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Offsite Environmental Monitoring Report

Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1993

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Offsite Environmental Monitoring Report:

Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1993

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Subsequent to the completion of this study but prior to publication of this report an internal EPA reorganization resulted in a name change for some organizational elements. The EPA Environmental Monitoring Systems Laboratory - Las Vegas (EMSL-LV) is now the Characterization Research Division - Las Vegas (CRD-LV), part of the EPA National Exposure Research Laboratory (NERL). The Radiation Sciences Division (RSD) is now the Office of Radiation and Indoor Air (ORIA), Radiation Sciences Laboratory-Las Vegas.

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Abstract

This report describes the Offsite Radiation Safety Program conducted during 1993 by the Environmental Protection Agency's (EPA's) Environmental Monitoring Systems Laboratory - Las Vegas (EMSL-LV). This laboratory operates an environmental radiation monitoring program in the region surrounding the Nevada Test Site (NTS) and at former test sites in Alaska, Colorado, Mississippi, Nevada, and New Mexico. The surveillance program is designed to measure levels and trends of radioactivity, if present, in the environment surrounding testing areas to ascertain whether current radiation levels and associated doses to the general public are in compliance with existing radiation protection standards. The surveillance program additionally has the responsibility to take action to protect the health and well being of the public in the event of any accidental release of radioactive contaminants. Offsite levels of radiation and radioactivity are assessed by sampling milk, water, and air; by deploying thermoluminescent dosimeters (TLDs) and using pressurized ionization chambers (PICs); by biological monitoring of foodstuffs including animal tissues and food crops; and by measurement of radioactive material deposited in humans.

No nuclear weapons testing was conducted in 1993 due to the continuing nuclear test moratorium. During this period, EMSL-LV personnel maintained capability to provide direct monitoring support if testing were to be resumed. In such a circumstance, personnel with mobile monitoring equipment are placed in areas downwind from the test site prior to each nuclear weapons test to implement protective actions, provide immediate radiation monitoring, and to collect environmental samples rapidly after any occurrence of radioactivity release.

Comparison of the measurements and sample analysis results with background levels and with appropriate standards and regulations indicated that there was no radioactivity detected offsite by the various EPA monitoring networks and that no radiation exposure above natural background, to the population living in the vicinity of the NTS could be attributed to current NTS activities. Annual and long-term (10-year) trends were evaluated in the Noble Gas, Tritium, Milk Surveillance, Biomonitoring, TLD, and PIC networks, and the Long Term Hydrological Monitoring Program (LTHMP). All evaluated data were consistent with previous data history. No radiation directly attributable to current NTS activities was detected in any samples. Monitoring network data indicate the greatest population exposure came from naturally occurring background radiation, which yielded an average exposure of 97 mrem/year (9.7×10^{-1} mSv/year). Worldwide fallout accounted for approximately 0.05 mrem/year (5×10^{-4} mSv/year). Calculation of maximum potential dose to offsite residents based on onsite source emission measurements provided by the Department of Energy (DOE) resulted in a maximum calculated dose from this source of 0.004 mrem/year (3.8×10^{-5} mSv/year). Calculation of the maximum potential dose to an individual based on EMSL-LV monitoring network measurements, using metabolic and dietary presumptions detailed in Chapter 8 of this report, indicates that the maximum dose to such a hypothetical individual would have been 0.054 mrem/year (5.4×10^{-4} mSv/year). When compared to radiation exposures attributable to natural background radiation, dose contributions from source emissions and from monitoring network measurements are considered to be insignificant.

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Abbreviations, Acronyms, Units of Measure, and Conversions

ABBREVIATIONS and ACRONYMS

AEC	--	Atomic Energy Commission
ALARA	--	As Low as Reasonably Achievable
ALI	--	Annual Limit on Intake
ASN	--	Air Surveillance Network
ANSI	--	American National Standards Institute
BOC	--	Bureau of Census
BOMAB	--	Bottle Mannequin Absorber
CEDE	--	Committed Effective Dose Equivalent
CFR	--	Code of Federal Regulations
CG	--	Concentration Guide
CP-1	--	Control Point One
CRMP	--	Community Radiation Monitoring Program
DAC	--	Derived Air Concentration
DCG	--	Derived Concentration Guide
DOE	--	U.S. Department of Energy
DOELAP	--	Department of Energy, Laboratory Accreditation Program
DQO	--	data quality objective
DRI	--	Desert Research Institute
ECF	--	Element Correction Factor
EDE	--	Effective Dose Equivalent
EML	--	Environmental Monitoring Laboratory
EMSL-LV	--	Environmental Monitoring Systems Laboratory-Las Vegas
EPA	--	U.S. Environmental Protection Agency
FDA	--	Food and Drug Administration
FRMAC and	--	Federal Radiological Monitoring Assessment Center
GOES	--	Geostationary Operational Environmental Satellite
GZ	--	Ground Zero
HTO	--	tritiated water
HpGe	--	High purity germanium
IAGs	--	Interagency Agreements
ICRP	--	International Commission on Radiological Protection
LGFSTF	--	Liquefied Gaseous Fuels Spill Test Facility
LTHMP	--	Long-Term Hydrological Monitoring Program
MDC	--	minimum detectable concentration
MSL	--	mean sea level
MSN	--	Milk Surveillance Network
NCRP	--	National Council on Radiation Protection and Measurements
NIST	--	National Institute of Standards and Technology
NGTSN	--	Noble Gas and Tritium Surveillance Network
NPDWR	--	National Primary Drinking Water Regulation
NPS	--	National Park Service
NTS	--	Nevada Test Site
NRD	--	Nuclear Radiation Assessment Division
ORSP	--	Offsite Radiological Safety Program
PHS	--	U.S. Public Health Service
PIC	--	pressurized ion chamber
QA	--	quality assurance
QC	--	quality control
RAWS	--	Remote Automatic Weather Station
RCF	--	reference correction factor
RCRA	--	Resource Conservation and Recovery Act
SASN	--	Standby Air Surveillance Network
S.D.	--	standard deviation
SGZ	--	Surface Ground Zero
SMSN	--	Standby Milk Surveillance Network
SOP	--	standard operating procedure
STDMS	--	Sample Tracking Data Management System
TLD	--	thermoluminescent dosimetry
USGS	--	U.S. Geological Survey
WSNSO	--	Weather Service Nuclear Support Office

Abbreviations, Acronyms, Units of Measure, and Conversions (continued)

UNITS OF MEASURE

Bq	--	Becquerel, one disintegration per second
C	--	coulomb
°C	--	degrees centigrade
Ci	--	Curie
cm	--	centimeter, 1/100 meter
eV	--	electron volt
°F	--	degrees Fahrenheit
g	--	gram
hr	--	hour
keV	--	one thousand electron volts
kg	--	kilogram, 1000 grams
km	--	kilometer, 1000 meters
L	--	liter
lb	--	pound
m	--	meter
MeV	--	one million electron volts
mg	--	milligram, 10^{-3} gram
min	--	minute
mL	--	milliliter, 10^{-3} liter
mo	--	month
mR	--	milliroentgen, 10^{-3} roentgen
mrem	--	millirem, 10^{-3} rem
mSv	--	millisievert, 10^{-3} sievert
pCi	--	picocurie, 10^{-12} curie
qt	--	quarter
R	--	roentgen
rad	--	unit of absorbed dose, 100 ergs/g
rem	--	dose equivalent, the rad adjusted for biological effect
Sv	--	sievert, equivalent to 100 rem
wk	--	week
yr	--	year
μCi	--	microcurie, 10^{-6} curie
μR	--	microroentgen, 10^{-6} roentgen
%	--	percent
±	--	plus or minus
<	--	less than
=	--	equals
≅	--	approximately equals

PREFIXES

a	atto	=	10^{-18}
f	femto	=	10^{-15}
p	pico	=	10^{-12}
n	nano	=	10^{-9}
μ	micro	=	10^{-6}
m	milli	=	10^{-3}
k	kilo	=	10^{3}

CONVERSIONS

Multiply	by	To Obtain
Concentrations		
μCi/mL	10^{9}	pCi/L
μCi/mL	10^{12}	pCi/m^3
SI Units		
rad	10^{-2}	Gray (Gy=1 Joule/kg)
rem	10^{-2}	Sievert (Sv)
pCi	3.7×10^{-2}	Becquerel (Bq)
mR/yr	2.6×10^{-7}	Coulomb (C)/kg-yr

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1 Introduction

The U.S. Atomic Energy Commission (AEC) used the Nevada Test Site (NTS), between January 1951 and January 1975, for conducting nuclear weapons tests, nuclear rocket engine development, nuclear medicine studies, and for other nuclear and nonnuclear experiments. Beginning in mid-January 1975, these activities became the responsibility of the U.S. Energy Research and Development Administration. Two years later this organization was merged with other energy-related agencies to form the U.S. Department of Energy (DOE).

Atmospheric weapons tests were conducted periodically at the NTS from January 1951 through October 1958, followed by a test moratorium which was in effect until September 1961. Since then all nuclear detonations at the NTS have been conducted underground, with the expectation of containment, except the above-ground and shallow underground tests of Operation Sunbeam and cratering experiments conducted under the Plowshare program between 1962 and 1968.

Prior to 1954, an offsite radiation surveillance program was performed by personnel from the Los Alamos Scientific Laboratory and the U.S. Army. Beginning in 1954, and continuing through 1970, this program was conducted by the U.S. Public Health Service (PHS). When the U.S. Environmental Protection Agency (EPA) was formed in December 1970, certain radiation responsibilities from several federal agencies were transferred to it, including the Offsite Radiological Safety Program (ORSP) of the PHS. Since 1970, the EPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) has conducted the ORSP, both in Nevada and at other U.S. nuclear test sites, under interagency agreements (IAGs) with the DOE or its predecessor agencies.

Since 1954, the three major objectives of the ORSP have been:

- Assuring the health and safety of the people living near the NTS.
- Measuring and documenting levels and trends of environmental radiation or radioactive contaminants in the vicinity of atomic testing areas.
- Verifying compliance with applicable radiation protection standards, guidelines, and regulations.

Offsite levels of radiation and radioactivity are assessed by gamma-ray measurements using pressurized ion chambers (PICs) and thermoluminescent dosimeters (TLDs); by sampling air, water, milk, food crops, other vegetation, soil, and animals; and by human exposure and biological assay procedures.

1.1 Program Description

Monitoring and surveillance on and around the Nevada Test Site (NTS) during 1993 indicated that operations on the NTS were conducted in compliance with applicable federal and DOE guidelines, i.e., the dose the maximally exposed offsite individual could have received was less than 0.04 percent of the 10 mrem per year guide for air exposure. No nuclear tests were conducted due to the moratorium. All discharges of radioactive liquids remained onsite in containment ponds, and there was no indication of potential migration of radioactivity to the offsite area through groundwater. Surveillance around the NTS indicated that airborne radioactivity from diffusion, evaporation of effluents, or resuspension was not detectable offsite. No measurable net exposure to members of the offsite population was detected through the offsite dosimetry program. Using the CAP88-PC model and NTS radionuclide emissions data, the calculated effective dose equivalent to the maximally exposed individual offsite would have been 4×10^{-3} mrem (4×10^{-5} mSv) Any person receiving this dose would also have received 97 mrem (9.7×10^{-1} mSv) from natural background radiation.

1.2 Offsite Environmental Surveillance

The offsite radiological monitoring program is conducted around the NTS by the EPA's EMSL-LV, under an Interagency Agreement with DOE. This program consists of several extensive environmental sampling, radiation detection, and dosimetry networks.

In 1993 the Air Surveillance Network (ASN) was made up of 30 continuously operating sampling locations surrounding the NTS and 77 standby stations (operated one week each quarter) in all states west of the Mississippi River. The 30 ASN stations included 18 located at Community Radiation Monitoring Program (CRMP) stations, described below. During 1993 no airborne radioactivity related to current activities at the NTS was detected on any sample from the ASN. Other than naturally occurring ^{7}Be, the only specific radionuclide possibly detected by this network was ^{238}Pu or $^{239+240}Pu$ on a few air filter samples.

The Noble Gas and Tritium Surveillance Network (NGTSN) consisted of 21 offsite noble gas samplers (8 on standby) and 21 tritium-in-air samplers (seven on standby) located outside the NTS and exclusion areas in the states of Nevada, California, and Utah. During 1993 no radioactivity that could be related to NTS activities was detected at any NGTSN sampling station.

As in previous years, results for ^{133}Xe and HTO were typically below the minimum detectable concentration (MDC). The annual average results for krypton, 28×10^{-12} μCi/mL, although above the MDC, were within the range of worldwide values expected from sampling background levels and the range was similar to last year's.

Sampling of Long-Term Hydrological Monitoring Program (LTHMP) wells and surface waters around the NTS showed only background radionuclide concentrations. The LTHMP also included groundwater and surface water monitoring at locations in Colorado, Mississippi, New Mexico, Alaska, and Nevada where underground tests were conducted. The results obtained from analysis of samples collected at those locations were consistent with previous data except for a sample from a deep well at Project GASBUGGY where the tritium concentration appears to be increasing and ^{137}Cs has been detected. No concentrations of radioactivity detected in water, milk, vegetation, soil, fish, or animal samples posed any significant health risk.

The Milk Surveillance Network (MSN) consisted of 24 sampling locations within 300 km (186 mi) of the NTS and 115 Standby Milk Surveillance Network (SMSN) locations throughout the major milk sheds west of the Mississippi River. Tritium and ^{90}Sr are rarely detected in milk samples at present and ^{89}Sr is practically never detected. The levels in both milk networks have decreased over time since reaching a maximum in 1964. The results from these networks are consistent with previous data and indicate little or no change.

Other foods were analyzed regularly, most of which were meat from domestic or game animals collected on and around the NTS. The ^{90}Sr levels in samples of animal bone remained very low, as did $^{239+240}Pu$ in both bone and liver samples. Carrots, kohlrabi, broccoli, summer squash, turnips, pears, potatoes, green onions, and apples from several offsite locations contained normal ^{40}K activity. Small amounts of $^{239+240}Pu$ and ^{90}Sr found on a few samples were attributed to incomplete washing of soil from the samples.

In 1993, external exposure was monitored by a network of 127 TLDs and 27 pressurized ion chambers (PICs). The PIC network in the communities surrounding the NTS indicated background exposures, ranging from 66 to 166 mR/yr, that were consistent with previous data and well within the range of background data in other areas of the U.S.

Internal exposure was assessed by whole-body counting through use of a single germanium detector, lung counting with six semi-planar detectors, and bioassay through radiochemical procedures. In 1993 counts were made on 144 individuals, of whom 56 were participants in the Offsite Internal Dosimetry Program. In general, the spectra obtained were representative of natural background with only normal ^{40}K being detected. No transuranics were detected in any lung counting data. Physical examination of offsite residents revealed only a normal, healthy population consistent with the age and sex distribution of that population.

No radioactivity attributable to current NTS operations was detected by any of the monitoring networks. However, based on the releases reported by NTS users, atmospheric dispersion model calculations (CAP88-PC) (EPA 1992) indicated that the maximum potential effective dose equivalent to any offsite individual would have been 4×10^{-3} mrem (4×10^{-5} mSv), and the dose to the population within 80 kilometers of the emission sites would have been 1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv). The hypothetical person receiving this dose was also exposed to 97 mrem from natural background radiation. A summary of the potential effective dose equivalents due to operations at the NTS is presented in Table 1.

A network of 18 CRMP stations is operated by local residents. Each station is an integral part of the ASN, NGTSN, and TLD networks. In addition, they are equipped with a PIC connected to a gamma-rate recorder. Each station also has satellite telemetry transmitting equipment so that gamma exposure measurements acquired by the PICs are transmitted via the Geostationary Operational Environmental Satellite (GOES) to the NTS and from there to the EMSL-LV by dedicated telephone line. Another nine PICs with the same capabilities are distributed in other locations around the NTS. Samples and data from these CRMP stations are analyzed and reported by EMSL-LV and interpreted and reported by the Desert Research Institute, University of Nevada System. All measurements for 1993 were within the normal background range for the U.S.

1.3 Groundwater Protection

DOE/NV instituted a Long-Term Hydrological Monitoring Program (LTHMP) in 1972 to be operated by the EPA under an Interagency Agreement. Groundwater was monitored on and around the NTS, at eight sites in other states, and at two off-NTS locations in Nevada in 1993 to detect the presence of any radioactivity that may be related to past nuclear testing activities. No radioactivity was detected above background levels in the ground-

Table 1. Summary of Effective Dose Equivalents from NTS Operations during 1993

	Maximum EDE at NTS Boundary[a]	Maximum EDE to an Individual[b]	Collective EDE to Population within 80 km of the NTS Sources
Dose	4.8×10^{-3} mrem (4.8×10^{-5} mSv)	$3.8 \pm 0.57 \times 10^{-3}$ mrem (3.8×10^{-5} mSv)	1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv)
Location	Site boundary 58 km SSE of NTS Area 12	Indian Springs, 80 km SSE of NTS Area 12	21,750 people within 80 km of NTS Sources
NESHAP[c] Standard	10 mrem per yr (0.1 mSv per yr)	10 mrem per yr (0.1 mSv per yr)	-----
Percentage of NESHAP	0.05	0.04	-----
Background	97 mrem (0.97 mSv)	97 mrem (0.97 mSv)	1747 person-rem (17.5 person Sv)
Percentage of Background	5.0×10^{-3}	4.0×10^{-3}	6.9×10^{-4}

(a) The maximum boundary dose is to a hypothetical individual who remains in the open continuously during the year at the NTS boundary located 58 km SSE from the Area 12 tunnel ponds.

(b) The maximum individual dose is to an individual outside the NTS boundary at a residence where the highest dose-rate occurs as calculated by CAP88-PC (Version 1.0) using NTS effluents listed in Table 20, assuming all tritiated water input to containment ponds was evaporated, and summing the contributions from each NTS source.

(c) National Emission Standards for Hazardous Air Pollutants.

water sampling network surrounding the NTS. Low levels of tritium, in the form of HTO, were detected in onsite wells as has occurred previously although none exceeded 0.2 percent of the National Primary Drinking Water Regulation level.

HTO was detected in samples from wells at formerly utilized sites, such as DRIBBLE (MS), GNOME (NM), and GASBUGGY (NM) at levels consistent with previous experience. The tritium concentration in Well EPNG 10-36 at GASBUGGY began increasing about 1984, and ^{137}Cs was detected for the second year in a row.

Because wells that were drilled for water supply or exploratory purposes are used in the NTS monitoring program rather than wells drilled specifically for groundwater monitoring, an extensive program of well drilling for groundwater characterization has been started. The design of the program is for installation of approximately 100 wells at strategic locations on and near the NTS. Five of these wells have been completed, six existing wells refurbished and water quality parameters are being collected for future use in the characterization project.

Other activities in this program included studies of groundwater transport of contaminants (radionuclide migration studies) and nonradiological monitoring for water quality assessment and RCRA requirements.

1.4 Offsite Radiological Quality Assurance

The policy of the EPA requires participation in a centrally managed QA program by all EPA organizational units involved in environmental data collection. The QA program developed by the Nuclear Radiation Assessment Division (NRD) of the EMSL-LV for the Offsite Radiological Safety Program (ORSP) meets all requirements of EPA policy, and also includes applicable elements of the Department of Energy QA requirements and regulations. The ORSP QA program defines data quality objectives (DQOs), which are statements of the quality of data a decision maker needs to ensure that a decision based on those data is defensible. Achieved data quality may then be evaluated against these DQOs.

1.5 Offsite Monitoring

Under the terms of an Interagency Agreement between DOE and EPA, the EPA EMSL-LV conducts the Offsite Radiation Safety Program (ORSP) in the areas surrounding the NTS. The largest component of EMSL-LV's program is routine monitoring of potential human exposure pathways. Another component is public information and community assistance activities.

As a result of the continuing moratorium on nuclear weapons testing, only simulated tests were conducted in 1993. Four simulated nuclear weapons test readiness exercises and one nonproliferation experiment using conventional (nonnuclear) explosives were conducted at the NTS. For each one, EMSL-LV senior personnel served on the Test Controller's Scientific Advisory Panel and on the EPA offsite radiological safety staff. To add as much realism as possible to the exercises, actual meteorological conditions were used and data flow was managed in the same manner as in a real test. Routine off-site environmental radiation monitoring continued throughout 1993 as in past years.

Town hall meetings and public information presentations provide a forum for increasing public awareness of NTS activities, disseminating radiation monitoring results, and addressing concerns of residents related to environmental radiation and possible health effects. This community education outreach program is discussed in Section 10. Community Radiation Monitoring Program (CRMP) stations have been established in prominent locations in a number of offsite communities. The CRMP stations contain samplers for several of the monitoring networks and are managed by local residents. The University of Utah and DRI are cooperators with EPA in the CRMP. The CRMP is discussed in Section 4.

Environmental monitoring networks, described in the following subsections, measure radioactivity in air, atmospheric moisture, milk, local foodstuffs, and groundwater. These networks monitor the major potential pathways of radionuclide transfer to man via inhalation, submersion, and ingestion. Direct measurement of offsite resident exposure through the external and internal dosimetry programs provides confirmation of the exposures measured in the monitoring networks. Ambient

gamma radiation levels are continuously monitored at selected locations using Reuter-Stokes pressurized ion chambers (PICs) and Panasonic TLDs. Atmospheric monitoring equipment includes air samplers, noble gas samplers, and atmospheric moisture (tritium-in-air) samplers. Milk, game and domestic animals, and foodstuffs (fruits and vegetables) are routinely sampled and analyzed.

Groundwater on and in the vicinity of the NTS is monitored in the Long-Term Hydrological Monitoring Program (LTHMP). Data from these monitoring networks are used to calculate an annual exposure dose to the offsite residents, as described in Section 8.

2 Description of the Nevada Test Site

The Nevada Test Site (NTS), located in southern Nevada, was the primary location for testing of nuclear explosives in the continental U.S. from 1951 until the present moratorium began. Historical testing has included (1) atmospheric testing in the 1950s and early 1960s, (2) underground testing in drilled, vertical holes and horizontal tunnels, (3) earth-cratering experiments, and (4) open-air nuclear reactor and engine testing. No nuclear tests were conducted in 1993. Limited non-nuclear testing has included controlled spills of hazardous material at the Liquified Gaseous Fuels Spill Test Facility. Low-level radioactive and mixed waste disposal and storage facilities for defense waste are also operated on the NTS.

The NTS environment is characterized by desert valley and Great Basin mountain terrain and topography, with a climate, flora, and fauna typical of the southern Great Basin deserts. Restricted access and extended wind transport times are notable features of the remote location of the NTS and adjacent U.S. Air Force lands. Also characteristic of this area are the great depths to slow-moving groundwaters and little or no surface water. These features afford protection to the inhabitants of the surrounding area from potential radiation exposures as a result of releases of radioactivity or other contaminants from operations on the NTS. Population density within 150 km of the NTS is only 0.5 persons per square kilometer versus approximately 29 persons per square kilometer in the 48 contiguous states. The predominant land use surrounding the NTS is open range for livestock grazing with scattered mining and recreational areas.

The EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV), conducts hydrological studies at eight U.S. nuclear testing locations off the NTS. The last test conducted at any of these sites was in 1973 (Project RIO BLANCO in Colorado).

2.1 Location

The NTS is located in Nye County, Nevada, with its southeast corner about 54 miles (90 km) northwest of Las Vegas (Figure 1). It occupies an area of about 1,350 square miles (3,750 square km), varies from 28 to 35 miles (46 to 58 km) in width (east-west) and from 49 to 55 miles (82 to 92 km) in length (north-south). This area consists of large basins or flats about 2,970 to 3,900 feet (900 to 1,200 m) above mean sea level (MSL) surrounded by mountain ranges rising from 5,940 to 7,590 feet (1,800 to 2,300 m) above MSL.

The NTS is surrounded on three sides by exclusion areas, collectively named the Nellis Air Force Base Range Complex, which provides a buffer zone between the test areas and privately owned lands. This buffer zone varies from 14 to 62 miles (24 to 104 km) between the test area and land that is open to the public. In the unlikely event of an atmospheric release of radioactivity (venting), two to more than six hours would elapse, depending on wind speed and direction, before any release of airborne radioactivity would reach private lands.

2.2 Climate

The climate of the NTS and surrounding area is variable, due to its wide range in altitude and its rugged terrain. Most of Nevada has a semi-arid climate characterized as mid-latitude steppe. Throughout the year, water is insufficient to support the growth of common food crops without irrigation. Climate may be classified by the types of vegetation indigenous to an area. According to *Nevada Weather and Climate* (Houghton et al., 1975), this method of classification developed by Köppen is further subdivided on the basis of "...seasonal distribution of rainfall and the degree of summer heat or winter cold." Table 2 summarizes the characteristics of climatic types for Nevada.

According to Quiring (1968), the NTS average annual precipitation ranges from about 4 inches (10 cm) at the lower elevations to around 10 inches (25 cm) at the higher elevations. During the winter months, the plateaus may be snow-covered for a period of several days or weeks. Snow is uncommon on the flats. Temperatures vary considerably with elevation, slope, and local air currents. The average daily temperature ranges at the lower altitudes are around 25 to 50°F (-4 to 10°C) in January and 55 to 95°F (13 to 35°C) in

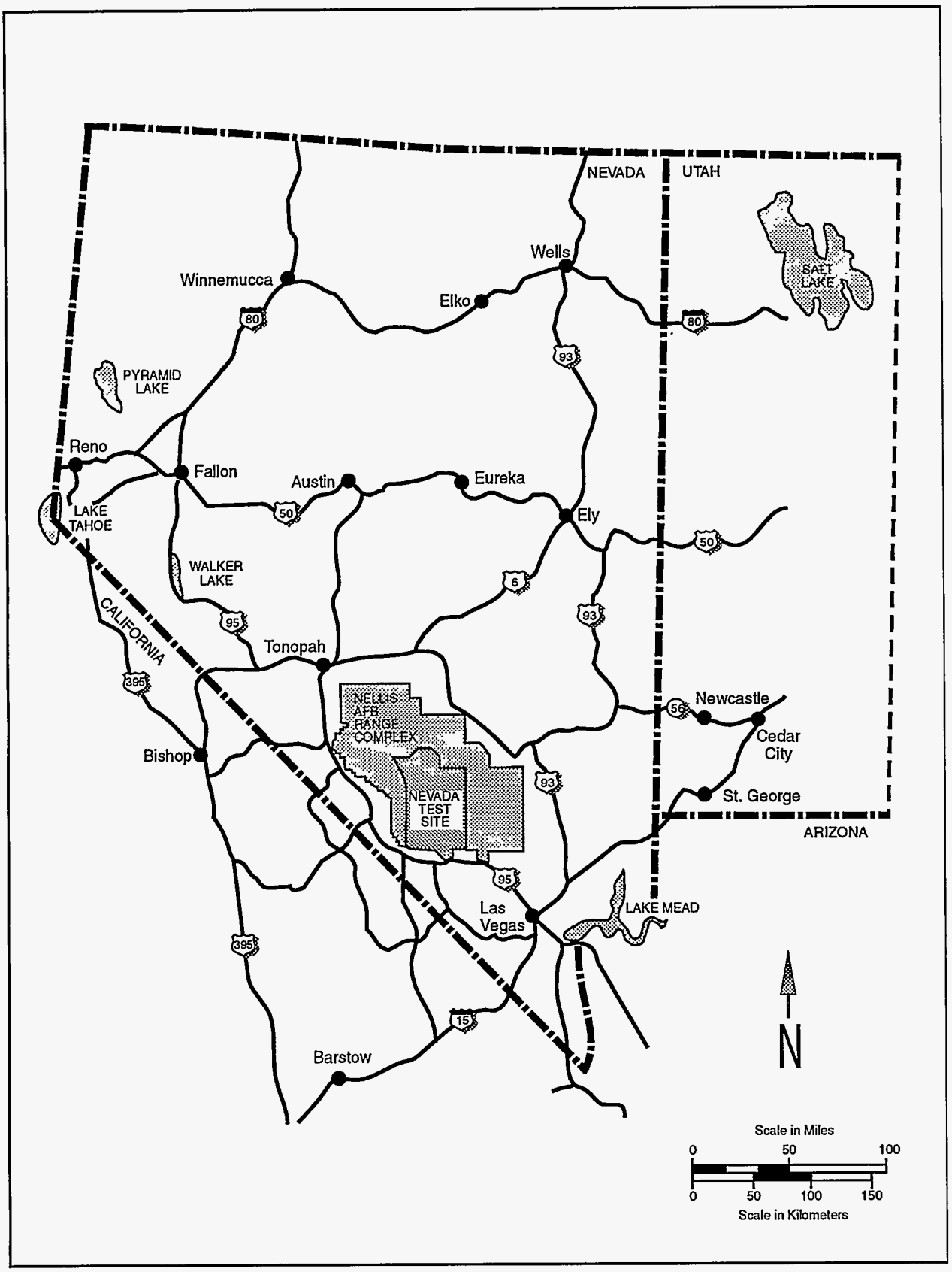


Figure 1. Location of the Nevada Test Site.

July, with extremes of -15°F (-26°C) and 120°F (49°C). Corresponding temperatures on the plateaus are 25 to 35°F (-4 to 2°C) in January and 65 to 80°F (18 to 27°C) in July with extremes of -30°F (-34°C) and 115°F (46°C).

The wind direction, as measured on a 98 ft (30 m) tower at an observation station approximately 7 miles (11 km) north-northwest of CP-1, is predominantly northerly except during the months of May through August when winds from the south-southwest predominate (Quiring, 1968). Because of the prevalent mountain/valley winds in the basins, south to southwest winds predominate during daylight hours of most months. During the winter months, southerly winds predominate slightly over northerly winds for a few hours during the warmest part of the day. These wind patterns may be quite different at other locations on the NTS because of local terrain effects and differences in elevation.

2.3 Hydrology

Two major hydrologic systems shown in Figure 2 exist on the NTS (U.S. Energy Research and Development Administration, 1977). Ground water in the northwestern part of the NTS (the Pahute Mesa area) flows at a rate of 6.6 to 600 feet (2 to 180 m) per year to the south and southwest toward the Ash Meadows discharge area in the Amargosa Desert. Ground water to the east of the NTS moves from north to south at a rate of not less than 6.6 feet (2 m) nor greater than 730 feet (220 m) per year. Carbon-14 analyses of this eastern ground water indicate that the lower velocity is nearer the true value. At Mercury Valley in the extreme southern part of the NTS, the eastern ground water flow shifts to the southwest, toward the Ash Meadows discharge area.

2.4 Regional Land Use

Figure 3 is a map of the off-NTS area showing a wide variety of land uses, such as mining, camping, fishing, and hunting within a 180-mile (300 km) radius of the NTS operations control center at CP-1 (the location of CP-1 is shown on Figures 2 and 5). West of the NTS, elevations range from 280 feet (85 m) below MSL in Death Valley to 14,600 feet (4,420 m) above MSL in the Sierra Nevada.

Table 2. Characteristics of Climatic Types in Nevada (from Houghton et al. 1975)

Climate Type	Temperature °F (°C) Winter	Summer	Annual Precipitation inches (cm) Total*	Snowfall	Dominant Vegetation	Percent of Area
Alpine tundra	0 to 15 (-18 to -9)	40 to 50 (4 to 10)	15 to 45 (38 to 114)	Medium to heavy	Alpine meadows	--
Humid continental	10 to 30 (-12 to -1)	50 to 70 (10 to 21)	25 to 45 (64 to 114)	Heavy	Pine-fir forest	1
Subhumid continental	10 to 30 (-12 to -1)	50 to 70 (10 to 21)	12 to 25 (30 to 64)	Moderate	Pine or scrub woodland	15
Mid-latitude steppe	20 to 40 (-7 to 4)	65 to 80 (18 to 27)	16 to 15 (15 to 38)	Light to moderate	Sagebrush, grass, scrub	57
Mid-latitude desert	20 to 40 (-7 to 4)	65 to 80 (18 to 27)	3 to 8 (8 to 20)	Light	Greasewood, shadscale	20
Low-latitude desert	40 to 50 (-4 to 10)	80 to 90 (27 to 32)	2 to 10 (5 to 25)	Negligible	Creosote bush	7

* Limits of annual precipitation overlap because of variations in temperature which affect the water balance.

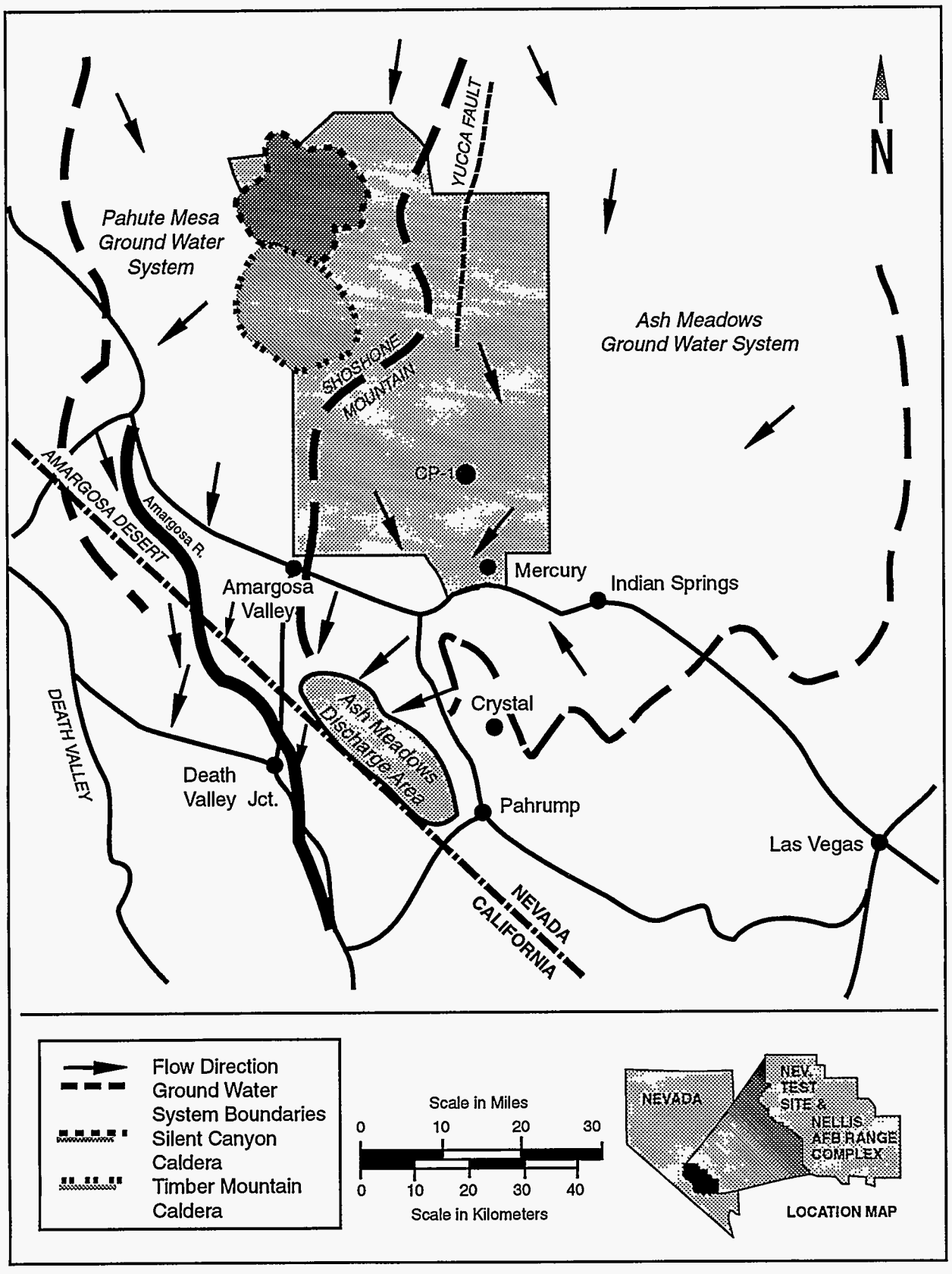


Figure 2. Ground water flow systems around the Nevada Test Site.

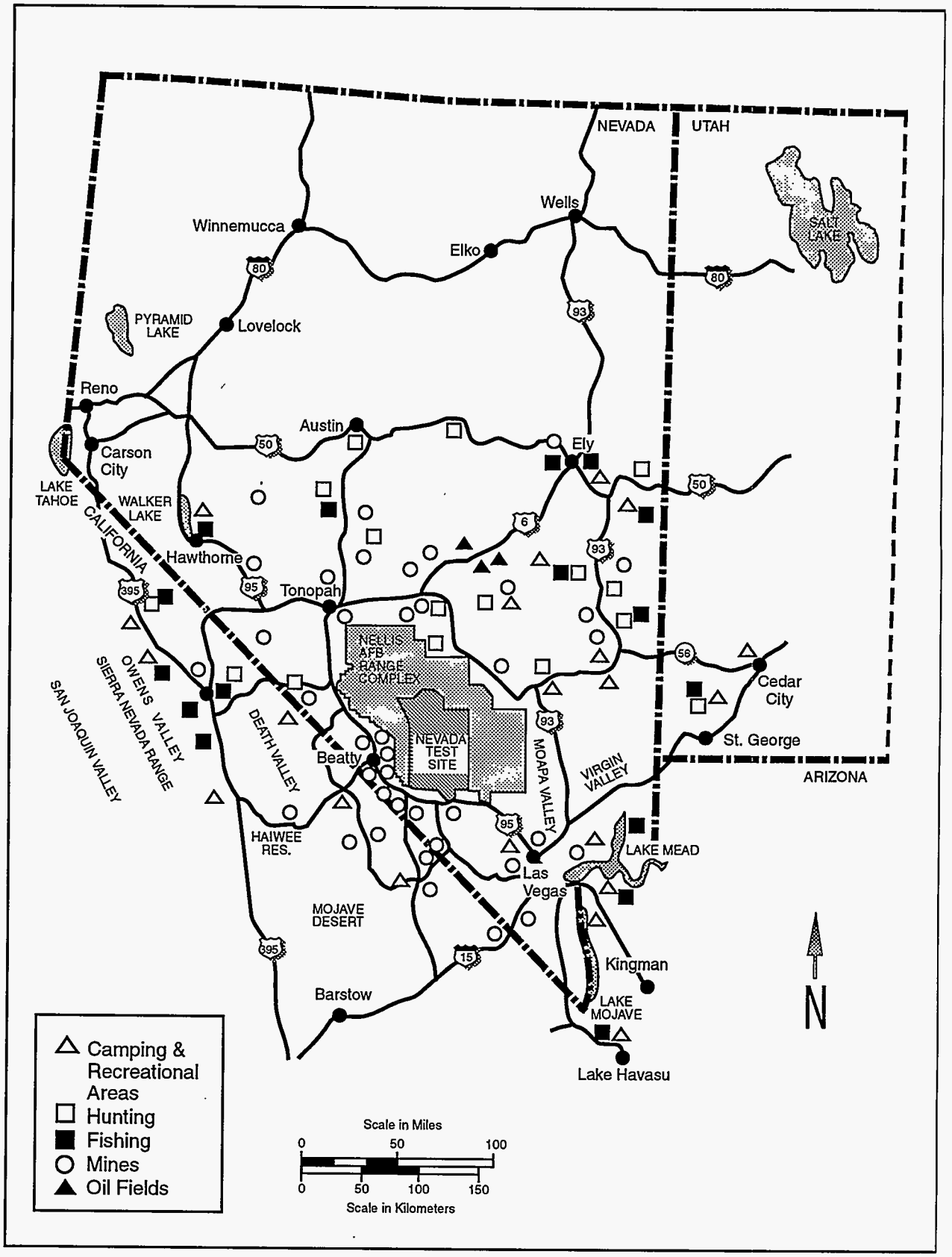


Figure 3. General land use within 180 miles (300 km) of the Nevada Test Site.

Portions of two major agricultural valleys (the Owens and San Joaquin) are included. The areas south of the NTS are more uniform since the Mojave Desert ecosystem (mid-latitude desert) comprises most of this portion of Nevada, California, and Arizona. The areas east of the NTS are primarily mid-latitude steppe with some of the older river valleys, such as the Virgin River Valley and the Moapa Valley, supporting irrigation for small-scale but intensive farming of a variety of crops. Grazing is also common in this area, particularly to the northeast. The area north of the NTS is also mid-latitude steppe, where the major agricultural activity is grazing of cattle and sheep. Minor agriculture, primarily the growing of alfalfa hay, is found in this portion of Nevada within 180 miles (300 km) of the CP-1. Many of the residents have access to locally grown fruits and vegetables.

Recreational areas lie in all directions around the NTS (Figure 4) and are used for such activities as hunting, fishing, and camping. In general, the camping and fishing sites to the northwest, north, and northeast of the NTS are closed during winter months. Camping and fishing locations to the southeast, south, and southwest are utilized throughout the year. The peak of the hunting season is from September through January.

2.5 Population Distribution

Knowledge of population densities and spatial distribution of farm animals is necessary to assess protective measures required in the event of an accidental release of radioactivity at the NTS. Figure 4 shows the population of counties surrounding the NTS based on the 1990 Bureau of Census (BOC) count (DOC, 1990). Excluding Clark County, the major population center (approximately 741,459 in 1990), the population density of counties adjacent to the NTS is about 0.7 persons per square mile (0.4 persons per square kilometer). For comparison, the population density of the 48 contiguous states was 70.3 persons per square mile (27 persons per square kilometer) (DOC, 1990). The estimated average population density for Nevada in 1990 was 10.9 persons per square mile (3.1 persons per square kilometer) (DOC, 1986).

The offsite area within 48 miles (80 km) of CP-1 (the primary area in which the dose commitment must be determined for the purpose of this report) is predominantly rural. Several small communities are located in the area, the largest being in Pahrump Valley. Pahrump, a growing rural community with a population of 7,425 (DOC, 1990), is located 48 miles (80 km) south of CP-1. The small residential community of Crystal, Nevada, also located in the Pahrump Valley, is several miles north of the town of Pahrump (Figure 3). The Amargosa farm area, which has a population of about 950, is located 30 miles (50 km) southwest of CP-1. The largest town in the near offsite area is Beatty, which has a population of about 1,500 and is located approximately 39 miles (65 km) to the west of CP-1.

The Mojave Desert of California, which includes Death Valley National Monument, lies along the southwestern border of Nevada. The National Park Service (NPS) estimated that the population within the Monument boundaries ranges from a minimum of 200 permanent residents during the summer months to as many as 5,000 tourists including campers on any particular day during the major holiday periods in the winter months, and as many as 30,000 during "Death Valley Days" in November (NPS, 1990). The largest populated area is the Ridgecrest, California area, which has a population of 27,725 and is located 114 miles (190 km) southwest of the NTS. The next largest town is Barstow, California, located 159 miles (265 km) south-southwest of the NTS, with a 1990 population of 21,472. The Owens Valley, where numerous small towns are located, lies 30 miles (50 km) west of Death Valley. The largest town in the Owens Valley is Bishop, California, located 135 miles (225 km) west-northwest of the NTS, with a population of 3,475 (DOC, 1990).

The extreme southwestern region of Utah is more developed than the adjacent part of Nevada. The largest community is St. George, located 132 miles (220 km) east of the NTS, with a 1990 population of 28,502. The next largest town, Cedar City, with a population of 13,443, is located 168 miles (280 km) east-northeast of the NTS (DOC, 1990).

The extreme northwestern region of Arizona is mostly range land except for that portion in the Lake Mead National Recreation Area. In addition, several small communities lie along the Colorado River.

The largest towns in the area are Bullhead City, 99 miles (165 km) south-southeast of the NTS, with a 1990 population of 21,951 and Kingman, located

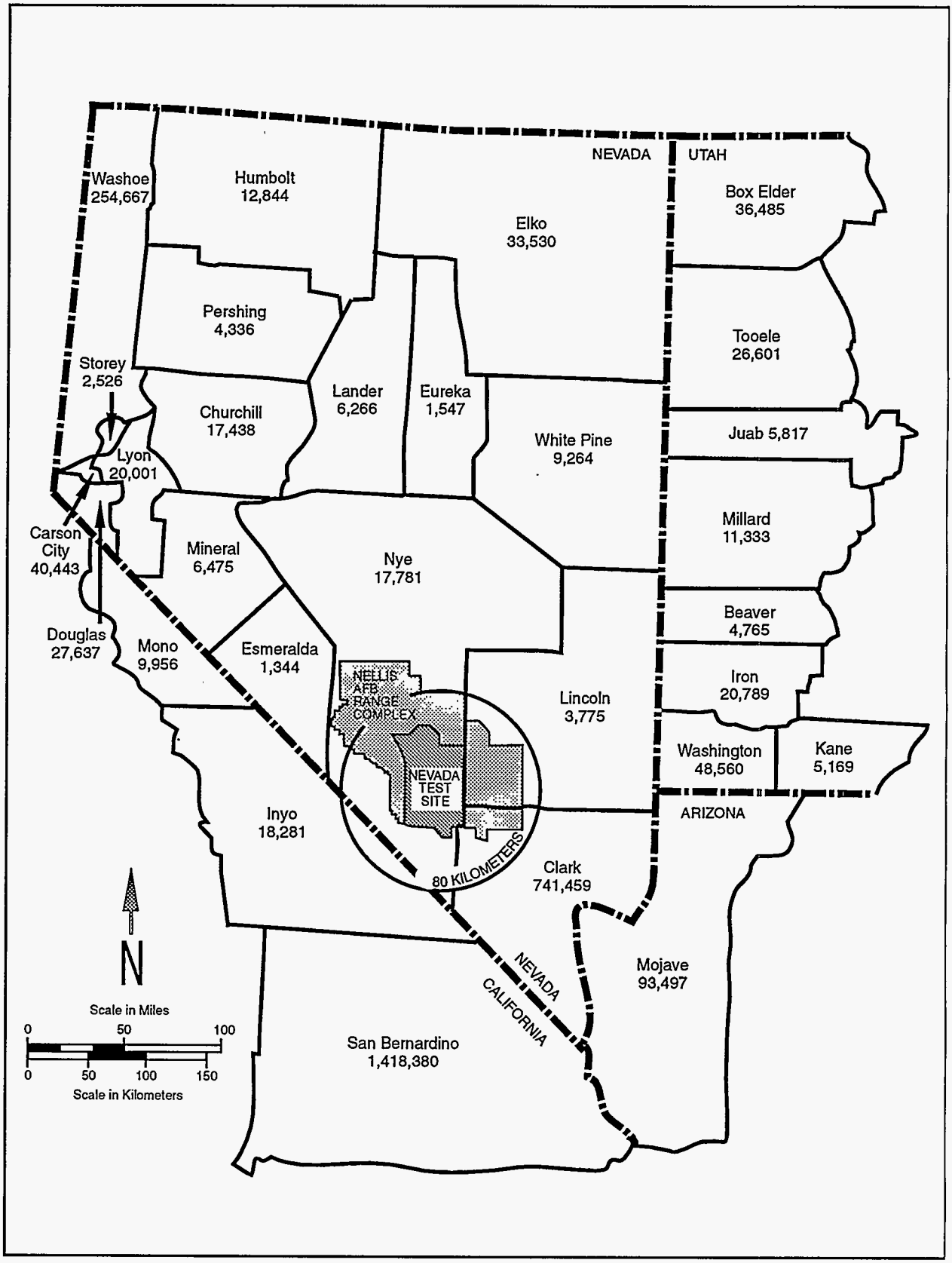


Figure 4. Population of Arizona, California, Nevada, and Utah counties near the Nevada Test Site.

168 miles (280 km) southeast of the NTS, with a population of 12,722 (DOC, 1990).

Figures 5 through 8 show the most recent estimates of the domestic animal populations in the counties near the NTS. Domestic animal numbers are updated through interim surveys as part of routine monitoring and by periodic resurveys. The numbers given in Figure 5, showing distribution of family milk cows and goats, are determined from these interim surveys. The numbers in Figures 6 to 8 were compiled for Nevada and Utah from the Nevada Agricultural Statistics 1994 report (Nevada Agricultural Statistics Service, 1994) and from the 1994 Utah Agricultural Statistics report (Utah Agricultural Statistics Service, 1994).

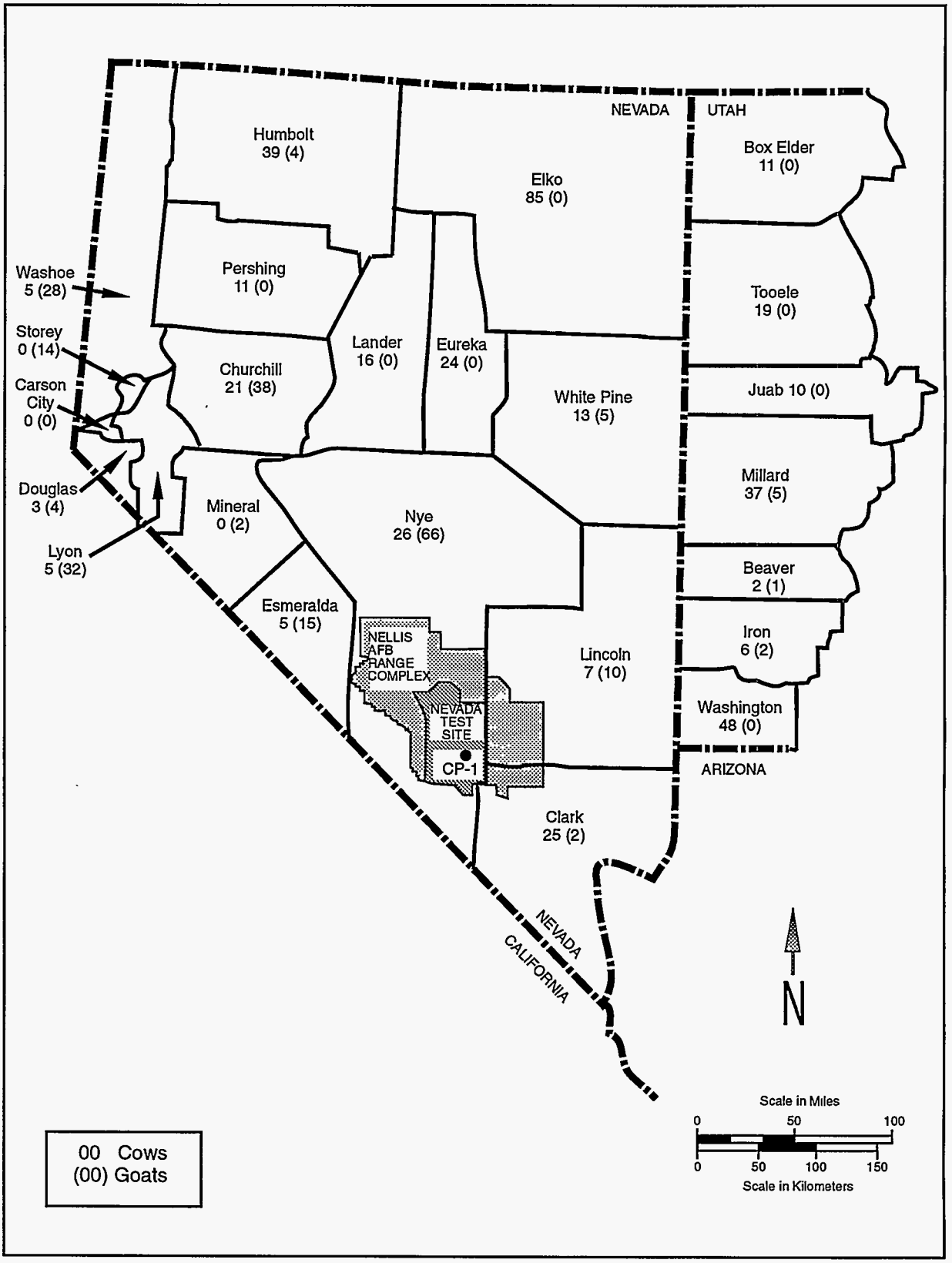


Figure 5. Distribution of family milk cows and goats, by county - 1993

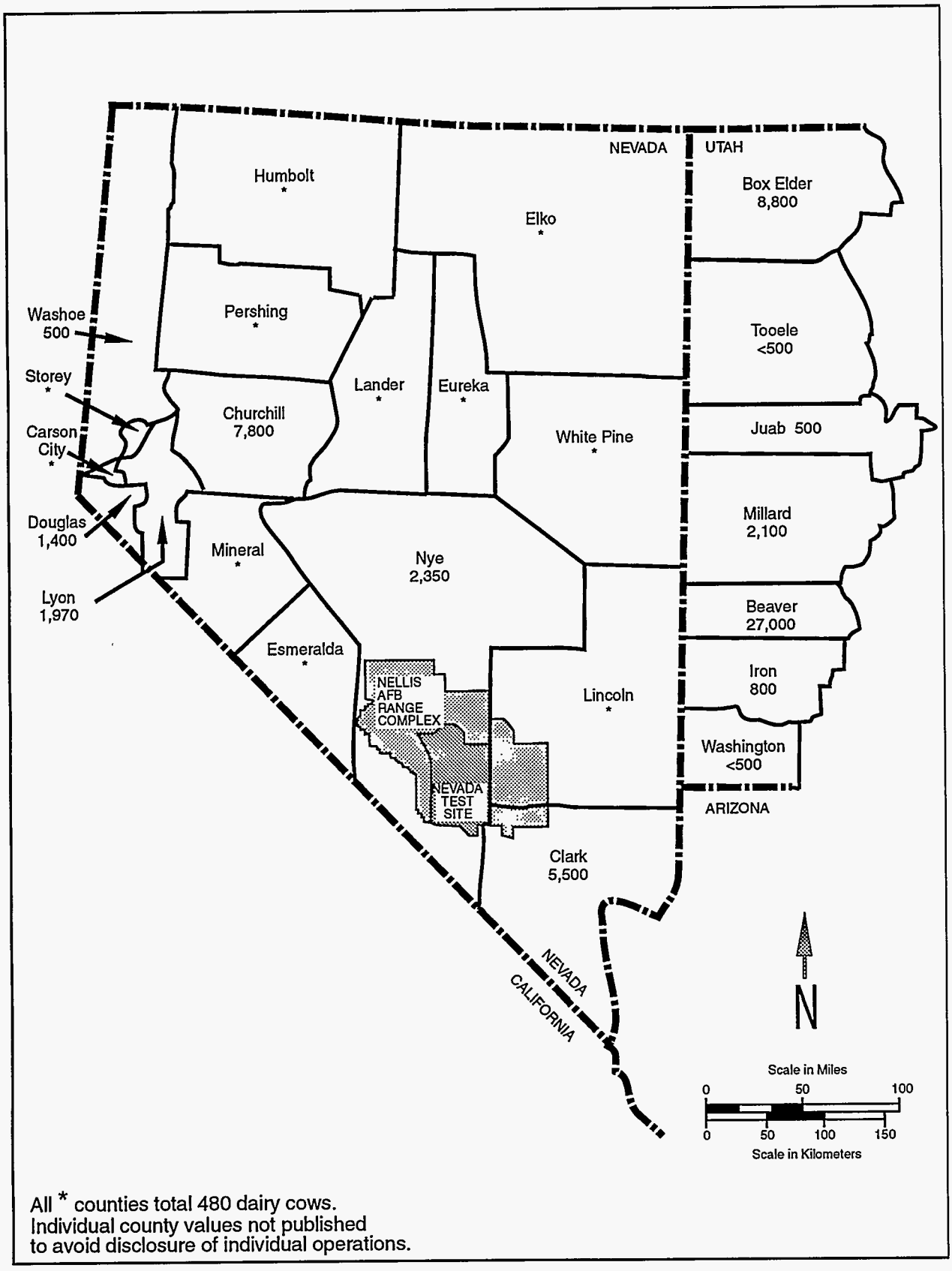


Figure 6. Distribution of dairy cows, by county - 1993

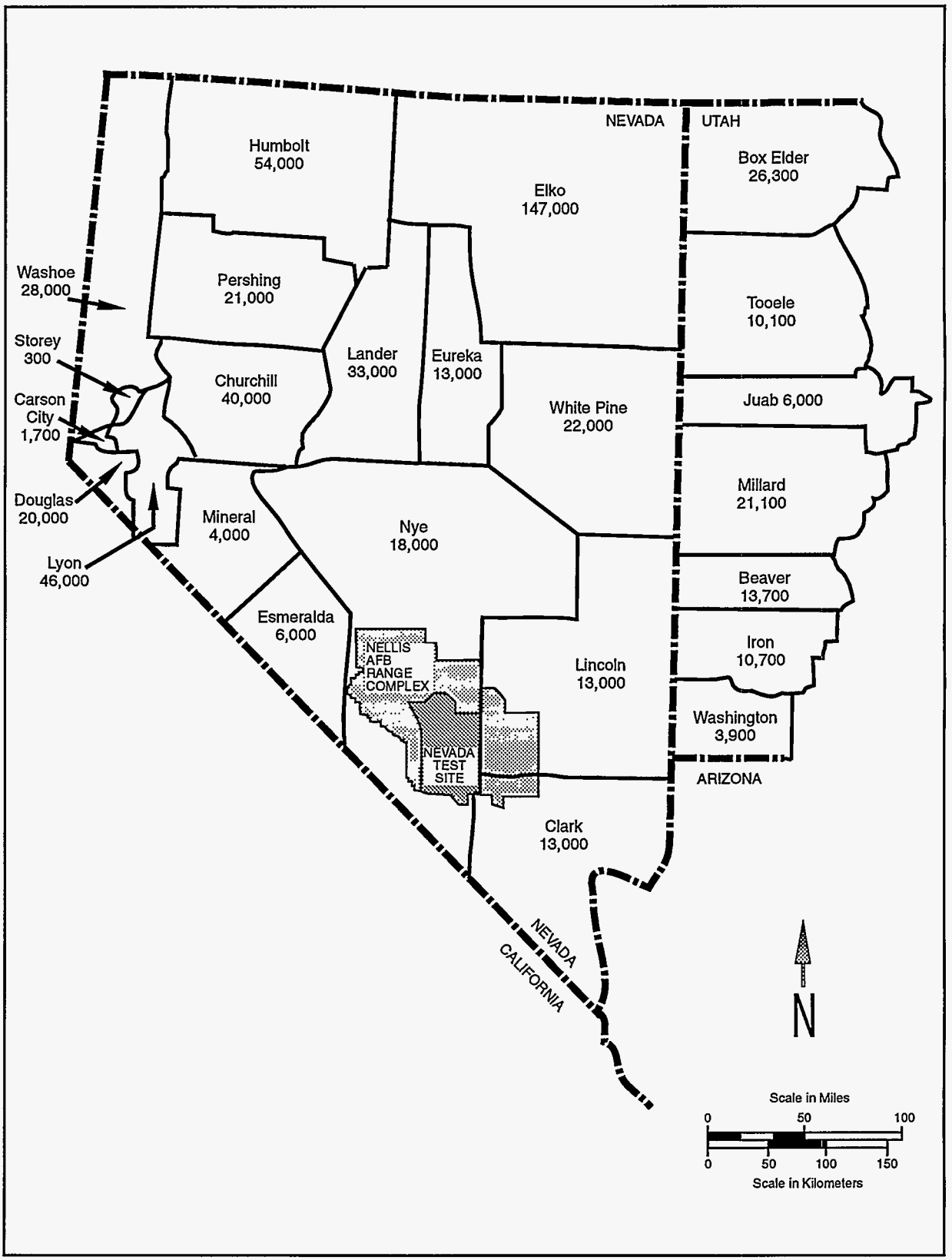
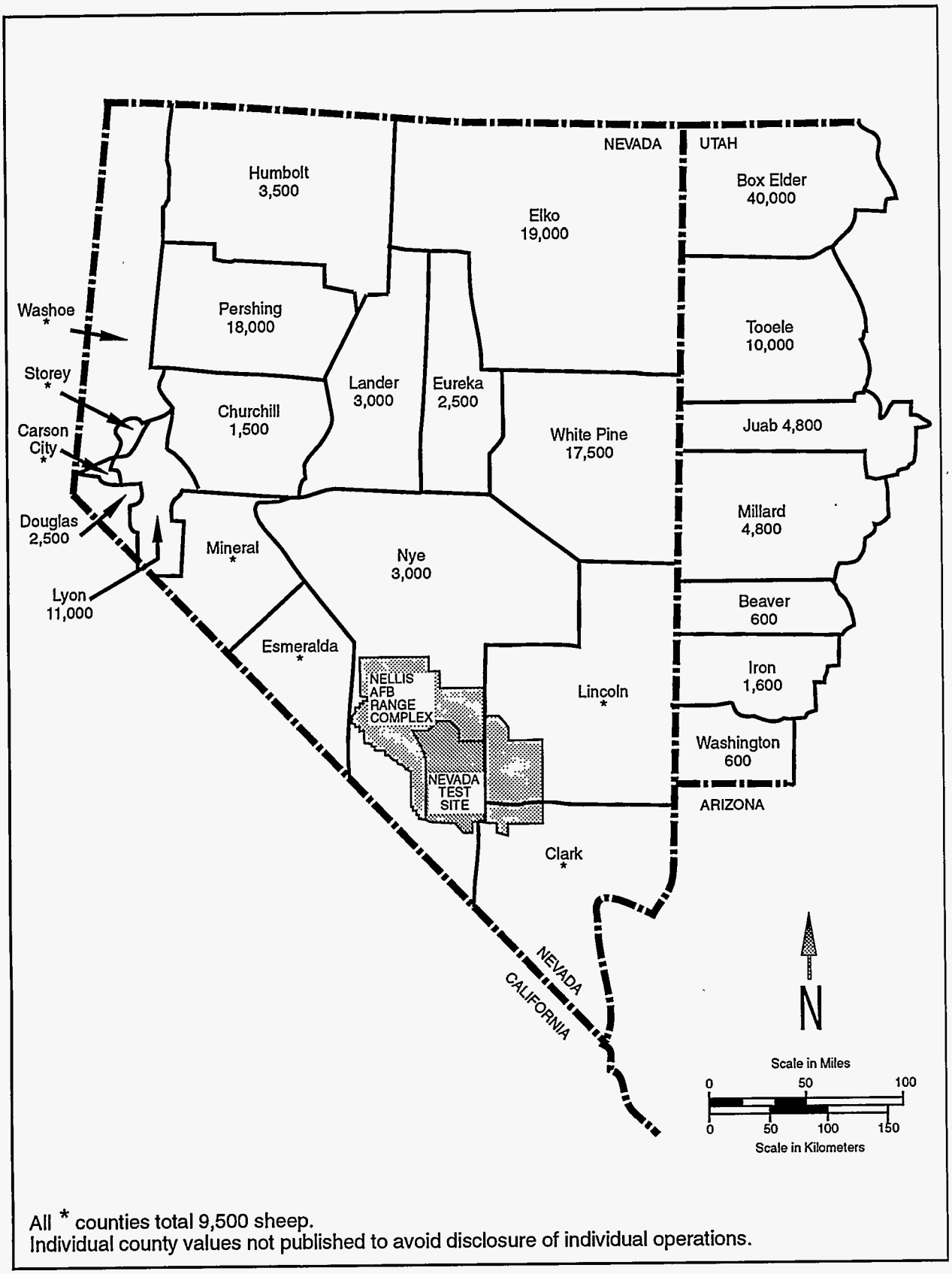


Figure 7. Distribution of beef cattle, by county - 1993



All * counties total 9,500 sheep.
Individual county values not published to avoid disclosure of individual operations.

