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Washington, DC 20460

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Offsite Environmental Monitoring Report

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Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1996

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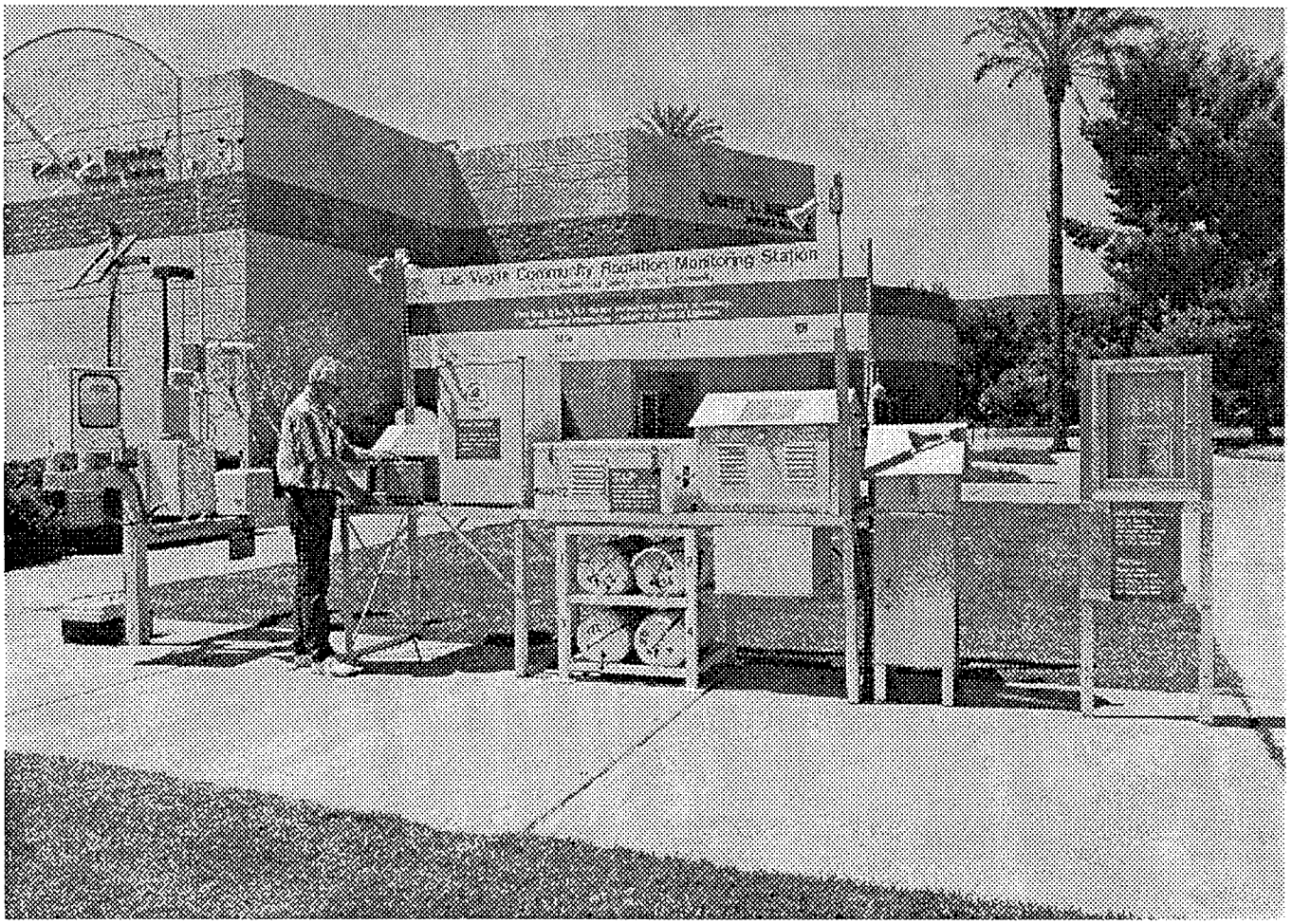

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June 2, 1998

Dear Reader:

Since 1954, the U.S. Environmental Protection Agency (EPA) and its predecessor the U.S. Public Health Service (PHS) has conducted radiological monitoring in the offsite areas around United States nuclear test areas. The primary objective of this monitoring has been, and continues to be, protection of the health and safety of residents in the unlikely event of release or environmental transport of radioactive material into public areas.

The enclosed report describes the Offsite Environmental Monitoring Program conducted during 1996 by the U.S. Environmental Protection Agency. This Laboratory operates an environmental radiation monitoring program in the region surrounding the Nevada Test Site 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. The program also ascertains whether current radiation levels and associated doses to the general public are in compliance with existing radiation protection standards. No nuclear weapons testing was conducted in 1996 due to the continuing nuclear test moratorium. During this period, personnel maintained capability to provide monitoring support for any emergencies that might occur.

If you have any questions regarding EPA's monitoring of radiation in areas around U.S. nuclear test areas, please feel free to contact me at the above address.

Sincerely yours,

Jed Harrison
Director

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Notice

The U.S. Environmental Protection Agency (EPA), through the Office of Air and Radiation (OAR), performed the work described with funding received from the U.S. Department of Energy under interagency agreement number RW89937611-01 (EPA)/DE-AI08-96NV11969 (DOE). EPA funded the publication of this report. It has been subjected to the Agency's peer review and has been approved as an EPA publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Subsequent to the completion of this study an internal EPA reorganization resulted in a name change for some organizational elements. The Radiation Sciences Laboratory- Las Vegas (RSL) is now the Office of Radiation and Indoor Environments National Laboratory, Las Vegas (R&IE).

Abstract

This report describes the Offsite Radiation Safety Program conducted during 1996 by the U. S. Environmental Protection Agency's (EPAs), Office of Radiation and Indoor Air-Las Vegas, Radiation Science Laboratory . This laboratory operated 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).

No nuclear weapons testing was conducted in 1996 due to the continuing nuclear test moratorium. During this period, R&IE personnel maintained readiness capability to provide direct monitoring support if testing were to be resumed and ascertained compliance with applicable EPA, DOE, state, and federal regulations and guidelines.

Comparison of the measurements and sample analysis results with background levels and with appropriate standards and regulations indicated that there was no airborne radioactivity from diffusion or resuspension detected by the various EPA monitoring networks surrounding the NTS. There was no indication of potential migration of radioactivity to the offsite area through groundwater and no radiation exposure above natural background was received by the offsite population. All evaluated data were consistent with previous data history. Using the EPAs CAP88-PC model and NTS radionuclide emissions and environmental monitoring data, the calculated effective dose equivalent (EDE) to the maximally exposed individual offsite would have been about 0.11 mrem. This value is less than two percent of the Federal dose limit prescribed for radionuclide air emissions. The dose received from natural background radiation was about 144 mrem.

The offsite Environmental Monitoring Report: Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1994 and 1995 was not and will not be published. Please refer to the 1994 and 1995 Nevada Test Site Annual Site Environmental Report, for data covering that time period.

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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
ARL/SORD -- Air Resources Laboratory Special Operations and Research Division
BOC -- Bureau of Census
CEDE -- committed effective dose equivalent
CFR -- Code of Federal Regulations
CG -- Concentration Guide
CP-1 -- Control Point One
CTLP -- Community Technical Liaison 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
EPA -- U.S. Environmental Protection Agency
FDA -- Food and Drug Administration
GOES -- Geostationary Operational Environmental Satellite
GZ -- Ground Zero
HMC -- Hazardous Materials Center
HTO -- tritiated water
HpGe -- High purity germanium
IAGs -- Interagency Agreements
ICRP -- International Commission on Radiological Protection
LTHMP -- Long-Term Hydrological Monitoring Program
MAPEP -- Mixed Analyte Performance Evaluation Program
MDC -- minimum detectable concentration
MEI -- maximally exposed individual
MQO -- measurement quality objective
MSL -- mean sea level
MSN -- Milk Surveillance Network
NCRP -- National Council on Radiation Protection and Measurements
NIST -- National Institute of Standards and Technology
NPDWR -- National Primary Drinking Water Regulation
NPS -- National Park Service
NTS -- Nevada Test Site
NVLAP -- National Voluntary Laboratory Accreditation Program
ORSP -- Offsite Radiological Safety Program
PHS -- U.S. Public Health Service
PIC -- pressurized ion chamber
QA -- quality assurance
QC -- quality control
ORIA -- Office of Radiation and Indoor Air
RAWS -- Remote Automatic Weather Station
RCRA -- Resource Conservation and Recovery Act
R&IE -- Radiation and Indoor Environments National Laboratory- Las Vegas
RWMS -- Radioactive Waste Management Site
S.D. -- standard deviation
SGZ -- Surface Ground Zero
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
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
=	-- equal to
≅	-- approximately equal to
>	-- greater than

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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The authors would like to thank Jed Harrison for his advice and assistance in the coordination and preparation of this report. We also want to thank the staff of the ORIA Radiation and Indoor Environments National Laboratory-Las Vegas for collecting samples, maintaining equipment, interfacing with offsite residents, and for analyzing the samples.

1.0 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 non-nuclear 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. In late 1992 a nuclear explosives test moratorium brought an end to nuclear weapons testing and only simulated readiness tests were conducted in 1996.

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. From 1970 to 1995, the EPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) 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 that time, EPA's Office of Radiation and Indoor Air, Radiation and Indoor Environments National Laboratory-Las Vegas (R&IE) has conducted a scaled down ORSP.

In 1996, the four major objectives of the ORSP were:

- 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 past atomic testing areas.
- Maintaining readiness to resume nuclear testing at some future date.
- 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); and by sampling air, water, and milk.

1.1 Program 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, and milk, exposure monitoring by thermoluminescent dosimetry, and pressurized ion chambers, and long-term hydrological monitoring of wells and surface waters. In 1996, 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 1996.

1.1.1 Thermoluminescent Dosimetry Program

In 1996, external exposure was monitored by a network of thermoluminescent dosimeters (TLDs) at 49 fixed locations surrounding the NTS and by TLDs worn by 25 offsite residents. No 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 and were slightly lower than those of the past.

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 0.11 mrem (1.1 x 10^{-3} mSv), and the dose to the population within 80 kilometers of the emission sites would have been 0.34 person-rem (3.4 x 10^{-3} person-Sv). The hypothetical person receiving this dose was also exposed to 144 mrem from normal background radiation. Details of this program may be found in Section 3 of this Report.

1.1.2 Pressurized Ion Chamber Network

The Pressurized Ionization Chamber (PIC) network measures ambient gamma radiation exposure rates on a near real-time basis. The 26 PICs deployed around the NTS in 1996 showed no unexplained deviations from background levels. These background exposures, ranging from 71 to 156 mR/yr are within the U.S. background range and are consistent with previous years' trends. Details of this program may be found in Section 3 of this Report.

1.1.3 Air Surveillance Network

In 1996, the Air Surveillance Network (ASN) included 20 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. The MDC for $^{239+240}$Pu was exceeded for one high volume sample from Rachel, NV. Details of the Atmospheric Monitoring program may be found in Section 4 of this Report.

1.1.4 Milk

Milk samples were collected from 11 Milk Surveillance Network (MSN) stations in 1996. The average total potassium concentration derived from ^{40}K was consistent with results obtained in previous years. No man-made gamma-emitting radionuclides were detected in any of the milk samples. Results of analyses for ^{89}Sr and ^{90}Sr were similar to those obtained in previous years. Neither increasing nor decreasing trends were evident. Detailed discussion of the collection and analysis of milk may be found in Section 5 of this report.

1.1.5 Long-Term Hydrological Monitoring Program

1.1.5.1 Nevada Test Site Monitoring

Nineteen wells on the NTS or immediately outside its borders on federally owned land were sampled. All samples collected during 1996 were analyzed for gamma-emitting radionuclides by gamma spectrometry and for tritium by the conventional and/or the enrichment method. No gamma-emitting radionuclides were detected. The highest tritium level, detected in a sample from Well UE-5n (4.5 x 10^{4} pCi/L), was less than 60% of the derived concentration guide for tritium. There were no indications that migration from any test cavity is affecting any domestic water supply.

1.1.5.2 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 12 wells, nine springs, and a surface water site. All the locations are sampled quarterly or semiannually. Gamma spectrometric analysis is completed on all samples. No man-made gamma-emitting radionuclides were detected. Tritium analysis is performed on a semiannual basis.

None of the 1996 samples analyzed for tritium using the conventional method had results above the MDC. Two that were analyzed for tritium by the enrichment method showed detectable activity. These results were felt to represent scavenged atmospheric tritium by precipitation.

1.1.5.3 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 biannual sampling has not been conducted since 1993 at the Projects

CANNIKIN, LONGSHOT, and MILROW sites on Amchitka Island, Alaska. Monitoring from well EPNG 10-36 at Project GASBUGGY contained tritium at a concentration of 130± 5.2 pCi/L. 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 6 of this Report.

1.1.6 Dose Assessment

The extensive offsite environmental surveillance system detailed in this report measured no radiation exposures that could be attributed to recent NTS activities. The potential Effective Dose Equivalent (EDE) to the maximally exposed offsite resident was calculated to be 0.015 mrem, using certain assumptions as all data were not available due to a decrease of funding. Calculation with the EPA CAP88-PC model, using estimated or calculated effluents from the NTS, resulted in a maximum dose of 0.11 mrem (1.1×10^{-3} mSv) to a hypothetical resident of Springdale, NV located 14 km (nine mi) west of the NTS boundary. Based on monitoring network data, this dose is calculated to be 0.005 mrem. This EDE is about 5 percent of the dose obtained using the CAP88-PC model. The calculated population dose (collective effective dose equivalent (CEDE)) to the approximately 32,210 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 0.34 person-rem (3.4×10^{-3} person-Sv). Background radiation yielded a CEDE of 3,064 person-rem(30.6 person-Sv). Details of the dose assessment calculations may be found in Section 7 of this Report.

1.1.7 Hazardous Spill Center

EPA participated on the control board for four series of spill tests using 28 different chemicals conducted at the HSC, located in Area 5 of the NTS. The amounts used in the tests were so small that boundary monitoring was not necessary.

Detailed discussion of R&IE-LV activities in support of this facility may be found in Section 8 of this Report.

1.2 Offsite Monitoring

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

As a result of the continuing moratorium on nuclear weapons testing, only simulated tests were conducted in 1996. Three simulated nuclear weapons test readiness exercises and one non-proliferation experiment using conventional (non-nuclear) explosives were conducted at the NTS. For each one, R&IE-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 a real test. Routine offsite environmental radiation monitoring continued throughout 1996, as in past years.

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. Community Technical Liaison Program (CTLP) stations have been established in prominent locations in a number of offsite communities. The CTLP 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 CTLP. The CTLP is discussed in Section 3.

Environmental monitoring networks, described in the following subsections, measure radioactivity in air, milk, and ground water. These networks monitor the major potential pathways of radionuclide transfer to man via inhalation, submersion, and ingestion. Gamma radiation levels are continuously monitored at selected locations using Reuter-Stokes pressurized ion chambers (PICs) and Panasonic TLDs. Atmospheric monitoring equipment includes both high- and low volume air samplers. Milk is sampled and analyzed annually. Ground water 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 7.

1.3 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 R&IE 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. In addition, R&IE meets the EPA policy which states that all decisions which are dependent on environmental data must be supported by data of known quality. EPA policy requires participation in a centrally managed Quality Assurance Program by all EPA elements as well as those monitoring and measurement efforts supported or mandated by contracts, regulations, or other formalized agreements. The R&IE QA policies and requirements are summarized in the "Quality Management Plan" (EPA/R&IE 1996).

1.4 Nonradiological Monitoring

R&IE also provides support for the HAZMAT Spill Center(HSC) located at Frenchman Flat in Area 5 of the NTS. The HSC was designed for safe research on the handling, shipping, and storage of liquified gaseous fuels and other hazardous liquids. The R&IE provides a chemist to participate in meetings of the Advisory Panel which reviews and approves all programs prior to testing and maintains readiness for monitoring emissions at the boundary of the NTS.

For those tests requiring monitoring, the R&IE personnel deploy air sampling sensors to detect any offsite releases. No spills required monitoring in 1996 as such small amounts were released that they would be far below the limit of detection for the R&IE monitoring equipment at the edge of the NTS under any reasonable scenario, including catastrophic failure of the container in which the spill material is stored.

2.0 Description of the Nevada Test Site

The 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 1996. Limited non-nuclear testing has included controlled spills of hazardous material at the HAZMAT Spill Center. 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 Radiation and Indoor Environments National Laboratory in Las Vegas, Nevada, conducts hydrological studies at eight U.S. nuclear testing sites in other states and two off the NTS in Nevada. 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 2.1). 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 mean sea level (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.

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 2.1 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 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

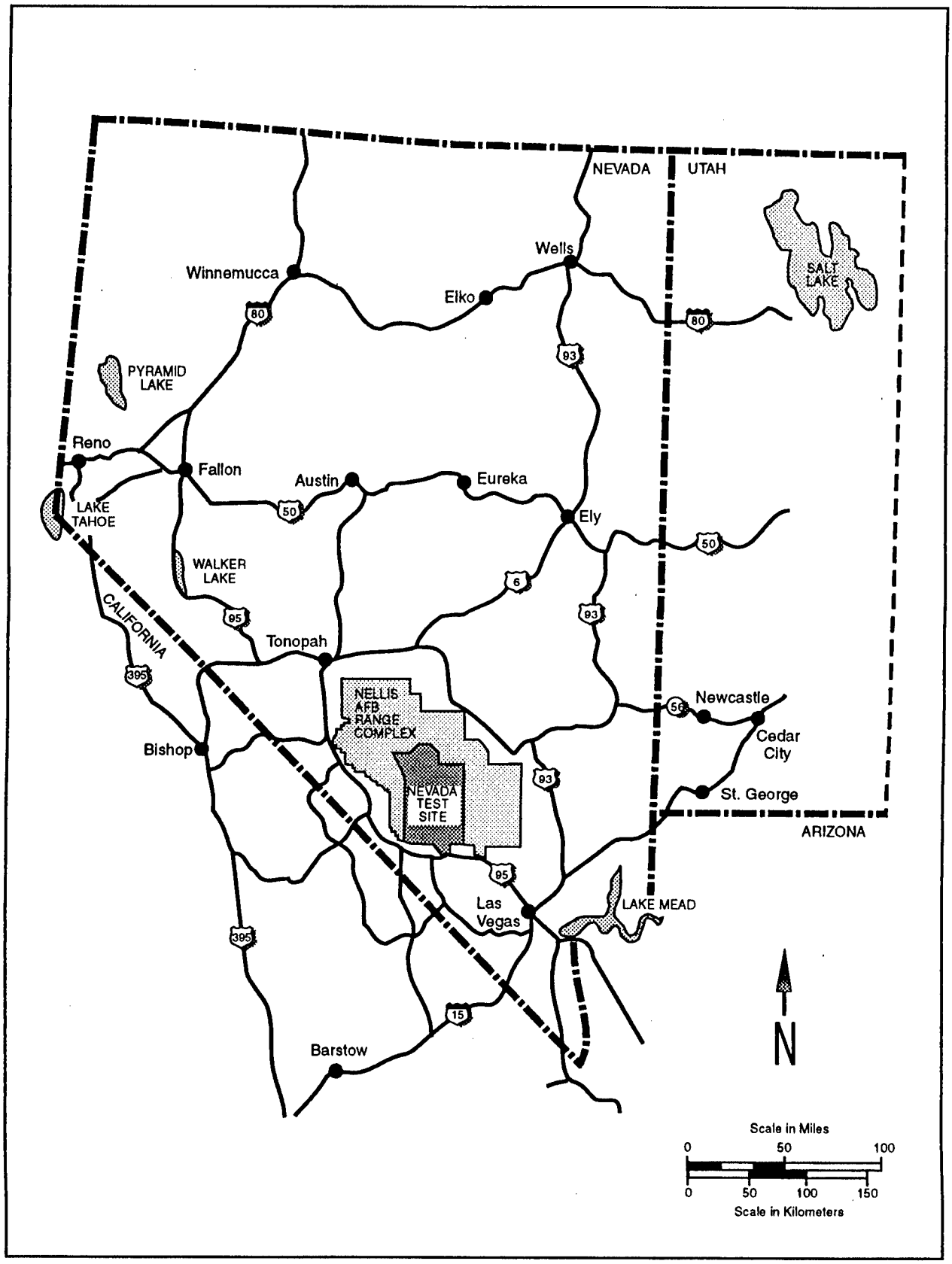

Figure 2.1 Location of the Nevada Test Site.

Table 2.1 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.

(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 2.2 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 2.3 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 Figure 2.2). 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. 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

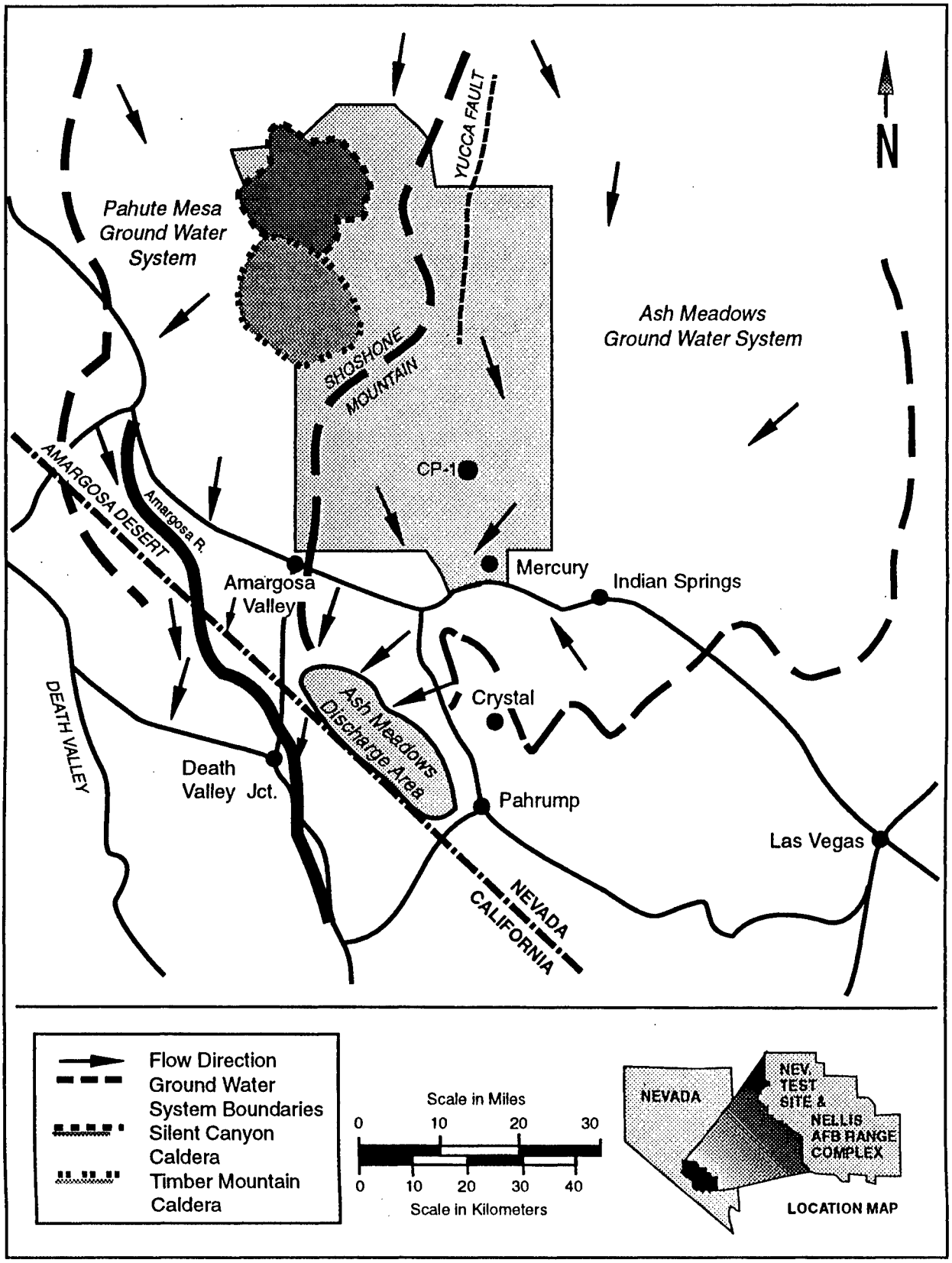

Figure 2.2 Ground water flow systems around the Nevada Test Site.

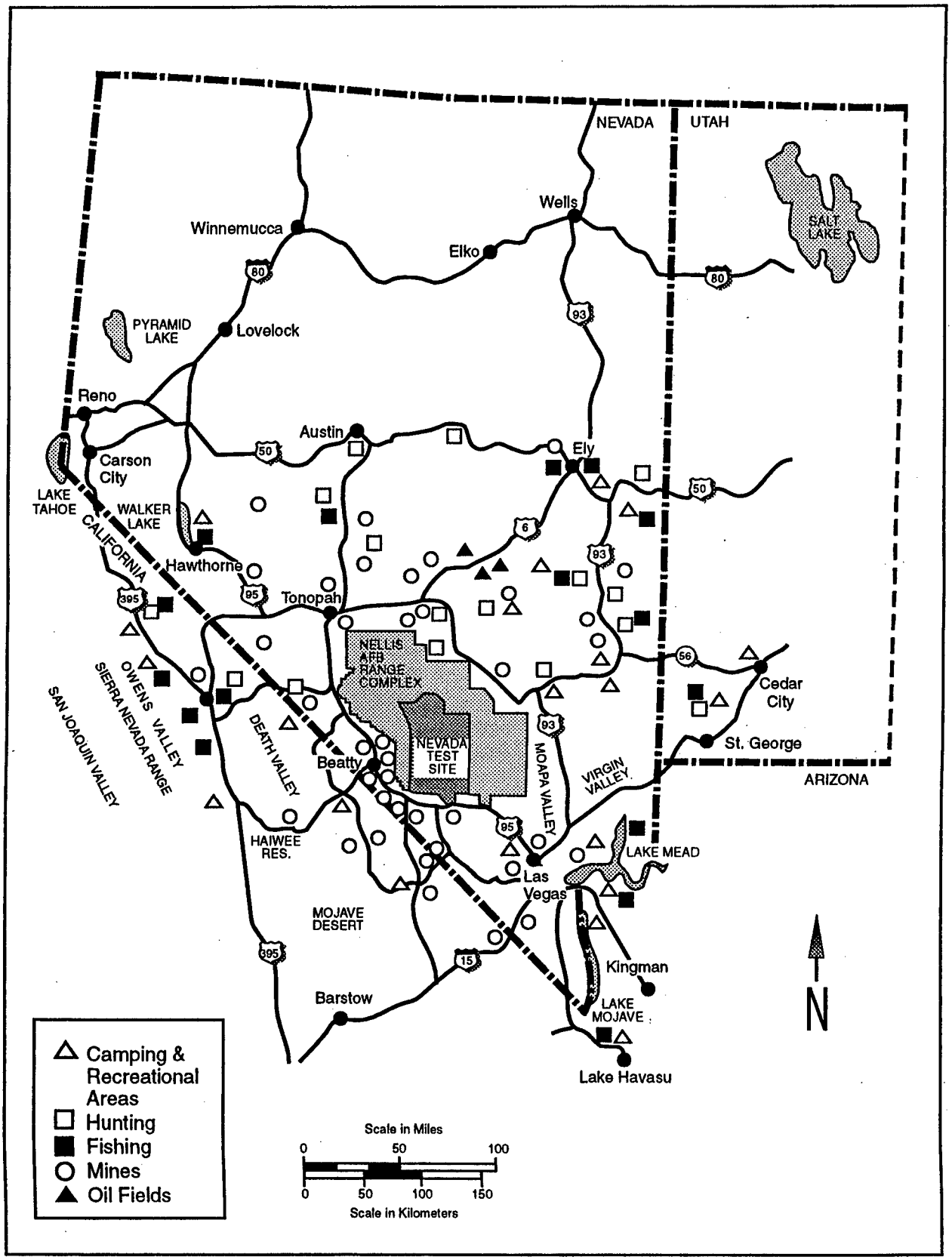

Figure 2.3. General land use within 180 miles (300 km) of the Nevada Test Site.

