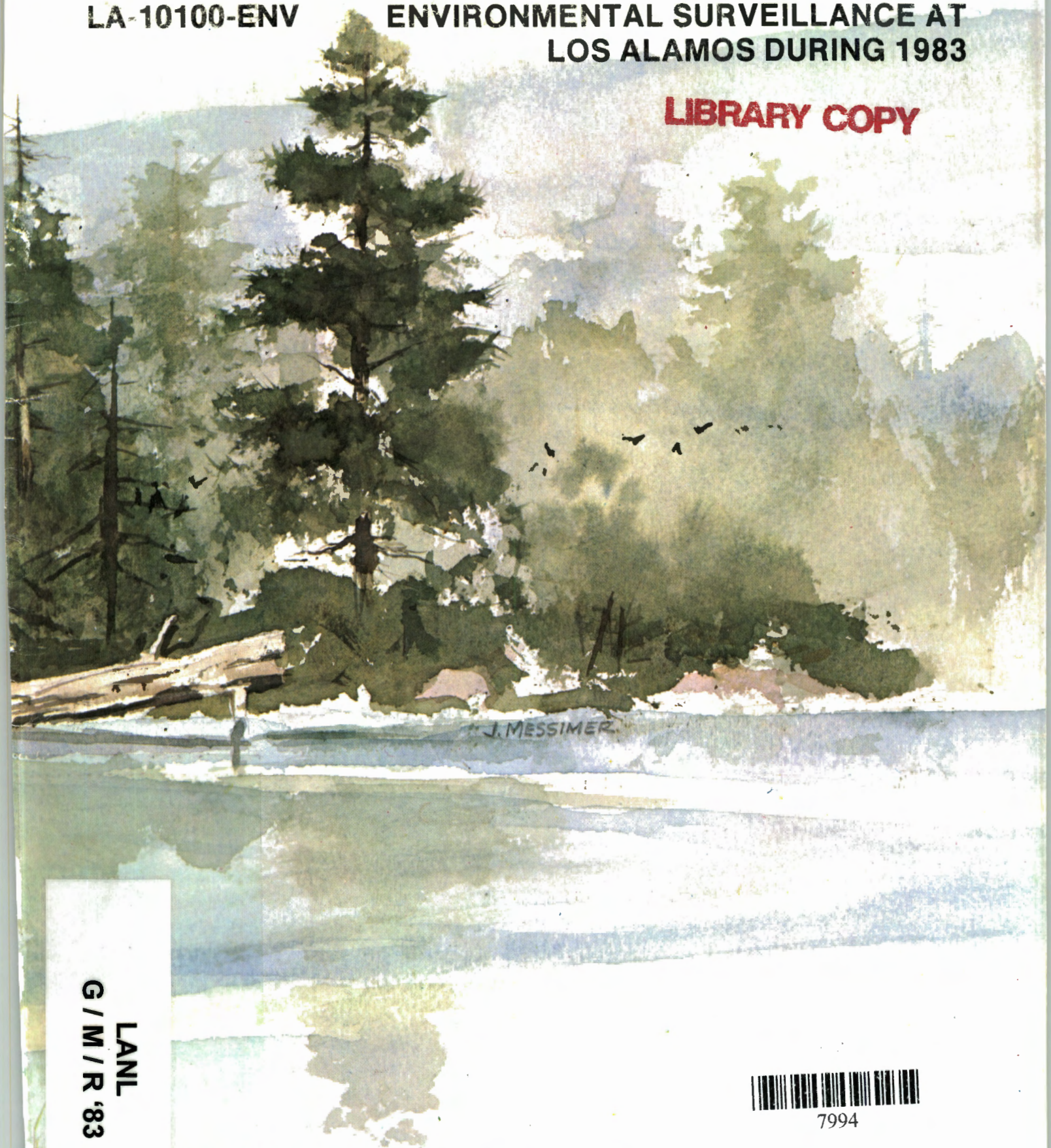
LA-10100-ENV

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1983

LIBRARY COPY



LANL
G / M / R '83

7994

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

Aerial view looking west toward the Jemez Mountains across the Pajarito Plateau, which is cut into numerous narrow mesas by southeast-trending canyons. The Los Alamos townsite is in the center of the photo, the main Laboratory technical area (TA-3) is in the upper left, and the airport is at left center.

RPB. 2373
JUN 04 1984

LA-10100-ENV

UC-41
Issued: April 1984

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1983

Environmental Surveillance Group

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

An Affirmative Action/Equal Opportunity Employer

The four most recent reports in this unclassified series are LA-8200-ENV, LA-8810-ENV, LA-9349-ENV, and LA-9762-ENV.

This report was compiled by the Environmental Surveillance Group HSE-8.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

FOREWORD

Suggestions on How to Read this Report

This report addresses both laypeople and scientists. These people may have a limited or comprehensive interest in this report. We have tried to make it accessible to all without compromising its scientific integrity. Following are directions advising each audience on how best to use this document.

1. **Layperson with Limited Interest.** Read Part I, the Environmental Monitoring Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for this year. Emphasis is on the significance of findings and the results are explained in common language. A glossary is in the back to assist you.

2. **Layperson with Comprehensive Interest.** Follow directions for the "Layperson with Limited Interest" given above. Also, summaries of each section of the report are in boldface type and precede the technical text. Read summaries of those sections that interest you. Further detail is in the text following each summary. Appendix A (Standards for Environmental Contaminants) and Appendix F (Descriptions of Technical Areas and Their Associated Programs) may also be helpful.

3. **Scientist with Limited Interest.** Read Part I, the Environmental Monitoring Summary, to determine the parts of the Laboratory's environmental monitoring program that interest you. You may then read summaries and technical details of these parts in the body of the report. Also, detailed data tables are in Appendix E.

4. **Scientist with Comprehensive Interest.** Read Part I, the Environmental Monitoring Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for this year. Also, read the boldface summaries that head each major subdivision of this report. Further detail is in the text and appendixes.

For further information about this report, contact the Los Alamos National Laboratory's Environmental Surveillance Group (HSE-8):

Los Alamos National Laboratory
P. O. Box 1663
Los Alamos, New Mexico 87545
Attn: Environmental Surveillance Group, Mail Stop K490
Commercial Telephone: (505) 667-5021
Federal Telephone System: 843-5021

ACKNOWLEDGMENTS

This report was compiled by the Environmental Surveillance Group (HSE-8) of the Laboratory's Health, Safety, and Environment Division. Personnel in Group HSE-8 include:

Wayne Hansen, Group Leader
Alan Stoker, Deputy Group Leader
John Ahlquist
Phyllis Baldwin
Naomi Becker
Brent Bowen
George Brooks
Thomas Buhl
Ili Chen
Jean Dewart
Kathy Derouin
Roger Ferenbaugh
Teralene Foxx
Anthony Gallegos
Thomas Gunderson
Keith Jacobsen
Mary Lou Keigher
Karen Kruse
Eddie Lujan
Max Maes
Donald Mayfield
Colleen Olinger
William Olsen
William Purtymun
Kenneth Rea
Richard Romero
John Salazar
Lois Schneider
David Snow
Suzanne Spingler
Charlie Steen
Daniel Talley
Gail Tierney
Mike Trujillo
Donald Van Etten
Lewis Walker
Walter Wenzel

Phyllis Baldwin, Mary Lou Keigher, and Lois Schneider typed the initial draft of this report. Kathy Derouin typed the final draft and did the final typesetting and assembly in a most professional and efficient manner.

The following personnel from the Laboratory's Health and Environmental Chemistry Group (HSE-9) analyzed most of the environmental samples for this report: Ernest Gladney, Colleen Burns, Wanita Eberhardt, Daryl Knab, Carolyn MacDonell, Daniel Perrin, Richard Peters, Nancy Raybold, Richard Robinson, and William Schweitzer.

Thanks to the Laboratory's Environmental Studies Group (LS-6) for descriptions of their environmental research.

Jerry Buchholz and Wally McCorkle of the Laboratory's Waste Management Group (HSE-7) and Frank Guevara of the Laboratory's Health Physics Group (HSE-1) provided data on the types and amounts of liquid effluents and airborne emissions, respectively.