Figure 8. Distribution of sheep, by county - 1993

3 External Ambient Gamma Monitoring

External ambient gamma radiation is measured by the Thermoluminescent Dosimetry (TLD) Network and also by the Pressurized Ion Chamber (PIC) Network. The primary function of the two networks is to detect changes in ambient gamma radiation. In the absence of nuclear testing, ambient gamma radiation rates naturally differ among locations since rates vary with altitude (cosmic radiation) and with radioactivity in the soil (terrestrial radiation). Ambient gamma radiation will also vary slightly at a location due to changes in weather patterns and other factors.

3.1 Thermoluminescent Dosimetry Network

The primary function of the EPA EMSL-LV environmental dosimetry program is to define a mechanism for identifying any increase in radiation levels in areas surrounding the NTS. This is accomplished by developing baseline information regarding ambient radiation levels from all radiation sources and looking for any deviations from data trends. In addition to the environmental TLD program, EPA deploys personnel TLDs to individuals volunteers living in areas surrounding the NTS. Information gathered from this program would help identify possible exposures to residents. Basic philosophies for program development for the personnel TLD program are essentially similar to the environmental TLD program.

3.1.1 Design

The current EPA TLD program utilizes the Panasonic Model UD-802 TLD for personnel monitoring and the UD-814 TLD for environmental monitoring. Each dosimeter is read using the Panasonic Model UD-710A automatic dosimeter reader.

The UD-802 TLD incorporates two elements of $Li_2B_4O_7$:Cu and two elements of $CaSO_4$:Tm phosphors. The phosphors are behind approximately 17, 300, 300, and 1000 mg/cm^2 of attenuation, respectively. With the use of different phosphors and filtrations, a dose algorithm can be applied to ratios of the different element responses. This process defines the radiation type and energy and provides a mechanism for assessing an absorbed dose equivalent.

Environmental monitoring is accomplished using the UD-814 TLD, which is made up of one element of $Li_2B_4O_7$:Cu and three elements of $CaSO_4$:Tm. The $CaSO_4$:Tm elements are behind approximately 1000 mg/cm^2 attenuation. An average of the corrected values for elements two through four gives the total exposure for each TLD. Two UD-814 TLDs are deployed at each station per monitoring period.

In general terms, TLDs operate by trapping electrons at an elevated energy state. After the collection period, each TLD element is heated. When heat is applied to the phosphor, the trapped electrons are released and the energy differences between the initial energies of the electrons and the energies at the elevated state are given off in the form of photons. These photons are then collected using a photomultiplier tube. The number of photons emitted, and the resulting electrical signal, is proportional to the initial deposited energy.

3.1.2 Results of TLD Monitoring

ENVIRONMENTAL DATA:

During 1993 a total of 127 offsite stations was monitored using TLDs. There was a dramatic decrease in the number of fixed environmental monitoring locations in 1993 due to the nuclear test moratorium that began in October 1992. Figure 9 shows current fixed environmental monitoring locations. Total annual exposures were calculated by dividing each quarterly result by the number of days representing each deployment period. The quarterly daily rates were averaged to obtain an annual daily average. If a deployment period overlapped the beginning or end of the year a daily rate was calculated, for that deployment period, and multiplied by the number of days that fell within 1993. The total average daily rate was then multiplied by 365.25 to determine the total annual exposure for each station.

During 1993 annual exposures ranged from 55 mR (0.55 mSv)/yr at Corn Creek, NV to 305 mR (3.0 mSv) at Warm Springs No.2 with a mean exposure of 98 mR (0.98 mSv)/yr for the network. The next

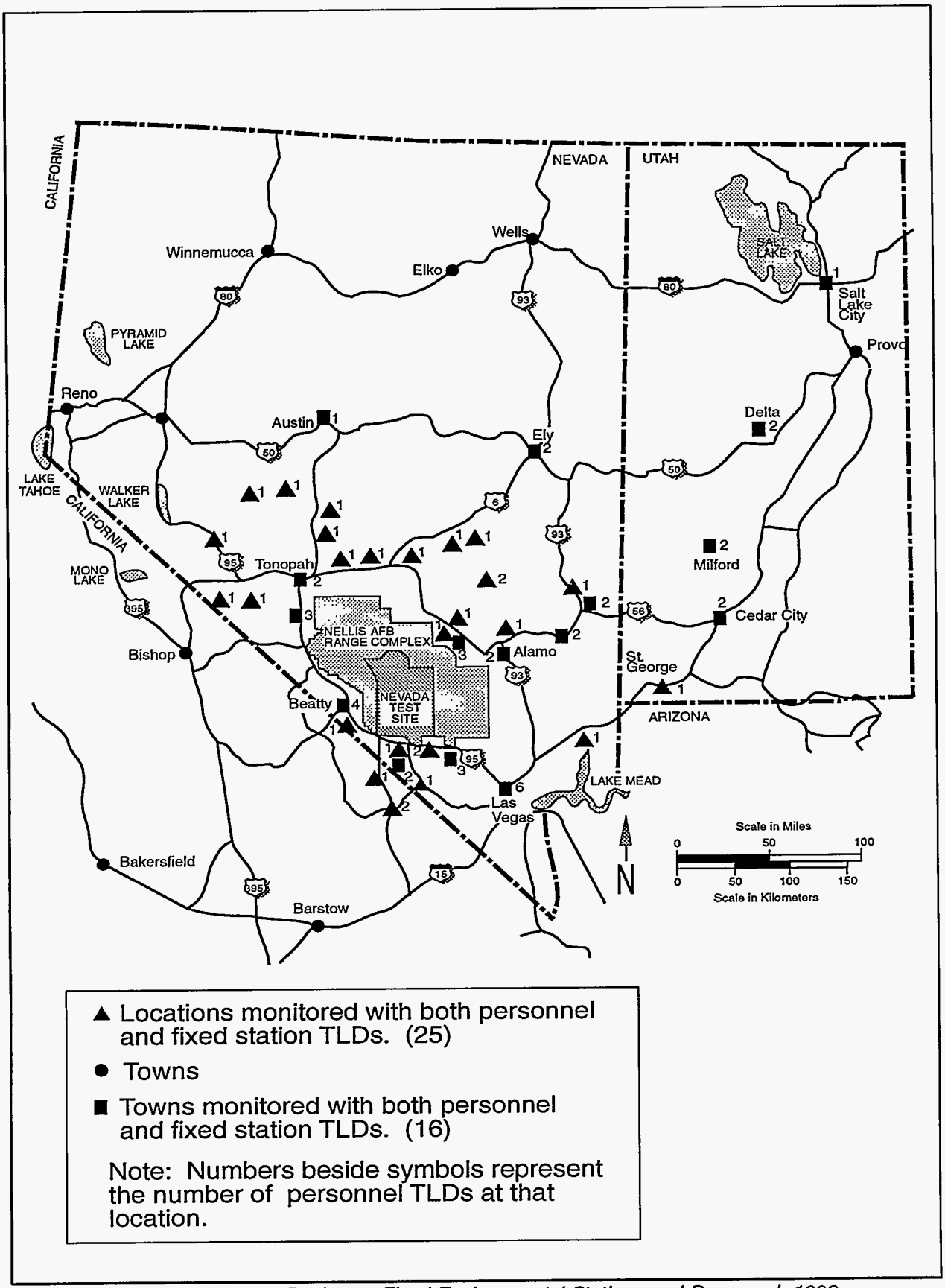


Figure 9. Thermoluminescent Dosimetry Fixed Environmental Stations and Personnel- 1993

highest exposure occurred at Manhattan, NV: 175 mR (1.8 mSv)/yr.

Transit control dosimeters accompany station TLDs during transit to the deployment location and during their return to the processing laboratory. Between 1988 and 1991 transit control TLDs were inappropriately subtracted from the station TLDs, this reduced the deployment exposure. Operational techniques have since changed for defining these transit exposures to provide more correct data for measurements since 1992. A summary of current and past annual exposure data is shown in Figure 10.

PERSONNEL DATA:

Detailed results for 1993 are shown in Appendix A, Table A.2. The number of personnel monitored with TLDs were 69 in 1993. The locations of the personnel monitored in 1993 are shown on the map in Figure 9. The total annual EDE was calculated by summing the quarterly exposure data for the year.

During 1993, the low was 61 mrem (0.61 mSv), the high was 190 mrem (1.9 mSv), and the mean was 106 mrem (1.1 mSv) for all monitored personnel.

Total annual whole body absorbed dose equivalents were calculated by summing all available data for the year. If data gaps occurred, all available data was summed and a daily rate was computed by dividing the sum by the number of days with available data. The daily rate was then multiplied by 365.25 days.

3.1.3 Quality Assurance/ Quality Control

During 1993, two calibration instruments were available to support the program. One is a TLD irradiator manufactured by Williston-Elin housing a nominal 1.8 Ci ^{137}Cs source. This irradiator provides for automated irradiations of the TLDs. The second calibration instrument is a nominal 10 Ci ^{137}Cs well type irradiator. Unlike the Williston-Elin irradiators, this well type does not provide automated capabilities. TLD exposures accomplished with the well type irradiator are monitored using a Victoreen E-5000 precision electrometer whose calibration is traceable to the National Institute of Standards and Technology (NIST). The exposure rates of both irradiators have been confirmed by measurement using a precision electrometer which has a calibration traceable to NIST. Panasonic UD-802 dosimeters exposed by these irradiators are used to calibrate the TLD readers and to verify TLD reader linearity. Control dosimeters of the same type as field dosimeters (UD-802 or UD-814) are exposed and read together with the field dosimeters. This provides daily on-line process quality control checks in the form of irradiated controls.

Each magazine containing TLDs to be read normally contains three irradiated control TLDs that have been exposed to a nominal 200 mR at least 24 hours prior to the reading. After the irradiated controls have been read, the ratio of recorded exposure to delivered exposure is calculated and recorded for each of the four elements of the dosimeter. This ratio is applied to all raw element readings from field and unirradiated control dosimeters to automatically compensate for reader variations.

Prior to being placed in service, element correction factors are determined for all dosimeters. Whenever a dosimeter is read, the mean of the three most recent correction factor determinations is applied to each element to compensate for normal variability (caused primarily by the TLD manufacturing process) in individual dosimeter response.

In addition to irradiated control dosimeters, each group of TLDs is accompanied by three unirradiated control dosimeters during deployment and during return. These unirradiated controls are evaluated at the dosimetry laboratory to ensure that the TLDs did not receive any excess dose while either in transit or storage. The exposure received while either in storage or transit is typically negligible and thus is not subtracted.

An assessment of TLD data quality is based on the assumption that exposures measured at a fixed location will remain substantially constant over an extended period of time. A number of factors will combine to affect the certainty of measurements. The total uncertainty of the reported exposures is a combination of random and systematic components. The random component is primarily the statistical uncertainty in the reading of the TLD elements themselves. Based on repeated known exposures, this random uncertainty for the calcium sulfate elements used to determine exposure to fixed environmental stations is estimated to be approximately ± 3 to 5%. There are also several

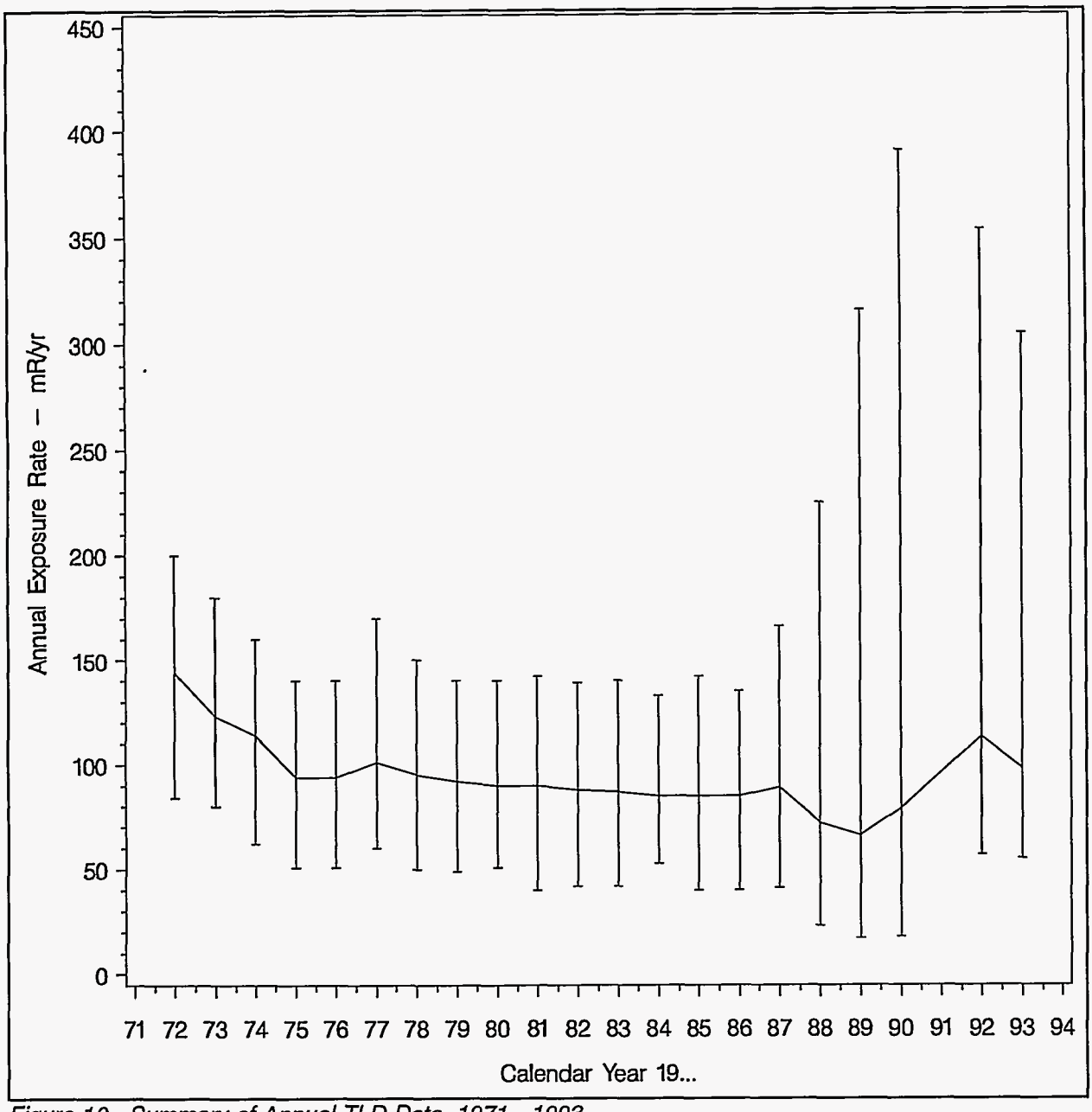


Figure 10. Summary of Annual TLD Data, 1971 - 1993.

systematic components of exposure uncertainty, including energy-directional response, fading, calibration, and exposures received while in storage. These uncertainties are estimated according to established statistical methods for propagation of uncertainty.

Accuracy and reproducibility of TLD processing has been evaluated via the Department of Energy Laboratory Accreditation Program (DOELAP). This process concluded that procedures and practices utilized by the EPA EMSL-LV TLD Laboratory comply with standards published by the Department of Energy. This evaluation includes three rounds of blind performance testing over the range of 50 mrem to 500 rads and a comprehensive onsite assessment by DOELAP site assessors.

The DOELAP accreditation process requires a determination of the lower limit of detectability and verification that the TLD readers exhibit linear performance over the range included in the performance testing program. The lower limit of detectability for the EMSL-LV TLD Laboratory has been calculated to be approximately 3 mrem above background at the 95% confidence level.

In addition to telemetry retrieval, PIC data are also recorded on both magnetic tapes and hard-copy strip charts at 24 of the 27 EPA stations and on magnetic cards for the other three EPA stations. The magnetic tapes and cards, which are collected weekly, provide a backup to the telemetry data and are also useful for investigating anomalies because the data are recorded in smaller increments of time (5-minute averages). The PICs also contain a liquid crystal display, permitting interested persons to monitor current readings.

The data are evaluated weekly by EMSL-LV personnel. Trends and anomalies are investigated and equipment problems are identified and referred to field personnel for correction. Weekly averages are stored in Lotus files on a personal computer. These weekly averages are compiled from the 4-hour averages from the telemetry data, when available, and from the 5-minute averages from the magnetic tapes or cards when the telemetry data are unavailable. Computer-generated reports of the PIC weekly average data are issued weekly for posting at each station. These reports indicate the current week's average gamma exposure rate, the previous week's and year's averages, and the maximum and minimum background levels in the U.S.

3.2.3 Results

Table 3 contains the number of weekly averages available from each station and the maximum, minimum, mean, standard deviation, and median of the weekly averages. The mean ranged from 7.5 μR/hr at Pahrump, Nevada to 19.0 μR/hr at Austin, Nevada or annual exposures from 66 to 166 mR (17 to 43 μC-kg). For each station, this table also shows the total mR/yr (calculated based on the mean of the weekly averages) and the average gamma exposure rate from 1992. Total mR/yr measured by this network ranged from 66 mR/yr at Pahrump, Nevada to 166 mR/yr at Austin, Nevada. Background levels of environmental gamma exposure rates in the U.S. (from the combined effects of terrestrial and cosmic sources) vary between 49 and 247 mR/yr (Committee on the Biological Effects of Ionizing Radiation, 1980). The annual exposure levels observed at each PIC station are well within these U.S. background levels. Figure 12 shows the distribution of the weekly averages from each station arranged by ascending means (represented by filled circles). The left and right edges of the box on the graph represent the 25th and 75th percentiles of the distribution of the weekly averages (i.e., 50 percent of the data falls within this region). The vertical line drawn inside the box represents the 50th percentile or median value. The horizontal lines extend from the box to the minimum and maximum values.

The data from the Las Vegas, Uhalde's Ranch, Rachel, and Austin stations show the greatest range and the most variability. The Las Vegas station was moved in February approximately 300 ft from one side of the parking lot to another. This caused an increase in the average PIC value from approximately 6.0 μR/hr to 9.0 μR/hr. This increase is probably caused by moving the station from a relatively paved area to a less paved area where more radon is able to emanate from the ground. The data from the Uhalde's Ranch, Rachel, and Austin stations have historically shown natural fluctuations during the winter months (EPA 600/R-93/141). In addition to these natural fluctuations, both the Uhalde's Ranch station and the Rachel station experienced equipment problems during the winter months. These equipment problems contributed to the variability in the data from these two stations. The mean exposure at the Indian Springs station increased from 8.9 μR/hr in 1992 to 11 μR/hr in 1993. This was due to landscaping changes made to the station in late 1992 and to the calibration of the PIC which was done in November 1993. The PIC data presented in this section are based on weekly averages of gamma exposure rates from each station. Weekly averages were compiled for every station for every week during 1993, with the exception of the weeks listed in Table 4. Data were unavailable during these weeks due to equipment failure.

3.2.4 Quality Assurance/Quality Control

Several measures are taken to ensure that the PIC data are of acceptable quality:

- The PICs are calibrated at least once every two years and usually once a year. The DOE requires that the PICs be calibrated every two years.

- Radiation monitoring technicians place a radioactive source of a known exposure on the PICs weekly to check the performance of the units.

Table 3. Summary of Weekly Gamma Exposure Rates as Measured by Pressurized Ion Chamber - 1993

Station	Number of Weekly Averages	Gamma Exposure Rate (μR/hr) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Median	mR/yr	1992 Mean (μR/hr)
Furnace Creek, CA	50	10.8	9.8	10.1	0.20	10.0	88	10.1
Shoshone, CA	52	12.4	11.5	12.0	0.14	12.0	105	11.9
Alamo, NV	52	13.9	13.0	13.3	0.24	13.3	117	13.7
Amargosa Valley, NV	52	14.3	13.6	14.0	0.11	14.0	123	14.4
Austin, NV	52	20.6	14.9	19.0	1.72	19.9	166	19.3
Beatty, NV	51	17.9	15.9	16.5	0.64	16.2	145	16.0
Caliente, NV	50	15.2	14.1	14.6	0.30	14.5	128	14.4
Complex I, NV	51	17.5	13.9	15.5	0.67	15.6	136	15.8
Ely, NV	52	14.9	11.6	13.4	0.74	13.4	117	12.6
Goldfield, NV	52	16.1	13.8	14.9	0.35	15.0	131	14.5
Indian Springs, NV	52	12.1	10.0	11.0	0.51	11.0	97	8.9
Las Vegas, NV	49	10.1	6.0	9.5	1.20	10.0	83	6.0
Medlin's Ranch, NV	51	16.3	14.7	15.8	0.34	15.9	138	15.8
Nyala, NV	51	13.0	11.0	11.9	0.65	11.9	104	11.9
Overton, NV	50	9.9	8.9	9.1	0.23	9.0	80	9.0
Pahrump, NV	52	9.1	7.0	7.5	0.65	7.2	66	7.7
Pioche, NV	52	12.4	10.7	11.8	0.43	12.0	103	12.0
Rachel, NV	47	18.1	13.6	16.6	0.92	17.0	145	16.2
Stone Cabin Ranch, NV	52	18.5	14.8	17.3	0.87	17.4	152	17.6
Tonopah, NV	52	18.1	14.8	17.2	0.58	17.1	151	16.9
Twin Springs, NV	51	17.5	15.0	16.6	0.57	16.7	146	16.7
Uhalde's Ranch, NV	51	18.4	11.1	16.3	2.16	17.3	143	17.4
Cedar City, UT	52	14.1	11.4	13.1	0.74	13.3	115	12.3
Delta, UT	52	12.6	10.1	11.9	0.50	12.0	104	12.1
Milford, UT	51	18.5	17.0	17.6	0.38	17.5	154	17.4
Salt Lake City, UT	49	11.2	8.5	10.6	0.63	11.0	93	11.0
St. George, UT	41	9.0	8.0	8.3	0.30	8.2	73	8.4

Note: Multiply μR/hr by 2.6×10^{-10} to obtain $C \cdot kg^{-1} \cdot hr^{-1}$

- Source check calibration and background exposure rate data are evaluated weekly and compared to historical values.

- Data transmitted via the telemetry system are compared to the magnetic tape data on a weekly basis to check that both systems are reporting the same numbers. Whenever weekly averages from the two sets of numbers are not in agreement, the cause of the discrepancy is investigated and corrected.

A data quality assessment of the PIC data is given in Section 11, Quality Assurance.

3.3 Comparison of TLD Results to PIC Measurements

A comparison was conducted between the 1993 TLD data and the 1993 PIC data. This comparison showed only minor fluctuations between the two sets of data. PIC data compared to TLD data ranged from a low of a 10% difference at Overton, Nevada to a high of a 25% difference at Cedar City, Utah, with a mean deviation of +5%. A visual representation of this comparison is shown in Figure 13.

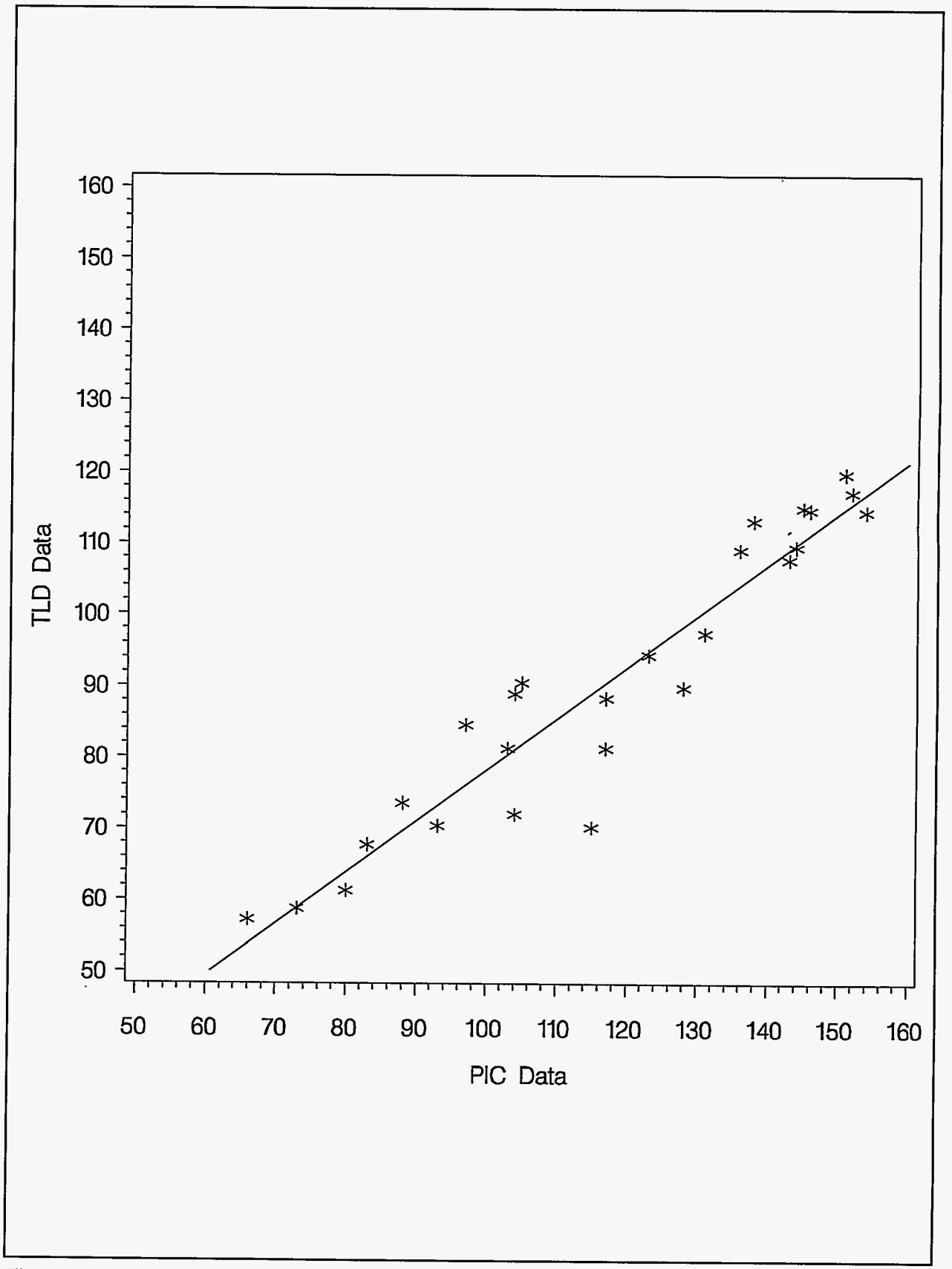


Figure 13. Thermoluminescent Dosimetry versus Pressurized Ion Chamber Networks - 1993

4 Atmospheric Monitoring

The inhalation of radioactive airborne particles can be a major pathway for human exposure to radiation. The atmospheric monitoring networks are designed to detect environmental radiation from NTS and non-NTS activities. Data from atmospheric monitoring can determine the concentration and source of airborne radioactivity and can project the fallout patterns and durations of exposure to man. Atmospheric monitoring networks include the Air Surveillance, Noble Gas, and Atmospheric Moisture (Tritium-in-Air) networks.

The atmospheric monitoring networks were designed to monitor the areas within 350 kilometers (220 miles) of the NTS. These continuously operating networks are supplemented by standby networks which cover the contiguous states west of the Mississippi River.

Many of the data collected from the atmospheric monitoring networks fall below the minimum detectable concentration (MDC). Averages of data presented in this chapter were calculated including measured results below MDCs. All of the data collected from the atmospheric monitoring networks reside on a VAX computer in the Sample Tracking Data Management System (STDMS).

4.1 Air Surveillance Network

4.1.1 Design

During 1993 the ASN consisted of 30 continuously operating sampling stations (see Figure 14 for these locations) and 77 standby stations (Figure 15) that were scheduled to be activated one week per quarter.

Twenty-four standby stations were activated over a three-week period during April 1993 immediately following the Russian TOMSK-7 incident. During the fourth quarter of 1993, only eleven of the standby stations were activated because of unforeseen budget restrictions.

The low-volume air sampler at each station is equipped to collect particulate radionuclides on fiber filters and gaseous radioiodines in charcoal cartridges. The filters and charcoal cartridge samples from all active stations and the filters from standby stations receive complete analyses at the EMSL-LV Radioanalysis Laboratory. The charcoal cartridge samples from standby stations are analyzed only if there is some reason to expect the presence of radioiodine. Duplicate air samples are collected from three routine ASN stations each week. The duplicate samplers operate at randomly selected stations continuously for three months and are then moved to a new location.

The air sampler at each station was equipped to collect particulate radionuclides on fiber prefilters and gaseous radioiodines in charcoal cartridges. Prefilters and charcoal cartridges collected from all ASN and prefilters collected from all SASN stations received complete analyses at EMSL-LV. Charcoal cartridges are collected from the SASN stations and would be available for analyses should the need arise.

4.1.2 Procedures

At each ASN station, samples of airborne particulates are collected as air is drawn through 5 cm (2.1 in) diameter, glass-fiber filters (prefilters) at a flow rate of about 80 m^3 (2800 ft^3) per day. Filters are exchanged after sampler operation periods of about one week (approximately 560 m^3 or 20,000 ft^3). Activated charcoal cartridges placed directly behind the filters to collect gaseous radioiodines are exchanged at the same time as the filters.

Duplicate air samples were obtained weekly from various stations. Four air samplers, which are identical to the ASN station samplers, were rotated between ASN stations for three to four week periods. The results of the duplicate field sample analyses are given in Section 11 as part of the data quality assessment.

At EMSL-LV, both the prefilters and the charcoal cartridges are initially analyzed by high resolution gamma spectrometry. Each of the prefilters is then analyzed for gross beta activity. Gross beta analysis is performed on the prefilters 7 to 14 days after sample collection to allow time for the decay of naturally occurring radon-thoron daughter products. Gross beta analysis is used to detect trends

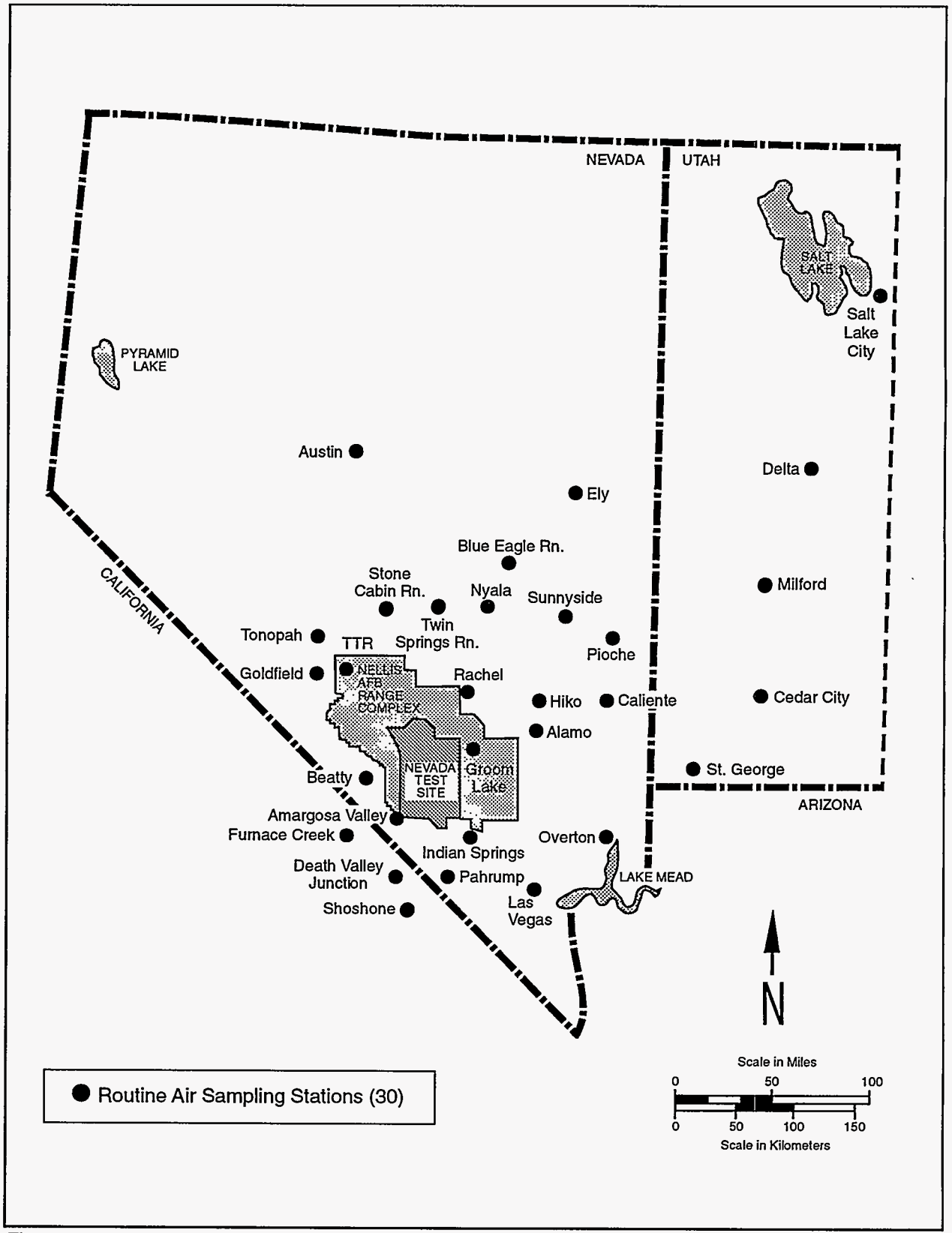


Figure 14. Air Surveillance Network stations - 1993.

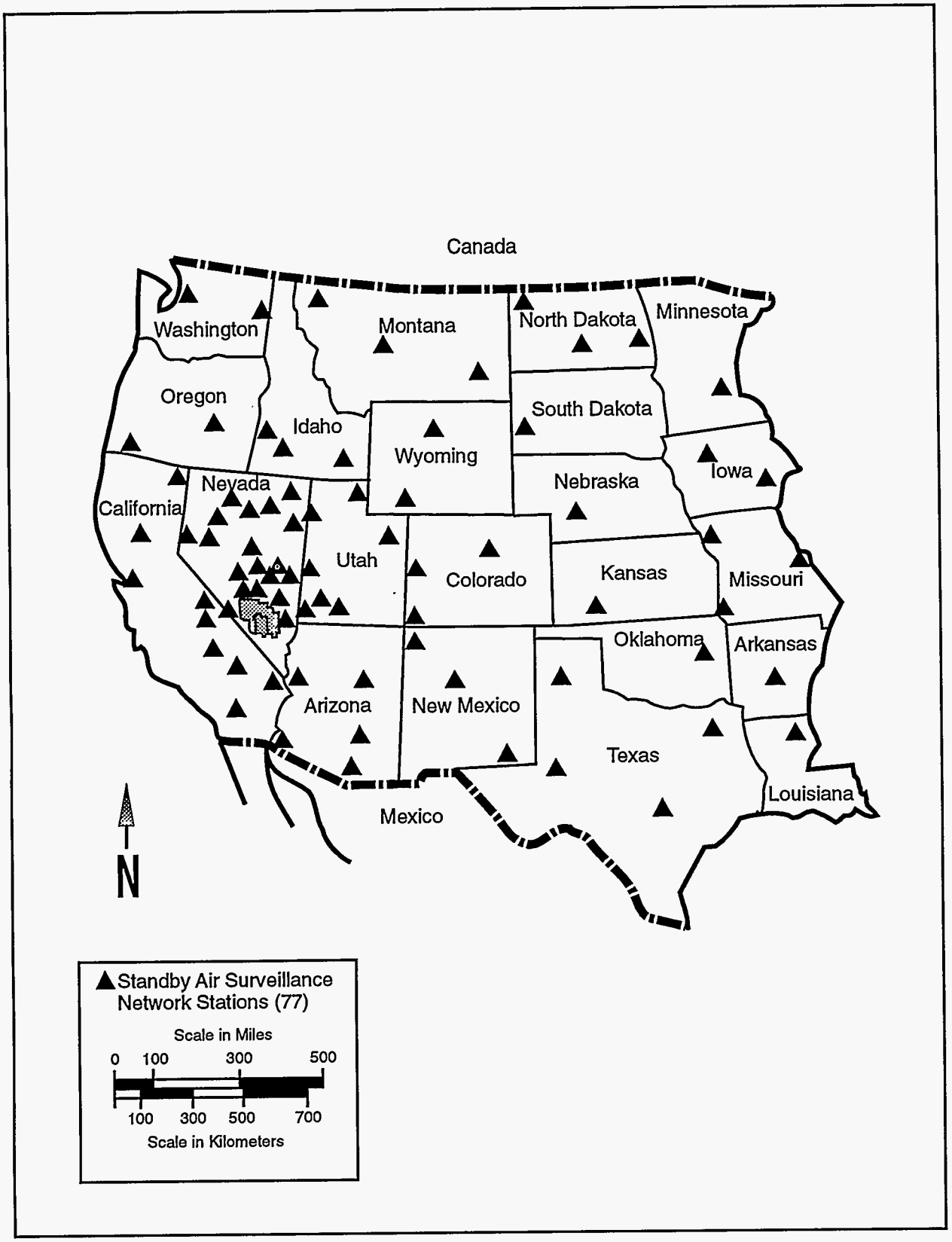


Figure 15. Standby Air Surveillance Network stations - 1993.

in atmospheric radioactivity since it is more sensitive than gamma spectrometry for this purpose. Selected prefilters are then composited (combined) and analyzed for plutonium isotopes. Additional information on the analytical procedures is provided in Section 12.

Selected air prefilters were also analyzed for plutonium isotopes. Prefilters are composited monthly for each of four ASN stations (Alamo, Amargosa Valley, Las Vegas, and Rachel, Nevada) and are composited quarterly for two SASN stations in each of 13 states: Arizona, California, Colorado, Idaho, Missouri, Montana, New Mexico, North Dakota, Oregon, Texas, Utah, Washington, and Wyoming.

4.1.3 Results

The following sections describe results for the ASN and its associated standby network (SASN), noble gas samplers, and atmospheric moisture samplers. The atmospheric monitoring networks measure the major radionuclides which could potentially be emitted from activities on the NTS. Collectively, these networks represent the possible inhalation and submersion components of radiation exposure pathways to the general public.

Gamma spectrometry was performed on all ASN and SASN samples. The majority of the samples were gamma-spectrum negligible (i.e., no gamma-emitting radionuclides detected). Naturally occurring ^{7}Be, averaging 3.0×10^{-13} µCi/mL, was infrequently detected. Alpha and beta results for 58 samples were not included in data analysis. These results were excluded because they met one or more of the following criteria: sampling duration of greater than 14 days, total volume of less than 400 m^3, average flow rate less than 2.9 m^3/hr or greater than 4.0 m^3/hr, or power outage lasting more than one-third of sampling interval length. All remaining results were used in data analysis, including preparation of tables.

As in previous years, the gross beta results from both networks consistently exceeded the analysis minimum detectable activity concentration (MDC). The annual average gross beta activity was 1.5×10^{-14} µCi/mL for the ASN and 1.5×10^{-14} µCi/mL for the SASN. Summary gross beta results for the ASN are in Table 5 and for the SASN in Table B-5, Appendix B. No samples were collected at the SASN station in Needles, CA in 1993. Twenty-four SASN samplers were activated following the TOMSK-7 incident in Russia. The period of sample collection varied from two to seven days. Gross beta results are given in Appendix B, Table B-6.

Gross alpha analysis was performed on all samples. The average annual gross alpha activities were 9.0×10^{-16} µCi/mL for the ASN and 8.1×10^{-16} µCi/mL for the SASN. Summary gross alpha results for the ASN are presented in Table 6 and for the SASN in Table B-1, Appendix B. Gross alpha results for the samples collected in the wake of the TOMSK-7 incident are provided in Table B-2, Appendix B.

Selected air prefilters were also analyzed for plutonium isotopes. This report contains results for samples collected during the first, second and third quarters of 1993, presented in Table 7 for the ASN and in Table B-3, Appendix B, for the SASN. Due to the length of time required for analysis of plutonium isotopes, the data for the fourth quarter were not available for inclusion in this report, but will be included in the combined report for 1994. Samples exceeding the analysis MDC within the ASN networks for the first three quarters of 1993 were the June and July samples from Alamo, NV for ^{238}Pu and the July sample from Rachel, NV for $^{239+240}Pu$ analysis. The SASN second quarter composite sample for New Mexico exceeded the MDC for ^{238}Pu. The MDC for $^{239+240}Pu$ was exceeded in the second quarter composite samples from New Mexico and Wyoming, and third quarter composite samples from Texas and Wyoming. In total, eight out of 146 analyses exceeded the MDC for Pu.

No samples were received from the Texas SASN stations for the second quarter of 1993 and the data for samples received from Oregon for the third quarter 1993 were not available at the time of this writing. Single SASN samples were analyzed for plutonium in instances when the second prefilter was not received and three prefilters were composited when a standby sampler was operated more than once in a given quarter.

4.2 Tritium In Atmospheric Moisture

Table 5. Gross Beta Results for the Offsite Air Surveillance Network - 1993

Sampling Location	Number	Gross Beta Concentration (10^{-14} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation
Death Valley Junction, CA	48	3.3	0.45	1.5	0.65
Furnace Creek, CA	48	4.6	0.47	1.8	0.96
Shoshone, CA	52	3.5	0.54	1.7	0.68
Alamo, NV	51	3.3	0.63	1.5	0.51
Amargosa Valley, NV	49	3.0	0.47	1.5	0.63
Austin, NV	50	3.0	0.03	1.4	0.61
Beatty, NV	52	2.9	0.62	1.7	0.56
Caliente, NV	50	3.3	0.12	1.4	0.53
Clark Station, NV					
Stone Cabin Ranch	52	3.0	0.29	1.4	0.60
Currant, NV					
Blue Eagle Ranch	51	3.9	-0.10	1.2	0.77
Ely, NV	52	3.4	0.44	1.4	0.54
Goldfield, NV	52	2.9	0.56	1.6	0.61
Groom Lake, NV	49	3.4	0.5	1.7	0.63
Hiko, NV	52	3.9	0.58	1.5	0.62
Indian Springs, NV	52	3.1	0.17	1.6	0.59
Las Vegas, NV	50	3.1	0.07	1.5	0.55
Nyala, NV	52	3.7	0.19	1.3	0.7
Overton, NV	51	3.5	0.11	1.7	0.65
Pahrump, NV	52	2.6	0.63	1.4	0.5
Pioche, NV	51	3.0	0.36	1.5	0.57
Rachel, NV	49	4.5	0.24	1.6	0.79
Sunnyside, NV	49	3.2	0.3	1.4	0.57
Tonopah, NV	50	3.1	0.56	1.6	0.64
Tonopah Test Range, NV	50	3.1	0.17	1.4	0.64
Twin Springs, NV					
Fallini's Ranch	51	4.4	0.84	1.9	0.82
Cedar City, UT	52	2.5	0.46	1.3	0.46
Delta, UT	48	4.7	0.33	1.8	0.87
Milford, UT	52	4.3	0.02	1.8	0.76
Salt Lake City, UT	51	4.2	0.44	1.6	0.69
St. George, UT	49	3.4	0.06	1.7	0.75

Mean MDC: 2.4×10^{-15} µCi/mL Standard Deviation of Mean MDC: 2.9×10^{-16} µCi/mL

Table 6. Gross Alpha Results for the Offsite Air Surveillance Network - 1993

		Gross Alpha Concentration (10^{-15} µCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Death Valley Jct, CA	48	4.1	-0.4	1.4	1.0
Furnace Creek, CA	48	4.7	-0.7	1.2	1.1
Shoshone, CA	52	3.0	-0.1	1.0	0.66
Alamo, NV	51	2.8	0.0	1.1	0.62
Amargosa Valley, NV	49	3.3	-0.1	1.3	0.85
Austin, NV	50	3.4	-0.6	0.91	0.74
Beatty, NV	52	3.6	-0.3	1.2	0.83
Caliente, NV	50	1.8	-0.5	0.68	0.52
Clark Station, NV					
Stone Cabin Ranch	52	4.4	-0.4	1.3	0.92
Currant, NV					
Blue Eagle Ranch	51	2.1	-0.4	0.58	0.59
Ely, NV	52	1.6	-0.2	0.58	0.41
Goldfield, NV	52	1.9	-0.6	0.63	0.48
Groom Lake, NV	49	3.5	-0.2	1.5	0.7
Hiko, NV	52	2.4	-0.1	0.9	0.52
Indian Springs, NV	52	1.8	-0.2	0.66	0.49
Las Vegas, NV	50	2.6	-0.4	0.94	0.69
Nyala, NV	52	1.9	-0.6	0.6	0.52
Overton, NV	51	2.0	-0.6	0.71	0.52
Pahrump, NV	52	3.3	-0.4	0.93	0.76
Pioche, NV	51	1.8	-0.5	0.55	0.48
Rachel, NV	49	2.1	-0.6	0.59	0.48
Sunnyside, NV	49	3.2	-0.2	0.89	0.74
Tonopah, NV	50	1.9	-0.2	0.71	0.52
Tonopah Test Range, NV	50	2.6	-0.3	0.83	0.65
Twin Springs, NV					
Fallini's Ranch	51	2.7	-0.3	0.77	0.54
Cedar City, UT	52	2.2	0.1	1.1	0.49
Delta, UT	48	2.0	-0.5	0.64	0.53
Milford, UT	52	3.0	-0.6	0.85	0.73
Salt Lake City, UT	51	2.5	-0.8	0.63	0.56
St. George, UT	49	4.0	-0.3	1.2	0.87

Mean MDC: 8.0×10^{-16} µCi/mL Standard Deviation of Mean MDC: 2.7×10^{-16} µCi/mL

Table 7. Offsite Airborne Plutonium Concentrations - 1993

Composite Sampling Location	Number	^{238}Pu Concentration (10^{-18} μCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Alamo, NV	9	7.1	-1.3	1.8	3	0.7
Amargosa Valley, NV	9	29	-4.9	4.3	10	1.7
Las Vegas, NV	9	52	5.7	6.8	18	2.6
Rachel, NV	9	9.5	-4.0	1.4	4.4	0.5

Mean MDC: 16 x 10^{-18} μCi/mL Standard Deviation of Mean MDC: 9.9 x 10^{-18} μCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 3 x 10^{-15} μCi/mL

Composite Sampling Location	Number	$^{239+240}$Pu Concentration (10^{-18} μCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Alamo, NV	9	6.1	-0.9	1.5	2.6	0.6
Amargosa Valley, NV	9	12	0.0	3	4.7	1.2
Las Vegas, NV	9	12	-1.3	1.6	3.9	0.6
Rachel, NV	9	41	-8.2	3.7	14	1.4

Mean MDC: 12 x 10^{-18} μCi/mL Standard Deviation of Mean MDC: 8.8 x 10^{-18} μCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 3 x 10^{-15} μCi/mL
NA Not applicable, result is <MDC

4.2.1 Design

Tritium is created by natural forces in the upper atmosphere and is also emitted from nuclear reactors, reprocessing facilities (non-NTS facilities), and worldwide nuclear testing.

At the beginning of 1993, the tritium network consisted of 14 continuously operated and seven standby stations. The routine stations are adjacent to the NTS to detect atmospheric tritium which could reach populated centers in the immediate offsite area. In addition, a tritium sampler is routinely operated near the nuclear research reactor in Salt Lake City, Utah. Samples were collected approximately once a week from the routine stations and once a quarter from the standby stations. Figure 16 shows the locations of the tritium network sampling stations in conjunction with the noble gas sampling network stations.

4.2.2 Procedures

A column filled with molecular sieve pellets is used to collect moisture from the air. Approximately 6 m^3 (212 ft^3) of air is drawn through the column during a typical 7-day sampling period. The water absorbed in the pellets is recovered and measured and the concentration of ^{3}H is determined by liquid scintillation counting. The volume of recovered water and the ^{3}H concentration is then used to calculate the concentration of HTO, the vapor form of tritium. HTO is the most common form of tritium encountered in the environment.

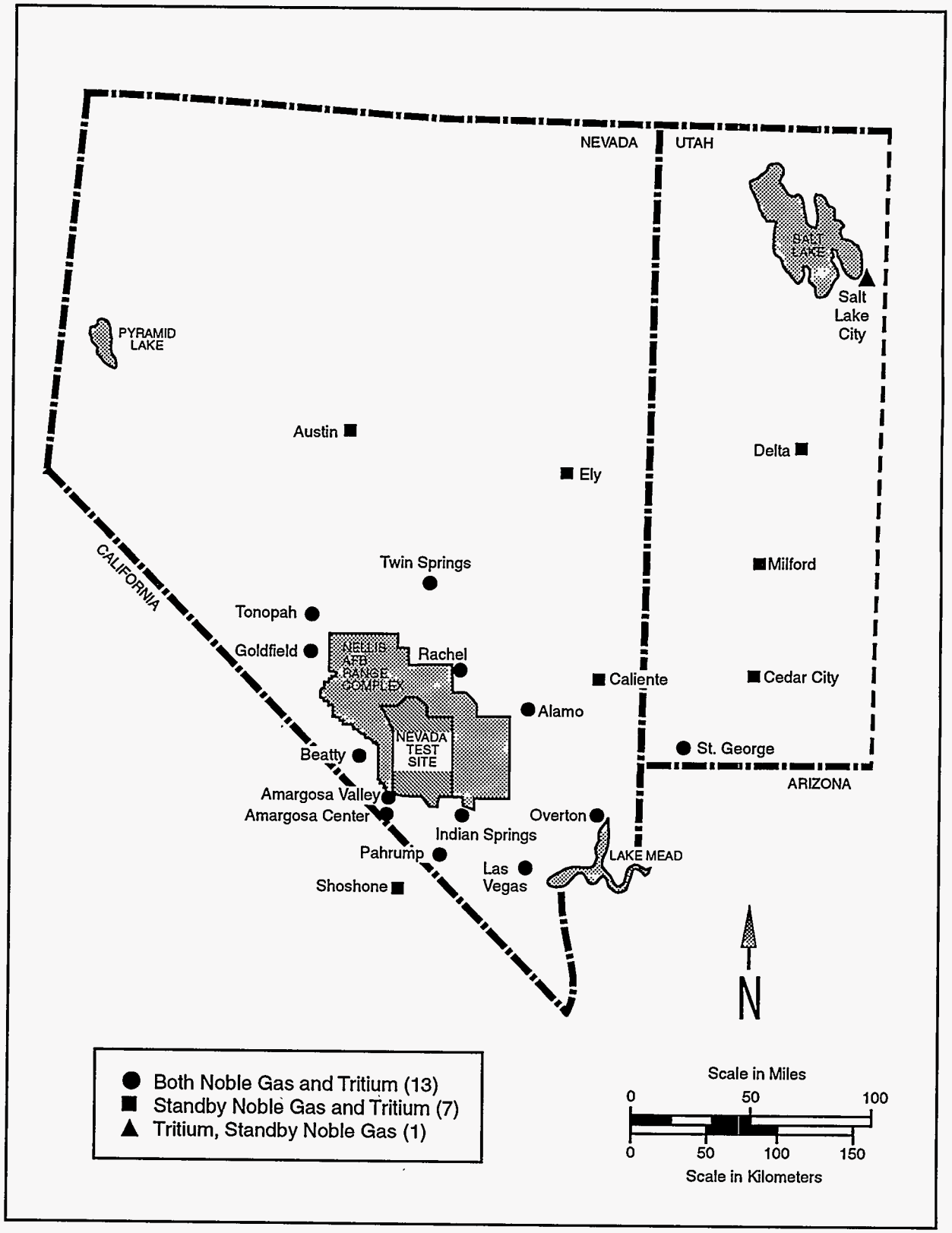


Figure 16. Offsite Noble Gas sampling and Tritium-in-Air Network stations - 1993.

4.2.3 Results

Approximately 5% of the total number of samples collected were invalid due to equipment malfunctions, power outages during collection, frozen lines, or insufficient sample volume. Sample results that exceeded the analysis MDC were: Amargosa Valley (December 6 - 13), Amargosa Center (July 22 - 29), and Goldfield (April 21 - 28). The annual HTO network average was 3.0 x 10^{-7} pCi/mL. Summary data results are given in Table 8 for the routine stations and in Table B-4, Appendix B, for the standby stations.

4.3 Noble Gas Sampling Network

4.3.1 Design

A second part of the EMSL-LV offsite air network is the Noble Gas and Tritium Surveillance Network (NGTSN). Noble gases may be released into the atmosphere from research and power reactor facilities, fuel reprocessing facilities, and from nuclear testing. Noble gases may also be released during drillbacks and tunnel purgings, which take place after a nuclear test. Environmental levels of the xenons, with their very short half-lives, are normally below the minimum detectable concentration (MDC). Krypton-85 disperses more or less uniformly over the entire globe because of its half-life, 10.7 years, and the lack of significant sinks (NCRP, 1975). For these reasons, ^{85}Kr results are expected to be above the MDC. Tritium is created by natural forces in the upper atmosphere and is also emitted from nuclear reactors, reprocessing facilities (non-NTS facilities), and worldwide nuclear testing.

The locations of the NGTSN stations are shown in Figure 20. The NGTSN is designed to detect any increase in offsite levels of xenon, krypton, or atmospheric tritium due to possible NTS emissions. Routinely operated network samplers are typically located in populated areas surrounding the NTS and standby samplers are located in communities at some distance from the NTS. In 1993, this network consisted of 13 routine noble gas tritium-in-air samplers, plus eight on standby, located in the states of Nevada, Utah, and California. The stations on routine sampling status ring the NTS to detect any emissions of noble gases or atmospheric tritium which reach the population centers in the immediate offsite area. In addition, a tritium sampler is routinely operated near a nuclear research reactor in Salt Lake City, Utah.

4.3.2 Procedures

Noble gas samples are collected by compressing air into storage tanks (bottles). Air is continuously sampled over a 7-day period, collecting approximately 0.6 m^3 (21.2 ft^3) of air into a four-bottle system. One bottle is filled over the entire sampling period. The other three bottles are filled consecutively over the same sampling period in 56-hour increments. The bottle containing the sample from the entire sampling period is the only sample which is routinely analyzed. If xenons or abnormally high levels of ^{85}Kr were detected in this sample, then the other three samples would be analyzed. For the analysis, samples are condensed at liquid nitrogen temperature. Gas chromatography is then used to separate the gaseous radionuclide fractions. The radioactive gases are dissolved in liquid scintillation "cocktails," then counted to determine activity.

4.3.3 Results

All samples were analyzed for ^{85}Kr and ^{133}Xe and the summary data results are given in Table 9 for the routine stations. Eight standby stations were run quarterly to ascertain operational status; the samples were not analyzed. Of the 676 samples collected in 1993, analyses were not performed on 63 samples (9.3 percent) due to insufficient volume collected or sampler malfunctions. As expected, all ^{85}Kr results exceeded the MDC and all ^{133}Xe results were below the MDC. The annual averages for the continuously operated samplers were 2.8 x 10^{-11} µCi/mL for ^{85}Kr and -2.1 x 10^{-11} µCi/mL for ^{133}Xe.

4.4 Quality Assurance/ Quality Control

General QA/QC guidelines for the atmospheric monitoring networks are as follows:

- All field sampling and laboratory instruments are calibrated and the date of calibration is marked on a decal affixed to the equipment.

Table 8. Offsite Atmospheric Tritium Results for Routine Samplers - 1993

		HTO Concentration (10^{-6} pCi/mL)				
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Alamo, NV	46	52	-23	5.5	16	5.5
Amargosa Valley, NV	51	38	-34	2.4	13	2.4
Amargosa Valley Community Center, NV	49	77	-53	4.7	22	4.7
Beatty, NV	44	32	-22	2.3	11	2.3
Goldfield, NV	48	34	-132	2.1	23	2.1
Indian Springs, NV	50	29	-18	8.5	8.5	2.9
Las Vegas, NV	51	32	-21	4.8	13	4.8
Overton, NV	52	45	-62	4.1	19	4.1
Pahrump, NV	49	48	-27	1.4	15	1.4
Rachel, NV	47	28	-26	1.1	11	1.1
Tonopah, NV	52	25	-45	2.4	11	2.4
Twin Springs, NV Fallini's Ranch	52	24	-27	3	9.5	NA
Salt Lake City, UT	49	36	-29	33	14	NA
St. George, UT	45	34	-51	32	16	NA

Mean MDC: 3.6×10^{-6} pCi/mL Standard Deviation of Mean MDC: 2.1×10^{-6} pCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 1×10^{-2} pCi/mL
MDC Minimum Detectable Concentration
NA Less than MDC. Not applicable.

- Maintaining a file of calibration records, control charts, and log books.
- Assigning unique sample numbers.
- Obtaining laboratory supervisor approval of all analytical results before they are entered into the permanent data base.
- Maintaining files of QA data, which includes raw analytical data, intermediate calculations, and review reports.
- Performing analysis of blanks to verify method interferences caused by contaminants in solvents, reagents, glassware, and other sample processing are known and minimized.
- Estimating analytical accuracy with performance evaluation samples. For the gamma analysis of fiber filters, spiked samples should be within ± 10% of the known value. Gross beta analysis should be within ± 20%. Plutonium analysis of internal spikes should produce results within ± 20% of the known value. For the noble gases, spiked samples should be within ± 20% of the known value.
- Estimating precision of laboratory analytical techniques and total precision for the entire system (both analytical and sampling error) using replicates. Field duplicate air samples as well as internal laboratory replicates are analyzed for the ASN. Only internal laboratory replicates are analyzed for the noble gas and the HTO samples.
- Determining bias (the difference between the value obtained and the true or reference value) by participating in intercomparison studies.

Further discussion of the QA program and the data quality assessment is given in Chapter 11.

Table 9. Offsite Noble Gas Results for Routine Samplers - 1993

Sampling Location	Number	^{85}Kr Concentration (10^{-11} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Alamo, NV	44	3.2	2.1	2.7	0.22	<0.01
Amargosa Valley, NV	49	3.1	2.4	2.8	0.19	<0.01
Amargosa Valley Community Center, NV	41	3.2	2.3	2.7	0.21	<0.01
Beatty, NV	48	3.3	2.3	2.7	0.23	<0.01
Goldfield, NV	47	3.2	2.3	2.7	0.24	<0.01
Indian Springs, NV	49	3.2	2.3	2.8	0.21	<0.01
Las Vegas, NV	51	3.2	2.3	3.2	3.1	<0.01
Overton, NV	50	3.2	2.2	2.7	0.23	<0.01
Pahrump, NV	48	3.3	2.1	2.8	0.24	<0.01
Rachel, NV	41	3.1	2.0	2.7	0.23	<0.01
Tonopah, NV	48	3.1	2.2	2.7	0.21	<0.01
Twin Springs, NV Fallini's Ranch	47	3.2	2.3	2.8	0.2	<0.01
St. George, UT	46	3.3	2.1	2.7	0.27	<0.01

Mean MDC: 0.57×10^{-11} µCi/mL Standard Deviation of Mean MDC: 0.11×10^{-11} µCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 6×10^{-7} µCi/mL

Sampling Location	Number	^{133}Xe Concentration (10^{-12} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Alamo, NV	44	8.6	-13	-1.6	4.5	NA
Amargosa Valley, NV	49	4.7	-10	-1.9	3.1	NA
Amargosa Valley Community Center, NV	41	8.6	-16	-2.8	5.1	NA
Beatty, NV	49	6.8	-14	-2.3	4.4	NA
Goldfield, NV	47	7.5	-11	-2.7	3.9	NA
Indian Springs, NV	50	11	-10	-1.5	4.2	NA
Las Vegas, NV	51	5.9	-8.1	-1.8	3.4	NA
Overton, NV	50	11	-20	-3.8	6.7	NA
Pahrump, NV	48	5.5	-13	-2.1	4.0	NA
Rachel, NV	41	8.4	-14	-2.4	5.4	NA
Tonopah, NV	49	12.0	-19	-1.4	6.1	NA
Twin Springs, NV Fallini's Ranch	47	12	-15	-2.7	5.3	NA
St. George, UT	47	19	-19	-0.9	7.2	NA

Mean MDC: 16.0×10^{-11} µCi/mL Standard Deviation of Mean MDC: 7.2×10^{-11} µCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 6.0×10^{-8} µCi/mL

NA Not applicable; mean is less than MDC

5.0 Foodstuffs

Ingestion is one of the critical exposure pathways for radionuclides to humans. Food crops may absorb radionuclides from the soil in which they are grown. Radionuclides may be found on the surface of fruits, vegetables, or food crops. The source of these radionuclides may be atmospheric deposition, resuspension, or adhering particles of soil. Weather patterns, especially precipitation, can affect soil inventories of radionuclides. Grazing animals ingest radionuclides which may have been deposited on forage grasses and, while grazing, ingest soil which could contain radionuclides.