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 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

The population of counties surrounding the NTS based on the 1990 Bureau of Census (BOC) count (DOC, 1990) is still fairly accurate although growth has occurred in all parts of the state. Excluding Clark County, which has grown tremendously since the 1990 census and is the major population center (approximately 1,000,000 in 1996), the population density within a 90-mi (150-km) radius of the NTS is about 0.9 persons per square mile (0.5 persons per square kilometer). For comparison, the population density of the 48 contiguous states was 76 persons per square mile (29 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 about 23,000 (Pahrump Times) in 1996, 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 2.2). 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 1996 population estimated at 40,000. The next largest town, Cedar City, with a population of over 18,000, is located 168 miles (280 km) east-northeast of the NTS. 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 168 miles (280 km) southeast of the NTS, with a population of 12,722 (DOC, 1990).

3.0 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 purpose of the EPA R&IE-LV offsite environmental dosimetry program is to establish dose estimates to populations living in the 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 Community Technical Liaison Program (CTLP) station managers and their alternates, living in areas surrounding the NTS. Information gathered from this program would help identify possible exposures to residents.

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.

New computers and software were installed in 1996 to increase report options, and further hardware upgrades will be completed in 1997.

3.1.2 Results of TLD Monitoring

ENVIRONMENTAL DATA:

In 1996, the TLD program consisted of 49 fixed environmental monitoring stations and 25 offsite personnel. Henderson and Boulder City, Nevada, were added to the network in the fourth quarter. Figure 3.1 shows the fixed environmental TLD monitoring stations and the location of personnel monitoring participants. 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 1996. The total average daily rate was then multiplied by 365.25 to determine the total annual exposure for each station.

There were 49 offsite environmental stations monitored using TLDs. Figure 3.1 shows current fixed environmental monitoring locations. Total annual exposure for 1996 ranged from 59 mR (0.59 mSv) per year at St. George, Utah, to 132 mR (1.3 mSv) per year at Manhattan, Nevada, with a mean annual exposure of 93 mR (0.93 mSv) per year for all oper-

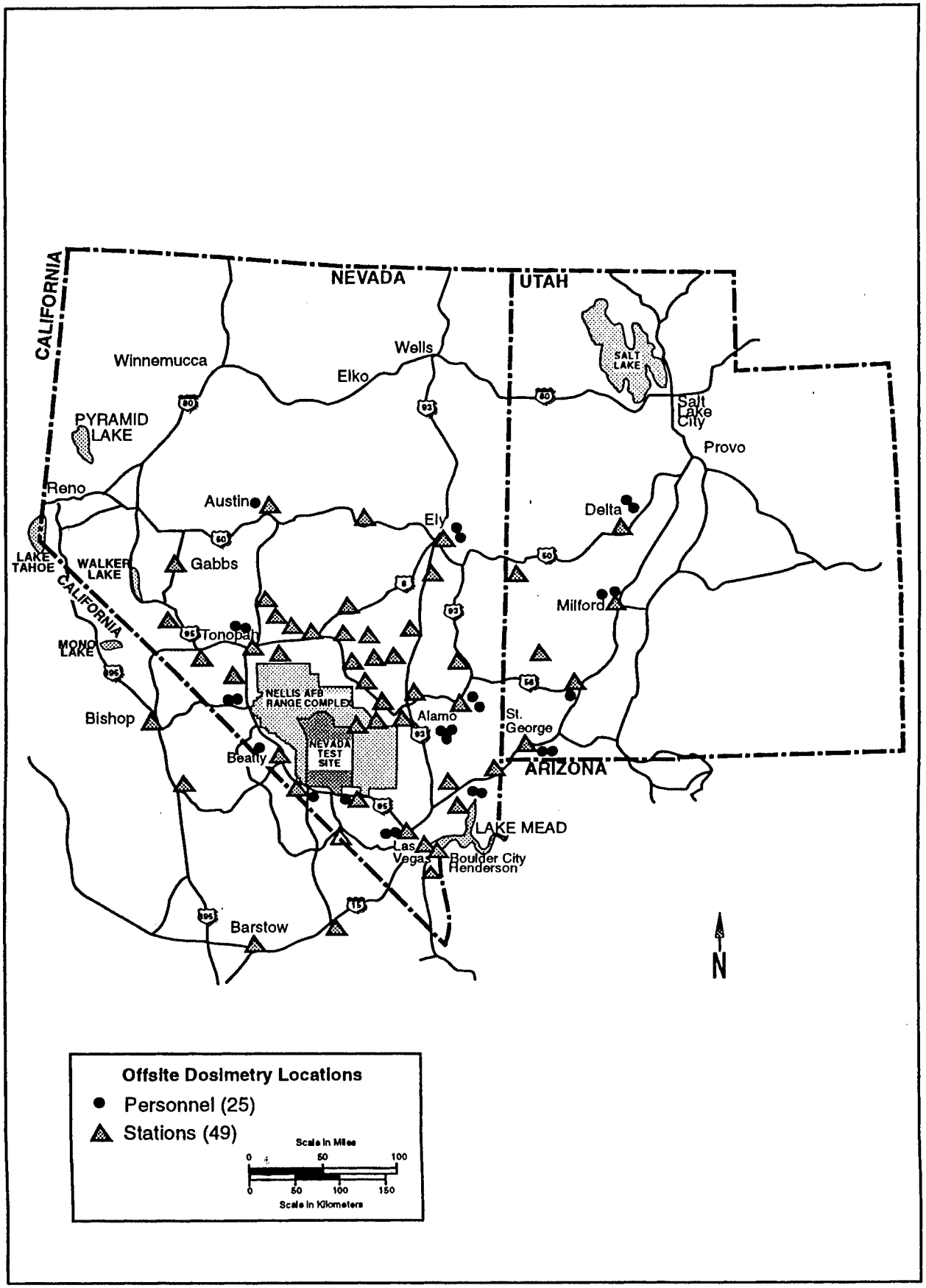

Figure 3.1 Location of TLD Fixed Stations and Personnel Monitoring Participants - 1996

ating locations. The next highest annual exposure was 130 mR (1.3 mSv) per year at Queen City Summit, Nevada. See Table 3.1 for 1996 results. These results are consistent with those for 1995.

PERSONNEL DATA:

Twenty-five offsite residents, managers, and alternates for the CTLP, were issued TLDs to monitor their annual dose equivalent. Locations of personnel monitoring participants are also shown in Figure 3.1 Annual whole body dose equivalents ranged from a low of 48 mrem (0.48 mSv) to a high of 125 mrem (1.2 mSv) with a mean of 96 mrem (0.96 mSv) for all monitored personnel during 1996. See Table 3.2 for 1996 results. These results are similar to those for 1995.

3.1.3 Quality Assurance/ Quality Control

The following procedures assure that the TLD data are of acceptable quality: 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 method used 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.

- For each read-out three irradiated control TLDs are included that have been exposed to a nominal 200 mR. 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 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 of personnel dosimeters has been evaluated via the Department of Energy Laboratory Accreditation Program (DOELAP). This process concluded that procedures and practices utilized by the EPA R&IE-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 rem 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 (L_D) for the R&IE-LV TLD Laboratory has been calculated to be approximately 3 mrem above background at the 95% confidence level. See Appendix A for L_D calculations.

3.1.4 Data Management

The TLD data base resides on a Digital Equipment Corporation MicroVAX II directly connected to the two Panasonic TLD readers. Samples are tracked using field data cards and an issue data base tracking system incorporated into the reader control software. Two major software packages are utilized by the TLD network. The first, a proprietary package written and supported by International Science Associates, controls the TLD readers, tracks dosimeter performance, completes necessary calculations to determine absorbed dose equivalent, performs automated QA/QC functions, and generates raw data files and reports. The second software package, locally developed, maintains privacy act information and the identifying data, generates reports in a number of predefined formats, and provides archival storage of TLD results.

3.2 Pressurized Ion Chambers

The Pressurized Ion Chamber (PIC) Network continuously measures ambient gamma radiation exposure rates, and because of its sensitivity, may detect low-level exposures not detected by other monitoring methods. The primary function of the PIC network is to detect changes in ambient gamma radiation due to anthropogenic activities. In the absence of anthropogenic activities, ambient gamma radiation rates naturally differ among locations as rates vary with altitude (cosmic radiation) and with radioactivity in the soil (terrestrial radiation). Ambient gamma radiation also varies slightly within a location due to weather patterns, i.e., snow changes the amount of radon-thoron released by the soil and detected by the PICs.

3.2.1 Network Design

There are 26 PICs located in communities around the NTS and one in Mississippi, which provide near real-time estimates of gamma exposure rates. Two new stations were added to the network in the fourth quarter of 1996. They were Henderson and Boulder City, Nevada. The PIC at Boulder City was vandalized after only five days of data collection. Another site in Boulder City is being proposed to prevent future incidents. The locations of the PICs for stations around the NTS are shown in Figure 3.2.

Because of the successful experience with the Citizen's Monitoring Program during the purging of the Three Mile Island containment in 1980, the Community Radiation Monitoring Program (CRMP) was begun. Because of reductions in the scope of monitoring, the CRMP was changed to the CTLP. It now consists of stations located in the states of Nevada and Utah. In 1996, there were 15 stations located in these two states. The CTLP is a cooperative project of the DOE, EPA, and DRI.

The DOE/NV 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. Shown in Figure 3.2 are the locations of the CTLP stations.

Each station is operated by a local resident. In most cases, this resident is a high-school science teacher. Samples are analyzed at the R&IE Laboratory. Thirteen of the 15 CTLP stations have a low volume air sampler, a tritium and noble gas sampler on standby, and a TLD. The two stations recently setup have no tritium or noble gas sampler. 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. Residents may visit the stations and if interested, they can check the data. Also, computer-generated reports of the PIC data are issued monthly by EPA for each station.

3.2.2 Procedures

The PIC Network utilizes Reuter-Stokes models 1011, 1012, and 1013 PICs. The PIC is a spherical shell filled with argon gas to a pressure 25 times that of atmospheric. In the center of the chamber is a spherical electrode with a charge opposite to the outer shell. When gamma radiation penetrates the sphere, ionization of the gas occurs and the ions are collected by the center electrode. The electrical current generated is measured, and the intensity of the radiation field is determined from the magnitude of this current.

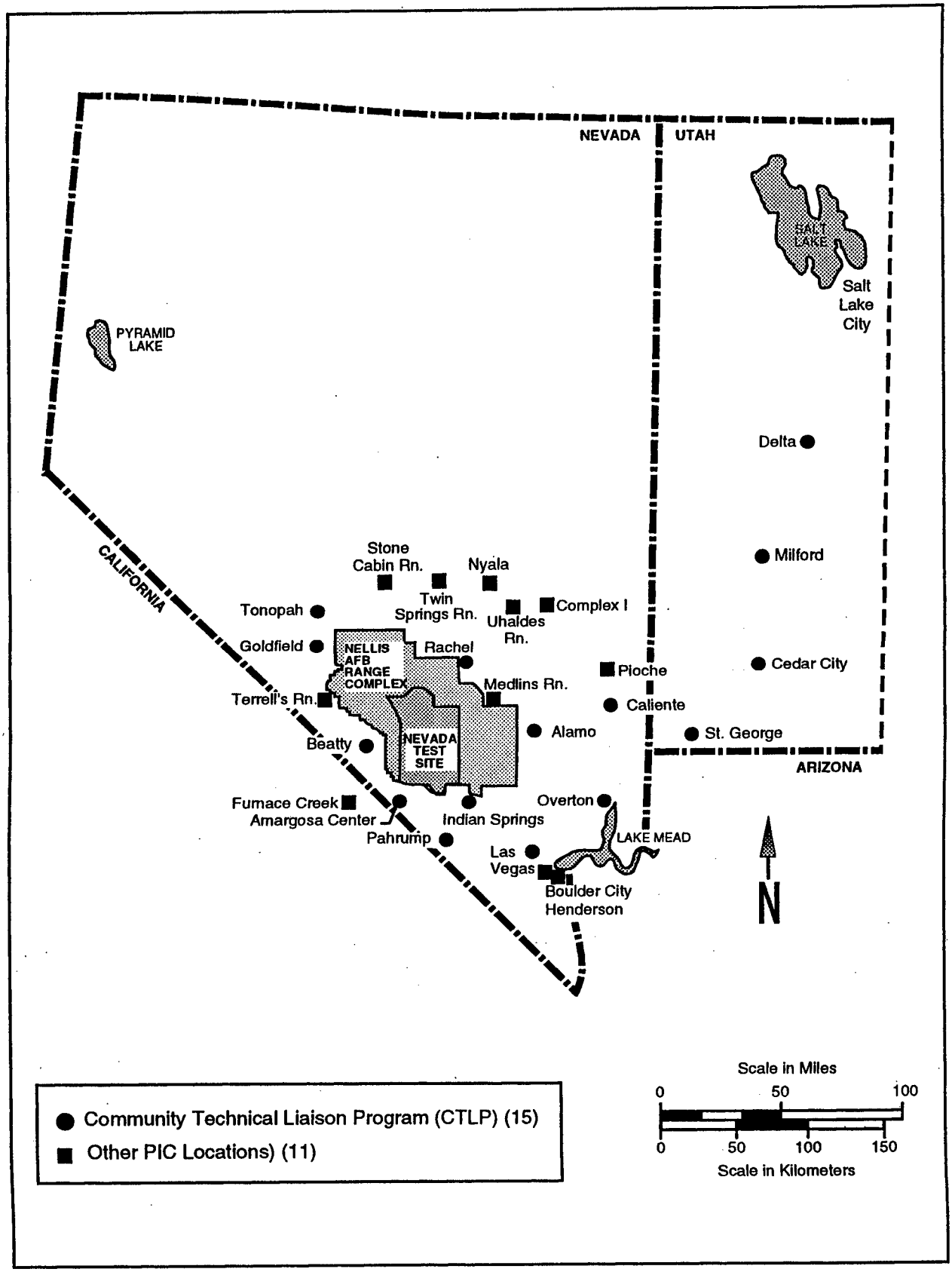

Figure 3.2 Community Technical Liaison Program (CTLP) and PIC station locations - 1996

Data are retrieved from the PICs shortly after measurements are made. The near real-time telemetry-based data retrieval is achieved by the connection of each PIC to a data collection platform which collects and transmits the data. Gamma exposure measurements are transmitted via the Geostationary Operational Environmental Satellite (GOES) directly to a receiver earth station at the NTS and from there to the R&IE-LV by dedicated telephone line. Each station routinely transmits data every four hours (i.e., 4-hour average, 1-minute maximum, and 1-minute minimum values) unless the gamma exposure rate exceeds the currently established alarm threshold. When the threshold is exceeded for two consecutive 1-minute intervals, the system goes into the alarm mode and transmits a string of nine consecutive 1-minute values every 2 to 15 minutes. Additionally, the location and status (i.e.,routine or alarm mode) of each station are shown on a map in the control room at the NTS and at R&IE-LV. Thus, the PIC Network is able to provide immediate documentation of radioactive cloud passage in the event of an accidental release of radioactivity.

The threshold limits are established at approximately two times background for each station location. These threshold values range from 16 µR/h for Pahrump, Nevada, to 35 µR/h for Milford, Utah, and Stone Cabin Ranch, Nevada. A significant improvement was made to the network in 1993. In previous years, 4-hour average, 1-minute minimum, and 1-minute maximum values were the only values transmitted every four hours. In 1993, the software at the stations was upgraded to allow a string of 48 five-minute averages to be transmitted every four hours.

In addition to telemetry retrieval, PIC data are also recorded on magnetic tapes 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 monthly, provide a backup to the telemetry data and are also useful for investigating anomalies in 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 daily by R&IE-LV personnel. Trends and anomalies are investigated and equipment problems are identified and referred to field personnel for correction. Monthly averages are stored in Lotus files on a personal computer. These monthly 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 monthly average data are issued monthly for posting at each station. These reports indicate the current month's average gamma exposure rate, the previous month's averages, and the maximum and minimum background levels in the U.S.

3.2.3 Results

Table 3.3 contains the number of monthly averages available from each station and the maximum, minimum, mean, standard deviation, and median of the monthly averages. The mean ranged from 8.0 µR/hr at Pahrump, Nevada, to 17.7 µR/hr at Tonopah, Nevada, or annual exposures from 71 to 156 mR (18 to 40 µC/kg). The table shows the total mR/yr (calculation based on the mean of the monthly averages) and the average gamma exposure rate for each station. 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 (13 to 64 µC/kg-yr) (BEIR III, 1980). The annual exposure levels observed at each PIC station are well within these U.S. background levels. Figure 3.3 shows the distribution of the monthly averages from each PIC station. The horizontal lines extend from the mean value (◆) to the minimum and maximum values. The vertical lines are the approximate U. S. background range.

The data from Milford, Rachel, Twin Springs, and Uhalde's Ranch stations show the greatest range and the most variability. These data are within a few tenths µR/hr from those of last year.

3.2.4 Quality Assurance/Quality Control

General QA/QC guidelines for the PICs follow the Quality Management Plan referenced on page 66 and are summarized as follows:

- Procedures for the operation, maintenance, and calibration, of PIC equipment and the data review, statistical analysis and records are documented in approved SOPs.
- Radiation monitoring specialists place a radioactive source of a known exposure on the PICs monthly to check the performance of the units.
- Source check calibration and background exposure rate data are evaluated monthly and compared to historical values.

- Data not transmitted via the telemetry system due to equipment failure are retrived by reading mag tapes.

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

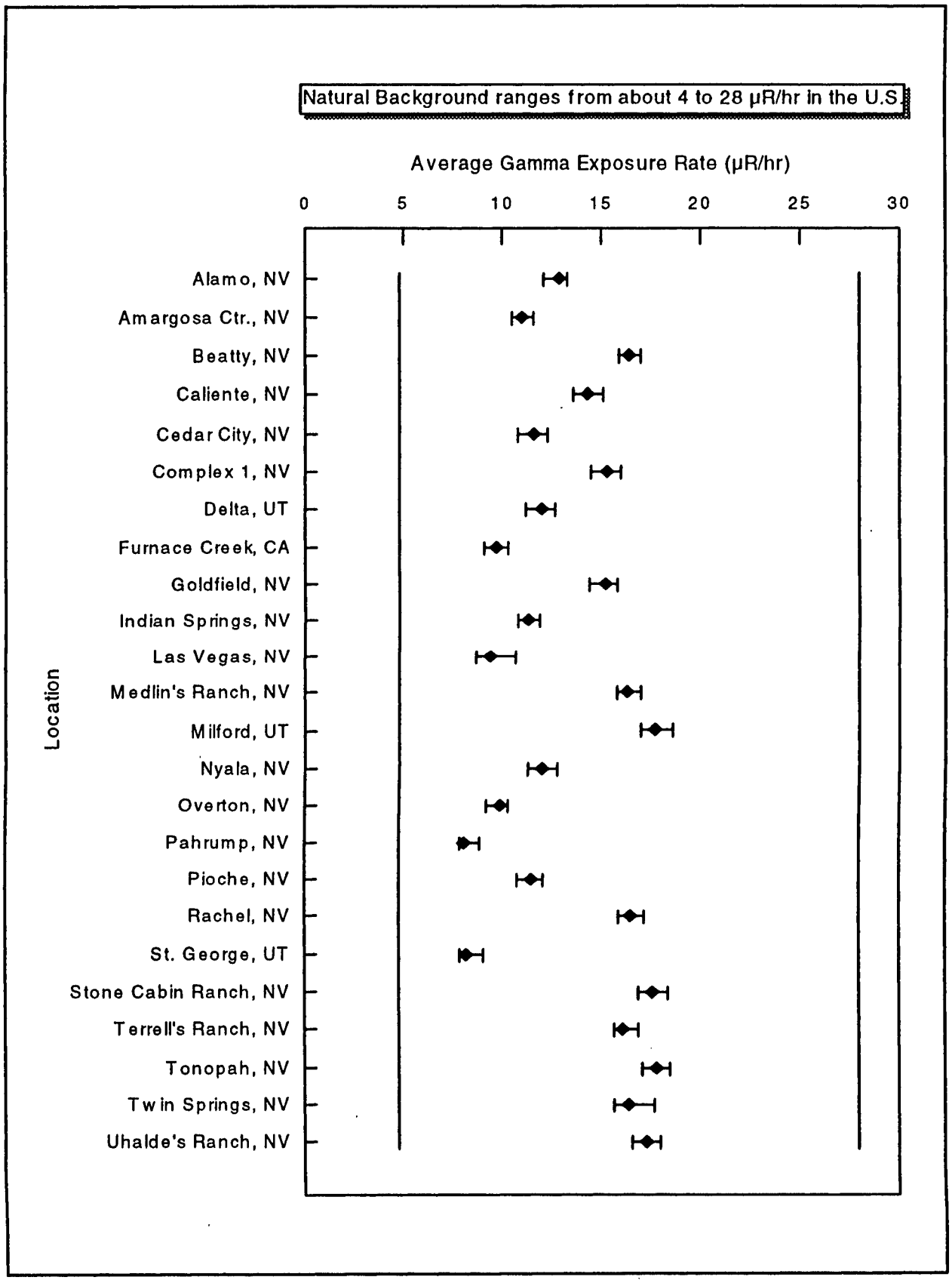

Figure 3.3 Monthly averages from each PIC Network station - 1996

Table 3.1 Environmental Thermoluminescent Dosimetry Results, 1996

Station Name	Number of Days Deployed	Daily Exposure (mR) Min	Max	Mean	Total (mR) Exposure
Alamo, NV	357	0.22	0.26	0.24	86
Amargosa Center, NV	356	0.18	0.32	0.22	81
Austin, NV	273	0.34	0.36	0.34	126
Baker, CA	334	0.23	0.26	0.24	87
Barstow, CA	356	0.26	0.31	0.27	99
Beatty, NV	357	0.14	0.32	0.26	95
Bishop, CA	356	0.26	0.32	0.27	100
Blue Jay, NV	358	0.15	0.37	0.28	101
Boulder City, NV	77	0.28	0.28	0.28	101
Caliente, NV	356	0.22	0.29	0.25	108
Cedar City, UT	357	0.18	0.21	0.19	71
Coaldale, NV	355	0.25	0.32	0.28	102
Complex I, NV	357	0.28	0.30	0.29	106
Coyote Summit, NV	357	0.28	0.38	0.33	120
Delta, UT	356	0.21	0.23	0.22	80
Ely, NV	357	0.17	0.24	0.19	88
Eureka, NV	356	0.22	0.27	0.24	87
Gabbs, NV	355	0.20	0.24	0.21	76
Garrison, UT	356	0.19	0.22	0.21	75
Goldfield, NV	357	0.12	0.28	0.22	81
Groom Lake, NV	349	0.23	0.28	0.26	93
Henderson, NV	77	0.32	0.32	0.32	118
Hiko, NV	356	0.18	0.21	0.19	70
Indian Springs, NV	83	0.28	0.28	0.28	103
Las Vegas UNLV, NV	350	0.16	0.24	0.19	67
Lone Pine, CA	334	0.23	0.29	0.26	117
Lund, NV	310	0.24	0.30	0.26	92
Lund, UT	357	0.28	0.32	0.29	107
Manhattan, NV	335	0.34	0.40	0.36	132
Medlins Ranch, NV	357	0.30	0.32	0.31	111
Mesquite, NV	357	0.18	0.21	0.20	71
Milford, UT	356	0.31	0.32	0.32	115
Mina, NV	355	0.23	0.29	0.26	95
Moapa, NV	357	0.22	0.25	0.23	85
Nyala, NV	356	0.12	0.26	0.19	74
Overton, NV	357	0.17	0.21	0.19	68
Pahrump, NV	356	0.14	0.22	0.16	60

Continued

Table 3.1 Environmental Thermoluminescent Dosimetry Results, 1996 (Con't)

Station Name	Number of Days Deployed	Daily Exposure (mR) Min	Max	Mean	Total (mR) Exposure
Pioche, NV	356	0.22	0.25	0.23	105
Queen City Summit, NV	358	0.31	0.35	0.34	130
Rachel, NV	357	0.29	0.32	0.31	111
Round Mountain, NV	356	0.30	0.34	0.32	116
St. George, UT	357	0.15	0.19	0.16	59
Stone Cabin, NV	358	0.15	0.33	0.26	98
Sunnyside, NV	357	0.16	0.19	0.17	61
Tonopah Test Range, NV	357	0.16	0.34	0.29	105
Tonopah, NV	357	0.15	0.33	0.27	101
Twin Springs, NV	358	0.15	0.33	0.26	95
Uhaldes Ranch, NV	357	0.26	0.33	0.30	109
Warm Springs #1, NV	189	0.13	0.27	0.20	75

Minimum total exposure is 59 at St. George, UT
Maximum total exposure is 132 at Manhattan, NV
Mean of total exposure is 93

* Based on 365.25 days per year.