CONTENTS

ABSTRACT 1

I. ENVIRONMENTAL MONITORING SUMMARY 1
A. Monitoring Operations 1
B. Summary of 1983 Results 3
1. Radiation Doses 3
2. Significance of Radiation Doses 3
3. External Penetrating Radiation 4
4. Radioactivity in Air and Water 6
a. Radioactivity in Air 6
b. Radioactivity in Water 7
c. Radioactivity in Other Media 7
6. Other Monitoring Results 7

II. BACKGROUND ON LOS ALAMOS 9
A. Description of the Area 9
1. Geographic Setting 9
2. Land Use 9
3. Geology-Hydrology 9
4. Climatology 13
5. Population Distribution 13
B. Los Alamos National Laboratory 14
1. Programs 14
2. Waste Management 14

III. RADIATION DOSES 15
A. Introduction 15
B. Doses to Individuals from Inhalation of and Exposure to Airborne Emissions 16
C. Doses to Individuals from Liquid Effluents 16
D. Doses to Individuals from Ingestion of Foodstuffs 16
E. Doses to Individuals from External Penetrating Radiation (from Airborne Emissions and Direct Radiation) 18
F. Whole Body Cumulative Doses 19
G. Estimates of Risk to an Individual from Laboratory Releases 19

IV. MONITORING RESULTS 21
A. Radiation and Radioactivity 21
1. External Penetrating Radiation 21
a. Introduction 21
b. Environmental TLD Network 21
c. Los Alamos Meson Physics Facility TLD Network 21
d. TLD Network for Low-Level Radioactive Solid Management Areas 23

2. Atmospheric Radioactivity 23
a. Introduction 23
b. Gross Beta Radioactivity 25
c. Tritium 25
d. Plutonium and Americium 26
e. Uranium 29
3. Radioactivity in Surface and Ground Waters 27
a. Introduction 27
b. Regional and Perimeter Waters 27
c. Onsite Surface and Ground Waters 30
d. Water Supply 30
4. Radioactivity in Soils and Sediments 31
a. Background Levels of Radioactivity in Soils and Sediments 31
b. Regional Soils and Sediments 31
c. Perimeter Soils and Sediments 31
d. Onsite Soils and Sediments 34
e. Radiological Soil Survey Adjacent to TA-35, TA-48, TA-50, and TA-55 . 36
f. Special Regional Soil Analyses 37
5. Transport of Radionuclides in Surface Runoff 38
a. Introduction 38
b. Snowmelt Runoff 38
c. Summer Runoff 40
d. Runoff in the Rio Grande 40
e. Summary 40
6. Radioactivity in Foodstuffs 41
a. Introduction 41
b. Fruits and Vegetables 41
c. Fish 42
d. Honey 43
7. Environmental Surveillance of Low-Level Radioactive Solid Waste Management Facilities 43
a. Introduction 43
b. External Penetrating Radiation Measurements 43
c. Radionuclide Concentrations in Soils and Bedrock 43
d. Air Sampling Results 44
e. Radionuclide Transport in Sediments and Runoff 46
8. Radioactive Airborne Emissions and Liquid Effluents 48
a. Radioactive Airborne Emissions 48
b. Radioactive Liquid Effluents 48
9. Unplanned Releases 49
a. Atmospheric Tritium Releases at TA-33 49
b. Fluoride Gas Release 50
B. Chemical Constituents 51
1. Chemical Quality of Water 51
a. Introduction 51
b. Regional and Perimeter Surface and Ground Waters 52
c. Onsite Surface and Ground Waters 52
d. Water Supply 54

2. Nonradioactive Airborne Emissions and Liquid Effluents 56
a. Particulate Air Quality 56
b. Airborne Emissions 56
c. Liquid Effluents 58
d. Monitoring Rain for Chemical Constituents 58
e. Monitoring Honey Bee Hives 58
C. Meteorology 58
1. Weather Summary 58
2. Wind Roses 60
3. Rainfall Summary 62

V. ENVIRONMENTAL PROTECTION PROGRAMS AT LOS ALAMOS 63
A. Laboratory Environmental Review Committee 63
B. Quality Assurance 63
C. Archeological and Historical Protection 63
D. Toxic and Hazardous Waste Management Program 63

VI. RELATED ENVIRONMENTAL STUDIES 65
A. Delta-Count Rate-Monitoring System 65
B. Development of Water Supply Well PM-5 65
C. Geohydrological Investigations at TA-54 (Area G) 65
1. Introduction 65
2. Construction of Pit 26 67
D. Environmental Monitoring at the Fenton Hill Site 67
1. Introduction 67
2. Chemical Quality of Surface and Ground Water 67
3. Soil and Vegetation Samples 69
E. Distribution of Moisture, Tritium, and Plutonium in the Alluvium, Aquifer, and Underlying Tuff in Mortandad Canyon 69
1. Introduction 69
2. Moisture Distribution 70
3. Tritium Distribution 70
4. Plutonium Distribution 70
5. Summary 71
F. Geochemical Mechanisms of Contaminant Transport 71
G. Transport of Radionuclides from the LAMPF Lagoons 72
H. BIOTRAN Model 72
I. Measurement and Modeling of Gamma Absorbed Doses Due to Atmospheric Releases from Los Alamos Meson Physics Facility 74
1. Introduction 74
2. Results 74
3. Further Study 74
J. The Los Alamos National Environmental Research Park 74
K. Rooting Depth of Vascular Plants 76

REFERENCES 77

APPENDIXES

A. STANDARDS FOR ENVIRONMENTAL CONTAMINANTS 81
B. SAMPLING PROCEDURES AND STATISTICAL TREATMENT OF DATA 85
C. ANALYTICAL CHEMISTRY METHODOLOGY 88
D. METHODS FOR DOSE CALCULATIONS 99
E. ENVIRONMENTAL DATA TABLES 103
F. DESCRIPTIONS OF TECHNICAL AREAS AND THEIR ASSOCIATED PROGRAMS 170
G. PUBLICATIONS OF THE ENVIRONMENTAL SURVEILLANCE GROUP DURING 1983 172

GLOSSARY 174

DISTRIBUTION 178

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1983

by

Environmental Surveillance Group

ABSTRACT

This report documents the environmental surveillance program conducted by the Los Alamos National Laboratory during 1983. Routine monitoring for radiation and radioactive or chemical substances is conducted on the Laboratory site and in the surrounding region to determine compliance with appropriate standards and permit early identification of possible undesirable trends. Results and interpretation of data for 1983 are included on external penetrating radiation; on the chemical and radiochemical quality of ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and on the quantities of airborne emissions and liquid effluents. Comparisons with appropriate standards, regulations, and background levels from natural or other non-Laboratory sources provide a basis for concluding that environmental effects attributable to Laboratory operations are insignificant and are not considered hazardous to the population of the area or Laboratory employees.

I. ENVIRONMENTAL MONITORING SUMMARY

A. Monitoring Operations

Routine monitoring for radiation, radioactive materials, and chemical substances on the Laboratory site and in the surrounding region documents compliance with appropriate standards, identifies undesirable trends, provides information for the public, and contributes to general environmental knowledge. It also helps fulfill the Laboratory's policy to protect the general public, employees, and environment from any harm that could be caused by Laboratory activities and to reduce environmental impacts to the greatest degree practicable. Information from monitoring of the environment complements data on specific releases, such as those from radioactive waste treatment plants and various stacks at nuclear research facilities.