Certain organs in the grazing animal, such as liver and muscle, may bioaccumulate radionuclides. These radionuclides are transported to humans by consumption of meat and meat products. In the case of dairy cattle, ingested radionuclides may be transferred to milk. Water is another significant ingestion transport pathway of radionuclides to humans.

To monitor the ingestion pathways, milk surveillance and biomonitoring networks are operated within the Offsite Radiological Safety Program (ORSP). The Milk Surveillance Network (MSN) includes commercial dairies and family-owned milk cows and goats representing the major milksheds within 186 miles (300 km) of the NTS. The MSN is supplemented by the Standby Milk Surveillance Network (SMSN) which includes all states west of the Mississippi. The biomonitoring network includes the animal investigation program and monitoring of radionuclides in locally grown fruits and vegetables.

5.1 Milk Surveillance Network

Milk is particularly important in assessing levels of radioactivity in a given area and the exposure of the population as a result of ingesting milk or milk products. Milk is one of the most universally consumed foodstuffs and certain radionuclides are readily traceable through the food chain from feed or forage to the consumer. This is particularly true of radioiodine isotopes which, when consumed by children, can cause significant impairment of thyroid function. Because dairy animals consume vegetation representing a large area of ground cover and because many radionuclides are transferred to milk, analysis of milk samples may yield information on the deposition of small amounts of radionuclides over a relatively large area. Accordingly, milk is closely monitored by EMSL-LV through the MSN and the SMSN. Records are kept of cow and goat locations by maintaining a dairy animal and population census.

5.1.1 Design

The MSN includes commercial dairies and family-owned milk cows and goats representing the major milksheds within 300 km (186 mi) of the NTS. At the beginning of 1993, there were 24 MSN collection sites. The 24 locations sampled in 1993 appear in Figure 17. Changes to the network are summarized in Table 10.

The SMSN consists of dairies or processing plants representing major milksheds west of the Mississippi River. The network is activated annually by contacting cooperating Food and Drug Administration (FDA) Regional Milk Specialists, who in turn contact State Dairy Regulators to enlist cooperating milk processors or producers. The annual activation permits trends to be monitored and ensures proper operation of the SMSN should an emergency arise. The 115 locations sampled in 1993 appear in Figure 18. There were no changes to the SMSN during 1993.

The dairy animal and population census is continually updated for those areas within 385 km (240 mi) north and east of CP-1 and within 200 km (125 mi) south and west of CP-1. The remainder of the Nevada counties and the western-most Utah counties are surveyed approximately every other year. The locations of processing plants and commercial dairy herds in Idaho and the remainder of Utah can be obtained from the milk and food sections of the respective state governments.

5.1.2 Procedures

Raw milk is collected in 1-gallon (3.8 L) collapsible cubitainers and preserved with formaldehyde. Routine sampling is conducted monthly for the MSN and annually for the SMSN, or whenever local or worldwide radiation events suggest possi-

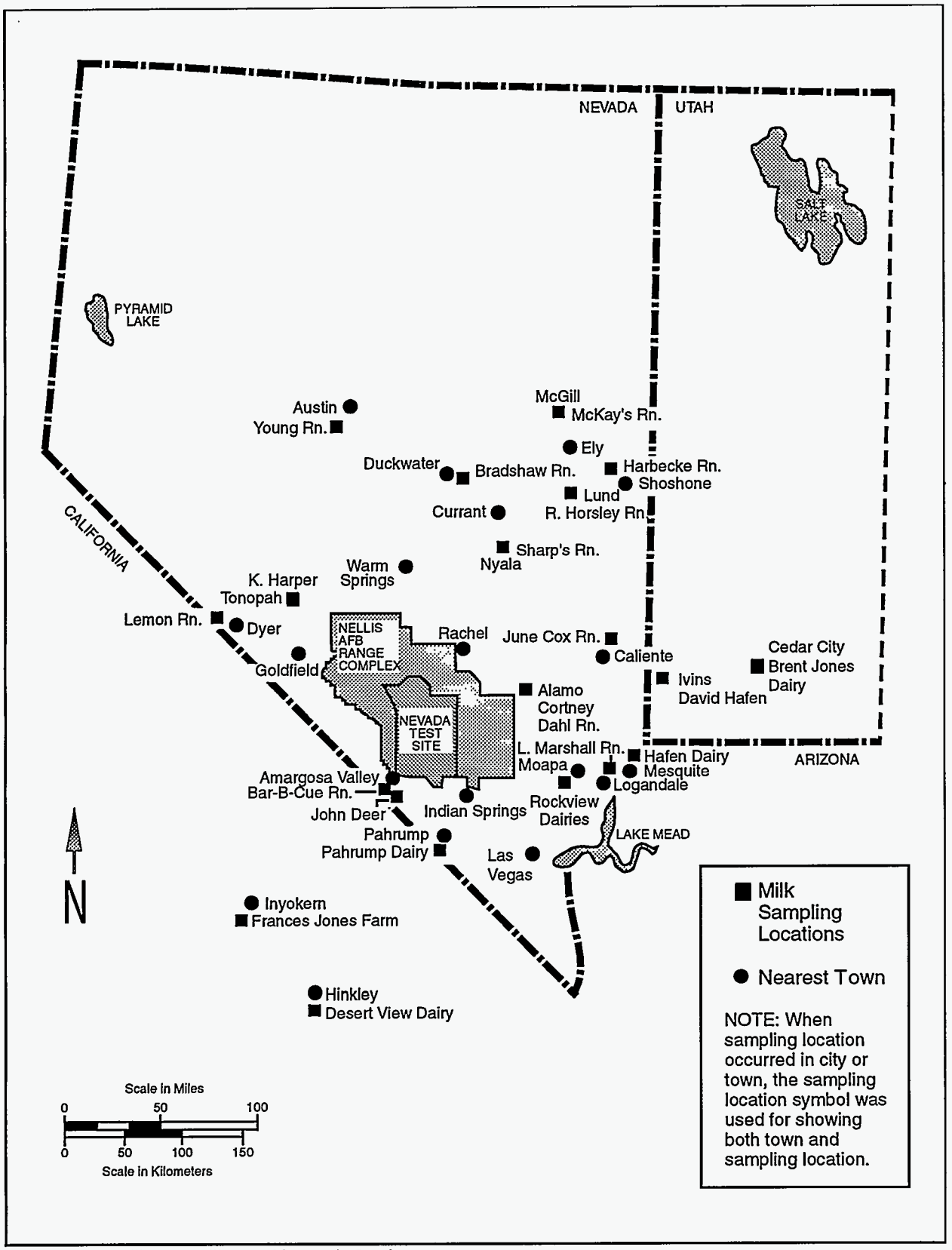


Figure 17. Milk Surveillance Network Stations - 1993.

Table 10. Milk Surveillance Network Sampling Location Changes - 1993

Location	Change	Effective Date	Reason for Change
Irene Brown Ranch, Benton, California	Deleted	04/15/93	Sold goats
Blue Eagle Ranch, Currant, Nevada	Deleted	10/03/93	Sold cow
Harbecke Ranch, Shoshone, Nevada	Deleted	07/06/93	Owner no longer wishes to participate
Frances Jones Farm Inyokern, California	Added	03/18/93	Added to network
Frayne Ranch Bellehelen, Nevada	Deleted	04/08/93	Moved No samples during 1993
Manzonie Ranch Currant, Nevada		12/07/93	No samples during 1993

ble radiation concerns, such as the Chernobyl incident or nuclear testing by foreign nations.

All milk samples are analyzed by high-resolution gamma spectroscopy to detect gamma-emitting radionuclides. One sample per quarter from each MSN location and two from each SMSN sampling location in each state excluding Nevada are evaluated by radiochemical analysis. These samples are analyzed for ^{3}H by liquid scintillation counting and for ^{89}Sr and ^{90}Sr by radiochemical separation and beta counting.

5.1.3 Results

The average total potassium concentration derived from ^{40}K activity was 1.5 g/L. No other non-natural gamma-emitting radionuclides were detected.

Selected MSN and SMSN milk samples were analyzed for ^{3}H, ^{89}Sr, and ^{90}Sr. Summaries of the MSN results are in Tables 12 for ^{3}H, 13 for ^{89}Sr, and 14 for ^{90}Sr. The results for the annual SMSN samples analyzed for ^{3}H, ^{89}Sr, and ^{90}Sr are given in Table C-1, Appendix C. Samples analyzed by gamma spectrometry for the SMSN are listed in Table C-2, Appendix C.

In conclusion, the MSN and SMSN data are consistent with previous years and are not indicative of increasing or decreasing trends. No radioactivity directly related to current NTS activities was evident.

5.1.4 Quality Assurance/Control

Procedures for the operation, maintenance and calibration of laboratory counting equipment, the control and statistical analysis of the sample and the data review and records are documented in approved SOPs. External and internal comparison studies were performed and field and internal duplicate samples were obtained for precision and accuracy assessments. Analytical results are reviewed for completeness and comparability. Trends are identified and potential risks to humans and the environment are determined based on the data. The data quality assessment is given in Chapter 11.

5.2 Animal Investigation Program

The primary purpose of the animal investigation program is monitoring of the ingestion transport pathway to humans. Therefore, animals which are likely to be consumed by humans are targeted by

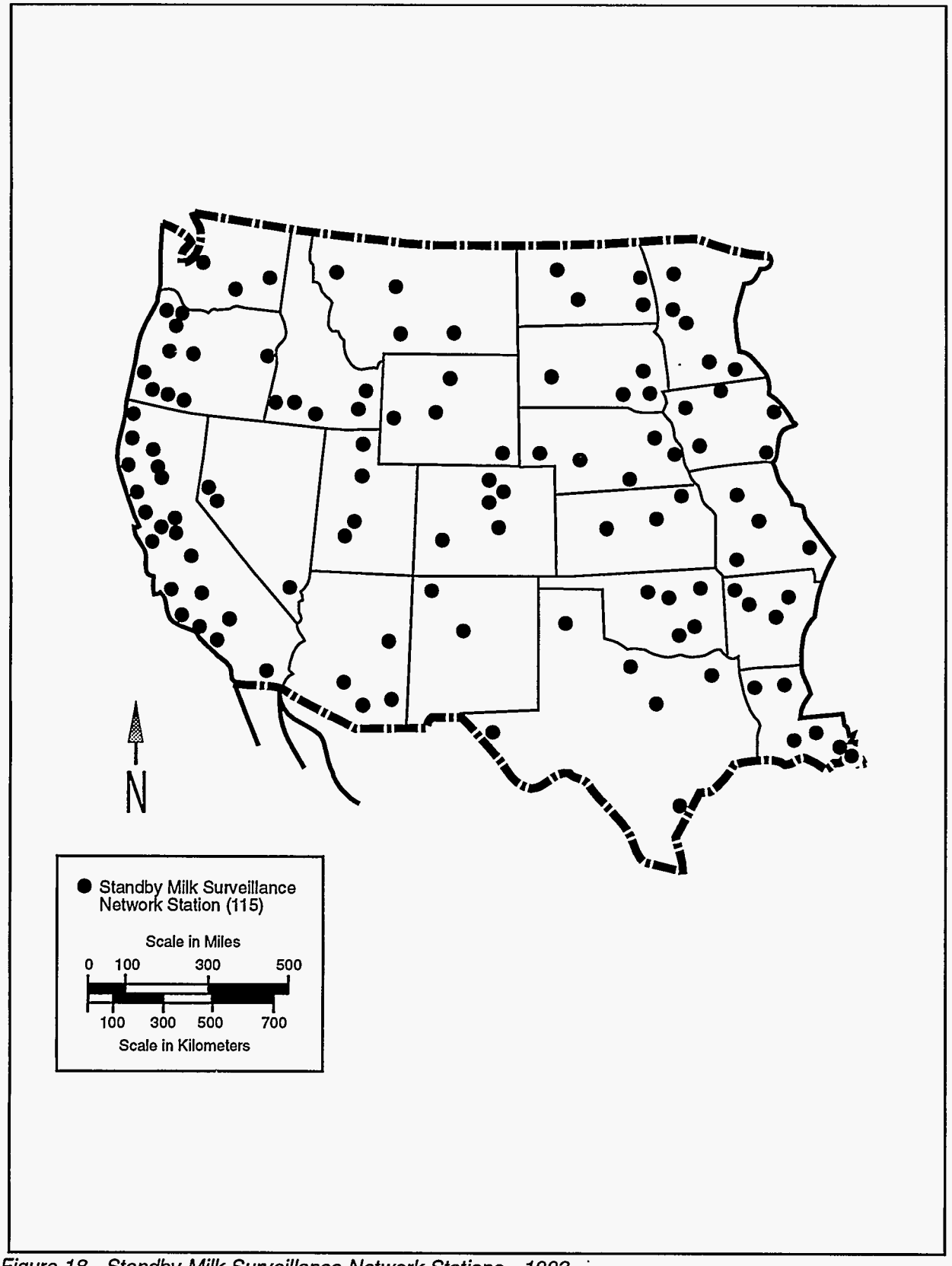


Figure 18. Standby Milk Surveillance Network Stations - 1993.

Table 11. Summary of Radionuclides Detected in Milk Samples

	Milk Surveillance Network			Standby Milk Surveillance Network		
	No. of samples with results > MDC (Network average concentration in pCi/L)			No. of samples with results > MDC (Network average concentration in pCi/L)		
	1993	1992	1991	1993	1992	1991
^{3}H	0 (122)	5 (153)	2 (152)	1 (164)	6 (158)	1 (153)
^{89}Sr	0 (-0.16)	4 (-0.011)	1 (0.303)	1 (0.0075)	4 (0.376)	3 (0.420)
^{90}Sr	2 (0.55)	5 (0.650)	4 (0.546)	15 (1.10)	17 (0.994)	18 (1.236)

the program. These are bighorn sheep, mule deer, and beef cattle.

A veterinarian retained through EPA EMSL-LV investigates any claims of damage to animals caused by radiation. No such claims were received in 1993.

5.2.1 Network Design

The objective of the animal investigation program is to determine whether there is any potential for radionuclides to reach humans through the ingestion pathway. To that end, the program is based upon what is considered to be a worst-case scenario. Mule deer are migratory; the ranges of the herds which inhabit the NTS include lands outside the federal exclusionary area in which hunting is permitted. Therefore, it is theoretically possible for a resident to consume meat from a deer which had become contaminated with radionuclides during its inhabitation of the NTS. During the years of atmospheric testing, fission products were carried outside the boundaries of the NTS and deposited in the offsite area. Longer-lived radionuclides, particularly plutonium and strontium isotopes, are still detected in soil in the area. Some of these radionuclides may be ingested by animals residing in those areas. Cattle are purchased from ranches where atmospheric tests are known to have deposited radionuclides. The continued monitoring of bighorn sheep provides a long-term history for examination of radioactivity trends in large grazing animals.

The collected animals are not selected to be representative of average radionuclide levels in animals residing in the offsite area, nor are they designed to be necessarily representative of the herd from which they are drawn. However, selection is not random. There is an inherent nonrandom selection in hunting and the ranchers select the cattle to be sold. Because the program is not statistically based, no conclusions can or should be drawn regarding average concentrations of radionuclides in animals in the offsite area, nor should any conclusions be drawn regarding average radionuclide ingestion by humans. The collection sites for the bighorn sheep, deer, and cattle analyzed in 1993 are shown in Figure 19.

5.2.2 Sample Collection and Analysis Procedures

During the bighorn sheep season in November and December, licensed hunters in Nevada are asked to donate one leg bone and two kidney samples from each bighorn sheep taken. The location where the sheep was taken and any other available information are recorded on the field data form. The bone and kidney samples are weighed, sealed in labeled sample bags, and stored in a controlled freezer until processing. Weights are recorded on the field data form. After completion of the hunting season, a subset of the samples is selected to represent areas around the NTS. The kidneys are delivered to the EPA EMSL-LV Radioanalysis Laboratory for analysis of gamma-emitting radionuclides and tritium. All bone samples are shipped in a single batch to a contract

Table 12. Offsite Milk Surveillance ^{3}H Results - 1993

Sampling Location	Number	^{3}H Concentration (10^{-7} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Hinkley, CA						
Desert View Dairy	4	1.4	0.0	0.7	0.7	NA
Inyokern, CA						
Frances Jones Farm	4	1.5	-1.1	0.5	1.1	NA
Alamo, NV						
Cortney Dahl Ranch	4	3.3	-1.6	0.9	2.0	NA
Amargosa Valley, NV						
Bar-B-Cue Ranch	2	2.5	1.8	2.1	0.5	NA
John Deer Ranch	3	2.0	-1.4	0.1	1.8	NA
Austin, NV						
Young's Ranch	3	1.8	-0.4	0.8	1.1	NA
Caliente, NV						
June Cox Ranch	4	2.8	0.6	1.8	1.0	NA
Currant, NV						
Blue Eagle Ranch	1	-0.8	-0.8	-0.8	--	NA
Duckwater, NV						
Bradshaw's Ranch	4	3.2	-0.6	0.8	1.8	NA
Dyer, NV						
Ozel Lemon	4	3.8	-0.5	1.2	2.0	NA
Logandale, NV						
Leonard Marshall	2	2.3	1.2	1.8	0.8	NA
Lund, NV						
Ronald Horsley Ranch	4	1.9	0.9	1.3	0.4	NA
McGill, NV						
McKay's Ranch	3	2.3	-0.1	1.2	1.2	NA
Mesquite, NV						
Hafen Dairy	4	1.7	0.4	0.9	0.6	NA
Moapa, NV						
Rockview Dairies	4	3.0	-0.4	1.2	1.6	NA
Nyala, NV						
Sharp's Ranch	4	4.0	1.6	2.5	1.1	NA
Pahrump, NV						
Pahrump Dairy	5	3.9	-1.2	1.4	1.9	NA
Shoshone, NV						
Harbecke Ranch	1	1.3	1.3	1.3	--	NA
Tonopah, NV						
Karen Harper Ranch	4	2.0	0.0	1.0	0.9	NA
Cedar City, UT						
Brent Jones Dairy	4	3.7	1.0	2.4	1.1	NA
Ivins, UT						
David Hafen Dairy	4	2.2	0.4	1.4	0.8	NA

Mean MDC: 3.5×10^{-7} µCi/mL Standard Deviation of Mean MDC: 0.80×10^{-7} µCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 9×10^{-5} µCi/mL
NA Less than MDC. Not applicable.

Table 13. Offsite Milk Surveillance ^{89}Sr Results - 1993

Sampling Location	Number	^{89}Sr Concentration (10^{-10} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Hinkley, CA						
Desert View Dairy	2	8.0	-18.0	-4.9	18.0	NA
Inyokern, CA						
Frances Jones Farm	1	-7.6	-7.6	-7.6	--	NA
Alamo, NV						
Cortney Dahl Ranch	3	7.8	-8.8	-0.4	8.3	NA
Amargosa Valley, NV						
Bar-B-Cue Ranch	2	5.6	-8.1	-1.3	9.7	NA
John Deer Ranch	1	6.5	6.5	6.5	--	NA
Caliente, NV						
June Cox Ranch	3	1.9	-9.7	-2.4	6.3	NA
Currant, NV						
Manzonie Ranch	1	0.0	0.0	0.0	--	NA
Duckwater, NV						
Bradshaw's Ranch	2	2.8	2.3	2.5	0.3	NA
Dyer, NV						
Ozel Lemon	2	0.4	-2.0	-0.9	1.8	NA
Logandale, NV						
Leonard Marshall	2	5.3	1.8	3.5	2.5	NA
Lund, NV						
Ronald Horsley Ranch	3	3.7	-6.2	-1.1	5.0	NA
McGill, NV						
McKay's Ranch	2	-0.9	-1.9	-1.4	0.7	NA
Mesquite, NV						
Hafen Dairy	2	4.9	-2.6	1.2	5.3	NA
Moapa, NV						
Rockview Dairies	2	12.0	-12.0	-0.3	17.0	NA
Nyala, NV						
Sharp's Ranch	2	-7.4	-10.0	-8.9	2.2	NA
Pahrump, NV						
Pahrump Dairy	3	6.7	-18.0	-2.1	14.0	NA
Tonopah, NV						
Karen Harper Ranch	2	-0.8	-10.0	-4.4	5.2	NA
Cedar City, UT						
Brent Jones Dairy	2	-2.4	-11.0	-6.8	6.2	NA
Ivins, UT						
David Hafen Dairy	2	2.1	-12.0	-5.0	10.0	NA

Mean MDC: 3.5×10^{-10} µCi/mL Standard Deviation of Mean MDC: 0.8×10^{-10} µCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 8×10^{-7} µCi/mL
NA Less than MDC. Not applicable.

Table 14. Offsite Milk Surveillance ^{90}Sr Results - 1993

Sampling Location	Number	^{90}Sr Concentration (10^{-10} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Hinkley, CA						
Desert View Dairy	4	7.0	-0.4	3.1	3.2	1.0
Inyokern, CA						
Frances Jones Farm	4	6.9	0.1	3.3	3.2	1.1
Alamo, NV						
Cortney Dahl Ranch	4	9.5	0.3	5.7	3.9	1.9
Amargosa Valley, NV						
Bar B Cue Ranch	2	6.7	0.1	3.4	4.7	1.1
John Deer Ranch	3	2.6	-0.8	0.5	1.8	0.2
Austin, NV						
Young's Ranch	2	3.9	3.6	3.8	0.2	1.3
Caliente, NV						
June Cox Ranch	3	8.5	2.1	6.3	3.7	2.1
Currant, NV						
Manzonie Ranch	1	13.0	13.0	13.0	.	4.3
Duckwater, NV						
Bradshaw's Ranch	3	7.3	2.9	4.6	2.3	1.5
Dyer, NV						
Ozel Lemon	4	9.4	0.5	5.2	3.7	1.7
Logandale, NV						
Leonard Marshall	2	1.8	1.2	1.5	0.4	0.5
Lund, NV						
Ronald Horsley Ranch	4	4.7	1.0	3.7	1.8	1.2
McGill, NV						
McKay's Ranch	3	6.4	4.3	5.3	1.0	1.8
Mesquite, NV						
Hafen Dairy	4	9.4	1.7	4.5	3.6	1.5
Moapa, NV						
Rockview Dairies	4	7.0	-0.5	3.4	3.8	1.1
Nyala, NV						
Sharp's Ranch	4	12.0	3.1	8.8	3.9	2.9
Pahrump, NV						
Pahrump Dairy	4	9.5	-0.1	4.3	4.1	1.4
Shoshone, NV						
Harbecke Ranch	1	21.0	21.0	21.0	.	7.0
Tonopah, NV						
Karen Harper Ranch	4	22.0	6.7	12.0	6.9	4.0
Cedar City, UT						
Brent Jones Dairy	4	12.0	0.9	7.1	4.9	2.4
Ivins, UT						
David Hafen Dairy	4	12.0	-1.6	6.6	5.8	2.2

Mean MDC: 14.2×10^{-10} µCi/mL Standard Deviation of Mean MDC: 1.1×10^{-10} µCi/mL

DCG Derived Concentration Guide; Established by DOE Order as 3×10^{-8} µCi/mL

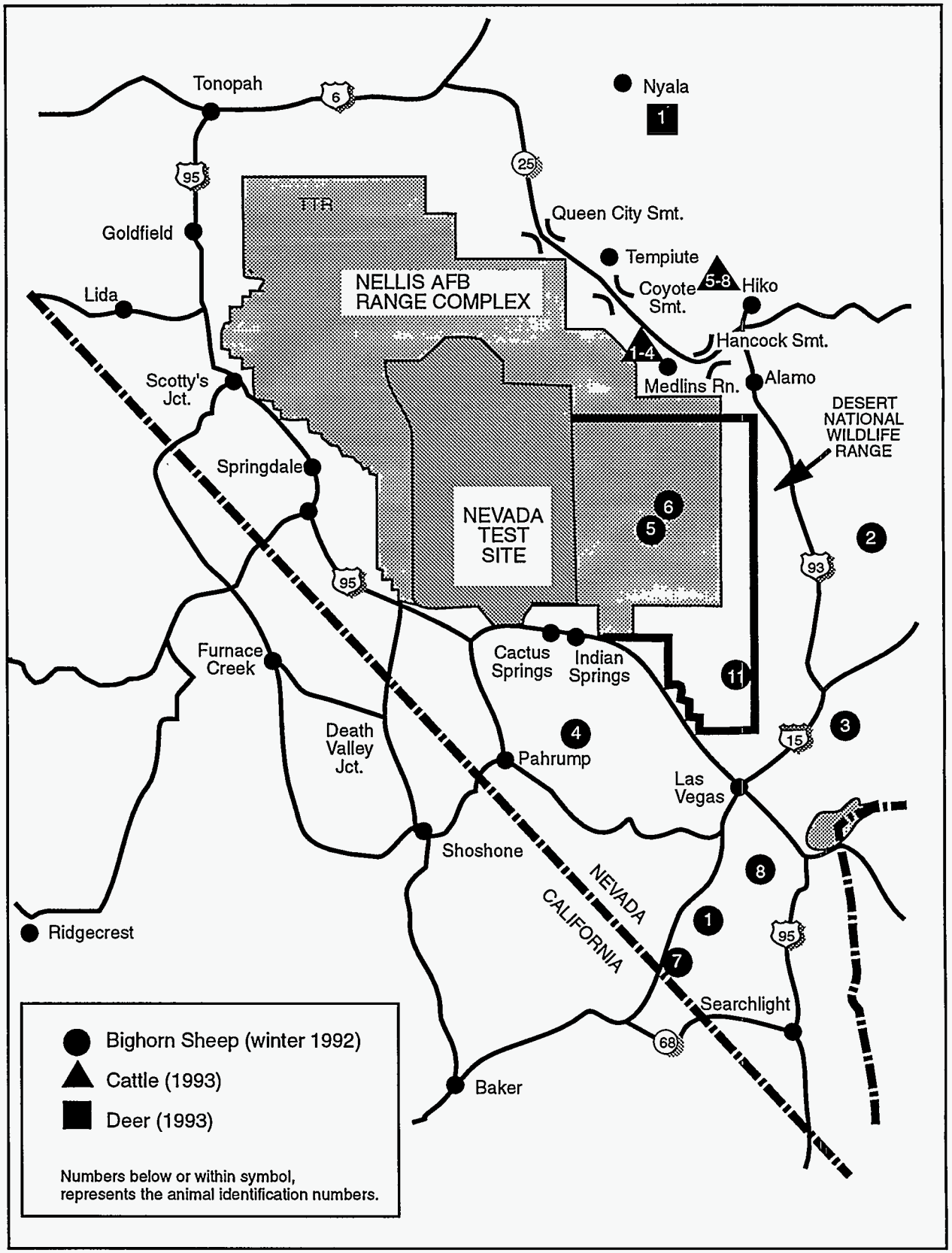


Figure 19. Collection Sites for Animals Sampled Offsite - 1993.

laboratory for ashing. Upon completion of ashing, the bone samples are analyzed for plutonium isotopes and the bone samples are additionally analyzed for strontium. All results are reported in units of pCi/g of ash. The ash weight to wet weight ratios (percent ash) are also reported, to permit conversion of radionuclide activity to a wet weight basis for use in dose calculations.

Each year, attempts are made to collect four mule deer from the NTS, on a one per quarter schedule. If a deer is killed on the road, that animal is used. If road kills are not available, a deer is hunted by personnel with a special permit to carry weapons on the NTS. The deer is usually sampled in the field, with precautions taken to minimize risk of contamination. The location of the deer, weight, sex, condition, and other information are recorded on a field data form. Organs are removed, weighed, and sealed in labeled sample bags. Soft tissue organs, including lung, liver, muscle, and rumen contents are divided into two samples, one for analysis of gamma-emitting radionuclides and one which is ashed prior to analysis for plutonium isotopes. Thyroid and fetus (when available), because of their small size, are analyzed only for gamma-emitting radionuclides. Samples of blood are analyzed for gamma-emitting radionuclides and tritium. Bone samples are ashed and analyzed for plutonium isotopes and strontium. The samples requiring ashing are shipped in a single batch each quarter to a contract laboratory. Analyses are completed in the EPA EMSL-LV Radioanalysis Laboratory.

Four cattle are purchased from ranches in the offsite area around the NTS each spring and another four are purchased each fall. In 1993, four cattle were purchased from the Steve Medlins Ranch in Tickaboo Valley and another four were purchased in the fall from Oran Nash Ranch on Mt. Irish near Hiko. Generally, two adult cattle and two calves are acquired in each purchase. The facility at the NTS farm facility on the NTS is used for the slaughter. This facility is designed to minimize risk of contamination. As with the bighorn sheep and mule deer, sampling information and sample weights are recorded on a field data form and samples are sealed in labeled sample bags. Samples of blood and soft tissues (lung, muscle, liver, thyroid, and kidney) are analyzed for gamma-emitting radionuclides; blood is also analyzed for tritium activity. Liver and bone samples are sent to a contract laboratory for ashing. Ashed liver samples are analyzed for plutonium isotopes; bone ash samples are analyzed for plutonium isotopes and strontium. A sample of the water used in processing the samples is also collected and analyzed.

5.2.3 Sample Results for Bighorn Sheep

The sheep hunt takes place in November and December, hence, the data presented here are from animals hunted in late 1992. The kidney samples were analyzed for gamma-emitting radionuclides and for tritium. The bone samples were ashed prior to analysis of ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$. A summary of results obtained from analysis of bighorn sheep bone and kidney is shown in Table 15. Other than naturally occurring ^{40}K, gamma-emitting radionuclides were not detected, nor was tritium detected, at activities greater than the MDC in any of the kidney samples. All of the bone tissue samples, however, yielded ^{90}Sr activities greater than the MDC of the analysis. The range and median values for ^{90}Sr, shown in Table 15, were similar to those obtained last year (DOE, 1993). The average ^{90}Sr levels found in bighorn sheep bone ash since 1955 are shown in Figure 20. None of the bone samples yielded ^{238}Pu results greater than the MDC of the analysis and only one sample (Bighorn sheep No. 5) yielded a $^{239+240}Pu$ result greater than the MDC. This animal was collected in Area 281, north of Indian Springs, Nevada, in the Pintwater Range. Medians and ranges of plutonium isotopes, given in Table 15, were similar to those obtained previously (DOE, 1993).

5.2.4 Sample Results for Mule Deer

Blood samples are analyzed for gamma-emitting radionuclides and tritium. Soft tissue samples (lung, kidney, muscle, liver, thyroid, rumen contents, and fetus, when available) are analyzed for gamma-emitting radionuclides. Additionally, samples of soft tissues and bones were ashed and then analyzed for plutonium isotopes; ashed bone samples are also analyzed for ^{90}Sr. Samples of kidney, thyroid, and fetal tissue are not ashed due to their small size. Duplicate bone samples from three animals were prepared and analyzed.

The mule deer collected in the first quarter of 1993 was a yearling female in fair to good condition. Collection was made in Area 16 about 1.5 miles

Table 15. Radiochemical Results for Animal Samples - 1993

Sample Type	Parameter	Number	Maximum	Minimum	Median[a]	Standard Deviation	Median MDC ± std. dev.
Cattle Blood	^{3}H[b]	8	3.16	−1.11	0.32	1.46	3.85 ± 0.93
Cattle Liver	% Ash	8	1.4	1.2	1.3	--	--
	^{238}Pu[c]		2.54*	−0.577	0.254	1.21	6.15 ± 3.42
	$^{239+240}Pu$[c]		52.7*	2.88	5.72	17.1	4.46 ± 2.20
Cattle Bone	% Ash	8	37.4	18.9	29.6	--	--
	^{90}Sr[d]		1.6*	0.29*	0.89*	0.37	0.26 ± 0.01
	^{238}Pu[c]		1.31*	−0.838	0.327	0.64	2.56 ± 1.69
	$^{239+240}Pu$[c]		16.5*	0.00	0.854	5.53	2.41 ± 1.41
Cattle Fetus	% Ash	1	--	--	2.4	--	--
	^{90}Sr[d]		--	--	0.32*	--	0.28 ± --
	^{238}Pu[c]		--	--	−1.63	--	4.29 ± --
	^{239}Pu[c]		--	--	11.8*	--	0.885 ± --
Deer Blood	^{3}H[b]	4	3.90*	0.52	229	1.54	3.92 ± 1.59
Deer Liver	% Ash	4	1.4	1.3	1.3	--	--
	^{238}Pu[c]		3.24	−0.0005	0.773	1.44	4.65 ± 4.73
	$^{239+240}Pu$[c]		72.9*	8.06*	24.3*	28.7	1.79 ± 5.19
Deer Lung	% Ash	4	1.2	1.0	1.1	--	--
	^{238}Pu[c]		2.33*	−0.392	−0.392	1.47	4.21 ± 3.00
	$^{239+240}Pu$[c]		130.*	0.640	10.7*	61.5	5.23 ± 3.16
Deer Muscle	% Ash	4	4.7	1.14	1.2	--	--
	^{238}Pu[c]		3.73	−1.41	1.07	2.12	5.53 ± 3.63
	$^{239+240}Pu$[c]		120.*	4.85*	13.8*	54.8	4.15 ± 5.29
Deer Rumen Content	% Ash	4	2.6	1.9	2.2	--	--
	^{238}Pu[c]		7.31*	−1.77	2.32*	3.79	3.57 ± 2.41
	$^{239+240}Pu$[c]		98.7*	2.83	20.1*	42.96	4.83 ± 2.12
Deer Bone	% Ash	4	33.6	27.8	30.9	--	--
	^{90}Sr[d]		1.6*	0.59*	0.85*	0.48	0.28 ± 0.02
	^{238}Pu[c]		5.24*	−0.267	1.34	2.47	2.40 ± 1.00
	$^{239+240}Pu$[c]		2.94*	0.771	2.38	0.98	1.90 ± 0.78
Bighorn Sheep Bone	% Ash	4	41.9	8.8	36.3	--	--
	^{90}Sr[d]		1.9*	0.67*	1.25*	0.50	0.26 ± 0.03
	^{238}Pu[c]		1.19	−0.308	0.443	0.71	2.04 ± 1.44
	$^{239+240}Pu$[c]		63.7*	0.444	1.05	31.4	2.04 ± 1.44
Bighorn Sheep Kidney	^{3}H[b]	7	2.38	−1.33	1.18	1.50	4.37 ± 2.02
Chukar Internal Organs	^{3}H[b]	4	38,700.*	−0.61	3.23	19,349	4.42 ± 0.04
Muscle	^{3}H[b]	4	32,800.*	1.33	3.64	16,398	436 ± 0.01
Chukar Bone	% Ash	3	19.0	4.2	5.8	--	--
	^{90}Sr[d]		3.5*	0.24	2.2*	1.64	0.35 ± 0.15
	^{238}Pu[c]		10.1*	1.30	2.46*	4.78	3.21 ± 1.65
	$^{239+240}Pu$[c]		490.*	8.70*	20.7*	274.5	1.34 ± 0.27
Quail Whole Body	^{3}H[b]	1	--	--	556	--	439 ± --

* Result is greater than the minimum detectable concentration.
(a) Median used instead of mean because small number of samples and large range.

east of U16a site.

The mule deer collected in the second quarter of 1993 was a mature male in good condition. Collection was made in Area 19 along the Pahute Mesa Road 0.5 miles north of U19ar.

The mule deer collected in the third quarter of 1993 was a mature male in excellent condition. Collection was made in Area 20 along the Pahute Mesa Road 0.5 miles east of the Area 20 water reservoir. A female deer was also collected during the third quarter in the offsite area of Cherry Creek Camp ground approximately three miles west of Adaven, Nevada.

No deer was collected on the NTS during the fourth quarter. Attempts were made but due to sudden weather changes during this period of time no collection was possible.

Naturally occurring ^{40}K was detected in all soft tissue samples. In addition, ^{137}Cs was detected in the kidney sample of the mule deer collected in the first quarter (result = 0.0516 ± 0.014 pCi/L) and in the muscle sample of the deer collected offsite (result = 0.0164 ± 0.005 pCi/L) and ^{7}Be was detected in the rumen contents of the first quarter-collected deer (result = 0.35 ± 0.08 pCi/L).

The only blood sample yielding a tritium result slightly greater than the detection limit was a value of 390 ± 120 pCi/L detected in the deer collected in the second quarter. In the past, one or more deer collected on the NTS have evidenced significant levels of tritium in blood. The low results for 1993 are probably due to the fact that no deer were collected in the vicinity of the Area 12 ponds, thought to be the source of tritium in past years' results.

All bone samples yielded ^{90}Sr results greater than the MDC. The average ^{90}Sr found in mule deer bone ash since 1955 is shown in Figure 21. The range and median results are similar to those obtained in recent years. Plutonium-238 was detected at concentrations greater than the MDC in the lung sample from the third quarter deer, the bone sample of the offsite deer, and in the rumen contents samples of all deer except the one col-

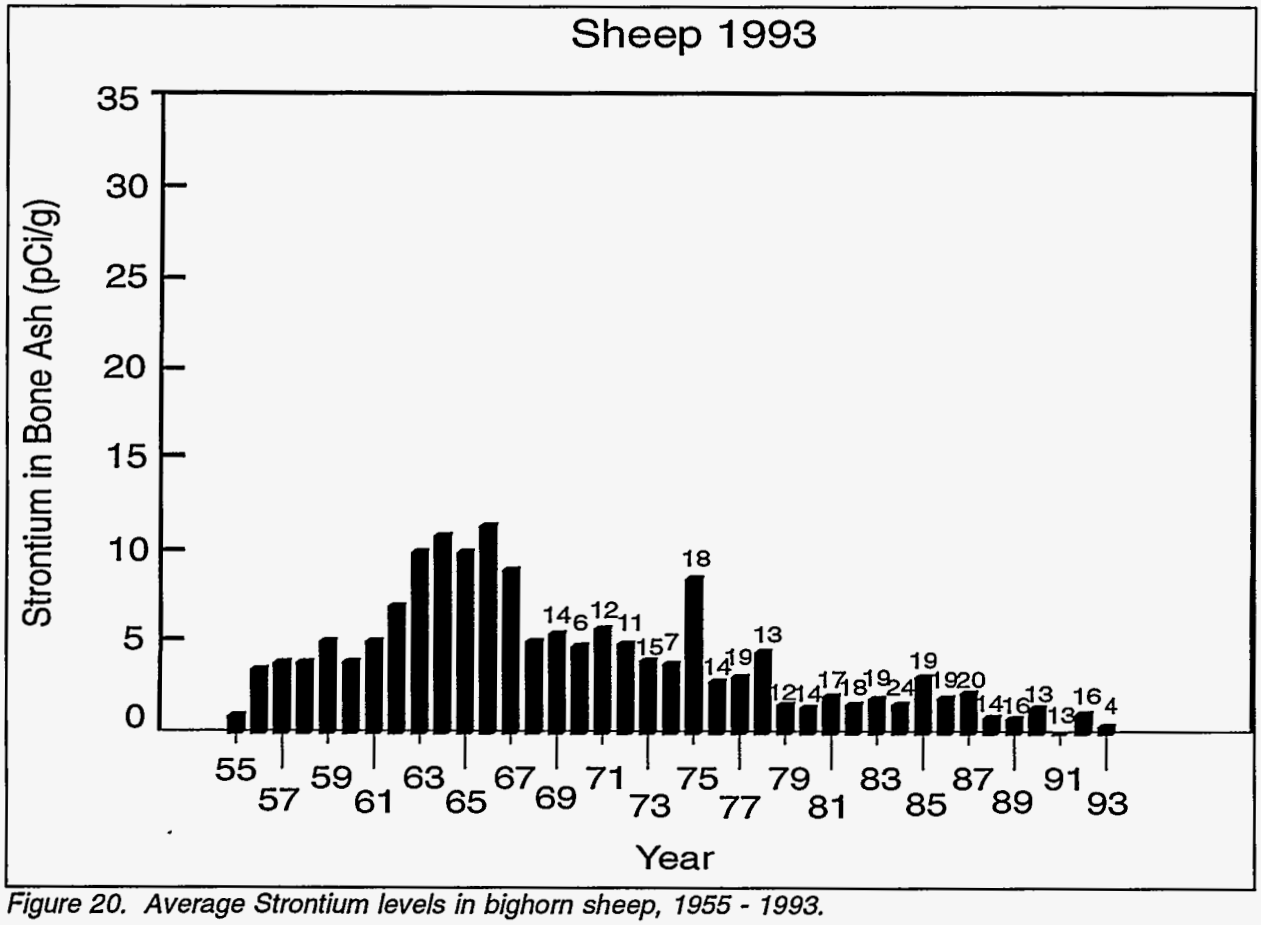


Figure 20. Average Strontium levels in bighorn sheep, 1955 - 1993.

lected in the third quarter from Area 20. The same three rumen contents samples yielded detectable concentrations of $^{239+240}$Pu. Greater-than-MDC $^{239+240}$Pu results were also obtained in the lung samples of all three deer collected on the NTS and the muscle and liver samples of all four deer collected in 1993. The highest $^{239+240}$Pu results in muscle, lung, and rumen contents were found in the deer collected in the first quarter from Area 16 of the NTS.

5.2.5 Sample Results for Cattle

Blood and soft tissues (lung, muscle, liver, thyroid, kidney and fetal tissue, when available) are analyzed for gamma-emitting radionuclides; blood is also analyzed for tritium activity. Samples of liver, bone, and fetal tissue are ashed and analyzed for plutonium isotopes; bone and fetus samples are also analyzed for ^{90}Sr. Duplicate liver and bone samples from two animals in each group of four are prepared and analyzed.

The four cattle purchased in May 1993 from Steve Medlin in Tickapoo Valley, Nevada, had detectable concentrations of ^{90}Sr in bone ash samples ranging from 0.29 ± 0.15 pCi/g ash to 0.85 ± 0.21 pCi/g ash. One bone sample contained 0.00413 ± 0.0031 pCi/g ash of ^{238}Pu. The livers of all four cattle contained $^{239+240}$Pu ranging from 0.00211 ± 0.000839 pCi/g ash to 0.0527 ± 0.0126 pCi/g ash. These cattle lived their entire life in the Tickapoo Valley area.

The four cattle purchased from the Orrin Nash Ranch near Hiko, Nevada in October 1993 included two adult females in fair to poor condition and two yearling females in good to very good condition. All had lived their entire lives on the Nash Ranch range. No gamma-emitting radionuclides other than ^{40}K were detected in any soft tissue samples or blood. Tritium concentrations greater than the MDC were not detected in the blood samples. Strontium-90 was detected in all four bone samples and in the fetus sample, ranging from 0.93 ± 0.10 pCi/L to 1.6 ± 0.12 pCi/L. The average ^{90}Sr found in cattle bone ash since 1955 is shown in Figure 22. None of the liver, bone, or fetus samples yielded ^{238}Pu activity greater than the MDC. Activities of $^{239+240}$Pu greater than the MDC were found in three liver samples, one bone sample, and in the fetus sample. The $^{239+240}$ Pu result for the bone sample from one of yearling cows was 0.0165 ± 0.003 pCi/L, the result for the

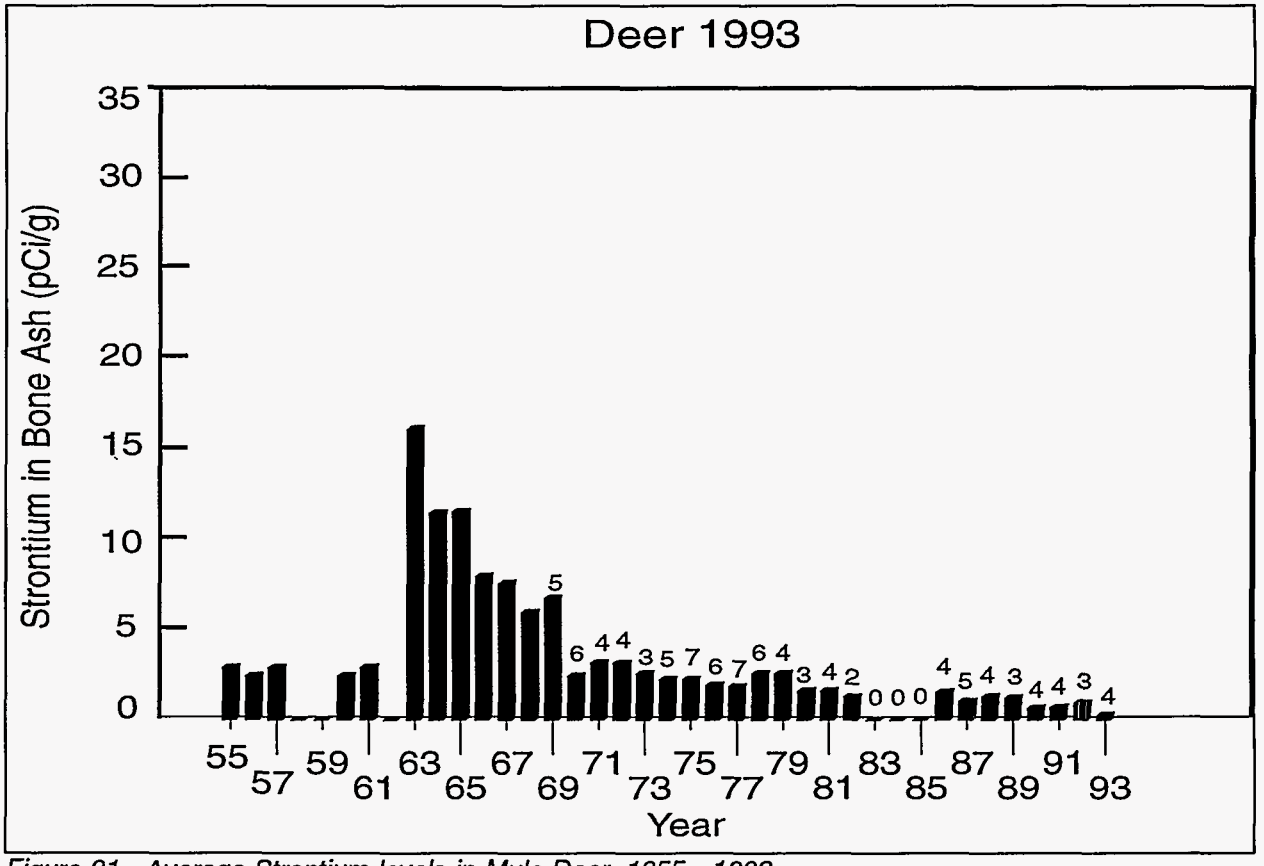


Figure 21. Average Strontium levels in Mule Deer, 1955 - 1993.

fetus sample was 0.0118 ± 0.002 pCi/L, and results for the liver samples ranged from 0.0034 ± 0.0023 pCi/L to 0.0076 ± 0.0021 pCi/L. Results for all cattle analyzed in 1993 are summarized in Table 15.

5.2.6 Sample Results for Chukar and Quail

During the third quarter of 1993 chukar and quail were collected at the following locations on the NTS shown in Figure 23. In the area adjacent to the "T" tunnel, Tub Spring, Tippipah Spring, and Topopah Spring. In addition, a quail was collected in the vicinity of White Rock Spring. Samples of chukar muscle tissue and internal organs were checked for gamma-emitting radionuclides and ^{3}H. Chukar bone samples were analyzed for ^{238}Pu, $^{239+240}Pu$ and ^{90}Sr. Because of it's small size, the whole body of the quail was only analyzed for gamma-emitting radionuclides and ^{3}H.

In addition to naturally occurring ^{40}K, ^{137}Cs was detected in three of the four chukar internal organ samples, ranging from 0.0295 ± 0.009 pCi/L in the chukar collected near Tippipah Spring to 0.19 ± 0.02 pCi/L in the sample from the bird collected near Tub Springs. Cesium-137 was also detected in the muscle samples of chukars collected near "T" tunnel and near Tub Springs, ranging from 0.0279 ± 0.006 pCi/L to 0.0558 ± 0.008 pCi/L. The quail whole-body sample also evidenced ^{137}Cs activity.

Tritium was detected at activities greater than the MDC in chukar muscle and samples from birds collected near "T" tunnel and near Tub Springs and in the internal organ samples from the bird collected near "T" tunnel. Results are given in Table 15. The tritium concentrations in the samples from the chukar collected near "T" tunnel exceeded 3×10^{6} pCi/L. Tritium activity greater than the MDC was also found in the quail whole-body sample.

Bone samples were analyzed from three of the chukar samples (excluding Topopah Spring). Strontium-90, ^{238} Pu, and $^{239+240}Pu$ were detected at activities greater than the MDC in the samples from birds collected near "T" tunnel and Tub Springs, while only $^{239+240}Pu$ was detected at concentrations greater than the MDC in the bone sample of the bird collected in the vicinity of Tippi-

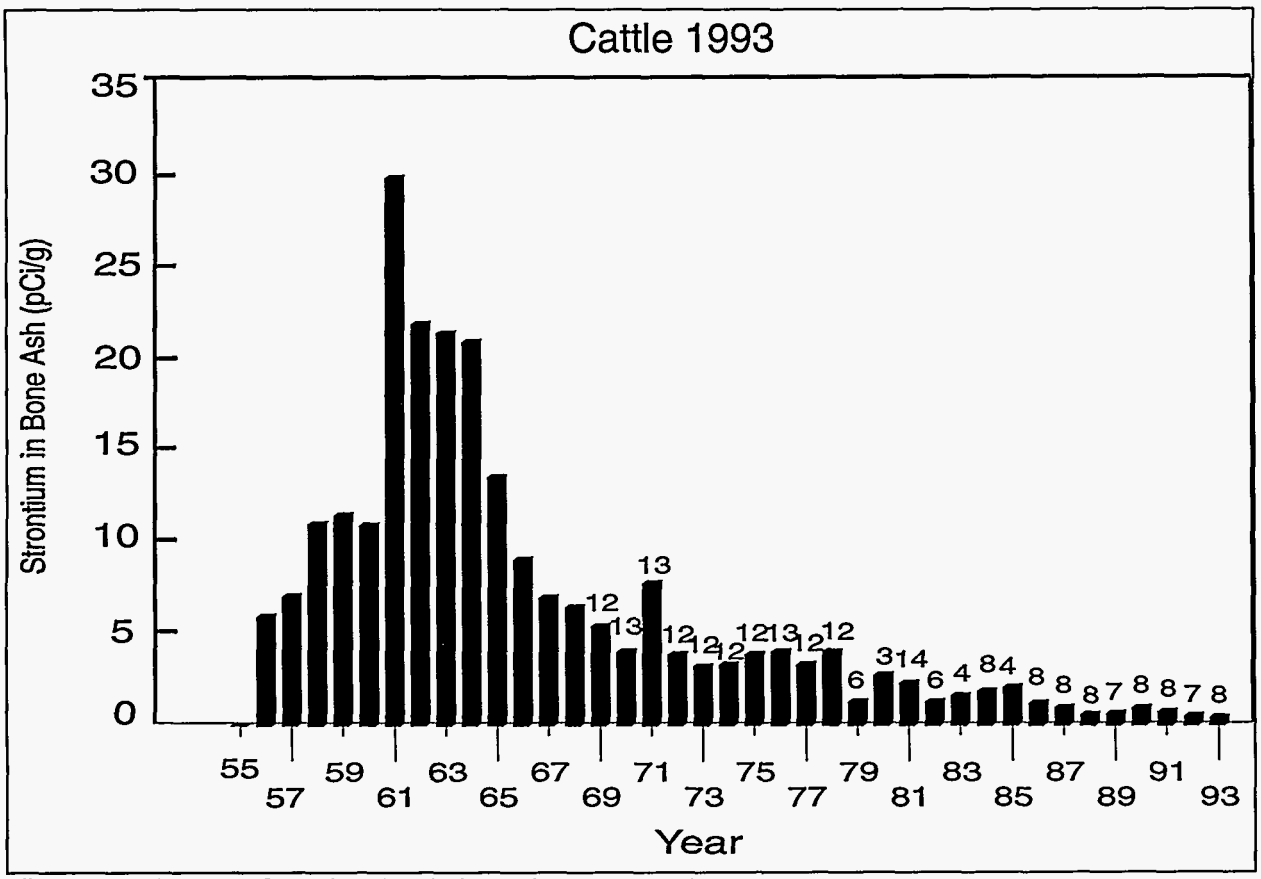


Figure 22. Average Strontium levels in cattle, 1955 - 1993

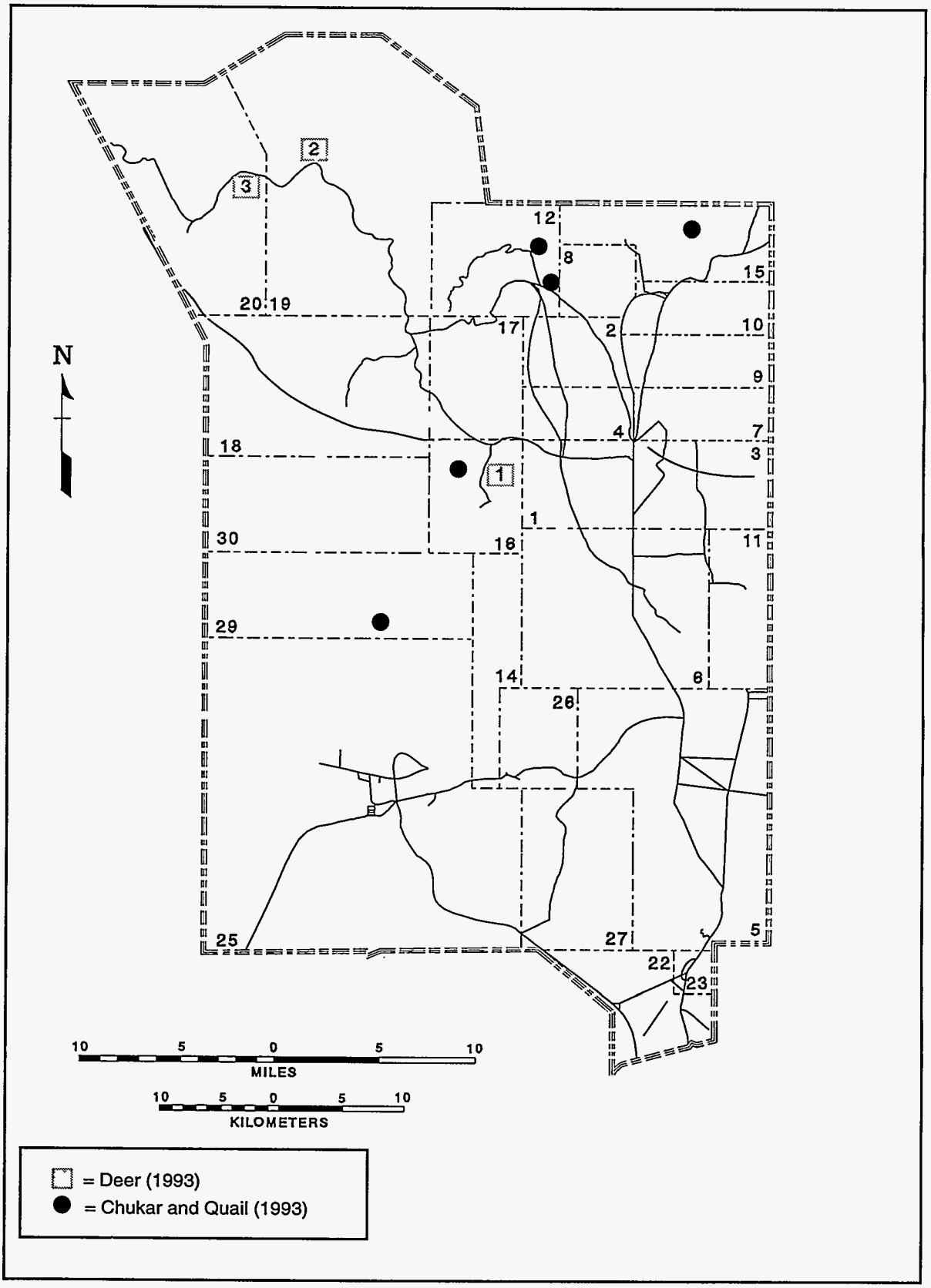


Figure 23. Collection Sites for Animals Sampled on the NTS - 1993

pah Springs. The median concentrations of all three parameters are shown in Table 15.

5.2.7 Quality Assurance/Quality Control

Standard operating procedures (SOPs) detail sample collection, preparation, storage, analysis, and data review procedures to ensure comparability among operators. Field personnel complete a standardized necropsy protocol form to ensure that all relevant information is recorded, such as date and location of collection, history and condition of the animals and tissues, and sample weights and assigned identification numbers. Standardized forms accompany each shipment of samples sent to the contract laboratory for ashing and are also used for analyses conducted in the Radioanalysis Laboratory. All information entered into the data base management system by Sample Control and the radioanalysis chemists is checked and verified by the Group Leader and assigned media expert.

An estimate of system precision is obtained from results of duplicate samples. Matrix spike samples are used to verify analytical accuracy. Matrix blank samples monitor any contamination resulting from sample preparation and analysis. The entire sample set analyzed in any given year is quite small (usually four or five sample batches) and, as a consequence, the quality assurance/quality control (QA/QC) sample results set contains fewer values than is considered minimal for statistical uses. Therefore, the results of QA/QC samples are considered to provide only an indication or estimate of true precision and accuracy. This is considered adequate because the animal investigation program itself is not statistically based.

Prior to 1991, analyses of animal tissue samples were performed by a contract laboratory. The EPA EMSL-LV Radioanalysis Laboratory assumed responsibility for sample analysis beginning with the results contained in this report. The change of laboratories raised concerns about comparability of analyses, so a special QA review was conducted. The procedures used by each laboratory are comparable, as are results of matrix spike samples. Generally, the result ranges obtained in 1991 were similar to those obtained in previous years when samples were analyzed by the contract laboratory. Finally, results of QA/QC samples, with the exception of one routine-duplicate pair, were within established control limits. Although a direct comparability study was not undertaken (i.e., analysis of replicate samples by both laboratories), the results of the QA review indicate the data obtained for 1993 analyses are comparable to data obtained in previous years.

The QA review also resulted in recommendations for some changes in the animal investigation program to be implemented in 1992. These recommendations included preparation of a large stock of matrix spike and blank sample material and addition of a system blank. The single stock of matrix spike sample material will permit an additional estimate of precision, in this case analytical precision, to be obtained. The system blank will be a bone sample known to contain no detectable concentrations of radionuclides (with the possible exception of strontium). It will be processed with each tissue sample batch to provide a check of possible contamination during the ashing and sample preparation processes.

5.3 Fruits And Vegetables Monitoring

Another possible pathway of radionuclide ingestion is through produce: fruits, vegetables, and grains. Commercial farming, other than alfalfa, is not a major industry in the offsite area around the NTS. Therefore, monitoring is limited to fruits and vegetables grown in local gardens for family consumption. In the event of a release of radioactivity from the NTS, monitoring of produce would be extended to include alfalfa, forage grasses, and feed grain supplies. No extensive monitoring was required in 1993.

5.3.1 Network Design

Like the animal investigation program, fruit and vegetable monitoring is based on a worst-case scenario. Local residents living in areas known to have received fallout from past atmospheric testing are asked to donate produce from their family gardens. These areas which received fallout are also the areas in the preferred downwind direction during past underground testing. As sample collection is not statistically based, no inference should be drawn regarding the representativeness of the sampled materials to concentrations of radionuclides in produce as a whole, nor should any conclusions be drawn regarding the average consumption of radionuclides from produce.

5.3.2 Sample Collection and Analysis Procedures

Fruit and vegetable contribution of samples is voluntary by the offsite residents. Sampling is done only once per year, in the late summer. Fruits and vegetables harvested at that time generally include root crops (onions, carrots, potatoes), melons and squash, and some leafy vegetables (e.g., cabbage).

Samples are processed by washing the material as it would be done by residents prior to eating or cooking. This washing procedure introduces an element of variability, as the thoroughness of washing varies by individual. Potatoes and carrots are not peeled. Further processing generally includes cutting the material into small pieces and/or blending in a mixer or food processor. Splits are prepared for analysis of gamma-emitting radionuclides and tritium. Other sample splits are ashed and analyzed for ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$.

5.3.3 Sample Results

In the fall of 1993, 16 samples of fruits and vegetables were donated by residents of Utah and Nevada. The samples included apples, potatoes, kohlrabi, turnips, carrots, pears, green onions, and squash. All samples were analyzed for gamma-emitting radionuclides and only naturally occurring ^{40}K was detected. All samples were analyzed for tritium; two samples had results greater than the MDC: pears from Adaven, Nevada and turnips from Warm Springs, Nevada. Samples were ashed and analyzed for ^{90}Sr, ^{238}Pu and $^{239+240}Pu$. One sample, broccoli from Rachel, Nevada, yielded a ^{90}Sr activity greater than the MDC. Three samples were above the MDC for $^{239+240}Pu$: green onions from Alamo, Nevada, carrots without tops from Rachel, and potatoes from Hiko, Nevada. This is possibly due to soil adhering to the surface of the vegetables. None of the smooth-skinned crops contained radionuclides above MDC. Results are listed in Table 16.

