Area 52. The Double Tracks site located outside of the western TTR boundary, is commonly accessed through roads on TTR and deemed part of Area 71 (on NTTR).

The AEC has collectively deemed NTS, NTTR, and TTR as the Test Range Complex in the assessment of whether a nuclear test was categorized as having off-site detection of a radiological release for most of the underground testing. While this was not an important distinction during the aboveground testing era, this was an important distinction for the era when only underground or cratering tests were accomplished at the NTS. Prior to 1963, off-site detections of radiological releases were in reference to the NTS boundary that existed during that period.

2.3. The Underground Testing Era.

Prior to 1957, all US nuclear tests were conducted either in the atmosphere or underwater. World-wide concerns about the effects of atmospheric testing of nuclear weapons gained attention after the Castle Bravo test in 1954 at Bikini Atoll, and led to a United Nations Disarmament Conference in 1955 and a Joint US-Union of Soviet Socialist Republics (USSR) nuclear testing moratorium in October 1958, US Congress (OTA-ISC-414 1989). The moratorium was broken by the USSR after the French began nuclear testing in September 1961, with the US also resuming nuclear testing shortly after in 1961, but only underground until several atmospheric tests in 1962. In 1963, the US, USSR, and UK deemed underground nuclear tests a reasonable alternative to atmospheric, underwater, and outerspace tests, and entered into the LTBT (OTA-ISC-414 1989). In 1974, the US signed the Threshold Test Ban Treaty (TTBT) which limited nuclear test explosions to a defined test site with yields below 150 kT. The last US underground nuclear test was conducted in 1992.

Figure 2-3. Map of NTS (now NNSS), NTTR, TTR, and Vicinity, Figure 1-1 of NV-03625-1788 (2023).

Article I1.(b) of the LTBT prohibited explosions that caused “radioactive debris to be present outside the territorial limits of the State under whose jurisdiction or control such explosion is conducted.” In the early period of underground testing, containment methods had not been fully developed, with many tests having unplanned releases. Nevertheless, the releases were very low compared to the release had the test been conducted aboveground. Three underground tests conducted in 1962 and one in 1970 had atmospheric releases of about 3.8 to 34% of the fission product inventory generated by the test. Most underground tests had fission product inventory release fractions well below one percent. It took the US more than a decade of underground testing before theories for the physical basis for containment were developed (OTA-ISC-414 1989). The Baneberry underground test in 1970 was the last with a significant containment failure.

Starting in 1954, the PHS conducted radiological monitoring of locations off the NTS with an objective “to measure levels and trends in radioactivity, if present, in the environment surrounding testing areas to ascertain whether the testing is in compliance with existing radiation protection standards” (EPA-600 4-81-047 1981). In 1970, the PHS and its off-site radiological monitoring program was absorbed into the EPA. With US entrance into the LTBT in 1963, this program had the added objective of demonstrating treaty compliance. An important conclusion in all reports documenting monitoring was the determination of whether public exposure standards had been adhered and whether or not radiological contamination from a test was detected in an off-site location.

2.4. Radiological Releases from Nuclear Tests.

2.4.1 General.

The radioactive materials generated from a nuclear test are dependent on the design of the device and surrounding environment. The fissile materials used, whether they are weapons grade plutonium (WGP), weapons grade uranium (WGU), or a combination of these impacts the efficiency of the detonation, fission product mixture, and the residual unburned (e.g., un-fissioned) fissile material left in the environment. Also, it is important whether a device incorporates fission reactions only, also incorporates fusion reactions, and the relative balance of fission and fusion processes in forming the nuclear yield. The characteristics of the radioactive debris are unique to each test device, and to some degree how the weapon was tested: land surface, water surface, underwater, tower on land, low altitude airburst, high altitude airburst, or underground. Specific to atmospheric releases, the characteristics of the radioactive debris from a detonation can be altered during transport of the debris cloud. Some radioactive elements produced in a detonation exist in gaseous form, i.e., noble gases, and will not be a part of fallout deposition on ground or water surfaces. For elements that are solids or liquids at ambient atmospheric temperatures, have some observed preferential fallout from the debris cloud earlier than other elements, dependent on the melting point. Elements with higher melting points will be observed in fallout deposition at higher fractions in the total fallout inventory at earlier times than for fallout occurring at later times. The opposite is true for those elements with lower melting points. These elements will form a greater fraction of the fallout debris at later times rather than the early fallout deposition. This phenomenon is termed “fractionation.”

Underground and underwater nuclear detonations have unique differences to those conducted above-ground. For well contained underground detonations, most releases are related to minor seepages and under controlled conditions where radioactive gases dominate. Often, controlled releases were accomplished many hours and days after detonation. This allows for the condensation of some fission products that are initially in liquid and gaseous forms, which have substantially lower permeability than gases in soil and rock, and affords radioactive decay.

The cratering nuclear tests conducted under Plowshare (Table 2-2) and some of the underground tests with significant containment failure will have a much higher fraction of the atmospheric release in the solid phase as compared to well contained underground nuclear tests. Nevertheless, each of these is much less than an unmitigated atmospheric test. In addition, the long-range transportability of the solid fraction of a cratering nuclear test and those with major containment failure will be much lower than most atmospheric tests conducted at NTS. For example, Test Smoky conducted on 31 Aug 57 in NTS Area 8 on a 700-foot tower, had a nuclear yield of 44 kT. The nuclear debris cloud for this test extended up to about 33,500 feet above ground level (AGL), while for the largest Plowshare cratering test, Sedan (6 Jul 62), with a yield of 104 kT, the debris cloud extended to only about 11,700 feet AGL, DNA-1251-1-EX (1979).

2.4.2 <u>Fission Products</u>.

Fission products are commonly the most important source of external radiation exposure from ground-deposited fallout and to sky-shine (when a nuclear debris cloud passes over a ground area). Fission products from nuclear detonations are a complex mixture of over 300 different radionuclides among 36 elements, Glasstone and Dolan (1977), with some subtle differences among fission product mixtures from the fission of ^{239}Pu, ^{235}U, and ^{238}U. Differences in the design of one weapon from another could also alter the fission product mixture for the same fission fuel, due primarily to the differences in the distribution of energies among neutrons produced in the detonation. Most of the fission products are radioactive, but have relatively short radioactive half-lives, affording a drastic reduction in external exposure rates over a short period after detonation. Within an hour after detonation, about 160 radioactive fission products exist in appreciable concentrations, but due to the relatively short half-life of many radionuclides, within a few hours, only about 80 have appreciable concentrations, NV-296 (1995). Figures 2-5 a and b, adapted from Glasstone and Dolan (1977), show the dose rate over time post detonation, as normalized to the dose rate at one-hour post detonation. The solid (gray) line is the average for a fission product mixture expected among varied weapon designs, with the dashed (black) line representing a power function fit to the data. This function fits reasonably well for time up to six months post detonation. After one day, the external dose rates from fission products drops to less than 3% of that at one-hour, while at one-month, over 3,000-fold lower. For long periods after a nuclear test, e.g., 20 to 25 years after detonation, exposure rates from fission products are expected to be nearly a hundred million-fold lower (10^{-8}) than compared to an hour after detonation. Key fission products remaining decades after are ^{137}Cs and ^{90}Sr, with respective half-lives if 30.2 and 29.2 y. Figure 2-4 contains residual radiation contours in units or Roentgen per hour (R/h), normalized to one-hour post detonation (H+1) for the Small Boy test. This plot type is common for displaying residual radiation. Measurements are commonly collected at many time points after detonation, but normalized using the $t^{-1.2}$ relationship, which applies many months after detonation (see Figure 2-5).

Table D-1 contains a listing of common radionuclides associated with nuclear detonations. Fission products listed are the largest group and provide the greatest contribution to external dose rates at early periods after detonation both in the aerial debris cloud and ground-deposited debris. The contribution to external exposures is due primarily to β-particle decay and associated photon emissions:

γ-and x-rays. Particularly important to well contained underground nuclear tests are noble gases: radio-kryptons and -xenons, and gaseous radioiodines. These radionuclides are the primary fission products detected in air samples. Among this group of fission products, ^{85}Kr has one of the longest half-lives, 10.7 y. Due to its long half-life and the fact that it is also produced by nuclear reactor operations, it was and still is commonly detected by noble gas monitor systems, even in the absence of nuclear detonations.

2.4.3 Activation Products.

The high neutron fluence existing during the detonation of a nuclear device also creates the potential for neutron-induced reactions in materials within the device, and the environment to include air, soils, water, and nearby structures. The common neutron activation reactions are capture reactions where an incident neutron is absorbed by the nucleus, and a γ-ray is emitted in the process, as shown below for ^{59}Co, an element commonly in ferrous alloys:

$$^{59}Co + n \rightarrow {}^{60}Co + \gamma$$

The product of the reaction, ^{60}Co, is radioactive and has a half-life of 5.3 y. Ferrous alloys are common to some parts used in nuclear devices, device test towers, ground buildings and other items incorporated into damage effect evaluations, i.e., test structures, vehicles. Among many activation products listed in Table D-1 are those also commonly produced by activation of stable precursors in steel: ^{55}Fe, ^{63}Ni, and ^{65}Zn. For underground nuclear tests, activation products of steel are not generally important radionuclides. For aboveground nuclear tests, they are generally important for tests conducted on steel towers, though the relative importance of these activation products decreases in proportion to fission products associated with the detonation as the distance from GZ increases.

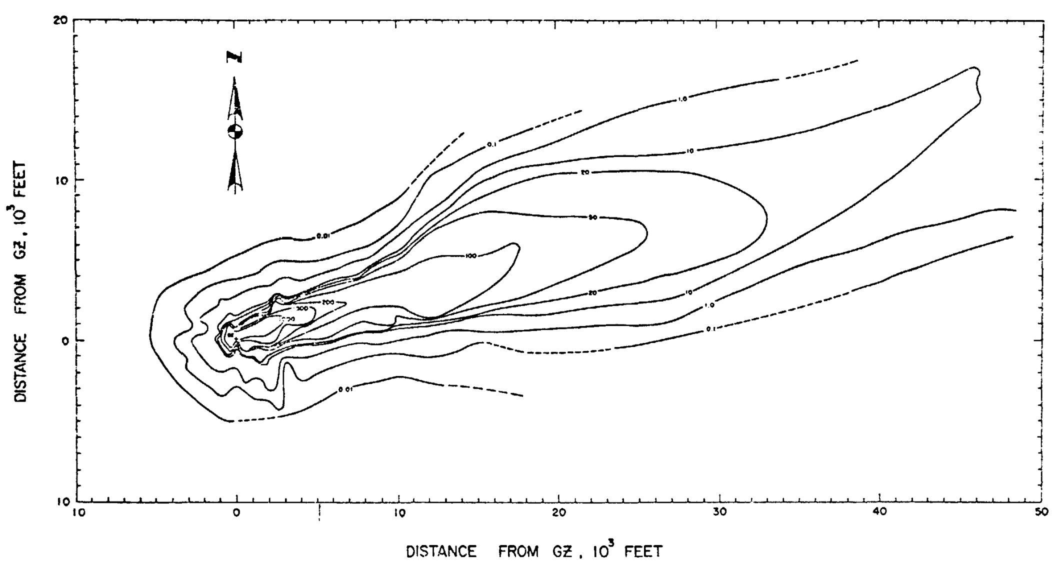
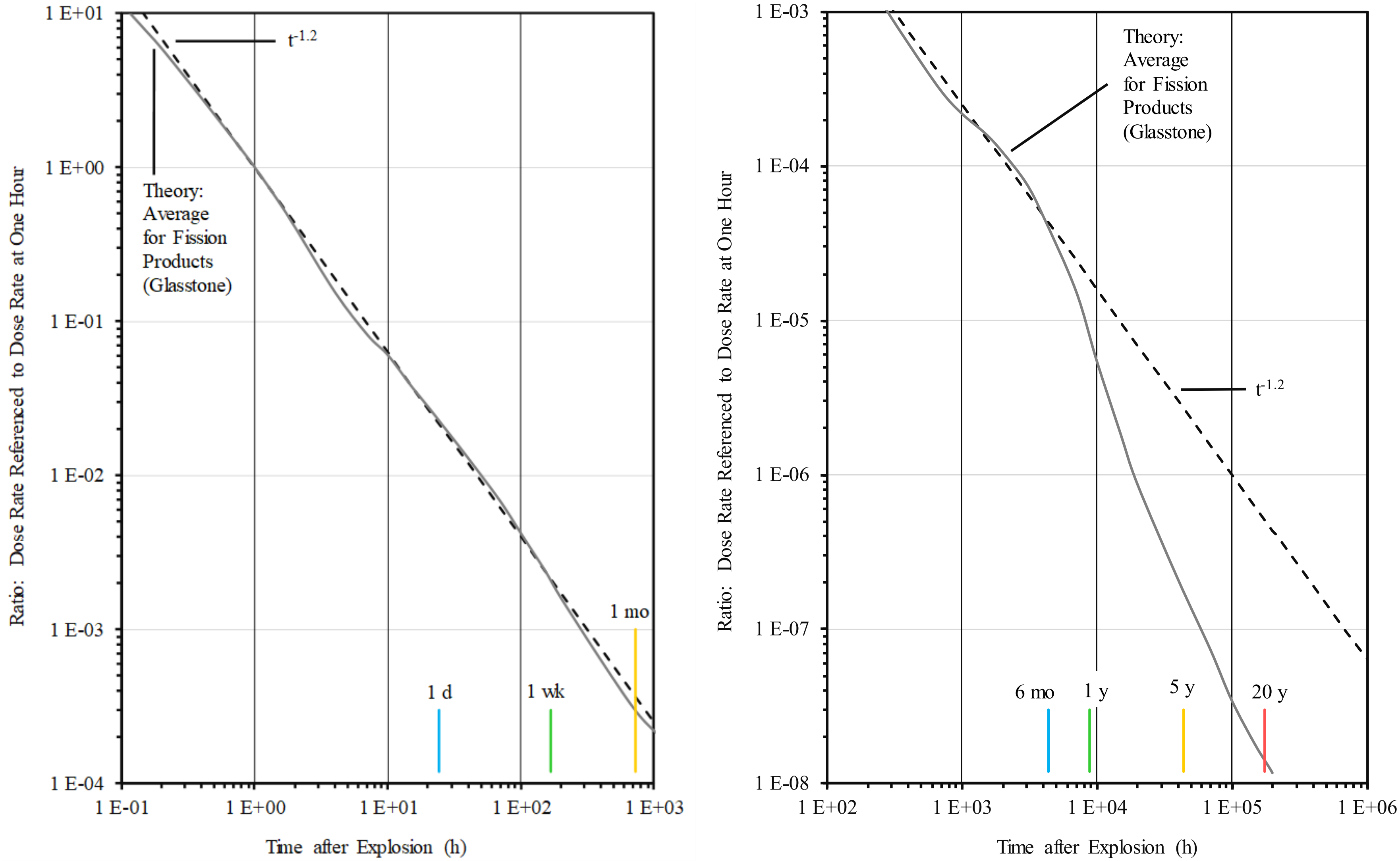


Figure 2-4. Small Boy Contours of Residual Radiation in R/h at H+1 hour up to 50,000 ft Downwind of GZ (Figure 330 from DNA-1251-1-EX [1979]).



a. Early Fallout Times

b. Late Fallout Times

Figure 2-5. External Dose Rate at Various Times After Detonation of Fission Products Reference to One-Hour After Detonation [Adapted from Glasstone and Dolan (1977)].

There are several other activation products associated with nuclear detonation. For detonations near the ground, elements in soil can be activated, e.g., ^{13}C, ^{23}Na, ^{151}Eu,^{153}Eu, ^{133}Ba. Similar to activation products from steel, these are generally not important for underground tests. While many of the noble gases are fission products, some are also produced from activation of stable noble gases in the atmosphere. Activation of unburned fission fuel is another source along with fuel remaining unaltered during detonation. For fissile ^{239}Pu and ^{235}U, most of these materials are not fissioned, though some are transmuted by neutrons, e.g., production of ^{240}Pu from an (n,γ) interaction, ^{238}Pu from an (n,2n) reaction. ^{181}W, ^{187}W, and ^{188}W are listed in Table D-1, based on detection from the Schooner cratering Plowshare test conducted on 8 Dec 68. ^{24}Na was important for early, and close-in fallout from the Palanquin cratering Plowshare test conducted on 14 Apr 65, PNE-197 (1966). Nevertheless, this was not an important radiological concern at off-site locations.

2.4.4 Late-Time Fission and Activation Products. Many decades after nuclear tests, residual fission and activation products are dominated by only a small number of long-lived radionuclides. The DOE completed an extensive soil monitoring program in the major test areas of NTS, and reported in 1990 an estimated inventory of fission and activation products, as listed in Table 2-3. The activity of the three activation products would be more concentrated near GZ, as compared to the fission products. A few other radionuclides were identified in surveys, but to a much lesser degree: ^{133}Ba (< 0.1 Ci), ^{134}Cs (< 0.1 Ci), ^{101}Rh (1 Ci), and ^{174}Lu (4.9 Ci). The latter was identified at only three sites, however.

TABLE 2-3. Estimated Inventories of Major Manmade Radionuclides in NTS Surface Soils as of January 1, 1990, NV-10845 (1991).

Parameter	Radionuclides						
	^{60}Co	^{137}Cs	^{90}Sr	^{152}Eu	^{154}Eu	^{155}Eu	^{102m}Rh
Inventory (Ci)	35	310	330	130	2.8	14	6.4
Half-Life (y)	5.27	30.2	29.1	13.6	8.8	5.0	2.9
Type	activation	fission	fission	activation	activation	fission	fission

2.4.5 Nuclear Fuel.

The primary fissile fuels used for nuclear weapons tests are weapons grade plutonium (WGP) and weapons grade uranium (WGU). As well, many test devices also contain depleted uranium (DU) and/or natural uranium (U-nat). WGP is primarily comprised of ^{239}Pu, by mass, with lesser amounts of ^{240}Pu, ^{241}Pu, ^{242}Pu, and ^{238}Pu. The relative balance is dependent on the production reactor design and irradiation period. As well, as noted above, the relative abundance of each isotope of plutonium is altered by detonation. Table 2-4 contains the isotopic composition of WGP assumed for the Enewetak Atoll rehabilitation from NVO-213 (1982). This composition should be similar to that of NTS tests, as most atmospheric tests among the two sites were conducted over a similar period. As noted in the table, the composition is prior to detonation. With exception to plutonium scatter safety shots, it is presumed when a test used plutonium as fissile material, its composition was altered. Table 2-5 contains isotopic composition for the plutonium used in the 1963 Double Tracks and Clean Slate plutonium scatter safety tests on NTTR and TTR from DASA (1966). The plutonium used in all four test shots was expected to be similar, DASA (1966). In 2015, the Air Force Safety Center evaluated data from Table 2-5, a

TABLE 2-4. Isotopic Composition of WGP Assumed for
Enewetak Rehabilitation, from NVO-213 (1982).

Isotope	Composition Fractions (Unburned)		Radiological Half-life (y)
	Mass	α-Particle Activity	
Pu-238	0.00012	0.028	87.8
Pu-239	0.934	0.783	24,131
Pu-240	0.0606	0.189	6,563
Pu-241	0.0055	0.00018*	14.4
Pu-242	0.0002	0.000011	376,000

* 99.998% β-particle decay, ~0.002% α-particle decay

1994/1995 characterization survey of the Double Tracks Site, DOE/NV-484 (1995), and the Double Tracks closure report, DOE/NV-1547 (2016) to provide an estimate of the isotopic relationships over time, AFSEC (2015). Figure D-1 contains the AFSEC plot. The plot includes the inclusion of ^{241}Am, the daughter from decay of ^{241}Pu. Over time, ^{241}Am becomes an important contributor to α-particle activity of WGP. In 2015, ^{241}Am was estimated to provide a contribution of about 6.5% of the total α-particle activity. The plutonium used in the Double Tracks and Clean Slate test had much higher ^{239}Pu content than that assumed for WGP involved in Enewetak Atoll nuclear tests. The WGP used in the 1957 Project 57 plutonium dispersal safety test, however, was similar to the composition listed in Table 2-4. From the 1998 DOE soil sampling effort, DOE/NV-1520 (2014), the ^{241}Am was estimated to provide a contribution of about 14.7% of the total α-particle activity. For common fissionable materials used in US nuclear tests, WGP provides the greatest contribution to α-particle activity in nuclear debris, as illustrated in Figure 2-6, due to its high specific activity compared to HEU, DU, and natural uranium metal. In the assessment of soils collected at Enewetak Atoll in preparation for the 1977 to 1980 clean-up, ^{235}U was detected in only a small fraction of the soil samples collected, and the maximum concentration among positive detections was only 0.3 pCi/g. Table 2-6 contains a generic composition of WGU, enriched to 93.3% ^{235}U, by mass. Though ^{234}U has the highest activity concentration in this example, the most detectable isotope through photon detection techniques is ^{235}U. The Double Tracks and Clean Slate tests also contained DU, with a mass and activity concentrations shown in Table 2-7. Table 2-8 contains the mass and α-particle activity ratios of uranium and WGP in the individual Double Tracks and Cleans Slate tests. Despite the large disparities in uranium to WGP masses for three of the

TABLE 2-5. Isotopic Composition of WGP for Double
Tracks and Clean Slate Sites, Data from DASA (1966).

Isotope	Composition Fractions		Radiological Half-life (y)
	Mass	α-Particle Activity	
Pu-238	3.87×10^{-5}	0.010	87.8
Pu-239	0.9731	0.903	24,131
Pu-240	0.0253	0.087	6,563
Pu-241	0.001487	-	14.4
Pu-242	0.0031	-	376,000

tests, the α-particle activity from the WGP is well over 1,000-fold higher than the contribution from uranium. Hence, the radiological exposure potential from uranium is deemed negligible in respect to the WGP.

2.4.6 Reactor Test Effluents. The nuclear reactor tests conducted on NTS have some similarity to nuclear detonations in the generation of fission products, but there are some important differences. First, a nuclear detonation potentially creates activation products, if a detonation was created near ground, while reactor effluents had relatively limited activation products. Second, nuclear detonations are completed in a small fraction of a second, while the nuclear reactor tests were completed over

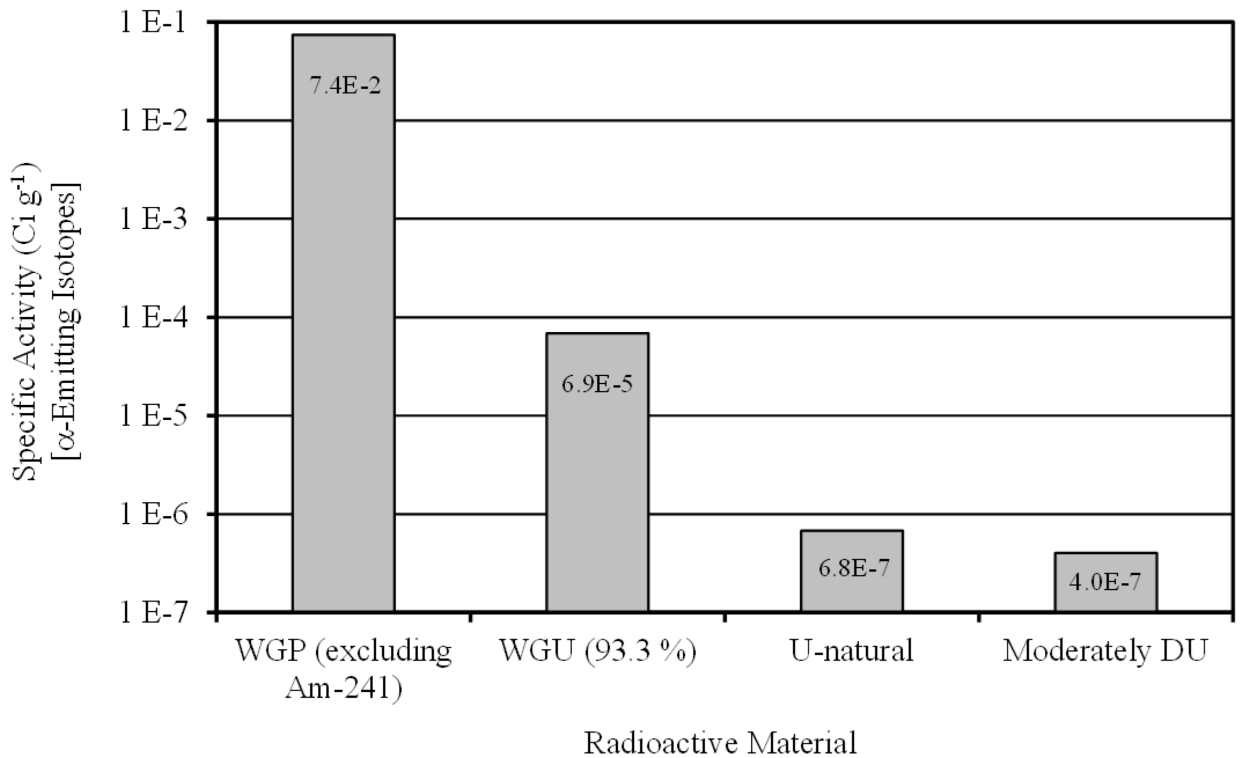


Figure 2-6. Comparison of Specific Activity of α-Particle Emitting Radionuclides in Materials Commonly Used in Nuclear Test Devices.

TABLE 2-6. Generic WGU Composition.

Isotope	Composition Fractions (Unburned)		Radiological Half-life (y)
	Mass	α-Particle Activity	
^{234}U	0.0106	0.97	244,500
^{235}U	0.933	0.0294	7.038×10^8
^{236}U*	0.00031	0.000293	2.342×10^7
^{238}U	0.0562	0.000275	4.468×10^9

* Found in spent and reprocessed fuel, but possibly not in all WGU

TABLE 2-7. Uranium Mass, α-Particle Activity Fractions, Specific Activities for Test Devices used in Double Tracks and Clean Slate Sites, from DASA (1966).

Isotope	Mass Fraction	α-Particle Activity Fraction	Specific Activity (pCi/g)
^{234}U	7.4×10^{-6}	0.118	6.1×10^{-3}
^{235}U	1.65×10^{-3}	0.00192	2.1×10^{-6}
^{238}U	0.998	0.873	3.35×10^{-7}
		Total	3.83×10^{-7}

TABLE 2-8. Ratios of Uranium to Plutonium Mass and α-Particle Activity for Double Track and Clean Slate Tests, Masses from DASA (1966).

Test	Ratios	
	Uranium to Plutonium Mass	$^{234+235+238}U$ to $^{238+239+240}Pu$ Activity
Double Tracks	4.35	2.52×10^{-5}
Clean Slate I	47.2	2.73×10^{-4}
Clean Slate II	100.1	5.80×10^{-4}
Clean Slate III	99.7	5.77×10^{-4}

minutes to hours. Third, the solid fuel in the reactor was not destroyed in tests, allowing effective retention of fission products with higher melting points, yet greater release of noble gases and volatile fission products. In some respects, the fission product effluents had some similarity to most underground nuclear tests. The DOE in 1995 estimated that the nuclear-powered rocket and ramjet engines tests which generated a detection of an off-site release, produced fission product radioactivity release equivalent to a 0.03 kT nuclear explosion, DOE/NV-401 (1995). This estimate excludes the Nuclear Furnace tests conducted in 1972, though only effluents of noble gases and tritium were detected off-site in those tests, NERC-LV-539-23 (1973). The Nuclear Furnace tests had the benefit of liquid scrubber system to partially mitigate airborne releases, NERC-LV-539-6 (1974).

2.4.7 Foreign Nuclear Tests and Commercial Power Reactor Releases. From 1963 to present, the US, UK, and the USSR have not performed any atmospheric nuclear tests. In the northern hemisphere, the Chinese conducted 22 atmospheric nuclear tests over the period of 1964 to 1980, as listed in Table B-2. The effluent from these tests were commonly detected by US monitoring stations that conducted external exposure measurements and air sampling. This required special analysis to discriminate the impacts of US underground nuclear and reactor tests from Chinese nuclear tests. The 1976 Chinese nuclear tests were notable for monitoring coverage by the EPA, EPA-402 R 5-77-002 (1977). Among the more prominent radionuclides released by both commercial nuclear power reactors and nuclear detonations was ^{85}Kr, half-life 10.7 y. Due to its long half-life, it was commonly detected in noble gas monitoring systems and was difficult to discriminate among the sources of the release. Nevertheless, ^{85}Kr radiological impacts are only a small fraction of natural background.

2.5. Releases from Underground Nuclear Tests.

Several reports were evaluated that provided information on containment history of US underground nuclear tests, as listed in Table B-3. AEC Report WASH-1183 (1971) listed 18 underground tests that had releases that were detected off NTS. The report detailed measurements of monitoring results from off-site locations but did not include reactor release information or releases from Plowshare tests. In 1987, the EPA published an update to the 1971 AEC report, as noted in Table B-3, Report 600 8 87-054 (EPA 1987). There were five more tests listed, 23 total, though only two were added to the list after 1970. There was a difference in the inclusion/omission of listing among six tests conducted prior to 1971. In general, releases that were only detected by aerial sampling platforms were not included as an off-site release, as there was no discernable impact on individuals at ground-level. For some tests with this characteristic, the test may not have been listed in a SWRHL report. NV-317 (1996) provides information on releases from 437 tests, which includes six Plowshare tests, three aboveground tests conducted in 1962, but not reactor tests. Overall, 47 tests had releases listed with an off-site radiological detection. This report listed three tests with off-site detections that were not listed in EPA Report 600 8 87-054: Misty Rain (5 Apr 85), Glencoe (22 Mar 86), and Mighty Oak (10 Apr 86). These three tests, nevertheless, were listed in other EPA reports, as noted in the Table B-3 reference list.

The US Congress Office of Technology Assessment (OTA) Report ISC-414 provided a comprehensive review of emissions related to underground tests conducted at NTS. Though the report only captured underground tests from 1958 to 1988; no off-site radiological detections were observed for tests conducted from 1989 – 1992. The summary information from this report is useful in placing a temporal perspective on radiological emissions from the NTS, as well as a perspective on greatly improved containment of underground tests over time. Table 2-9 provides a summary of radiological releases from NTS, with numerous comparisons. First, the difference in radiological emissions from underground tests conducted after the Baneberry Test (December 1970) compared to this and all previous underground tests is significant, being disparate by a factor of 470. Only four underground tests, post Baneberry, had containment failures, though only two: Diagonal Line and Riola had off-site radiological detections. Among the latter underground tests, Mighty Oak's (1986) release was under a controlled tunnel purge operation, but accounted for two-thirds of the total radiological release post Baneberry and did have off-site radioactivity detection. Among pre-1971 underground tests, the Des Moines (1962) test had a significant activity release, and based on its yield of 2.9 kT, this test released to the atmosphere 34% of the activity generated by the detonation, as benchmarked to H+12 h. The other underground test with containment failure prior to 1971, Baneberry, had an estimated release of 6.7 x 10^6 Ci (@ H+ 12 h) and provided a fractional release to the atmosphere of only 6%. For comparison purposes, the atmospheric nuclear tests conducted from 1951 to 1962 had an estimated radioactivity release about 500-fold higher than that released from underground tests conducted at NTS. The lower portion of Table 2-9 lists other key radiological release sources from NTS prior to 1971. Most effluents are attributed to Plowshare cratering tests. The inclusion of reactor test releases, discussed earlier in this report, are also provided. The radioactivity from these other sources is about 25% higher than the total from pre-1971 underground tests.

2.6 Monitoring Systems during Underground Testing at NTS.

2.6.1 General.

The primary objective of the comprehensive radiological monitoring system implemented by the PHS was to assure public health, SWRHL-501r (1971). The PHS established the SWRHL at Las Vegas, NV, in 1954 to support this mission. Over its initial inception, monitoring techniques have advanced with technology improvements. For the purposes of this report, we will provide limited details on systems and methods used in the 1960s, as those were important to the period when greater degree of

TABLE 2-9. Radioactivity Releases at NTS from Underground Nuclear Tests and Other Sources, Data from OTA ISC-414 (1989), and Other NTS Radioactivity Releases.

Radioactivity Releases from Underground NTS Tests from 1970 - 1989†			
Containment Failures*		Controlled Tunnel Purgings	
Test	Release (Ci)	Test	Release (Ci)
Camphor (1971)	360	Hybla Fair (1974)	500
Diagonal Line (1971)	6,800	Hybla Gold (1977)	0.005
Riola (1980)	3,100	Miners Iron (1980)	0.3
Agrina (1984)	690	Huron Landing (1982)	280
Late-Time Seeps		Mini Jade (1983)	1
Kappeli (1984)	12	Mill Yard (1985)	5.9
Tierra (1984)	600	Diamond Beech (1985)	1.1
Labquark (1986)	20	Misty Rain (1985)	63
Bodie (1986)	52	Mighty Oak (1986)	36,000
Operational Releases from Other Tests		Mission Ghost (1987)	3
108 tests	5,500	Total Release: 54,000 Ci	
Major Pre-1971 Radioactive Releases from Underground Tests*			
Test	Release (Ci)	Test	Release (Ci)
Platte (1962)	1,900,000	Eel (1962)	1,900,000
Des Moines (1962)	11,000,000	Baneberry (1970)	6,700,000§
26 others (1958 – 1970)	3,800,000	Total Release: 25,300,000 Ci	
Other Releases for Reference			
Event	Release (Ci)	Event	Release (Ci)
NTS Atmospheric (1951 – 1963)	12,000,000,000	Chernobyl (1986)	81,000,000
Other Key Pre-1971 NTS Releases [not covered in OTA ISC-414 (1989)]			
Cratering Event	Yield (kT)	Release (Ci)*⦚	Fraction of Total
Danny Boy (Weapons)	0.43	850,000	0.18
Sedan (Plowshare)	104	15,000,000	> 0.043⸙
Palaquin (Plowshare)	4.3	11,000,000	0.23
Cabriolet (Plowshare)	2.3	220,000	0.009
Buggy (Plowshare)	5.4	1,200,000	0.02
Schooner (Plowshare)	30	3,700,000	0.011
Reactor Tests (1959 - 1969)	Yield Equivalent	Release (Ci)	No. of Tests
Tests w/ Off-site Detection‡	0.03 kT	843,000	35

* Normalized to H+12 h † Excluding Baneberry (Dec 1970) § 6% of H+12 h inventory ⦚ Data from NV-317
⸙ DOE/NV-209 (2015) lists fission contribution as < 30% ‡ From Table 2, DOE/NV-401 (1995)

radiological emissions occurred. For more details, the reader is directed to the individual test series, semi-annual, or annual monitoring reports that are listed in the reference. Monitoring over the decades had some changes in monitoring locations, as well as special monitoring for certain tests based on weather conditions.

This report will not detail the extensive radiological monitoring results conducted on milk produced at local, regional, or national dairies that were part of the monitoring program, with the exception of some maps providing details on the various dairies that were monitored. This report provides an extensive list of references with details on dairy monitoring. Dairy products were specifically targeted because animal milk is a source of iodine, related to radioactively contaminated forage. Similarly, extensive sampling of water wells was conducted on a routine basis and shortly after the completion of some tests. Some examples will be provided, however, sampling results will not be discussed. The reader can refer to listed references for more details. In relation to the drinking water wells near Groom Lake, on TTR, at Indian Springs, and Tonopah, the wells were normally very deep and unsusceptible to impacts of short-lived radiological materials released from tests. Vegetation and animals were also monitored for radiological content, but these were not deemed important exposure pathways for AF personnel assigned to duties in vicinity of the NTS. The animal investigation program was initiated in 1957. Numerous reference reports have significant details of the findings for this program.

2.6.2 Weather Monitoring, On-Site Radiological Monitoring, and Aerial Plume Tracking.

The AEC, and later the DoE, maintained an extensive network of radiological monitors on NTS as well as mobile monitoring capabilities. This network in conjunction with weather prediction and active weather monitoring allowed accurate predictions of radioactive debris cloud transport to off-site locations. Another key monitoring tool was aerial plume tracking and sampling. Some debris clouds created by nuclear tests were visibly apparent. This condition was common to the Plowshare tests, the few nuclear tests conducted in 1962 that had only a shallow burial depth in soil (e.g., Danny Boy, Little Feller I and II, and Small Boy), and underground nuclear tests with significant containment failures.

Similar to the aboveground testing era, the aircraft supporting aerial debris monitoring had photon (e.g., γ- and x-rays) exposure monitoring systems that aided in assessing debris cloud trajectory and radiation exposure strength. Air sampling collection systems were also fielded on aircraft to assess the radionuclide-specific content of debris clouds, with some sampling specialized for noble gas collections.

2.6.3 External Radiation Exposure Monitoring.

External radiation exposures from passing debris clouds and ground deposited aerosol were monitored by active and passive monitoring systems. For nuclear tests conducted in the 1950's to latter 1960's film badge monitoring was the primary method of passive exposure monitoring used for nuclear tests. Badges were placed at numerous locations, which were deemed environmental monitors, as well as on personnel and members of the public at off-site locations. In 1965, the SWRHL added the use of thermoluminescent dosimeters (TLDs) to their monitoring techniques, SWRHL-58r (1969). From 1965 until early 1970 both sets of passive monitors were used. In early 1970, film badge use was discontinued by the EPA in their NTS off-site monitoring program, SWRHL-108r (1972). The film badges had a detection limit (DL) of about 30 mR, while the TLDs had a sensitivity of about 10 mR. Figure C-3 contains a plot of TLD and film badge monitoring at off-site locations during the first year when both monitoring types were in use from SWRHL-58r (1969). Notably, in relation to the focus of this report, TTR had two monitoring sites: one at the northern main entry gate and the other at the CP, to the southeast of the TTR airport, Groom Lake had two sites, while Indian Springs and Tonopah had a single site each. One important point regarding the information in this report, some SWRHL and EPA off-site monitoring reports had TTR and Groom Lake as off-site monitoring sites, while others did not.

Active monitoring systems included the use of portable and fixed detection systems. Some of the monitoring systems were coupled to automated recorder systems. Table 2-10 contains a list of systems used for monitoring during Operation Nougat. Figure C-4 shows off-site feature surrounding the NTS for Operation Nougat tests. Figure C-5, from the same SWRHL report lists the off-site monitoring locations for air and dose rate recorders. Mobile γ-radiation monitoring is not included in the example map and table. Many of the locations that were not instrumented with dose rate recorders, nevertheless, they did have film badge monitoring.

TABLE 2-10. Ground Monitors used During Operation Nougat, 15 September 1961 – 30 June 1962, from SWRHL-1r (1964).

Instrument	Type	Sensitivity
Tracerlab AN/PDR-T1B	Ionization Chamber	0.5 mR/h (1/10 full scale on lowest scale) to 50 R/h
Beckman MX-5	Geiger-Mueller	0.02 mR (1/10 full scale on lowest scale) to 20 mR/h
Precision Radiation Model 111	NaI Scintillator	0.005 mR/h (full scale on lowest scale) to 5 mR/h
Eberline Model E500-B	Geiger-Mueller	0.02 mR (1/10 full scale on lowest scale)
Eberline Radiation Monitor RM-5, with strip chart recorder	Geiger-Mueller	0.01 to 100 mR/h

2.6.4 Air Sampling.

A common air sampling system in use in the 1960s to support off-site monitoring was the Staplex Company sampler that was fitted with glass fiber filters for the collection of suspended aerosol. Many of these sampling apparatuses also contained an in-line activated charcoal filter stage after the fiber filter. The activated charcoal was effective at capturing the volatile radioactive iodines, but also some aerosols that penetrated the fiber filter. The combination had a normal flow rate between 20 and 30 cubic feet per minute (cfm), SWRHL-1r (1964). During Operation Nougat, 16 permanent air samplers were initially placed at off-site locations, but by the end of this test series, the number was 26.

Fiber air filters were laboratory tested for gross β-particle activity, with follow-on γ-spectrometry to identify individual radionuclides. The majority of SWRHL reports would list air sample results with the highest concentrations of radionuclides, as well as the locations that had positive detections of radioactive material in a sample. For some samples, a slight elevation above typical background rates in the gross β-radiation levels were observed, but the activity on the sample was too low for an isotopic specific identification.

Figures C-6 and C-7 from EPA-600-4-82-061 (1982) show the air sampling network in Nevada and other parts of the US implanted by the EPA in 1982 off-site monitoring. These plots are more applicable to concerns raised by veterans working on TTR and Groom Lake in more recent times. Samplers were at these two locations, as well as Tonopah and Indian Springs AFB. Notably, for each set of monitors, some were part of the EPA air surveillance network (ASN), while others were standby stations. Figure C-10 shows air monitoring stations on NTS during the period of July 1968 to June 1969. Notably, NTS included the Groom Lake area in their on-site monitoring protocol, though this area was technically on NTTR. Figure C-13 provides a map of off-site air sampling stations, dose rate recorders, milk sampling locations, and water sampling locations for Operation Niblick in 1964. Figure C-14 shows the air surveillance network station in Nevada for a series of reactor tests at the NRDS in 1967. This network included sampling at Indian Springs, Tonopah, TTR and Groom Lake, but also a series of temporary air samplers to the north of Groom Lake. This was a common feature of the off-site sampling network – the placement of additional sampling resources in areas of increased monitoring concern.

In 1970, the EPA initiated an air sampling program for tritium (H-3) and noble gases, with extensive details in EPA-402 R-99-005 (1999). Figure C-12 provides a map of sampling sites for these specialized monitoring sites in 1981, EPA-600-4-82-061 (1982). SWRHL-91 (1970) provides extensive technical details on the monitoring systems. Table E-4 contains a list of annual radiological releases from the NTS over the period of 1972 to 1993. For most years, the dominant release was encompassed by noble gases, e.g., Ar, Kr, and Xe, while for a few years, noble gas releases were negligible, leaving the largest release tritium. Tritium was released in greater activity than noble gases in 1978, 1979, 1982, 1983, 1988, and 1989. Though noble gases were not routinely sampled around the NTS prior to 1970, the important radiological impact from noble gases is external radiation only. This source of external radiation was captured by personal dosimeters and the instrumentation described above. The airborne tritium had acceptable levels in air for occupational workers of similar magnitude to the common noble gas emissions from nuclear tests, though the levels vary by the individual noble gas.

2.6.5 Water Sampling.

On and Off-Site water sampling was accomplished to assess impacts from nuclear tests under the Long-Term Hydrological Monitoring Program (LTHMP). Figures C-8 and C-9, respectively show sampling locations near the NTS and on the NTS. Notably, the TTR well # 6 is shown as an off-site location, while the two wells associated with Groom Lake are displayed on the NTS sampling map. On TTR, Sandia National Laboratories (SNL) performed routine well monitoring in support of Safe Drinking Water Act (SDWA) requirements. SDWA has requirements for radionuclide assessment. The referenced list SNL annual site environmental monitoring reports (1983-present). These reports note the results of the EPA's off-site monitoring program for the NTS. SNL sampled water from the same well, #6, as the EPA did in its off-site monitoring program. The SNL maintained a State of Nevada permit for the well as a potable water source, as documented in annual SNL environmental monitoring reports. Figure C-11 shows potable water sampling locations from July 1968 to July 1969. Like the air sampling network on NTS, water wells in the Groom Lake area were monitored as part of the NTS program.

In SNL's 1988 environmental monitoring report, SAND89-1367 (1989), Table 8 lists all potable water wells on TTR which were subject to the SDWA. In addition to the SNL well, the other three were Well BLM, Well AF, and Well 3A. The radiological sampling results were unremarkable for tritium, gross-α, -β, γ-radiations, and isotopic ^{90}Sr and $^{239+240}$Pu. The potential for ground surface deposited radiological contamination at TTR from nuclear tests conducted on NTS and the CS plutonium dispersal tests to reach groundwater sources used for human consumption is remote, due to the depth of groundwater. The depth to groundwater in the vicinity of CS sites are in the range of 59 – 75 m, 111 –

127 m, and 43 – 82 m, respectively at CS 1, 2, and 3, based on Navarro-Intera Report 28091-076 (2013). At the Project 57 site on NTTR, the depth to groundwater at three wells at Groom Lake (Watertown 1, 2, and 3) are respectively 194, 75, and 77 m, Navarro-Intera Report 28091-076 (2013). In relation to surface-deposited plutonium contaminants at the CS and Project 57 sites, the plutonium has poor mobility in soil and subsequently is not expected in deep water well samples.

2.6.6 Milk Sampling. Dairy milk monitoring was a key activity of the PHS and EPA during the period of nuclear testing on NTS. Figure C-13 notes milk sampling among other environmental sampling locations during Operation Niblick. The reference list contains several reports that were solely dedicated to milk sampling, while annual, semi-annual, or operation-specific reports contain detailed sampling results.

2.7 Basics on Ionizing Radiation.

Radiation is simply the emanation of energy in the form of waves or particles from a source. Compared to other energy transport mechanisms, e.g., conduction and convection, radiation does not require a conducting medium, allowing emanation in a vacuum. Radiation can be classified into ionizing and non-ionizing types, dependent on the energy. Ionizing types have sufficient energy to dislodge orbital electrons from atoms and molecules, while non-ionizing radiations do not. Figure 2.7 contains a diagram of various radiation types across the electro-magnetic spectrum. Energy increases from left to right in the diagram, with 60 hertz (Hz) line current and AM broadcast frequencies having lower energies. Types that have sufficient energy for ionization begin on the violet-end of the visible light spectrum, and continue through soft and hard x-rays to highly energetic cosmic rays. There are distinct differences in known adverse health effects between the two forms. The primary adverse health effect from exposures to low-levels of ionizing radiation is increased risk of cancer. This effect is delayed, with the onset taking many years to decades. On the other hand, the primary effects from non-ionizing radiations are those related to the heating of tissue, with adverse effects dependent on the affected tissue. In the example of a visible or near-infrared laser exposure to the eye, if energy deposition on the retina is sufficiently high, thermal injury can occur, providing immediate damage to the affected area and effects on vision.

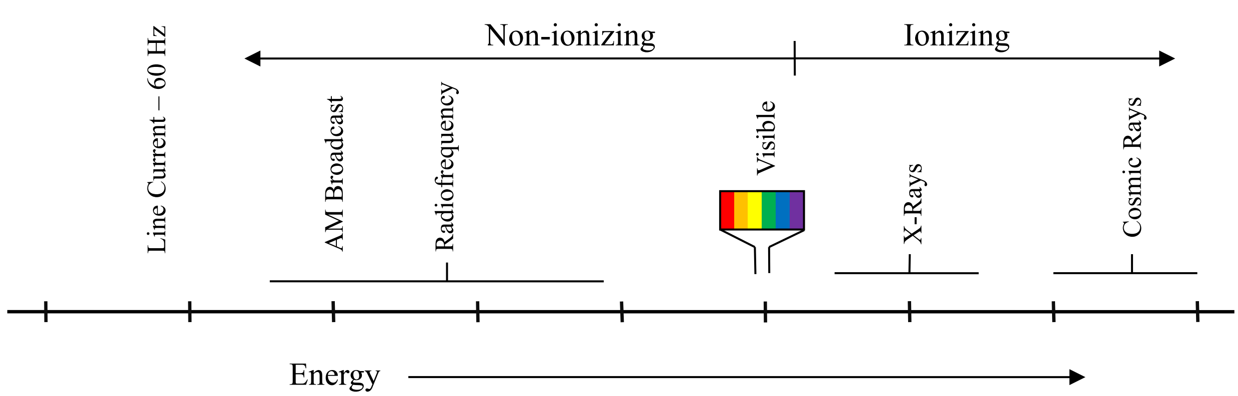


Figure 2-7. Example Emissions across the Electromagnetic Spectrum.

Ionizing radiation is produced as either particles or electromagnetic emissions. They can be produced from the spontaneous decay of radioactive materials or from machines that are specifically designed to produce the radiation, such as medical diagnostic X-ray machines, or coincidental to its operation, like cathode ray tubes used in older televisions. For the scope of this report, ionizing radiation from the spontaneous decay of radioactive materials is important. The magnitude and types of ionizing radiation are specific to the individual radionuclides undergoing decay.

There are five basic radioactive decay mechanisms. Of these, only alpha (α)- and beta (β)-particle decay will be discussed as most pertinent to the scope of this report. α-particle decay is a common decay mechanism for many of the very heavy radionuclides. The example equation in Figure 2.8 illustrates the decay of ^{239}Pu, the primary radionuclide, by mass, in WGP. The α-particle is a helium (He) nucleus, stripped of its orbital electrons, while ^{235}U is the daughter product, also radioactive. β-particle decay is a common decay mechanism for radioactive materials. Figure 2.9 shows the decay of tritium, a radioactive isotope of hydrogen. As depicted in the diagram, the nucleus of tritium contains two neutrons (red) and a proton (blue). When the atom decays, one of the neutrons spontaneously decays into a proton and an electron, which in this case is called a β-particle. The resultant atom is a stable isotope of helium, ^{3}He. β-particles are a singly, negatively-charged particle. On an equal kinetic energy basis, they penetrate much greater distances in materials than α-particles, but lose most kinetic energy in the same manner, through excitation and ionization of atoms and molecules. When a β-particle is emitted for a given isotope, there is a vast range of potential energies. The total energy of the nuclear transformation is split between the β-particle ($\bullet^{-}$) and neutrino, ν, a nearly massless uncharged particle. In contrast, α-particles have discrete energy emissions from decay. Figure 2.10 contains an example of β-particle decay for ^{137}Cs, where a γ-ray is also emitted within minutes by the decay product. Most fission products decay in this manner.

$$^{239}_{94}\mathrm{Pu} \rightarrow {}^{235}_{92}\mathrm{U} + {}^{4}_{2}\mathrm{He}$$

Figure 2.8. Example Decay of Pu-239.

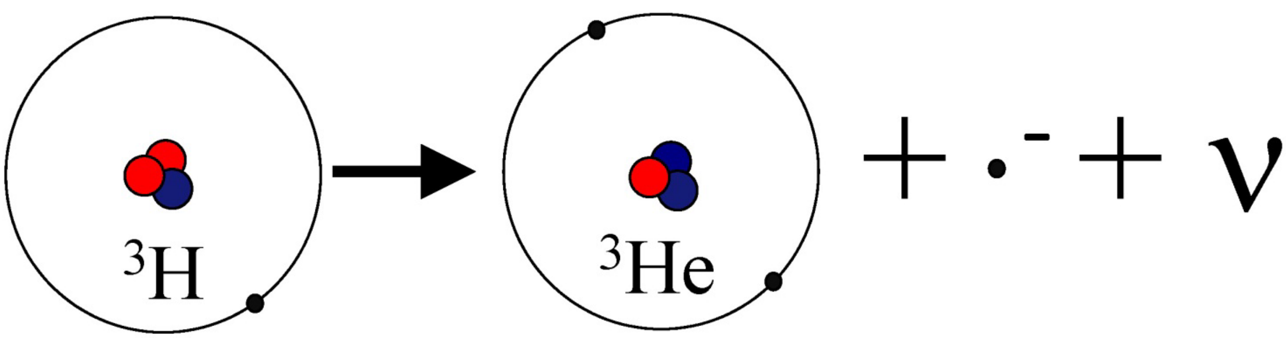


Figure 2.9. β-Particle Decay for Tritium (^{3}H) Atom.

$$ {}^{137}_{55}\mathrm{Cs} \rightarrow {}^{137}_{56}\mathrm{Ba} + \bullet^{-} + \gamma $$

Figure 2.10. β-Particle Decay for ^{137}Cs Atom.

The interactions of ionizing radiation with matter are important in penetrability, measurements of radiation fields, biological effects, and proper interpretation of personnel radiation dosimetry. The interactions of ionizing radiation with matter are important in penetrability, measurements of radiation fields, biological effects, and proper interpretation of personnel radiation dosimetry. In the example of Figure 2.11, kinetic energy of the positively-charged α-particle attracts electrons, exciting some electrons to a higher orbital shell or to be ejected from the atom or molecule (ionization). The overall effect is a loss of kinetic energy in the α-particle and numerous excited atoms, molecules, and electrons, some of which have sufficient energy to ionize other atoms and molecules. Further, while not shown in this illustration, electron removal events can break chemical bonds in molecules. For negatively charged particles, like electrons, kinetic energy transfer is similar, but through electrostatic repulsion of similar charges. In addition, when high-energy electrons interact with nuclei of dense atoms, like lead, tungsten, uranium, etc., part or all the kinetic energy can be converted to a photon (referred to as Bremsstrahlung x-rays).

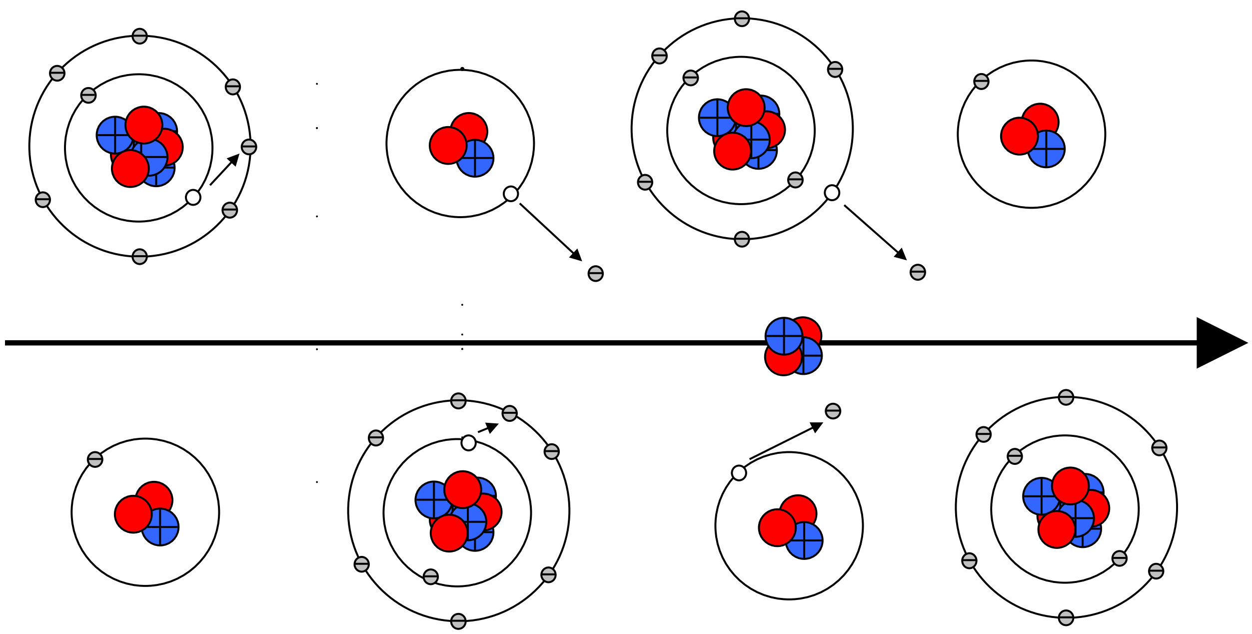
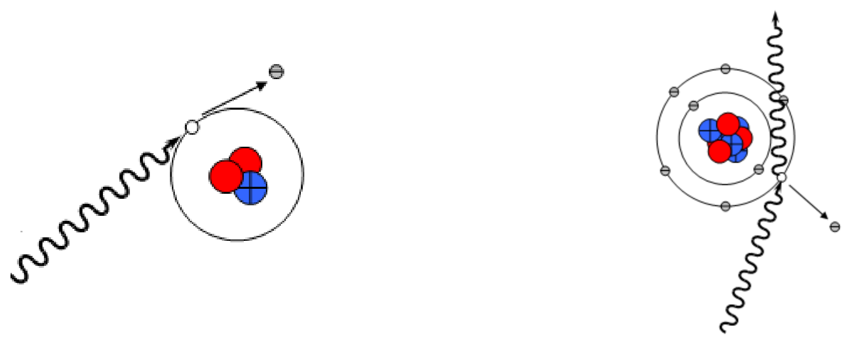


Figure 2.11. Excitation and Ionizations Produced from Transversal of α-Particle.

X- and γ-rays, collectively referred to as photons, have different origins. X-rays are produced outside the nucleus, while γ-rays originate from within the nucleus. Once emitted, the only distinguishing feature is their energy, with gamma rays generally having higher energy. Because photons do not possess charge, they have a significantly lower probability of interaction with matter than charged particles. In contrast to charged particles that directly ionize materials by their traversal, photons are indirectly ionizing, requiring the transfer of energy to charged particles. Figure 2.12a and Figure 2.12b illustrate the photoelectric effect and Compton scatter, respectively.



a. Photoelectric Effect b. Compton Scatter

Figure 2.12. Photon Interactions with Matter.

2.8 Aspects of Radiation Safety for Ionizing Radiation.

2.8.1 External vs. Internal Exposures. Individuals can receive exposures either externally or internally based on the origin of the radiation source. As depicted in Figure 2.13, external exposures originate from sources outside the body, which for nuclear tests is primarily from ground-deposited underground tests, the dominant source of exposure is from sky-shine, as the dominant radioactive radioactive material and sky-shine from a debris cloud passing over a ground area. For underground nuclear tests, most material releases to the atmosphere were in gaseous form. On the other hand, internal exposures result from radioactive materials deposited inside the body, through inhalation, ingestion, skin absorption, injection, or through wounds. Estimates of internal exposures in this report are based on inhalation exposures, because well-based drinking water sources at assignment locations for AF members were monitored and had low potential for impacts.

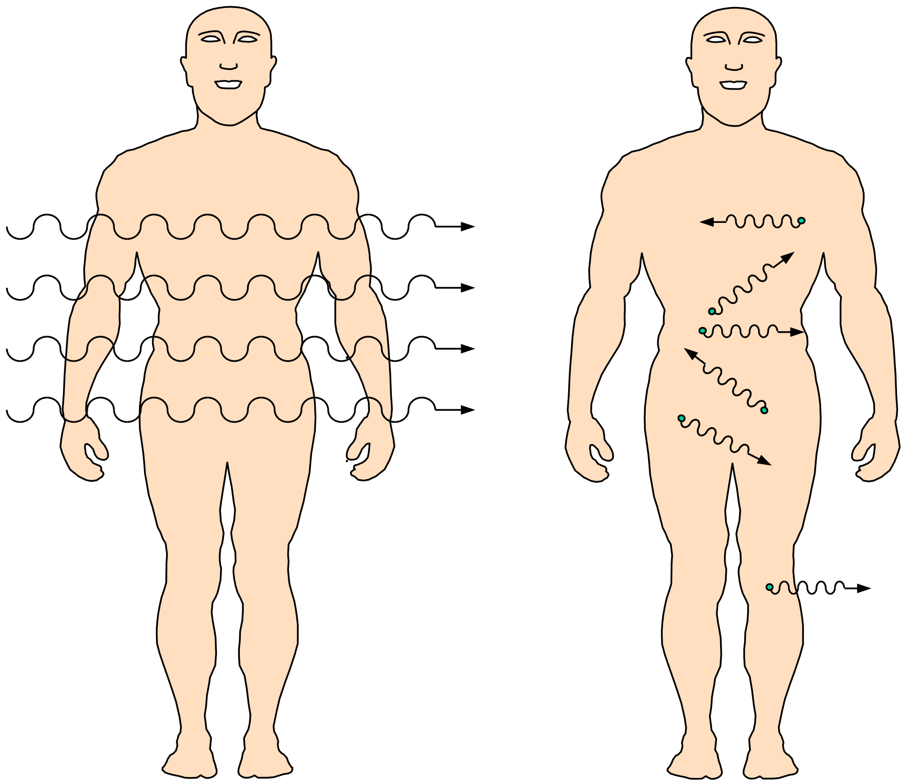
2.8.2 Health Effects from Ionizing Radiation Exposure.

Radiation is one of the most thoroughly investigated causes of disease. Significant study was accomplished on the Japanese atomic bomb survivors and later with worldwide use of nuclear power and stockpile of nuclear weapons. Some of the earliest studies, however, were accomplished at the turn of the 20th century shortly after the discovery of x-rays and radium. Effects are broadly categorized as non-stochastic or stochastic. Non-stochastic effects, also called deterministic, have the following characteristics:

- threshold, below which there is no clinically observable effect,

- dose-effect relationship, where the effect increases with the magnitude of the dose, and

- clear causal relationship.



a. External b. Internal

Figure 2.13. External vs. Internal Exposures.

Deterministic effects generally manifest shortly after acute exposures. Acute radiation exposures are responsible for several syndromes that affect the bone marrow's ability to produce blood cells, degradation of the lining of the gastrointestinal tract, and effects on the central nervous system. These syndromes are related to cell death, or damage preventing the proper division and functioning of a cell, where the functionality of an organ or tissue is related to the degree of impairment. High exposures also produce reddening of the skin, opacity of the lens, temporary or permanent sterility, and other effects. Cell effects are related to damage to constituents of the cell, especially the deoxyribonucleic acid (DNA) strands. Indirect effects of radiation can occur through the production of free radicals in water molecules.

In contrast to deterministic effects, stochastic effects occur randomly and their probability of occurrence is related to the degree of exposure, not to the degree of the detrimental effect. Stochastic effects of ionizing radiation include cancer and genetic effects on germ (reproductive) cells. Since these effects can result from exposure to toxic chemicals (including those in tobacco), genetic predisposition or susceptibility, other environmental or occupational exposures, and endogenous causes, a clear causal relation to an individual's radiation exposure cannot be established. As such, a link to a detrimental effect such as cancer can only be established on a probabilistic basis when the effect occurs with greater frequency than in an unexposed population. Hence, stochastic effects are best understood in terms of population incidence. Also, in contrast to deterministic effects, stochastic effects can have significant delays, sometimes decades, between exposure and an observable manifestation.

Individuals are exposed to low-levels of radiation from a variety of non-occupational sources to include natural background and medical sources, as summarized in Figure 2.14. Among these, medical exposures are the largest, while the largest background source is attributable to indoor radon and its associated decay products. Smaller amounts are from cosmic rays such as muons and pions, emissions from radioactive materials in soils, and from small quantities of radioactive materials in water and food. Figure 2.15 shows terrestrial γ-ray absorbed dose rates for US and Parts of Canada. Due to much higher

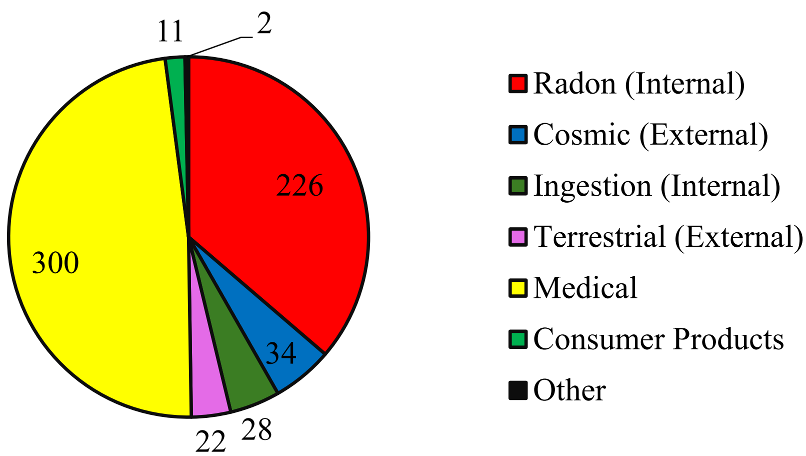


Figure 2.14. Average Annual Dose-Equivalent (mrem) to Americans from Non-Occupational Sources (NCRP 2009).

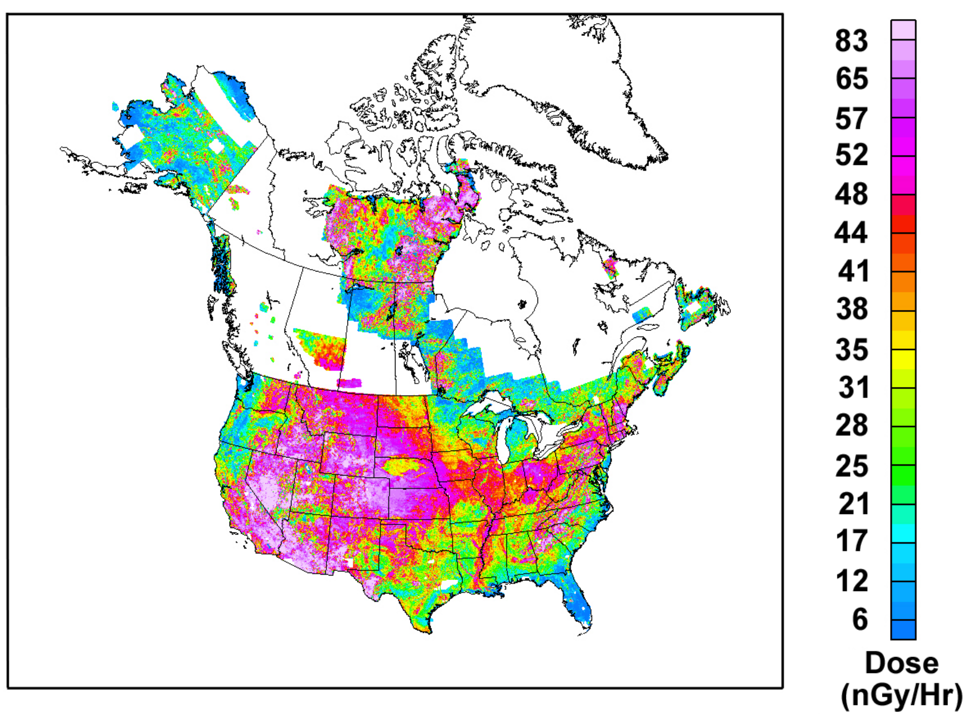


Figure 2.15. Terrestrial γ-Ray Absorbed Dose Rates for US and Parts of Canada, USGS (2005) [For µrad/h, divide by 10; for mrad/h, divide by 10,000].

levels of natural radioactivity in surface soil/rock in many parts of the western US, dose rates are much higher than the US average. The NTS region in Nevada has some of the higher levels. Figure 2.16 shows the cosmic ray dose rates for US, and parts of Canada and Mexico. These dose rates are primarily correlated to altitude, and to a lesser degree latitude. Like the magnitude of terrestrial sources, levels of cosmic ray dose rates in the NTS region are much higher than the US average. These two sources of background radiation contribute to the response of γ-radiation detection systems and dosimeters used in environmental measurements and for personnel monitoring. Commonly, terrestrial radiation is afforded some shielding for the interior of dwellings. Due to the greater penetrating nature of cosmic radiations, as compared to terrestrial γ-rays, interior locations in dwelling do not typically provide the same degree of shielding. Some outdoor locations around NTS provide an annual background dose of about 150 mrem from terrestrial and cosmic sources. Natural annual background at TTR is about 98 mrem, while at Tonopah it is about 112 mrem, SAND85-0551 (1985).

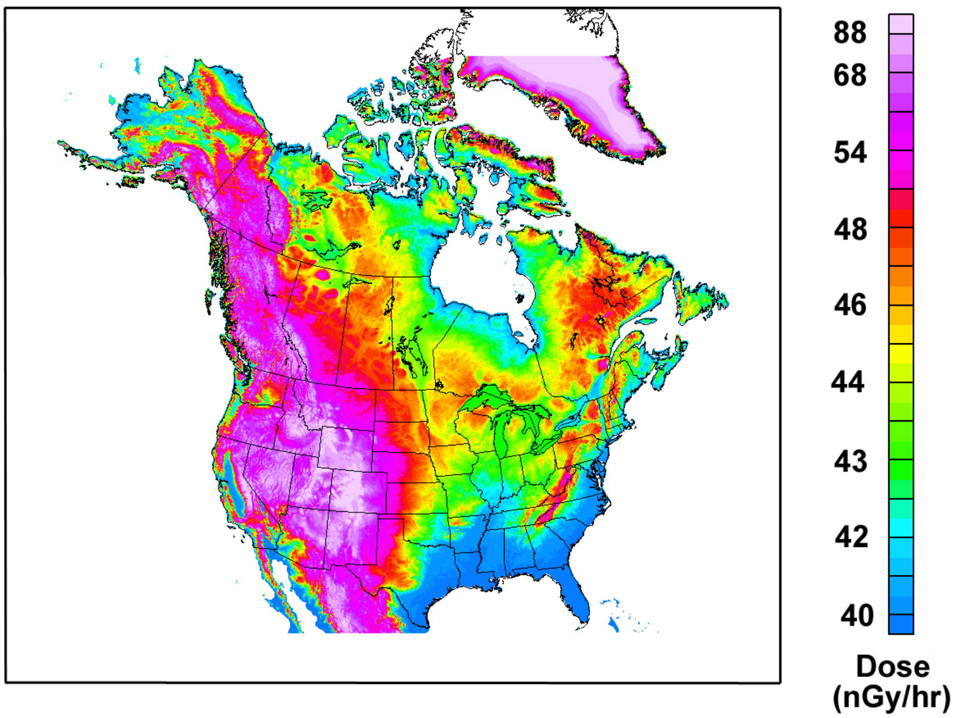


Figure 2.16. Cosmic Ray Dose Rates for US, and Parts of Canada and Mexico, USGS (2005).

Similarly, there are naturally-occurring radioactive materials in air and water. Some are due to long-lived radioactive materials indigenous to soils and rock: ^{232}Th (half-life 14.1 x 10^9 y) and decay products, ^{238}U (half-life 4.5 x 10^9 y) and decay products, ^{235}U (half-life 7.0 x 10^8 y) and decay products, and ^{40}K (half-life 1.3 x 10^9 y). The largest source of radon in air is from ^{222}Rn, a decay product in the ^{238}U decay chain. A commonly identified radionuclide in air is ^7Be, produced in the atmosphere from cosmic ray interactions with oxygen or nitrogen. Others are ^3He, ^{10}Be, ^{14}C, ^{26}Al.

2.8.3 Units for Measurements of Radiation.

2.8.3.1 Activity. The quantity of radioactive materials is quantified by the number of nuclear transformations (decay) per unit time. The traditional unit is the Curie, named after Madame Curie, and is equivalent to 3.7×10^{10} transformations per second (s). The System International (SI) unit is the Becquerel (Bq), which is one transformation per s. In this report, activity is primarily used as a concentration of activity in air, where the volume is cubic meters (m^3). Because most historical reports cited in this report used the traditional unit of Ci, that unit will be used in this report.

2.8.3.2 Exposure. The first quantitative unit adopted for radiation measurements was "exposure," which is a measure of the charge (of either sign) produced in a unit mass of air from photons (x- and γ-ray) interactions. One roentgen (R) is equal to 2.58×10^{-4} Coulombs per kilogram (C/kg) produced in air. Exposure is a convenient unit for photons because a common instrument, the ion chamber, is used to quantify exposure and measures the rate of charge production (or integrated over a period) in a specified volume. For radiation protection purposes, one R is approximately equivalent to one rad (in tissue). Exposure is only defined for photons with energy less than 3 MeV.

2.8.3.3 Absorbed Dose. Absorbed dose is the basic unit to measure the interaction of ionizing radiation with materials, and importantly in the context of this report, humans. Absorbed dose is energy deposited per unit mass, with the SI unit being the Gray (Gy), equivalent to joule/kilogram (J/kg). The more common historical unit used in the U.S. is the rad, which is equivalent to 1/100th of a Gy. This unit is independent of the type of radiation. In this report, traditional units will be more commonly used, as historical documents being referenced used these units.

2.8.3.4 RBE Dose, Dose Equivalent, and Equivalent Dose.

Different forms of ionizing radiation have a varied dose required to produce a given biological endpoint, e.g., cell killing, genetic alteration, or cancer induction. In radiobiology, this effect is termed relative biological effectiveness (RBE). In general, radiation types with high linear energy transfer (LET) tend to have higher RBEs than radiation types with low-LET. LET is simply the amount of energy transferred by radiation along an interaction track in matter. Among the types of radiation discussed above, α-particles are high-LET, depositing dense patterns of ionization along their tracks. On the other hand, photons (x- and γ-rays) and β-particles are low-LET, sparsely depositing energy along their tracks.

Table 2-11 provides modification factors to dose to account for the varied RBE implemented by the International Commission on Radiological Protection (ICRP) over the period of 1959 to 2007. Standards in use within the US commonly reference ICRP recommendation. ICRP, in Report 2 used the term RBE to modify the absorbed dose in units of rad into an "RBE dose," which used the unit of rem. The term dose was used for either absorbed dose (e.g., rad) or RBE dose, which used the units of rem. During the early period of underground testing, the principles of ICRP Report 2 were implemented in the US. For the radiation types within the scope of this report, the RBE of 1 was used for electrons and photons, while 10 was used for α-particles. While electrons and photons were important for radiation exposures associated with fission and activation products, assessment of internal exposure potential from WGP on the CS sites on TTR, and Double Tracks and Project 57 have greater impacts from α-particle exposure evaluations. In the US, NBS Handbook 69 (1959) and NCRP Report 22 (1959) had almost identical criteria to ICRP Report 2. Over the course of the four sets of ICRP recommendations, there have been changes in the application of RBE. ICRP Report 4 (1964) introduced the use of quality factor (Q or QF) to replace use of RBE for modification of dose for the various types of radiation and introduced the use of dose equivalent (DE) as the measure of absorbed dose modified by Q, an almost identical criteria to ICRP Report 2. Over the course of the four sets of ICRP recommendations, there have been changes in the application of RBE. ICRP Report 26 used this unit in its 1977 recommendations update, but used the abbreviation, *H*, for dose equivalent. ICRP Reports 26, 60, and 103 changed the modification factor for α-particles to 20, yet kept the factor of one for photons and electrons. Quality factor was replaced with radiation weighting factor, w_R, in ICRP Report 60 (1990), which continued in its Report 103 (2007). The radiation modification factors discussed here were developed for stochastic effects from radiation, with induction of cancer being the primary interest.

Table 2-11. ICRP Report 2 RBEs, Report 26 Quality Factors (Q) and Reports 60 and 103 Radiation Weighting Factors (w_R).

<table>
<tr><th colspan="2">Type and Energy Range</th><th>RBE (Report 2) 1959</th><th>Q (Report 26) 1977</th><th>w_R, (Report 60) 1990</th><th>w_R, (Report 103) 2007</th></tr>
<tr><td colspan="2">Photons, all energies</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td colspan="2">Electrons, positrons, muons*</td><td>1, 1.7 for (E_m < 30 keV)</td><td>1</td><td>1</td><td>1</td></tr>
<tr><td rowspan="5">Neutrons</td><td>< 10 keV</td><td rowspan="6">Not defined, further guidance in ICRP Report 4 (1964)</td><td>2</td><td>5</td><td rowspan="5">Continuous Distribution</td></tr>
<tr><td>10 to 100 keV</td><td>5</td><td>10</td></tr>
<tr><td>0.1 to 2 MeV</td><td>10</td><td>20</td></tr>
<tr><td>2 to 20 MeV</td><td>8</td><td>10</td></tr>
<tr><td>> 20 MeV</td><td>5</td><td>5</td></tr>
<tr><td colspan="2">Protons, other than recoils</td><td>10</td><td>5 (energy > 2 MeV)</td><td>2 (also +/- pions)</td></tr>
<tr><td colspan="2">α-particles, fission fragments, heavy nuclei</td><td>10 (α)
20 (others)</td><td>20</td><td>20</td><td>20</td></tr>
</table>

* Not discussed until Report 60.

ICRP Report 60 replaced the term, dose equivalent, with equivalent dose, H_T, which provides a summed modified dose from all types of radiation in a tissue or organ. This unit remained essentially the same in ICRP Report 103. The SI unit for dose equivalent and equivalent dose is the Sievert (Sv). One Sv is equivalent to 100 rem. Within the scope of fission and activations product exposures discussed in this report, the absorbed dose, and either dose equivalent or equivalent dose should be the same. As an extension, external exposures from photons in units of R are assumed to be of the same magnitude as absorbed dose, dose equivalent, and equivalent dose.

2.8.3.5 <u>Critical Organ Concept, Committed Dose Equivalent, and Committed Effective Dose</u>.

Application of radiation safety principles of internal exposures to radioactive materials are more complicated and varied than the protection from external sources of radiation. Early radiation protection standards developed by the ICRP and the NCRP in the early 1950's limited radiation exposures by the critical organ concept,

> "*A critical organ is defined as that organ of the body whose damage by a given radiation source results in the greatest impairment to the body. Criteria appropriate to the determination of critical organs for external or internal exposure are: (1) the radiosensitivity of the organ, i.e., the organ damaged by the lowest dose; (2) the essentialness or indispensability of the organ to the well-being of the entire body; (3) the organ that accumulates the greatest concentration of the radioactive material; and (4) the organ damaged by the radionuclide enroute into, through, or out of the body*."

The concept was based on the standard for radium developed in the US in 1941, National Bureau of Standards (NBS) Handbook H27 (1941). The standard recommended a limit of 0.1 μg of radium in the skeleton. This standard was later modified for application to plutonium, another α-particle emitter which had a propensity for deposition and retention in the bone. In relation to fission products produced from nuclear tests, radioactive iodines have the thyroid as the critical organ, with the ICRP Report 2 limited by the dose to this organ of 0.3 rem per week. For some radionuclides like ^3H, which has a somewhat uniform deposition and retention across all organs of the body, limits under ICRP were based on dose to the total body. In ICRP Report 26, the Commission developed a radiation exposure limiting system based on the total risk of all tissues irradiation. The system implemented a single whole-body dose equivalent limit, but developed a system to weigh dose equivalent to individual tissues when doses were not equal to all tissues, but maintained a higher limit for any individual tissue or organ. With some changes, this system was also used in ICRP Reports 60 and 103. Table 2-12 lists the individual tissue weighting factors for ICRP Reports 26, 60, and 103. The method developed by ICRP Report 26 used an annual limit of exposure. For internally-deposited radionuclides, the dose equivalent accumulated in an organ or tissue over 50 y was applied to the year of an intake and termed the committed dose equivalent (CDE), H_{50}. The weighted sum (e.g., by w_T) of CDE among tissues was termed the committed effective dose equivalent (CEDE). The summation of CDE and external doses was termed the total effective dose equivalent (TEDE). Similar units were developed for ICRP Report 60 and 103. The equivalent dose accumulated in an organ or tissue over 50 y was termed the committed equivalent dose, with the weighted sum over all tissues being the committed effective dose. The summation of external and internal dose contributions are termed effective dose, E. For estimates of internal dose from inhalation of airborne contamination from nuclear tests contained in this report, ICRP Report 60 methods were used, and internal doses are simply referred to as effective dose.

2.8.3.5 Exposure Limits Established for Off-Site Populations Surrounding NTS.

SWRHL-1r (1964) lists exposure limits established by the AEC for off-site populations for tests planning purposes. The external whole-body exposure limit to γ-radiation was set at 3.9 R per year, but not more than 10 R in any 10 consecutive year period. These limits included exposures from non-weapons test activities, but excluded background sources of radiation and medical x-rays. Maximum permissible concentrations of radioactivity in air and in water, milk, and foodstuffs were not to exceed one-tenth the permissible continuous exposure concentrations listed in NBS Handbook 69 (1959), assuming the concentrations could be averaged over one year. The non-weapons tests activities would have included test reactor releases and Plowshare tests. For controlled releases, a limit of 0.5 R

TABLE 2-12. Tissue Weighting Factors, w_T.

Tissue	ICRP 26	ICRP 60	ICRP 103
Gonads	0.25	0.2	0.08
Breast	0.15	0.05	0.12
Red bone marrow (RBM)	0.12	0.12	0.12
Lung	0.12	0.12	0.12
Thyroid	0.03	0.05	0.04
Bone surfaces (BS)	0.03	0.01	0.01
Colon	-	0.12	0.12
Stomach	-	0.12	0.12
Bladder	-	0.05	0.04
Esophagus	-	0.05	0.04
Liver	-	0.05	0.04
Brain	-	-	0.01
Kidney	-	-	-
Salivary glands	-	-	0.01
Skin	-	0.01	0.01
Remainder	0.30*	0.05§	0.12

* Five remaining tissues with the highest dose equivalent values, w_T = 0.06 for each tissue
§ Remaining tissues: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus, and uterus. If a single tissue among remainder tissues has an equivalent dose greater than one with a specified w_T, then a w_T of 0.025 shall be applied to that tissue with 0.025 applied to the average of the other remaining tissues.

for any individual or 0.17 R for population groups, EPA-600-8-87 (1988). These exposure standards were used until 1976.

In 1977, the Energy Research and Development Administration (ERDA) lowered the exposure limits for tests planning purposes to 500 mrem per year for an individual or 170 mrem for population groups from external exposures, air and water concentrations were limited to 1/30 of the continuous exposure levels listed in NBS Handbook 69, EPA-600-8-87 (1988). No special limit was established for controlled releases.

In 1986, the DOE established an annual effective dose equivalent limit of 500 mrem per year, which incorporated the ICRP 26 framework of combining external and internal exposures, with a series of publications under ICRP Report 30 (1977 – 1982). The 500 mrem limit was established under the "occasional" provision, with the expectation that it would occur over only a few years, but over prolonged periods it would average less than 100 mrem/y. For comparison purposes, Table 2-13 contains the occupational exposure guidance of the EPA promulgated by a 1987 Presidential order. This guidance included use of ICRP Report 26 methods for internal exposures. The Nuclear Regulatory Commission (NRC) adopted these criteria in 1991, with implementation in 1994.

2.8.3.6 Maximum Concentration Limits, Derived Air Concentrations, and Other Factors.

ICRP Report 2 contains maximum concentration limit (MCL) values for air and waterborne radionuclides. These values were guidelines to control exposures. For occupational workers, the values were tailored to a 2,000-hour work year, while for members of the public continuous exposure scenarios were assumed. ICRP Report 30 used a similar approach for occupational exposures, but used the term derived air concentration (DAC). SWRHL and EPA reports summarizing measured airborne radiological concentrations commonly compared them to MPCs for air, and later to DAC values. In relation to emissions from effluents from atmospheric tests, it is important to understand that the effluent releases were commonly limited to brief periods. For effluent releases from individual tests, this was commonly limited to a few hours or periods of a few days. Under these conditions, the comparison to MPCs and DACs have limited use, unless airborne concentrations are weighted over an annual period.

TABLE 2-13. Federal Guidance Report 11, Occupational Exposure Guidance, EPA-520/1-88-020 (1988).

Application	Criterion
Effective Dose Equivalent (EDE)	5 rem (0.05 Sv) in a year
Deep Dose-Equivalent and Committed Dose Equivalent (internal)	50 rem (0.5 Sv) to an individual organ or tissue (except lens) in a year
Dose Equivalent to Lens of the Eye	15 rem (0.15 Sv) in a year
Dose Equivalent to Skin	50 rem (0.5 Sv) in a year
Dose Equivalent to Extremities	50 rem (0.5 Sv) in a year

Dose conversion factors (DCFs) are useful in the conversion of internal intakes into doses, dose equivalent, etc. The DCF was used by the EPA in Federal Guidance Report 11, EPA-520-88-020 (1988), and later reports published by the EPA. The ICRP uses the term dose coefficient (DC) in its publications that follow ICRP 60 and 103. DC are used for tissue equivalent and effective dose. Appendix D contains DC values for some radionuclides pertinent to the scope of this report.

2.9 Brief History of AF Installations Around NTS.

2.9.1. Indian Springs AFB. Indian Spring AFB was located one mile to the NW of the community of Indian Springs, on Hwy 95, and lies about 35 miles NW of Las Vegas. The base is now known as Creech AFB. The airfield was originally established in 1942 by the US Army Air Forces as an auxiliary landing field for the parent installation, Las Vegas Army Airfield. Indian Springs AFB was re-opened in 1949 by the AF as part of Air Training Command. In 1952, the AFB was transferred to Air Research and Development Command and realigned under the AF Special Weapons Center. The installation provided ground support to aircraft supporting nuclear tests at the NTS. In 1961, the installation was assigned to Tactical Air Command. In 1964, it was re-designated as Indian Spring Air Force Auxiliary Field and assigned to Nellis AFB. The Field provided support to the Nellis and Training Range, which later was re-designated the Nevada Tests and Training Range (NTTR). In 1992, Tactical Air Command was inactivated, and the installation fell under Air Combat Command. In 1996, the Field supported the first RQ-1 Predator flight. In 2005, the installation was re-designated Creech AFB and remains operational today.

2.9.2 Tonopah Air Force Station (AFS). Tonopah AFS was located on the southern part of the Town of Tonopah, south of the intersection of US Highways 6 and 95. The AFS became operational in 1956, with the establishment of an Aircraft Control and Warning Squadron, as part of Air Defense Command. The AFS was inactivated in 1970.

2.9.3 Stead Air Force Base. Stead AFB originated as Reno Army Base in 1942. In 1951, its was named Stead AFB. The base served as a multi-service training center from 1954 to 1964, specializing in basic survival advantaging the harsh mountain terrain near the base. The base also supported Air Defense Command with the Semi-Automatic Ground Environment Direction Center. This mission was operational at the base from 1959 to 1966. The base was transferred to civilian use in 1966 as an airport. Due to the distance of about 250 miles between Mercury and Reno, NV, and the location of Reno to the NW of the NTS, this report will not provide discussion on radiological impacts from NTS nuclear tests, though reports referenced in this report do contain pertinent monitoring data for this location.

2.9.4. Fallon Air Force Station. The former Fallon AFS is located within Naval Air Station Fallon. It is southeast of Fallon, NV. Air Defense Command operated a general surveillance radar at this location from 1956 to 1975. The airfield was built in 1942 as a defense site during WWII. Prior to 1972, it was a Naval Auxiliary Field and used for aviation training to support the Vietnam War. The facility remains in use today by the Navy. Due to the distance of about 240 miles between Mercury and Fallon, NV, and the location of Fallon to the NNW of the NTS, this report will not provide discussion on radiological impacts from NTS nuclear tests, though reports referenced in this report do contain pertinent monitoring data for this location.

2.9.5 Tonopah Test Range.

The TTR was established in 1957 as an isolated location for the AEC to test ballastics and nonnuclear features of atomic weapons. AEC's use of the site was based on a memorandum of understanding with the Air Force in 1956. Sandia began operations at TTR after similar facilities at Salton Sea, CA, and Yucca Flat, NV became inadequate, SAND-85-0551 (1985). In relation to the scope of this report, the CS sites are detailed later in this report. In addition to these sites, details will be provided on other environmental corrective actions. With early operations on TTR being conducted by the AEC, some AF operations on the range were initiated in 1974, with establishment of the 554th Range Group. In 1977, CONSTANT PEG was established with the 4477th Test and Evaluation Flight at Nellis AFB and TTR, AF Historical Research Agency (2022). In 1980, the unit was re-designated the 4477th Test and Evaluation Squadron, AF Historical Research Agency (2022). CONSTANT PEG was an AF, Navy, and Marine Corp program to train US aircrew to fly against Soviet designed aircraft, National Museum of the AF (2025). The TTR infrastructure was greatly expanded in 1979 with facility design and construction oversight by Holmes and Narver, and Reynolds Electrical and Engineering Co. (REECO). The 4450th Tactical Group started operations in 1979 at TTR in support of the F-117A program, Tactical Air Command (1991). Upon initial announcement of the F-117A program in 1988, the F-117A program was transferred to the 37th Tactical Fighter Wing, with use of the aircraft in Operations Just Cause and Desert Storm. The F-117A mission was assigned to the 49th Fighter Wing at Holloman AFB, NM in 1992. Currently, the NNSA conducts operations at TTR, though the land is under the Bureau of Land Management authority and managed by the AF. SNL has been delegated responsibility for operations at TTR by AEC, ERDA, and DOE since 1969.

2.9.6 Groom Lake.

The Central Intelligence Agency (CIA) with the assistance of the AEC initiated development of an aircraft test on the northeast corner of the NTS in 1955 to support development of the U-2 aircraft program, CIA (2015). The area contained a dry lake bed, Groom Lake, that provided an excellent landing field and remoteness that aided in program security, CIA (2015). The location has been previously used by Army pilots in WWII, CIA (2015). CIA, AF and private industry personnel supported the development of the U-2 program at Groom Lake, CIA (2022). Operations in 1955 were conducted after the last aboveground nuclear test under Operation Teapot, 15 May. The AEC controlled operations at Groom Lake during the series of nuclear tests conducted in 1957 under Operation Plumbbob. Plumbbob tests were conducted from May until October 1957, though the test program for the U-2 had moved to Edwards AFB, CA in June of this year, while operational U-2's were assigned to the 4028th Strategic Reconnaissance Squadron, Laughlin AFB, as noted by Merlin (2023).

A predecessor aircraft to the SR-71, the CIA's A-12 was also flight-tested at Groom Lake. The first A-12 flight-test was conducted on 25 April 1962, CIA (2015). The AF currently maintains operational control of the facilities at Groom Lake.

2.9.7 Boron Air Force Station. Boron AFS, CA, is West-Northwest of Barstow, CA. It was part of Air Defense Command. It maintained operational radar system from 1952 to 1975. Due to the distance of about 180 miles to the west-southwest of NTS and generally unfavorable atmospheric conditions for contamination transport, no further discussion will be provided in this report.