Table 3.2 Personnel Thermoluminescent Dosimetry Results, 1996

Location		Number of Days Worn	Daily Deep Dose Exposure (mrem) Min	Max	Mean	Total Annual Exposure
022	Alamo, NV	356	0.14	0.30	0.23	85.2
028	Beatty, NV	357	0.32	0.37	0.35	125
040	Goldfield, NV	357	0.22	0.33	0.28	101
042	Tonopah, NV	357	0.30	0.34	0.32	117
045	St. George, UT	169	0.19	0.22	0.20	74.0
293	Pioche, NV	274	0.26	0.34	0.31	111
307	Mina, NV	216	0.26	0.31	0.29	99.7
336	Caliente, NV	341	0.21	0.29	0.25	91.1
344	Delta, UT	356	0.20	0.27	0.23	84.9
345	Delta, UT	356	0.24	0.28	0.26	95.1
346	Milford, UT	356	0.21	0.36	0.29	107
347	Milford, UT	265	0.26	0.36	0.30	109
348	Overton, NV	357	0.15	0.21	0.19	71.0
380	Amargosa Valley, NV	183	0.21	0.24	0.23	81.8
427	Alamo, NV	357	0.22	0.32	0.26	93.0
592	Alamo, NV	357	0.22	0.29	0.26	94.8
593	Cedar City, UT	286	0.25	0.32	0.28	104
594	St. George, UT	273	0.11	0.19	0.15	48.8
595	Las Vegas, NV	361	0.16	0.40	0.27	90.4
596	Las Vegas, NV	361	0.14	0.30	0.22	76.1
607	Tonopah, NV	357	0.30	0.36	0.34	124
608	Logandale, NV	357	0.19	0.21	0.20	74.9
610	Caliente, NV	356	0.27	0.38	0.32	116
621	Indian Springs, NV	267	0.15	0.30	0.21	76.5
651	Amargosa Valley, NV	84	0.24	0.24	0.24	86.9

Mean of total exposure is: 96.3mrem

Total data completeness: 98%

Table 3.3 Summary of Gamma Exposure Rates as Measured by Pressurized Ion Chamber - 1996

Station	Number of Days Station Reported	Gamma Exposure Rate (μR/hr) Maximum	Minimum	Arithmetic Mean	Standard Deviation	Median	mR/yr	Mean (μR/hr)
Alamo, NV	281	13.3	12.1	12.8	1.08	13.0	113	12.9
Amargosa Center, NV	267	11.6	10.5	10.9	0.73	11.0	96	11.0
Beatty, NV	283	17.0	15.9	16.3	1.08	16.0	144	16.4
Caliente, NV	262	15.1	13.6	14.2	0.48	14.0	125	14.3
Cedar City, UT	277	12.3	10.8	11.5	0.83	12.0	102	11.6
Complex I, NV	275	16.0	14.5	15.3	0.86	15.0	134	15.3
Delta, UT	266	12.7	11.2	12.0	0.71	12.0	105	12.0
Furnace Creek, CA	267	10.3	9.1	9.7	0.64	10.0	85	9.7
Goldfield, NV	242	15.8	14.4	15.2	1.16	15.0	133	15.2
Indian Springs, NV	253	11.9	10.8	11.2	1.06	11.0	99	11.3
Las Vegas, NV	359	10.7	8.7	9.4	0.16	9.4	82	9.4
Medlin's Ranch, NV	276	17.0	15.8	16.3	0.68	16.0	143	16.3
Milford, UT	275	18.6	17.0	17.7	0.93	18.0	155	17.7
Nyala, NV	223	12.8	11.3	12.0	0.21	12.0	105	12.0
Overton, NV	270	10.3	9.2	9.8	0.62	10.0	87	9.9
Pahrump, NV	269	8.9	7.9	8.0	0.41	8.0	71	8.1
Pioche, NV	248	12.1	10.8	11.5	2.03	12.0	101	11.5
Rachel, NV	255	17.2	15.9	16.4	1.37	17.0	145	16.5
St. George, UT	266	9.1	7.9	8.1	0.75	8.0	72	8.2
Stone Cabin Ranch, NV	274	18.4	16.9	17.5	1.22	18.0	154	17.6
Terrell's Ranch, NV	276	16.9	15.7	16.1	0.84	16.0	141	16.1
Tonopah, NV	275	18.5	17.1	17.7	1.22	18.0	156	17.8
Twin Springs, NV	262	17.7	15.7	17.6	1.0	16.0	144	16.4
Uhalde's Ranch, NV	276	18.0	16.6	17.2	0.73	17.0	152	17.3

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

4.0 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. The only atmospheric monitoring network still operating is the Air Surveillance Network (ASN). The ASN was designed to monitor the areas within 350 kilometers (220 miles) of the NTS.

Most of the data collected from the ASN 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 network reside on a VAX computer in the Sample Tracking Data Management System (STDMS).

4.1 Air Surveillance Network

4.1.1 Design

During 1996 the ASN consisted of 18 continuously operating sampling stations. Two stations were added during the fourth quarter to bring the total number of stations to 20 (see Figure 4.1 for these locations).

Each station is equipped with a low volume air sampler to collect particulate radionuclides on fiber filters and gaseous radioiodines in charcoal cartridges. The filters and charcoal cartridges receive complete analyses at the R&IE-LV Radioanalysis Laboratory. Duplicate air samples are collected from two ASN stations each week. The duplicate samplers operate at randomly selected stations continuously for three months and are then moved to a new location.

Six of the air sampling stations are equipped with high volume air samplers that collect particulate radionuclides on glass fiber filters. The filters are analyzed by gamma spectrometry in the R&IE-LV Radioanalysis Laboratory. The filters are then composited by month and analyzed for plutonium isotopes by wet chemistry methods. One duplicate high volume sampler is co-located at a randomly selected high volume sampling station and is moved to a new location at the beginning of each quarter. Duplicate samples are collected and analyzed by the same methods as the routine samples.

4.1.2 Procedures

Low volume samplers collect airborne particulates at each ASN station. The samples are collected as air is drawn through 5 cm (2.1 in) diameter, glass-fiber filters (prefilters) at a flow rate of about 100 m^3 (2800 ft^3) per day. Activated charcoal cartridges are placed directly behind the filters to collect gaseous radioiodines. Filters and cartridges are exchanged after sampler operation periods of about one week (approximately 560 m^3 or 20,000 ft^3). High volume (hi-vol) samplers are located at selected stations within the ASN. The hi-vol samplers collect airborne particulates as air is drawn through an eight inch by ten inch glass fiber filter at a rate of about 2000m^3 (58,000 ft^3) per day. The hi-vol filters are collected monthly with a total volume of approximately 60,000 m^3 (1,700,000 ft^3).

Duplicate air samples are obtained weekly from selected stations. Two low volume air samplers and one high volume air sampler, which are identical to the ASN station samplers, are rotated between ASN stations quarterly. The results of the duplicate field sample analyses are given in Chapter 8 as part of the data quality assessment.

Prefilters and charcoal cartridges from low volume samplers, and high volume filters are initially analyzed by high resolution gamma spectrometry. The low volume prefilters are then analyzed for gross alpha and gross beta activity. Analysis is performed 7 to 14 days after sample collection to allow time for the decay of naturally occurring radon-thoron daughter products. Gross alpha/beta analysis is used to detect trends in atmospheric radioactivity since it is more sensitive than gamma spectrometry for this purpose. High volume filters are submitted for wet chemistry analysis for plutonium isotopes upon completion of gamma spectrometry. Additional information on the analytical procedures is provided in Chapter 10.

4.1.3 Results

The ASN measures the major radionuclides which could potentially be emitted from activities on the NTS. Data from the ASN represents

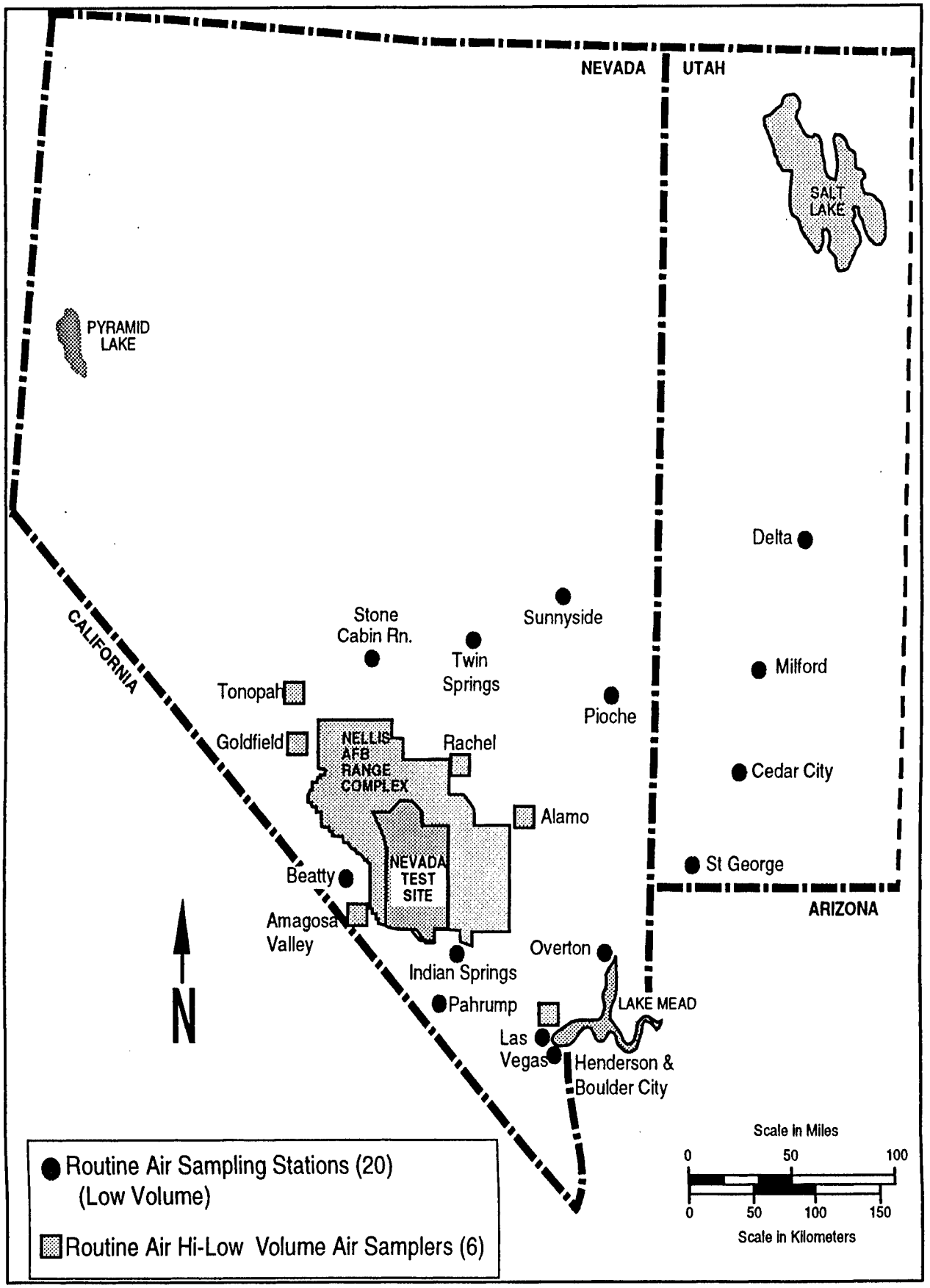

Figure 4.1 Air Surveillance Network stations - 1996

the inhalation pathway component of radiation exposure to the general public.

Gamma spectrometry was performed on all ASN low and high volume samples. The majority of the samples were gamma-spectrum negligible (i.e., no gamma-emitting radionuclides detected). Naturally occurring ^{7}Be, averaging 2.5×10^{-13} µCi/mL, was detected ocasionally by the low volume network of samplers. Beryllium-7 was detected consistently by the high volume sample method with average activity of 2.4×10^{-13} µCi/mL. Alpha and beta low volume air sample results were not included in data analysis if 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 the low volume sampling network consistently exceeded the analysis minimum detectable concentration (MDC). The annual average gross beta activity was 1.42×10^{-14} µCi/mL. Summary gross beta results for the ASN are shown in Table 4.1.

Gross alpha analysis was performed on all low volume network samples. The average annual gross alpha activities were 1.32×10^{-16} µCi/mL. Summary gross alpha results for the ASN are presented in Table 4.2.

During the first three quarters of 1996, samples collected at high volume sampling sites were composited by month and analyzed for plutonium isotopes. Starting with the last quarter of 1996, the hi-vol samples were collected on a monthly basis to improve the ease of sample preparation in the laboratory. Due to a lower limit of detection for high volume sampling and analysis methods, environmental levels of plutonium were occasionally detected at all six of the sampling sites. Plutonium results for the high volume air sampling network are presented in Table 4.3.

4.1.4 Quality Assurance/ Quality Control

General QA/QC guidelines for the ASN 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.
- A file of calibration records, control charts, and log books is maintained.
- Unique sample numbers are assigned.
- The laboratory supervisor approves all analytical results before they are entered into the permanent data base.
- Files of QA data, which includes raw analytical data, intermediate calculations, and review reports are maintained.
- Blanks are analyzed to verify the absence of method interferences. These may be caused by contaminants in solvents, and reagents, on glassware, or introduced by sample processing.
- Analytical accuracy is estimated 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.
- The combined error due to both sampling and analytical technique is estimated by using replicates.
- An estimate of bias (the difference between the value obtained and the true or reference value) is determined by participating in intercomparison studies.

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

Table 4.1 Gross Beta Results for the Offsite Air Surveillance Network - 1996

Gross Beta Concentration (10^{-14} µCi/mL [0.37 mBq/m^3])

Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Alamo, NV	52	2.56	0.53	1.4	0.47
Amargosa Center, NV	52	4.64	0.59	1.6	0.65
Beatty, NV	52	2.95	0.53	1.5	0.48
Boulder City, NV	9	3.09	0.34	1.4	0.87
Clark Station, NV					
Stone Cabin Ranch	52	2.74	0.50	1.5	0.48
Goldfield, NV	51	2.72	0.49	1.4	0.52
Henderson, NV	13	3.04	0.22	1.5	0.88
Indian Springs, NV	50	2.49	0.02	1.3	0.49
Las Vegas, NV	52	2.44	0.24	1.3	0.44
Overton, NV	50	3.37	0.62	1.5	0.58
Pahrump, NV	50	2.26	0.48	1.4	0.47
Pioche, NV	50	2.21	0.66	1.4	0.44
Rachel, NV	49	2.50	0.22	1.4	0.49
Sunnyside, NV	50	2.73	-0.05	1.4	0.51
Tonopah, NV	52	2.22	0.48	1.3	0.41
Twin Springs, NV					
Fallini's Ranch	50	2.73	0.26	1.6	0.56
Cedar City, UT	52	3.06	0.18	1.2	0.61
Delta, UT	49	3.04	0.22	1.5	0.88
Milford, UT	53	5.74	0.19	1.5	0.82
St. George, UT	22	5.38	0.66	1.8	1.0

Mean MDC: 2.4 x 10^{-15} µCi/mL Standard Deviation of Mean MDC: 0.36 x 10^{-15} µCi/mL

Table 4.2 Gross Alpha Results for the Offsite Air Surveillance Network - 1996

Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
		Concentration (10^{-15} µCi/mL [37 µBq/m^3])			
Alamo, NV	52	5.9	0.4	1.6	0.94
Amargosa Center, NV	52	6.6	0.0	1.6	1.1
Beatty, NV	52	2.8	0.2	1.1	0.64
Boulder City, NV	9	4.1	1.3	2.6	1.0
Clark Station, NV					
Stone Cabin Ranch	52	4.5	0.5	2.0	0.72
Goldfield, NV	51	3.2	0.2	1.0	0.60
Henderson, NV	13	3.6	0.8	2.3	0.84
Indian Springs, NV	50	3.9	0.2	1.0	0.70
Las Vegas, NV	52	2.9	0.2	1.5	0.74
Overton, NV	50	6.3	-0.1	1.2	1.1
Pahrump, NV	50	4.0	-0.2	1.0	0.81
Pioche, NV	49	3.6	-0.2	0.95	0.66
Rachel, NV	49	4.3	0.1	1.3	0.98
Sunnyside, NV	50	1.6	0.0	0.74	0.43
Tonopah, NV	52	2.9	-0.3	0.92	0.56
Twin Springs, NV					
Fallini's Ranch	50	3.2	-0.1	1.2	0.77
Cedar City, UT	52	3.5	0.2	1.6	0.78
Delta, UT	49	7.1	0.1	1.4	1.2
Milford, UT	53	1.6	0.0	0.74	0.43
St. George, UT	22	3.6	-0.2	0.95	0.66

Mean MDC: 7.7 x 10^{-16} µCi/mL Standard Deviation of Mean MDC: 2.4 x 10^{-16} µCi/mL

Table 4.3 Offsite High Volume Airborne Plutonium Concentrations - 1996

^{238}Pu Concentration (10^{-18} µCi/mL)

Composite Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Alamo, NV	12	0.54	-0.09	0.17	0.17
Amargosa Valley, NV	8	0.94	-0.76	0.22	0.30
Goldfield, NV	12	0.37	-0.05	0.13	0.14
Las Vegas, NV	8	0.17	-0.24	0.02	0.14
Rachel, NV	7	0.94	-0.76	0.22	0.30
Tonopah, NV	9	0.31	-0.08	0.11	0.14

Mean of MDC: 0.73 x10^{-18}µCi/mL Std. Dev. of Mean MDC: 1.66 x10^{-18}µCi/mL

$^{239+240}$Pu Concentration (10^{-18} µCi/mL)

Composite Sampling Location	Number	Maximum	Minimum	Arithmetic Mean	Standard Deviation
Alamo, NV	12	4.91	0.07	1.15	1.29
Amargosa Valley, NV	8	1.64	0.23	0.71	0.47
Goldfield, NV	12	2.76	0.06	1.18	0.85
Las Vegas, NV	8	2.19	0.00	0.71	0.66
Rachel, NV	7	65.7	0.39	12.7	22.1
Tonopah, NV	9	2.18	0.19	0.77	0.59

Mean of MDC: 0.52 x10^{-18}µCi/mL Std. Dev. of Mean MDC: 0.99 x10^{-18}µCi/mL

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

5.0 Milk

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.

These radionuclides may be transferred to milk. Water is another significant ingestion transport pathway of radionuclides to humans.

5.1 Milk Surveillance Network

Milk is an important source for evaluating potential human exposures to radioactive material. It is one of the most universally consumed foodstuffs and certain radionuclides are readily traceable through the 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. The samples collected in July are from animals consuming local feed. Accordingly, milk is monitored by R&IE-LV through the Milk Surveillance Network (MSN).

5.1.1 Design

The MSN includes commercial dairies and family-owned milk cows and goats representing the major milksheds within 186 mi (300 km) of the NTS. The 11 locations comprising the MSN at the beginning of 1996 and any changes are shown in Figure 5.1. Samples were collected from only ten of these locations because the Hafen Ranch in Ivins, Utah, was not milking during the collection period.

5.1.2 Procedures

Raw milk was collected in 3.8-L (1-gal) cubitainers from each MSN location in July and preserved with formaldehyde. This network was designed to monitor areas adjacent to the NTS, which could be affected by a release of activity, as well as from areas unlikely to be so affected.

All milk samples are analyzed by high-resolution gamma-ray spectroscopy to detect gamma-ray emitting radionuclides. These samples are also analyzed for ^{89}Sr and ^{90}Sr by radiochemical separation and beta counting (see Table 5.1).

5.1.3 Results

The average total potassium concentration derived from naturally occurring ^{40}K activity was 1.5 g/L for samples analyzed by gamma spectrometry. All MSN milk samples were analyzed for ^{89}Sr and ^{90}Sr, and the results are similar to those obtained in previous years. The MSN network average values are shown in Table 5.2 for ^{89}Sr and ^{90}Sr.

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

5.1.4 Quality Assurance/Control

General QA/QC guidelines for the MSN are as follows:

- Procedures for the operation, maintenance and calibration of laboratory counting equipment, the control and statistical analysis of the samples 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 10.

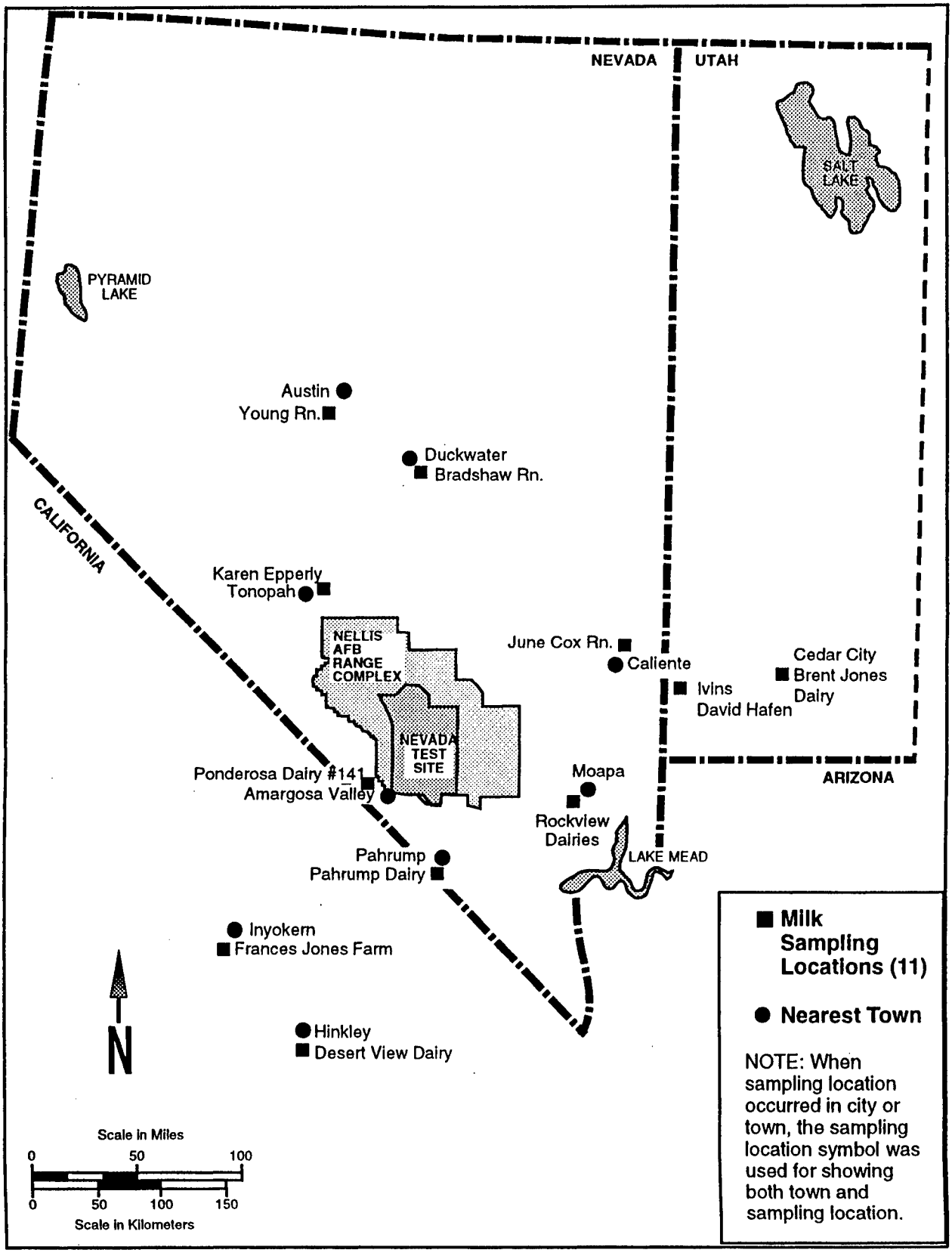

Figure 5.1 Milk Surveillance Network stations - 1996

Table 5.1 Offsite Milk Surveillance ^{90}Sr Results - 1996

Sampling Location	Number	^{90}Sr Concentration (10^{-10} μCi/mL) Mean
Hinkley, CA		
Desert View Dairy	1	2.1
Inyokern, CA		
Frances Jones Farm	1	0.9
Amargosa Valley, NV		
Ponderosa Dairy #141	0	Sample Lost*
Austin, NV		
Young's Ranch	1	2.6
Caliente, NV		
June Cox Ranch	0	Sample Lost*
Duckwater, NV		
Bradshaw's Ranch	1	0.7
Moapa, NV		
Rockview Dairies	1	1.4
Pahrump, NV		
Pahrump Dairy	1	3.0
Tonopah, NV		
Karen Epperly	1	0.8
Cedar City, UT		
Brent Jones Dairy	1	1.8
Ivins, UT		
David Hafen Dairy	0	No Sample**

* Sample lost in analysis.
** Currently not milking.

Table 5.2 Summary of Radionuclides Detected in Milk Samples

	Milk Surveillance Network No. of samples with results > MDC (Network average concentration in pCi/L)		
	1996	1995	1994
^{3}H	Not analyzed	0(37)	0(85)
^{89}Sr	0(0.01)	0(0.03)	0(0.22)
^{90}Sr	0(0.63)	0(0.61)	2(0.44)

6.0 Long-Term Hydrological Monitoring Program

One of the concerns of underground nuclear weapons testing is the possibility of radionuclide contamination of groundwaters. Since 1973, underground nuclear weapons tests were conducted only on the Nevada Test Site (NTS), but between 1961 and 1973, eleven tests were conducted in eight other locations in the United States. The initial ground and surface water monitoring program was established by the U.S. Public Health Service (USPHS) in the early 1950s. Pretest and post-test monitoring for the locations off the NTS was conducted by the USPHS, the U.S. Geological Survey (USGS), and Teledyne Isotopes, Inc. In 1972, the Long-Term Hydrological Monitoring Program (LTHMP) was established by the Nevada Operations Office (NVO) of the Atomic Energy Commission (AEC), a predecessor agency to DOE. Through an interagency agreement between AEC (later DOE) and EPA, responsibility for operation of the LTHMP was assigned to the U.S. EPA's Radiation and Indoor Environments National Laboratory formerly the Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). The LTHMP is only one component of the total surface and ground water monitoring program conducted under the auspices of DOE/NV.

The LTHMP conducts routine monitoring of specific wells on the NTS and of wells, springs, and surface waters in the offsite area around the NTS. In addition, sampling for the LTHMP is conducted at other locations in the U.S. where nuclear weapons tests have been conducted. These locations include sites in Nevada, Colorado, New Mexico, Mississippi, and Alaska.

6.1 Network Design

The LTHMP was instituted because AEC (later DOE/NV) acknowledged its responsibility for obtaining and for disseminating data acquired from all locations where nuclear devices have been tested. The three objectives originally established for the LTHMP were to:

- Assure public safety.