5.3.4 Quality Assurance/Quality Control

The fruits and vegetables are considered to be a batch within the animal investigation program. The same QA/QC samples are used, including matrix-spikes and matrix blanks (NOTE: animal bone ash is the matrix). If sufficient material is received, at least one of the samples may be analyzed in duplicate, however, in many years not enough of any one type of material is received from any one source to permit preparation of replicates. As with the animal investigation program, the QA/QC samples provide only an estimate or indication of the analytical precision and accuracy.

Table 16. Detectable[a] ^{3}H, ^{90}Sr, ^{238}Pu and $^{239+240}Pu$ Concentrations in Vegetables

Vegetable	Collection Location	% Ash	$^{3}H \pm 1\sigma$[b] (MDC)	$^{90}Sr \pm 1\sigma$[c] (MDC)	$^{239+240}Pu \pm 1\sigma$[d] (MDC)
Broccoli	Rachel, NV	0.805		0.60 ± 0.17 (.56)	
Green Onions	Alamo, NV	0.598			7.59 ± 4.39 (6.86)
Carrots without tops	Rachel, NV	0.527			18.7 ± 6.65 (6.34)
Potatoes	Hiko, NV	0.700			2.59 ± 1.50 (2.34)
Pears	Adaven, NV	0.511	525 ± 137 (443)		
Turnips	Twin Springs, NV	0.522	503 ± 138 (443)		

(a) Detectable is defined as results greater than the minimum detectable concentration.
(b) Units are pCi/L.
(c) Units are pCi/g ash.
(d) Units are 10^{-3} pCi/g ash.

6.0 Internal Dosimetry

Internal exposure is caused by ingested, absorbed, or inhaled radionuclides that remain in the body either temporarily or for longer periods of time because of storage in tissues. At EMSL-LV, two methods are used to detect body burdens: whole-body counting and urinalysis.

6.1 Network Design

The Internal Dosimetry Program consists of two components, the Offsite Internal Dosimetry Program and the Radiological Safety Program.

The Offsite Internal Dosimetry Program is designed to (1) measure radionuclide body burdens in a representative number of families who reside in areas that were subjected to fallout during the early years of nuclear weapons tests, and (2) provide a biological monitoring system for present nuclear testing activities. A few families who reside in areas not affected by fallout were selected for comparative study. Members of the general public concerned about possible exposure to radionuclides are also counted periodically as a public service.

The program was initiated in December 1970 to determine levels of radionuclides in some of the families residing in communities and ranches surrounding the NTS. For these families, counting is performed in the spring and fall of each year. This program started with 34 families (142 individuals). In 1993, there were a total of 54 families (158 individuals) in the program. Not all individuals participated in the program in 1993. The locations and number of individuals taking part in the program in 1993 are shown in Figure 24. Biannually, participants travel to EMSL-LV for a whole-body and lung count, and submission of a urine specimen. At 18-month intervals, a medical laboratory examination is performed and the participant is examined by a physician.

The Radiological Safety Program is designed to assess internal exposure for EPA employees, DOE contractor employees, and by special request, employees of companies or government agencies who may have had an accidental exposure to radioactive material. Individuals with potential for occupational exposure are counted at the request of their employers. Counting is done routinely for DOE contractors. EPA personnel in radiation programs or those who work with radioactive materials undergo a whole body count and a urinalysis annually.

In 1993, internal dosimetry monitoring was also performed on participants in the Radiological Safety Program, and other workers who might have been occupationally exposed. In 1992 and 1993, by special request, whole body counting was performed on Desert Storm soldiers who were injured with shrapnel possibly containing depleted uranium. In addition, counts and urinalysis were performed on members of the public who contacted EMSL-LV with concerns about radiation exposures.

6.2 Procedures

The whole-body counting facility has been maintained at EMSL-LV since 1966 and is equipped to determine the identity and quantity of gamma-emitting radionuclides that may have been inhaled, absorbed, or ingested. Routine examinations consist of a 2,000-second count in each of the two shielded examination vaults. In one vault, a single intrinsic germanium coaxial detector positioned over an adjustable chair allows detection of gamma radiation with energies ranging from 60 keV to 2.0 meV in the whole body. The other vault contains an adjustable chair with six intrinsic germanium semiplanar detectors mounted above the chest area. The semiplanar array is designed to detect gamma- and X-ray-emitting radionuclides with energy ranges from 10 to 300 keV. Specially designed software allows individual detector spectra to be analyzed to obtain a summation of left- or right-lung arrays and of the total lung area. This provides much greater sensitivity for the transuranic radionuclides while still maintaining the ability to pinpoint "hot spots." Custom-designed detector mounts allow maximum flexibility for the placement of detectors in various configurations for skull, knee, ankle, or other geometries.

To complete the evaluation, a urine sample is collected for ^{3}H analysis. Not all participants in the Radiological Safety Program submit urine samples for ^{3}H analysis.

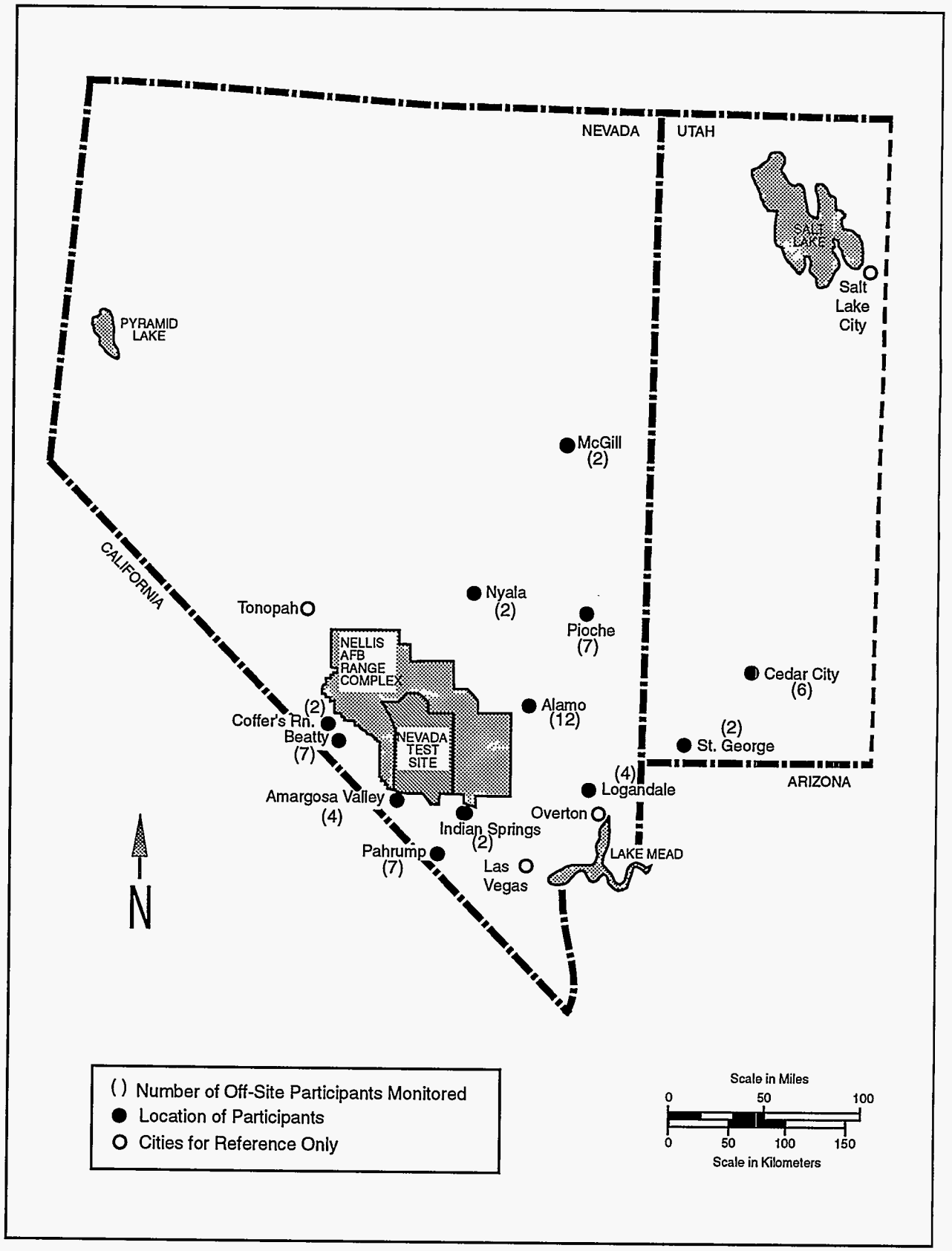


Figure 24. Number and Location of Participants in the Offsite Dosimetry Program - 1993

Before the Offsite Internal Dosimetry Program participants leave the facility, results of the whole-body and lung counts are made available and are discussed with the subjects. Results of the urine ^{3}H analysis are reported later if the result is abnormal. At 18-month intervals, a physical exam, health history, and the following are performed: complete urinalysis, complete blood count, serology, chest X-ray (three-year intervals), sight screening, audiogram, vital capacity, EKG (for individuals over 40 years old), and thyroid panel. The results of the examination can be requested for use by the individual's family physician.

6.3 Results

In 1993, whole-body and lung counts were performed on 144 individuals, of whom 56 were participants in the Offsite Internal Dosimetry Network (see Section 4.1.2.7). An additional 88 gamma-ray spectra were obtained for radiation workers, including EPA, DOE, and contractor personnel. In none of the spectra were transuranic radionuclides detected. The spectra for the Offsite Dosimetry Network and Radiological Safety Program participants showed only low-level activities on the same order of intensity of those observed in normal background measurements. As in 1992, depleted uranium shrapnel was detected in participating Desert Storm soldiers, but the absolute amounts could not be determined by whole body counting alone.

Of the analytical results of the urine samples available at the time of this publication, two showed tritium concentrations exceeding the MDC and were not related in location or collection time, see Table 17. The highest concentration was 8.3 x 10^{-7} ± 2.14 x 10^{-7} μCi/mL, which if assumed to be equal to the average intake concentration, corresponds to four percent of the drinking water regulation (2.0 x 10^{-5} μCi/mL) for tritium.

6.4 Quality Assurance/Quality Control

Quality Assurance procedures consist of daily equipment operations checks using QA software obtained specifically for this facility. Some of the parameters monitored daily include energy calibration of each detector using a NIST-traceable point source to check for zero, gain shift, and resolution over a wide range of energies. A background measurement is also taken once or twice daily depending on the count schedule.

The whole-body detector efficiency is calibrated annually using a Bottle Mannequin Absorber (BOMAB) phantom containing a NIST-traceable mixed radionuclide source. The lung counter is also calibrated annually with a male realistic lung phantom. A separate set of efficiency calibration data is kept for each combination of sample shape/organ geometry.

The following MDCs were calculated after recalibration of the lung counting system in February 1992: ^{241}Am, 0.2 μCi; ^{238}Pu, 18 μCi; and ^{239}Pu, 130 μCi. There were no significant differences from previous MDC's. These were calculated for a standard chest wall thickness of 3 cm.

All efficiency curves are generated by the vendor-supplied whole-body counting and lung counting software. QA software is used to monitor the systems by performing out-of-range tests for predetermined parameters. Results are plotted and reports are generated daily and monthly. All data are stored in the computer. Replicate counting of the standard BOMAB phantom provides a measure of consistency. Replicate counts of blind intercalibration phantoms and of people counted previously in other facilities provide additional measurements of precision and accuracy. Verification and validation are completed before results are entered into a data base. Calculation of internal dose is done utilizing software based on the International Commission on Radiological Protection (ICRP) methodology (ICRP, 1979).Dose calculation is verified using ICRP and National Council on Radiation Protection and Measurements (NCRP) guidelines (NCRP, 1989). Preventive maintenance and repair of analytical equipment are done by the vendor service representative. Data are retained permanently. Subject confidentiality and data security are maintained through well-established procedures. EPA whole-body counting technicians participate in DOE and EPA QA training programs.

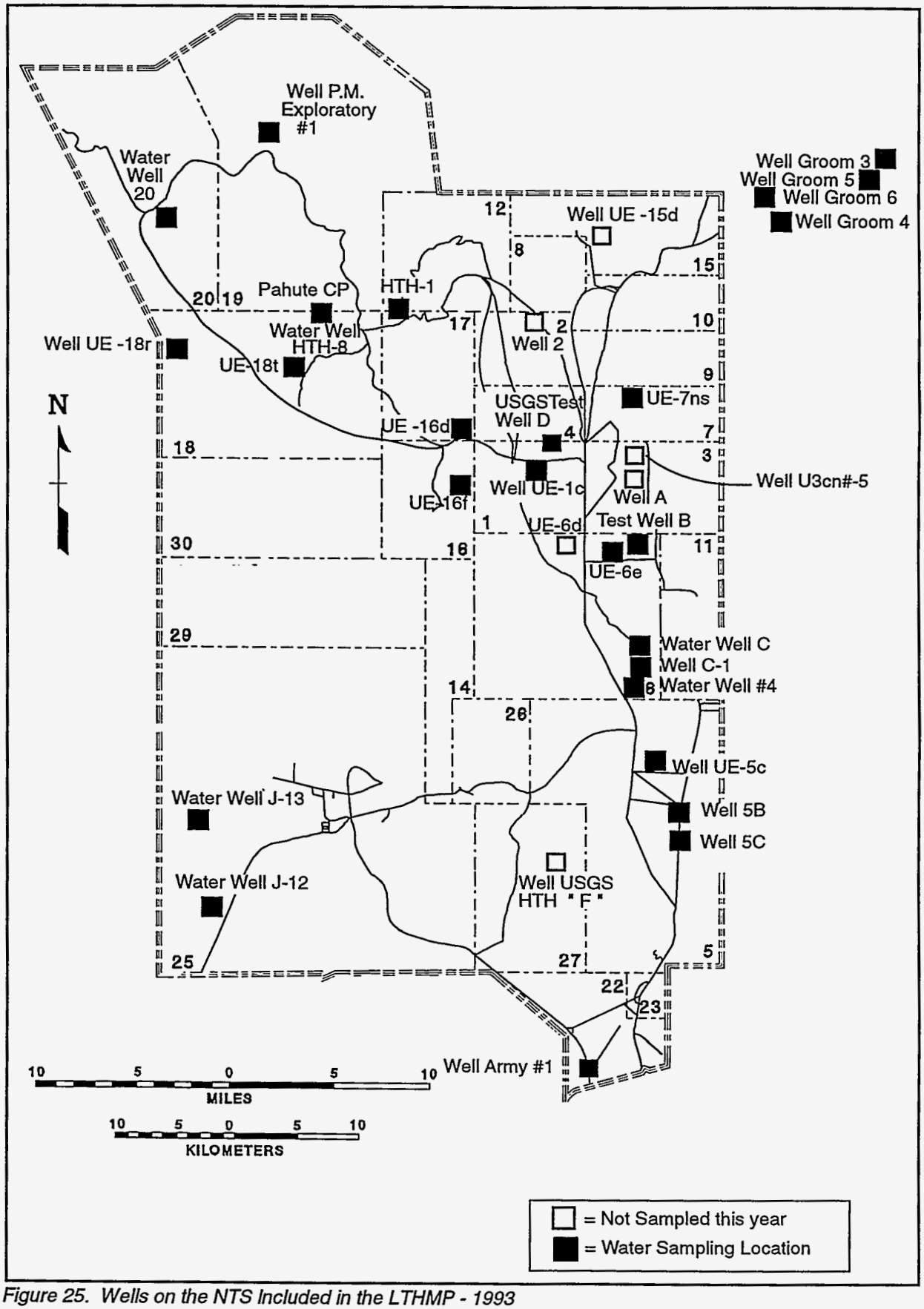


Figure 25. Wells on the NTS Included in the LTHMP - 1993

Table 18. Long-Term Hydrological Monitoring Program Summary of Tritium Results for Nevada Test Site Network, 1993

Location	Tritium concentration (pCi/L) Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Test Well B	11	111.0*	82.0*	98.0*	9.0	0.11
Test Well D	2	3.9	2.5	3.2	1.0	<0.01
Test Well 7	2	6.6*	4.3	5.5*	1.6	<0.01
Well Army #1	12	2.5	-3.7	-0.5	1.6	<0.01
Well Army #6A	2	3.0	0.1	1.5	2.0	<0.01
Water Well C	12	25.0*	5.5*	12.0*	5.3	0.01
Well C-1	2	11.0*	8.2*	9.8*	2.2	0.01
Well Groom 3	12	3.3	-1.0	1.0	1.3	<0.01
Well Groom 4	12	4.0	-2.0	0.1	2.1	<0.01
Water Well #4	12	3.2	-3.9	-0.3	2.2	<0.01
Well Groom 5	12	1.5	-3.0	-0.2	1.5	<0.01
Well 5B	3	1.4	-2.4	-1.0	2.1	<0.01
Water Well 5C	10	3.8	-2.5	0.1	2.0	<0.01
Well Groom 6	12	0.3	-2.2	-0.7	0.9	<0.01
Well HTH #8	12	5.5*	-2.0	0.0	2.1	<0.01
Water Well 20	2	2.1	-1.0	0.6	2.2	<0.01
Well HTH #1	2	13.0*	10.0*	12.0*	2.2	0.01
Well J-12	12	3.0	-2.9	-0.5	1.8	<0.01
Well J-13	12	1.7	-3.8	-0.5	1.9	<0.01
Well P.M. Expl. #1	2	221.0*	215.0*	218.0*	4.2	0.24
Well UE-1c	2	7.4*	2.8	5.1	3.2	<0.01
Well UE-5c	3	1.8	-3.7	-1.7	3.0	<0.01
Well UE-7ns	2	317.0*	273.0*	295.0*	31.0	0.33
Well UE-16d	2	2.6	2.3	2.4	0.2	<0.01
Well UE-16f	2	6.2*	6.0*	6.1*	0.2	<0.01
Well UE-17a	2	2.4	1.5	1.9	0.7	<0.01
Well UE-18r	2	5.4*	-0.3	2.5	4.0	<0.01
Well UE-18t	2	166.0*	156.0*	161.0*	7.0	0.18
Well A	Well inactivated by DOE, last sampled October 1988					
Water Well 2	Well shut down, last sampled December 1990					
Well USGS HTH "F"	Not sampled in 1993, last sampled February 1980					
Well U-3cn #5	Well shut down, last sampled December 1981					
Well UE-4t #1	Instrument in well, couldn't sample 1993					
Well UE-6e	Drill rig over hole, couldn't sample 1993					
Well UE-15d	Pump inoperative, last sampled 1992					
Well UE-19c	Road closed, (winter), pump inoperative, couldn't sample 1993					

Mean MDC: 5.38 pCi/L Standard Deviation of Mean MDC: 0.72 pCi/L

DCG = derived concentration guide. Established by DOE Order as 90,000 pCi/L
* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable; Percent of concentration guide is not applicable: the tritium result is less than the MDC or the water is known to be nonpotable.

Summary results of tritium analyses are presented in Table 18. Three of the monthly sampled wells and nine of the wells sampled semiannually yielded tritium results greater than the MDC of the enrichment analysis (approximately 5 to 7 pCi/L) in one or more samples. Two of the monthly sampled wells, Test Well B and water Well C, have consistently shown detectable tritium over their sampling history. The 1993 average for Test Well B was 98 ± 9 pCi/L (range 82 to 111 pCi/L, 0.09 to 0.12 percent of the DCG) and for water Well C was 12.0 ± 5.3 pCi/L (range 5.5 to 25.0 pCi/L, 0.01 to 0.03 percent of the DCG). A decreasing trend is evident in Test Well B, as shown in Figure 26.[4]

As shown in Table 18, both of the semiannual samples collected from the following wells showed tritium results above the MDC: Well C-1, HTH #1, UE-7ns, UE-16f, P.M. Exploratory #1, and UE-18t. Four of these sampling locations do not have sufficient data to discern any trends, as they have been added to the sampling network in recent years. Well UE-7ns was routinely sampled between 1976 and 1987; an increasing trend was evident, with tritium concentrations in excess of 2500 pCi/L at the time sampling ceased in September 1987. Results obtained for Well C-1 indicate a decreasing trend in tritium concentration over the period 1970 through 1979; since 1979, tritium concentrations have been generally stable.

7.3 Offsite Monitoring In The Vicinity Of The Nevada Test Site

The monitoring sites located in the offsite area around the NTS are shown in Figure 27. Most of the sampling locations represent drinking water sources for rural residents in the offsite area and public drinking water supplies in most of the communities in the area. The sampling sites include 23 wells, seven springs, and two surface water sites. Thirty of the locations are routinely sampled every month. The remaining two sites,

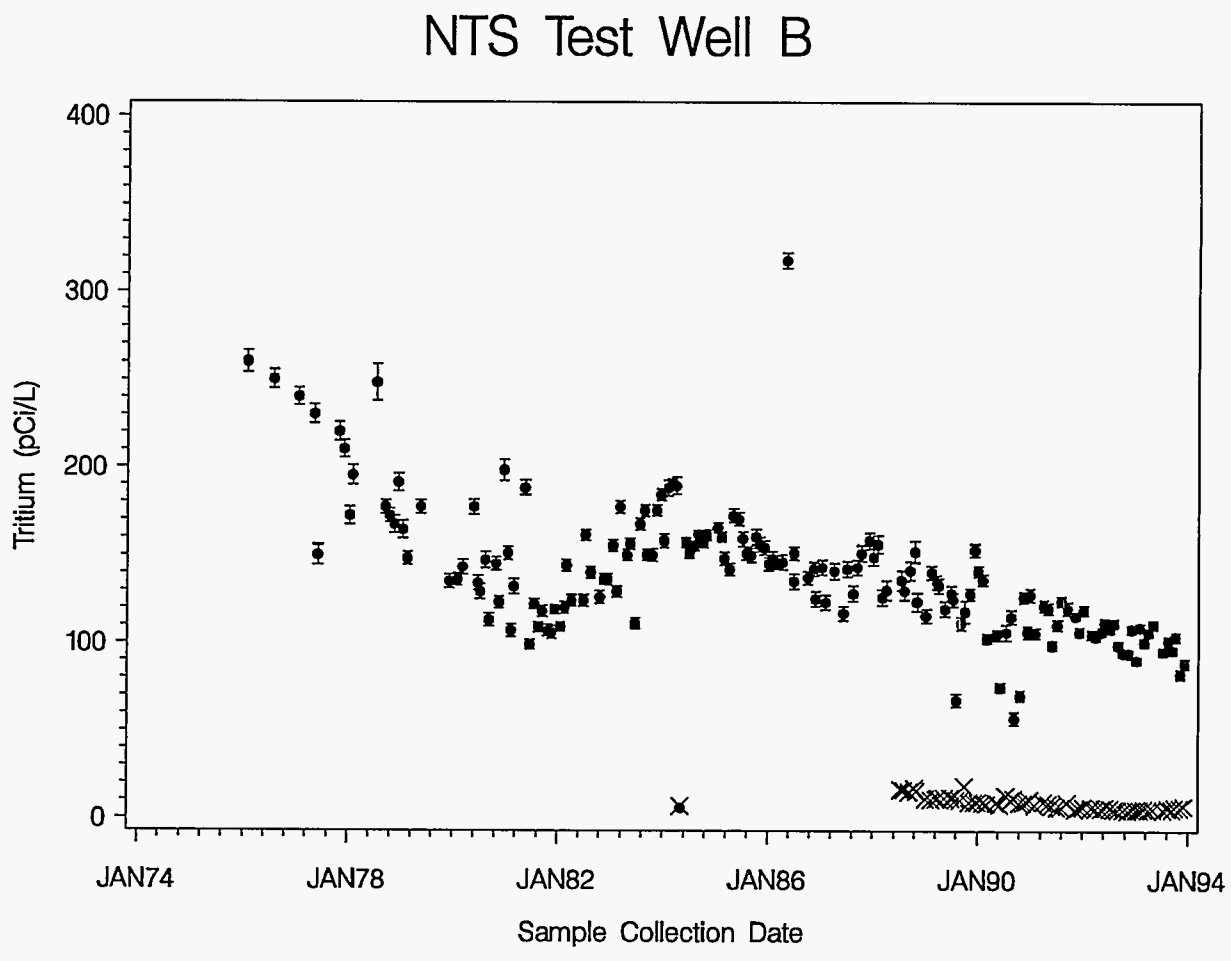


Figure 26. Tritium Concentration Trends in Test Well B on the NTS.

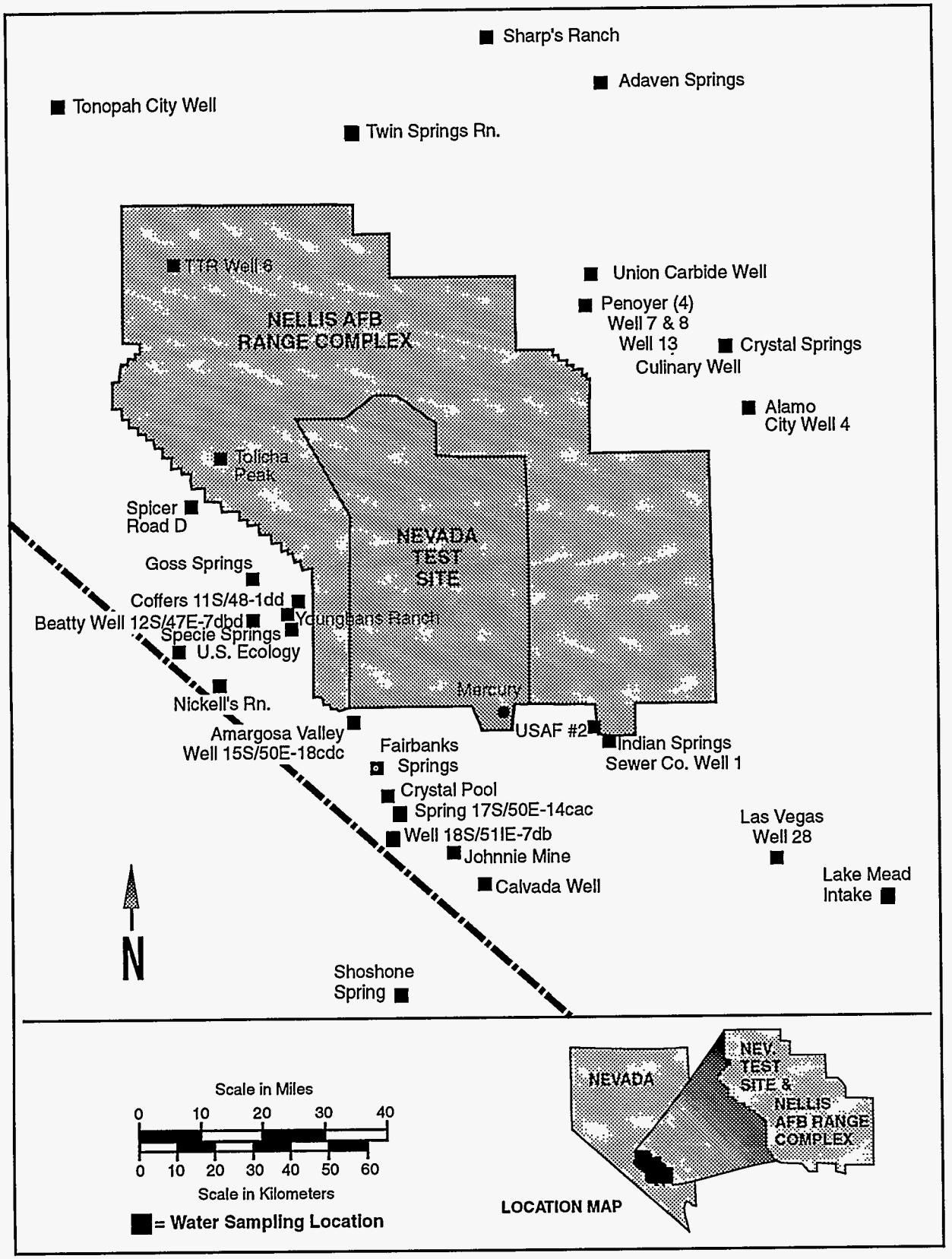


Figure 27. Wells Outside the Nevada Test Site Included in the LTHMP.

Penoyer Well 13 and Penoyer Wells 7 and 8, are in operation only part of the year; samples are collected whenever the wells are in operation. One sampling location, the Johnnie Mine well in Johnnie, Nevada, was deleted from the sampling network when the mine was sold in August 1993. This site had been sampled since 1989; the only tritium result greater than the MDC was a concentration of 6.0 ± 1.7 pCi/L observed in 1992. Water samples are collected each month for gamma spectrometric analysis. Samples for tritium analysis are collected on a semiannual basis. In the past, one of these semiannual tritium analyses was done by the conventional analysis method; the other analysis was done by the enrichment method. In April 1993 this procedure was changed so that both annual tritium analyses are completed by the enrichment method.

Over the last decade, only three sites have evidenced detectable tritium activity on a consistent basis. These three sites are in Nevada, namely Lake Mead Intake (Boulder City), Adaven Spring (Adaven), and Specie Springs (Beatty). In all three cases, the tritium activity represents environmental levels that have been generally decreasing over time.

In 1993, five of the samples analyzed for tritium by the enrichment method yielded detectable tritium activities. The January result for Adaven Spring of 31 ± 2 pCi/L and the July result of 36 ± 2 pCi/L were consistent with tritium levels noted in recent years as shown in Figure 28. The September result for Lake Mead Intake was 54 ± 2 pCi/L as indicated in Figure 29. These results were similar to results obtained in 1992. This surface water site may be impacted by rainfall containing scavenged atmospheric tritium to a greater extent than the well and spring sites in the offsite network. The sample collected in July from Species Springs yielded a tritium concentration of 18 ± 2 pCi/L and the December sample was 20 ± 2 pCi/L. Tritium results for all samples are shown in Table D-1, Appendix D. No gamma-emitting radionuclides were detected in any sample taken in 1993 from the network.

7.4 Hydrological Monitoring At Other United States Nuclear Device Testing Locations

In addition to the groundwater monitoring conducted on and in the vicinity of the NTS, monitoring is conducted under the LTHMP at sites of past nuclear device testing in other parts of the U.S. Annual sampling of surface and ground waters is conducted at the Projects SHOAL and FAULTLESS sites in Nevada, the Projects GASBUGGY and GNOME sites in New Mexico, the Projects RULISON and RIO BLANCO sites in Colorado, and the Project DRIBBLE site in Mississippi. Additionally, sampling is conducted every two years on Amchitka Island, Alaska, site of Projects CANNIKIN, LONG SHOT, and MILROW; sampling was conducted in 1993. The primary purposes of this portion of the LTHMP are to ensure the safety of public drinking water supplies and, where suitable sampling points are available, to monitor any migration of radionuclides from the test cavity. The following subsections summarize results of sampling conducted in 1993; analytical results for all samples are provided in Appendix C.

The sampling procedure is the same as that used for sites on the NTS and offsite areas (described in Section 7.1.2), with the exception that two 3.8-L samples are collected in Cubitainers. The second sample serves as a backup or as a duplicate sample. Because of the variability noted in past years in samples obtained from the shallow monitoring wells near Project DRIBBLE ground zero (GZ), the sampling procedure was modified. A second sample is now taken after pumping for a specified period of time or after the well has been pumped dry and permitted to refill with water. These second samples may be more representative of formation water, whereas the first samples may be more indicative of recent area rainfall.

7.4.1 Project FAULTLESS

Project FAULTLESS was a "calibration test" conducted on January 19, 1968, in a sparsely populated area near Blue Jay Maintenance Station, Nevada. The test had a yield of less than 1 Mt and was designed to test the behavior of seismic waves and to determine the usefulness of the site for high-yield tests. The emplacement depth was

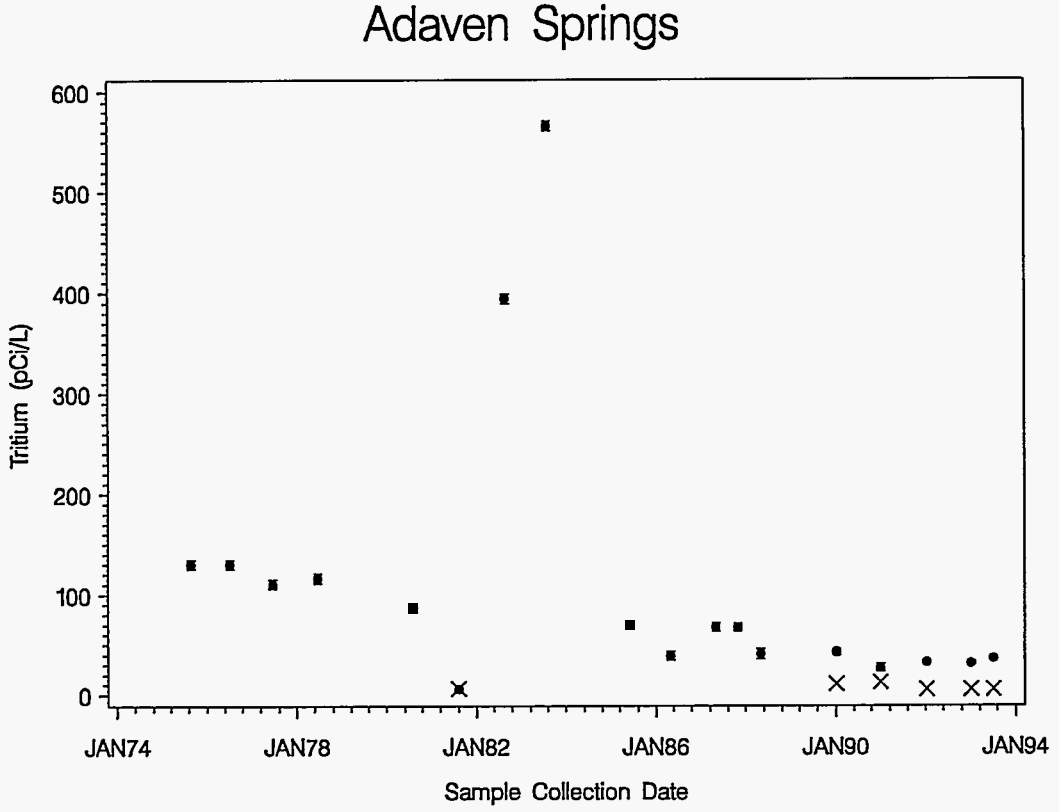


Figure 28. Tritium Results in Water from Adaven Springs, Nevada.

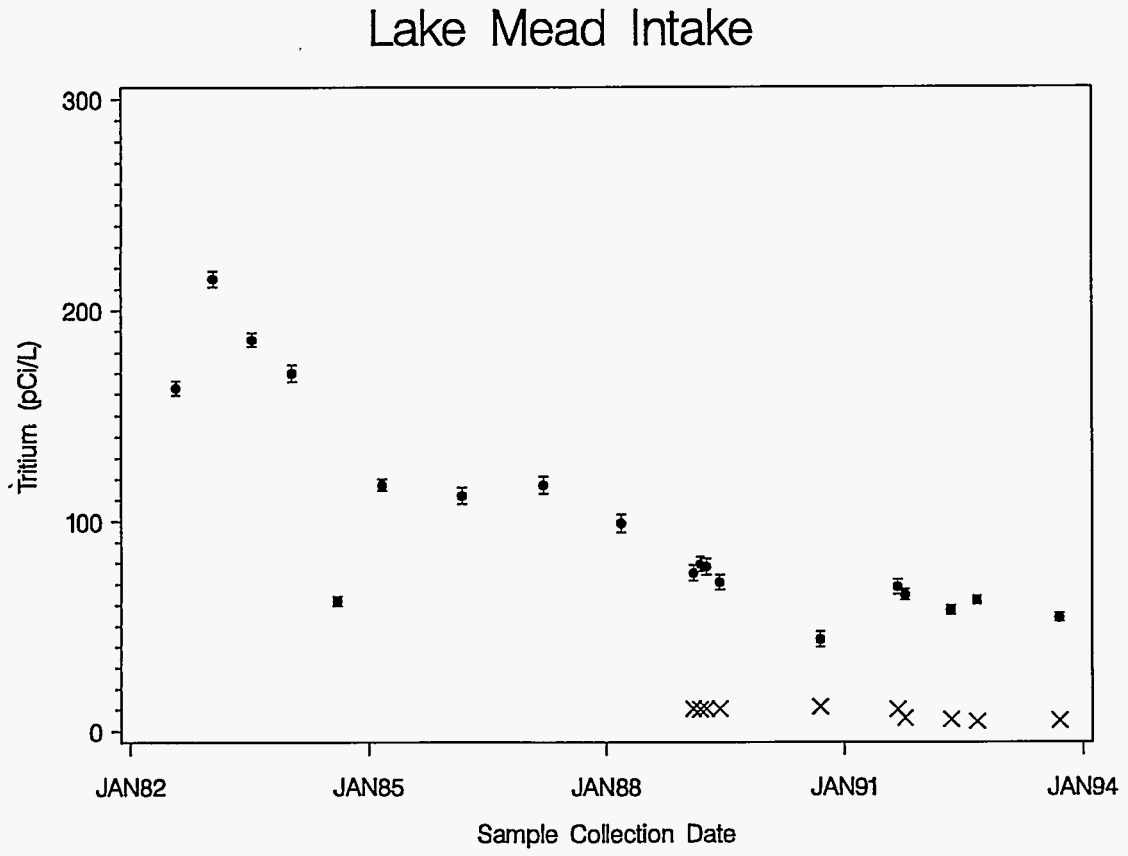


Figure 29. Trend of Tritium Results in Water from Lake Mead, Nevada.

975 m (3200 ft). A surface crater formed, but as an irregular block along local faults rather than as a saucer-shaped depression.

Sampling was conducted on March 16, 17, and 23, 1993. Sampling locations are shown in Figure 30. Routine sampling locations include one spring and five wells of varying depths. Six Mile Well was not sampled this year because the pump motor was missing. All of the sampling locations are being used as, or are suitable for, drinking water supplies. At least two wells (HTH-1 and HTH-2) are positioned to intercept migration from the test cavity, should it occur (Chapman and Hokett, 1991). All samples yielded negligible gamma activity. The only sample with tritium activity greater than the MDC was from Blue Jay Maintenance Station, 7.3 ± 1.8 pCi/L, which is less than 0.01 percent of the DCG (Table D-2, Appendix D). These results for tritium indicate that, to date, migration of radioactivity into the sampled wells, and into the area drinking water supplies, has not occurred.

7.4.2 Project SHOAL

Project SHOAL, a 12-kt test emplaced at 365 m (1200 ft), was conducted on October 26, 1963, in a sparsely populated area near Frenchman Station, Nevada. The test, a part of the Vela Uniform Program, was designed to investigate detection of a nuclear detonation in an active earthquake zone. The working point was in granite and no surface crater was formed.

Samples were collected on February 24 and 25, 1993. Five of the six routine sampling locations shown in Figure 31 were sampled at that time. No sample was collected from Spring Windmill because the well has been removed. Samples and sites deleted from the routine sampling locations include one spring, one windmill, and four wells of varying depths. At least one location, Well HS-1, should intercept radioactivity migration from the test cavity, should it occur (Chapman and Hokett, 1991).

No gamma activity was detected in any of the samples. A tritium result of 62 ± 2 pCi/L was detected in the water sample from Smith/James Spring, equivalent to 0.07 percent of the DCG (see Table D-3, Appendix D). All of the remaining samples yielded tritium results less than the MDC. The result for Smith/James Springs is consistent with values obtained in previous samples shown in Figure 32. It is unlikely that the tritium source is the Project SHOAL cavity; the most probable source is assumed to be rainwater infiltration.

Because Well H-3 had not been sampled since 1986, analyses of ^{89,90}Sr and Pu and U isotopes were completed in addition to tritium analysis. Results were less than the MDC of the analysis for strontium, plutonium, and ^{235}U. Uranium-234 and ^{238}U were detected at low levels (0.14 ± 0.02 pCi/L of ^{234}U and 0.042 ± 0.011 pCi/L of ^{238}U) and are probably of natural origin.

7.4.3 Project RULISON

Co-sponsored by AEC and Austral Oil Co. under the Plowshare Program, Project RULISON was designed to stimulate natural gas recovery in the Mesa Verde formation. The test, conducted near Rifle, Colorado on September 10, 1969, consisted of a 43-kt nuclear explosive emplaced at a depth of 2568 m (8426 ft). Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972 and wells were plugged in 1976. Some surface contamination resulted from decontamination of drilling equipment and fallout from gas flaring. Soil was removed during the cleanup operations.

Sampling was completed on June 16, 1993, with collection of nine samples in the area of Grand Valley and Rulison, Colorado. Routine sampling locations, depicted in Figure 33, include the Grand Valley municipal drinking water supply springs, water supply wells for five local ranches, and three sites in the vicinity of GZ, including one test well, a surface-discharge spring, and a surface sampling location on Battlement Creek. An analysis of the sampling locations performed by Desert Research Institute (DRI) indicated that none of the sampling locations are likely to detect migration of radionuclides from the test cavity (Chapman and Hokett, 1991).

Tritium has never been observed in measurable concentrations in the Grand Valley City Springs. The sample collected in 1993 from Potter's Ranch was invalidated following analysis. All of the remaining sampling sites show detectable levels of tritium, which have generally exhibited a decreasing to stable trend over the last two decades. The range of tritium activity in the 1993 samples was 116 ± 3 pCi/L at Lee Hayward Ranch

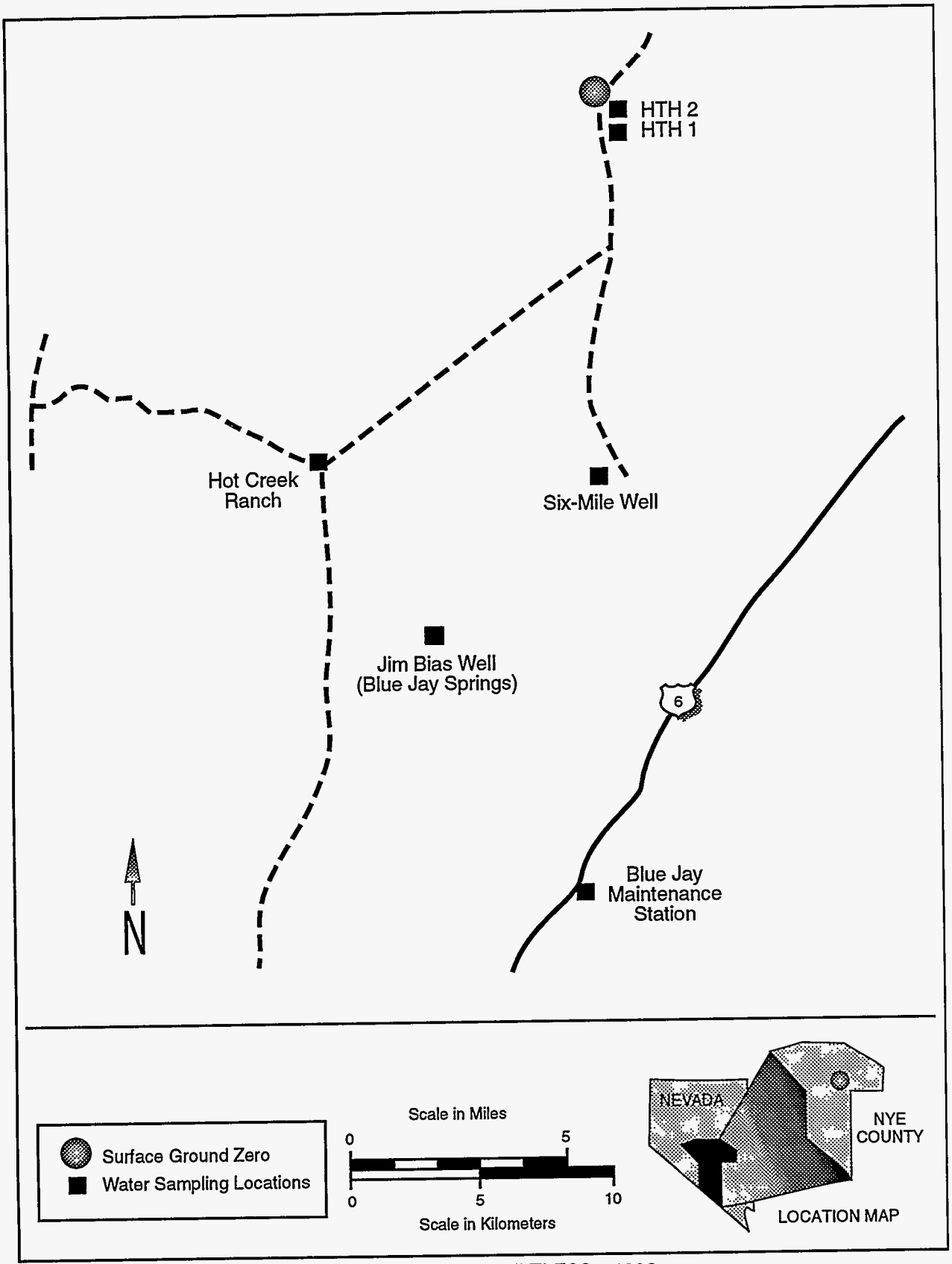


Figure 30. LTHMP Sampling Locations for Project FAULTLESS - 1993

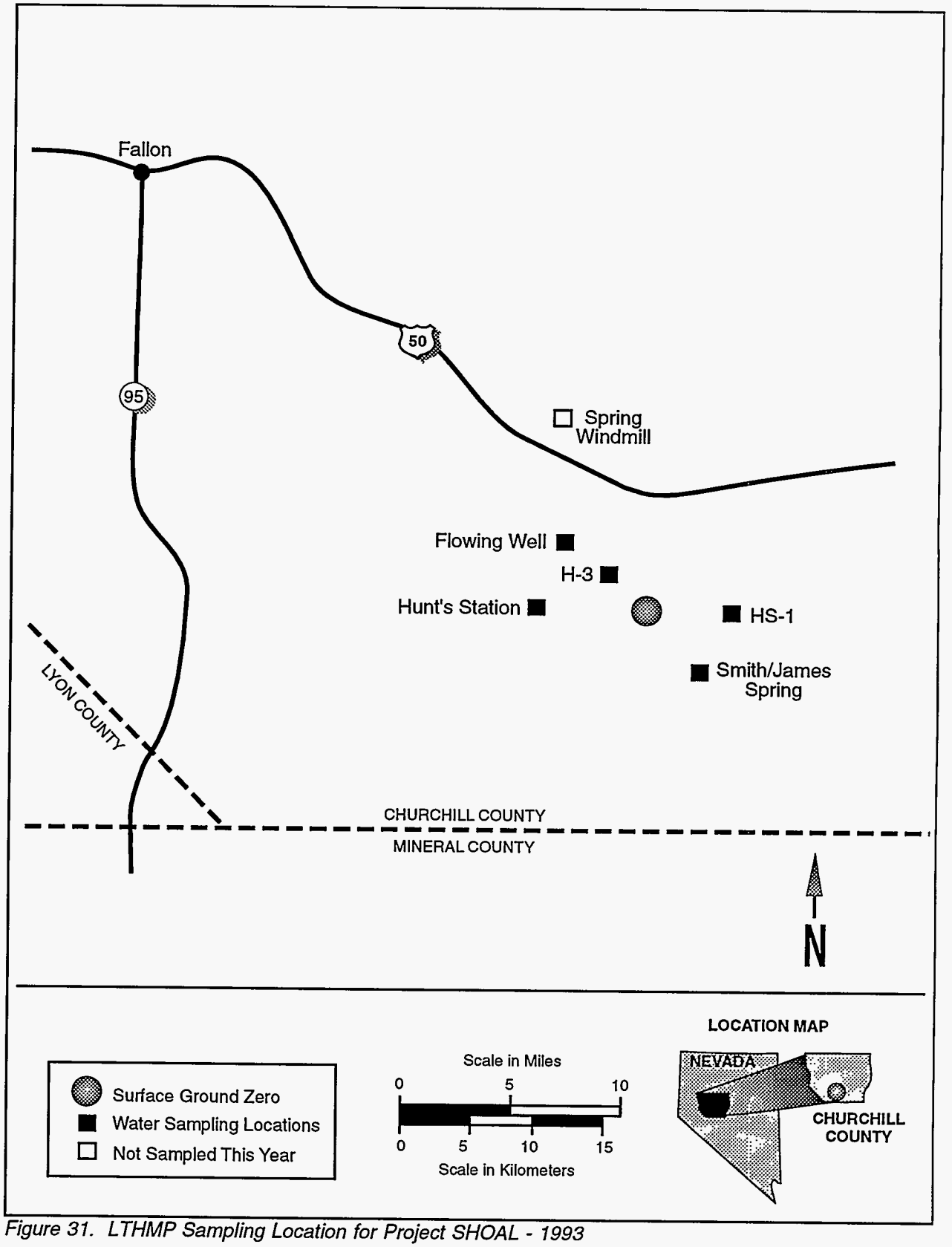


Figure 31. LTHMP Sampling Location for Project SHOAL - 1993

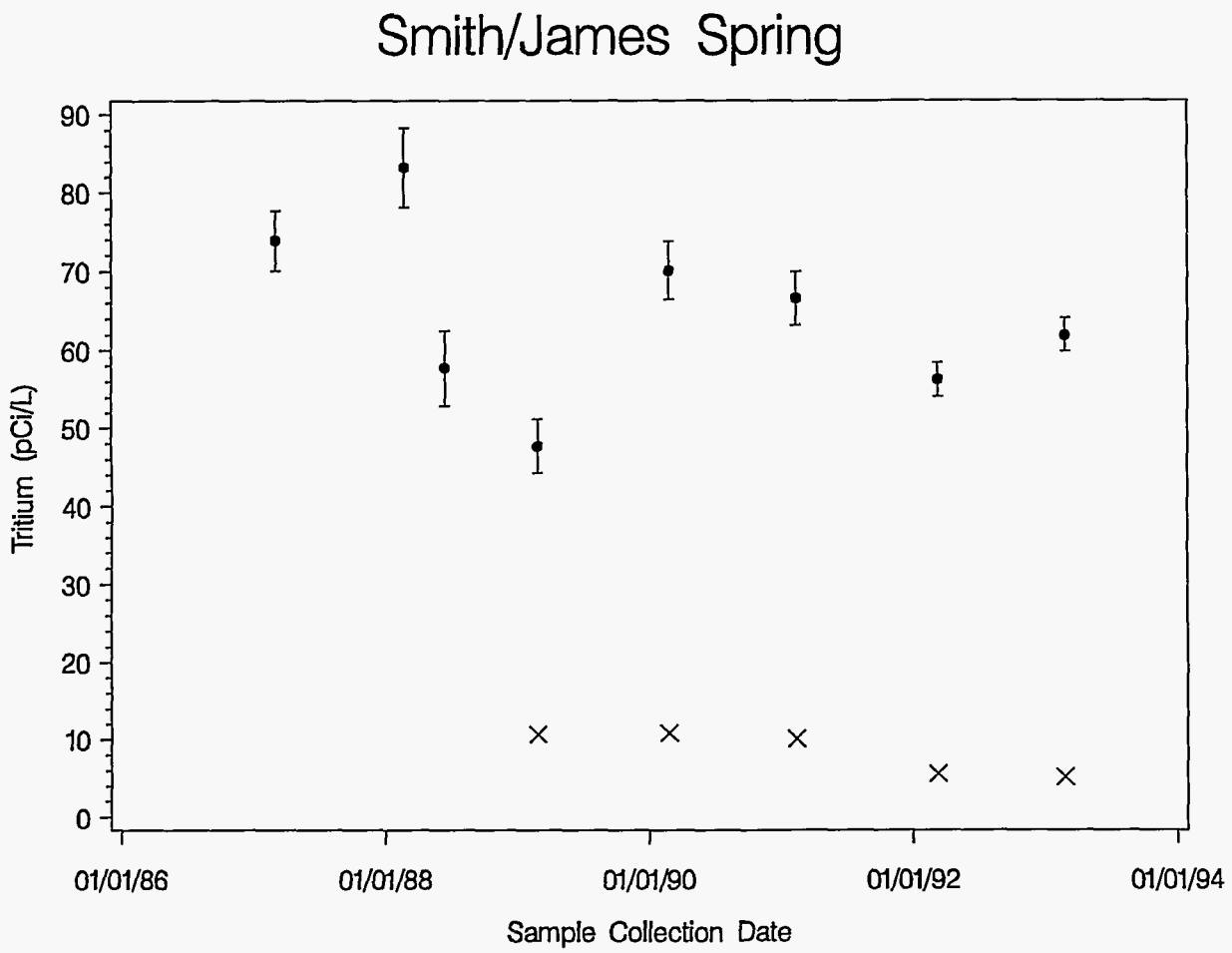


Figure 32. Tritium Results for Water from Smith/James Spring, Nevada.

to 49 ± 2 pCi/L in the sample from Battlement Creek (see Table D-4, Appendix D). These values are less than one percent of the DCG. The detectable tritium activities are probably a result of the natural high background in the area. This is supported by the DRI analysis, which indicated that most of the sampling locations are shallow, drawing water from the surficial aquifer which is unlikely to become contaminated by any radionuclides arising from the Project RULISON cavity (Chapman and Hokett, 1991). Figure 34 displays data for the last 20 years for Lee Hayward Ranch. The low value obtained in 1990 may be attributed to analytical bias and was observed consistently for all Project RULISON sampling locations.

7.4.4 Project RIO BLANCO

Like Project RULISON, Project RIO BLANCO was a joint government-industry test designed to stimulate natural gas flow and was conducted under the Plowshare Program. The test was conducted on May 17, 1973, at a location between Rifle and Meeker, Colorado. Three explosives with a total yield of 90 kt were emplaced at 1780-, 1920-, and 2040-m (5838-, 6229-, and 6689-ft) depths in the Ft. Union and Mesa Verde formations. Production testing continued to 1976; tritiated water produced during testing was injected to 1710 m (5600 ft) in a nearby gas wells. Cleanup and restoration activities were completed by November 1976.

Samples were collected on June 17 and 18, 1993. The sampling sites, shown in Figure 35, include two shallow domestic water supply wells, six surface water sites along Fawn Creek, three springs, and three monitoring wells located near the cavity. At least two of the monitoring wells (wells RB-D-01 and RB-D-03) are suitable for monitoring possible migration of radioactivity from the cavity. Tritium activity in the three springs ranged from 49 to 58 pCi/L. These values are <0.1 percent of the DCG (see Table D-5, Appendix

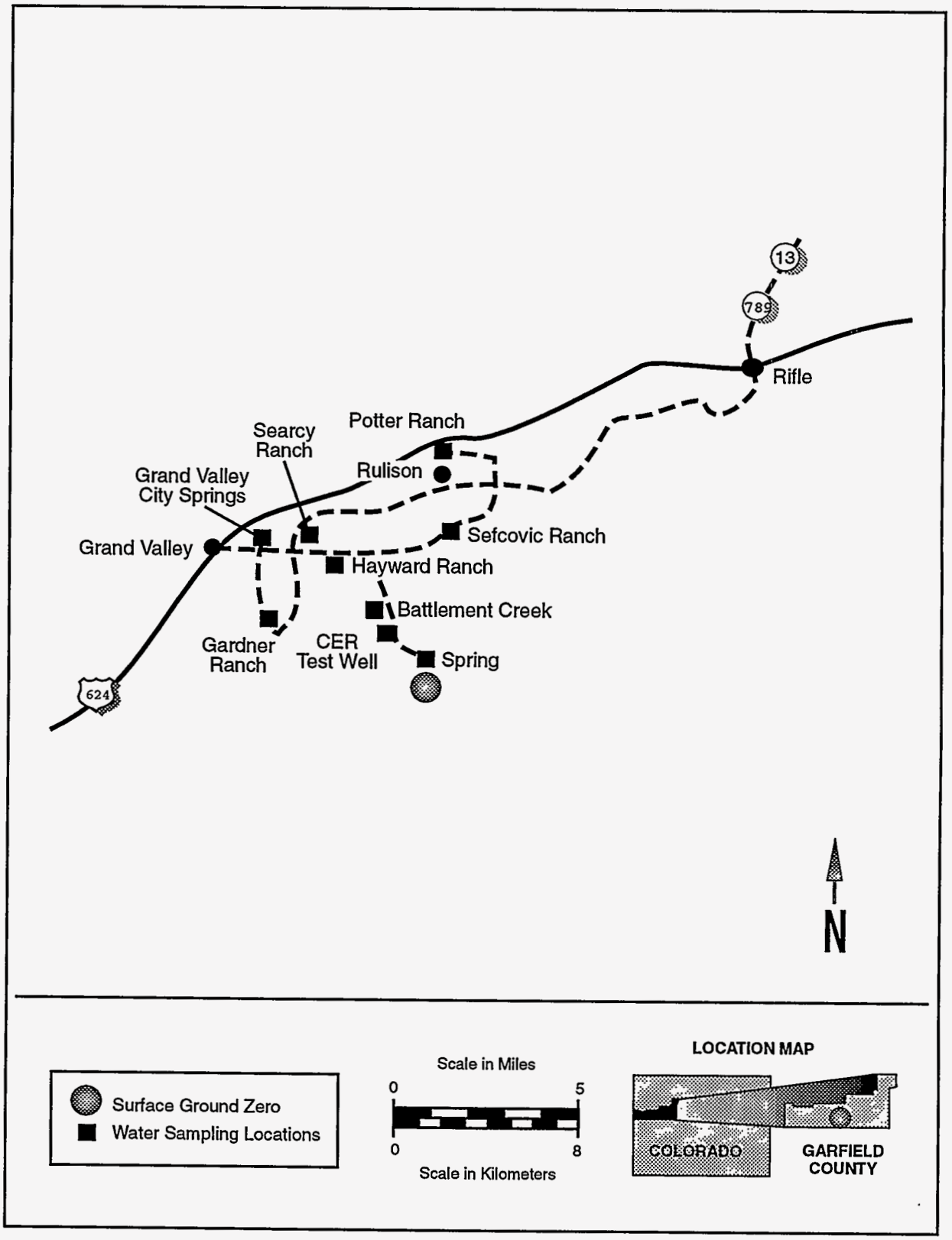


Figure 33. LTHMP Sampling Locations for Project RULISON - 1993

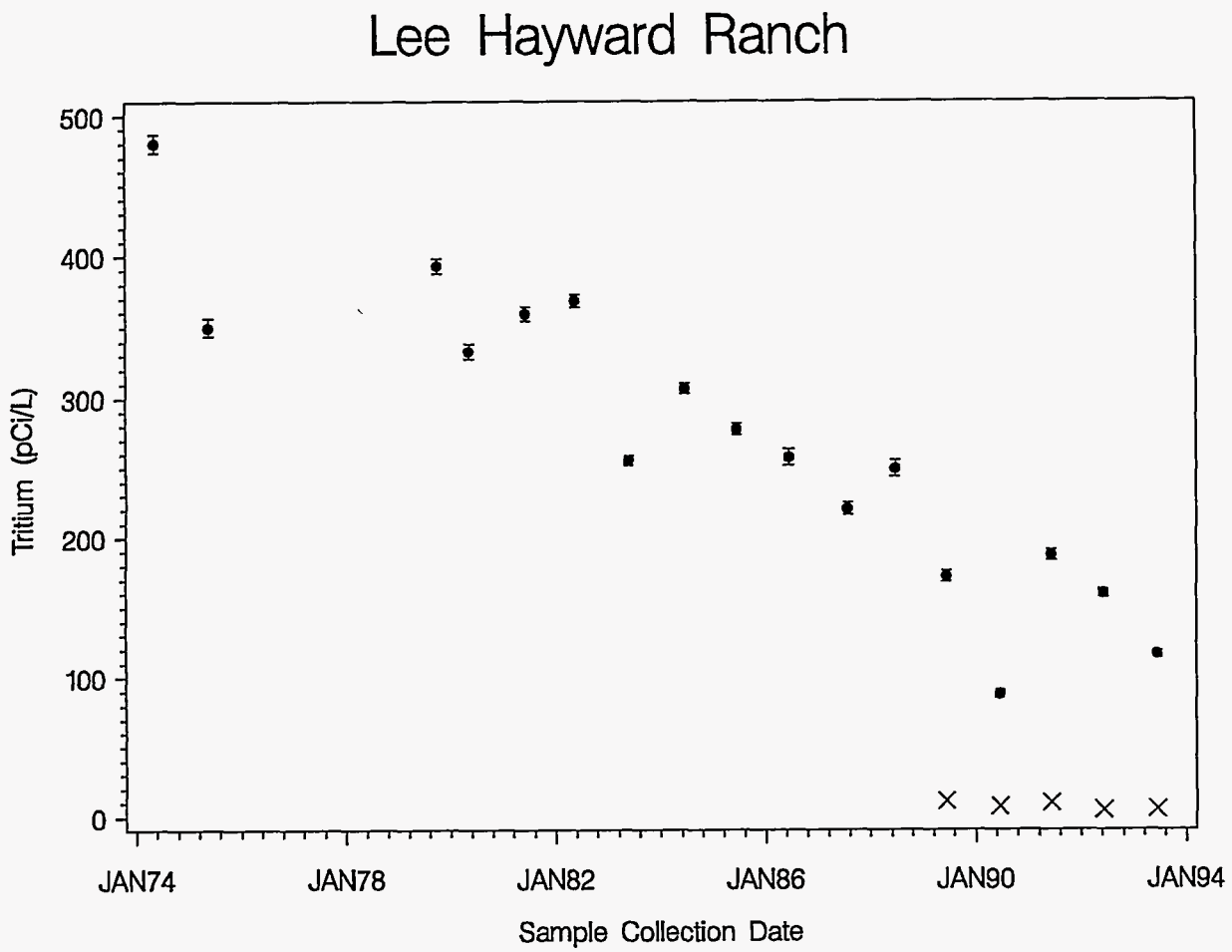


Figure 34. Tritium Trends in Groundwater, Hayward Ranch, Colorado.