2.9.8 Nellis AFB, NV. Nellis AFB is located to the east of North Las Vegas. Nellis AFB was named in 1950 from the previous Las Vegas AFB. During above-and underground nuclear tests, there was extensive radiological monitoring of the City of Las Vegas area. Due to this condition, radiological impacts to Nellis AFB are expected to be similar to those for Las Vegas. No further discussion will be provided in this report.

3.0 Radiological Exposure Evaluations.

3.1 Operation Roller Coaster and Project Sites.

3.1.1 History.

The Roller Coaster series of tests evaluated storage and transportation safety involving the release of Pu due to conventional explosives detonations. The tests were considered by the AEC and DoD a continuation of Projects 56 and 57 to define the problems associated with scattered plutonium, POIR-2500-Vol 1 (1963). Project 56 involved four plutonium dispersal safety experiments conducted in November 1955 (3) and January 1956 (1) on Area 11 of NTS and the Project 57 test conducted in April 1957 on NTTR. The tests had an extensive network of air monitoring designed to evaluate airborne concentration of plutonium in the event of an accidental, conventional high explosive detonation. The tests involved exposure to dogs, sheep, and burrows to airborne releases, POIR-2500-Vol 1 (1963).

Extensive ground measurements were made with portable α-particle and γ-radiation detection systems, which supported contour plots of ground deposition density of plutonium, $\mu g/m^2$ POIR-2500-Vol 1 (1963). Figures G-1 through -6 contain example plots from POIR-2500-Vol 1 (1963), which show details of deposition density from very close-in out to 48,000 ft. Integration of the contour plots down to 1 $\mu g/m^2$, provided plutonium quantities encompassed by each site: 206 g (Double Tracks), 65 g (Clean Slate 1), 275 g (Clean Slate 2), and 202 g (Clean Slate 3). Using a specific activity estimate of 0.066 Ci/g, the estimated activity for each site within the surveyed area was: 13.7, 4.3, 18.2, and 13.4 Ci, respectfully. Later surveys had estimates that varied from these, as they were based on different criterion. The Clean Slate sites had some blading accomplished after the tests to cover “hot spots,” e.g., areas with higher concentrations of plutonium in surface soils, while the Double Tracks site was never disturbed in this manner, SAND 87-0605 (1987).

In addition to the mapping of ground-deposition patterns, extensive airborne sampling was conducted within the radiation exclusion (RADEX) zones and at greater distances, many of which were at off-site locations. The RADEX zones were established near each test site for personnel safety purposes. About 1,300 air sampler devices were used in the four experiments. Air sampler numbers were the greatest within RADEX zones, which also possessed a greater number of cascade impactor types of samplers. These allowed discrimination between respirable and non-respirable fractions of the sampled aerosol. On the other hand, samplers at substantial distance were primarily air filter samples, which contained combined respirable and non-respirable fractions.

Figure G-8 contains a plot of respirable aerosol contours for the Double Tracks (DT) safety shot. The grid arc distances used for the Roller Coaster tests are listed in Table 3-1. The contours are in units of $\mu g\text{-}sec/m^3$, with $^{239+240}Pu$ mass-integrated concentration over the air sampling period. Under an assumed $^{239+240}Pu$ specific activity of 0.066 Ci/g, multiplication by 18.33 allows conversion to units of $pCi\text{-}h/m^3$. The air monitoring conducted within the RADEX for each Roller Coaster test provided a basis for exposures under accident conditions. This information was useful for planning purposes in the event of a future accident. Nevertheless, personnel supporting the Roller Coaster tests within RADEX zones were afforded respiratory protection. As such, the integrated airborne concentrations of $^{239+240}Pu$ serve a limited purpose for this report. DoD civilians and service members provided support to the AEC for Operation Roller Coaster. They were incorporated into the radiation safety program established by

TABLE 3-1. Roller Coaster Sampling Grid Distances, from POIR-2500-Vol 1 (1963).

Contour	Distance (ft)	Contour	Distance (ft)	Contour	Distance (ft)	Contour	Distance (ft)
A	1250	F	7500	K	15000	P	35000
B	2500	G	8750	L	17500	Q	41250
C	3750	H	10000	M	20000	R	48000
D	5000	I	11500	N	23500		
E	6250	J	13000	O	28500		

the AEC and listed in DASA Report HRE-925 (1963). Location dependent, respiratory protection requirements ranged from supplied air for those within 300 feet of the GZ (after detonation and cleared for re-entry) to full-face respirators for personnel in contaminated areas 13k to 50k feet from GZ, POIR-2500-Vol 2 (1963). Personnel within 300 feet of GZ were required to wear a double layer of anti-contamination clothing. The 100 $\mu g/m^2$ plutonium aerial concentration contour was expected to be within the 13k foot distance from GZ, based on pre-test predictions in DASA Report HRE-925 (1963). Figure G-23 contains predicted airborne concentrations adapted from the Maxwell and Anspaugh model (Figure G-22) for varied plutonium areal concentrations on soil surfaces and times after deposition.

Figure G-7 shows air sampling locations outside of the RADEX zones established for each test. Air sampling locations were in publicly-accessible locations, as shown on the map in Figure G-7, as well as others on TTR and NTTR. The most prominent locations on TTR and NTTR for air sampling outside of the RADEX samples were from the SW to SE, due to the generally S to SE prevailing wind conditions among the tests on their respective test days. Table G-1 lists air sampling results, as separated by test. Locations within the scope of interest of this report are highlighted in gray, e.g. Tonopah, Groom Lake, TTR, and Indian Springs. Because three of the Roller Coaster tests were conducted on TTR, the sample at the TTR Operations was deemed of importance, as this location was outside of RADEX zones. Data in Table G-1 was compiled from two sources: DASA Report WT-2511 (1968) and SC-RR-69-788 (1970). The latter report contains time-integrated airborne concentration values, but without details on sampling period, volume, and mean $^{239+240}$Pu concentrations. DASA Report WT-2511 contained details on sampling period, volume, and mean $^{239+240}$Pu concentrations, except for samples that did not have a positive detection for $^{239+240}$Pu. The table contains color-shaded cells to denote the source of data. For time-integrated airborne concentrations in μg-sec/m^3, the value of 18.33 was used to convert to units of pCi-h/m^3. Estimated inhalation intakes for an individual present at the sampling location were based on a breathing rate of 0.54 m^3/h. Multiplication of this value by the time-integrated airborne concentration provides an estimated intake in units of pCi.

For locations outside TTR and NTTR, the DT test produced the greatest time-integrated airborne concentrations of $^{239+240}$Pu. This was due to three factors: the DT GZ was closer to the NTTR western boundary, the prevailing winds were to the south, while the Clean Slate test had more SE prevailing winds, and the DT test was on a bare pad testing condition. Clean Slate tests 2 and 3 were simulated igloo storage conditions (POIR-2500-Vol 1 1963), which afforded greater mitigation of the airborne releases. Table 3-2 contains summary excerpts from Table G-1, with details on airborne monitoring results at Tonopah, Groom Lake, Indian Springs, and the TTR Operations monitoring station. In addition, the highest three results for publicly accessible area samples for DT are listed as the highest for

CS1. For each sample, the estimated effective dose from inhalation is provided using DC values from Table D-4 if a positive intake was listed. Clear from Table 3-2, estimated intakes and effective doses are very low at Tonopah, TTR, Indian Springs, and Groom Lake. Additionally, the estimated inhalation intakes at off-NTTR/TTR locations are low, with the highest being from DT. Stake 76 was located at an asphalt batch plant along Hwy 95 and had a projected effective dose of 10.0 mrem.

TABLE 3-2. Summary Excerpts from Table G-1 and Effective Dose from Inhalation of $^{239\text{-}240}Pu$.

Location	Test	Sampling Dates	Estimated Intake (pCi)	*Effective Dose (mrem)
Tonopah	DT	14 – 16 May	0.20	0.020
TTR (Operations)	DT	14 – 16 May	0.30	0.031
Indian Springs	CS1	24 – 27 May	0.0	-
Tonopah	CS1	24 – 27 May	0.20	0.020
TTR (Operations)	CS1	24 – 27 May	0.0	-
TTR (Operations)	CS2	31 May – 1 Jun	0.17	0.017
Indian Springs	CS2	30 May – 1 Jun	0.0	-
Tonopah	CS2	30 May – 1 Jun	0.0	-
Groom Lake	CS2	30 May – 1 Jun	0.0	-
Groom Lake	CS3	8 – 10 Jun	0.0	-
Indian Springs	CS3	8 – 10 Jun	0.0	-
Tonopah	CS3	8 – 10 Jun	0.0	-
Stake 76 (Asphalt Plant)	DT	14 – 15 May	98.0	10.0†
Beatty	DT	14 – 16 May	94.0	9.6
Scotty's Junction	DT	14 – 16 May	74.2	7.6
Lathrop Wells	CS1	26 – 28 May	2.2	0.22

* ICRP 103/130/141, Type S, 1 μm AMAD † Committed Equivalent Dose (mrem): lungs-54.4, liver-27.5

The Roller Coaster series of tests also had similarity to the 22 tests at the GMX site on Area 5 of NTS. This site was smaller in physical size than the Clean Slate sites but did have surface-deposited plutonium that was studied and managed by the AEC in a similar manner.

3.1.2 Early Environmental Measurements on Sites.

Operation Roller Coaster sites were resurveyed on a quarterly basis shortly after the tests were conducted in late spring of 1963. The purpose of the surveys were to determine the current radiological conditions and to repair exclusion fences, barricades, and radiation warning signs at appropriate locations, NVO 162-17 (1964). The most common radiological sampling conducted in these surveys was surface emissions of α-radiation from the ground-deposited plutonium. Other samples included vegetation, soils, water, and air. Figure G-9 contains a plot of α-radiation measurements on surface soils of the CS2. The surface measurements were collected with portable survey instruments, while air sampling details are provided for two samples collected along Arc A, 1,250 ft from GZ, and Arc B, 2,500 feet from GZ. The results of the air samples are listed in Table G-2. As these samples were analyzed for gross α-radiation, some contributions to the total activity were also provided by naturally-occurring α-particle emitters, e.g., ^{238}U, ^{235}U, ^{232}Th and their daughter products. The respective Arc A and B air sample results were 61 and 35 pCi/m^3, which in the range of the ICRP Report 2 MPC of

40 pCi/m^3 (see Table D-5). Importantly, the MPC values were developed for a 2,000 h work year. Presence of personnel at locations close to the GZ would have only been for brief periods during a year, but limited to those with duties supporting scientific studies and site maintenance.

Within a couple years of the tests, the Roller Coaster sites were evaluated on an annual basis. The surveys were similar to the quarterly surveys in assessment of soils, vegetation, and air samples, and evaluation of perimeter fences. The survey results for surface α-radiation measurements on surface soils of the CS1, at a distance of 1,250 ft from GZ. The most notable difference from the survey conducted one year after the test is the substantial reduction in detectable α-radiation on the soil surface. This reduction directly impacts the airborne resuspension of contamination from the site. Air sampling results listed in Table G-3 for each of the four Roller Coaster sites illustrate this condition. Air samples collected within the general area of the interiors of each site have gross α-radiation levels less than one pCi/m^3. Air samples collected downwind of the exclusion fences were even lower than those collected within the fenced areas.

Overall, plutonium deposited on the surface of materials has a degraded response to α-particle measurement instrument that occurs over a short period after initial deposition. The plot in Figure 3-1 illustrates this phenomenon for measurement conducted at Roller Coaster sites. For plutonium deposited on soils, the impacts to airborne resuspension have been studied at several of the sites on NTS, NTTR, and TTR, and modelled over decades by various researchers. Figure G-22 is a more recent airborne resuspension model by Maxwell and Anspaugh (2011). This model shows a drop in the resuspension factor by three orders of magnitude over the first 100 days and by four orders of magnitude for periods after about six years.

3.1.3 Environmental Measurements 1970 – mid-1990s.

Between 1970 and 1980, the Nevada Applied Ecology Group initiated intensive studies on plutonium in the environment on numerous sites on the NTS, TTR, and NTTR. Much of the key findings for this research formed the basis for information contained in the 1975 EA for TTR, ERDA 79-2 (1975). Also, since the bases for ecological and human health issues were very similar across these sites on NTS, TTR, and NTTR, many conclusions were mirrored in the 1977 EA for the NTS, ERDA 1551 (1977). These studies formed a foundation for current health assessments for plutonium in the environment, with findings in several other Nevada Operations Reports: NVO-142 (1974), NVO-166 (1976), NVO-171 (1977).

In the early 1970's, radiological surveys were conducted on plutonium safety tests in Area 5 of NTS, Project 57 and Double Tracks (on NTTR), and the Clean Slate Sites on TTR. The surveys were conducted with field instruments for the detection of low-energy radiation (FIDLER). These surveys were designed to estimate the current extent and amount of plutonium contamination on each site. Table G-6 contains information on the Roller Coaster sites, while Figure G-30 contains survey measurement isopleths for the Project 57 site. In addition, air sampling was conducted on many of these sites, which supported the establishment of relationships between contamination levels in surface soils and airborne contamination, e.g., similar to the plot in Figure G-22. Figures G-11 and G-12 contain $^{239+240}$Pu airborne concentrations at various locations around the GMX site, Area 5 on NTS, from NVO-142 (1974). The plot also contains FIDLER measurement contours, based on a 1971 survey. Airborne sampling data corresponding to that annotated on Figures G-11 and G-12 are listed in Table G-5, but in units of pCi/m^3.

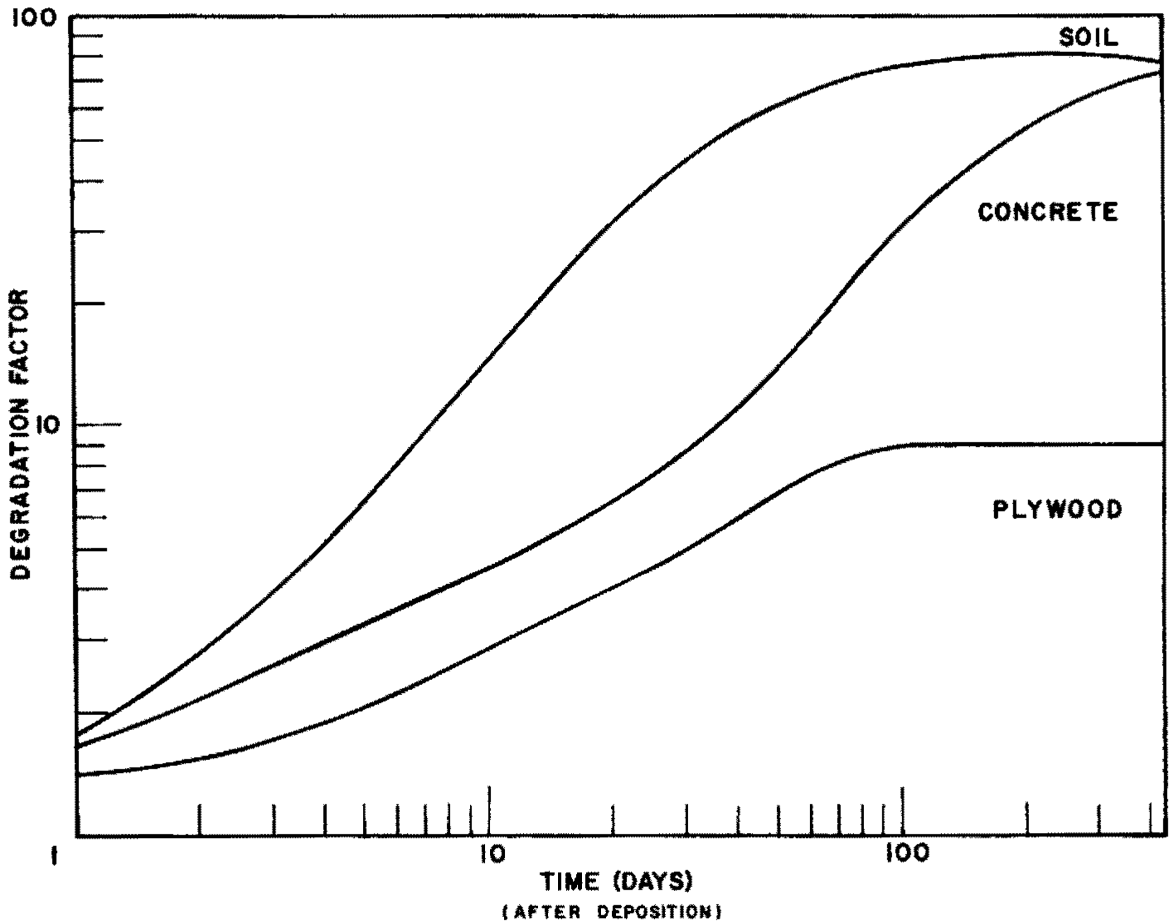


Figure 3-1. Activity Degradations Apparent to Alpha
Survey Instruments (Pu), Figure 2.4 of WT-2511 (1968).

Results from a long-term air sampling at the GMX site are listed in Table G-4, as reported in NVO-142 (1974). The results in Table G-4 are in units of fCi/m^3, a 1,000-fold lower than pCi/m^3. The 1971 measurements demonstrate that airborne concentrations were well below the established MPC for occupational exposures, e.g., ICRP Report 2. Nevertheless, due to the remote location of this site, occupancy by workers maintaining these sites would have been well below 2000 h per year, the exposure basis used to establish MPC values.

In 1977, EG&G performed in-situ measurements of the four Roller Coaster sites, with results published in EG&G 1183-1737 (1978). Contamination isopleth plots are provided in Figures G-13 through G-16. Like surveys conducted in the early 1970s, these surveys used FIDLER instruments. The plots also show the existing fencelines at the time of the surveys, which encompassed area of the greatest degree of contamination. The contours corresponded to two contamination indices: the depth integral of contamination, in terms of an areal concentration (μCi/m^2), and average soil activity concentration in the top 5 cm, in units of pCi/g.

In 1993, EG&G performed aerial radiological surveys in areas of TTR to include the Clean Slate Sites, the Roller Coaster Decontamination Area (identified as corrective action unit [407]), target area of TTR, and an animal burial area near Double Tracks, EG&G 11265-1145 (1995). In 1993, ground-based in-situ radiological surveys were conducted at downwind areas of the Clean Slate sites, EG&G 11265-1147, while in 1995 ground-based in-situ measurements were performed on the Double Tracks site, DOE/NV 11718-013 (1996). Data from both survey types were composited to form $^{239+240}$Pu in surface soils concentration contours for each site, as shown in Figure G-17 through G-20. These surveys provided support to the corrective action strategy being implemented by the Nevada Environmental Restoration Project, DOE/NV-456 (1996).

In-line with impending mitigation of the Clean Slate sites, the Desert Research Institute (DRI) was tasked to perform base-line air sampling in the vicinity of the Clean Slates sites in 1996, DRI-45181 (2001). Similarly, around the same time, SNL also performed air sampling in the vicinity of the Clean Slate sites as a part of their responsibilities to evaluate compliance with the National Emission Standards for Hazardous Airborne Pollutants, DRI-45181 (2001), that were promulgated by the EPA in 1989 for DOE facilities, 54 Federal Register 51695 (15 Dec 89). Figure G-21 shows the location of the DRI Clean Slate Background Site air sampling location and the SNL sampling location at the TTR airport. Each set of samples were collected over about one year, though SNL started in February of 1996, while SNL started in January of 1996. The DRI sampling location was located about 3 km WNW of CS3, while the SNL sampling location was about 8 km WNW of CS3.

Table 3-3 a summary of the air sampling results. Composited air samples were analyzed for ^{241}Am, ^{238}Pu, and $^{239+240}$Pu activity concentration. For both the DRI and SNL air samples, most samples did not have a positive detection of activity. For example, only eight of the 24 composited SNL air samples had detection of $^{239+240}$Pu at or above the minimum detection activity (MDA); for ^{241}Am only nine of 24 samples met this condition and only two of 24 for ^{238}Pu. Under these circumstances, the data in Table 3-3 lists the maximum activity for three-month composited air samples, where samples with activity less than the MDA used the MDA value in the calculation.

TABLE 3-3. Maximum Activity for Three-Month Composite Air Samples from SNL and Desert Research Institute (DRI) Monitoring Stations in 1996-1997, Data from DRI-45181 (2001).

Sampling Period	Volume (m^3)	Mass (mg)	Mean Mass Loading ($\mu g/m^3$)	Activity Concentration (fCi/m^3)		
				^{241}Am	^{238}Pu	$^{239+240}$Pu
SNL						
20 Feb – 29 Apr 96	105612	554.9	5.3	0.00085	0.00047	0.00047
30 Apr – 9 Aug 96	146417	1301	8.9	0.00089	0.0020	0.00062
10 Aug – 1 Nov 96	118821	1024	8.6	0.0063	0.0085	0.0086
2 Nov 96 – 3 Feb 97	190187	291	1.5	0.016	0.0062	0.010
DRI						
26 Jan – 29 Apr 96	278.5	1.45	5.2	-	0.16	0.4
3 May – 29 Jul 96	249.6	2.69	10.8	-	0.19	0.19
2 Aug – 28 Oct 96	252.4	2.18	8.6	-	0.048	0.048
1 Nov 96 – 31 Jan 97	244.2	0.83	3.4	-	0.041	0.041

The maximum airborne concentrations for the composited samples listed in Table 3-3 are negligible compared to MPC and DAC values listed in Table D-5 for workers. In the case of the SNL samples at the TTR airport, the three-month composites range from 500,000- to 127,000,000-fold lower than the highest and lowest MPC or DAC value over the five sets of ICRP recommendations for $^{239+240}$Pu. For the DRI samples, the maximum airborne concentrations of $^{239+240}$Pu range from 12,500- to 1,500,000-fold lower than the highest and lowest MPC or DAC values. It is notable that the maximum airborne $^{239+240}$Pu were on par with the ambient $^{239+240}$Pu in air measured at numerous locations world-wide from the latter 1960's to 1977, as shown in Figure G-34.

The NTS environmental surveillance program had numerous on-site air monitoring stations, as discussed above and illustrated in Figure C-10. While 1960's air samples were subjected to gross β-particle activity analysis, and when warranted γ-spectrometry analysis for samples higher than typical results, in fiscal year (FY) 1971 plutonium analysis of samples was added to the routine analysis. Table G-7 contains a listing of yearly average plutonium analysis of air samples collected on NTS. Within the scope of this report, the air sampling results for the cafeteria at the Groom Lake monitoring site are pertinent, as this sampling location is ESE of the Project 57 site. Table 3-4 contains a listing of annual sampling at the Groom Lake cafeteria as excerpted from Table G-7. All annual concentrations are a negligible fraction of the MPC and DAC values in Table D-5 for workers. The FY 1971 samples may have been higher due to the Chinese test conducted on 14 October 1970 (see Table B-2). Except for that FY year, the samples from the other years are not significantly higher than the typical levels of plutonium observed at world-wide northern hemisphere monitoring sites, as shown in Figure G-34.

TABLE 3-4. Yearly (FY) Averages of Air Surveillance for Plutonium at Groom Lake Cafeteria Air Sampling Station, Excerpt from Table G-7, as Copied from Table 4 of NVO-410-39 (1978).

	Yearly (FY) Average Plutonium Concentration (fCi/m^3)					
Year	1971	1972	1973	1974	1975	1976
Value	1.76	0.166	0.043	0.095	0.043	0.017

In January 1996, DRI initiated an air sampling program around the Double Tracks site, in a similar manner to the monitoring site to the NW of the Clean Slate sites. The sampler was placed on the north of the fenced boundary of the site, which was the closest approach to the most highly contaminated soil areas. The sampling continued into the summer and fall of 1996, which also encompassed the period of soil excavation in latter June. DRI perform gross α- and γ-radiation measurements on many of the weekly samples. A gross β-radiation measurement was performed on all samples. On a quarterly basis, filters were composited and analyzed for $^{239+240}$Pu and ^{238}Pu. A summary of the results are in Table 3-5. Since gross α-radiation measurements were not completed for each weekly sample in the first two quarters, a quarterly average could not be calculated. All quarterly mean plutonium concentrations were over three orders of magnitude below the MDC and DAC listed in Table D-5 for workers. Clearly CY quarter 2 had a much higher mean concentration, which was logical because this quarter encompassed the soil excavation activities completed in latter June. For CY quarter 3, the mean $^{239+240}$Pu was about 1,000-fold lower than the gross α-radiation levels, which are clearly dominated by source(s) natural to the environment. The Double Tracks site is in a remote area of NTTR without an expected prolonged presence of personnel.

TABLE 3-5. DRI Air Sampling Data on North Fence Boundary of Double Tracks in 1996, from Table 1, DOE/NV-11718-112 (1996).

1996 CY Quarter	Activity Concentration (fCi/m^3)		Composite Plutonium (fCi/m^3)	
	Mean Gross α	Mean Gross β	$^{239+240}Pu$	^{238}Pu
1	*	15.9	0.0031	0.00034
2†	*	14.7	1.39	0.011
3	2.71	17.2	0.003	0.39

* Not all samples have had analysis † Soil excavation completed over six-days in late June

3.1.4 Corrective Actions Activities on Roller Coaster and Project 57 Sites.

The Roller Coaster and Project 57 sites were evaluated for corrective actions under the Nevada Environmental Restoration Project starting in the mid-1990s. Despite the plans for corrective actions, none of the Roller Coaster sites or the Project 57 sites presented a hazard to workers or members of the public due to the very low airborne resuspension of plutonium, the existing fencing, and warning signs. Because access to NTTR and TTR are controlled, corrective actions were developed to allow re-use of the sites for other mission purposes, as there were no near-term expectations NTTR and TTR would be released for public use. Initial corrective actions on two sites implemented a 200 pCi/g total transuranic (TRU) activity concentration in surface soils. The transuranics encompass the isotopes of plutonium and americium. Later, a 25 mrem/y effective dose criterion was used for on-site industrial use. This approach included inhalation, incidental ingestion, and external exposure pathways. Table 3-6 provides a summary of the actions for each site and the primary reference. A listing of numerous other applicable references is provided in this report.

Figure G-24 contains plots of surveys conducted on Clean Slate 1 before and after completion of correction actions. It is noteworthy that the remediation only involved a small fraction of the surface soils with activity concentrations greater than 50 pCi/g. This action was effective at reducing the greatest potential exposures to an on-site worker, which is presumed to have occupancy at the most highly contaminated area, e.g., within the orange contour. However, for airborne sampling at distances far from this site (termed the far-field) airborne concentrations will have a much smaller reduction because of the remediation because the total surface soil source term was only reduced by perhaps a factor of 2 to 4. Nevertheless, reduction in far-field airborne concentrations was not the established goal of the corrective action, but a positive outcome.

Figures G-25 and G-26 contain pre- and post-corrective action FIDLER survey plots for the Clean Slate 2 site. In contrast to the Clean Slate 1 corrective action, this site had removal of soils from several disconnected zones. Figures G-27 and G-28 contain pre- and post-corrective action FIDLER survey plots for Clean Slate 3, and Figure G-29 contains the pre- and post-corrective survey plots for the Double Tracks site corrective action.

3.1.5 Later Air Monitoring Around Clean Slate and Project 57 Sites.

DRI conducted airborne sampling at locations surrounding the Clean Slate Site, Project 57, at the TTR airport, and at publicly-accessible locations near the TTR. Figure G-31 shows the sampling locations around Project 57, as superimposed over a 1997 aerial survey for ^{241}Am. Figure G-32 shows

TABLE 3-6. Corrective Actions on Roller Coaster and Project 57 Sites.

CAU	Site	Location	Description	Reference
411	Double Tracks	NTTR	1996 interim corrective action implemented using a 200 pCi/g TRU activity concentration criterion. About 2000 cubic yards of soil and debris removed. Soil disposed at NTS. Decision made in 2015 that site also met 25 mrem/y worker criterion. No additional correction actions post 1996 work deemed necessary.	DOE/NV-1547-ADD (2016)
412	Clean Slate 1	TRR	1997 interim corrective action was implemented using 200 pCi/g TRU criterion. About 5,400 cubic yards of soil and debris removed. Soil disposed at NTS. Decision made in 2015 that site met exposure goals for closure. No additional actions post 1997 work deemed necessary.	DOE/NV-1548 (2016)
413	Clean Slate 2	TRR	2017 effort removed soil to meet 25 mrem/y exposure goal for on-site worker. About 1,550 cubic yards of soil was removed and disposed at NNSS. No additional actions are deemed necessary.	DOE/NV-1598 (2018)
414	Clean Slate 3	TTR	2018-2019 effort removed 6,300 cubic meters of soil removed to meet 25 mrem/y criterion for on-site worker occupancy. Soil disposed at NNSS. No additional actions deemed necessary.	DOE/EMNV-0011 (2019)
415	Project 57	NTTR	Approximately 1.9 km^2 of land was impacted to a degree that was fenced and posted, and internal fence encompasses about 0.4 km^2. In 1974, Nevada Applied Ecology Group completed large soil and vegetation sampling effort, based on in-situ FIDLER measurements. 1997 radiological survey completed by DOE using helicopter-based platform. Ground-based in-situ radiological surveys conducted in 2007, 2010, and 2012. Remediation goal established for on-site occupational use with dose less than 25 mrem/y. Small quantities of contaminated soil (138 ft^3) and metallic debris removed and disposed at NNSS; transformer oil provided off-site treatment in 2015-2016. Closure in place in lieu of excavation and disposal chosen as preferred alternative. Justification: 1) already implemented for Area 11 Pu Valley on NTS and others with similar Pu/Am, 2) has limited migration in environment, 3) location is remote and effectively controlled by fencing and signage, 4) risks for removal higher.	DOE/NV-1581 (2017)

the air sampling locations associated with the Clean Slate sites on TTR, while Figure G-33 shows the DRI sampling locations around TTR. Table G-8 contains DRI air sampling results for locations on TTR from 2012 to 2020, along with DRI publication numbers listed at the bottom of the table. Greyed cells represent a year where sampling was not conducted at a specific location. The air sampling results for Station 400 (TTR airport) are key, because this area of TTR has a significant amount of worker presence. The mean gross α-particle activity concentrations range from 1.22 to 2.51 fCi/m^3, which are more than three orders of magnitude below ICRP MDC and DAC values for $^{239+240}$Pu, as listed in Table D-5. It is important to note that the gross α-radiation analysis method includes α-emitting isotopes of plutonium and americium, ^{238}U, ^{235}U, ^{232}Th, and the α-particle emitting decay products in the ^{238}U, ^{235}U, and ^{232}Th decay chains. While the Clean Slate sites have negligible amounts of uranium deposited in comparison to the plutonium from the test shots, the most significant contribution of uranium in air is from sources naturally-occurring in the environment. In review of air sampling analysis results for areas around TTR (Table G-10), there is not any appreciable difference when considering the fluctuations in the annual mean airborne concentrations.

It is clear from the monitoring conducted along the fence boundaries of the Clean Slate sites, e.g. Stations 401 through 405, that there are higher gross α-radiation airborne concentrations than at Station 400. In comparison among the eight monitoring years for Stations 400 and 401, the mean concentration at Station 401 is about 19% higher than Station 400. In a comparison between Stations 400 and 402, over the five common years of air sampling, Station 402 had a mean concentration about 13% higher than that at Station 400. In comparison between Stations 400 and 403, 404, and 405, over the four common years of air sampling, Station 403 had a mean concentration about 37% higher than that at Station 400. Stations 404 and 405 were respectively 85% and 26% higher than that at Station 400. Nevertheless, over this period of monitoring, worker presence at the fence boundaries is very limited, yet clearly the plutonium contribution to airborne gross α-radiation is only a small fraction of natural background. The dose consequence from ambient airborne gross α-radiation is dwarfed by external radiation exposures and ingestion of natural radioactivity in foods.

The Project 57 air sampling data for locations at the boundary fence are in Table G-9. The mean concentrations of gross α-radiation are higher than those observed around the TTR. Among the four sampling locations, clearly the mean concentrations are highest at location P57-4. This is logical, as this location is closest to the most highly contaminated soils within the fence boundary. The mean gross α-radiation level for 2017 to 2020 was 5.8 fCi/m^3. This concentration is about three-fold higher than the mean concentration over the same period at Station 400 (TTR airport), yet the highest net concentration from plutonium is more than three orders of magnitude lower than ICRP MDC and DAC values for $^{239+240}$Pu, as listed in Table D-5. The only workers in the vicinity of the fence boundaries would be those with duties related to site maintenance and monitoring. Personnel assigned duties at the main base by Groom Lake are about 10 miles to the SE.

3.2 Other CAU on TTR and NTTR (of Interest to Scope of Report).

TTR and NTTR have several other CAUs, some of which had the potential for radiological contamination that are in the scope of this report. Table G-11 provides a summary of the CAU along with descriptions and references. Additional references are also provided in this report with applicability to these CAUs. In addition, several of the sites are subject to periodic inspections. The list of references also contains notation of reports documenting the results of these inspections.

Among the CAUs listed in Table G-11 several are related to the Roller Coaster tests: 404, 407, 426, 485, and 486. These were areas used for decontamination of personnel/equipment/animals, management of animals supporting the tests, and burial of wastes. Based on the summaries provided in Table G-11, only low-level radiological contamination was identified on some of the sites. For the sites with burials, waste was not accessible between the time of creation in 1963 and investigations initiated in the latter 1990's due to the clean soil barriers. Some of these sites were subjected to the 1993 aerial radiological survey, EG&G 11265-1145 (1995).

CAUs 408, 430, 461, and 495 were associated with the potential for DU. In the case of CAUs 430, 461, and 495, suspected DU had a connection to DU used to simulate the weight of nuclear munitions, associated with non-nuclear testing, e.g., ballastics. None of these sites had DU, based on investigations conducted. CAU 408 was afforded radiological survey via aerial methods in the 1993 surveys that were primarily focused on the Clean Slate site surveys. The 1993 aerial radiological survey had negative findings, though the survey team was informed after that most of the DU debris had been removed from TTR immediately after each impact tests, making it unlikely that detectable quantities could be identified in the survey area, EG&G 11265-1145 (1995). A ground-based investigation of target areas, as shown in Figure G-35, was performed in 2009 and 2010 to assess potential for munition and explosives of concern (MEC) and DU. Eighteen small pieces of DU fragments and seven pieces of DU-impacted fragments were identified, in addition to numerous intact bomblets and MEC. Five cubic feet of DU-impacted soils were identified within a concrete bunker. The DU-contaminated materials were disposed off-site, while MEC was destroyed on-site by explosive ordnance disposal personnel. A listing of the DU items identified and removed during the correction action are listed in Table G-12. Most parts were small in dimension, typically of a fraction of an inch to a few inches. Portable survey instrument response was collected with a thin-window thallium-drifted sodium iodide [NaI(Tl)], that was sensitive to β-particles and low-energy photons, and a portable α-scintillator. The results of these survey measurements are listed for each of the parts. Numerous soils samples were collected in the bomblet target area as part of the correction action surveillance. The samples were analyzed for isotopic uranium. A scatterplot of the ^{234}U vs. ^{238}U activity concentrations is contained in Figure G-36. The samples have activity concentrations typical for uranium in this part of Nevada and do not have an activity concentration ratio of ^{234}U to ^{238}U typical for DU. Moderately-depleted uranium has a ^{234}U to ^{238}U ratio of about 0.2, while natural uranium in soils is 1:1. Overall, the sample set has a natural uranium isotopic characteristic.

The other CAUs are unique. CAU 453 is an unexploded ordnance landfill that is closed in-place. The Thunderwell Site was a site impacted by conventional explosives-only tests conducted in early to mid-1960, where SNL detonated high explosives at the bottom of large cylindrical steel tubes. One of the test units was believed to contain DU, DOE/NV-676 (2001). Test units were projected by the force of the gas created by the conventional explosives detonating in the tube. All test units were reported to have been recovered intact, DOE/NV-676 (2001). Radiological contaminants were not identified in a 2000 investigation completed at the site. This site has been mistakenly identified by some veterans expressing concern over radiological exposures at TTR as a nuclear test site. This may be due to plans to use this type of technology with a nuclear detonation to propel spacecraft, of which never came to fruition among US nuclear tests. CAU 453 is a landfill that has the potential for unexploded ordnance (UXO). Sampling of the soil beneath the burial level did not identify toxic materials. This measure provides evidence that if contaminated materials are within the burial zone, they are not leaching to greater depths. This site is currently capped in-place. CAU 541 is the Small Boy site, which had the

14 Jul 1962 low-yield nuclear detonation. This site is on NTTR, adjacent to Area 5 of NTS. A 2014 evaluation determined that the site met a 25 mrem/y effective dose criterion for limited on-site presence of personnel 80 hours per year. No corrective actions were deemed necessary to meet this criterion. Due to the rapid decay in most fission products deposited from the fallout in this area from the 1962 test, the radiological conditions have not changed significantly since the mid-1960s.

3.3 Radiological Impacts to Personnel on Groom Lake, TTR, Tonopah, and Indian Springs from NTS Tests, 1959 – 1992.

3.3.1 General.

Section 2 provided extensive details on the nuclear tests conducted on NTS and the monitoring conducted to assess exposure off-site. Based on DOE reports for nuclear and reactors tests, assessment of radiological impacts to Groom Lake, TTR, Tonopah, and Indian Springs have been refined to a sub-set of tests, primarily based on the screening of test with off-site radiological detections. Table E-5 provides the initial screening results, with details on the areas impacted by the radiological emissions, radionuclides, and magnitude of impacts. Numerous plots are provided to illustrate debris cloud transport and monitoring for many of the key tests. Table E-5 contains a list of 82 tests, with the detection of off-site radiological detections. Table E-6 contains a listing of 30 tests with radiological detections on Groom Lake, TTR, Tonopah, and/or Indian Springs. Among these 30, three tests: Schooner, Baneberry, and Mighty Oak had detectable impacts at three of the four locations. Bandicoot and Red Hot had detections at two locations.

Indian Springs AFB had detectable radiological impacts from 10 tests, with four of them reactor tests, five underground tests and one plowshare cratering event. Three shots in 1964 had detectable radiological impacts, as well as 1968. Tonopah only had three tests with detectable radiological impacts. The low number is logical for this location due to this location being at greater distance than the other locations from NTS and typical wind conditions. Groom Lake had eighteen tests with detectable impacts. This is logical being off the NE corner of NTS with winds in many cases heading in this direction. Nevertheless, 10 are attributed to reactor test releases, which had much lower radiological releases than cratering tests and undergrounds with containment failures. For each location, tests with higher radiological impacts are red highlighted in Table E-6. A subset of the 30 will be discussed below.

3.3.2 Shot Bandicoot.

Bandicoot was a 19 October 1962 underground test conducted in Area 3 of NTS. Surface winds initially carried some radiological debris to the NNE of the GZ to Area 9, where it had become stagnant, with some further transport to the NNW (Area 12). Upper winds carried most of the debris to the S of the GZ. The plot in Figure E-4 shows the close-in ground-based radiological impacts, up to about 4 miles. The eastern fringe of the outer contour is about 1.5 miles in extent. The maximum exposure rate monitored at Indian Springs was 0.45 mR/h on the day of the shot and at background levels the next day, which indicates that the dominant source of external exposure was due to the passing debris cloud, yet much lower due to ground deposition of fallout. The upper winds, which carried the debris pattern initially to the S, eventually carried the debris cloud SW toward Los Angeles, CA. The maximum integrated exposure rate at Indian Springs was less than 10 mR, assuming the exposure was constant over one day, but more likely only a few mR.

Due to the surface winds debris pattern becoming stagnant, it is possible that some impacts would have been detectable at GL, though off-site monitoring did not detail impacts NE of the GZ. SWRHL-4R (1965) noted, "activity was detected north, south, and west of surface GZ, and a small amount was detected to the east." It is our assumption that impacts to GL would have been on par or less than those observed at Indian Springs. None of the off-site monitoring stations to the NW of GZ had detections of this event from external γ-radiation detection systems.

The highest airborne concentration monitored in off-site air samples was at the Death Valley, CA location. The air sample collected at Indian Spring had identification of $^{131+132+133}I$, ^{132}Te, $^{140}Ba/La$, $^{95}Zr/Nb$, and ^{103}Ru. The estimated integrated effective dose from the inhalation pathway at Indian Springs from radioiodines, ^{132}Te and $^{140}Ba/La$ is 0.156 mrem using ICRP 68 dose conversion factors and a 0.54 m^3/h inhalation rate. The $^{95}Zr/Nb$ concentration was too low for quantification, while the ^{103}Ru had negligible concentrations compared to the radioiodines, ^{132}Te, and $^{140}Ba/La$. About 50% of the estimated inhalation dose at Indian Springs was from the ^{133}I, 20% from ^{131}I, and 24% from ^{132}Te. Air sampling locations to the NE of NTS: Alamo and Hiko, NV, which were in proximity to GL, and in-line with GL and the GZ, had detectable levels of the same radionuclides, though the integrated airborne concentrations of radioiodines and ^{132}Te were one to two orders of magnitude lower than those at Indian Springs.

Table E-7 shows the calculation details for the Indian Springs air sample. The Table provides DC values for each radionuclide based on ICRP Report 68 (1994) recommendations and separate assumptions on the aerosol characteristics, e.g., 1 or 5 μm activity median aerodynamic diameter (AMAD). For ^{132}Te, ICRP lists DCs for Types F and M. The sum max row at the bottom provides the maximum summation of effective dose for each radionuclide. For radioiodines, the 5 μm AMAD aerosol characteristic provided the maximum effective dose. This was similar for ^{132}Te and ^{140}Ba. For ^{132}Te, the absorption type M provides a higher effective dose than type F.

3.3.3 Shot Pike. The 13 March 1964 underground test had its GZ on Area 4 of NTS. The radioactive release was dominated by radioiodines and travelled in a SE direction toward Cactus Springs, which was near Indian Springs. The maximum exposure rate at Cactus Springs was 5.9 mR/h, but had dropped to 0.28 mR/h by the time the plume reached Las Vegas. The maximum exposure rate at Indian Springs was 1.5 mR/h. The maximum integrated γ-radiation external dose was estimated as 55 mR, as noted in SWRHL-20r (1966). It is assumed that this estimate was for the area west of Cactus Springs, which also had the highest air sample result. The integrated γ-radiation dose would have been less at Indian Springs. The plume was monitored as far south as Yuma, AZ. The estimated effective dose from inhalation was 0.59 and 0.26 mrem, respectively at Cactus Springs and Indian Springs, and was dominated by radioiodines. As noted in Table E-5, some assumptions in the calculations were based on details of one sample at Cactus Springs. The estimated effective dose from inhalation is a very small fraction of the external dose.

3.3.4 Shot Baneberry. The 18 December 1970 underground test had a fissure near surface GZ at H+3.5 minutes. The GZ was in Area 8, which is in the northern, east-central part of NTS. The Baneberry test was the last NTS underground test with a significant containment failure. Figure E-34 provides a graphical display of maximum γ-radiation exposure rates recorded by ground monitoring, while Figure E-35 provides net infinity external γ-radiation exposure contours. The key radiological materials released were noble gases, radioiodines, and ^{132}Te. Monitoring was negative at Indian Springs, but external exposures and air sampling had positive results at Groom Lake, Tonopah, and TTR. A summary of external and internal dose estimates is provided in Table 3-7. Like Pike, the estimated effective dose from inhalation is a very small fraction of the external dose.

TABLE 3-7. External and Internal Exposure Values for Baneberry Shot at Groom Lake, Tonopah, and TTR.

Location	Peak External Exposure Rate (mR/h)	Net Infinity External γ-Radiation Exposure (mR)	Effective Dose from Inhalation (mrem)
Groom Lake	0.2	0.1	0.0055
Tonopah	0.2	3	0.127
TTR	3.5	30	0.22

3.3.5 <u>Shot Sedan</u>. The 8 July 1962 test was the highest yield Plowshare cratering test conducted on NTS. Due to the GZ being on Area 10, in the NE of NTS, and its NNE plume direction, TTR, Tonopah, and Indian Springs did not have any airborne detections of the effluents (see Figures E-10 and -11. As well, Groom Lake was outside of the initial plume, but did receive some low-level impacts in the evening after the test, as detailed in the γ-radiation monitoring shown in Figure E-12. The infinity γ-radiation exposure at Groom Lake is estimated to be less than 10 mR, while effective dose from inhalation is estimated at 0.46 mrem, with contributions from radioiodines, ^{132}Te-132, and ^{140}Ba. The Sedan shot produced external exposure levels as high as 945 mR at publicly-accessible area north of the NTTR, yet these locations were evacuated prior to the test. The highest exposure in an area with residents that were not evacuated was 178 mR (Nayla).

3.3.6 <u>Shot Palaquin</u>. The 14 Apr 65 was a low-yield Plowshare cratering test conducted on Area 20 in the NW corner of NTS. Figure E-21 provides the fallout contours for this test, which illustrates a northern plume direction. The Figure shows Stone Cabin Ranch, which possessed the highest off-site integrated exposure measurement, 45 mR. Groom Lake, Tonopah, and Indian Springs are well outside the plume. The TTR airport is near, but outside the 10 mR/h exposure rate (H+1 h), as shown in Figure E-21. Figure E-20 shows off-site and checkpoint arrays on NTTR (10- and 20-mile arcs) where exposure rate monitoring occurred. While it is likely that the TTR airport was impacted to some degree, the integrated external γ-radiation exposure is expected to be well below the 45 mR, as measured at Stone Cabin Ranch. An air monitoring station at Warm Springs, proximity to Stone Cabin Ranch, had the highest off-site integrated airborne concentrations of radioiodines. The estimated effective dose was 2.4 mrem. This value is also expected to be higher than the integrated airborne concentrations at the TTR airport.

3.3.7 <u>Shot Schooner</u>.

The 8 Dec 68 Schooner shot was a moderate yield Plowshare cratering test on Area 20 in the NW corner of NTS. The plume travelled to the NE, with Tonopah, Indian Springs, Groom Lake, and TTR outside the primary plume pattern, as shown in Figure E-30. The TTR airport was on the western fringe of the plume pattern. Despite being outside the plume pattern at these locations, some had positive detections of external γ-radiation and in air samples. At Tonopah, a maximum γ-radiation exposure rate of 0.1 mR/h was observed, while SE of Queen City Summit along Hwy 25, the maximum was 350 mR/h, with the highest integrated γ-radiation exposure in a populated area being 188 mR at the Diablo Maintenance Station along Hwy 25. Among TLDs assigned to individuals in off-site areas, the highest TLD was 165 mrem. Measurements to the E of GZ at off-site locations, e.g. Koyne's Mill, Alamo, and Caliente were negative. As such, Groom Lake is expected to have similar results, as it is along the same trajectory from GZ as Alamo, but about 20 miles S of Koyne's Mill (see Figure E-33). Due to TTR and Tonopah being outside the primary plume, the expected integrated external dose at these locations is expected to be only a couple of mrem.

The airborne effluents had identifications of ^{131}I, ^{54}Mn, ^{106}Ru, ^{137}Cs, ^{181}W, and ^{187}W. The Clark Station, along Hwy 25, had the highest integrated airborne concentration from sampling on the first day. The estimated effective dose from inhalation is 2.3 mrem, dominated by ^{187}W. The effective dose from inhalation at Tonopah is estimated at 0.4 mrem. While TTR is SSW of Clark Station, it is assumed that the inhalation dose at TTR is on par or less with that at Clark Station. Radionuclides of tungsten have a recommended lung absorption type F by ICRP 66 (1994), with a 5 μm AMAD assumption providing the highest effective dose under ICRP 68.

3.3.8 Shot Mighty Oak. The 10 April 1986 Mighty Oak shot had a primary release of ^{131}Xe due to tunnel purges conducted from 22 April to 19 May. Due to the long period between the detonation and the purges, only gaseous radioactive materials were expected. Only negligible amounts of ^{131}I were detected. The doses to individuals in areas where noble gases were detected had only external submersion doses. The estimated submersion dose at Groom Lake was 1.5 μrad, while it was estimated at 0.25 μrad for Indian Springs. These levels are negligible compared to the background external dose from terrestrial and cosmic sources, which have a summed rate of about 12 μrad/h. The positive detection of noble gases at the sampling locations on and around the NTS provide examples of the high sensitivity of this analytical method. This network was not around NTS until 1970. Had this method been introduced for earlier tests, there would have been many more positive detections of off-site radiological emissions. Nevertheless, from a practical standpoint, detections of the very low-level releases of noble gases have negligible impact on overall radiation exposure in relation to existing background radiation levels. Higher levels of noble gas presence would, however, be discriminable from background by the external γ-radiation monitoring networks and personal dosimetry, e.g., TLDs and film badges. The 6 April 1985 Misty Rain and 25 September 1980 Riola shots also had positive detections of noble gases at off-site air monitoring sites.

3.4 Internal Doses. The estimated doses to individuals from inhalation of airborne effluents from reactor and nuclear tests conducted on NTS have the listing of effective dose in Table E-5, based on ICRP 68 dose coefficients. The primary source of effective dose is due to radioiodines, with a key exception being the Shot Schooner. Because the internal dose from inhalation are generally low in comparison to external doses, individual organ doses were not detailed in Table E-5. Some examples of individual organ doses are provided here for informational purposes.

3.4.1 Radioiodines.

The thyroid was identified in ICRP 2 (1959) as the critical organ for inhalation of soluble radioiodines. ICRP 30, Part 1 (1979), notes that about 90% of the iodines in adults are retained in the thyroid, with 30% entering the body being translocated to the thyroid and the remainder being excreted.

Due to the relatively small mass of the thyroid gland, 20 g, based on ICRP 23 (1975), most of the contribution of the weighted (tissue) dose equivalent or equivalent dose (e.g., for ICRP 26 or ICRP 60) to effective dose is from the thyroid. The other tissues receiving appreciable doses and have reasonably high w_T are the lungs and the bladder. Table E-8 contains an example of thyroid gland dose, as compared to effective dose for inhalation of radioiodines at Indian Springs from the Pike Shot. In this example, the top set of rows are applicable to the calculation of effective dose, under the assumption of 1 and 5 μm AMAD aerosol distributions. Because the 5 μm AMAD aerosol distribution provided the highest effective dose, the calculation for equivalent dose to the thyroid was per made only for this aerosol distribution. Overall, the equivalent dose to the thyroid is 19.2-fold higher than the effective dose. For ^{131}I, ^{133}I, and ^{135}I, the ratios of equivalent dose to thyroid to the effective dose are: 19.1, 19.0, and 17.6, respectively. The estimated inhalation dose to the thyroid is only 5.0 mrem.

The daughter of ^{132}Te is ^{132}I. Therefore, there is preferable absorption and retention of ^{132}I in the thyroid based on ICRP 67 metabolism modelling. For ^{132}Te, the ratio of equivalent dose to thyroid to the effective dose is 14.9.

3.4.2 Radiotungstens.

The Schooner test had a dominating presence of ^{187}W in the air sampling at the Clark Station on Hwy 25. The 12 March 1968 Buggy test also had contributions from ^{187}W detected in air samples. The latter test though did not have positive detections at Indian Springs, Groom Lake, TTR, or Tonopah. ICRP 2 (1959) listed the lower large intestine (LLI) as the critical organ for inhalation of soluble and insoluble chemical forms. ICRP 30, Part 3 (1981) noted a substantial fraction of tungsten entering system circulation is excreted, with small fractions deposited in bone, kidneys, liver, and spleen. Due to the Class D (ICRP 30) and Type F (ICRP 66) chemical form assumptions for inhalation of tungsten compounds, a large fraction entering the lung is transferred to the GI tract.

Because the 5 μm AMAD aerosol distribution had the higher effective dose, our evaluation will be for equivalent dose to organs using this assumption. Among the primary organs considered under ICRP 60 (1990), the lung had a ratio of its equivalent dose to effective dose of 14-fold. This is reasonable due to the relatively short half-life of ^{187}W, 24 h. In essence, there is a substantial amount of radioactive decay before lung-deposited material is cleared to the GI tract or systemic circulation. The LLI had a ratio of equivalent dose to effective dose of 5.8 and the upper large intestine had a ratio of equivalent dose to effective dose of 3.3. The effective dose of 2.3 mrem estimated for inhalation exposures at Clark Station would provide an equivalent dose to the lung of only 32 mrem.

3.4.3 Plutonium.

Airborne plutonium is of interest in this report in relation to the Operation Roller Coaster and Project 57 safety shots. Due to the recent concerns of veterans of radiation exposure potential at TTR in the 1980s, primary interest is from resuspension of plutonium deposited about two decades earlier. There was limited presence of DoD personnel at Groom Lake in 1957 when the Project 57 test was conducted. Similarly, in 1963 during the Roller Coaster tests, DoD personnel exposure potential appears limited to personnel providing operational support to the tests. Due to the respiratory protection and protective clothing, internal intakes of plutonium are expected to be over 1,000-fold lower than for unprotected exposures. As well, exposure potential for personnel working on TTR and NTTR are expected to be a negligible fraction of occupational exposure limits based on air sampling results discussed above.

The health effects of internal exposures to plutonium are perhaps the most extensively studied radioactive material. Study of the effects of internally-deposited plutonium were initiated during the Manhattan Project, where animal studies confirmed preferable systemic deposition and retention in the bone and liver. Due to the relatively insoluble nature of plutonium related to the tests conducted on NTTR, NTS, TTR, and military accidents, deposition and retention of inhaled plutonium provides preferable exposure to the lung, as the organ of entry into the body. Increased risks for cancer induction in animals exposed via inhalation have been demonstrated in the lung, liver, and bone. Table D-2 and -3 provide inhalation dose coefficients. For lung absorption Type S, the ratios of lung, liver, and bone surface equivalent dose to effective dose are: 5.3, 2.3, and 11, respectively, for ICRP 68 (1 μm AMAD). In similar order, the ratios are: 5.4, 2.8, and 2.2 for ICRP 141 (1 μm AMAD).

Epidemiology studies have been conducted on British and U.S. plutonium workers with findings limited by small cohort size and relatively low exposures. The ICRP, Report 150 (2021), explored the cancer risks for plutonium intakes by workers primarily based on the health studies published in the last 25 years for Russian Mayak workers. These workers had intakes of plutonium substantially higher as a cohort compared to British and U.S. plutonium workers. ICRP reported an association between plutonium exposure and risk of lung, liver, and bone cancers, but not risk of leukemia for Mayak workers. Risks for cancer induction are substantially lower due to the limited deposition and retention of plutonium in other organs of the body.

3.5 Summary.

Nuclear and reactor tests conducted on NTS from 1959 to 1992 were evaluated for external exposure potential at Groom Lake, TTR, Tonopah, and Indian Springs. Among the nearly 900 nuclear and reactor tests over this period, the DOE listed 82 events with off-site detection of radiological effluents. The primary factor in the detection of an off-site release is the activity released. In general, effluents released by reactor tests were substantially lower than from underground and Plowshare cratering tests. Thirty tests had detections (or assumed positive detections) at Groom Lake, TTR, Tonopah, and Indian Springs. Tests with the higher levels of radiological impacts at these locations were primarily underground tests with high activity releases and a couple of Plowshare cratering tests.

Radiological effluents released from underground nuclear tests, cratering nuclear tests, and reactors are dominated by noble gases and radioiodines. Due to this condition, the majority of external dose received at locations of interest for this report is dominated by the dose from passing radioactive debris clouds, rather than from residual contamination deposited on ground surfaces. This contrasts with most of the aboveground tests conducted at the NTS.

The highest estimate external dose from nuclear and reactor tests conducted at NTS at the four locations of interest by this report was less than 60 mR. Estimated dose from inhalation of radiological debris clouds are substantially lower. The primary organ with equivalent dose much greater than effective dose from inhalation exposure is the thyroid. Radiological impacts on the thyroid was a priority issue for assessment in off-site monitoring programs established by the AEC (and later DOE) around the NTS. Radiological impacts to personnel serving at Groom Lake, TTR, Tonopah, and Indian

Springs are below 100 mrem in a year effective dose based on historical monitoring data for external radiation and inhalation. One-hundred mrem is the current US recommended exposure limit for member of the public. Background radiation doses from terrestrial and cosmic sources in the vicinity of the NTS is about 100 mrem in a year. Additionally, individuals receive radiation exposure from indoor radon, medical procedures, consumer products, and other sources. For the average American, these sources are higher than those from cosmic and terrestrial sources.

4.0 Discussion.

4.1 Dosimetry Monitoring for DoD Personnel Assigned Duties at NTS from 1962 to 1992.

DoD personnel participated with the AEC (and later DoD) in nuclear tests. External dosimetry data is provided in this report for the period of testing from 1962 to 1992 (see Figures F-1, F-2, and F-3). Over some years, shallow dose was also recorded. These Figures only represent the recorded deep dose. Table F-1 provides the list of DNA reports containing the data for these Figures. These reports were developed to support a DNA review of dosimetry for the underground testing era, though some low-yield above-ground tests were conducted in 1962, and some underground nuclear tests were conducted prior to 1962. This data is provided to allow the reader a basis of comparison of doses received by personnel assigned to duties on NTS over this period and those assigned duties at location adjacent to NTS: Groom Lake, TTR, Tonopah, and Indian Springs.

Over the period of 1962 to 1992, annual individual dosimetry reports for DoD personnel monitored for external radiation exposure range from about 900 to 4,000. The year with the highest number of monitored personnel was 1962, 3,950 monitored, while only 892 were monitored in 1973. For 1962, three-quarters of the personnel monitored had film badge doses less than the DL of 30 mR, with the highest film badge reading for an individual at 5,790 mR. Among the 25% of individuals with exposures > 30 mR, the mean was 546 mR. Over the period 1963 to 1992, there was a gradual decrease in the number of individuals with annual doses greater than the DL, though there was considerable variability by individual year (Figure F-2). Over the same period, there was also a gradual decrease in the mean annual external dose among monitored personnel, as well as the maximum external dose for an individual. Prior to 1970, the maximum dose for an individual on an annual basis ranged from 1,600 to 5,300 mrem. After 1970, the maximum dose for an individual on an annual basis was less than 1,000 mrem.

Table 4-1 contains a histogram of multi-year cumulative dose for individuals with either a deep dose or shallow dose greater than the DL over the period of 1963 to 1992. The individual with the maximum deep dose over multiple years was 11,026 mrem. Twelve individuals had a multi-year cumulative deep dose between 3,000 and 5,000 mrem, and 100 individuals had multi-year cumulative dose between 1,000 and 3,000 mrem. In comparison, individuals assigned to duties at Tonopah, TTR, GL, and Indian Springs, had annual doses well below 100 mrem. The 100 mrem dose criterion is currently accepted in the US for exposure to members of the public, excluding natural background and medical sources.

4.2 Compensation Programs for Veterans and Energy Employees Assigned to Duties on NTS.

The Energy Employees Occupational Illness Occupational Program (EEOICP) has a Special Exposure Cohort (SEC) status for DOE employees or DOE contractor or subcontractor employees who worked at the Nevada Test Site from 27 January 1951 through 31 December 1962 for a number of work dates aggregating at least 250 work days, either solely under this employment or in combination with work days within the parameters established for other classes of employees included in the SEC, and who were monitored or should have been monitored, ORAU [SEC-00055] (2006). This SEC allowed compensation for an employee with a qualifying cancer condition without the necessity of a dose and probability of causation (PoC) assessment. The list of qualifying cancers is contained in Table A-3.

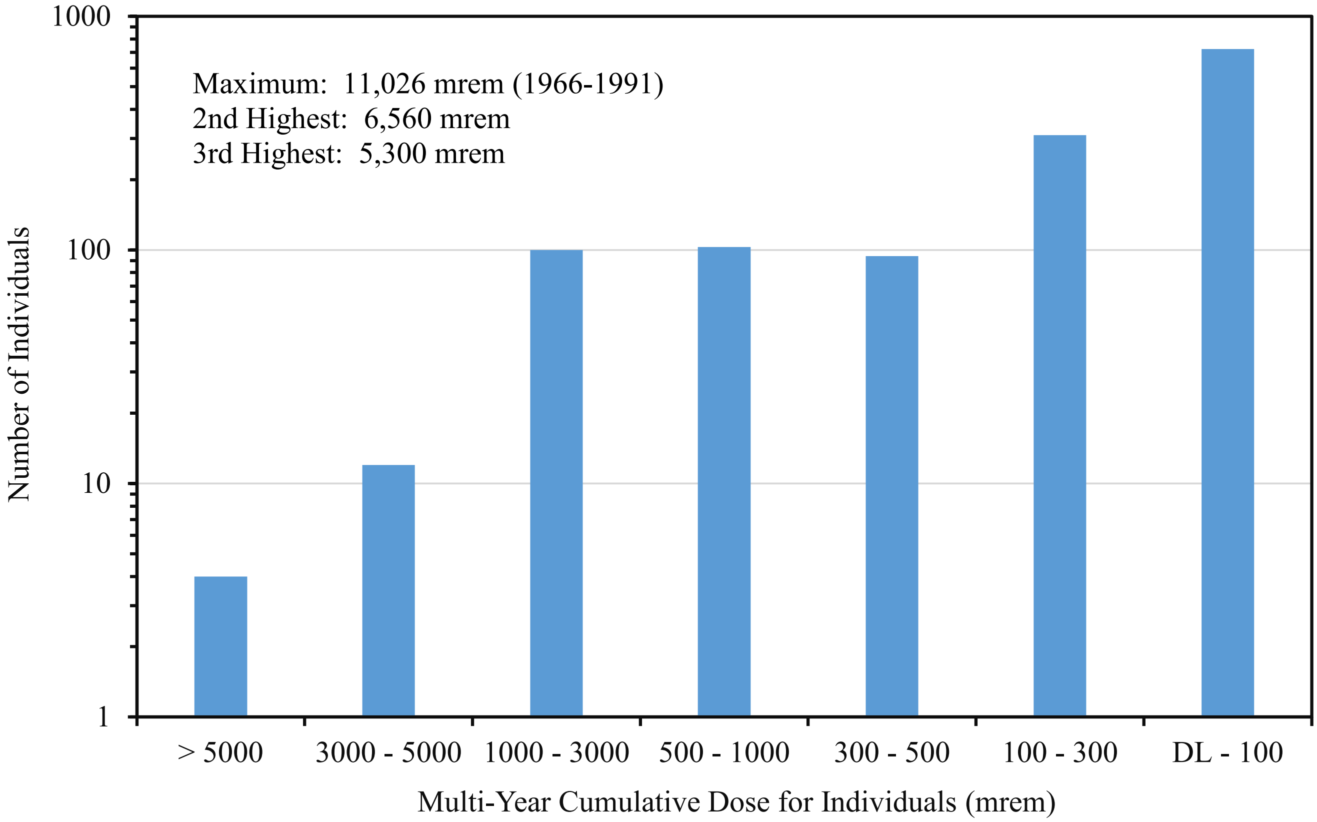


Figure 4-1. Multi-Year Cumulative Deep Dose for Individuals (mrem) Over Period 1963 – 1992.

The compensation program under EEOICPA has a similar list of cancers currently covered for veterans with presumptive service connection from radiation exposures. In relation to veterans with on-site participation on the NTS, Table A-2 has highlighted in yellow the covered periods, as specified in 38 CFR 3.309, *Diseases Subject to Presumptive Service Connection*. A notable difference between the covered periods of the Energy Employees and veterans are the breaks in coverage for veterans. There are no breaks for coverage of Energy Employees, though Energy Employees had minimum on-site exposure days to qualify.

The EEOICP addressed a 2007 SEC petition for Energy Employee coverage from 1963 to 1992 on NTS, ORAU [SEC-00084] (2010). Despite greater worker and environmental surveillance conducted on and off the NTS during the underground testing era versus that accomplished during the aboveground testing era, some difficulty existed in the assessment of internal doses to some groups of NTS workers. This was important for work in areas that were previous GZs for aboveground nuclear tests and access by workers in tunnels used for DoD underground tests. The VA followed suit in addition of veterans with work on NTS during the underground testing area for presumptive coverage provided the veteran met the 250-day period of work on NTS and had a qualifying condition.

4.3 Compensation Programs for Energy Employees Assigned to Duties on TTR.

Energy Employees assigned to duties on TTR are not a SEC under the EEOICP. The EEOICP Site Profile is in ORAUT-TKBS-0037 (2013). Under these conditions, Energy Employees filing medical claims for radiation exposures from their work on TTR require a dose and PoC assessment. This process is similar to veteran claims managed under 38 CFR 3.311, *Claims Based on Exposure to Ionizing Radiation*, which require an assessment of dose. The Site Profile completed for TTR recognized the use of DU in non-nuclear munitions testing and the scattered WGP associated with the Clean Slate sites. The WGP at the Clean Slate site was identified as a potential source of inhalation exposures. The airborne monitoring program instituted by SNL in 1996 was noted in the Site Profile and the results of this sampling as a basis for high-sided estimates of inhalation exposures at the TTR airport. It is important to recognize that a reasonable portion of the $^{239+240}Pu$, ^{238}Pu, and ^{241}Am in the air samples collected in 1996 was from global fallout, and not from the Clean Slate site resuspension. As such, the approach taken by EEOICP was conservative in nature, e.g., providing a high-sided estimate of exposure.

The Site Profile noted that SNL security personnel in 1991 handled M-16 rifles with leaking tritium sights, which entailed urine bioassay assessment. This type of exposure potential is not deemed an environmental type of radiation exposure and provisions for exposure assessment would have been on an individual basis. This is also the case for individuals that would have participated in handling DU and work on the Clean Slate sites, to include remedial action efforts.

5.0 Conclusions

The United States (US) conducted 1054 nuclear tests from 1945 to 1992, with 928 tests conducted at the NTS.) On-hundred on NTS were atmospheric and 828 underground. Three tests were conducted on the NTTR, while three were on the TTR. Among the six tests conducted on TTR and NTTR, five were conventional explosives detonations associated with plutonium scatter safety experiments. One of the tests was intended for detonation on NTS, but decades later discovered to have been 300 feet outside the NTS boundary and on NTTR. The NTTR provides a boundary on three sides of the NTS, while three sides of the TTR are also bounded by NTTR. The NRDS was located within the boundary of NTS, with numerous reactor tests conducted over the period of 1959 to 1972.

Recently, AF veterans with assignments to TTR during the 1980's have expressed concerns over their radiation and toxic materials exposure potential (CBS Chicago 2024). Public interest stimulated questions to the DoD from Nevada congressional members regarding exposure potential. The primary concerns for radiation exposure are related to three plutonium scatter safety experiments conducted in 1963 under the Project Roller Coaster. Concern also existed from nuclear tests conducted on NTS and other activities conducted on TTR. Over the years, the Air Force Surgeon General's office has addressed veteran claims for radiation exposures from operations on NTS. Though some individuals had duties on NTS, many claims were for individuals that had duties in areas outside NTS, e.g., TTR, Indian Springs AFB, Tonopah AFS, Groom Lake, and Nellis AFB. This report concentrated on radiological exposures for personnel assigned duties on TTR, Indian Springs AFB, Tonopah, and Groom Lake over the period of 1959 to 1992.

Most of the off-site radiological fallout from nuclear tests conducted on NTS was due to atmospheric test conducted from 1951 to 1958. Over the period of 1959 to 1992, almost all nuclear tests conducted on NTS were underground tests. There were four low-yield atmospheric nuclear tests conducted in 1962, one cratering weapons-related nuclear test in 1962 and five cratering Plowshare tests conducted from 1962 to 1968. The early years of underground tests had containment failures, with the last significant containment failure being the Baneberry test in December 1970. Post Baneberry, radiological effluents from underground NTS nuclear tests were about 0.2% of the effluents released by prior NTS underground tests. Additionally, effluents from reactor tests conducted on the NRDS were a small fraction of effluent releases from others tests on NTS over the period of 1959 to 1972.

The radionuclides produced from atmospheric and underground nuclear tests are similar, but have distinct differences in those released to the atmosphere. Due to containment provided by underground tests, and to some degree for cratering Plowshare tests, effluents released to the atmosphere are dominated by noble gases and fission products with low melting points, e.g., radioiodines. Under these circumstances, at off-site locations where radiological effluents were detected by the extensive monitoring network, external exposures are primarily due to the passing radioactive debris clouds, with lesser amounts from ground-deposited radionuclides. Also, projected internal dose from the inhalation pathway was usually dominated by radioiodines. Internal exposures to radioiodines have a propensity for deposition and retention in the thyroid, which was a key public exposure interest for the off-site monitoring program.

The PHS and later the EPA provided an extensive radiological monitoring network at off-site locations surrounding the NTS and throughout the US. Data from this monitoring network was evaluated to assess potential exposures to personnel off the NTS. The extensive network implemented aerial monitoring, sampling of air, dairy milk, food, animals, and the monitoring of external exposure with active instruments and passive dosimetry monitors. The off-site monitoring program was augmented by weather monitoring data, as well as on-site monitoring provided by the AEC, and later the ERDA and DOE.

Over the period of 1959 to 1992, 82 tests had detection of radiological effluents at locations off the NTS complex from atmospheric, underground, Plowshare, or reactor tests. Of these 30 were deemed of interest for exposure potential on TTR, Indian Springs AFB, Tonopah AFS, Groom Lake. External exposures at these locations were estimated to below 60 mR per test, with effective dose from internal exposure being much lower. Estimated exposures to personnel on an annual basis at these locations were estimated to be less that 100 mrem. This exposure criterion is the current recommended limit for members of the public, excluding background and medical exposures. Radiological exposures at these locations were negligible after 1970. One primary concern prompting an assessment of historical exposure potential was from individuals assigned to TTR in the 1980s.

The Clean Slates sites on TTR was of concern for exposure potential for veterans assigned to duties at this location. Based on extensive historical monitoring data, inhalation exposure potential for those assigned duties on TTR were negligible compared to background and occupational exposure limits. The concentrations of airborne $^{239+240}$Pu at the TTR airport were of similar magnitude to those observed world-wide in the 1970s from fallout. This report provides historical air monitoring data collected during the operational phase of the Roller Coaster tests. Personnel with on-site support of the 1963 tests were afforded radiological protection, which would have mitigated internal exposure potential. Project 57 had similar characteristics to the Roller Coaster tests conducted in 1963. The location of the Project 57 test was about 10 miles to the NW of the main base at Groom Lake. Historical monitoring in the 1970's at the cafeteria of Groom Lake demonstrated negligible exposure potential from airborne resuspension of plutonium.

Veterans assigned duties at TTR in the 1980's expressed some generalized concerns for radiological exposures and exposures to toxic materials, and impacts of these on groundwater. This report details on key CAU managed by the DOE environmental management program. Some CAUs had the potential radiological constituents of concern, but based on investigations, some sites did not have confirmed contaminants, while others identified only low-level contaminants that did not present a general exposure concerns for site personnel. Further, the program is currently under active management by the DOE. In relation to underground wells used for potable water, routinely samples were collected during the underground testing era to assess potential radiological impacts. Due to the depth of these wells, however, radiological impacts were deemed improbable.

Energy Employees that worked at NTS over separate periods of 1951 to 1962 and 1963 to 1992 are part of EEOICP SECs. These employees with qualifying cancers and a work-period minimum do not require a dose assessment. The VA has similar provisions for veterans with service on NTS under 38 CFR 3.309. The EEOICP does not have a SEC for Energy Employees with duties on the TTR. Under these conditions, an assessment of dose is required. The EEOICPA recommends use of air sampling data collected by SNL in 1996 as a basis for inhalation exposures from airborne $^{239+240}$Pu associated with the Clean Slate sites.

To maintain a practical length, this report maintained some limits on detail. Greater details can be ascertained through review of the extensive list of references. These documents were acquired from several sources. The reports produced by the US Government were mostly acquired through web-based document archives of the EPA, the DOE's Office of Science and Technology Information, and Nuclear Testing Archive. The ICRP and NCRP have web-based document archives.

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6321F	Operations Flintlock and Latchkey, Events Red Hot, Pin Stripe, Discus Thrower, Pile Driver, Double Play, Newpoint, and Midi Mist, 5 March 1966 - 26 June 1967	1-Oct-84
6322F	Operations Crosstie and Bowline, Events Door Mist, Dorsal Fin, Milk Shake, Diana Moon, Hudson Seal, and Ming Vase, 31 August 1967 - 20 November 1968	15-Dec-85
6323F	Operations Mandrel & Grommet, Events Minute Steak, Diesel Train, Diana Mist, Mint Leaf, Hudson Moon, Diagonal Line, and Misty North, 12 September 1969 - 2 May 1972	30-Jan-87
6324F	Operations Toggle, Arbor, and Bedborck, Events Diamond Skulls, Dido Queen, Husky Ace, Ming Blade, Hybla Fair, and Dining Car	30-Nov-87
6325F	Operations Anvil, Cresset, Tinderbox, and Guardian, Events Husky Pup, Mighty Epic, Hybla Gold, Diablo Hawk, Huron King, and Miners Iron, 24 October 1975 - 31 October 1980	30-Apr-89
6327F	Operations Praetorian, Phalanx, Fusileer, and Greandier, Events Huron Landing/Diamond Ace, Mini Jade, Tomme/Midnight Zephyr, Midas Myth/Milagro, and Misty Rain, 23 September 1982 - 6 April 1985	1-Jul-93
6326F	Operations Nogaut, Flintlock, Latchkey, Bowline, and Emery, Events Des Moines, Tapestry, Ajax, Cypress, and Camphor, 13 June 1962 - 5 December 1972	1-Sep-97
6328F	Operations Charioteer, Musketeer, Touchstone, Cornerstone, Aqueduct, Sculpin, and Julin, Events Mill Yard, Diamond Beech, Mighty Oak, Middle Note, Mission Ghost, Mission Cyber, Misty Echo, Disko Elm, Mineral Quarry, Distant Zenith, Diamond Fortune, and Hunters Trophy, 9 October 1985 - 18 September 1992	1-May-99

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2020-10353	2019 Annual Site Environmental Report for Sandia National Laboratories, TTR, Nevada, and Kauai Test Facility, Hawaii	2020
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2022-10689	2021 Annual Site Environmental Report for Sandia National Laboratories, TTR, Nevada	2022
2023-079090	2022 Annual Site Environmental Report for Sandia National Laboratories, TTR, Nevada	2023
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Appendix A

Presumptive Diseases and On-Site Participation Periods for US Atmospheric Nuclear Tests

TABLE A-1. Presumption of Service Connection, Radiation-Exposed Diseases for Veterans.

PL 100-321 (1988)		
Leukemia (other than chronic lymphocytic leukemia)	Thyroid	Breast
	Pharynx	Esophagus
Stomach	Small Intestine	Pancreas
Multiple Myeloma	Lymphomas (except Hodgkin's)	Bile Ducts
Gall Bladder	Liver Cancer	
PL 102-578 (1992)		
Urinary tract (Kidney, ureter, urinary bladder, renal pelves, urethra)		Salivary gland
Veteran Administration Administrative Action (2004)		
Bone	Brain	Colon
Lung	Ovaries	Bronchi-alveoli

TABLE A-2. On-Site Participation Periods for US Atmospheric Nuclear Tests.

Test Series	Period*	Test Series	Period*
Enewetak garrison	21 Jun 51 – 1 Jul 52	Castle	1 Mar – 30 Nov 54
Trinity	16 Jul – 6 Feb 46	Teapot	18 Feb – 10 Dec 55
Crossroads	1 Jul – 31 Feb 47	Wigwam	14 – 15 May 55
Sandstone	15 Apr – 20 Nov 48	Redwing	5 May 56 – 6 Feb 57
Ranger	27 Jan – 6 Aug 51	Plumbbob	28 May 57 – 22 Apr 58
Greenhouse	8 Apr – 20 Dec 51	Hardtack I	28 Apr 58 – 30 Apr 59
Buster-Jangle	22 Oct 51 – 20 Jun 52	Argus	27 Aug 58 – 10 Sep 58
Tumbler-Snapper	1 Apr – 20 Dec 52	Hardtack II	19 Sep 58 – 30 Apr 59
Ivy	1 Nov 52 – 30 Jun 53	Dominic I	25 Apr 62 – 30 Jun 63
Upshot-Knothole	17 Mar – 20 Dec 53	Dominic II	7 Jul 62 – 15 Feb 63
	NTS Test Series		

* Includes on-site presence six-months after completion of test series

TABLE A-3. EEOICPA SEC Cancers, as of 29 Jan 26.

Bone	Leukemia	Brain	Lymphomas, except Hodgkin's	Ovary
Renal	Lung	Breast		Pancreas
Lung	Multiple Myeloma	Colon	Liver, except if cirrhosis of hepatitis B indicated	Salivary Gland
Bile Ducts	Gall Bladder	Esophagus		Small Intestine
Thyroid	Urinary Bladder	Pharynx	Stomach	

Appendix B

US Nuclear Tests from 1961 to 1992, Reactor Experiments at NRDS, and Radiological Impacts from Foreign Atmospheric Nuclear Tests to Radiological Detection Network Around NTS

TABLE B-1. CONUS US Nuclear Tests from 1961 to 1992 and Reactor Experiments at NRDS*

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA† Report	SWRHL Report§, EPA, or DOE
Reactor	30-Jun-59	Kiwi A (EP-XVI)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	1-Jul-59	Kiwi A (EP-XVI)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Reactor	6-Jul-60	Kiwi A' (EP-XVII-116-A)	Not in NV-317			Reactor Test		92r, DOE NV-401
Reactor	8-Jul-60	Kiwi A' (EP-XVII-116-B)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Reactor	19-Oct-60	Kiwi A-3 (EP-216-B)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Reactor	14-May-61	Tory II-A Reactor	Not in NV-317			Reactor Test		DOE NV-401
Nougat	15-Sep-61	Antler	Off-Site	2.6	1320	Weapons-related		1r
Nougat	16-Sep-61	Shrew	On-Site Only	Low	325	Weapons-related		1r
Reactor	28 Sep 61	Tory II-A Reactor	Not in NV-317			Reactor Test		DOE NV-401
Nougat	1-Oct-61	Boomer	On-Site Only	Low	330	Weapons-related		1r
Reactor	5-Oct-61	Tory IIA Reactor	Not in NV-317			Reactor Test		DOE NV-401
Reactor	6-Oct-61	Tory II-A Reactor	Not in NV-317			Reactor Test		DOE NV-401
Nougat	10-Oct-61	Chena	On-Site Only	Low	840	Weapons-related		1r
Nougat	29-Oct-61	Mink	On-Site Only	Low	630	Weapons-related		1r
Nougat	3-Dec-61	Fisher	On-Site Only	13.4	1200	Weapons-related		1r
Reactor	7-Dec-61	Kiwi B-1A (EP-VI/A)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Nougat	10-Dec-61	Gnome {Near Carlsbad, NM}	Off-Site	3.0	1185	Plowshare		1r
Nougat	13-Dec-61	Mad	On-Site Only	0.5	600	Weapons-related		1r
Nougat	17-Dec-61	Ringtail	On-Site Only	Low	1200	Weapons-related		1r

	Nuclear test or reactor experiment with radiological detection of effluents off-site. Off-site meaning outside combined boundary of NTS, TTR, and NTTR for tests conducted on NTS, TTR, NTTR.	† DNA reports focused on nuclear tests with significant DoD member presence; primarily weapons effects tests. § SWRHL reports listed as “xx”r.
	Limited to reactor operations with expectation for important radiological emissions requiring monitoring, based on review of DOE NV-401.	* Tests conducted on Nevada Test Site unless otherwise noted. US Nuclear Tests information from DOE NV-209, Rev 16 (2016).