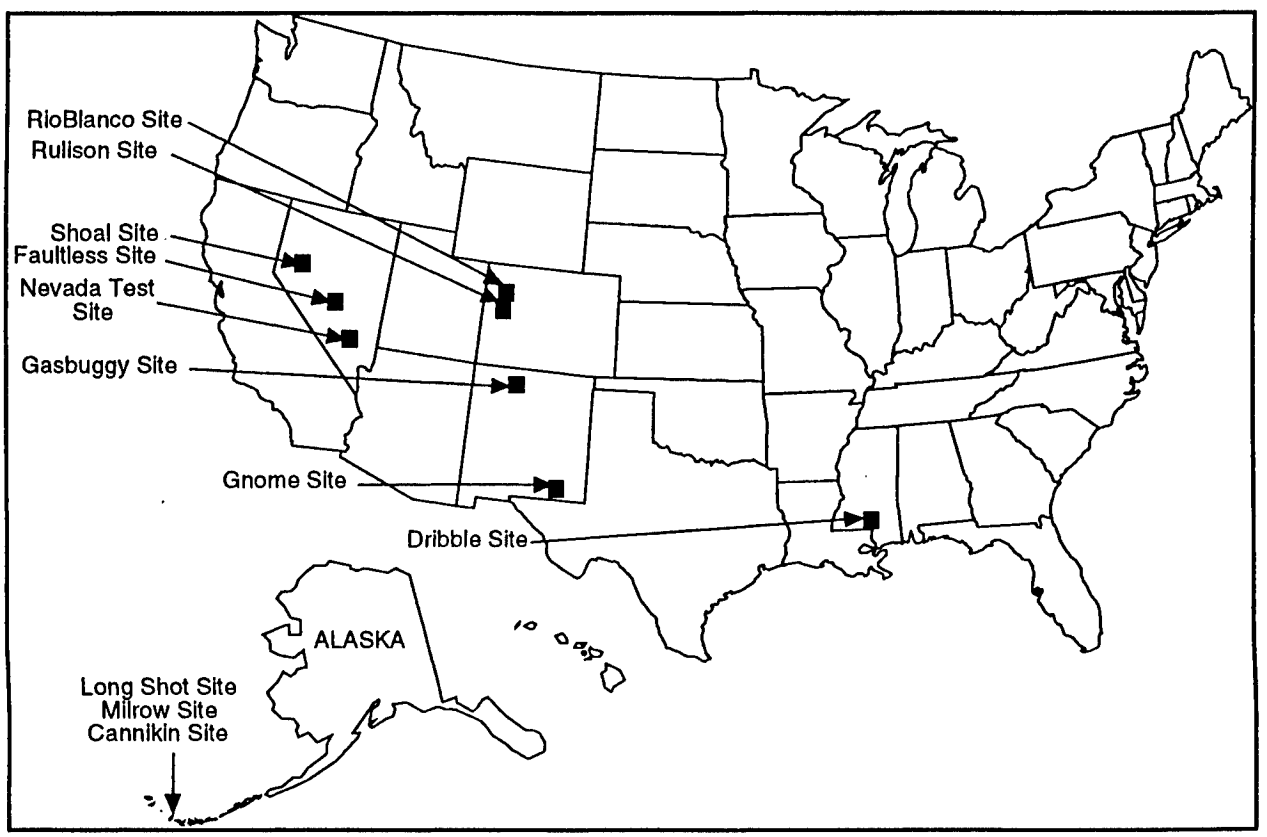

Figure 6.1 Long-Term Hydrological Monitoring Program sampling sites around the United States.

- Inform the public, news media, and scientific community about any radiological contamination.

- Document compliance with existing federal, state, and local antipollution requirements.

Another objective which has been incorporated into the LTHMP is to, where possible, detect trends in radionuclide activities which may be indicative of migration from test cavities.

The primary radionuclide analyzed in the LTHMP is tritium. As a product of nuclear weapons testing, high levels of tritium are found in test cavities. Because tritium can be incorporated into water molecules, it is expected to be the first radionuclide to migrate from a test cavity. Therefore, tritium serves as an indicator of radionuclide migration. Atmospheric tritium may also be deposited into water, primarily by precipitation. Tritium from this source is primarily found in surface waters, surficial aquifers, and springs closely connected to surficial aquifers.

6.1.1 Sampling Locations

In order to meet the objective of ensuring public safety, R&IE-LV monitors drinking water supply wells and springs around the NTS and in the vicinity of surface ground zero (SGZ) at the other locations. The majority of these sampling sites are privately owned and participation in the LTHMP is voluntary. Municipal drinking water supplies are also represented. Regardless of the number of individuals served by a particular water supply, the National Primary Drinking Water Regulation[1] (NPDWR) pertaining to radioactivity is used as the compliance standard.[2]

All of the nuclear weapons tested at locations other than the NTS were emplaced at depths of greater than 1200 feet. Nuclear weapons tested on the NTS are also emplaced at great depths, with the exception of some shallow underground tests conducted in the early 1960s. The drinking water supply wells tap shallow aquifers and, consequently, do not represent groundwater in the geologic strata containing the test cavities. Therefore, wherever possible, deep wells are included in the monitoring program. These wells include some which were drilled soon after a nuclear test specifically to monitor activities in or near the test cavity and others which can be considered only as "targets of opportunity;" e.g., existing wells for which sampling permission has been obtained. Most of the deep wells tap non-potable water sources. Monitoring design standards, such as those in the Resource Conservation and Recovery Act (RCRA), did not become available until long after the LTHMP deep wells had been drilled. Cost has delayed emplacement of new wells, although a program to drill more than 90 new wells on the NTS was initiated in 1990. The sampling locations not associated with the NTS are defined by DOE as inactive hazardous waste sites and are exempt from the RCRA monitoring design requirements. Table 6.1 is a listing of routine sampling locations, on and offsite, where well water samples contained tritium concentrations greater than 0.2 percent of the National Primary Drinking Water Standards.

6.1.2 Sampling and Analysis Procedures

The procedures for the analysis of samples collected for this report were described by Johns, et al. (1979) and are summarized in Table 6.2 (see Table 6.3 for Typical MDA Values for Gamma Spectroscopy). These procedures include gamma spectral analysis and radiochemical analysis for tritium. The procedures were based on standard methodology. Two methods for tritium analysis were performed: conventional and electrolytic enrichment. The samples are initially analyzed by the conventional method. If the tritium result is less than 700 pCi/L, selected samples are analyzed by the electrolytic enrichment method which lowers the minimum detectable concentration (MDC) from approximately 300 pCi/L to 5 pCi/L. An upper level of 700 pCi/L has been established for use of the tritium enrichment method. Sample cross contamination becomes a problem at higher ranges.

For wells with operating pumps, the samples are collected at the nearest convenient outlet. If the well has no pump, a truck-mounted sampling unit is used. With this unit it is possible to collect three-liter samples from wells as deep as 1,800 meters (5,900 ft). At the normal sample collection sites, the pH, conductivity, water temperature, and sampling depth is measured and recorded when the sample is collected.

The first time samples are collected from a well, ^{3}H, $^{89,90}Sr$, $^{238,\ 239+240}Pu$, and uranium isotopes are determined. At least one of the one gallon samples from each site is analyzed by gamma spectrometry. In late 1995, because there was no indication of migration and because of funding cutbacks, it was decided that only 25% of tritium samples collected would be analyzed by the enrichment method. Sampling locations in a position to show migration are usually selected.

6.1.3 Quality Assurance/Quality Control Samples

Sample collection and analysis procedures are described in standard operating procedures (SOPs). Data base management and data analysis activities are described in the Quality Assurance Program Plan (EPA, QAPP 1992).

- Use of standardized procedures ensures comparability of operations and data among monitoring locations and across temporal intervals.

- Annual data quality assessments of precision, accuracy, and comparability are based on the results of quality assurance/quality control samples. The data quality assessment results for 1996 are given in Section 8.0.

- Overall system precision is estimated from the results of field duplicates. A field duplicate is a second sample collected from a sampling location immediately following collection of the routine sample using identical procedures.

- Field duplicates are collected from sampling locations on the NTS and in the vicinity of the NTS according to a schedule established by the LTHMP Technical Leader. Generally, all samples from the other locations are collected in duplicate; the second sample may be used as a duplicate or may be used as a replacement for the routine sample, if necessary.

- Accuracy is estimated from results of intercomparison study samples. These intercomparison study samples are spiked samples (i.e., a water sample to which a known amount of particular radionuclide(s) have been added).

- Intercomparison study programs managed by R&IE-LV and DOE's Environmental Monitoring Laboratory (EML) both include water matrix samples. The R&IE-LV intercomparison study samples are also used as an estimate of comparability. Generally, sixty to more than 300 laboratories participate in a given intercomparison study. Results for each laboratory are reported, as are pooled results (mean, standard deviation).

- Comparison of the R&IE-LV Radioanalysis Laboratory results to the mean for all laboratories provides an estimate of the comparability of results.

In addition to the above described QA/QC samples which are used in annual data quality assessments, the Radioanalysis Laboratory employs a number of internal QC samples and procedures to ensure data quality on a day-to-day basis. Internal QC samples include blanks, regular calibrations, matrix spike samples, and duplicate analyses (gamma spectroscopy only). If results of these internal QC samples fall outside prescribed control limits, analysis is stopped until the cause of the discrepant data is found and resolved and corrective actions are implemented.

6.1.4 Data Management and Analysis

A bar code pilot program for the LTHMP was completed in 1991, and was extremely successful. It has been expanded to other monitoring networks. Bar code labels are prepared prior to each sampling excursion, based on the sampling schedule prepared by the LTHMP Technical Leader. Upon receipt of samples in Sample Control, the bar code label was read and the information transferred into the Sample Tracking Data Management System (STDMS), along with information from the field data card.

Analysis data are entered into STDMS after they have been generated and reviewed by the analyst and Group Leader. Special software written in Fortran (referred to as "Chemistry Programs") is used for a majority of the radiochemical data reduction. The Chemistry Programs are used for calculating final data such as activity per unit volume, MDC, and 2-sigma error terms. All hand-entered data are checked for transcription errors. Once data is entered and checked, they are transferred from a "review" data base to a permanent data base, where further changes may be made only by authorized personnel.

Periodically, the assigned media expert reviews the data base and checks for completeness of sample collection, transcription errors, completion of sample analysis and QA/QC samples, and accuracy of information input. All discrepancies are resolved and corrected. Once the data base is complete for a given location, time series plots were generated. Data review of the LTHMP is held with DOE and Desert Research Institute (DRI) hydrology personnel. The time series plots which indicated consistent data trends are included as figures in the subsections

which follow. The filled circles on the time series plots represent the result values, the error bars indicate ± one standard deviation of the result, and the (x) represents the MDC value.

6.2 Nevada Test Site Monitoring

The present sample locations on the NTS, or immediately outside its borders on federally owned land are shown in Figure 6.2. All sampling locations are selected by DOE and primarily represent potable water supplies. In 1995, sampling on the NTS was modified so that EPA only samples wells without pumps and, for Quality Assurance purposes, collects samples from 10 percent of the potable wells sampled by Bechtel Nevada. A total of 21 wells was scheduled to be sampled, but only 19 wells were sampled because the pumps were not working.

All samples were analyzed by gamma spectrometry and for tritium. No gamma-emitting radionuclides were detected in any of the NTS samples collected in 1996. Summary results of tritium analyses are given in Table 6.4. The highest average tritium activity was 4.5×10^4 pCi/L (1,700 Bq/L) in a sample from Well UE-5n. This activity is less than 60 percent of the DCG for tritium established in DOE Order 5400.5 for comparison with the dose limit (4 mrem) in the National Primary Drinking Water Regulations. Eight of the wells sampled yielded tritium results greater than the minimum detectable concentration (MDC). Well UE-7ns was routinely sampled between 1978 and 1987 and sampling began again in 1992. An increasing trend in tritium activity was evident at the time sampling ceased in 1987. Recent results have shown a decrease from those previous results, although the present result is higher than results for 1995.

6.3 Offsite Monitoring In The Vicinity Of The Nevada Test Site

The monitoring sites in the area around the NTS are shown in Figure 6.3. Most of the sampling locations represent drinking water sources for rural residents or public drinking water supplies for the communities in the area. The sampling locations include 12 wells, nine springs, and a surface water site. All of the locations are sampled quarterly or semiannually. Gamma spectrometric analyses are performed on the samples when collected. No man-made gamma-emitting radionuclides were detected in any sample. Tritium analyses are performed on a semiannual basis. Adaven Spring is the only site which consistently shows detectable tritium activity. The tritium activity in this spring represents environmental levels that have been decreasing over time. All results for this project for 1996 are shown in Table 6.5.

6.4 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 United States 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. 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 (for results, see Appendix A). Sampling is normally conducted in odd numbered years on Amchitka Island, Alaska, at the sites of Projects CANNIKIN, LONG SHOT, and MILROW. Sampling was not done last year due to lack of DOE funding.

The sampling procedure is the same as that used for sites on the NTS and offsite areas (described in Section 6.1.2), 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 several years ago. A second sample is taken after pumping for a specified period of time or after the well has been pumped dry and permitted to recharge. These second samples may be more representative of formation water, whereas the first samples may be more indicative of recent area rainfall.

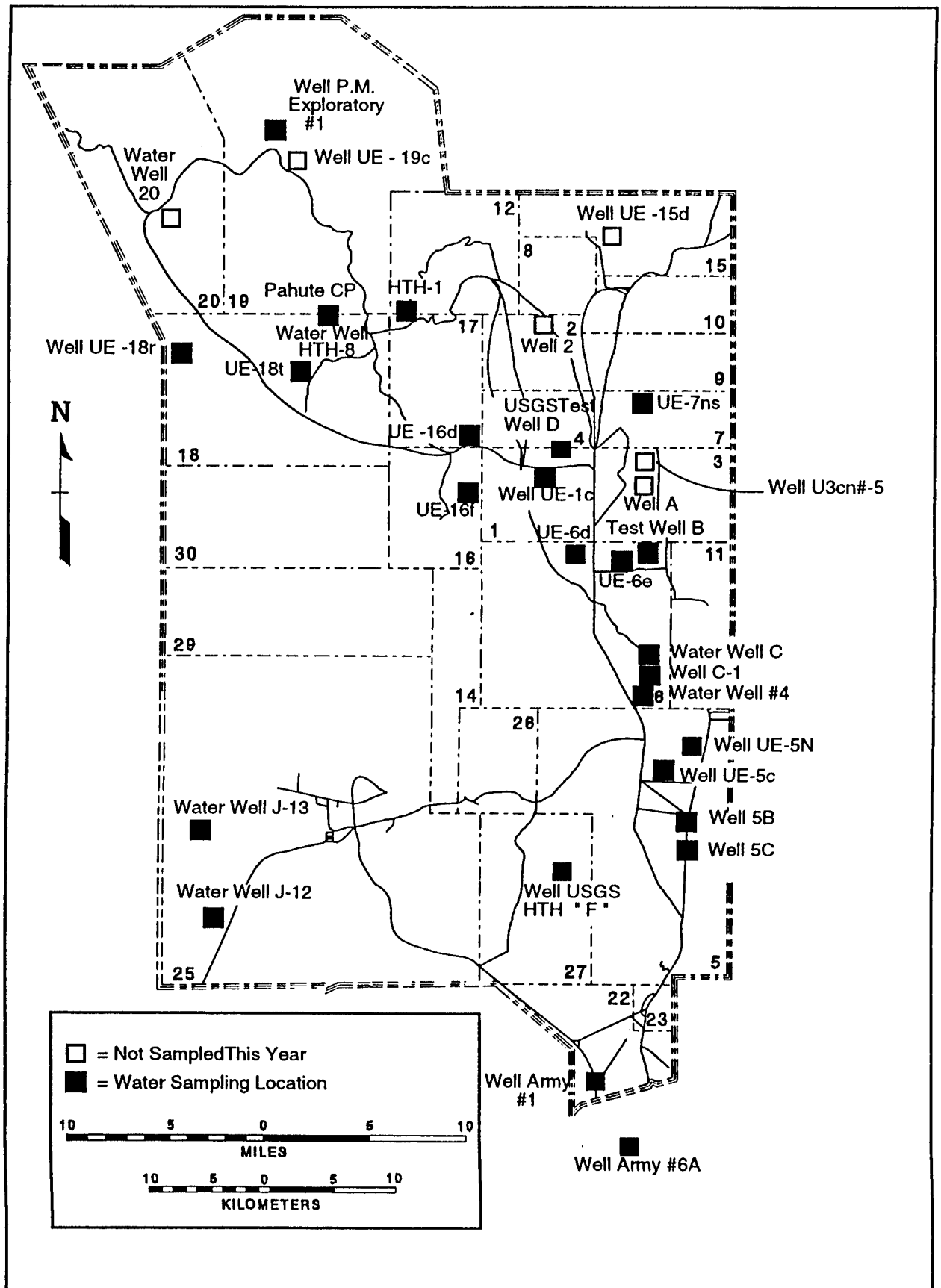

Figure 6.2 Wells on the NTS Included in the LTHMP - 1996

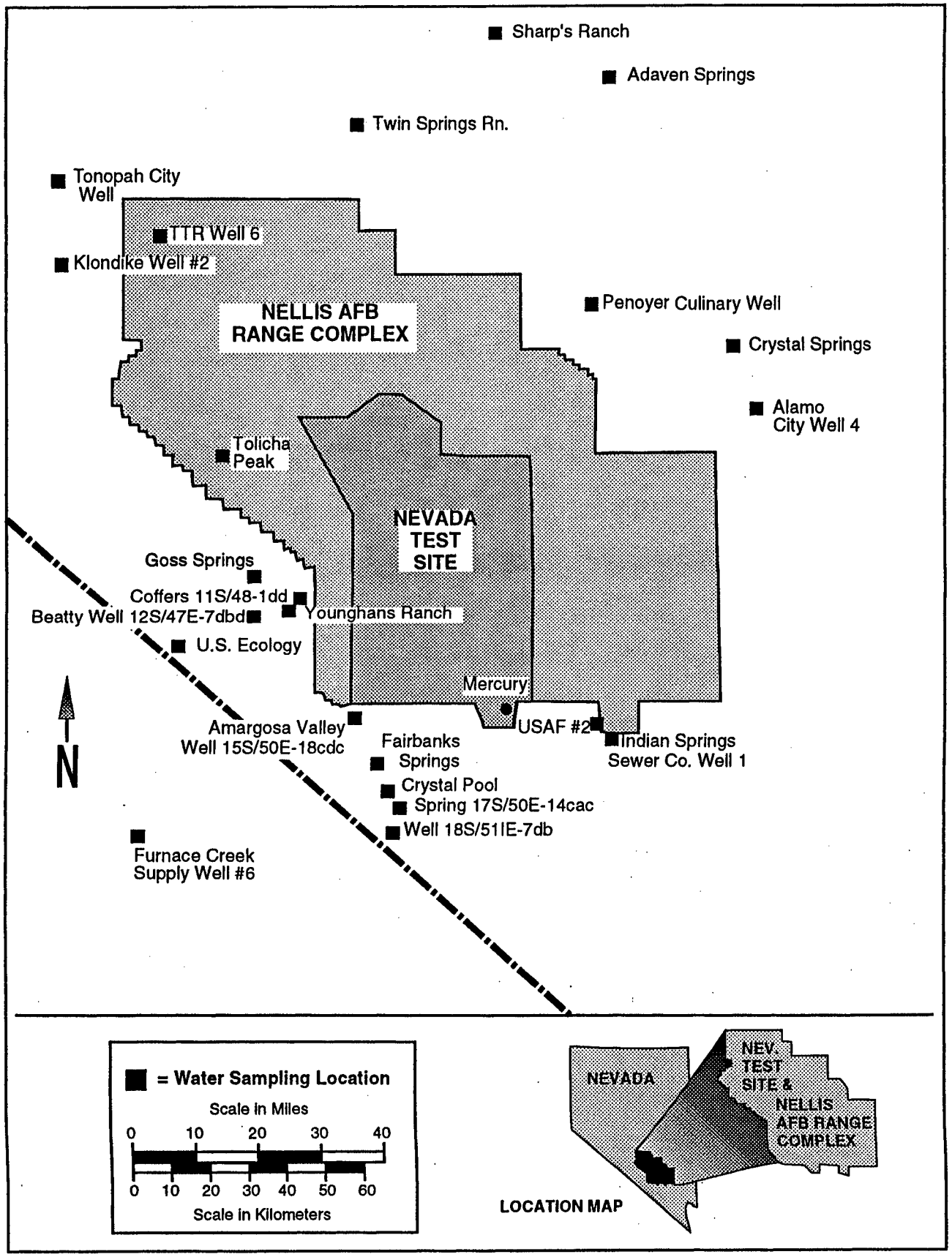

Figure 6.3 Wells Outside the NTS Included in the LTHMP - 1996

6.4.1 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 975 m (3,199 ft). A surface crater was created, but as an irregular block along local faults rather than as a saucer-shaped depression. The area is characterized by basin and range topography, with alluvium overlying tuffaceous sediments. The working point of the test was in tuff. The groundwater flow is generally from the highlands to the valley and through the valley to Twin Springs Ranch and Railroad Valley (Chapman and Hokett, 1991).

Sampling was conducted on March 6 and 7, 1996, at locations shown in Figure 6.4. Routine sampling locations include one spring and five wells of varying depths. The Bias Well was not sampled because the ranch was closed and Six-Mile Well was not sampled because the pump was removed. A new sampling location (site C Complex) was established to replace the Bias Ranch Well. This site is approximately 8 mi from Blue Jay Maintenance Station and is approximately 20 mi from surface ground zero (SGZ).

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.

Tritium concentrations were less than the MDC. These results are all consistent with results obtained in previous years. The results for tritium indicate that, to date, migration into the sampled wells has not taken place and no event-related radioactivity has entered area drinking water supplies.

6.4.2 Project SHOAL

Project SHOAL, a 12-kt test emplaced at 365 m (1,198 ft), was conducted on October 26, 1963, in a sparsely populated area near Frenchman Station, Nevada. The test, 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 created. An effluent was released during drillback but was detected onsite only and consisted of 110 Ci of ^{131}Xe and ^{133}Xe, and less than 1.0 Ci of ^{131}I.

Samples were collected on March 4 and 5, 1996. The sampling locations are shown in Figure 6.5. Only five of the seven routine wells were sampled. No sample was collected from Spring Windmill because the pump was removed. No sample was collected from Well H-2 because the well was locked and no key was available to EPA until after sampling was completed. This well will be sampled in the 1997 annual sampling. The routine sampling locations include one spring, one windmill, and five wells of varying depths. At least one location, Well HS-1, should intercept radioactivity migrating from the test cavity, should it occur (Chapman and Hokett, 1991).

Gamma-ray spectral analysis results indicated that no man-made gamma-emitting radionuclides were present in any samples above the MDC. All tritium results were also below the MDC.

6.4.3 Project RULISON

Co-sponsored by the AEC and Austral Oil Company under the Plowshare Program, Project RULISON was designed to stimulate natural gas recovery in the Mesa Verde formation. The test, conducted near Grand Valley, Colorado, on September 10, 1969, consisted of a 40-kt nuclear explosive emplaced at a depth of 2,568 m (8,425 ft). Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972 and the wells were plugged in 1976. Some surface contamination resulted from decontamination of drilling equipment and fallout from gas flaring. Contaminated soil was removed during the cleanup operations.

Sampling was conducted June 4-7, 1996, with collection of samples from eight out of nine wells in the area of Grand Valley and Rulison, Colorado. The spring 300 yards from SGZ was dry. Routine sampling locations are shown in Figure 6.6, including the Grand Valley municipal drinking water supply springs, water supply wells for five local ranches, and three sites in the vicinity of SGZ, including one test well, a surface-discharge spring which was dry, and a surface sampling location on Battlement Creek. Seven new monitoring wells were completed at the RULISON Site in 1995 as part of the Remedial Investigation and Feasibility Study. These wells will be added to the LTHMP in 1998.

Tritium has never been observed in measurable concentrations in the Grand Valley City Springs. All of the remaining sampling sites show detectable levels of tritium, which have generally exhibited a stable or decreasing trend over the last two decades.