D). A generally decreasing trend in tritium activity is evident in the three springs; Figure 36 depicts tritium results from one of the three springs. Only one of the two shallow domestic wells located near the Project RIO BLANCO site yielded detectable tritium (7.0 ± 2.0 pCi/L from the Brennan Windmill sample). Two of the Fawn Creek surface sites were analyzed by the conventional tritium method, yielding results less than the MDC. The tritium activity observed in the remaining four sites ranged from 28 to 39 pCi/L, less than 0.1 percent of the DCG. There is no statistically significant difference between sites located upstream and downstream of the cavity area. The three monitoring wells all yielded no detectable tritium activity, indicating that migration from the test cavity has not yet been detected. No gamma activity was detected in any sample.

7.4.5 Project GNOME

Project GNOME, conducted on December 10, 1961, near Carlsbad, New Mexico, was a multipurpose test conducted in a salt formation. A slightly more than three kiloton nuclear explosive was emplaced at a depth of 1216 ft in the Salado salt formation. Oil and gas are produced from the geologic units below the working point. The overlying Rustler formation contains three water-bearing zones: brine located at the boundary of the Rustler and Salado formations, the Culebra Dolomite which is used for domestic and stock supplies, and the Magenta Dolomite which is above the zone of saturation (Chapman and Hokett, 1991). The groundwater flow is generally to the west and southwest.

Radioactive gases were unexpectedly vented during the test. In 1963, USGS conducted a tracer study involving injection of 20 Ci tritium, 10 Ci ^{137}Cs, 10 Ci ^{90}Sr, and 4 Ci ^{131}I in the Culebra

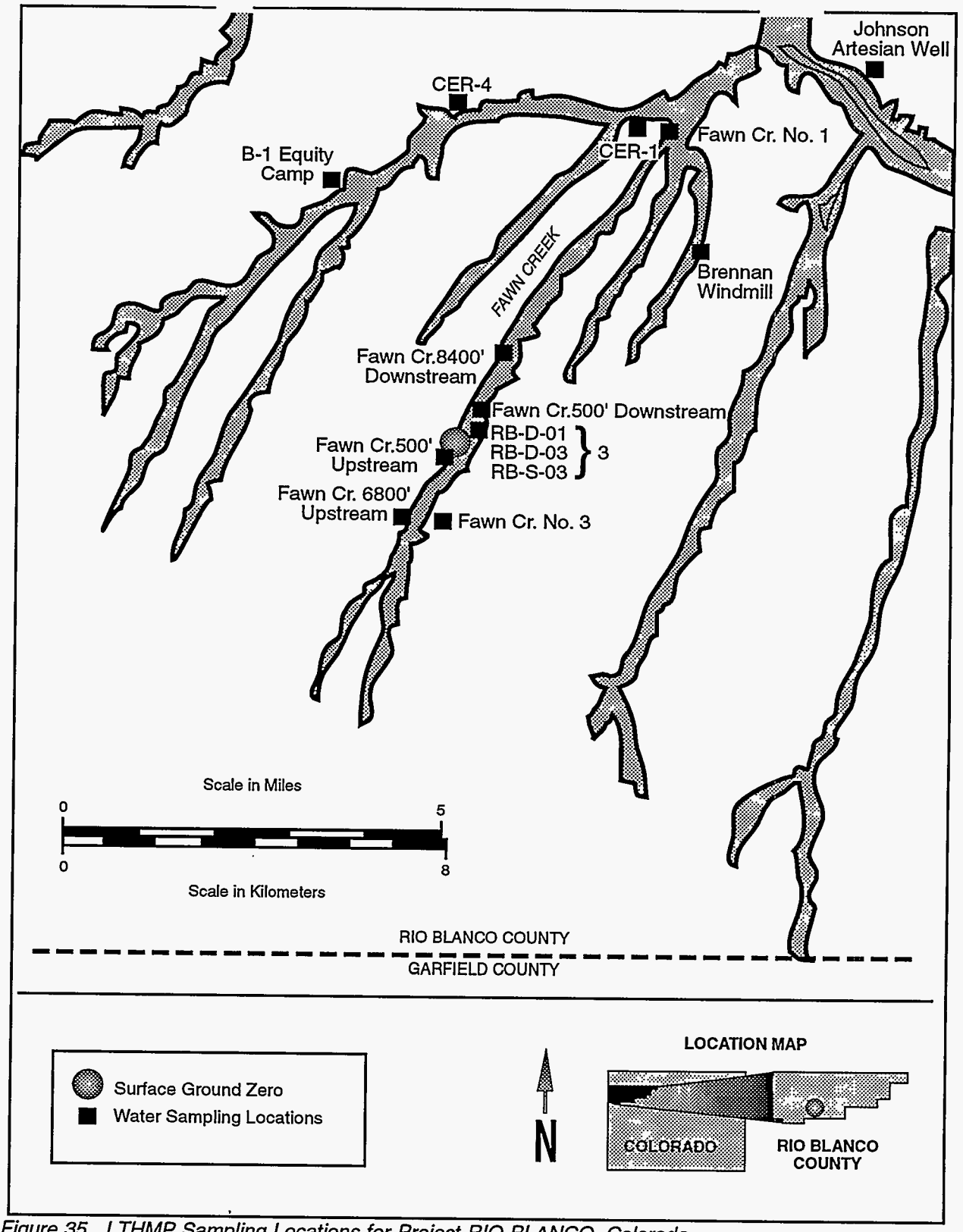


Figure 35. LTHMP Sampling Locations for Project RIO BLANCO, Colorado.

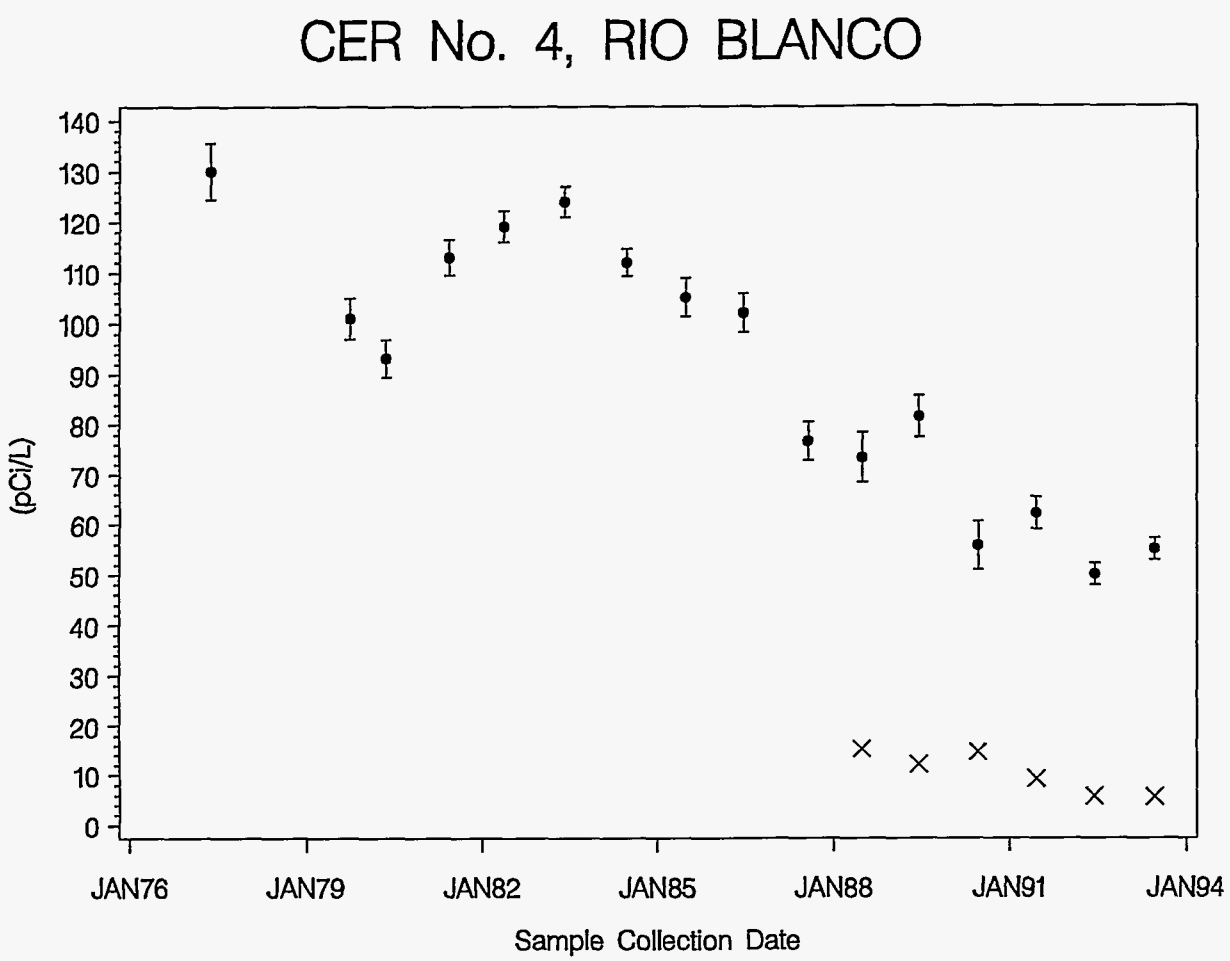


Figure 36. Tritium Results in Water from CER No. 4, RIO BLANCO, Colorado.

Dolomite zone; wells USGS 4 and 8 were used for this tracer study. During remediation activities in 1968-69, contaminated material was placed in the test cavity and shaft up to within 7 ft of the surface. More material was slurried into the cavity and drifts in 1979. There is a potential for discharge of this slurry to the Culebra Dolomite and to Rustler-Salado brine. This potential may increase as the salt around the cavity will compress, forcing contamination upward and distorting and cracking the concrete stem and grout.

Annual sampling at Project GNOME was completed between June 26 and 28, 1993. The routine sampling sites, depicted in Figure 37, include nine monitoring wells in the vicinity of surface GZ, the municipal supplies at Loving and Carlsbad, New Mexico. The Pecos River Pumping Station well is no longer sampled. A new sampling location added in 1993 is the J. Mobley Ranch located near Loving, New Mexico. The sampling site is a 50m (165 ft) deep well used to supply drinking water. No tritium activity above the MDC was detected in the Carlsbad municipal supply. Tritium concentrations of 9.1 ± 1.7 pCi/L in the Loving municipal supply and of 4.9 ± 1.5 pCi/L in the J. Mobley Ranch well were detected. An analysis by DRI (Chapman and Hokett, 1991) indicates these three sampling locations, located on the opposite side of the Pecos River from the Project GNOME site, are not connected hydrologically to the site and, therefore, cannot become contaminated by Project GNOME radionuclides except via surface pathways.

Tritium results greater than the MDC were detected in water samples from six of the water samples taken in the immediate vicinity of GZ. Tritium activities in wells DD-1, LRL-7, USGS-4, and USGS-8 ranged from 7300 ± 150 pCi/L in Well LRL-7 to $7.4 \times 10^7 \pm 3.2 \times 10^5$ pCi/L in Well DD-1. These wells all sample nonpotable water. Well DD-1 collects water from the test cavity. Well LRL-7 collects water from a side drift. Wells USGS-4 and USGS-8 were used in the radionuclide tracer study conducted by USGS. In addition to tritium,

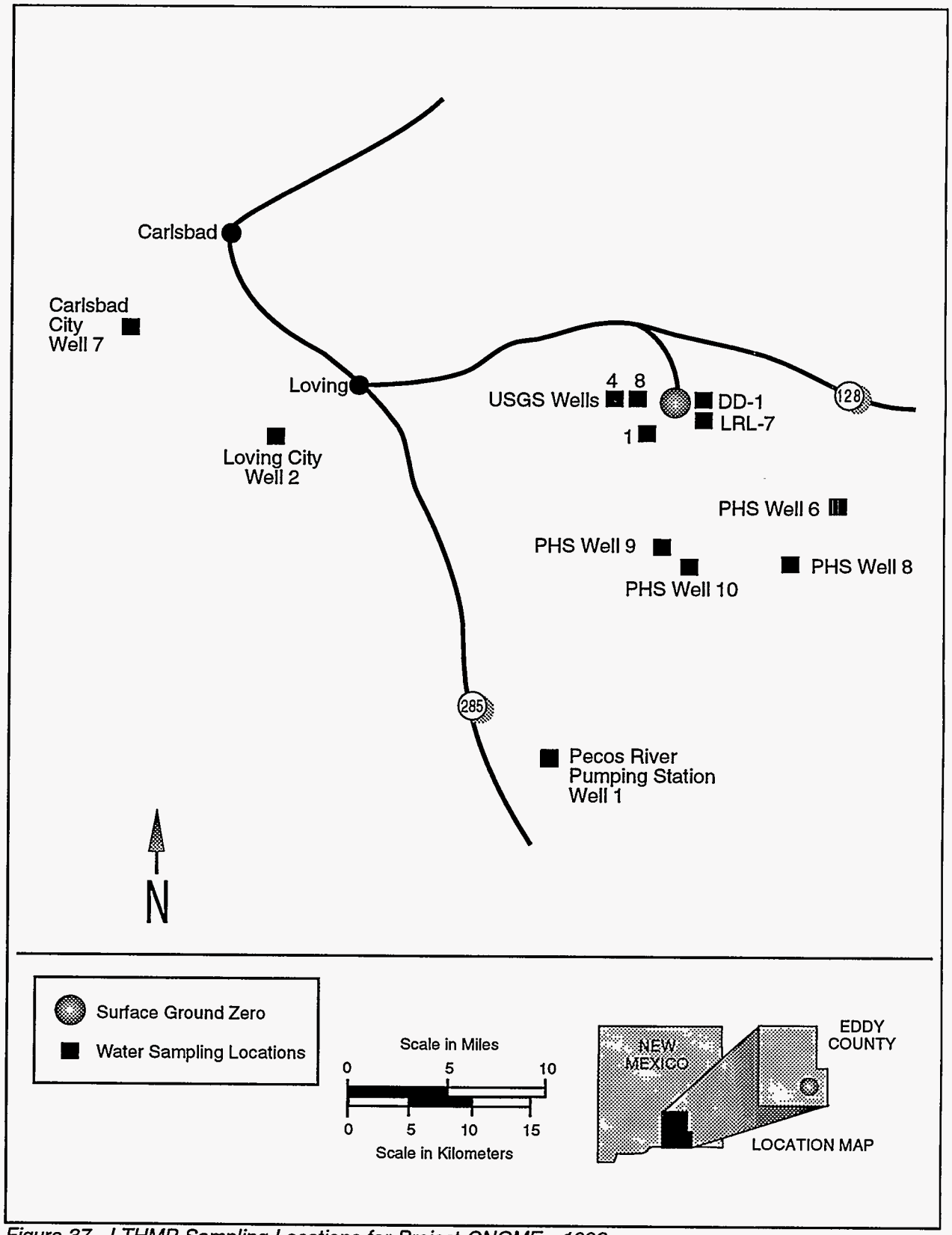


Figure 37. LTHMP Sampling Locations for Project GNOME - 1993

samples from wells DD-1, LRL-7, and USGS-8, were analyzed for several radionuclides, with results obtained as shown in (Table D-6, Appendix D). With the exception of Well DD-1, the concentrations of these radionuclides decreased from 1992 results (see Figure 38). Results for both cesium-137 and strontium-90 increased in Well DD-1 over 1992 results. Wells PHS-6 and PHS-8 also showed detectable tritium concentrations above the MDC. Observed results were 30 ± 2 and 9.0 ± 1.7 pCi/L, respectively. These results were less than 0.04 percent of the DCG.

7.4.6 Project GASBUGGY

Project GASBUGGY was a Plowshare Program test co-sponsored by the U.S. Government and El Paso Natural Gas Co. Conducted near Gobernador, New Mexico on December 10, 1967, the test was designed to stimulate a low productivity natural gas reservoir. A nuclear explosive with a 29-kt yield was emplaced at a depth of 1290 m (4240 ft). Production testing was completed in 1976 and restoration activities were completed in July 1978.

The principal aquifers are the Ojo Alamo Sandstone, an aquifer containing non-potable water located above the test cavity, the San Jose formation and Nacimiento formation, both surficial aquifers containing potable water. The flow regime of the San Juan Basin is not well known, although it is likely that the Ojo Alamo Sandstone discharges to the San Juan River 50 miles northwest of the Gasbuggy site. Hydrologic gradients in the vicinity are downward, but upward gas migration is possible (Chapman and Hokett, 1991).

Sampling was conducted June 20 through 25, 1993. Twelve samples were collected. No sample was collected from Well 30.3.32.343 N as the pump has been removed. The Old School House Well, first sampled in 1991, was sealed by the state of New Mexico in 1992, thus ending plans to add this station to the routine sampling directory.

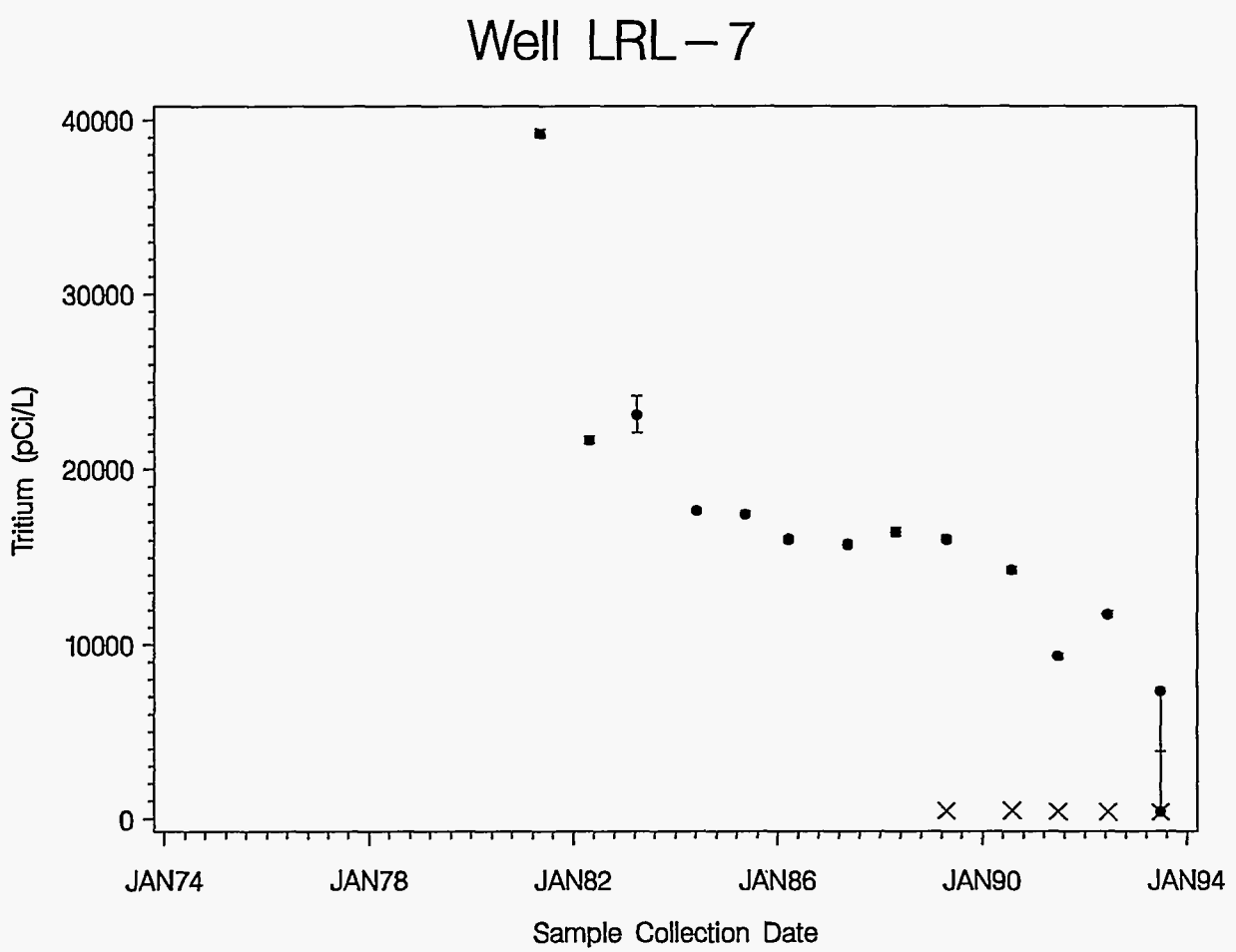


Figure 38. Tritium Results in Water from Well LRL-7 near Project GNOME, New Mexico.

The routine sampling locations include six wells, one windmill, three springs, and two surface water sites, depicted in Figure 39. The two surface water sampling sites yielded tritium activities of 36 ± 1.8 pCi/L and 41 ± 1.8 pCi/L. These values are 0.04 to 0.05 percent of the DCG. The three springs yielded tritium activities ranging from 20 ± 1.9 pCi/L to 49 ± 1.9 pCi/L, which are less than 0.1 percent of the DCG and similar to the range seen in previous years. Tritium activities in three shallow wells which were sampled this year varied from less than the MDC to 40 ± 1.9 pCi/L, which is 0.04 percent of the DCG. The sample collected from the windmill was less than the MDC. Analytical results are presented in Table D-7, Appendix D.

Well EPNG 10-36, a gas well located 132 m (435 ft) northwest of the test cavity with a sampling depth of approximately 1100 m (3600 ft), had yielded tritium activities between 100 and 560 pCi/L in each year since 1984, except 1987. The sample collected in 1993 yielded a tritium activity of 330 ± 3.5 pCi/L and cesium-137 activity of 16 ± 3.9 pCi/L. The tritium activity is roughly the same as observed in 1992, but the cesium-137 activity represents an increase over results obtained in previous years.

The continued presence of fission products in samples collected from EPNG 10-36 confirms that migration from the Project GASBUGGY cavity is occurring. The migration mechanism and route are not currently known, although an analysis by DRI indicated two feasible routes, one through the Painted Cliffs sandstone and the other through the Ojo Alamo sandstone, one of the principal aquifers in the region (Chapman, 1991). In either case, fractures extending from the cavity may be the primary or a contributing mechanism.

7.4.7 Project DRIBBLE

Project DRIBBLE was comprised of four explosive tests, two nuclear and two gas, conducted in the Tatum Salt Dome area of Mississippi under the Vela Uniform Program. The purpose of Project DRIBBLE was to study the effects of decoupling on seismic signals produced by explosives tests. The first test, SALMON, was a nuclear device with a yield of about 5 kt, detonated on October 22, 1964, at a depth of 826 m (2710 ft). This test created the cavity used for the subsequent tests, including STERLING, a nuclear test conducted on December 3, 1966, with a yield of about 380 tons, and the two gas explosions, DIODE TUBE, conducted on February 2, 1969, and HUMID WATER, conducted on April 19, 1970. The ground surface and shallow groundwater aquifers were contaminated by disposal of drilling muds and fluids in surface pits. The radioactive contamination was primarily limited to the unsaturated zone and upper, non-potable aquifers. Shallow wells, labeled HMH wells on Figure 40, have been added to the area near surface GZ to monitor this contamination. In addition to the monitoring wells surrounding GZ, extensive sampling is conducted in the nearby offsite area. Most private drinking water supply wells are included, as shown in Figure 41.

Sampling on and in the vicinity of the Salmon Test Site was conducted between April 18 through 21, 1993. A total of 109 samples were collected; two of these were from new sampling locations in Lumberton, Mississippi. One offsite resident withdrew from the sampling program (Johnny Hudson Quail House), and one residence changed owners (the B. Chambliss location is now identified as Billy Hibley).

In the 52 samples collected from offsite sampling locations, tritium activities ranged from less than the MDC to 37 ± 1.8 pCi/L, equivalent to 0.04 percent of the DCG. These results do not exceed the natural tritium activity expected in rainwater in the area. In general, results for each location were similar to results obtained in previous years. Long-term decreasing trends in tritium concentrations are evident only for a few locations, such as the Baxterville City Well, depicted in Figure 42. Low levels of uranium isotopes were detected in both of the two new sampling locations with greater than MDC values for ^{234}U at one location and for ^{235}U and ^{238}U at both locations. Results are listed in the footnotes of Table D-8, Appendix D. These low levels are probably of natural origin.

Due to the high rainfall in the area, the normal sampling procedure is modified for the shallow onsite wells. Following collection of a first sample, the well is pumped for a set period of time or until dry and a second sample is collected the next day. The second samples are thought to be more representative of the formation water. Of 32 locations sampled onsite, (7 sites sampled once, the remainder sampled twice) 26 yielded tritium activities greater than the MDC in either the first or second sample. Of these, eleven yielded results higher than normal background (approximately 60 pCi/L). Overall, tritium activities ranged from less

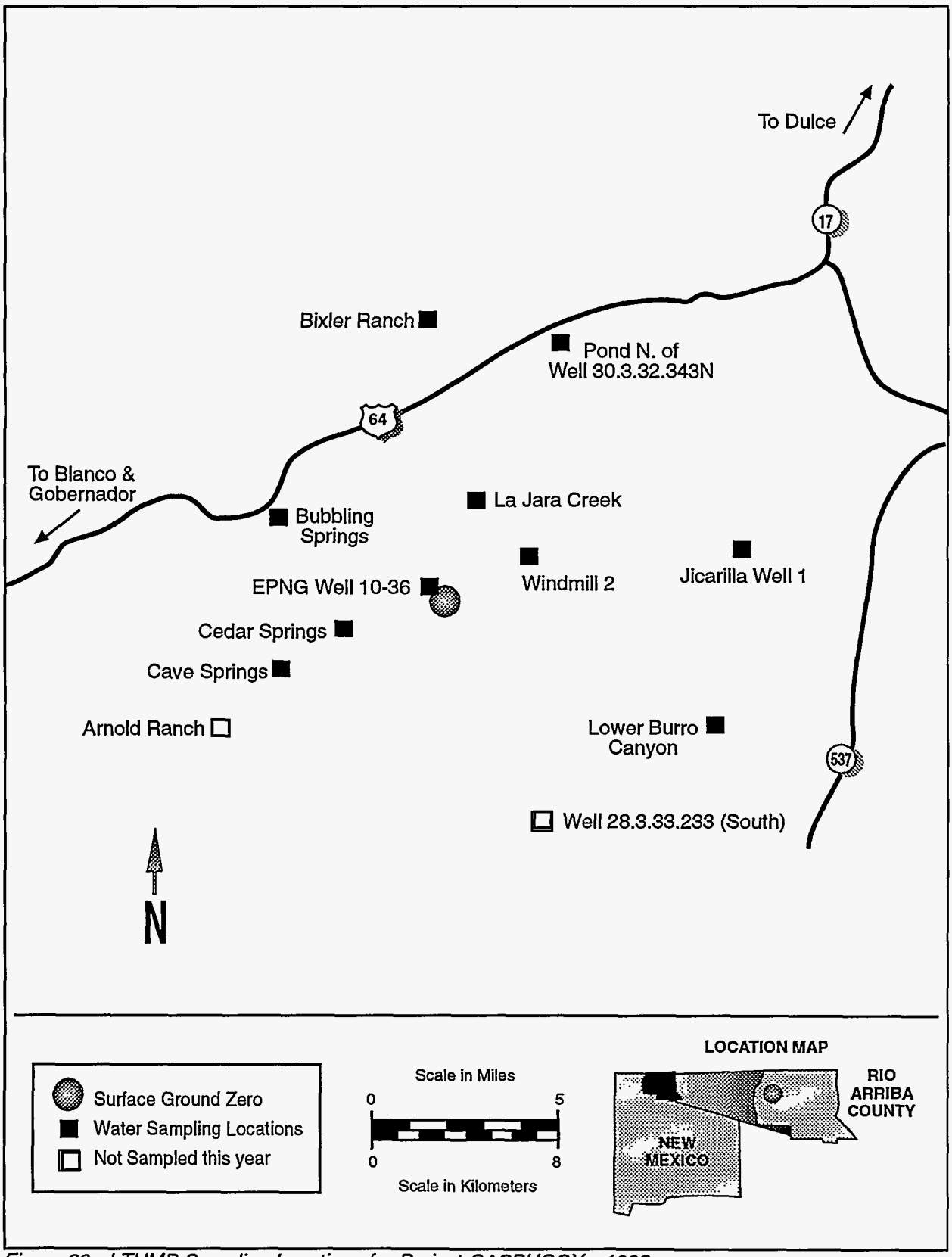


Figure 39. LTHMP Sampling Locations for Project GASBUGGY - 1993

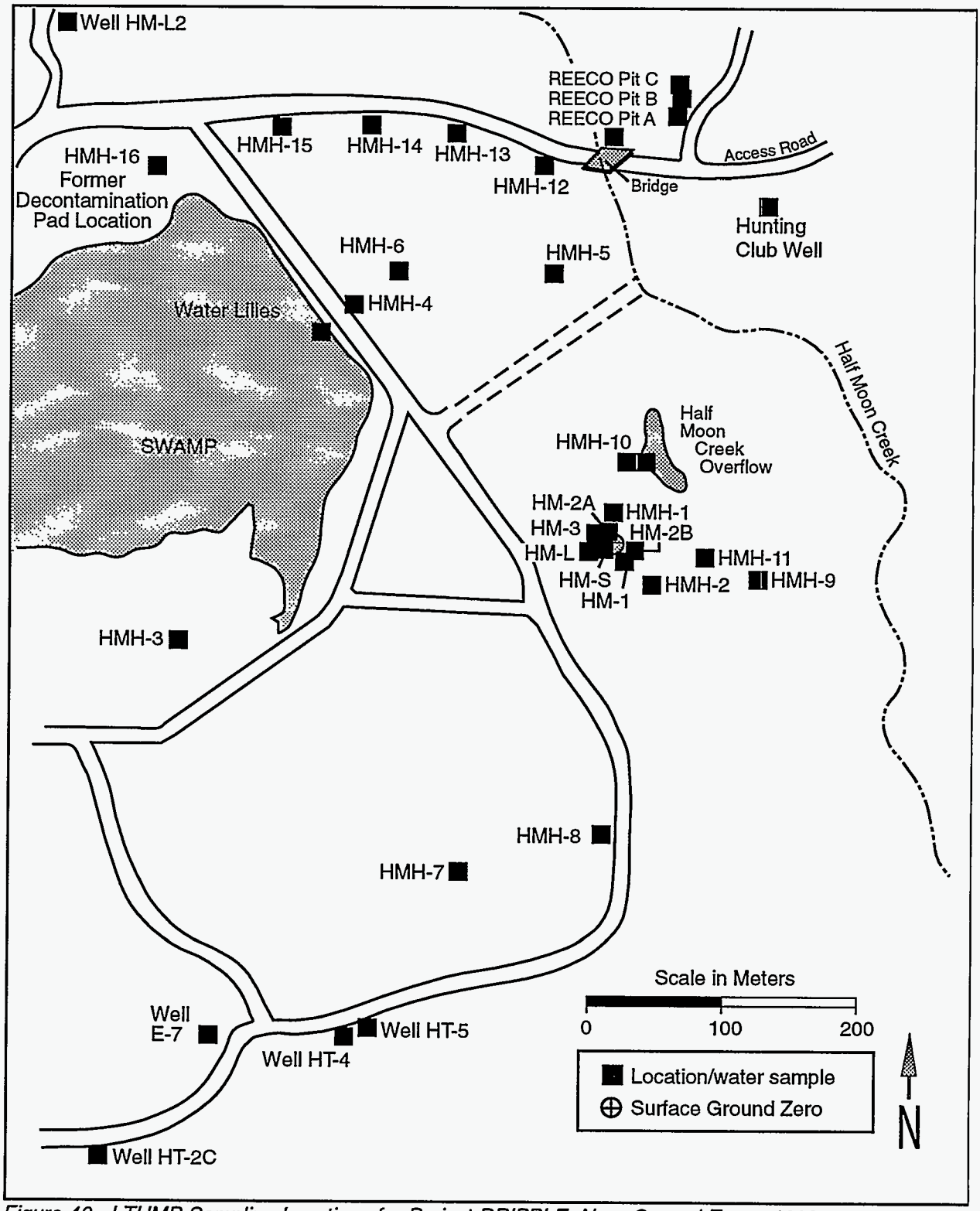


Figure 40. LTHMP Sampling Locations for Project DRIBBLE, Near Ground Zero - 1993

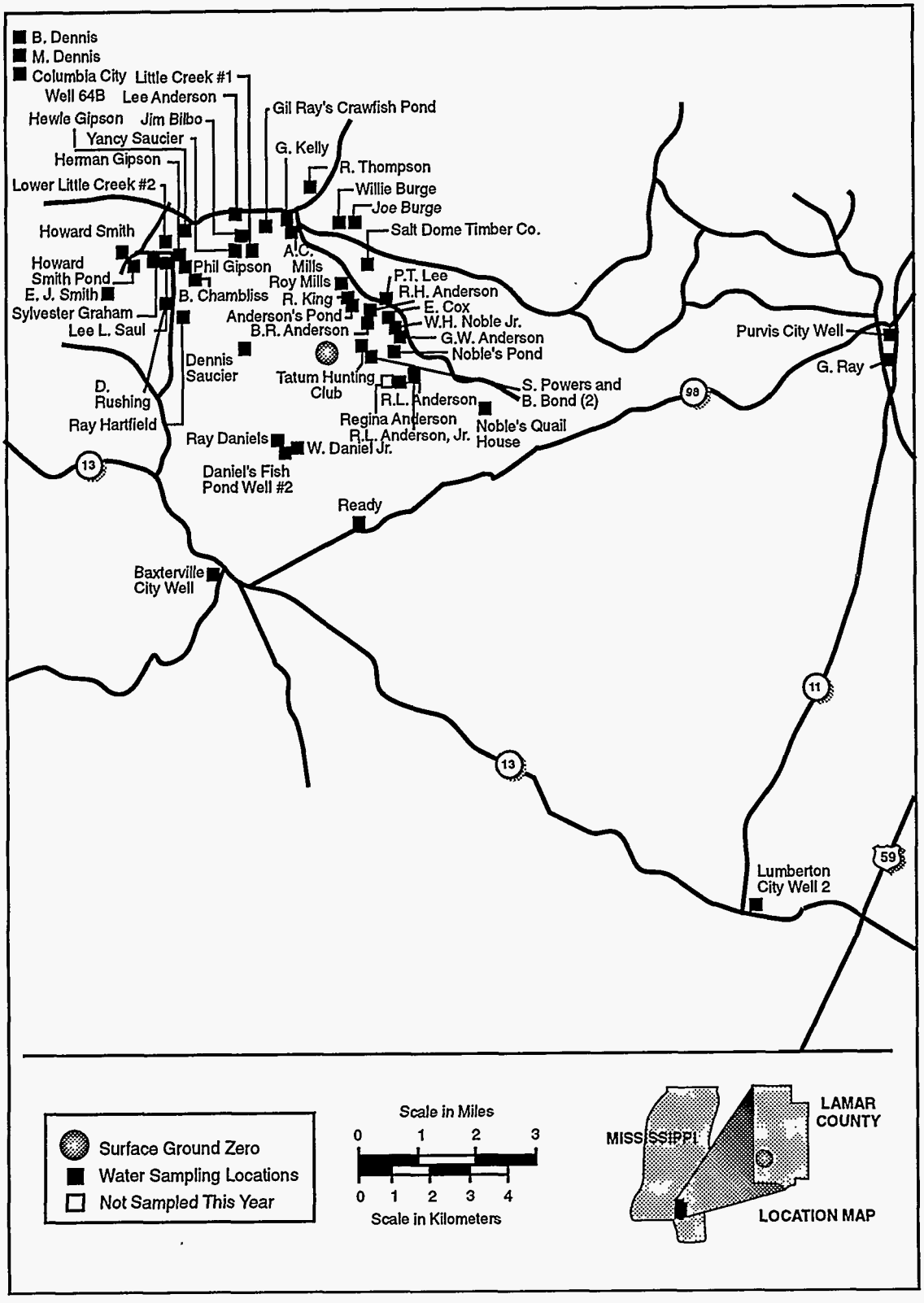


Figure 41. LTHMP Sampling Locations for Project DRIBBLE, Towns and Residences - 1993

than the MDC to 7.79 x 10^3 ± 150 pCi/L, as shown in Table D-8, Appendix D. The locations where the highest tritium activities were measured generally correspond to areas of known contamination. Decreasing trends were noted for the wells where high tritium activities have historically been noted, such as Well HM-S depicted in Figure 43. Results of sampling related to Project DRIBBLE are discussed in greater detail in *Onsite and Offsite Environmental Monitoring Report: Radiation Monitoring around Salmon Test Site, Lamar County, Mississippi, April 1993* (Max G. Davis).

7.4.8 AMCHITKA ISLAND, ALASKA

Three nuclear weapons tests were conducted on Amchitka Island in the Aleutian Island chain of Alaska. Project LONG SHOT, conducted on October 29, 1965, was an 85-kt test under the Vela Uniform Program, designed to investigate seismic phenomena. Project MILROW, conducted on October 2, 1969, was an approximately 1-Mt "calibration test" of the seismic and environmental responses to the detonation of large-yield nuclear explosives. Project CANNIKIN, conducted on November 6, 1971, was a proof test of the Spartan antiballistic missile warhead with less than a 5-Mt yield. Project LONG SHOT resulted in some surface contamination, even though the chimney did not extend to the surface.

Amchitka Island is composed of several hundred feet of permeable tundra overlaying tertiary volcanics. The groundwater system consists of a freshwater lens floating on seawater; estimates of the depth to the saline freshwater-interface range from 3900 to 5250 ft (Chapman and Hokett, 1991). It is likely that any migration from the test cavities would discharge to the nearest salt water body, Project MILROW to the Pacific Ocean and Projects LONG SHOT and CANNIKIN to the Bering Sea (Chapman and Hokett, 1991). The sampling locations on Amchitka Island are shallow wells and surface sampling sites. Therefore, the monitoring network for Amchitka Island is restricted to monitoring of surface contamination and drinking water

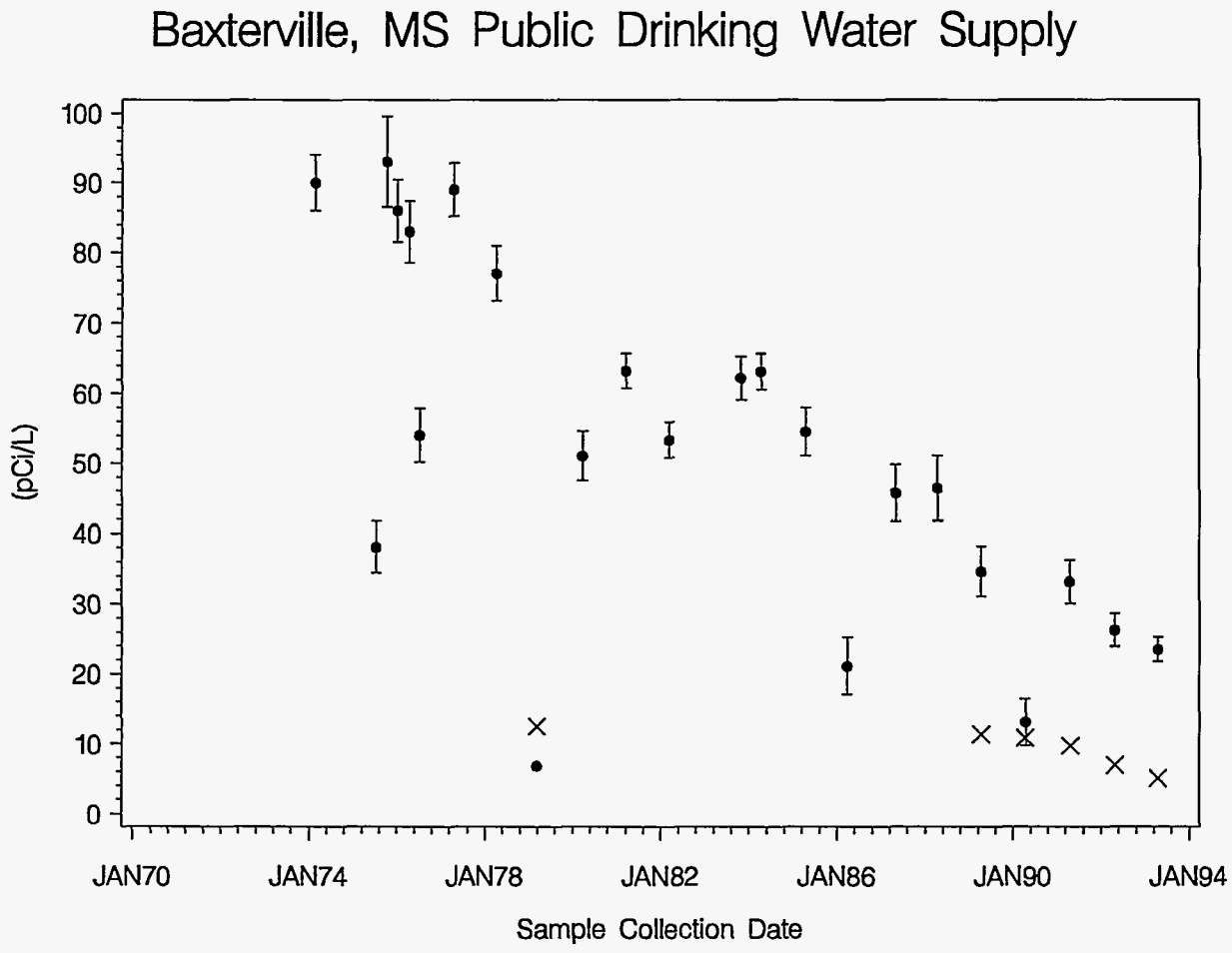


Figure 42. Tritium Result Trends in Baxterville, MS Public Drinking Water Supply - 1993

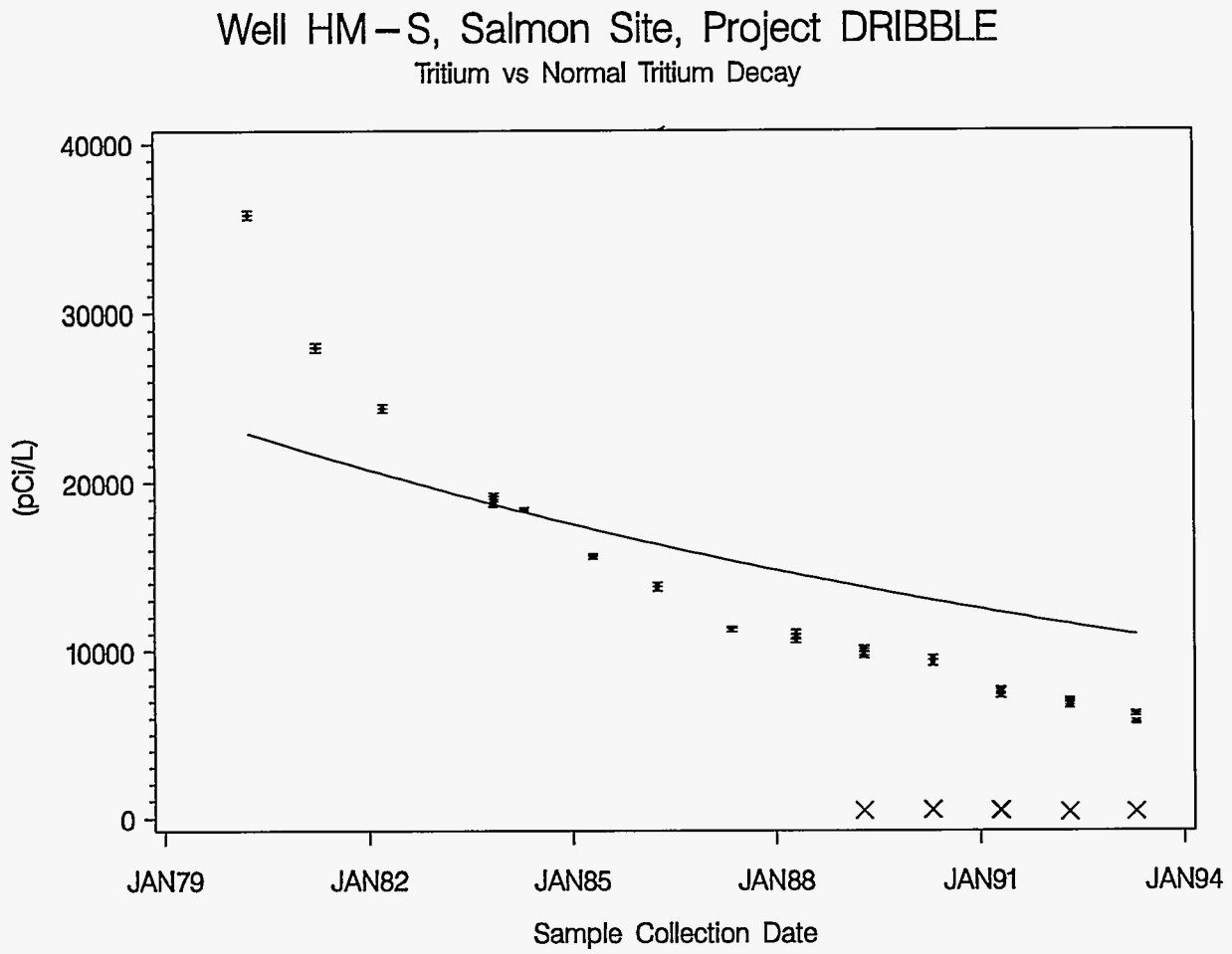


Figure 43. Tritium Results in Well HM-S, Salmon Site, Project DRIBBLE.

supplies.

Sampling on Amchitka Island, Alaska, is conducted every other year. Results for samples taken July 29 to Aug 1, 1993 are shown in Table D-9, Appendix D. All samples were above the MDC for tritium. The water from the background sites had tritium concentrations ranging from 4.5 ± 1.7 in a rain sample collected at the Base Camp to 30 ± 1.7 pCi/L at Constantine Spring Pump House, corresponding to 0.01 to 0.03 of the DCG. Samples from Project Cannikin site yielded tritium concentrations ranging from 16 ± 1.6 pCi/L to 23 ± 1.8 pCi/L; 0.02 to 0.03 percent of the DCG. Project Milrow samples yielded tritium concentrations ranging from 13 ± 1.6 pCi/L to 36 ± 2.0 pCi/L, corresponding to 0.01 to 0.04 percent of the DCG.

The highest tritium concentrations were observed in samples collected from Project Long Shot sites, ranging from 10 ± 1.1 pCi/L to 1.4 x 10^3 ± 130 pCi/L, equivalent to 0.01 to 1.6 percent of the concentration guide. The highest tritium result was obtained from well GZ No. 1, located near the Project Long Shot cavity. Figure 44 depicts the decreasing trend in tritium activity in this well.

An analysis of the monitoring locations by DRI indicated that none of the sites are suitable for detection of migration (Chapman and Hokett, 1991). Migration from the Project Milrow cavity would likely discharge to the Pacific Ocean, while the Bering Sea is the likely discharge area for migration from Projects Long Shot and Cannikin.

7.5 Summary

None of the domestic water supplies monitored in the LTHMP in 1993 yielded tritium activities of any health concern. The greatest tritium activity measured in any water body which has potential to be a drinking water supply was less than one percent of the limit prescribed by the NPDWRs. In general, surface water and spring samples yielded tritium

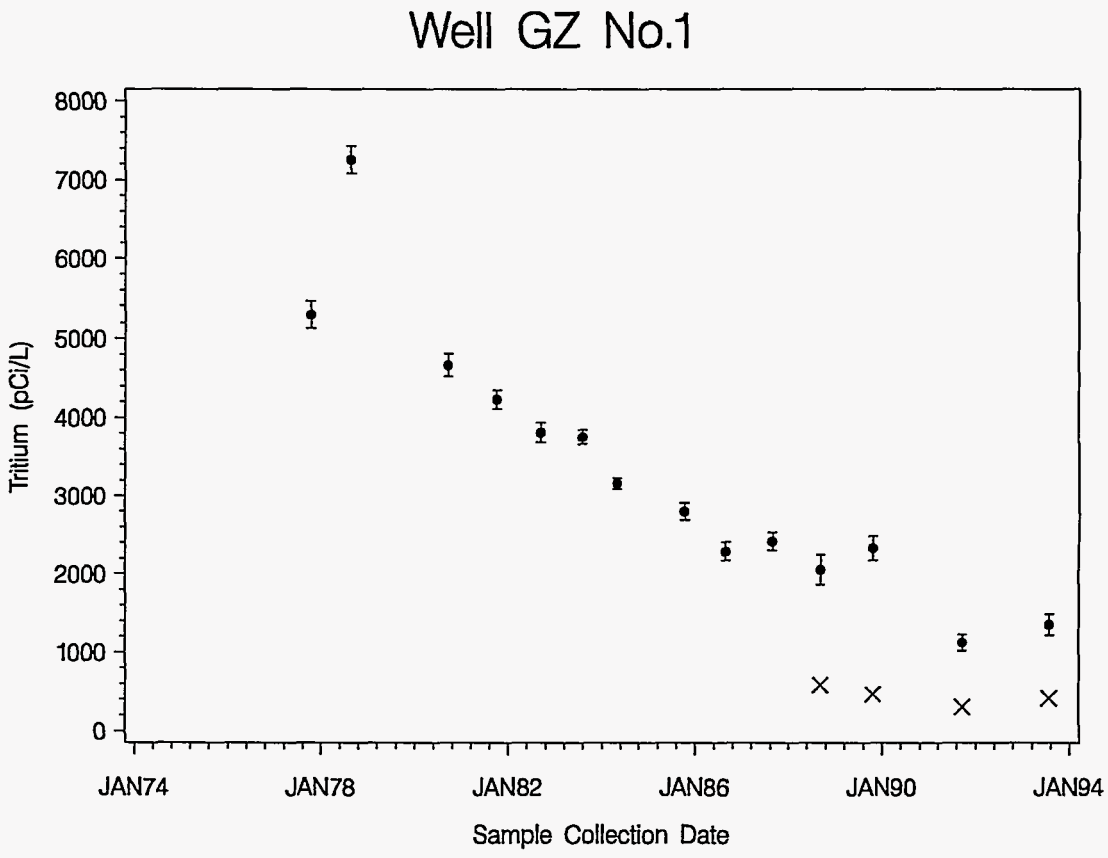


Figure 44. *Tritium Results in Water from Well GZ No. 1 near Project LONGSHOT, Amchitka Island, Alaska.*

activities greater than those observed in shallow domestic wells in the same area. This is probably due to scavenging of atmospheric tritium by precipitation. Where suitable monitoring wells exist, there were no indications that migration from any test cavity is affecting any domestic water supply.

In most cases, monitoring wells also yielded no radionuclide activity above the MDC. Exceptions include wells into test cavities, wells monitoring known areas of contamination, and one well at GASBUGGY. Known areas of contamination exist at Project GNOME where USGS conducted a tracer study experiment, some areas onsite at Project DRIBBLE, and a few surface areas near Project LONG SHOT. The 1993 results for these monitoring wells are consistent with decreasing trends observed over time. Monitoring well EPNG 10-36 at Project GASBUGGY was a notable exception to wells showing decreasing trends.

This well is a former gas well located 435 feet northwest of SGZ. The sampling depth of this well is approximately 3600 ft in the Ojo Alamo Sandstone, an aquifer containing nonpotable water. The tritium activity in 1992 was 364 ± 3.4 pCi/L and in 1991 was 484 ± 4.2 pCi/L, approximately 10 times the historic background activity. An increase in tritium activity was first observed in 1984, seventeen years after the test was conducted. In every year since then, with the exception of 1987, tritium activities have been between 100 and 560 pCi/L, with wide variability sometimes noted between consecutive years. The proximity of the well to the test cavity suggests the possibility that the increased activity may be indicative of migration from the test cavity.

1. The NPDWR states that the sum of all beta/gamma emitter concentrations in drinking water cannot lead to a dose exceeding 4 mrem/year, assuming a person were to drink two liters per day for a year (40 CFR 141). Assuming tritium to be the only radioactive contaminant yields a maximum allowable concentration of 2×10^4 pCi/L.

2. The NPDWR applies only to public systems with at least 15 hookups or 25 users. Although many of the drinking water supplies monitored in the LTHMP serve fewer users and are therefore exempt, the regulations provide a frame of reference for any observed radionuclide activity.

3. The derived concentration guide (DCG) used in this report is 90,000 pCi/L of tritium in water. This DCG is taken from the ALI for ^3H in ICRP-30 modified for a maximum dose of 4 mrem/year for ingestion of beta/gamma emitters in water, assuming consumption of two liters of water per day and assuming tritium to be the only radioactive contaminant. The current U.S. standard given in the National Primary Drinking Water Regulations (40 CFR 141), although based on the same maximum dose and assumptions, specifically limits tritium to 20,000 pCi/L in drinking water. A revision of standard has been proposed which will, when enacted, raise the permissible tritium concentration to 63,000 pCi/L in U.S. drinking water.

4. In the time series plots used as figures in this section and the one that follows, the filled circles represent the result value, the error bars indicate ± one standard deviation of the analysis, and the (x) represents the MDC value.

8. Dose Assessment

Four pathways of possible radiation exposure to the population of Nevada were monitored by EPA's offsite monitoring networks during 1993. The four pathways were:

- Background radiation due to natural sources such as cosmic radiation, natural radioactivity in soil, and ^{7}Be in air.
- Worldwide distributions of radioactivity, such as ^{90}Sr in milk, ^{85}Kr in air, and plutonium in soil.
- Operational releases of radioactivity from the NTS, including those from drillback and purging activities.
- Radioactivity accumulated in migratory game animals during their residence on the NTS.

8.1 Estimated Dose From Nevada Test Site Activity Data

The potential Committed Effective Dose Equivalent (CEDE) to the offsite population due to NTS activities is estimated annually. Two methods are used to calculate the CEDE to a resident of the community potentially most impacted by airborne releases of radioactivity from the NTS. In the first method, effluent release estimates and meteorological data are used as inputs to EPA's CAP88-PC model. The second method uses data from the ORSP with documented assumptions and conversion factors to calculate the CEDE. Both methods provide an estimate of the CEDE to a hypothetical person who would have to have been continuously present in one outdoor location. In addition, a collective CEDE is calculated by the first method for the total offsite population residing within 80 km (50 mi) of the NTS. Background radiation measurements are used to provide a comparison with the calculated CEDEs. In the absence of detectable releases of radiation from the NTS, the PIC Network provides a measurement of background gamma radiation in the offsite area.

The extensive offsite environmental surveillance system operated around the NTS by EPA EMSL-LV measured no radiation exposures that could be attributed to recent NTS operations. The Committed Effective Dose Equivalent (CEDE) to the maximally exposed offsite residents resulted in a maximum dose of 3.8×10^{-3} mrem (3.8×10^{-5} mSv) to a hypothetical resident of Indian Springs, Nevada 54 km (32 mi) southeast of the NTS CP-I. This value was based on onsite source emission measurements and estimates provided by DOE and calculated by EPA's CAP88-PC model. The calculated population dose (collective effective dose equivalent) to the approximately 21,750 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv). Monitoring network data indicated a 1993 dose of 97 mrem (0.97 mSv) from normal background radiation occurred in Indian Springs. The calculated dose to this individual from world-wide distributions of radioactivity as measured from surveillance networks was 0.054 mrem (5.4×10^{-4} mSv). An additional CEDE of 0.56 mrem (5.6×10^{-3} mSv) would be received if edible tissues from a chukar and contaminated deer collected on the NTS were to be consumed. All of these maximum dose estimates are about one percent of the most restrictive standard.

Onsite source emission measurements, as provided by DOE, are listed in Table 19 and include tritium, radioactive noble gases, and radioiodine. These are estimates of releases made at the point of origin. Meteorological data collected by the Weather Service Nuclear Support Office (WSNSO) were used to construct wind roses, indicating the prevailing winds for the following areas: Desert Rock, Area 12, Area 20, Yucca Flat, and RWMS in Area 5. A calculation of estimated dose from NTS effluents was performed using EPA's CAP88-PC model (EPA 1992). The population living within a radius of 80 km (50 mi) from each of the sources was estimated to be 21,750 individuals, based on 1991 DOC. The collective population dose within 80 km (50 mi) from these sources was calculated to be 1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv). Activity concentrations in air that would cause these calculated doses are much higher than actually detected by the offsite monitoring network. For

Table 19. NTS Radionuclide Discharges and Releases - 1993

Onsite Liquid Discharges

Curies[a]

Containment Ponds	Gross Beta	^{3}H	^{90}Sr	^{137}Cs	^{238}Pu	$^{239+240}Pu$
Area 12, E Tunnel	2.8×10^{-3}	6.0×10^{1}	2.0×10^{-4}	7.8×10^{-4}	1.8×10^{-5}	1.6×10^{-4}
Area 12, N Tunnel		3.6×10^{-1}				2.6×10^{-7}
Area 12, T Tunnel	4.1×10^{-3}	6.5×10^{2}			3.9×10^{-7}	1.2×10^{-5}
TOTAL	6.9×10^{-3}	7.1×10^{2}	2.0×10^{-4}	7.8×10^{-4}	1.8×10^{-5}	1.7×10^{-4}

Airborne Effluent Releases

Facility Name (Airborne Releases)	Curies[a] ^{3}H[b]	^{85}Kr	$^{239+240}Pu$
Area 3[c]			1.0×10^{-3}
Area 5, RWMS[c]	2.9×10^{-1}		
Area 9 Bunker[c]			7.5×10^{-4}
Area 12, P Tunnel Portal[d]	3.7×10^{0}		
Areas 19 and 20, Pahute Mesa[c]		$1.6 \times 10^{+2}$	
TOTAL	4.0×10^{0}	$1.6 \times 10^{+2}$	1.8×10^{-3}

(a) Multiply by 3.7×10^{10} to obtain Bq. Calculated releases of transuranics from laboratory spills and losses are shown in Table 20.

(b) In the form of tritiated water vapor, primarily HTO.

(c) Calculated from air sampler data.

(d) From measurements of air exhausted through ventilation duct.

example, 3.4×10^{-3}mrem of the calculated CEDE to the maximally exposed individual is due to tritium. The annual average HTO in air concentration that would cause this CEDE is 14 times that actually measured in Indian Springs. Table 21 summarizes the annual contributions to the CEDEs due to 1993 NTS operations as calculated using CAP88-PC and the radionuclides listed in Table 19 and Table 20.

Input data for the CAP88-PC model include meteorological data from WSNSO and effluent release data reported by DOE. The effluent release data are estimates and the meteorological

Table 20. Radionuclide Emissions on the NTS - 1993[a]

Radionuclide	Half-Life (years)	Quantity Released (Ci)[b]
	Airborne Releases	
^{3}H	12.35	[c]3.7
^{85}Kr	10.72	160
^{131}I	0.022	[c]2.0×10^{-6}
^{133}Xe	0.0144	0.04
$^{239+240}Pu$	24065	[c]1.8×10^{-3}
	Tunnel Ponds	
^{3}H	12.35	[d]710.
^{238}Pu	87.743	1.8×10^{-5}
$^{239+240}Pu$	24065.	1.7×10^{-4}
^{90}Sr	29	2.0×10^{-4}
^{137}Cs	30.17	7.8×10^{-4}
Gross Beta	--	6.9×10^{-3}

(a) Assumes worst case point and diffuse source releases

(b) Multiply by 37 to obtain Gbq

(c) Includes calculated data from air sampling results and/or postulated loss of laboratory standards

(d) This amount is assumed to evaporate to become an airborne release

data are mesoscale; i.e., representative of an area approximately 40 km (25 mi) or less around the point of collection. However, these data are considered sufficient for model input, primarily because the model itself is not designed for complex terrain such as that on and around the NTS. Errors introduced by the use of the effluent and meteorological data are small compared to the errors inherent in the model. Results obtained by using the CAP88-PC model are considered only estimates of the dose to offsite residents although these results are consistent with the data obtained by offsite monitoring.

8.2 Estimated Dose From ORSP Monitoring Network Data

Potential CEDEs to individuals may be estimated from the concentrations measured by the EPA monitoring networks during 1993. Actual results obtained in analysis are used; the majority of which are less than the reported MDC. Data quality objectives for precision and accuracy are, by necessity, less stringent for values near the MDC so confidence intervals around the input data are

Table 21. Summary of Effective Dose Equivalents from NTS Operations during 1993

	Maximum EDE at NTS Boundary[a]	Maximum EDE to an Individual[b]	Collective EDE to Population within 80 km of the NTS Sources
Dose	4.8×10^{-3} mrem (4.8×10^{-5} mSv)	$3.8 \pm 0.57 \times 10^{-3}$ mrem (3.8×10^{-5} mSv)	1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv)
Location	Site boundary 58 km SSE of NTS Area 12	Indian Springs, 80 km SSE of NTS Area 12	21,750 people within 80 km of NTS Sources
NESHAP[c] Standard	10 mrem per year (0.1 mSv per yr)	10 mrem per year (0.1 mSv per yr)	-----
Percentage of NESHAP	0.05	0.04	-----
Background	97 mrem (0.97 mSv)	97 mrem (0.97 mSv)	1747 person-rem (17.5 person Sv)
Percentage of Background	5.0×10^{-3}	4.0×10^{-3}	6.9×10^{-4}

(a) The maximum boundary dose is to a hypothetical individual who remains in the open continuously during the year at the NTS boundary located 60 km SSE from the Area 12 tunnel ponds.

(b) The maximum individual dose is to a person outside the NTS boundary at a residence where the highest dose-rate occurs as calculated by CAP88-PC (Version 1.0) using NTS effluents listed in Table 20 and assuming all tritiated water input to the Area 12 containment ponds was evaporated.