TABLE B-1. CONUS US Nuclear Tests from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Nougat	22-Dec-61	Feather	Off-Site	0.15	812	Weapons-related		1r
Nougat	9-Jan-62	Stoat	On-Site Only	5.1	1000	Weapons-related		1r
Nougat	18-Jan-62	Agouti	Not in NV-317	6.4	856	Weapons-related		1r
Nougat	30-Jan-62	Dormouse	On-Site Only	Low	1190	Weapons-related		1r
Nougat	8-Feb-62	Stillwater	On-Site Only	3.07	595	Weapons-related		1r
Nougat	9-Feb-62	Armadillo	On-Site Only	7.1	786	Weapons-related		1r
Nougat	15-Feb-62	Hardhat	On-Site Only	5.7	950	Weapons-related	6320F; WT-2293	1r
Nougat	19-Feb-62	Chinchilla	On-Site Only	1.9	492	Weapons-related		1r
Nougat	19-Feb-62	Codsaw	On-Site Only	Low	696	Weapons-related		1r
Nougat	23-Feb-62	Cimarron	On-Site Only	11.9	1000	Weapons-related		1r
Nougat	24-Feb-62	Platypus	On-Site Only	Low	190	Weapons-related		1r
Nougat	1-Mar-62	Pampas	Off-Site	9.5	1200	Joint US-UK		1r
Nougat	5-Mar-62	Danny Boy (cratering)	Off-Site	0.43	110	Weapons-related	6320F; WT-2293	1r
Nougat	6-Mar-62	Ermine	On-Site Only	Low	240	Safety Experiment		1r
Nougat	8-Mar-62	Brazos	On-Site Only	8.4	841	Weapons-related		1r
Nougat	15-Mar-62	Hognose	On-Site Only	Low	800	Weapons-related		1r
Nougat	28-Mar-62	Hoosic	On-Site Only	3.4	613	Weapons-related		1r
Nougat	31-Mar-62	Chinchilla II	On-Site Only	Low	458	Weapons-related		1r
Nougat	5-Apr-62	Dourmouse Prime	On-Site Only	10.6	856	Weapons-related		1r
Nougat	6-Apr-62	Passaic	On-Site Only	Low	766	Weapons-related		1r
Nougat	12-Apr-62	Hudson	On-Site Only	Low	480	Weapons-related		1r
Nougat	14-Apr-62	Platte	Off-Site	1.85	560	Weapons-related		1r
Nougat	21-Apr-62	Dead	On-Site Only	Low	634	Weapons-related		1r
Nougat	27-Apr-62	Black	On-Site Only	Low	714	Weapons-related		1r
Nougat	7-May-62	Paca	On-Site Only	Low	848	Weapons-related		1r
Nougat	10-May-62	Arikaree	On-Site Only	Low	547	Weapons-related		1r
Nougat	12-May-62	Aardvark	On-Site Only	40	1424	Weapons-related		1r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Nougat	19-May-62	Eel	Off-Site	4.5	714	Weapons-related		1r
Nougat	25-May-62	White	On-Site Only	Low	632	Weapons-related		1r
Nougat	1-Jun-62	Raccoon	Not in NV-317	Low	539	Weapons-related		1r
Nougat	6-Jun-62	Packrat	On-Site Only	Low	860	Weapons-related		1r
Nougat	13-Jun-62	Des Moines	Off-Site	2.9	660	Weapons-related	6326F	1r
Nougat	21-Jun-62	Daman I	On-Site Only	Low	854	Weapons-related		1r
Nougat	27-Jun-62	Haymaker	On-Site Only	67	1340	Weapons-related		1r
Nougat	28-Jun-62	Marshmallow	On-Site Only	Low	1020	Weapons-related	6320F; WT-2293	1r
Nougat	30-Jun-62	Sacramento	On-Site Only	Low	500	Weapons-related		1r
Storax I	6-Jul-62	Sedan (Excavation, Crater)	Off-Site	104	635	Plowshare		PNE-200
Dominic II	7-Jul-62	Little Feller II	On-Site Only	Low	-3	Weapons-related	WT-2293	3r
Dominic II	11-Jul-62	Johnnie Boy (Crater)	Off-Site	0.5	1.92	Weapons-related	WT-2293	3r
Storax I	13-Jul-62	Merrimac	On-Site Only	Intermediate	1366	Weapons-related		4r
Dominic II	14-Jul-62	Small Boy {300 ft outside NTS, on NTTR}	Off-Site	Low	-10	Weapons-related	WT-2293	3r
Dominic II	17-Jul-62	Little Feller I	Off-Site	Low	-3	Weapons-related	WT-2293	3r
Storax I	27-Jul-62	Wichita	On-Site Only	Low	493	Weapons-related		4r
Storax I	24-Aug-62	York	On-Site Only	Low	743	Weapons-related		4r
Storax I	24-Aug-62	Bobac	On-Site Only	Low	680	Weapons-related		4r
Reactor	29-Aug-62	Kiwi B-1B (EP-III)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	1-Sep-62	Kiwi B-1B (EP-IV)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Storax I	6-Sep-62	Raritan	On-Site Only	Low	516	Weapons-related		4r
Storax I	14-Sep-62	Hyrax	On-Site Only	Low	709	Weapons-related		4r
Storax I	20-Sep-62	Peba	Not in NV-317	Low	792	Weapons-related		4r
Storax I	29-Sep-62	Allegheny	On-Site Only	Low	692	Weapons-related		4r
Storax II	5-Oct-62	Mississippi	On-Site Only	115	1620	Weapons-related		4r
Storax II	12-Oct-62	Roanoke	On-Site Only	Low	577	Weapons-related		4r
Storax II	12-Oct-62	Wolverine	On-Site Only	Low	240	Weapons-related		4r
Storax II	18-Oct-62	Tioga	Not in NV-317	Low	195	Weapons-related		4r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Storax II	19-Oct-62	Bandicoot	Off-Site	12.5	800	Weapons-related		4r
Storax II	27-Oct-62	Santee	On-Site Only	Low	1048	Weapons-related		4r
Storax II	9-Nov-62	St. Lawrence	On-Site Only	Low	546	Weapons-related		4r
Storax II	15-Nov-62	Gundi	Not in NV-317	Low	792	Weapons-related		4r
Reactor	20-Nov-62	Kiwi B-4A (EP-V)	Not in NV-317			Reactor Test		DOE NV-401
Storax II	27-Nov-62	Anacostia	On-Site Only	Low	747	Plowshare		4r
Reactor	30-Nov-62	Kiwi B-4A (EP-VI)	Not in NV-317			Reactor Test		92r, LV-539-6, DOE NV-401
Storax II	4-Dec-62	Tauton	On-Site Only	Low	748	Weapons-related		4r
Storax II	7-Dec-62	Tendrac	Not in NV-317	Low	993	Joint US-UK		4r
Storax II	12-Dec-62	Madison	On-Site Only	Low	1318	Weapons-related		4r
Storax II	12-Dec-62	Numbat	On-Site Only	Low	761	Weapons-related		4r
Storax II	14-Dec-62	Manatee	On-Site Only	Low	192	Weapons-related		4r
Storax III	8-Feb-63	Casselman	On-Site Only	Low	994	Weapons-related		4r
Storax III	8-Feb-63	Hatchie	Not in NV-317	Low	200	Weapons-related		4r
Storax III	8-Feb-63	Ferret	Not in NV-317	Low	1069	Weapons-related		4r
Storax III	8-Feb-63	Acushi	Not in NV-317	Low	956	Weapons-related		4r
Storax III	21-Feb-63	Carmel	On-Site Only	Low	536	Weapons-related		4r
Storax III	21-Feb-63	Kaweah	On-Site Only	Low	745	Plowshare		4r
Storax III	3-Mar-63	Jerboa	Not in NV-317	Low	988	Weapons-related		4r
Storax III	15-Mar-63	Toyah	On-Site Only	Low	729	Weapons-related		4r
Storax III	29-Mar-63	Gerbil	Not in NV-317	Low	917	Weapons-related		4r
Storax IV	5-Apr-63	Ferret Prime	Not in NV-317	Low	792	Weapons-related		4r
Storax IV	10-Apr-63	Coypu	Not in NV-317	Low	245	Safety Experiment		4r
Storax IV	11-Apr-63	Cumberland	On-Site Only	Low	745	Weapons-related		4r
Storax IV	24-Apr-63	Kootanai	On-Site Only	Low	597	Weapons-related		4r
Storax IV	24-Apr-63	Paisano	Not in NV-317	Low	190	Weapons-related		4r
Storax IV	9-May-63	Gundi Prime	Not in NV-317	Low	892	Weapons-related		4r
Storax IV	15-May-63	Double Tracks {NAFR}	Off-Site	Zero	Ground	Pu Dispersal		4r
Storax IV	17-May-63	Harkee	Not in NV-317	Low	792	Weapons-related		4r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Storax IV	17-May-63	Tejon	Not in NV-317	Low	245	Safety Experiment		4r
Storax IV	22-May-63	Stones	On-Site Only	Intermediate	1295	Weapons-related		4r
Storax IV	25-May-63	Clean Slate I {TTR}	Off-Site	Zero	Ground	Pu Dispersal		4r
Storax IV	29-May-63	Pleasant	On-Site Only	Low	690	Weapons-related		4r
Storax IV	31-May-63	Clean Slate II {TTR}	On-Site Only	Zero	Ground	Pu Dispersal		4r
Storax IV	5-Jun-63	Yuba	Off-Site	3.1	795	Weapons-related		4r
Storax IV	6-Jun-63	Hutia	Not in NV-317	Low	442	Weapons-related		4r
Storax IV	6-Jun-63	Apshapa	On-Site Only	Low	295	Weapons-related		4r
Storax IV	9-Jun-63	Clean Slate III {TTR}	Off-Site	Zero	Ground	Pu Dispersal		4r
Storax IV	14-Jun-63	Mataco	Not in NV-317	Low	642	Weapons-related		4r
Storax IV	25-Jun-63	Kennebec	On-Site Only	Low	742	Weapons-related		4r
Niblick	12-Aug-63	Pekan	On-Site Only	Low	991	Weapons-related		12r
Niblick	15-Aug-63	Satsop	Not in NV-317	Low	738	Weapons-related		12r
Niblick	23-Aug-63	Kohocton (w/ Nateches)	On-Site Only	Low	835	Weapons-related		12r
Niblick	13-Sep-63	Ahtanum	On-Site Only	Low	740	Weapons-related		12r
Niblick	13-Sep-63	Bilby	On-Site Only	249	2343	Weapons-related		12r
Niblick	27-Sep-63	Carp	On-Site Only	Low	1081	Weapons-related		12r
Niblick	27-Sep-63	Narraguagus	On-Site Only	Low	493	Weapons-related		12r
Niblick	11-Oct-63	Grunion	On-Site Only	Low	856	Weapons-related		12r
Niblick	11-Oct-63	Tornillo (Excavation, Shaft)	On-Site Only	Low	489	Plowshare		12r
Niblick	16-Oct-63	Clearwater	On-Site Only	Intermediate	1798	Weapons-related		12r
Niblick	17-Oct-63	Mullet	Not in NV-317	Low	198	Safety Experiment		12r
Niblick	26-Oct-63	Shoal {Fallon, NV}	On-Site Only	12	1204	Vela Uniform		12r
Niblick	14-Nov-63	Anchovy	On-Site Only	Low	853	Weapons-related		12r
Niblick	15-Nov-63	Mustang	On-Site Only	Low	544	Weapons-related		12r
Niblick	22-Nov-63	Greys	On-Site Only	Intermediate	987	Weapons-related		12r
Niblick	4-Dec-63	Barrcuda	On-Site Only	Low	864	Weapons-related		12r
Niblick	4-Dec-63	Sardine	On-Site Only	Low	860	Weapons-related		12r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Niblick	12-Dec-63	Eagle	Off-Site	5.3	540	Weapons-related		12r, EPA-600-8-87
Niblick	20-Dec-63	Tuna	On-Site Only	Low	1359	Weapons-related		12r
Niblick	16-Jan-64	Fore	On-Site Only	20 - 200	1609	Weapons-related		12r, 20r
Niblick	23-Jan-64	Oconto	Off-Site	10.5	868	Weapons-related		12r,20r
Niblick	30-Jan-64	Club	On-Site Only	< 20	590	Weapons-related		12r, 20r
Niblick	12-Feb-64	Solendon	On-Site Only	< 20	493	Weapons-related		12r, 20r
Niblick	13-Feb-64	Bunker	On-Site Only	< 20	745	Weapons-related		12r, 20r
Niblick	18-Feb-64	Bonefish	On-Site Only	< 20	984	Weapons-related		12r, 20r
Niblick	18-Feb-64	Mackerel	Not in NV-317	< 20	1095	Weapons-related		12r, 20r
Niblick	20-Feb-64	Klickitat (Excavation, Shaft)	On-Site Only	20 - 200	1616	Plowshare		12r, 20r
Niblick	12-Mar-64	Handicap	On-Site Only	< 20	470	Weapons-related		12r, 20r
Niblick	13-Mar-64	Pike	Off-Site	< 20	374	Weapons-related		12r,14r,20r, EPA-600-8-87
Niblick	14-Apr-64	Hook	On-Site Only	< 20	668	Weapons-related		12r, 20r
Niblick	15-Apr-64	Sturgeon	On-Site Only	< 20	492	Weapons-related		12r, 20r
Niblick	17-Apr-64	Bogey	On-Site Only	< 20	390	Weapons-related		12r, 20r
Niblick	24-Apr-64	Turf	On-Site Only	20 - 200	1663	Weapons-related		12r, 20r
Niblick	29-Apr-64	Pipefish	On-Site Only	< 20	860	Weapons-related		12r, 20r
Niblick	7-May-64	Driver	On-Site Only	< 20	492	Weapons-related		12r, 20r
Reactor	8-May-64	Kiwi B4D Reactor (Intermediate)	Not in NV-317			Reactor Test		20r
Reactor	12-May-64	Tory II-C Reactor	Not in NV-317			Reactor Test		10r, 12r, 20r
Reactor	13-May-64	Kiwi B4D Reactor (Full)	Not in NV-317			Reactor Test		7r, 20r, 92r, LV-539-6, DOE NV-401
Niblick	14-May-64	Backswing	On-Site Only	< 20	536	Weapons-related		12r, 20r
Niblick	15-May-64	Minnow	Not in NV-317	< 20	792	Weapons-related		12r, 20r
Reactor	20-May-64	Tory II-C Reactor	Not in NV-317			Reactor Test		10r, 12r, 20r, DOE NV-401
Niblick	11-Jun-64	Ace (Excavation, Shaft)	On-Site Only	< 20	862	Plowshare		12r, 20r
Niblick	12-Jun-64	Bitterling	Not in NV-317	< 20	632	Weapons-related		12r, 20r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Niblick	18-Jun-64	Duffer	On-Site Only	< 20	1463	Weapons-related		12r, 20r
Niblick	25-Jun-64	Fade	On-Site Only	< 20	673	Weapons-related		12r, 20r
Niblick	30-Jun-64	Dub	On-Site Only	< 20	848	Plowshare		12r, 20r
Whetstone	16-Jul-64	Bye	On-Site Only	20 - 200	1277	Weapons-related		22r
Whetstone	17-Jul-64	Cormorant	On-Site Only	< 20	892	Joint US-UK		22r
Whetstone	23-Jul-54	Links	On-Site Only	< 20	394	Weapons-related		22r
Whetstone	23-Jul-64	Trojon	Not in NV-317	< 20	633	Weapons-related		22r
Whetstone	19-Aug-64	Alva	Off-Site	4.4	545	Weapons-related		22r, EPA-600-8-87
Whetstone	22-Aug-64	Canvasback	On-Site Only	< 20	1470	Weapons-related		22r
Whetstone	27-Aug-64	Player	Not in NV-317	< 20	296	Safety Experiment		22r
Whetstone	28-Aug-64	Haddock	Not in NV-317	< 20	1193	Weapons-related		22r
Whetstone	4-Sep-64	Guanay	Not in NV-317	< 20	856	Weapons-related		22r
Whetstone	11-Sep-64	Spoon	On-Site Only	< 20	590	Weapons-related		22r
Reactor	28-Aug-64	Kiwi B4E Reactor (EP-V)	Not in NV-317	NA	NA	Reactor Test		22r, 15r, 92r, NERC-LV-539-6
Reactor	10-Sep-64	Kiwi B4E Reactor (EP-VI)	Not in NV-317	NA	NA	Reactor Test		22r, 15r, 92r, NERC-LV-539-6
Whetstone	9-Oct-64	Par	On-Site Only	38	1325	Plowshare		22r
Reactor	24-Sep-64	NRX-A2 (EP-IV)	Not in NV-317	NA	NA	Reactor Test		22r, 16r, 92r, NERC-LV-539-6
Whetstone	25-Sep-64	Courser	Not in NV-317	Zero	1178	Joint US-UK		22r
Whetstone	2-Oct-64	Auk	Not in NV-317	< 20	1331	Weapons-related		22r
Whetstone	9-Oct-64	Par	Not in NV-317	38	412, 849	Plowshare		22r
Reactor	15-Oct-64	NRX-A2 (EP-V)	Not in NV-317	NA	NA	Reactor Test		22r, 16r, 92r, NERC-LV-539-6
Whetstone	16-Oct-64	Turnstone (w/Barbel)	On-Site Only	< 20	850	Weapons-related		22r
Whetstone	22-Oct-64	Salmon {near Hattiesburg MS}	Not in NV-317	5.3	2710	Vela Uniform		22r
Whetstone	23-Oct-64	Garden	Not in NV-317	< 20	491	Weapons-related		22r
Whetstone	31-Oct-64	Forest	Not in NV-317	< 20	1269	Weapons-related		22r
Whetstone	5-Nov-64	Handcar	On-Site Only	12	1322	Plowshare		22r
Whetstone	5-Dec-64	Crepe	On-Site Only	20 - 200	1326	Weapons-related		21r, 22r, EPA-600-8-87
Whetstone	5-Dec-64	Drill (Source-Lower)	Off-Site	< 20, 3.4	725	Weapons-related		21r, 22r, EPA-600-8-87
Whetstone	5-Dec-64	Drill (Target-Upper)	Off-Site	Same hole	624	Weapons-related		22r, 16r, 92r, NERC-LV-539-6

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Whetstone	16-Dec-65	Parrot	Off-Site	1.3	591	Weapons-related		22r, EPA-600-8-87
Whetstone	16-Dec-65	Cassawary (w/ Hooppoe)	Not in NV-317	< 20 each	493, 231	Weapons-related		22r
Whetstone	16-Dec-64	Mudpack	On-Site Only	2.7	498	Weapons Effects	6320F	22r
Whetstone	18-Dec-64	Sulky (Excavation, Shaft)	Off-Site	0.092	90	Plowshare		22r, 29r
Reactor	12-Jan-65	Kiwi TNT Reactor	Not in NV-317			Reactor Test		17r, 23r, 26r, 92r, NERC-LV-539-6
Whetstone	14-Jan-65	Wool	On-Site Only	< 20	706	Weapons-related		23r
Whetstone	29-Jan-65	Tern	On-Site Only	< 20	689	Weapons-related		23r
Whetstone	4-Feb-65	Cashmere	On-Site Only	< 20	762	Weapons-related		23r
Whetstone	12-Feb-65	Alpaca	Off-Site	0.33	737	Weapons-related		23r, EPA-600-8-87
Whetstone	16-Feb-65	Merlin	On-Site Only	10.1	971	Weapons-related		23r
Whetstone	18-Feb-65	Wishbone	On-Site Only	< 20	588	Weapons Effects	6320F	23r
Whetstone	19-Feb-65	Seersucker	On-Site Only	< 20	472	Weapons-related		23r
Whetstone	3-Mar-65	Wagtail	On-Site Only	20 - 200	2461	Weapons-related		23r
Whetstone	20-Mar-65	Suede	On-Site Only	< 20	469	Weapons-related		23r
Whetstone	26-Mar-65	Cup	On-Site Only	20 - 200	1761	Weapons-related		23r
Whetstone	5-Apr-65	Kestrel	On-Site Only	< 20	1467	Weapons-related		23r
Whetstone	14-Apr-65	Palanquin (Excavation, Crater)	Off-Site	4.3	280	Plowshare		23r
Whetstone	21-Apr-65	Gum Drop	On-Site Only	< 20	1000	Weapons Effects	6320F	23r
Whetstone	22-Apr-65	Chenille	On-Site Only	< 20	459	Weapons-related		23r
Whetstone	23-Apr-65	Muscovy	Not in NV-317	< 20	592	Weapons-related		23r
Reactor	23-Apr-65	NRX-A3 (EP-4)	Not in NV-317			Reactor Test		18r, 23r, 92r, NERC-LV-539-6
Whetstone	7-May-65	Tee	Off-Site	7	624	Weapons Effects	Whetstone	7-May-65
Whetstone	12-May-65	Buteo	Not in NV-317	< 20	2282	Weapons-related		23r
Whetstone	14-May-65	Cambric	Not in NV-317	0.75	967	Weapons-related		23r
Whetstone	14-May-65	Scaup	Not in NV-317	< 20	1401	Weapons-related		23r
Whetstone	21-May-65	Tweed	On-Site Only	< 20	922	Weapons-related		23r
Reactor	20-May-65	NRX-A3 (EP-5)	Not in NV-317			Reactor Test		18r, 23r, 92r, NERC-LV-539-6
Whetstone	11-Jun-65	Petrel	Not in NV-317	1.3	593	Weapons-related		23r

TABLE B-1. US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Whetstone	11-Jun-65	Organdy	On-Site Only	< 20	551	Weapons-related		23r
Reactor	28-May-65	NRX-A3 (EP-6)	Not in NV-317			Reactor Test		18r, 23r, 92r, NERC-LV-539-6
Whetstone	16-Jun-65	Diluted Waters	Off-Site	< 20	625	Weapons-related	6320F	23r, EPA-600-8-87
Whetstone	17-Jun-65	Tiny Tot	On-Site Only	< 20	364	Weapons Effects	6320F	23r
Reactor	25-Jun-65	Phoebus 1-A Experiment	Not in NV-317			Reactor Test		19r, 23r, 92r, NERC-LV-539-6
Flintlock	16-Jul-65	Izzer	On-Site Only	< 20	535	Weapons-related		24r
Flintlock	22-Jul-65	Pongee	On-Site Only	< 20	440	Weapons-related		24r
Flintlock	23-Jul-65	Bronze	On-Site Only	20 - 200	1742	Weapons-related		24r
Flintlock	6-Aug-65	Mauve	Not in NV-317	< 20	1053	Weapons-related		24r
Flintlock	21-Aug-65	Ticking	On-Site Only	< 20	682	Weapons-related		24r
Flintlock	27-Aug-65	Centaur	On-Site Only	< 20	564	Weapons-related		24r
Flintlock	1-Sep-65	Screamer (w/Moa)	On-Site Only	< 20	991	Weapons Effects		24r
Flintlock	10-Sep-65	Charcoal	Not in NV-317	20 - 200	1494	Joint US-UK		24r
Flintlock	17-Sep-65	Elkhart	On-Site Only	< 20	720	Weapons-related		24r
Flintlock	29-Oct-65	Long Shot {Amchitka, AK}	Not in NV-317	80	2297	Vela Uniform		6r, 24r
Flintlock	12-Nov-65	Sepia	On-Site Only	< 20	791	Weapons-related		24r
Flintlock	23-Nov-65	Kermet	On-Site Only	< 20	643	Weapons-related		24r
Flintlock	3-Dec-65	Corduroy	On-Site Only	20 - 200	2236	Weapons-related		24r
Flintlock	16-Dec-65	Emerson	On-Site Only	< 20	853	Weapons-related		24r
Flintlock	16-Dec-65	Buff	Not in NV-317	20 - 200	1642	Weapons-related		24r
Flintlock	13-Jan-66	Maxwell	On-Site Only	< 20	601	Weapons-related		37r
Flintlock	18-Jan-66	Lampblack	Not in NV-317	20 - 200	1842	Weapons-related		37r
Flintlock	18-Jan-66	Sienna	On-Site Only	< 20	902	Weapons-related		37r
Flintlock	21-Jan-66	Dovekie	Not in NV-317	< 20	1093	Weapons-related		37r
Flintlock	22-Jan-66	Reo	On-Site Only	< 20	682	Weapons-related		37r
Flintlock	3-Feb-66	Plaid II	On-Site Only	< 20	886	Weapons-related		37r
Reactor	3-Feb-66	NRX-A4 (EP-IIB)	Not in NV-317			Reactor Test		30r, 37r, 92r, NERC-LV-539-6
Reactor	11-Feb-66	NRX-A4 (EP-IIC)	Not in NV-317			Reactor Test		30r, 37r, 92r, NERC-LV-539-6
Flintlock	24-Feb-66	Rex	On-Site Only	19	2204	Weapons-related		37r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Reactor	3-Mar-66	NRX-A4 (EP-III)	Not in NV-317			Reactor Test		30r, 37r, 92r, NERC-LV-539-6, EPA-600-8-87
Flintlock	5-Mar-66	Red Hot	Off-Site	< 20	1329	Weapons-related	6321F	37r
Flintlock	7-Mar-66	Finfoot & Cinnamon	On-Site Only	< 20 each	393, 640	Safety Experiment & Weapons-related		37r
Flintlock	12-Mar-66	Clymer	On-Site Only	< 20	1306	Weapons-related		37r
Reactor	16-Mar-66	NRX-A4 (EP-IV)	Not in NV-317			Reactor Test		30r, 37r, 92r, NERC-LV-539-6
Flintlock	18-Mar-66	Purple	Not in NV-317	< 20	1092	Weapons-related		37r
Flintlock	24-Mar-66	Templar (Excavation, Shaft)	On-Site Only	< 20	495	Plowshare		37r
Reactor	25-Mar-66	NRX-A4 (EP-IVA)	Not in NV-317			Reactor Test		30r, 37r, 92r, NERC-LV-539-6
Flintlock	1-Apr-66	Lime	Not in NV-317	< 20	1842	Weapons-related		37r
Flintlock	6-Apr-66	Stutz	On-Site Only	< 20	739	Weapons-related		37r
Flintlock	7-Apr-66	Tomato	Not in NV-317	< 20	742	Weapons-related		37r
Flintlock	14-Apr-66	Duryea	On-Site Only	70	1786	Weapons-related		37r
Flintlock	23-Apr-66	Fenton	Off-Site	1.4	549	Weapons-related		37r, EPA-600-8-87
Flintlock	25-Apr-66	Pin Stripe	Off-Site	< 20	971	Weapons Effects	6321F	37r, 41r, 59r, EPA-600-8-87
Flintlock	29-Apr-66	Ochre	Not in NV-317	< 20	970	Safety Experiment		37r
Flintlock	4-May-66	Traveler	On-Site Only	< 20	646	Weapons-related		37r
Flintlock	5-May-66	Cyclamen	Not in NV-317	12	1001	Weapons-related		37r
Flintlock	6-May-66	Chartreuse	Not in NV-317	73	2188	Weapons-related		37r
Flintlock	12-May-66	Tapestry	On-Site Only	< 20	811	Weapons-related	6326F	37r
Flintlock	13-May-66	Piranha	Not in NV-317	20 - 200	1800	Weapons-related		37r
Flintlock	19-May-66	Dumont	On-Site Only	20 - 200	2201	Weapons-related		37r
Reactor	26-May-66	NRX-A5 (EP-I)	Not in NV-317			Reactor Test		32r, 37r
Flintlock	27-May-66	Discus Thrower	Not in NV-317	22	1105	Weapons Effects	6321F	37r
Flintlock	2-Jun-66	Pile Driver	On-Site Only	62	1519	Weapons-related	6321F	37r
Flintlock	3-Jun-66	Tanya	Not in NV-317	20 - 200	1840	Weapons-related		37r
Reactor	8-Jun-66	NRX-A5 (EP-II and -III)	Not in NV-317			Reactor Test		32r, 37r, 92r, NERC-LV-539-6
Flintlock	10-Jun-66	Puce	Not in NV-317	< 20	1593	Weapons-related		37r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Flintlock	15-Jun-66	Double Play	Off-Site	< 20	1050	Weapons Effects	6321F	37r, EPA-600-8-87
Flintlock	15-Jun-66	Kankakee	On-Site Only	20 - 200	1494	Weapons-related		37r
Reactor	23-Jun-66	NRX-A5 (EP-IV)	Not in NV-317			Reactor Test		32r, 37r, 92r, NERC-LV-539-6
Flintlock	25-Jun-66	Vulcan	On-Site Only	25	1057	Plowshare		37r
Flintlock	30-Jun-66	Halfbreak	Not in NV-317	365	2688	Weapons-related		37r
Latchkey	28-Jul-66	Saxon (Excavation, Shaft)	On-Site Only	< 20	502	Plowshare		38r
Latchkey	10-Aug-66	Rovena	On-Site Only	< 20	641	Weapons-related		38r
Latchkey	12-Aug-66	Tangerine	Not in NV-317	< 20	288	Safety Experiment		38r
Latchkey	12-Sep-66	Derringer	Off-Site	7.8	837	Weapons Effects		38r, EPA-600-8-87
Latchkey	23-Sep-66	Daiquiri	Not in NV-317	< 20	1841	Weapons-related		38r
Latchkey	29-Sep-66	Newark	On-Site Only	< 20	750	Weapons-related		38r
Latchkey	15-Oct-66	Khaki	Not in NV-317	< 20	763	Weapons-related		38r
Latchkey	5-Nov-66	Simms (Excavation, Shaft)	On-Site Only	< 20	650	Plowshare		38r
Latchkey	11-Nov-66	Ajax	On-Site Only	< 20	782	Weapons-related	6326F	38r
Latchkey	18-Nov-66	Cerise	On-Site Only	< 20	692	Weapons-related		38r
Latchkey	22-Nov-66	Vigil	On-Site Only	< 20	299	Safety Experiment		38r
Latchkey	3-Dec-66	Sterling {near Hattiesburg MS}	Not in NV-317	0.38	2710	Vela Uniform		38r
Latchkey	13-Dec-66	Sidecar	On-Site Only	< 20	788	Weapons-related		38r
Latchkey	13-Dec-66	New Point	On-Site Only	< 20	784	Weapons Effects	6321F	38r
Latchkey	20-Dec-66	Greeley	Not in NV-317	870	3991	Weapons-related		38r
Latchkey	18-Jan-67	Rivet I	Not in NV-317	< 20	498	Weapons-related		47r
Latchkey	19-Jan-67	Nash	Off-Site	39	1194	Weapons-related		47r, EPA-600-8-87
Latchkey	20-Jan-67	Bourbon	Not in NV-317	20 - 200	1836	Weapons-related		47r
Reactor	25-Jan-67	Phoebus 1-B (EP-I)	Not in NV-317			Reactor Test		45r, 47r
Latchkey	26-Jan-67	Rivet II	On-Site Only	< 20	646	Weapons-related		47r
Reactor	2-Feb-67	Phoebus 1-B (EP-II)	Not in NV-317			Reactor Test		45r, 47r
Latchkey	8-Feb-67	Ward	Not in NV-317	< 20	853	Weapons-related		47r
Reactor	10-Feb-67	Phoebus 1-B (EP-III)	Not in NV-317			Reactor Test		45r, 47r, 92r, NERC-LV-539-6

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Reactor	23-Feb-67	Phoebus 1-B (EP-IV)	Not in NV-317			Reactor Test		45r, 46r, 47r, 92r, NERC-LV-539-6
Latchkey	23-Feb-67	Persimmon	Not in NV-317	< 20	981	Weapons-related		47r
Latchkey	23-Feb-67	Agile	Not in NV-317	20 - 200	2406	Weapons-related		47r
Latchkey	2-Mar-67	Rivet III	On-Site Only	< 20	890	Weapons-related		47r
Latchkey	3-Mar-67	Mushroom	On-Site Only	< 20	587	Weapons-related		47r
Latchkey	10-Mar-67	Fizz	Not in NV-317	< 20	386	Safety Experiment		47r
Latchkey	4-Apr-67	Oakland	On-Site Only	< 20	542	Weapons-related		47r
Latchkey	6-Apr-67	Heilman	On-Site Only	< 20	499	Weapons-related		47r
Latchkey	7-Apr-67	Fawn	Not in NV-317	< 20	889	Weapons-related		47r
Latchkey	21-Apr-67	Chocolate	Not in NV-317	< 20	789	Weapons-related		47r
Latchkey	27-Apr-67	Effendi	Not in NV-317	< 20	725	Weapons-related		47r
Latchkey	10-May-57	Mickey	Not in NV-317	20 - 200	1639	Weapons-related		47r
Latchkey	20-May-67	Commodore	On-Site Only	250	2449	Weapons-related		47r
Latchkey	23-May-67	Scotch	Not in NV-317	155	389	Weapons-related		47r
Latchkey	26-May-67	Absinthe	Not in NV-317	< 20	2075	Safety Experiment		47r
Latchkey	26-May-67	Knickerbocker	On-Site Only	76	2069	Weapons-related		47r
Latchkey	22-Jun-67	Switch (Excavation, Shaft)	On-Site Only	< 20	990	Plowshare		47r
Latchkey	26-Jun-67	Midi Mist	Off-Site	< 20	1240	Weapons Effects	6321F	47r
Latchkey	29-Jun-67	Umber	Off-Site	10	1017	Weapons Effects		47r, EPA-600-8-87
Crosstie	14-Jul-67	Vito	Not in NV-317	< 20	317	Weapons-related		64r
Crosstie	27-Jul-67	Stanley	On-Site Only	20 - 200	1587	Weapons-related		64r
Crosstie	4-Aug-67	Gibson	Not in NV-317	< 20	790	Weapons-related		64r
Crosstie	10-Aug-67	Washer	On-Site Only	< 20	1536	Weapons-related		64r
Crosstie	18-Aug-67	Bordeaux	Not in NV-317	< 20	1089	Weapons-related		64r
Crosstie	24-Aug-67	Lexington	On-Site Only	< 20	741	Weapons-related		64r
Crosstie	31-Aug-67	Door Mist	Off-Site	< 20	1463	Weapons-related	6322F	64r, EPA-600-8-87
Crosstie	7-Sep-67	Yard	On-Site Only	20 - 200	1708	Weapons-related		64r
Crosstie	15-Sep-67	Gilroy	On-Site Only	< 20	787	Weapons-related		64r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Crosstie	21-Sep-67	Marvel	On-Site Only	2.2	572	Weapons-related		64r
Crosstie	27-Sep-67	Zaza	Not in NV-317	20 - 200	2188	Weapons-related		64r
Crosstie	18-Oct-67	Lanpher	On-Site Only	20 - 200	2343	Weapons-related		64r
Crosstie	25-Oct-67	Cognac	On-Site Only	< 20	787	Weapons-related		64r
Crosstie	25-Oct-67	Sazerac	On-Site Only	< 20	988	Weapons-related		64r
Crosstie	25-Oct-67	Worth	On-Site Only	< 20	614	Weapons-related		64r
Crosstie	8-Nov-67	Cobbler	Not in NV-317	< 20	2189	Weapons-related		64r
Reactor	21-Nov-67	NRX-A6 (EP-I)	Not in NV-317			Reactor Test		64r, 78r
Reactor	6-Dec-67	NRX-A6 (EP-II)	Not in NV-317			Reactor Test		64r, 78r
Crosstie	6-Dec-67	Polka	On-Site Only	< 20	623	Weapons-related		64r
Crosstie	12-Dec-67	Gasbuggy {near Farmington, NM}	On-Site Only	29	4227	Plowshare		64r, 87r, 99r, 100r, 105r
Crosstie	15-Dec-67	Stilt	Not in NV-317	< 20	1091	Weapons-related		64r
Reactor	15-Dec-67	NRX-A6 (EP-IIIA)	Not in NV-317			Reactor Test		64r, 78r, 92r, NERC-LV-539-6
Crosstie	18-Jan-68	Hupmobile	Off-Site	7.4	810	Weapons-related		81r, EPA-600-8-87
Crosstie	19-Jan-68	Faultless {Central Nevada}	Not in NV-317	200 - 1000	3200	Seismic Calibration		51r, 81r
Crosstie	19-Jan-68	Staccato	On-Site Only	20 - 200	1455	Weapons-related		81r
Crosstie	24-Jan-68	Brush	On-Site Only	< 20	388	Weapons-related		81r
Crosstie	26-Jan-68	Cabriolet (Excavation, Crater)	Off-Site	2.3	170	Plowshare		81r
Crosstie	31-Jan-68	Mallet	Not in NV-317	< 20	788	Weapons-related		81r
Crosstie	21-Feb-68	Torch	Not in NV-317	< 20	789	Weapons-related		81r
Crosstie	21-Feb-68	Knox	On-Site Only	20 - 200	2116	Weapons-related		81r
Crosstie	29-Feb-68	Dorsal Fin	Not in NV-317	< 20	1345	Weapons Effects	6322F	81r
Crosstie	5-Mar-68	Russet	On-Site Only	< 20	393	Weapons-related		81r
Crosstie	12-Mar-68	Buggy-A, -B, -C, -D, -E (Excavation, Crater)	Off-Site	1.08 each	135	Plowshare		81r
Crosstie	14-Mar-68	Pommard	Not in NV-317	1.5	686	Weapons-related		81r
Crosstie	22-Mar-68	Stinger	Not in NV-317	20 - 200	2191	Weapons-related		81r
Crosstie	25-Mar-68	Milk Shake	On-Site Only	< 20	869	Weapons Effects	6322F	81r
Crosstie	4-Apr-68	Bevel	Not in NV-317	< 20	790	Weapons-related		81r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Crosstie	10-Apr-68	Noor, Throw	On-Site Only	20 - 200, < 20	1253, 757	Weapons-related		81r
Crosstie	18-Apr-68	Shuffle	On-Site Only	20 - 200	1619	Weapons-related		81r
Crosstie	23-Apr-68	Scroll	On-Site Only	< 20	750	Vela Uniform		81r
Crosstie	26-Apr-68	Boxcar	Not in NV-317	1300	3825	Weapons-related		81r
Crosstie	3-May-68	Hatchet	Not in NV-317	< 20	789	Weapons-related		81r
Crosstie	8-May-68	Crock	On-Site Only	< 20	594	Weapons-related		81r
Crosstie	17-May-68	Clarksmobile	Not in NV-317	20 - 200	1551	Weapons-related		81r
Reactor	22-May-68	Phoebus 2A (EP-I)	Not in NV-317			Reactor Test		72r, 81r
Crosstie	28-May-68	Adze	On-Site Only	< 20	787	Weapons-related		81r
Reactor	29-May-68	Phoebus 2A (EP-II)	Not in NV-317			Reactor Test		72r, 81r
Crosstie	5-Jun-68	Wembley	Not in NV-317	< 20	781	Weapons-related		81r
Crosstie	6-Jun-68	Tub-A, -B, -C, -D, -F	On-Site Only	< 20 each	620-896	Weapons-related		81r
Reactor	8-Jun-68	Phoebus 2A EPIII	Not in NV-317			Reactor Test		72r, 81r, 92r, NERC-LV-539-6
Crosstie	15-Jun-68	Rickey	Not in NV-317	20 - 200	2242	Weapons-related		81r
Crosstie	25-Jun-68	Funnel	On-Site Only	< 20	387	Weapons-related		81r
Crosstie	25-Jun-68	Sevilla	On-Site Only	< 20	1175	Weapons-related		81r
Reactor	26-Jun-68	Phoebus 2A EP IV	Not in NV-317			Reactor Test		60r, 72r, 81r, 92r, NERC-LV-539-6
Crosstie	28-Jun-68	Chateaugay	Not in NV-317	20 - 200	1992	Weapons-related		81r
Reactor	18-Jul-68	Phoebus 2A EP V (A&B)	Not in NV-317			Reactor Test		60r, 72r, 83r, 92r, NERC-LV-539-6
Bowline	17-Jul-68	Spud	Not in NV-317	< 20	788	Weapons-related		83r
Bowline	30-Jul-68	Tanya	On-Site Only	20 - 200	1250	Weapons-related		83r
Bowline	9-Aug-68	Imp	On-Site Only	< 20	597	Weapons-related		83r
Bowline	15-Aug-68	Rack	On-Site Only	< 20	655	Weapons-related		83r
Bowline	27-Aug-68	Diana Moon	On-Site Only	< 20	794	Weapons-related	6322F	83r
Bowline	29-Aug-68	Sled	Not in NV-317	20 - 200	2391	Weapons-related		83r
Bowline	6-Sep-68	Noggin	On-Site Only	20 - 200	1909	Weapons-related		83r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Bowline	12-Sep-68	Knife A	Not in NV-317	< 20	2391	Weapons-related		83r
Bowline	17-Sep-68	Stoddard (Excavation, Shaft)	On-Site Only	20 - 200	1535	Plowshare		83r
Bowline	24-Sep-68	Hudson Seal	Not in NV-317	< 20	1130	Weapons Effects		83r
Bowline	3-Oct-68	Welder	Not in NV-317	< 20	386	Safety Experiment		83r
Bowline	3-Oct-68	Knife C	Not in NV-317	< 20	989	Weapons Effects		83r
Bowline	1-Oct-68	Vat	Not in NV-317	< 20	640	Weapons-related		83r
Bowline	29-Oct-68	Hula	On-Site Only	< 20	656	Weapons-related		83r
Bowline	31-Oct-68	Bit-A & -B	Not in NV-317	< 20 each	487/387	Safety Experiment		83r
Bowline	31-Oct-68	File	Not in NV-317	< 20	751	Weapons-related		83r
Bowline	4-Nov-68	Crew, Crew 2 and 3	Not in NV-317	20-150, < 20	1977	Weapons-related		83r
Bowline	15-Nov-68	Auger	Not in NV-317	< 20	789	Weapons-related		83r
Bowline	15-Nov-68	Knife B	Not in NV-317	< 20	1191	Weapons-related		83r
Bowline	20-Nov-68	Ming Vase	Not in NV-317	< 20	1010	Weapons Effects	6322F	83r
Reactor	21-Nov-68	Pewee 1 (EP II)	Not in NV-317			Reactor Test		83r, 87r
Bowline	22-Nov-68	Tinderbox	On-Site Only	< 20	1450	Weapons-related		83r
Reactor	4-Dec-68	Pewee 1 (EP III)	Not in NV-317			Reactor Test		83r, 87r, 92r, NERC-LV-539-6
Reactor	4 Dec 68	XE Prime	Not in NV-317			Reactor Test		DOE NV-401
Reactor	6 Dec 68	XE Prime	Not in NV-317			Reactor Test		DOE NV-401
Bowline	8-Dec-68	Schooner (Excavation, Crater)	Off-Site	30	365	Plowshare		83r, 503r, UCRL-50718
Bowline	12-Dec-68	Bay Leaf	Not in NV-317	< 20	427	Safety Experiment		83r
Bowline	12-Dec-68	Tyg-A, -B, -C	On-Site Only	< 20 each	749,824,749	Weapons-related		83r
Bowline	12-Dec-68	Scissors	On-Site Only	< 20	789	Weapons-related		83r
Bowline	19-Dec-68	Benham	Not in NV-317	1150	4600	Weapons-related		83r
Bowline	15-Jan-69	Packard	On-Site Only	10	810	Weapons Effects		97r
Bowline	15-Jan-69	Wineskin	Not in NV-317	20 - 200	1700	Weapons-related		97r
Bowline	22-Jan-69	Shave	Not in NV-317	< 20	790	Weapons-related		97r
Bowline	30-Jan-69	Vice	Not in NV-317	20 - 200	1490	Weapons-related		97r
Bowline	30-Jan-69	Biggin	Not in NV-317	< 20	795	Weapons-related		97r
Bowline	4-Feb-69	Nipper	Not in NV-317	< 20	790	Weapons-related		97r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Bowline	4-Feb-69	Winch	Not in NV-317	< 20	789	Weapons-related		97r
Bowline	12-Feb-69	Cypress	Not in NV-317	< 20	1350	Weapons Effects	6326F	97r
Reactor	20 Feb 69	XE-Prime (EP-1A)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	27 Feb 69	XE-Prime (EP-1B)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	13 Mar 69	XE-Prime (EP-2)	Not in NV-317			Reactor Test		DOE NV-401
Bowline	18-Mar-69	Valise	On-Site Only	< 20	296	Safety Experiment		97r
Bowline	18-Mar-69	Chatty	On-Site Only	< 20	639	Weapons-related		97r
Bowline	20-Mar-69	Barsac	On-Site Only	< 20	997	Weapons-related		97r
Reactor	20 Mar 69	XE-Prime (EP-2A)	Not in NV-317			Reactor Test		DOE NV-401
Bowline	21-Mar-69	Coffer	On-Site Only	< 100	1525	Weapons-related		97r
Reactor	17 Apr 69	XE-Prime (EP-3C)	On-Site Only			Reactor Test		DOE NV-401
Bowline	24-Apr-69	Gourd-Amber & -Brown	Not in NV-317	< 20 each	595 & 744	Weapons-related		97r
Bowline	30-Apr-69	Blenton	On-Site Only	20 - 200	1831	Weapons-related		97r
Bowline	30-Apr-69	Thistle	Not in NV-317	20 - 200	1839	Weapons-related		97r
Bowline	7-May-69	Purse	Not in NV-317	20 - 200	1964	Weapons-related		97r
Bowline	15-May-69	Ailment	Not in NV-317	< 20	789	Weapons-related		97r
Bowline	27-May-69	Ipecac-A & -B	On-Site Only	< 20 each	407	Safety Experiment		97r
Bowline	27-May-69	Torrido	Not in NV-317	20 - 200	1689	Weapons-related		97r
Reactor	11-Jun-69	XE-Prime (EP-VC)	Not in NV-317			Reactor Test		97r, 92r, NERC-LV-539-6 & -13
Bowline	12-Jun-69	Tapper	On-Site Only	< 20	994	Weapons-related		97r
Mandrel	26-Jun-69	Bowl-1 & -2	Not in NV-317	< 20 each	650	Weapons-related		97r
Reactor	26 Jun 69	XE-Prime (EP-4A)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	10 Jul 69	XE-Prime (EP-6A)	Not in NV-317			Reactor Test		DOE NV-401
Mandrel	16-Jul-69	Ildrim	Not in NV-317	20 - 200	1346	Weapons-related		98r
Mandrel	16-Jul-69	Hutch	On-Site Only	20 - 200	1800	Weapons-related		98r
Reactor	24 Jul 69	XE-Prime (EP-7A)	Not in NV-317			Reactor Test		DOE NV-401
Reactor	13 Aug 69	XE-Prime (EP-8A)	Not in NV-317			Reactor Test		DOE NV-401
Mandrel	14-Aug-69	Spider-A, -B	On-Site Only	< 20 each	699,745	Weapons-related		98r
Mandrel	27-Aug-69	Horehound	Not in NV-317	< 20	1,089	Weapons-related		98r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Mandrel	27-Aug-69	Pliers	On-Site Only	< 20	784	Weapons-related		98r
Reactor	28-Aug-69	XE-Prime (EP-IXA)	Not in NV-317			Reactor Test		97r, 92r, NERC-LV-6, & -13
Reactor	10-Sep-69	Rulison {Grand Valley CO}	Off-Site	40	8425	Plowshare		98r
Reactor	11 Sep 69	XE-Prime (EP-XA)	Not in NV-317			Reactor Test		DOE NV-401
Mandrel	12-Sep-69	Minute Steak	On-Site Only	< 20	867	Weapons Effects	6323F	98r
Mandrel	16-Sep-69	Jorum	Not in NV-317	< 1000	3802	Weapons-related		98r
Mandrel	20-Sep-69	Kyack-A & -B	On-Site Only	< 20 each	630/610	Weapons-related		98r
Mandrel	1-Oct-69	Seaweed-C, -D, -E	On-Site Only	< 20	387	Safety Experiment		98r
Mandrel	2-Oct-69	Milrow {Amchitka, AK}	Not in NV-317	~ 1000	4003	Seismic Calibration		95r, 98r
Mandrel	8-Oct-69	Pipkin	On-Site Only	200 - 1000	2050	Weapons-related		98r
Mandrel	16-Oct-69	Seaweed-B	On-Site Only	< 20	387	Safety Experiment		98r
Mandrel	29-Oct-69	Cruet	Not in NV-317	11	865	Weapons-related		98r
Mandrel	29-Oct-69	Pod-A, -C, & -B, -D	Off-Site	16.7 total	876,1024	Weapons-related		98r, EPA-600-8-87
Mandrel	29-Oct-69	Calabash	Not in NV-317	110	2050	Weapons-related		98r
Mandrel	13-Nov-69	Scuttle	Off-Site	1.7	540	Weapons-related		98r, EPA-600-8-87
Mandrel	21-Nov-69	Piccallili	Not in NV-317	20 - 200	1292	Weapons-related		98r
Mandrel	21-Nov-69	Planer	Not in NV-317	< 20	1240	Weapons-related		98r
Mandrel	6-Dec-69	Diesel Train	Not in NV-317	< 20	867	Weapons Effects	6323F	98r
Mandrel	10-Dec-69	Culantra-A & -B	Not in NV-317	< 20 each	3696/3967	Weapons-related		98r
Mandrel	10-Dec-69	Tun-B, -C, -D, & -A	On-Site Only	< 20 each	637,637,840	Weapons-related		98r
Mandrel	17-Dec-69	Grape A	Not in NV-317	20 - 200	1,807	Weapons-related		98r
Mandrel	17-Dec-69	Lovage	Not in NV-317	< 20	1,240	Weapons-related		98r
Mandrel	18-Dec-69	Terrine-White, -Yellow	On-Site Only	20 - 200	1499,1368	Weapons-related		98r
Mandrel	23-Jan-70	Fob-Blue, -Yellow, -Red	Not in NV-317	< 20 each	330/802/872	Weapons-related		108r
Mandrel	30-Jan-70	Ajo	Not in NV-317	< 20	998	Weapons-related		108r
Mandrel	4-Feb-70	Grape B	Not in NV-317	20 - 200	1819	Weapons-related		108r
Mandrel	4-Feb-70	Belen	Not in NV-317	20 - 200	1381	Weapons-related		108r
Mandrel	5-Feb-70	Labis	Not in NV-317	25	1450	Weapons-related		108r
Mandrel	11-Feb-70	Diana Mist	Not in NV-317	< 20	1319	Weapons Effects	6323F	108r

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Mandrel	25-Feb-70	Cumarin	Not in NV-317	20 - 200	1340	Weapons-related		108r
Mandrel	26-Feb-70	Yannigan-Red, -Blue, -Yellow	On-Site Only	20 – 200 ea	1286,1293,1191	Weapons-related		108r
Mandrel	6-Mar-70	Cyathus	On-Site Only	8.7	950	Weapons-related		108r
Mandrel	3-Mar-70	Arabis-Blue, -Green, -Red	Not in NV-317	< 20 each	964	Weapons-related		108r
Mandrel	19-Mar-70	Jal	Not in NV-317	< 20	330/849/820	Weapons-related		108r
Mandrel	23-Mar-70	Shaper	Not in NV-317	20 - 200	989	Weapons-related		108r
Mandrel	26-Mar-70	Handley	Not in NV-317	> 1000	3967	Weapons-related		108r
Mandrel	21-Apr-70	Snubber	Off-Site	12.7	1129	Weapons Effects		108r, EPA-600-8-87
Mandrel	26-Mar-70	Can-Green & -Red	Not in NV-317	20 - 200 ea	900/1310	Weapons-related		108r
Mandrel	21-Apr-70	Beebalm	Not in NV-317	< 20	1280	Weapons-related		108r
Mandrel	1-May-70	Hod-A, -B	On-Site Only	< 20	870, 790	Weapons-related		108r
Mandrel	5-May-70	Mint Leaf	Off-Site	< 20	1300	Weapons Effects	6323F	108r
Mandrel	12-May-70	Diamond Dust	On-Site Only	< 20	728	Vela Uniform		108r
Mandrel	15-May-70	Cornice-Green, -Yellow	Not in NV-317	20 - 200	1455/1280	Weapons-related		108r
Mandrel	21-May-70	Manzanas	On-Site Only	< 20	791	Weapons-related		108r
Mandrel	21-May-70	Morrones	Not in NV-317	20 - 200	1594	Weapons-related		108r
Mandrel	26-May-70	Hudson Moon	On-Site Only	< 20	1385	Weapons Effects	6323F	108r
Mandrel	26-May-70	Flask-Green, -Yellow & -Red	On-Site Only	105, < 20	1736,1099,499	Plowshare		108r
Mandrel	28-May-70	Piton-C	On-Site Only	< 220	330	Weapons-related		108r
Mandrel	28-May-70	Piton-A, & -B	On-Site Only	< 20 each	774	Weapons-related		108r
Emery	26-Jun-70	Arnica-Violet, -Yellow	On-Site Only	< 20	866	Weapons-related		108r
Emery	13-Oct-70	Scree-Acajour, -Alhambra, -Chamois	On-Site Only	< 20 each	815,630	Weapons-related		NERC-LV-539-17
Emery	14-Oct-70	Tijeras	Not in NV-317	20 - 200	1839	Weapons-related		NERC-LV-539-17
Emery	28-Oct-70	Truchas-Chacon, -Chamisal, Rodarte	Not in NV-317	< 20 each	389/388/874	Weapons-related		NERC-LV-539-17
Emery	5-Nov-70	Abeytas	Not in NV-317	20 - 200	1291	Weapons-related		NERC-LV-539-17
Emery	19-Nov-70	Penasco	Not in NV-317	< 20	889	Weapons-related		NERC-LV-539-17
Emery	3-Dec-70	Carrizozo, Corazon	Not in NV-317	< 20 each	916/791	Weapons-related		NERC-LV-539-17
Emery	16-Dec-70	Canjilo	Not in NV-317	< 20	991	Weapons-related		NERC-LV-539-17
Emery	16-Dec-70	Artesia	Not in NV-317	20 - 200	1591	Weapons-related		NERC-LV-539-17

TABLE B-1. US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Emery	16-Dec-70	Avens-Cream (w/ 3 more)	On-Site Only	< 20 each	1001, 1245, 1009, 961	Weapons-related		NERC-LV-539-17
Emery	17-Dec-70	Carpetbag	On-Site Only	220	2170	Weapons-related		NERC-LV-539-17
Emery	18-Dec-70	Baneberry	Off-Site	10	912	Weapons-related		107r, NERC-LV-539-10 & -17 EPA-600-8-87
Emery	16-Jun-71	Embudo	Not in NV-317	< 20	994	Weapons-related		EMSL-LV-539-1
Emery	23-Jun-71	Dexter	Not in NV-317	< 20	394	Safety Experiment		EMSL-LV-539-1
Emery	23-Jun-71	Laguna	Not in NV-317	20 - 200	1493	Weapons-related		EMSL-LV-539-1
Emery	24-Jun-71	Harebell	On-Site Only	20 - 200	1702	Weapons-related		EMSL-LV-539-1
Grommet	29-Jun-71	Camphor	On-Site Only	< 20	1390	Weapons Effects	6326F	EMSL-LV-539-1
Grommet	1-Jul-71	Diamond Mine	Not in NV-317	< 20	873	Vela Uniform		EMSL-LV-539-1
Grommet	8-Jul-71	Miniata (Excavation)	On-Site Only	83	1735	Plowshare		EMSL-LV-539-1
Grommet	9-Jul-71	Bracken	On-Site Only	< 20	1000	Weapons-related		EMSL-LV-539-1
Grommet	21-Jul-71	Apodaca	Not in NV-317	< 20	792	Weapons-related		EMSL-LV-539-1
Grommet	4-Aug-71	Barranca	Not in NV-317	< 20	888	Weapons-related		EMSL-LV-539-1
Grommet	5-Aug-71	Nama-Amarylis, -Mephisto	Not in NV-317	< 20	895/800	Weapons-related		EMSL-LV-539-1
Grommet	6-Aug-71	Baltic	Not in NV-317	< 20	1351	Weapons-related		EMSL-LV-539-1
Grommet	18-Aug-71	Algodones	Not in NV-317	20 - 200	1731	Weapons-related		EMSL-LV-539-1
Grommet	22-Sep-71	Frijoles-Deming, -Espuela, -Guaje, -Petaca	Not in NV-317	< 20	492/490/843/741	Weapons-related & Safety		EMSL-LV-539-1
Grommet	29-Sep-71	Pedernal	Not in NV-317	< 20	1242	Weapons-related		EMSL-LV-539-1
Grommet	29-Sep-71	Chantilly	Not in NV-317	< 20	1805	Weapons-related		EMSL-LV-539-1
Grommet	8-Oct-71	Cathay	Not in NV-317	< 20	1240	Weapons-related		EMSL-LV-539-1
Grommet	14-Oct-71	Lagoon	Not in NV-317	< 20	1000	Weapons-related		EMSL-LV-539-1
Grommet	6-Nov-71	Cannikin {Amchitka, AK}	Not in NV-317	< 5000	5873	Weapons-related		NERC-LV-539-2
Grommet	24-Nov-71	Diagonal Line	Off-Site	< 20	867	Weapons Effects	6323F	EMSL-LV-539-1, EPA-600-8-87
Grommet	30-Nov-71	Parnassia	Not in NV-317	< 20	1085	Weapons-related		EMSL-LV-539-1
Grommet	14-Dec-71	Chaenactis	Not in NV-317	20 - 200	1086	Weapons-related		EMSL-LV-539-1

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Grommet	14-Dec-71	Hospah	Not in NV-317	< 20	991	Weapons-related		EMSL-LV-539-1
Grommet	14-Dec-71	Yerba	Not in NV-317	< 20	1089	Weapons-related		EMSL-LV-539-1
Grommet	5-Jan-72	Mescalero	Not in NV-317	< 20	394	Weapons-related		NERC-LV-539-23
Grommet	3-Feb-72	Cowles	Not in NV-317	< 20	990	Weapons-related		NERC-LV-539-23
Grommet	17-Feb-72	Dianthus	On-Site Only	< 20	1000	Weapons-related		NERC-LV-539-23
Grommet	23-Mar-72	Sappho	On-Site Only	< 20	646	Weapons-related		NERC-LV-539-23
Grommet	30-Mar-72	Onajo, Ocate	Not in NV-317	< 20 each	915/689	Weapons-related		NERC-LV-539-23
Grommet	19-Apr-72	Longchamps	Not in NV-317	< 20	1071	Weapons-related		NERC-LV-539-23
Grommet	19-Apr-72	Jicarillo	Not in NV-317	< 20	486	Weapons-related		NERC-LV-539-23
Grommet	2-May-72	Misty North	Not in NV-317	< 20	1234	Weapons Effects	6323F	NERC-LV-539-23
Grommet	11-May-72	Kara	On-Site Only	< 20	850	Weapons-related		NERC-LV-539-23
Grommet	17-May-72	Zinnia	On-Site Only	< 20	1059	Weapons-related		NERC-LV-539-23
Grommet	19-May-72	Monero	Not in NV-317	< 20	1763	Weapons-related		NERC-LV-539-23
Reactor	24-May-72	Nuclear Furnace-1 (IA-1)	Not in NV-317			Reactor Test		NERC-LV-539-23
Reactor	25-May-72	Nuclear Furnace-1 (IA-2)	Not in NV-317			Reactor Test		NERC-LV-539-23
Reactor	1-Jun-72	Nuclear Furnace-1 (IB)	Not in NV-317			Reactor Test		NERC-LV-539-23
Grommet	7-Jun-72	Merida	On-Site Only	< 20	670	Weapons-related		NERC-LV-539-23
Reactor	28-Jun-72	Nuclear Furnace-1 (II)	Not in NV-317			Reactor Test		NERC-LV-539-23
Grommet	28-Jun-72	Capitan	Not in NV-317	< 20	441	Weapons-related		NERC-LV-539-23
Grommet	28-Jun-72	Tajique	Not in NV-317	< 20	1090	Weapons-related		NERC-LV-539-23
Grommet	28-Jun-72	Haplopappaus	Not in NV-317	< 20	605	Weapons-related		NERC-LV-539-23
Reactor	12-Jul-72	Nuclear Furnace-1 (III)	Not in NV-317			Reactor Test		NERC-LV-539-23
Toggle	20-Jul-72	Diamond Skulls	Not in NV-317	< 20	1391	Weapons Effects	6324F	NERC-LV-539-23
Reactor	21-Jul-72	Nuclear Furnace-1 (IV)	Not in NV-317			Reactor Test		NERC-LV-539-23
Toggle	25-Jul-72	Atarque	On-Site Only	< 20	964	Weapons-related		NERC-LV-539-23
Reactor	27-Jul-72	Nuclear Furnace-1 (V)	Not in NV-317			Reactor Test		NERC-LV-539-23, DOE-NV-401
Toggle	9-Aug-72	Cebolla, Cuchillo, Solano	On-Site Only	< 20	941	Weapons-related		NERC-LV-539-23
Toggle	21-Sep-72	Oscuro	Not in NV-317	20 - 200	1838	Weapons-related		NERC-LV-539-23

TABLE B-1. CONUS US Nuclear Tests from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Toggle	26-Sep-72	Delpinium	Not in NV-317	15	970	Weapons-related		NERC-LV-539-23
Toggle	9-Nov-72	Akbar	Not in NV-317	< 20	875	Weapons-related		NERC-LV-539-23
Toggle	9-Nov-72	Arsenate	On-Site Only	< 20	821	Weapons-related		NERC-LV-539-23
Toggle	17-Nov-72	Canna-Limoges & - Umbrinus	Not in NV-317	< 20	700, 800	Weapons-related & Safety		NERC-LV-539-23
Toggle	12-Dec-72	Tulosa	Not in NV-317	< 20	< 20	Weapons-related		NERC-LV-539-23
Toggle	14-Dec-72	Solanum	On-Site Only	< 20	660	Weapons-related		NERC-LV-539-23
Toggle	21-Dec-72	Flax-Source	Not in NV-317	< 20	2260	Weapons Effects		NERC-LV-539-23
Toggle	21-Dec-72	Flax-Test & -Backup	Not in NV-317	<20, 20-200	1430	Weapons Effects		NERC-LV-539-23
Toggle	14-Feb-73	Alumroot	Not in NV-317	< 20	600	Weapons-related		NERC-LV-539-31
Toggle	8-Mar-73	Miera	On-Site Only	20 - 200	1867	Weapons-related		NERC-LV-539-31
Toggle	23-Mar-73	Gazook	On-Site Only	< 20	1070	Weapons-related		NERC-LV-539-31
Toggle	5-Apr-73	Natoma	Not in NV-317	< 20	800	Weapons-related		NERC-LV-539-31
Toggle	25-Apr-73	Angus (also w/ Velarde)	On-Site Only	< 20	1486	Weapons-related		NERC-LV-539-31
Toggle	25-Apr-73	Velarde	On-Site Only	< 20	908	Weapons-related		NERC-LV-539-31
Toggle	26-Apr-73	Colmore	On-Site Only	< 20	806	Weapons-related		NERC-LV-539-31
Toggle	26-Apr-73	Starwort	On-Site Only	90	1820	Weapons-related		NERC-LV-539-31
Toggle	9-May-73	Mesita	On-Site Only	< 20	490	Weapons-related		NERC-LV-539-31
Toggle	17-May-73	Rio Blanco-1,-2,&-3 {near Meeker CO}	Not in NV-317	33 each	6630/6230/6690	Plowshare		NERC-LV-539-31
Toggle	24-May-73	Cabresto	Not in NV-317	< 20	649	Weapons-related		NERC-LV-539-31
Toggle	24-May-73	Kashan	On-Site Only	< 20	870	Weapons-related		NERC-LV-539-31
Toggle	5-Jun-73	Dido Queen	Not in NV-317	< 20	1284	Weapons Effects	6324F	NERC-LV-539-31
Toggle	6-Jun-73	Alemendro	Not in NV-317	200 - 1000	3499	Weapons Effects		NERC-LV-539-31
Toggle	21-Jun-73	Potrillo	On-Site Only	20 - 200	1865	Weapons-related		NERC-LV-539-31
Toggle	28-Jun-73	Portulaca	Not in NV-317	20 - 200	1528	Weapons-related		NERC-LV-539-31
Arbor	28-Jun-73	Silene	Not in NV-317	< 20	850	Weapons-related		NERC-LV-539-31
Arbor	2-Oct-73	Polygonum	Not in NV-317	< 20	700	Weapons-related		NERC-LV-539-31
Arbor	2-Oct-73	Waller	On-Site Only	< 20	1017	Weapons-related		NERC-LV-539-31
Arbor	12-Oct-73	Husky Ace	Not in NV-317	< 20	1356	Weapons Effects	6324F	NERC-LV-539-31

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Arbor	28-Nov-73	Bernal	On-Site Only	< 20	928	Weapons-related		NERC-LV-539-31
Arbor	12-Dec-73	Pajara	On-Site Only	< 20	912	Weapons-related		NERC-LV-539-31
Arbor	13-Dec-73	Seafoam	On-Site Only	< 20	650	Weapons-related		NERC-LV-539-31
Arbor	19-Dec-73	Spar	Not in NV-317	< 20	487	Safety Experiment		NERC-LV-539-31
Arbor	19-Dec-73	Elida	On-Site Only	< 20	1250	Weapons-related		NERC-LV-539-31
Arbor	10-Jan-74	Pinedrops-Bayou (also-Sloat & -Tawny	On-Site Only	< 20	1125	Weapons-related		NERC-LV-539-39
Arbor	27-Feb-74	Latir	Not in NV-317	20 - 200	2102	Weapons-related		NERC-LV-539-39
Arbor	14-Mar-74	Hulsea	On-Site Only	< 20	640	Weapons-related		NERC-LV-539-39
Arbor	12-Apr-74	Sapello	Not in NV-317	< 20	593	Weapons-related		NERC-LV-539-39
Arbor	23-Apr-74	Potrero	Not in NV-317	< 20	8892	Weapons-related		NERC-LV-539-39
Arbor	1-May-74	Plomo	Not in NV-317	< 20	490	Weapons-related		NERC-LV-539-39
Arbor	8-May-74	Jib	Not in NV-317	< 20	592	Weapons-related		NERC-LV-539-39
Arbor	22-May-74	Grove	On-Site Only	< 20	1027	Weapons-related		NERC-LV-539-39
Arbor	23-May-74	Fallon	On-Site Only	20 - 200	1529	Joint US-UK		NERC-LV-539-39
Arbor	6-Jun-74	Jara	On-Site Only	< 20	1240	Weapons-related		NERC-LV-539-39
Bedrock	19-Jun-74	Ming Blade	Not in NV-317	< 20	1276	Weapons Effects	6324F	NERC-LV-539-39
Bedrock	10-Jul-74	Escabosa	On-Site Only	20 - 200	2100	Weapons-related		NERC-LV-539-39
Bedrock	18-Jul-74	Crestlake-Tansan, -Briar	On-Site Only	< 20	892, 1229	Weapons-related		NERC-LV-539-39
Bedrock	16-Aug-74	Puye	On-Site Only	< 20	1411	Weapons-related		NERC-LV-539-39
Bedrock	30-Aug-74	Portmanteau	Not in NV-317	20 - 200	2150	Weapons-related		NERC-LV-539-39
Bedrock	25-Sep-74	Pratt	Not in NV-317	< 20	1030	Weapons-related		NERC-LV-539-39
Bedrock	26-Sep-74	Trumbull	Not in NV-317	< 20	863	Weapons-related		NERC-LV-539-39
Bedrock	26-Sep-74	Stanyan	Not in NV-317	20 - 200	1880	Weapons-related		NERC-LV-539-39
Bedrock	17-Oct-74	Estaca	Not in NV-317	< 20	1053	Weapons-related		NERC-LV-539-39
Bedrock	28-Oct-74	Hybla Fair	On-Site Only	< 20	1325	Weapons Effects	6324F	NERC-LV-539-39
Bedrock	2-Nov-74	Temescal	On-Site Only	< 20	859	Weapons-related		NERC-LV-539-39
Bedrock	26-Nov-74	Puddle	Not in NV-317	< 20	804	Safety Experiment		NERC-LV-539-39
Bedrock	16-Dec-74	Keel	Not in NV-317	< 20	1000	Weapons-related		NERC-LV-539-39
Bedrock	6-Feb-75	Portola, Portola-Larkin	On-Site Only	< 20	649, 899	Weapons-related		EMSL-LV-0539-4

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Bedrock	6-Feb-75	Teleme	Not in NV-317	< 20	1001	Weapons-related		EMSL-LV-0539-4
Bedrock	10-Feb-75	Bilge	On-Site Only	< 20	1046	Weapons-related		EMSL-LV-0539-4
Bedrock	28-Feb-75	Topgallant	Not in NV-317	20 - 200	2340	Weapons-related		EMSL-LV-0539-4
Bedrock	5-Apr-75	Dining Car	Not in NV-317	< 20	1257	Weapons-related	6324F	EMSL-LV-0539-4
Bedrock	24-Apr-75	Edam	Not in NV-317	20 - 200	1350	Weapons-related		EMSL-LV-0539-4
Bedrock	30-Apr-75	Obar	Not in NV-317	20 - 200	1866	Weapons-related		EMSL-LV-0539-4
Bedrock	14-May-75	Tybo	Not in NV-317	200 - 1000	2510	Weapons-related		EMSL-LV-0539-4
Bedrock	3-Jun-75	Stilton	Not in NV-317	20 - 200	2400	Weapons-related		EMSL-LV-0539-4
Bedrock	3-Jun-75	Mizzen	Not in NV-317	20 - 200	2090	Weapons-related		EMSL-LV-0539-4
Bedrock	11-Jun-75	Alviso	Not in NV-317	< 20	600	Safety Experiment		EMSL-LV-0539-4
Bedrock	18-Jun-75	Futtock	Not in NV-317	< 20	612	Safety Experiment		EMSL-LV-0539-4
Bedrock	19-Jun-75	Mast	Not in NV-317	200 - 1000	2988	Weapons-related		EMSL-LV-0539-4
Anvil	26-Jun-75	Camembert	Not in NV-317	200 - 1000	4304	Weapons-related		EMSL-LV-0539-4
Anvil	6-Aug-75	Marsh	Not in NV-317	< 20	1402	Weapons-related		EMSL-LV-0539-4
Anvil	24-Oct-75	Husky Pup	Not in NV-317	< 20	1142	Weapons-related	6325F	EMSL-LV-0539-4
Anvil	28-Oct-75	Kasseri	On-Site Only	200 - 1000	4150	Weapons-related		EMSL-LV-0539-4
Anvil	18-Nov-75	Deck	Not in NV-317	< 20	1070	Weapons-related		EMSL-LV-0539-4
Anvil	20-Nov-75	Inlest	Not in NV-317	200 - 1000	2685	Weapons-related		EMSL-LV-0539-4
Anvil	26-Nov-75	Leyden	Not in NV-317	< 20	1070	Weapons-related		EMSL-LV-0539-4
Anvil	20-Dec-75	Chiberto	Not in NV-317	20 - 200	2350	Weapons-related		EMSL-LV-0539-4
Anvil	3-Jan-76	Muenster	Not in NV-317	200 - 1000	4765	Weapons-related		EMSL-LV-0539-12
Anvil	4-Feb-76	Keelson	Not in NV-317	20 - 200	2098	Weapons-related		EMSL-LV-0539-12
Anvil	4-Feb-76	Esrom	Not in NV-317	20 - 200	2149	Weapons-related		EMSL-LV-0539-12
Anvil	12-Feb-76	Fontina	Not in NV-317	200 - 1000	3997	Weapons-related		EMSL-LV-0539-12
Anvil	14-Feb-76	Cheshire	Not in NV-317	200 - 500	3829	Weapons-related		EMSL-LV-0539-12
Anvil	26-Feb-76	Shallows	On-Site Only	< 20	803	Weapons-related		EMSL-LV-0539-12
Anvil	9-Mar-76	Estrurary	Not in NV-317	< 20	2811	Weapons-related		EMSL-LV-0539-12
Anvil	14-Mar-76	Colby	On-Site Only	500 - 1000	4176	Weapons-related		EMSL-LV-0539-12
Anvil	17-Mar-76	Pool	Not in NV-317	200 - 500	2891	Weapons-related		EMSL-LV-0539-12

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Anvil	17-Mar-76	Strait	Not in NV-317	200 - 500	2567	Weapons-related		EMSL-LV-0539-12
Anvil	12-May-76	Mighty Epic	Not in NV-317	< 20	1306	Weapons Effects	6325F	EMSL-LV-0539-12
Anvil	20-May-76	Rivoli	On-Site Only	< 20	656	Weapons-related		EMSL-LV-0539-12
Anvil	27-Jul-76	Billet	On-Site Only	20 - 150	2087	Weapons-related		EMSL-LV-0539-12
Fulcrum	26-Aug-76	Banon	On-Site Only	20 - 150	1759	Joint US-UK		EMSL-LV-0539-12
Fulcrum	6-Oct-76	Gouda	Not in NV-317	< 20	656	Weapons-related		EMSL-LV-0539-12
Fulcrum	10-Nov-76	Sprit	Not in NV-317	< 20	601	Weapons-related		EMSL-LV-0539-12
Fulcrum	23-Nov-76	Chevre	Not in NV-317	< 20	1040	Weapons-related		EMSL-LV-0539-12
Fulcrum	8-Dec-76	Redmud	Not in NV-317	< 20	1400	Weapons-related		EMSL-LV-0539-12
Fulcrum	21-Dec-76	Asiago	Not in NV-317	< 20	1083	Weapons-related		EMSL-LV-0539-12
Fulcrum	21-Dec-76	Sutter	Not in NV-317	20 - 150	657	Weapons-related		EMSL-LV-0539-12
Fulcrum	28-Dec-76	Rudder	Not in NV-317	< 20	2095	Weapons-related		EMSL-LV-0539-12
Fulcrum	16-Feb-76	Oarlock, Cove	Not in NV-317	< 20	1042/1098	Weapons-related		EMSL-LV-0539-12
Fulcrum	8-Mar-77	Dofino, Dofino-Lawton	On-Site Only	< 20 each	600, 925	Weapons-related		EMSL-LV-0539-18
Fulcrum	5-Apr-77	Marsilly	On-Site Only	20 - 150	2264	Weapons-related		EMSL-LV-0539-18
Fulcrum	27-Apr-77	Bulkhead	Not in NV-317	20 - 150	1851	Weapons-related		EMSL-LV-0539-18
Fulcrum	25-May-77	Crewline	Not in NV-317	20 - 150	635	Weapons-related		EMSL-LV-0539-18
Fulcrum	2-Jun-77	Forefoot	Not in NV-317	< 20	684	Weapons-related		EMSL-LV-0539-18
Fulcrum	28-Jul-77	Carnelian	On-Site Only	< 20	682	Weapons-related		EMSL-LV-0539-18
Fulcrum	4-Aug-77	Strake	Not in NV-317	20 - 150	1698	Weapons-related		EMSL-LV-0539-18
Fulcrum	16-Aug-77	Gruyere-Gradino	On-Site Only	< 20	1050	Weapons-related		EMSL-LV-0539-18
Fulcrum	16-Aug-77	Flotost	On-Site Only	< 20	902	Weapons-related		EMSL-LV-0539-18
Fulcrum	19-Aug-77	Scupper	Not in NV-317	< 20	1475	Weapons-related		EMSL-LV-0539-18
Fulcrum	19-Aug-77	Scantling	Not in NV-317	20 - 150	2300	Weapons-related		EMSL-LV-0539-18
Fulcrum	15-Sep-77	Ebbtide	Not in NV-317	< 20	1245	Weapons-related		EMSL-LV-0539-18
Cresset	27-Sep-77	Coulommiers	On-Site Only	20 - 150	1739	Weapons-related		EMSL-LV-0539-18
Cresset	26-Oct-77	Bobstay	On-Site Only	< 20	1250	Weapons-related		EMSL-LV-0539-18
Cresset	1-Nov-77	Hybla Gold	On-Site Only	< 20	1263	Weapons Effects	6325F	EMSL-LV-0539-18
Cresset	9-Nov-77	Sandreef	Not in NV-317	20 - 150	2299	Weapons Effects		EMSL-LV-0539-18

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Cresset	17-Nov-77	Seamount	Not in NV-317	< 20	1214	Weapons Effects		EMSL-LV-0539-18
Cresset	14-Dec-77	Rib	Not in NV-317	< 20	698	Weapons Effects		EMSL-LV-0539-18
Cresset	14-Dec-77	Farallones	On-Site Only	20 - 150	2192	Weapons-related		EMSL-LV-0539-18
Cresset	13-Feb-78	Campos	On-Site Only	< 20	1050	Weapons-related		EMSL-LV-0539-31
Cresset	23-Feb-78	Reblochon	On-Site Only	20 - 150	2160	Weapons-related		EMSL-LV-0539-31
Cresset	16-Mar-78	Karab	On-Site Only	< 20	1086	Weapons-related		EMSL-LV-0539-31
Cresset	23-Mar-78	Topmast	Not in NV-317	< 20	1502	Weapons-related		EMSL-LV-0539-31
Cresset	23-Mar-78	Iceberg	Not in NV-317	20 - 150	2101	Weapons-related		EMSL-LV-0539-31
Cresset	11-Apr-78	Fundutta	Not in NV-317	20 - 150	2077	Joint US-UK		EMSL-LV-0539-31
Cresset	11-Apr-78	Backbeach	Not in NV-317	20 - 150	2204	Weapons-related		EMSL-LV-0539-31
Cresset	25-Apr-78	Asco	Not in NV-317	< 20	600	Safety Experiment		EMSL-LV-0539-31
Cresset	10-May-78	Transcom	Not in NV-317	Zero	2100	Weapons-related		EMSL-LV-0539-31
Cresset	1-Jun-78	Jackpots	Not in NV-317	< 20	998	Weapons-related		EMSL-LV-0539-31
Cresset	7-Jul-78	Satz	On-Site Only	< 20	1033	Weapons-related		EMSL-LV-0539-31
Cresset	12-Jul-78	Lowball	Not in NV-317	20 - 150	1853	Weapons-related		EMSL-LV-0539-31
Cresset	31-Aug-78	Panir	Not in NV-317	20 - 150	2234	Weapons-related		EMSL-LV-0539-31
Cresset	13-Sep-78	Diablo Hawk	Not in NV-317	< 20	1273	Weapons Effects	6325F	EMSL-LV-0539-31
Cresset	27-Sep-78	Cremino, & Cremino-Caephilly	Not in NV-317	< 20 each	688/1377	Weapons-related		EMSL-LV-0539-31
Cresset	27-Sep-78	Draughts	Not in NV-317	20 - 150	1449	Weapons-related		EMSL-LV-0539-31
Cresset	27-Sep-78	Rummy	Not in NV-317	20 - 150	2099	Weapons-related		EMSL-LV-0539-31
Cresset	2-Nov-78	Emmenthal	Not in NV-317	< 20	1891	Weapons-related		EMSL-LV-0539-31
Cresset	18-Nov-78	Quargel	On-Site Only	20 - 150	1778	Joint US-UK		EMSL-LV-0539-31
Cresset	1-Dec-78	Concentration	Not in NV-317	< 20	812	Weapons-related		EMSL-LV-0539-31
Cresset	16-Dec-78	Farm	On-Site Only	20 - 150	2260	Weapons-related		EMSL-LV-0539-31
Cresset	24-Jan-78	Baccarat	Not in NV-317	< 20	1071	Weapons-related		EMSL-LV-0539-31
Cresset	8-Feb-78	Quintella	Not in NV-317	20 - 150	1900	Weapons-related		EMSL-LV-0539-31
Cresset	15-Feb-79	Kloster	On-Site Only	20 - 150	1759	Weapons-related		EMSL-LV-0539-36
Cresset	14-Mar-79	Memory	Not in NV-317	< 20	1100	Weapons-related		EMSL-LV-0539-36
Cresset	11-May-79	Freezeout	Not in NV-317	< 20	2239	Weapons-related		EMSL-LV-0539-36

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Cresset	11-Jun-79	Pepato	On-Site Only	20 - 150	2233	Weapons-related		EMSL-LV-0539-36
Cresset	20-Jun-79	Chess	Not in NV-317	< 20	1100	Weapons-related		EMSL-LV-0539-36
Cresset	28-Jun-79	Fajy	On-Site Only	20 - 150	1759	Weapons-related		EMSL-LV-0539-36
Cresset	3-Aug-79	Burzet	On-Site Only	20 - 150	1476	Weapons-related		EMSL-LV-0539-36
Cresset	8-Aug-79	Offshore	Not in NV-317	20 - 150	1301	Weapons-related		EMSL-LV-0539-36
Cresset	29-Aug-79	Nessel	On-Site Only	20 - 150	1522	Joint US-UK		EMSL-LV-0539-36
Cresset	6-Aug-79	Hearts	Not in NV-317	140	2100	Weapons-related		EMSL-LV-0539-36
Cresset	8-Sep-79	Pera	Not in NV-317	< 20	656	Weapons-related		EMSL-LV-0539-36
Tinderbox	26-Sep-79	Sheepshead	Not in NV-317	20 - 150	2100	Weapons-related		EMSL-LV-0539-36
Tinderbox	29-Nov-79	Backgammon	Not in NV-317	< 20	750	Weapons-related		EMSL-LV-0539-36
Tinderbox	14-Dec-79	Azul	Not in NV-317	< 20	672	Weapons-related		EMSL-LV-0539-36
Tinderbox	28-Feb-80	Tarko	On-Site Only	< 20	1211	Weapons-related		EPA-600 4-81-047
Tinderbox	8-Mar-80	Norbo	On-Site Only	< 20	889	Weapons-related		EPA-600 4-81-047
Tinderbox	3-Apr-80	Liptauer	Not in NV-317	20 - 150	1368	Weapons-related		EPA-600 4-81-047
Tinderbox	16-Apr-80	Pyramid	Not in NV-317	20 - 150	1900	Weapons-related		EPA-600 4-81-047
Tinderbox	26-Apr-80	Colwick	On-Site Only	20 - 150	2077	Joint US-UK		EPA-600 4-81-047
Tinderbox	2-May-80	Canfield	Not in NV-317	< 20	1150	Weapons-related		EPA-600 4-81-047
Tinderbox	22-May-80	Flora	On-Site Only	< 20	1099	Weapons-related		EPA-600 4-81-047
Tinderbox	12-Jun-80	Kash	On-Site Only	20 - 150	2116	Weapons-related		EPA-600 4-81-047
Tinderbox	24-Jun-80	Huron King	Not in NV-317	< 20	1050	Weapons Effects	6325F	EPA-600 4-81-047
Tinderbox	25-Jul-80	Tafi	On-Site Only	20 - 150	2231	Weapons-related		EPA-600 4-81-047
Tinderbox	31-Jul-80	Verdello	On-Site Only	< 20	1200	Weapons-related		EPA-600 4-81-047
Tinderbox	25-Sep-80	Bonardo	Not in NV-317	20 - 150	1250	Weapons-related		EPA-600 4-81-047
Guardian	25-Sep-80	Riola	Off-site	1.07	1390	Weapons-related		EPA-600 4-81-047 & -8-87
Guardian	24-Oct-80	Duchess	Not in NV-317	< 20	1400	Joint US-UK		EPA-600 4-81-047
Guardian	31-Oct-80	Miners Iron	On-Site Only	< 20	1280	Weapons Effects	6325F	EPA-600 4-81-047
Guardian	14-Nov-80	Dauphin	Not in NV-317	< 20	10540	Weapons Effects		EPA-600 4-81-047
Guardian	17-Dec-80	Serpa	Not in NV-317	20 - 150	1879	Joint US-UK		EPA-600 4-81-047
Guardian	15-Jan-81	Baseball	Not in NV-317	20 - 150	1850	Weapons-related		EPA-600 4-82-061

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Guardian	2-Feb-81	Clairette	Not in NV-317	< 20	1160	Weapons-related		EPA-600 4-82-061
Guardian	25-Feb-81	Seco	Not in NV-317	< 20	656	Weapons-related		EPA-600 4-82-061
Guardian	30-Apr-81	Vide	On-Site Only	< 20	1060	Weapons-related		EPA-600 4-82-061
Guardian	29-Mar-81	Aligote	Not in NV-317	< 20	1050	Weapons-related		EPA-600 4-82-061
Guardian	6-Jun-81	Harzer	Not in NV-317	20 - 150	2090	Weapons-related		EPA-600 4-82-061
Guardian	10-Jul-81	Niza	On-Site Only	< 20	1119	Weapons-related		EPA-600 4-82-061
Guardian	16-Jul-81	Pinea	Not in NV-317	< 20	680	Weapons-related		EPA-600 4-82-061
Guardian	5-Aug-81	Havarti	Not in NV-317	< 20	656	Weapons-related		EPA-600 4-82-061
Guardian	27-Aug-81	Islay	On-Site Only	< 20	965	Weapons-related		EPA-600 4-82-061
Guardian	4-Sep-81	Trebbiano	On-Site Only	< 20	1001	Weapons-related		EPA-600 4-82-061
Praetorian	24-Sep-81	Cernada	Not in NV-317	< 20	699	Weapons-related		EPA-600 4-82-061
Praetorian	1-Oct-81	Paliza	Not in NV-317	20 - 150	1549	Weapons-related		EPA-600 4-82-061
Praetorian	11-Nov-81	Tilci	On-Site Only	20 - 150	1460	Weapons-related		EPA-600 4-82-061
Praetorian	12-Nov-81	Roussanne	Not in NV-317	20 - 150	1697	Joint US-UK		EPA-600 4-82-061
Praetorian	3-Dec-81	Akavi	On-Site Only	20 - 150	1621	Weapons-related		EPA-600 4-82-061
Praetorian	16-Dec-81	Caboc	On-Site Only	< 20	1100	Weapons-related		EPA-600 4-82-061
Praetorian	28-Jan-82	Jomada	Not in NV-317	139	2096	Weapons-related		EPA-600 4-83-032
Praetorian	12-Feb-82	Molbo	On-Site Only	20 - 150	2093	Weapons-related		EPA-600 4-83-032
Praetorian	12-Feb-82	Hosta	Not in NV-317	20 - 150	2098	Weapons-related		EPA-600 4-83-032
Praetorian	17-Apr-82	Tenaja	Not in NV-317	< 20	1169	Weapons-related		EPA-600 4-83-032
Praetorian	25-Apr-82	Gibne	On-Site Only	20 - 150	1870	Joint US-UK		EPA-600 4-83-032
Praetorian	6-May-82	Kryddost	Not in NV-317	< 20	1100	Weapons-related		EPA-600 4-83-032
Praetorian	7-May-82	Bouschet	On-Site Only	20 - 150	1850	Weapons-related		EPA-600 4-83-032
Praetorian	16-Jun-82	Kesti	Not in NV-317	< 20	945	Weapons-related		EPA-600 4-83-032
Praetorian	24-Jun-82	Nebbiolo	Not in NV-317	20 - 150	2098	Weapons-related		EPA-600 4-83-032
Praetorian	29-Jul-82	Monterey	On-Site Only	20 - 150	1310	Weapons-related		EPA-600 4-83-032
Praetorian	5-Aug-82	Atrisco	Not in NV-317	138	2099	Weapons-related		EPA-600 4-83-032
Praetorian	11-Aug-82	Queso	Not in NV-317	< 20	71	Weapons-related		EPA-600 4-83-032
Praetorian	2-Sep-82	Cerro	Not in NV-317	< 20	750	Weapons-related		EPA-600 4-83-032

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Praetorian	23-Sep-82	Huron Landing (w/Diamond Ace)	On-Site Only	< 20	1340	Weapons-related	6327F	EPA-600 4-83-032
Praetorian	23-Sep-82	Diamond Ace (w/ Huron Landing)	On-Site Only	< 20	1335	Weapons-related	6327F	EPA-600 4-83-032
Praetorian	29-Sep-82	Borrego	Not in NV-317	< 20	1201	Weapons-related		EPA-600 4-83-032
Phalanx	23-Sep-82	Frisco	On-Site Only	20 - 150	1480	Weapons-related		EPA-600 4-83-032
Phalanx	12-Nov-82	Seyval	Not in NV-317	< 20	1201	Weapons-related		EPA-600 4-83-032
Phalanx	10-Dec-82	Manteca	On-Site Only	20 - 150	1355	Weapons-related		EPA-600 4-83-032
Phalanx	11-Feb-83	Coalora	Not in NV-317	< 20	899	Weapons-related		600/4-84-040
Phalanx	17-Feb-83	Cheedam	On-Site Only	< 20	1125	Weapons-related		600/4-84-040
Phalanx	26-Mar-83	Cabra	Not in NV-317	20 - 150	1781	Weapons-related		600/4-84-040
Phalanx	14-Apr-83	Turquoise	On-Site Only	< 150	1749	Weapons-related		600/4-84-040
Phalanx	22-Apr-83	Armada	On-Site Only	< 20	869	Joint US-UK		600/4-84-040
Phalanx	5-May-83	Crowdie	On-Site Only	< 20	1280	Weapons-related		600/4-84-040
Phalanx	26-May-83	Mini Jade	On-Site Only	< 20	1243	Weapons Effects	6327F	600/4-84-040
Phalanx	26-May-83	Fahada	Not in NV-317	< 20	1261	Weapons-related		600/4-84-040
Phalanx	9-Jun-83	Danablu	On-Site Only	< 20	1050	Weapons-related		600/4-84-040
Phalanx	3-Aug-83	Laban	On-Site Only	< 20	1070	Weapons-related		600/4-84-040
Phalanx	11-Aug-83	Sabado	Not in NV-317	< 20	1050	Weapons-related		600/4-84-040
Phalanx	27-Aug-83	Jarlsberg	On-Site Only	< 20	656	Weapons-related		600/4-84-040
Phalanx	1-Sep-83	Chancellor	Not in NV-317	143	2046	Weapons-related		600/4-84-040
Phalanx	21-Sep-83	Tomme/Midnight Zephyr	Not in NV-317	< 20	1325	Weapons Effects	6327F	600/4-84-040
Phalanx	21-Sep-83	Branco/Branco-Herlkimer	Not in NV-317	< 20 each	960/1400	Weapons-related		600/4-84-040
Phalanx	22-Sep-83	Techado	Not in NV-317	< 150	1747	Weapons-related		600/4-84-040
Fusileer	29-Sep-83	Navata	Not in NV-317	< 20	600	Safety Experiment		600/4-84-040
Fusileer	9-Dec-83	Muggins	Not in NV-317	< 20	800	Weapons-related		600/4-84-040
Fusileer	16-Dec-83	Romano	On-Site Only	20 - 150	1690	Weapons-related		600/4-84-040
Fusileer	31-Jan-84	Gorbea	On-Site Only	20 - 150	1273	Weapons-related		EPA-600 4-85-035
Fusileer	15-Feb-84	Midas Myth/Milagro	Not in NV-317	< 20	1181	Weapons Effects	6327F	EPA-600 4-85-035
Fusileer	1-Mar-84	Tortugas	Not in NV-317	20 - 150	2095	Weapons-related		EPA-600 4-85-035
Fusileer	31-Mar-84	Agrini	On-Site Only	< 20	1050	Weapons-related		EPA-600 4-85-035

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Fusileer	1-May-84	Mundo	Not in NV-317	20 - 150	1857	Joint US-UK		EPA-600 4-85-035
Fusileer	2-May-84	Orkney	On-Site Only	< 20	689	Weapons-related		EPA-600 4-85-035
Fusileer	16-May-84	Bellow	Not in NV-317	< 20	680	Weapons-related		EPA-600 4-85-035
Fusileer	31-May-84	Caprock	On-Site Only	20 - 150	1969	Weapons-related		EPA-600 4-85-035
Fusileer	20-Jun-84	Duoro	Not in NV-317	20 - 150	1250	Weapons-related		EPA-600 4-85-035
Fusileer	12-Jul-84	Normanna	Not in NV-317	< 20	656	Weapons-related		EPA-600 4-85-035
Fusileer	25-Jul-84	Kappeli	On-Site Only	20 - 150	2100	Weapons-related		EPA-600 4-85-035
Fusileer	2-Aug-84	Correo	Not in NV-317	20 - 150	1096	Weapons-related		EPA-600 4-85-035
Fusileer	30-Aug-84	Wexford	Not in NV-317	< 20	1030	Weapons-related		EPA-600 4-85-035
Fusileer	30-Aug-84	Dolcetto	Not in NV-317	< 20	1198	Weapons-related		EPA-600 4-85-035
Grenadier	13-Sep-84	Breton	On-Site Only	20 - 150	1585	Weapons-related		EPA-600 4-85-035
Grenadier	2-Oct-84	Vermejo	Not in NV-317	< 20	1149	Weapons-related		EPA-600 4-85-035
Grenadier	10-Nov-84	Villita	Not in NV-317	< 20	1221	Weapons-related		EPA-600 4-85-035
Grenadier	15-Dec-84	Tierra	On-Site Only	20 - 150	2100	Weapons-related		EPA-600 4-85-035
Grenadier	20-Dec-84	Minero	Not in NV-317	< 20	803	Weapons-related		EPA-600 4-85-035
Grenadier	15-Mar-85	Vaughn	On-Site Only	20 - 150	1396	Weapons-related		EPA-600 4-85-035
Grenadier	23-Mar-85	Cottage	Not in NV-317	20 - 150	1690	Weapons-related		EPA-600 4-85-035
Grenadier	2-Apr-85	Hermosa	Not in NV-317	20 - 150	2094	Weapons-related		EPA-600 4-85-036
Grenadier	6-Apr-85	Misty Rain	Off-Site	< 20	1276	Weapons Effects	6327F	EPA-600 4-85-036
Grenadier	2-May-85	Towanda	Not in NV-317	20 - 150	2166	Weapons-related		EPA-600 4-85-036
Grenadier	12-Jun-85	Salut	On-Site Only	20 - 150	1995	Weapons-related		EPA-600 4-85-036
Grenadier	12-Jun-85	Ville	On-Site Only	< 20	961	Weapons-related		EPA-600 4-85-036
Grenadier	26-Jun-85	Maribo	On-Site Only	< 20	1250	Weapons-related		EPA-600 4-85-036
Grenadier	25-Jul-85	Serena	On-Site Only	20 - 150	1969	Weapons-related		EPA-600 4-85-036
Grenadier	14-Aug-85	Cebrero	On-Site Only	< 20	600	Weapons-related		EPA-600 4-85-036
Grenadier	14-Aug-85	Chamita	Not in NV-317	< 20	1088	Weapons-related		EPA-600 4-85-036
Chariotier	27-Sep-85	Ponil	Not in NV-317	< 20	1217	Weapons-related		EPA-600 4-85-036
Grenadier	9-Oct-85	Mill Yard	On-Site Only	< 20	1230	Weapons Effects	6328F	EPA-600 4-85-036
Grenadier	9-Oct-85	Diamond Beech	On-Site Only	< 20	1325	Weapons Effects	6328F	EPA-600 4-85-036

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Grenadier	16-Oct-85	Roquefort	On-Site Only	20 - 150	1362	Weapons-related		EPA-600 4-85-036
Grenadier	30-Oct-85	Abo	On-Site Only	< 20	644	Weapons-related		EPA-600 4-85-036
Grenadier	5-Dec-85	Kinibito	Not in NV-317	20 - 150	1901	Joint US-UK		EPA-600 4-85-036
Grenadier	28-Dec-85	Goldstone	Not in NV-317	20 - 150	1800	Weapons-related		EPA-600 4-85-036
Grenadier	22-Mar-86	Glencoe	Off-Site	29	2000	Weapons-related		EPA-600 4-87-017
Grenadier	10-Apr-86	Mightly Oak	Off-Site	< 20	1294	Weapons Effects	6328F	EPA-600 4-87-017 & 86-030
Grenadier	20-Apr-86	Mogollon	Not in NV-317	< 20	851	Weapons-related		EPA-600 4-87-017
Grenadier	22-Apr-86	Jefferson	On-Site Only	20 - 150	1998	Weapons-related		EPA-600 4-87-017
Grenadier	21-May-86	Panamint	On-Site Only	< 20	1575	Weapons-related		EPA-600 4-87-017
Grenadier	5-Jun-86	Tajo	Not in NV-317	20 - 150	1700	Weapons-related		EPA-600 4-87-017
Grenadier	17-Jul-86	Cybar	On-Site Only	119	2060	Weapons-related		EPA-600 4-87-017
Grenadier	24-Jul-86	Cornucopia	On-Site Only	< 20	1250	Weapons-related		EPA-600 4-87-017
Grenadier	4-Sep-86	Galveston	Not in NV-317	< 20	1598	Weapons-related		EPA-600 4-87-017
Grenadier	11-Sep-86	Aleman	Not in NV-317	< 20	1248	Weapons-related		EPA-600 4-87-017
Musketeer	30-Sep-86	Labquark	On-Site Only	20 - 150	2020	Weapons-related		EPA-600 4-87-017
Musketeer	16-Oct-86	Belmont	On-Site Only	20 - 150	1985	Weapons-related		EPA-600 4-87-017
Musketeer	14-Nov-86	Gascon	On-Site Only	20 - 150	1949	Weapons-related		EPA-600 4-87-017
Musketeer	13-Dec-86	Bodie	On-Site Only	20 - 150	2083	Weapons-related		EPA-600 4-87-017
Musketeer	3-Feb-87	Hazebrook-Emerald, -Checkerberry, -Apricot	On-Site Only	< 20 each	610, 742, 860	Weapons-related & Safety		EPA-600 4-88-021
Musketeer	11-Feb-87	Tomero	On-Site Only	< 20	979	Weapons-related		EPA-600 4-88-021
Musketeer	18-Mar-87	Middle Note	Not in NV-317	< 20	1308	Weapons Effects	6328F	EPA-600 4-88-021
Musketeer	18-Apr-87	Delamar	Not in NV-317	20 - 150	1785	Weapons-related		EPA-600 4-88-021
Musketeer	22-Apr-87	Presidio	Not in NV-317	< 20	1049	Weapons-related		EPA-600 4-88-021
Musketeer	30-Apr-87	Hardin	On-Site Only	20 - 150	2051	Weapons-related		EPA-600 4-88-021
Musketeer	18-Jun-87	Brie	Not in NV-317	< 20	666	Weapons-related		EPA-600 4-88-021
Musketeer	20-Jun-87	Mission Ghost	On-Site Only	< 20	1054	Weapons Effects	6328F	EPA-600 4-88-021
Musketeer	30-Jun-87	Panchuela	On-Site Only	< 20	1050	Weapons-related		EPA-600 4-88-021
Musketeer	16-Jul-87	Midland	Not in NV-317	20 - 150	1597	Joint US-UK		EPA-600 4-88-021

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Musketeer	13-Aug-87	Tohoka	Not in NV-317	20 - 150	2095	Weapons-related		EPA-600 4-88-021
Touchstone	24-Sep-87	Lockney	On-Site Only	20 - 150	2020	Weapons-related		EPA-600 4-88-021
Touchstone	23-Oct-87	Borate	On-Site Only	20 - 150	1780	Weapons-related		EPA-600 4-88-021
Touchstone	1-Dec-87	Waco	Not in NV-317	< 20	600	Weapons-related		EPA-600 4-88-021
Touchstone	2-Dec-87	Mission Cyber	Not in NV-317	< 20	888	Weapons Effects	6328F	EPA-600 4-88-021
Touchstone	15-Feb-87	Kernville	Not in NV-317	20 - 150	1777	Weapons-related		EPA-600 4-88-021
Touchstone	7-Apr-88	Abilene	Not in NV-317	< 20	804	Weapons-related		EPA-600 4-89-019
Touchstone	13-May-88	Schellbourne	On-Site Only	< 150	1520	Weapons-related		EPA-600 4-89-019
Touchstone	21-May-88	Laredo	Not in NV-317	< 150	1153	Weapons-related		EPA-600 4-89-019
Touchstone	2-Jun-88	Comstock	On-Site Only	< 150	2035	Weapons-related		EPA-600 4-89-019
Touchstone	22-Jun-88	Nightingale/Rhyolite	Not in NV-317	< 150 each	780/680	Weapons-related & Safety		EPA-600 4-89-019
Touchstone	7-Jul-88	Alamo	Not in NV-317	< 150	2041	Weapons-related		EPA-600 4-89-019
Touchstone	17-Aug-88	Kearsarge	Not in NV-317	100 - 150	2020	Weapons-related		EPA-600 4-89-019
Touchstone	23-Aug-88	Harlingen-A & -B	Not in NV-317	< 20 each	950	Weapons-related		EPA-600 4-89-019
Cornerstone	30-Aug-88	Bullfrog	On-Site Only	< 150	1605	Weapons-related		EPA-600 4-89-019
Cornerstone	13-Oct-88	Dalhart	Not in NV-317	< 150	2099	Weapons-related		EPA-600 4-89-019
Cornerstone	9-Nov-88	Monahans-A & -B	Not in NV-317	< 20 each	951	Weapons-related		EPA-600 4-89-019
Cornerstone	9-Dec-88	Kawich A-Blue & -White	Not in NV-317	< 20 each	1260/1210	Safety Experiment		EPA-600 4-89-019
Cornerstone	10-Dec-88	Misty Echo	On-Site Only	< 150	1313	Weapons Effects	6328F	EPA-600 4-89-019
Cornerstone	24-Feb-89	Kawich-Red, -Black	On-Site Only	< 20 each	1214, 1414	Weapons-related & Safety		EPA-600 4-89-019
Cornerstone	9-Mar-89	Ingot	Not in NV-317	20 - 150	1640	Weapons-related		EPA-600 4-90-016
Cornerstone	15-May-89	Palisade-1, -2, -3	On-Site Only	< 20	1132, 1286, 1326	Weapons-related & Safety		EPA-600 4-90-016
Cornerstone	26-May-89	Tulia	Not in NV-317	< 20	1305	Weapons-related		EPA-600 4-90-016
Cornerstone	22-Jun-89	Contact	On-Site Only	20 - 150	1785	Weapons-related		EPA-600 4-90-016
Cornerstone	27-Jun-89	Amarillo	On-Site Only	20 - 150	2100	Weapons-related		EPA-600 4-90-016
Aqueduct	14-Sep-89	Disko Elm	On-Site Only	< 20	857	Weapons Effects	6328F	EPA-600 4-90-016

TABLE B-1. CONUS US Nuclear Test from 1961 to 1992 and Reactor Experiments at NRDS, continued

Test Series	Date	Name	NV-317 Specified Release	Yield (kT)	Depth (ft)	Program	DNA Report	SWRHL Report, EPA, or DOE
Aqueduct	31-Oct-89	Hornitos	Not in NV-317	20 - 150	1850	Weapons-related		EPA-600 4-90-016
Aqueduct	15-Nov-89	Muleshoe	Not in NV-317	< 20	802	Weapons-related		EPA-600 4-90-016
Aqueduct	8-Dec-89	Barnwell	On-Site Only	20 - 150	1971	Joint US-UK		EPA-600 4-90-016
Aqueduct	20-Dec-89	Whiteface-A, -B	Not in NV-317	< 20 each	646, 599	Safety Experiment		EPA-600 4-90-016
Aqueduct	10-Mar-90	Metropolis	On-Site Only	20 - 150	1540	Weapons-related		EPA-600 4-91-030
Aqueduct	6-Apr-90	Bowie	Not in NV-317	< 20	700	Weapons-related		EPA-600 4-91-030
Aqueduct	13-Jun-90	Bullion	Not in NV-317	20 - 150	2211	Weapons-related		EPA-600 4-91-030
Aqueduct	21-Jun-90	Austin	Not in NV-317	< 20	1150	Weapons-related		EPA-600 4-91-030
Aqueduct	25-Jul-90	Mineral Quarry & Randsburg	On-Site Only	< 20	1278	Weapons Effects	6328F	EPA-600 4-91-030
Aqueduct	20-Sep-90	Sundown-A, -B	Not in NV-317	< 20 each	887	Safety Experiment		EPA-600 4-91-030
Sculpin	27-Sep-90	Ledoux	Not in NV-317	< 20	840	Weapons-related		EPA-600 4-91-030
Sculpin	12-Oct-90	Tenabo	On-Site Only	20 - 150	1969	Weapons-related		EPA-600 4-91-030
Sculpin	14-Nov-90	Houston	On-Site Only	20 - 150	1950	Joint US-UK		EPA-600 4-91-030
Sculpin	8-Mar-91	Cozo-Bronze, -Gray, -Silver	Not in NV-317	< 20 each	1093, 1450, 1559	Weapons-related, Safety Experiment		EPA-600 4-94-209
Sculpin	4-Apr-91	Bexar	On-Site Only	20 - 150	2066	Weapons-related		EPA-600 4-94-209
Sculpin	16-Apr-91	Montello	Not in NV-317	20 - 150	2105	Weapons-related		EPA-600 4-94-209
Sculpin	15-Aug-91	Floydada	Not in NV-317	< 20	1650	Weapons-related		EPA-600 4-94-209
Sculpin	14-Sep-91	Hoya	Not in NV-317	20 - 150	2159	Weapons-related		EPA-600 4-94-209
Julin	19-Sep-91	Distant Zenith	On-Site Only	< 20	865	Weapons Effects	6328F	EPA-600 4-94-209
Julin	18-Oct-91	Lubbock	On-Site Only	20 - 150	1500	Weapons Effects		EPA-600 4-94-209
Julin	26-Nov-91	Bristol	Not in NV-317	< 20	1500	Joint US-UK		EPA-600 4-94-209
Julin	26-Mar-92	Junction	Not in NV-317	20 - 150	2041	Weapons-related		EPA-600 4-94-209
Julin	30-Apr-92	Diamond Fortune	On-Site Only	< 20	776	Weapons Effects	6328F	EPA-600 4-94-209
Julin	19 Jun 92	Victoria	Not in NV-317	< 20	801	Weapons-related		EPA-600 4-94-209
Julin	23 Jun 92	Galena-Green, -Orange, -Yellow	Not in NV-317	< 20	1312, 1247, 951	Safety Experiment		EPA-600 4-94-209
Julin	18-Sep-92	Hunters Trophy	On-Site Only	< 20	1264	Weapons Effects	6328F	EPA-600 4-94-209
Julin	23-Sep-92	Divider	On-Site Only	< 20	1397	Weapons-related		EPA-600 4-94-209

TABLE B-2. List of Chinese Atmospheric Nuclear Tests, Summarized from Norris et al. (1994).