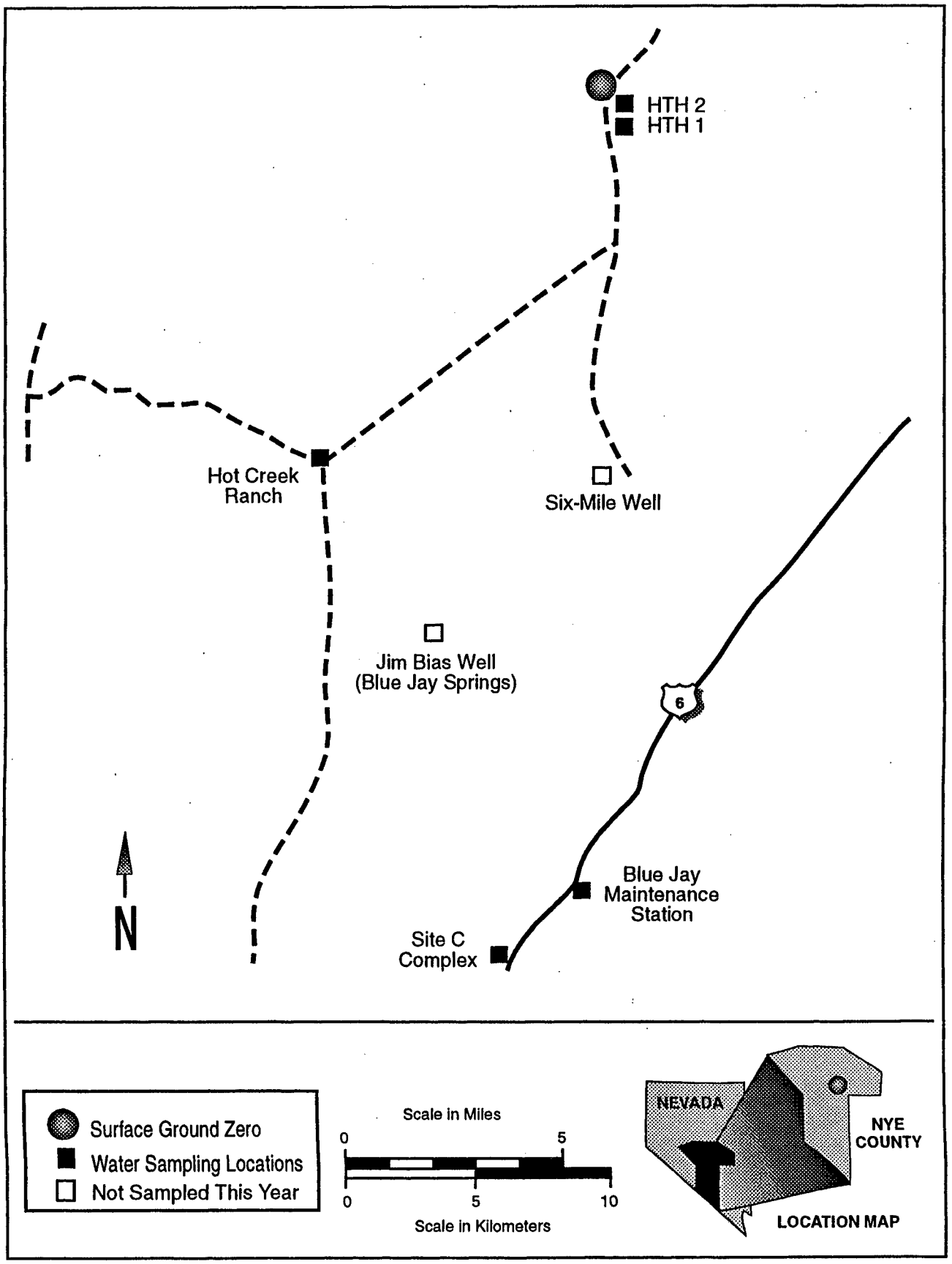

Figure 6.4 LTHMP Sampling Locations for Project FAULTLESS - 1996

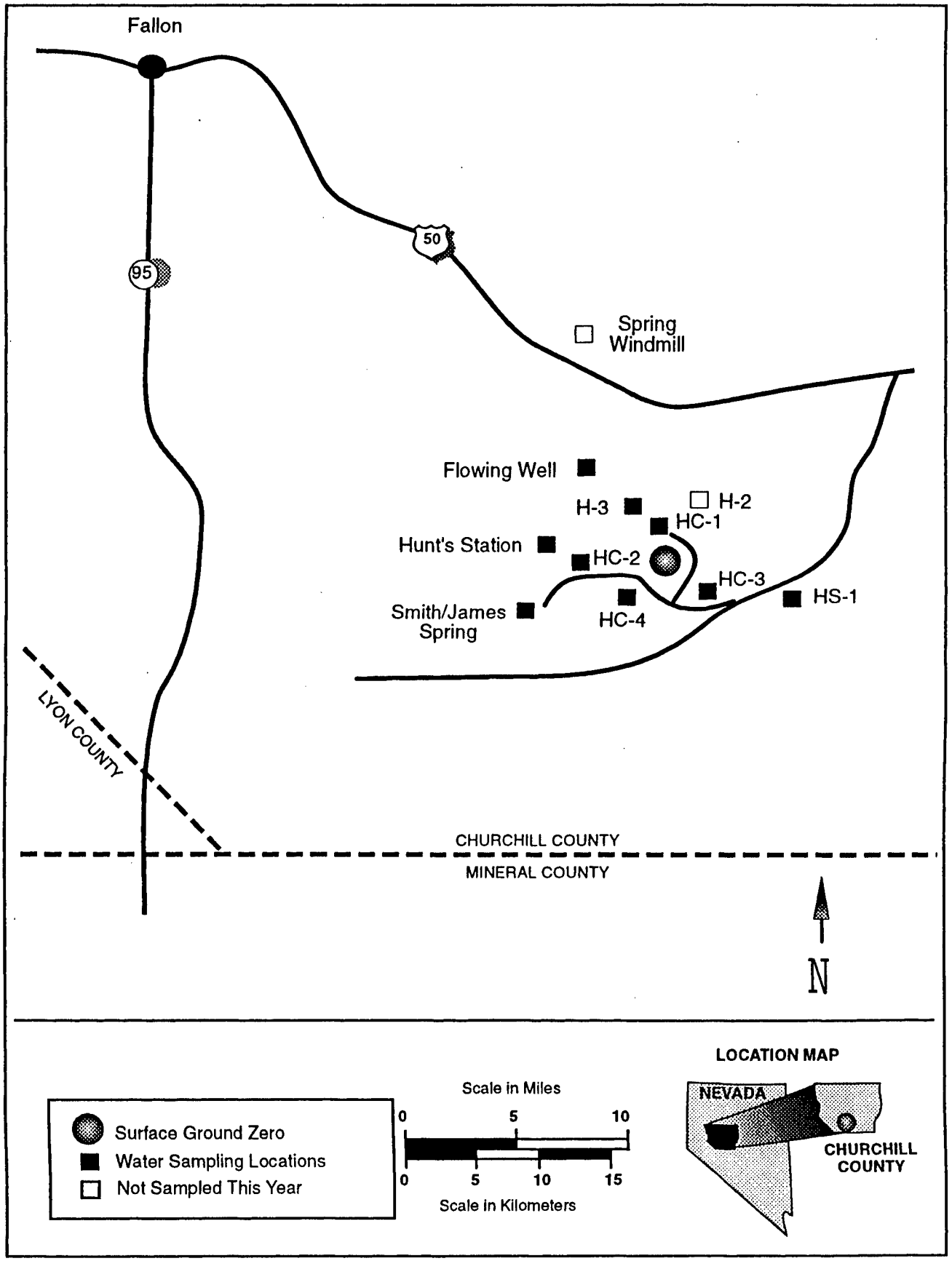

Figure 6.5 LTHMP Sampling Locations for Project SHOAL - 1996

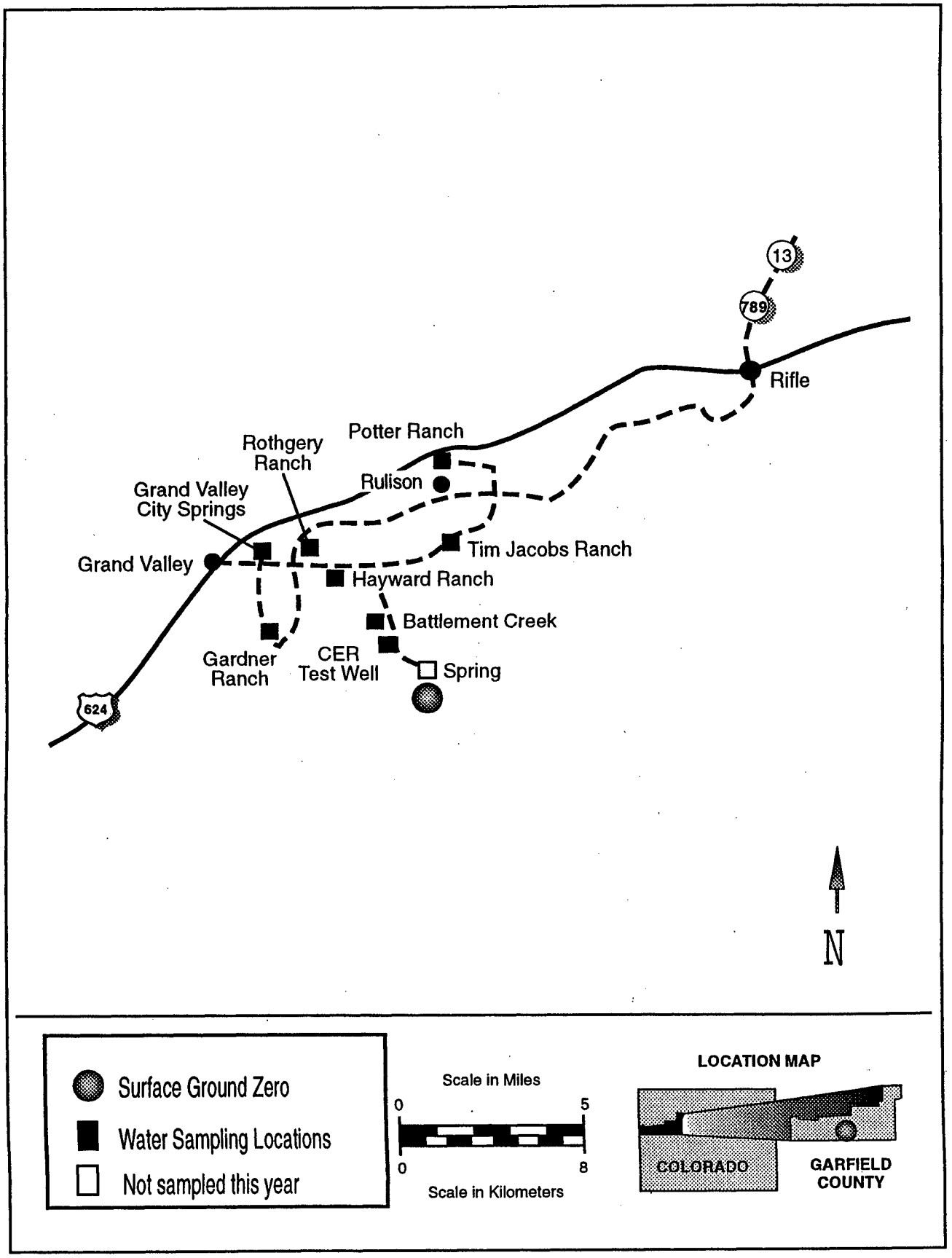

Figure 6.6 LTHMP Sampling Locations for Project RULISON - 1996

The range of tritium activity in 1996 was from 242 ± 140 pCi/L (9 Bq/L) at Battlement Creek, to 112 ± 6.9 pCi/L (4.1 Bq/L) at Lee Hayward Ranch. All values were less than one percent of the DCG. The detectable tritium activities were probably a result of the high natural background in the area. This was supported by the DRI analysis, which indicated that most of the sampling locations were shallow, drawing water from the surficial aquifer which was unlikely to become contaminated by any radionuclides arising from the Project RULISON cavity (Chapman and Hokett, 1991). All samples were analyzed for presence of gamma-ray emitting radionuclides. None were detected above the MDC.

6.4.4 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 when cleanup and restoration activities were completed. Tritiated water produced during testing was injected to 1710 m (5610 ft) in a nearby gas well.

Samples were collected June 6 and 7, 1996, from the sampling sites shown in Figure 6.7. Only 13 of the 14 routine wells were sampled. No sample was collected from Brennan Windmill because the pump was inoperable. The sample taken from CER #1; was lost in transit. The routine sampling locations included three springs and six wells. Three of the wells are located near the cavity and at least two of the wells (Wells RB-D-01 and RB-D-03) were suitable for monitoring possible migration of radioactivity from the cavity.

No radioactive materials attributable to the RIO BLANCO test were detected in samples collected in the offsite areas during June 1996. Three of the eleven samples collected were above the MDC for tritium and the rest were less than the MDC. The tritium concentrations are well below 20,000 pCi/L level defined in the EPA National Primary Drinking Water Regulations (40 C.F.R. 141). All samples were analyzed for presence of gamma-ray emitting radionuclides, and none were detected. The tritium concentrations were consistent with those collected previously at this site.

6.4.5 Project GNOME

Project GNOME, conducted on December 10, 1961, near Carlsbad, New Mexico, was a multipurpose test performed in a salt formation. A slightly more than 3-kt nuclear explosive was emplaced at 371 m (1217 ft) depth in the Salado salt formation. Radioactive gases were unexpectedly vented during the test. The USGS conducted a tracer study in 1963, involving injection of 20 Ci ^{3}H, 10 Ci ^{137}Cs, 10 Ci ^{90}Sr, and 4Ci ^{131}I (740, 370, 370 and 150 GBq, respectively) into Well USGS-8 and pumping water from Well USGS-4. During cleanup activities in 1968-69, contaminated material was placed in the test cavity access well. More material was slurried into the cavity and drifts in 1979.

Sampling at Project GNOME was conducted June 22-25, 1996. The routine sampling sites, depicted in Figure 6.8, include nine monitoring wells in the vicinity of GZ and the municipal supplies at Loving and Carlsbad, New Mexico. Stock tanks at wells PHS 8, PHS 9, and PHS 10, were sampled at the request of DOE. Tritium results from stock tank PHS 8 was greater than the MDC. The remaining two were below the MDC.

Tritium results greater than the MDC were detected in water samples from seven of the nine sampling locations in the immediate vicinity of GZ. Tritium activities in Wells DD-1, LRL-7, USGS-4, and USGS-8 ranged from 5×10^{3} pCi/L (185 Bq/L) in Well LRL-7 to 6.8×10^{7} pCi/L (2.5 MBq/L) in Well DD-1. Well DD-1 collects water from the test cavity; Well LRL-7 collects water from a sidedrift; and Wells USGS-4 and -8 were used in the radionuclide tracer study conducted by the USGS. None of these wells are sources of potable water.

In addition to tritium, ^{137}Cs concentrations were observed in samples from Wells DD-1 ($7.29 \times 10^{5} \pm 3.19 \times 10^{3}$), USGS 8 (6.8 ± 1.2) and LRL-7 (1.03×10^{2} ± 15) while ^{90}Sr activity was detected in Wells DD - 1 ($1.04 \times 10^{4} \pm 1.43 \times 10^{3}$), LRL - 7 (<MDA), USGS - 4 (3.53×10^{3} ± 23) and USGS-8 (3.98×10^{4} ± 23) as in previous years. The remaining two wells with detectable tritium concentrations were PHS-6 and -8, with results less than 0.02 percent of the DCG. No tritium was detected in the remaining sampling locations, including Well USGS-1, which the DRI analysis (Chapman and Hokett, 1991) indicated is positioned to detect any migration of radioactivity from the cavity.

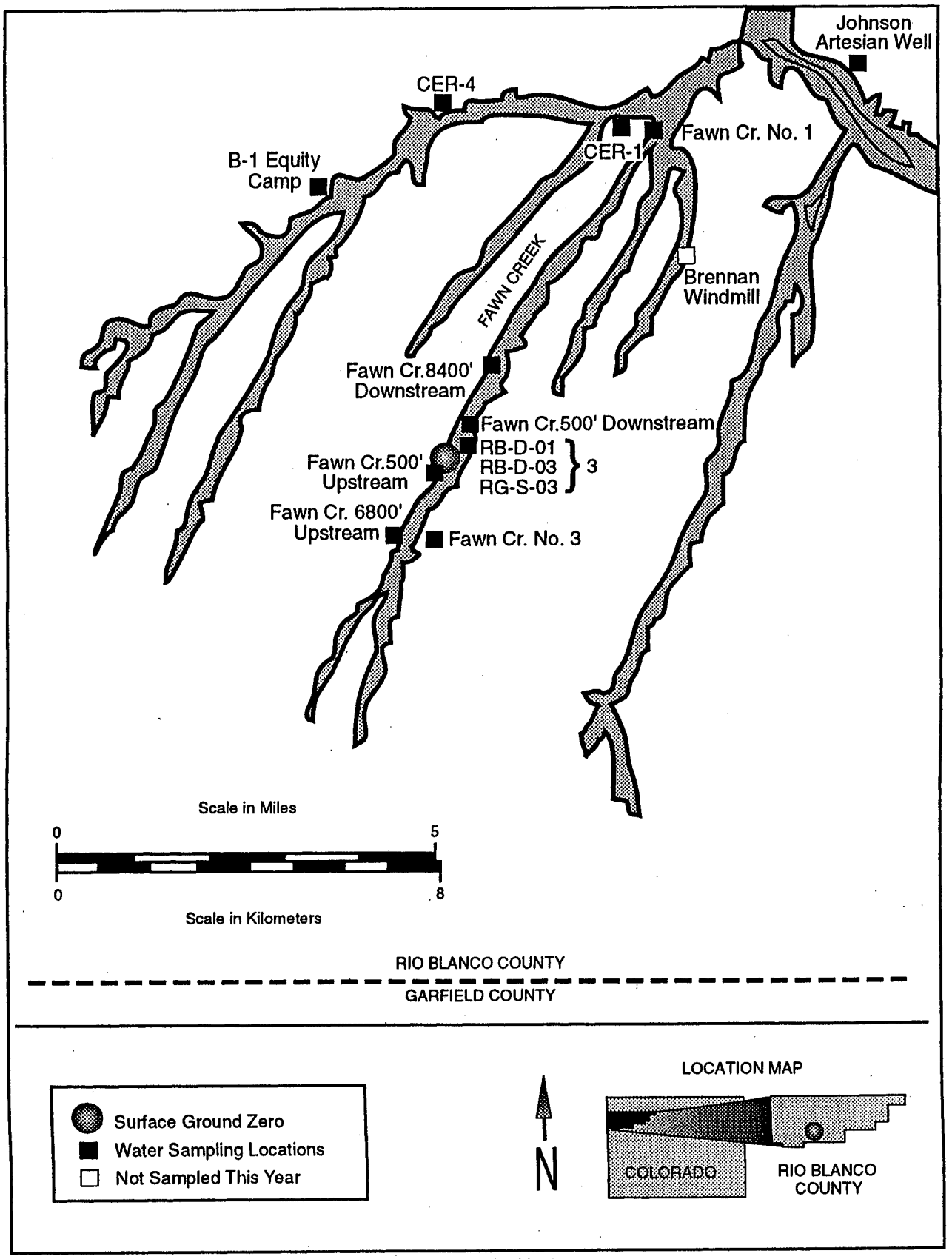

Figure 6.7 LTHMP Sampling Locations for Project RIO BLANCO - 1996

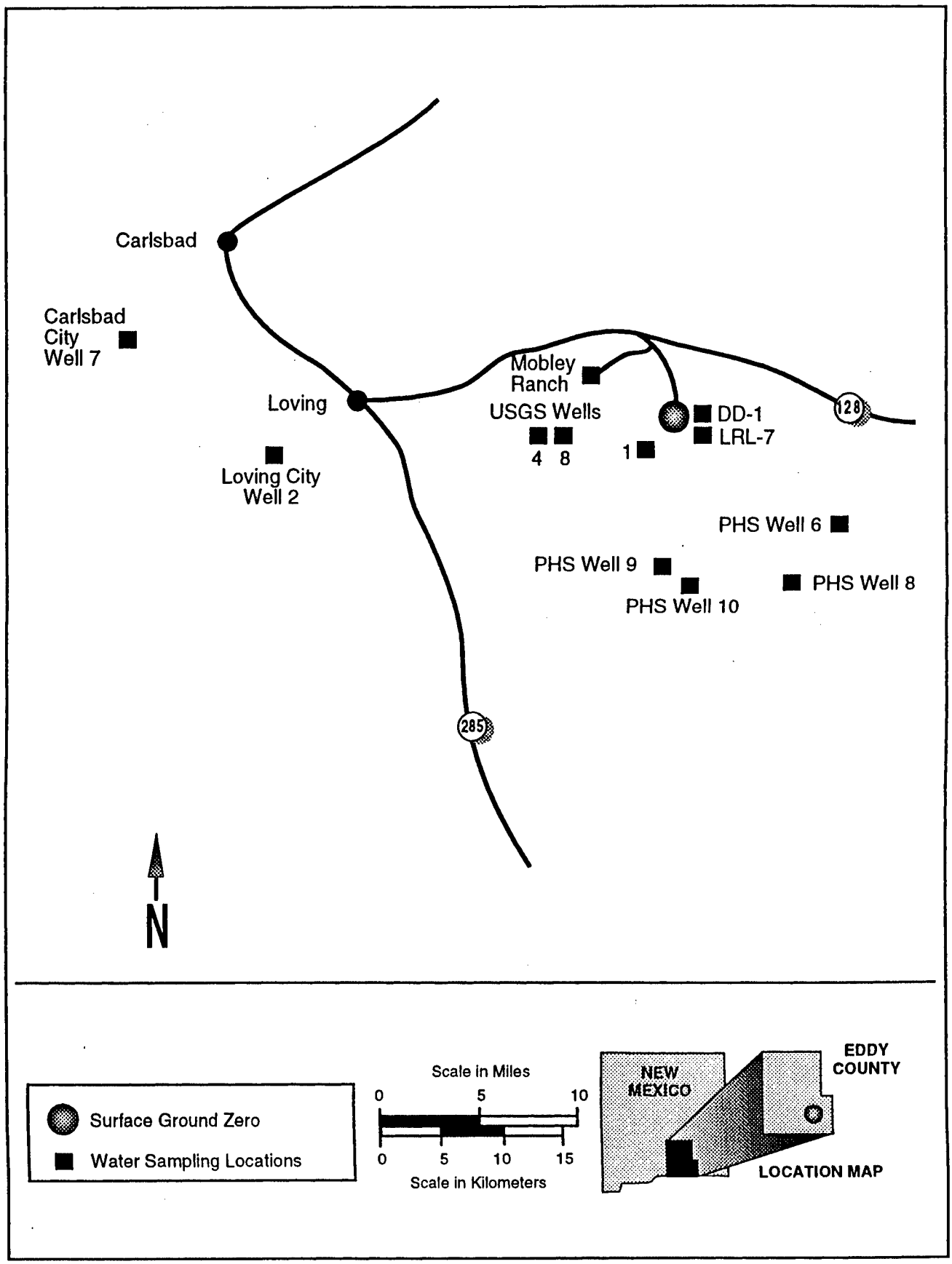

Figure 6.8 LTHMP Sampling Locations for Project GNOME - 1996

6.4.6 Project GASBUGGY

Project GASBUGGY was a Plowshare Program test co-sponsored by the U.S. Government and El Paso Natural Gas. Conducted near Farmington, 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 1,290 m (4,240 ft). Production testing was completed in 1976 and restoration activities were completed in July 1978.

The principal aquifers near the test site are the Ojo Alamo sandstone, an aquifer containing nonpotable water located above the test cavity and 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 mi northwest of the GASBUGGY site. Hydrologic gradients in the vicinity are downward, but upward gas migration is possible (Chapman and Hokett, 1991).

Sampling at GASBUGGY was conducted during June 1996. Only ten samples were collected at the designated sampling locations shown in Figure 6.9. The Bixler Ranch has been sealed up and the pond north of Well 30.3.32.343N was dry.

The three springs sampling sites yielded tritium activities of 26 ± 4.3 pCi/L for Bubbling Springs, 43 ± 4.0 pCi/L for Cedar Springs, and 54 ± 6.2 pCi/L for Cave Springs (0.96, 1.6, and 2.0 Bq/L, respectively), which were less than 0.2 percent of the DCG and similar to the range seen in previous years. Tritium samples from the three shallow wells were all below the average MDC.

Well EPNG 10-36, a gas well located 132 m (435 ft) northwest of the test cavity, with a sampling depth of approximately 1,100 m (3,600 ft), has yielded detectable tritium activities since 1984. The sample collected in June 1996 contained tritium at a concentration of 130 ± 5.2 pCi/L (4.8 Bq/L). The migration mechanism and route is not currently known, although an analysis by DRI indicated two feasible routes, one through the Printed Cliffs sandstones and the other one through the Ojo Alamo sandstone, one of the principal aquifers in the region. In either case, fractures extending from the cavity may be the primary or a contributing mechanism.

All gamma-ray spectral analysis results indicated that no man-made gamma-emitting radionuclides were present in any offsite samples. Tritium concentrations of water samples collected onsite and offsite are consistent with those of past studies at the GASBUGGY site.

6.4.7 Project DRIBBLE

Project DRIBBLE was comprised of two nuclear and two gas explosive tests, conducted in the SALMON test site 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 nuclear 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 (2,710 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 380 tons, and the two gas explosions, DIODE TUBE (on February 2, 1969) and HUMID WATER (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, nonpotable aquifers. Shallow wells, labeled HMH wells on Figure 6.10, have been added to the area near surface GZ to monitor this contamination. In addition to the monitoring wells near GZ, extensive sampling of water wells is conducted in the nearby offsite area as shown in Figure 6.11.

Of the twenty-eight wells that are sampled on the SALMON test site, five regularly have tritium values above those expected in surface water samples. In the 52 samples collected from offsite sampling locations, tritium activities ranged from less than the MDC to 28 pCi/L (1.0 Bq/L), 0.02 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 those locations that had detectable tritium activity at the beginning of the LTHMP, such as in the samples from the Baxterville City Well depicted in Figure 6.12 and Well HM-S shown in Figure 6.13.