Monitoring and sampling locations for various types of measurements are organized into three main groups. Regional stations are located within the five counties surrounding Los Alamos County (see Fig. 1) at distances up to 80 km (50 mi) from the Laboratory. They provide a basis for determining natural conditions beyond the range for potential influence of Laboratory operations. Perimeter stations are located primarily within about 4 km (2.5 mi) of the Laboratory boundary and emphasize

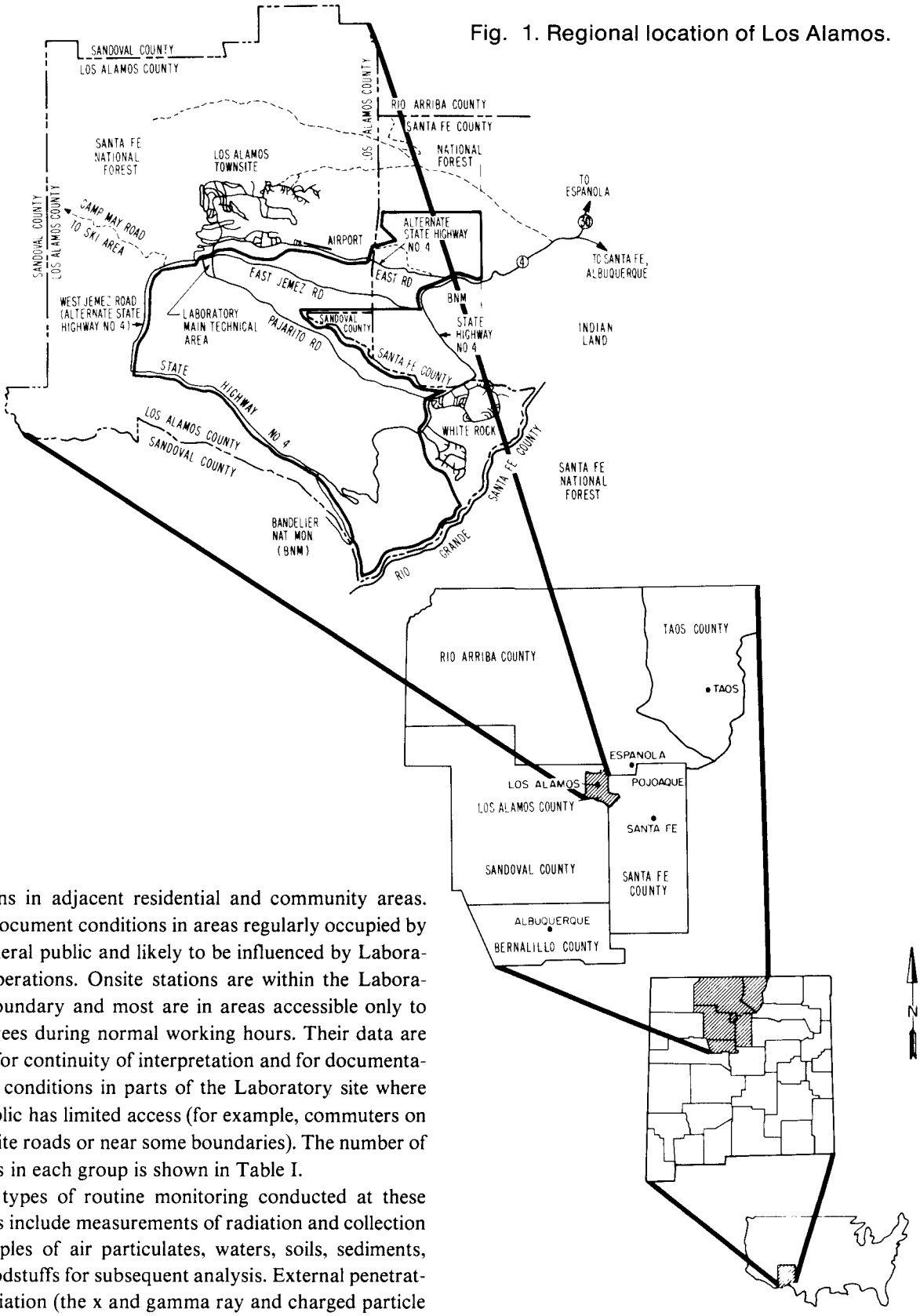


Fig. 1. Regional location of Los Alamos.

locations in adjacent residential and community areas. They document conditions in areas regularly occupied by the general public and likely to be influenced by Laboratory operations. Onsite stations are within the Laboratory boundary and most are in areas accessible only to employees during normal working hours. Their data are useful for continuity of interpretation and for documentation of conditions in parts of the Laboratory site where the public has limited access (for example, commuters on cross-site roads or near some boundaries). The number of stations in each group is shown in Table I.

The types of routine monitoring conducted at these stations include measurements of radiation and collection of samples of air particulates, waters, soils, sediments, and foodstuffs for subsequent analysis. External penetrating radiation (the x and gamma ray and charged particle

Table I

Number of Sampling Locations

Type of Monitoring	Regional	Perimeter	Onsite
External radiation	4	12	139
Air	3	11	12
Surface and ground water[a]	6	33	27
Soils and sediments	16	16	32
Foodstuffs	8	5	9

[a]An additional 23 stations for the water supply and 37 special surface and ground water stations related to the Fenton Hill Geothermal Program were also sampled and analyzed as part of the monitoring program.

contributions from cosmic and terrestrial sources, plus any Laboratory contributions) is also measured by thermoluminescent dosimeters.

Additional samples are collected at various times and locations to gain information about particular events, such as major runoff events in intermittent streams, nonroutine releases, or special studies. During 1983, more than 18 000 analyses for chemical and radiochemical constituents were performed on these environmental samples. Resulting data are used for comparison with standards and background levels of radiation, dose calculations, and other interpretations.

B. Summary of 1983 Results

1. Radiation Doses. Calculated individual whole body radiation doses to the public attributable to Laboratory operations are compared to applicable Radiation Protection Standards in this report. They are expressed as a percentage of the 500 mrem/yr Radiation Protection Standard for whole body radiation. This Radiation Protection Standard is for doses from exposures that exclude contributions from background radiation (cosmic, terrestrial, global fallout, and self-irradiation sources). The doses calculated are those believed to be possible doses to individuals under realistic conditions of exposure.

Calculated maximum boundary doses and maximum individual doses for the past 6 years are shown in Fig. 2. These estimated doses historically have been less than 4% of the 500 mrem/yr standard. In 1983 the estimated maximum individual dose was 6.8% of the Radiation Protection Standard. The increase in this dose between 1982 and 1983 resulted from a combination of increased airborne emissions from the Los Alamos Meson Physics Facility, a shift in the isotopic ratio of the emissions, and a slight change in meteorological conditions. Engineering design modifications (increasing the holdup time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from the airborne activation products have been conceptually designed and included in Laboratory funding requests.

Another perspective is gained by comparing these estimated doses with the estimated whole body dose attributable to background radiation. The highest estimated dose caused from Laboratory operations was about 26% of the dose attributable to naturally occurring radioactivity in Los Alamos in 1983.

2. Significance of Radiation Doses. To provide a perspective for comparing the significance of radiation exposures, estimates of the added risk of cancer were calculated. Increases in risk estimated for average individual exposures to ionizing radiation from 1983 Laboratory operations are in Table II, along with estimated incremental risks from natural and medical diagnostic radiation. The maximum potential Laboratory contribution to cancer risk is small when compared to overall