Date	Yield (kT)	Location
16-Oct-64	20 - 22	Lop Nor
14-May-65	20 - 40	Lop Nor
9-May-66	200 - 300	Lop Nor
27-Oct-66	12 - 30	Lop Nor
28-Dec-66	12 / 300-500	Lop Nor
17-Jun-67	3000 - 3300	Lop Nor
24-Dec-67	15 - 25	Lop Nor
27-Dec-68	3000	Lop Nor
29-Sep-69	3000	Lop Nor
14-Oct-70	3000 - 3400	Lop Nor
18-Nov-71	15 - 20	Lop Nor
7-Jan-72	8 - 20	Lop Nor
18-Mar-72	100 - 200	Lop Nor
27-Jun-73	2000 - 3000	Lop Nor
17-Jun-74	200 - 1000	Lop Nor
23-Jan-76	< 20	Lop Nor
26-Sep-76	200	Lop Nor
17-Nov-76	4000	Lop Nor
17-Sep-77	< 20	Lop Nor
23-Mar-78	6 - 20	Lop Nor
14-Dec-78	< 20	Lop Nor
16-Oct-80	200 - 1000	Lop Nor

TABLE B-3. Some Documents with Summary of Releases of Radioactivity Off the Nevada Test Site and Underground Nuclear Testing Containment Failures.

Organization	Report No.	Date	Covered Period	No. Tests	Notes
Atomic Energy Commission (AEC)	WASH-1183	June 1971	5 August 1963 – 30 June 1971	18	- Listed as off-site detection only if there was a ground-based detection of release. - Did not include reactor test releases. - Concentrated on accidental releases.
Environmental Protection Agency (EPA)	600 8 87-054	August 1988	1963 – 1986	23	- Update to WASH-1183. Included both off-site detections in air and/or ground-level. - Did not include reactor test releases. - Concentrated on accidental releases
Office of Technology Assessment (OTA), US Congress	ISC-414	October 1989	1958 – 1988	General Summary of All Tests	- Concentration on containment issues from a public exposure potential. - Included summary of radioactivity releases from all underground tests, with highlighting of circumstances for release.
Department of Energy, Nevada Operations Office	NV-317	August 1996	1961 - 1992	437 (All) 47 (Off-Site)	- <u>Tests in 1961 – 1962</u>: 12, 1 Plowshare (Sedan), 3 aboveground or shallow burial - <u>Tests 1963 – June 1971</u>: 30, 5 Plowshare - <u>Tests July 1971 – 1992</u>: 5 - Covered 437 test events to include underground and Plowshare program tests. - Provided details on circumstances for underground test releases, amounts of radiological material released, and primary radionuclides

Appendix C

Maps

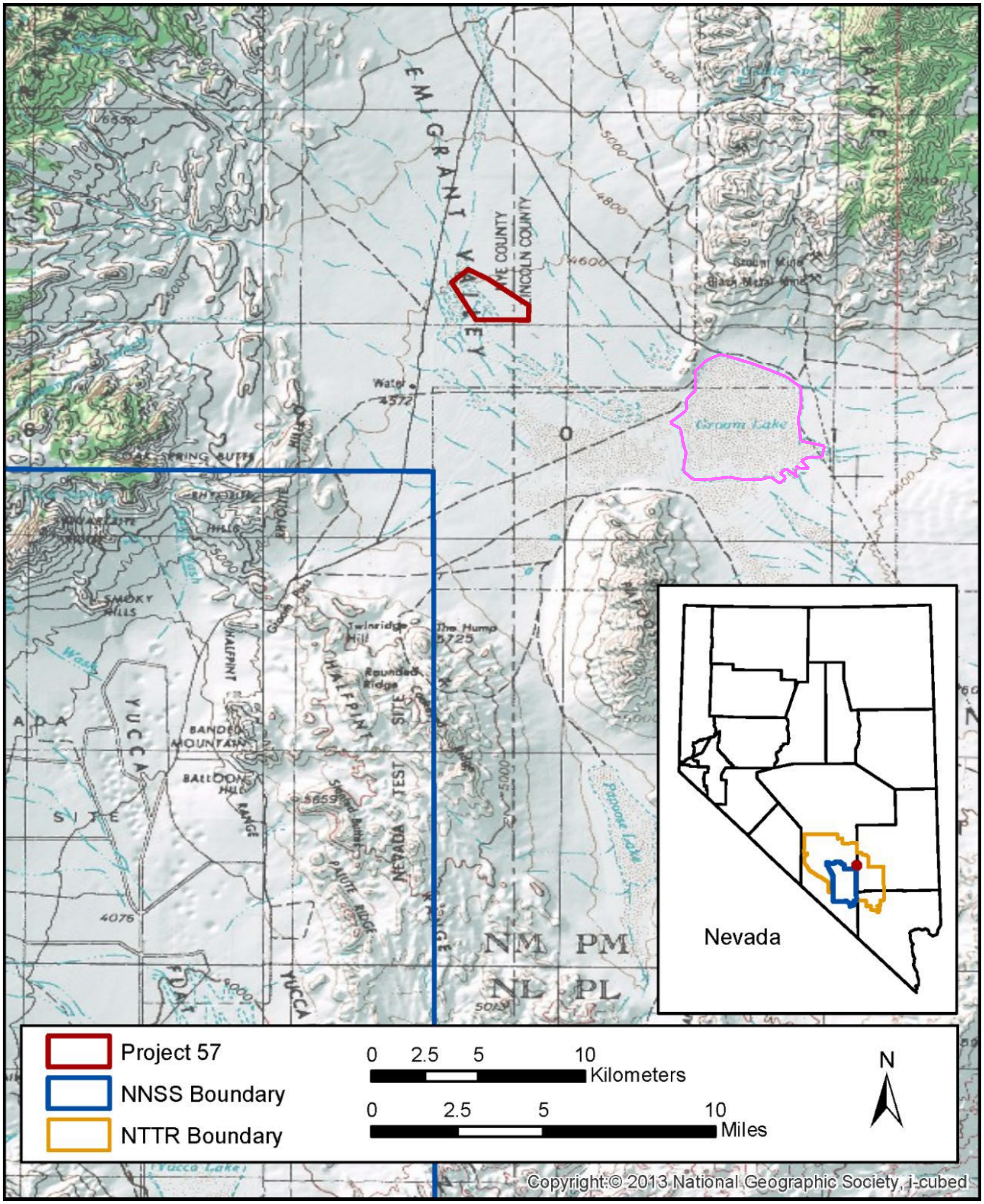

Figure C-1. Map Showing Location of Project 57 in Relation to NNSS (former NTS) and NTTR Boundaries from NV/0003590-29 (2018).

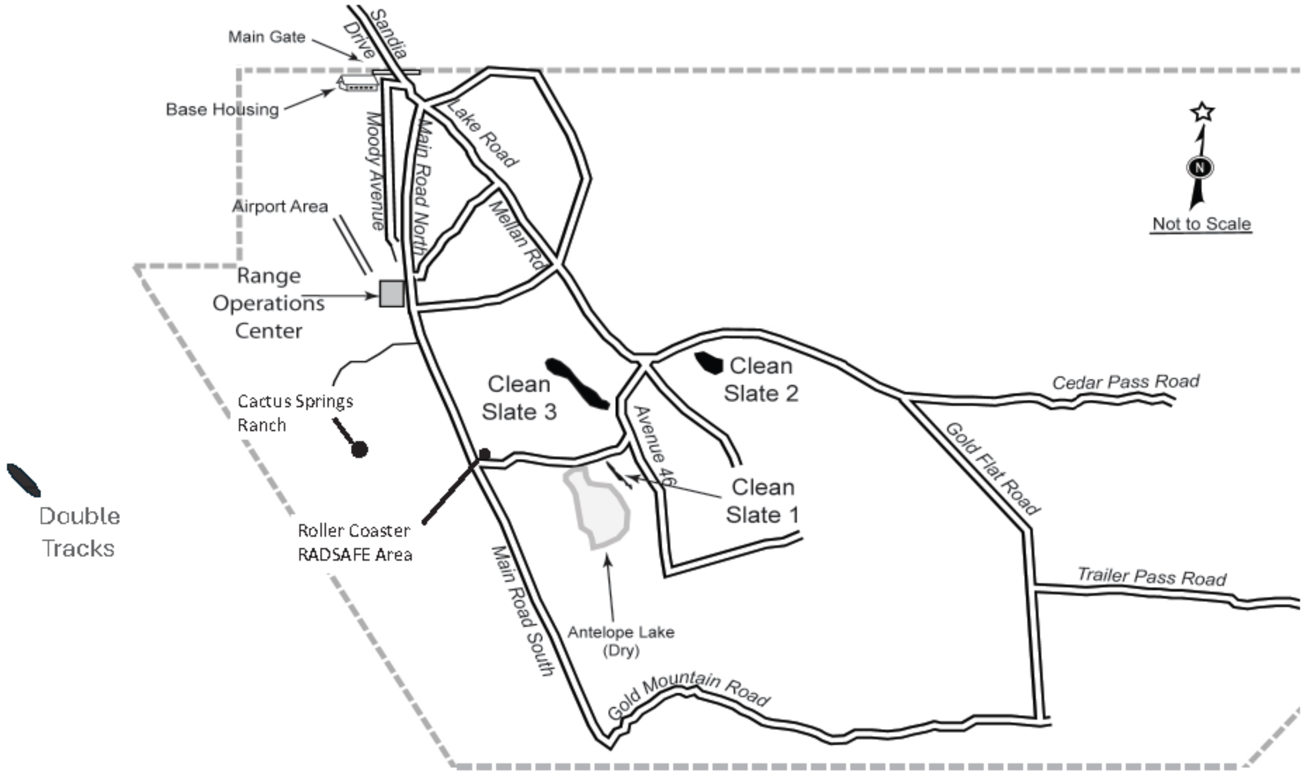

Figure C-2. Map Showing Location of Clean Slate Sites on TTR and Double Tracks West of TTR Boundary, Adapted from Figure 1, NV/26383-29 (2012).

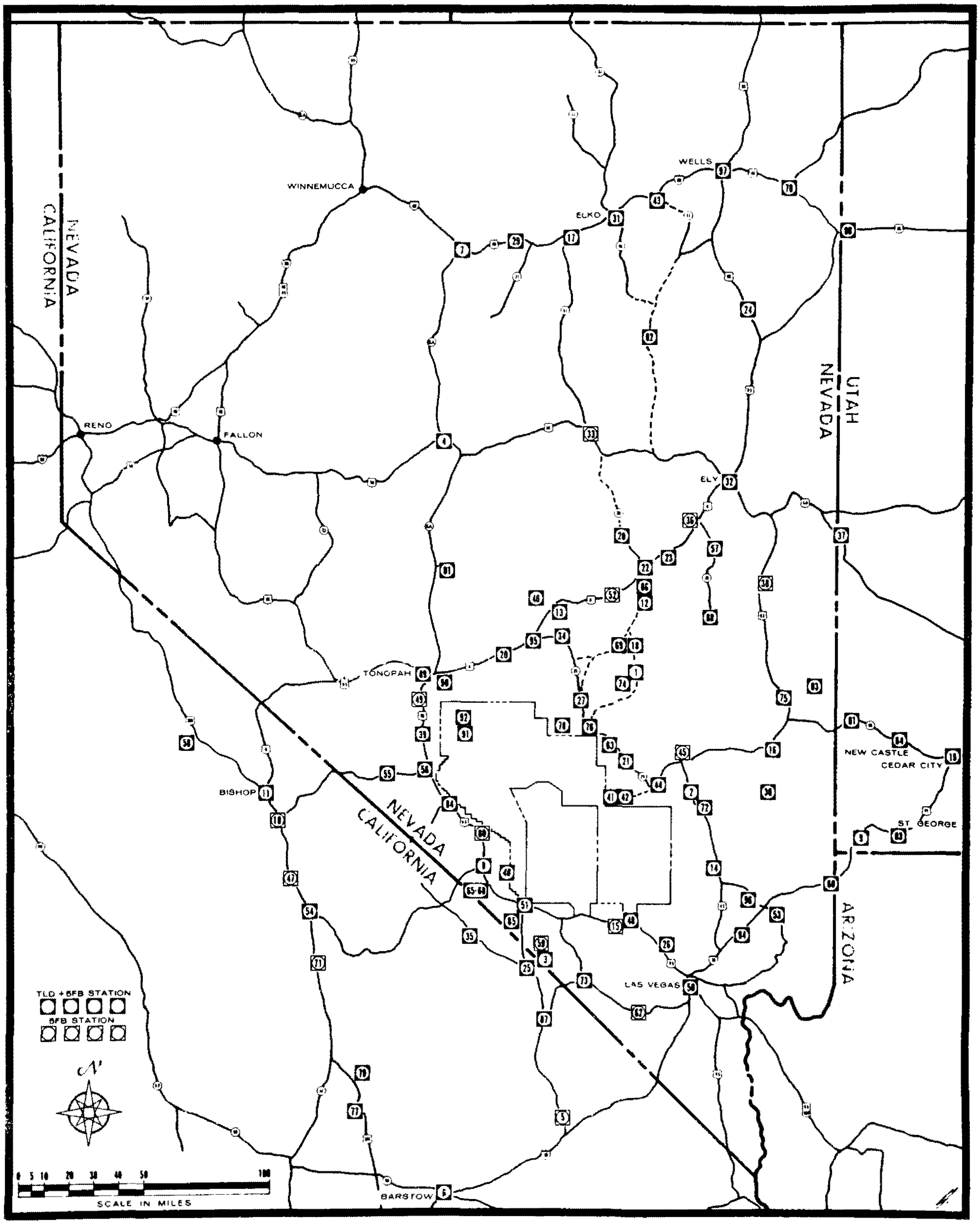

Figure C-3. Film Badge and TLD Stations, Environmental Surveillance Program, Figure 5 of SWRHL-58-r (1969).

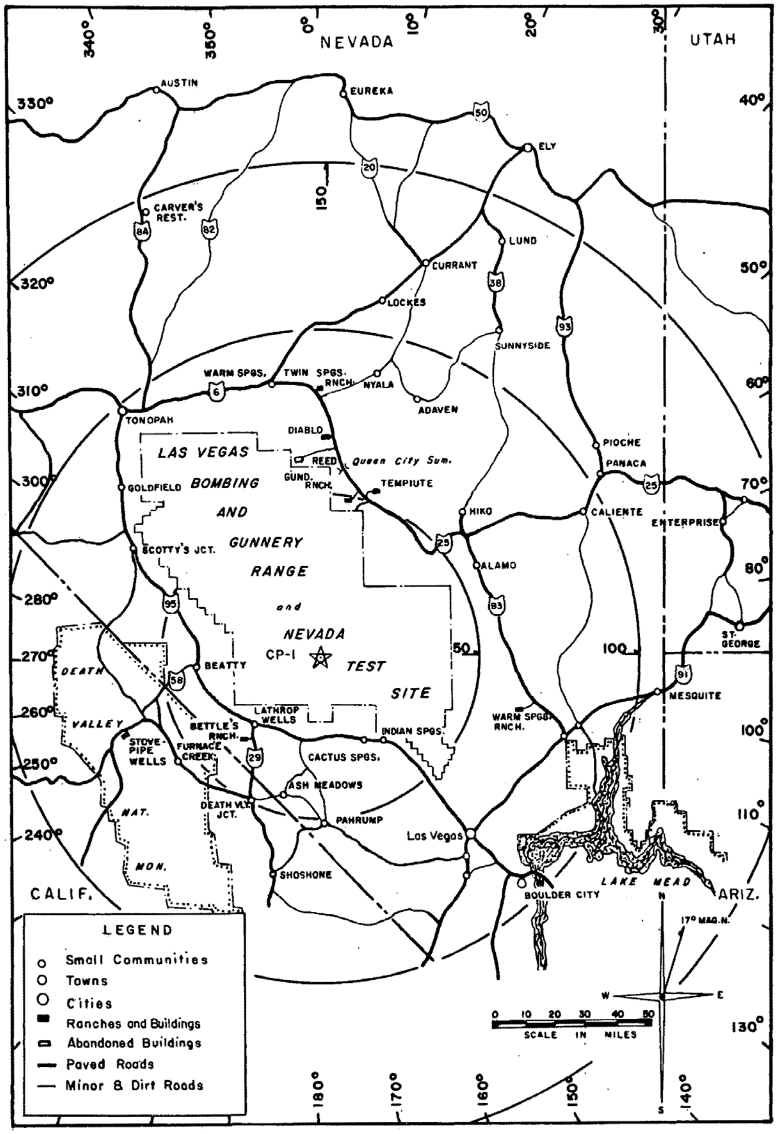

Figure C-4. The Off-Site Area Surrounding the Nevada Test Site and Vas Vegas Bombing and Gunnery Range, Figure 1 from SWRHL-1r (1964).

LOCATION	Antler	Feather	Pampas	Danny Boy	Platte	Eel	Des Moines
Alamo	FC	F	F	F	F	F	F
Ash Meadows		FC					
Beatty	FC	FC	F	F	F	F	F
Bettle's Ranch		FC					
Caliente	F	F	F	F	F	F	F
Carver's Rest.				FCR			
Currant			F	F	F	FCR	FR
Death Valley Jct.		FCR	F	F	F	F	F
Diablo	FCR	F	FCR	FR	FCR	FC	FCR
Ely			F	F	F	FC	F
Enterprise, Utah			F	F	F	F	F
Eureka							FC
Furnace Creek		FCR	F	F	F	F	F
Goldfield	FC	F	F	F	F	F	F
Gunderson's R.	FCR	FC	FCR	FCR	FCR	FCR	FCR
Hiko	FC	F	F	F	F	F	F
Indian Springs		F	F		F	F	F
Las Vegas		F	F	F	F	F	F
Lathrop Wells	FC	FCR	F	F	F	F	F
Lockes							R
Lund			F	F	F	FC	FC
Mesquite			F		F	F	F
Pahrump			F	F	F	F	F
Pioche			F	F	F	F	F
St. George, Utah	F	F	F	F	F	F	F
Scotty's Jct.			F	FCR	F	F	F
Shoshone		FC					
Stovepipe Wells		FCR					
Tempiute						FC	
Tonopah	FC	F	F	FCR	F	F	F
Twin Springs R.						FC	F
Warm Springs	FC	F	FC	FCR	FCR	F	FCR
Warm Springs R.	F	F	F	F	F	F	F
Bald Mountain	FC						
Queen City Summit					FCR		FC
Reed	R			FCR	FCR		R
Currant Mnt. Sta.							R

F - air sampler with filter; C - air sampler with filter and charcoal cartridge; R - dose rate recorder.

Figure C-5. Off-Site Locations Instrumented during Seven Events of Operation Nougat, Table 5.2.2 from SWRHL-1r (1964).

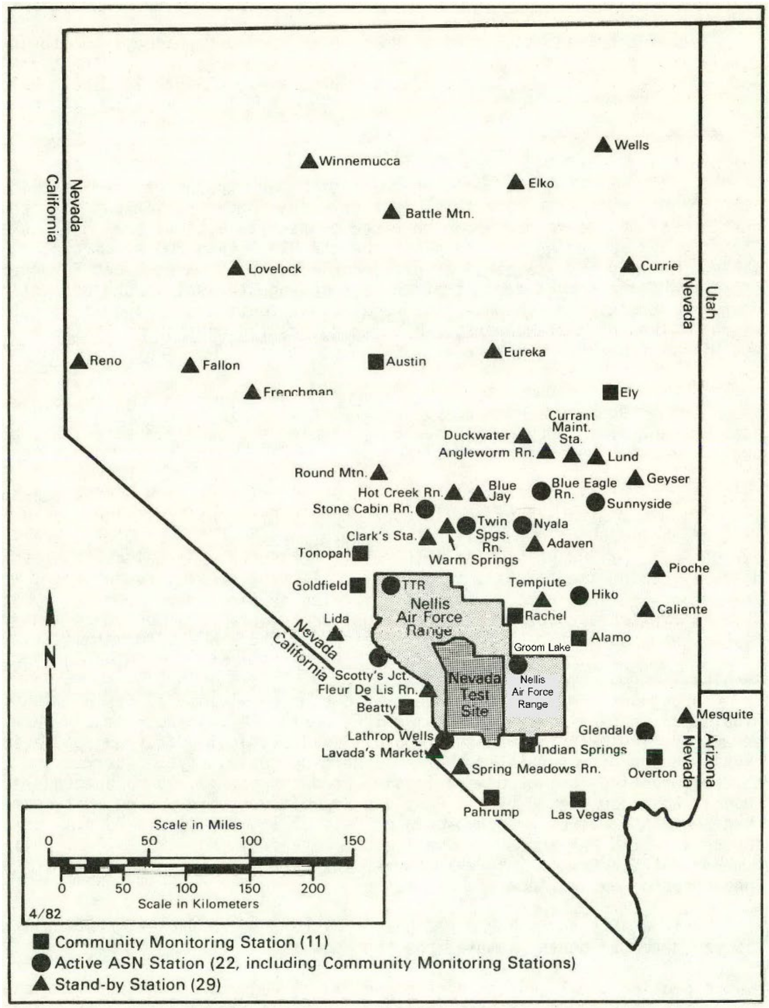

Figure C-6. Air Surveillance Network Stations within Nevada, Adapted from Figure 2, EPA-600-4-82-061 (1982).

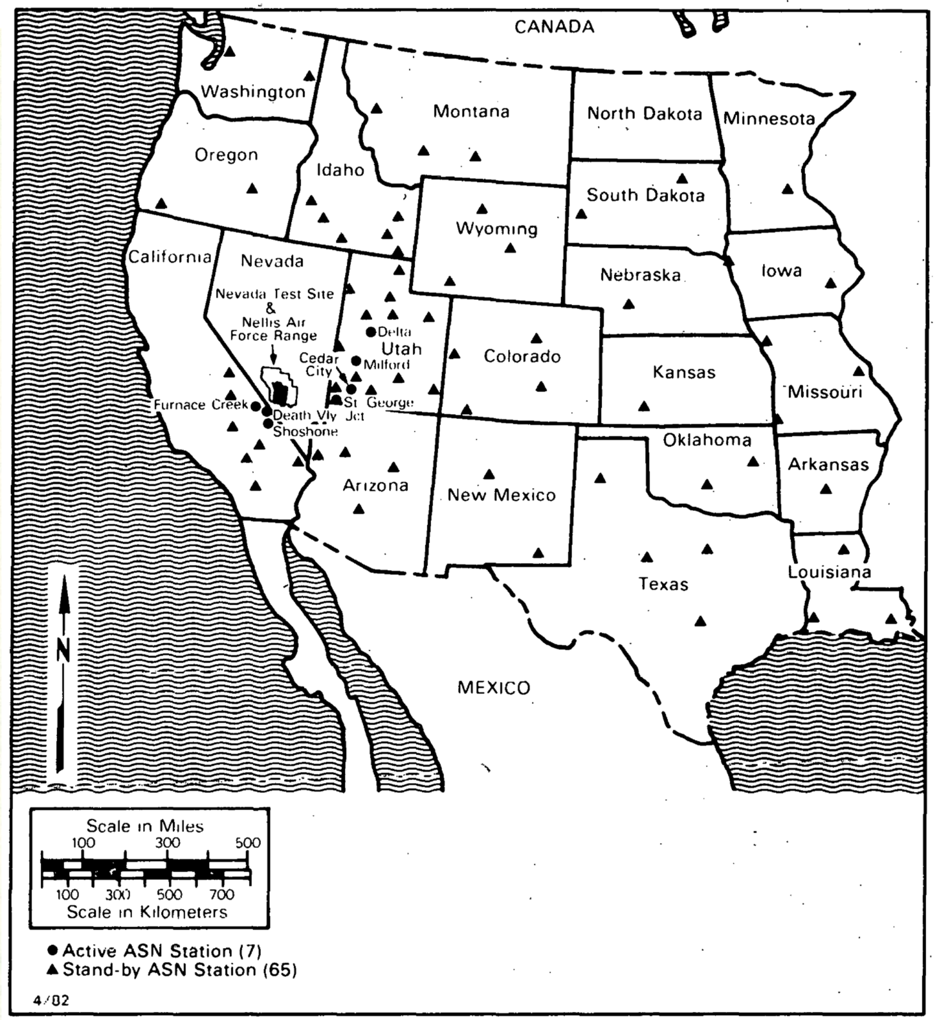

Figure C-7. Air Surveillance Network Stations in States other than Nevada, Figure 3, EPA-600-4-82-061 (1982).

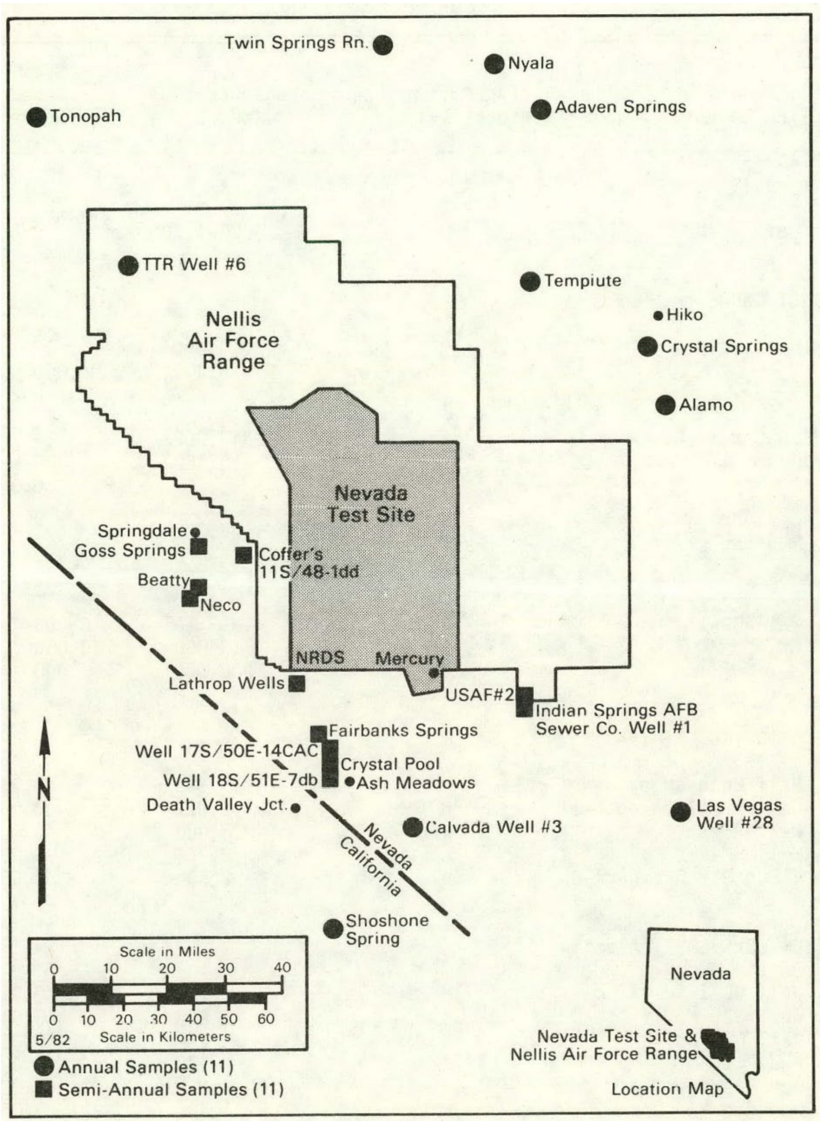

Figure C-8. LTHMP Sampling Locations near the NTS, Figure 9, EPA-600-4-82-062 (1981).

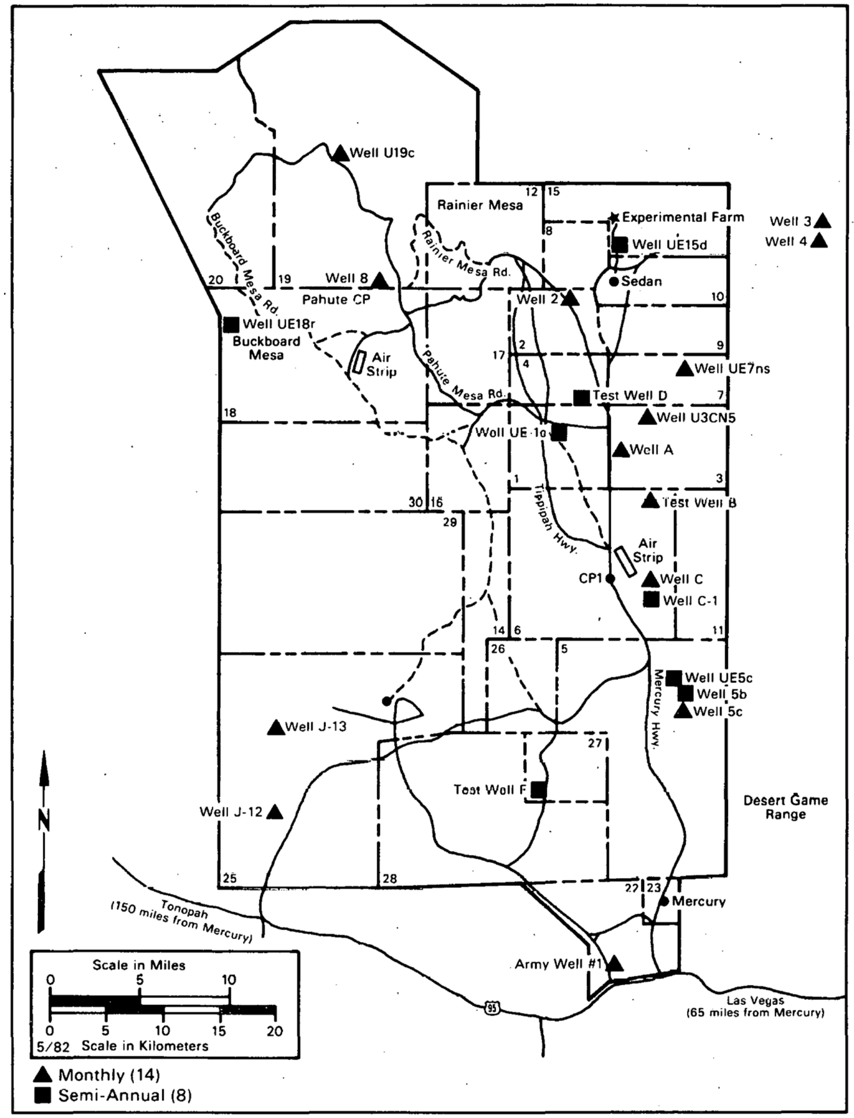

Figure C-9. LTHMP Sampling Locations on the NTS, Figure 8, EPA-600-4-82-062 (1981).

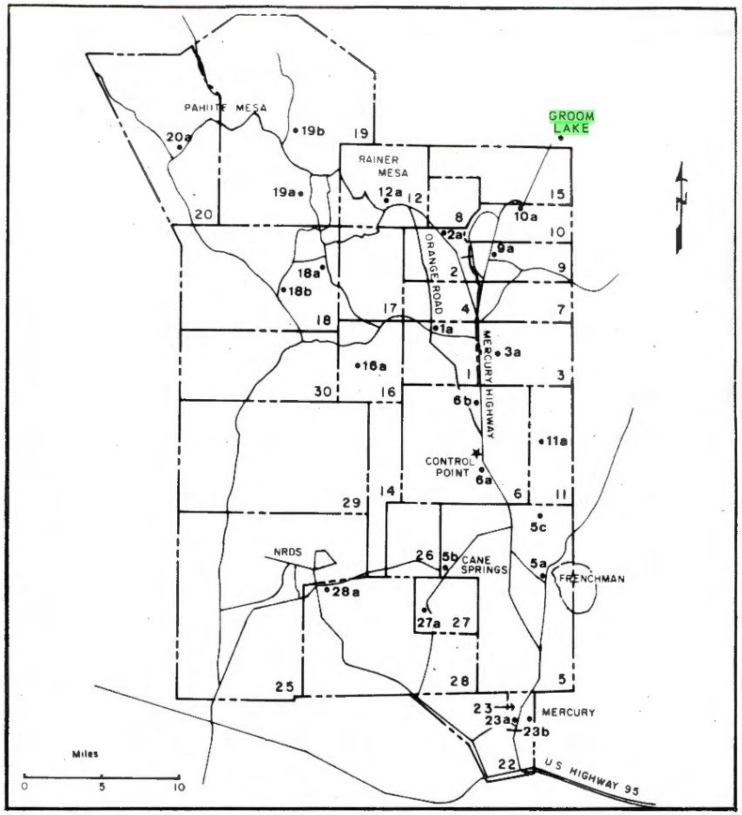

Figure 1 NTS Environmental Surveillance Air Sampling Locations

TABLE 1 – NTS ENVIRONMENTAL SURVEILLANCE AIR SAMPLING STATION LOCATIONS

Area	Sample Station Location	Map Code	Area	Sample Station Location	Map Code
1	Gravel Pit	1a	16	Tunnel Site Maintenance	16a
2	Camp Compound	2a	18	East of Cafeteria	18a
3	North of Cafeteria	3a		North of Cafeteria	18b
5	East of Well 5B Reservoir	5a	19	Echo Peak	19a
	Guard Station 250	5b		Stake 19C-10	19b
6	Maintenance Complex	5c	20	West of Aid Station	20a
6	Air Station	6a	23	Building 214	23a
	Well 3 Complex	6b		Health & Safety Building Rooftop	23b
9	9-300 Bunker	9a	27	West of Dispensary	27a
10	Guard Station 700	10a	28	Project HENRE	28a
11	Guard Station 293	11a	Groom Lake	East of Station 1	
12	Changehouse	12a			

Figure C-10. NTS Environmental Surveillance Air Sampling Locations for July 1968 – June 1969, Figure 1 and Table 1 of NVO-410-16 (1971).

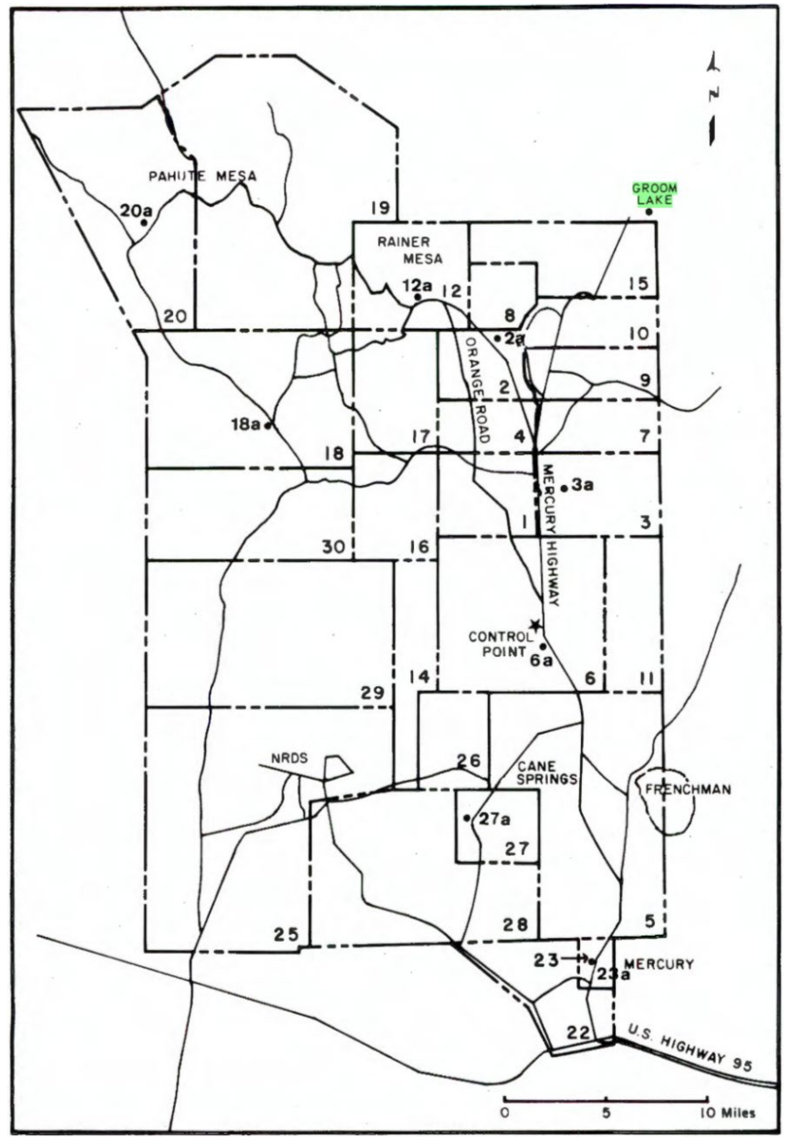

Figure C-11. NTS Environmental Surveillance Potable Water Sampling Locations for July 1968 – June 1969, Figure 4 of NVO-410-16 (1971).

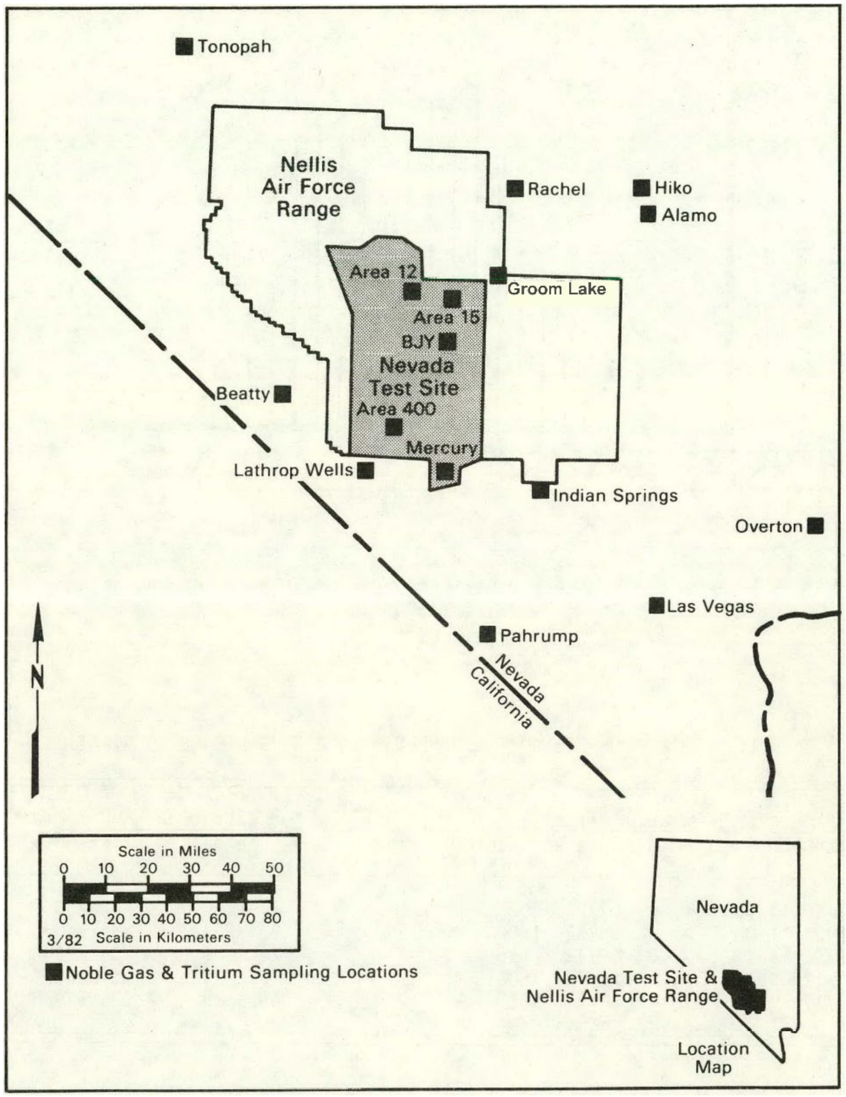

Figure C-12. Noble Gas and Tritium Surveillance Network Sampling Locations, Adapted from Figure 5, EPA-600-4-82-061 (1982).

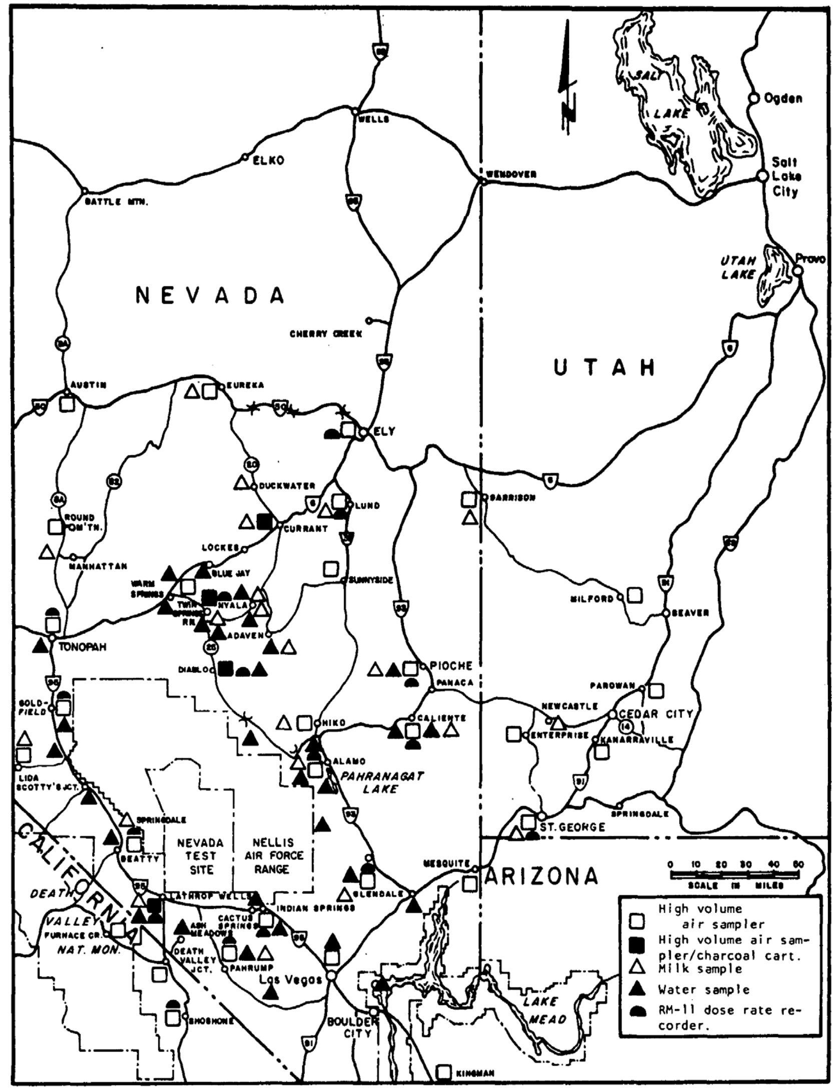

Figure C-13. Environmental Sampling Points as of June 10, 1964, Operation Niblick, Figure 1 from SWRHL-12r (1966).

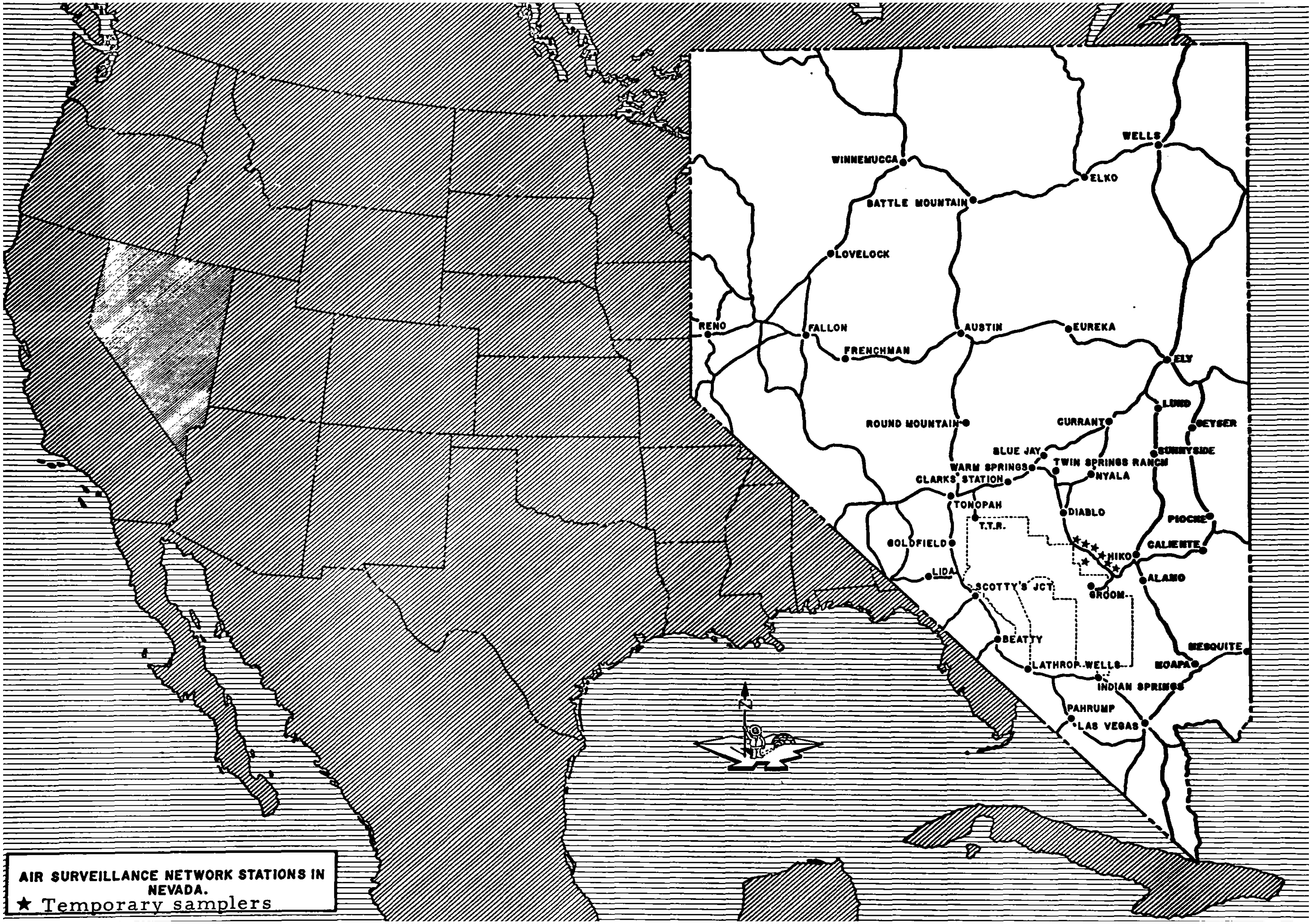

Figure C-14. Air Surveillance Network Stations in Nevada for the Phoebus 1B, EP-1, EP-II, EP-III, EP-IV Reactor Test Series, Figure 1 from SWRHL-45r (1969).

Appendix D

Radionuclide Data

TABLE D-1. Common Radionuclides Associated with Nuclear Detonations.

Radionuclide	Source		Half-life
	Primary	Other (Non-Fission Interactions)	
Pu-238	Unburned fuel	Fast neutron (n,2n) with Pu-239	87.8 y
Pu-239	Unburned fuel	Fast neutron (n,γ) with U-238 + decay	24,131 y
Pu-240	Unburned fuel	Thermal neutron capture with Pu-239	6,563 y
Pu-241	Unburned fuel	Thermal neutron capture with Pu-240	14.4 y
Am-241		Decay product of Pu-241	432 y
U-234	Unburned fuel		245,000 y
U-235	Unburned fuel		7.04×10^8 y
U-236		Thermal neutron capture with U-235	2.34×10^7 y
U-237		Fast neutron (n,2n) with U-238	6.75 d
U-238	Unburned fuel		4.47×10^9 y
U-239		Fast neutron capture with U-238	23.5 min
Np-239		Decay product of U-239	2.4 d
H-3	Unburned fuel	Fusion and neutron activation product	12.4 y
C-14	Activation	Soil, concrete, air, (n,γ) with C-13	5,730 y
Na-24	Activation	Soil	15 h
Ar-37	Activation	Atmosphere (n,γ) with Ar-36	35 d
Fe-55	Activation	Steel (n,γ) with Fe-54	2.7 y
Co-60	Activation	Steel (n,γ) with Co-59	5.27 y
Ni-63	Activation	Steel (n,γ) with Ni-62	96 y
Cu-64	Activation	Copper (n,γ) with Cu-63	12.7 h
Zn-65	Activation	Steel (n,γ) with Zn-64	244 d
As-77	Fission		39 h
Br-83	Fission		2.4h
Kr-85	Fission		10.7 y
Kr-85m	Fission	Also activation (n,γ) with Kr-84	4.5 h
Kr-87	Fission		76 min
Rb-88	Fission	Also, daughter Kr-88	18 min
Kr-88	Fission		2.8 h
Sr-89	Fission		50.5 d
Sr-90	Fission		29.1 y
Y-90		Serial decay product of Sr-90	64 h
Sr-91	Fission		9.6 h
Y-91m	Fission		50 min
Sr-92	Fission		2.7 h
Y-92	Fission		3.5 h
Y-93	Fission		10 h
Zr-95	Fission		64 d
Nb-95	Fission		35 d
Zr-97	Fission		17 h
Nb-97m	Fission		53 s
Mo-99	Fission		66 h

TABLE D-1. Common Radionuclides Associated with Nuclear Detonations (continued).

Radionuclide	Source		Half-life
	Primary	Other (Non-Fission Interactions)	
Tc-99m	Fission		6.0 h
Rh-102m	Fission	Tracer [^{103}Rh (n,2n)^{102m}Rh]	2.9 y
Rh-102	Fission	Tracer [^{103}Rh(n,2n)^{102}Rh]	284 d
Ru-103	Fission		39 d
Rh-103m	Fission		56 min
Ru-105	Fission		35 h
Ru-106	Fission		374 d
Pd-109	Fission		14 h
Ag-112	Fission		3.1 h
Cd-115	Fission		53 h
Cd-117	Fission		2.5 h
In-117m	Fission		2.0h
Sn-121	Fission		27 h
Sb-125	Fission		2.8 y
Sn-127	Fission		2.1 h
Sb-127	Fission		3.9 d
Te-129	Fission		70 m
Sb-129	Fission		4.4 h
Te-131m	Fission		30 h
I-131	Fission		8.0 d
Xe-131m	Activation	Atmosphere (n,γ) with Xe-130	11.8 d
Te-132	Fission		78 h
I-132	Fission	Daughter of Te-132	2.3 h
Te-133m	Fission		55 min
I-133	Fission		21 h
Xe-133	Fission	Also, activation (n,γ) with Xe-132	5.2 d
Xe-133m	Fission	Also, activation (n,γ) with Xe-132	2.2 d
Ba-133	Activation	Soil (n,γ) with Ba-132	10.5 y
I-135	Fission		6.6 h
Xe-135	Fission	Also, activation (n,γ) with Xe-134	9.1 h
Xe-135m	Fission	Also, activation (n,γ) with Xe-134, daughter I-135	15.4 m
Cs-137	Fission		30.2 y
Xe-137	Fission	Also, activation (n,γ) with Xe-136	3.9 min
Xe-138	Fission		14.1 min
Ba-139	Fission		83 min
Ba-140	Fission		13 d
La-140	Fission		1.7 d
La-141	Fission		3.9 h
Ce-141	Fission		33 d
La-142	Fission		91 min
Ce-143	Fission		33 h

TABLE D-1. Common Radionuclides Associated with Nuclear Detonations (continued).

Radionuclide	Source		Half-life
	Primary	Other (Non-Fission Interactions)	
Pr-143	Fission		14 d
Ce-144	Fission		280 d
Pr-144	Fission		17 min
Pr-145	Fission		6.0 h
Nd-147	Fission		11 d
Pm-147	Fission		2.62 y
Pm-149	Fission		53 h
Nd-149	Fission		1.7 h
Pm-151	Fission		28 h
Sm-151	Fission		90 y
Eu-152	Activation	Rare earth in soil, (n,γ) with Eu-151	13.6 y
Sm-153	Fission		46 h
Eu-154	Activation	Rare earth in soil, (n,γ) with Eu-153	8.8 y
Eu-155	Fission		5.0 y
W-181	Activation	Activation (n,γ) with W-180	121 d
W-187	Activation	Activation (n,γ) with W-186	24 h
W-188	Activation	Activation (n,γ) with W-187	69 d

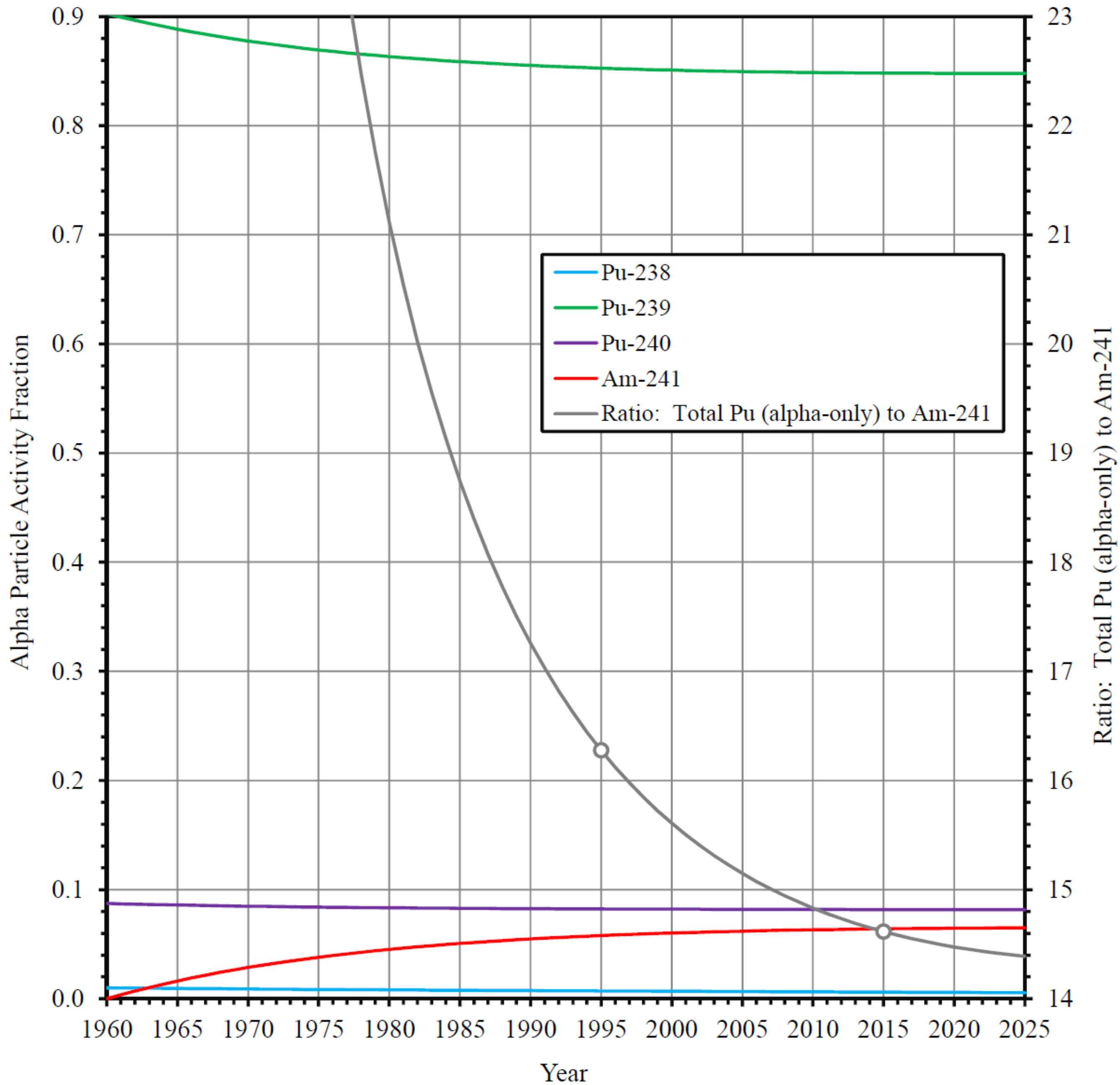

Figure D-1. Estimated α-Particle Emitting Isotopic Fractions for Plutonium in the Double Tracks Test Device, from AFSEC (2015).

TABLE D-2. Inhalation Dose Coefficients, ^{239}Pu, 1 μm AMAD (ICRP Report 71), 5 μm AMAD (ICRP Report 68, Effective Only) and Committed Equivalent Organ/Tissue Doses for 75 nCi Acute Inhalation Intake. [Table B-10 of Rademacher (2020)]

Organ/Tissue		Committed Equivalent and Effective Doses (rem μCi^{-1})		w_T	Type S		
		Type M	Type S		Committed Equivalent Dose [CED] (rem) for 75 nCi	Weighted CED (rem)	Fraction of CED
Adrenals		1.0 E+1	1.2 E+0	-	0.09	-	-
Bladder Wall		1.0 E+1	1.2 E+0	0.05	0.09	4.44 E-03	0.00098
Bone Surface		5.6 E+3	6.7 E+2	0.01	50.0	0.500	0.11
Brain		1.0 E+1	1.2 E+0	-	0.09	-	-
Breast		1.0 E+1	1.2 E+0	0.05	0.09	4.44 E-03	0.00098
GI Tract	Esophagus	1.0 E+1	1.2 E+0	0.05	0.09	4.44 E-03	0.00098
	St Wall	1.0 E+1	1.2 E+0	0.12	0.09	0.0107	0.0024
	SI Wall	1.0 E+1	1.2 E+0	-	0.09	-	-
	ULI Wall	1.0 E+1	1.2 E+0	0.01	0.09	8.89 E-04	0.00020
	LLI Wall	1.0 E+1	1.2 E+0	0.01	0.09	9.17 E-04	0.00020
	Colon	1.0 E+1	1.2 E+0	0.12	0.09	1.10 E-02	0.0024
Kidneys		2.4 E+1	3.0 E+0	0.01	0.22	2.22 E-03	0.00049
Liver		1.2 E+3	1.4 E+2	0.05	10.8	0.542	0.12
Muscle		1.0 E+1	1.2 E+0	0.01	0.09	8.89 E-04	0.00020
Ovaries		7.4 E+1	8.9 E+0	0.2	0.67	0.133	0.029
Pancreas		1.0 E+1	1.2 E+0	-	0.09	-	-
Red Bone Marrow		2.7 E+2	3.4 E+1	0.12	2.5	0.303	0.067
Respirat. Tract	Ex. Thor. Air	3.3 E+1	1.4 E+2	0.01	10.6	0.106	0.023
	Lungs	1.2 E+2	3.2 E+2	0.12	24.2	2.90	0.64
Skin		1.0 E+1	1.2 E+0	0.01	0.09	8.89 E-04	0.00020
Spleen		1.0 E+1	1.2 E+0	-	0.09	-	-
Testes		7.8 E+1	9.3 E+0	0.2	0.69	0.139	0.031
Thymus		1.0 E+1	1.2 E+0	-	0.09	-	-
Thyroid		1.0 E+1	1.2 E+0	0.05	0.09	4.44 E-03	0.00098
Uterus		1.0 E+1	1.2 E+0	-	0.09	-	-
Remainder		1.0 E+1	1.3 E+0	-	0.09	-	-
Effective Dose		1.9 E+2	6.0 E+1	-	-	4.54	-
Effective (5 μm AMAD)		1.3 E+2	3.1 E+1	-	-	-	-

TABLE D-3. Inhalation Dose Coefficients, ^{131}I, ^{132}I , ^{133}I , ^{135}I, ^{132}Te,
5 μm AMAD, Type F (ICRP Report 68).

Organ/Tissue		Committed Equivalent and Effective Doses (rem μCi^{-1})				
		I-131	I-132	I-133	I-135	Te-132
Adrenals		9.3 E-5	5.9 E-5	7.8 E-5	7.8 E-5	9.6 E-4
Bladder Wall		1.4 E-3	6.3 E-4	2.0 E-5	1.2 E-3	1.1 E-2
Bone Surface		2.6 E-4	7.0 E-5	1.1 E-4	1.1 E-4	4.4 E-3
Brain		3.0 E-4	6.7 E-5	1.3 E-4	1.1 E-4	9.6 E-4
Breast		1.2 E-4	4.8 E-5	7.8 E-5	7.0 E-5	7.0 E-4
GI Tract	Esophagus	3.1 E-4	8.5 E-5	1.4 E-4	1.4 E-4	1.1 E-3
	St Wall	2.7 E-4	4.8 E-4	4.4 E-4	4.4 E-4	1.3 E-3
	SI Wall	8.5 E-5	6.7 E-5	8.5 E-5	8.5 E-5	2.0 E-3
	ULI Wall	1.2 E-4	6.7 E-5	1.1 E-4	9.6 E-5	7.0 E-3
	LLI Wall	1.9 E-4	6.3 E-5	1.4 E-4	1.0 E-4	1.7 E-2
	Colon	1.5 E-4	6.7 E-5	1.3 E-4	1.0 E-4	1.1 E-2
Kidneys		8.1 E-5	5.6 E-5	7.4 E-5	7.4 E-5	1.5 E-3
Liver		8.9 E-5	5.2 E-5	7.4 E-5	7.4 E-5	9.3 E-4
Muscle		2.6 E-4	7.4 E-5	1.2 E-4	1.1 E-4	1.1 E-3
Ovaries		8.9 E-5	5.9 E-5	8.5 E-5	8.5 E-5	2.2 E-3
Pancreas		1.0 E-4	8.5 E-5	8.9 E-5	1.0 E-6	1.0 E-3
Red Bone Marrow		2.0 E-4	6.7 E-5	1.1 E-4	1.0 E-4	1.5 E-3
Respirat. Tract	Ex. Thor. Air	1.8 E-2	1.0 E-2	1.5 E-4	1.5 E-2	6.3 E-2
	Lungs	3.0 E-4	1.6 E-4	2.0 E-4	1.9 E-4	1.0 E-3
Skin		1.4 E-4	4.8 E-5	8.1 E-5	7.4 E-5	7.4 E-4
Spleen		9.3 E-5	6.7 E-5	7.8 E-5	8.5 E-5	9.3 E-4
Testes		7.0 E-5	4.8 E-5	7.0 E-5	7.0 E-5	9.6 E-4
Thymus		3.1 E-4	8.5 E-5	1.4 E-6	1.4 E-4	1.1 E-3
Thyroid		7.8 E-1	7.0 E-3	1.5 E-1	3.0 E-2	1.2 E-1
Uterus		1.0 E-4	7.4 E-5	1.0 E-4	1.1 E-4	1.7 E-3
Effective (5 μm AMAD)		4.1 E-2	7.4 E-4	7.8 E-3	1.7 E-3	9.3 E-3
Effective (1 μm AMAD)		2.8 E-2	3.6 E-4	5.6 E-3	1.2 E-3	6.7 E-3

TABLE D-4. Inhalation DCs and Weighted Fractions of *E* for ^{239}Pu, ICRP Reports 103/130/141. [Table B-12 of Rademacher (2020)]

Organ/Tissue		Committed Equivalent Dose (rem μCi^{-1})				w_T	Weighted Fraction of Effective Dose (*E*)			
		Type S ($f_A = 5 \times 10^{-6}$)		PuO_2 of Pu/U Oxides ($f_A = 2 \times 10^{-6}$)			Type S ($f_A = 5 \times 10^{-6}$)		PuO_2 of Pu/U Oxides ($f_A = 2 \times 10^{-6}$)	
		1 μm	5 μm	1 μm	5 μm		1 μm	5 μm	1 μm	5 μm
Adrenals		1.92	0.96	0.322	0.167	0.0092	0.0002	0.0002	0.00002	0.00002
Bladder Wall		2.29	1.15	0.370	0.196	0.04	0.001	0.001	0.0001	0.0001
Bone Surface		229	118	40.7	20.4	0.01	0.023	0.020	0.003	0.002
Brain		2.22	1.15	0.370	0.192	0.01	0.0002	0.0002	0.00002	0.00002
Breast		2.22	1.15	0.370	0.192	0.12	0.003	0.002	0.0003	0.0003
GI Tract	Esophagus	1.85	0.93	0.315	0.163	0.04	0.001	0.001	0.0001	0.0001
	St Wall	1.85	0.93	0.311	0.159	0.12	0.002	0.002	0.0002	0.0002
	SI Wall	1.78	0.93	0.303	0.155	0.0092	0.0002	0.0001	0.00002	0.00002
	Colon	1.78	0.93	0.303	0.155	0.12	0.002	0.002	0.0002	0.0002
Heart		2.00	1.04	0.340	0.174	0.0092	0.0002	0.0002	0.0000	0.0000
Kidneys		5.55	2.81	0.925	0.481	0.0092	0.001	0.0004	0.0001	0.0001
Liver		281	144	48.1	24.4	0.04	0.11	0.098	0.013	0.011
Muscle		2.26	1.15	0.370	0.196	0.0092	0.0002	0.0002	0.00002	0.00002
Salivary Glands		2.22	1.15	0.370	0.192	0.01	0.0002	0.0002	0.00002	0.00002
Oral Mucosa		2.33	1.18	0.407	0.204	0.0092	0.0002	0.0002	0.00002	0.00002
Pancreas		1.92	0.96	0.322	0.167	0.0092	0.0002	0.0002	0.00002	0.00002
Red Bone Marrow		25.9	13.3	4.44	2.33	0.12	0.031	0.027	0.004	0.003
Respirat. Tract	Ex. Thor. Air	407	777	444	851	0.0092	0.037	0.12	0.027	0.092
	Lungs	555	292	925	481	0.12	0.65	0.60	0.73	0.68
Lymph Nodes		1330	740	3550	1960	0.0092	0.12	0.12	0.22	0.21
Skin		2.22	1.15	0.370	0.192	0.01	0.0002	0.0002	0.00002	0.00002
Spleen		1.59	0.81	0.270	0.137	0.0092	0.0001	0.0001	0.00002	0.00001
Testes		16.3	8.14	2.81	1.44	0.08	0.013	0.011	0.0015	0.0014
Thymus		2.22	1.15	0.370	0.192	0.0092	0.0002	0.0002	0.00002	0.00002
Thyroid		2.04	1.04	0.348	0.178	0.04	0.0008	0.0007	0.0001	0.0001
Gall Bladder		2.22	1.15	0.370	0.192	0.0092	0.0002	0.0002	0.00002	0.00002
Prostate		2.22	1.15	0.370	0.192	0.0092	0.0002	0.0002	0.00002	0.00002
Effective Dose (males)		102	58.9	151	85.4	-	-	-	-	-

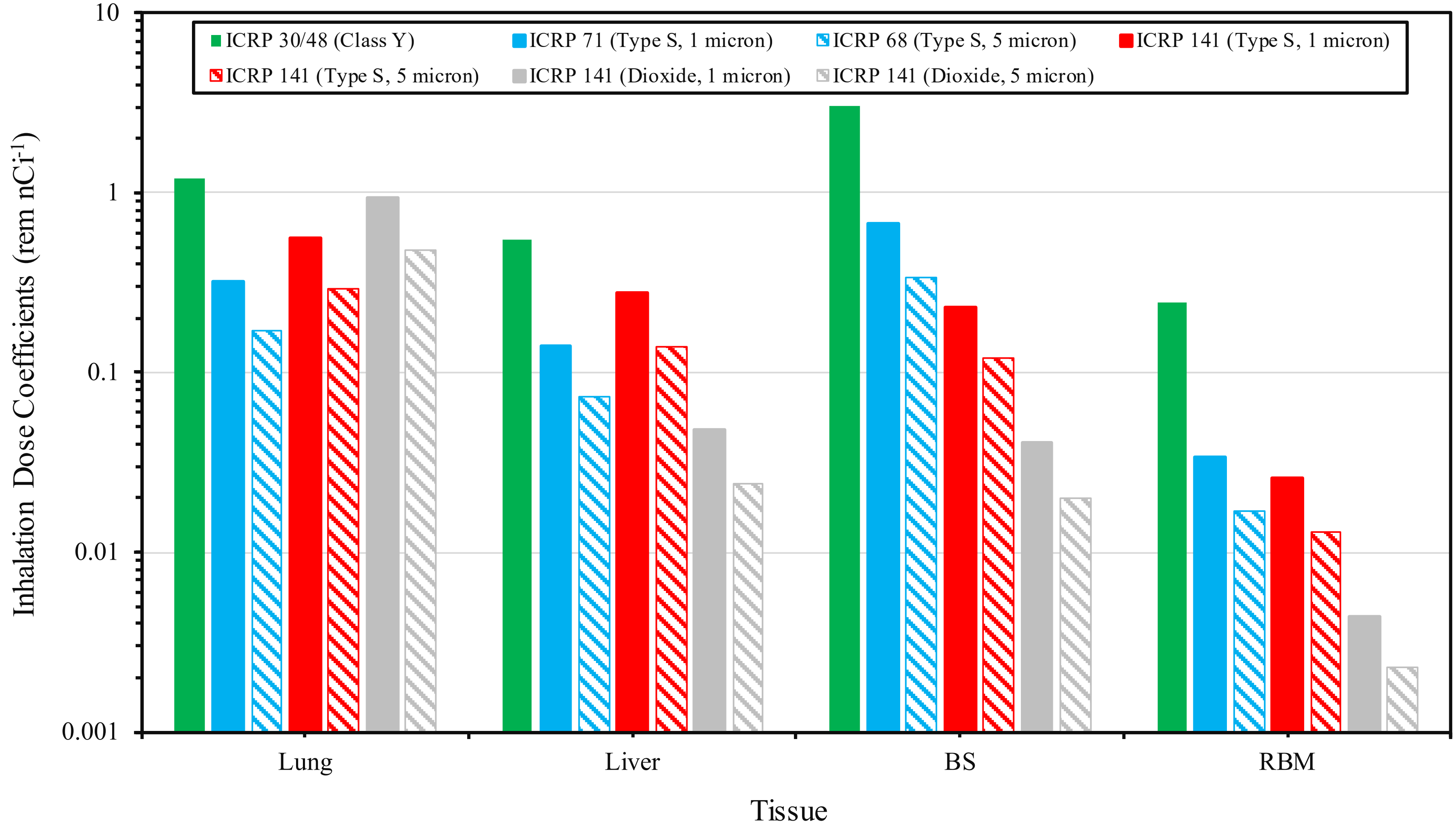

Figure D-2. Inhalation Dose Coefficients for ICRP Reports 30/48, ICRP 68/71, and ICRP 141 for Lung, Liver, Bone Surfaces (BS), and Red Bone Marrow (RBM) for ^{239}Pu.

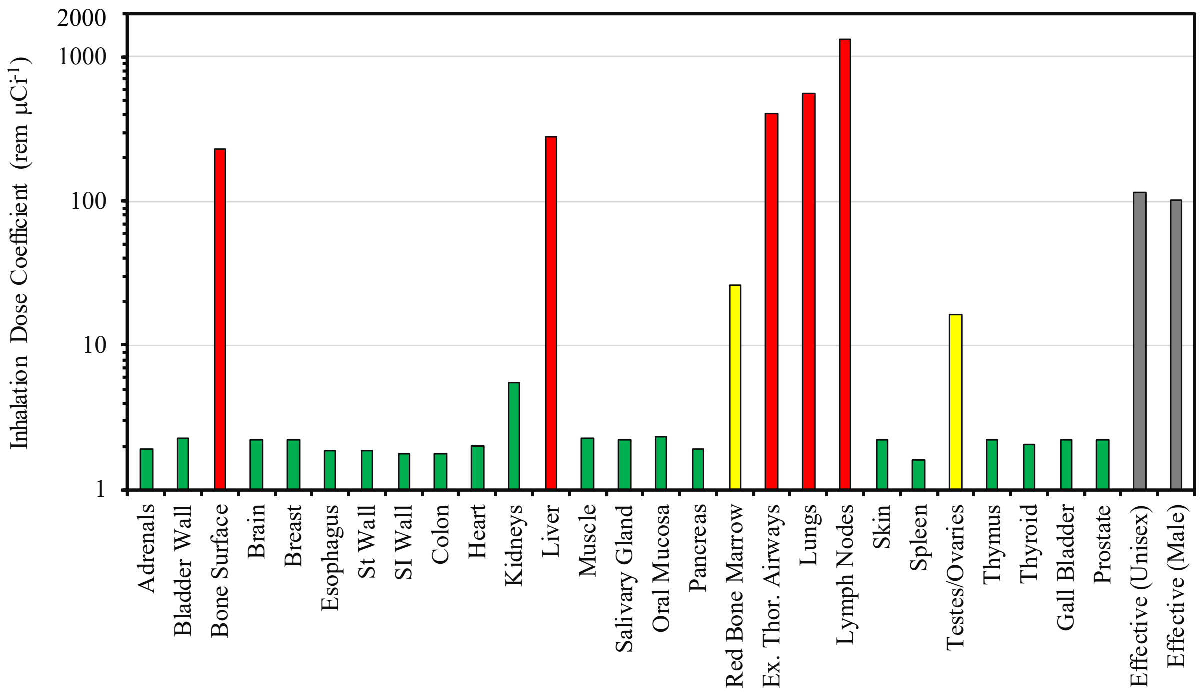

Figure D-3. Bar Graph of Inhalation Dose Coefficient Values, Inhalation Type S, Pu-239, 1 µm AMAD, Adults, ICRP Report 141.

TABLE D-5. Summary of Maximum Permissible Concentration in Air or Derived Air Concentrations for Insoluble Pu-239 over Five Sets of ICRP Recommendations for Workers*.

ICRP Publication(s)	MPC or DAC		Notes
	pCi/m³	fCi/m³	
2 (1959)	40	40,000	Lung limiting organ, insoluble forms
26/30 (1979)	5	5,000	Bone surface limiting tissue, Class Y, 1 µm AMAD
26/30/48 (1986)	7	7,000	Bone surface limiting tissue, Class Y, 1 µm AMAD
60/66/68 (1994)	60	60,000	Bone surface limiting, Type S, 5 µm AMAD
103/130/141 (2019)	30	30,000	Type S, 5 µm AMAD, males

* ICRP 30 used 1 µm AMAD as a default aerosol distribution for workers, while ICRP 66 and 130 used 5 µm AMAD

Appendix E

Off NTS Detection of Radiological Releases, Dose Impacts, and Plots

Table E-1. Nuclear Tests at the Nevada Test Range Complex Associated with the Release of Radioactivity Detected in the Atmosphere, 1961 – 1992, Table 3 from DOE/NV-296 (1995).

Year	Total Tests	No Release Detected	Accidental Releases		Other Releases		Secondary Release
			On-Site Detection Only	Detected Off-Site	On-Site Detection Only	Detected Off-Site	
1961	9	0	7	2	0	0	2
1962	62	6	19	5	27	5	17
1963	46	11	9	1	21	4	8
1964	46	10	15	4	15	2	9
1965	38	9	11	3	14	1	5
1966	47	16	10	5	16	0	5
1967	41	23	5	3	9	1	3
1968	55	30	12	1	9	3	1
1969	44	26	11	2	5	0	1
1970	39	20	9	2	7	1	3
Sub-Total	427	151	108	28	123	17	54
1971	23	19	1	1	2	0	1
1972	27	26	0	0	1	0	0
1973	23	18	0	0	5	0	0
1974	23	19	0	0	4	0	0
1975	22	21	0	0	1	0	0
1976	21	18	0	0	3	0	0
1977	20	15	0	0	5	0	0
1978	21	18	0	0	3	0	0
1979	16	14	0	0	2	0	0
1980	17	11	0	1	5	0	0
1981	17	12	0	0	5	0	0
1982	19	12	0	0	7	0	0
1983	19	11	0	0	8	0	0
1984	20	14	1	0	5	0	2

Table E-1. Nuclear Tests at the Nevada Test Range Complex Associated with the Release of Radioactivity Detected in the Atmosphere, 1962 – 1992, Table 3 from DOE/NV-296 (1995), continued.

Year	Total Tests	No Release Detected	Accidental Releases		Other Releases		Secondary Release
			On-Site Detection Only	Detected Off-Site	On-Site Detection Only	Detected Off-Site	
1985	18	11	0	0	6	1	0
1986	15	5	0	0	8	2	0
1987	15	9	0	0	6	0	0
1988	15	11	0	0	4	0	0
1989	12	8	0	0	4	0	0
1990	9	5	0	0	4	0	0
1991	8	8	0	0	0	0	0
1992	6	6	0	0	0	0	0
Sub-Total	386	291	2	2	88	3	3
Totals	813	442	110	30	211	20	57

Table E-2. Nuclear Tests at the NTS, 1951 – 1958, Adapted from Table 1 of DOE/NV-296 (1995).

Year	Number of Tests	Yield (kT)		
		Total	Mean	Range
1951	12	112	9	< 0.1 – 31
1952	8	104	13	1 – 31
1953	11	252	23	0.2 – 61
1955	18‡	167	10	0 – 43
1956	1*	0.001	0.001	0.001
1957	32§	344	11	0 – 74
1958	39†	46	1	0 - 22
Totals	170	1025	-	-
Mean	-	-	9	-

* Safety Experiment ‡3 Safety Experiments §8 Safety Experiments †18 Safety Experiments

TABLE E-3. Off NTS Radiological Releases, Monitoring and Detection at Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON).