(c) National Emission Standards for Hazardous Air Pollutants.

broad. The concentrations of radioactivity detected by the monitoring networks and used in the calculation of potential CEDEs are shown in Table 22. The concentrations given in Table 22 are expressed in terms of activity per unit volume, weight, or time. These concentrations are converted to a dose by using the assumptions and dose conversion factors described below. The dose conversion factors assume continuous presence at a fixed location and no loss of radioactivity in meat and vegetables through storage and cooking.

- Adult respiration rate = 8,400 m^3/yr (2.3×10^4 L/day [ICRP 1975]).
- Milk intake for a 10-year old child = 164 L/yr (ICRP 1975).
- Consumption of beef liver = 0.5 lb/wk (11.5 kg/yr).
- An average deer has 100 lb (45 kg) of meat.
- Water consumption for adult-reference man = 2 L/day (approximately 1,900 mL/day [ICRP 1975]).

Table 22. Monitoring Networks Data used in Dose Calculations

Medium	Radionuclide	Concentration	Comment
Animals			
Beef Liver	$^{239+240}Pu$	6.8×10^{-4} pCi/g (2.5×10^{-5} Bq/g)	Concentrations are the maximum concentrations observed for each animal tissue type
Deer Muscle	$^{239+240}Pu$	1.44×10^{-3} pCi/g (5.3×10^{-5} Bq/g)	
Deer Liver	$^{239+240}Pu$	9.48×10^{-4} pCi/g (3.5×10^{-5} Bq/g)	
Chukar	^{3}H	3.3×10^{3} pCi/g (1.2×10^{5} Bq/g)	Maximum measured in one bird
Milk	^{90}Sr	0.55 pCi/L (0.020 Bq/L)	Concentration is the average of all network strontium results
	^{3}H	120 pCi/L (4.4 Bq/L)	Concentration is the average of all network tritium results
Drinking Water	^{3}H	1.2 pCi/L	Concentration is the average of (0.04 Bq/L) results from the two wells in Indian Springs, Nevada
Vegetables			
Broccoli	^{90}Sr	4.8×10^{-3} pCi/g (1.8×10^{-4} Bq/g)	Concentrations are maximum observed for each sample type
Carrots	$^{239+240}Pu$	1×10^{-4} pCi/g (3.7×10^{-6} Bq/g)	
Pears	^{3}H	0.52 pCi/g (0.019 Bq/g)	
Turnips	^{3}H	0.5 pCi/g (0.019 Bq/g)	
Air	^{3}H	0.3 pCi/m^3 (0.011 Bq/m^3)	Concentrations are average of all results from the air network
	^{7}Be	0.3 pCi/m^3 (0.011 Bq/m^3)	
	^{85}Kr	28 pCi/m^3 (0.99 Bq/m^3)	
	^{238}Pu	6.8×10^{-6} pCi/m^3 (2.5×10^{-7} Bq/m^3)	
	$^{239+240}Pu$	3.7×10^{-6} pCi/m^3 (1.4×10^{-7} Bq/m^3)	

- Fresh vegetable consumption for North America = 516 g/day (1.1 lb/day) for a four-month growing season (ICRP 1975).

The CEDE conversion factors are derived from EPA-520/1-88-020 (Federal Guidance Report No. 11). Those used here are:

- ^{3}H: 6.4×10^{-8} mrem/pCi (ingestion or inhalation).
- ^{90}Sr: 1.4×10^{-4} mrem/pCi (ingestion).
- ^{85}Kr: 1.5×10^{-5} mrem/yr/pCi/m^3 (submersion).
- $^{238,239+240}Pu$:
  3.7×10^{-4} mrem/pCi (ingestion).
  3.1×10^{-1} mrem/pCi (inhalation).

The algorithm for the dose calculation is:

(concentration) x (assumption in volume/unit time) x (CEDE conversion factors) = CEDE

As an example calculation, the following is the result of breathing tritium in air:

- $(3 \times 10^{-1}$ pCi/$m^3)$ x (8400 m^3/yr) x $(6.4 \times 10^{-8}$ mrem/pCi) = 1.61×10^{-4} mrem/yr

However, in calculating the inhalation CEDE from ^{3}H, the value is increased by 50 percent to account for absorption through the skin. The total dose in one year, therefore, is 1.61×10^{-4} mrem/yr x 1.5 = 2.4×10^{-4} mrem/yr. Dose calculations from ORSP data are in Table 22.

The dose from consumption of a mule deer and chukar collected on the NTS is not included in Table 21. The individual CEDEs from the various pathways added together give a total of 0.053 mrem/yr. The additional dose from ingestion of deer meat and liver containing the $^{239+240}Pu$ activities given in Table 20 would be:

$$\{[(1.44 \times 10^{-3} \text{ pCi/g}) \times (4.5 \times 10^{4} \text{ g})] + [(9.48 \times 10^{-4} \text{ pCi/g}) \times (280 \text{ g})]\} \times (3.7 \times 10^{-4} \text{ mrem/pCi}) = 2.41 \times 10^{-2} \text{ mrem}$$

The weight of the liver (280 g) used in the above equation is the median weight of the livers from the three mule deer obtained in 1993. For the chukar, assume 250 g edible meat and 10 chukar consumed per individual during the hunting season. The CEDE would be:

3.3×10^{3} pCi/g x 250 g x 10 x 6.4×10^{-8} mrem/pCi = 0.53 mrem

Total CEDEs can be calculated based on different combinations of data. If an individual were interested in just one area, for example, the concentrations from those stations closest to that area could be substituted into the equation.

8.3 Dose from Background Radiation

In addition to external radiation exposure due to cosmic rays and gamma radiation from naturally occurring radionuclides in soil (e.g., ^{40}K, uranium and thorium daughters), there is a contribution from ^{7}Be that is formed in the atmosphere by cosmic ray interactions with oxygen and nitrogen. The annual average ^{7}Be concentration measured by the offsite surveillance network was 0.3 pCi/m^3. With a dose conversion factor for inhalation of 2.6×10^{-7} mrem/pCi, and an annual breathing volume of 8400 m^3/yr, this equates to a dose of 6.6×10^{-4} mrem as calculated in Table 23. This is a negligible quantity when compared with the PIC network measurements that vary from 66 to 166 mR/year, depending on location.

8.4 Summary

The extensive offsite environmental surveillance system operated around the NTS by EPA EMSL-LV detected no radiological exposures that could be attributed to recent NTS operations, but a calculated EDE of 0.053 mrem can be obtained if certain assumptions are made. Calculation with the CAP88-PC model, using estimated or calculated effluents from the NTS during 1993, resulted in a maximum inhalation dose of 3.8×10^{-3} mrem (3.8×10^{-5} mSv) to a hypothetical resident of Indian Springs, NV, 54 km (32 miles) SE of the NTS CP-I. Based on monitoring network data, this dose is calculated to be 0.054 mrem. This latter EDE is about 14 times the dose obtained from CAP88-PC calculation, and is mostly due to inhalation of plutonium. If this individual were also to collect and consume a NTS deer such as the one discussed above, the estimated EDE would increase by another 2.4×10^{-2} mrem (2.4×10^{-4} mSv) to a total possible EDE of about 0.078 mrem (7.8×10^{-4} mSv), and consumption of 10 chukar

Table 23. Dose Calculations from Monitoring Network Data

Medium	Route of Exposure	Radionuclide	Calculation	Dose (EDE) (mrem/yr)
Milk	Ingestion	^{90}Sr	(0.55 pCi/L) x (110 L/year) x (1.4×10^{-4} mrem/pCi)	8.5×10^{-3}
		^{3}H	(120 pCi/L) x (110 L/year) x (6.4×10^{-8} mrem/pCi)	8.4×10^{-4}
Water	Ingestion	^{3}H	(1.2 pCi/L) x 730 L x (6.4×10^{-8} mrem/pCi)	5.6×10^{-5}
Total from Liquid Ingestion				9.4×10^{-3}
Foodstuffs				
Beef Liver	Ingestion	^{238}Pu	(3.3×10^{-5} pCi/g) x (11.5×10^{3} g/yr) x (3.7×10^{-4} mrem/pCi)	1.4×10^{-4}
		$^{239+240}Pu$	(6.8×10^{-4} pCi/g) x (11.5×10^{3} g/yr) x (3.7×10^{-4} mrem/pCi)	2.9×10^{-3}
Broccoli[a]	Ingestion	^{90}Sr	(4.8×10^{-3} pCi/g) x (129 g/day) x (125 days/yr) x (1.4×10^{-4} mrem/pCi)	1.1×10^{-2}
Carrots[a]	Ingestion	$^{239+240}Pu$	(9.84×10^{-5} pCi/g) x (129 g/day) x (125 days/yr) x (3.7×10^{-4} mrem/pCi)	5.9×10^{-4}
Pears[a]	Ingestion	^{3}H	(0.52 pCi/g) x (129 g/day) x (125 days/yr) x (6.4×10^{-8} mrem/pCi)	5.4×10^{-4}
Turnips[a]	Ingestion	^{3}H	(0.50 pCi/g) x (129 g/day) x (125 days/yr) x (6.4×10^{-8} mrem/pCi)	5.2×10^{-4}
Total from Foodstuff Consumption				1.6×10^{-2}
Air	Submersion/ Inhalation	^{3}H	(3×10^{-1} pCi/m^3 x 8400 m^3/yr x 1.5 x 6.4 x 10^{-8} mrem/pCi)	2.4×10^{-4}
		^{7}Be	(0.3 pCi/m^3) x 8400 m^3/yr x (2.6×10^{-7} mrem/pCi)	6.6×10^{-4}
	Submersion	^{85}Kr	(2.8×10^{1} pCi/m^3 x 1.5×10^{-5} mrem/yr per pCi/m^3)	4.2×10^{-4}
	Inhalation	^{238}Pu	(6.8×10^{-6} pCi/m^3 x 8400 m^3/yr x 3.1×10^{-1} mrem/pCi)	1.8×10^{-2}
	Inhalation	$^{239+240}Pu$	(3.7×10^{-6} pCi/m^3 x 8400 m^3/yr x 3.1×10^{-1} mrem/pCi)	9.6×10^{-3}
Total from Air				2.9×10^{-2}
Total from Ingestion, Inhalation, Absorption and Submersion			5.4×10^{-2}	

(a) The fruit and vegetable intake of 516 g/d was split between all fruits and vegetables and the number of days used for consumption was 125, slightly more than 4 months.

with the maximum ^{3}H content would add 0.53 mrem for a total of 0.61 mrem. This maximum dose estimate is less than 1 percent of the International Commission on Radiological Protection (ICRP) recommendation that an annual effective dose equivalent for the general public not exceed 100 mrem/yr (ICRP 1985). The calculated population dose (collective effective dose equivalent) to the approximately 21,750 residents living within 80 km (50 mi) of each of the NTS airborne emission sources was 1.2×10^{-2} person-rem (1.2×10^{-4} person-Sv). Background radiation would yield a CEDE of 1747 person-rem (17.5 person-Sv).

Data from the PIC gamma monitoring indicated a 1993 dose of 97 mrem from background gamma radiation measured in Indian Springs. This gamma background value is derived from an average PIC field measurement of 8.9 μR/hr. The 0.054 mrem CEDE calculated from the monitoring networks and model as discussed above is a negligible amount by comparison.

The uncertainty (2σ) for the PIC measurement at the 97 mrem exposure level is approximately 6 percent. Extrapolating to the calculated annual exposure at Indian Springs, Nevada, yields a total uncertainty of approximately 4.5 mrem. Because the estimated dose from NTS activities is less than 1 mrem (the lowest level for which DQOs are defined, as given in Chapter 11) no conclusions can be made regarding the achieved data quality as compared to the DQO for this insignificant dose.

9.0 Weapons Test and Liquefied Gaseous Fuels Spills Facility Support

Nonradiological monitoring was conducted in 1993 for four tests conducted at the Liquified Gaseous Fuels Spill Test Facility (LGFSTF) on the NTS.

9.1 Weapons Tests Support

For each test the EMSL-LV provided an advisor on offsite public health and safety for the Operations Controller's Test Safety Review Panel. At the beginning of each test series and at other tests depending on projected need, a field monitoring technician from the EPA with appropriate air sampling equipment was deployed downwind of the test at the NTS boundary to measure chemical concentrations that may have reached the offsite area. Based on wind direction and speed, the boundary monitor was instructed to collect samples at the time of projected maximum concentration. Samples were collected with a hand-operated Dräger pump and sampling tube appropriate for the chemical being tested. Not all tests were monitored by EPA if professional judgement indicated that, based on previous experience with the chemical and the proposed test parameters, NTS boundary monitoring was unnecessary.

The EPA field monitoring technicians at the NTS boundary, in contact by two-way radio, were placed at the projected cloud center line at the time when the cloud was expected at the boundary, so the air samples would be collected at the time and place of maximum concentration. The exact location of the boundary monitor was adjusted during the test by use of two-way radio to ensure that monitoring was performed at the projected cloud center line. To determine the feasible remedial actions for an area, EPA uses its best judgment based on experience gained during atmospheric tests and from those tests conducted in the 1960s that contaminated offsite areas. No remedial actions have been necessary since 1970. However, through routine contact with offsite residents and through continuing population and road surveys, EPA maintains a sense of the degree to which it could implement remedial actions and the kind of cooperation that would be provided by officials and residents of the area.

9.2 Liquefied Gaseous Fuels Spills Test Facility Support

The LGFSTF in Area 5 is a source of potential release of nonradiological contaminants to the environment, depending on the individual tests conducted. In 1993 there were four tests all involving carbon dioxide conducted at this facility. Monitoring was performed at the NTS boundary by the EMSL-LV to assure these contaminants did not move to offsite areas.

The LGFSTF was established in the Frenchman Basin in Area 5 as a basic research tool for studying the dynamics of accidental releases of various hazardous materials and the effectiveness of mitigation procedures. The LGFSTF was designed and equipped to: (1) discharge a measured volume of a hazardous fluid at a controlled rate on a specially prepared surface; (2) monitor and record down-wind gaseous concentrations, operating data, and close-in/down-wind meteorological data; and (3) provide a means to control and monitor these functions from a remote location.

DOE/NV provides the facilities, security, and technical support, but all costs are borne by the organization conducting the tests. In 1993 four tests were conducted involving carbon dioxide. The plans for each test series were examined by an Advisory Panel that consisted of DOE/NV and EMSL-LV professional personnel augmented by personnel from the organization performing the tests.

10. Public Information and Community Assistance Programs

10.1 Community Radiation Monitoring Program

Because of the successful experience with the Citizen's Monitoring Program during the purging of the TMI containment in 1980, the Community Radiation Monitoring Program (CRMP) consisting of 15 monitoring stations located in the states of California, Nevada and Utah was begun. Today there are 18 stations located in these three states (see Figure 45). The CRMP is a cooperative project of the DOE, EPA, DRI, and University of Utah.

The DOE sponsors the program. The EPA provides technical and scientific direction, maintains the instrumentation and sampling equipment, analyzes the collected samples, and interprets and reports the data. The DRI administers the program by hiring the local station managers and alternates, securing rights-of-way, providing utilities, and performing additional quality assurance checks of the data. The University of Utah provides detailed training twice a year for the station managers and alternates on all issues related to nuclear science, radiological health, and radiation monitoring.

Each station is operated by a local resident, in most cases a high-school science teacher. Samples are analyzed at the EMSL-LV Radioanalysis Laboratory. Data interpretation is provided by DRI to the communities involved. All of the 18 CRMP stations have one of the samplers for the ASN, NGTSN, on either routine or standby status, and TLD networks. In addition a PIC and recorder for immediate readout of external gamma exposure and a recording barograph are located at the station.

All of the equipment is mounted on a stand at a prominent location in each community so the residents are aware of the surveillance and, if interested, can check the data. Also, computer-generated reports of the PIC data are issued weekly for each station as explained above.

10.2 Community Education Outreach Program

DOE sponsors Public Information Presentations which are forums for increasing the public's awareness of NTS activities, disseminating radiation monitoring results, and addressing concerns of residents related to environmental radiation and possible health effects. These public information presentations were initiated in February of 1982 in the form of town hall meetings. Between 1982 and 1990, 95 town hall meetings were held in the communities surrounding the NTS in the states of Arizona, California, Nevada, and Utah.

In the fall of 1990 the focus of this outreach program was changed. Rather than a single subject presented at general town hall meetings, audiences from schools, service clubs, and civic groups from the various communities were targeted and offered presentations on many different subjects. Table 24 lists the outreach presentations conducted in 1993. A list of presentation subjects is provided in Table 25. An annual report on the CRMP and outreach program is published by the DRI under the name "Community Radiation Monitoring Program Annual Report for FY 19xx," with a report number such as DOE/NV-10845-xx, which may be obtained from either DRI or DOE/NV.

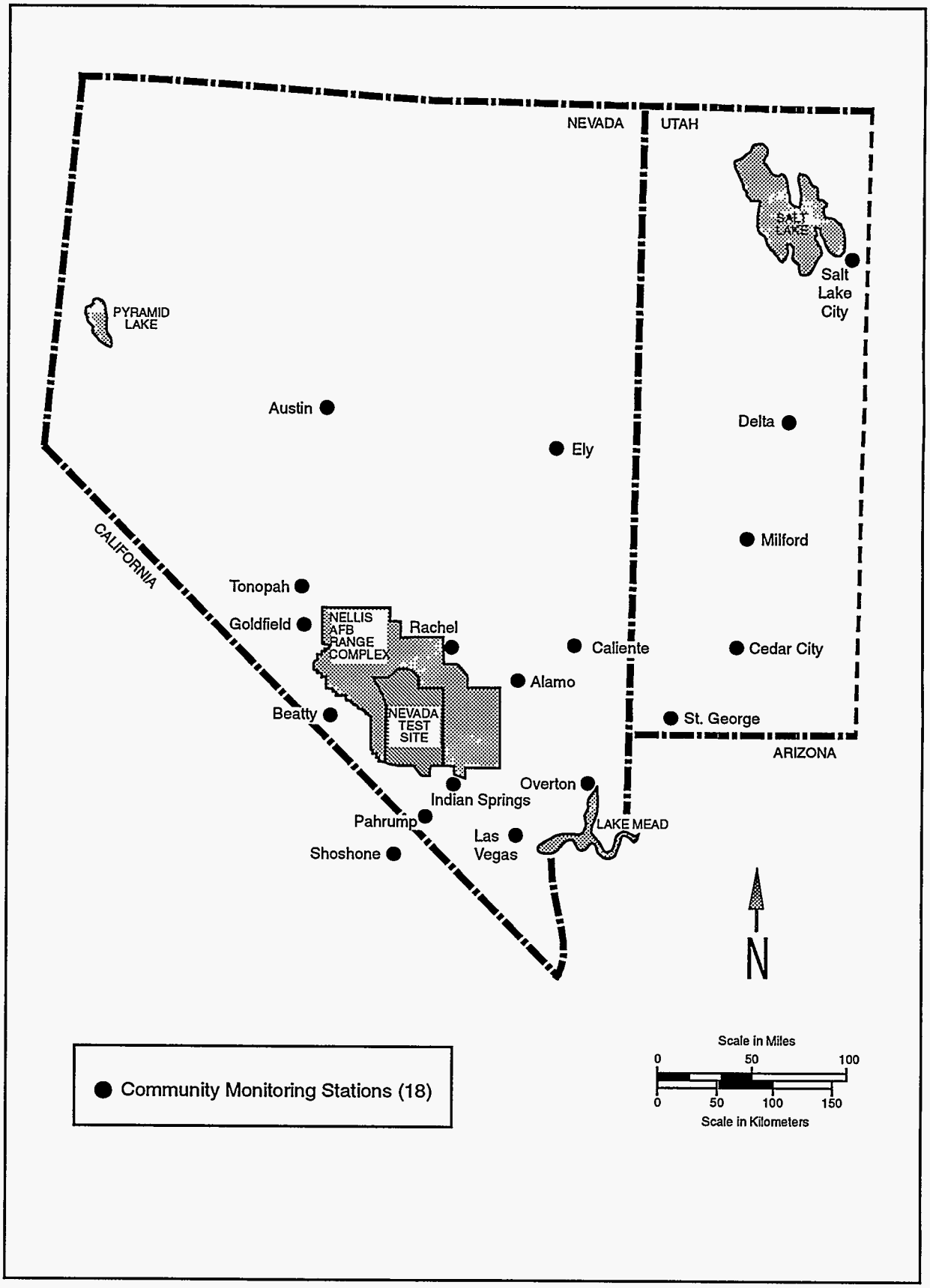


Figure 45. Community Monitoring Station Locations - 1993

Table 24. Community Radiation Monitoring Program Outreach Presentations - 1993

Date	Location	Audience	Subject	Attendance
01/16	Henderson, Nevada	Iota Chapter of Beta Sigma Phi	NTS Deer Migration Study	20
01/29	St. George, Utah	Utah State Teachers Assn.	NTS Activities and Related Matters	36
01/29	St. George, Utah	Utah State Teachers Assn.	ABC's of Radiation	20
02/25	Ely, Nevada	Ely Middle School	ABC's of Radiation	94
04/27	Beatty, Nevada	Beatty High School	Careers in Science and Engineering	22
06/13	Tonopah, Nevada	Tonopah Rotary Club	Consumer Electronic Product Radiation	22
11/17	Cedar City, Utah	Cedar City High School	Pack Rat Midden	38
11/17	Cedar City, Utah	Exchange Club	Pack Rat Midden	20
11/19	Alamo, Nevada	Alamo High School	Hydrology	94
11/23	Las Vegas, Nevada	Bonanza High School	Archaeology at the NTS	516
12/13	Beatty, Nevada	Beatty High School	Photography	21
			Attendance Total	903

Table 25. Community Radiation Monitoring Program Presentation Topics

ABC's of Radiation. Radiation explained in understandable terms; when it is dangerous and when it is not.
Testing Nuclear Weapons. How nuclear weapons are tested (safely) on the Nevada Test Site (NTS).
Joint Verification Experiment. Interaction with the USSR during exchange of weapons tests at the NTS and the USSR.
Downwind Radiation Exposures and Legislation. The different studies that have been done to calculate the radiation exposures to people who were living in the downwind area during atmospheric testing.
Offsite Radiation Monitoring and the Community Monitoring Program. The offsite monitoring program which is performed by the Environmental Protection Agency in areas and communities surrounding the NTS. The Community Radiation Monitoring Program details how science teachers and local residents in Nevada, California, and Utah have been and are involved in understanding activities on the NTS.
Hiroshima-Nagasaki Experience. Predicted radiation effects based on the Japanese data.
Environmental Restoration. Current environmental restoration programs on the NTS and those planned for the future.
Onsite Environmental Monitoring. The NTS onsite environmental monitoring program.
Consumer Electronic Product Radiation. Risks and benefits of safe usage of common household electronic products.
NTS Archaeology. Prehistory and cultural resources of the southern great basin and NTS that also includes studies of pack rat middens.
NTS Hydrology. Groundwater flow studies and subsurface contamination on the NTS and surrounding areas.
Surficial Radioactive Contamination. Occurrence of radioactive contamination on the NTS and surrounding area as a result of weapons testing.
NTS Deer Migration Study. Seven year deer tagging study to understand migration patterns.
Low Level Waste. A description of how low level waste is managed and controlled at the Low Level Waste Management Site on the NTS.
Emergency Response Training. The training program for Nevada policemen and firemen who are first-on-the-scene accident responders.

11 Quality Assurance

11.1 Policy

One of the major goals of the EPA is to ensure that all agency decisions which are dependent on environmental data are supported by data of known quality. Agency policy initiated by the Administrator in memoranda of May 30, 1979, and June 14, 1979, requires participation in a centrally managed QA Program by all EPA Laboratories, Program Offices, Regional Offices, and those monitoring and measurement efforts supported or mandated through contracts, regulations, or other formalized agreements. Further, by EPA Order 5360.1, Agency policy requires participation in a QA Program by all EPA organizational units involved in environmental data collection.

The QA policies and requirements of EPA's EMSL-LV are summarized in the *Quality Assurance Program Plan* (EPA, 1987). Policies and requirements specific to the ORSP are documented in the *Quality Assurance Program Plan for the Nuclear Radiation Assessment Division Offsite Radiation Safety Program* (EPA, 1992). The requirements of these documents establish a framework for consistency in the continuing application of quality assurance standards and procedures in support of the ORSP. Administrative and technical procedures based on these QA requirements are maintained in appropriate manuals or are described in SOPs. It is NRD policy that personnel adhere to the requirements of the QA Plan and all SOPs applicable to their duties to ensure that all environmental radiation monitoring data collected by the EMSL-LV in support of the ORSP are of adequate quality and properly documented for use by the DOE, EPA, and other interested parties.

11.2 Data Quality Objectives

Data quality objectives (DQOs) are statements of the quality of data a decision maker needs to ensure that a decision based on that data is defensible. Data quality objectives are defined in terms of representativeness, comparability, completeness, precision, and accuracy. Representativeness and comparability are generally qualitative assessments while completeness, precision, and accuracy may be quantitatively assessed. In the ORSP, representativeness, comparability, and completeness objectives are defined for each monitoring network. Precision and accuracy are defined for each analysis type or radionuclide.

Achieved data quality is monitored continuously through internal QC checks and procedures. In addition to the internal QC procedures, NRD participates in external intercomparison programs. One such intercomparison program is managed and operated by a group within EMSL-LV. These external performance audits are conducted as described in and according to the schedule contained in "Environmental Radioactivity Laboratory Intercomparison Studies Program" (EPA, 1992a). The analytical laboratory also participates in the DOE Environmental Measurements Laboratory (EML) Quality Assurance Program in which real or synthetic environmental samples that have been prepared and thoroughly analyzed are distributed to participating laboratories. Periodically (every two or three years) external systems and performance audits are conducted for the TLD network as part of the certification requirements for DOE's Laboratory Accreditation Program (DOELAP).

11.2.1 Representativeness, Comparability, and Completeness Objectives

Representativeness is defined as "the degree to which the data accurately and precisely represent a characteristic of a parameter, variation of a property, a process characteristic, or an operation condition" (Stanley and Verner, 1985). In the ORSP, representativeness may be considered to be the degree to which the collected samples represent the radionuclide activity concentrations in the offsite environment. Collection of samples representative of all possible pathways to human exposure as well as direct measurement of offsite resident exposure through the TLD and internal dosimetry monitoring programs provides assurance of the representativeness of the calculated exposures.

Comparability is defined as "the confidence with which one data set can be compared to another"

(Stanley and Verner, 1985). Comparability of data is assured by use of SOPs for sample collection, handling, and analysis; use of standard reporting units; and use of standardized procedures for data analysis and interpretation. In addition, another aspect of comparability is examined through long-term comparison and trend analysis of various radionuclide activity concentrations, and TLD, and PIC data. Use of SOPs, maintained under a document control system, is an important component of comparability, ensuring that all personnel conform to a unified, consistent set of procedures.

Completeness is defined as "a measure of the amount of data collected from a measurement process compared to the amount that was expected to be obtained under the conditions of measurement" (Stanley and Verner, 1985). Data may be lost due to instrument malfunction, sample destruction, loss in shipping or analysis, analytical error, or unavailability of samples. Additional data values may be deleted due to unacceptable precision, accuracy, or detection limit or as the result of application of statistical outlier tests. The completeness objective for all networks except the LTHMP is 90%. The completeness objective for the LTHMP is 80%; a lower objective has been established because dry wells or access restrictions occasionally preclude sample collection.

11.2.2 Precision and Accuracy Objectives of Radioanalytical Analyses

Measurements of sample volumes should be accurate to ± 5% for aqueous samples (water and milk) and to ± 10% for air and soil samples. The sensitivity of radiochemical and gamma spectrometric analyses must allow no more than a 5% risk of either a false negative or false positive value. Precision to a 95% confidence interval, monitored through analysis of duplicate and blind samples, must be within ± 10% for activities greater than 10 times the minimum detectable concentration (MDC) and ± 30% for activities greater than the MDC but less than 10 times the MDC. There are no precision requirements for activity concentrations below the MDC, which by definition cannot be distinguished from background at the 95% confidence level. Control limits for accuracy, monitored with matrix spike samples, are required to be no greater than ± 20% for all gross alpha, gross beta, and gamma spectrometric analyses, depending upon the media type.

At concentrations greater than 10 times the MDC, precision is required to be within ± 10% for:

- Conventional Tritium Analyses
- Uranium
- Thorium (all media)
- Strontium

and within ± 20% for:

- Enriched Tritium Analyses
- Strontium (in milk)
- Noble Gases
- Plutonium.

At concentrations less than 10 times the MDC, both precision and accuracy are expressed in absolute units, not to exceed 30% of the MDC for all analyses and all media types.

11.2.3 Quality of Dose Estimates

The allowable uncertainty of the effective dose equivalent to any human receptor is ± 0.1 mrem annually. This uncertainty objective is based solely upon the precision and accuracy of the data produced from the surveillance networks and does not apply to uncertainties in the model used, effluent release data received from DOE, or dose conversion factors. Generally, effective dose equivalents must have an accuracy (bias) of no greater than 50% for annual doses greater than or equal to 1 mrem but less than 5 mrem and no greater than 10% for annual doses greater than or equal to 5 mrem.

11.3 Data Validation

Data validation is defined as "A systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use." Data validation consists of data editing, screening, checking, auditing, verification, certification, and review (Stanley et al; 1983). Data validation procedures are documented in SOPs. All data are reviewed and checked at various steps in the collection, analysis, and reporting processes.

The first level of data review consists of sample tracking; e.g., that all samples planned to be collected are collected or reasons for noncollection are documented; that all collected samples are delivered to Sample Control and are entered into

the appropriate data base management system; and that all entered information is accurate. Next, analytical data are reviewed by the analyst and by the laboratory supervisor. Checks at this stage include verifying that all samples received from Sample Control have been analyzed or reasons for nonanalysis have been documented; that data are "reasonable" (e.g., within expected range), and that instrumentation operational checks indicate the analysis instrument is within permissible tolerances. Discrepancies indicating collection instrument malfunction are reported to the Field Operations Branch. Analytical discrepancies are resolved; individual samples or sample batches may be reanalyzed if required.

Raw data are reviewed by a designated media expert. A number of checks are made at this level, including:

1. Completeness - all samples scheduled to be collected have, in fact, been collected and analyzed or the data base contains documentation explaining the reasons for noncollection or nonanalysis.

2. Transcription errors - checks are made of all manually entered information to ensure that the information contained in the data base is accurate.

3. Quality control data - field and analytical duplicate, audit sample, and matrix blank data are checked to ensure that the collection and analytical processes are within specified QC tolerances.

4. Analysis schedules - lists of samples awaiting analysis are generated and checked against normal analysis schedules to identify backlogs in analysis or data entry.

5. Unidentified malfunctions - sample results and diagnostic graphics of sample results are reviewed for reasonableness. Conditions indicative of instrument malfunction are reported to Field and/or Laboratory Operations.

Once the data base has been validated, the data are compared to the DQOs. Completeness, accuracy, and precision statistics are calculated. The achieved quality of the data is reported at least annually. If data fail to meet one or more of the established DQOs, the data may still be used in data analysis; however, the data and any interpretive results are to be qualified.

All sample results exceeding the natural background activity range are investigated. If data are found to be associated with a non-environmental condition, such as a check of the instrument using a calibration source, the data are flagged and are not included in calculations. Only data verified to be associated with a non-environmental condition are flagged; all other data are used in calculation of averages and other statistics, even if the condition is traced to a source other than the NTS (for example, higher-than-normal activities were observed for several radionuclides following the Chernobyl accident). When activities exceeding the expected range are observed for one network, the data for the other networks at the same location are checked. For example, higher-than-normal-range PIC values are compared to data obtained by the air, noble gas, TLD, and tritium-in-air samplers at the same location.

Data are also compared to previous years' data for the same location using trend analysis techniques. Other statistical procedures may be employed as warranted to permit interpretation of current data as compared to past data. Trend analysis is made possible due to the length of the sampling history, which in some cases is 30 years or longer.

Data from the offsite networks are used, along with NTS source emission estimates prepared by DOE, to calculate or estimate annual committed effective dose equivalents to offsite residents. Surveillance network data are the primary tools for the dose calculations. Additionally, EPA's CAP88-PC model (EPA, 1992) is used with local meteorological data to predict doses to offsite residents from NTS source term estimates. An assessment of the uncertainty of the dose estimate is made and reported with the estimate.

11.4 Quality Assessment Of 1993 Data

Data quality assessment is associated with the regular QA and QC practices within the radioanalytical laboratory. The analytical QC plan, documented in SOPs, describes specific procedures used to demonstrate that data are within prescribed requirements for accuracy and precision. Duplicate samples are collected or prepared

and analyzed in the exact manner as the regular samples for that particular type of analysis. Data obtained from duplicate analyses are used for determining the degree of precision for each individual analysis. Accuracy is assessed by comparison of data from spiked samples with the "true" or accepted values. Spiked samples are either in-house laboratory blanks spiked with known amounts of radionuclides, or QC samples prepared by other organizations in which data are compared between several laboratories and assessed for accuracy.

Achieved data quality statistics are compiled on a quarterly and annual basis. This data quality assessment is performed as part of the process of data validation, described in Section 11.3. The following subsections describe the achieved data quality for 1993.

11.4.1 Completeness

Completeness is calculated as:

$$\%C = \left(\frac{V}{n}\right) x\ 100$$

where:
$\%C$ = *percent completeness*
V = *number of measurements judged valid*
n = *total number of measurements*

The percent completeness of the 1993 data is given in Table 26. Reasons for sample loss include instrument malfunction, inability to gain site access, monitoring technician error, or laboratory error. Completeness is not applicable to the Internal Dosimetry Network, as all individuals who request a whole body or lung count receive one, resulting in a completeness of 100 percent by definition.

The achieved completeness of over 93 percent for the LTHMP exceeds the DQO of 80 percent. If the wells which have been shut down by DOE are included the completeness becomes 85 percent overall but only 75 percent for onsite wells.

Overall completeness for the routine Air Surveillance Network was greater than 97 percent, exceeding the DQO of 90 percent. Individually, all stations exceeded 95 percent data recovery and four stations achieved completeness of 100 percent. Plutonium analyses, conducted on composited filters from selected routine and standby air stations, were over 97 percent complete, exceeding the DQO of 90 percent.

Overall, the noble gas network met the DQO of 90 percent completeness. On an individual station basis, data recovery was over 90 percent for seven routine sampling locations, and greater than 80 percent for another nine routine sampling locations, and greater than 79 percent for another four routine sampling locations. The achieved completeness for the atmospheric moisture network was 88 percent, slightly below the DQO of 90 percent.

Overall data recovery for the MSN was less than the DQO of 90 percent. Many of the milk sampling locations consist of family-owned cows or goats that can provide milk only when the animal is lactating. Less than 75 percent of the total possible number of samples were collected from six ranches: Dahl (Alamo, Nevada), Lemon (Dyer, Nevada), John Deer (Amargosa Valley, Nevada), Frayne (Goldfield, Nevada), Brown (Benton, California), and Blue Eagle (Currant, Nevada). Annual means for these locations individually cannot be considered to be representative of the year. However, the milkshed may be adequately represented if an alternate location in the area was sampled when the primary station could not supply milk.

All of the animals scheduled for collection in the AIP were collected, with the exception of a mule deer from the NTS in the fourth quarter of 1993. No deer were found that could be collected on two separate hunting trips. Overall completeness exceeded the DQO of 90 percent.

The achieved completeness of over 98 percent for the PIC Network exceeds the DQO of 90 percent. The redundant data systems used in the PIC Network (i.e., satellite telemetry, magnetic tape or card data acquisition systems, and strip charts) are responsible for the high rates of recovery. Gaps in the satellite transmissions are filled by data from the magnetic tape or card media. If necessary, strip charts would be digitized to fill gaps if data were not available from either of the other two sources; however, no digitized data were needed in 1993.

Table 26. Data Completeness of Offsite Radiological Safety Program Networks

Network	Number of Sampling Locations	Total Samples Possible	Valid Samples Collected	Percent Completeness
LTHMP[b]	271	479	447	93.3
Air Surveillance	30	10,950 days[c]	10,666	97.4
	17 ($^{238, 239+240}$Pu)[d]	75	73	97.3
Noble Gas	13[e]	676	613	90.7
Atmospheric Moisture	21[f]	756	665	88.0
Milk Surveillance	24	304	228	75.0
Animal Investigation	[g]	101	92	91.1
PIC	27[h]	52 (weeks)	1370	98.0

(a) The Data Quality Objectives (DQO) for completeness for monitoring networks summarized in this table are 90 percent.

(b) Does not include wells which were shut down by DOE for part or all of the year (see Section 9.5.2), nor unoccupied residences in Mississippi (see Section 9.6.7).

(c) Continuous samplers with samples collected at intervals of approximately one week. Days used as units to account for differences in sample interval length.

(d) Includes three quarters (January 1993 through September 1993) of data for 13 standby network locations and four routine sampling locations.

(e) Thirteen stations are operated on a routine basis and another eight are operated one week per quarter.

(f) Fourteen stations are operated on a routine basis and another seven are operated one week per quarter.

(g) Includes four mule deer (three from the Nevada Test Site and one from offsite) and eight cows (four from each of two locations). Does not include bighorn sheep, fruits and vegetables, and other animals which are "samples of opportunity."

(h) Continuous samplers with data summarized on a weekly basis.

(*) Data for three quarters.

11.4.2 Precision

Precision is monitored through analysis of duplicate samples. Field duplicates (i.e., a second sample collected at the same place and time and under the same conditions as the routine sample) are collected in the ASN, LTHMP, and MSN. For the ASN, a duplicate sampler is collocated with the routine sampler at randomly selected sites for a period of one to three months to provide the field duplicate. A total of four samplers is used; these second samplers are moved to various site locations throughout the year. Noble gas and atmospheric moisture samples are split to provide duplicate samples for analysis; the number of duplicates is limited by the number of routine samples which contain sufficient volume to permit division into two samples. In 1993, an experiment was conducted to see if a composite sample composed of the three noble gas bottles collected over 56-hour increments could be used as a "duplicate" sample for comparison to the fourth bottle, collected over the entire one-week sampling period. Animal tissue, vegetable, and bioassay (urine) samples are also split after processing, if the volume of material is sufficient. Two TLDs, each with three identical phosphors, are deployed to each fixed station, providing a total of six replicates. In lieu of field duplicates, precision for the PICs is determined by the variance of measurements over a specific time interval when only background activities are being measured. Precision may also be determined from repeated analyses of routine or laboratory spiked samples. The spiked QC samples are generally not blind to the analyst; i.e., the analyst both recognizes the sample as a QC sample and knows the expected (theoretical) activity of the sample.

Precision is expressed as percent relative standard deviation (%RSD), also known as coefficient of variation, and is calculated by:

$$\%RSD = \left(\frac{std.\ dev.}{mean}\right) x\ 100$$

The precision or %RSD (also called Coefficient of Variation) is not reported for duplicate pairs in which one or both results are less than the MDC of the analysis. For most analyses, the DQOs for precision are defined for two ranges: values greater than or equal to the MDC but less than ten times the MDC and values equal to or greater than ten times the MDC. The %RSDs is partially dependent on statistical counting uncertainty so it is expected to be more variable for duplicate analyses of samples with low activities.

Figure 46 displays %RSDs for LTHMP field and spiked sample duplicate pairs analyzed by the conventional tritium method. This figure includes one matrix spike sample pair with a mean equal to or greater than ten times the MDC and 54 pairs of matrix spike samples and two field duplicate pairs with means equal to or greater than the MDC but less than ten times the MDC. The %RSD for the one pair with mean equal to or greater than 10 times the MDC was less than one percent, well within the DQO of ten percent. All pairs with means greater than the MDC but less than ten times the MDC yielded %RSDs of less than 15 percent; the DQO for precision of samples in this activity range is 30 percent.

Figure 47 displays %RSDs for duplicate pairs analyzed by the enriched tritium method. All 31 matrix spike sample duplicate pairs had means equal to or greater than ten times the MDC; all %RSDs were within the DQO of 20 percent. In addition, eight field duplicate pairs had means equal to or greater than ten times the MDC. The %RSDs of these pairs were all less than 8 percent. Of 19 field duplicate pairs with means equal to or greater than the MDC but less than ten times the MDC, all were within the DQO of 30 %RSD, and only two %RSDs were greater than 20 percent.

In the ASN, field duplicate pairs are analyzed for gross alpha, gross beta, and gamma-emitting radionuclides. Figure 48 shows the %RSD distribution for gross alpha field duplicate analyses. Of 52 field duplicate pairs with means greater than or equal to the MDC but less than ten times the MDC, 44 pairs had %RSD of less than 40 percent. Figure 49 displays %RSDs for gross beta analyses of the 17 field duplicate pairs with means equal to or greater than ten times the MDC and the 125 field duplicate pairs with means equal to or greater than the MDC but less than ten times the MDC. All but one of the pairs with means equal to or greater than ten times the MDC yielded %RSDs of less than 20 percent. Of the 125 pairs with means equal to or greater than the MDC but less than ten times the MDC, the %RSDs for 113 pairs was less than 30 percent. Of the nine field duplicate pairs with ^{7}Be activities greater than or equal to 10 MDC, all yielded %RSDs less than 20 percent and, of these, all but one were less than 10 %RSD.

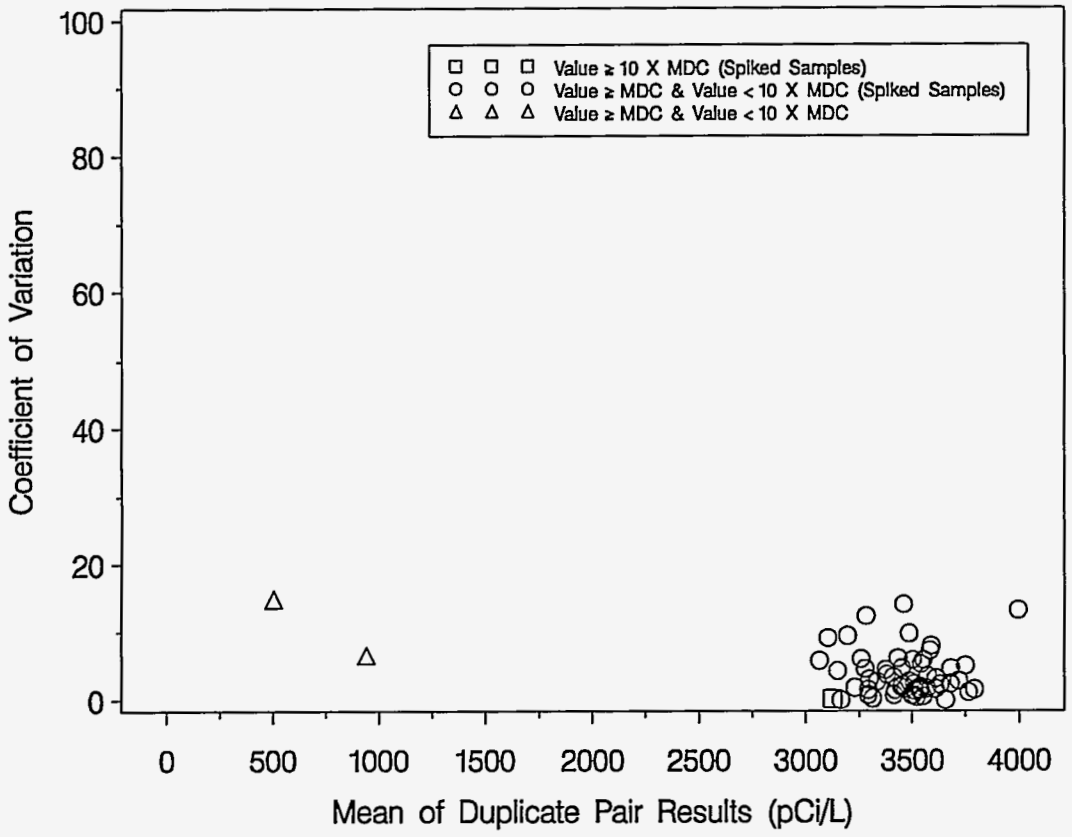


Figure 46. Precision results for conventional method tritium.

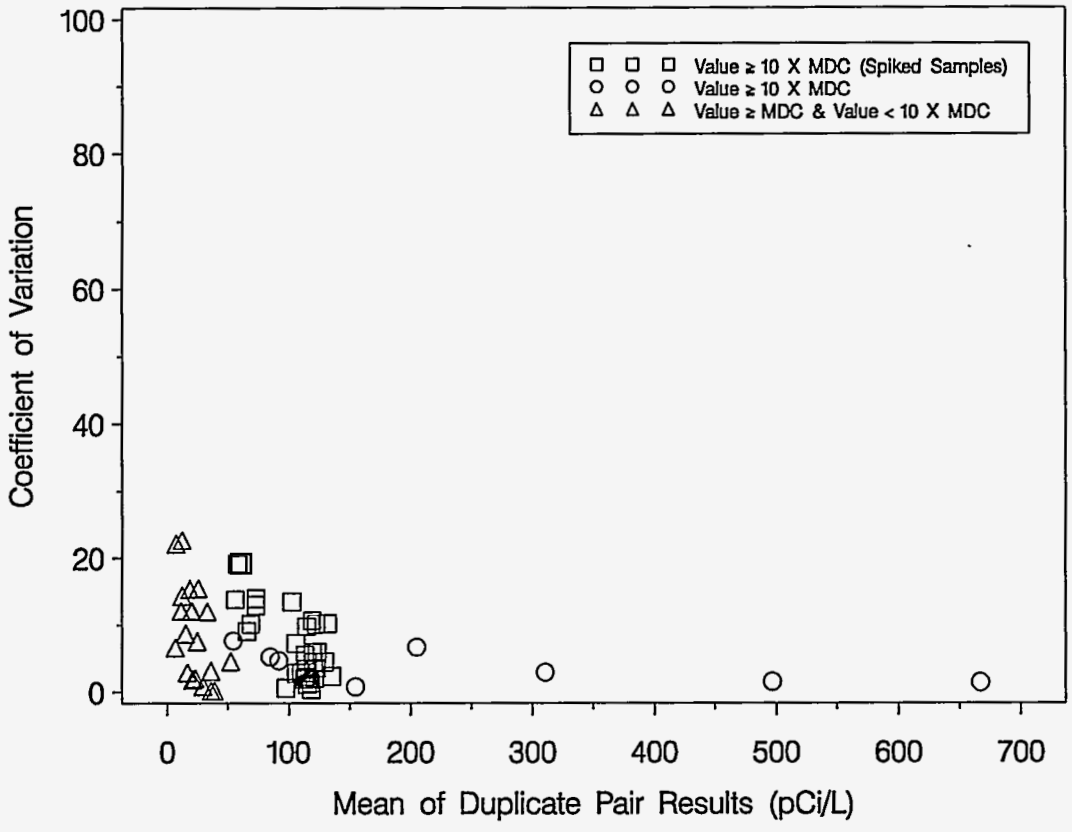


Figure 47. Precision results for enriched method tritium in water.

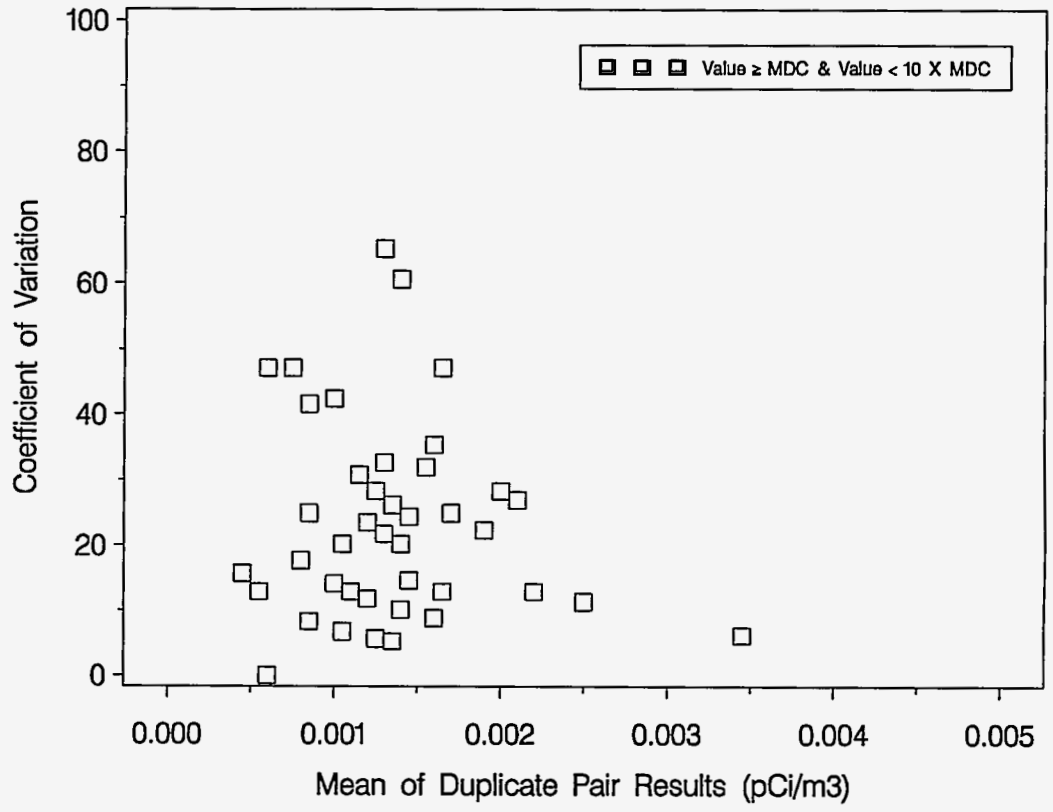


Figure 48. Precision results for alpha in air.

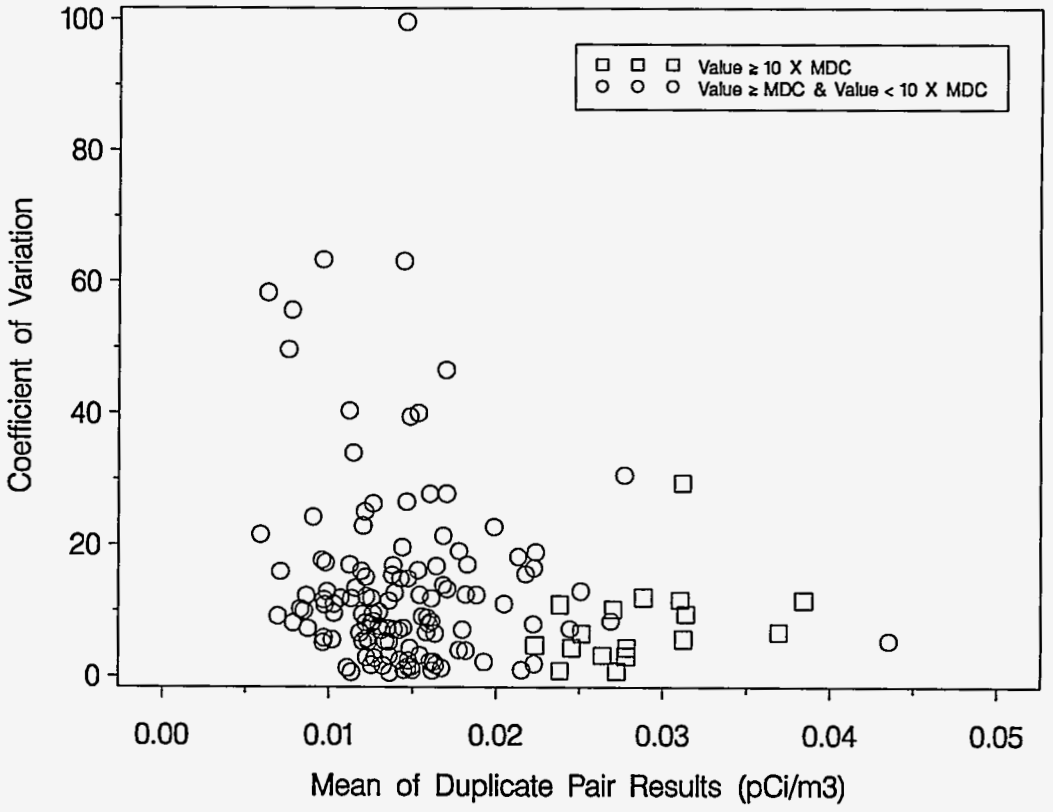


Figure 49. Precision results for beta in air.

In addition to analysis of field duplicate pairs, selected routine sample filters are analyzed twice for gross alpha, gross beta, and gamma-emitting radionuclides. Of 80 duplicate analyses for gross alpha with results greater than or equal to MDC but less than 10 MDC, 68 yielded %RSDs of less than 40 percent. Of 168 duplicate analyses for gross beta with means greater than or equal to MDC but less than 10 MDC, all but five yielded %RSDs of less than 20 percent. In addition, nine duplicate analyses for gross beta yielded means greater than or equal to 10 MDC; the %RSDs for these pairs were all less than 10 percent. Seven duplicate gamma spectrometry analyses yielded ^{7}Be results with means greater than or equal to 10 MDC and the %RSDs for these pairs were less than 20 percent.

In 1993, precision estimates for noble gas samples were made by two methods. As an experiment, the three bottles collected over consecutive 56-hour increments were composited; results were compared to the results obtained for Bottle 4 which collected samples over the entire one-week sampling period. As in previous years, estimates of precision were obtained from sample splits. The range of %RSDs for the 44 composited sample pairs was 0.1 to 20.3 percent while the range for the 23 split sample pairs was 0.8 to 19.5 percent. All duplicate sample pairs had means greater than or equal to MDC but less than 10 MDC. The DQO for this activity range is 30 percent; all %RSDs for both methods were well within this DQO. Figure 50 displays the %RSDs for the composited sample pairs and Figure 51 displays %RSDs for the split sample pairs.

All split samples analyzed for the atmospheric moisture network yielded means that were less than the MDC. By definition, no DQOs are established for activities less than the MDC.

None of the field duplicate pairs from the MSN and SMSN analyzed for tritium or ^{90}Sr yielded results equal to or greater than the MDC. Total potassium was measured at concentrations ≥10 MDC in 68 field duplicate pairs and in 39 duplicate analyses. All but one pair had %RSD of less than 25 percent and 93 pairs yielded %RSD of less than 10 percent. The %RSD results for the field duplicate pairs are shown in Figure 52. The DQO for these is ≤10%.

Duplicate samples of mule deer and cattle bone and cattle liver were prepared and analyzed to estimate precision for the AIP. The bone and liver ash samples were analyzed for ^{238}Pu and $^{239+240}$Pu; bone ash samples were additionally analyzed for ^{90}Sr. None of the three mule deer bone ash sample pairs, four cattle bone ash, or four cattle liver ash samples yielded results greater than or equal to MDC in both samples for ^{238}Pu. One mule deer bone, two cattle liver, and one cattle bone ash samples yielded valid results for $^{239+240}$Pu that were greater than or equal to MDC but less than 10 MDC in both samples; the %RSD was less than 10 percent for each pair. Except for one mule deer bone ash sample, all of the bone ash duplicate sample pairs yielded results greater than or equal to MDC but less than 10 MDC for ^{90}Sr. The %RSDs for these pairs were all less than the DQO of 30%, and all but one were less than 20%. There were no splits of vegetable samples analyzed in 1993.

Seven bioassay samples were split for duplicate tritium analysis; all yielded results less than the MDC by conventional method.

In addition to examination of %RSDs for individual duplicate pairs, an overall precision estimate was determined by calculating the pooled standard deviation, based on the algorithm given in (Taylor 1987). To convert to a unitless value, the pooled standard deviation was divided by the grand mean and multiplied by 100 to yield a %RSD. Table 27 presents the pooled data and estimates of overall precision. The pooled standard deviations and %RSD indicate the estimated achieved precision for 1993 samples.

11.4.3 Accuracy

The accuracy of all analyses is controlled through the use of approved or NIST-traceable standards in instrument calibrations. Internal checks of instrument accuracy may be periodically performed, using spiked matrix samples. These internal QC procedures are the only control of accuracy for whole body and lung counts and PICs. For spectroscopic and radiochemical analyses, an independent measurement of accuracy is provided by participation in intercomparison studies using samples of known activities. The EPA EMSL-LV Radioanalysis Laboratory participates in two such intercomparison studies. An independent verification of the accuracy of the TLDs is performed every two or three years by DOELAP. This involves a three-part, single blind, performance

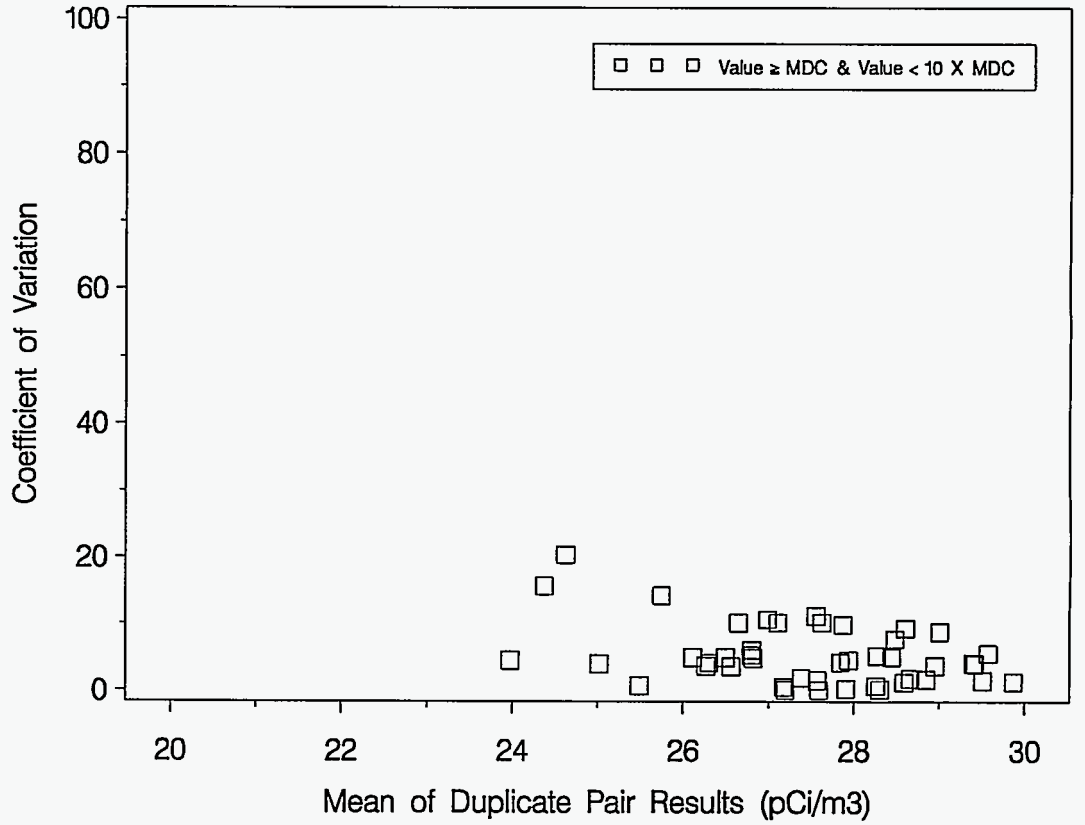


Figure 50. Precision results from composite samples for ^{85}Kr in noble gas.

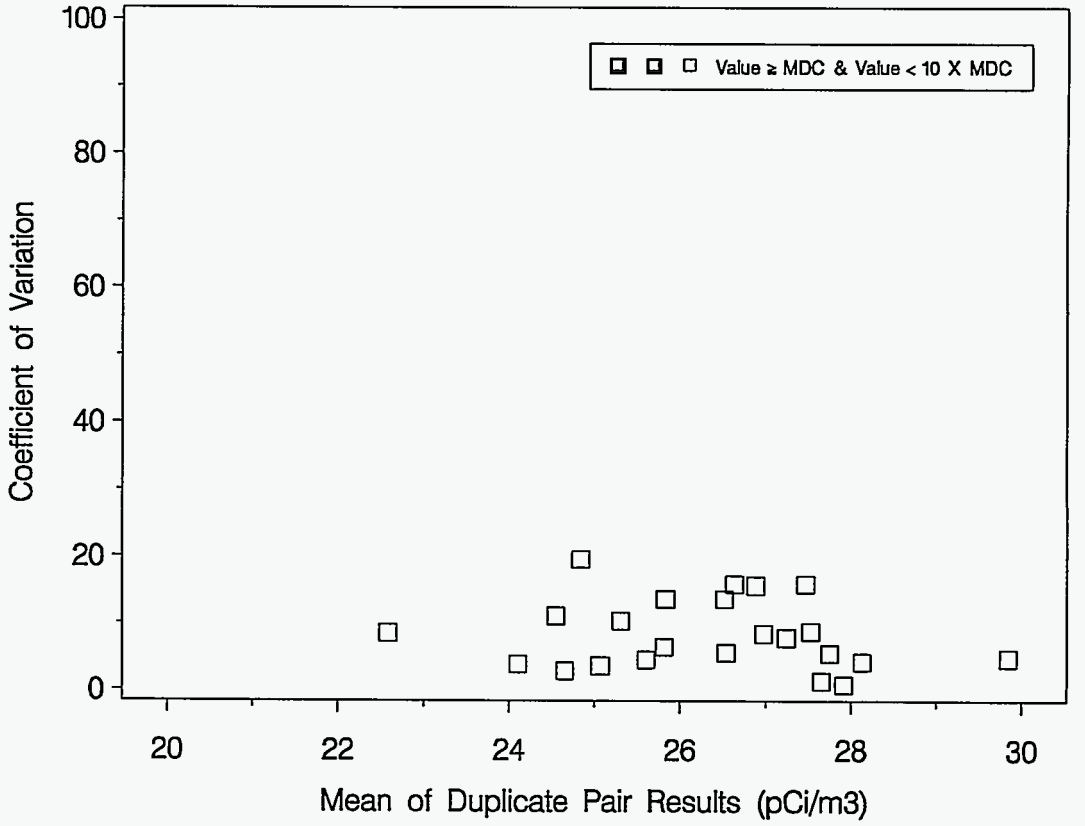


Figure 51. Precision results from split samples for ^{85}Kr in noble gas.