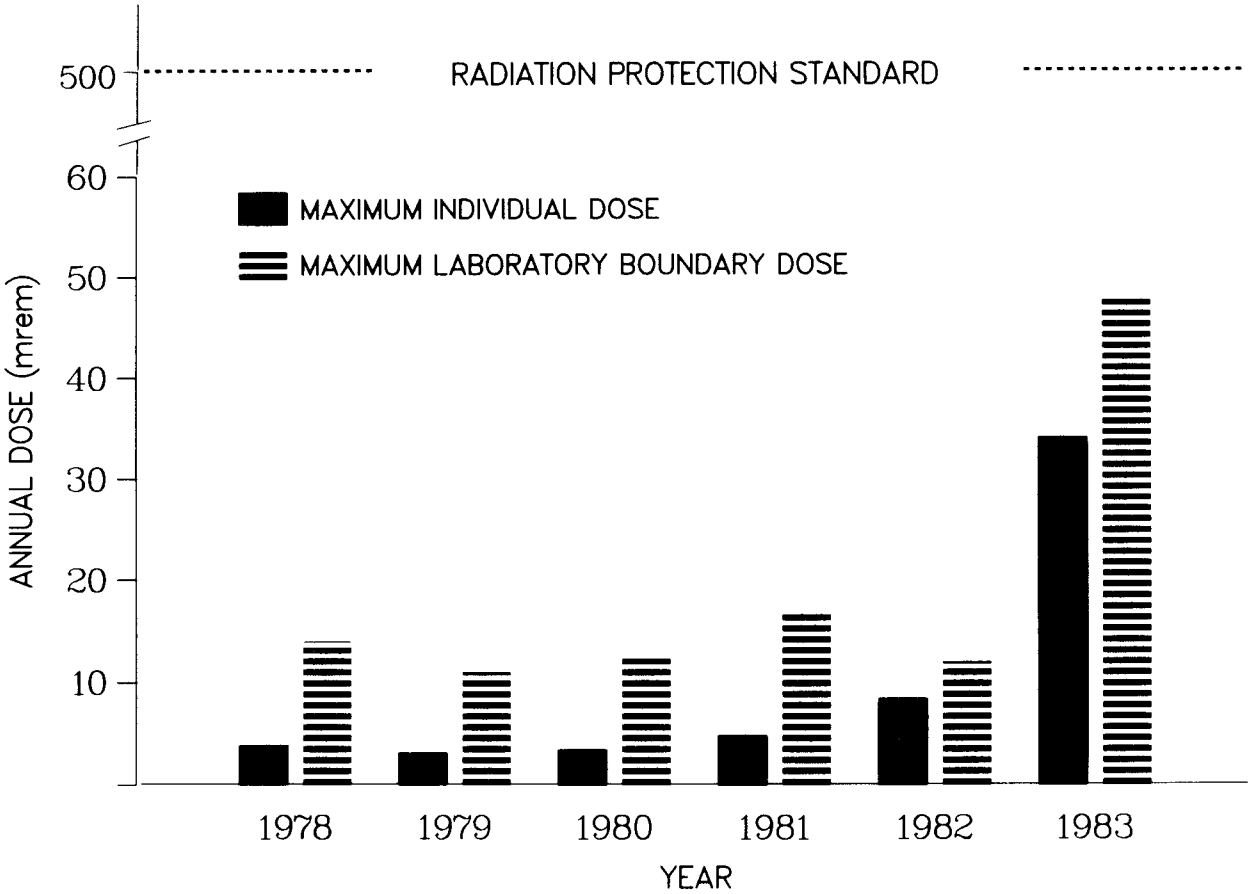


Fig. 2. Summary of estimated maximum individual and maximum Laboratory boundary doses (excluding contributions from cosmic, terrestrial, and medical diagnostic sources) from Laboratory operations.

cancer risks. The overall United States lifetime risks of contracting some form of cancer from all causes is 1 chance in 4. The lifetime risk of cancer mortality is 1 chance in 5. The Los Alamos incremental dose attributable to the 1983 Laboratory operations is equivalent to the additional exposure from cosmic rays a person would get flying in a commercial jet for 1.6 hours.

3. External Penetrating Radiation. Levels of external penetrating radiation (including x and gamma rays and charged particle contributions from cosmic, terrestrial, and manmade sources) in the Los Alamos area are monitored with thermoluminescent dosimeters (TLDs) at 155 locations divided into three networks. The TLD network monitoring radiation from airborne activation products released by the Los Alamos Meson Physics Facility (a linear particle accelerator) measured 48 ± 3 mrem/yr (excludes background radiation from cosmic and terrestrial sources), which is 9.6% of the Department of Energy's Radiation Protection Standard. Figure 3 shows this measurement has increased over the past few years. This trend is primarily from higher operating levels (beam currents) in the particle accelerator. Engineering design modifications (increasing the holdup time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from airborne activation products have been conceptually designed and included in Laboratory funding requests.

Radiation levels (including natural background radiation from cosmic and terrestrial sources) are also measured at regional, perimeter, and onsite locations (Fig. 4) in the environmental network. No measurements at the regional or perimeter locations showed any statistically distinguishable increase in radiation that

Table II

Added Individual Lifetime Cancer Mortality Risks
Attributable to 1983 Radiation Exposure

Exposure Source	Added Risk (Chance) to an Individual of Cancer Mortality	Incremental Dose (mrem) Used in Risk Estimate
Average Exposure from Laboratory Operations		
Los Alamos Townsite	1 in 29 000 000	0.35
White Rock Area	1 in 32 000 000	0.31
Natural Radiation		
Cosmic, Terrestrial, and Self-Irradiation		
Los Alamos Townsite	1 in 76 000	132
White Rock Area	1 in 83 000	121
Medical X-Rays (Diagnostic Procedures)		
Average Whole Body Exposure	1 in 97 000	103

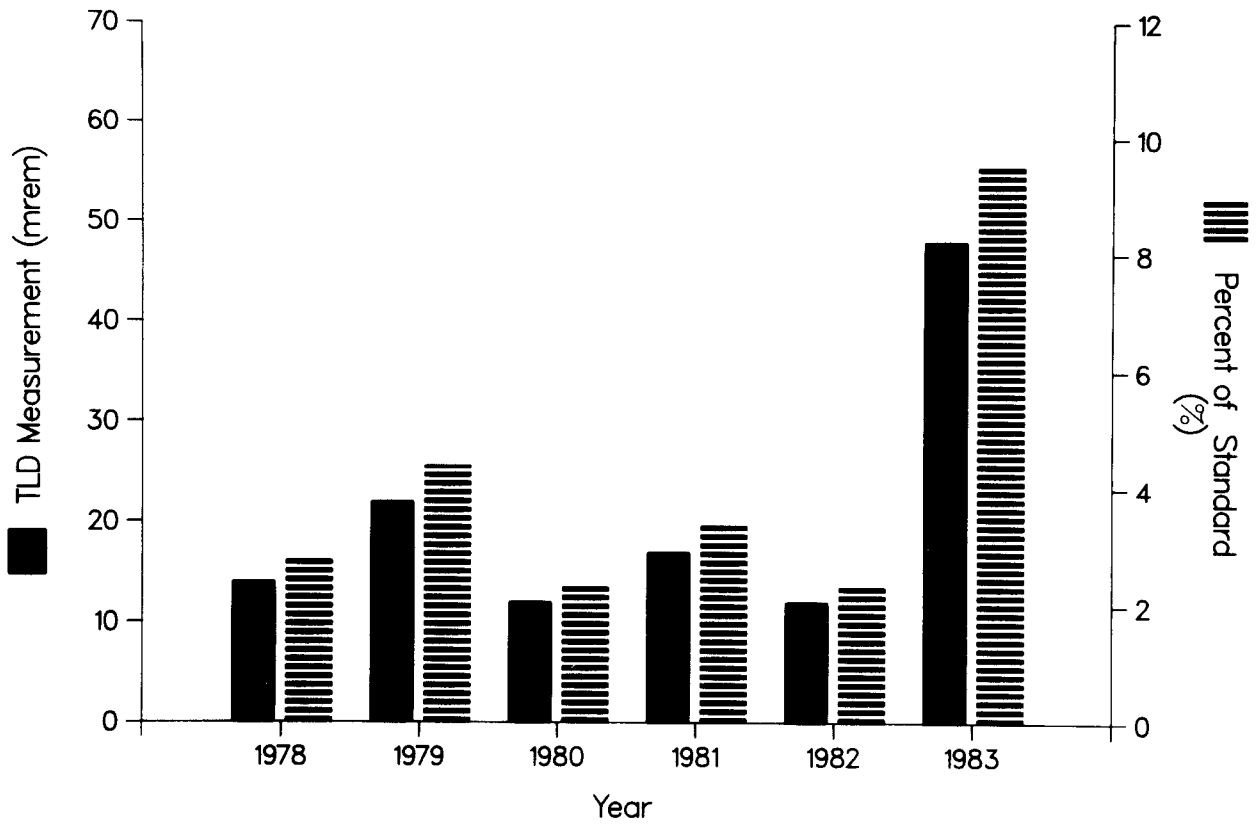


Fig. 3. Annual above-background radiation TLD measurements (and TLD measurements as percent of standard) due to operation of the Los Alamos Meson Physics Facility during the past 6 years.

