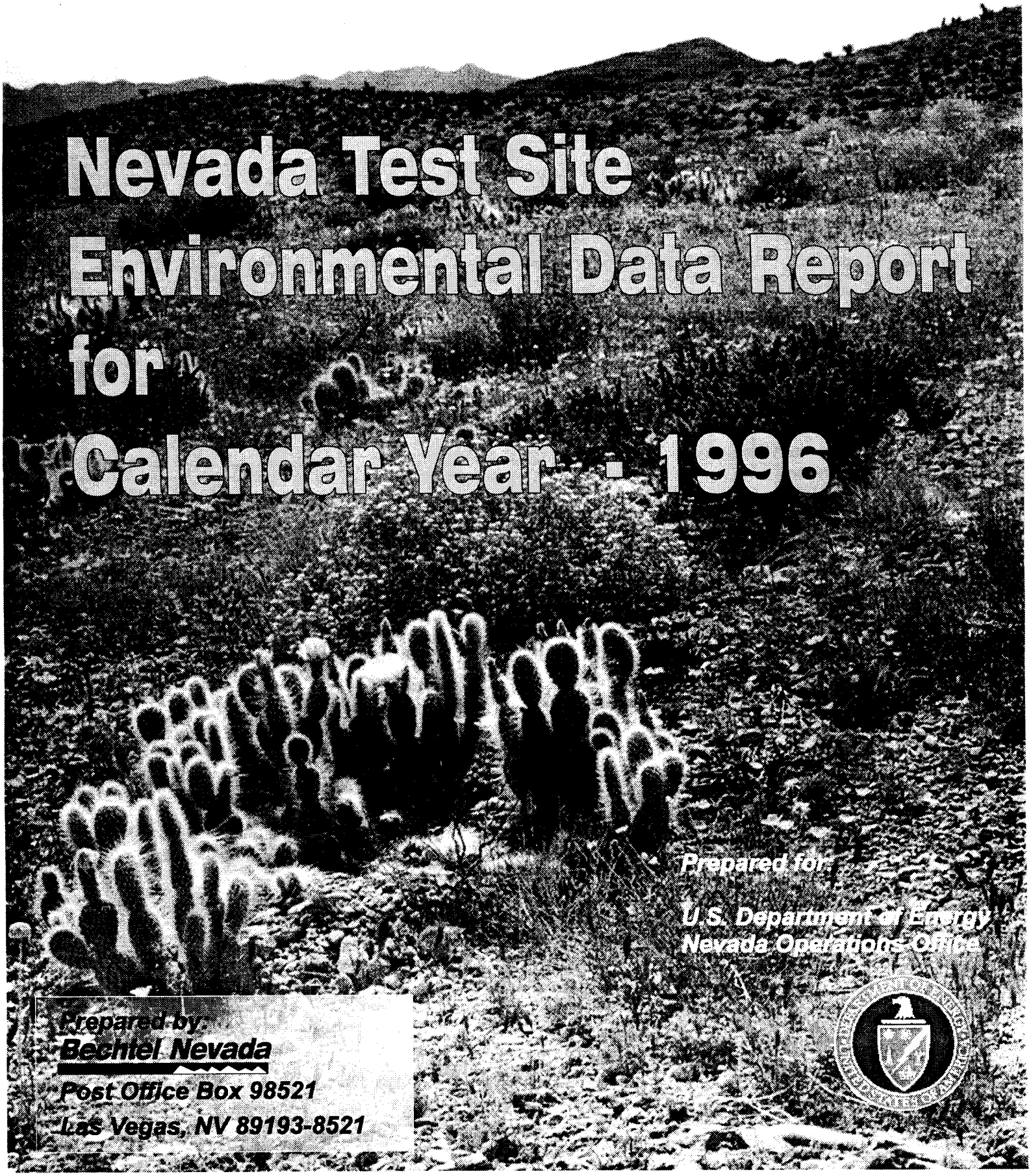
Contract No. DE-AC08-96NV11718
March 1998



Nevada Test Site Environmental Data Report for Calendar Year 1996

Prepared for:
U.S. Department of Energy
Nevada Operations Office

Prepared by:
Bechtel Nevada
Post Office Box 98521
Las Vegas, NV 89193-8521

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the:

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, Tennessee 37831

Prices available from (423) 576-8401

Available to public from the:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd.
Springfield, VA 22161

Prices available from (703) 487-4650

DOE/NV/11718-138
UC-600

Nevada Test Site Environmental Data Report for Calendar Year - 1996

Author: Robert R. Kinnison

Editors: Stuart C. Black and Yvonne E. Townsend

March 1998

Work Performed Under
Contract No. DE-AC08-96NV11718

Prepared for the

U.S. Department of Energy
Nevada Operations Office

Prepared by
Bechtel Nevada
Post Office Box 98521
Las Vegas, NV 89193-8521

FOREWORD

The chapters in this report contain the 1996 Nevada Test Site (NTS) onsite and offsite environmental monitoring results. Other offsite data collected by the U.S. Environmental Protection Agency (EPA) are available from the EPA, Radiation and Indoor Environments National Laboratory, Las Vegas, Nevada. Most of the onsite data presented in this document are accompanied by summaries and statistical evaluations of the data, and are summarized in the 1996 Annual Site Environmental Report.

TABLE OF CONTENTS

Page

Foreword iii
Table of Contents v
List of Figures vii
List of Tables ix

Executive Summary EX-1

1.0 Onsite Gross Alpha in Air 1-1
Attachment 1.1 Gross Alpha in Air - 1996 1-8

2.0 Onsite Gross Beta in Air 2-1
Attachment 2.1 Gross Beta in Air - 1996 2-14

3.0 Onsite ^{238}Pu and $^{239+240}$Pu in Air 3-1
Attachment 3.1 ^{238}Pu in Air - 1996 3-20
Attachment 3.2 $^{239+240}$Pu in Air - 1996 3-26

4.0 Onsite Tritium in Air 4-1
Attachment 4.1 Tritiated Water Vapor in Air Sampling Results - 1996 4-18

5.0 Onsite Thermoluminescent Dosimeter Data 5-1
Attachment 5.1 TLD Gama Exposure Rates - 1996 5-12

6.0 Historical Trends in Onsite Thermoluminescent Dosimeter Data 6-1
Attachment 6.1 Average Millirem per Year for NTS Thermoluminescent Dosimeters . . 6-8

7.0 Radioactive Noble Gases in Air Onsite 7-1
Attachment 7.1 Sample Results for ^{85}Kr - 1996 7-9

8.0 Onsite Gamma-Emitting Radionuclides in Air and Water and Radium and Strontium in Water 8-1
Attachment 8.1 ^{137}Cs in Air - 1996 8-5
Attachment 8.2 ^{137}Cs in Water - 1996 8-5
Attachment 8.3 ^{226}Ra in Water - 1996 8-5
Attachment 8.4 ^{228}Ra in Water - 1996 8-6
Attachment 8.5 ^{90}Sr in Water - 1996 8-8

9.0 Onsite Gross Alpha and Gross Beta in Water 9-1
Attachment 9.1 Gross Alpha in Water - 1996 9-19
Attachment 9.2 Gross Beta in Water - 1996 9-21

10.0 Onsite ^{238}Pu and $^{239+240}$Pu in Water 10-1
Attachment 10.1 ^{238}Pu in Water - 1996 10-7
Attachment 10.2 $^{239+240}$Pu in Water - 1996 10-11

11.0 Onsite Tritium in Water 11-1
Attachment 11.1 Tritium in Water - 1996 11-5

12.0 Summary of 1996 Results of Offsite TLD and Groundwater Monitoring 12-1

Distribution D-1

LIST OF FIGURES

Page

Figure 1.1 Locations of air Sampling Stations on NTS 1-4
Figure 1.2 Probability Plot for All Data Combined 1-4
Figure 1.3 Time Series Plot of Gross Alpha in Air with LOWESS Line 1-5
Figure 1.4 Thematic Map of 1996 Gross Alpha in Air 1-5