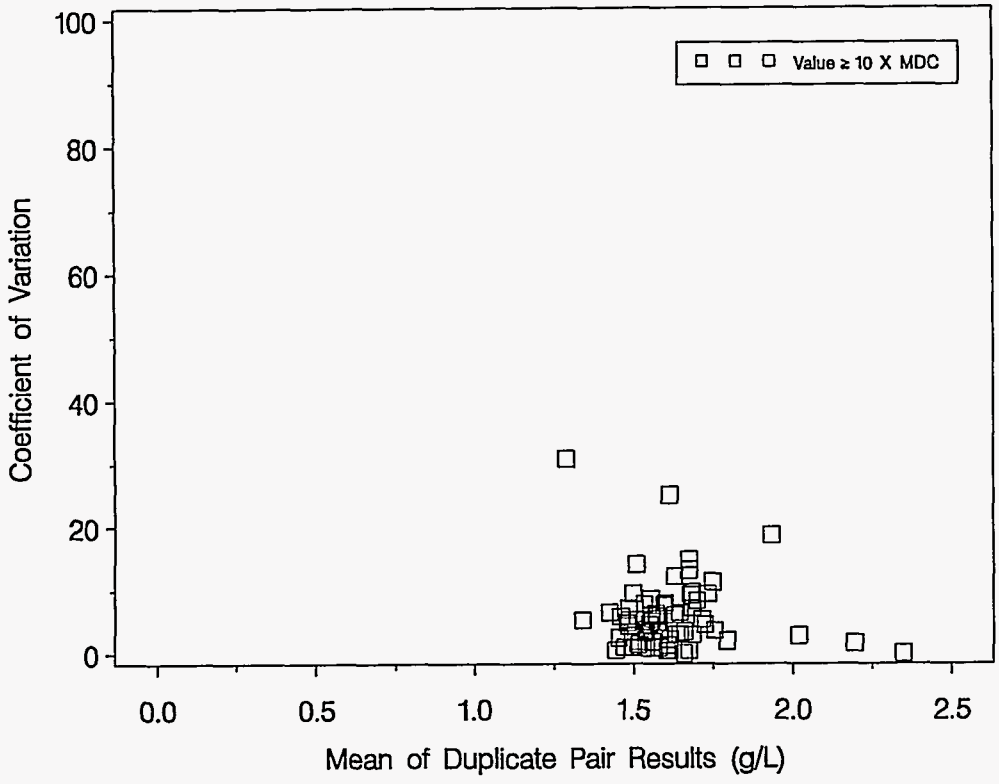


Figure 52. Precision results for K (total) in milk.

Table 27. Overall Precision of Analysis

Network	Analysis	Sample Type	Range	n	Pooled Standard Deviation	%RSD
LTHMP	Conv. Tritium	Spiked	≥MDC, <10x MDC	54	176	5.1
	Conv. Tritium	Field	≥MDC, <10x MDC	2	69	9.6
	Conv. Tritium	Spiked	≥10x MDC	1	5.0	0.2
	Enrich. Tritium	Field	≥MDC, <10x MDC	19	2.0	8.5
	Enrich. Tritium	Spiked	≥10x MDC	31	7.3	6.8
	Enrich. Tritium	Field	≥10x MDC	8	7.7	3.0
ASN	Gross Alpha	Field	≥MDC, <10x MDC	52	0.0003	26.1
	Gross Alpha	Lab Dup	≥MDC, <10x MDC	80	0.0004	28.3
	Gross Beta	Field	≥MDC, <10x MDC	125	0.0028	19.6
	Gross Beta	Lab Dup	≥MDC, <10x MDC	168	0.0017	12.1
	Gross Beta	Field	≥10x MDC	17	0.0032	11.1
	Gross Beta	Lab Dup	≥10x MDC	9	0.0011	3.9
	^{7}Be	Field	≥10x MDC	9	0.0599	18.6
	^{7}Be	Lab Dup	≥10x MDC	7	0.0641	19.3
Noble Gas	^{85}Kr	Comp.	≥MDC, <10x MDC	44	1.84	6.7
	^{85}Kr	Split	≥MDC, <10x MDC	23	2.56	9.7
Milk	Potassium (total)	Field	≥10x MDC	68	0.12	7.8
	Potassium (total)	Lab Dup	≥10x MDC	39	0.12	7.3

testing program followed by an independent onsite assessment of the overall program.

In the EPA EMSL-LV Intercomparison Study program, samples of known activities of selected radionuclides are sent to participating laboratories on a set schedule throughout the year. Water, milk, and air filters are used as the matrices for these samples. Results from all participating laboratories are compiled and statistics computed comparing each laboratory's results to the known value and to the mean of all laboratories. The comparison to the known value provides an independent assessment of accuracy for each participating laboratory.

Table 28 presents accuracy (referred to therein as Percent Bias) results for these intercomparison studies. Comparison of results among all participating laboratories provides a measure of comparability, discussed in Section 11.4.4. Approximately 70 to 290 laboratories participate in any given intercomparison study. Accuracy, as percent difference or percent bias is calculated by:

$$\%BIAS = \left(\frac{C_m - C_a}{C_a}\right) 100$$

where
%BIAS = percent bias
C_m = *measured sample activity*
C_a = *known sample activity*

With the exception of ^{89}Sr in January and in the April blind PE water sample, ^{134}Cs in the October blind PE water sample, and ^{137}Cs in the single air filter intercomparison study sample, the achieved accuracy was better than ± 20 percent. For most analyses, the DQOs are ± 20 percent for values greater than ten times the MDC and ± 30 percent for results greater than the MDC but less than ten times the MDC.

The other intercomparison study in which the EPA EMSL-LV Radioanalysis Laboratory participates is the semiannual DOE QA Program conducted by EML in New York, NY. Approximately 20 laboratories participate in this performance evaluation program. Sample matrices include water, air filters, vegetation, and soil. Results for these performance audit samples are given in Table 29. The DQOs for accuracy were exceeded for ^{90}Sr and ^{60}Co in the March air sample, ^{144}Ce in the September air sample, $^{239+240}Pu$ in the September soil sample, and ^{90}Sr in the March water sample.

In addition to use of irradiated control samples in the processing of TLDs, DOELAP monitors accuracy as part of the accreditation program. As with the intercomparison studies, samples of known activity are submitted as single blind samples. The designation "single blind" indicates the analyst recognizes the sample as being other than a routine sample, but does not know the concentration or activity contained in the sample. Individual results are not provided to the participant laboratories by DOELAP; issuance of the accreditation certificate indicates that acceptable accuracy reproducibility has been achieved as part of the performance testing process and that an onsite independent review has indicated conformance with established accreditation standards. No DOELAP samples were received in 1993.

11.4.4 Comparability

The EPA Performance Evaluation Program provides results to each laboratory participating in each study that includes a grand average for all values, excluding outliers.

A normalized deviation statistic compares each laboratory's result (mean of three replicates) to the known value and to the grand average. If the value of this statistic (in multiples of standard normal deviate, unitless) lies between control limits of -3 and +3, the accuracy (deviation from known value) or comparability (deviation from grand average) is within normal statistical variation. Table 30 displays data from the 1993 intercomparison studies for all variables measured. There were three instances in which the EPA EMSL-LV Radioanalysis Laboratory results deviated from the grand average by more than three standard normal deviate units. These were the gross alpha in the January and ^{89}Sr in the April water intercomparison study samples and total potassium in the single milk intercomparison study sample. The gross alpha and total potassium results were within the DQO for accuracy. All other analyses were within three standard normal deviate units of the grand mean. This indicates acceptable comparability of the Radioanalysis Laboratory with the 73 to 262 laboratories participating in the EPA Intercomparison Study Program.

11.4.5 Representativeness

Representativeness cannot be evaluated quantitatively. Rather, it is a qualitative assessment of the ability of the sample to model the objectives of the

Table 28. Accuracy of Analysis from EPA Performance Evaluation

Nuclide	Month	Known Value (pCi/L)[a]	EPA Average (pCi/L)[a]	Percent Bias
		Water Performance Evaluation Studies		
Alpha	Jan	34	37	8.8
Alpha	Apr[b]	95	110	15.8
Alpha	Jul	15	17	13.3
Alpha	Oct	20	17	-15.0
Alpha	Oct[b]	40	41	2.5
Beta	Jan	44	44	0.0
Beta	Apr[b]	177	166	-5.5
Beta	Jul	43	41	-4.7
Beta	Oct	15	18	20.0
Beta	Oct[b]	58	52	-10.3
^{89}Sr	Jan	15	11	-26.7
^{89}Sr	Apr[b]	41	26	-36.6
^{89}Sr	Jul	34	37	8.8
^{89}Sr	Oct[b]	15	17	13.3
^{90}Sr	Jan	10	9	-10.0
^{90}Sr	Apr[b]	29	26	-10.3
^{90}Sr	Jul	25	26	4.0
^{90}Sr	Oct[b]	10	10	0.0
^{239}Pu	Jan	20	19	-5.0
^{131}I	Feb	100	95	-5.0
^{131}I	Oct	117	114	-8.3
U-Nat	Apr[b]	29	28	-3.4
U-Nat	Aug	25	26	4.0
U-Nat	Oct	15	15	0.0
^{3}H	Jun	9800	9300	-5.1
^{3}H	Nov	7400	7000	-5.4
^{60}Co	Apr[b]	39	39	0.0
^{60}Co	Jun	15	14	-6.7
^{60}Co	Oct[b]	10	8	-20.0
^{60}Co	Nov	30	32	6.7
^{134}Cs	Apr[b]	27	24	-11.1
^{134}Cs	Jun	5	5	0.0
^{134}Cs	Oct[b]	12	9	-25.0
^{134}Cs	Nov	59	58	-1.7
^{137}Cs	Apr[b]	32	31	-3.1
^{137}Cs	Jun	5	5	0.0
^{137}Cs	Oct[b]	10	11	10.0
^{137}Cs	Nov	40	45	12.5
^{65}Zn	Jun	103	112	10.0
^{65}Zn	Nov	150	173	13.3
^{106}Ru	Jun	119	107	-8.3
^{106}Ru	Nov	201	190	-5.0
^{133}Ba	Jun	99	94	-6.0
^{133}Ba	Nov	79	82	3.8

(a) The grand average of all participating laboratories that are non-outliers.
(b) Refers to Blind Performance Evaluation (PE) Study.

Table 28. (Accuracy of Analysis from EPA Performance Evaluation, cont.)

Nuclide	Month	Known Value (pCi/L)[a]	EPA Average (pCi/L)[a]	Percent Bias
		Air Filter Performance Evaluation Studies		
Alpha	Aug	19	19	0.0
Beta	Aug	47	47	0.0
^{137}Cs	Aug	9	12	33.3
		Milk Performance Evaluation Studies		
^{89}Sr	Sept	30	24	-20.0
^{90}Sr	Sept	25	23	-8.0
^{131}I	Sept	120	117	-2.5
^{137}Cs	Sept	49	50	2.0
K(total)	Sept	1679	1452	-13.5

(a) The grand average of all participating laboratories that are non-outliers
(b) Refers to Blind Performance Evaluation (PE) Study

program. The primary objective of the ORSP is to protect the health and safety of the offsite residents. Therefore, the DQO of representativeness is met if the samples are representative of the radiation exposure of the resident population. Monitoring stations are located in population centers. Siting criteria specific to radiation sensors are not available for many of the instruments used. Existing siting criteria developed for other pollutants are applied to the ORSP sensors as available. For example, siting criteria for the placement of air sampler inlets are contained in Prevention of Significant Deterioration guidance documents (EPA, 1976). Inlets for the air samplers at the ORSP stations have been evaluated against these criteria and, in most cases, meet the siting requirements. Guidance or requirements for handling, shipping, and storage of radioactivity samples are followed in program operations and documented in SOPs. Standard analytical methodology is used and guidance on the holding times for samples, sample processing, and results calculations are followed and documented in SOPs.

In the LTHMP, the primary objectives are protection of drinking water supplies and monitoring of any potential cavity migration. Sampling locations are primary "targets of opportunity", i.e., the sampling locations are primarily wells developed for purposes other than radioactivity monitoring. Guidance or requirements developed for Comprehensive Environmental Response, Compensation, and Liability Act and Resource Conservation Recovery Act regarding the number and location of monitoring wells have not been applied to the LTHMP sampling sites. In spite of these limitations, the samples are representative of the first objective, protection of drinking water supplies. At all of the LTHMP monitoring areas, on and around the NTS, all potentially impacted drinking water supplies are monitored, as are many supply sources with virtually no potential to be impacted by radioactivity resulting from past or present nuclear weapons testing. The sampling network at some locations is not optimal for achieving the second objective, monitoring of any migration of radionuclides from the test cavities. An evaluation conducted by DRI describes, in detail, the monitoring locations for each LTHMP location and the strengths and weaknesses of each monitoring network (Chapman and Hokett, 1991). This evaluation is cited in the discussion of the LTHMP data in Section 7.

Table 29. Accuracy of Analysis from DOE Performance Evaluation Studies

Nuclide	Month	EML Value[a]	EPA Value	Percent Bias
		Air Intercomparison Studies		
^{7}Be	March	28.	27	-3.6
^{54}Mn	March	12	12	0
^{54}Mn	September	16	15	-6.2
^{57}Co	March	2.6	2.7	3.8
^{57}Co	September	16	17	6.2
^{60}Co	March	.94	1.7	81
^{60}Co	September	21	20	-4.8
^{90}Sr	March	.54	.76	41
^{134}Cs	March	2.2	2	-9.1
^{134}Cs	September	13	12	-7.7
^{137}Cs	March	3.4	3.1	-8.8
^{137}Cs	September	19	19	0
^{144}Ce	March	18	19	5.6
^{144}Ce	September	28	40	43
^{238}Pu	March	.033	.036	9.1
^{238}Pu	September	.12	.13	8.3
$^{239+240}Pu$	March	.022	.023	4.5
$^{239+240}Pu$	September	.072	.080	11
U-Nat	September	.15	.14	-6.7
		Soil Intercomparison Studies		
$^{239+240}Pu$	March	11	11	9.1
$^{239+240}Pu$	September	2.2	1.5	–32
U-Nat	March	42	50.3	19
		Vegetation Intercomparison Studies		
^{90}Sr	March	280.	240	–14
^{90}Sr	September	200.	220.	10
^{238}Pu	March	1.2	1.1	-8.3
^{238}Pu	September	.42	.46	9.5
$^{239+240}Pu$	March	0.33	0.32	-3.00
$^{239+240}Pu$	September	0.91	0.96	5.5
		Water Intercomparison Studies		
^{3}H	March	110	97	-12
^{3}H	September	260	270	3.8
^{54}Mn	March	110	100	-9.1

(a) Values were obtained from the Environmental Measurements Laboratory (EML) with all values rounded to two significant figures. Units are Bq/filter for air, Bq/L for water, and Bq/Kg for the remaining matrices.

Table 29. (Accuracy of Analysis from DOE Performance Evaluation Studies, cont.)

Nuclide	Month	EML Value[a]	EPA Value	Percent Bias
		Water Intercomparison Studies		
^{54}Mn	September	120	110	-8.3
^{60}Co	March	47	45	-4.2
^{60}Co	September	100	100	0
^{90}Sr	March	1.5	1.0	-33
^{90}Sr	September	2.7	2.5	-7.4
^{134}Cs	March	48	42	-12
^{134}Cs	September	63	56	-11
^{137}Cs	March	55	51	-7.3
^{137}Cs	September	83	76	-8.4
^{144}Ce	March	91	84	-7.7
^{144}Ce	September	170	170	0
^{238}Pu	March	0.48	0.49	2.1
^{238}Pu	September	1.1	1.1	0
$^{239+240}Pu$	March	0.84	0.83	-1.2
$^{239+240}Pu$	September	0.32	0.34	6.2
U-Nat	September	2.2	2.1	-4.5

(a) Values were obtained from the Environmental Measurements Laboratory (EML) with all values rounded to two significant figures. Units are Bq/filter for air, Bq/L for water, and Bq/kg for the remaining matrices.

Table 30. Comparability of Analysis from EPA Performance Evaluation Studies[a]

Nuclide	Month	Known Value pCi/L	EPA Lab Average pCi/L	Grand Average pCi/L	Expected Precision	Normalized Dev. of EPA Average from Grand Average	Normalized Dev. of EPA Average from Known Value
			Water Performance Evaluation Study				
Alpha	Jan	34	37	17	9.0	3.8	0.58
Alpha	Apr[b]	95	110	97	24.0	0.92	1.0
Alpha	Jul	15	17	12	5.0	1.6	0.58
Alpha	Oct	20	17	14	5.0	1.1	-0.92
Alpha	Oct[b]	40	41	41	10.0	-0.02	0.12
Beta	Jan	44	44	42	5.0	0.58	-0.12
Beta	Apr[b]	177	166	155	27.0	0.67	-0.71
Beta	Jul	43	41	38	6.9	0.75	-0.58
Beta	Oct	15	18	17	5.0	0.34	1.0
Beta	Oct[b]	58	52	53	10.0	-0.18	-0.98
^{89}Sr	Jan	15	11	15	5.0	-1.2	-1.4
^{89}Sr	Apr[b]	41	26	38	5.0	-4.0	-5.2
^{89}Sr	Jul	34	37	34	5.0	1.1	1.2
^{89}Sr	Oct[b]	15	17	14	5.0	1.1	0.69
^{90}Sr	Jan	10	9	10	5.0	-0.23	-0.35
^{90}Sr	Apr[b]	29	26	28	5.0	-0.63	-1.0
^{90}Sr	Jul	25	26	24	5.0	0.69	0.35
^{90}Sr	Oct[b]	10	10	10	5.0	-0.09	0.0
$^{239+240}$Pu	Jan	20	19	19	2.0	0.18	-1.1
^{131}I	Feb	100	95	101	10.0	-1.2	-0.92
^{131}I	Oct	117	114	118	12.0	-0.53	-0.43
U-Nat	Apr[b]	29	28	28	3.0	0.34	-0.38
U-Nat	Aug	25	26	25	3.0	0.55	0.33
U-Nat	Oct	15	15	14	3.0	0.25	-0.17
^{3}H	Jun	9800	9300	9600	984.0	-0.51	-0.96
^{3}H	Nov	7400	7000	7200	740.0	-0.60	-1.3
^{60}Co	Apr[b]	39	39	39	5.0	-0.24	-0.12
^{60}Co	Jun	15	14	15	5.0	-0.20	-0.23
^{60}Co	Oct[b]	10	8	10	5.0	-0.72	-0.58
^{60}Co	Nov	30	32	30	5.0	0.91	0.81
^{134}Cs	Apr[b]	27	24	25	5.0	-0.37	-0.92
^{134}Cs	Jun	5	5	5	5.0	-0.13	0.0
^{134}Cs	Oct[b]	12	9	10	5.0	-0.27	-1.0
^{134}Cs	Nov	59	58	54	5.0	1.2	-0.35
^{137}Cs	Apr[b]	32	31	33	5.0	-0.44	-0.23
^{137}Cs	Jun	5	5	6	5.0	-0.15	0.12
^{137}Cs	Oct[b]	10	11	11	5.0	0.02	0.35
^{137}Cs	Nov	40	45	42	5.0	.99	1.7

Table 30. (Comparability of Analysis from EPA Performance Evaluation Studies[a], cont.)

Nuclide	Month	Known Value pCi/L	EPA Lab Average pCi/L	Grand Average pCi/L	Expected Precision	Normalized Dev. of EPA Average from Grand Average	Normalized Dev. of EPA Average from Known Value
^{65}Zn	Jun	103	112	108	10.0	0.71	1.5
^{65}Zn	Nov	150	173	156	15.0	2.0	2.7
^{106}Ru	Jun	119	107	104	12.0	.50	-1.7
^{106}Ru	Nov	201	190	175	20.0	.88	-1.4
^{133}Ba	Jun	99	94	97	10.0	-0.48	0.87
^{133}Ba	Nov	79	82	76	8.0	1.1	0.58
			Air Filter Performance Evaluation Study[c]				
Alpha	Aug	19	19	20	5.0	-0.46	-0.12
Beta	Aug	47	47	49	5.0	-0.69	0.12
^{137}Cs	Aug	9	12	10	5.0	-0.69	1.0
			Milk Performance Evaluation Study				
^{89}Sr	Sep	30	24	24	5.0	-0.11	-2.0
^{90}Sr	Sep	25	23	20	5.0	1.2	-0.58
^{131}I	Sep	120	120	120	12.0	-0.40	-0.38
^{137}Cs	Sep	49	50	50	5.0	-0.12	0.23
K[d] (Total)	Sep	1679	1452	1674	84.0	-4.6	-4.7

(a) The grand average of all participating laboratories that are non-outliers
(b) Refers to Blind Performance Evaluation (PE) Study
(c) pCi/filter
(d) mg/liter

12. Sample Analysis Procedures

The procedures for analyzing samples collected for this report are described in *Radiochemical and Analytical Procedures for Analysis of Environmental Samples* (Johns, 1979) and are summarized in Table 31. These include gamma analysis, gross beta on air filters, strontium, tritium, plutonium, and noble gas analyses. These procedures outline standard methods used to perform given analytical procedures.

Table 31. Summary of Analytical Procedures

Type of Analysis	Analytical Equipment	Counting Period (min)	Analytical Procedures	Sample Size	Approximate Detection Limit[a]
HpGe Gamma[b]	HpGe detector-calibrated at 0.5 keV/ channel (0.04 to 2 meV range) individual detector efficiencies ranging from 15 to 35%.	Air charcoal cartridges and individual air filters, 30; 100 for milk, water, suspended solids.	Radionuclide concentration quantified from gamma spectral data by online computer program.	1.0 and 3.5 L for routine liquids; 560 m^3 for low-volume air filters, and approximately 10,000 m^3 for high-volume air filters.	For Cs-137, routine liquids; 5×10^{-9} µCi/mL (1.8×10^{-1} Bq/L) low-volume airfilters; 5×10^{-14} µCi/mL (1.8×10^{-3} Bq/m^3), high-volume airfilters; 5×10^{-16} µCi/mL (1.8×10^{-5} Bq/m^3).
Gross alpha and beta on air filters	Low-level end windows, gas flow proportional counter with a 5-cm diameter window.	30	Samples are counted after decay of naturally occurring radionuclides.	560 m^3	alpha: 8.0×10^{-16} µCi/mL (3.0×10^{-5} Bq/m^3) beta: 2.5×10^{-15} µCi/mL (9.25×10^{-5} Bq/m^3)
$^{89,90}Sr$	Low background thin-window, gas-flow, proportional counter.	50	Chemical separation by ion exchange. Separated sample counted successively; activity calculated by simultaneous solution of equations.	1.0 L for milk or water. 0.1 to 1 kg for tissue.	^{89}Sr=5×10^{-9} µCi/mL (1.85×10^{-1} Bq/L) ^{90}Sr=2×10^{-9} µCi/mL (7.4×10^{-2} Bq/L)
^{3}H	Automatic liquid scintillation counter with output printer.	300	Sample prepared by distillation.	5 to 10 mL for water.	300 to 700 x 10^{-9} µCi/mL (11-26 Bq/L)[c]

Continued

In August there was a FRMAC Hanford Exercise Preparation Course put on by the EMSL-LV that was attended by various state and Radiological Assistance Program team members. Field monitoring methods were discussed, and the course covered instrumentation (including the use of a FIDLER), sample collection, hotline procedures, documentation and included a field exercise.

Three EMSL-LV staff members attended a week long Basic Instructor Training (BIT) course and were awarded certifications. These same staff members taught Radiation Worker I and II at the NTS.

Most of the EMSL-LV monitoring personnel completed a Transportation Emergency Training and Radiological Assistance (TEP Module), Hazardous Material Awareness, and a Hazard Communication Standard course.

Figure 54. FRMAC Team members collect a representative vegetation sample.

14. Radiation Protection Standards For External and Internal Exposure

Design and operation of the ORSP are based on requirements and guidelines contained in applicable legislation and literature. A summary of applicable regulations and guidelines follows.

14.1 Dose Equivalent Commitment

For stochastic effects in members of the public, the following limits are used:

	Effective Dose mrem/yr	Dose Equivalent[a] mSv/yr
Occasional annual exposures[b]	500	5
Prolonged period of exposure	100	1

[a] Includes both effective dose equivalent from external radiation and committed effective dose equivalent from ingested and inhaled radionuclides.

[b] Occasional exposure implies exposure over a few years with the provision that over a lifetime the average exposure does not exceed 100 mrem (1 mSv) per year (ICRP, 1983).

14.2 Concentration Guides

ICRP-30 (ICRP, 1979) lists Derived Air Concentrations (DAC) and Annual Limits on Intake (ALI). The ALI is the secondary limit and can be used with assumed breathing rates and ingested volumes to calculate concentration guides. The concentration guides (CGs) in Table 32 were derived in this manner and yield the committed effective dose equivalent (50 year) of 100 mrem/yr for members of the public.

14.3 U.S. Environmental Protection Agency Drinking Water Guide

The EPA has set allowable concentrations for continuous controlled releases of radionuclides to drinking water sources. These were published in 40 CFR 141 (CFR 1988). These limits are based on the standard that exposure to any single or combination of beta and gamma emitters in drinking water should not lead to exposures exceeding 4 mrem/year. For tritium, this is 2.0 X 10^{-5} µCi/mL (740 Bq/L). For ^{90}Sr, the limit is 8.0 X 10^{-9} µCi/mL (0.3 Bq/L).

Table 32. Routine Monitoring Guides

Nuclide	Sampling Frequency	Locations	Sample Size	Count Time	Concentrations Guide[a]		MDC	MDC (%CG)
Air Surveillance Network		(ASN)	m^3	Minutes	Bq/m^3	µCi/mL	mBq/m^3	
^{7}Be	1/wk	all	560	30	1700	4.7×10^{-8}	17	1×10^{-3}
^{95}Zr	1/wk	all	560	30	12	3×10^{-10}	4.1	4×10^{-2}
^{95}Nb	1/wk	all	560	30	110	3×10^{-9}	1.8	2×10^{-3}
^{99}Mo	1/wk	all	560	30	110	3×10^{-9}	1.5	2×10^{-3}
^{103}Ru	1/wk	all	560	30	58	1.5×10^{-9}	1.8	3×10^{-3}
^{131}I	1/wk	all	560	30	4	1×10^{-10}	1.8	4×10^{-2}
^{132}Te	1/wk	all	560	30	17	5×10^{-10}	1.8	1×10^{-2}
^{137}Cs	1/wk	all	560	30	12	3×10^{-10}	1.8	2×10^{-2}
^{140}Ba	1/wk	all	560	30	120	3×10^{-9}	4.8	4×10^{-3}
^{140}La	1/wk	all	560	30	120	3×10^{-9}	2.6	2×10^{-3}
^{141}Ce	1/wk	all	560	30	52	1.4×10^{-9}	3.0	6×10^{-3}
^{144}Ce	1/wk	all	560	30	1.2	3×10^{-11}	12	1.0
^{238}Pu	1/mo	all	2400	1000	5×10^{-4}	1×10^{-14}	1.5×10^{-3}	0.32
Gross Beta	1/wk	all	560	30	2×10^{-2}	5×10^{-13}	0.11	6×10^{-1}
^{3}H	1/wk	19	5	150	4.6×10^{3}	1.2×10^{-7}	148	3×10^{-3}
^{85}Kr	1/wk	16	0.4	200	2.2×10^{4}	6.2×10^{-7}	148	6×10^{-4}
^{133}Xe	1/wk	16	0.4	200	1.8×10^{4}	4.9×10^{-7}	370	2×10^{-3}
^{135}Xe	1/wk	16	0.4	200	2.3×10^{3}	6.2×10^{-8}	370	2×10^{2}
Water Surveillance Network (LTHMP)[b]			Liters	Minutes	Bq/L	µCi/mL	Bq/L	
^{3}H	1/mo	all	1	300	740	2×10^{-5}	12	1.6
$^{3}H+$ (enriched tritium)	1/mo	all	0.25	300	740	2×10^{-5}	0.37	5×10^{-2}
^{89}Sr	1st time	all	1	50	16	4.4×10^{-7}	0.18	1.1
^{90}Sr	1st time	all	1	50	0.8	2.2×10^{-8}	0.074	9.2
^{137}Cs	1/mo	all	1	100	3.3	8.8×10^{-8}	0.33	10
^{226}Ra	1st time	all	1	1000	1.4	3.9×10^{-8}	0.037	2.6
^{234}U	1st time	all	1	1000	8.2	2.2×10^{-7}	0.0035	0.04
^{235}U	1st time	all	1	1000	10	2.8×10^{-8}	0.0035	0.035
^{238}U	1st time	all	1	1000	10	2.8×10^{-8}	0.0035	0.035
^{238}Pu	1st time	all	1	1000	6.2	1.7×10^{-8}	0.003	0.05
$^{239+240}Pu$	1st time	all	1	1000	4.1	1.1×10^{-8}	0.002	0.05
Gamma	1/mo	all	3.5	30	--	--	0.18	<0.2
Milk Surveillance Network		(MSN)	Liters	Minutes	Bq/L	µCi/mL	Bq/L	
^{3}H	1/mo	all	3.5	300	12×10^{4}	3×10^{-3}	12	0.01
^{131}I	1/mo	all	3.5	100	41	1×10^{-6}	0.18	0.44
^{137}Cs	1/mo	all	3.5	100	160	4×10^{-6}	0.33	0.2
^{89}Sr	1/mo	all	3.5	50	820	2×10^{-5}	0.18	0.02
^{90}Sr	1/mo	all	3.5	50	40	1×10^{-6}	0.074	0.18

Dosimetry Networks		Locations	Number	Exposure Guide	MDC	MDC(%CG)
TLD (Personnel)	1/mo	72	1	100mR	3.01mrem	2
TLD (Station)	1/quarter	130	3 to 6	--	5.10mrem	--
PIC	weekly	29	Continuous	--	2µR/hr	--

[a] ALI and DAC values from ICRP-30 modified to 1 mSv annual effective dose equivalent for continuous exposure. Te and I data corrected to 2 g thyroid, greater milk intake, and smaller volume of air breathed annually (1 year-old infant).

[b] For tritium, Sr, and Cs the concentration guide is based on Drinking Water Regs, (4 mrem/yr) (CFR, 1988).

15 Summary and Conclusions

The primary functions of the ORSP are to conduct routine environmental monitoring for radioactive materials in areas potentially impacted by nuclear tests and, when necessary, to implement actions to protect the public from radiation exposure. Components of the ORSP include surveillance networks for air, noble gases, atmospheric tritium, and milk; biomonitoring of meat, game animals, and vegetables; exposure monitoring by thermoluminescent dosimetry, pressurized ion chambers, and whole body counting; and long-term hydrological monitoring of wells and surface waters. In 1993, data from all networks and monitoring activities indicated no radiation directly attributable to current activities conducted at the NTS. Therefore, protective actions were not required. The following sections summarize the ORSP activities for 1993.

15.1 Thermoluminescent Dosimetry Program

In 1993, external exposure was monitored by a network of thermoluminescent dosimeters (TLDs) at 127 fixed locations surrounding the NTS and by TLDs worn by 69 offsite residents. No apparent net exposures were related to NTS activities. Neither administrative, ALARA, nor regulatory investigation limits were exceeded for any individual or fixed location cumulative exposure. The range of exposures was similar to those observed in other areas of the United States. Details of this program may be found in Section 3.1 of this Report.

15.2 Pressurized Ion Chamber Network

The Pressurized Ionization Chamber (PIC) network measures ambient gamma radiation exposure rates on a near real-time basis. The 27 PICs deployed around the NTS in 1993 showed no unexplained deviations from background levels. Based on average exposure rates recorded at each PIC location, the maximum annual exposure was at Milford, Utah and Stone Cabin Ranch. The minimum annual exposure was at Pahrump, Nevada. These values are within the U.S. background range and are consistent with previous years' trends. Details of this program may be found in Section 3.2 of this Report.

15.3 Air Surveillance Network

In 1993, the Air Surveillance Network (ASN) included 30 continuously operating sampling stations at locations surrounding the NTS. In the majority of cases, no gamma emitting radionuclides were detected by gamma spectrometry (i.e., the results were gamma-spectrum negligible). Naturally occurring ^{7}Be was the only radionuclide occasionally detected. As in previous years, the majority of the gross beta results exceeded the MDC. Analysis of air samples for gross alpha showed results to be either below or very slightly above (*i.e.* statistically indistinguishable from) the MDC. Plutonium results from two composite samples from Alamo, NV exceeded the MDC for ^{238}Pu. The MDC for $^{239+240}Pu$ was exceeded for one sample from Rachel, NV. Details of the Atmospheric Monitoring program, including the Air Surveillance Network, Standby Air Surveillance Network, Special sampling, Tritium in Atmospheric Moisture, and Noble Gas Sampling networks may be found in Section 4 of this Report.

15.3.1 Standby Air Surveillance Network

In 1993, the Standby Air Surveillance Network (SASN) included 77 stations that were scheduled to be activated one week per quarter. These stations are located in each of the contiguous states west of the Mississippi River. Results of gamma spectroscopy, gross beta, and gross alpha were consistent with those obtained from the ASN. The composite sample from the New Mexico standby stations exceeded the MDC for ^{238}Pu. Four composite samples from the SASN exceeded the MDC for $^{239+240}Pu$.

15.3.2 Special Monitoring TOMSK-7 Incident

Samplers at 24 SASN stations were activated over a three week period during April, 1993 immediately following the TOMSK-7 incident in Russia. No

alpha or beta activity was detected in any of these special samples.

15.4 Tritium In Atmospheric Moisture

A total of 14 routine and 7 standby sampling locations was evaluated for tritium in atmospheric moisture during 1993. Of the 686 routine and 26 standby samples analyzed, three showed results that exceeded the analysis MDC, but this could represent normal statistical variation. The operation of the tritium samplers and the data results are discussed in Section 4.2.

15.5 Noble Gas Sampling Network

Samples from 13 routine air sampling locations were analyzed for ^{85}Kr and ^{133}Xe. As in previous years, all of the results for ^{133}Xe were below the MDC. All ^{85}Kr samples were above the MDC and were within the range anticipated from sampling background levels.

15.6 Foodstuffs

Milk samples were collected from 24 Milk Surveillance Network (MSN) and 110 Standby Milk Surveillance Network (SMSN) stations in 1993. For both MSN and SMSN samples, the average total potassium concentration derived from ^{40}K was consistent with results obtained in previous years. No manmade gamma-emitting radionuclides were detected in any of the milk samples. Results of analyses for ^{3}H, ^{89}Sr, and ^{90}Sr were similar to those obtained in previous years. Neither increasing nor decreasing trends were evident.

Sampling under the animal investigation program continued in 1993. Detectable concentrations of ^{3}H were found in four mule deer collected from the NTS. Detectable concentrations of $^{239+240}Pu$ were found in one or more tissues from the four mule deer collected. The median $^{239+240}Pu$ concentration in the cattle liver samples was also above the MDC of the analysis. Each of the bone samples from the various species collected showed detectable amounts of ^{90}Sr. No gamma-emitting radionuclides other than naturally occurring ^{40}K were detected in tissue samples. Medians and ranges of radionuclides in bighorn sheep and cattle tissues were generally similar to those obtained in previous years.

Sixteen samples of locally grown fruits and vegetables were collected in the fall of 1993. All were analyzed for gamma-emitting radionuclides, with only naturally occurring ^{40}K being detected. All were also analyzed for tritium. Two samples were found to be greater than the MDC. Two samples were also found to be above the MDC for ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$. None of the smooth skinned crops or root crops without tops contained radionuclides above the MDC. The observed plutonium may be contained in the fruit or vegetable material or may be contained in soil or dust being trapped in the leafy portion of the vegetables. In the later case, residents could reduce the potential for radionuclide ingestion by thorough washing of vegetables prior to eating and by peeling of root crops such as potatoes and carrots. The worst-case dose that could potentially result from eating these fruits and vegetables is discussed in Section 8 of this Report, Dose Assessment.

Detailed discussion of the collection and analysis of foodstuffs may be found in Section 5 of this Report.

15.7 Internal Dosimetry

Internal radiation exposure is caused by radionuclides that are ingested, absorbed, or inhaled and retained within the body for varying amounts of time. The EMSL-LV Internal Dosimetry Program assesses this internal deposition by whole body counting, lung counting, and bioassay (urinalysis). During 1993, whole body and lung counts were performed on 144 individuals, of whom 56 were participants in the offsite internal dosimetry network. The spectra obtained showed only low-level activities on the same order of intensity as those observed in normal background measurements.

Special whole body counting was conducted on soldiers who had incurred shrapnel wounds during Operation Desert Storm. These evaluations were conducted to detect the presence of depleted uranium.

Bioassay results showed that the concentration of tritium in single urine samples for participants in the Offsite Internal Dosimetry Program varied from

below the MDC to 8.3 X 10^{-7} μCi/mL (3.1 X 10^{-6} Bq/L). This can be accounted for by random statistical fluctuation. The highest value is less than 1% of the applicable derived concentration guide.

Details of the internal dosimetry program may be found in Section 6 of this Report.

15.8 Long-Term Hydrological Monitoring Program

15.8.1 Nevada Test Site Monitoring

Sixteen wells on the NTS or immediately outside its borders on federally owned land are scheduled to be sampled monthly. An additional twenty wells are scheduled for sampling at approximately six month intervals. All samples collected during 1993 were analyzed by gamma spectrometry and for tritium by the enrichment method. No gamma-emitting radionuclides were detected. The highest tritium level, detected in a sample from Well UE-7ns, was less than 1% of the derived concentration guide for tritium. There were no indications that migration from any test cavity is affecting any domestic water supply.

15.8.2 Offsite Monitoring in the Vicinity of the Nevada Test Site

These sampling locations represent drinking water sources for rural residents and for communities in the area. Sampling locations include 23 wells, seven springs, and two surface water sites. Thirty locations are routinely sampled monthly. Gamma spectrometric analysis is completed on monthly samples. Tritium analysis is performed on a semiannual basis.

None of the 1993 samples analyzed for tritium using the conventional method had results above the MDC. Five that were analyzed for tritium by the enrichment method showed detectable activity. These results were felt to represent scavenged atmospheric tritium by precipitation.

15.8.3 LTHMP at Off-NTS Nuclear Device Test Locations

Annual sampling of surface and ground waters is conducted at Projects SHOAL and FAULTLESS sites in Nevada, Projects GASBUGGY and GNOME sites in New Mexico, Projects RULISON and RIO BLANCO sites in Colorado, and the Project DRIBBLE site in Mississippi. Routine biennial sampling was conducted in 1993 at the Projects CANNIKIN, LONG SHOT, and MILROW sites on Amchitka Island, Alaska.

As in previous years, monitoring of well EPNG 10-36 at Project GASBUGGY was a notable exception to wells evidencing decreasing trends. The mechanism and route of migration from the Project GASBUGGY cavity is not currently known.

Details of the on-site, near NTS, and off-NTS hydrological monitoring programs may be found in Section 7 of this Report.

15.9 Dose Assessment

The extensive offsite environmental surveillance system detailed in this Report measured no radiation exposures that could be attributed to recent NTS operations. The potential Effective Dose Equivalent (EDE) to the maximally exposed offsite resident resulted in a maximum dose of 3.8 X 10^{-3} mrem (3.8 X 10^{-5} mSv) to a hypothetical resident of Indian Springs, NV located 54 km (32 mi) SE of the NTS control point. This value was based on onsite source emission measurements and estimates provided by DOE and calculated by EPA's CAP88-PC model. The calculated population dose (collective effective dose equivalent) to the approximately 21,750 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 1.2 X 10^{-2} person-rem (1.2 X 10^{-4} person-Sv). Monitoring network data indicated a 1993 dose of 97 mrem (0.97 mSv) from normal background radiation occurred in Indian Springs. The calculated dose to this individual from worldwide distributions of radioactivity as measured from surveillance networks was 0.054 mrem (5.4 X 10^{-4} mSv). An additional EDE of 0.56 mrem (5.6 X 10^{-3} mSv) would be received if edible tissues from a chukar and contaminated deer collected on the NTS were to be consumed. All of these maximum dose estimates are < 1% of the most restrictive standard.

Details of the dose assessment calculations may be found in Section 8 of this Report.

15.10 Weapons Test and Liquified Gaseous Fuels Spills Test Facility

Nonradiological monitoring was conducted in 1993 for four tests conducted at the Liquified Gaseous Fuels Spill Test Facility (LGFSTF), located in Area 5 of the NTS.

Detailed discussion of EMSL-LV activities in support of this facility may be found in Section 9 of this Report.

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Glossary of Terms

Definitions of terms given here are modified from the U.S. Nuclear Regulatory Commission Glossary of terms (NRC81).

background radiation — The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of humans and animals. It is also called natural radiation. The usually quoted average individual exposure from background radiation is 125 millirem per year in midlatitudes at sea level.

becquerel (Bq) — A unit, in the International System of Units, of measurement of radioactivity equal to one nuclear transformation per second.

beta particle (*B*) — A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/837 that of a proton. A positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

blind samples — A spiked sample, the composition of which is unknown to the technician, which has been introduced into the laboratory as a separate sample. These samples are used for the verification of analytical accuracy. Approximately one percent of the sample load shall be blind samples.

Committed Effective Dose Equivalent — The summation of Dose Equivalents to specific organs or tissues that would be received from an intake of radioactive material by an individual during a 50-year period following the intake, multiplied by the appropriate weighting factor.

cosmic radiation — Penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem of the 125 millirem background radiation that an average individual receives in a year.

curie (Ci) — The basic unit used to describe the rate of radioactive disintegration. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium; named for Marie and Pierre Curie, who discovered radium in 1898.

dosimeter — A portable instrument for measuring and registering the total accumulated dose of ionizing radiation.

duplicate — A second aliquot of a sample which is approximately equal in mass or volume to the first aliquot and is analyzed for the sample parameters. The laboratory performs duplicate analyses to evaluate the precision of an analysis.

half-life — The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical half-life.

ionization — The process of creating ions (charged particles) by adding one or more electrons to, or removing one or more electrons from, atoms or molecules. High temperatures, electrical discharges, nuclear radiation, and X-rays can cause ionization.

ionization chamber — An instrument that detects and measures ionizing radiation by measuring the electrical current that flows

	when radiation ionizes gas in a chamber.
isotope	One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Thus, ^{12}C, ^{13}C, and ^{14}C are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but often different physical properties (for example, ^{13}C and ^{14}C are radioactive).
matrix spike	An aliquot of a sample which is spiked with a known concentration of the analyte of interest. The purpose of analyzing this type of sample is to evaluate to the effect of the sample matrix upon the analytical methodology.
method blank	A method blank is a volume of demineralized water for liquid samples, or an appropriate solid matrix for soil/sediment samples, carried through the entire analytical procedure. The volume or weight of the blank must be approximately equal to the volume or weight of the sample processed. Analysis of the blank verifies that method interferences caused by contaminants in solvents, reagents, glassware, and other sample processing hardware are known and minimized.
minimum detectable concentration (MDC)	The smallest amount of radioactivity that can be reliably detected with a probability of Type I and Type II error at five percent each (DOE81).
millirem (mrem)	A one-thousandth part of a rem. (See rem.)
milliroentgen (mR)	A one-thousandth part of a roentgen. (See roentgen.)
noble gas	A gaseous element that does not readily enter into chemical combination with other elements. An inert gas.
personnel monitoring	The determination of the degree of radioactive contamination on individuals using survey meters, or the determination of radiation dosage received by means of internal or external dosimetry methods.
picocurie (pCi)	One trillionth part of a curie.
quality factor	The factor by which the absorbed dose is to be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiations, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than other types.
rad	Acronym for radiation absorbed dose. The basic unit of absorbed dose of radiation. A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing material.
radioisotope	An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.
radionuclide	A radioisotope.
rem	Acronym for roentgen equivalent man. The unit of dose of any ionizing radiation that produces the same biological effect as a unit of absorbed dose of ordinary X-rays. (See quality factor.)
roentgen (R)	A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered X-rays in 1895.
scintillation (dectector or counter)	The combination of phosphor, photomultiplier tube, and associated counter electronic circuits for count-

	ing light emissions produced in the phosphor by ionizing radiation.
Sievert (Sv)	A unit, in the International System of Units (SI), of dose equivalent which is equal to one joule per kilogram (1 Sv equals 100 rem).
terrestrial	The portion of natural radiation (background) that is emitted by naturally occurring radiation radioactive materials in the earth.
tritium	A radioactive isotope of hydrogen that decays by beta emission. It's half-life is about 12.5 years.
verification/ reference standard	A prepared sample of known concentration of a purchased standard reference material. These samples are analyzed in triplicate and the results are used to verify accuracy and precision of the procedure.
X-rays	Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. These rays are usually produced by excitation of the electron field around certain nuclei. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and to those originating in the electron field of the atom as X-rays. These rays are sometimes called roentgen rays after their discoverer, Wilhelm K. Roentgen.

Appendix A

Thermoluminescent Dosimetry Tables and Figures

Table A-1 Environmental Thermoluminescent Dosimetry Results - 1993

Table A-2 Personnel Thermoluminescent Dosimetry Results - 1993

Table A.1. Environmental Thermoluminescent Dosimetry Results - 1993

Station Name	# of Days	Daily Exposure (mR) Min	Max	Mean	Total Exposure[a] (mR)	Percent Completeness
Alamo, NV	365	0.22	0.25	0.24	88	100
Amargosa Valley, NV	365	0.20	0.32	0.25	94	100
American Borate, NV	365	0.25	0.33	0.29	108	100
Angleworm Ranch, NV	365	0.29	0.33	0.31	115	100
Atlanta Mine, NV	365	0.20	0.31	0.26	94	100
Austin, NV	365	0.33	0.39	0.35	131	100
Baker, CA	134	0.23	0.23	0.23	86	37
Barstow, CA	181	0.28	0.34	0.30	109	50
Battle Mountain, NV	296	0.20	0.22	0.21	76	81
Beatty, NV	365	0.28	0.34	0.31	115	100
Bishop, CA	180	0.29	0.34	0.32	114	49
Blue Eagle Ranch, NV	365	0.18	0.23	0.20	77	100
Blue Jay, NV	365	0.33	0.39	0.36	130	100
Boulder, UT	312	0.20	0.25	0.23	102	85
Bryce Canyon, UT	365	0.18	0.23	0.21	76	100
Cactus Springs, NV	290	0.16	0.20	0.18	68	79
Caliente, NV	365	0.21	0.27	0.25	90	100
Carp, NV	355	0.23	0.26	0.24	89	97
Cedar City, UT	365	0.17	0.21	0.19	70	100
Cherry Creek, NV	365	0.24	0.27	0.26	95	100
Clark Station, NV	365	0.30	0.33	0.31	113	100
Coaldale, NV	365	0.29	0.32	0.30	112	100
Complex I, NV	365	0.27	0.33	0.30	109	100
Corn Creek, NV	359	0.13	0.16	0.15	55	98
Cortez Hwy 278, NV	225	0.26	0.30	0.29	105	62
Coyote Summit, NV	365	0.31	0.38	0.34	128	100
Crescent Valley, NV	365	0.23	0.25	0.24	86	100
Currie, CA	365	0.29	0.31	0.30	108	100
Death Valley Jct, C	365	0.21	0.29	0.25	94	100
Delta, UT	365	0.15	0.22	0.20	72	100
Diablo Wells, NV	365	0.35	0.38	0.36	131	100
Duchesne, UT	365	0.13	0.20	0.18	65	100
Duckwater, NV	365	0.27	0.33	0.30	110	100
Elgin, NV	355	0.31	0.37	0.35	126	97
Elko, NV	365	0.20	0.24	0.22	80	100
Ely, NV	365	0.20	0.24	0.22	81	100
Enterprise, UT	304	0.34	0.57	0.45	164	83
Eureka, NV	365	0.28	0.40	0.34	122	100
Fallon, NV	365	0.21	0.23	0.22	93	100
Ferron, UT	202	0.14	0.69	0.29	87	55
Flying Diamond, NV	365	0.19	0.23	0.21	80	100
Furnace Creek, NV	365	0.17	0.22	0.19	74	100
Gabbs, NV	365	0.20	0.23	0.22	82	100

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-1. (Environmental Thermoluminescent Dosimetry Results - 1993, con't)

Station Name	# of Days	Daily Exposure (mR) Min	Max	Mean	Total Exposure[a] (mR)	Percent Completeness
Garrison, UT	365	0.18	0.21	0.20	88	100
Geyser Ranch, NV	365	0.19	0.24	0.21	79	100
Goldfield, NV	365	0.25	0.27	0.26	97	100
Grantsville, UT	296	0.13	0.29	0.20	66	81
Green River, UT	295	0.18	0.21	0.19	71	81
Groom Lake, NV	365	0.21	0.29	0.24	88	100
Gunnison, UT	310	0.16	0.19	0.18	64	85
Hancock Summit, NV	365	0.39	0.45	0.42	153	100
Hiko, NV	365	0.19	0.24	0.21	77	100
Hot Creek Ranch, NV	359	0.30	0.44	0.35	123	98
Ibapah, UT	365	0.27	0.28	0.28	101	100
Independence, CA	88	0.19	0.32	0.25	95	24
Indian Springs, NV	346	0.17	0.27	0.22	85	95
Ione, NV	315	0.29	0.33	0.31	111	86
Jacob Lake, AZ	295	0.23	0.29	0.27	127	81
Kanab, UT	295	0.14	0.18	0.17	62	81
Kirkby Ranch, NV	365	0.18	0.22	0.21	75	100
Koyens, NV	365	0.24	0.30	0.27	97	100
Las Vegas Airport, NV	355	0.14	0.17	0.16	57	97
Las Vegas UNLV, NV	355	0.16	0.21	0.19	68	97
Las Vegas USDI, NV	355	0.17	0.20	0.19	68	97
Lida, NV	365	0.27	0.30	0.28	106	100
Loa, UT	289	0.28	0.33	0.31	148	79
Lone Pine, CA	358	0.10	0.30	0.23	95	98
Lovelock, NV	365	0.21	0.22	0.22	78	100
Lund, NV	365	0.20	0.24	0.23	82	100
Lund, UT	365	0.26	0.31	0.29	106	100
Mammoth Geothermal, CA	180	0.30	0.34	0.32	116	49
Mammoth Lake, CA	272	0.23	0.36	0.30	94	75
Manhattan, NV	365	0.28	0.46	0.36	175	100
Medlins Ranch, NV	365	0.29	0.35	0.31	113	100
Mesquite, NV	365	0.15	0.18	0.16	61	100
Milford, UT	365	0.29	0.34	0.31	114	100
Mina, NV	365	0.28	0.30	0.28	105	100
Moapa, NV	127	0.20	0.22	0.21	80	35
Monticello, UT	296	0.21	0.26	0.24	89	81
Mtn Meadows Ranch, NV	270	0.21	0.21	0.21	83	74
Nash Ranch, NV	365	0.20	0.27	0.23	120	100
Nephi, UT	312	0.17	0.66	0.31	79	85
Nyala, NV	365	0.22	0.26	0.24	89	100
Olancha, CA	345	0.24	0.28	0.25	123	95
Overton, NV	365	0.15	0.17	0.16	61	100

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-1. (Environmental Thermoluminescent Dosimetry Results - 1993, con't)

Station Name	# of Days	Daily Exposure (mR) Min	Max	Mean	Total Exposure[a] (mR)	Percent Completeness
Page, AZ	295	0.16	0.19	0.18	67	81
Pahrump, NV	291	0.13	0.17	0.15	57	80
Parowan, UT	289	0.14	0.22	0.19	68	79
Penoyer Farms, NV	365	0.29	0.37	0.33	117	100
Pine Creek, NV	203	0.32	0.86	0.52	158	56
Pioche, NV	365	0.21	0.24	0.22	81	100
Price, UT	365	0.15	0.23	0.19	72	100
Provo, UT	365	0.23	0.26	0.24	88	100
Youngs Ranch, NV	365	0.12	0.25	0.19	70	100
Queen City Summ., NV	365	0.36	0.37	0.37	133	100
Rachel, NV	365	0.28	0.32	0.30	109	100
Reed Ranch, NV	365	0.28	0.34	0.32	116	100
Reno, NV	365	0.20	0.24	0.22	80	100
Ridgecrest, CA	134	0.26	0.27	0.27	97	37
Round Mountain, NV	365	0.32	0.36	0.34	124	100
Ruby Valley, NV	365	0.24	0.32	0.29	106	100
Desert Cor. Center, NV	365	0.13	0.17	0.16	60	97
Salt Lake City, UT	364	0.14	0.22	0.19	70	100
Shoshone, CA	324	0.20	0.29	0.24	90	89
Shurz, NV	365	0.27	0.30	0.29	105	100
Silver Peak, CA	364	0.22	0.33	0.25	86	100
Springdale, NV	365	0.27	0.37	0.31	119	100
St. George, UT	365	0.14	0.17	0.16	59	100
Steward Ranch, NV	365	0.25	0.33	0.29	111	100
Stone Cabin, NV	365	0.32	0.37	0.33	117	100
Sunnyside, NV	365	0.15	0.18	0.16	59	100
Tempuite, NV	278	0.27	0.30	0.29	107	76
Tonopah Test Range, NV	364	0.33	0.37	0.35	127	100
Tonopah, NV	364	0.31	0.34	0.32	120	100
Trout Creek, NV	365	0.20	0.24	0.22	81	100
Twin Springs, NV	365	0.29	0.34	0.32	115	100
U.S. Ecology, NV	365	0.30	0.36	0.32	121	100
Uhalde's Ranch, NV	364	0.27	0.34	0.30	108	100
Valley Crest, CA	365	0.13	0.20	0.16	62	100
Vernal, UT	365	0.14	0.22	0.20	70	100
Vernon, UT	296	0.15	0.33	0.23	77	81
Warm Springs #1, NV	365	0.36	1.17	0.53	145	100
Warm Springs #2, NV	270	0.81	0.85	0.84	305	74
Well, CA	365	0.21	0.25	0.23	85	100
Wendover, CA	365	0.20	0.22	0.21	76	100

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-1. (Environmental Thermoluminescent Dosimetry Results - 1993, con't)

Station Name	# of Days	Daily Exposure (mR) Min	Max	Mean	Total Exposure[a] (mR)	Percent Completeness
Willow Springs, UT	296	0.11	0.28	0.18	62	81
Winnemucca, NV	365	0.25	0.28	0.26	97	100

Minimum total exposure is 55 mR at Corn Creek, NV
Maximum total exposure is 305 mR at Warm Springs #2, NV
Mean of total exposure is 98 mR

TOTAL DATA COMPLETENESS: 91.4%

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-2. Personnel Thermoluminescent Dosimetry Results, 1993

Station Name		# of Days	Daily Deep Dose Exposure (mrem) Min	Max	Mean	Total Annual[a] Exposure (mrem)	Percent Completeness
427	Alamo, NV.	361	0.16	0.31	0.24	95	99
022	Alamo, NV.	358	0.12	0.36	0.24	91	98
426	Amargosa Center, NV.	358	0.20	0.32	0.27	100	98
380	Amargosa Valley, NV.	358	0.20	0.50	0.30	104	98
025	American Borate, NV.	365	0.09	0.20	0.14	62	100
056	American Borate, NV.	365	0.10	0.35	0.18	81	100
329	Austin, NV.	325	0.11	0.37	0.31	112	89
555	Beatty, NV.	321	0.24	0.35	0.30	113	88
429	Beatty, NV.	109	0.19	0.33	0.26	103	30
038	Beatty, NV.	296	0.20	0.64	0.36	115	81
556	Beatty, NV.	266	0.29	0.34	0.31	112	73
021	Beatty, NV.	361	0.14	0.44	0.31	117	99
009	Blue Eagle Ranch, NV.	347	0.22	0.41	0.30	117	95
002	Caliente, NV.	361	0.22	0.50	0.33	114	99
336	Caliente, NV.	361	0.18	0.30	0.24	91	99
044	Cedar City, UT.	361	0.07	0.40	0.26	117	99
454	Cedar City, UT.	361	0.04	0.32	0.21	96	99
011	Complex I, NV.	361	0.30	0.39	0.33	124	99
010	Complex I, NV.	361	0.17	0.39	0.31	117	99
014	Coyote Summit, NV.	361	0.22	0.35	0.28	108	99
015	Coyote Summit, NV.	361	0.26	0.46	0.33	120	99
304	Death Valley Jct, CA.	354	0.26	0.45	0.36	133	97

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-2. (Personnel Thermoluminescent Dosimetry Results - 1993, con't)

Station Name		# of Days	Daily Deep Dose Exposure (mrem) Min	Max	Mean	Total Annual[a] Exposure (mrem)	Percent Completeness
359	Death Valley, CA.	354	0.26	0.39	0.32	113	97
345	Delta, UT.	358	0.10	0.32	0.22	102	98
344	Delta, UT.	310	0.11	0.31	0.18	81	85
444	Ely, NV.	361	0.25	0.39	0.29	100	99
455	Ely, NV.	361	0.22	0.29	0.25	91	99
302	Gabbs, NV.	354	0.20	0.33	0.28	106	97
019	Goldfield, NV.	350	0.26	0.62	0.41	133	96
040	Goldfield, NV.	350	0.22	0.49	0.38	131	96
007	Goldfield, NV.	259	0.23	0.45	0.34	106	71
232	Hiko, NV.	361	0.19	0.40	0.28	106	99
405	Indian Springs, NV.	354	0.18	0.30	0.23	89	97
006	Indian Springs, NV.	354	0.21	0.37	0.28	99	97
037	Indian Springs, NV.	361	0.15	0.27	0.21	76	99
448	Ione, NV.	266	0.21	0.54	0.37	131	73
580	Ione, NV.	91	0.34	0.34	0.34	124	25
300	Koyne Ranch, NV.	358	0.19	0.31	0.26	96	98
379	Manhattan, NV.	350	0.28	0.57	0.36	127	96
346	Milford, UT.	358	0.10	0.36	0.26	108	98
347	Milford, UT.	358	0.13	0.36	0.28	110	98
307	Mina, NV.	255	0.12	0.47	0.28	131	70
018	Nyala, NV.	339	0.21	0.85	0.51	190	93
348	Overton, NV.	361	0.03	0.23	0.17	72	99
372	Pahrump, NV.	208	0.25	0.42	0.32	123	57
450	Pahrump, NV.	263	0.03	0.31	0.20	76	72
411	Pahrump, NV.	354	0.08	0.29	0.22	90	97
248	Penoyer Farms, NV.	358	0.21	0.35	0.27	105	98
293	Pioche, NV.	361	0.11	0.30	0.23	94	99
264	Rachel, NV.	336	0.18	0.35	0.27	105	92
334	Rachel, NV.	358	0.22	0.36	0.29	112	98
443	Rachel, NV.	350	0.24	0.31	0.28	107	96
449	Round Mountain, NV.	350	0.31	0.84	0.48	152	96
052	Salt Lake City, UT.	358	0.05	0.33	0.22	85	98
060	Shoshone, CA.	354	0.20	0.54	0.34	139	97
404	Shoshone, CA.	354	0.23	0.43	0.30	115	97
341	Silver Peak, NV.	266	0.18	0.37	0.28	106	73
045	St. George, UT.	361	0.04	0.25	0.18	74	99
029	Stone Cabin Ranch, NV	288	0.29	0.42	0.32	114	79
445	Terrell's Ranch, NV.	358	0.28	0.38	0.34	123	98
042	Tonopah, NV.	325	0.32	0.55	0.39	137	89
339	Tonopah, NV.	354	0.28	0.36	0.32	114	97
370	Twin Springs Ranch, NV.	91	0.23	0.52	0.37	126	25

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Table A-2. (Personnel Thermoluminescent Dosimetry Results - 1993, con't)

Station Name	# of Days	Daily Deep Dose Exposure (mrem) Min	Max	Mean	Total Annual[a] Exposure (mrem)	Percent Completeness
470 USDI	365	0.12	0.21	0.15	65	100
557 USDI	189	0.13	2.73	1.00	98	52
582 USDI	91	0.23	0.23	0.23	83	25
453 USDI	365	0.11	0.27	0.17	75	100
467 USDI	365	0.13	0.23	0.17	80	100
468 USDI	281	-0.03	0.18	0.13	61	77

Total data completeness: 88.8%

(a) Total annual exposure is calculated by multiplying the mean daily exposure rate for each quarterly deployment period by the number of days in that deployment period and then summing the values.