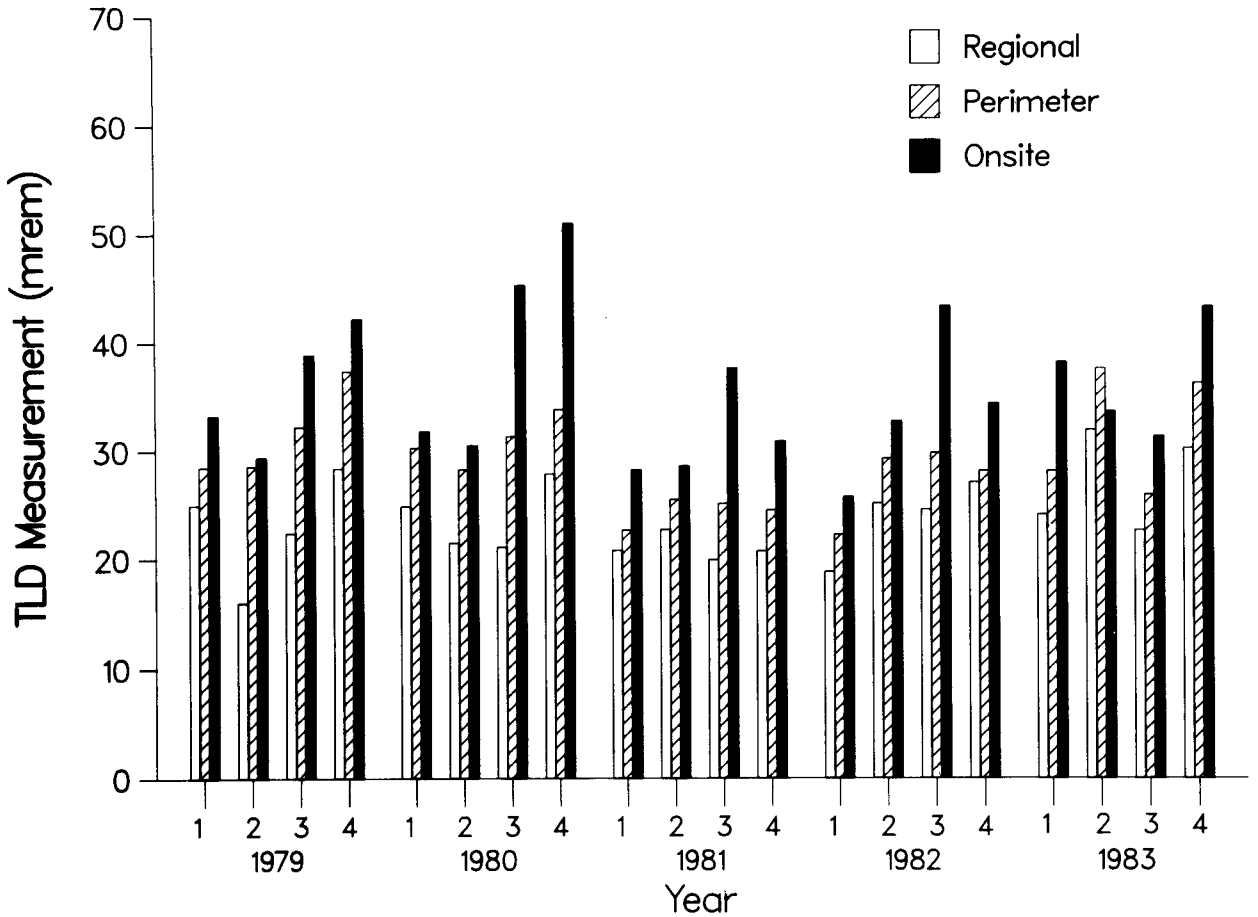


Fig. 4. Quarterly radiation TLD measurements, which include contributions from cosmic, terrestrial, and Laboratory radiation sources, for regional, perimeter, and onsite locations for the past 5 years.

could be attributed to Laboratory operations. Some measurements at onsite stations were slightly above background levels, as expected, reflecting ongoing research activities at the Laboratory.

Radiation levels were measured by a TLD network covering one active and eight inactive low-level radioactive solid waste management areas. The general public is excluded from these waste management sites because they are controlled-access areas. Several transient elevated measurements at the one active site were caused from waste management operations (handling and storing).

4. Radioactivity in Air and Water. Measurements of radioactivity in air and water are compared to standards, known as Concentration Guides, that are set by the Department of Energy (see Appendix A). The Concentration Guides are concentrations of radioactivity in air breathed continuously or water constituting all that is drunk during a year that result in whole body or organ doses equal to the Radiation Protection Standards (standards for external or internal exposure to radioactivity in Appendix A). For 1983 the annual averages (including amounts from cosmic, terrestrial, and global fallout sources) of the principal radionuclides in air and water potentially influenced by Laboratory operations were all less than 1% of the Concentration Guides.

a. Radioactivity in Air. During 1983, atmospheric concentrations of tritium, gross beta, americium, plutonium, and uranium were measured at regional, perimeter, and onsite sampling locations. The annual averages for 1983 for all these radioactive constituents were much less than 1% of the Department of Energy's Concentration

Guides. Only the atmospheric tritium concentrations showed any measurable impact from Laboratory operations. The impart was insignificant and does not pose an environmental or health problem.

b. Radioactivity in Water. Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from Laboratory operations. Only the waters in onsite liquid effluent release areas contain radioactivity in concentrations that are above natural terrestrial and worldwide fallout levels. However, these concentrations are still small fractions of the Concentration Guides. These onsite waters are not a source of industrial, agricultural, or municipal water supplies. Results for the 1983 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite areas (where no effluents are released) indicate no significant effect from effluent releases from the Laboratory.

The water supply met all applicable US Environmental Protection Agency chemical quality and radioactivity standards. The integrity of geological formations protecting the deep ground water aquifer was confirmed by lack of any measurements indicative of nonnatural radioactivity or chemical contamination in municipal water supply sources.

5. Radioactivity in Other Media. Measurements of radioactivity in samples of soils, sediments, and foodstuffs are made to provide information on less direct natural mechanisms that could result in exposures to people. Estimated doses potentially resulting from these mechanisms, or pathways, such as wind resuspension of dust and incorporation into food chains, are summarized in Section I.B.1.

Measurements of radioactivity in soils and sediments are also useful for monitoring and understanding hydrologic transport of some radioactivity that occurs in intermittent stream channels in and adjacent to low-level radioactive waste management areas. Pueblo, Los Alamos, and Mortandad Canyons all have concentrations of radioactivity on sediments at levels higher than those attributable to natural terrestrial or worldwide fallout concentrations. Some radioctivity on sediments in Pueblo Canyon (from pre-1964 effluent disposal) and upper Los Alamos Canyon (from 1952 to current treated effluent disposal) has been transported during runoff events to the Rio Grande. Theoretical estimates, confirmed by measurements, show the incremental effect on Rio Grande sediments is small in comparison with levels of activity on soils and sediments attributable to worldwide fallout and to variability in such measurements. The low levels of radioactivity in Mortandad Canyon are from treated liquid effluents from the treatment plant. No radioactivity on sediments or in water has been transported past the Laboratory boundary in Mortandad Canyon. Radionuclide concentrations in onsite soil samples were at or below natural terrestrial and global fallout background levels.

Most fruit, vegetable, fish, and honey samples from offsite locations showed no increments of radioactivity distinguishable from that attributable to natural sources or worldwide fallout. Fruit from onsite trees had slightly elevated tritium concentrations. A person eating all the fruit from the trees with the maximum tritium concentration would receive a dose of 0.017% of the Department of Energy's Radiation Protection Standard. Game fish samples from Cochiti Reservoir, when compared to samples from the background stations, had slightly higher uranium concentrations. These levels are believed to be caused by natural phenomena. Eating a year's supply of fish with these levels would give a 50-year dose commitment of 0.016% of the Radiation Protection Standard. Doses from eating honey from hives located on Laboratory land would be a maximum of 0.012% of the Radiation Protection Standard.

6. Other Monitoring Results. Airborne radioactive emissions were monitored as released from 84 points at the Laboratory. The results are summarized in Table III and show an approximate 77% increase (about 205 000 Ci more) in total radioactivity released during 1983 versus 1982. Almost all this increase was caused from higher operating levels of the linear particle accelerator at the Los Alamos Meson Physics Facility. This increased the quantities of short-lived (2 to 20 minute half-lives) airborne activation product emissions. Liquid effluents from two radioactive waste treatment plants (Table III) and one sanitary sewage lagoon system contained some radioactivity, all at levels well within the Concentration Guides.