Figure 2.1 Locations of Air Sampling Stations on NTS 2-5
Figure 2.2 Thematic Map of 1996 Gross Beta in Air 2-5
Figure 2.3 Probability Plot of All Stations and Dates Combined 2-6
Figure 2.4 Boxplot of Gross Beta in Air by Area 2-6
Figure 2.5 Time Series Plot for Gross Beta in Air 2-7
Figure 2.6 Histogram of 1996 Gross Beta in Air Coefficients of Variation 2-7
Figure 2.7 Histogram of 1996 Gross Beta in Air Detection Limits 2-8
Figure 2.8 Historical Time Series, All Selected Stations Combined 2-8

Figure 3.1 NTS Air Sampling Locations 3-6
Figure 3.2 Probability Plot of Positive ^{238}Pu Concentrations 3-6
Figure 3.3 Boxplots of ^{238}Pu Concentrations by NTS Operational Area 3-7
Figure 3.4 Time Series Plot of ^{238}Pu Concentrations for 1996 3-7
Figure 3.5 Histogram of Empirical Coefficients of Variation 3-8
Figure 3.6 Probability Plot of $^{239+240}$Pu in Air Concentrations 3-8
Figure 3.7 Boxplots of $^{239+240}$Pu Concentrations by NTS Area 3-9
Figure 3.8 Boxplots of Natural Logarithms of $^{239+240}$Pu Concentrations by NTS Area 3-9
Figure 3.9 Time Series Plot of $^{239+240}$Pu Concentrations 3-10
Figure 3.10 Time Series Plot of Natural Logarithms of $^{239+240}$Pu Concentrations 3-10
Figure 3.11 Histogram of 1996 $^{239+240}$Pu Coefficients of Variation 3-11
Figure 3.12 Time Series Plot of $^{239+240}$Pu Annual Averages 3-11
Figure 3.13 Time Series Plot of ^{238}Pu Annual averages 3-12

Figure 4.1 Tritium in Air Sampling Stations 4-5
Figure 4.2 Time Series Plot for Area 3 Mud Plant 4-5
Figure 4.3 Time Series Plot for U-3ah/at North 4-6
Figure 4.4 Time Series Plot for U-3ah/at North 4-6
Figure 4.5 Time Series Plot for RWMS No.1 4-7
Figure 4.6 Time Series Plot for RWMS No. 3 4-7
Figure 4.7 Time Series Plot for RWMS No. 4 4-8
Figure 4.8 Time Series Plot for RWMS No. 5 4-8
Figure 4.9 Time Series Plot for RWMS No. 6 4-9
Figure 4.10 Time Series Plot for RWMS No. 7 4-9
Figure 4.11 Time Series Plot for RWMS No. 8 4-10
Figure 4.12 Time Series Plot for RWMS No. 9 4-10
Figure 4.13 Time Series Plot for SEDAN Crater 4-11
Figure 4.14 Time Series Plot for Area 12 Camp 4-11
Figure 4.15 Time Series Plot for E Tunnel Pond No. 1 4-12
Figure 4.16 Time Series Plot for EPA Farm 4-12
Figure 4.17 Time Series Plot for H & S Building 4-13
Figure 4.18 Time Series Plot for All NTS Stations Combined 4-13

List of Figures, cont. Page

Figure 4.19 Normal Probability Plot, All NTS Stations Combined 4-14
Figure 4.20 Lognormal Probability Plot, All NTS Stations Combined 4-14
Figure 4.21 Historical Time Series Plot for RWMS 4-15
Figure 4.22 Historic Time Series Plot for NTS 4-15

Figure 5.1 Thematic Map of NTS Environmental TLD Averages by Area 5-6
Figure 5.2 Probability Plot for 1996 TLD Annual Averages 5-6
Figure 5.3 Probability Plot of Operational and Atypical Sampling Locations 5-7

Figure 6.1 Time Series of Boxplots of Historical Background TLD Data 6-4
Figure 6.2 Probability Plot of Residuals from Two-Way ANOVA 6-4
Figure 6.3 Time Series of Boxplots for Environmental TLDs 6-5

Figure 7.1 Nevada Test Site Map With Noble Gas Sampling Locations 7-4
Figure 7.2 Time Series Plot of All Kr Results . . . . . -4
Figure 7.3 Time Series Plot of BJY Kr Results 7-5
Figure 7.4 Time Series Plot of Pahute Substation Kr Results 7-5
Figure 7.5 Time Series Plot of Area 20 Camp Kr Results 7-6