Due to the high rainfall in the area, the normal sampling procedure is modified for the shallow onsite wells as described in Section 6.4. Of the 32 locations sampled onsite (20 sites sampled twice), 14 yielded tritium activities greater than the MDC in either the first or second sample. Of these, eight yielded results higher than normal background (approximately 60 pCi/L [2.2 Bq/L]) as shown in Table 6.1. The locations where the highest tritium

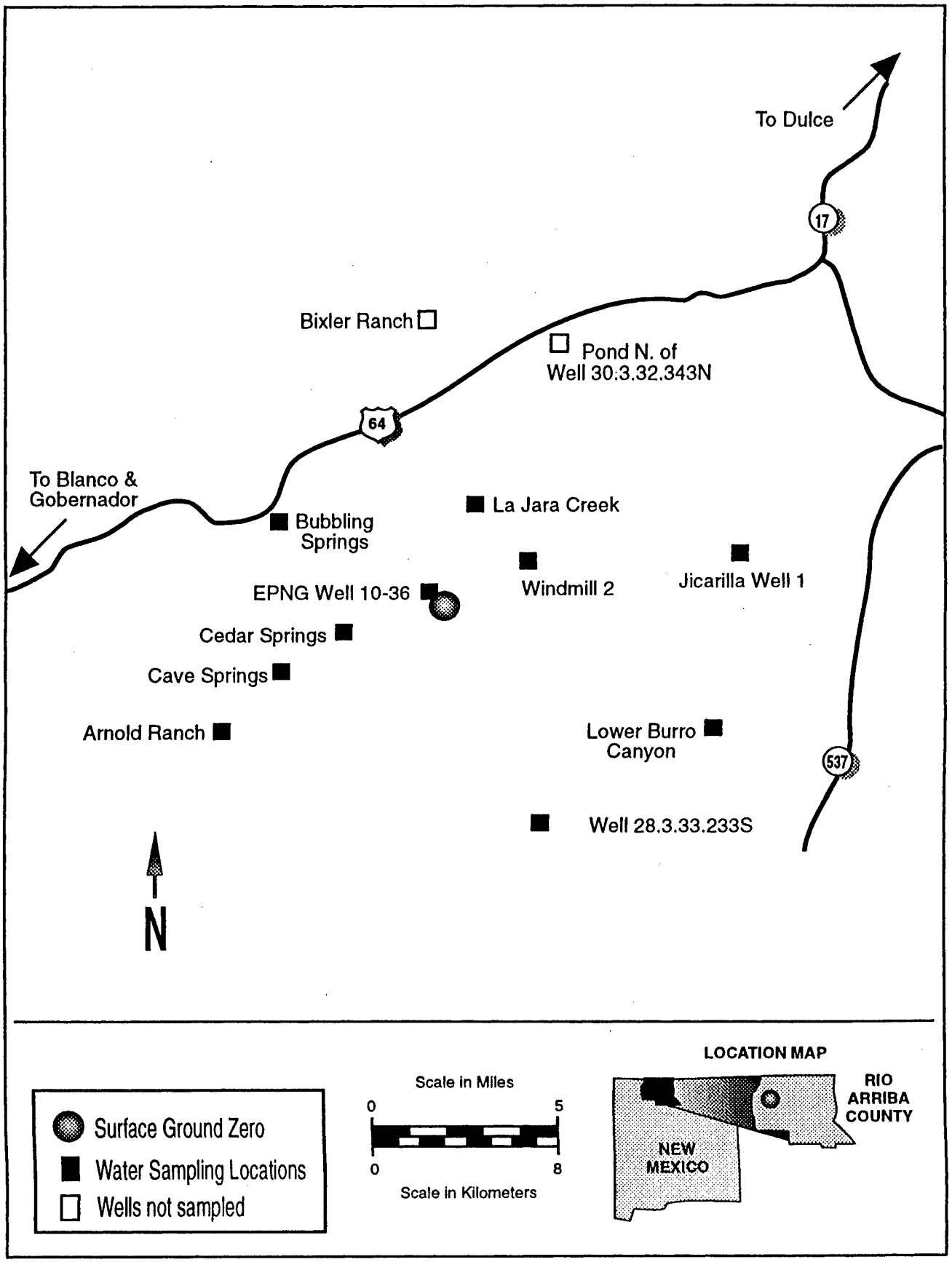

Figure 6.9 LTHMP Sampling Locations for Project GASBUGGY - 1996

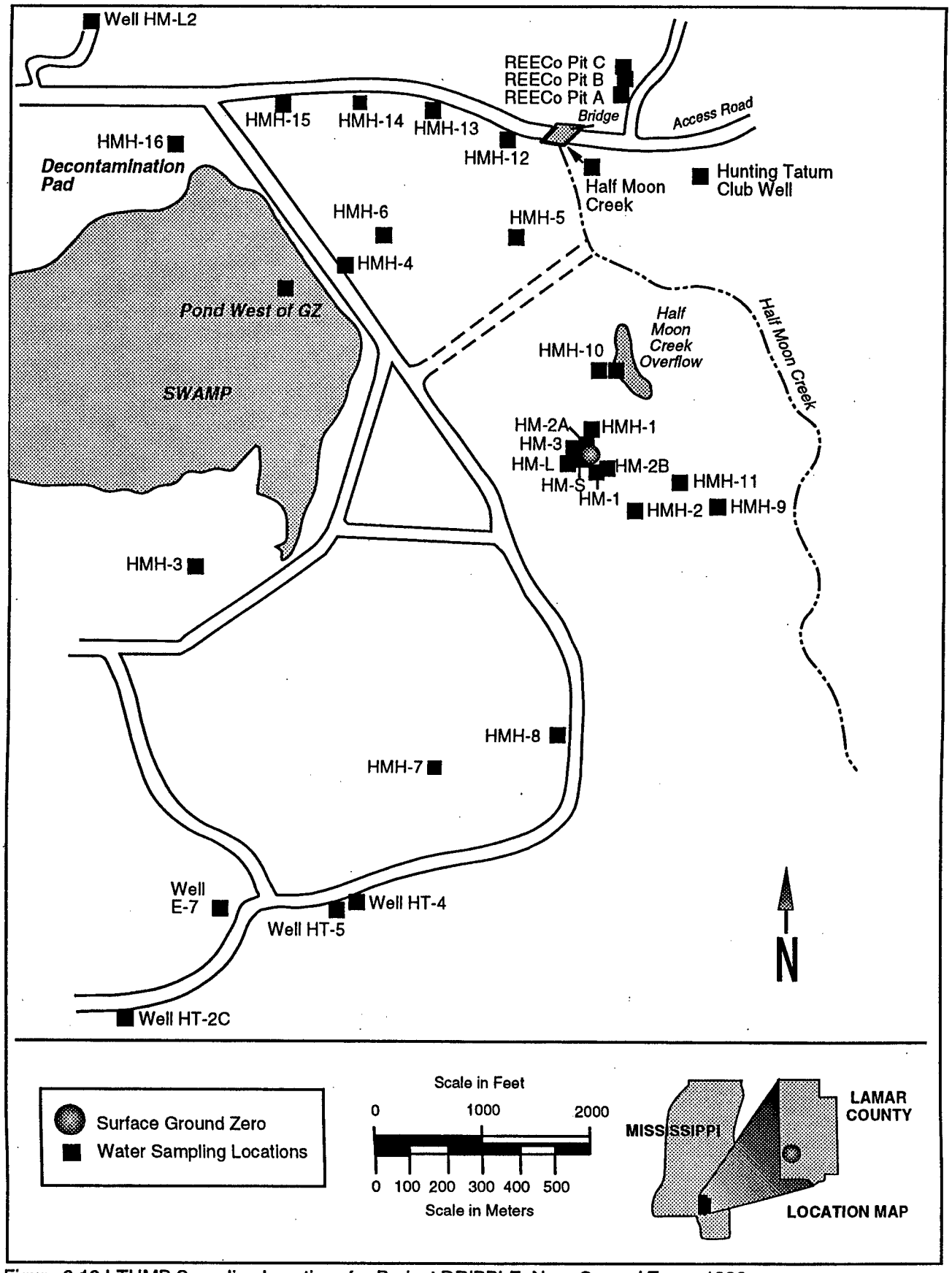

Figure 6.10 LTHMP Sampling Locations for Project DRIBBLE, Near Ground Zero - 1996

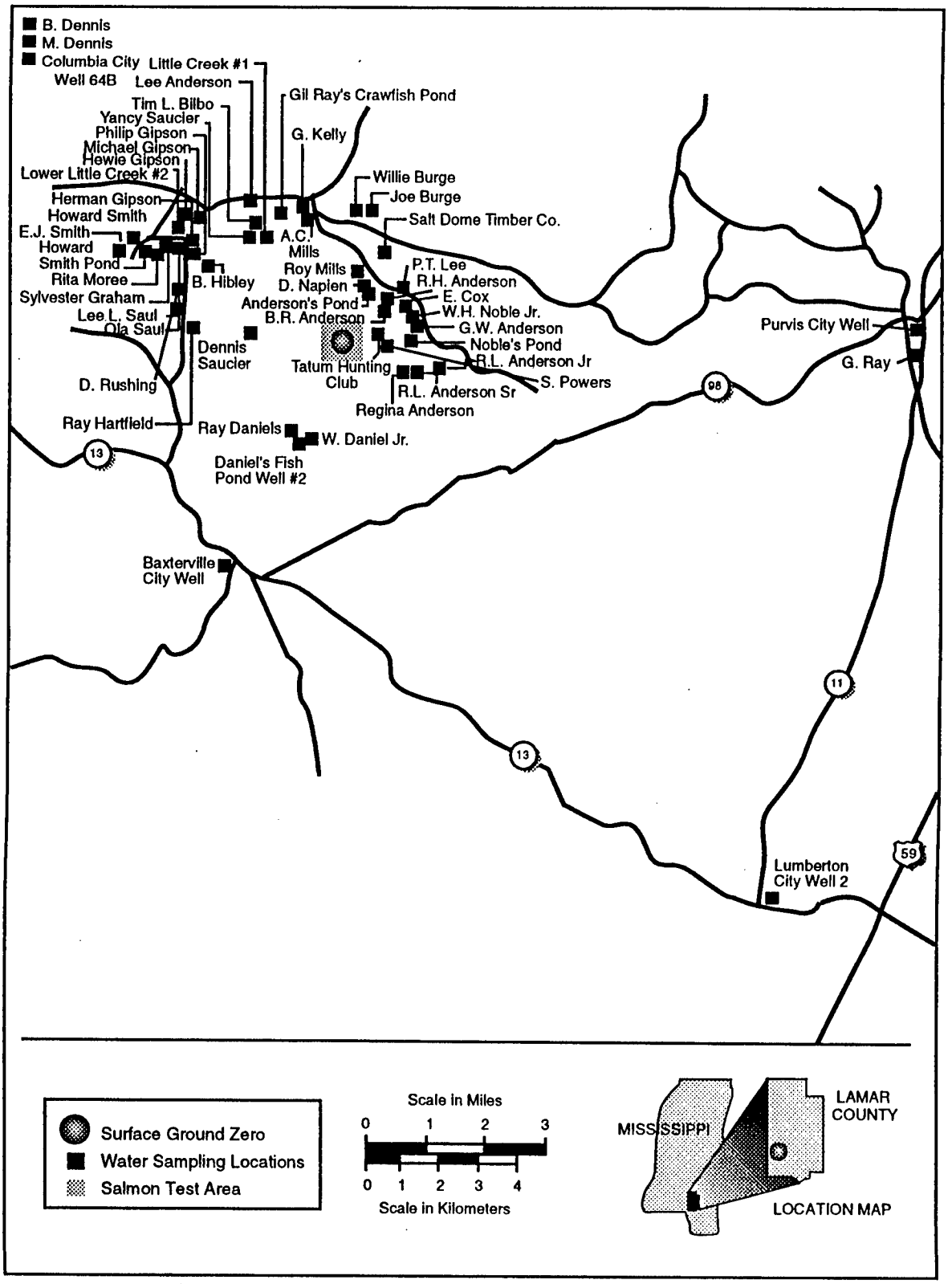

Figure 6.11 LTHMP sampling Locations for Project DRIBBLE, towns and residences - 1996

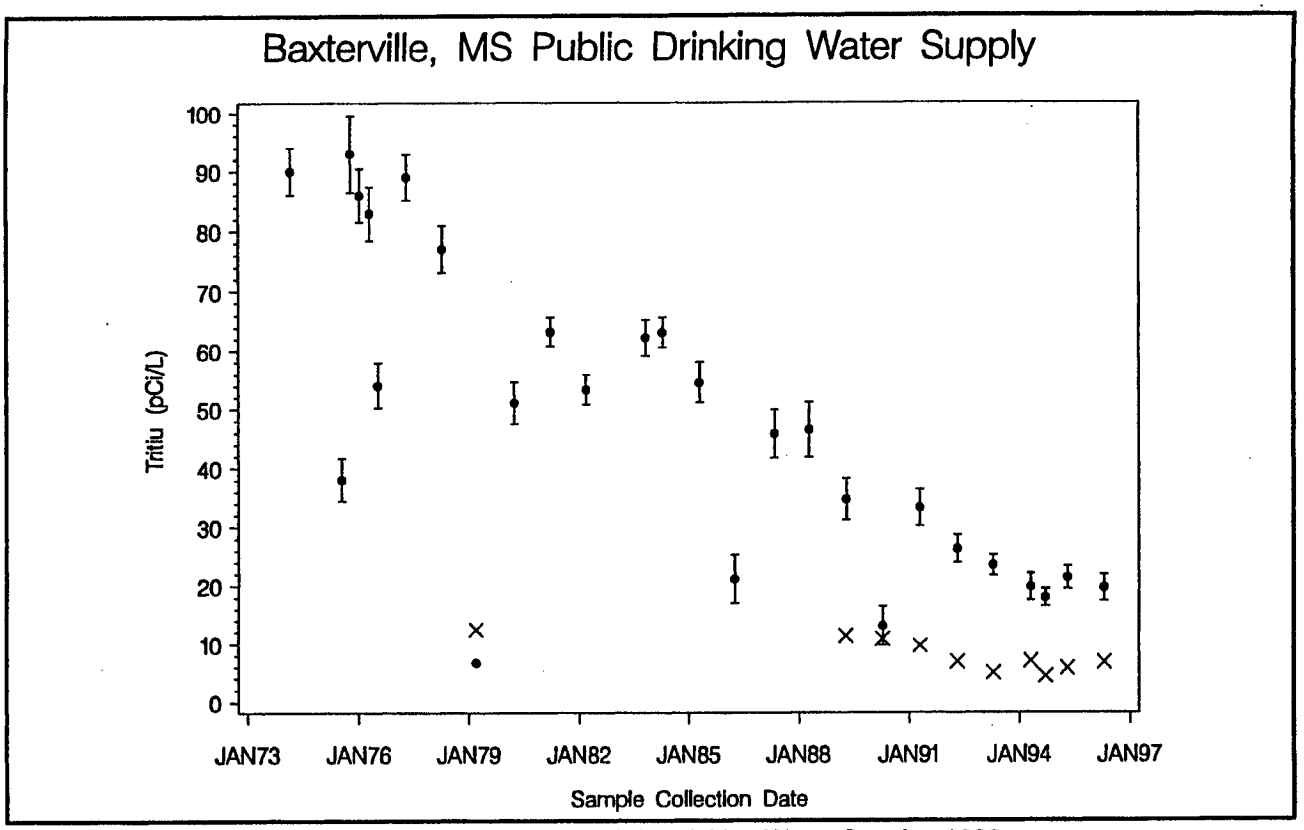

Figure 6.12 Tritium Results Trends in Baxterville, Public Drinking Water Supply - 1996

Xs = MDC values for both figures.

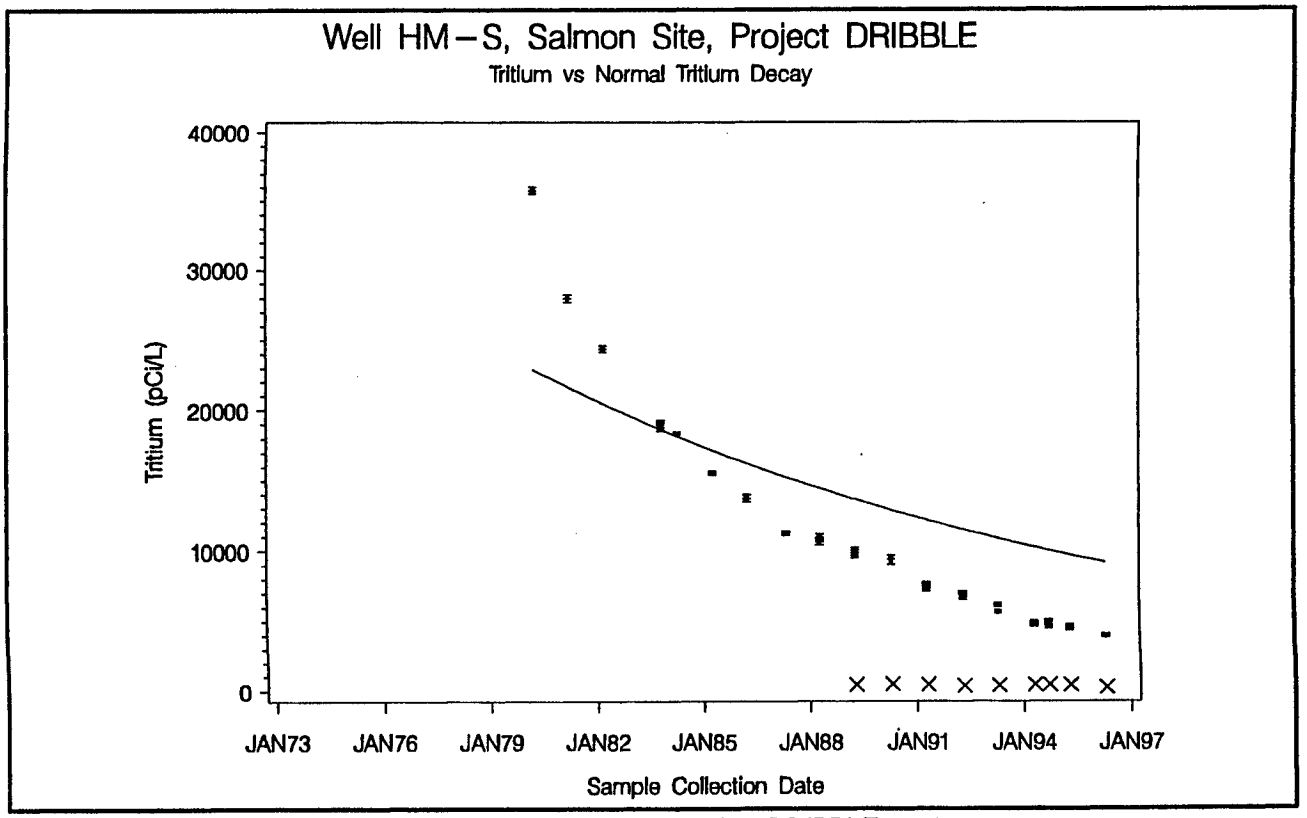

Figure 6.13 Tritium Results in Well HM-S, SALMON Site, Project DRIBBLE - 1996

activities were measured generally correspond to areas of known contamination. Decreasing trends are evident for the wells where high tritium activities have been found, such as Well HM-S depicted in Figure 6.13. No tritium concentrations above normal background values were detected in any offsite samples. Man-made gamma-ray emitting radionuclides were not detected in any sample collected in this study.

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 1996 (Davis 1996, available from R&IE-LV).

6.4.8 AMCHITKA ISLAND, ALASKA

Sampling is normally conducted biannually on odd years. The next sampling is scheduled for 1997.

6.5 Summary

None of the domestic water supplies monitored in the LTHMP in 1996 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 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 1996 results for these monitoring wells are consistent with decreasing trends observed over time.

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.

Table 6.1 Locations with Detectable Tritium and Man-Made Radioactivity in 1996 [(a)]

Sampling Location	Radionuclide	Concentration x 10^{-9} µCi/mL
NTS Onsite Network		
Well PM-1	^{3}H	200
Well UE-5n	^{3}H	52,000*
Well UE-6d	^{3}H	700
Well UE-7ns	^{3}H	500
Well UE-18t	^{3}H	200
Test Well B	^{3}H	230
Project DRIBBLE, Mississippi (B)		
Well HMH-1	^{3}H	2,100
Well HMH-2	^{3}H	230
Well HMH-5	^{3}H	1,200
Well HM-L	^{3}H	1,200
Well HM-S	^{3}H	4,400
Half Moon Creek Overflow	^{3}H	210
REECo Pit B	^{3}H	240
REECo Pit C	^{3}H	260
Project GNOME, New Mexico		
Well DD-1	^{3}H	6.8×10^{7}
	^{90}Sr	10,000
	^{137}Cs	7.3×10^{5}
Well LRL-7	^{3}H	5,300
	^{90}Sr	2.1
	^{137}Cs	100
Well USGS-4	^{3}H	90,000
	^{90}Sr	3,500
	^{137}Cs	<5.6
Well USGS-8	^{3}H	77,000
	^{90}Sr	4,000
	^{137}Cs	<6.8

(a) Only ^{3}H concentrations greater than 0.2 percent of the 4 mrem DCG are shown {i.e., greater than 1.6×10^{-7} µCi/mL [160 pCi/L (6 Bq/L)]}. Detectable levels of other radioisotopes are also shown.

* Highest analytical result for Well UE-5n in 1996.

Table 6.2 Summary of EPA Analytical Procedures - 1996

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 percent.	100	Radionuclide concentration quantified from gamma spectral data by online computer program.	3.5L	Varies with radionuclides and detector used, see Table 6.3 below.
^{3}H	Automatic liquid scintillation counter.	300	Sample prepared by distillation.	5-10 mL	300 to 700 pCi/L
^{3}H+ Enrichment	Automatic liquid scintillation counter.	300	Sample concentrated by electrolysis followed by distillation.	250 mL	5 pCi/L

(a) The detection limit is defined as the smallest amount of radioactivity that can be reliably detected, i.e., probability of Type I and Type II error at 5 percent each (DOE 1981).

(b) Gamma spectrometry using a high purity intrinsic germanium (HpGe) detector.

Table 6.3 Typical MDA Values for Gamma Spectroscopy

All MDA values are computed for a water matrix sample (1.0 g/ml density) in a 3.5 Marinelli beaker geometry, counted for 100 minutes on a Canbarra model 430G HpGe detector.

Isotope	MDA (pCi/L)	Isotope	MDA (pCi/L
		Ru-106	47.6
Be-7	45.6	Sn-113	8.32
K-40	49.2	Sb-125	16.5
Cr-51	58.8	I-131	8.28
Mn-54	45.5	Ba-133	9.16
Co-57	9.65	Cs-134	6.12
Co-58	4.71	Cs-137	6.43
Fe-59	10.7	Ce-144	75.9
Co-60	5.38	Eu-152	28.6
Zn-65	12.4	Ra-226	15.8
Nb-95	5.64	U-235	101
Zr-95	9.06	Am-241	66.0

Disclaimer

The MDAs provided are for background matrix samples presumed to contain no known analytes and no decay time. All MDAs provided here are for one specific high purity Germanium detector and the geometry of interest. The MDAs in no way should be used as a source of reference for determining MDAs for any other type of detector. All gamma spectroscopy MDAs will vary with different types of shielding, geometries, counting times, and decay time of sample.

Table 6.4 Long-Term Hydrological Monitoring Program Summary of Tritium Results for Nevada Test Site Network, 1996

		Tritium Concentration (pCi/L)					
Location	Number	Maximum	Minimum	Arithmetic Mean	1 Sigma	Mean as %DCG	Mean MDC
Test Well B	1	230	230	230	70	0.26	220
Test Well D	1	38	38	38	70	<MDC	220
Well UE-6d	2	724	633	680	180	0.75	110
Well UE-6e	2	190	170	180	67	<MDC	210
Well UE-7ns	2	496	466	480	160	0.53	210
Well UE-16f	1	8.1	8.1	8.1	1.7	0.01	5.5*
Well UE-18r	2	230	28	130	67	<MDC	210
Well UE-18t	1	220	220	220	3.5	0.24	7.0*
Well 6A Army	2	3.3	-1.3	1.0	0.35	<MDC	4.2*
Well HTH-1	1	-77	-77	-77	70	<MDC	230
Well PM-1	1	210	210	210	3.1	0.23	6.0*
Well U3CN-5		Packer In Hole					
Well UE-1c	2	114	93	100	62	<MDC	210
Well UE-15d		Pump Inoperative					
Well HTH "F"	1	93	93	93	65	<MDC	240
Well C-1	1	270	270	270	68	0.30	220
Well 1 Army	1	-77	-77	-77	68	<MDC	230
Well 5B	2	1.8	77	39	20	<MDC	110
Well 5C	2	38	0.18	19	10	<MDC	110
Well UE-5n	2	52500	38100	45000	13000	50	210
Well J-13	1	77	77	77	70	<MDC	230

Conventional and/or enrichment *tritium analysis techniques were used for the samples summarized in this table.

DCG Derived Concentration Guide; established by DOE Order as 90,000 pCi/L for water.

NA Not applicable; percent of concentration guide is not applicable as the tritium result is less than the MDC or the water is known to be nonpotable.

Table 6.5 Long-Term Hydrological Monitoring Program Summary of Tritium Results for Wells near the NTS - 1996

Location	Number of Samples[a]	Tritium Concentration (pCi/L) Max.	Min.	Mean	1 s.d.	% of DCG	Mean MDC
Adaven							
Adaven Spring	2	28	19	22	1.7	0.02	5.1
	2	110	0	55	67	NA	220
Alamo							
Well 4 City	1	--	--	-2.3	3.0	NA	10
	1	--	--	39	68	NA	220
Ash Meadows							
Crystal Pool	3	2.9	2.9	-0.3	1.9	NA	6.3
	1	--	--	150	67	NA	210
Fairbanks Spring	2	0.33	-1.1	-0.8	1.7	NA	5.8
	0						
17S-50E-14cac	1	--	--	0.8	1.8	NA	5.8
	1	--	--	0	68	NA	220
Well 18S-51E-7db	1	--	--	1.0	1.4	NA	4.3
	1	--	--	39	68	NA	220
Beatty							
Low Level Waste Site	1	--	--	6.2	1.8	<0.01	5.9
	3	190	0	94	65	NA	220
Tolicha Peak	1	--	--	-2.8	1.6	NA	5.4
	3	110	0	57	66	NA	220
11S-48E-1dd Coffer's	1	--	--	-0.6	1.6	NA	5.4
	3	150	38	110	67	NA	220
12S-47E-7dbd City	1	--	--	-1.0	2.2	NA	7.5
	1	--	--	0	68	NA	220
Younghans Ranch House Well	0						
	3	190	-77	59	67	NA	220
Boulder City							
Lake Mead Intake	1	--	--	40	1.8	0.04	4.9
	0						
Clark Station							
TTR Well 6	0						
	2	56	39	48	67	NA	220
Goldfield							
Klondike #2 Well	0						
	2	39	-38	0.5	140		220

(a) For each sample: 1st row is from enrichment analysis, 2nd row from conventional analysis. Derived Concentration Guide (DCG) established by DOE Order as 90,000 pCi/L.

N/A Not applicable. Percent of concentration guide is not applicable because the result is less than the MDC or the water is known to be nonpotable.

Table 6.5 (Long-Term Hydrological Monitoring Program Summary of Tritium Results for Wells near the NTS - 1996, con't.)

Location	Number of Samples[a]	Tritium Concentration (pCi/L) Max.	Min.	Mean	1 s.d.	% of DCG	Mean MDC
Hiko							
Crystal Springs	1	--	--	-1.7	3.1	NA	10
	1	--	--	0	68	NA	220
Indian Springs							
Sewer Co. Well 1	0						
	1	--	--	0	68	NA	220
Air Force Well 2	1	--	--	2.6	1.3	NA	4.3
	1	--	--	0	68	NA	220
Lathrop Wells							
15S-50E-18cdc City	1	--	--	-0.08	1.2	NA	4.0
	1	--	--	0	68	NA	220
Nyala							
Sharp's Ranch	1	--	--	2.0	3.2	NA	10
	1	--	--	0	68	NA	220
Oasis Valley							
Goss Springs	DRY						
Rachel							
Penoyer Culinary	1	--	--	1.2	1.4	NA	4.8
	3	150	56	95	67	NA	210
Tonopah							
City Well	0						
	2	39	-19	10	66	NA	220
Warm Springs							
Twin Springs Ranch	1	--	--	0.6	1.3	NA	4.3
	3	470	56	320	67	NA	220

(a) For each sample: 1st row is from enrichment analysis, 2nd row from conventional analysis. Derived Concentration Guide (DCG) established by DOE Order as 90,000 pCi/L.

N/A Not applicable. Percent of concentration guide is not applicable because the result is less than the MDC or the water is known to be nonpotable.

Table 6.6 Analysis Results for Water Samples Collected in June 1996.

RULISON Site							
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium pCi/L ± 2 SD	(MDC)	Gamma Spectrometry pCi/L	(MDC)
Battlement Creek	6/04/96			242 ± 140	(224)	ND	(5.7)
City Springs	6/05/96			<MDC	(244)	ND	(5.9)
Albert Gardner	6/04/96			242 ± 140	(224)	ND	(4.3)
CER Test Well	6/04/96	75 ± 4.7	(5.9)			ND	(5.4)
Lee Hayward Rn.	6/04/96	112 ± 6.9	(8.6)			ND	(6.1)
Potter Ranch	6/04/96			<MDC	(244)	ND	(5.9)
Wayne & Debra Rothgery	6/04/96			<MDC	(244)	ND	(5.6)
Tim Jacobs	6/04/96			242 ± 140	(224)	ND	(5.5)
Spring 300 yds N. of GZ	6/07/96			No Sample Spring Dry			

(<MDC) Indicate samples are below the MDC.
ND Non-detected, no gamma radionuclides detected above MDC.