Nonradioactive airborne emissions from the beryllium fabrication shop, gasoline storage and combustion, power plant, gases and volatile chemicals, waste explosive burning, and dynamic testing did not result in any measurable or theoretically calculable degradation of air

quality. A single National Pollutant Discharge Elimination System (NPDES) permit covers 103 industrial discharge points and 11 sanitary sewage treatment facilities. This year 9 of 11 sanitary sewage treatment facilities exceeded one or more of the NPDES limits (biochemical oxygen demand, total suspended solids, fecal coliform, and/or pH) in one or more months. Fewer than 4% of all samples from the domestic and industrial outfalls exceeded NPDES limits.

Table III

Comparison of 1982 and 1983 Radioactive Releases from the Laboratory

Airborne Stack Emissions

Radioactive Constituent	Units	Activity Released 1982	Activity Released 1983	Ratio [1983/1982]
^{241}Am	μCi	0.035	0.095	2.7
^{41}Ar	Ci	342	418	1.2
^{3}H	Ci	15 856	7 847	0.5
^{131}I	μCi	785	83	0.1
^{32}P	μCi	4.8	2.7	0.6
$^{238,239,240}Pu$	μCi	112	113	1.0
U	μCi	1 373	888	0.7
Gaseous Mixed Activation Products	Ci	251 000	461 111	1.8
Mixed Fission Products	μCi	1 184	843	0.7
Particulate/Vapor Activation Products	Ci	182	2 640	14.5
Total	Ci	267 380	472 016	1.8

Liquid Effluents

Radioisotopes	Activity Released (mCi) 1982	Activity Released (mCi) 1983	Ratio [1983/1982]
$^{238,239,240}Pu$	19.9	53.3	2.7
^{241}Am	19	38.4	2.0
$^{89,90}Sr$	25	59.3	2.4
^{3}H	15 330	10 350	0.7
^{137}Cs	210	45.0	0.2
^{234}U	2.1	2.1	1.0
Total	15 606	10 548	0.7

II. BACKGROUND ON LOS ALAMOS

A. Description of the Area

1. Geographic Setting. The Los Alamos National Laboratory and associated residential areas of Los Alamos and White Rock are located in Los Alamos County in northcentral New Mexico, approximately 100 km (60 mi) NNE of Albuquerque and 40 km (25 mi) NW of Santa Fe (Fig. 1). The 111 km^2 (27 500 acres) Laboratory site and adjacent communities are situated on Pajarito Plateau. The Plateau consists of a series of finger-like mesas separated by deep east-west oriented canyons cut by intermittent streams. The mesa tops range in elevation from approximately 2400 m (7800 ft) at the flank of the Jemez Mountain to about 1800 m (6200 ft) on their eastern margin terminating above the Rio Grande valley.

All Los Alamos County and vicinity locations referenced in this report are identified by the Laboratory cartesian coordinate system, which is based on English units of measurement. This system is standard throughout the Laboratory, but is independent of the US Geological Survey and New Mexico State Survey coordinate systems. The major coordinate markers shown on the maps are at 3048 km (10 000 ft) intervals, but for the purpose of this report are identified to the nearest 0.30 km (1000 ft). The area within the Laboratory boundary is controlled by the Department of Energy, which has the option to completely restrict access. This control can be instituted when necessary.

2. Land Use. Most Laboratory and community developments are confined to mesa tops (see Fig. 5 and inside front cover). The surrounding land is largely undeveloped with large tracts of land north, west, and south of the Laboratory site held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, General Services Administration, and Los Alamos County (see land ownership map inside back cover). The San Ildefonso Pueblo borders the Laboratory to the east.

Laboratory land is used for building sites, test areas, waste disposal locations, roads, and utility rights-of-way. However, these account for only a small fraction of the total land area. Most land provides isolation for security and safety and as reserves for future structure locations. A long range site development plan (Engineering 1982) for Laboratory lands helps assure adequate planning for the best possible uses of available land in the future.

Limited access by the public is allowed in certain areas of the Laboratory reservation. An area north of Ancho Canyon between the Rio Grande and State Road 4 is open to hikers, rafters, and hunters, but woodcutting and vehicles are prohibited. Portions of Mortandad and Pueblo Canyons are also open to the public. An archeological site (Otowi Tract) northwest of State Road 4 is open to the public subject to the restrictions of the Antiquities Act.

3. Geology-Hydrology. Most of the finger-like mesas in the Laboratory area are formed by Bandelier Tuff (see Fig. 6, tuff). This is ashfall and ashfall pumice and rhyolite tuff that form the surface of Pajarito Plateau. The tuff ranges from nonwelded to welded and is in excess of 300 m (1000 ft) thick in the western part of Pajarito Plateau and thins to about 80 m (260 ft) toward the east above the Rio Grande. It was deposited as a result of a major eruption of a volcano in the Jemez Mountains to the west about 1.1 to 1.4 million years ago.

The tuffs lap onto older volcanics of the Tschicoma Formation, which form the Jemez Mountains along the western edge of the Plateau. They are underlain by the conglomerate of the Puye Formation (see Fig. 6, conglomerate) in the central and eastern edge along the Rio Grande. Chino Mesa basalts (see Fig. 6, basalt) interfinger with the conglomerate along the river. These formations overlie the siltstone/sandstone Tesuque Formation (see Fig. 6, sediments), which extends across the Rio Grande valley and is in excess of 1000 (3300 ft) thick.

Los Alamos area surface water is primarily in intermittent streams. Springs on flanks of the Jemez Mountains supply base flow to upper reaches of some canyons, but the amount is insufficient to maintain surface flows across Laboratory area before it is depleted by evaporation, transpiration, and infiltration. Runoff from heavy thunderstorms or heavy snowmelt reaches the Rio Grande several times a year. Effluents from sanitary sewage, industrial waste treatment plants, and cooling tower blowdown are released to some canyons at rates sufficient to maintain surface flows for as long as about 1.5 km (1 mi).

Ground water occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in canyons, (2) perched water (a ground water body above an