Figure 9.1 Locations of Water Sampling Stations on NTS 9-6
Figure 9.2 Probability Plot of All Gross Alpha in Water Results 9-6
Figure 9.3 Time Series Plot of Gross Alpha in Water Results 9-7
Figure 9.4 Histogram of 1996 Gross Alpha in Water Analytical Errors 9-7
Figure 9.5 Histogram of 1996 Gross Alpha in Water Detection Limits 9-8
Figure 9.6 Time Series Plot of Historical Gross Alpha in Water Data 9-8
Figure 9.7 Time Series Plot for Gross Beta in Water 9-9
Figure 9.8 Probability Plot of ANOVA Residuals 9-9
Figure 9.9 Histogram of Gross Beta in Water Relative Errors 9-10
Figure 9.10 Time Series Plot of Annual Averages 9-10
Figure 9.11 Time Series Plot of Annual Averages 9-11
Figure 9.12 Time Series Plot of Annual Averages 9-11
Figure 9.13 Time Series Plot of Annual Averages 9-12

LIST OF TABLES

Page

Table 1.1 Descriptive Statistic for Gross Alpha in Air by Sampling Location, µCi/mL × 10^{-15} 1-6
Table 1.2 Descriptive Statistic for Gross Alpha in Air by Operational Area, µCi/mL × 10^{-15} 1-7

Table 2.1 Descriptive Statistic for Gross Beta in Air by Sampling Location, µCi/mL × 10^{-15} 2-9
Table 2.2 Descriptive Statistic for Gross Beta in Air by Operational Areas, µCi/mL × 10^{-15} 2-10
Table 2.3 One Way ANOVA on Natural Log of Gross Beta Results for Differences Between Operational Areas, µCi/mL 2-11
Table 2.4 One Way ANOVA on Natural Log of Gross Beta Results for Differences Between Month of Sample Collection, µCi/mL 2-12
Table 2.5 Gross Beta in Air Historical Annual Averages at Selected Locations and for All Active Sampling Locations Combined, µCi/mL × 10^{-15} 2-13

Table 3.1 Radiological Waste Operations Monitoring Locations 3-13
Table 3.2 Descriptive Statistics for ^{238}Pu in Air by Location Type, µCi/mL x 10^{-18} 3-13
Table 3.3 Summary Statistics for ^{238}Pu Concentrations Compared Among NTS Operational Areas µCi/mL x 10^{-18} 3-13
Table 3.4 Descriptive Statistics for ^{238}Pu Concentrations by Sampling Location, µCi/mL x 10^{-18} 3-14
Table 3.5 Descriptive Statistics for $^{239+240}$Pu in Air by Location Type, µCi/mL x 10^{-18} 3-16
Table 3.6 Summary Statistics for $^{239+240}$Pu Concentrations Compared Among NTS Operational Areas, µCi/mL x 10^{-18} 3-16
Table 3.7 Descriptive Statistics for $^{239+240}$Pu Concentrations by Sampling Location, µCi/mL x 10^{-18} 3-17
Table 3.8 Historical $^{239+240}$Pu Annual Averages at Selected Locations, µCi/mL x 10^{-18} 3-18
Table 3.9 Historical ^{238}Pu Annual Averages at Selected Locations, µCi/mL x 10^{-18} 3-18

Table 4.1 1996 Descriptive Statistics by Sampling Station 4-16
Table 4.2 ANOVA on the Natural Log of Tritium in Air Concentrations by Sampling Location 4-16
Table 4.3 Comparison of Station Medians for Significant Differences 4-16
Table 4.4 Historical Annual Station Averages, Tritium in Air (10^{-6} pCi/mL) 4-17

Table 5.1 Summary of Boundary (B) and Control (C) TLD Data for 1996 5-8
Table 5.2 List of Operational Monitoring Thermoluminescent Dosimeter Locations 5-8
Table 5.3 Listing of Atypical TLD Data Values for 1996 5-9
Table 5.4 Descriptive Statistics for TLD Exposure Levels at Environmental Sampling Locations 5-9
Table 5.5 Two-Way ANOVA on 1996 Environmental TLD Data 5-9
Table 5.6 One-Way ANOVA on 1996 Environmental TLD Data 5-10
Table 5.7 Cross Tabulation of Counts and Average mR/day of 1996 Environmental TLD Data 5-10