Date	Name	Type*	Plume Direction	Activity Release (Ci)	GZ Area on NTS	Monitoring				Radiological Detection				
						IS	GL	TTR	TON	IS	GL	TTR	TON	Other
I Jul 59	Kiwi A (EP-XVI)	R	N	840†	25					negative	negative	negative	negative	
8-Jul-60	Kiwi A' (EP-XVII-116-B)	R	NNE	2,500†	25	Y	N	N	Y	negative	negative	negative	negative	
19-Oct-60	Kiwi A-3 (EP-216-B)	R	NNE	2,500†	25	Y	N	N	Y	negative	assumed positive	negative	negative	
15-Sep-61	Antler	U	N	2.1 x 10^{5}†	12	Y	N	N	Y	negative	negative	negative	negative	
6-Oct-61	Tory II-A Reactor	R	NNE	635†	25	Y	N	N	Y	negative	assumed positive	negative	negative	
7-Dec-61	Kiwi B-1A (EP-VI/A)	R	ENE	1,300†	25	Y	N	N	Y	positive air	negative	negative	negative	
22-Dec-61	Feather	U	SW	380†	12	Y	N	N	Y	negative	negative	negative	negative	
1-Mar-62	Pampas	U	N	2,000†	3	Y	N	N	Y	negative	assumed positive	negative	negative	
5-Mar-62	Danny Boy	C	NNW	8.5 x 10^{5}†	18	Y	N	N	Y	negative	negative	assumed positive	negative	
14-Apr-62	Platte	U	N	1.9 x 10^{6}†	12	Y	N	N	Y	negative	negative	negative	negative	
19-May-62	Eel	U	N	1.9 x 10^{6}†	9	Y	N	N	Y	negative	negative	negative	negative	
13-Jun-62	Des Moines	U	N	1.1 x 10^{7}†	12	Y	N	N	Y	negative	negative	negative	negative	
6-Jul-62	Sedan	C	NNE	1.5 x 10^{7}†	10	Y	Y	Y	Y	negative	positive air	negative	negative	
11-Jul-62	Johnie Boy	A	N	-	18	Y	Y	Y	Y	negative	negative	negative	negative	
14-Jul-62	Small Boy	A	ENE	-	5	Y	Y	Y	Y	negative	negative	negative	negative	
17-Jul-62	Little Feller I	A	NW	-	18	Y	Y	Y	Y	negative	negative	negative	negative	
1-Sep-62	Kiwi B-1B (EP-IV)	R	S	1,300†	25	Y	Y	Y	Y	negative	negative	negative	negative	
19-Oct-62	Bandicoot	U	S, N (low)	3.0 x 10^{6}†	3	Y	Y	Y	Y	ground air & γ	assumed positive	negative	negative	
30-Nov-62	Kiwi B-4A (EP-VI)	R	WSW	1,700†	25	Y	Y	Y	Y	negative	negative	negative	negative	Russian test
5-Jun-63	Yuba	U	SW	110†	12	Y	Y	Y	Y	negative	negative	negative	negative	
12-Dec-63	Eagle	U	SW	760†	9	Y	Y	Y	Y	positive air	negative	negative	negative	
23-Jan-64	Oconto	U	N	3,000†	9	Y	Y	Y	Y	No ground network detection, aerial monitoring detection only to N of NTS				
13-Mar-64	Pike	U	SE	1.2 x 10^{5}†	3	Y	Y	Y	Y	ground air & γ	negative	negative	negative	
12-May-64	Tory II-C Reactor	R	NNE	256†	25	Y	Y	Y	Y	negative	negative	negative	negative	
13-May-64	Kiwi B4D Reactor (Full)	R	N	4,600†	25	Y	Y	Y	Y	negative	negative	negative	negative	
20-May-64	Tory II-C Reactor	R	NNE	741†	25	Y	Y	Y	Y	negative	negative	negative	negative	
19-Aug-64	Alva	U	N	6,100†	2	Y	Y	Y	Y	No ground network detection, aerial monitoring detection only to N of NTS				
28-Aug-64	Kiwi B4E Reactor (EP-V)	R	NNE	21,000†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	

TABLE E-3. Off NTS Radiological Releases, Monitoring and Detection at Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Type*	Plume Direction	Activity Release (Ci)	GZ Area on NTS	Ground-Based Monitoring				Radiological Detections				
						IS	GL	TTR	TON	IS	GL	TTR	TON	Other
10-Sep-64	Kiwi B4E Reactor (EP-VI)	R	NE	7,600†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	
24-Sep-64	NRX-A2 (EP-IV)	R	SSW	1,100†	25	Y	Y	Y	Y	negative	negative	negative	negative	
15-Oct-64	NRX-A2 (EP-V)	R	NE	1,100†	25	Y	Y	Y	N	positive air	negative	negative	negative	
5-Dec-64	Drill (Source-Target)	U	SE	61,000†	2	Y	Y	Y	Y	negative	negative	negative	negative	
16-Dec-64	Parrot	U	N	2.3 x 10^{5}†	3	Y	Y	Y	Y	positive air	negative	negative	negative	
18-Dec-64	Sulky	U	N	1.3 x 10^{5}†	18	Y	Y	Y	Y	negative	negative	negative	negative	
12-Jan-65	Kiwi TNT Reactor	R	SW	15,000†	25	Y	Y	Y	Y	negative	negative	negative	negative	
12-Feb-65	Alpaca	U	S	40,000†	2	Y	Y	Y	Y	negative	negative	negative	negative	
14-Apr-65	Palanquin	C	N	1.1 x 10^{7}†	20	Y	Y	Y	Y	negative	negative	assumed positive	negative	
23-Apr-65	NRX-A3 (EP-4)	R	SSE	530†	25	Y	Y	Y	Y	negative	negative	negative	negative	
7-May-65	Tee	U	S	1,600†	2	Y	Y	Y	Y	negative	negative	negative	negative	
20-May-65	NRX-A3 (EP-5)	R	NE	2,400†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	Chinese test
28-May-65	NRX-A3 (EP-6)	R	WSW	1,200†	25	Y	Y	Y	Y	negative	negative	negative	negative	
16-Jun-65	Diluted Waters	U	NE	30,000†	5	Y	Y	Y	Y	negative	assumed positive	negative	negative	Chinese test
25-Jun-65	Phoebus 1-A Experiment	R	NNE	22,000†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	Chinese test
3-Feb-66	NRX-A4 (EP-IIB)	R	N	12†	25	Y	Y	Y	Y	negative	negative	negative	negative	
3-Mar-66	NRX-A4 (EP-III)	R	SSE	100†	25	Y	Y	Y	Y	negative	negative	negative	negative	
5-Mar-66	Red Hot	U	NE	1.0 x 10^{6}†	12	Y	Y	Y	Y	negative	negative	positive	positive	
16-Mar-66	NRX-A4 (EP-IV)	R	ESE	27,000†	25	Y	Y	Y	Y	negative	negative	negative	negative	
25-Mar-66	NRX-A4 (EP-IVA)	R	WSW	28,000†	25	Y	Y	Y	Y	negative	negative	negative	negative	
23-Apr-66	Fenton	U	W	17,000†	2	Y	Y	Y	Y	No ground network detection, aerial monitoring detection near Baker CA				
25-Apr-66	Pin Stripe	U	NE	2.1 x 10^{5}†	11	Y	Y	Y	Y	negative	negative	negative	negative	
8-Jun-66	NRX-A5 (EP-II and -III)	R	SW to S	1,200†	25	Y	Y	Y	Y	negative	negative	negative	negative	
15-Jun-66	Double Play	U	NE	8.0 x 10^{5}†	16	Y	Y	Y	Y	negative	assumed positive	negative	negative	
23-Jun-66	NRX-A5 (EP-IV)	R	NNE	80,000†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	
12-Sep-66	Derringer	U	NE	12,000†	5	Y	Y	Y	Y	negative	negative	negative	negative	
19-Jan-67	Nash	U	SW	69,000†	2	Y	Y	Y	Y	negative	negative	negative	negative	
10-Feb-67	Phoebus 1-B (EP-III)	R	SSE	34,000†	25	Y	Y	Y	Y	negative	negative	negative	negative	Chinese test

TABLE E-3. Off NTS Radiological Releases, Monitoring and Detection at Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Type*	Plume Direction	Activity Release (Ci)	GZ Area on NTS	Monitoring				Radiological Detections				
						IS	GL	TTR	TON	IS	GL	TTR	TON	Other
23-Feb-67	Phoebus 1-B (EP-IV)	R	NNE	2.4 x 10^{5}†	25	Y	Y	Y	Y	negative	negative	negative	negative	
26-Jun-67	Midi Mist	U	NE	1,300†	12	Y	Y	Y	Y	No ground network detection, aerial monitoring detection only to N of NTS				
29-Jun-67	Umber	U	SW	26,000†	3	Y	Y	Y	Y	negative	negative	negative	negative	
31-Aug-67	Door Mist	U	N	3.9 x 10^{5}†	12	Y	Y	Y	Y	negative	negative	assumed positive	negative	
15-Dec-67	NRX-A6 (EP-3A)	R	SE	53,000†	25	Y	Y	Y	Y	negative	negative	negative	negative	
18-Jan-68	Hupmobile	U	SW	1.2 x 10^{5}†	2	Y	Y	Y	Y	negative	negative	negative	negative	
26-Jan-68	Cabriolet	C	N	2.2 x 10^{5}†	2	Y	Y	Y	Y	negative	negative	negative	negative	
12-Mar-68	Buggy-A, -B, -C, -D, -E	C	N	1.2 x 10^{6}†	30	Y	Y	Y	Y	negative	negative	negative	negative	
8-Jun-68	Phoebus 2A EP III	R	SE	7,100†	25	Y	Y	Y	Y	positive	negative	negative	negative	
26-Jun-68	Phoebus 2A EP IV	R	NE	21,000†	25	Y	Y	Y	Y	positive	positive	negative	negative	
18-Jul-68	Phoebus 2A EP V	R	NNE	2,100†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	
4-Dec-68	Pewee 1 EP III	R	ESE	2.3 x 10^{5}†	25	Y	Y	Y	Y	positive	negative	negative	negative	
8-Dec-68	Schooner	C	NE	3.7 x 10^{6}†	20	Y	Y	Y	Y	positive	positive	positive	positive	
11-Jun-69	XE-Prime (EP-VC)	R	N	820†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	
28-Aug-69	XE-Prime (EP-IXA)	R	NNE	530†	25	Y	Y	Y	Y	negative	assumed positive	negative	negative	
29-Oct-69	Pod-A, -C, & -B, -D	U	S	3,900†	2	Y	Y	Y	Y	negative	negative	negative	negative	
13-Nov-69	Scuttle	U	S	210†	2	Y	Y	Y	Y	No ground network detection, aerial monitoring detection SW of Lathrop Wells				
21-Apr-70	Snubber	U	NE	55,000†	3	Y	Y	Y	Y	negative	assumed positive	negative	negative	
5-May-70	Mint Leaf	U	NE	3.9 x 10^{5}†	12	Y	Y	Y	Y	negative	negative	negative	negative	
18-Dec-70	Baneberry	U	NE	6.7 x 10^{6}†	8	Y	Y	Y	Y	negative	ground air & γ	ground air & γ	ground air & γ	
24-Nov-71	Diagonal Line	U	SW	6,800†	25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection only				Chinese test
24-May-72	Nuclear Furnace-1 (IA-1)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
25-May-72	Nuclear Furnace-1 (IA-2)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
1-Jun-72	Nuclear Furnace-1 (IB)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
28-Jun-72	Nuclear Furnace-1 (II)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
12-Jul-72	Nuclear Furnace-1 (III)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
21-Jul-72	Nuclear Furnace-1 (IV)	R			25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection of Rb-88, daughter of Kr-88				
27-Jul-72	Nuclear Furnace-1 (V)	R	NNE	10,190†	25	Y	Y	Y	Y	No ground network detection, aerial monitoring detection only				

TABLE E-3. Off NTS Radiological Releases, Monitoring and Detection at Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Type*	Plume Direction	Activity Release (Ci)	GZ Area on NTS	Monitoring				Radiological Detections				
						IS	GL	TTR	TON	IS	GL	TTR	TON	Other
25-Sep-80	Riola	U	SSW	960†	2	Y	Y	Y	Y	negative	negative	negative	negative	Chinese tests
6-Apr-85	Misty Rain	U	NNE	63†	12	Y	Y	Y	Y	negative	negative	negative	negative	
22-Mar-86	Glencoe	U	SW	0.074†	4	Y	Y	Y	Y	negative	negative	negative	negative	
10-Apr-86	Mighty Oak	U	NNW	3,300†	12	Y	Y	Y	Y	noble gas	noble gas	negative	noble gas	Chernobyl

* R = reactor U = underground C = cratering A = aboveground † Normalized to 12 h post release

TABLE E-4. Annual Atmospheric Radiological Releases from 1972 to 1993 at NTS, with EPA Report Reference.

Year	Activity by Radionuclide																					EPA Report
	H-3	Ar-37	Kr-83m	Kr-85	Kr-85m	Kr-87	Kr-88	Kr-89	I-131	I-132	I-133	I-135	Cs-137	Xe-131m	Xe-133	Xe-133m	Xe-135	Xe-135m	Xe-137	Xe-138	Total	
1972									1.9E-6		1.4E-6				62	1.0	0.04				63.1	LV 539-23
1973	1.3						0.73	0.03	0.03	0.05	0.12	0.02			287	9.1	17.8	1.4	0.34	3.7	322	LV 539-31
1974	< 2														663	11	31				705	LV 539-39
1975	2.2														19.6	0.3					22.1	LV 539-4
1976	3.1														87.7	0.23	0.01				91.1	LV 539-12
1977	6.9								2.6						28.3	0.62	0.85				39.2	LV 539-18
1978	90.5			15					0.0001						8.21	1.44	0.39				116	LV 539-31
1979	12.6																				12.6	LV 539-36
1980	450			87					1						1,262	1.7	2,229	476			4,506	4-81-047
1981	534								0.05						2,700	29	142				3,405	4-82-061
1982	165								0.0001						74	2.5	4.2				246	4-83-032
1983	98.2								0.00001			0.00003			26.6	1.5	28.9				155	4-84-040
1984	197	9.6	21		34	0.8			160						160	8.5	1297	156			2,044	4-85-035
1985	116	9		17					0.007		0.042	0.042			735	8.3	28.9				914	4-86-022
1986	121			4.3					2.4						36000	0.058	0.041				36,128	4-87-017
1987	126	1		5.0									0.000002	1	44.0	2	0.005				180	4-88-021
1988	68.2								0.000032		0.00011				18.1	0.44	8				94.7	4-89-019
1989	73	15.1		0.21									7.3E-6	0.33	63	1.1	3.9				157	4-90-016
1990	28	2.4		4.4					0.0013		0.0002			1.2	30	0.18	0.08				66.3	4-91-031
1991	0.68	0.45		0.0066					0.00013					0.007	0.85	0.004					2.0	4-93-141
1992	1	2.9		280					0.000019					0.015	0.39						284	4-94-209
1993	4			160																	164	R 96-007

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON).

Date	Name	Information on Release and Dose Information
I Jul 59	Kiwi A (EP-XVI)	- Minor effluent release to NNE (10°). No γ-radiation exposures in excess of background detected off-site. Low-level detection of radiological impact in air sample collected at Diablo Maintenance Station on Hwy 25. TON, IS, GL and TTR outside plume pattern.
8-Jul-60	Kiwi A' (EP-XVII-116-B)	- Minor effluent release to NNE (15°). No γ-radiation exposures in excess of background detected off-site. Low-level detection of radiological impact in air sample collected at Diablo Maintenance Station on Hwy 25. TON, IS, GL and TTR outside plume pattern.
19-Oct-60	Kiwi A-3 (EP-216-B)	- Minor effluent release to NNE (40°). No γ-radiation exposures in excess of background detected off-site. Low-level detection of radiological impacts in air samples collected at Alamo, Diablo, Lathrop Wells, and Warm Springs Ranch. TON, IS, and TTR outside plume pattern. GL within plume pattern, though negligible dose consequences due to low emissions and negligible levels found in positive air samples.
15-Sep-61	Antler	- Minor effluent release from GZ on Area 12 to N, as shown in Figure 5.3.1 of SWRHL-1r (1964). Plume centerline around Reed, where cloud was estimated at 5.5 mi wide. Peak exposure rate at Twin Springs Ranch was 12.5 mR/h, but dropped by factor of 10 in an hour, and to 0.04 mR/h in three hours. Diablo had a peak of 0.15 mR/h, but dropped by a factor of five within two hours. Warm Springs Peak exposure rate was 0.28 mR/h, but reached background a little over two hours later. TON, IS, TTR, and GL outside plume pattern. Low level fission products in air samples at Diablo and Warm Springs.
6-Oct-61	Tory II-A Reactor	- Minor effluent release to NNE (30°). No γ-radiation exposures in excess of background detected off-site. Low-level detection of radiological vapors (e.g., radioiodines) in air samples at Alamo and Diablo. TON, IS, and TTR outside plume pattern. GL within plume pattern, though negligible dose consequences due to low emissions and negligible levels found in positive air samples.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
7-Dec-61	Kiwi B-1A (EP-VI/A)	- Minor effluent release to ENE (55°). No γ-radiation exposures in excess of background detected. Slightly elevated γ-radiation levels detected in air samples at Indian Springs and other air samples to S of NTS and Beatty. TON, GL, and TTR outside plume pattern. Negligible dose consequences at Indian Springs.
22-Dec-61	Feather	- Plume travelled from GZ on Area 12 on NTS to SSW toward Death Valley Junction. The peak γ-exposure rate recorded at Lathrop Wells was 0.02 mR/h, while a peak exposure rate at Bettle's Farm (48 mi from GZ and 4 mi SW of Lathrop Wells), a maximum exposure rate was 0.06 mR/h,but dropped to 0.02 mR/h 24 min later. Peak exposure rate at Death Valley Junction 0.08 mR/h. TON, IS, TTR, and GL outside plume pattern. Positive air samples at five sampling locations: Ash Meadows, Bettle's Farm, Death Valley Jct., Lathrop Wells, and Shoshone. All but Death Valley Jct. and Bettle's Farm air concentrations negligible. Estimated effective dose from inhalation 37 μrem from air samples at Bettles' Farm.
1-Mar-62	Pampas	- Plume travelled from GZ on Area 3 to NNE, as shown by Figure E-19. Peak exposure from plume on Hwy 25 near Gunderson's Ranch (between Queen City and Coyote Summits). Peak γ-exposure at the Ranch was 0.22 mR/h, but returned to background within 30 min, illustrating the dominance of gaseous radioactive material in plume vice aerosol deposition on ground. Integrated external exposure estimated to be less than 1 mrem. TON, IS, and TTR outside the plume pattern. GL on eastern edge of plume. External exposures expected to be less than those at Gunderson's Ranch. Positive air samples at Diablo, Gunderson's Ranch, and Hiko, dominated by radioiodines. Estimated effective dose from inhalation 19 μrem from air samples at Gunderson Ranch.
5-Mar-62	Danny Boy	- Plume travelled from GZ on Area 18 to NNE, as shown by Figure E-17 and E-18. Plume center crossed Hwy 6, 18 Mi W of Warm Springs; peak γ-exposure at this location was 3.2 mR/h (unpopulated), with a peak exposure rate at Warm Springs of 0.47 mR/h. TON, IS, and GL outside the plume pattern. Road to TTR entrance off Hwy 6 negative, based on Fig. 5.3.4. TTR operations area on western fringe of plume. Radiological impacts expected to be less than those at Clarks Station on Hwy 6, which had a peak exposure rate of 0.17 mR/h. Total exposure at Clarks Station estimated < 3 mR. Film badges not expected to exceed 30 mR threshold of sensitivity. Positive air sampling results for air sample at Warm Springs, dominated by radioiodines. Estimated effective dose from inhalation 16 μrem.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
14-Apr-62	Platte	- Plume travelled from GZ on Area 12 to NNE, as shown by Figure E-16. The plume centerline crossed Hwy 25 near Queen City Summit. The highest dose rate observed, 47 mR/h, at Queen City Summit. The highest airborne concentrations in off-site air samplers was at Queen City Summit, with dominance of radioiodines. TON, IS, TTR, and GL outside plume pattern.
19-May-62	Eel	- Plume travelled from GZ on Area 9 to N, as shown by Figure E-15. The plume crossed Hwy 25 between Queen City Summit and Diablo. The maximum net γ-radiation dose at Queen City Summit was 10 mR/h. TON, IS, TTR, well outside plume pattern, with GL to east of plume edge. Very low-levels of airborne fission product detections on air samples.
13-Jun-62	Des Moines	- Plume travelled from GZ on Area 12 to NNE, as shown by Figure E-13 and Figure E-14. The highest external γ-radiation levels were 100 mR/h on Hwy 6, 13 mi SW of Current and 160 mR/h at Queen City Summit, on Hwy 25. The exposure rate at Queen City Summit remained between 80 and 160 mR for 20 min, then dropped below 10 mR/h. Numerous air samples had positive detections for fission products, primarily radioiodines. TON, IS, TTR, and GL outside plume pattern.
6-Jul-62	Sedan	- Thermonuclear device with fission yield < 30%. Plume travelled to NNE, as illustrated in Figure E-10 and Figure E-11. Indian Springs, TTR, and Tonopah outside plume pattern. GL outside initial ground deposition. Evening resuspension of Sedan Crater dust caused minor γ-radiation monitoring response at Groom Lake, based on Figure E-12. Highest estimated off-site infinity outdoor exposures (mR) 945 (Diablo) and 225 (Penoyer Ranch); exposures less, due to evacuation of residents. Highest among off-site infinity outdoor exposures (not evacuated): Nayla (178 mR), Blue Eagle Ranch (173 mR), Pine Creek Ranch (163 mR), and Twin Springs (122 mR). Groom Lake infinity outdoor exposures expected to be less than 10 mR, based on Figure 12. The highest off-site film badge result for a member of the public was 275 mR (PNE-200 1963). SWRHL-3r lists TTR film badge exposure 35 mR for one individual over period: 5 Jul – 10 Aug, but corrected for background, only 16 mR. Film badge reading could be from the contribution of Sedan, Johnie Boy, Little Feller I, Little Feller II, and/or some alternate exposure location during a portion of the period of monitoring, or heat damage. Air sampling at Tonopah, TTR, and Indian Springs unremarkable for fission product impacts from Sedan. Air sampling at GL over 6 – 11 Jul provided negligible effective dose from inhalation, only 0.46 mrem from I-131,133, 135, Te-132, and Ba-140.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
11-Jul-62	Johnie Boy	- Debris cloud moved in a N direction; cloud split, with the western portion (lower altitude) travelled between Tonopah and Warm Springs, then in a NE direction; the upper elevation portion of the debris cloud travelled in a NE direction, but provided much lower radiological impacts on the ground than the lower elevation portion. Figure E-6, shows the initial ground deposition pattern. TTR outside western edge plume, Figure E-7 (PHS 1962) and negative from ground γ-radiation monitoring. TON, GL, and IS not in plume pattern.
14-Jul-62	Small Boy	- Low-yield detonation of slightly-buried (10 ft) device, plume travelled E then NE from its GZ in Area 5 (later found to be 300 ft E of NTS eastern boundary). Ground deposition pattern shown by Figure E-5. Ground air and γ-radiation exceedance detected from off-site network, but TON, IS, TTR, and GL outside plume pattern. Highest exposure rate at off-site populated location: 2.5 mR/h, Alko, 4 mi N. of Alamo, on Hwy 93.
17-Jul-62	Little Feller I	- Low-yield detonation of slightly-buried (3 ft) device, plume travelled in a NNE direction from GZ in Area 18, as shown by Figure 337 of DNA-1251-1-EX. Peak dose rates observed at Twin Springs Ranch of 0.7 mR/h, with peak of Lockes (near Blue Jay of only 0.1 mR/h. Positive detections in air samples collected at Twin Springs, Warm Springs Ranch, Currant, Lockes, and Diablo, based on gross β-radiation, but only a few positive fission product identifications. TON, IS, TTR, and GL outside plume pattern, see Figure E-8.
1-Sep-62	Kiwi B-1B (EP-IV)	- Minor effluent release to S of GZ, positive γ-radiation readings at Lathrop Wells and Ash Meadows. Maximum γ-exposure rate 0.28 mR/h 2.25 mi E of Lathrop Wells. TON, IS, TTR, and GL outside plume pattern.
19-Oct-62	Bandicoot	- Surface winds carried effluents NNE of GZ on Area 3 to Area 9 (stagnant), then NNW to the Area 12 compound. Upper debris cloud travelled S, over Mercury, Cactus Springs, Indian Springs, and Lathrop Wells. Cloud became diffuse near Hwy 95, then travelled SW, passing over LA, CA. The maximum off-site γ-radiation exposure rate was 20 mR/h, 7 mi W of Mercury turnoff from Hwy 95. Maximum γ-radiation at Indian Springs 0.45 mR/h on 19 Oct, reading was at background levels at 11:58 AM on 20 Oct; integrated γ-radiation < 10 mR. Film badges in off-site locations with positive results during Storax (underground test series) attributed to 1962 Plowshare and/or Dominic II tests). Estimated integrated effective dose from inhalation of I-131, I-133, I-135, Te-132, & Ba-140 at Indian Springs 0.156 mrem (ICRP 68). TON and TTR outside plume pattern. GL likely impacted to minor degree. Figure E-4 γ-radiation contour.
30-Nov-62	Kiwi B-4A (EP-VI)	- Minor effluent release to WSW, with γ-radiation excesses only at Goldspar Mine. Low-level activity in three air samples at Goldspar Mine, Furnace Creek, and Beatty. TON, IS, TTR, and GL outside plume pattern.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
5-Jun-63	Yuba	- No off-site detection of radiological release day of test. On 7 June, test release caused small amount of I-131 being detected in an air sample collected at Lathrop Wells, SW of GZ. GL, TTR, TON, and IS not in plume release area.
12-Dec-63	Eagle	- Plume travelled in a SSE direction from GZ on Area 9 of NTS. No detections by ground γ-radiation surveillance or film badges. However, very low-levels of radioiodines detected on air samples at only four monitoring stations SSE to SSW of NTS, to include Indian Springs (I-131 only). Estimated integrated effective dose from inhalation of I-133 at Indian Springs 0.4 μrem (ICRP 68).
23-Jan-64	Oconto	- Releases dominated by radioxenons, off-site detections in aerial monitoring platforms only to NW. No ground network detections.
13-Mar-64	Pike	- Release dominated by radioiodines, with plume travelling in a SE direction from MTS, Area 3 GZ. Cactus Springs key location initially impacted, and near Indian Springs. Maximum external exposure rate < 10 mR/h, with maximum cumulative exposure 55 mR, near Cactus Springs. Numerous positive detections of airborne radioiodines to SE of NTS. However, radioiodines were the primary radioactive element in samples. Estimated integrated effective dose from inhalation of radioiodines 0.59 (Cactus Springs) and 0.26 (Indian Springs) mrem (ICRP 68). High-sided estimates of the aerosol fraction based on relationships noted for the first sample collected at Cactus Springs (Table 1, SWRHL Report 20r). GL, TON, TTR not in plume pattern.
12-May-64	Tory II-C Reactor (Intermed)	- Plume travelled NNE of NTS. Low off-site γ-radiation detections at the junction of Valley Road and Hwy 25 (4 mi W. of Coyote Summit), peak exposure rate of 0.02 mR/h net above background, with an exceedance from background lasting only 45 min, thus net exposure is less than 0.015 mR. Other sampling was negative. TTR, TON, IS, and GL not in plume pattern.
13-May-64	Kiwi B4D Reactor (Full)	- Flume traveled to N of NTS, with off-site detection at Diablo, where peak exposure rate was 0.43 mR/h, and detection at Lund, peak exposure rate 0.028 mR/h. Detection of low-levels I-133 in three air samples: Currant, Diablo, and Queen City Summit. TTR, TON, IS, and GL not in plume pattern. Film badges negative.
20-May-64	Tory II-C Reactor (Full Power)	- Low off-site γ-radiation detection at only two off-site locations, peak 0.05 mR/h to NNE of NTS at Goss' Ranch, with background excesses lasting only 22 min same at Queen City Summit - peak < 0.05 mR/h and exceeses from background of only 20 minutes. Low-levels of I-133 detected in three air samples, maximum at Goss' Ranch; estimated cumulative effective dose of 0.1 μrem from inhalation of I-133 vapor. TTR, TON, IS, and GL not in plume pattern.
19-Aug-64	Alva	- Releases dominated by radioxenons, off-site detections in aerial monitoring platforms only to NW. No ground network detections.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
28-Aug-64	Kiwi B4E Reactor (EP-V)	- Low off-site γ-radiation detections to NNE; Coyote Summit and Goss' Ranch max 0.17 and 0.18 mR/h (just WNW of Coyote Summit); excess exposure rate only lasted an hour, maximum integrated exposure < 0.17 and 0.8 mR for each location, respectively. Film badges negative. Low levels of radioiodines in Goss' Ranch air sample; estimated cumulative effective dose of 6 μrem from inhalation of radioiodines. TTR, TON, and IS not in plume pattern; GL edge of plume, but expected to have negligible impacts; a little higher than air concentrations as Goss' Ranch and external exposure, due to closer proximity to GZ.
10-Sep-64	Kiwi B4E Reactor (EP-VI)	- Minor radiological contamination in three off-site air samplers and elevated γ-radiation detection in airborne monitoring platforms only; no increased ground level γ-radiation detections. Plume travelled in NNE direction. Positive air samples at Goss' Ranch, Hiko, and Caliente. Highest in air sampler at Goss' Ranch (just WNW of Coyote Summit) and Hiko; estimated cumulative effective dose of 0.7 μrem from inhalation of radioiodines at both locations (ICRP 68). TTR, TON, and IS not in plume pattern; GL in plume pattern, but expected to have negligible impacts; a little higher magnitude than air concentrations as Goss' Ranch and Hiko, due to closer proximity to GZ.
24-Sep-64	NRX-A2 (EP-IV)	- Plume travelled in SW direction, with elevated γ-radiation exposures in the vicinity of Lathrop Wells, net peak rate 0.43 mR/h. Minor radioiodones in air samples SW of reactor, with highest in air sampler at Lathrop Wells; estimated cumulative effective dose of 8 μrem from inhalation of radioiodines (ICRP 68).
15-Oct-64	NRX-A2 (EP-V)	- Plume travelled to NE, with low-levels of γ-radiation detection by airborne monitoring. No off-site ground stations established to NE, but no on-NTS detectors showed elevated response. Low-level I-131 in Indian Springs air sample (believed to be due to nighttime drainage winds to the south). Due to motor failure during sampling period, precise quantity could not be established. Conservative assumptions for a two-hour sampling period provided estimated effective dose from inhalation of I-131 at 80 nrem (ICRP 68).
5-Dec-64	Drill	- Small release of radioactivity travelled to S. Peak exposure rate, 0.2 mR/h detected 5 mi E. of Lathrop Wells, 0.01 mR/h detected 17 mi South of Lathrop Wells. TON, IS, TTR, and GL not in plume pattern.
16-Dec-64	Parrot	- Small release of radioactivity was carried to the N, though nighttime drainage winds carried some radioactivity to S of NTS. Peak exposure rate from initial plume northerly transport was 0.14 mR/h at 6.3 mi NW of Coyote Springs, along Hwy 25 in an unpopulated area. Airborne monitoring had positive detections of radioiodines in two samples, but at very low levels. TTR, TON, and GL not in plume pattern. A positive charcoal canister at Indian Springs had an estimate cumulative effective dose of 1.2 μrem from I-133 (ICRP 68).

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
18-Dec-64	Sulky	- Only off-site detection of plume carried to NNE from GZ was at Nyala, which had a maximum exposure rate of 0.06 mR/h, with integrated exposure less than 0.1 mR. IS, RRT, GL, and TON outside plume path.
12-Jan-65	Kiwi TNT Reactor	- Low off-site γ-radiation detections to SW of NTS, highest reading 70 mR/h, 1.5 mi W of Lathrop Springs, but no film badge reading exceeded 20 mR. Highest integrated inhalation effective dose, 0.23 mrem, estimated (ICRP 68) for air sample collected at station 1.5 mi W of Lathrop Springs.
12-Feb-65	Alpaca	- Effluent release to SW of NTS. Maximum exposure rate of 0.01 mR/h net measured in vicinity of the junction of the Mercury turn-off and Hwy 95. Monitoring was negative at populated locations SW of NTS, e.g., Ash Meadows, Pahrump, Lathrop Wells, and Shoshone. No positive detections from off-site air sampling network.
14-Apr-65	Palanquin	- Effluent release contained multiple fission products, dominated by radioiodines, travelled in N direction toward Stone Cabin Ranch (4 mi NNW of Clark Station on US 6); maximum off-site exposure rate observed at Stone Cabin Ranch (64 mi from GZ, with a film badge exposure of 45 mR, and maximum exposure rate of 3 mR/h; ground-level exposure rate contours from Figure E-21 and checkpoints in E-20. TTR airport on fringe western of fallout pattern, integrated exposure expected to be less than film badge exposure at Stone Cabin Ranch. Maximum off-site resident thyroid estimated integrated exposure of 162 mR, based on in-situ thyroid measurements. The highest estimated effective dose from inhalation of radioiodines at off-site areas was at Warm Springs, 2.4 mrem (ICRP 68).
23-Apr-65	NRX-A3 (EP-4)	- Reactor active for four minutes, effluents released to SSE, (160°), cloud passage over Pahrump, maximum exposure rate < 0.03 mR/h, integrated exposure less than 0.03 mrem. Film badge recovery and analysis not performed
7-May-65	Tee	- Effluent release from line-of-sight pipe and from surface GZ, extensive list of fission products, but dominated by noble gases and radioiodines. Plume travelled to S, 15 mi stretch of Hwy 95 monitored, with highest exposure rate 0.05 mR four mi E of Mercury. Plume trajectory no in direction of IS, TON, TTR, and IS. - Air sample charcoal canisters analyzed with negative results, maximum pre-filter β-particle activity concentration was only 28 pCi/m^3 for sampler at 4 mi E of Mercury.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
20-May-65	NRX-A3 (EP-5)	- Reactor active for 14 minutes, airborne effluent travelled to NE, 40 – 60°, ground-level portable γ-radiation monitors positive, but maximum integrated exposures were less than 0.03 mrem, peak exposure rate at Coyote Summit, 0.06 mR/h, though fixed recorder network readings were negative. IS, TON, TTR not within plume trajectory, GL SE edge of plume. GL ~ 60% of distance from GZ, compared to Coyote Summit, integrated dose as GL possibly higher than Coyote Summit, but likely < 0.1 mrem. - Air samples positive at Diablo, Goss Ranch, Coyote Summit (highest), Hancock Summit, Hiko, and Alamo; detection of radioiodine aerosol and vapors; effective dose from inhalation at Coyote Summit 10 μrem. Effective dose from inhalation at GL possibly higher than Coyote Summit, but likely < 30 μrem.
28-May-65	NRX-A3 (EP-6)	- Reactor active for ~ 30 minutes, airborne effluent travelled to WSW; negative detections from ground-level γ-radiation monitoring; IS, TON, TTR, GL outside plume. - Only one off-site air sampler detected radioactivity, the Lathrop Wells charcoal canister stage (e.g., iodine vapors) has identified I-131 and -133, effective dose from inhalation 0.5 μrem.
16-Jun-65	Diluted Waters	- Venting occurred up to H+20 minutes due a stemming failure, release contained Mo-99, Ru-103, -105, radioiodines, Te-132, Xe-135, Cs-137 Ba/La-140, Ba-139, Ce-141; light wind caused plume to remain on NTS for over and hour, slow airborne transport to NE. Outlying off-site detection systems negative, pushed monitoring to NTS NE boundary; ground-level γ-radiation monitors reading only net of 0.02 mR/h. - Alamo, Hiko, and Ely air monitors negative, Nayala slightly elevated gross β-radiation levels (~ 3X background), but negligible; TTR, TON, and IS outside plume pattern, GL near plume pattern, but expected impacts deemed negligible.
25-Jun-65	Phoebus 1-A Experiment	- Effluent released initially in N direction, with off-site monitoring indicating a contamination sector from 10 – 50°. Hotline N of NTS at Queen City Summit (unpopulated, 65 mi from GZ at 15°), with maximum γ-exposure rate 0.065 mR/h, Diablo 0.05 mR/h maximum; negative film badge results. - Positive air samples from four locations: Queen City Summit, Diablo, Alamo, and Hiko, radionuclides: I-131, -132, -133, -135, negative at all other sampling sites; maximum at Queen City Summit, effective dose from inhalation 10 μrem. - TTR, TON, IS not in plume direction; GL within plume sector of 10 – 50°, GL ~ ½ distance to GZ as Hiko, inhalation dose potentially higher than Queen City Summit, but nevertheless negligible.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
3-Feb-66	NRX-A4 (EP-IIB)	-Effluent released in N direction, but due to wind shear, samples over azimuths of 270 to 45° had detections in vegetation, air, and milk; no ground-based γ-radiation detections, TLDs and film badges negative. - Positive detections on air samples of I-133 at Twin Spring Ranch, Diablo, and Hiko; GL within azimuthal ranges of these air sampling sites; TON, IS, TTR not along trajectories of GZ to Twin Spring Ranch, Diablo, and Hiko; effective dose from inhalation at Hiko 14 nrem.
3-Mar-66	NRX-A4 (EP-III)	- Effluent released in SSE direction, no increase in ground-based γ-detectors, negative excesses in TLDs and film badges. GL, TON, TTR, and IS outside plume. - Two air samplers with positive detections: Ash Meadows Junction on Hwy 95 and Pahrump, positive only for I-133, but at negligible levels
5-Mar-66	Red Hot	- Effluent release due to seepage from the tunnel portal, contained kryptons, xenons, and radioiodines; plume travelled in NNE direction, but the plume became very diffuse, affording some detection in air samples S of NTS; no off-site γ-radiation monitors had positive detection, TLDs and film badges negative. - Thirteen air sampling sites had positive detections, contained radioiodines, IS negative, GL outside plume pattern; highest air samples results at Lathrop Wells, effective dose from inhalation 1.9 mrem (dominated by radioiodine vapor from I-131), effective dose from inhalation at TON 0.31 mrem (dominated by I-131+133 vapors); TTR air sample results not reported by SWRHL, but expected to be similar to those at TON.
16-Mar-66	NRX-A4 (EP-IV)	- Effluent released in ENE direction, Hwy 93 monitored between Alamo and Glendale, 0.03 mR/h in excess of background detected 36 mi NE of Glendale, no TLD and film badge in excess of background, IS, GL, TON, TTR outside plume. - Positive air samples in Nevada at Alamo, Butler Ranch turn-off, Warm Springs Ranch, Glendale, and Caliente, only radioiodine detected at negligible levels.
25-Mar-66	NRX-A4 (EP-IVA)	- Effluent released to WSW direction from GZ, monitor 14 mi SE of Beatty (unpopulated) had integrated exposure of 2.7 mR from cloud passage, infinity dose estimated at 17 mR, estimated infinity exposure at Beatty 0.05 mR, other ground monitors had insignificant exposures; film and TLDs less than MDC of 30 and 10 mR, respectfully. GL, TON, TTR, and IS outside plume. - Radioiodine effluents detected in air samples, highest at Lone Pine CA, effective dose from inhalation 80 μrem.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
23-Apr-66	Fenton	- Effluent releases of radioiodines and radioxenons from access shaft at H+1.5 minute for three minutes drillback release next day, no off-site ground monitoring network detection of release, only aerial platform detection to SW. GL, IS, TO, and TTR not along plume direction.
25-Apr-66	Pin Stripe	- Effluent releases from fissure near surface GZ, travelled in NE direction, contained kryptons, xenons, and radioiodines, highest ground γ-radiation monitoring station exposure rate 8 mR/h (18 mi NE Groom Lake, unpolulated), 1.5 mR/h at Hiko; TLDs all negative, one film badge positive, but deemed a questionable result. Winds changed direction to SW at ~ two days after detonation, but diminished airborne radioactivity carried by latter releases. TON, TTR, and IS outside plume direction, GL NE of initial plume release. - Highest air sample 18 mi NE of GL, effective dose from inhalation 0.48 mrem.
8-Jun-66	NRX-A5 (EP-III)	- Effluent plume travelled in W direction for 25 mi, then more S, as illustrated by Figure E-22, γ-radiation ground monitors negative, as well as film and TLD badges; TON, TTR, GL, IS outside plume. - Positive air samples had presence of I-131, -133, but at negligible concentrations.
15-Jun-66	Double Play	- Seepage from cable holes and portal, and controlled ventilations, released noble gases and radioiodines in NE direction from GZ. No off-site ground γ-radiation network detections, negative TLD and film badges. TON, TTR, and IS outside plume pattern, but GL on NW edge of plume trajectory. - Positive detection in air samples at Hiko and Alamo for I-131, -133, -135 (vapor-partition only), effective dose from inhalation 0.9 μrem - GL expected to have radiological impacts possibly greater than Hiko and Alamo due to distance between GZ and GL being ~ 40% of distance between Hiko and GZ, but nevertheless negligible.
23-Jun-66	NRX-A5 (EP-IV)	- Effluent plume travelled in a NNE direction, as illustrated by Figure E-22, γ-radiation exposures along Hwy 25 between the Queen City and Coyote Summits detected elevated response with portable instruments, with highest response was 1.2 mR/h at Goss Ranch (NW of Coyote Summit, 60 mi from GZ, 25°), Goss' Ranch integrated exposure estimated at 1 mR; negative film and TLD badge responses; TON, TTR, and IS outside plume, GL to SE of plume boundary. - Positive air samples had presence of I-131, -132, -133, -135, effective dose from inhalation at Goss' Ranch 0.12 mrem.
12-Sep-66	Derringer	- Effluent plume travelled to NE with a slightly above background reading at Hancock Summit (unpopulated) and 10 mi SE on Coyote Summit, both on Hwy 25. TON, TTR, and IS not near plume trajectory. GL to NW of plume trajectory. - None of the off-site air samplers had positive detections.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
19-Jan-67	Nash	- Effluent release started H+9.25 h and ended 41 h later travelled to SW, release contained Kr-87, -88, I-131, -133, -135, and Xe-133, -135. Due to duration of release, latter winds were to NE, undetectable in N an E quadrants. External γ-radiation measured on Hwy 95 20 mi W of Mercury to 14 mi NW of Lathrop Wells, with highest at 0.14 mR/h. TLDs all negative. - Radioiodines identified in off-site air samples to SW, but attributed to Chinese nuclear test, as air samples collected prior to the Nash test, in some cases, had higher I-131. Air sample collected at Indian Springs had I-131 attributed to Chinese test, but effective dose consequence from inhalation only 2 μrem. Key to discrimination from impacts from Nash were lack of I-133, -135, and Te-132.
10-Feb-67	Phoebus 1B (EP-III)	- Effluent released to SSE, measurement of radioactivity at ground level near junction of Hwy 95 and State Road 16. Exceedance was only slightly above background, but lasted only 30 minutes. - Only negligible levels of radioactivity on portable air sampler at junction of Hwy 95 and State Road 16. GL, TTR, TON, and IS outside plume trajectory.
23-Feb-67	Phoebus 1B (EP-IV)	- Effluent release carried to NNE, then later drainage to S, winds were of moderate speed with very little sheer. Centerline near Twin Springs on Hwy 25. TTR, TON, and GL not along NNE plume heading, as detailed by Figures E-23 and E-24. Queen City Summit recorded a peak exposure ~ 2-3-fold higher than background on scintillator. γ-recorders had exposure rate readings twice background at Diablo and Twin Springs, and Lathrop Wells (S of reactor). TLDs were negative. - Airborne radioactive detected in excess of background at numerous sites, excluding IS, TTR, TON, and GL. Diablo and Lathrop Wells highest, with radionuclides detected: I-131, -133, -135, Te-132, and Ce-141. Effective dose from inhalation at Lathrop Wells 0.14 mrem.
26-Jun-67	Midi Mist	- Effluent release carried to N, with no ground network monitoring network detections, only detected by aerial sampling platform. - Radionuclides identified: Kr-85, -88, Rb-88, I-131, -133, -135, Xe-133, -135.
29-Jun-67	Umber	- Effluent release carried in a SW direction toward Lathrop Wells, maximum exposure rate 0.7 mR/h along Hwy 95 (Rt 16 junction). - Air samples identified radioiodines and radioxenons, with maximum in air sampler at Lathrop Wells. IS, GL, TON, TTR outside effluent cloud path.
31-Aug-67	Door Mist	- Effluent release shortly after detonation, drifted in a NNW direction. Slight increase in γ-exposure at Clark Station and Diablo ground monitoring stations: 0.01 mR/h. Due to low exposures TLDs remained in place – no assessment. - Negligible air sampling results for gross β-particle radiation, slight detections for I-133+-135 at Diablo station; TON air sampler negative. - TTR along fallout trajectory, impacts negligible, based on nearby off-site results.

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON).

Date	Name	Information on Release and Dose Information
15-Dec-67	NRX-A6 (EP-3A)	- Airborne debris cloud was carried to SW; highest off-site ground γ-radiation exposure rate was 0.8 mR/h along Hwy 95, 8.1 mi W of Lathrop Wells, with integrated exposure estimated at 2.0 mR. Ranch by Lathrop Wells had integrated exposure estimate of 1.3 mR. TLD dosimeter network had negative net exposures. - Highest air sample at Death Valley Junction (I-131), effective dose from inhalation 3.3 μrem. IS, GL, TTR, and TON outside debris cloud path.
18-Jan-68	Hupmobile	- Debris cloud was carried to the southwest over the Amargosa Farm Area and Death Valley. Maximum γ-exposure rate on ground monitors was 0.7 mR/h, four miles W of Lathrop Wells. Maximum γ-exposure rate at Death Valley Junction was 0.1 mR/h. No net response on dosimeters. - Detection among eight air sampling stations (I-131, -133, -135, and Ce-141); maximum at Dansby's Ranch, effective dose from inhalation 0.04 mrem; negative airborne for impacts at IS, GL, TON, and TTR.
26-Jan-68	Cabriolet	- Debris cloud was carried to the north. Highest off-site γ-radiation exposure at Clark Station, 16 mi west of Warm springs, 43 mR/h, 7-day TLD exposure at this location was 8 mR. The maximum off-site TLD worn by a resident was 8 mR, at Stone Cabin Ranch (15 mi W Warm Spring, 4 mi N of Clark Station). - Highest air sample result (I-131, -133, Te-132, W-187, and Sr-91), Stone Cabin Ranch, effective dose from inhalation 0.37 mrad; sample period: 10:20 – 15:00, mean gross β-radiation: 16,370 pCi/m^3; highest mean gross β-radiation at TTR over 26 Jan – 5 Feb, 0.1 pCi/m^3 (deemed background). IS, GL, TTR, and TON outside debris cloud path. See Figure E-25.
12-Mar-68	Buggy-A, -B, -C, -D, -E	- Plume travelled to north of GZ, maximum exposure rate was 8.5 mR/h during plume passage, four miles E of Warm Springs on Hwy 25 (unpopulated), with all other stations less than this value, Twin Springs (20 mi E of Warm Spring on Hwy 25) only peaked at 0.08 mR/h. IS, GL, TON, and TTR outside primary fallout pattern, as in Figure E-26. No exposures above background were observed on TLDs located in populated areas. One TLD placed 4 mi E of Warm Springs on Hwy 25 (unpopulated) had a net of 11 mR (cloud passage plus 8 days). - Air samples had detections of I-131, -133, -135, Ba-140, W-187, and Sr-91; maximum airborne at Warm Springs, effective dose from inhalation 0.20 mrad.
8-Jun-68	Phoebus 2A EP III	- Plume travelled SE toward Cactus Spring and Indian Springs; no TLD exceedances, maximum γ-radiation monitor at Cactus Springs 0.05 mR/h. - Detectable I-133, -135 in air samples at Cactus Springs and Indian Springs, maximum of 4.7 pCi/m^3 of I-135 at Indian Springs (inference that value was so low, additional details not important – for Phoebus 2A EP IV, maximum I-131, Te-132, and I-133 were: 20, 73, and 97 pCi/m^3, respectfully).

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON).

Date	Name	Information on Release and Dose Information
26-Jun-68	Phoebus 2A EP IV	- Plume travelled initially to NE, then down to SE; no positive TLDs or ground monitoring γ-radiation. - Positive detection in 15 air samples (radionuclides: I-131, -133, Te-132); highest between Hancock and Coyote Summits on Hwy 25 (NE of GZ), effective dose from inhalation 38 μrem, Indian Springs effective dose from inhalation 5 μrem. - GL on trajectory from GZ to between Hancock and Coyote Summits on Hwy 25 (about 2/3 distance), expected inhalation effective dose at GZ < 0.1 mrem.
18-Jul-68	Phoebus 2A EP V	- Plume carried to NNE; no TLDs exceedances; only positive ground monitoring γ-radiation at Queen City Summit (unpopulated), maximum reading 0.1 mR/h. - Positive air samples at numerous stations to NNE; GL on right fringe of airmass movement; Coyote Summit sampler best in-line with GL trajectory, effective dose from inhalation – 0.038 mrem, highest at Queen City Summit, effective inhalation dose – 0.035 mrem. Air sample radionuclide detections: I-131, -133, -135, Te-132.
4-Dec-68	Pewee 1 EP III	- Plume carried to ESE; no TLDs or ground monitoring γ-radiation exceedances. - Positive air sampling results at Indian Springs (I-131, Te-132), effective inhalation dose – 9 μrem; highest at Lathrop Springs, effective inhalation dose – 3 μrem
8-Dec-68	Schooner	- Release identified Mn-54, Ru-106, I-131, Cs-137, W-181+187, which occurred up to one minute after the detonation. - TON, TTR, IS, and GL outside primary deposition pattern, but positive air samples (most air samplers in vicinity of NTS had positive detection), despite being outside the primary deposition pattern, Figure E-30. Figures E-28 thru E-33 applicable to Schooner monitoring. Plume travelled to NE. - TTR airport on western fringe of ground deposition pattern, per Figure E-30 [adapted version of Figure 18, (AEC 1969)]. - Highest off-site recorded exposure rate just SE of Queen City Summit on Hwy 25, 350 mR/h (unpopulated), highest integrated exposure in populated off-site area, Diablo, 188 mR. - Highest TLD result among issued to individuals: 165 mrem (Uhalde Ranch, sheepherder); Diablo Maintenance Station 58 and 35 mrem. - Highest integrated air sample at Clark Station (55 mi from GZ) on Hwy 25 provided effective dose from inhalation of 2.3 mrem, TON station about six-fold lower.
11-Jun-69	XE-Prime (EP-VC)	- Release identified I-131+133 and Te-132, but due to low radiation exposure levels in plume monitored by aircraft, 1.5 mR/h, and the slow-moving plume special monitors not established. - Only indication of off-site release was detection in air sample at Diablo Maintenance Station, NNE of GZ, effective dose from inhalation – 1.3 μrad.

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Date	Name	Information on Release and Dose Information
28-Aug-69	XE-Prime (EP-IXA)	- Release identified I-131+133+135, Te-132, and Sr-90. - G-M detectors had a peak exposure level of 0.04 mR/h from cloud passage - Highest air sample result at Koyne's Mill; effective dose - 0.013 mrem. - GL expected to have external radiation and airborne impacts higher than Koyne's Mill due to GL on fallout path between GZ (Area 3) and Koyne's Mill; nevertheless combined (inhalation and external) expected to be < 1 mrem.
29-Oct-69	Pod-A, -C, & -B, -D	- Release identified I-131+133+135, Xe-133+135, and Cs-138. - Ground off-site air sampling and TLD network negative. - G-M detector at Lathrop Wells detected small increase, up to 0.04 mR/h maximum.
13-Nov-69	Scuttle	- Release identified Rb-88 (particulate) in equilibrium with Kr-88, I-133, Xe-135, and Cs-138. - No ground network detection.
21-Apr-70	Snubber	- Planned test ventilation, airborne plume tracked by aircraft to 90 miles from GZ contained radioxenons and radioiodines. - Maximum off-site γ-exposure rate: 0.6 mR/h at Coyote Summit (unpopulated), deviation in γ-exposure rate from background was ~ one hour; therefore, integrated γ-exposure < 0.6 mR. - Maximum off-site air at Coyote Summit, with detection of I-33 and I-135, inhalation-related effective dose exposure ~ 8 μrem (ICRP) - GL expected to have external radiation and airborne impacts higher than Coyote Summit due to GL on fallout path between GZ (Area 3) and Coyote Summit; nevertheless combined (inhalation and external) expected to be only a few mrem.
5 May 70	Mint Leaf	- Planned tunnel ventilations, the first of three conducted on 5 May, 2nd on 6 May, with 3rd on 11 May. Ventilations had filtering to limit particulate release, thus release had detected only noble gases and radioiodines. - Negative ground γ-radiation detection at IS, TON, GL, or TTR, but maximum of 0.02 mR/h near Queen City Summit. TLDs negative. - One off-site charcoal air filter absorption of Xe-133 at Valley Road Junction (near Koyne's Mill). Retention of xenons on charcoal estimated at ~ 10 – 15%. Therefore, concentration of 700 pCi/m^3 Xe-135, multiplied by 10: 7,000 pCi/m^3.
18-Dec-70	Baneberry	- Venting occurred from a fissure near surface GZ at H+3.5 minutes, with plume travelling to NE, as shown in Figures E-35 and E-36. - Estimated infinity external exposure of 0.1 mR at GL and 3 mR at TON from SWRHL-107r (Table A-1), and 30 mR at TTR from E-25. - Positive air sample detections at TTR, TON, and GL, with dominating I-131, I-133, I-135 and Te-132. Effective doses from inhalation (ICRP 68): TTR – 0.22 mrem, TON – 0.127 mrem, and GL - 0.055 mrem (Data from Appendix B, SWRHL-107r).

TABLE E-5. Radiological Dose Impacts from Off-Site Releases from Reactor, and Nuclear Tests Conducted at Nevada Test Site with Emphasis on Key Sites: Indian Springs (IS) AFB, Groom Lake (GL), Tonopah Test Range (TTR), and Tonopah (TON), continued.

Date	Name	Information on Release and Dose Information
24-Nov-71	Diagonal Line	- Seepage released gases from H+3.3 to H-20 h, dominated by Xe-135 (80-85%), other noble gases and radioiodines - No detection in ground monitoring network; aerial sampling tracked plume to SW near Lathrop Wells - Chinese nuclear test on 18 Nov 71 influenced US monitoring network
27-Jul-72	Nuclear Furnace-1 (V)	- Releases dominated by noble gases: Kr-85m, Kr-88, and Xe-133; Rb-88 (particulate) in equilibrium with Kr-88. - No ground network detection.
25 Sep 80	Riola	- Releases due to test, seepage, and gas sampling operation, containing noble gases and tritium, Xe-135 dominant by activity, lesser Xe-133, Xe-135m, and H-3 - γ-radiation monitors negative - Positive detection in noble gas sample at Lathrop, NV (populated) had a mean Xe-133 and Xe-135 of 34 and 360 pCi/m^3, respectfully, over 50.17 h. Integrated air concentrations 1,706 and 18,061 pCi-h/m^3 respectfully Xe-133 & Xe-135. Doses 0.03 and 2.7 μrad, respectfully (ICRP 68 submersion coefficients). - Air monitors negative at IS, GL, TTR, and TON
6 Apr 85	Misty Rain	- Tunnel ventilation produced primary release of Xe-133, with lesser amounts of Xe-133m & Xe-135. Special noble gas sampler set-up at Rachel. Positive detections only at Rachel and Reed Ranch Road (NNE on Hwy 25). Rachel (populated) had a mean Xe-133 of 11 pCi/m^3, 264 pCi-h/m^3, 5 nrad (ICRP 68 submersion coefficients). - γ-radiation monitors negative - Air monitors negative at IS, GL, TTR, and TON
22 Mar 86	Glencoe	- Drillback operation conducted on 27 Mar, produced primary release of Xe-133, with negligible amounts of Xe-135, I-131+133 - Lathrop Wells air sample had a mean Xe-133 of 84 pCi/m^3, 1.4 x 10^4 pCi-h/m^3, 0.26 μrad (ICRP 68 submersion coefficients). - γ-radiation monitors negative - Air monitors negative at IS, GL, TTR, and TON
10 Apr 86	Mighty Oak	- Planned T-tunnel purge actions conducted from 22 Apr to 19 May, produced primary release of Xe-133, with negligible amounts of Kr-85 and I-131. - Maximum Xe-133 (public) at Medlin's Ranch (near Rachel) had a mean of 430 pCi/m^3. Maximum I-131 at Twin Springs Range (Hwy 25, N. of NTS) had a mean 4.6 pCi/m^3. Nine days of positive noble gas samples at Groom Lake provided Xe-133: 8.2 x 10^4 pCi-h/m^3 – 1.5 μrad submersion dose. Fourteen days of positive noble gas samples at Indian Springs Xe-133: 1.3 x 10^4 pCi-h/m^3 – 0.25 μrad submersion dose. (ICRP 68 submersion coefficients) - γ-radiation monitors negative - Special sampler locations and centerline winds for Mighty Oak in Figure E-36.

TABLE E-6. Summary Listing of Radiological Detections for Indian Springs, Groom Lake, Tonopah Test Range, and Tonopah from Tables E-3 and E-5. [Higher Radiological Impact Events in Red for Each Location].

Indian Springs		
Date	Name	Type
7-Dec-61	Kiwi B-1A (EP-VI/A)	R
19-Oct-62	Bandicoot	U
12-Dec-63	Eagle	U
13-Mar-64	Pike	U
15-Oct-64	NRX-A2 (EP-V)	R
16-Dec-64	Parrot	U
8-Jun-68	Phoebus 2A EP III	R
4-Dec-68	Pewee 1 EP III	R
8-Dec-68	Schooner	C
10-Apr-86	Mighty Oak	U

Tonopah		
Date	Name	Type
6 Mar 66	Red Hot	C
8-Dec-68	Schooner	C
18-Dec-70	Baneberry	U
10-Apr-86	Mighty Oak	U

Tonopah Test Range		
Date	Name	Type
5-Mar-62	Danny Boy	C
14-Apr-65	Palanquin	C
6 Mar 66	Red Hot	C
31-Aug-67	Door Mist	U
8-Dec-68	Schooner	C
18-Dec-70	Baneberry	U

Groom Lake		
Date	Name	Type
19-Oct-60	Kiwi A-3 (EP-216-B)	R
6-Oct-61	Tory II-A Reactor	R
1-Mar-62	Pampas	U
6-Jul-62	Sedan	C
19-Oct-62	Bandicoot	U
28 Aug 64	Kiwi B4E Reactor (EP-V)	R
10-Sep-64	Kiwi B4E Reactor (EP-VI)	R
20 May 65	NRX-A3 (EP-V)	R
16 Jun 65	Diluted Waters	U
22 Jun 65	Phoebus 1-A	R
15 Jun 66	Double Play	U
23 Jun 66	NRX-A3 (EP-V)	R
18 Jul 68	Phoebus 2A (EP-V)	R
11 Jun 69	XE-Prime (EP-VC)	R
28 Aug 69	XE-Prime (EP-VC)	R
21 Apr 70	Snubber	U
18 Dec 70	Baneberry	U
10-Apr-86	Mighty Oak	U

R = reactor U = underground C = cratering

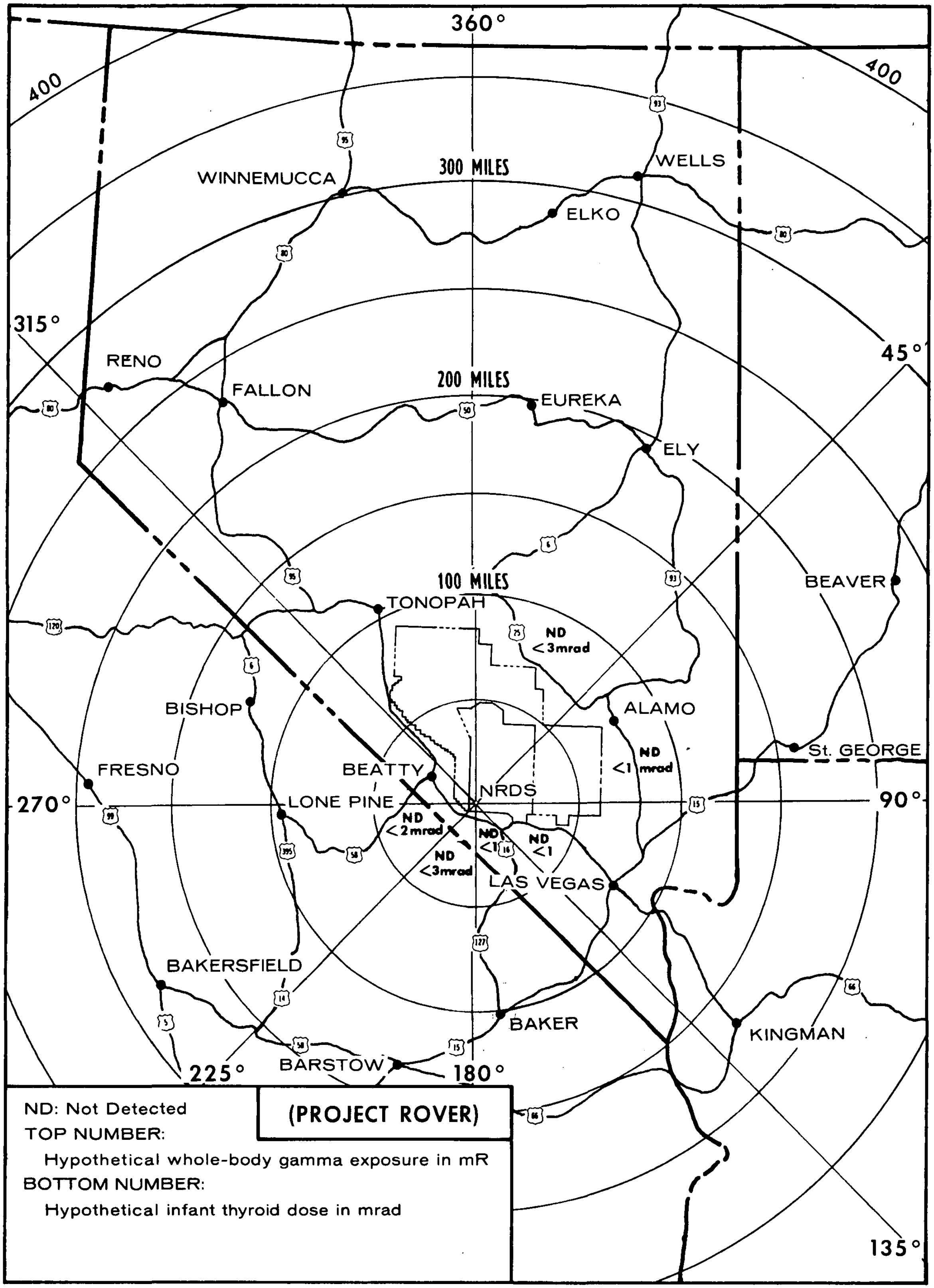

Figure E-1. Off-Site Whole-Body Gamma Exposures and Infant Thyroid Doses Resulting from Reactor/Engine Tests from CY 1959 to 1963, Figure 1 of SWRHL-92r (1970).

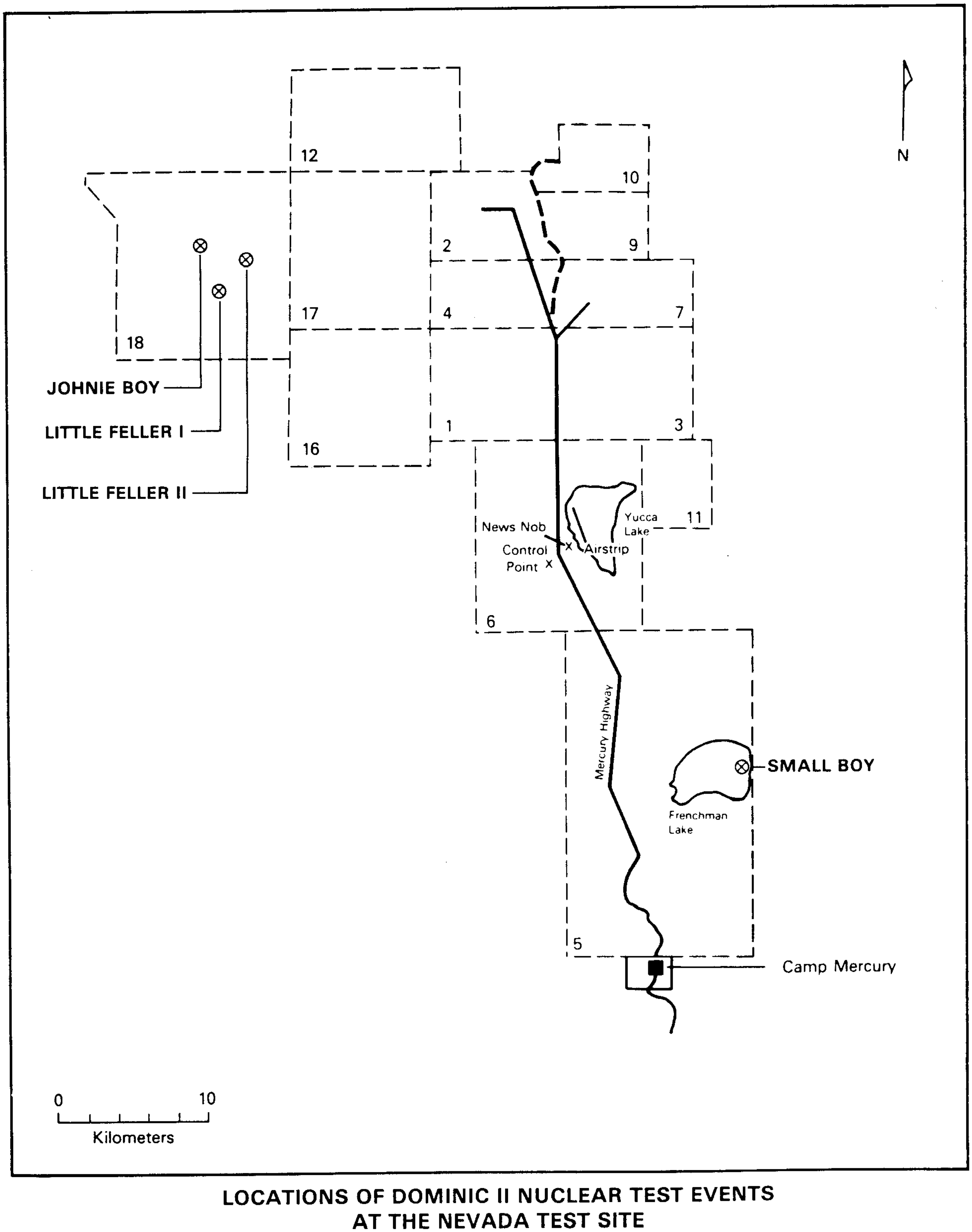

Figure E-2. Locations of Dominic II Nuclear Test Events at the Nevada Test Site, from DTRA Fact Sheet.

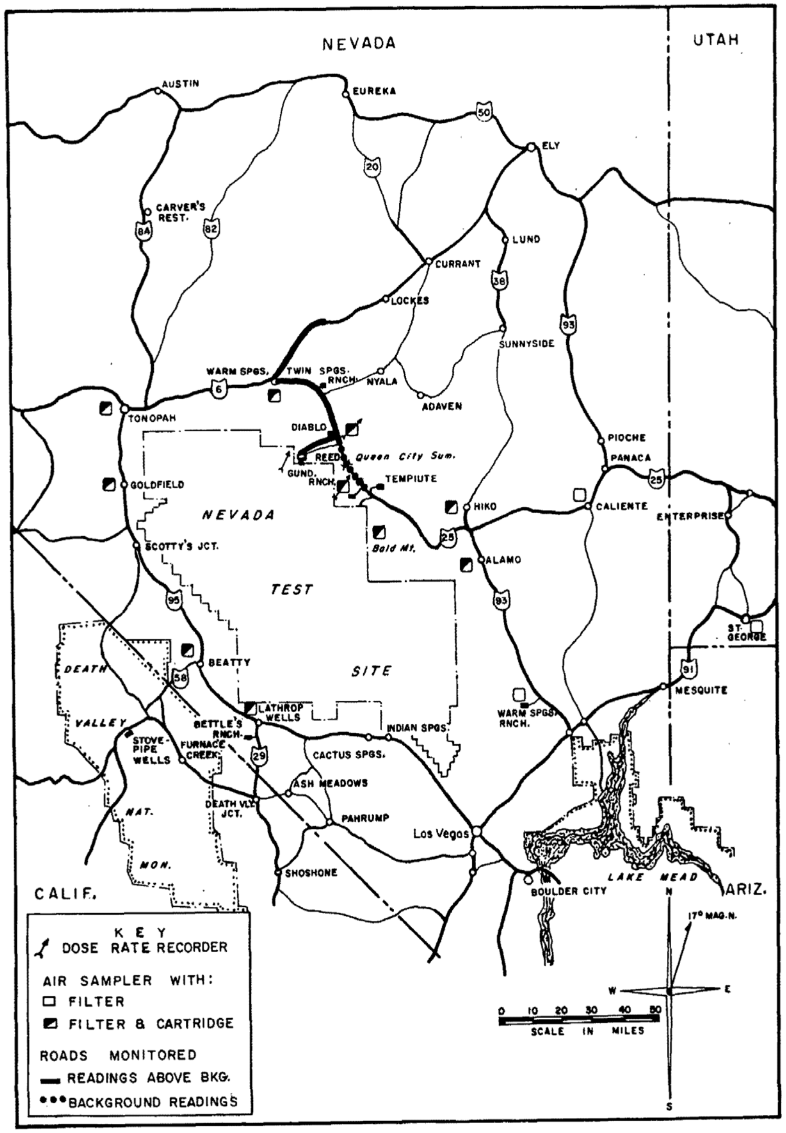

Figure E-3. Off-Site Surveillance Locations for the Antler Event on September 15, 1961, Figure 5.3.1 of SWRHL-1r (1964).

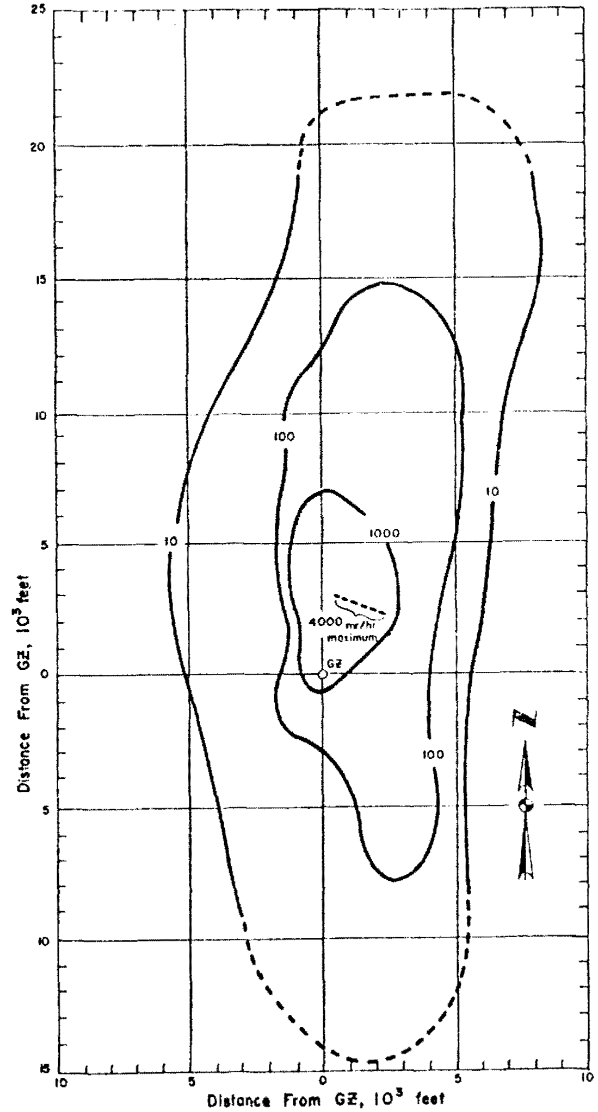

Figure E-4. Operation Nougat – Bandicoot Contours of Residual Gamma Radiation in R/h at Midtime of H+24 hours to 22,000 feet Downwind, Figure 340 (DNA 1251-1-EX 1979).

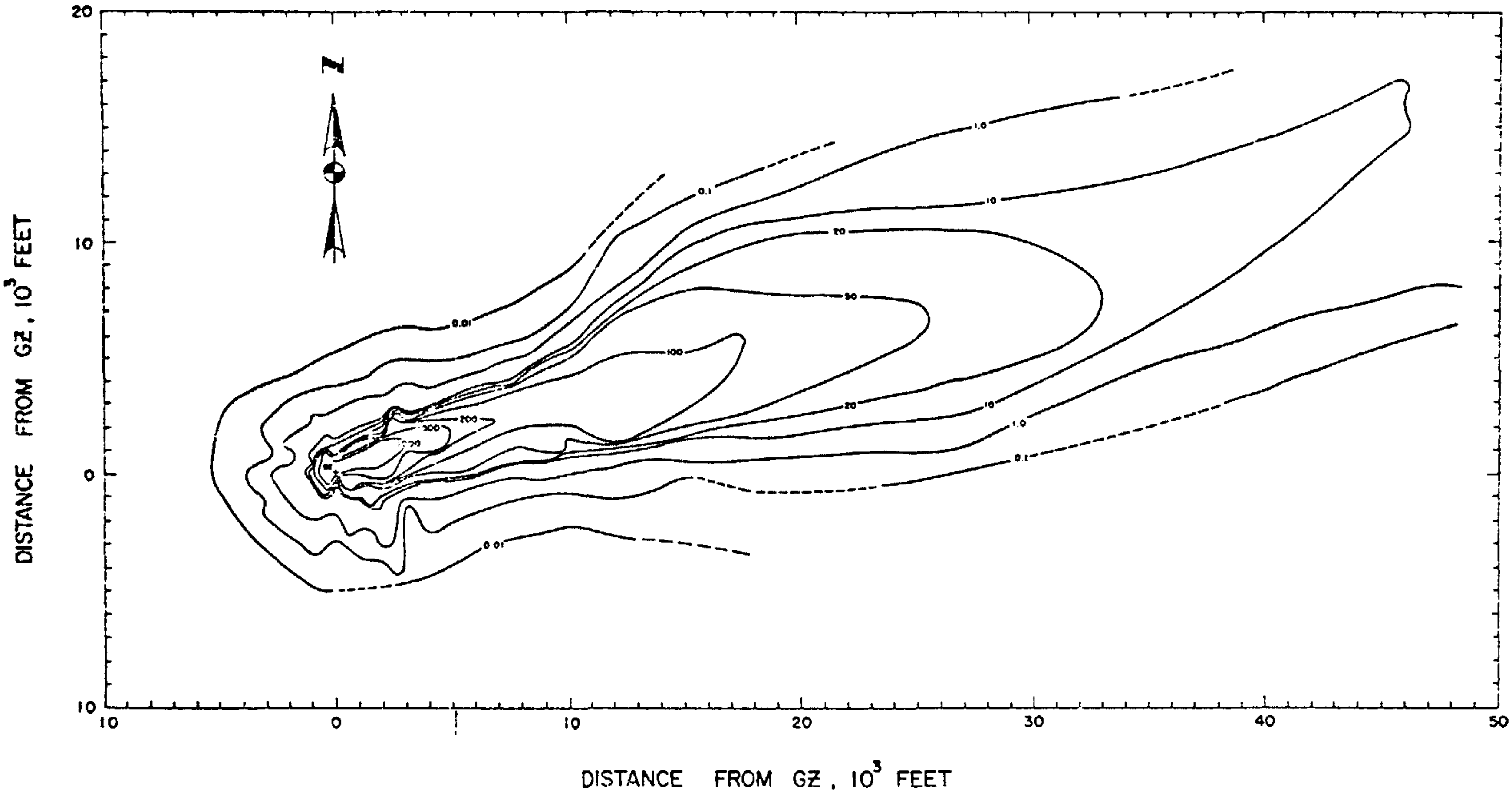

Figure E-5. Operation Dominic II – Small Boy Contours of Residual Gamma Radiation in R/h ar H+1 h to 50,000 ft Downwind, Figure 330 (DNA 1251-1-EX 1979).

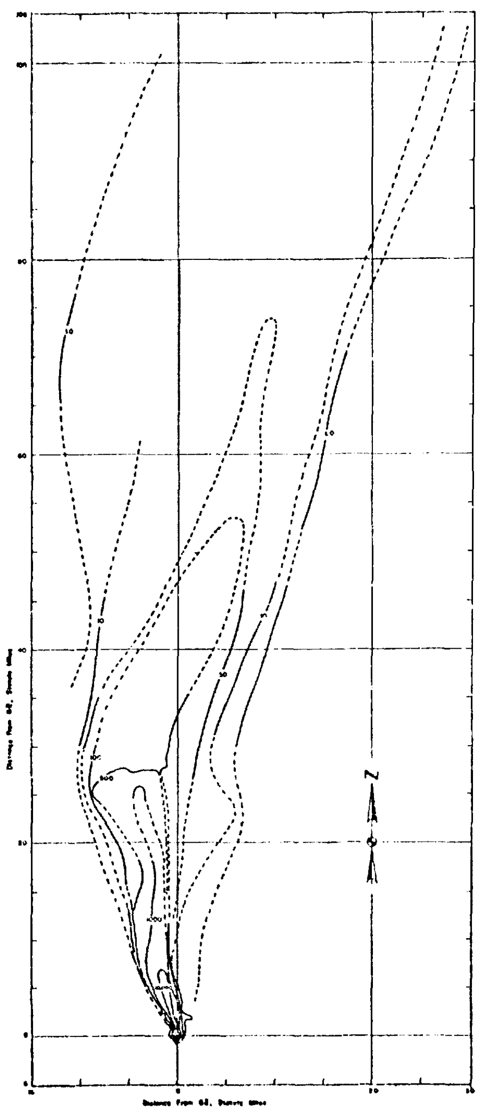

Figure E-6. Operation Dominic II – Johnie Boy Contours of Residual Gamma Radiation in mR/h at H+ 1 h to 100 miles Downwind, Figure 327 (DNA 1251-1-EX 1979).

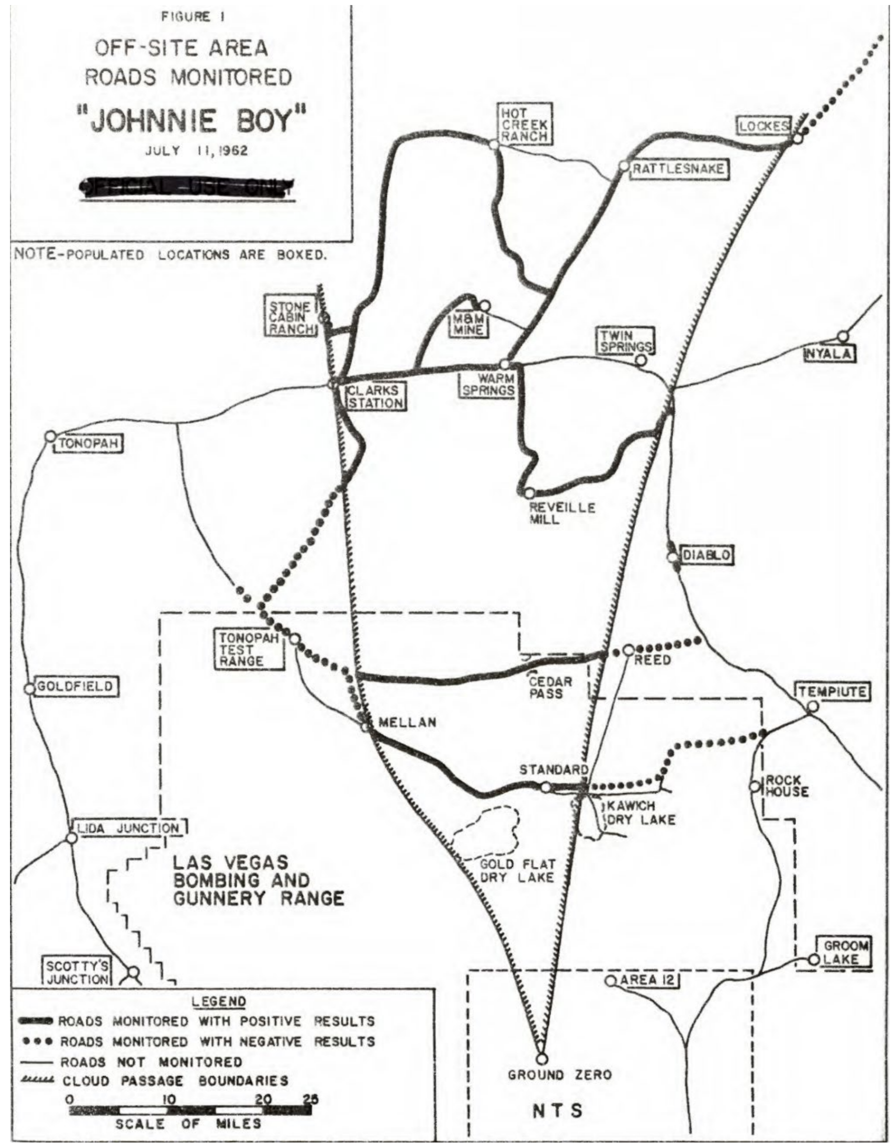

Figure E-7 Operation Dominic II – Area Roads Monitored, Johnie Boy, Figure 1 (PHS 1962).

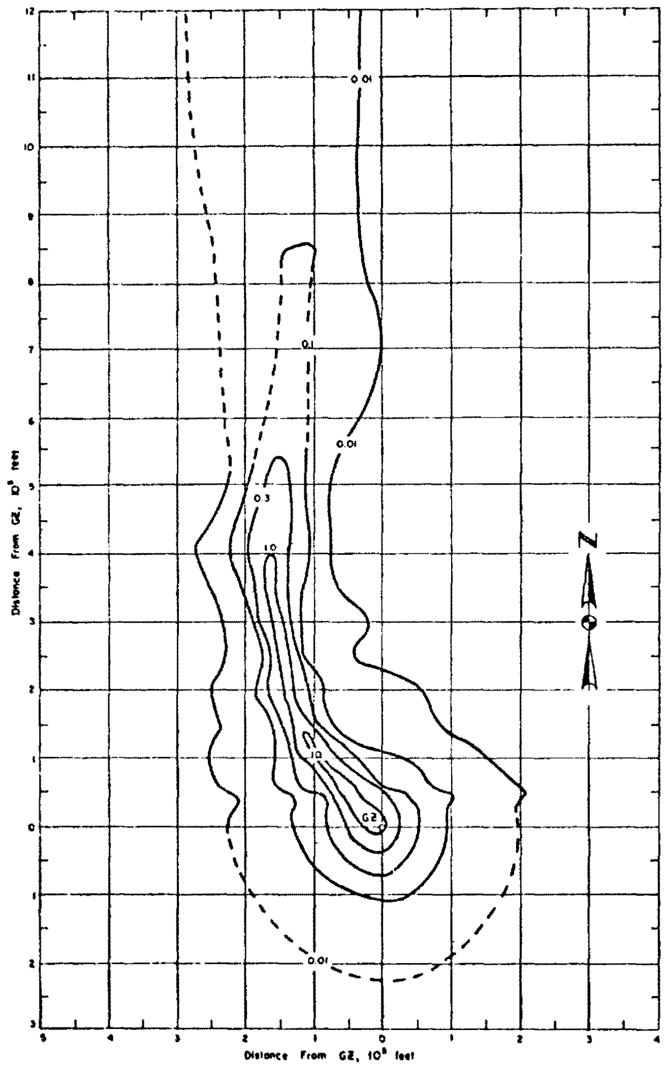

Figure E-8. Operation Dominic II – Little Feller I Contours of Residual Gamma Radiation in R/h at H+4 Hour 12,000 feet, Figure 337 (DNA 1251-1-EX 1979).

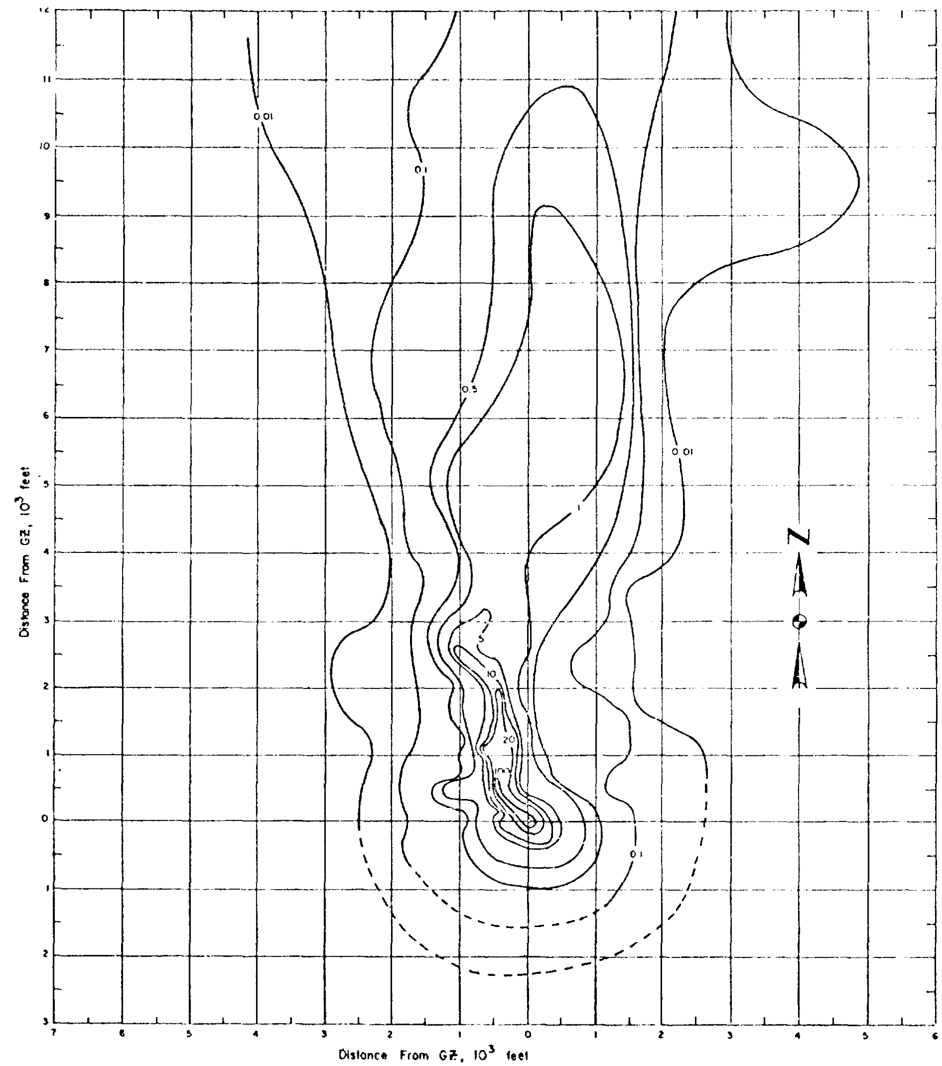

Figure E-9. Operation Dominic II – Little Feller II Contours of Residual Gamma Radiation in R/h at H+1 Hour 12,000 feet, Figure 323 (DNA 1251-1-EX 1979).

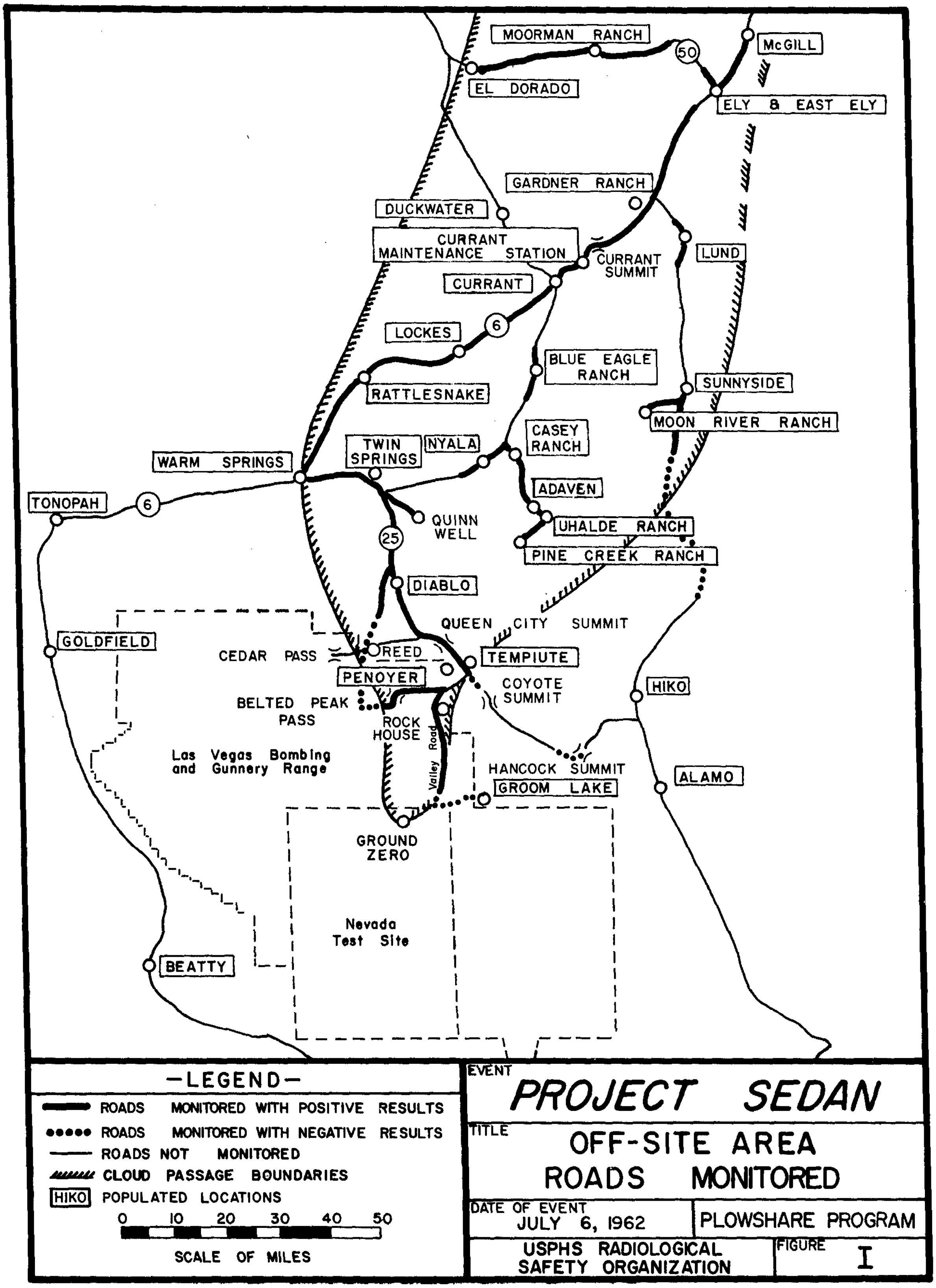

Figure E-10. Off-Site Area Roads Monitored, Project Sedan, Figure 1 (PNE-200 1963).