Table 6.7 Analysis Results for Water Samples Collected in June 1996.

RIO BLANCO Site							
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium pCi/L ± 2 SD	(MDC)	Gamma Spectrometry pCi/L	(MDC)
B-1 Equity Camp	6/06/96	47 ± 5.2	(7.2)			ND	(5.5)
Brennan Windmill	6/06/96					No Sample inoperable	
CER #1 Black Sulpher	6/06/96					Sample lost in transit	
CER #4 Black Sulpher	6/06/96	46 ± 4.7	(6.4)			ND	(5.2)
Fawn Creek #1	6/06/96			<MDC	(224)	ND	(5.2)
Fawn Creek #3	6/06/96			<MDC	(224)	ND	(5.6)
Fawn Creek 500' Upstream	6/06/96			<MDC	(224)	ND	(7.9)
Fawn Creek 6800' Upstream	6/06/96			<MDC	(224)	ND	(7.0)
Fawn Creek 500' Downstream	6/06/96			<MDC	(224)	ND	(7.0)
Fawn Creek 8400' Downstream	6/06/96	32 ± 4.9	(7.0)			ND	(6.3)
Johnson Artesian Well	6/06/96			<MDC	(224)	ND	(5.5)
Well RB-D-01	6/07/96	<MDC	(6.5)			ND	(5.2)
Well RB-D-03	6/06/96			<MDC	(224)	ND	(6.2)
Well RB-S-03	6/07/96			<MDC	(224)	ND	(6.8)

(<MDC) Indicates sample are below the MDC.
ND Non-detected, no gamma radionuclides detected above MDC.

Table 6.8 Analysis Results for Water Samples Collected in March 1996.

FAULTLESS Site							
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium pCi/L ± 2 SD	(MDC)	Gamma Spectrometry pCi/L	(MDC)
Hot Creek Ranch Spring	3/06/96			<MDC	(216)	ND	(5.6)
Blue Jay Maint Station	3/06/96			<MDC	(216)	ND	(6.9)
Well HTH-1	3/03-07/96	<MDC	(216)			ND	(7.5)
Well HTH-2	3/03-07/96	<MDC	(216)			ND	(6.3)
Site C Base Camp	3/03-07/96			<MDC	(216)	ND	(6.0)

(<MDC) Indicates results are less than MDC.
ND Non-detected, no gamma radionuclides detected above MDC.

Table 6.9 Analysis Results for Water Samples Collected in March 1996.

SHOAL Site							
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium pCi/L ± 2 SD	(MDC)	Gamma Spectrometry pCi/L	(MDC)
Hunts Station	3/04/96			<MDC	(216)	ND	(6.4)
Smith James Sps.	3/04/96			<MDC	(216)	ND	(5.4)
Spring Windmill	3/04/96					No Pump	
Flowing Well	3/04/96			<MDC	(216)	ND	(5.6)
Well 2	3/04/96					Well locked	
Well H-3	3/04/96	<MDC	(5.1)			ND	(6.3)
Well HS-1	3/05/96	<MDC	(6.0)			ND	(6.6)

(<MDC) Indicates results are less than MDC.
ND Non-detected, no gamma radionuclides detected above MDC.

Table 6.10 Analysis Results for Water Samples Collected in June 1996.

GASBUGGY Site							
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD	(MDC)	Tritium pCi/L ± 2 SD	(MDC)	Gamma Spectrometry pCi/L	(MDC)
Arnold Ranch	6/10/96			<MDC	(224)	ND	(6.1)
Bixler Ranch	6/09/96					No Sample Ranch Closed	
Bubbling Springs	6/09/96	26 ± 4.3	(6.2)			ND	(6.4)
Cave Springs	6/09/96	54 ± 6.2	(8.5)			ND	(7.6)
Cedar Springs	6/09/96	43 ± 4.0	(5.6)			ND	(5.3)
La Jara Creek	6/10/96			<MDC	(224)	ND	(5.8)
Lower Burro Canyon	6/10/96			<MDC	(224)	ND	(5.8)
Pond N. of Well 30.3.32.343	6/10/96					No Sample Pond Dry	
Well EPNG-10-36	6/09/96	133 ± 5.2	(5.2)			ND	(5.1)
Jicarilla Well 1	6/09/96			<MDC	(224)	ND	(5.6)
Well 28.3.33.233 (South)	6/09/96			<MDC	(224)	ND	(6.0)
Well 30.3.32.343 (North)	6/10/96					No Sample Windmill Inoperable	
Windmill #2	6/10/96			<MDC	(224)	ND	(6.0)

(<MDC) Indicates results are less than MDC.
ND Non-detected, no gamma radionuclides detected above MDC.

Table 6.11 Tritium Results for Water Samples Collected in June 1996.

GNOME Site				
Sample Location	Collection Date 1996	Enriched Tritium pCi/L ± 2 SD (MDC)	Tritium pCi/L ± 2 SD (MDC)	Gamma Spectrometry pCi/L (MDC)
Well 7 City	6/13/96		<MDC (224)	ND
Well 2 City	6/13/96		<MDC (224)	ND
PHS 6	6/14/96	33 ± 4.7 (6.9)		ND
PHS 8	6/14/96	7.8 ± 2.9 (4.5)		ND
PHS 9	6/14/96		<MDC (224)	ND
PHS 10	6/14/96		<MDC (244)	ND
USGS Well 1	6/13/96	<MDC (5.9)		ND
USGS Well 4	6/15/96		$9.04E^{+04} \pm 6.4\ E^{+02}$ (224)	ND
Well USGS 8	6/15/96		$7.65E^{+04} \pm 6.4E^{+02}$ (224)	Cs-137 6.8 ± 1.2 (2.5)
J. Mobley Ranch	6/14/96	<MDC (4.8)		ND
Well DD-1	6/15/96		$6.79E^{+07} \pm 6.06E^{+05}$ (223)	Cs-137 $7.29E^{+05} \pm 7.07E^{+04}$ ($3.19E^{+03}$)
LRL-7	6/15/96		$5.32E^{+03} \pm 214$ (224)	Cs-137 $1.03E^{+02} \pm 15$ (2.5)

(<MDC) Indicates results are less than MDC (enriched and conventional method).
ND Non-detected, no gamma radionuclides detected above MDC.

7.0 Dose Assessment

There are several sources of possible radiation exposure to the population of Nevada which were monitored by EPA's offsite monitoring networks during 1996. The pathways are:

- Background radiation due to natural sources such as cosmic radiation, natural radioactivity in soil, and ^{7}Be in air, and H in water.
- Worldwide distributions of radioactivity, such as ^{90}Sr in milk, ^{85}Kr in air, and plutonium in soil.
- Airborne emissions and radioactive liquid discharges to onsite containment ponds.

7.1 Estimated Dose From Nevada Test Site Activity Data

The potential EDE to the offsite population due to NTS activities is estimated annually. Two methods are used to estimate the EDE to residents in the offsite area in order to determine the community potentially most impacted by airborne releases of radioactivity from the NTS. In the first method, effluent release estimates, based on monitoring data or calculated resuspension of deposited radioactivity, and meteorological data are used as inputs to EPA's CAP88-PC model which then produces estimated EDEs. The second method entails using data from the Offsite Radiological Safety Program (ORSP) with documented assumptions and conversion factors to calculate the committed effective dose equivalent (CEDE). The latter method provides an estimate of the EDE to a hypothetical individual continuously present outdoors at the location of interest that includes both NTS emissions and worldwide fallout. In addition, a collective EDE is calculated by the first method for the total offsite population residing within 80 km (50 mi) of each of the NTS emission sources. Background radiation measurements are used to provide a comparison with the calculated EDEs. In the absence of detectable releases of radiation from the NTS, the Pressurized Ion Chamber (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 R&IE-LV measured no radiation exposures attributed to recent NTS operations. However, using onsite emission measurements, estimates provided by U.S. Department of Energy (DOE) and calculated resuspension data as input to the EPA's CAP88-PC model, a potential effective dose equivalent (EDE) to the maximally exposed individual (MEI) was calculated to be 0.11 mrem (1.1×10^{-3} mSv) to a hypothetical resident of Springdale, NV, located 58 km (36 mi) west-northwest of Control Point 1 (CP-1), on the NTS. The calculated population dose (collective EDE) to the approximately 32,210 residents living within 80 km (50 mi) from each of the NTS airborne emission sources was 0.34 person-rem (3.4×10^{-3} person-Sv). Monitoring network data indicated a 1996 exposure to the MEI of 144 mrem (1.44 mSv) from normal background radiation. The calculated dose to this individual from worldwide distributions of radioactivity as measured from surveillance networks was 0.023 mrem (2.3×10^{-4} mSv). These maximum dose estimates, excluding background, are less than one percent of the most restrictive standard.

Onsite source emission measurements, as provided by DOE, are listed in Table 7.1, and include tritium, radioactive noble gases, and plutonium. These are estimates of releases made at the point of origin. Meteorological data collected by the Air Resources Laboratory Special Operations and Research Division, (ARL/SORD) were used to construct wind roses and stability arrays for the following areas: Mercury, Area 12, Area 20, Yucca Flat, and the Radioactive Waste Management Site (RWMS) in Area 5. A calculation of estimated dose from NTS effluents was performed using EPA's CAP88-PC model (EPA 1992). The results of the model indicated that the hypothetical individual with the maximum calculated dose from airborne NTS radioactivity would reside at Springdale, Nevada, 58 km (36 mi) west-northwest of CP-1. The maximum dose to that individual could have been 0.1 mrem (1×10^{-3} mSv). For comparison, data from the PIC monitoring network indicated a 1996 dose of 144 mrem (1.44 mSv) from background gamma radiation occurring in that area. The population living within a radius of 80 km (50 mi) from the airborne sources on the NTS was estimated to be 32,210 individuals, based on 1995 population data. The collective population dose within 80 km (50 mi) from each of these sources was calculated to be 0.3 person-rem (3×10^{-3} person-Sv). Activity concentrations in air that would cause these calculated doses are much

higher than actually detected by the offsite monitoring network. For example, 0.107 mrem of the calculated EDE to the MEI is due to plutonium. The annual average plutonium concentration in air that would cause this EDE is 4.1×10^{-17} µCi/mL. This is about 20 times the annual average plutonium in air measured in Goldfield (nearest community) of 0.19 $\times 10^{-17}$ µCi/mL (Chapter 4, Table 4.3). Table 7.2 summarizes the annual contributions to the EDEs due to 1996 NTS operations as calculated by use of CAP88-PC and the radionuclides listed in Table 7.1.

Input data for the CAP88-PC model included meteorological data from ARL/SORD and effluent release data calculated from monitoring results and from resuspension estimates. These release data are known to be estimates and the meteorological data are mesoscale; e.g., 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. The model results are considered overestimates of the dose to offsite residents. This has been confirmed by comparison with the offsite monitoring results.

7.2 Estimated Dose From ORSP Monitoring Network Data

Potential CEDEs to individuals may be estimated from the concentrations of radioactivity, as measured by the EPA monitoring networks during 1996. Actual results obtained in analysis are used; the majority of which are less than the reported minimum detectable concentration (MDC). No krypton or tritium in air data were collected offsite, so the onsite krypton for this year, and an average value for previous year's offsite tritium were used. No vegetable or animal samples were collected in 1996, so calculations for these intakes were not done.

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 broad. The concentrations of radioactivity detected by the monitoring networks and used in the calculation of potential CEDEs are shown in Table 7.3.

The concentrations given in Table 7.3 are expressed in terms of activity per unit volume. 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 storage or handling of ingested materials.

- 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).
- Water consumption for adult-reference man = 2 L/day (approximately 1,900 mL/day [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).
- ^{7}Be 2.6×10^{-7} mrem/pCi (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 concentration of 0.2 pCi/m^3:

- (2×10^{-1} pCi/m^3) x (8400 m^3/yr) x (6.4×10^{-8} mrem/pCi) = 1.1×10^{-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 (ICRP, 1975). The total dose in one year, therefore, is $1.1 \times 10^{-4} \times 1.5 = 2.4 \times 10^{-4}$ mrem/ yr. Dose calculations from ORSP data are summarized in Table 7.3.

The individual CEDEs, from the various pathways, added together give a total of 0.015 mrem/yr. Total EDEs can be calculated based on different combinations of data. If the interest was in just one area, for example, the concentrations from those stations closest to that area could be substituted into the equations used here.

In 1996, because of budget cuts and the standby status of nuclear device testing, samples of game animals and garden vegetables were not collected. Also, the noble gas and tritium sampling network was discontinued in the offsite locations, and the air sampling network was reduced. In order to calculate an EDE for a resident of Springdale, the MEI from the CAP88-PC operation, it is necessary to make some assumptions. The NTS average krypton-85 concentration is representative of statewide levels; tritium in air does not change significantly from year to year; and, because Goldfield has the nearest air sampler to Springdale, its plutonium concentration is used to calculate the EDE.

7.3 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, U, and Th and their progeny), 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 0.24 pCi/m^3. With a dose conversion factor for inhalation of 2.6×10^{-7} mrem/pCi, and a breathing volume of 8,400 m^3/yr, this equates to a dose of 5.2×10^{-4} mrem as calculated in Table 7.3. This is a negligible quantity when compared with the PIC network measurements that vary from 73 to 156 mR/year, depending on location.

7.4 Summary

The offsite environmental surveillance system operated around the NTS by EPA's R&IE-LV detected no radiological exposures that could be attributed to recent NTS operations, but a calculated EDE of 0.015 mrem can be obtained, if certain assumptions are made, as shown in Table 7.2. Calculation with the CAP88-PC model, using estimated or calculated effluents from the NTS during 1996, resulted in a maximum dose of 0.11 mrem (1.1×10^{-3} mSv) to a hypothetical resident of Springdale, Nevada, 14 km (9 mi) west of the NTS boundary. Based on monitoring network data, this dose is calculated to be 0.005 mrem. This latter EDE is about 5 percent of the dose obtained from CAP88-PC calculation. This maximum dose estimate is less than one percent of the International Commission on Radiological Protection (ICRP) recommendation that an annual EDE for the general public not exceed 100 mrem/yr (ICRP 1985). The calculated population dose (collective EDE) to the approximately 32,210 residents living within 80 km (50 mi) of each of the NTS airborne emission sources was 0.34 person-rem (3.4×10^{-3} person-Sv). Background radiation yielded a CEDE of 3,064 person-rem (30.6 person-Sv).

Data from the PIC gamma monitoring indicated a 1996 dose of 144 mrem from background gamma radiation measured in the Springdale area. The CEDE calculated from the monitoring networks or the model, as discussed above, is a negligible amount by comparison. The uncertainty (2σ) for the PIC measurement at the 144 mrem exposure level is approximately five percent. Extrapolating to the calculated annual exposure at Springdale, Nevada, yields a total uncertainty of approximately 7 mrem which is greater than either of the calculated EDEs. Because the estimated dose from NTS activities is less than 1 mrem (the lowest level for which Data Quality Objectives (DQOs) are defined, as given in Chapter 10) no conclusions can be made regarding the achieved data quality as compared to the DQOs for this insignificant dose.

Table 7.1 NTS Radionuclide Emissions - 1996

Onsite Liquid Discharges

Containment Ponds	Curies[a]				
	^{3}H	^{90}Sr	^{137}Cs	^{238}Pu	$^{239+240}Pu$
Area 12, E Tunnel	1.1×10^{1}	4.4×10^{-5}	1.5×10^{-3}	3.4×10^{-6}	2.7×10^{-5}
Area 20, Well ER-20-5	1.1×10^{2}				
Area 20, Well ER-20-6	8.2×10^{0}				
TOTAL	1.3×10^{2}	4.4×10^{-5}	1.5×10^{-3}	3.4×10^{-6}	2.7×10^{-5}

Airborne Effluent Releases

Facility Name (Airborne Releases)	Curies[a]	
	^{3}H[b]	$^{239+240}Pu$
Areas 3 and 9[c]		0.036
Area 5, RWMS[d]	3.5×10^{-1}	
Atlas Facility[d]	5.2×10^{-3}	
SEDAN Crater [d]	1.4×10^{2}	
Other Areas[c]		0.24
TOTAL	1.2×10^{-0}	0.28

(a) Multiply by 3.7×10^{10} to obtain Bq. Calculated releases from laboratory spills and losses are included in Table 7.4.
(b) In the form of tritiated water vapor, primarily HTO.
(c) Resuspension from known surface deposits.
(d) Calculated from air sampler data.

Table 7.2 Summary of Effective Dose Equivalents from NTS Operations - 1996

	Maximum EDE at NTS Boundary[a]	Maximum EDE to an Individual[b]	Collective EDE to Population within 80 km of the NTS Sources
Dose	0.12 mrem (1.2×10^{-3} mSv)	0.11 mrem (1.1×10^{-3} mSv)	0.34 person-rem (3.4×10^{-3} person-Sv)
Location	Site boundary 40 km WNW of NTS CP-1	Springdale, NV 58 km WNW of NTS CP-1	32,210 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	1.2	1.1	-----
Background	144 mrem (1.44 mSv)	144 mrem (1.44 mSv)	3064 person-rem (30.6 person-Sv)
Percentage of Background	0.08	0.08	0.011

(a) The maximum boundary dose is to a hypothetical individual who remains in the open continuously during the year at the NTS boundary located 40 km (25 mi) west-northwest from CP-1.
(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 6.1 and assuming all tritiated water input to the Area 12 containment ponds was evaporated.
(c) National Emission Standards for Hazardous Air Pollutants.

Table 7.3 Monitoring Networks Data used in Dose Calculations - 1996

Medium	Radionuclide	Concentration	Mrem\Year	Comment
Meat				Not collected this year
Milk	^{90}Sr	0.63 [a] (0.023)	9.7×10^{-3}	Concentration is the average of all network results
	^{3}H	0	0	Not Analyzed
Drinking Water	^{3}H	0.71 [a] (0.026)	3.3×10^{-5}	Concentration is the average from wells in the area
Vegetables				Not collected this year
Air	^{3}H	0.2 [b] (0.007)	1.6×10^{-4}	Concentration is average network result (1994 data)
	^{7}Be	0.24 [b] (0.010)	5.2×10^{-4}	Annual average for Goldfield, Nevada
	^{85}Kr	25.2 [b] (0.93)	3.8×10^{-4}	NTS network average
	$^{239+240}Pu$	1.7×10^{-6} [b] (6.3×10^{-8})	4.4×10^{-3}	Annual average for Goldfield

TOTAL (Air = 5.5×10^{-3}, Liquids = 9.7×10^{-3}) = 1.5×10^{-2} mrem/yr

(a) Units are pCi/L and Bq/L.
(b) Units are pCi/m^3 and Bq/m^3.

Table 7.4 Radionuclide Emissions on the NTS - 1996[a]

Radionuclide	Half-life (year)	Quantity Released (Ci) [b]
Airborne Releases:		
^{3}H	12.35	[c]0.35
^{85}Kr	10.72	0.019
$^{239+240}Pu$	24065.	[c]0.28
Containment Ponds:		
^{3}H	12.35	[d]130
^{238}Pu	87.743	3.4×10^{-6}
$^{239+240}Pu$	24065.	2.7×10^{-5}
^{90}Sr	29.	4.4×10^{-6}
^{137}Cs	30.17	1.5×10^{-3}
Gross Beta	---	1.2×10^{-6}

(a) Assumes worst-case point and diffuse source releases.
(b) Multiply by 37 to obtain Gbq.
(c) Includes calculated data from air sampling results, postulated loss of laboratory standards, and calculated resuspension of surface deposits.
(d) This amount is assumed to evaporate to become an airborne release.

8.0 Training Program

Proper and efficient performance of radiological health functions by qualified personnel is required to ensure protection from radiological hazards. The purpose of the training program is to provide well-trained, qualified personnel to safely and efficiently perform their assigned duties at a predetermined level of expertise.

8.1 Emergency Response Training Program

Emergency response training is essential to maintain a cadre of personnel who are qualified to perform approved radiological health and field monitoring practices. The training program includes: tracking training requirements; maintaining training records; developing in-house training; and documenting personnel qualifications and accomplishments. Systematic determination of job functions promotes consistent training activities and develops or improves knowledge, skills and abilities that can be utilized in the work environment.

In 1996, the EPA ORIA/R&IE National Laboratory in Las Vegas (R&IE-LV) supported DOE by instructing or co-instructing radiological training courses for state and local emergency responders nationwide. One such program is the Transportation Emergency Training for Radiological Assistance (TETRA); another is the Federal Radiological Monitoring and Assessment Center (FRMAC). TETRA training includes railway simulated accidents known as TETRA/RAIL; an intensive course in radiological emergency response called Radiological Emergency Operations (REO) at the Nevada Test Site (NTS); and Radiological Emergency Response for Local Responders (RETLR). FRMAC training is given at drills and exercises in the form of classroom and hands-on training followed by a drill or exercise involving field monitoring practical experience simulating an actual emergency response scenario.

In addition, R&IE-LV supports other emergency response needs. Several personnel are trained in the Radiological Assistance Program (RAP). Radiation field monitors are required to complete an initial 40 hr. Hazardous Waste Site Operations and Emergency Response (HAZWOPER) (29 CFR 1910.120) with 8 hour annual refreshers course and complete a RAP training class, plus maintain respirator fit qualification to be on the RAP team. In February, three R&IE-LV personnel attended a Transportation Emergency Training for Response Assistance (TTT), train-the-trainer course in Idaho Falls, ID. This course prepared the students to become trainers of trainers in the specific area of transportation emergency response along transportation corridors.

Co-instructed Training Courses - 1996

Course Name	Location	Dates	EPA Co-instructors Provided
RETLR	Columbia, SC	June 12-20	(1)
TETRA/RAIL	Pueblo, CO	June 24-28	(4)
REO	NTS, NV	May 6-10	(9)
REO	NTS, NV	May 25-29	(9)
REO	NTS, NV	March 4-8	(9)
RETLR	Charleston, SC	August 20-23	(1)

Emergency Response Classes Attended -1996

Course Name	Location	Dates
RAP	Ft. Smith, AK	January 24-28
Radiological Field Team Leader Class	Las Vegas, NV (R&IE sponsored)	March 12-14
Field Instrument for the Detection of Low Energy Radiation (FIDLER) Class	Las Vegas, NV (R&IE sponsored)	April 9-10
FRMAC Readiness Class	Las Vegas, NV (R&IE sponsored)	April 15-17
8-hr. HAZWOPER Refresher	Las Vegas, NV (EPA sponsored)	May 3
Handshake II	Savannah River Site, SC	May 13-17
FRMAC Readiness Class	Las Vegas, NV (R&IE sponsored)	June 10-12
FRMAC Readiness Class	Las Vegas, NV (R&IE sponsored)	July 8-10
Operational Radiation Protection	Bechtel, NV	December 2-6

8.2 Hazardous Materials Spill Center Support

The Hazardous Materials Spill Center (formerly the Liquified Gaseous Fuels Spill Test Facility) is located at Frenchman Flat in Area 5 of the Nevada Test Site. Originally completed in 1986, the HAZMAT Spill Center was designed for safety research on the handling, shipping, and storage of liquified gaseous fuels and other hazardous liquids. Early research was aimed at understanding the physics of spill dispersion, spill effects mitigation, and clean-up technology. More recently the Center has been used by industry for conducting tests on protective clothing, to give hands-on spill mitigation experience to industrial emergency response workers, and to test a variety of sensors designed to detect airborne hazardous materials. Organizations conducting tests range from the Federal government, and corporations, to foreign governments working in co-operation with the U.S. Government. The facility is completely supported by user fees paid by the organizations conducting the tests.

The HAZMAT Spill Center has the advantages of being located far from populated areas, inside of a secure facility, and subjected to well characterized and predictable meteorological conditions. The EPA provides a chemist to participate in meetings of the Advisory Panel which reviews and approves all programs prior to testing and maintains a readiness for monitoring emissions at the boundary of the NTS. Recent spills have involved such small amounts of material that monitoring at the boundary was not justified. Dispersion models show that even a catastrophic release of the entire supply of the test materials would not be measurable at the test site boundary. Four spill programs were conducted in 1996. These included a U.S. Navy incinerator test, testing a variety of laser sensors, and a spill mitigation workshop conducted by an industrial user.

9.0 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 9.1 and (see Table 6.2 page 52). 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 9.1 Summary of Analytical Procedures

Type of Analysis	Analytical Equipment	Counting Period (min)	Analytical Procedures	Sample Size	Approximate Detection Limit[a,c]
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%.	60 - Air charcoal cartridges and individual air filters. 100 - milk, water, suspended solids.	Radionuclide concentration quantified from gamma spectral data by online computer program.	1.0 L & 3.5 L - routine liquids. 560 m^3 - low-volume air filters. 10,000 m^3 - high-volume air filters.	Cs-137, routine liquids; 5×10^{-9} µCi/mL (1.8×10^{-1} Bq/L). Also see Table 6.3, page 52. Low-volume air filters: 5×10^{-14} µCi/mL (1.8×10^{-3} Bq/m^3), High-volume air filters; 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 - milk or water.	^{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.	150 - 300	Sample prepared by distillation.	4 to 10 mL for water.	300 to 700 x 10^{-3} pCi/mL (11^{-26} Bq/L)[c]

Continued

Table 9.1 (Summary of Analytical Procedures, cont.)

Type of Analysis	Analytical Equipment	Counting Period (min)	Analytical Procedures	Sample Size	Approximate Detection Limit[a]
^{3}H Enrichment (LTHMP samples)	Automatic liquid scintillation counter with output printer.	300	Sample concentrated by electrolysis followed by distillation.	250 mL - water.	10×10^{-3} pCi/mL (3.7×10^{-1} Bq/L)
$^{238,239+240}Pu$	Alpha spectrometer with silicon surface barrier detectors operated in vacuum chambers.	1,000	Water sample, or acid-digested filter separated by ion exchange and electroplated on stainless steel planchet.	1.0 L - water. 5,000 to 10,000 m^3 - air.	^{238}Pu: 0.08×10^{-9} µCi/mL (2.9×10^{-3} Bq/L). $^{239+240}Pu$: 0.04×10^{-9} µCi/mL (1.5×10^{-3} Bq/L) - water. ^{238}Pu: 5×10^{-17} (1.9×10^{-6} 3.7×10^{-6} Bq/m^3) $^{239+240}Pu$: 10×10^{-17} µCi/mL - air filters.