Appendix B

Atmospheric Monitoring Tables And Figures

Table B-1 Gross Alpha Results for the Offsite Standby Air Surveillance Network, 1993

Table B-2 Gross Alpha Results for the TOMSK - 1993

Table B-3 Offsite Atmospheric Plutonium Results for Standby Samplers, 1993

Table B-4 Offsite Atmospheric Tritium Results for Standby Samplers, 1993

Table B-5 Gross Beta Results for the Offsite Standby Air Surveillance Network, 1993

Table B-6 Gross Beta Results for the TOMSK - 1993

Table B-1. Gross Alpha Results for the Offsite Standby Air Surveillance Network - 1993

		Gross Alpha Concentration (10^{-15} μCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Little Rock, AR	3	1.6	0.3	0.8	0.7
Globe, AZ	3	2.3	1.2	1.7	0.6
Kingman, AZ	3	0.8	0.3	0.5	0.3
Tucson, AZ	1	1.2	1.2	1.2	--
Winslow, AZ	3	1.0	0.7	0.8	0.2
Yuma, AZ	3	1.4	0.8	1.1	0.3
Alturas, CA	2	0.4	0.1	0.3	0.2
Baker, CA	3	0.8	0.3	0.5	0.3
Bishop, CA	3	1.5	1.2	1.3	0.2
Chico, CA	3	0.9	0.0	0.4	0.5
Indio, CA	3	1.7	0.7	1.3	0.5
Lone Pine, CA	1	1.5	1.5	1.5	--
Ridgecrest, CA	3	2.8	1.1	1.8	0.9
Santa Rosa, CA	3	1.4	0.6	0.9	0.5
Cortez, CO	2	0.6	0.2	0.4	0.3
Denver, CO	3	0.7	0.3	0.5	0.2
Grand Junction, CO	2	1.1	1.0	1.1	0.1
Mountain Home, ID	2	0.3	0.3	0.3	0.0
Nampa, ID	4	1.4	-0.4	0.4	0.7
Pocatello, ID	3	3.6	0.4	1.8	1.6
Fort Dodge, IA	3	2.2	0.8	1.4	0.7
Iowa City, IA	3	1.6	0.8	1.2	0.4
Dodge City, KS	3	0.9	0.3	0.7	0.3
Monroe, LA	3	0.6	0.5	0.5	0.1
Minneapolis, MN	3	0.5	-0.1	0.3	0.3
Clayton, MO	3	0.8	-0.2	0.3	0.5
Joplin, MO	3	1.5	-0.2	0.7	0.9
St. Joseph, MO	3	0.9	0.1	0.5	0.4
Great Falls, MT	2	1.2	0.6	0.9	0.4
Kalispell, MT	3	1.0	-0.5	0.2	0.8
Miles City, MT	3	0.9	0.5	0.7	0.2
North Platte, NE	3	1.0	0.4	0.7	0.3
Adaven-Uhalde Ranch, NV	3	1.0	0.4	0.7	0.3
Battle Mountain, NV	4	1.4	0.1	0.7	0.5
Blue Jay, NV	3	1.1	0.0	0.5	0.6
Clark Station, NV	3	0.6	0.1	0.4	0.3
Currant-Angle Worm Ranch, NV	3	2.4	0.6	1.4	0.9

Mean MDC: 8.41×10^{-16} μCi/mL Standard Deviation of Mean MDC: 2.29×10^{-16} μCi/mL

MDC = minimum detectable concentration.
• = result is greater than the MDC of analysis.

Table B-1. (Gross Alpha Results for the Offsite Standby Air Surveillance Network - 1993, cont.)

Sampling Location	Number	Gross Alpha Concentration (10^{-15} µCi/mL) Maximum	Minimum	Arithmetic Mean	Standard Deviation
Currie Maint. Station, NV	3	2.4	0.8	1.5	0.8
Duckwater, NV	3	1.0	0.0	0.6	0.6
Elko, NV	4	1.7	0.5	0.9	0.6
Eureka, NV	3	2.0	–0.1	1.0	1.1
Fallon, NV	4	2.0	–0.2	0.7	0.9
Geyser Ranch, NV	2	0.6	0.2	0.4	0.3
Lida, NV	3	2.3	0.1	1.0	1.2
Lovelock, NV	3	0.9	0.2	0.6	0.4
Lund, NV	3	1.5	–0.2	0.6	0.9
Mesquite, NV	1	1.4	1.4	1.4	--
Reno, NV	4	1.4	0.2	0.9	0.6
Round Mountain, NV	3	0.7	–0.4	0.2	0.6
Wells, NV	4	1.7	–0.2	0.8	0.8
Winnemucca, NV	4	1.3	0.2	0.7	0.5
Albuquerque, NM	4	1.4	0.2	0.6	0.6
Carlsbad, NM	3	1.3	–0.2	0.6	0.8
Shiprock, NM	3	1.7	0.4	0.9	0.7
Bismarck, ND	3	0.6	0.3	0.5	0.2
Fargo, ND	3	0.8	0.1	0.5	0.4
Williston, ND	3	4.4	0.8	2.2	2.0
Muskogee, OK	4	0.9	0.4	0.6	0.3
Burns, OR	3	0.8	0.5	0.6	0.2
Medford, OR	1	0.0	0.0	0.0	--
Rapid City, SD	3	0.3	–0.5	0.0	0.4
Amarillo, TX	1	1.6	1.6	1.6	--
Austin, TX	2	2.7	2.4	2.6	0.2
Midland, TX	3	3.8	1.1	2.1	1.5
Tyler, TX	1	0.5	0.5	0.5	--
Bryce Canyon, UT	3	0.3	–0.2	0.1	0.3
Enterprise, UT	3	1.2	0.3	0.6	0.5
Garrison, UT	3	1.4	0.8	1.1	0.3
Logan, UT	3	0.7	0.1	0.5	0.3
Parowan, UT	1	2.6	2.6	2.6	--
Vernal, UT	3	1.3	0.6	1.0	0.4
Wendover, UT	4	1.8	0.4	1.0	0.6
Seattle, WA	3	1.1	0.3	0.6	0.5
Spokane, WA	3	0.3	–0.2	0.1	0.3
Rock Springs, WY	3	1.9	0.6	1.1	0.7
Worland, WY	3	0.6	0.1	0.4	0.3

Mean MDC: 8.41×10^{-16} µCi/mL Standard Deviation of Mean MDC: 2.29×10^{-16} µCi/mL

MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.

Table B-2. Gross Alpha Results for the TOMSK - 1993

		Gross Alpha Concentration (10^{-15} μCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Yuma, AZ	1	1.2	1.2	1.2	--
Alturas, CA	1	0.4	0.4	0.4	--
Baker, CA	1	2.1	2.1	2.1	--
Bishop, CA	1	0.5	0.5	0.5	--
Lone Pine, CA	1	0.4	0.4	0.4	--
Ridgecrest, CA	1	0.9	0.9	0.9	--
Santa Rosa, CA	3	-0.2	-0.9	-0.5	0.4
Mountain Home, ID	3	0.6	-0.9	0.1	0.9
Pocatello, ID	1	0.2	0.2	0.2	--
Kalispell, MT					
Equity Supply Co.	3	0.2	-1.9	-0.8	1.1
Miles City, MT	1	0.1	0.1	0.1	--
Adaven, NV					
Uhalde Rranch	1	0.4	0.4	0.4	--
Battle Mountain, NV	1	0.4	0.4	0.4	--
Blue Jay, NV	3	1.6	0.1	0.8	0.8
Elko, NV					
Phillips 66 Truck Stop	1	0.7	0.7	0.7	--
Geyser Ranch, NV	1	0.9	0.9	0.9	--
Lovelock, NV	3	0.7	-0.9	-0.3	0.9
Lund, NV	1	0.7	0.7	0.7	--
Reno, NV	1	0.5	0.5	0.5	--
Round Mountain, NV	1	0.4	0.4	0.4	--
Winnemucca, NV	4	2.2	0.0	0.7	1.0
Medford, OR	3	0.3	-0.6	-0.2	0.5
Seattle, WA	3	-0.3	-1.6	-0.9	0.7
Spokane, WA	1	0.3	0.3	0.3	--

Mean MDC: 2.19 x 10^{-15} μCi/mL Standard Deviation of Mean MDC: 1.21 x 10^{-15} μCi/mL

MDC = minimum detectable concentration.

* = result is greater than the MDC of analysis.

Table B-3. Offsite Atmospheric Plutonium Results for Standby Samplers - 1993

Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
^{238}Pu Concentration (10^{-18} μCi/mL)						
AZ (Winslow & Tucson)	3	26	-9.9	5.3	18	1.8
CA (Bishop & Ridgecrest)	3	3.9	-1.0	1.3	2.5	0.4
CO (Denver & Cortez)	3	19	-8.3	3.5	14	1.2
ID (Nampa & Mountain Home)	3	16	1.9	7.3	7.9	2.4
MO (Clayton & Joplin)	3	0.0	-9.6	-4.6	4.8	-1.8
MT (Great Falls & Miles City)	3	36	-13.0	7.4	25	2.5
NM (Albuquerque & Carlsbad)	3	11.0*	-1.5	4.4	6.1	1.5
ND (Bismarck & Fargo)	3	5.9	-18.0	-5.1	12	1.7
OR (Burns & Medford)	2	7.6	-12.0	-2.3	14	-0.8
TX (Austin & Amarillo)	2	7.9	5.4	6.6	1.8	2.2
UT (Logan & Vernal)	3	16	-44.0	-13.0	30	-4.3
WA (Seattle & Spokane)	3	12	-65.0	-19.0	40	-6.3
WY (Worland & Rock Springs)	3	33	5.2	21	14	7

Mean MDC: 4.15×10^{-17} μCi/mL Standard Deviation of Mean MDC: 4.30×10^{-17} μCi/mL

DCG = derived concentration guide. Established by DOE Order as 3×10^{-15} μCi/mL.

$^{239+240}$Pu Concentration (10^{-18} μCi/mL)						
AZ (Winslow & Tucson)	3	8.6	2.5	5.3	3.1	2.6
CA (Bishop & Ridgecrest)	3	-2.3	-3.9	-3.1	0.8	-1.5
CO (Denver & Cortez)	3	0.0	-4.1	-1.4	2.4	-0.7
ID (Nampa & Mountain Home)	3	16	0.0	6	8.9	3
MO (Clayton & Joplin)	3	2.1	-1.7	0.1	1.9	0.0
MT (Great Falls & Miles City)	3	1.9	0.0	0.6	1.1	0.3
NM (Albuquerque & Carlsbad)	3	11.0*	-2.0	2.9	6.8	1.4
ND (Bismarch & Fargo)	3	8.9	1.6	5	3.7	2.5
OR (Burns & Medford)	2	4.1	-7.6	-5.8	2.5	-2.9
TX (Austin & Amarillo)	2	7.2*	-7.9	-0.4	11	-0.2
UT (Logan & Vernal)	3	2.9	-11.0	-3.8	6.9	-1.9
WA (Seattle & Spokane)	3	12	0.0	4.4	6.3	2.2
WY (Worland & Rock Springs)	3	34.0*	0.0	18	17	9

Mean MDC: 2.89×10^{-17} μCi/mL Standard Deviation of Mean MDC: 3.0×10^{-17} μCi/mL

DCG = derived concentration guide. Established by DOE Order as 2×10^{-15} μCi/mL.
MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.
NA = not applicable.
Note = these data are from 1st, 2nd and 3rd quarters only.

Table B-4. Offsite Atmospheric Tritium Results for Standby Samplers - 1993

Sampling Location	HTO Concentration (10^{-7} pCi/mL) Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation	Mean as %DCG
Shoshone, CA	3	3	–13	–7	9	NA
Austin, NV	3	11	–17	–5	14	NA
Caliente, NV	3	20	–3	7	12	NA
Ely, NV	4	16	–2	5	8	NA
Cedar City, UT	5	21	–13	1	13	NA
Delta, UT	4	8	–2	2	4	NA
Milford, UT	4	13	–1	5	7	NA

Mean MDC: 4.3×10^{-6} pCi/mL Standard Deviation of Mean MDC: 5.0×10^{-6} pCi/mL

DCG = derived concentration guide. Established by DOE Order as 1×10^{-2} pCi/mL.
MDC = minimum detectable concentration.
NA = not applicable.

Table B-5. Gross Beta Results for the Offsite Standby Air Surveillance Network - 1993

Sampling Location	Gross Beta Concentration (10^{-14} µCi/mL) Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Little Rock, AR	3	2.4	1.5	1.8	0.5
Globe, AZ	3	1.7	1.6	1.7	0.1
Kingman, AZ	3	1.8	0.3	1.1	0.8
Tucson, AZ	1	1.7	1.7	1.7	--
Winslow, AZ	3	2.0	1.1	1.6	0.5
Yuma, AZ	3	1.5	0.1	1.0	0.7
Alturas, CA	2	1.4	0.5	1.0	0.6
Baker, CA	3	1.6	1.0	1.2	0.3
Bishop, CA	3	1.8	1.4	1.6	0.2
Chico, CA	3	2.3	1.0	1.5	0.7
Indio, CA	3	3.0	1.6	2.3	0.7
Lone Pine, CA	1	1.6	1.6	1.6	--

Mean MDC: 2.32×10^{-15} µCi/mL Standard Deviation of Mean MDC: 2.99×10^{-16} µCi/mL

MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.

Table B-5. (Gross Beta Results for the Offsite Standby Air Surveillance Network - 1993, cont.)

		Gross Beta Concentration (10^{-14} µCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Ridgecrest, CA	3	2.1	1.4	1.7	0.4
Santa Rosa, CA	3	1.2	1.0	1.1	0.1
Cortez, CO	2	1.8	1.2	1.5	0.5
Denver, CO	3	1.8	1.0	1.4	0.4
Grand Junction, CO	2	3.7	2.1	2.9	1.1
Mountain Home, ID	2	0.6	0.3	0.4	0.3
Nampa, ID	4	2.2	0.8	1.4	0.7
Pocatello, ID	3	2.4	0.8	1.6	0.8
Fort Dodge, IA	3	3.4	1.5	2.2	1.0
Iowa City, IA	3	1.9	1.2	1.5	0.3
Dodge City, KS	3	1.8	1.4	1.6	0.3
Monroe, LA	3	1.7	1.3	1.5	0.2
Minneapolis, MN	3	1.2	0.8	1.0	0.2
Clayton, MO	3	1.8	0.9	1.4	0.5
Joplin, MO	3	3.3	1.2	2.2	1.1
St. Joseph, MO	3	1.2	0.0	0.6	0.6
Great Falls, MT	2	0.9	0.6	0.8	0.2
Kalispell, MT	3	1.4	0.7	1.1	0.3
Miles City, MT	3	3.7	0.9	1.9	1.6
North Platte, NE	3	1.7	1.2	1.4	0.3
Adaven-Uhalde Ranch, NV	3	1.9	1.0	1.5	0.5
Battle Mountain, NV	4	2.9	0.9	1.6	0.9
Blue Jay, NV	3	1.6	0.9	1.4	0.4
Clark Station, NV	3	1.4	0.5	1.1	0.6
Currant-Angle Worm Ranch, NV	3	1.8	1.2	1.5	0.3
Currie Maint. Station, NV	3	1.8	1.2	1.4	0.3
Duckwater, NV	3	1.5	0.6	1.2	0.5
Elko, NV	4	2.5	0.4	1.5	0.9
Eureka, NV	3	1.5	0.5	1.1	0.6
Fallon, NV	4	2.7	1.3	1.8	0.6
Geyser Ranch, NV	2	2.5	1.2	1.8	0.9
Lida, NV	3	1.8	1.0	1.3	0.4
Lovelock, NV	3	2.6	0.4	1.4	1.1
Lund, NV	3	1.9	1.2	1.6	0.3
Mesquite, NV	1	1.6	1.6	1.6	--

Mean MDC: 2.32×10^{-15} µCi/mL Standard Deviation of Mean MDC: 2.99×10^{-16} µCi/mL

MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.

Table B-5. (Gross Beta Results for the Offsite Standby Air Surveillance Network - 1993, cont.)

		Gross Beta Concentration (10^{-14} µCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Reno, NV	4	2.4	1.2	1.6	0.5
Round Mountain, NV	3	1.9	1.0	1.5	0.5
Wells, NV	4	1.8	0.1	1.2	0.7
Winnemucca, NV	4	2.2	0.9	1.4	0.6
Albuquerque, NM	4	2.1	0.2	1.2	0.8
Carlsbad, NM	3	2.2	1.3	1.7	0.5
Shiprock, NM	3	1.6	1.3	1.5	0.2
Bismarck, ND	3	2.0	0.9	1.3	0.6
Fargo, ND	3	2.5	0.5	1.3	1.1
Williston, ND	3	4.1	1.4	2.3	1.6
Muskogee, OK	4	1.5	0.5	1.1	0.5
Burns, OR	3	1.0	0.6	0.8	0.2
Medford, OR	1	0.9	0.9	0.9	--
Rapid City, SD	3	1.6	0.7	1.1	0.5
Amarillo, TX	1	1.1	1.1	1.1	--
Austin, TX	2	3.6	2.2	2.9	0.9
Midland, TX	3	3.3	0.8	1.7	1.4
Tyler, TX	1	1.2	1.2	1.2	--
Bryce Canyon, UT	3	1.4	0.1	0.6	0.7
Enterprise, UT	3	1.7	1.2	1.5	0.3
Garrison, UT	3	2.4	1.2	1.7	0.6
Logan, UT	3	1.3	1.1	1.2	0.1
Parowan, UT	1	2.1	2.1	2.1	--
Vernal, UT	3	4.8	0.9	2.2	2.2
Wendover, UT	4	1.8	1.1	1.4	0.3
Seattle, WA	3	1.5	0.3	0.8	0.7
Spokane, WA	3	2.1	0.6	1.1	0.8
Rock Springs, WY	3	3.5	1.3	2.1	1.2
Worland, WY	3	2.7	0.2	1.1	1.4

Mean MDC: 2.32×10^{-15} µCi/mL Standard Deviation of Mean MDC: 2.99×10^{-16} µCi/mL

MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.

Table B-6. Gross Beta Results for the TOMSK - 1993

		Gross Beta Concentration (10^{-14} μCi/mL)			
Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Yuma, AZ	1	0.9	0.9	0.9	--
Alturas, CA	1	0.4	0.4	0.4	--
Baker, CA	1	1.3	1.3	1.3	--
Bishop, CA	1	0.9	0.9	0.9	-
Lone Pine, CA	1	1.2	1.2	1.2	--
Ridgecrest, CA	1	1.4	1.4	1.4	--
Santa Rosa, CA	3	0.6	0.3	0.4	0.2
Mountain Home, ID	3	0.2	-0.4	-0.1	0.3
Pocatello, ID	1	0.6	0.6	0.6	--
Kalispell, MT					
Equity Supply Co.	3	1.1	0.2	0.6	0.4
Miles City, MT	1	0.6	0.6	0.6	--
Adaven, NV					
Uhalde Rranch	1	0.7	0.7	0.7	--
Battle Mountain, NV	1	1.1	1.1	1.1	--
Blue Jay, NV	3	1.4	1.0	1.3	0.3
Elko, NV					
Phillips 66 Truck Stop	1	1.3	1.3	1.3	--
Geyser Ranch, NV	1	0.9	0.9	0.9	--
Lovelock, NV	3	1.1	-0.1	0.6	0.6
Lund, NV	1	0.9	0.9	0.9	--
Reno, NV	1	0.9	0.9	0.9	--
Round Mountain, NV	1	0.8	0.8	0.8	--
Winnemucca, NV	4	1.2	0.2	0.6	0.4
Medford, OR	3	0.7	0.5	0.6	0.1
Seattle, WA	3	0.3	0.1	0.2	0.1
Spokane, WA	1	1.0	1.0	1.0	--

Mean MDC: 5.17×10^{-15} μCi/mL Standard Deviation of Mean MDC: 2.88×10^{-15} μCi/mL

MDC = minimum detectable concentration.
* = result is greater than the MDC of analysis.

Appendix C

Milk Surveillance Network Tables

Table C-1 Standby Milk Surveillance Network Radiochemical Analyses Results - 1993

Table C-2 Standby Milk Surveillance Network Gamma Spectrometry Results - 1993

Table C-1. Standby Milk Surveillance Network Radiochemical Analyses Results - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s (MDC)[a] ^{3}H x 10^{-9} µCi/mL[b]	^{89}Sr x 10^{-9} µCi/mL[b]	^{90}Sr x 10^{-9} µCi/mL[b]
Little Rock, AR Borden's	07/06	382 ± 143 (462)	N/A	2.1 ± 0.41 (1.4)*
Russellville, AR Arkansas Tech Univ	08/25	–33 ± 117 (386)	N/A	0.73 ± 0.45 (1.5)
Taylor, AZ Sunrise Dairy	09/19	N/A	N/A	0.18 ± 0.28 (1.2)
Tucson, AZ University of Arizona	08/26	75 ± 116 (380)	N/A	0.28 ± 0.31 (1.4)
Delta, CO Meadow Gold Dairy	06/09	271 ± 144 (469)	0.98 ± 1.1 (1.7)	0.29 ± 0.35 (1.5)
Denver, CO Safeway Dairy Plant	06/15	134 ± 142 (466)	–0.49 ± 0.99 (1.5)	0.80 ± 0.34 (1.5)
Quincy, IL Prairie Farms Dairy	06/23	121 ± 141 (462)	0.081 ± 1.1 (1.4)	1.4 ± 0.40 (1.5)
Boise, ID Meadow Gold Dairies	10/29	N/A	0.49 ± 0.68 (1.1)	0.30 ± 0.27 (1.3)
Idaho Falls, ID Reed's Dairy	10/26	N/A	–0.050 ± 0.71 (1.2)	0.59 ± 0.27 (1.3)
Dubuque, IA Swiss Valley Farms, Inc	08/31	–24 ± 116 (382)	N/A	1.8 ± 0.34 (1.3)*
Ellis, KS Mid-America Dairymen	08/18	356 ± 118 (382)	–1.3 ± 1 (1.4)	1.5 ± 0.37 (1.4)*
Sabetha, KS Mid-America Dairymen	07/14	153 ± 137 (449)	–1.5 ± 1.3 (1.8)	1.6 ± 0.39 (1.5)*
Baton Rouge, LA Borden's	05/17	117 ± 140 (457)	–0.39 ± 1 (1.3)	1.9 ± 0.41 (1.5)*

(a) = minimum detectable concentration (MDC).
(b) = multiply the results by 3.7×10^{-7} to obtain Bq/L.
* = result is greater than the MDC of analysis.
N/A = not analyzed.

Table C-1. (Standby Milk Surveillance Network Radiochemical Analyses Results - 1993, cont.)

Sampling Location	Collection Date in 1993	Concentration ± 1s (MDC)[a] ^{3}H x 10^{-9} µCi/mL[b]	^{89}Sr x 10^{-9} µCi/mL[b]	^{90}Sr x 10^{-9} µCi/mL[b]
Monroe, LA Borden's Dairy	05/17	325 ± 139 (451)	N/A	1.3 ± 0.38 (1.5)
New Orleans, LA Brown's Velvet Dairy	04/22	338 ± 141 (457)	−1.1 ± 1.5 (1.9)	2.4 ± 0.44 (1.5)*
Rochester, MN Assoc Milk Prod Inc	05/10	279 ± 138 (449)	−0.73 ± 0.99 (1.4)	1.6 ± 0.37 (1.4)*
Thief River Falls, MN Bridgeman Dairy	09/09	58 ± 113 (370)	N/A	1 ± 0.35 (1.3)
Monett, MO Mid-America Dairy Inc	11/01	N/A	0.14 ± 0.88 (1.2)	1.7 ± 0.35 (1.3)*
Chillicothe, MO Mid-America Dairymen	07/15	312 ± 119 (386)	N/A	1.7 ± 0.41 (1.3)*
Billings, MT Meadow Gold Dairy	11/03	N/A	0.24 ± 0.77 (1.1)	1.2 ± 0.32 (1.3)
Norfolk, NE Gillette Dairy	07/30	32 ± 113 (370)	0.52 ± 1.6 (1.9)	1.8 ± 0.44 (1.4)*
North Platte, NE Mid-America Dairymen	07/30	261 ± 119 (387)	0.68 ± 1.5 (1.9)	1.4 ± 0.42 (1.4)
Albuquerque, NM Borden's Valley Gold	08/23	101 ± 119 (392)	N/A	0.65± 0.35 (1.4)
La Plata, NM River Edge Dairy	08/27	221 ± 118 (386)	−0.20 ± 1.0 (1.2)	1.4 ± 0.41 (1.4)
Bismarck, ND Bridgeman Creamery, Inc	06/21	420 ± 141 (455)	1 ± 1.3 (1.5)	1.9 ± 0.45 (1.5)*
Grand Forks, ND Minnesota Dairy	06/01	301 ± 144 (469)	N/A	0.64± 0.31 (1.3)

(a) = minimum detectable concentration (MDC).
(b) = multiply the results by 3.7×10^{-7} to obtain Bq/L.
* = result is greater than the MDC of analysis.
N/A = not analyzed.

Table C-1. (Standby Milk Surveillance Network Radiochemical Analyses Results - 1993, cont.)

Sampling Location	Collection Date in 1993	Concentration ± 1s (MDC)[a] ^{3}H x 10^{-9} µCi/mL[b]	^{89}Sr x 10^{-9} µCi/mL[b]	^{90}Sr x 10^{-9} µCi/mL[b]
Medford, OR Dairygold Farms	10/18	N/A	N/A	0.62± 0.35 (1.3)
Redmond, OR Eberhard's Creamery Inc	12/09	N/A	N/A	N/A
Salem, OR Curly's Dairy	11/01	N/A	0.38 ± 0.76 (1.1)	0.73± 0.30 (1.3)
Tillamook, OR Tillamook Creamery	10/27	N/A	−0.75 ± 0.80 (1.2)	1.5 ± 0.31 (1.3)*
Rapid City, SD Gillette Dairy - Black Hills	07/23	−8 ± 115 (380)	N/A	1.4 ± 0.35 (1.3)*
Sulphur Springs, TX Tommy Rue Potts Dairy	11/30	N/A	1.1 ± 8.85 (1)*	1.5 ± 0.42 (1.4)*
Windthorst, TX Lloyd Wolf Dairy	09/28	N/A	N/A	0.97 ± 0.31 (1.2)
Seattle, WA Darigold Inc.	09/28	N/A	N/A	1.1 ± 0.34 (1.3)
Spokane, WA Darigold Inc.	10/28	N/A	0.063 ± 0.90 (1.3)	1.5 ± 0.35 (1.3)*
Cheyenne, WY Dairy Gold Foods	09/01	−23 ± 116 (383)	N/A	0.95 ± 0.31 (1.3)
Sheridan, WY Mydland Dairy	06/04	151 ± 139 (453)	N/A	1.6 ± 0.41 (1.5)*

(a) = minimum detectable concentration (MDC).
(b) = multiply the results by 3.7 x 10^{-7} to obtain Bq/L.
* = result is greater than the MDC of analysis.
N/A = not analyzed.

Table C-2. Standby Milk Surveillance Network Gamma Spectrometry Results - 1993

Samples from the following locations were analyzed by gamma spectrometry only: in all cases only naturally occuring radionuclides were detected.

Sampling Location	Collection Date
Duncan, AZ	
Lunt Dairy	09/29
Taylor, AZ	
Sunrise Dairy	09/19
Tempe, AZ	
United Dairymen of Arizona	09/29
Tucson, AZ	
University of Arizona	08/26
Batesville, AR	
Hills Valley Foods	08/16
Fayetteville, AR	
University Of Arkansas	08/17
Little Rock, AR	
Bordens	07/06
Russellville, AR	
Arkansas Tech University	08/25
Chino, CA	
CA Institute for Men	09/27
Crescent City, CA	
Rumiano Cheese Company	09/07
Fernbridge, CA	
Humboldt Creamery Assn	09/08
Fresno, CA	
CA State University Creamery	09/27
Helendale, CA	
Osterkamp Dairy No. 2	09/27
Holtville, CA	
Schaffner & Son Dairy	09/21
Lancaster, CA	
High Desert Dairy	09/21
Lompoc, CA	
Federal Penitentiary Camp	12/07
Manchester, CA	
Point Arena Dairies	09/14
Manteca, CA	
Supremo Foods	09/26
Modesto, CA	
Foster Farms - Jersey Dairy	12/07
Petaluma, CA	
Point Reyes Seashore Dairy	09/14
Redding, CA	
McColl's Dairy Produce	12/09
San Jose, CA	
Marquez Bros Mexican Cheese	10/04
San Luis Obispo, CA	
Cal Poly University Dairy	10/14
Soledad, CA	
Correction Training Industry	09/27
Tracy, CA	
Deuel Vocational Institute	12/07
Tulare, CA	
Dairymen's Co-Op Cream	10/25
Willows, CA	
Mid-America Dairies	12/15
Colorado Springs, CO	
Sinton Dairy	06/06
Delta, CO	
Meadow Gold Dairy	06/09
Denver, CO	
Safeway Dairy Plant	06/15
Ft Collins, CO	
Poudre Valley Creamery	06/07
Boise, ID	
Meadow Gold Dairies	10/29
Buhl, ID	
Smiths Dairy Products	09/20
Caldwell, ID	
Darigold Inc.	10/30
Pocatello, ID	
Rowland's Meadowgold Dairy	10/27
Dubuque, IA	
Swiss Valley Farms, Inc	08/31
Lake Mills, IA	
Lake Mills Coop Creamery	07/16
Lemars, IA	
Wells Dairy	07/19
Marion, IA	
Mid-America Dairymen	12/03
Ellis, KS	
Mid-America Dairy	08/18
Sabetha, KS	
Mid-America Dairymen	07/14
Manhattan, KS	
Kansas State University	07/27
Baton Rouge, LA	
Borden's Dairy	05/17
Lafayette, LA	
Borden's Dairy	09/15
Monroe, LA	
Borden's Dairy	05/17
New Orleans, LA	
Brown's Velvet Dry Produce	04/22
New Orleans, LA	
Walker Roemer Dairy	04/22
Shreveport, LA	
Foremost Dairy	06/01

Table C-2. (Standby Milk Surveillance Network Gamma Spectrometry Results - 1993, cont.)

Samples from the following locations were analyzed by gamma spectrometry only: in all cases only naturally occuring radionuclides were detected.

Sampling Location	Collection Date
Fergus Falls, MN	
Mid-America Dairymen	05/12
Browerville, MN	
Land O' Lakes, Inc.	06/17
Nicollet, MN	
Doug Schultz Farm	05/27
Rochester, MN	
Association Milk Produce Inc.	05/10
Thief River Falls, MN	
Bridgeman Dairy	09/09
Monett, MO	
Mid-America Dairy Inc.	11/01
Chillicothe, MO	
Mid-America Dairymen Inc.	07/15
Jackson, MO	
Mid-America Dairymen Inc	12/30
Jefferson City, MO	
Central Dairy Company	12/10
Billings, MT	
Meadow Gold Dairy	11/03
Bozeman, MT	
Country Classic-DBA-Darigold	11/03
Great Falls, MT	
Meadow Gold Dairy	12/08
Kalispell, MT	
Equity Supply Co	12/06
Bismarck, ND	
Bridgeman Creamery, Inc	06/21
Fargo, ND	
Cass Clay Creamery	06/21
Grand Forks, ND	
Minnesota Dairy	06/01
Minot, ND	
Bridgemen Creamery	06/15
Chappell, NE	
Leprino Foods	07/28
Norfolk, NE	
Gillette Dairy	07/30
North Platte, NE	
Mid-America Dairymen	07/30
Omaha, NE	
Roberts Dairy, Marshall Green	11/03
Superior, NE	
Mid-America Dairymen	07/29
Albuquerque, NM	
Borden's Valley Gold	08/23
La Plata, NM	
River Edge Dairy	08/27
Las Vegas, NV	
Anderson Dairy	10/01
Reno, NV	
Model Dairy	09/24
Yerington, NV	
Valley Dairy	11/29
Coalgate, OK	
Larry Krebs Dairy	11/29
Claremore, OK	
Swan Brothers Dairy	11/19
Mcalester, OK	
Jackie Brannon Corr Center	12/10
Stillwater, OK	
OK State University Dairy	11/22
Grants Pass, OR	
Valley Of Rouge Dairy	09/13
Junction City, OR	
Lockmead Farms Inc	10/25
Klamath Falls, OR	
Klamath Dairy Products	09/20
Medford, OR	
Dairygold Farms	10/18
Myrtle Point, OR	
Safeway Stores Inc	09/14
Ontario, OR	
Eastway Dairy	12/13
Portland, OR	
Darigold Farms	12/31
Redmond, OR	
Eberhard's Creamery Inc	12/09
Salem, OR	
Curly's Dairy	11/01
Tillamook, OR	
Tillamook Company Creamery	10/27
Ethan, SD	
Ethan Dairy Products	06/29
Rapid City, SD	
Gillette Dry-Black Hills	07/23
Sioux Falls, SD	
Lakeside Dairy	12/13
Volga, SD	
Land O'Lakes Inc	06/14
Canyon, TX	
West Texas State Dairy	10/11
Corpus Christi, TX	
Hygeia Milk Plant	11/30
Fabens, TX	
Island Dairy - El Paso County	12/08
Glen Rose, TX	
Dewayne Hankins Dairy	10/21

Table C-2. (Standby Milk Surveillance Network Gamma Spectrometry Results - 1993, cont.)

Samples from the following locations were analyzed by gamma spectrometry only: in all cases only naturally occuring radionuclides were detected.

Sampling Location	Collection Date	Sampling Location	Collection Date
Sulphur Springs, TX		Seattle, WA	
Tommy Rue Potts Dairy	11/30	Darigold, Inc	09/28
Windthorst, TX		Spokane, WA	
Lloyd Wolf Dairy	09/28	Darigold, Inc	10/28
Beaver, UT		Cheyenne, WY	
Cache Valley Dairy	12/30	Dairy Gold Foods	09/01
Provo, UT		Riverton, WY	
BYU Dairy Products Laboratory	12/30	Western Dairymen's Co-op	06/03
Richfield, UT		Sheridan, WY	
Ideal Dairy	12/17	Mydland Dairy	06/04
Smithfield, UT		Thayne, WY	
Cache Valley Dairy	12/13	Western Dairymen's Co-op	06/17
Moses Lake, WA			
Safeway Stores, Inc	10/28		

Appendix D

Long-Term Hydrological Monitoring Tables

Table D-1 Long-Term Hydrological Monitoring Program Analytical Results for Locations in the NTS Vicinity - 1993

Table D-2 Long-Term Hydrological Monitoring Program Analytical Results for Project FAULTESS - 1993.

Table D-3 Long-Term Hydrological Monitoring Program Analytical Results for Project SHOAL - 1993

Table D-4 Long-Term Hydrological Monitoring Program Analytical Results for Project RULISON - 1993

Table D-5 Long-Term Hydrological Monitoring Program Analytical Results for Project RIO BLANCO - 1993

Table D-6 Long-Term Hydrological Monitoring Program Analytical Results for Project GNOME - 1993

Table D-7 Long-Term Hydrological Monitoring Program Analytical Results for Project GASBUGGY - 1993

Table D-8 Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE - 1993

Table D-9 Long-Term Hydrological Monitoring Program Analytical Results for Amchitka Island, Alaska - 1993

Table D-1. Long-Term Hydrological Monitoring Program Analytical Results for Locations in the Vicinity of the Nevada Test Site - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Shoshone, CA			
Shoshone Spring	02/08	−0.18 ± 1.6	NA
	08/16	1.4 ± 1.5	NA
Amargosa Valley, NV			
Well Mary Nickell's	02/02	1.5 ± 1.5	NA
	08/10	0.38 ± 1.6	NA
Adaven, NV			
Adaven Spring	01/06	31 ± 2.0*	0.03
	07/07	36. ± 2.0*	0.04
Alamo, NV			
Well 4 City	01/06	−0.59 ± 1.6	NA
	07/08	−0.08 ± 1.3	NA
Ash Meadows, NV			
Crystal Pool	05/12	−1.6 ± 1.4	NA
	11/09	1.1 ± 1.5	NA
Fairbanks Springs	05/12	2.0 ± 1.7	NA
	11/09	−0.92 ± 2.1	NA
Spring-17S-50E-14cac	06/17	−0.83 ± 1.4	NA
	10/06	1.4 ± 1.5	NA
	12/14	−3.1 ± 1.7	NA
Well 18S-51E-7db	05/12	2.3 ± 1.5	NA
	11/09	1.4 ± 1.5	NA
Beatty, NV			
U.S. Ecology	03/03	−0.19 ± 1.7	NA
	09/16	1.5 ± 1.7	NA
Specie Springs	02/04	−85 ± 137.[b]	NA
	07/21	18 ± 1.6*	0.02
	12/15	20 ± 1.9*	0.02
Tolicha Peak	02/10	62 ± 137.[b]	NA
	04/08	0.67 ± 1.6	NA
Well 11S-48-1dd Coffers	02/03	−121 ± 136	NA
	07/15	0.61 ± 1.4	NA
Well 12S-47E-7dbd City	01/13	37. ± 140.[b]	NA
	07/21	0.1 ± 1.6	NA
Well Road D Spicers	02/10	209 ± 138.[b]	NA
	06/08	0.76 ± 1.4	NA
Younghans Ranch	06/24	3.8 ± 1.6	NA
(House Well)	12/15	2.0 ± 2.8	NA

(a) Established by DOE Order as 90,000 pCi/L tritium
(b) Multiply the results by 3.7×10^7 to obtain Bq/L
N/A Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable

Table D-1. (Long-Term Hydrological Monitoring Program Analytical Results for Locations in the NTS Vicinity - 1993, cont.)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Boulder City, NV			
Lake Mead Intake	03/08	37 ± 138.[b]	NA
	09/07	54 ± 2.0*	<0.01
Clark Station, NV			
Well 6 TTR	02/02	0.41 ± 1.75	NA
	08/12	−0.92 ± 1.50	NA
Hiko, NV			
Crystal Springs	01/06	1.6 ± 1.6	NA
	07/13	2.5 ± 1.9	NA
Indian Springs, NV			
Well 1 Sewer Company	03/15	11 ± 138.[b]	NA
	09/13	−1.4 ± 1.6	NA
Well 2 US Air Force	03/15	137 ± 139.[b]	NA
	09/13	3.7 ± 1.8	NA
Johnnie, NV			
Well Johnnie Mine	03/15	−159 ± 137.[b]	0.18
	09/15	2.1 ± 1.8	<0.01
Las Vegas, NV			
(Alt. Well 23A)	04/05	−1.7 ± 1.6	NA
Well 28 Water District	10/01	−0.24 ± 1.9	NA
Lathrop Wells, NV			
City 15S-50E-18cdc	04/09	4.1 ± 1.6	NA
	10/06	−1.3 ± 1.9	NA
Nyala, NV			
Sharp's Ranch	02/02	−11 ± 137.[b]	NA
	08/12	1.7 ± 1.6	NA
Oasis Valley, NV			
Goss Springs	02/09	74 ± 137.[b]	NA
	08/20	0.29 ± 1.55	NA
Pahrump, NV			
Calvada Well	02/08	0.40 ± 1.40	NA
	08/16	0.65 ± 1.35	NA
Rachel, NV			
Wells 7 & 8 Penoyer	05/10	3.8 ± 1.4	NA
	10/05	−1.4 ± 1.5	NA
Well 13 Penoyer	04/28	−0.30 ± 1.70	NA
	10/05	−1.4 ± 1.7	NA

(a) Established by DOE Order as 90,000 pCi/L tritium
(b) Multiply the results by 3.7×10^7 to obtain Bq/L
N/A Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable

Table D-1. (Long-Term Hydrological Monitoring Program Analytical Results for Locations in the NTS Vicinity - 1993, cont.)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Well Penoyer Culinary	07/13	−1.7 ± 1.4	NA
	12/07	−2.2 ± 1.6	NA
Tempiute, NV			
Union Carbide Well	05/05	3.1 ± 1.4	NA
Tonopah, NV			
City Well	03/01	−48 ± 138.[b]	NA
	09/15	1.1 ± 1.3	NA
Warm Springs, NV			
Twin Springs Ranch	04/07	−4.1 ± 1.7	NA
	10/05	1.1 ± 1.9	NA

Mean MDC: 5.3 pCi/L Standard Deviation of Mean MDC: 0.8 pCi/L

• = Activity is greater than the minimum detectable concentration (MDC)
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 454 pCi/L Std. Dev. of Mean MDC: 3 pCi/L).

Table D-2. Long-Term Hydrological Monitoring Program Analytical Results for Project FAULTLESS - 1993.

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Blue Jay, NV			
Hot Creek Ranch Spring	03/17	−2.0 ± 1.4	NA
Maintenance Station	03/16	7.3 ± 1.8*	<0.01
Well Bias	03/17	−0.78 ± 1.6	NA
Well HTH-1	03/23	3.8 ± 1.8	NA
Well HTH-2	03/23	−4.5 ± 1.7	NA
Well Six Mile	03/17	Not Sampled, Pump motor removed	

Mean MDC: 5.4 pCi/L Standard Deviation of Mean MDC: 0.5 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.

Table D-3. Long-Term Hydrological Monitoring Program Analytical Results for Project SHOAL - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Frenchmen Station, NV			
Hunt's Station	02/24	−2.6 ± 1.6	NA
Smith/James Springs	02/25	62 ± 2.1*	0.07
Spring Windmill	02/24	Not Sampled - Well removed	
Well Flowing	02/25	−2.5 ± 1.8	NA
Well H-3	02/24	0.92 ± 1.60	NA
Well HS-1	02/25	2.7 ± 1.8	NA

Mean MDC: 5.6 pCi/L Standard Deviation of Mean MDC: 0.5 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.

Table D-4. Long-Term Hydrological Monitoring Program Analytical Results for Project RULISON - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Rulison, CO			
Lee Hayward Ranch	06/16	116 ± 3.*	0.13
Potter Ranch	06/16	Sample Invalid	NA
Robert Searcy Ranch	06/16	57 ± 2.1*	0.06
Felix Sefcovic Ranch	06/16	100 ± 2.4*	0.11
Grand Valley, CO			
Battlement Creek	06/16	49 ± 1.9*	0.05
City Springs	06/16	−1.6 ± 1.5	NA
Albert Gardner Ranch	06/16	80 ± 2.2*	0.09
Spring 300 Yd. N of GZ	06/16	57 ± 2.1*	0.06
Well CER Test	06/16	51 ± 2.1*	0.06

Mean MDC: 5.1 pCi/L Standard Deviation of Mean MDC: 0.3 pCi/L

• = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.

Table D-5. Long-Term Hydrological Monitoring Program Analytical Results for Project RIO BLANCO - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Rio Blanco, CO			
B-1 Equity Camp (spring)	06/18	58 ± 2.5*	0.06
CER No.1 Black Sulfur (spring)	06/18	49 ± 1.9*	0.05
CER No.4 Black Sulfur (spring)	06/18	55 ± 2.2*	0.06
Fawn Creek 1	06/17	179 ± 114.[b]	NA
Fawn Creek 3	06/17	28 ± 1.7*	0.03
Fawn Creek 500 Ft Upstream	06/17	75 ± 113.[b]	NA
Fawn Creek 500 Ft Downstream	06/17	39 ± 2.2*	0.04
Fawn Creek 6800 Ft Upstream	06/17	34 ± 2.1*	0.04
Fawn Creek 8400 Ft Downstream	06/17	39 ± 1.9*	0.04
Johnson Artesian Well	06/17	1.8 ± 1.8	NA
Brennan Windmill (well)	06/17	7.0 ± 2.0*	<0.01
Well RB-D-01	06/17	−0.48 ± 1.60	NA
Well RB-D-03	06/17	2.5 ± 1.8	NA
Well RB-S-03	06/17	−0.80 ± 1.60	NA

Mean MDC: 5.7 pCi/L Standard Deviation of Mean MDC: 0.6 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC = 373 Std. Dev. of Mean MDC: 0 pCi/L

Table D-6. Long-Term Hydrological Monitoring Program Analytical Results for Project GNOME - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Malaga, NM			
Well DD-1	06/27	7.4E+07 ± 3.2E05*	NA[b,c]
Well LRL-7	06/27	7300 ± 150.*	NA[b,d]
Well PHS 6	06/26	30 ± 1.8*	0.03
Well PHS 8	06/26	9.0 ± 1.7*	0.01
Well PHS 9	06/26	1.8 ± 1.8	NA
Well PHS 10	06/26	0.0 ± 1.8	NA
Well USGS 1	06/27	0.87 ± 1.70	NA
Well USGS 4	06/27	140,000 ± 400.*	NA[b,e]
Well USGS 8	06/27	88,000 ± 350.*	NA[b,f]
Carlsbad, NM			
Well 7 City	06/28	1.9 ± 1.7	NA
Loving, NM			
Well 2 City	06/26	9.1 ± 1.7*	0.01
J. Mobley Ranch	06/27	4.9 ± 1.5*	0.01[g]

Mean MDC: 5.5 pCi/L Standard Deviation of Mean MDC: 0.4 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC = 373 ± 0 pCi/L)
(c,d,e,f,g) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(c)	Cs-137	821,000	39,800	NA	pCi/L
	Sr-90	17,000	1400	4700	pCi/L
(d)	Cs-137	112	7	NA	pCi/L
(e)	Sr-90	4,000	12	1.4	pCi/L
(f)	Cs-137	59	5	NA	pCi/L
	Sr-90	2,400	10	1.5	pCi/L
(g)	U-234	11	0.4	0.03	pCi/L
	U-235	0.21	0.02	0.02	pCi/L
	U-238	4.4	0.18	0.02	pCi/L

Table D-7. Long-Term Hydrological Monitoring Program Analytical Results for Project GASBUGGY - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Gobernador, NM			
Arnold Ranch	06/20	14 ± 1.9*	0.02
Bixler Ranch	06/22	11 ± 1.7*	0.01
Bubbling Springs	06/21	34 ± 1.7*	0.04
Cave Springs	06/22	20 ± 1.9*	0.02
Cedar Springs	06/21	49 ± 1.9*	0.05
La Jara Creek	06/20	41 ± 1.8*	0.05
Lower Burro Canyon	06/20	0.0 ± 1.9	NA
Pond N of Well 30.3.32.343	06/21	36 ± 1.8*	0.04
Well EPNG 10-36	06/25	327 ± 3.5*	0.36[b]
Well Jicarilla 1	06/20	14 ± 1.5*	0.02
Well 28.3.33.233 (South)	06/20	40 ± 1.9*	0.04
Windmill 2	06/20	0.26 ± 1.4	NA

Mean MDC: 5.1 pCi/L Standard Deviation of Mean MDC: 0.5 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

(a) = Established by DOE Order as 90,000 pCi/L tritium.

(b) = Additional analyses greater than MDC:

Analysis	Result	1 sigma	MDC	Units
Cs-137	16	3.9	NA	pCi/L

Table D-8. Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE (Salmon Test Site) - 1993

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
Onsite Sampling Locations			
Baxterville, MS			
Half Moon Creek	04/18	20 ± 1.6*	0.02
	04/19	486 ± 4.2*	0.54
Half Moon Creek Overflow	04/18	492 ± 4.7*	0.54
	04/19	26 ± 2.4*	0.03
Pond West Of GZ	04/18	17 ± 1.6*	0.02
	04/19	19 ± 2.1*	0.02
REECO Pit Drainage-A	04/22	15 ± 1.5*	0.02
REECO Pit Drainage-B	04/22	22 ± 1.9*	0.02
REECO Pit Drainage-C	04/22	159 ± 2.6*	0.18
Well E-7	04/19	2.2 ± 1.6	NA
Well HM-1	04/19	−0.83 ± 1.5	NA
	04/19	−0.67 ± 1.4	NA
Well HM-2A	04/19	−0.09 ± 1.5	NA
	04/19	−0.61 ± 1.4	NA
Well HM-2B	04/19	−0.94 ± 1.5	NA
	04/19	−0.17 ± 1.4	NA
Well HM-3	04/19	0.82 ± 1.5	NA
	04/19	0.70 ± 1.4	NA
Well HM-L	04/19	896 ± 113.*	1.0[b]
	04/19	660 ± 4.9*	0.73
Well HM-L2	04/19	1.9 ± 1.6	NA
	04/19	1.4 ± 2.2	NA
Well HM-S	04/18	6240 ± 150*	6.9[b]
	04/19	5750 ± 140*	6.4[b]
Well HMH-1	04/18	2760 ± 130*	3.1[b]
	04/19	3340 ± 130*	3.7[b]

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 379.4 pCi/L, Std. Deviation of Mean MDC: 7.7 pCi/L.
(c) = Rain sample.
(d) = Formerly the residence of Talmadge S. Saucier.
(e) = Formerly the residence of B. Chambliss.
(f) = New Sampling location.
(g,h) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(g)	U-235	0.049	0.008	0.010	pCi/L
	U-238	0.0485	0.015	0.027	pCi/L
(h)	U-234	0.013	0.017	0.016	pCi/L
	U-235	0.0194	0.006	0.0058	pCi/L
	U-238	0.0323	0.017	0.0058	pCi/L

Table D-8. (Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE (Salmon Test Site) - 1993, con't)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)	Percent of Concentration Guide[a]
		Onsite Sampling Locations (continued)	
Well HMH-2	04/18	3640 ± 130*	4.0[b]
	04/19	7790 ± 150*	8.7[b]
Well HMH-3	04/18	36 ± 2.2*	0.04
	04/19	37 ± 2.0*	0.04
Well HMH-4	04/18	13 ± 1.6*	0.01
	04/19	13 ± 1.7*	0.01
Well HMH-5	04/18	1770 ± 130*	2.0[b]
	04/19	2970 ± 130*	3.3[b]
Well HMH-6	04/18	100 ± 2.5*	0.11
	04/19	57 ± 2.0*	0.06
Well HMH-7	04/18	Not Sampled - Well under water	
	04/19	Not Sampled - Well under water	
Well HMH-8	04/18	17 ± 1.9*	0.02
	04/19	14 ± 1.4*	0.02
Well HMH-9	04/18	39 ± 1.9*	0.04
	04/19	40 ± 1.9*	0.04
Well HMH-10	04/18	74 ± 2.6*	0.08
	04/19	66 ± 1.9*	0.07
Well HMH-11	04/18	21 ± 1.8*	0.02
	04/19	23 ± 1.7*	0.03
Well HMH-12	04/18	17 ± 2.0*	0.02
	04/19	25 ± 1.8*	0.03
Well HMH-13	04/18	14 ± 1.9*	0.02
	04/19	13 ± 1.8*	0.01

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 379.4 pCi/L, Std. Deviation of Mean MDC: 7.7 pCi/L.
(c) = Rain sample.
(d) = Formerly the residence of Talmadge S. Saucier.
(e) = Formerly the residence of B. Chambliss.
(f) = New Sampling location.
(g,h) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(g)	U-235	0.049	0.008	0.010	pCi/L
	U-238	0.0485	0.015	0.027	pCi/L
(h)	U-234	0.013	0.017	0.016	pCi/L
	U-235	0.0194	0.006	0.0058	pCi/L
	U-238	0.0323	0.017	0.0058	pCi/L

Table D-8. (Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE (Salmon Test Site) - 1993, con't)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)			Percent of Concentration Guide[a]
Onsite Sampling Locations (continued)					
Well HMH-14	04/18	18	±	2.0*	0.02
	04/19	17	±	1.6*	0.02
Well HMH-15	04/18	15	±	1.6*	0.02
	04/19	17	±	2.1*	0.02
Well HMH-16	04/18	57	±	1.9*	0.06
	04/19	113	±	2.8*	0.13
Well HT-2C	04/21	15	±	1.6*	0.02
Well HT-4	04/20	6.7	±	1.7*	0.01
Well HT-5	04/19	-0.40	±	1.7	NA
Offsite Sampling Locations					
Baxterville, MS					
Little Creek #1	04/20	20	±	1.7	0.02
Lower Little Creek #2	04/20	21	±	2.0*	0.02
Salt Dome Hunting Club	04/19	21	±	1.9*	0.02
Salt Dome Timber Co.	04/19	23	±	1.9*	0.03
Anderson Pond	04/19	17	±	2.0*	0.02
Anderson, Billy Ray	04/19	16	±	1.8*	0.02
Anderson, Robert Harvey	04/19	16	±	1.9	0.02
	04/20	15	±	2.0*	0.02[c]
Anderson, Robert Lowell, Sr.	04/19	19	±	1.8*	0.02
Anderson, Robert Lowell, Jr.	04/19	18	±	1.8*	0.02
Bilbo, Timothy	04/20	23	±	2.0*	0.03[d]

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NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 379.4 pCi/L, Std. Deviation of Mean MDC: 7.7 pCi/L.
(c) = Rain sample.
(d) = Formerly the residence of Talmadge S. Saucier.
(e) = Formerly the residence of B. Chambliss.
(f) = New Sampling location.
(g,h) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(g)	U-235	0.049	0.008	0.010	pCi/L
	U-238	0.0485	0.015	0.027	pCi/L
(h)	U-234	0.013	0.017	0.016	pCi/L
	U-235	0.0194	0.006	0.0058	pCi/L
	U-238	0.0323	0.017	0.0058	pCi/L

Table D-8. (Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE (Salmon Test Site) - 1993, con't)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)			Percent of Concentration Guide[a]
		Offsite Sampling Locations (continued)			
Baxterville,MS (cont.)					
Burge, Joe	04/19	13	±	2.0*	0.01
Daniels, Ray	04/21	19	±	1.7*	0.02
Daniels, Webster Jr.	04/21	22	±	1.9*	0.02
Daniels Fish Pond Well #2	04/21	19	±	1.8*	0.02
Hibley, Billy	04/20	-2.7	±	1.7	NA[e]
Kelly, Gertrude	04/20	-0.47	±	1.6	NA
Napier, Denise	04/19	16	±	1.9*	0.02
Lee, P. T.	04/19	37	±	1.8*	0.04
Mills, A. C.	04/19	-2.3	±	1.7	NA
Mills, Roy	04/19	14	±	1.7*	0.02
Nobles Pond	04/19	18	±	2.0*	0.02
Noble, W. H., Jr.	04/19	32	±	2.1*	0.04
Saucier, Dennis	04/20	29	±	1.9*	0.03
Saucier, Wilma/Yancy	04/20	1.6	±	1.7	NA
Well Ascot 2	04/22	Not Sampled - Inaccessable			
City Well	04/21	23	±	1.8*	0.03
Columbia, MS					
Dennis, Buddy	04/21	17	±	1.6*	0.02
Dennis, Marvin	04/21	19	±	1.6*	0.02
City Well 64B	04/19	9.7	±	1.7*	0.01

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 379.4 pCi/L, Std. Deviation of Mean MDC: 7.7 pCi/L.
(c) = Rain sample.
(d) = Formerly the residence of Talmadge S. Saucier.
(e) = Formerly the residence of B. Chambliss.
(f) = New Sampling location.
(g,h) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(g)	U-235	0.049	0.008	0.010	pCi/L
	U-238	0.0485	0.015	0.027	pCi/L
(h)	U-234	0.013	0.017	0.016	pCi/L
	U-235	0.0194	0.006	0.0058	pCi/L
	U-238	0.0323	0.017	0.0058	pCi/L

Table D-8. (Long-Term Hydrological Monitoring Program Analytical Results for Project DRIBBLE (Salmon Test Site) - 1993, con't)

Sampling Location	Collection Date in 1993	Concentration ± 1s of Tritium (pCi/L)			Percent of Concentration Guide[a]
		Offsite Sampling Locations (continued)			
Lumberton, MS					
Anderson, G. W.	04/19	21	±	1.6*	0.02
Anderson, Lee L.	04/21	21	±	2.1*	0.02
Bond, Bradley K.	04/21	21	±	2.1*	0.02
Cox, Eddie	04/19	23	±	1.7*	0.03
Gil Ray's Crawfish Pond	04/20	20	±	1.5*	0.02
Gipson, Herman	04/20	−0.83	±	1.8	NA
Gipson, Hewie	04/20	21	±	1.6*	0.02
Gipson, Michael	04/20	15	±	1.7*	0.02[f,g]
Gipson, Phillip	04/20	13	±	1.8*	0.01
Graham, Sylvester	04/20	5.2	±	1.5*	0.01
Hartfield, Ray	04/20	0.79	±	1.5	NA
Powers, Shannon	04/21	21	±	1.6*	0.02
Rushing, Debra	04/20	20	±	1.4*	0.02
Saul, Ola	04/20	24	±	1.8*	0.03[f,h]
Saul, Lee L.	04/20	−1.9	±	1.5	NA
Smith, E. J.	04/20	14	±	2.1*	0.02
Smith, Howard	04/20	6.3	±	1.4*	0.01
Smith, Howard-Pond	04/20	24	±	1.8*	0.03
Thompson, Roswell	04/20	20	±	2.2*	0.02
Well 2 City	04/21	−1.8	±	1.7	NA
Purvis, MS					
Burge, Willie Ray and Grace	04/19	18	±	1.7*	0.02
City Supply	04/21	−1.4	±	1.6	NA
Gil, Ray-House Well	04/20	4.3	±	1.4	NA

Mean MDC: 5.4 pCi/L Standard Deviation of Mean MDC: 0.6 pCi/L

* = Activity is greater than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.
(a) = Established by DOE Order as 90,000 pCi/L tritium.
(b) = Analysis by conventional method (Mean MDC: 379.4 pCi/L, Std. Deviation of Mean MDC: 7.7 pCi/L.
(c) = Rain sample.
(d) = Formerly the residence of Talmadge S. Saucier.
(e) = Formerly the residence of B. Chambliss.
(f) = New Sampling location.
(g,h) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(g)	U-235	0.049	0.008	0.010	pCi/L
	U-238	0.0485	0.015	0.027	pCi/L
(h)	U-234	0.013	0.017	0.016	pCi/L
	U-235	0.0194	0.006	0.0058	pCi/L
	U-238	0.0323	0.017	0.0058	pCi/L

Table D-9. Long-Term Hydrological Monitoring Program 1993 Analytical Results for Amchitka Island, Alaska - 1993

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	Percent of Concentration Guide[a]
		BACKGROUND SITES	
Clevenger Lake	07/30	20 ± 1.6*	0.02
Constantine Spring	07/30	26 ± 1.3*	0.03
Constantine Spring-Pump House	07/30	30 ± 1.7*	0.03
RX-Site Pump House	07/30	14 ± 1.4*	0.02
TX-Site Springs	07/30	19 ± 1.7*	0.02
TX-Site Water Tank House	07/30	Not Sampled - Tank Dry, Pump Removed	
Dove Cove Creek	07/31	16 ± 1.4*	0.02
Jones Lake	07/30	13 ± 1.2*	0.01
Rain Base Camp	07/31	6.5 ± 1.7*	0.01
Rain Base Camp	08/01	4.5 ± 1.7*	0.01
Site D Hydro Exploratory Hole	07/30	Not Sampled - Well Plugged	
Site E Hydro Exploratory Hole	07/30	Not Sampled - Well Plugged	
Well 1 Army	08/01	16 ± 1.6*	0.02
Well 2 Army	07/30	6.6 ± 1.5*	0.01
Well 3 Army	07/30	Not Sampled - Well Plugged	
Well 4 Army	07/30	24 ± 1.8*	0.03
		PROJECT CANNIKIN	
Cannikin Lake (North End)	07/29	19 ± 1.7*	0.02
Cannikin Lake (South End)	07/29	21 ± 1.8*	0.02
DECON Pond	07/29	Not Sampled - Discontinued	
DECON Sump	07/29	Not Sampled - Discontinued	
DK-45 Lake	07/30	17 ± 1.7*	0.02
Ice Box Lake	07/29	20 ± 1.8*	0.02
Pit South of Cannikin GZ	07/29	16 ± 1.6*	0.02
Well HTH-3	07/29	23 ± 1.8*	0.03
White Alice Creek	07/29	19 ± 1.6*	0.02
		PROJECT LONG SHOT	
Long Shot Pond 1	08/01	13 ± 1.5*	0.01
Long Shot Pond 2	08/01	12 ± 1.6*	0.01
Long Shot Pond 3	08/01	21 ± 1.7*	0.02
Mud Pit No.1	08/01	102 ± 1.9*	0.11
Mud Pit No.2	08/01	140 ± 2.3*	0.16
Mud Pit No.3	08/01	152 ± 2.0*	0.17
Reed Pond	08/01	10 ± 1.1*	0.01
Stream East-Longshot	08/01	184 ± 2.8*	0.20
Well EPA-1	08/01	11 ± 1.7*	0.01
Well GZ No.1	08/01	1350 ± 130.*[b]	1.5

Table D-9. (Long-Term Hydrological Monitoring Program 1993 Analytical Results for Amchitka Island, Alaska - 1993, cont.)

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	Percent of Concentration Guide[a]
		PROJECT LONG SHOT (Continued)	
Well GZ No.2	08/01	51 ± 1.5*	0.06
Well WL-1	08/01	12 ± 1.3*	0.01
Well WL-2	08/01	67 ± 1.6*	0.07
		PROJECT MILROW	
Clevenger Creek	07/31	22 ± 1.6*	0.02
Heart Lake	07/31	16 ± 1.5*	0.02
Well W-2	07/31	19 ± 1.8*	0.02
Well W-3	07/31	15 ± 1.7*	0.02
Well W-4	07/31	Not Sampled - Well Dry	
Well W-5	07/31	18 ± 1.6*	0.02
Well W-6	07/31	18 ± 1.7*	0.02
Well W-7	07/31	16 ± 1.7*	0.02
Well W-8	07/31	24 ± 2.1*	0.03
Well W-9	07/31	Not Sampled - Well Under Water	
Well W-10	07/31	18 ± 1.5*	0.02
Well W-11	07/31	36 ± 2.0*	0.04
Well W-12	07/31	Not Sampled - Well Under Water	
Well W-13	07/31	18 ± 2.0*	0.02
Well W-14	07/31	13 ± 1.6*	0.10
Well W-15	07/31	19 ± 1.8*	0.02
Well W-16	07/31	Not Sampled - Well Under Water	
Well W-17	07/31	Not Sampled - Well Under Water	
Well W-18	07/31	24 ± 1.8*	0.03
Well W-19	07/31	Not Sampled - Well Under Water	

Mean MDC: 4.7 pCi/L Standard Deviation of Mean MDC: 0.7 pCi/L

* = Concentration is greater than the minimum detectable concentration (MDC).
(a) = Derived from the ^{3}H ALI in ICRP-30 as 90,000 pCi/L tritium
(b) = Analysis by conventional method (MDC = 421)

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