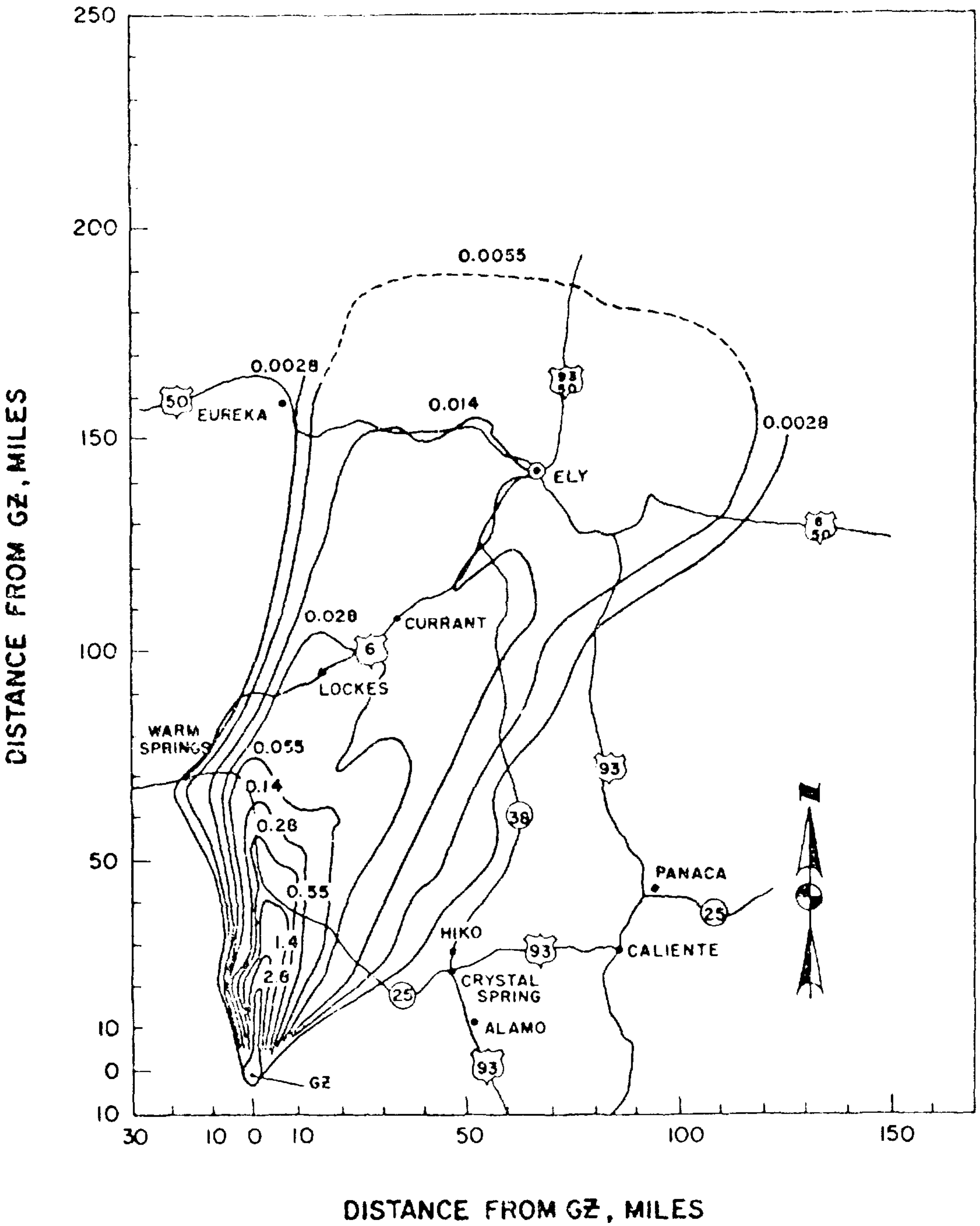

Figure E-11. Project Sedan – Contours of Residual Gamma Radiation (for Fission Products) in R/h at H+1 h to 140 Miles Downwind, Figure 320 (DNA 1251-1-EX 1979).

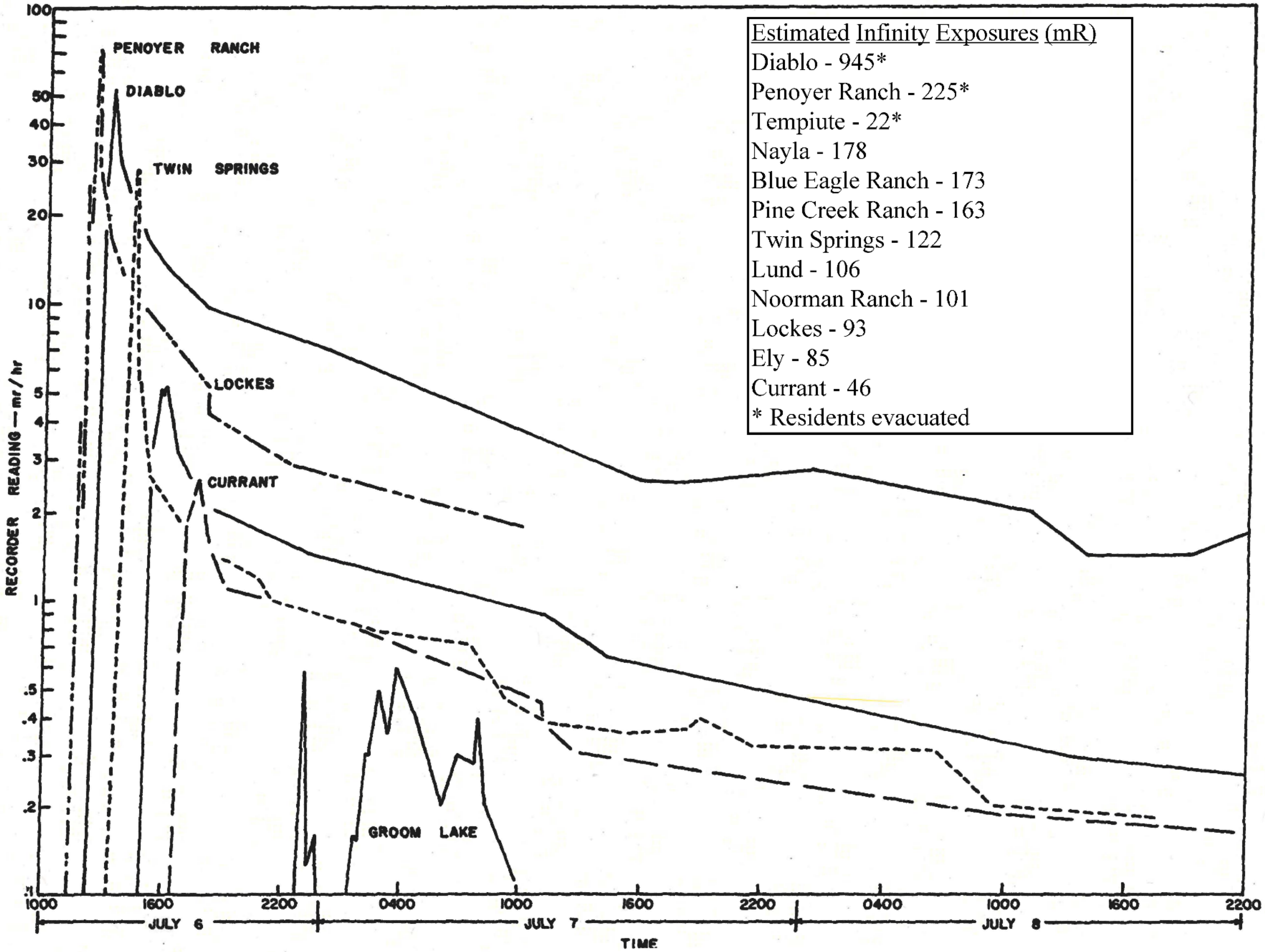

Figure E-12. Gross Gamma Activity, Project Sedan, Modified from Figure IV (PNE-200 1963).

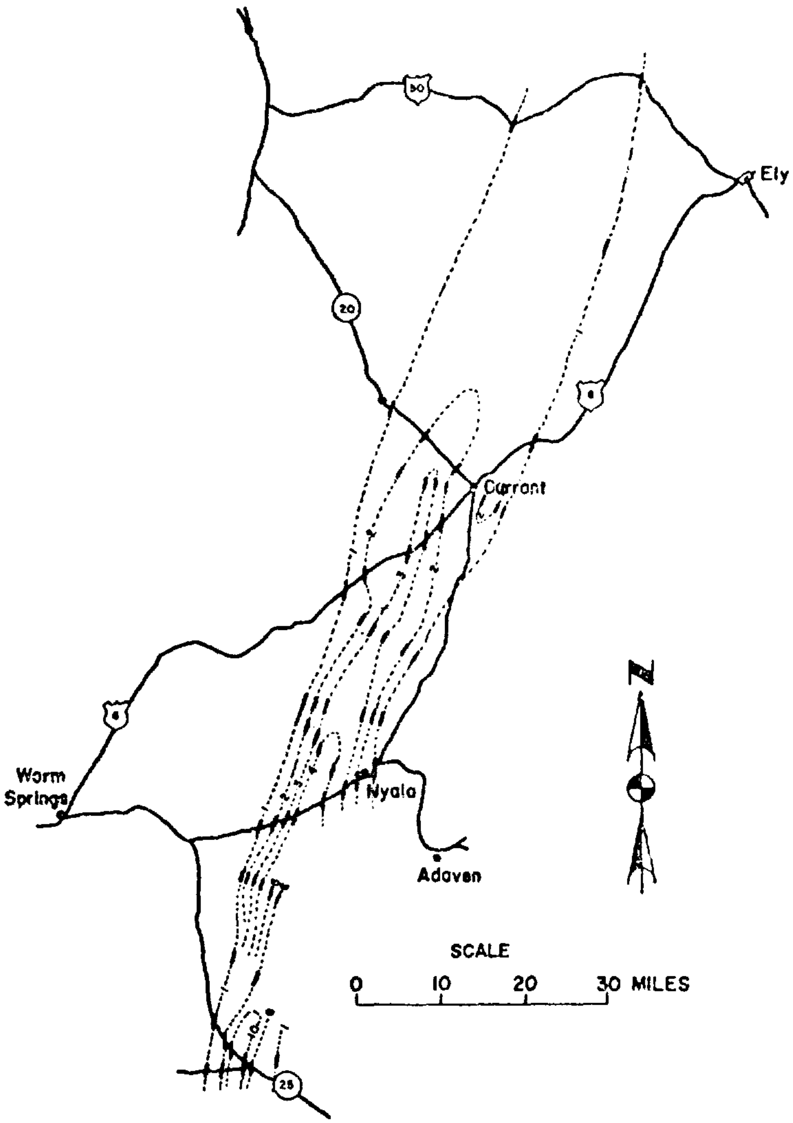

Figure E-13. Operation Nougat – Des Moines Contours of Residual Gamma Radiation in Thousands of Counts per Second at 500 feet Above the Ground at H+14 days, Figure 317 (DNA 1251-1-EX 1979).

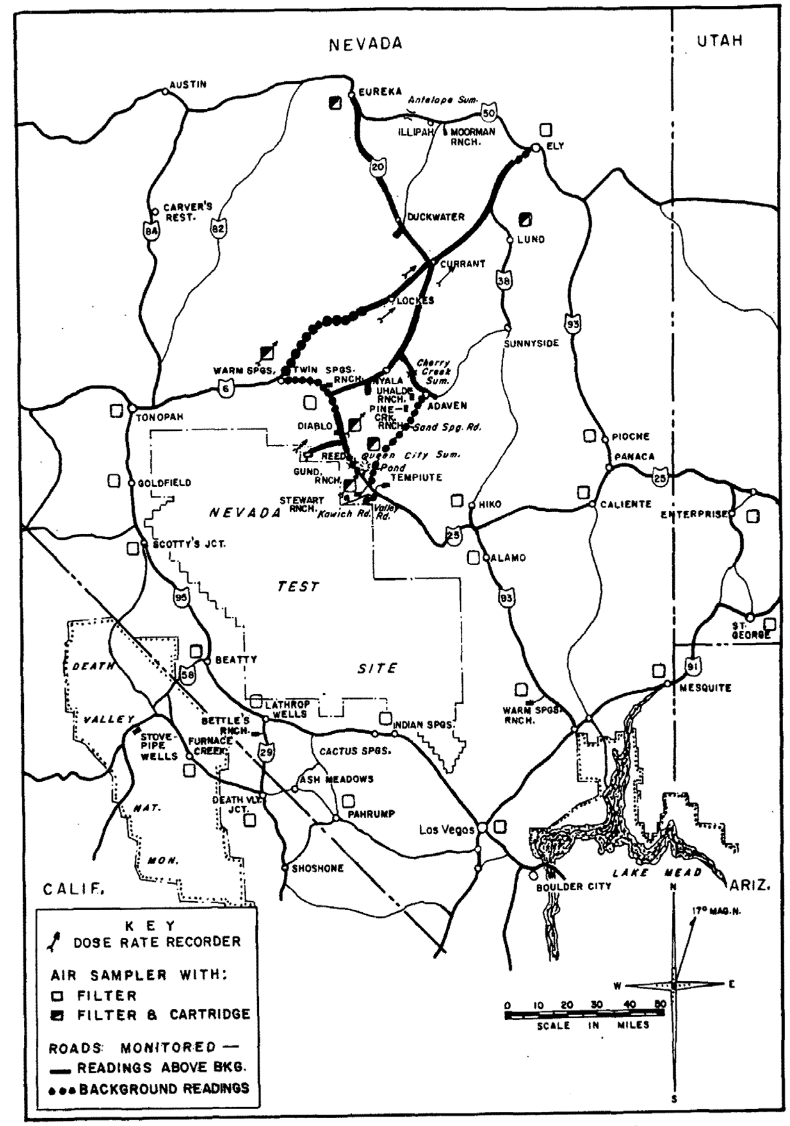

Figure E-14. Off-Site Surveillance Locations for the Des Moines Event on June 13, 1962, Figure 5.3.7 of SWRHL-1r (1964).

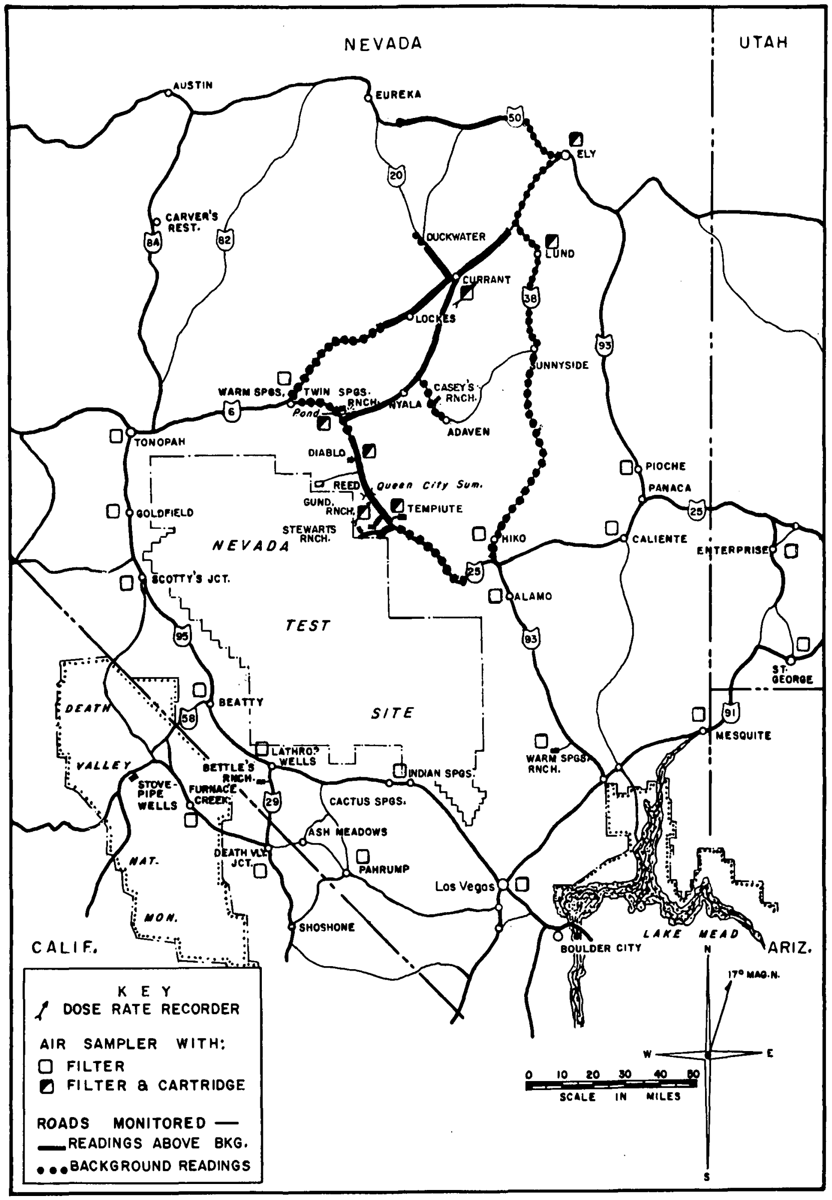

Figure E-15. Off-Site Surveillance Locations for the Eel Event on May 19, 1962, Figure 5.3.6 of SWRHL-1r (1964).

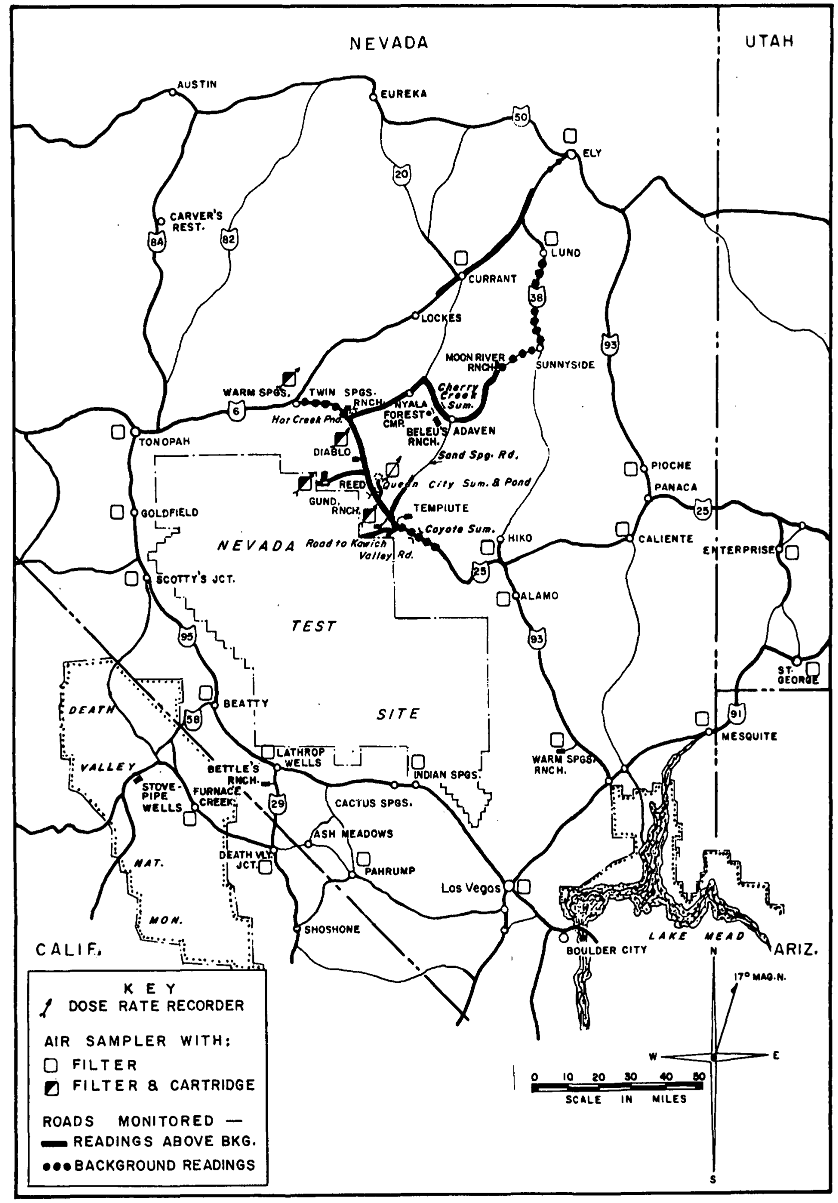

Figure E-16. Off-Site Surveillance Locations for the Platte Event on May 19, 1962, Figure 5.3.5 of SWRHL-1r (1964).

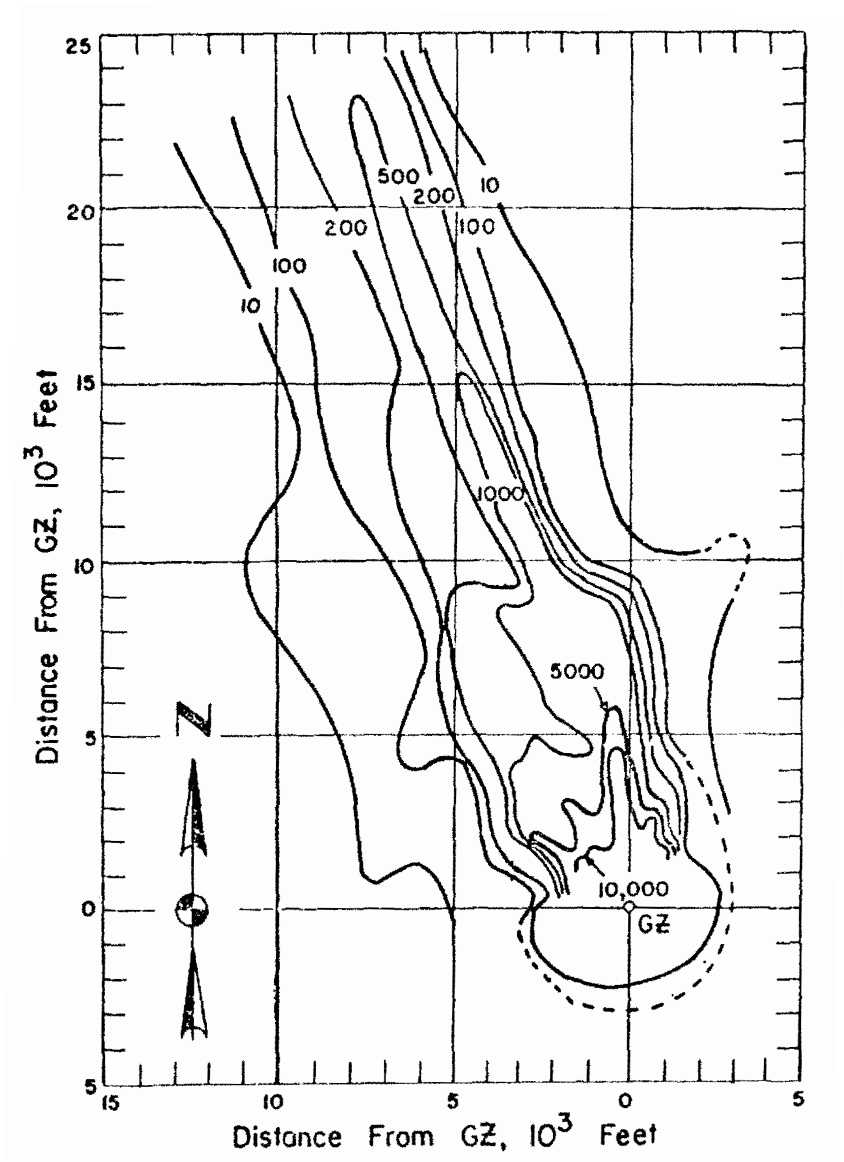

Figure E-17. Operation Nougat – Danny Boy Contours of Residual Gamma Radiation in mR/h at H+1 hour to 25,000 feet Downwind, Figure 313 (DNA 1251-1-EX 1979).

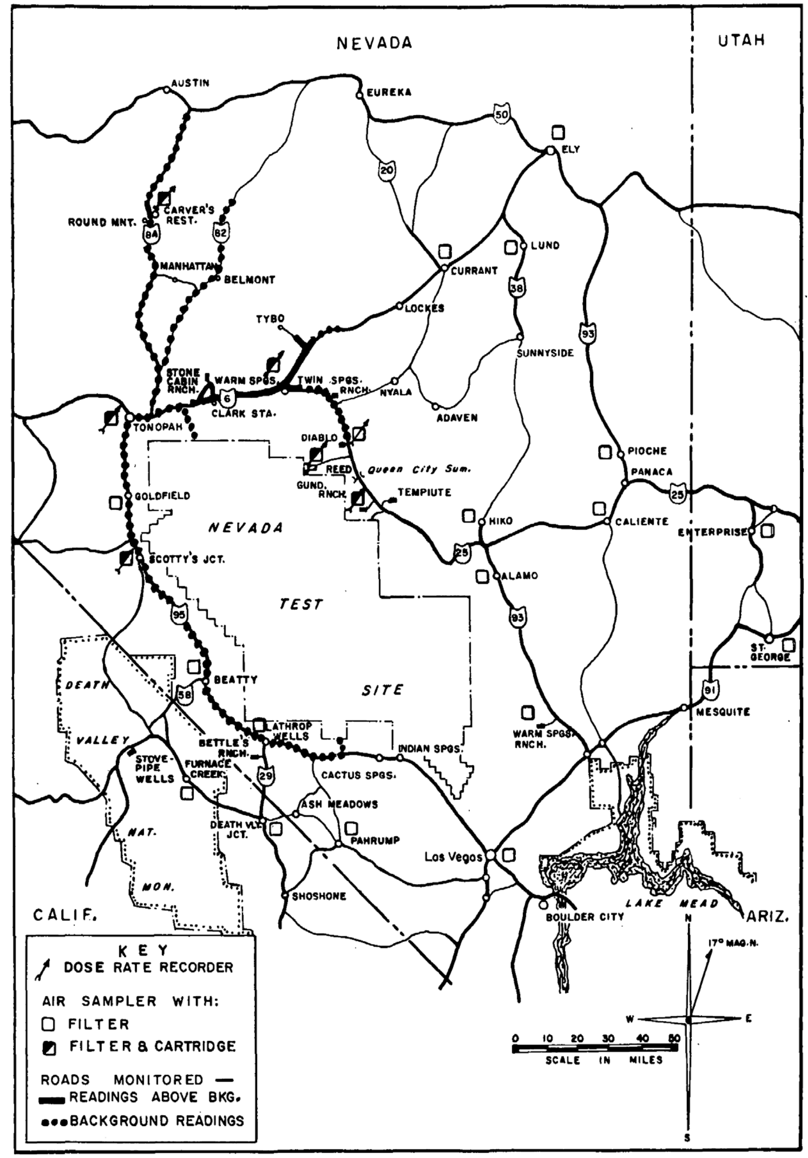

Figure E-18. Off-Site Surveillance Locations for the Danny Boy Event on March 5, 1962, Figure 5.3.4 of SWRHL-1r (1964).

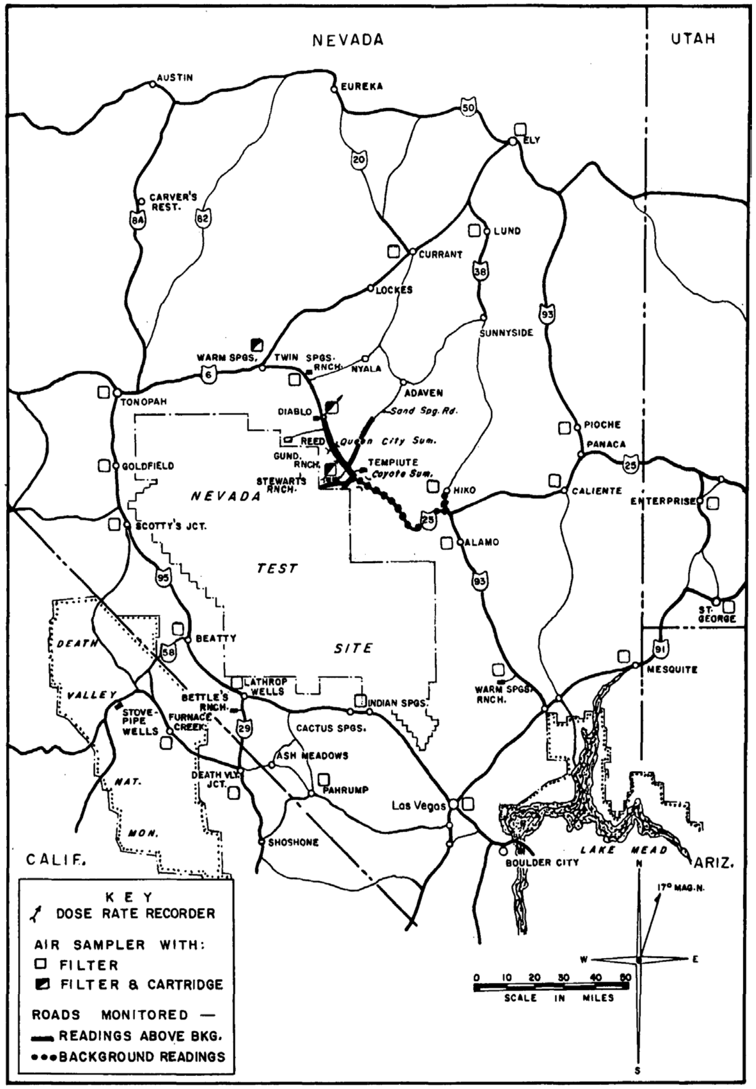

Figure E-19. Off-Site Surveillance Locations for the Pampas Event on March 1, 1962, Figure 5.3.3 of SWRHL-1r (1964).

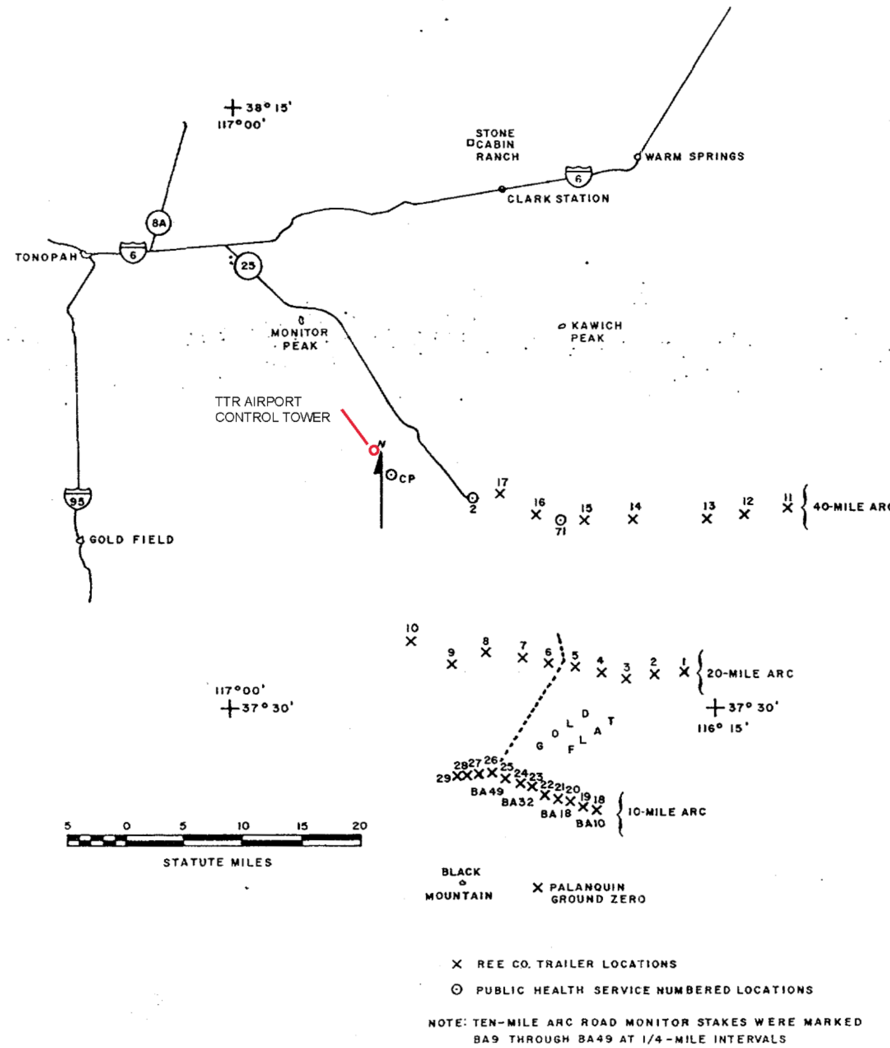

Figure E-20. Palanquin Off-Site Stations Locations and Monitoring Team Check Points, Figure 2.2 (AEC 1965).

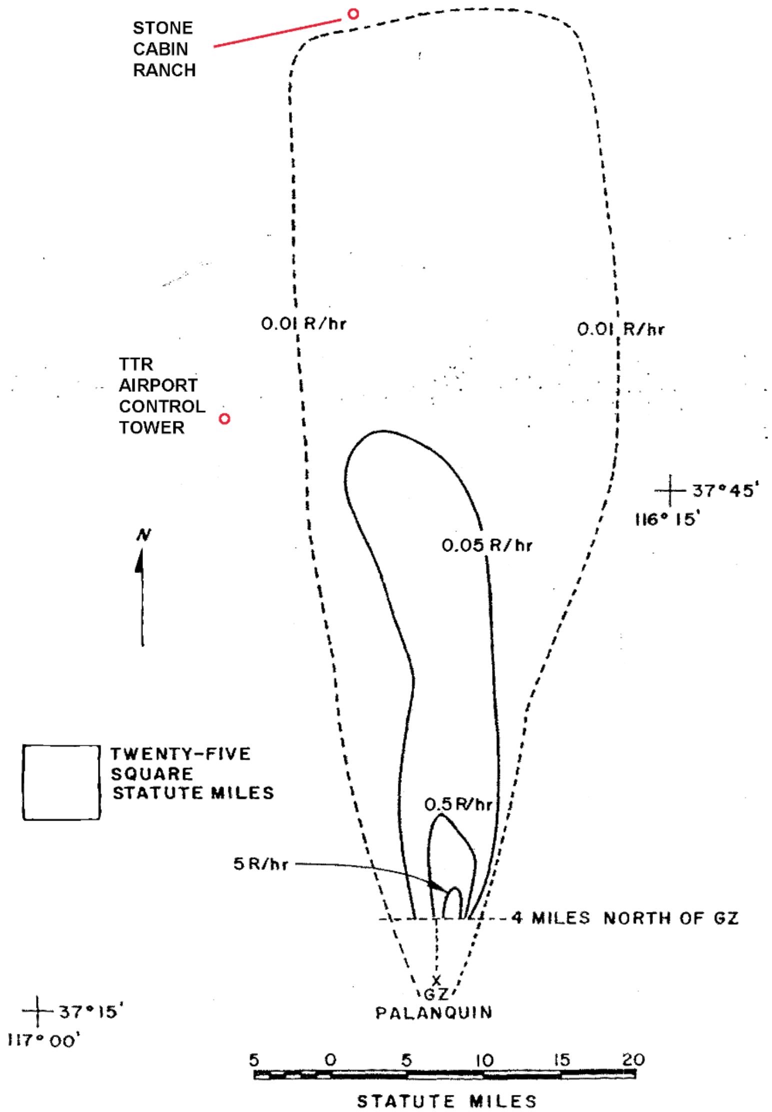

Figure E-21. Palanquin Exposure Rates (R/h at H+1 h), Figure 3.19 (AEC 1965).

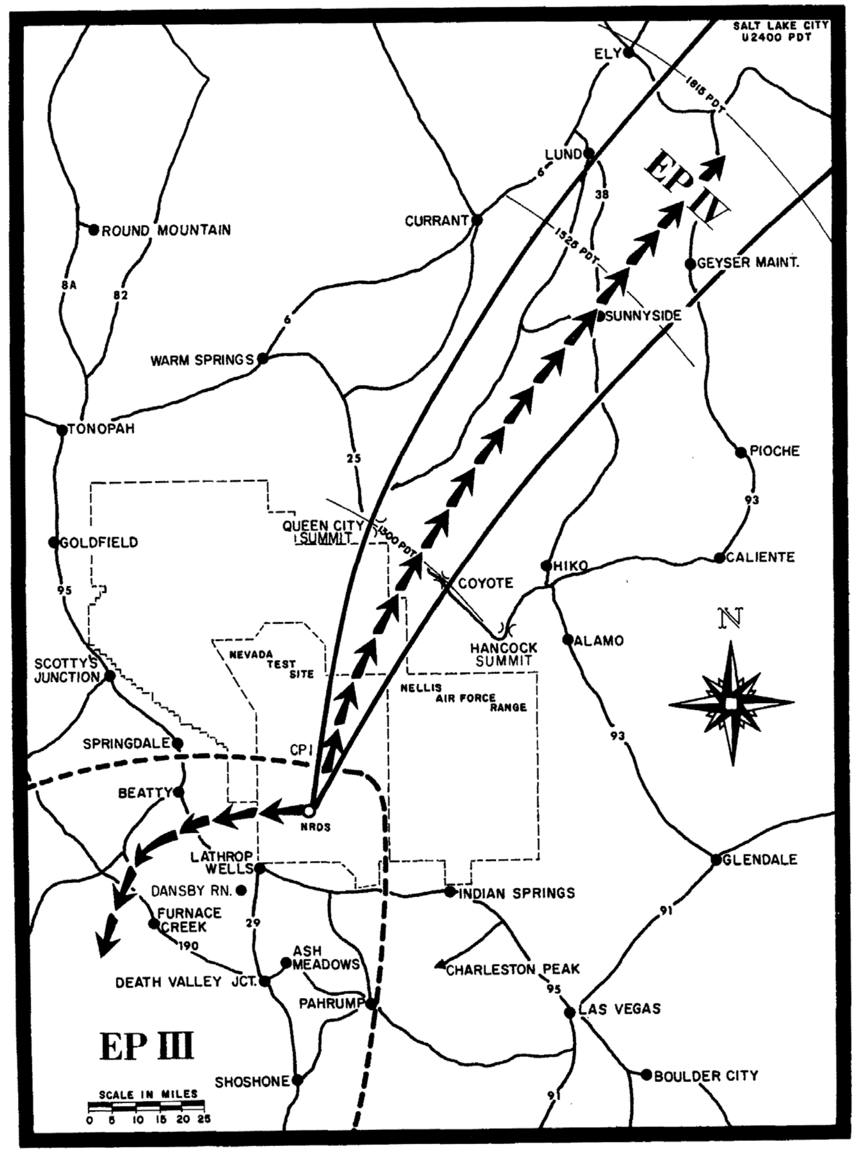

Figure E-22. Hotlines for NRX-A5 EP-III, June 8 1966, and EP-IV, June 23, 1966. (Cloud Arrival Times for EP-IV are Based on Aircraft Tracking), Figure 1, SWRHL-32r (1968).

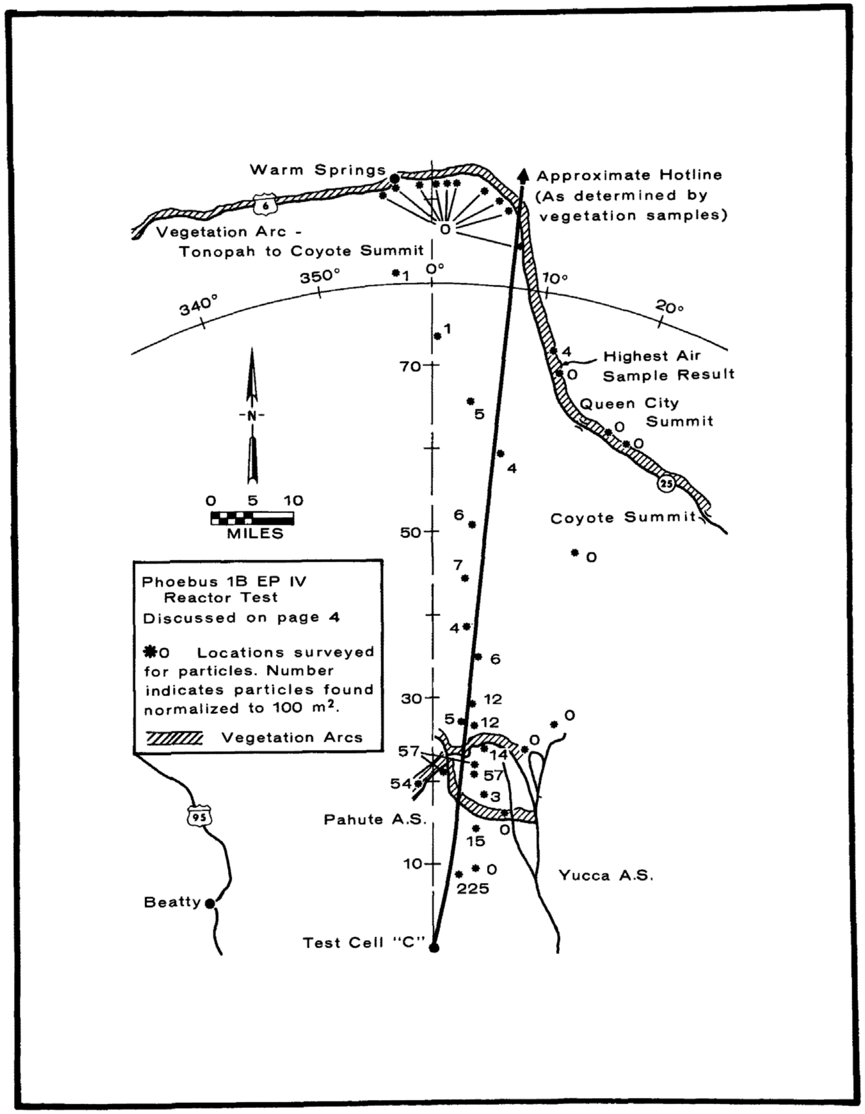

Figure E-23. Particle Sampling Areas [Phoebus 1B, EP-IV], Figure 1 of SWRHL-46r (1970).

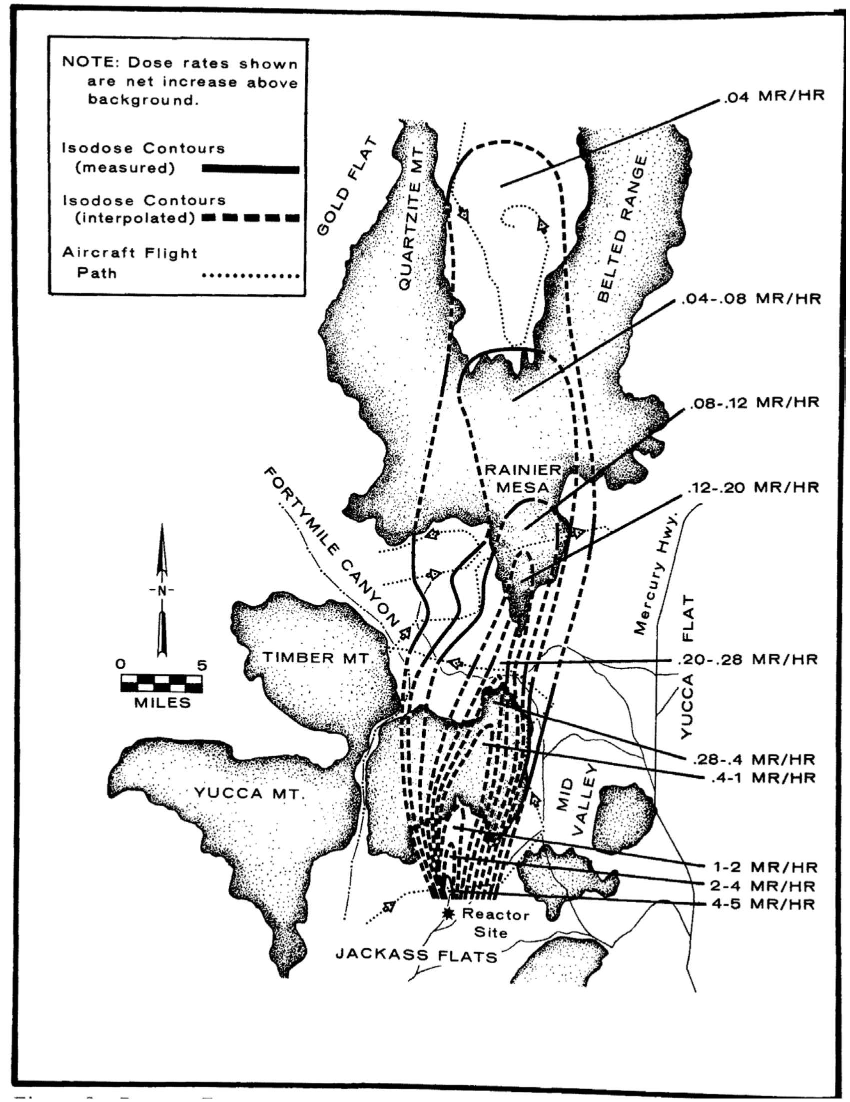

Figure E-24. Reactor Test Ground Deposition Pattern for Phoebus 1B, EP-IV, Figure 2 of SWRHL-46r (1970).

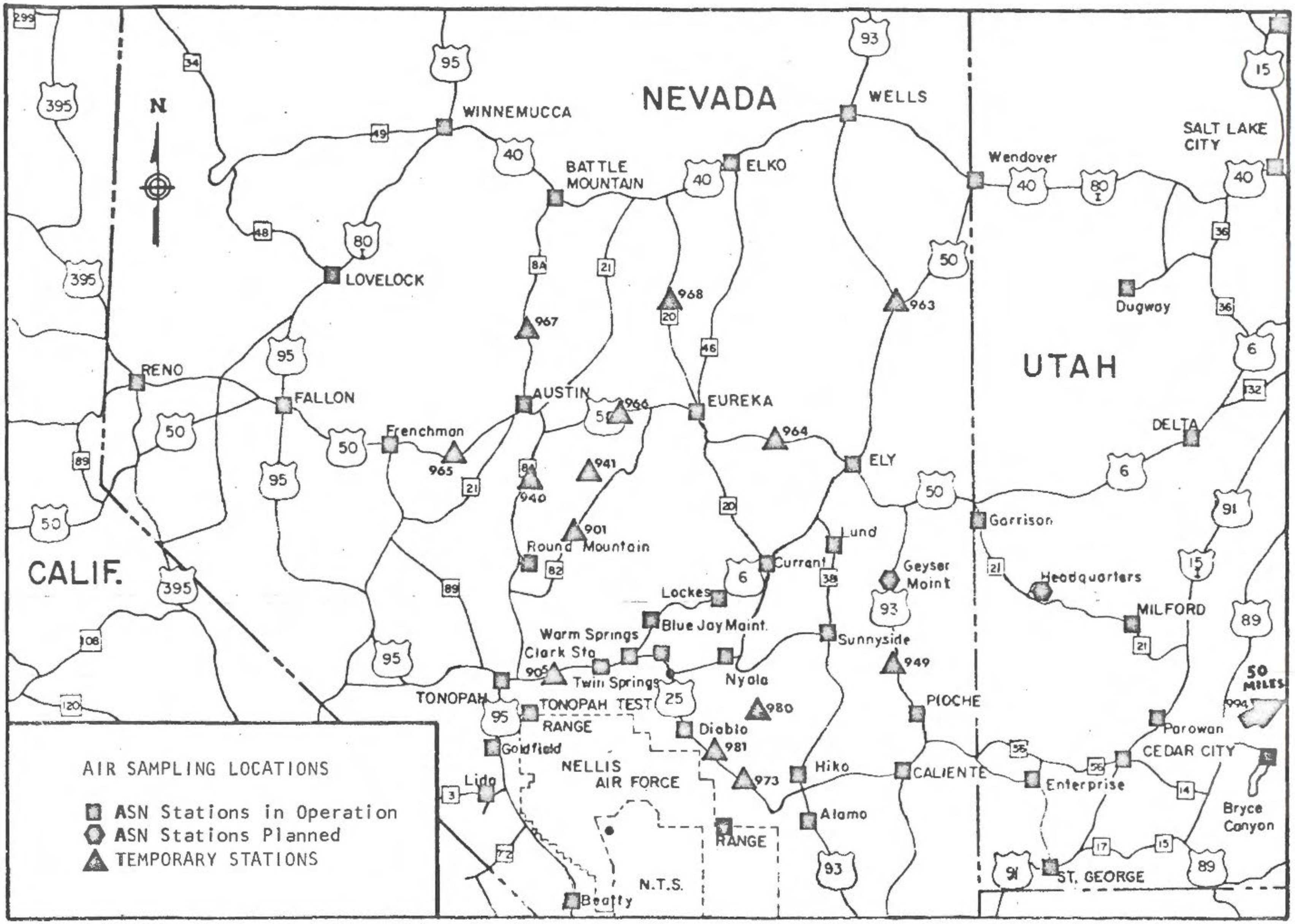

Figure E-25. Air Sampling Stations in Nevada and Western Utah for Cabriolet Surveillance, (SWRHL 1966).

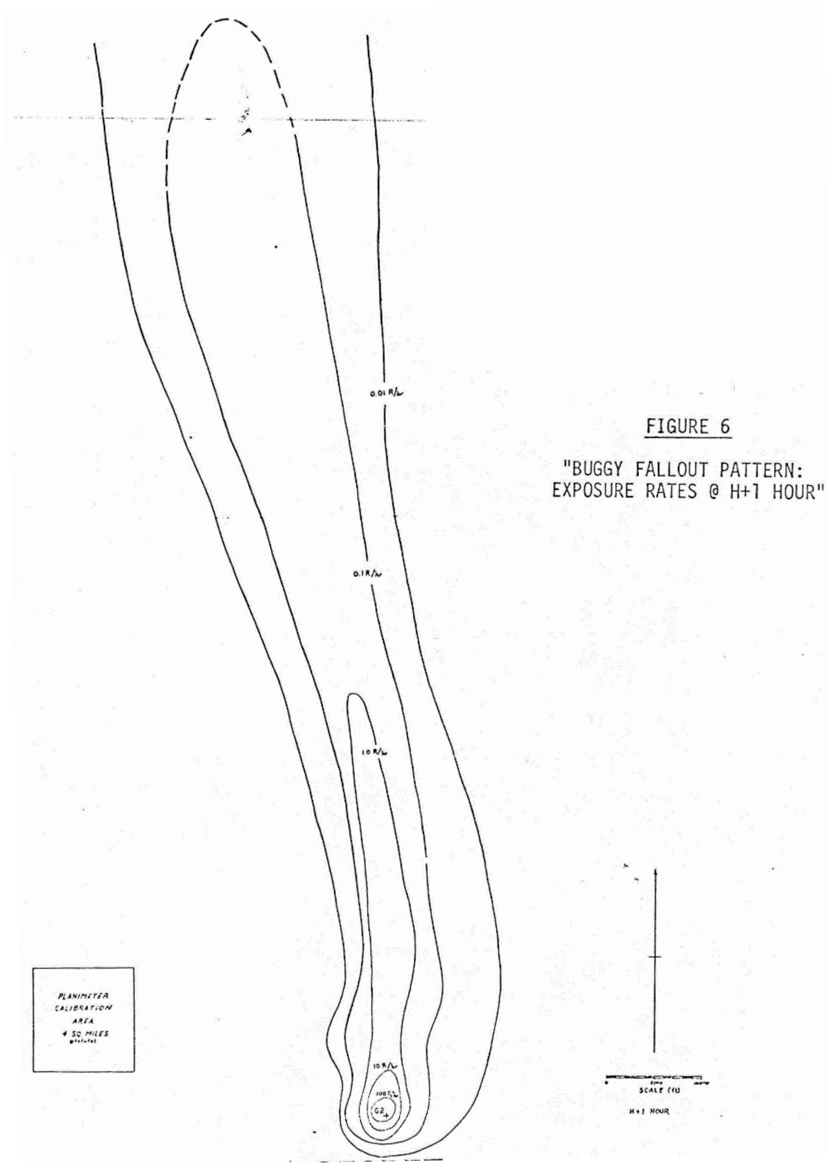

Figure E-26. Buggy Fallout Pattern Exposure Rates @ H+1 h, Figure 6 (AEC 1968).

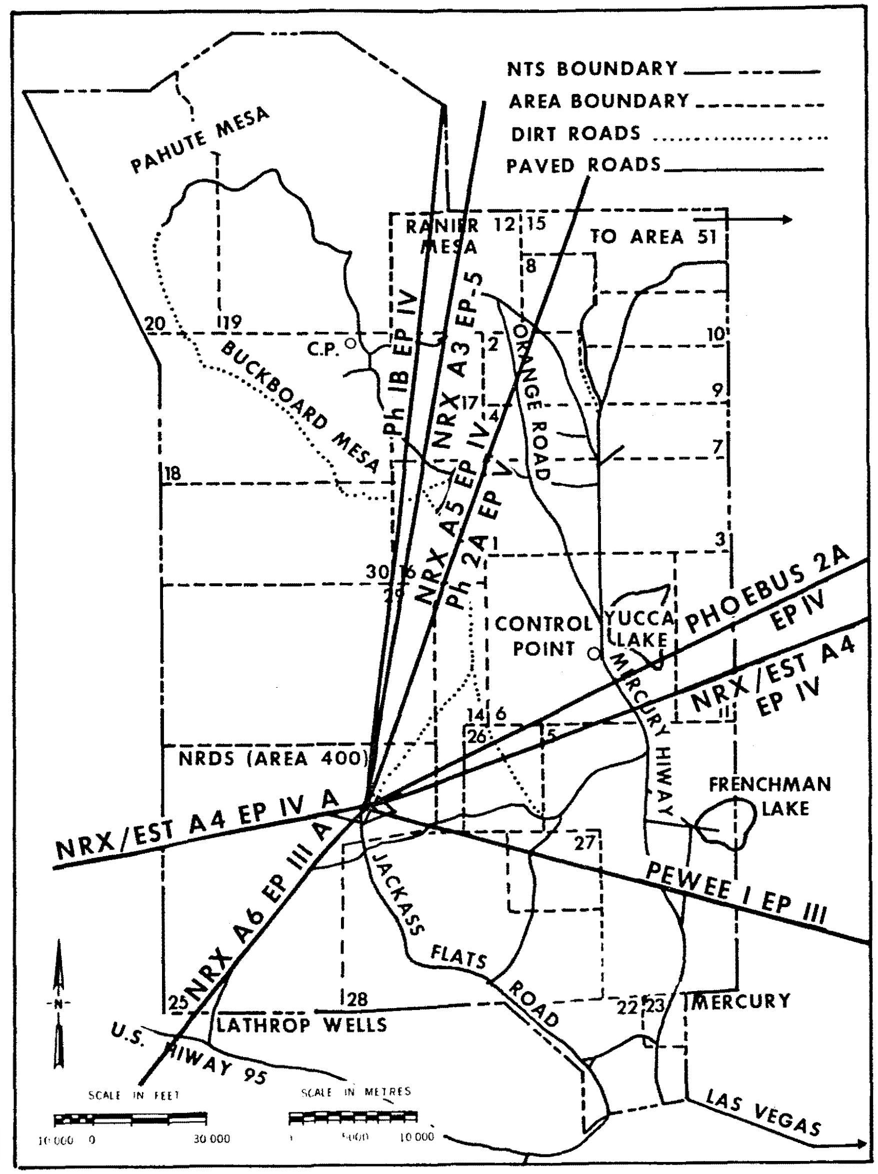

Figure E-27. Cloud Centerlines for Selected Reactor Tests, Figure 11, NERCL-LV-539-6 (EPA 1974).

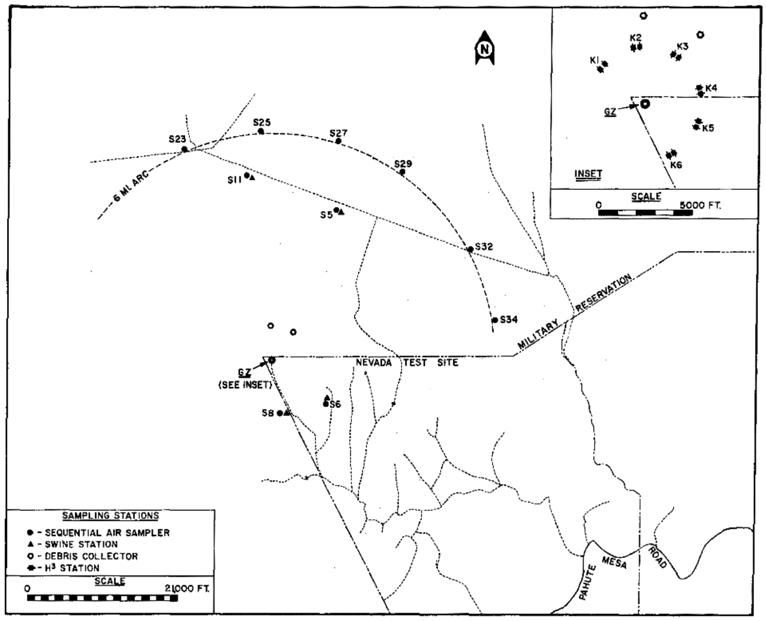

Figure E-28. Locations of All of the Bio-Medical Division's
Close-In Field Instrumentation - Schooner, Figure 10 (AEC 1968).

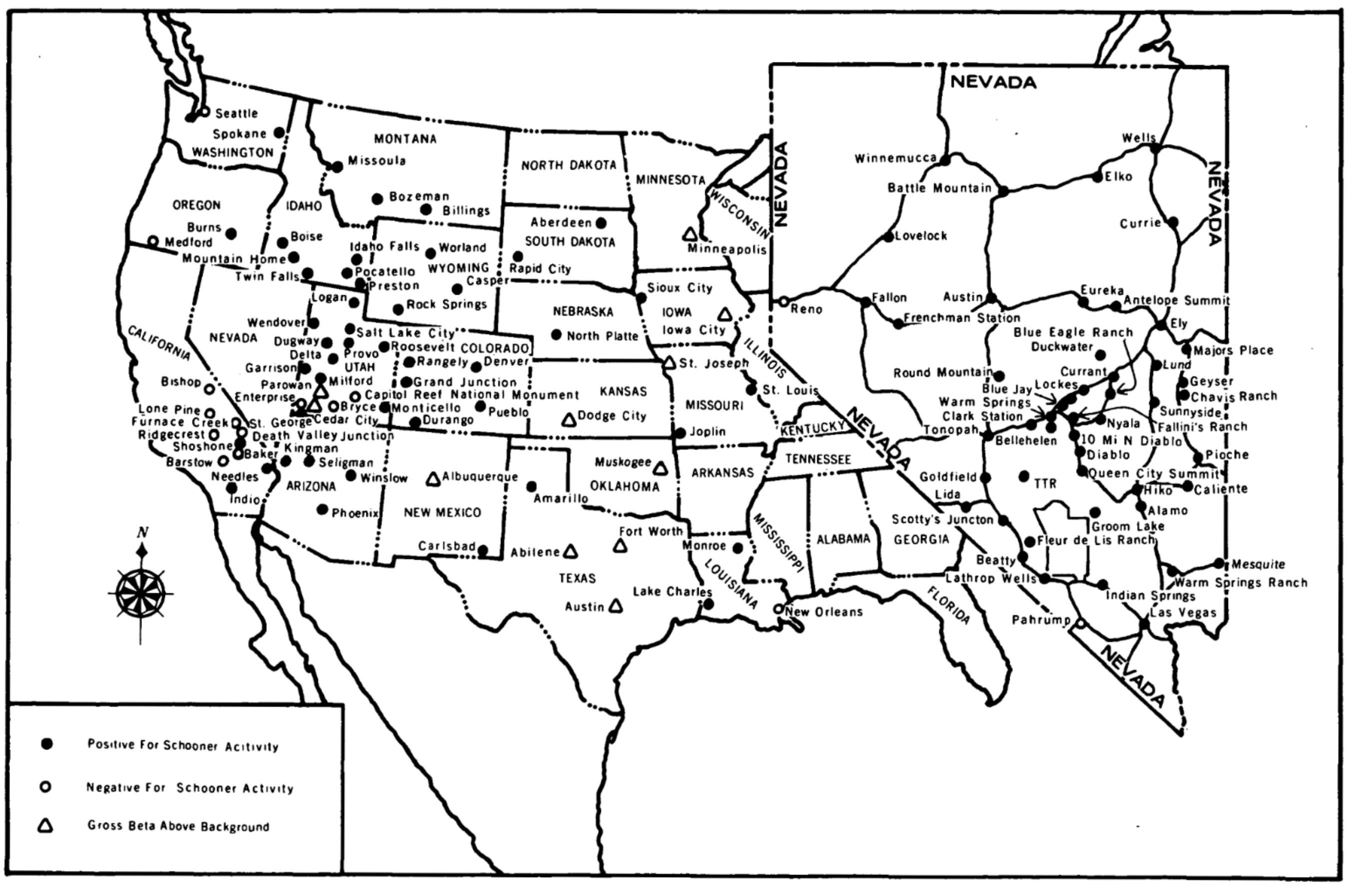

Figure E-29. Air Sampling Locations – Schooner, Figure 6 of SWRHL-83r (1968).

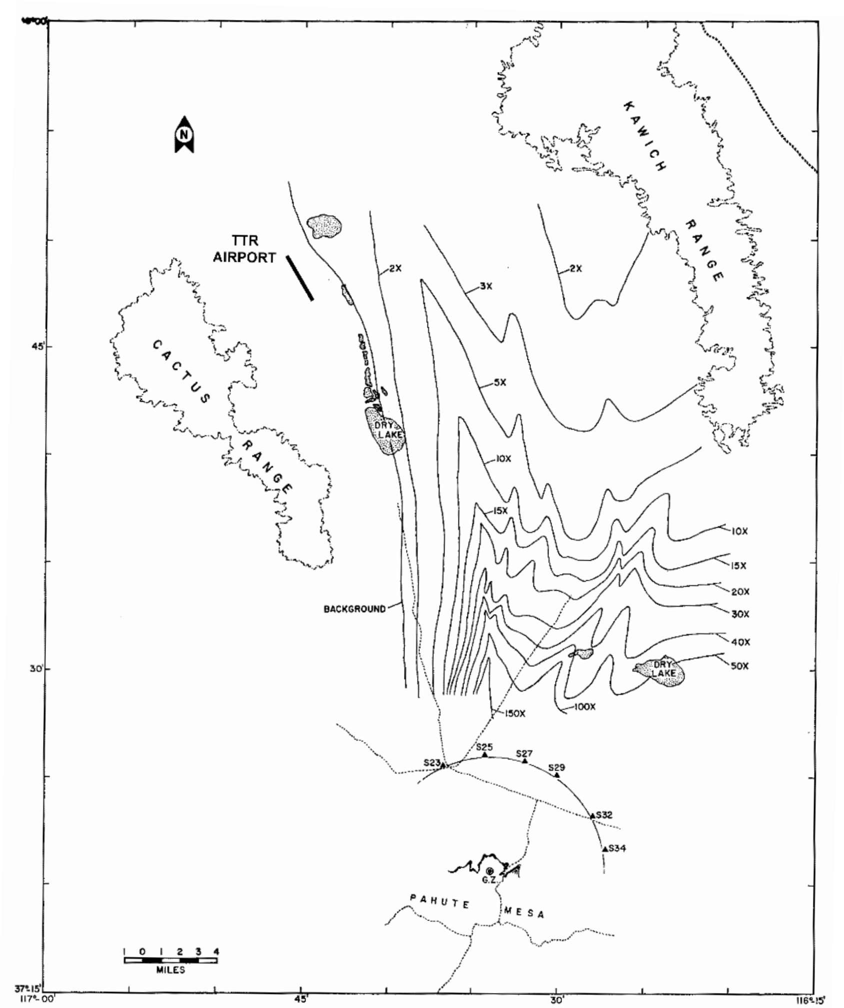

Figure E-30. Aerial Measurements of the Schooner Fallout Field as Measured by EG&G Corporate NATS Aircraft 7 days After the Event. The Contours Represent Multiples (2X, 10X, 50X, etc.) of Background, which was ~ 15 to 20 μR/h, Adapted from Figure 18 (AEC 1969).

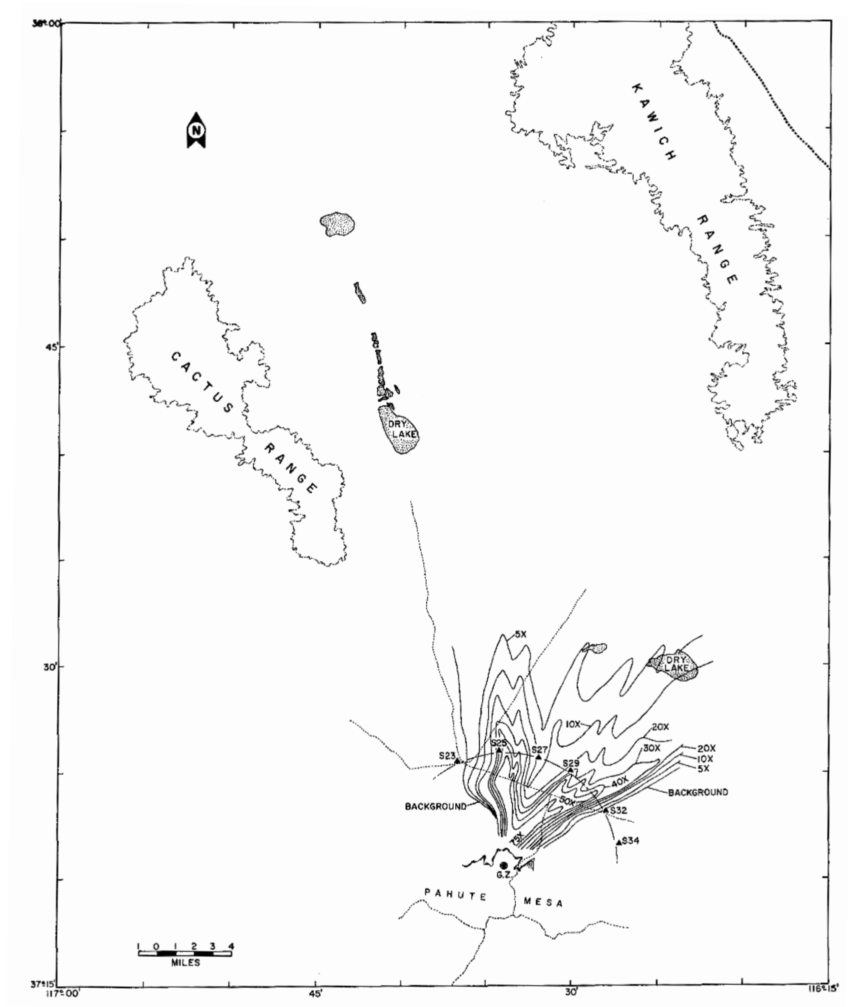

Figure E-31. Aerial Measurements of the Schooner Fallout Field as Measured by EG&G Corporate NATS Aircraft 13 days After the Event. The Contours Represent Multiples (2X, 10X, 50X, etc.) of Background, which was ~ 15 to 20 μR/h, Figure 19 (AEC 1969).

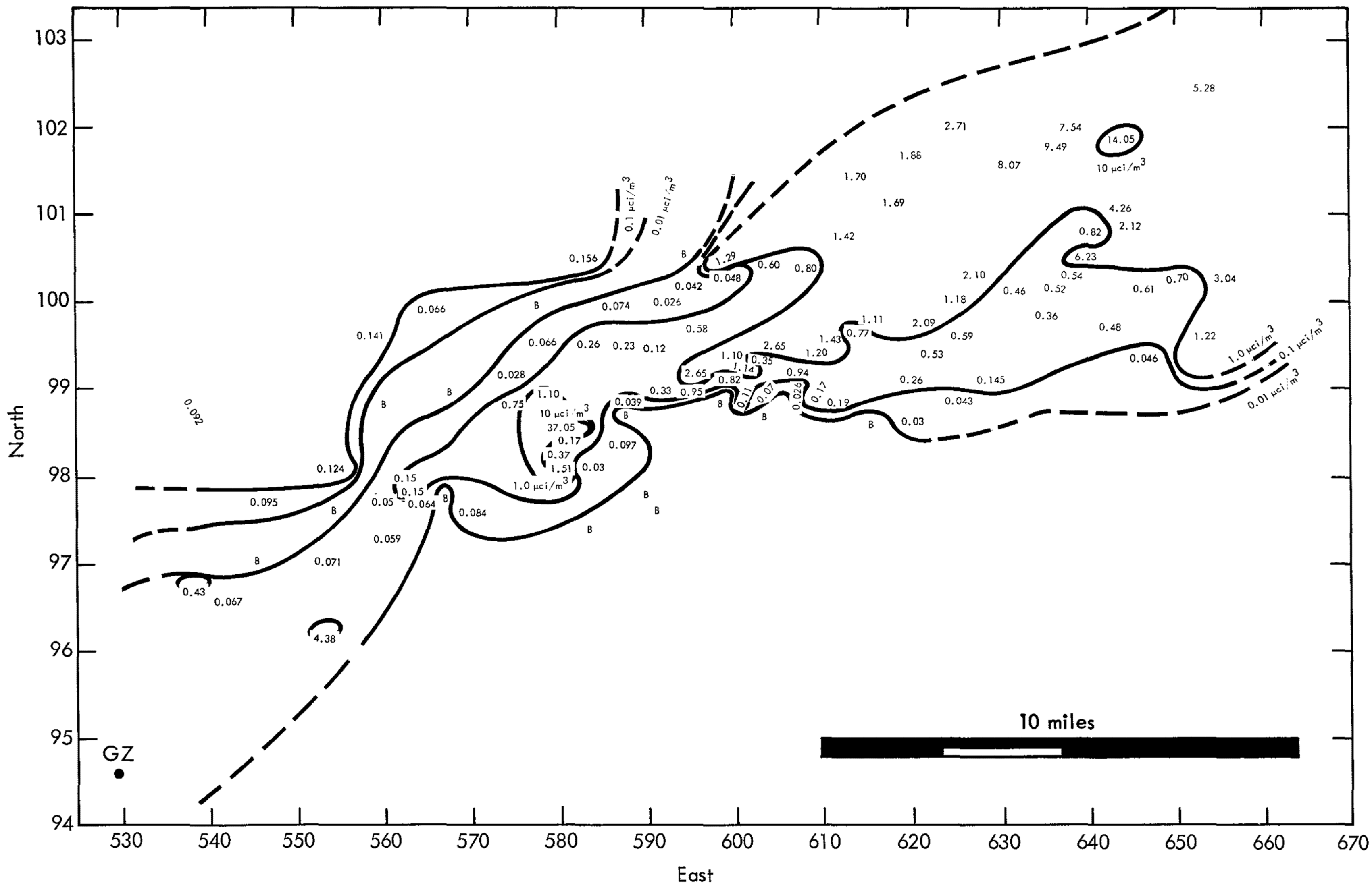

Figure E-32. The Schooner Cloud Contour Based on Measurements Made at H+1 h. The Isopleths are Based on the Concentration of Gross Activity at H+50 h Integrated from 18,500ft MSL to Terrain Surface. The Coordinates are Based on the Central Nevada Grid Coordinate System and the Unit is 10,000 ft. The dashed-line Contours are Based on Extrapolated Data. B = background reading. Figure 30 (AEC 1969).

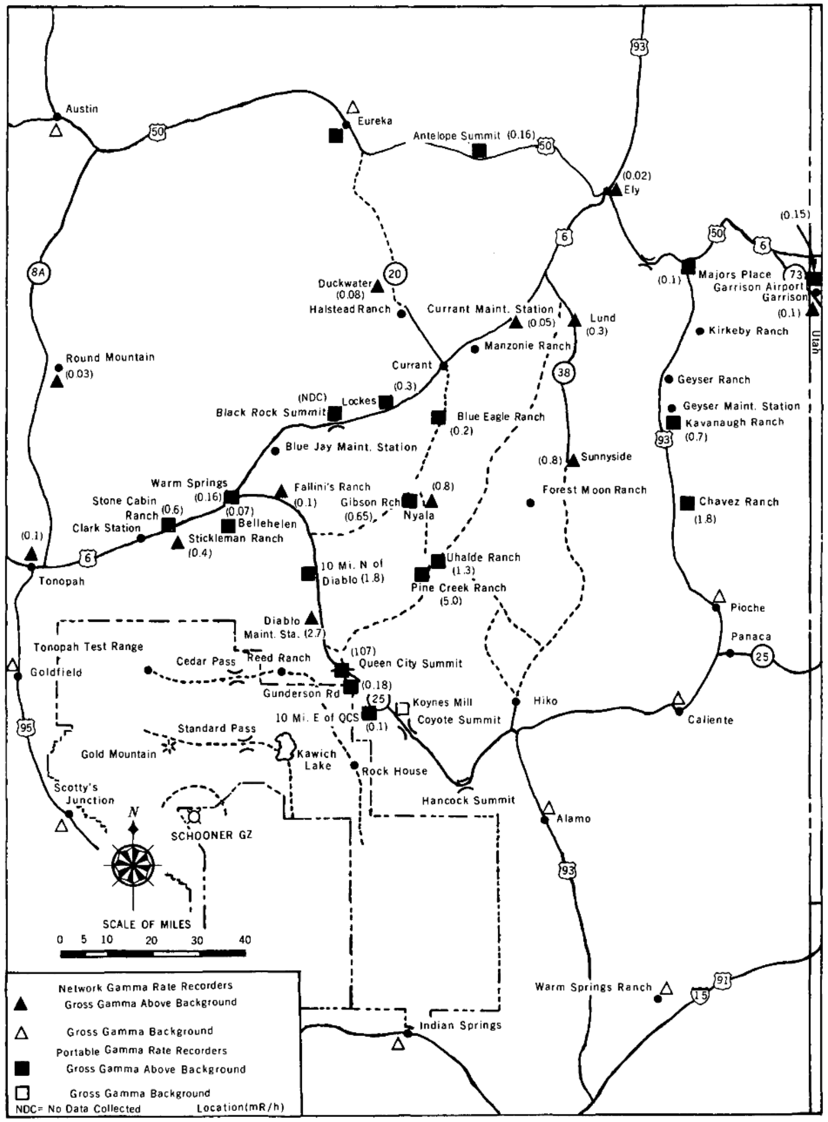

Figure E-33. Maximum Observed Exposure Rates by Recorders - Schooner, Figure 5 of SWRHL-83r (1968).

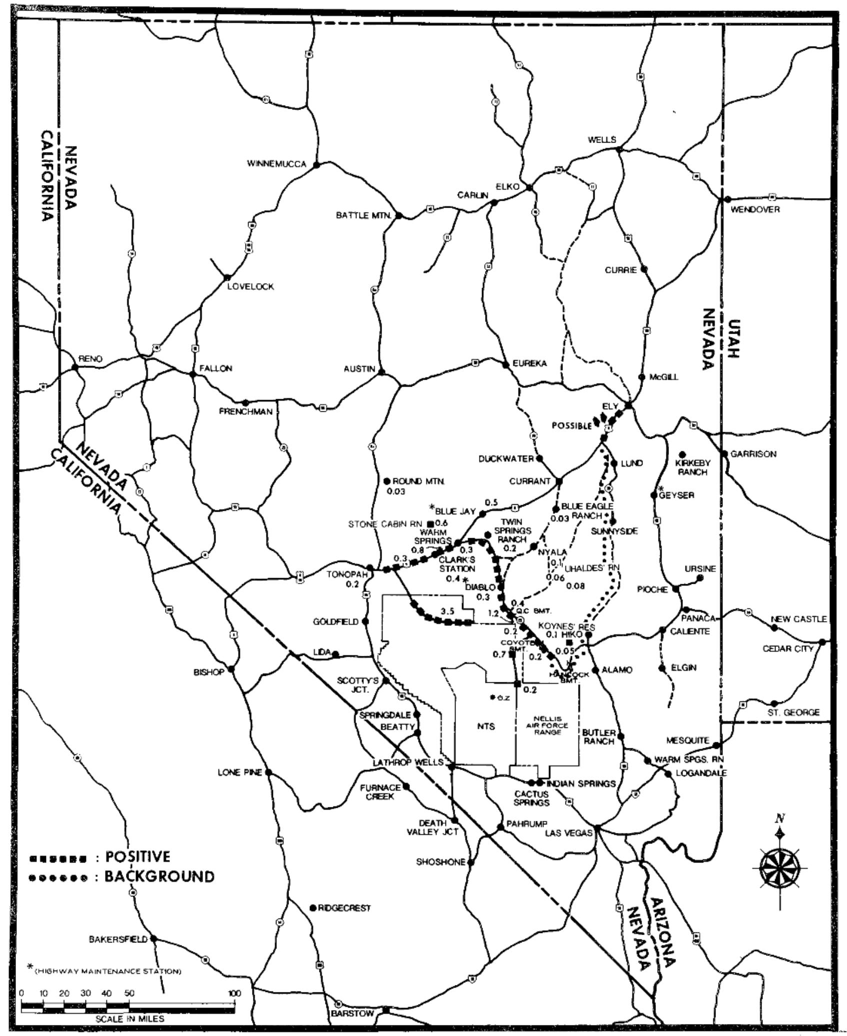

Figure E-34. Areas Monitored and Highest Exposure Rates (mR/h) – Nevada Baneberry D-Day (18 Dec 70), Figure 6 of SWRHL-107r (1972).

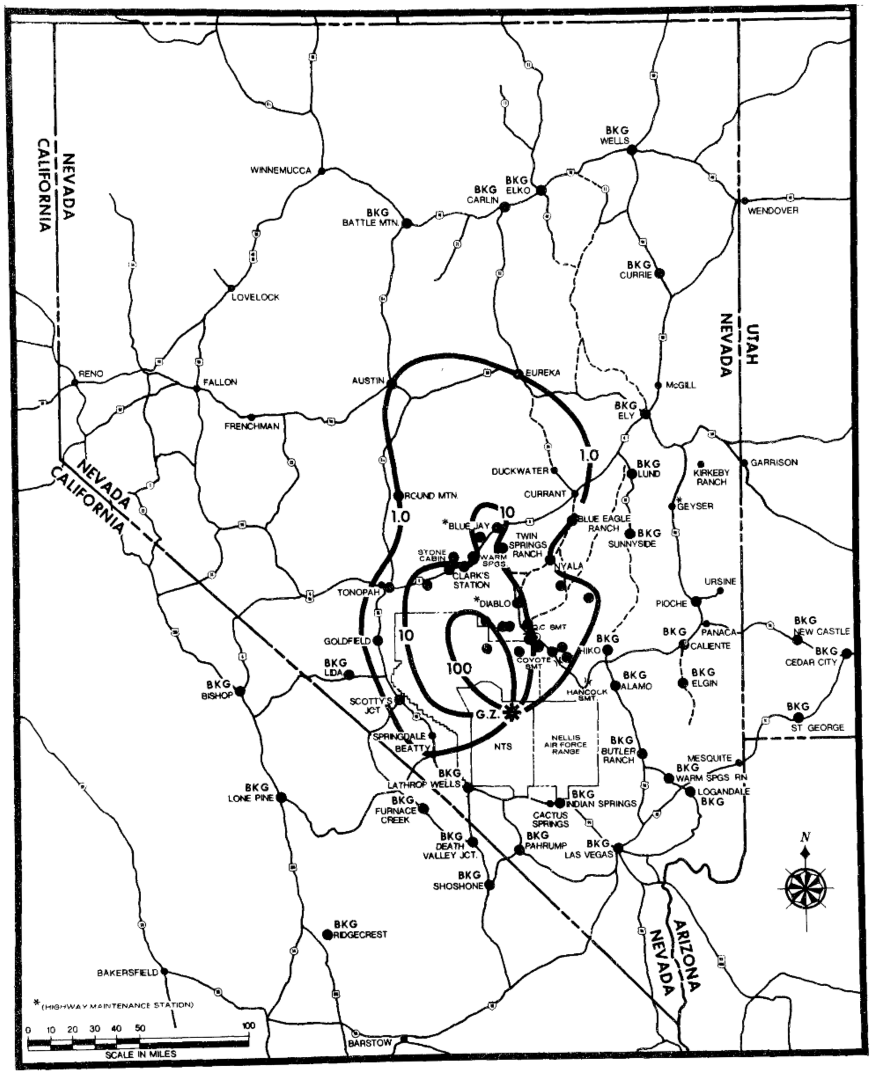

Figure E-35. Net Infinity External Gamma Exposures (mR) - for Baneberry Test, Figure 9 (SWRHL-107r 1972).

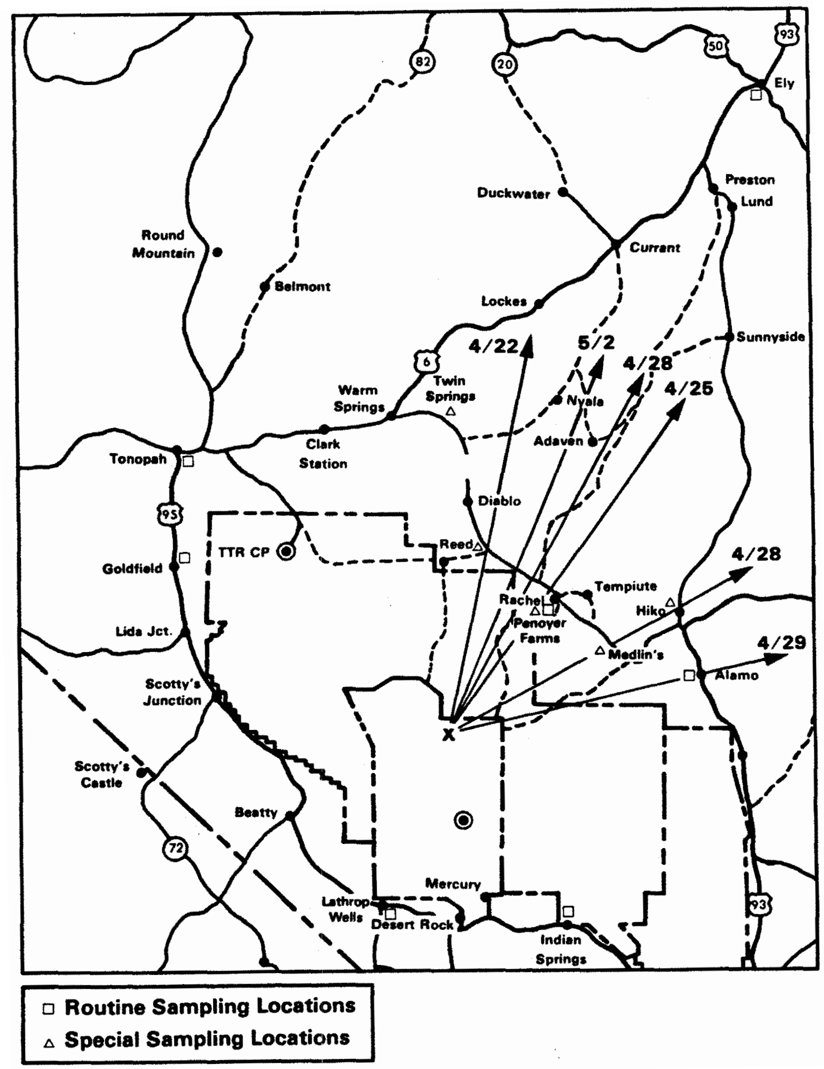

Figure E-36. Special Sampler Locations and Centerline Winds, Mighty Oak, Figure 2, EPA-600 4-86-030 (1986).

TABLE E-7. Example of Estimated Effective Dose from Inhalation Exposure for Indian Springs from Shot Bandicoot.

Factor	Chemical Form	Key Radionuclides					
		I-131	I-133	I-135	Te-132	Ba-140	Data Source
Integrated Airborne Concentration (pCi-h/m^3)	Aerosol	1194	9861		6211	1102	TABLE 5, SWRHL-4r
	Vapor	124.6	4671	2768			
Estimated Inhalation Intake (pCi)	Aerosol	644.6	5324.9		3353.8	595.1	-
	Vapor	67.3	2522.3	1494.7			
	Inhalation Type/AMAD	I-131	I-133	I-135	Te-132	Ba-140	Data Source
Effective Dose Coefficients (mrem/pCi)	F / 1 µm	2.81E-05	5.55E-06	1.22E-06	6.66E-06	3.70E-06	ICRP Report 68
	F / 5 µm	4.07E-05	7.77E-06	1.70E-06	8.88E-06	5.92E-06	
	M / 1 µm	-	-	-	8.14E-06	-	
	M / 5 µm	-	-	-	1.11E-05	-	
	Vapor	7.40E-05	1.48E-05	3.40E-06			
Effective Dose (mrem)	F / 1 µm	1.81E-02	2.96E-02			2.20E-03	
	F / 5 µm	2.62E-02	4.14E-02			3.52E-03	
	M / 1 µm				2.73E-02		
	M / 5 µm				3.72E-02		
	Vapor	4.98E-03	3.73E-02	5.09E-03			Total
	Sum Max	0.0312	0.0787	0.00509	0.0372	0.00352	0.156

TABLE E-8. Example of Estimated Effective Dose and Equivalent Dose to Thyroid from Inhalation Exposure for Indian Springs from Shot Pike.

Factor	Inhalation Type/AMAD	Key Radionuclides			Data Source
		I-131	I-133	I-135	
Effective Dose (mrem)	F / 1 μm	0.0242	0.155		ICRP Report 68
	F / 5 μm	0.0351	0.216		
	Vapor	0.000959	0.00762	0.00138	Total
	Sum Max	0.0361	0.224	0.00138	0.261
Equivalent Dose to Thyroid (mrem)	F / 5 μm	0.695	4.13		
	Vapor	0.0190	0.146	0.0263	Total
	Sum	0.713	4.27	0.0263	5.01

Appendix F

External Exposure Monitoring Data for DoD Personnel Assigned Duties on Nevada Test Site

Table F-1. Dosimetry Data References, Defense Nuclear Agency Reports.

Report Number	Title	Date
6330F-1	Operations, Events, Census Report, Volume 1, 1962 - 1966	15-Aug-85
6330F-2	Operations, Events, Census Report, Volume II, 1967 - 1974	15-Aug-85
6330F-3	Operations, Events, Census Report, Volume III, 1975 - 1980	15-Aug-85
6330F-4	Operations, Events, Census Report, Volume IV, 1980 - 1985	15-Aug-85
6330F-5	Operations, Events, Census Report, Volume V, 1986	15-Aug-85
6330F-6	Operations, Events, Census Report, Volume VI, 1987 - 1992	15-Aug-85

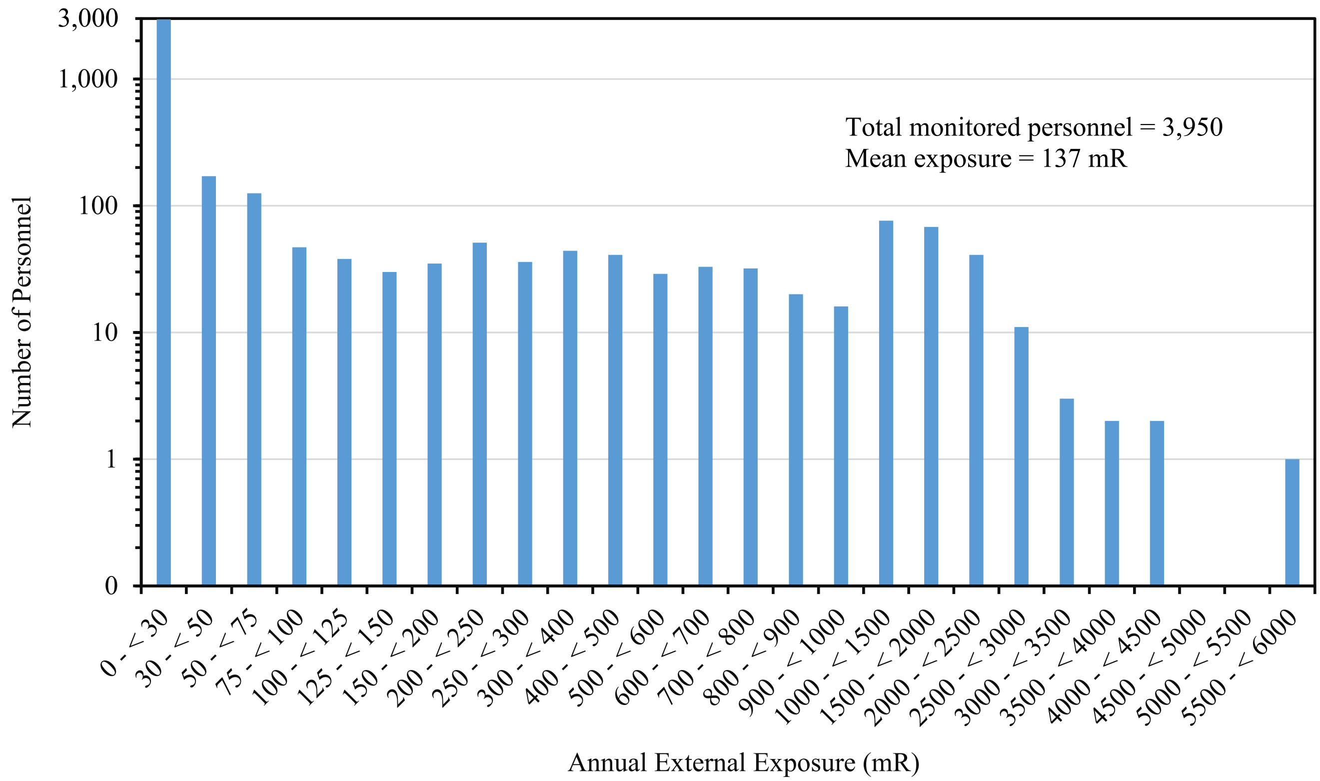

Figure F-1. Dosimetry Monitoring for External Exposure to DoD Personnel Assigned Duties on NTS in 1962, Data from DNA Report 6330F-1 (1985).