List of Tables, cont. Page

Table 6.1 Average Annual Millirem per Year for Designated Background and Control Locations 6-6
Table 6.2 One-Way ANOVA on Background Locations for Differences Among Years 6-7
Table 6.3 ANOVA on mR/year for Effects of Years and Operational Areas 6-7

Table 7.1 Descriptive Statistics of 1996 Krypton Data (µCi/mL × 10^{-12}) 7-7
Table 7.2 One-Way ANOVA on Krypton Concentrations for Differences between Stations (µCi/mL × 10^{-12}) 7-7
Table 7.3 NTS Krypton History 7-8

Table 8.1 Descriptive Statistics for Gamma Emitting Radionuclides in Air (µCi/mL) - 1996 8-3
Table 8.2 Descriptive Statistics for Gamma Emitting Radionuclides in Water (µCi/mL) - 1996 8-3
Table 8.3 Descriptive Statistics for Radium in Water (µCi/mL) - 1996 8-3
Table 8.4 Descriptive Statistics for ^{226}Ra in Water by Quarter (µCi/mL x 10^{-9}) - 1996 8-3
Table 8.5 Descriptive Statistics for ^{228}Ra in Water by Quarter (µCi/mL x 10^{-10}) - 1996 8-4
Table 8.6 Descriptive Statistics for ^{90}Sr in Water at Environmental Locations (µCi/mL x 10^{-11}) - 1996 8-4
Table 8.7 Descriptive Statistics for ^{90}Sr in Water From Supply Wells (µCi/mL x 10^{-11}) - 1996 8-4

Table 9.1 Descriptive Statistics for Gross Alpha in Water by Sampling Location, (µCi/mL × 10^{-9}) 9-13
Table 9.2 Descriptive Statistics for Gross Alpha in Water by Quarter of Year, (µCi/mL × 10^{-9}) 9-13
Table 9.3 Kruskal-Wallis Test for Equality of Gross Alpha Results by Type of Water Source 9-14
Table 9.4 Historical Gross Alpha Annual Averages from Selected Sampling Locations, (µCi/mL ×10^{-9}) 9-14
Table 9.5 Descriptive Statistics for Gross Beta in Water by Sampling Location, (µCi/mL × 10^{-9}) 9-15
Table 9.6 Gross Beta in Water Averages by Type of Sampling Location and 1996 Quarter of Sample Collection, (µCi/mL × 10^{-9}) 9-16
Table 9.7 Two Way ANOVA for Differences Between Sample Types and Quarter of Sample Collection on Ln (µCi/mL) - 1996 9-17
Table 9.8 One Way ANOVA for Differences Between Sample Types on Ln (µCi/mL) - 1996 9-17
Table 9.9 Historical Gross Beta Annual Averages for Representative Locations (µCi/mL × 10^{-9}) - 1996 9-17

Table 10.1 Descriptive Statistics for ^{238}Pu in Water by Sampling Location (µCi/mL × 10^{-12}) - 1996 10-4
Table 10.2 Descriptive Statistics for $^{239+240}$Pu in Water by Sampling Location (µCi/mL × 10^{-12}) - 1996 10-5
Table 10.3 Historical ^{238}Pu in Water Annual Averages at Selected Locations (µCi/mL × 10^{-12}) - 1996 10-6
Table 10.4 Historical $^{239+240}$Pu in Water Annual Averages at Selected Locations (µCi/mL × 10^{-12}) - 1996 10-6

List of Tables, cont. Page

Table 11.1 Two-Way ANOVA on Tritium in Effluent and Containment Ponds Response Variable is 1996 Tritium Concentration (µCi/mL × 10^{-6}) 11-4
Table 11.2 Descriptive Statistics for 1996 Tritium in Effluent and Containment Ponds 11-4
Table 11.3 Historical Annual Averages for Tritium in Water at Representative Sampling Locations 11-4