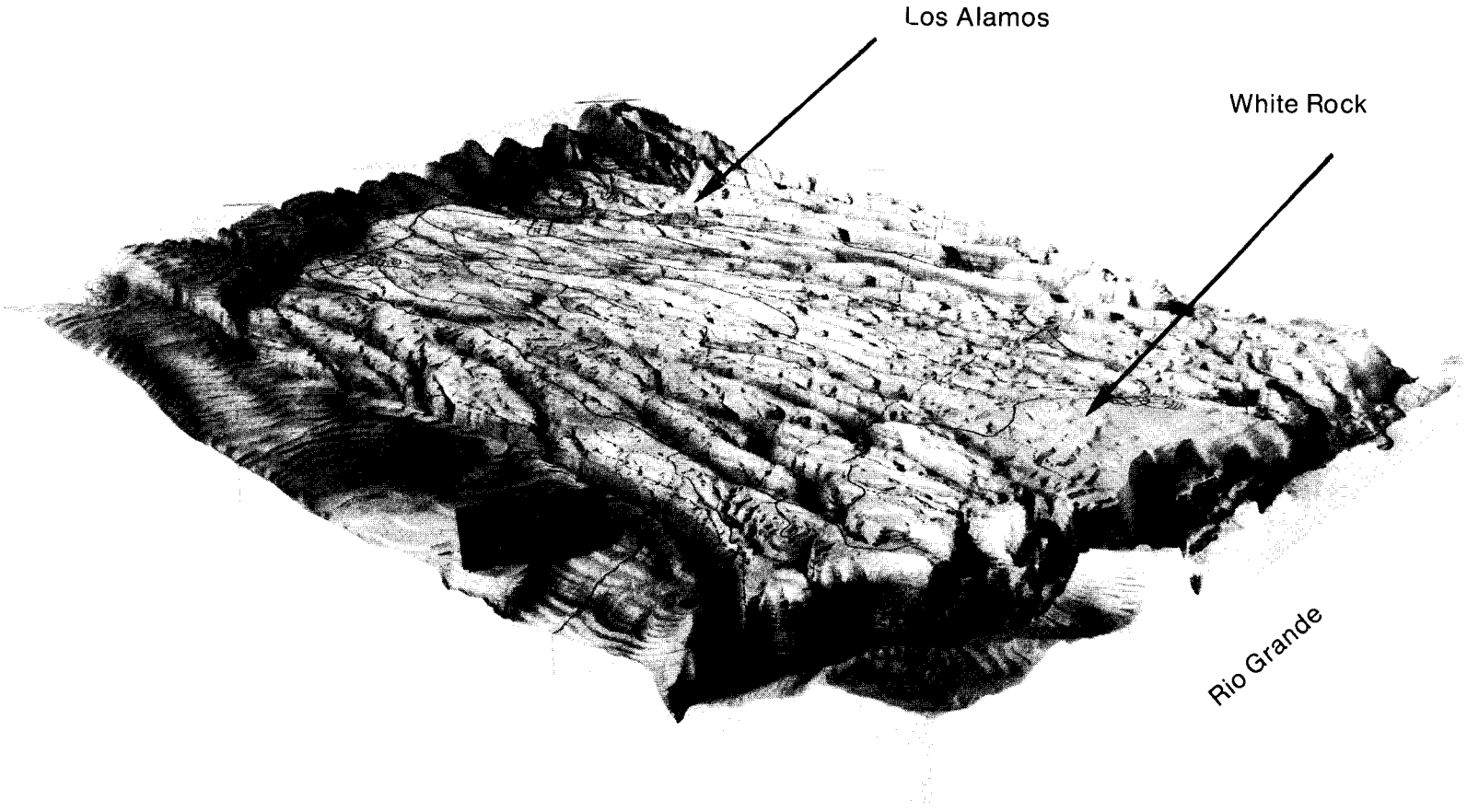


Fig. 5. Topography of the Los Alamos area.

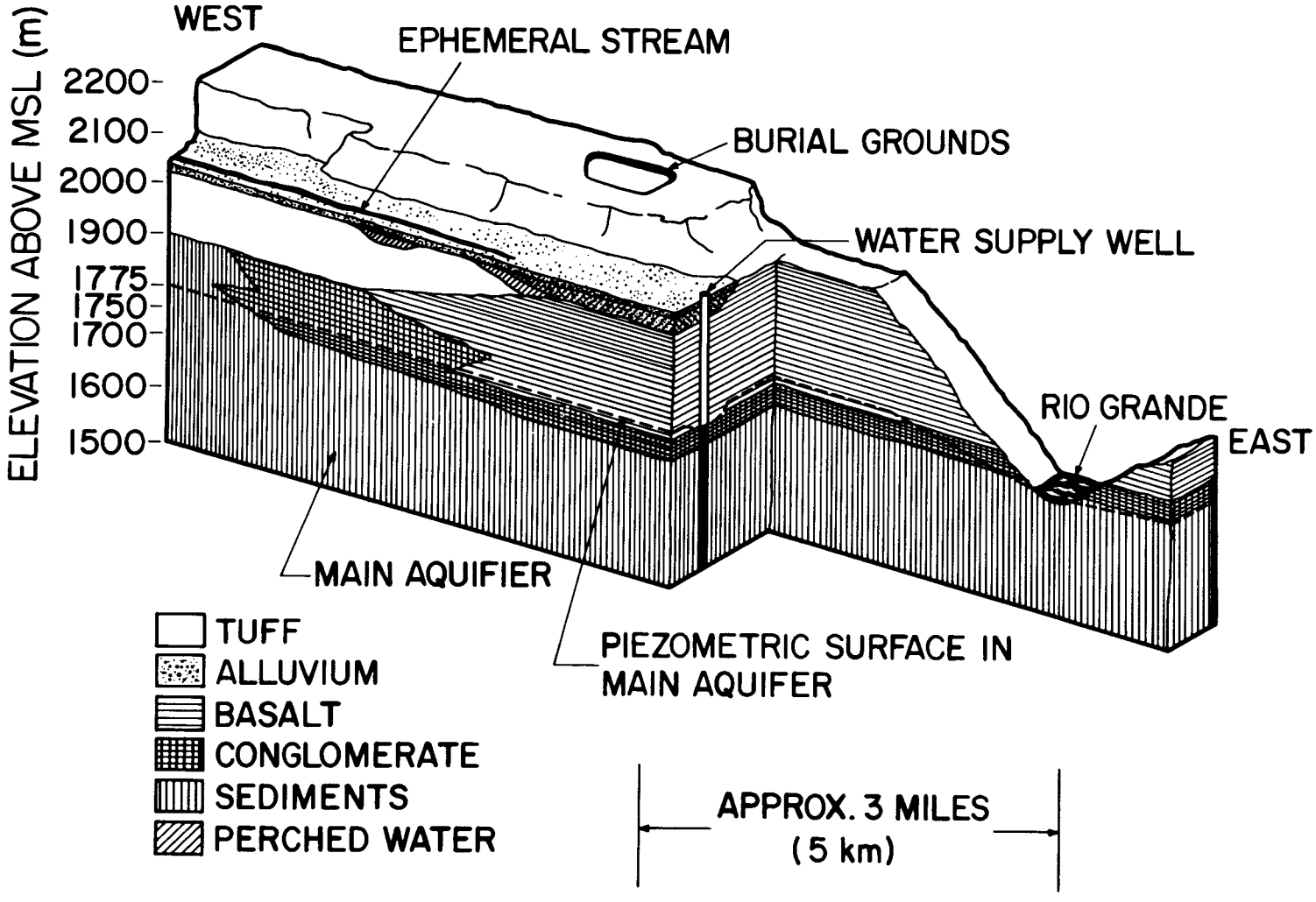


Fig. 6. Conceptual illustration of geologic-hydrologic relationships in the Los Alamos area.

impermeable layer that is separated from an underlying main body of ground water by an unsaturated zone), and (3) the main aquifer of the Los Alamos area (see Fig. 6, alluvium, perched water, and main aquifer).

Intermittent stream flows in canyons of the Plateau have deposited alluvium that ranges from less than 1 m (3 ft) to as much as 30 m (100 ft) in thickness. The alluvium is quite permeable, in contrast to the underlying volcanic tuff and sediments. Intermittent runoff in canyons infiltrates alluvium until its downward movement is impeded by the less permeable tuff and volcanic sediment. This results in a shallow alluvial ground water body that moves downgradient in the alluvium. As water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into underlying volcanics (Purtymun 1977).

Perched water occurs in one limited area about 40 m (120 ft) beneath the mid-reach of Pueblo Canyon and in a second area about 50 to 70 m (150 to 200 ft) beneath the surface in lower Pueblo and Los Alamos Canyons near their confluence. The second area is mainly in the basalts (see Fig. 6, perched water and basalt) and has one discharge point at Basalt Springs in Los Alamos Canyon.

The main aquifer of the Los Alamos area is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the Plateau. Depth to the aquifer decreases from 360 m (1200 ft) along the western margin of the Plateau to about 180 m (600 ft) at the eastern margin. The main aquifer is isolated from alluvial water and perched water by about 110 to 190 m (350 to 620 ft) of dry tuff and volcanic sediments. Thus, there is no hydrologic connection or potential for recharge to the main aquifer from alluvial or perched water.

Water in the main aquifer is under water table conditions in the western and central part of the Plateau and under artesian conditions in the eastern part and along the Rio Grande (Purtymun 1974B). The major recharge area to the main aquifer is from the intermountain basin of the Valles Caldera in the Jemez Mountains west of Los Alamos (see Fig. 1 and inside front cover). The water table in the Caldera is near land surface. The underlying lake sediment and volcanics are highly permeable and recharge the aquifer through Tschicoma Formation interflow breccias (rock consisting of sharp fragments embedded in a fine-grained matrix) and the Tesuque Formation. The Rio Grande receives ground water discharge from springs fed by the main aquifer. The 18.4 km (11.5 mi) reach of the river in White Rock Canyon between Otowi Bridge and the mouth of Rito de Frijoles receives an estimated 5.3 to 6.8 $\times 10^3$ m^3 (4300 to 5500 acre-feet) annually from the aquifer.

4. Climatology. Los Alamos has a semiarid, temperate mountain climate. The average annual precipitation is nearly 18 in. (45 cm). Forty per cent of the annual precipitation occurs during July and August due to thundershowers. The rest of the precipitation is from winter storms moving through New Mexico. Winter precipitation falls primarily as snow, with accumulations of about 51 in. (130 cm) annually.