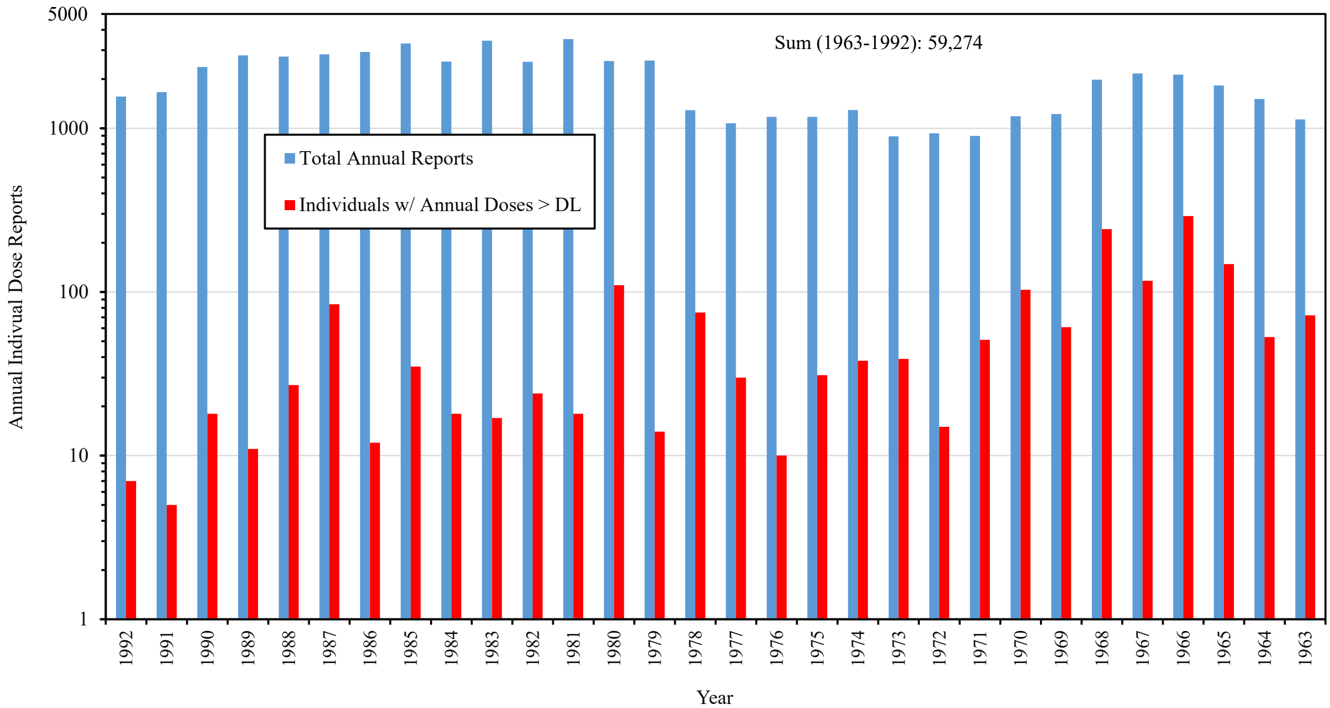

Figure F-2. Dosimetry Monitoring Personnel Numbers for External Exposure to DoD Personnel Assigned Duties on NTS from 1963 to 1992, Data from DNA Reports Listed in Table F-1.

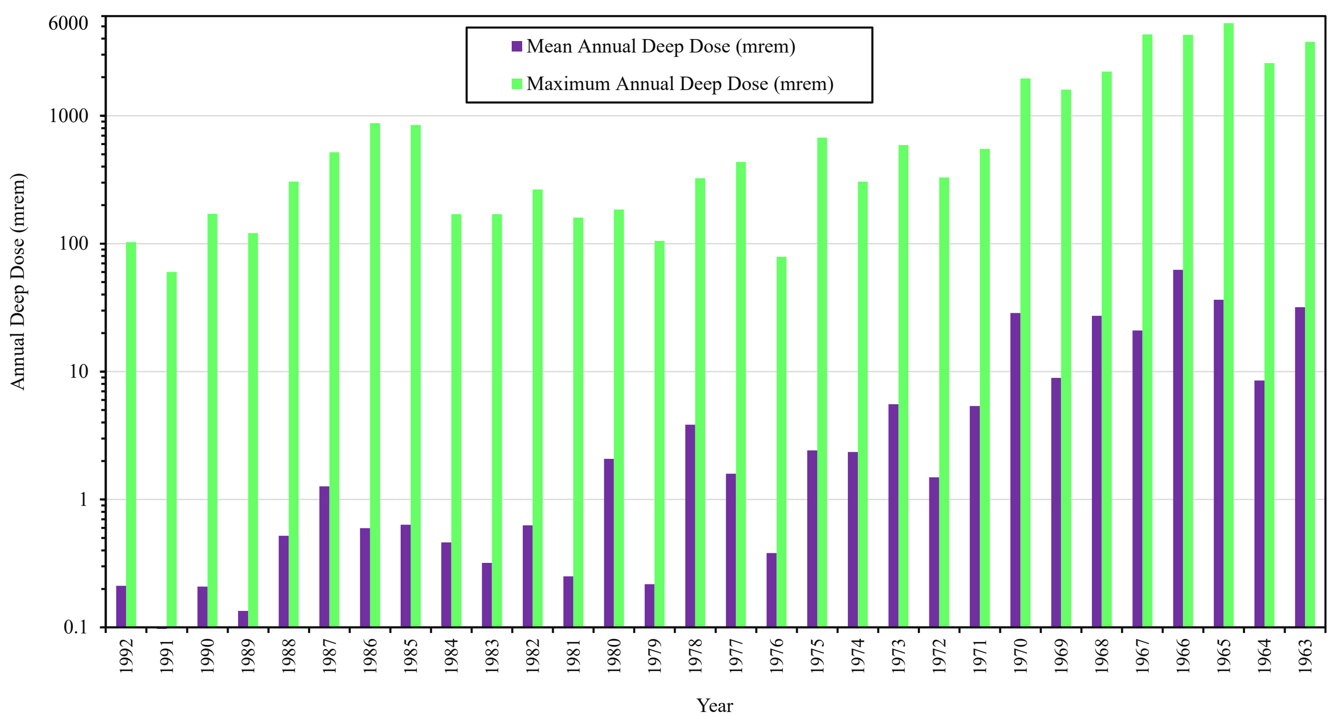

Figure F-3. Dosimetry Monitoring Exposure Summaries Data for DoD Personnel Assigned Duties on NTS from 1963 to 1992, Data from DNA Reports Listed in Table F-1.

Appendix G

Clean Slates, Double Tracks, and Project 57 Data, and Miscellaneous Data for Other Sites

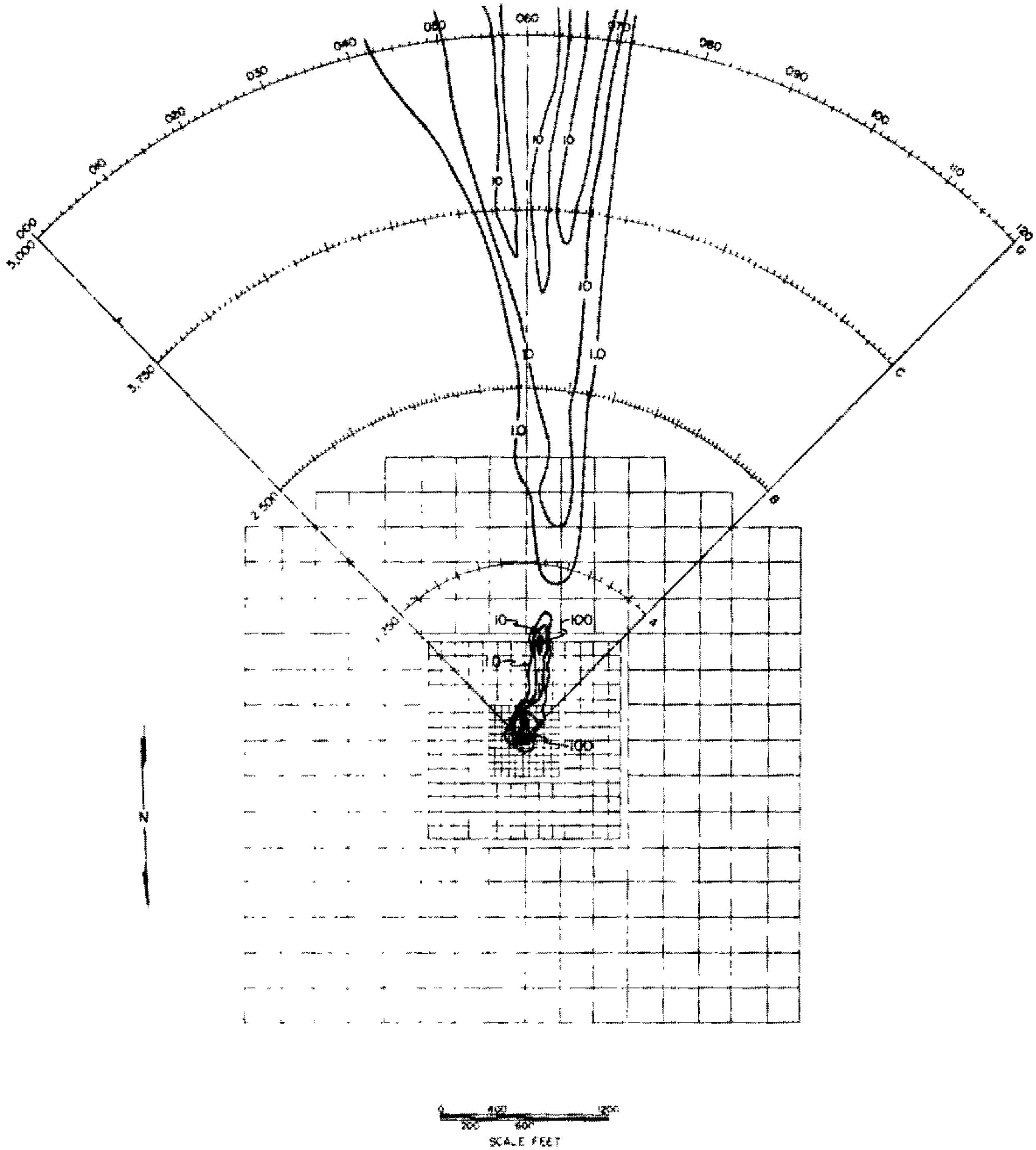

Figure G-1. Double Tracks Deposition Contours by Alpha Survey in μg/m², Figure 4.3 of DASA POIR 2500 (1963).

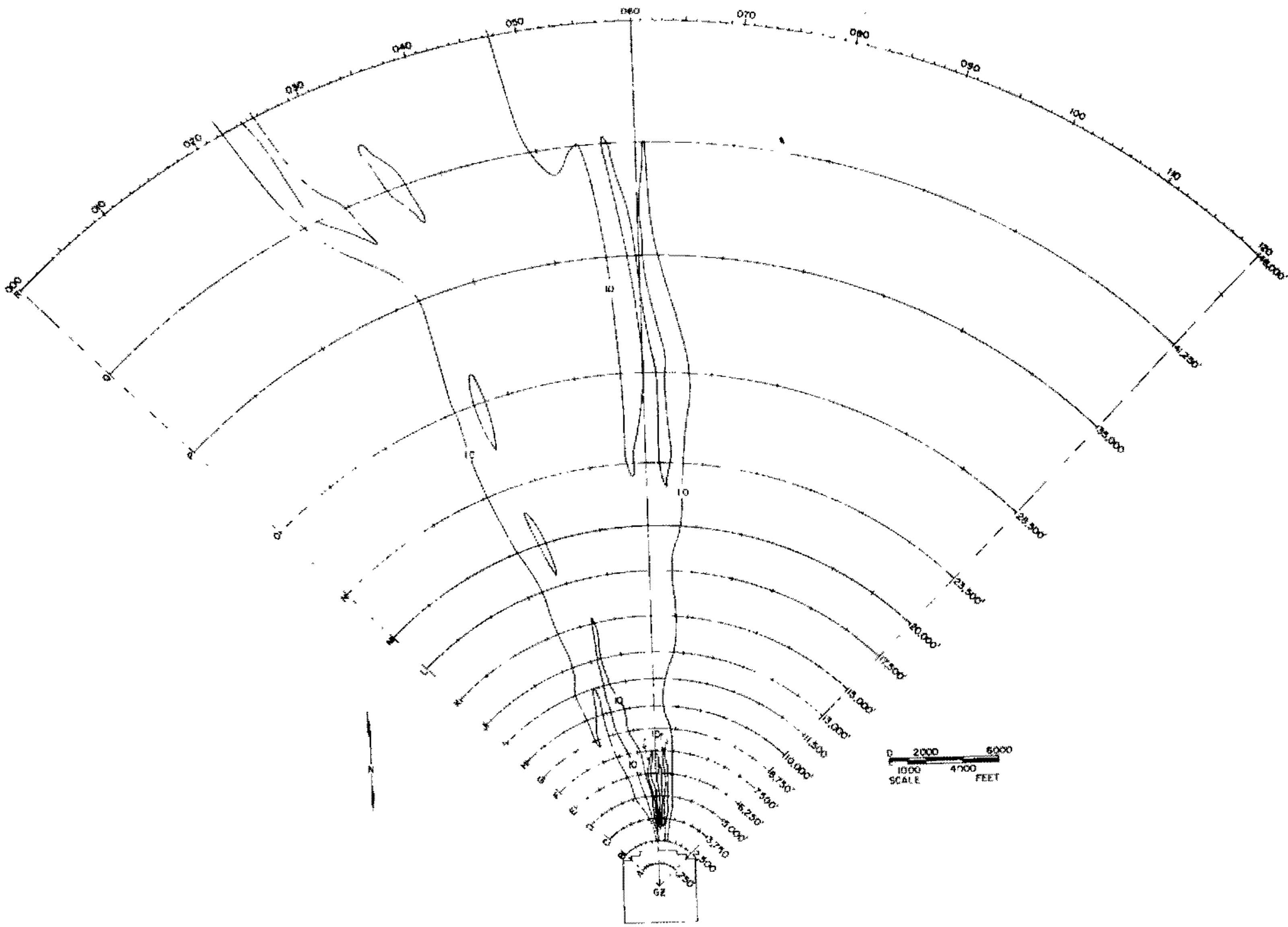

Figure G-2. Double Tracks Deposition Contours by Alpha Survey in $\mu g/m^2$, Figure 4.4 of DASA POIR 2500 (1963).

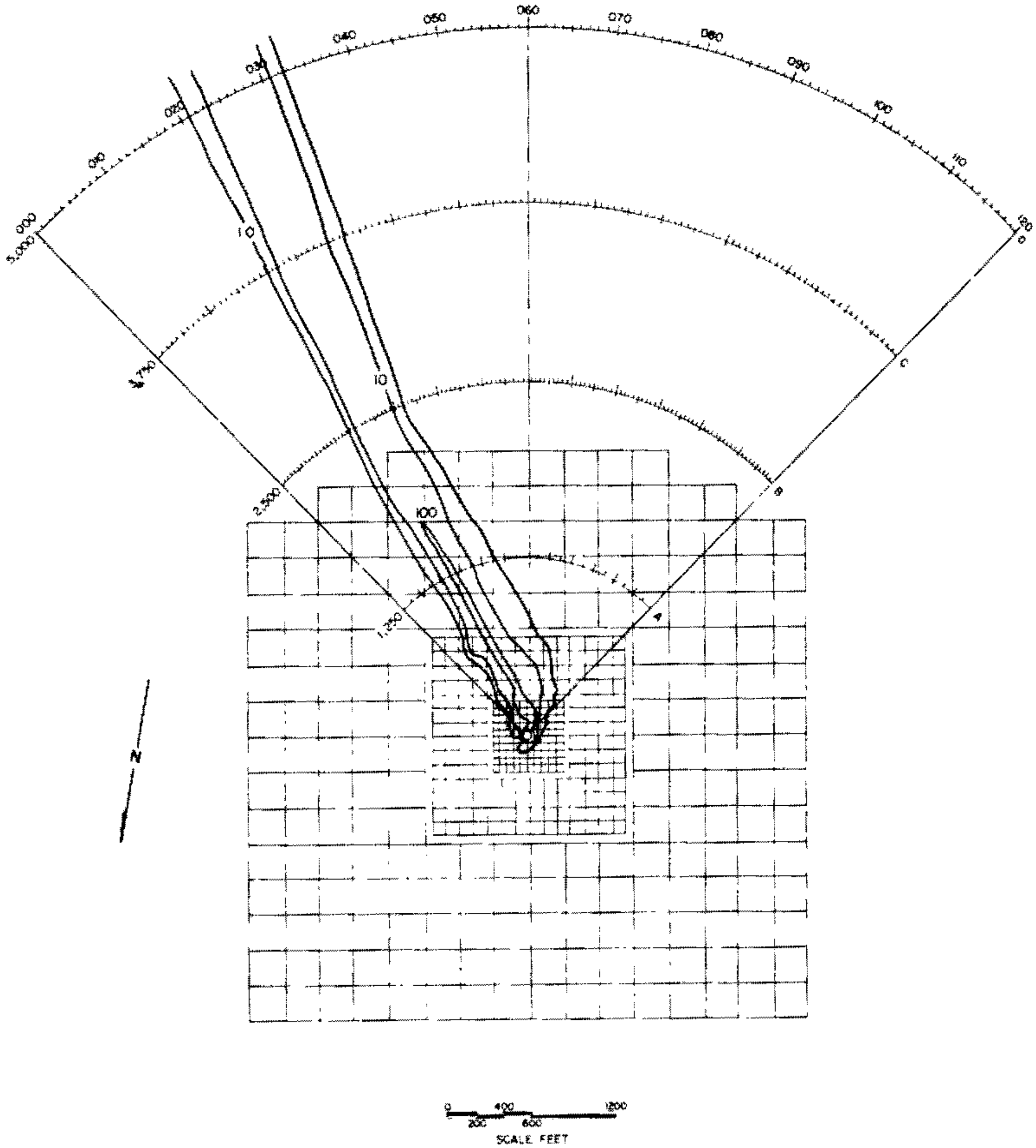

Figure G-3. Clean Slate No. 1 Deposition Contours by Alpha Survey in μg/m^2, Figure 5.2 of DASA POIR 2500 (1963).

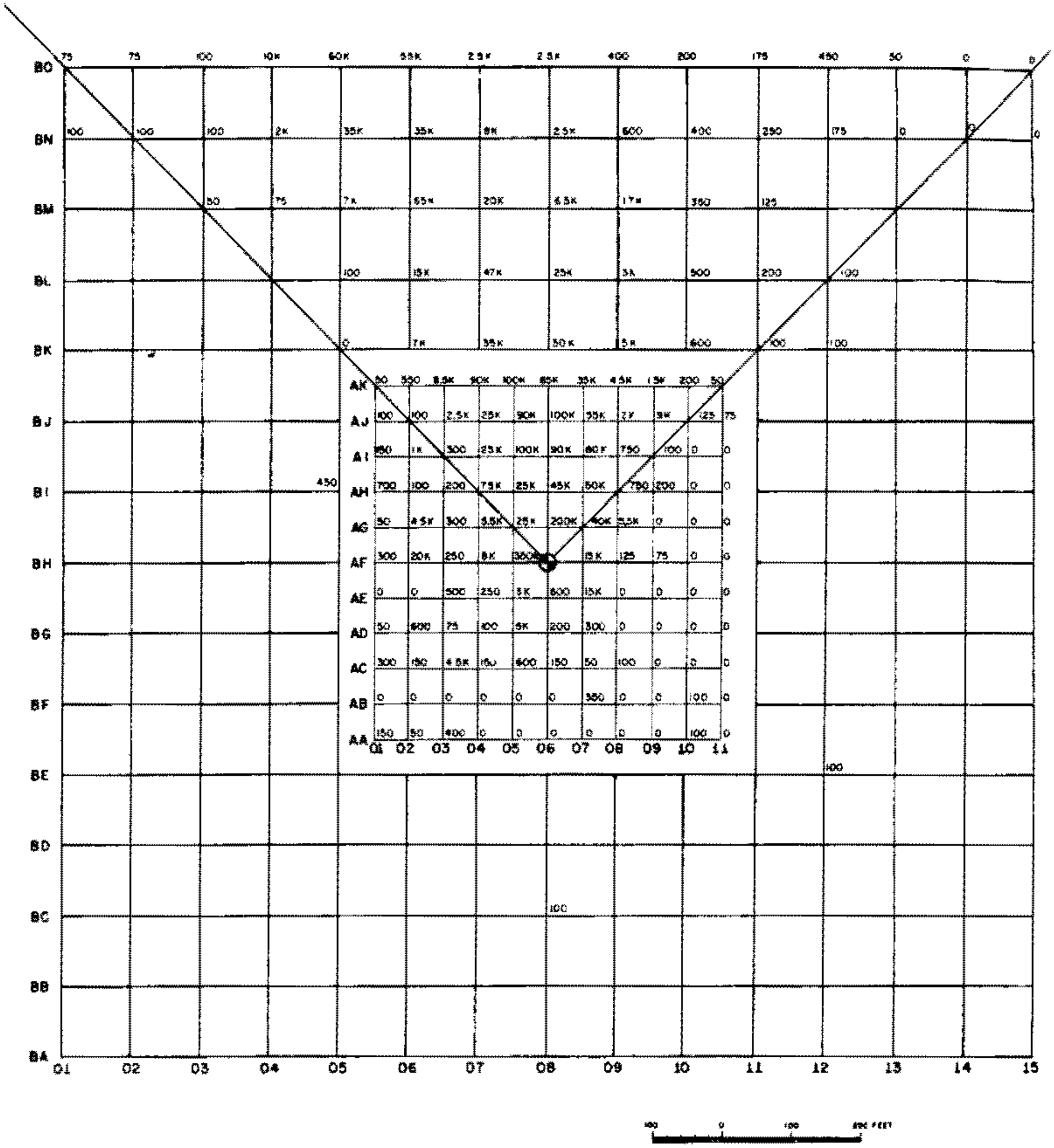

Figure G-4. Clean Slate No. 1 Deposition Contours by Alpha Survey Meter Readings (cpm) in GZ Areas A and B, Figure 5.4 of DASA POIR 2500 (1963).

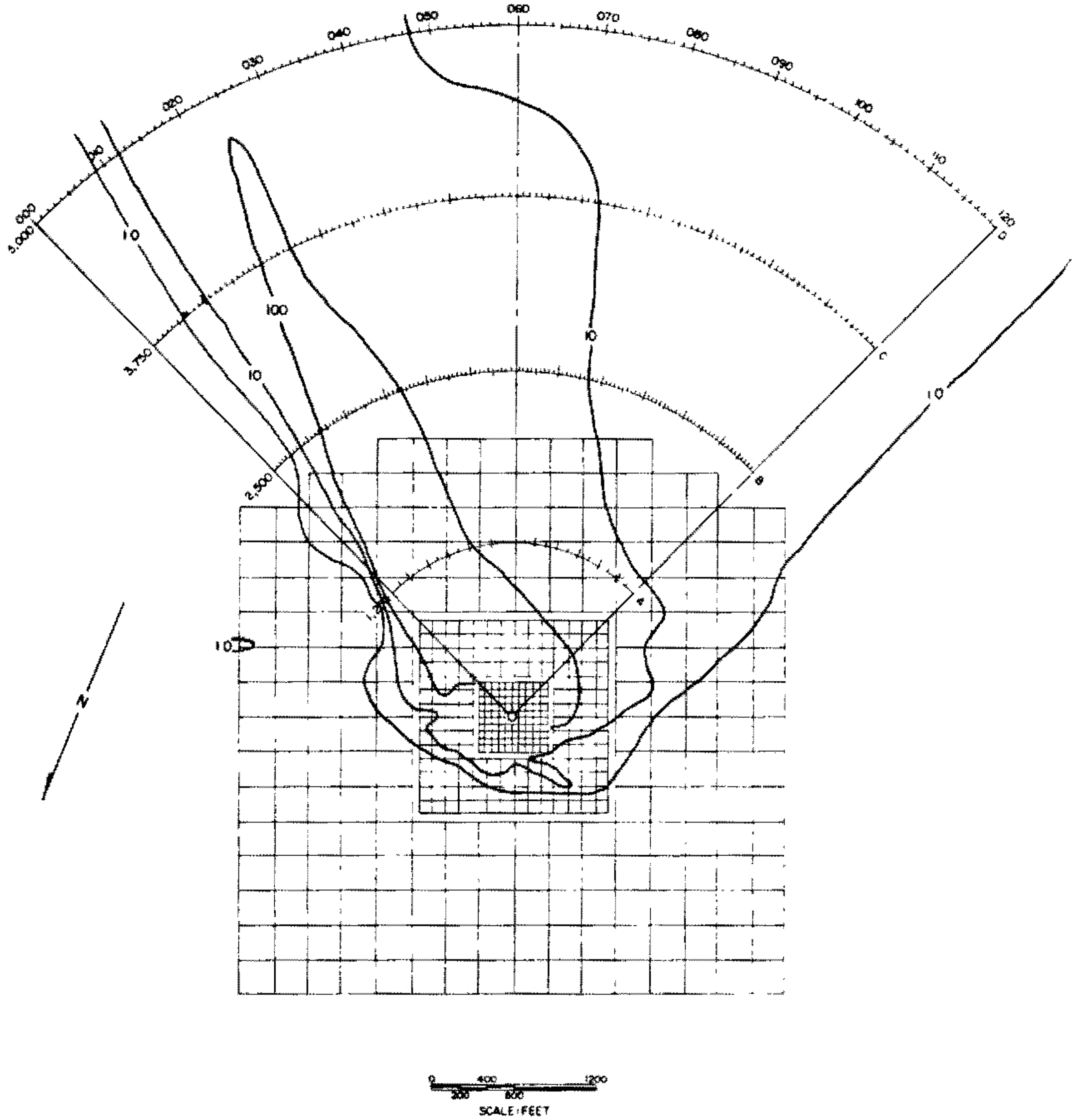

Figure G-5. Clean Slate No. 2 Deposition Contours by Alpha Survey in $\mu g/m^2$, Figure 6.5 of DASA POIR 2500 (1963).

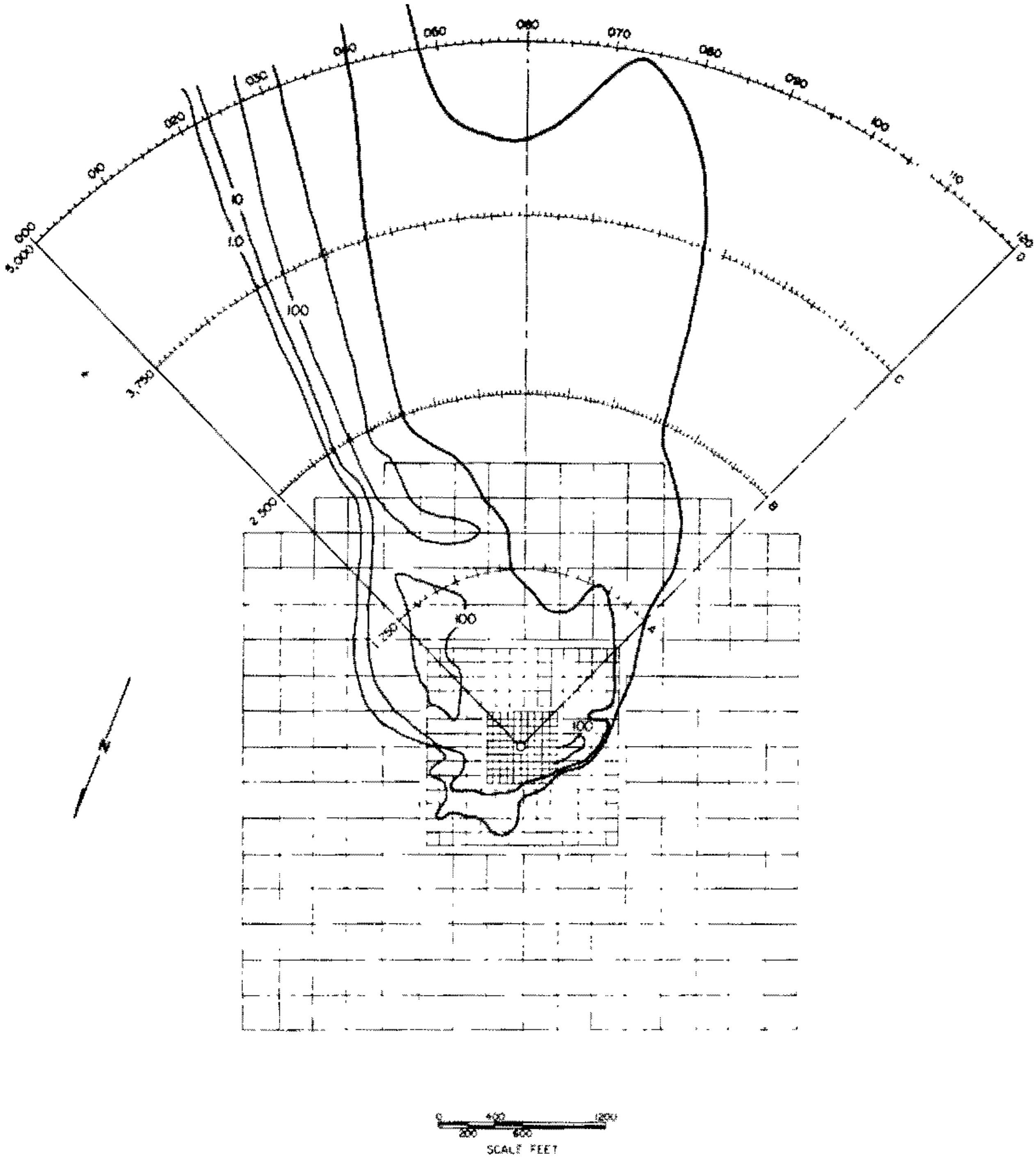

Figure G-6. Clean Slate No. 3 Deposition Contours by Alpha Survey in $\mu g/m^2$, Figure 6.5 of DASA POIR 2500 (1963).

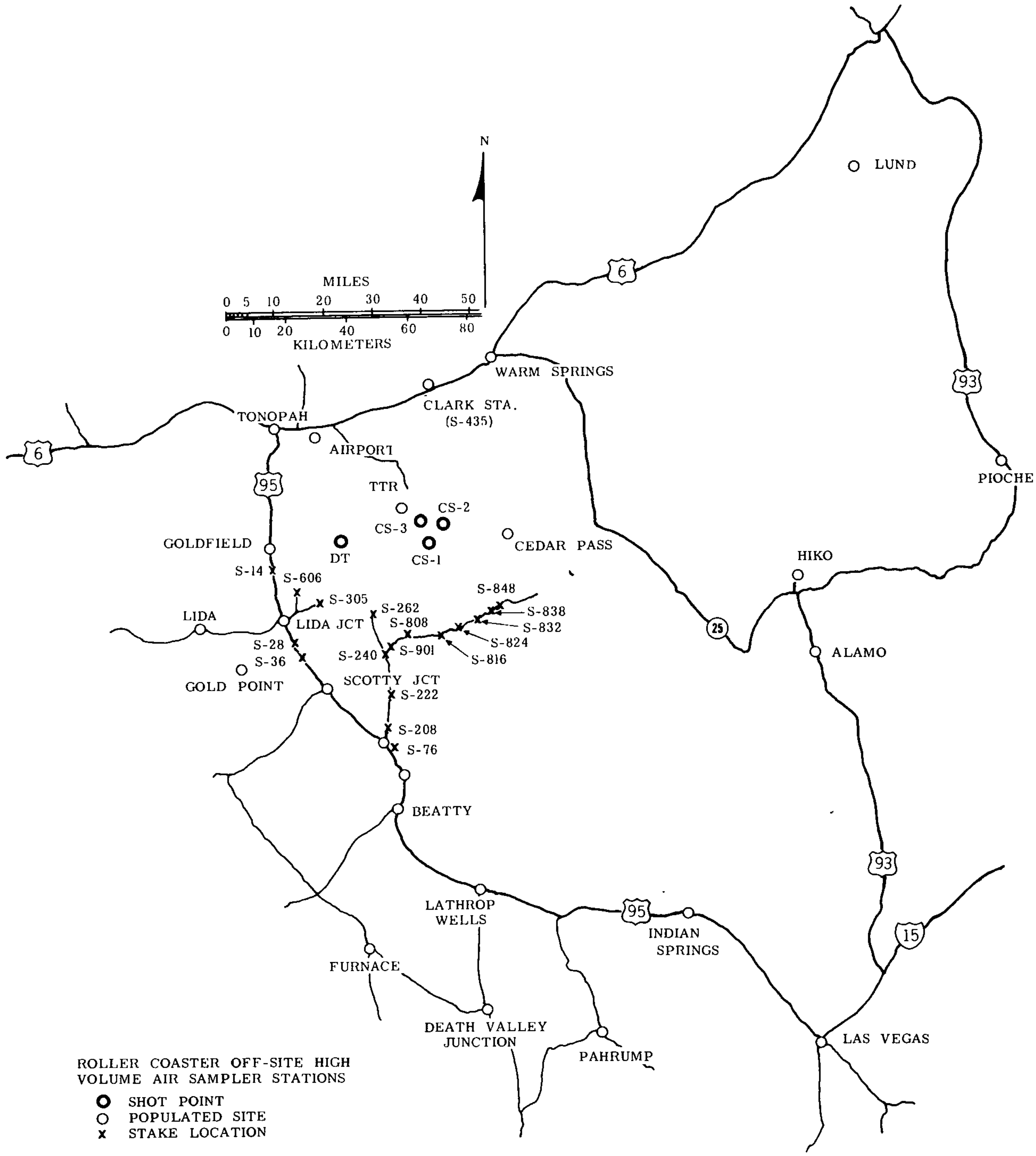

Figure G-7. Roller Coaster Off-Site Higher Volume Air Sampler Stations, Figure 4 from SC-RR-69-788 (1970).

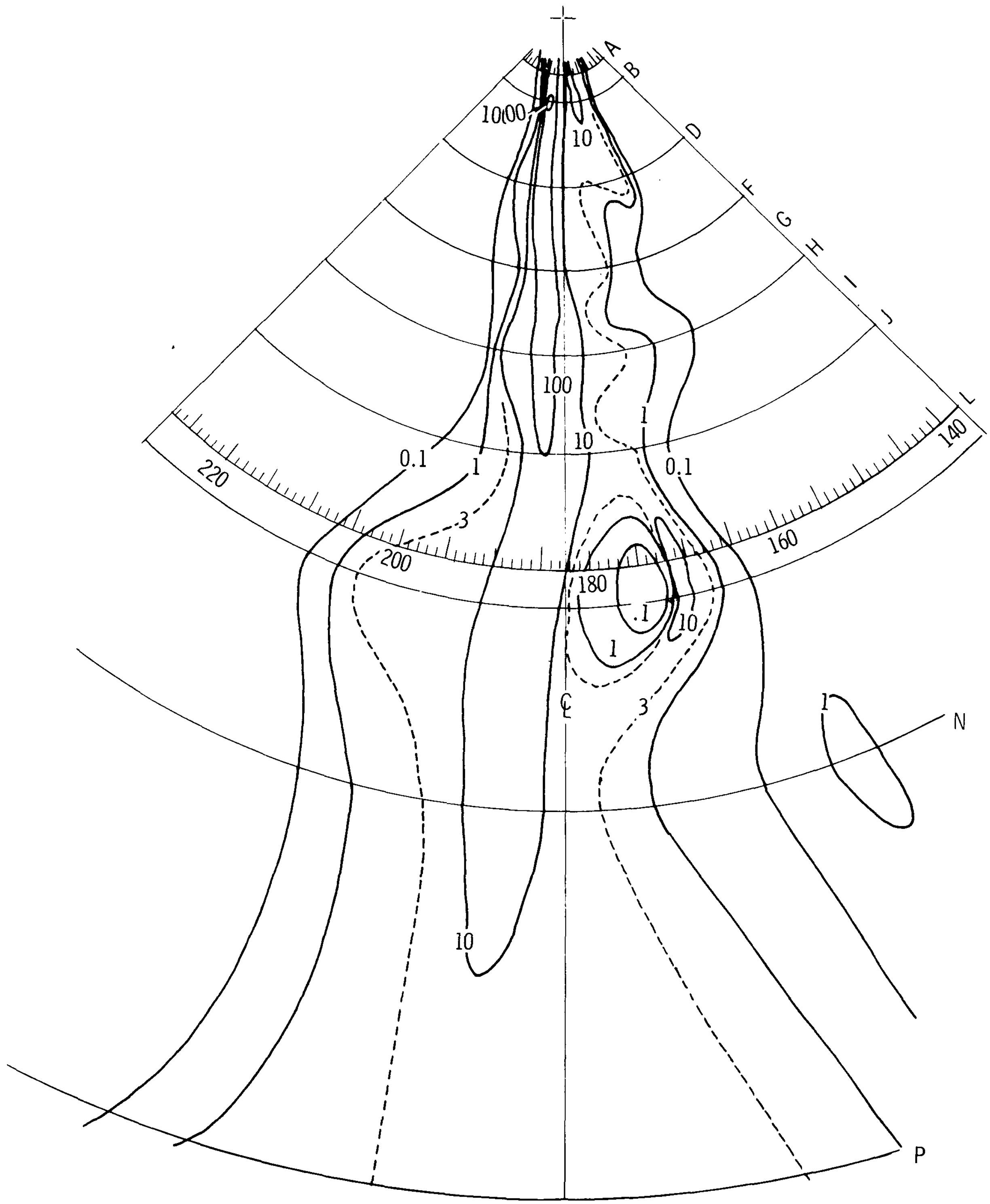

Figure G-8. Double Tracks Respirable Contours, μg sec/m^3, Figure 4 from SC-RR-69-788 (1970).

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†$\mu g\text{-}sec/m^3$	$pCi\text{-}h/m^3$	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
Stake 14	Y	15 - 16 May	18	1650	0.027	0.10	0.01	0.18				DT
Stake 28	Y	14 - 16 May	33.9	3000	2.98	58.4	5.9	108				DT
Stake 435 (Clark Station)	Y	14 - 16 May	42	3798	0.0135	0.40	0.04	0.73				DT
Stake 36	Y	14 - 15 May	28.4	2560	1.28	19.3	1.95	35.8				DT
Stake 76 (Asphalt Plant)	Y	14 - 15 May	30.7	2750	6.21	98.0	9.9	182				DT
Stake 208	Y	14 - 15 May	20.7	2180	0.0643	0.20	0.02	0.37				DT
Stake 222	N	14 - 16 May	20.7	2425	0.209	2.87	0.29	5.32				DT
Stake 240	N	14 - 16 May	31.9	3004	0.0989	1.48	0.15	2.75				DT
Stake 262	N	14 - 16 May	35.1	3333	47.3	960	97	1780				DT
Stake 305 (Stonewall Springs)	Y	14 - 16 May	32.2	3200	0.776	13.0	1.31	24.0				DT
Stake 606	Y	14 - 15 May	29.6	3000	0.771	13.8	1.39	25.5				DT
Beatty	Y	14 - 16 May	48.6	6091	2.54	94.0	9.5	174				DT
Death Valley Junction	Y	14 - 15 May	48	5140	0.601	20.8	2.1	38.5				DT
Furnace Creek	Y	15 - 15 May	23.5	1896	0.257	3.96	0.4	7.33				DT
Goldfield	Y	14 - 16 May	48	4611	0.0113	0.20	0.02	0.37				DT
Gold Point	Y	14 - 16 May	48.0	3168	0.149	1.09	0.11	2.02				DT
Lathrop Wells	Y	14 - 16 May	48.0	2714	0.266	4.06	0.41	7.52				DT
Lida	Y	14 - 15 May	15.5	1291	0.0405	0.40	0.04	0.73				DT
Lida Junction	Y	14 - 15 May	23.9	2841	1.53	23.8	2.4	44.0				DT
Scotty's Junction	Y	14 - 16 May	48	4860	2.66	74.2	7.5	137				DT
Tonopah	Y	14 - 16 May	49	5062	0.0203	0.20	0.02	0.37				DT
Tonopah Airport	Y	14 - 16 May	47.8	5140	0.049	0.79	0.08	1.47				DT
TTR (Operations)	N	14 - 16 May	48	5304	0.0248	0.30	0.03	0.55				DT
Warm Springs	Y	14 - 16 May	48	4590	0.0295	1.39	0.14	2.57				DT
Stake 108	Y	25 May	8	782	0.0855	0.37	0.037	0.68				CS1
Stake 108	Y	25 - 26 May	16	1237	0.0221	0.19	0.019	0.35				CS1

* Inhalation intake estimated using breathing rate of 0.54 m^3/h and assuming receptor at location † Assume 0.066 Ci/g for DT and CS WGP; To convert from $\mu g\text{-}sec/m^3$ to $pCi\text{-}h/m^3$ multiply by 18.33

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†$\mu g\text{-}sec/m^3$	$pCi\text{-}h/m^3$	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
Stake 808	N					17.8	1.8	33.0				CS1
Stake 816	N					198	20	367				CS1
Stake 824	N					238	24	440				CS1
Stake 832	N					2.4	0.24	4.4				CS1
Stake 838	N					0.6	0.06	1.10				CS1
Stake 843	N					0.2	0.02	0.37				CS1
Stake 848	N					2.7	0.27	4.95				CS1
Stake 913	N					0.5	0.05	0.92				CS1
Stake 921	N					0.1	0.01	0.18				CS1
Alamo	Y	24 - 27 May	71.5	6977	0.0164	0.69	0.07	1.28				CS1
Beatty	Y	24 - 27 May	73.7	9179	0	0.00	0.00	0.00				CS1
Caliente	Y	24 - 27 May	67.4	7421	0	0.00	0.00	0.00				CS1
Currant	Y	24 - 27 May	72	2969	0	0.00	0.00	0.00				CS1
Death Valley Junction	Y	24 - 27 May	72	7936	0	0.00	0.00	0.00				CS1
Diablo	Y	24 - 27 May			0	0.00	0.00	0.00				CS1
Twin Springs	Y	24 - 27 May	72	2981	0	0.00	0.00	0.00				CS1
Furnace Creek	Y	24 - 27 May	72.5	7648	0.003	0.20	0.02	0.37				CS1
Goldfield	Y	24 - 27 May	72	6997	0	0.00	0.00	0.00				CS1
Hiko	Y	24 - 27 May	72	7896	0.003	0.20	0.02	0.37				CS1
Indian Springs	Y	24 - 27 May	72	1814	0	0.00	0.00	0.00				CS1
Las Vegas	Y	24 - 27 May	78.4	4013	0.0451	0.20	0.02	0.37				CS1
Lathrop Wells	Y	26 - 28 May	47.75	4809	0.0829	2.2	0.22	4.03				CS1
Lund	Y	24 - 27 May				0.49	0.05	0.92				CS1
Mesquite	Y	24 - 27 May	72	8465	0.0105	0.69	0.07	1.28				CS1
Pahrump	Y	23 - 26 May	72	4483	0	0.00	0.00	0.00				CS1
Pioche	Y	24 - 26 May	72	7548	0.12	0.69	0.07	1.28				CS1
Scotty's Junction	Y	24 - 27 May	75.5	6286	0	0.00	0.00	0.00				CS1

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†$\mu g\text{-}sec/m^3$	$pCi\text{-}h/m^3$	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
Tonopah	Y	24 - 27 May	73	7296	0.00294	0.20	0.02	0.37				CS1
TTR (Operations)	N	24 - 27 May	71.5	7900	0	0.00	0.00	0.00				CS1
Warm Springs	Y	24 - 27 May	82	8451	0.00293	0.20	0.02	0.37				CS1
Springdale	Y					0.59	0.06	1.10				CS1
Stake 824	N	30 May - 1 Jun	45.666	4124	0.0152	0.37	0.07	0.69				CS2
Stake 832	N	30 May - 1 Jun	33.2	3104	0.044	0.79	0.11	1.46				CS2
Stake 838	N	30 - 31 May	17.5	1904	0.063	0.60	0.12	1.10				CS2
Stake 843	N	30 May - 1 Jun	31.583	3319	0.00708	0.12		0.22				CS2
Stake 848	N	30 May - 1 Jun	36.5	3173	0.299	5.89	1.04	10.9				CS2
TTR (Operations)	N	31 May - 1 Jun	23.66	2591	0.0135	0.17	0.02	0.32				CS2
Warm Springs	Y	31 May - 2 Jun	48	4692	0.009	0.23	0.03	0.43				CS2
Alamo	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Beatty	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Caliente	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Currant	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Death Valley Junction	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Diablo	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Ely	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Enterprise	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Twin Springs	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Furnace Creek, CA	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Goldfield	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Hiko	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Indian Springs	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Las Vegas	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Lathrop Wells	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Lund	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†µg-sec/m^3	pCi-h/m^3	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
Lund	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Mesquite	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Pahrump	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Pioche	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Scotty's Junction	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
St George, UT	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Tonopah	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Warm Springs Ranch	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Warm Springs	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Eureka	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Blue Jay	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Garrison	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Groom Lake	N	30 May - 1 Jun				0.00	0.00	0.00				CS2
Lida	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Lida Junction	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Tonopah Airport	Y	30 May - 1 Jun				0.00	0.00	0.00				CS2
Stake 240	N	30 May - 1 Jun	18.08	2126		0.00	0.00	0.00				CS2
Stake 435	N	30 May - 1 Jun	31.58	2932		0.00	0.00	0.00				CS2
Stake 808	N	30 May - 1 Jun	32.35	2709		0.00	0.00	0.00				CS2
Stake 816	N	30 May - 1 Jun	44.52	3535		0.00	0.00	0.00				CS2
Stake 834	N					0.2	0.02	0.37				CS2
Stake 913	N	30 - 31 May	20.92	1848		0.00	0.00	0.00				CS2
Stake 915	N	30 May - 1 Jun	46.9	2199		0.00	0.00	0.00				CS2
Stake 921	N	30 - 31 May	19.83	1020		0.00	0.00	0.00				CS2
CS1 Array D 000	N	8 - 10 Jun				2.28	0.23	4.22				CS3
CS1 Array E 001	N	8 - 10 Jun				12.9	1.3	23.8				CS3
CS1 Array F 001	N	8 - 10 Jun				17.6	1.78	32.6				CS3

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†$\mu g\text{-}sec/m^3$	$pCi\text{-}h/m^3$	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
CS1 Array G 001	N	8 - 10 Jun				56.4	5.7	104				CS3
CS1 Array H 001	N	8 - 10 Jun				73.3	7.4	136				CS3
CS1 Array I 001	N	8 - 10 Jun				8.12	0.82	15.0				CS3
CS1 Array J 001	N	8 - 10 Jun				20.8	2.1	38.5				CS3
CS1 Array K 001	N	8 - 10 Jun				6.53	0.66	12.1				CS3
CS1 Array L 001	N	8 - 10 Jun				2.57	0.26	4.77				CS3
CS1 Array M 001	N	8 - 10 Jun				11.0	1.11	20.3				CS3
CS1 Array O 001	N	8 - 10 Jun				19.3	1.95	35.7				CS3
CS1 Array N 001	N	8 - 10 Jun				111	11.2	205				CS3
CS1 Array N 006	N	8 - 10 Jun				20.8	2.1	38.5				CS3
CS1 Array N 012	N	8 - 10 Jun				13.0	1.31	24.0				CS3
CS1 Array N 018	N	8 - 10 Jun				426	43	788				CS3
CS1 Array N 024	N	8 - 10 Jun				37.6	3.8	69.7				CS3
CS1 Array N 030	N	8 - 10 Jun				27.7	2.8	51.3				CS3
CS1 Array N 036	N	8 - 10 Jun				10.7	1.08	19.8				CS3
CS1 Array N 048	N	8 - 10 Jun				46.5	4.7	86.2				CS3
CS1 Array N 054	N	8 - 10 Jun				1.68	0.17	3.12				CS3
CS1 Array N 060	N	8 - 10 Jun				11.1	1.12	20.5				CS3
CS1 Array N 066	N	8 - 10 Jun				56.4	5.7	104				CS3
CS1 Array N 072	N	8 - 10 Jun				73.3	7.4	136				CS3
CS1 Array N 078	N	8 - 10 Jun				8.12	0.82	15.0				CS3
CS1 Array N 084	N	8 - 10 Jun				20.8	2.1	38.5				CS3
CS1 Array N 090	N	8 - 10 Jun				6.53	0.66	12.1				CS3
CS1 Array N 096	N	8 - 10 Jun				2.57	0.26	4.77				CS3
CS3 Mellan 1 (TTR)	N	8 - 10 Jun				11.0	1.11	20.3				CS3
CS3 Mellan 2 (TTR)	N	8 - 10 Jun				19.3	1.95	35.7				CS3
CS3 Mellan 3 (TTR)	N	8 - 10 Jun				111	11.2	205				CS3

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†$\mu g\text{-}sec/m^3$	$pCi\text{-}h/m^3$	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
CS3 Mellan 4 (TTR)	N	8 - 10 Jun				3.27	0.33	6.05				CS3
CS3 Mellan 5 (TTR)	N	8 - 10 Jun				2.47	0.25	4.58				CS3
Stake 240	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 435	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 838	N	8 - 10 Jun				1.78	0.18	3.30				CS3
Stake 808	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 816	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 824	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 832	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 838	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 843	N	8 - 10 Jun				0.00	0	0.00				CS3
Stake 848	N	8 - 10 Jun				17.9	1.81	33.2				CS3
Stake 915	N	8 - 10 Jun				0.00	0.00	0.00				CS3
Stake 921	N	8 - 10 Jun				0.00	0.00	0.00				CS3
Alamo	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Beatty	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Blue Jay	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Caliente	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Cedar Pass	N	8 - 10 Jun				0.00	0.00	0.00				CS3
Currant	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Death Valley Junction	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Diablo	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Ely	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Enterprise	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Eureka	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Furnace Creek, CA	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Goldfield	Y	8 - 10 Jun				0.00	0.00	0.00				CS3

TABLE G-1. Off-Site Air Sampling Data during Operation Roller Coaster Safety Tests, continued.

Location	Publicly Accessible Area	Sampling Period		Sampling Volume (m^3)	Mean $^{239+240}Pu$ (pCi/m^3)	*Estimated Intake (pCi)	Time-Integrated Airborne Concentration		Data References			Test
		Dates	Hours				†µg-sec/m^3	pCi-h/m^3	WT-2511 (Table 3.1)	WT-2511 (Appendix)	SNL SS-RR-69-788	
Groom Lake	N	8 - 10 Jun				0.00	0.00	0.00				CS3
Hiko	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Indian Springs	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Lathrop Wells	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Lida Junction	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Lund	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Mesquite	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Pahrump	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Pioche	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Scotty's Junction	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Springdale	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
St George, UT	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Tonopah	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Tonopah Airport	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Twin Springs	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Warm Springs	Y	8 - 10 Jun				0.00	0.00	0.00				CS3
Warm Springs Ranch	Y	8 - 10 Jun				0.00	0.00	0.00				CS3

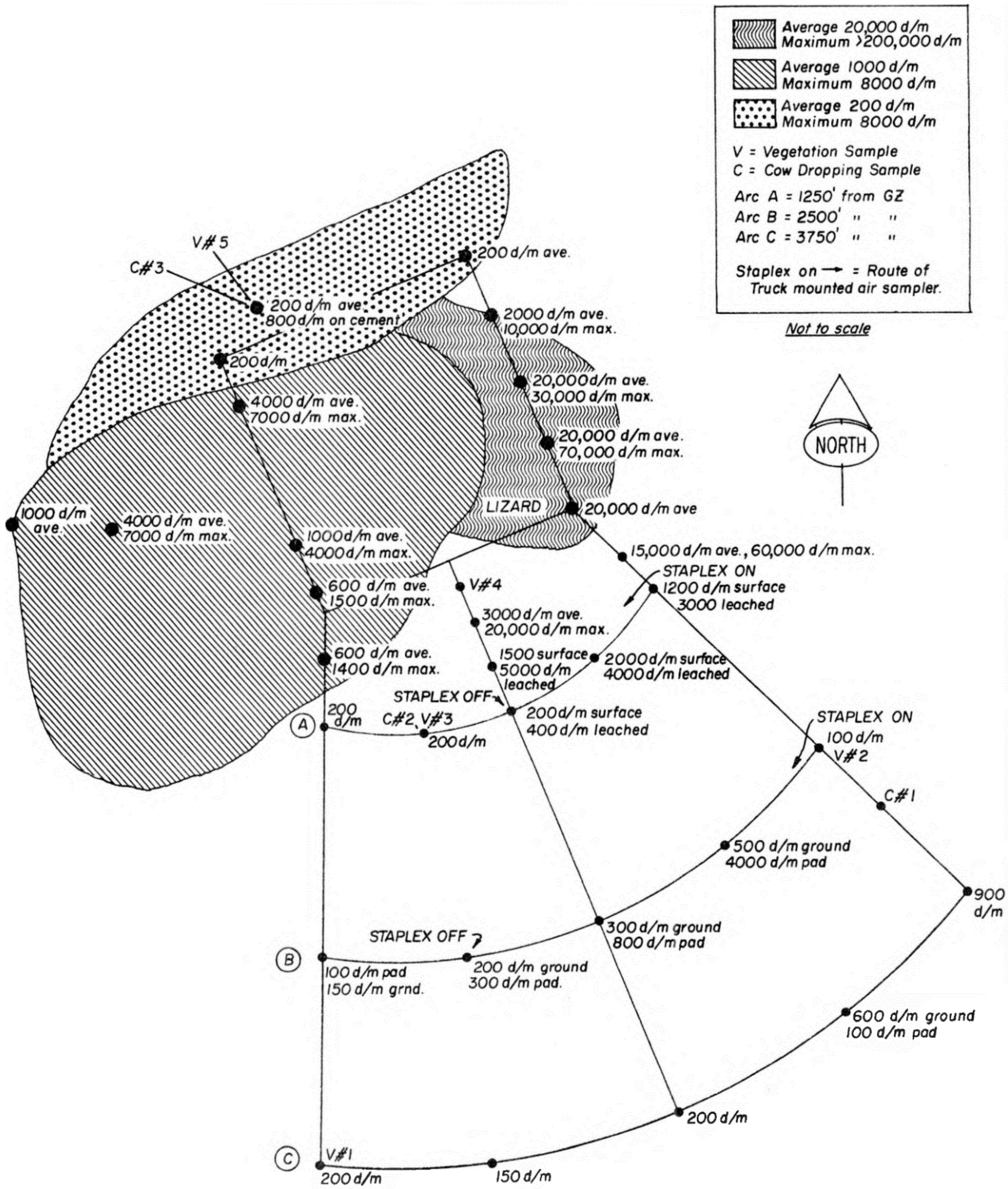

Figure G-9. Ground Surface α-Particle Survey on 2-3 June 1964
at Clean Slate 2, Exhibit 3 from NVO 162-17 (1964).

TABLE G-2. Gross Alpha Radioactivity of Air Samples Collected on 2-3 Jun 1964 Quarterly Resurvey of Clean Slate 2, on Arcs A & B, on Truck (15 mph), from NVO 162-17 (1964).

Sample	Distance from GZ (ft)	Gross α-Radiation Concentration (pCi/m^3)
Arc A	1250	61
Arc B	2500	35

TABLE G-3. Gross Alpha Radioactivity of Air Samples Collected at Operation Roller Coaster Sites, June 1966, from NVO 162-28 (1966).

Sampling Location	Volume (m^3)	Gross Alpha Radiation Concentration	
		Value (pCi/m^3)	2 σ Error (%)
Double Tracks general area	4.95	0.482	52.3
Double Tracks 25 ft So. of exclusion fence	8.49	0.281	52.3
Double Tracks 25 ft So. of exclusion fence	16.13	0.723	18.1
Double Tracks general area	9.41	0.476	32.2
Clean Slate I general area (in truck cab)	8.7	0.207	*
Clean Slate II and III general (in truck cab)	15.85	0.0736	82
Downwind of Clean Slate I exclusion fence	25.54	0.0743	*
Downwind of Clean Slate II exclusion fence	25.54	0.0705	*
Downwind of Clean Slate III exclusion fence	25.54	0.0515	*

* The detection limit is two times the value for which the relative 2σ counting error equals 100%

TABLE G-4. Results of the REECO Measurements for $^{239+240}$Pu Air Concentrations (fCi/m^3) at the GMX Area and the Control Location at Mercury (Bldg 214, NTS), February 1971 to July 1972. Data from Table 1, "Results and Data Analysis . . ." NVO-142 (1974).

Location	All Samples			Samples with Detectable $^{239+240}$Pu			
	N	Mean*	Median*	N	Mean	Geom Mean	Median
GMX NE†	254	6.1	0.56	236	6.6	0.79	0.62
GMX SE†	31	0.87	0.2	23	1.2	0.40	0.32
GMX SW†	186	0.58	0.12	156	0.69	0.19	0.15
GMX NW†	32	0.31	0.18	29	0.34	0.23	0.20
Bldg 214	200	0.23	0.087	147	0.31	0.14	0.13

* Non-detectable results set equal to zero. † Fence boundary.

TABLE G-5. $^{239+240}$Pu Air Concentration Derived from Two Sample Sets Collected with the Ultrahigh-Volume Air Samplers, as Shown in Figures G-11 and G-12, from NVO-142 (1974).

Location	^{239,240}Pu Air Concentration (pCi/m^3)			
	May 31, 1973		Jun 13, 1973	
	West	East	West	East
800 ft, upwind	0.0041	0.008	0.0018	0.0022
Ground Zero	0.56	1.1	0.082	0.22
1,200 ft, downwind	0.047	0.053	0.0097	0.023
2,400 ft, downwind	0.0031	0.0031	0.0051	0.0026
4,800 ft, downwind	0.014	0.031	0.00071	not available

Control air sample = 0.0013 pCi/m^3

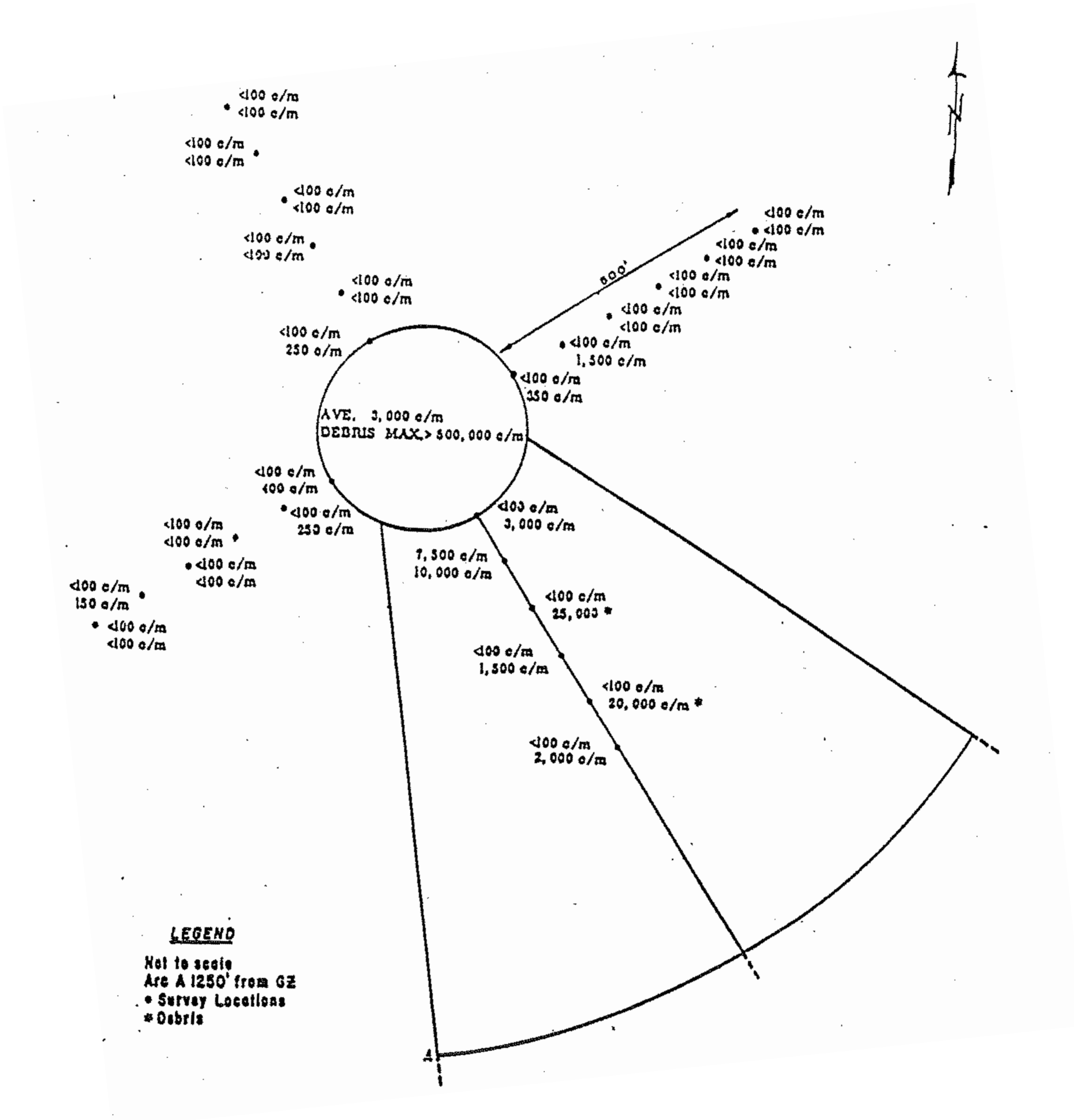

Figure G-10. Clean Slate I Alpha Survey Results, from NVO 162-28 (1966).

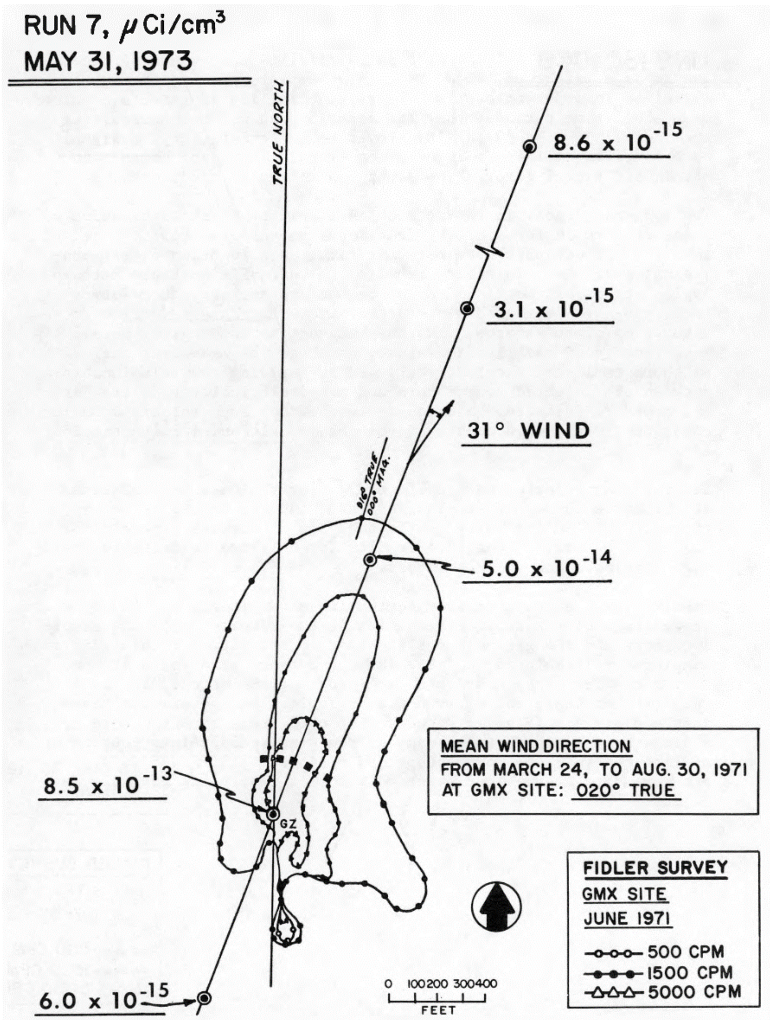

Figure G-11. ^{239,240}Pu Air Concentration at the GMX Site Derived from Average of Two Ultrahigh-Volume Filter Samples. The Samples were Run from 1150-1400 PST on 31 May 1973, Figure 7, "Results and Data Analysis: Resuspension Element Status Report," NVO-142 (1974). [μCi/cm^3 = 10^{+12} pCi/m^3].

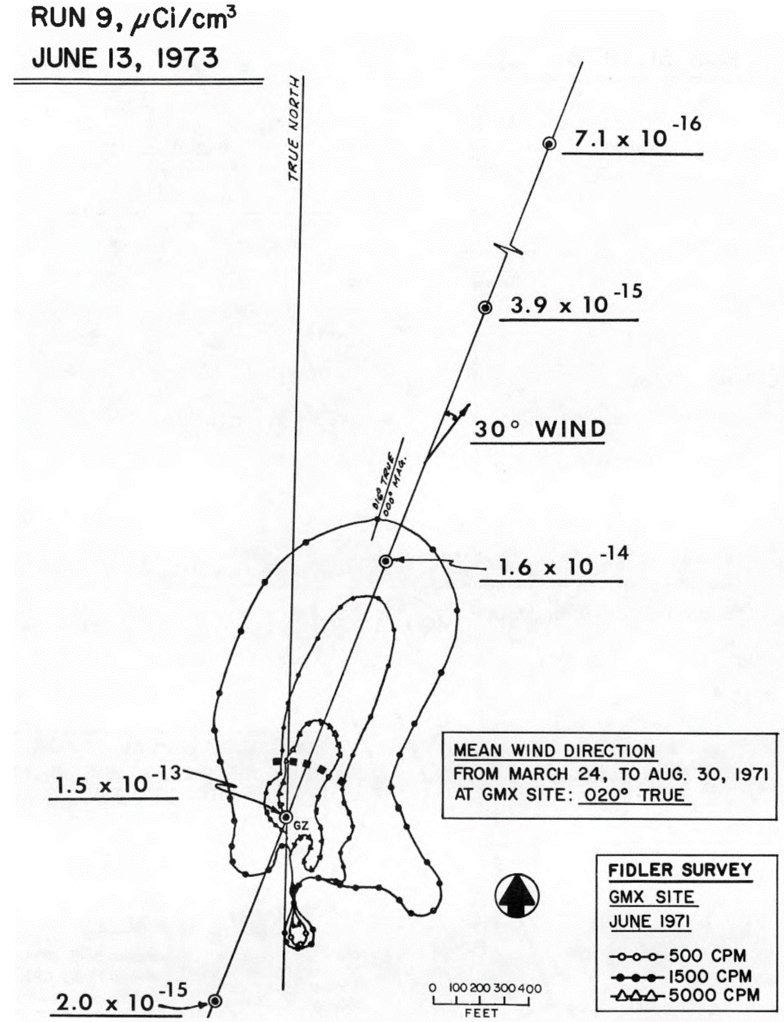

Figure G-12. ^{239,240}Pu Air Concentration at the GMX Site Derived from Average of Two Ultrahigh-Volume Filter Samples. The Samples were Run from 1220-1830 PST on 13 June 1973, Figure 8, "Results and Data Analysis: Resuspension Element Status Report," NVO-142 (1974). [μCi/cm^3 = 10^{+12} pCi/m^3].

TABLE G-6. Corrected Estimates of Inventory of $^{239+240}Pu$ in Surface Soils (0 – 5 cm depth) at Four Operation Roller Coaster Sites, Table 3.1.7 of CERLA Preliminary Assessment of DOE's NVO, Nuclear Weapons Testing Areas (1988).

Area	Strata	Size of Area m	Size of Area Percent	n	Mean ± S.E. †† (μCi/m²)	Estimated Inventory ± S.E. (Curies)	Percent of Total Inventory	Estimated 95% C.L. on Inventory (Curies) Lower	Estimated 95% C.L. on Inventory (Curies) Upper	c††† of Inventory Estimate
Double Track	1	176,000	98.3	23	6.7 ± 3.5	1.2 ± 0.62	33	-0.09	2.5	0.52
	2	1,600	0.9	11	350 ± 250	0.56 ± 0.40	16	-0.33	1.5	0.71
	3	800	0.4	10	190 ± 59	0.15 ± 0.047	4	0.044	0.26	0.31
	4	600	0.3	9	2,800 ± 1,000	1.7 ± 0.60	47	0.32	3.1	0.35
	Total	179,000	99.9	53		3.6 ± 0.95	100	1.7	5.5	0.26
Clean Slate 1	1	157,000	88.9	21	15 ± 7.0	2.4 ± 1.1	58	0.11	4.7	0.46
	2	10,000	5.7	13	64 ± 22	0.64 ± 0.22	15	0.16	1.1	0.34
	3	8,400	4.5	13	110 ± 35	0.92 ± 0.29	22	0.29	1.6	0.32
	4	1,700	1.0	10	120 ± 39	0.20 ± 0.066	5	0.05	0.35	0.33
	Total	177,100	100.1	57		4.2 ± 1.2	99	1.8	6.6	0.29
Clean Slate 2	1	351,000	74.7	18	4.1 ± 1.3	1.4 ± 0.46	8	0.43	2.4	0.33
	2	82,300	17.4	12	73 ± 30	6.0 ± 2.5	34	0.50	12	0.42
	3	26,200	5.5	13	270 ± 99	7.1 ± 2.6	41	1.4	13	0.37
	4	11,000	2.3	20	260 ± 65	2.9 ± 0.72	17	1.4	4.4	0.25
	Total	470,500	99.9	63		17 ± 3.7	100	9.6	24	0.22
Clean Slate 3	1	1,615,000	93.2	28	12 ± 2.2	19.4 ± 3.6	52	12	27	0.19
	2	61,000	3.5	12	58 ± 16	3.5 ± 0.98	9	1.3	5.6	0.28
	3	40,000	2.3	13	210 ± 63	8.4 ± 2.5	23	3.0	14	0.30
	4	16,000	0.9	10	370 ± 190	5.9 ± 3.0	16	-0.89*	13	0.51
	Total	1,732,000	99.9	63		37 ± 5.4	100	26	48	0.15

* These negative values result from the statistical uncertainty in the estimate of $^{239-240}Pu$.
††, ††† Reported in Romney et al. (1975), p. 64.

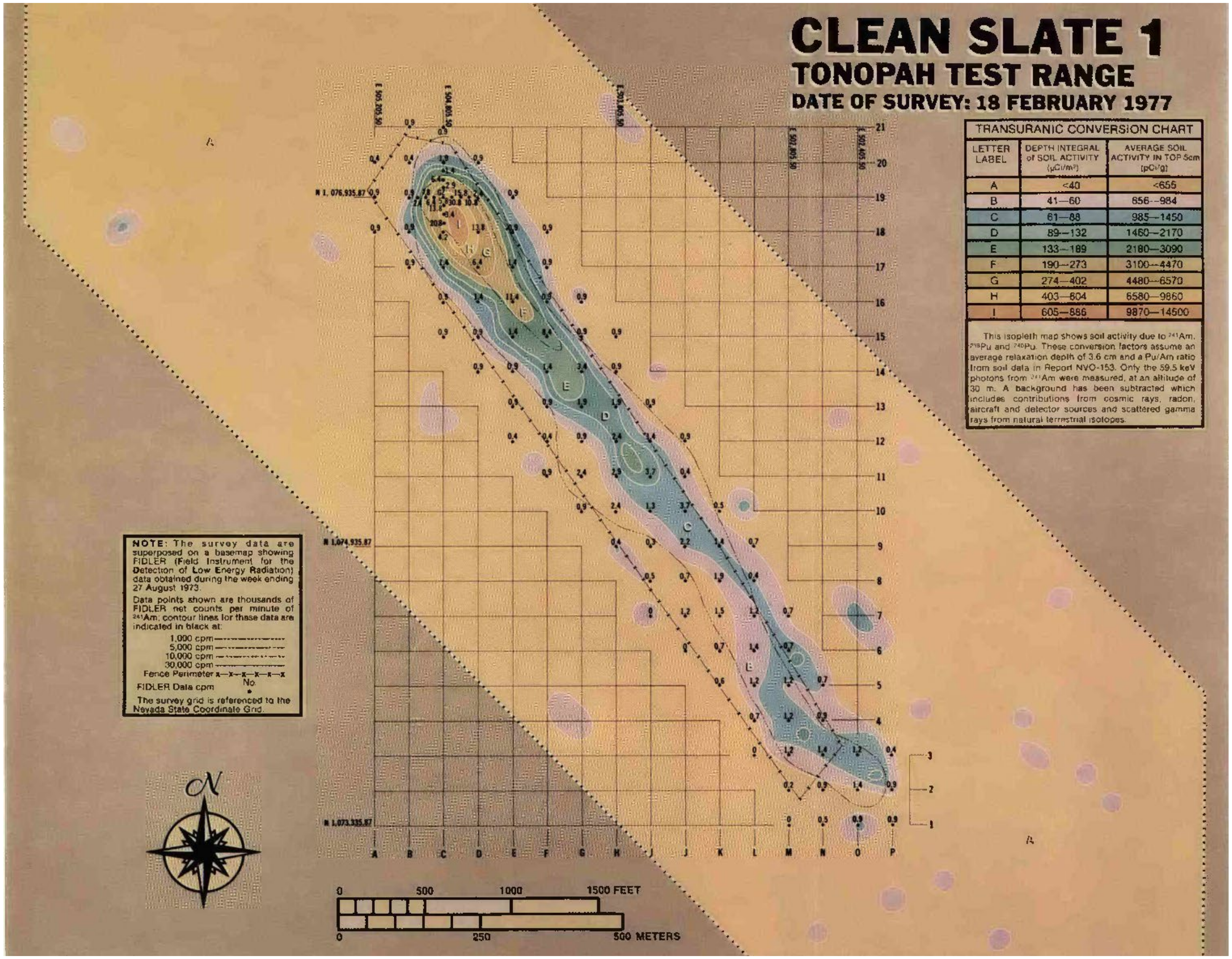

Figure G-13. The Clean Slate 1 Isopleth Map Shows Transuranic Soil Activity due to ^{241}Am, ^{239}Pu, and ^{240}Pu, Based on Measurement of 59.5 keV γ-Ray from ^{241}Am, Figure 11 from EG&G 1183-1737 (1978).

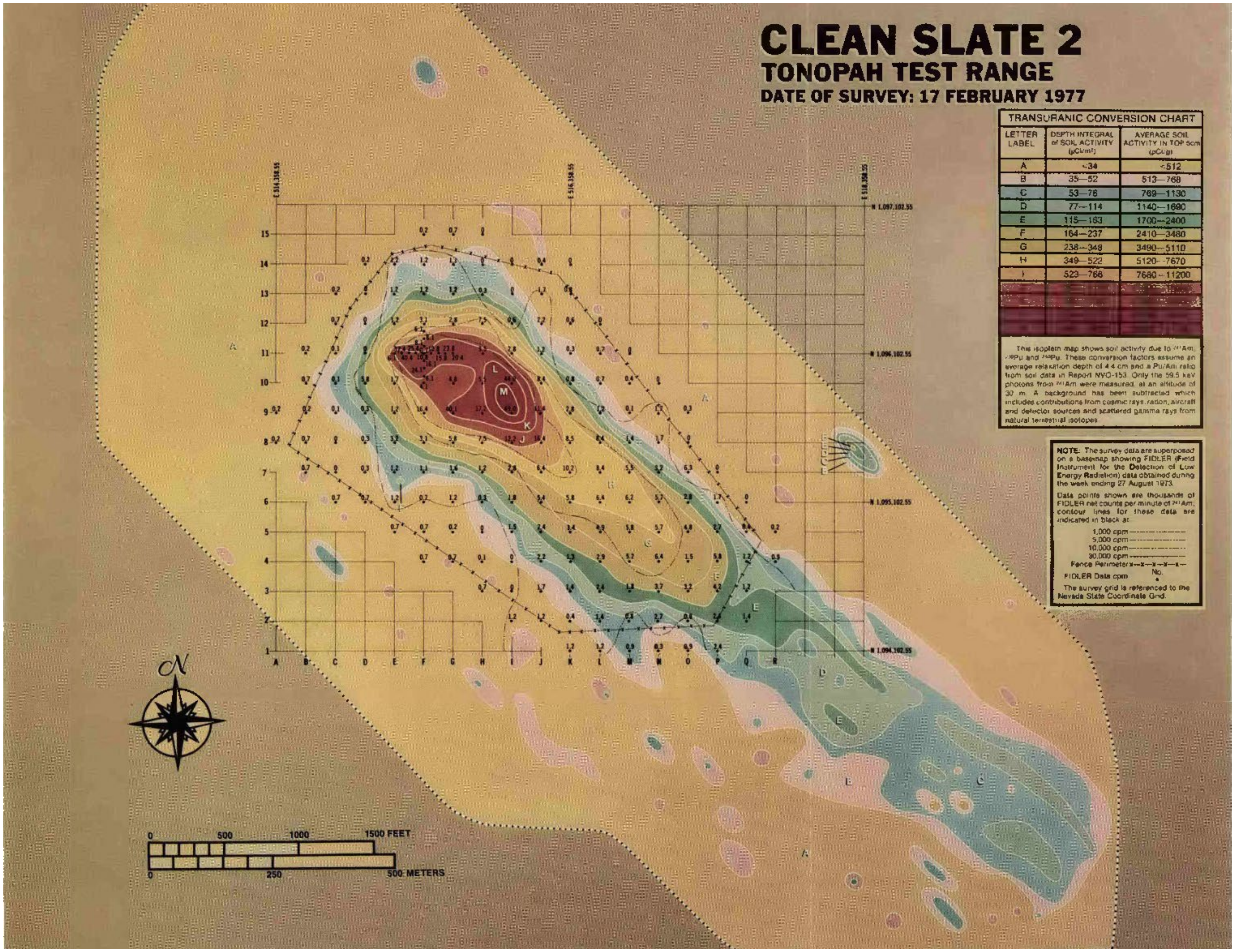

Figure G-14. The Clean Slate 2 Isopleth Map Shows Transuranic Soil Activity due to ^{241}Am, ^{239}Pu, and ^{240}Pu, Based on Measurement of 59.5 keV γ-Ray from ^{241}Am, Figure 12 from EG&G 1183-1737 (1978).

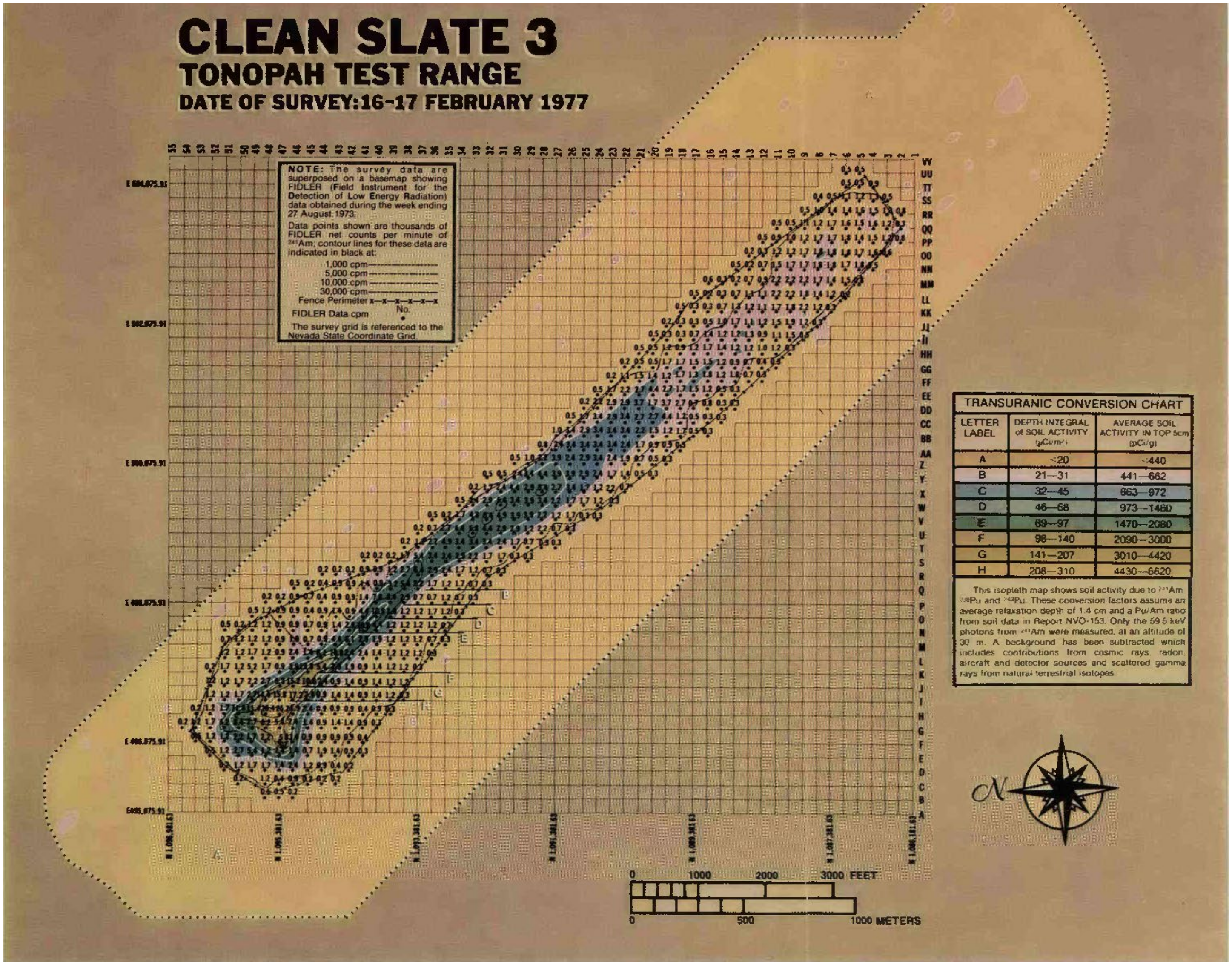

Figure G-15. The Clean Slate 3 Isopleth Map Shows Transuranic Soil Activity due to ^{241}Am, ^{239}Pu, and ^{240}Pu, Based on Measurement of 59.5 keV γ-Ray from ^{241}Am, Figure 13 from EG&G 1183-1737 (1978).

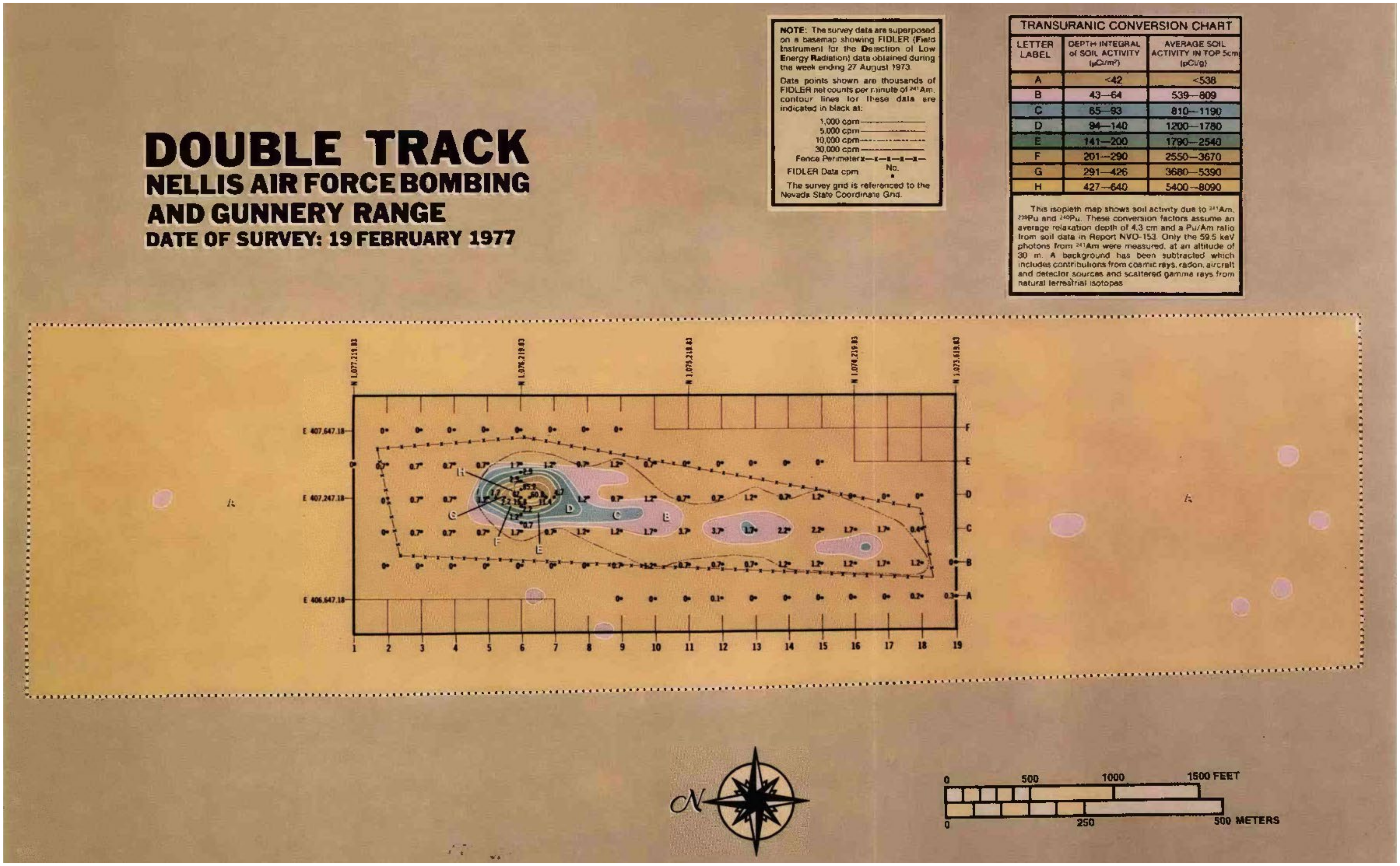

Figure G-16. The Double Tracks Isopleth Map Shows Transuranic Soil Activity due to ^{241}Am, ^{239}Pu, and ^{240}Pu, Based on Measurement of 59.5 keV γ-Ray from ^{241}Am, Figure 14 from EG&G 1183-1737 (1978).

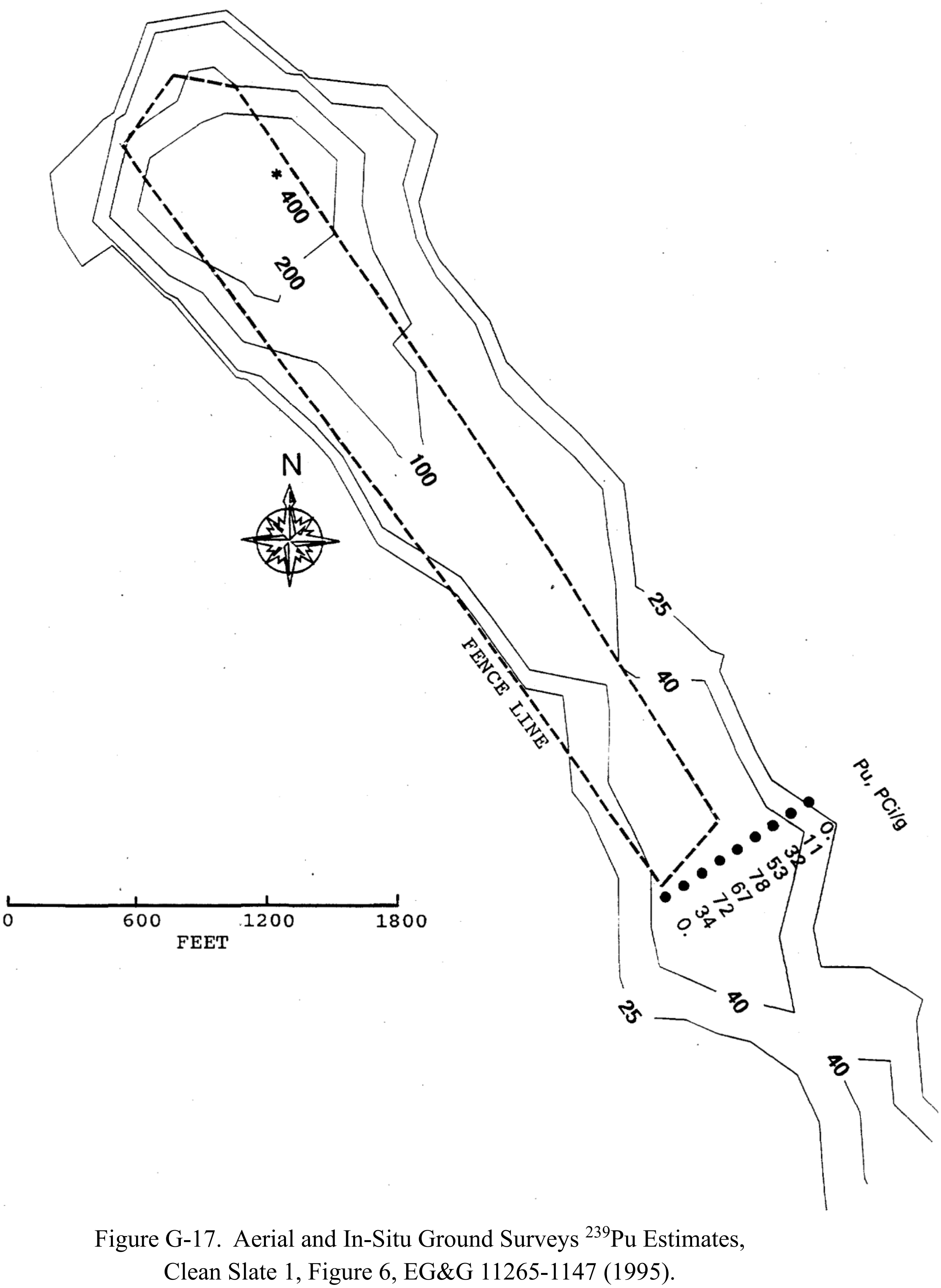

Figure G-17. Aerial and In-Situ Ground Surveys ^{239}Pu Estimates, Clean Slate 1, Figure 6, EG&G 11265-1147 (1995).