Table 12.1 Personnel Thermoluminescent Dosimetry Results - 1996 12-1
Table 12.2 Environmental Thermoluminescent Dosimetry Results - 1996 12-2
Table 12.3 LTHMP Summary of Tritium Results for Project FAULTLESS - 1996 12-3
Table 12.4 LTHMP Summary of Tritium Results for Project SHOAL - 1996 12-4
Table 12.4 LTHMP Summary of Tritium Results for Project SHOAL - 1996 12-4
Table 12.6 LTHMP Summary of Tritium Results for Project RIO BLANCO - 1996 12-5
Table 12.7 LTHMP Summary of Tritium Results for Project GNOME - 1996 12-5
Table 12.8 LTHMP Summary of Tritium Results for Project GASBUGGY - 1996 12-6
Table 12.9 LTHMP Summary of Tritium Results for Project SALMON - April 1996 12-7

EXECUTIVE SUMMARY

INTRODUCTION

Department of Energy (DOE) Order 5400.1 “General Environmental Protection Program,” establishes environmental protection program requirements, authorities, and responsibilities for DOE operations. These mandates require compliance with applicable federal, state, and local environmental protection regulations. During calendar year (CY) 1996, environmental protection and monitoring programs were conducted at the Nevada Test Site (NTS) and other DOE Nevada Operations Office (DOE/NV) managed sites in Nevada and across the United States. A detailed discussion of these environmental protection and monitoring programs and summary data and assessments for environmental monitoring results are provided in the U.S. DOE/NV Annual Site Environmental Report - 1996 (ASER) DOE/NV/11718-137. This document provides summary data results and detailed assessments for the environmental monitoring conducted for all DOE/NV managed sites in CY 1996. A brief description of the scope of this environmental monitoring is provided below, categorized by “on-NTS” and “off-NTS” monitoring.

ON-NTS ENVIRONMENTAL MONITORING

Environmental monitoring on the 3500 km^2 (1350 mi^2) NTS is designed to cover the entire area with emphasis on areas of past nuclear testing and present operational activities. In CY 1996, monitoring included: (1) air sampling for particulates, tritium in atmospheric moisture, and noble gas; (2) water sampling from supply wells, water taps, natural springs and seeps, open reservoirs, containment ponds, and sewage lagoons; and (3) ambient radiation levels using thermoluminescent dosimeters (TLDs).

AIR MONITORING

Air sampling units for particulates were located at 49 stations on the NTS in 1996. Fourteen of these are located at the Area 5 Radiological Waste Management Site. Sampling filters were changed weekly and analyzed for gross alpha activity, gross beta activity, and by gamma spectroscopy. Additionally, the filters for each sampling location were composited either monthly (for waste management monitoring locations) or quarterly (for environmental monitoring locations) and analyzed for ^{238}Pu and $^{239+240}Pu$ isotopes. Airborne tritiated water (HTO) vapor was sampled at 16 permanent locations throughout the NTS. Samples were collected for two-week periods and analyzed for HTO content. Samples were collected for radioactive noble gas (^{85}Kr) at three permanent locations across the NTS.

WATER MONITORING

Surface water sampling was conducted annually at nine open reservoirs and seven natural springs. An additional six open reservoir locations and one natural spring were dry when visited for sampling. Surface water sampling was conducted quarterly at nine sewage lagoons and two containment ponds. Samples were analyzed for gross alpha, gross beta, tritium, gamma-emitting radionuclides, ^{238}Pu, and $^{239+240}Pu$ activity. Additionally, surface waters were analyzed annually for ^{90}Sr activity.

Water samples were collected quarterly from 12 supply wells and 7 potable water distribution system end points. Samples were analyzed for gross alpha, gross beta, tritium, gamma emitting radionuclides, and plutonium activity. Water supply wells were also analyzed for ^{90}Sr, ^{226}Ra, and ^{228}Ra activity. One annual sample from each potable water distribution end point was also analyzed for ^{90}Sr.

AMBIENT RADIATION LEVELS

Ambient gamma radiation level monitoring was conducted at 179 locations within the NTS in 1996, using Panasonic UD-814™ environmental TLDs. The TLDs were deployed in a holder placed about one meter above ground level and were exchanged quarterly.