[a] The detection limit is defined as the smallest amount of radioactivity that can be reliably detected, i.e., probability of Type I and Type II error at 5 percent each (DOE81).
[b] Gamma spectrometry using a high purity intrinsic germanium (HpGe) detector.
[c] Depending on sample type.

10.0 Quality Assurance

10.1 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. EPA Order 5360.1, "Policy and Program Requirements to Implement the Quality Assurance Program" requires participation in a QA Program by all EPA organizational units involved in environmental data collection. This policy further 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.

The QA policies and requirements of EPA's R&IE-LV are summarized in the *Quality Management Plan* (R&IE, draft 1997). 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, under revision). 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 R&IE 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 R&IE in support of the ORSP are of adequate quality and properly documented for use by the DOE, EPA, and other interested parties.

10.2 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, R&IE participates in external intercomparison programs. One such intercomparison program is managed and operated by a group within EPA/CRD-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. The R&IE laboratory also began participation in the DOE Mixed Analyte Performance Evaluation Program (MAPEP) during 1996. External Dosimetry is accredited every two years. In 1996 the program was accredited under the Department of Energy Accreditation Program (DOELAP). Accreditation includes performance testing as well as an on-site assessment. The R&IE External Dosimetry Program is currently seeking National Voluntary Laboratory Accreditation Program (NVLAP) accreditation, which will also include performance testing and an on-site assessment.

10.2.1 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 pathways to human exposure as well as direct measurement of offsite resident exposure through the TLD 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.

10.2.2 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)
- 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.

10.2.3 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 parameter uncertainties 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.

10.3 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 R&IE Center for Environmental Restoration and Emergency Response (CERMER). 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 CERMER/CRQA.

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 or TLD 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.

10.4 Quality Assessment Of 1996 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.

Table 10.1 Data Completeness of Offsite Radiological Safety Program Networks

Network	Number of Sampling Locations	Total Samples Possible	Valid Samples Collected	Percent Completeness
LTHMP[a]	271	479	468	97.8
Low-volume Air	20	6,745 days[b]	6,440	95.5
High-volume Air	6	1,993 days	1673	83.9
Milk Surveillance	10	10	9	90.0
PIC	24[c]	8,760 days	6,477	73.9[d]
Environmental TLD	49	17,897 days	17,537	98.0
Personnel TLD	25	9,011 days	8,831	96.9

(a) The Data Quality Objectives (DQO) for completeness for monitoring networks summarized in this table are 90 percent.
(b) Continuous samplers with samples collected at intervals of approximately one week. Days used as units to account for differences in sample interval length.
(c) Continuous samplers with data summarized on a weekly basis.
(d) Satellite telemetry data only, does not include backup data systems.
(*) Data for three quarters.

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 10.3. The following subsections describe the achieved data quality for 1996.

10.4.1 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 1996 data is given in Table 10.1. Reasons for sample loss include instrument malfunction, inability to gain site access, monitoring technician error, or laboratory error.

The achieved completeness of over 97 percent for the LTHMP exceeds the DQO of 80 percent.

Overall completeness for the routine Air Surveillance Network low volume samples was greater than 95 percent, exceeding the DQO of 90 percent. Individually, seventeen of twenty stations exceeded 95 percent data recovery and nine stations achieved completeness of 100 percent. Plutonium analyses, conducted on composited filters from six high volume samplers at selected air stations, were over 83 percent complete, falling below the DQO of 90 percent due to equipment failures and difficulty obtaining replacement parts for new systems. Three of the six stations achieved completeness greater than 90 percent.

Overall sample completion for the MSN was equal to 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.

Ninety-one percent of the total possible number of samples were collected from ten ranches (see Figure 4.1). Annual means for these locations, individually, cannot be considered to be representative of the year. However, milk collected in July is representative of cows grazing on pasture or fed green chop which represent the typical food chain for those areas. The Hafen Ranch in Ivins, UT was not sampled as they were not milking during the collection period and there was no alternate sampling site in the area.

The achieved completeness of over 76 percent for the PIC Network fails to meet the DQO of 90 percent. This completeness value represents satellite telemetry data only, which is used for reporting purposes. Gaps in the satellite transmissions are filled by data from the magnetic tape or card media. The redundant data systems used in the PIC Network (i.e., magnetic tape or card data acquisition systems) are responsible for high rates of recovery of the collected data, and are stored electronically for reference.

10.4.2 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 three months to provide the field duplicate. A total of two samplers are used for low volume sample duplicates and one sampler is used for a duplicate high volume sample. The duplicate samplers are moved to randomly selected sampling sites throughout the year. Approximately ten percent of samples submitted to the laboratory are analyzed twice for intra laboratory comparison whenever possible. 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 Measurement Quality Objectives (MQOs) 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.

From duplicate samples collected and analyzed throughout the year, the %RSD was calculated for various types of analyses and sampling media. The results of these calculations are shown in Table 10.2. Samples not meeting the precision MQO were low activity, air particulate samples in which ^{7}Be was detected. The precision data for all other analyses were well within their respective MQOs. The R&IE data presented in Table 10.2 includes only those duplicate pairs that exceeded the minimum detectable concentration (MDC).

A total of 161 low volume duplicate pairs was analyzed for gross alpha and gross beta. Field duplicates account for sixty-nine of the samples and ninety-two were laboratory duplicates.

A total of 84 duplicate pairs exceeded the analysis MDC for gross alpha. Twenty-six of these were field duplicates and fifty-eight were laboratory duplicates. Of the field duplicates, ten of the twenty-six exceeded the MQO of 30 percent for samples greater than MDC but less than ten times MDC. One of the field duplicate samples exceeded ten times the MDC and the RSD for that sample was zero percent. Of the fifty-eight laboratory duplicates, nineteen exceeded the MQO of thirty percent. None of the laboratory duplicates were greater than ten times the MDC. Sixty-seven of the sixty-nine field duplicates exceeded the analysis MDC for gross beta. Of these, three were greater than ten times the MDC. The average RSD for the pairs greater than ten times MDC was 13.2 percent, exceeding the MQO of 10 percent for samples greater than ten times MDC. All three samples had RSDs of less than 15 percent.

Table 10.2 Precision Estimates from Duplicate Sampling, 1996

Analysis Type	Number of duplicate Analysis > MDC	Estimated Precision, %RSD
Gross Alpha	85	28.8
Gross Beta	156	16.9
Gamma Spectroscopy (low-vol ^{7}Be)	25	31.4
Gamma Spectrometry (hi-vol ^{7}Be)	11	46.8
Tritium in Water (enriched)	12	7.9
Tritium in Water (unenriched)	2	26.2

The average RSD for the sixty-four pairs greater than MDC but less than ten times MDC was 19.9 percent, well below the MQO of thirty percent for the analysis.

Ten of the sixty-four samples exceeded the MQO. Of ninety-two laboratory duplicate pairs, five were greater than ten times the MDC. The average RSD for these five samples was 3.5 percent with all samples less than the MQO of 10 percent. Eighty-four samples were greater than the MDC but less than ten times MDC for the analysis. The average RSD for this group of samples was 15.5 percent, well below the MQO of 30 percent. Eight of the samples exceeded the MQO value.^{7}Be was detectable on 25 low volume duplicate pairs. Eleven were field duplicates and 14 were laboratory duplicates. The average RSD of 31.4 percent is above the precision MQO of 30 percent for samples above MDC and less than ten times MDC. Of the eleven field duplicates, the average RSD was 29.8 percent which meets the MQO. The average RSD for the laboratory duplicates was 32.7 percent. Eight duplicate pairs from the field samples and 11 of the duplicate pairs from the laboratory samples were less than the MQO of 30 percent. High volume duplicate pairs where ^{7}Be was detected did not meet the MQO. The average of 11 samples was 46.8 percent. Four of the eleven samples met the MQO of 30 percent.

Forty-two duplicate pairs were analyzed for tritium using the unenriched method. Of the 42 samples analyzed, two were above the MDC for the analysis. The average RSD for these two samples was 26.2 percent which meets the MQO for this type of analysis. A total of 25 samples was analyzed for tritium using the enrichment method. Five of the duplicate pairs were above ten times MDC for the analysis with an average RSD of 7.1 percent, within the MQO of 10 percent for the analysis. Seven duplicate pairs were greater than MDC and less than ten times MDC, with RSD of 8.6 percent which is well within the MQO of 20 percent for this type of analysis.

10.4.3 Accuracy

The accuracy of all analyses is controlled through the use of NIST-traceable standards for 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 Pressurized Ion Chambers. For spectroscopic and radiochemical analyses, an independent measurement of accuracy is provided by participation in intercomparison studies using samples of known activities. The EPA R&IE-LV Radioanalysis Laboratory participates in three such intercomparison studies.

In the ***EPA CRD/RADQA*** 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 10.3 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 10.4.4. 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

The other intercomparison studies in which the EPA R&IE-LV Radioanalysis Laboratory participates are the semiannual DOE QA Program conducted by EML in New York, NY. and the DOE Mixed Analyte Performance Evaluation Program (MAPEP). Approximately 20 laboratories participate in the EML performance evaluation program. The MAPEP program evaluates the performance of approximately forty laboratories. Sample matrices for both of these programs include water, air filters, vegetation, and soil. Results for these performance audit samples are given in Tables 10.5 and 10.6. One of the two EML studies for 1996 was reported outside of acceptable limits for gamma spectroscopy in both air and water matrices. Follow-up investigation established a volume data entry error in both cases. Corrective actions were implemented.

In addition to use of irradiated control samples in the processing of TLDs, DOELAP and NVLAP both monitor accuracy as part of their 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 or NVLAP; 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.

10.4.4 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 10.4 displays data from the 1996 intercomparison studies for all variables measured. There were five instances in which the EPA R&IE-LV Radioanalysis Laboratory results deviated from the grand average by more than three standard normal deviate units. All of these were gamma spectrometry analyses of the June gamma in water intercomparison study sample. After investigation of the error in the reported data for this sample, it was found that the initial dilution of the sample had been improperly performed. The sample data was recalculated by the laboratory using the proper values for dilution which provided satisfactory analytical results for 4 of the 5 analytes in question. All other analyses were within three standard normal deviate units of the grand mean. This indicates acceptable comparability of the Radioanalysis Laboratory with the 70 to 290 laboratories participating in the EPA Intercomparison Study Program.

10.4.5 Representativeness

Representativeness cannot be evaluated quantitatively. Rather, it is a qualitative assessment of the ability of the sample to model the objectives of the 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). Corrective actions are dependent upon DOE funding of new wells. This evaluation is cited in the discussion of the LTHMP data in Section 6.

Table 10.3 Accuracy of Analysis from ***RADQA*** Performance Evaluation Study, 1996

Nuclide	Month	Known Value (pCi/L)	EPA Average (pCi/L)	Percent Bias
		Water Performance Evaluation Studies		
Alpha	Jan	12.1	13.3	8.3
Alpha	Apr[a]	74.8	71.3	-4.7
Alpha	Jul	24.4	24.0	-1.6
Alpha	Oct	10.3	12.4	16.9
Alpha	Oct[a]	59.1	58.5	1.0
Beta	Jan	7.0	12.8	-82.9
Beta	Apr[a]	167	162	-3.2
Beta	Jul	44.8	51.5	13.0
Beta	Oct	34.6	37.5	8.4
Beta	Oct[a]	112	111	-0.4
^{3}H	Mar	22002	21311	-3.1
^{3}H	Aug	10879	10805	-0.7
^{60}Co	Jun	99.0	869	778
^{60}Co	Oct[a]	15.0	15.7	4.7
^{60}Co	Nov	44.0	44.0	0.0
^{65}Zn	Jun	300	2801	834
^{65}Zn	Nov	35.0	37.7	7.2
^{89}Sr	Jul	25.0	24.0	4.0
^{89}Sr	Oct[a]	10.0	12.3	23.0
^{90}Sr	Jul	12.0	12.0	0.0
^{90}Sr	Oct[a]	25.0	24.0	-4.0
^{131}I	Feb	67.0	77.0	14.9
^{131}I	Oct	27.0	26.3	-2.6
^{133}Ba	Jun	745	6289	744
^{133}Ba	Nov	64.0	58.0	-10.3
^{134}Cs	Jun	79.0	648	720
^{134}Cs	Oct[a]	20.0	21.7	8.5
^{134}Cs	Nov	11.0	12.7	15.5
^{137}Cs	Jun	197	1761	794
^{137}Cs	Oct[a]	30.0	33.7	12.3
^{137}Cs	Nov	19.0	19.7	3.7
$U_{(Nat)}$	Apr[a]	58.4	54.9	-6.0
$U^{(Nat)}$	Jun	20.2	20.8	3.0
$U^{(Nat)}$	Sep	10.1	10.2	1.0
$U^{(Nat)}$	Oct[a]	40.9	38.3	-6.4
$U^{(Nat)}$	Dec	5.0	5.0	0.0

(a) Sample from Blind Performance Evaluation (PE) Study

Table 10.4 Comparability of Analysis from ***RADQA*** Performance Evaluation Study, 1996

Nuclide	Month	Known Value (pCi/L)	EPA 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 Studies				
Alpha	Jan	12.1	13.3	11.9	5.0	0.47	0.40
Alpha	Apr[a]	74.8	71.3	68.7	18.7	0.24	-0.32
Alpha	Jul	24.4	24.0	19.7	6.1	1.24	-0.10
Alpha	Oct	10.3	12.4	8.9	5.0	1.21	0.72
Alpha	Oct[a]	59.1	58.5	59.9	14.8	-0.17	-0.07
Beta	Jan	7.0	12.8	8.5	5.0	1.48	2.00
Beta	Apr[a]	167	162	159	25.0	0.20	-0.37
Beta	Jul	44.8	51.5	44.4	5.0	2.47	2.32
Beta	Oct	34.6	37.5	35.3	5.0	0.76	0.99
Beta	Oct[a]	112	111	108	16.8	0.37	-0.05
^{3}H	Mar	22002	21311	21573	2200	-0.21	-0.54
^{3}H	Aug	10879	10805	10591	1088	0.34	-0.12
^{60}Co	Jun	99.0	869	98.1	5.0	267	267
^{60}Co	Oct[a]	15.0	15.7	15.2	5.0	0.15	0.23
^{60}Co	Nov	44.0	44.0	44.5	5.0	-0.19	0.00
^{65}Zn	Jun	300	2801	309	30.0	144	144
^{65}Zn	Nov	35.0	37.7	36.1	5.0	0.55	0.92
^{89}Sr	Jul	25.0	24.0	23.9	5.0	0.04	-0.35
^{89}Sr	Oct[a]	10.0	12.3	10.4	5.0	0.68	0.81
^{90}Sr	Jul	12.0	12.0	11.8	5.0	0.07	0.00
^{90}Sr	Oct[a]	25.0	24.0	23.7	5.0	0.11	-0.35
^{131}I	Feb	67.0	77.0	68.5	7.0	2.09	2.47
^{131}I	Oct	27.0	26.3	27.6	6.0	-0.37	-0.19
^{133}Ba	Jun	745	6289	720	75.0	129	128
^{133}Ba	Nov	64.0	58.0	61.4	6.0	-0.98	-1.73
^{134}Cs	Jun	79.0	648	72.9	5.0	199	197
^{134}Cs	Oct[a]	20.0	21.7	18.5	5.0	1.11	0.58
^{134}Cs	Nov	11.0	12.7	10.6	5.0	0.71	0.58
^{137}Cs	Jun	197	1761	201	10.0	270	271
^{137}Cs	Oct[a]	30.0	33.7	30.5	5.0	1.10	1.27
^{137}Cs	Nov	19.0	19.7	20.4	5.0	-0.24	0.23
$U_{(Nat)}$	Apr[a]	58.4	54.9	55.5	5.8	-0.20	-1.06
$U^{(Nat)}$	Jun	20.2	20.8	19.9	3.0	0.54	0.37
$U^{(Nat)}$	Sep	10.1	10.2	10.0	3.0	0.12	0.08
$U^{(Nat)}$	Oct[a]	40.9	38.3	39.4	4.1	-0.46	-1.08
$U^{(Nat)}$	Dec	5.0	5.0	5.1	3.0	-0.08	0.00

(a) Sample from Blind Performance Evaluation (PE) Study

Table 10.5 Accuracy of Analysis from DOE/EML Performance Evaluation Studies

Nuclide	Month	EML Value	EPA Value	Percent Bias
Air Intercomparison Studies				
^{54}Mn	March	3.44	3.24	-5.81
^{54}Mn	September	6.35	9.23	45.4
^{57}Co	March	8.90	7.71	-13.4
^{57}Co	September	14.8	21.1	42.6
^{60}Co	March	29.5	29.8	1.02
^{60}Co	September	8.64	12.2	41.2
^{106}Ru	March	11.6	11.3	2.59
^{106}Ru	September	10.8	14.8	27.0
^{125}Sb	March	9.78	9.35	-4.40
^{125}Sb	September	10.8	14.6	35.2
^{134}Cs	March	14.7	14.4	-2.04
^{134}Cs	September	10.8	15.3	41.7
^{137}Cs	March	6.64	6.19	-6.78
^{137}Cs	September	8.52	11.2	31.5
^{144}Ce	March	33.3	26.9	19.2
^{238}Pu	March	0.09	0.093	3.33
^{238}Pu	September	0.118	0.122	3.39
^{239}Pu	March	0.093	0.099	6.45
Soil Intercomparison Studies				
^{90}Sr	March	1340.	1.22	-99.9
^{238}Pu	March	43.0	42.2	-1.86
^{238}Pu	September	1.13	0.79	-30.1
^{239}Pu	March	9.23	8.99	-2.60
^{239}Pu	September	21.8	21.1	-3.21
Vegetation Intercomparison Studies				
^{90}Sr	March	1300.	1.15	-99.9
^{90}Sr	September	1390.	129.	-90.7
^{239}Pu	March	9.82	8.75	-10.9
^{239}Pu	September	1.96	2.22	13.3
Water Intercomparison Studies				
^{3}H	March	251.	222.	-11.6
^{3}H	September	587.	492.	-16.2
^{54}Mn	March	38.4	45.4	18.2
^{54}Mn	September	60.5	9.45	-84.4
^{60}Co	March	32.8	36.1	10.1
^{60}Co	September	61.1	9.28	-84.8

Table 10.5 Accuracy of Analysis from DOE/EML PE Studies (Con't)

Nuclide	Month	EML Value	EPA Value	Percent Bias
^{90}Sr	March	1.45	1.29	-11.0
^{90}Sr	September	2.71	3.12	15.1
^{137}Cs	March	38.3	46.1	20.4
^{137}Cs	September	89.5	13.4	-85.0
^{234}U	March	0.274	0.329	20.1
^{234}U	September	0.480	0.489	1.88
^{238}U	March	0.275	0.313	13.8
^{238}U	September	0.480	0.484	-0.83
^{238}Pu	March	0.982	0.990	0.81
^{238}Pu	September	1.91	1.92	0.52
^{239}Pu	March	0.772	0.778	-0.78
^{239}Pu	September	0.840	0.851	1.31

Table 10.6. Accuracy of Analysis from DOE/MAPEP PE Studies

Result (Bq/L)	Unc.	Ref. Value	Mean Result	Std. Dev.	Bias [%]	Flag	Mean Uncert.	Uncert. Flag
Cesium-137								
57.1	3.6	58.77	55.47	3.54	-5.62	A	3.43	
57.9	3.5							
51.4	3.2							
Cobalt-57								
93.8	4.1	92.38	91.37	4.39	-1.10	A	3.83	L
94.0	4.1							
86.3	3.8							
Manganese-54								
103.9	5.5	99.08	103.6	6.56	4.56	A	4.93	L
110	5.5							
96.9	3.8							
Plutonium-238								
1.69	.061	1.83	1.74	0.05	-4.79	A	0.06	L
1.71	.061							
1.78	.062							
Plutonium-239								
1.29	.048	1.34	1.29	0.01	-4.02	A	0.05	L
1.28	0.46							
1.30	.047							
Strontium-90								
13.8	0.48	15.69	13.20	1.13	-15.87	A	0.59	L
13.9	0.41							
11.9	0.88							

Flags:
A = Mean result is acceptable (Bias <= 20%)
W = Mean result is acceptable with a warning (20% < Bias <= 30%)
N = Mean result is not acceptable (Bias > 30%)
L = Mean uncertainty potentially too low (for informational purposes only)
H = Mean uncertainty potentially too high (for informational purposes only)

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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).

alpha particles (α) Positively charged moving particles identical with the nuclei of helium atoms. They penetrate tissues to usually less than 0.1mm (1/250 inch) but create dense ionization and heavy absorbed doses along these short tracks.

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 (β) 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.

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 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, on 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.)

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 in air to ionizing radiation. It is that amount in air 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.

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.

Appendix
(L_D Calculations)

Determination of L_D:

- Accomplished upon the addition of a new dosimeter type to the program. Once completed, this test is not normally repeated. Two methods are acceptable for accomplishing the task.

- Method #1: At least 10 dosimeters for irradiation per category, plus 10 dosimeters for background evaluation, for each dosimeter design, are selected from the routine processed pool of dosimeters. The dosimeters are placed in an unshielded environment for a time sufficient to obtain an unirradiated background signal typical for routine processed dosimeters. At least 10 dosimeters are irradiated for each category to a dose significantly greater (e.g., 500 mrem) than the estimated lower limit of detectability. Both the irradiated and unirradiated dosimeters are processed and evaluated. The following quantities are calculated:

$$H_o = \frac{1}{n}\sum_{i=1}^{n} x_{io}$$

$$S_o = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (x_{io} - H_o)^2}$$

Where:

$$S_1 = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} (x_{i1} - H_1)^2}$$

$$H_1 = \frac{1}{n}\sum_{i=1}^{n} x_{i1}$$

X_{io} = Unirradiated dosimeter values.
X_i = Irradiated dosimeter values.

H_o = Mean evaluated dose equivalent values for unirradiated dosimeters.
H_1 = Mean evaluated dose equivalent values for irradiated dosimeters.
S_o = Associated standard deviation of unirradiated dosimeters dose equivalent values.
S_1 = Associated standard deviation of irradiated dosimeters dose equivalent values.

- The dosimeter readings are processed through the standard dose algorithms without truncation or distortion (i.e., readings are not rounded to zero). If a background is subtracted, negative values are retained for the calculation of S_o. The algorithms for the calculation of shallow and/or deep dose equivalent are used to calculate H_o and H_1, depending on the category test specifications. The lower limit of detection, L_D is then calculated as follows:

$$L_D = \frac{2\left[t_p S_o + \left(t_p \frac{S_1}{H_1}\right)^2 H'_o\right]}{\left[1 - \left(\frac{t_p S_1}{H_1}\right)^2\right]}$$

Method # 1 - Lower Limit of Detectability Determination

Where:

t_p = The t distribution for n - 1 degrees of freedom and a p value of 0.95.
H'_o = The average of the unirradiated dosimeter values without subtracting a background signal.

- Method #2: If NAVLAP performance testing was completed within six months of this study, then the values of B and S may be used to calculate [1.75 X S/(1 + B)] which may be used in place of $t_p S_1/H_1$ in the above equation. Only one set of unirradiated dosimeters is required to determine L_D using this method.

The above equation is based on the desire to minimize both false negative and false positive results. All values below the detection threshold should be set to zero.

For example, t_pS_o for p = 0.95 is an estimate of the detection threshold allowing 5% false positive values. For the lower limit of detection false negative values are also minimized. For p = 0.95, the probability of no more than 5% false positive and false negative values provides a lower limit of detection of:

$$L_D = t_{p,o}S_o + t_{p,D}S_D$$

Where:

S_o = The standard deviation of unirradiated dosimeters.

$t_{p,o}$ and $t_{p,D}$ depend on the number of dosimeters used to estimate S_o and S_D, respectively.

The above equation is an estimate of the relationship:

$$L_D = K_p\,\sigma_o + K_p\,\sigma_D$$

Where:

σ_o and σ_D = The true standard deviations.

K_p = The abscissa of the standard normal distribution below which the total relative area under the curve is P.

The σ_D value is composed of the fluctuation of the background (σ_o) and the fluctuation inherent in the readout process. If σ_1/H_1 is the relative standard deviation at high doses, then

$$\sigma_D^2 \cong \sigma_o^2 \left(\frac{\sigma_i}{H_1}\right)^2 (L_D^2 + 2L_DH_o)$$

and solving for L_D,

$$L_D = \frac{2\left[K_p\sigma_o + \left(K_p\frac{\sigma_1}{H_1}\right)^2 H_o\right]}{\left[1 - \left(K_p\frac{\sigma_1}{H_1}\right)^2\right]}$$

Method #2 - Lower Limit of Detectability Determination

Using t_p for K_p and S for σ, the final equation in Method #1 is obtained. If $t_{p,o}$ is not equal to $t_{p,D}$, the formula for L_D is not exact, but should be a close approximation of the lower limit of detectability.

Lower Limit of Detectability Determination -

Two methods of calculation are considered acceptable and are detailed in this document. This Determination uses the data obtained from a 6-month fade study conducted with both UD-802 (personnel) and UD-814 (environmental) dosimeters. In each case, the following calculation is accomplished to determine lower limit of detectability:

$$L_D = \frac{2\left[t_pS_o + \left(t_p\frac{S_1}{H_1}\right)^2 H_o\right]}{\left[1 - \left(\frac{t_pS_1}{H_1}\right)^2\right]}$$

Where:

LD = Lower limit of detectability.

t_p = The t distribution for n - 1 degrees of freedom and a p value of 0.95.

S_o = Associated standard deviation of unirradiated dosimeter dose equivalent values.

S_1 = Associated standard deviation of irradiated dosimeter dose equivalent values.

H_o = Mean evaluated dose equivalent values for unirradiated dosimeters.

H'_o = The average of the unirradiated dosimeter values without subtracting a background signal.

H_1 = Mean evaluated dose equivalent values for irradiated dosimeters.

L_D = Calculation for Personnel dosimeters:

$$L_D = \frac{2\,[2.262 \times 0.583 + \left((2.262)\frac{15.014}{174.05}\right)^2 3.425]}{1 - \left(\frac{2.262 \times 15.014}{174.05}\right)^2}$$

L_D = 3.01 mR; (for UD 802s)

$$L_D = \frac{2\,[2.571 \times 0.983 + \left((2.571)\frac{5.039}{168.33}\right)^2 1.033]}{1 - \left(\frac{2.571 \times 5.039}{168.33}\right)^2}$$

L_D = 5.10 mR; (for UD814s, $CaSO_4$ elements only)

Similarly L_D = 44.73 mR (for UD814s, Li B O elements only)

Where:

T_p = 12.706

S_i = 19.315

S_o = 2.081

H_o = 4.5

H_1 = 163.300

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