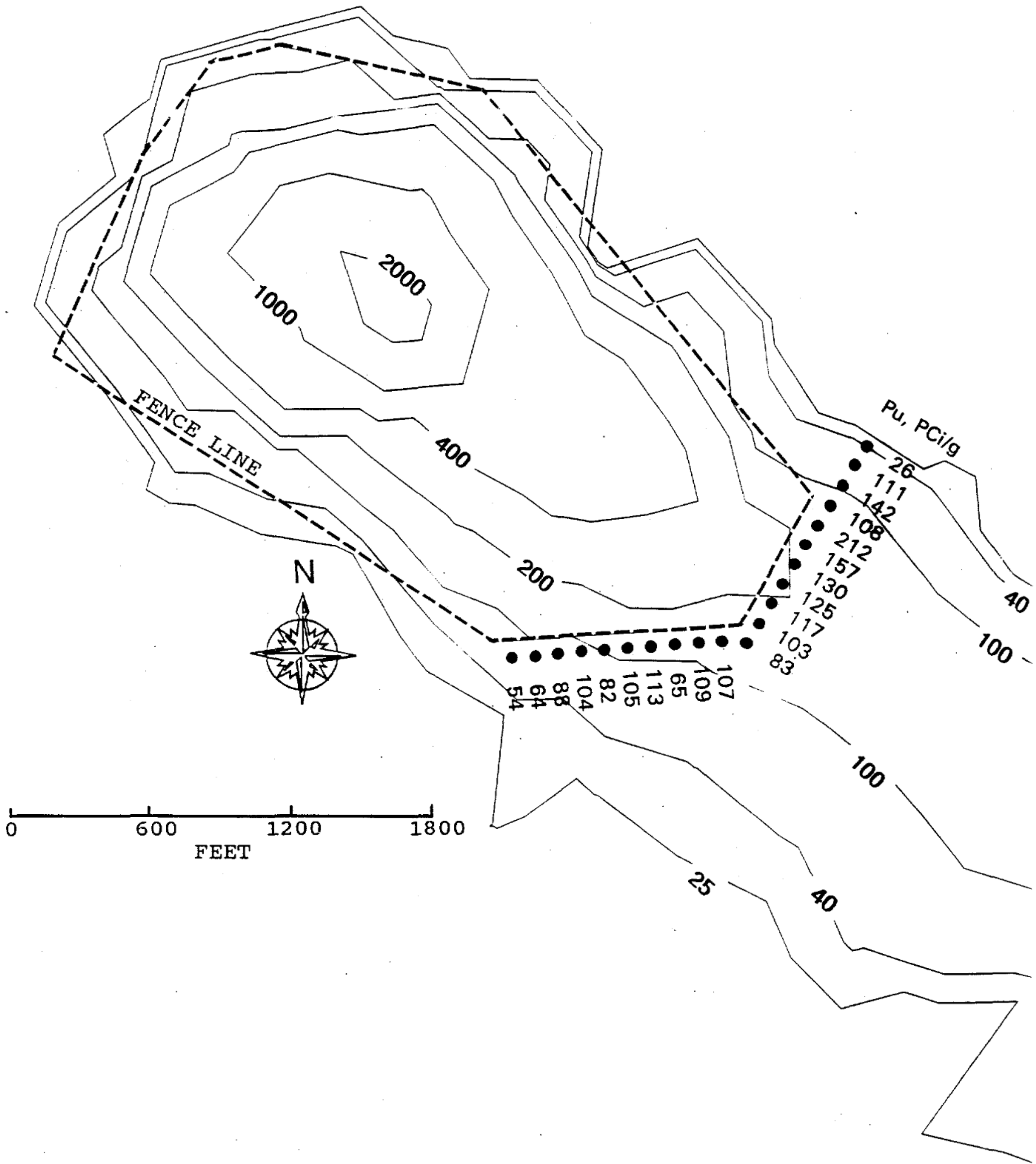

Figure G-18. Aerial and In-Situ Ground Surveys ^{239}Pu Estimates, Clean Slate 2 Figure 7, EG&G 11265-1147 (1995).

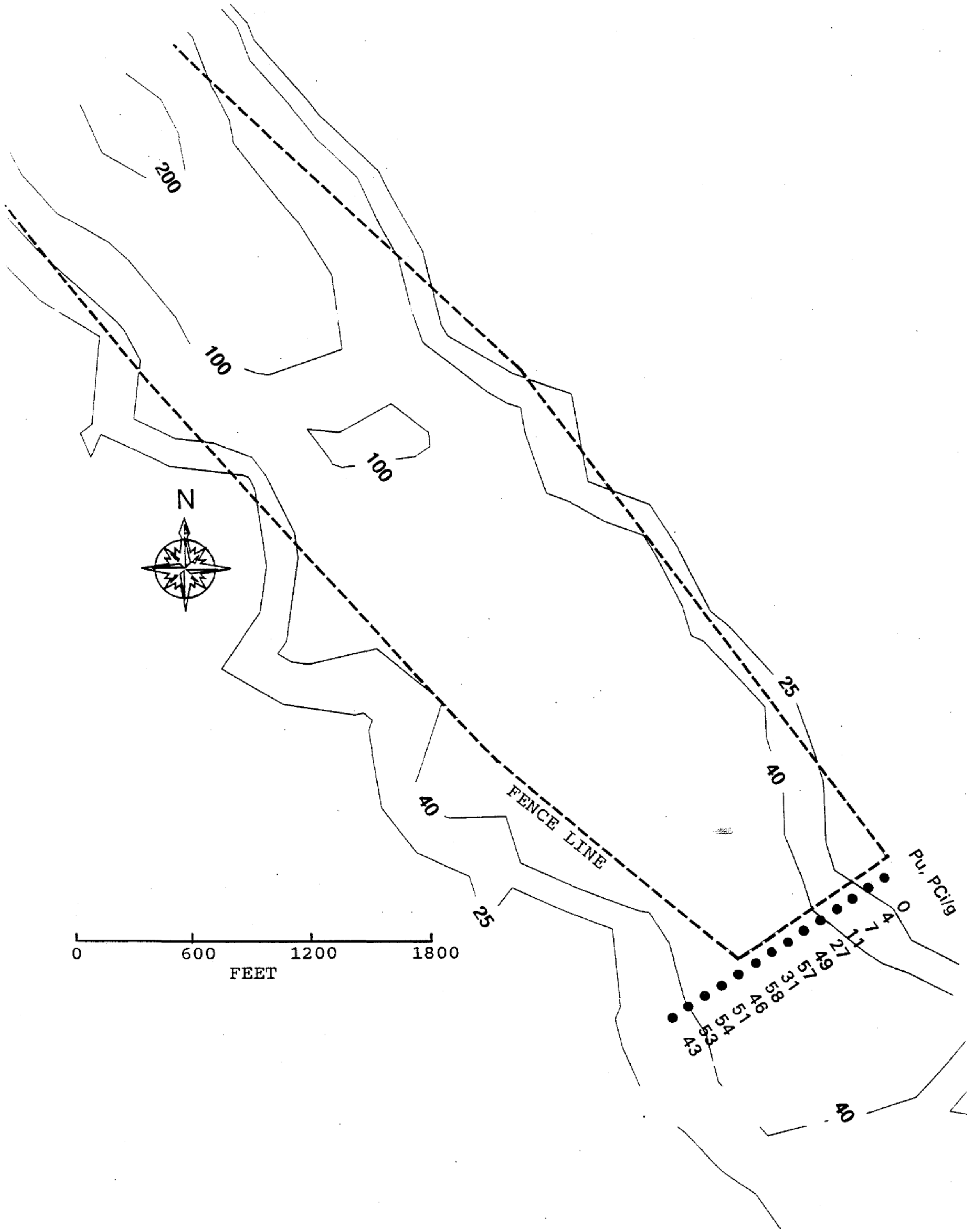

Figure G-19. Aerial and In-Situ Ground Surveys ^{239}Pu Estimates,
Clean Slate 3, Figure 8, EG&G 11265-1147 (1995).

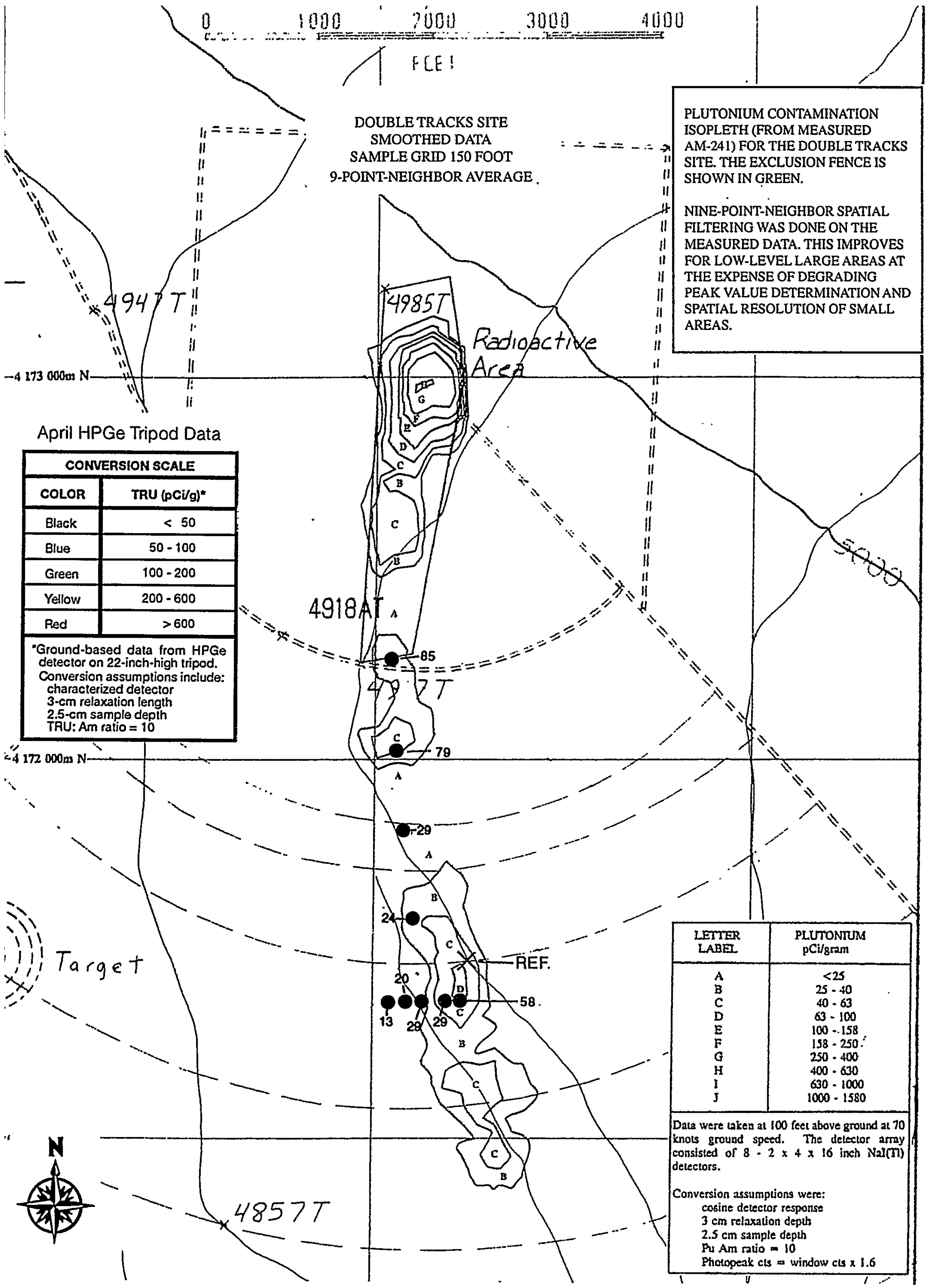

Figure G-20. Tripod Measurements made South of The Double Tracks (April 1995), Superimposed on the Smoothed Aerial Data from December 1993, using Pu:Am Ratio of 10:1, Figure 9, EG&G 11718-013 (1996).

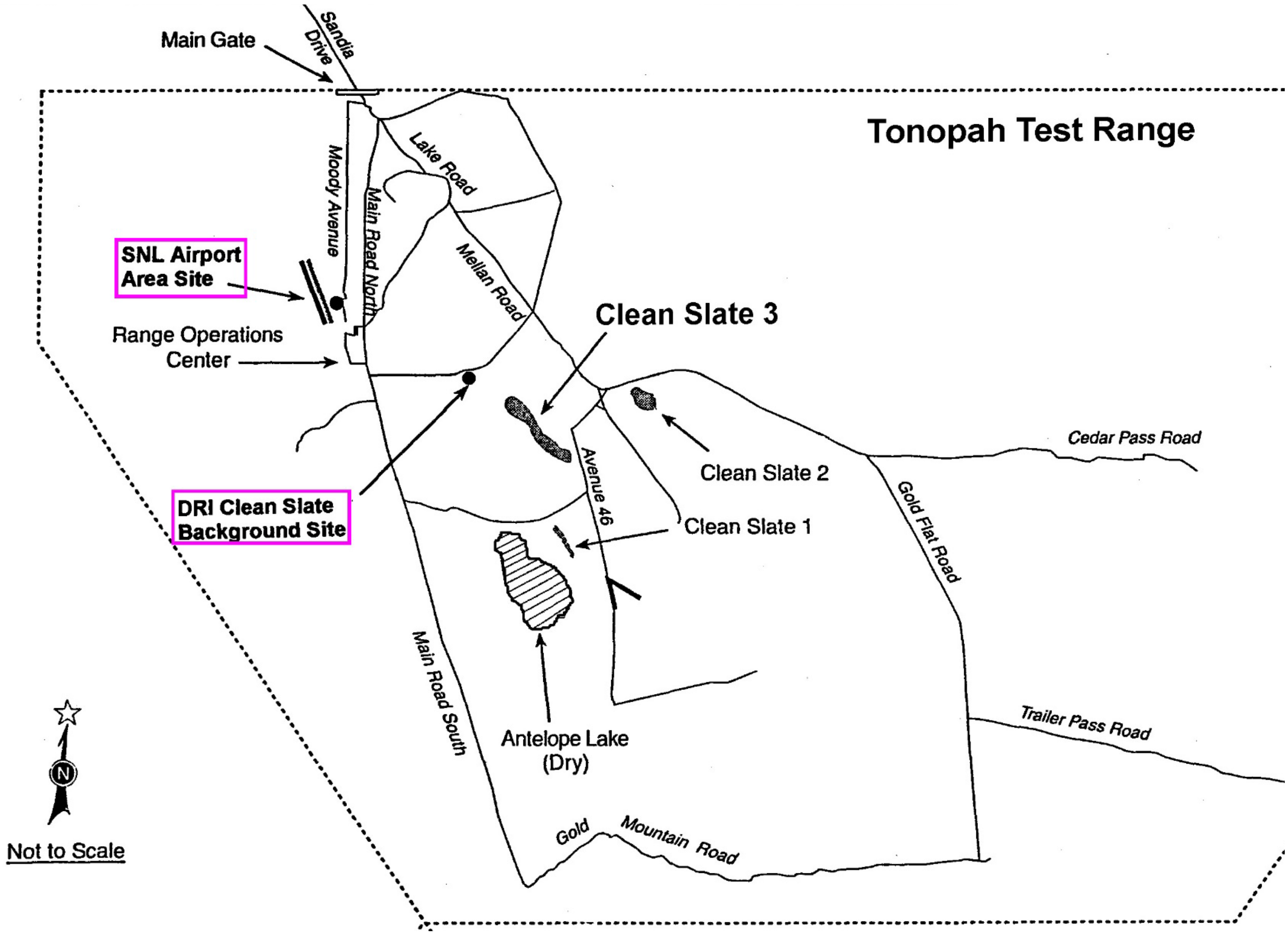

Figure G-21. Map of DRI and DOE Air Samplings Locations on TTR in 1996, DRI 45181 (2001).

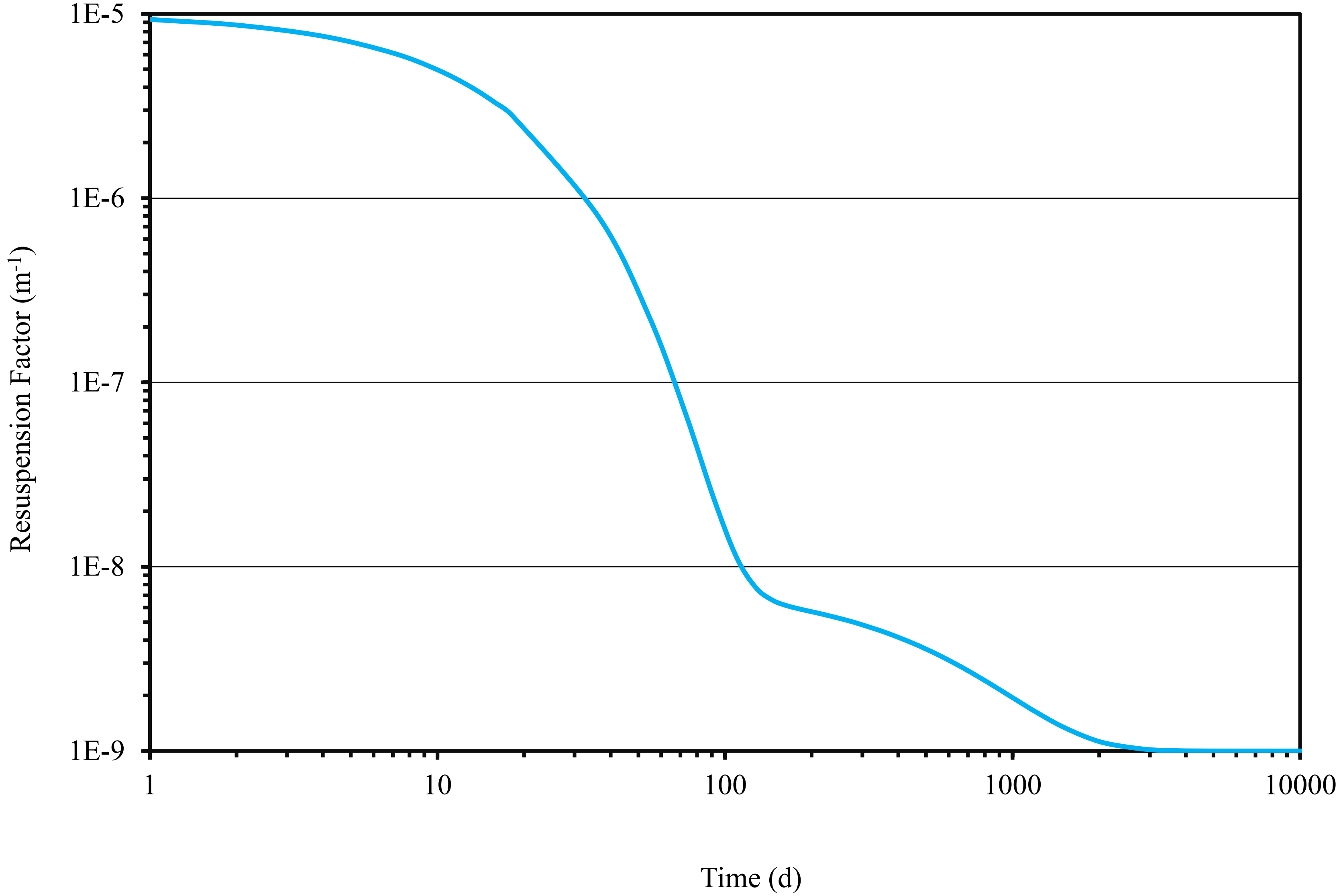

Figure G-22. Airborne Resuspension Model, Based on Maxwell and Anspaugh (2011).

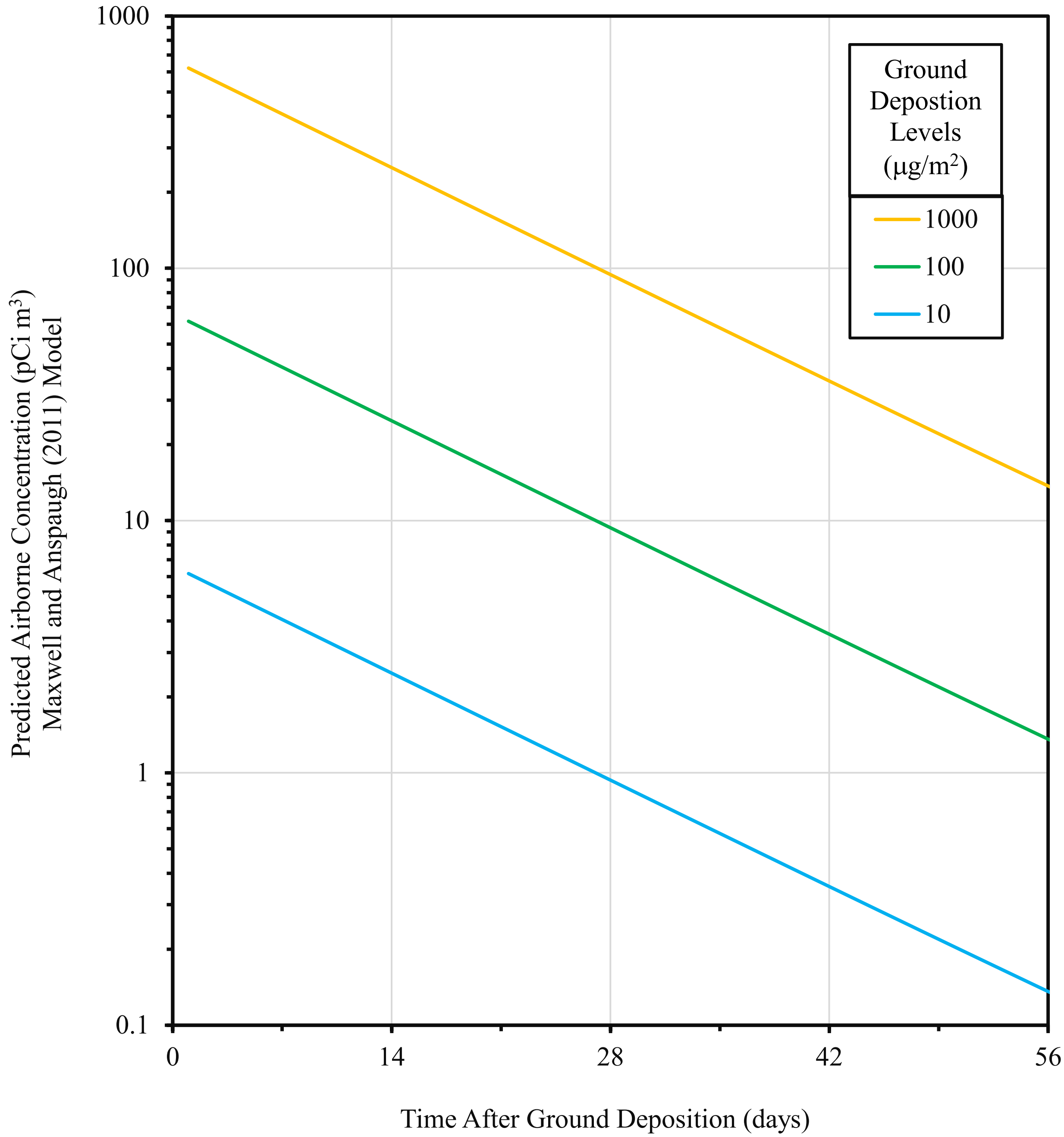

Figure G-23. Predicted Airborne Concentrations from the Maxwell and Anspaugh Model for Varied Plutonium Areal Concentrations on Soil Surfaces and Varied Times after Deposition. [Assumption of 0.066 Ci/g].

TABLE G-7. Yearly (FY) Averages of Air Surveillance Data for Plutonium (1 x 10^{-17} μCi/ml) at NTS Air Surveillance Monitoring Stations, Table 4 from NVO-410-39 (1978). [Multiple by 10^{12} for units of pCi/m^3].

STATION		1971	1972	1973	1974	1975	1976
Area 1	GRAVEL PIT	37.9	14.8	8.7	8.0	2.9	28.7
Area 2	COMPOUND	66.1	22.4	22.3	6.8	3.8	17.2
Area 3	CAFETERIA	16.5	36.8	20.6	12.6	14.6	104.
Area 5	MAINTENANCE COMPLEX	18.3	10.6	5.6	4.2	4.1	17.9
Area 5	WELL 5B	8.3	19.6	15.1	5.8	4.5	12.1
Area 5	GATE 250	8.8	11.7	5.5	6.4	----	----
Area 6	YUCCA COMPLEX	12.5	31.8	10.7	10.1	6.0	57.5
Area 6	CP-2 COMPLEX	8.0	16.8	17.8	7.2	5.3	35.4
Area 6	WELL 3 COMPLEX	31.1	353.	7.6	6.5	7.5	39.7
Area 9	9-300 BUNKER	72.1	429.	85.9	21.1	16.8	318.
Area 10	GATE 700	20.8	29.0	4.4	5.7	5.7	21.3
Area 11	GATE 293	9.1	24.3	8.7	8.0	4.9	23.6
Area 12	CHANGE HOUSE	16.3	78.6	4.3	5.8	3.3	27.9
Area 16	TUNNEL MAINTENANCE	19.3	16.9	4.4	6.0	4.5	15.6
Area 18	CAFETERIA	8.0	14.5	3.8	----	----	----
Area 19	ECHO PEAK	36.9	532.	3.9	4.8	3.3	7.9
Area 19	PM SUBSTATION	8.3	14.5	10.4	8.4	3.4	11.9
Area 20	DISPENSARY	7.5	11.7	9.1	3.7	5.9	18.4
Area 23	CETO	9.4	57.0	7.0	7.4	5.5	87.6
Area 23	H&S BUILDING	9.3	12.2	4.2	9.6	3.3	26.0
Area 25	WAREHOUSE	----	----	----	8.6	5.7	20.1
Area 27	DISPENSARY	8.4	16.6	3.7	7.2	6.8	13.7
Area 28	HENRE SITE	9.8	15.6	3.9	5.1	3.3	11.7
GROOM LAKE	CAFETERIA	176.	16.6	4.3	9.5	4.3	17.0

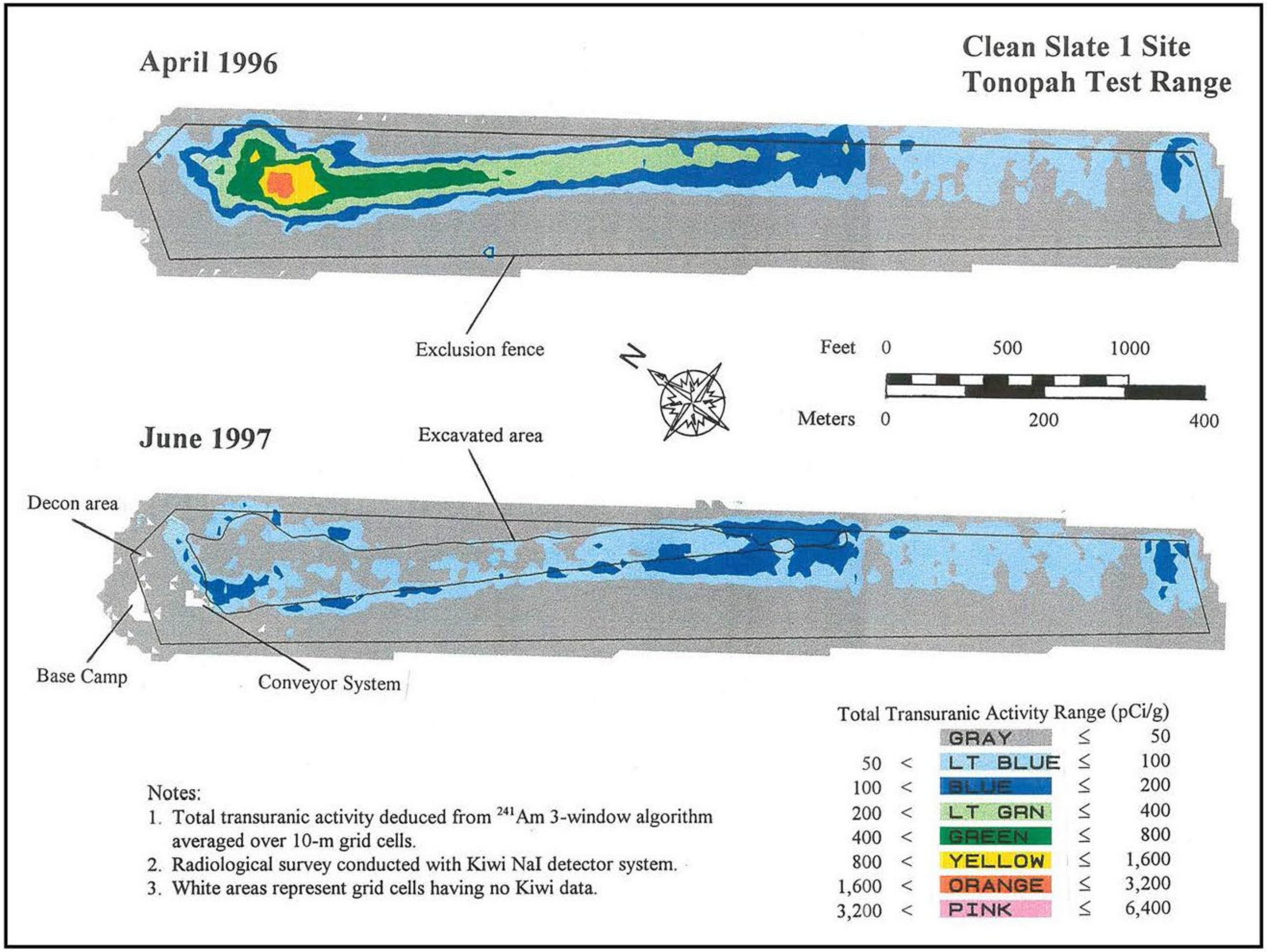

Figure G-24. Transuranic Activities Measured with the Kiwi Before and After Excavation (Contour), Figure 6, DOE/NV/11718-218 (1998). [The total transuranic activity from April 1996 and June 1997 is based on the measured ^{241}Am counts and collected into 33-ft grid cell averaged].

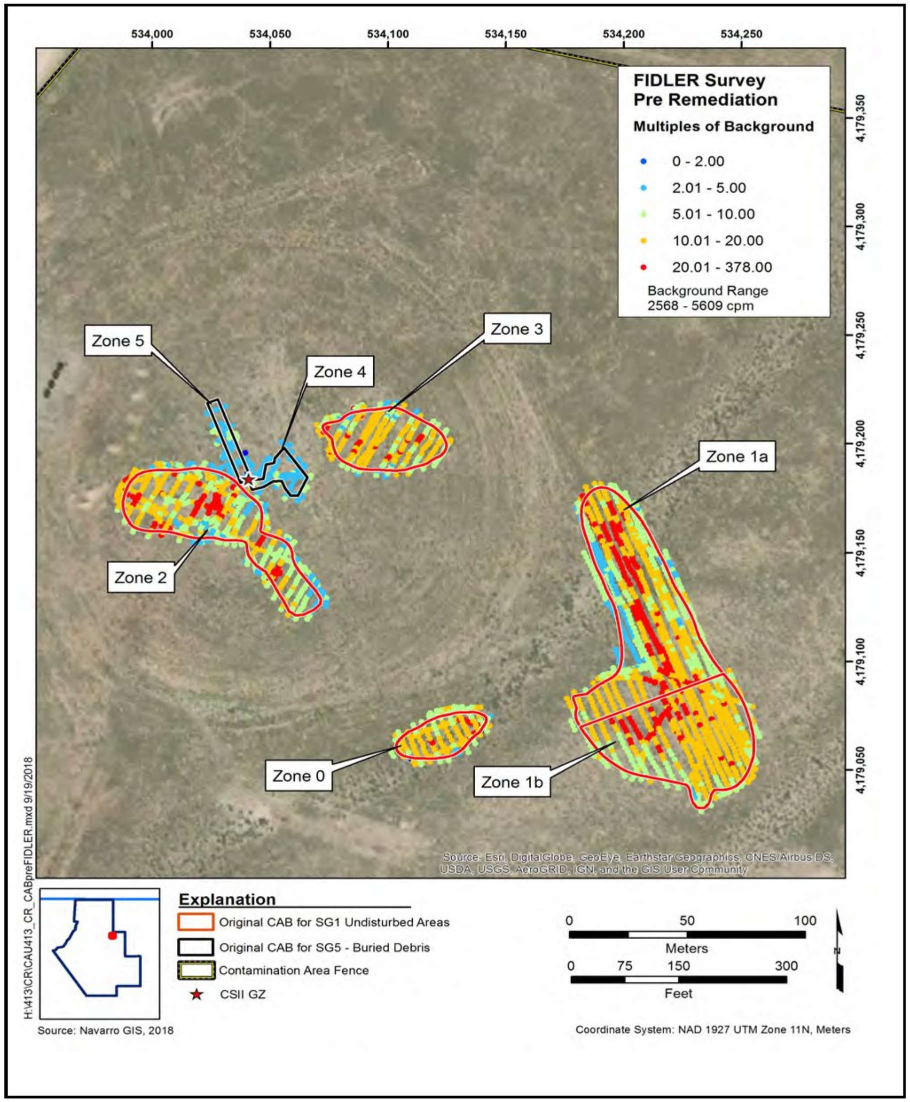

Figure G-25. CAU 413 Pre-Corrective Action FIDLER Survey Results, Figure D.2-1 from DOE/NV-1598 (2018).

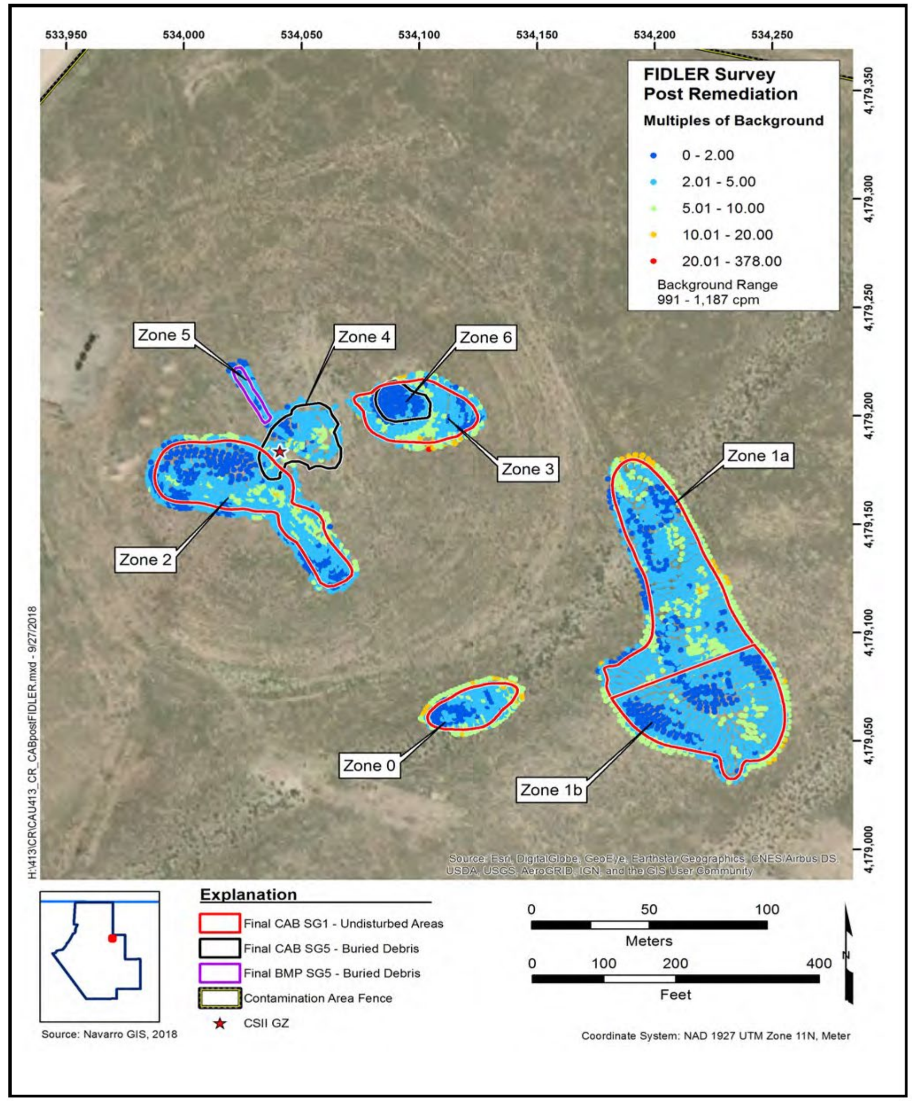

Figure G-26. CAU 413 Post-Corrective Action FIDLER Survey Results and Final CABs, Figure D.2-2 from DOE/NV-1598 (2018).

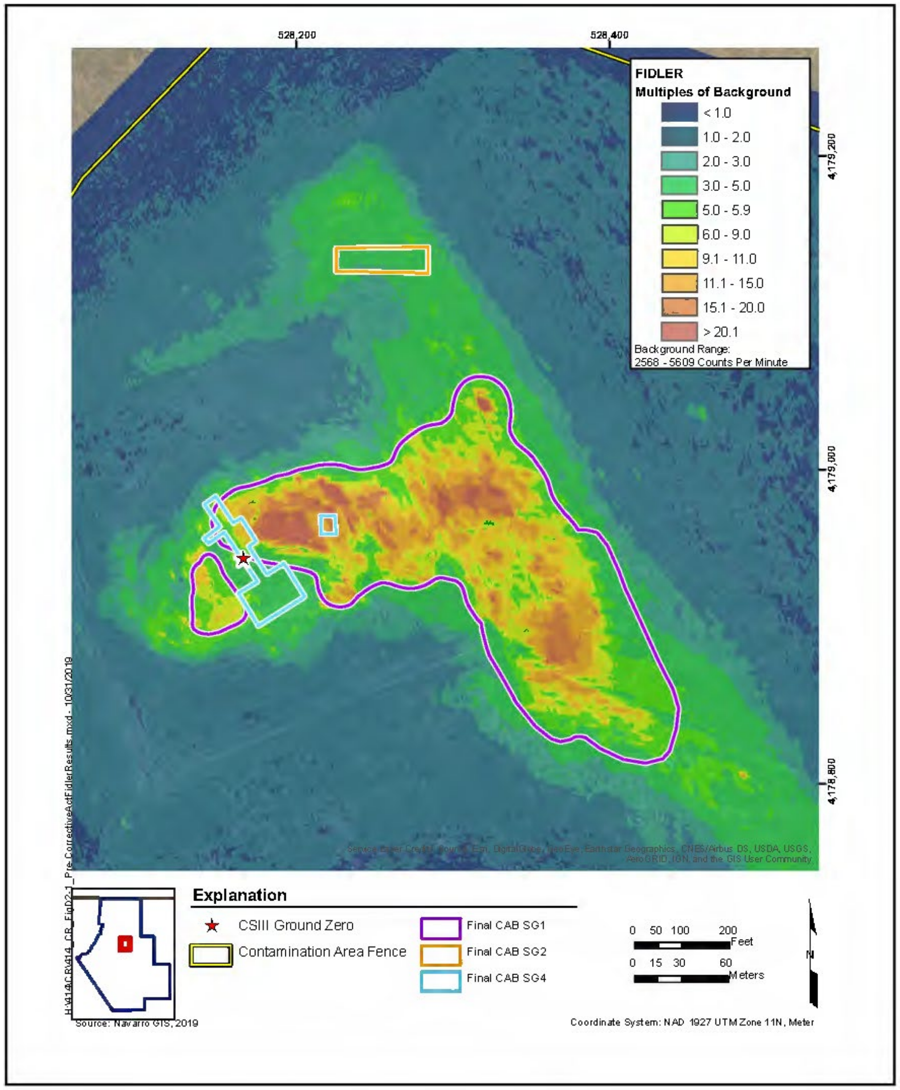

Figure G-27. CAU 414 Pre-Corrective Action FIDLER Survey Results, Figure D.2-1 from DOE/EMNV-0011 (2019).

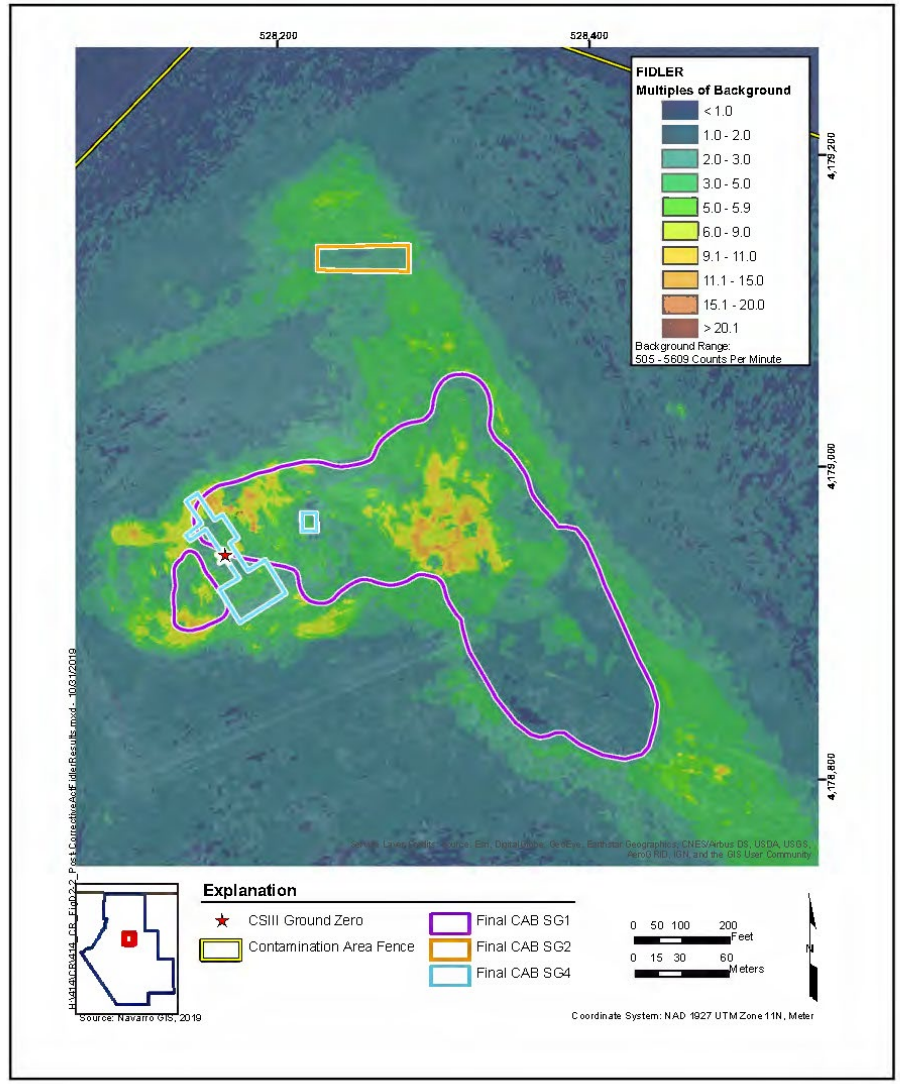

Figure G-28. CAU 414 Post-Corrective Action FIDLER Survey Results, Figure D.2-2 from DOE/EMNV-0011 (2019).

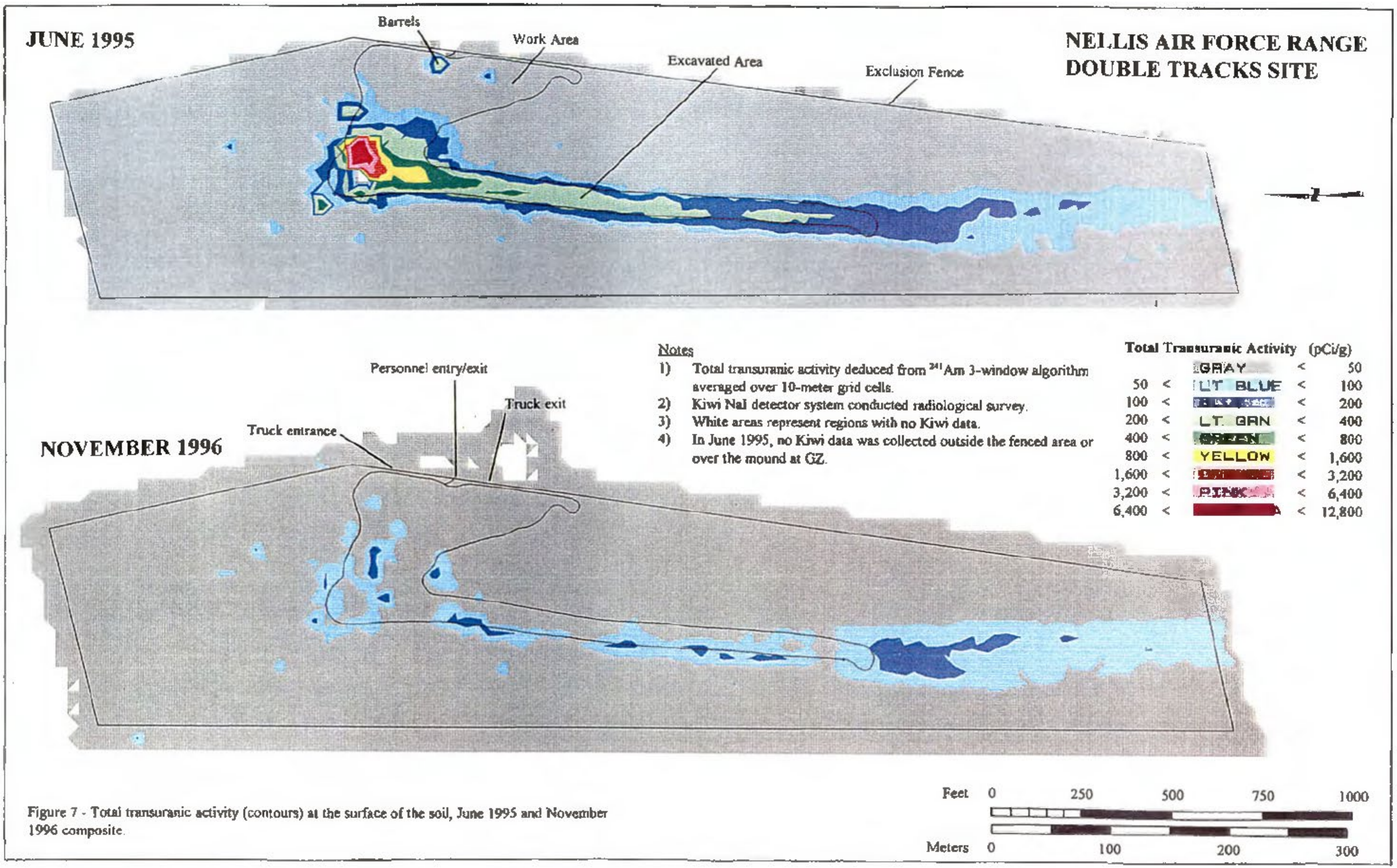

Figure 7 - Total transuranic activity (contours) at the surface of the soil, June 1995 and November 1996 composite.

Figure G-29. Total Transuranic Activity Contours at the Surface of the Soil, June 1995 and November 1996 Composite, Figure 7, DOE/NV-11718-313 (1997).

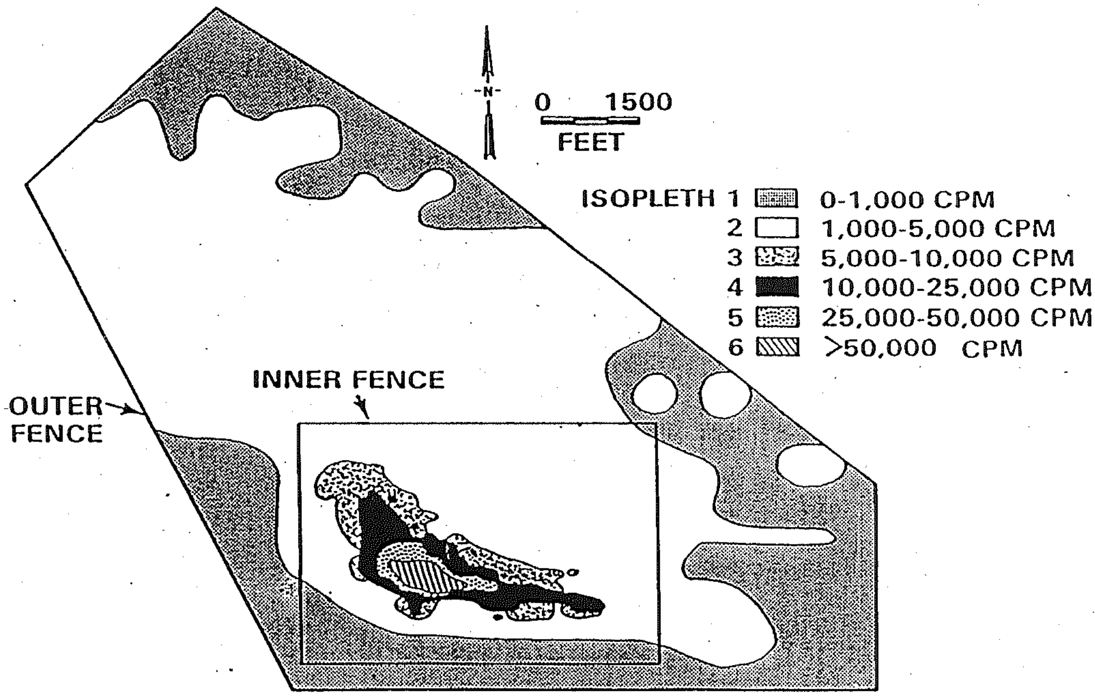

Figure G-30. Strada Used for Sampling as Determined by 1972 FIDLER In-Situ Survey of Project 57 Site, Figure 3.10.2 of CERLA Preliminary Assessment of DOE's NVO, Nuclear Weapons Testing Areas (1988).

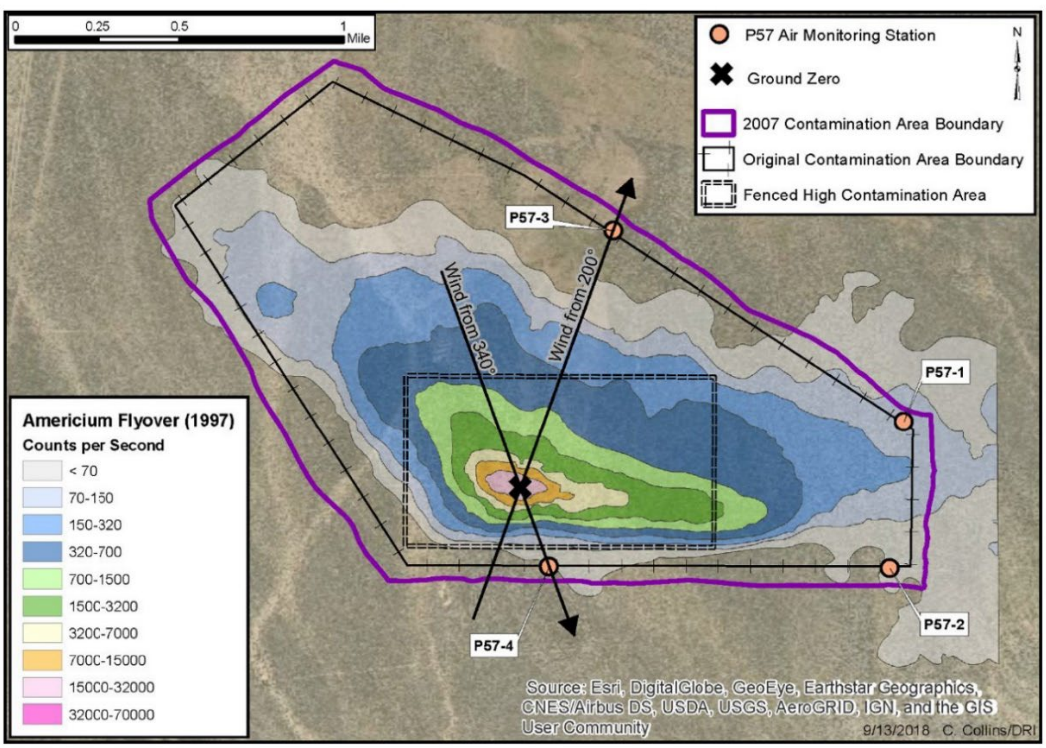

Figure G-31. Locations of the Original Monitoring Stations (P57-1 and P57-2) and Those Downwind of Ground Zero (P57-3 and P57-4) are Shown in Relation to the Am-241 Concentrations Measured during the 1997 Flyover Survey, Figure 2 from DRI 45286 (2018).

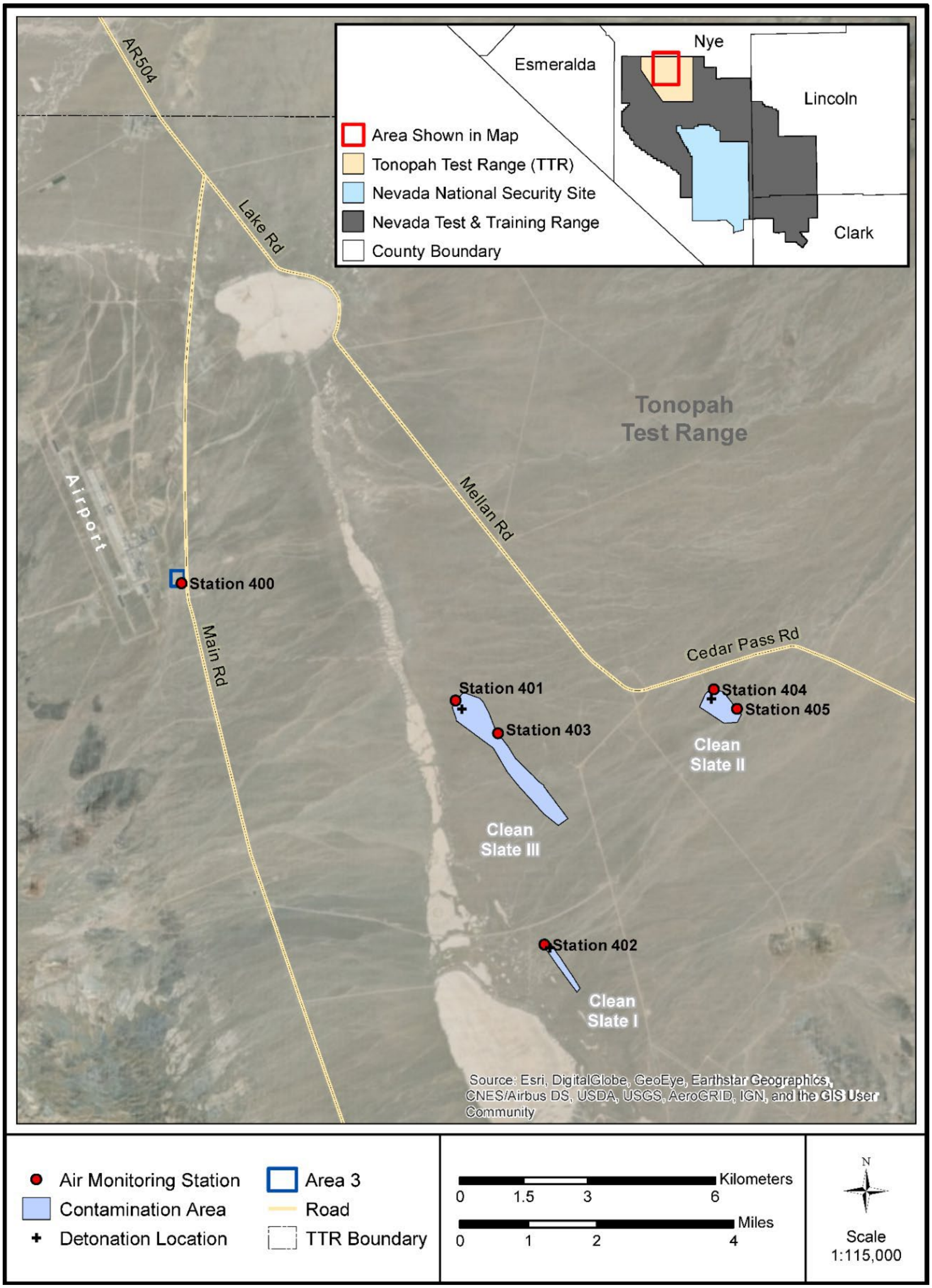

Figure G-32. Map of DRI and DOE Air Sampling Locations
on TTR in 2017, Figure 2 of DRI 45287 (2017).

TABLE G-8. DRI Air Sampling Results, Annual Airborne Gross α-Particle Activity Concentrations, fCi/m^3, for Respective Locations on TTR, data from DRI Publications.

	Station 400, TTR Airport								
Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020
Min	0.32		0.28	0.6	0.32	0.52	0.84	0.38	0.74
Max	4.36		3.5	2.9	5.7	3.44	5.31	3.2	3.86
Mean	2.01		1.6	1.22	1.79	1.89	2.51	1.75	2.02
	Station 401, Northwest Fence Boundary Clean Slate III								
Min	0.32		0.22	0.35	0.27	0.31	0.89	0.5	1.08
Max	4.36		2.59	2.31	3.5	3.67	8.91	19.19	10.29
Mean	2.01		1.14	1.08	1.67	1.68	2.59	4.39	3.19
	Station 402, Northwest Fence Boundary Clean Slate I								
Min	0.73		0.62	0.51	0.45	0.91			
Max	5.76		2.9	2.19	5.09	2.67			
Mean	2.8		1.66	1.3	2.01	1.85			
	Station 403, East Fence Boundary Clean Slate III								
Min						0.52	1.06	0.38	0.67
Max						4.46	8.35	5.71	4.8
Mean						2.04	3.56	2.49	3.1
	Station 404, Northwest Fence Boundary Clean Slate II								
Min						1.06	1.09	0.46	0.89
Max						7.06	30.5	3.82	7.65
Mean						2.85	6.99	2.09	3.21
	Station 405, Southeast Fence Boundary Clean Slate II								
Min						0.95	1.17	0.45	1.02
Max						3.89	9.59	2.95	4.5
Mean						2.34	3.21	1.98	2.73
Desert Research Institute Reports									
Report	Date	Report	Date	Report	Date	Report	Date	Report	Date
45181	May 01	45243	Jan 12	45250	Jul 13	45263	Oct 15	45271	Sep 16
45279	Oct 17	45284	Nov 18	45290	Dec 19	45296	Mar 21	41285	Aug 21

TABLE G-9. DRI Air Sampling Results, Annual Airborne Gross α-Particle Activity Concentrations, fCi/m^3, for Fence Boundary Locations at Project 57, data from DRI Publications.

	P57-1								
Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020
Min	0.26	0.56	0.79						
Max	4.67	5.68	5.42						
Mean	2.03	2.3	2.1						
	P57-2								
Min	0.56	0							
Max	5.38	5.59							
Mean	2.49	1.77							
	P57-3								
Min						0.52	0.35	0.8	1.39
Max						11.08	6.39	16.56	23.01
Mean						2.62	3.1	2.45	4.74
	P57-4								
Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020
Min						0.74	0.7	0.76	1.34
Max						96.62	20.8	22.15	26.87
Mean						11.21	4.75	2.82	4.43
Desert Research Institute Reports									
Report	Date	Report	Date	Report	Date	Report	Date	Report	Date
45256	Jul 14	45286	Nov 18	45291	Mar 20	45297	Apr 21	45298	Oct 21

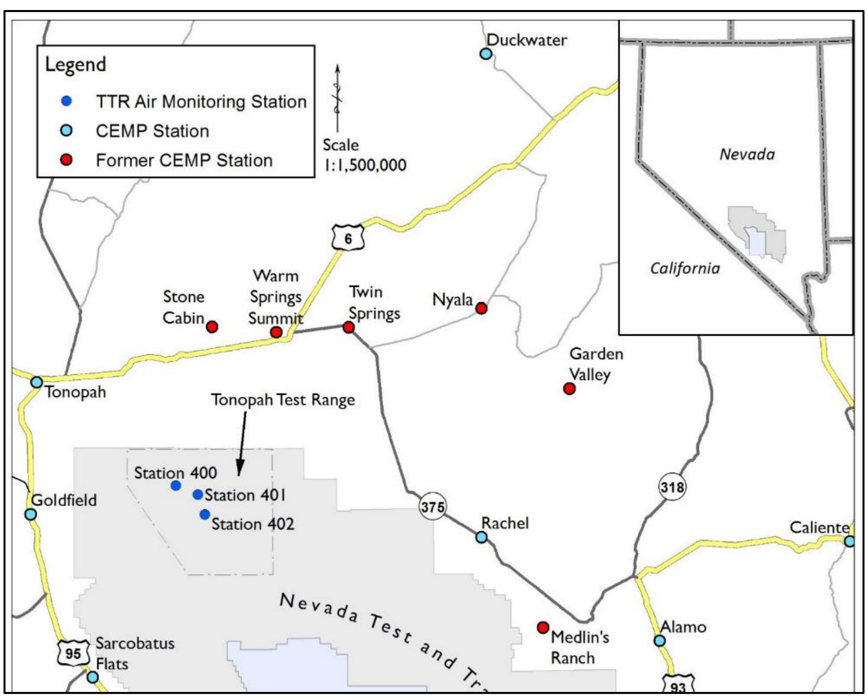

Figure G-33. Map of DRI Sampling Locations Around TTR, Adapted from DRI 45286 (2018).

TABLE G-10. DRI Air Sampling Results, Annual Airborne Gross α-Particle Activity Concentrations, fCi/m^3, for Respective Locations near TTR, data from DRI Publications Listed in Table G-7.

	Goldfield								
Parameter	2012	2013	2014	2015	2016	2017	2018	2019	2020
Min	0.48		0.63	0.59	0.56	0.383	0.84	0.45	1.34
Max	1.88		2.83	1.77	2.44	2.5	2.87	2.37	4.44
Mean	1.05		1.02	1.05	1.13	1.22	1.38	1.51	2.45
	Rachel								
Min	0.56		0.4	0.53	0.38	0.6	0.7	0.37	1.1
Max	1.66		1.65	2.1	2.84	2.68	1.82	2.4	2.93
Mean	1.03		0.95	1.07	1.23	1.25	1.23	1.58	1.94
	Sarcobatus Flats								
Min	0.51		0.67	0.58	0.57	0.6	0.71	0.59	1.51
Max	4.61		3.5	5.16	4.88	4.24	2.2	2.39	3.37
Mean	1.83		1.71	1.81	1.9	1.77	1.17	1.71	2.08
	Stone Cabin								
Min	0.47								
Max	1.99								
Mean	0.91								
	Tonopah								
Min	0.41		0.5	0.42	0.44	0.51	1.17	0.48	1.26
Max	2.14		1.93	1.82	1.82	2.56	3.08	2.63	2.71
Mean	1.08		0.9	1.02	1.02	1.1	1.91	1.69	1.75
	Twin Springs								
Min	0.53								
Max	1.81								
Mean	0.95								
	Alamo								
Min			0.51	0.46	0.73	0.74	0.61	1	1.35
Max			3.24	3.98	3.97	3.85	2.71	1.75	4.48
Mean			1.38	1.79	1.8	1.68	1.6	1.52	2.88
	Beatty								
Min			0.25	0.49	0.51	0.74	0.66	0.68	1.44
Max			1.35	1.76	2.43	2.62	4.76	1.62	3.01
Mean			0.91	1.05	1.19	1.43	1.89	1.33	2.03

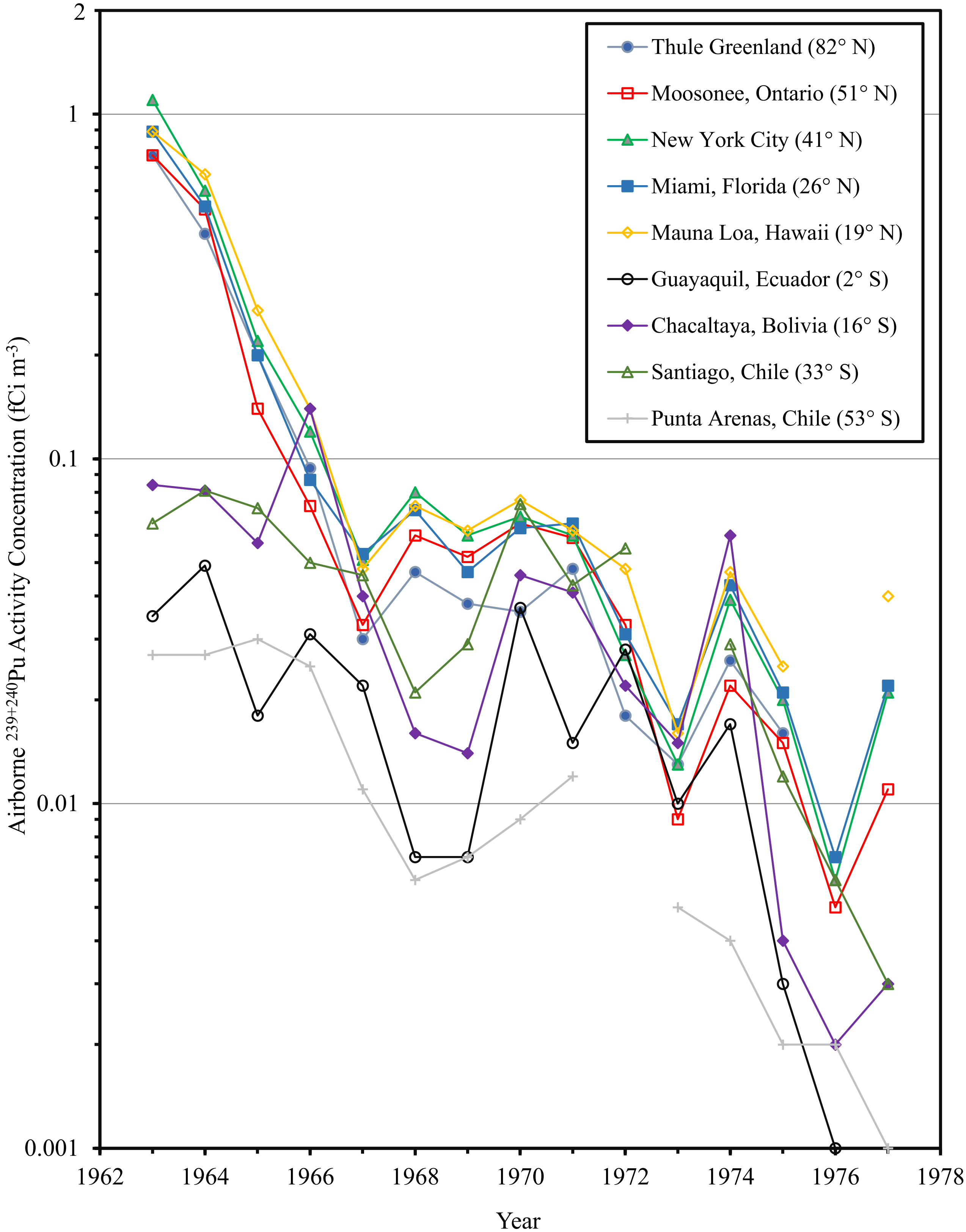

Figure G-34. Airborne $^{239+240}$Pu Activity Concentrations for Various Sampling Locations from 1963 to 1977, from Harley (1980).

TABLE G-11. Corrective Action Units on TTR and NTTR of Interest.

CAU	Site	Location	Description	References
404	Roller Coaster Sewage Lagoons and North Trench	TTR	Sewage lagoon rec'd liquid sanitary waste from the Roller Coaster man-camp used in 1963. North Trench rec'd solid debris. No radiological material identified in 1997 survey. Vegetative cover constructed, site fenced, and signage installed in 1997. 2008 modification of the use restriction established in 1998.	DOE/NV-11718-187 (1999) & Addendum-Rev 1 (2009)
407	Roller Coaster RADSAFE Area	TTR	Site used in May - June 1963 to decontaminate vehicles, equipment, and personnel from DT and CS 1, 2, & 3. Later in 1963, waste was removed and buried at NTS. Surveys conducted in 1998 to identify and remove residuals, which were partially successful. Additional hot-spots and debris removed in 2000 and sent to NTS. Soil cover added and fencing.	DOE/NV-694 Rev 1 (2001)
408	Bomblet Target Area (DU)	TTR	Bomblet drops conducted from 1960s to 1985 in area, with BLU-62, -63, and -97, Mk-118, and BLU-72. DU potential. 2009 - 2010 investigated potential MEC, disposal pits, DU fragments, and removed DU. Eighteen small pieces of DU frag and seven pieces of DU-impacted frag identified. Five cubic feet of DU-impacted soil in concrete bunker found, several intact bomblets, and MEC located. MEC destroyed during operation five times. DU fragments and soil disposed off-site.	DOE/NV-1409 (2010)
426	Cactus Springs Waste Trenches	TTR	Four waste trenches used in 1963 Roller Coaster tests and backfilled with clean cover. Site investigated by borehole sampling in 1996. Waste items were located 3 to 7 feet below ground surface, though no contaminants of concern identified above preliminary remediation goals. The trenches were capped over in 1997.	DOE/NV-11718-226 (1999)

TABLE G-11. Corrective Action Units on TTR and NTTR of Interest, continued.

CAU	Site	Location	Description	Reference
430	Buried DU Artillery Round No. 1	TTR	Suspected burial of W-79 Joint Test Assembly (JTA), which would have contained conventional high explosives and DU. DU was used to simulate the mass of SNM in a war reserve item. W-79 JTA not located, rather a concrete-filled shape was located. No radiological contamination was identified in activity. Suspect JTA is based on a 1987 test on TTR.	DOE/NV-469 (1997)
453	Area 9 Unexploded Ordnance Landfill	TTR	Waste cells operated from early 1960's through 1993 with waste material from Area 9 and range clean-ups. Some UXO is suspected in landfill. 1997 investigation of soil beneath burial layer screened, with negative findings for toxics. Currently closed in-place with a soil cover.	DOE/NV-284 (1999)
461 & 495	Test Area JTA Sites	TTR	Suspected burial of W-79 JTA and DU artillery round test packages. 1998 survey of CAU 495 found no evidence of DU or explosives residues, though an inert nose cone was located. 1998 survey of CAU 461 found no evidence of DU or explosives residue, except some metallic debris. Debris removed and excavated areas backfilled.	DOE/NV/11718-312 (1999) & DOE/NV-566 (1999)
485	Cactus Spring Ranch	TTR	Supported animal inhalation research studies for Project Roller Coaster tests Double Tracks and Clean Slate II. Grazing studies for animals also. Radiological studies of the ranch area conducted in 1993, 1997, and 1998. 1993 aerial survey was negative, yet had limited sensitivity for low-level Pu contamination. Surface soil samples negative for plutonium. No further action recommended.	DOE/NV-13052-026 (1998)

TABLE G-11. Corrective Action Units on TTR and NTTR of Interest, continued.

CAU	Site	Location	Description	Reference
486	Double Tracks RADSAFE Area	NTTR	Area to east of Double Tracks GZ used in May 1963 to decontaminate vehicles, personnel and animals from the DT test. Liquid wastes from decontamination drained from a gravel decontamination pad to a sump. Gravel placed in sump possibly with other material and animal decontamination wastes. Sump and pits were backfilled. Site investigated in 1998, with finding of waste associated with operation, and low-level radiological detections on debris. Waste removed and disposed off-site.	DOE/NV-555 (1999)
487	Thunderwell Site	TTR	Conventional explosives tests only. One test believed to use DU in a projectile. Investigation completed in 2001. None of the samples analyzed had concentrations in excess of preliminary action levels, except arsenic which was consistent with levels natural to the area soils. No further action recommended.	DOE/NV-761 (2001)
541	Small Boy	NTTR	14 July 1962 low-yield nuclear test conducted at site at an elevation of 10 feet. Site initial planned for Area 5 of NTS. Later determined that the GZ was 300 feet of the NTS boundary. Evaluated in 2014, final action level based on an occasional use scenario (80 h/y) 25 mrem/y effective dose. Site met criterion. No additional efforts deemed necessary.	DOE/NV-1539 (2016)

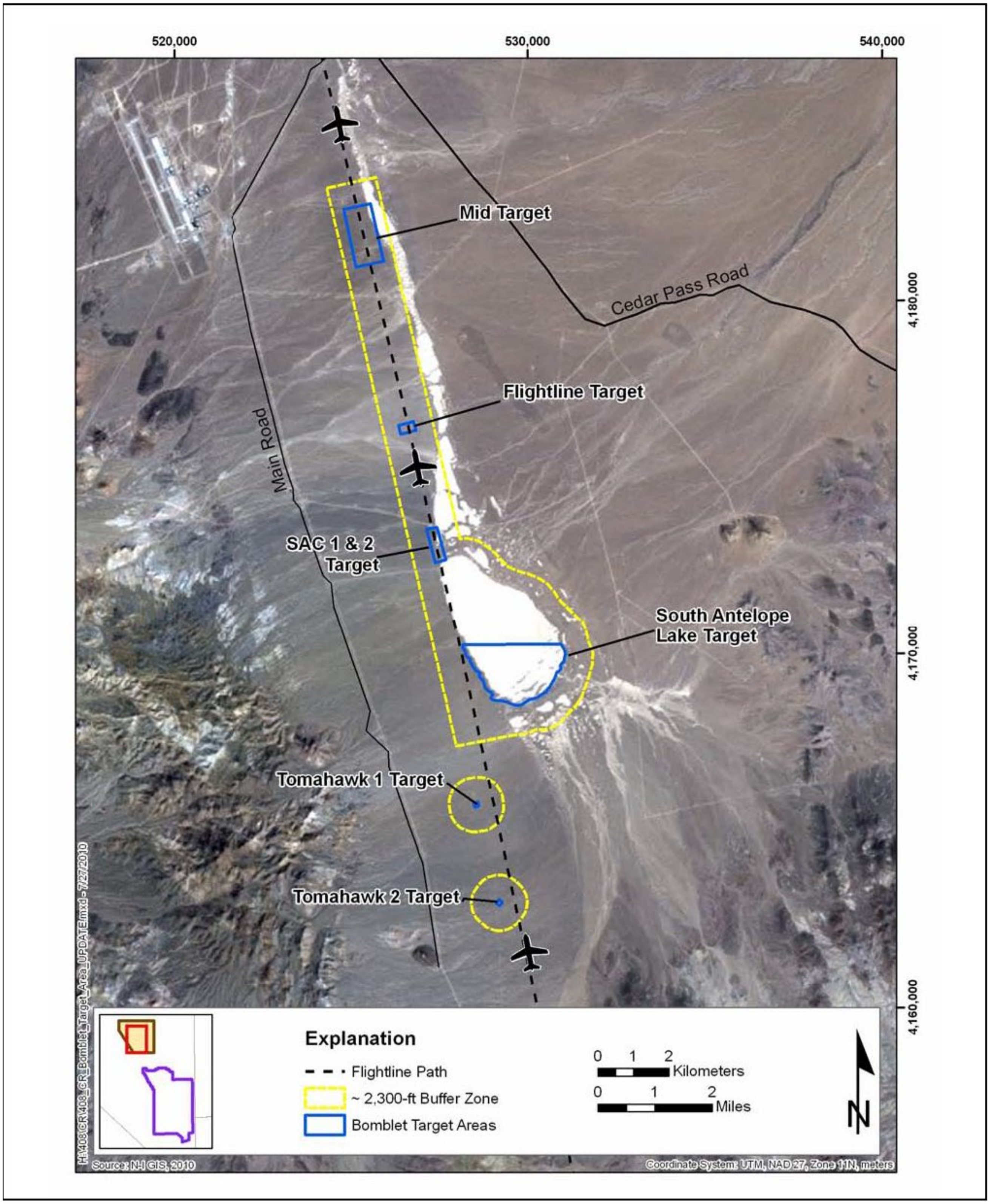

Figure G-35. CAU 408 (Bomblet Target Area), TTR, Figure 1-2 of DOE/NV-1409 (2010).

TABLE G-12. DU-Impacted Debris from CAU 408, from Table 2-2 of DOE/NV-1409 (2010).

Date	Description	Grid	Grid Coordinates
11/18/2009	One small piece of DU-impacted debris, limited to one face of the metal, about 1 by 1 in. found on grid 90/703 exhibiting 600 dpm/100cm^2 alpha fixed and 17,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 90/703	UTM83N, UTM83E 4170344, 529158 4170344, 529058 4170444, 529058 4170444, 529158
11/18/2009	One small piece of DU-impacted debris, limited to one face of the metal, about 1 by 1 in. found on grid 92/702 exhibiting 100 dpm/100cm^2 alpha fixed and 13,600 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 92/702	UTM83N, UTM83E 4170244, 529258 4170344, 529258 4170244, 529358 4170344, 529358
11/19/2009	Two small pieces of DU-impacted debris about 1 by 1 in. found on grid 91/702 exhibiting 600 dpm/100cm^2 alpha fixed and 17,000 dpm/100cm^2 beta/gamma fixed, and 600 dpm/100cm^2 alpha fixed and 21,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 91/702	UTM83N, UTM83E 4170244, 529258 4170244, 529158 4170344, 529158 4170344, 529258
11/20/2009	One piece of DU-impacted debris 1 by 1 in. found on grid 93/702 exhibiting 250 dpm/100cm^2 alpha fixed and 15,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 93/702	UTM83N, UTM83E 4170244, 529358 4170344, 529358 4170244, 529458 4170344, 529458
12/16/2009	One piece of DU frag 1 by 2 in. found on grid 93/696 exhibiting 200 dpm/100cm^2 alpha fixed and 56,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 93/696	UTM83N, UTM83E 4169644, 529458 4169644, 529358 4169744, 529358 4169744, 529458
01/04/2010	One piece of DU frag approximately 1 ft square found on grid 89/697 exhibiting 14,000 dpm/100cm^2 alpha fixed and 1,000,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 89/697	UTM83N, UTM83E 4169744, 529058 4169744, 528958 4169844, 528958 4169844, 529058
01/14/2010	One piece of DU frag 1.5 by 2 in. found on grid 93/693 exhibiting 250 dpm/100cm^2 alpha and 75,000 dpm/100cm^2 beta/gamma.	South Antelope Lake 93/693	UTM83N, UTM83E 4169344, 529458 4169344, 529358 4169444, 529358 4169444, 529458
01/15/2010	One piece of DU alloy found on grid 94/695 exhibiting 13,000 dpm/100cm^2 alpha fixed and 1,500,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 94/695	UTM83N, UTM83E 4169544, 529558 4169544, 529458 4169644, 529458 4169644, 529558
01/19/2010	One piece of DU frag 1 by 2 in. found on grid 93/689 exhibiting 150 dpm/100cm^2 alpha fixed and 8,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 93/689	UTM83N, UTM83E 4168944, 529358 4168944, 529458 4169044, 529358 4169044, 529458

TABLE G-12. DU-Impacted Debris from CAU 408, from Table 2-2 of DOE/NV-1409 (2010), continued.

Date	Description	Grid	Grid Coordinates
01/20/2010	One piece of DU frag 2 by 2 in. found on grid 92/688 exhibiting 125 dpm/100cm^2 alpha fixed and 11,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 92/688	UTM83N, UTM83E 4168844, 529258 4168944, 529258 4168844, 529358 4168944, 529358
01/21/2010	One piece of DU alloy 1.5 by 1.5 in. found on grid 91/688 exhibiting 3,200 dpm/100cm^2 alpha fixed, and 902,000 dpm/100cm^2 on beta/gamma fixed.	South Antelope Lake 91/688	UTM83N, UTM83E 4168844, 529258 4168844, 529158 4168944, 529158 4168944, 529258
01/21/2010	One piece of DU alloy 0.5 by 0.75 in. found on grid 91/691 exhibiting 2,000 dpm/100cm^2 alpha fixed and 316,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 91/691	UTM83N, UTM83E 4169144, 529158 4169144, 529258 4169244, 529158 4169244, 529258
01/21/2010	One piece of DU alloy 1 by 2 in. found on grid 91/690 exhibiting 15,000 dpm/100cm^2 alpha fixed and 1,300,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 91/690	UTM83N, UTM83E 4169044, 529158 4169144, 529158 4169044, 529258 4169144, 529258
01/21/2010	One piece of DU alloy 1 by 0.5 in. found on grid 90/690 exhibiting 750 dpm/100cm^2 alpha fixed and 547,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 90/690	UTM83N, UTM83E 4169044, 529158 4169044, 529058 4169144, 529058 4169144, 529158
02/24/2010	One piece of DU alloy 1 by 5 in. found South Antelope Lake exhibiting 276 dpm/100cm^2 alpha fixed and 1,067,000 dpm/100cm^2 beta/gamma fixed in grid 97/688.	South Antelope Lake 97/688	UTM83N, UTM83E 4168844, 529858 4168844, 529758 4168944, 529758 4168944, 529858
03/12/2010	Two pieces of DU frag, 1 by 1.5 in. found at south end of Antelope Lake exhibiting 200 dpm/100cm^2 alpha fixed and 5,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake South Boundary	No coordinates available
04/07/2010	Two pieces of DU frag found at grid 00/702 exhibiting 124 dpm/100cm^2 alpha fixed, 35,000 beta/gamma, and 74 dpm/100cm^2 alpha, 95,000 beta/gamma fixed, respectively.	South Antelope Lake 00/702	UTM83N, UTM83E 4170244, 530158 4170244, 530058 4170344, 530058 4170344, 530158
04/26/2010	One 1.5 by 1.5 in. of DU alloy in grid 96/692 exhibiting 2,800 dpm/100cm^2 alpha fixed and 885,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 96/692	UTM83N, UTM83E 4169244, 529758 4169244, 529658 4169344, 529658 4169344, 529758

TABLE G-12. DU-Impacted Debris from CAU 408, from Table 2-2 of DOE/NV-1409 (2010), continued.

Date	Description	Grid	Grid Coordinates
04/28/2010	One 1 by 2 in. DU alloy frag found on grid 94/688 exhibiting 15,000 dpm/100cm^2 alpha fixed and 1,800,000 dpm/100cm^2 beta/gamma fixed.	South Antelope Lake 94/688	UTM83N, UTM83E 4168844, 529558 4168844, 529458 4168944, 529458 4168944, 529558
05/20/2010	One 6-by-14-in. piece of DU-impacted debris found 500 m from the south end of NEDS Lake in the buffer zone exhibiting 3,000 dpm/100cm^2 alpha fixed and 170,000 dpm/100 cm^2 beta/gamma. A second piece of DU metal 2 by 1 in. found on the southwest corner of NEDS Lake just outside the buffer zone exhibiting 649 dpm/100cm^2 alpha fixed and 2,409,000 dpm/100cm^2 beta/gamma fixed.	Southwest corner NEDS Lake and 500 m south of NEDS Lake	No coordinates available
05/24/2010	One DU-impacted piece of debris found in scrub area west of NEDS Lake/DU Bunker area exhibiting 132 dpm/100cm^2 alpha fixed and 210,000 dpm/100 cm^2 beta/gamma fixed. A second piece of DU-impacted debris found exhibiting 112 dpm/100cm^2 alpha fixed and 274,000 dpm/100cm^2 beta/gamma fixed in the same general area as the location of the first piece.	Buffer Zone - north of Flightline and west of NEDS Lake	No coordinates available
06/21/2010	One piece of DU-impacted metal frag approximately 6 by 6 in. in size. Radiological readings on the item exhibiting 115 dpm/100cm^2 alpha fixed and 17,000 dpm/100 cm^2 beta/gamma fixed.	Buffer Zone on the east side of Flightline Road, between Flightline and Mid Targets	No coordinates available

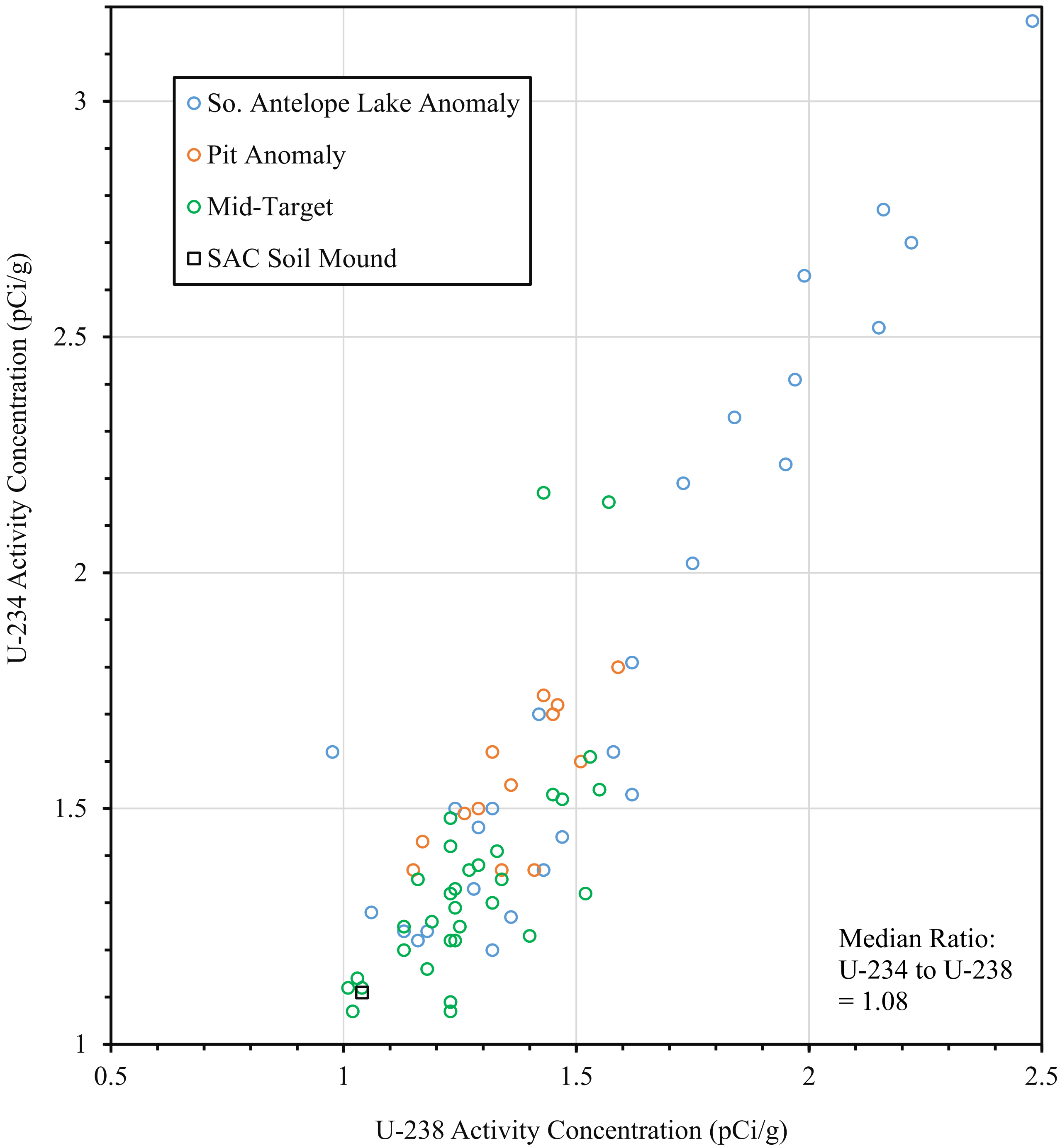

Figure G-36. Scatterplot of ^{234}U vs. ^{238}U for Soil Samples Collected in Bomblet Target Areas, Data from Table 3-4 of DOE/NV-1409 (2010).