OFF-NTS ENVIRONMENTAL MONITORING

Environmental monitoring was conducted in areas adjacent to the NTS and other DOE/NV managed sites, by the U.S. Environmental Protection Agency's (EPA's) Radiation and Indoor Environments National Laboratory, Las Vegas (R&IE-LV). This environmental monitoring included measurements of radioactivity in air, milk, and groundwater.

AIR SAMPLING

The Air Surveillance Network is made up of 20 sampling locations surrounding the NTS. Samples were collected weekly from this network and analyzed for gross alpha, gross beta, and gamma emitting radionuclide activity. Samples from selected locations were composited quarterly and analyzed for ^{238}Pu and $^{239+240}$Pu activity.

MILK SAMPLING

The Milk Surveillance Network consists of 11 sampling locations within 300 km (186 mi) of the NTS. Samples were collected annually from this network and analyzed for tritium, ^{89}Sr, and ^{90}Sr.

GROUNDWATER SAMPLING

Supply wells and surface waters around the NTS were sampled as part of the Long-Term Hydrological Monitoring Program. This program also included groundwater and surface water monitoring at locations in Alaska, Colorado, Mississippi, Nevada, and New Mexico where underground nuclear tests have been previously conducted. Samples from specific locations are collected monthly, biannually, annually, or biennially in accordance with a preset schedule. These samples are analyzed for gamma emitting radionuclides and tritium activity.

AMBIENT RADIATION LEVELS

In CY 1996, ambient gamma radiation levels were monitored by a network of 51 TLDs and 27 pressurized ion chambers (PICs) at locations around the NTS. This network uses Panasonic UD-814™ environmental TLDs (the same as are used for onsite monitoring) and Reuter-Stokes™ Model 1011, 1012, and 1013 PICs. The TLDs were exchanged and processed quarterly. The PICs provided near real-time data. PIC data are collected and transmitted through the Geostationary Operational Environmental Satellite to a receiving station at Los Alamos National Laboratory and then by dedicated telephone lines to R&IE-LV. In addition to telemetry retrieval, PIC data are also recorded at the sampling location on either magnetic tapes and hard copy strip charts, or on magnetic cards.

COMMUNITY TECHNICAL LIAISON PROGRAM

In 1996, the Community Radiation Monitoring Program was renamed the Community Technical Liaison Program. This program consists of a network of 15 monitoring stations located in communities surrounding the NTS and operated by local residents. Each station is a part of the Air Sampling Network, the TLD network, and the real-time PIC network.

REPORTING OF DETECTION LIMITS

1996 was a transition year for the method used in this data report for reporting detection limits. In previous years reports, the sensitivity of the analytical methods to detect the presence of radioisotopes in a sample were quantified using the detection limit. In 1996, a change was initiated to replace the detection limit with the minimum detectable concentration (MDC). In this 1996 data report, the analyses of air samples use the detection limit and the analyses of water samples use the MDC. In subsequent reports, only the MDC will be used. The relationship of these two quantifiers, as defined below, should be kept in mind when evaluating historical data.

The detection limit is defined as the concentration of a radioisotope that is equal to twice the standard deviation of the counting error. The conversion from counts to concentration is included in the computation. Stated as a formula, the detection limit (DL) is:

$$DL = \frac{2 \times s}{K \times E \times R \times T \times S}$$

where:
- s = the standard deviation of the background (blank) count
- K = the conversion constant from disintegrations per minute to units of radioactivity
- E = counting efficiency
- R = chemical recovery
- T = counting time
- S = sample size (volume or weight)

The minimum detectable concentration is defined as the smallest concentration of radioactivity in a sample that can be detected with a 0.05 probability of erroneously detecting radioactivity, when in fact none was present (type I error) and also, a 0.05 probability of not detecting radioactivity, when in fact it is present (type II error). The formula for the MDC, using the same constants as defined above is:

$$MDC = \frac{4.65 \times s + 3}{K \times E \times R \times T \times S}$$

Note that, for any analytical procedure, the MDC is larger than the DL by both a multiplicative factor of 2.3 and an additive constant of $3/(K \times E \times R \times T \times S)$. The +3 in the numerator of the MDC equation is often given as +2.71.