Summers are generally sunny with moderately warm days and cool nights. Maximum temperatures are usually below 90°F (32°C). Brief afternoon and evening thundershowers are very common, especially in July and August. The high altitude, light winds, clear skies, and dry atmosphere allow night temperatures to drop below 60°F (16°C) after even the warmest days. Winter temperatures typically range from about 15 to 25°F (−10 to −4°C) during the night to 30 to 50°F (−1 to 10°C) during the day. Occasionally, temperatures drop to near 0°F (−18°C) or below. Many winter days are clear with light winds, so strong sunshine can make conditions quite comfortable even when air temperatures are cold. Snowstorms with accumulations exceeding 4 in. (10 cm) are quite common in Los Alamos.

Surface winds in Los Alamos often vary dramatically with time-of-day and with location because of complex terrain. With light, large-scale winds and clear skies, a distinct daily wind cycle often exists: a light southeasterly upslope wind during the day and a light westerly drainage wind during the night. However, several miles to the east toward the edge of Pajarito Plateau, near the Rio Grande Valley, a different daily wind cycle is common: a moderate southwesterly up-valley wind during the day and a light down-valley wind during the night. On the whole, the predominant winds are southerly to westerly over Los Alamos County.

Historically, no tornadoes have been reported to have touched down in Los Alamos County. However strong dust devils can potentially produce strong winds up to 75 mph (120 km/h) or so at isolated spots in the county, especially at lower elevations. Strong winds with gusts exceeding 60 mph (97 km/h) are common and widespread during the spring. Lightning is very common over Pajarito Plateau. There are 58 thunderstorm days during

an average year, with most occurring during the summer. Lightning protection is an important design factor for most facilities at the Laboratory. Hail damage can also occur. Hailstones with diameters up to 0.25 in. (0.6 cm) are common, while 0.5 in. (1.2 cm) diameter hailstones are rather rare.

5. Population Distribution. Los Alamos County has an estimated 1983 population of 18 500 (based on the 1980 census adjusted for 1983). Two residential and related commercial areas exist in the county (see Fig. 7 and inside back cover). The Los Alamos townsite, the original area of development (and now including residential areas known as the Eastern Area, the Western Area, North Community, Barranca Mesa, and North Mesa), has an estimated population of 11 604. The White Rock area (including the residential areas of White Rock, La Senda, and Pajarito Acres) has about 6896 residents. About one-third of those employed in Los Alamos commute from other counties. Population estimates for 1983 place about 162 000 people within an 80 km (50 mi) radius of Los Alamos.

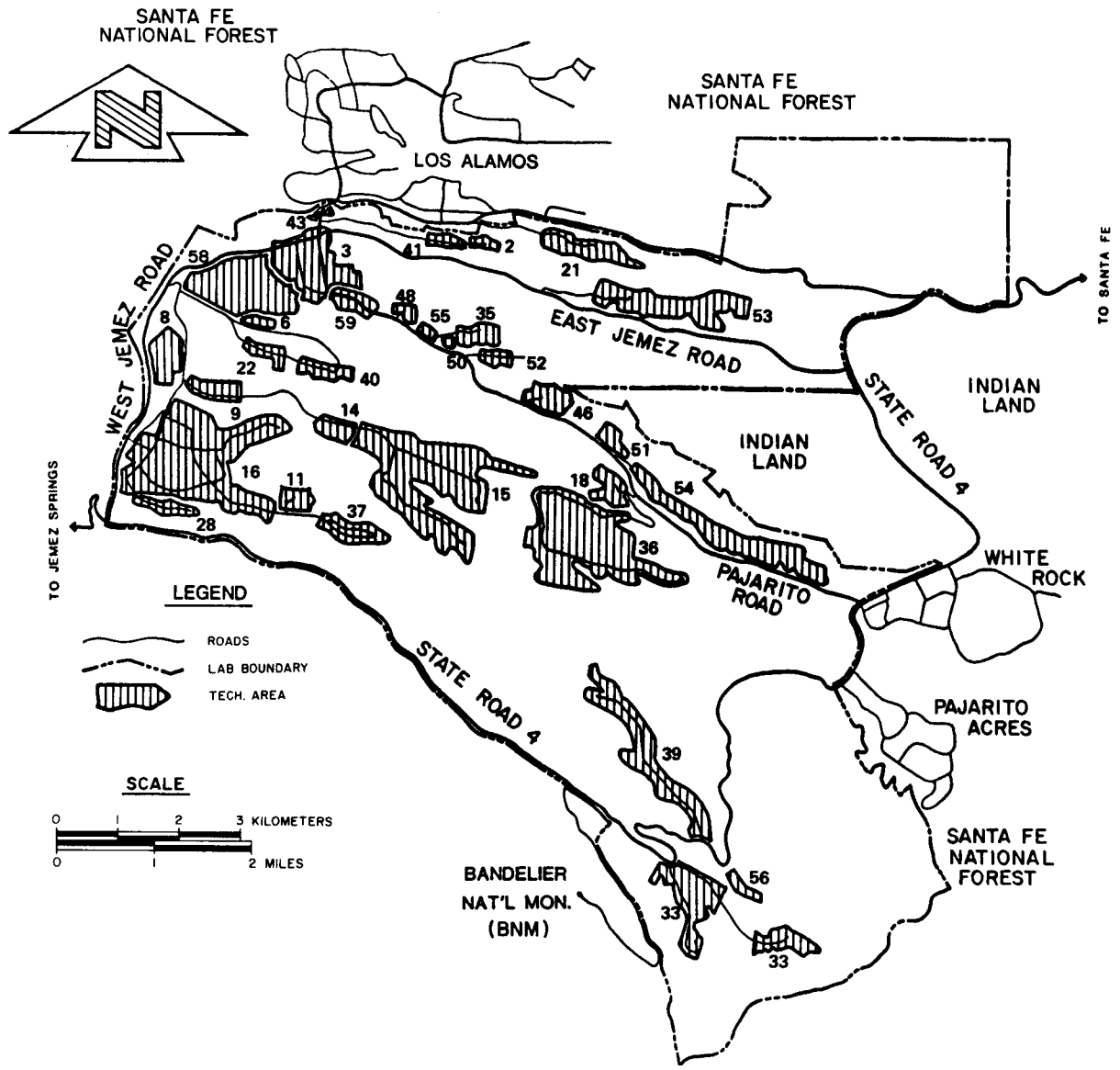


Fig. 7. Los Alamos National Laboratory's technical areas and adjacent communities.

B. Los Alamos National Laboratory

1. Programs. Since its inception in 1943, the Laboratory's primary mission has been nuclear weapons research and development. Programs include weapons development, magnetic and inertial fusion, nuclear fission, nuclear safeguards and security, and laser isotope separation. There is also basic research in the areas of physics, chemistry, and engineering that support such programs. Research on peaceful uses of nuclear energy has included space applications, power reactor programs, radiobiology, and medicine. Other programs include applied photochemistry, astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, computer sciences, solar energy, geothermal energy, biomedical and environmental research, and nuclear waste management research.

In August 1977 the Laboratory site, encompassing 111 km^2 (27 500 acres), was dedicated as a National Environmental Research Park. The ultimate goal of programs associated with this regional facility is to encourage environmental research that will contribute understanding of how man can best live in balance with nature while enjoying the benefits of technology. Park resources are available to individuals and organizations outside of the Laboratory to facilitate self-supported research on these subjects deemed compatible with the Laboratory programmatic mission (DOE 1979).

A Final Environmental Impact Statement (DOE 1979) that assesses potential cumulative environmental impacts associated with current, known future, and continuing activities at the Laboratory was completed in 1979. The report provides environmental input for decisions regarding continuing activities at the Laboratory. It also provides detailed information on the environment of the Los Alamos area.

The Laboratory is administered by the University of California for the Department of Energy. The Laboratory's environmental program, conducted by the Environmental Surveillance Group, is part of a continuing investigation and documentation program.

2. Waste Management. The Laboratory's activities are conducted in 32 active technical areas (TAs) distributed over the site (see Fig. 7 and Appendix F for descriptions of activities at the TAs). Wastes requiring disposal are generated at virtually all these locations. Sanitary sewage is handled by a number of plants employing conventional secondary treatment processes or by septic tanks. Uncontaminated solid waste is disposed of in the County-operated landfill located within the Laboratory boundary. Nonradioactive airborne emissions include combustion products from the power and steam plants, vapors or fumes from numerous local exhaust systems (such as chemistry laboratory hoods), and burning of high-explosive wastes.

Most liquid radioactive and chemical laboratory waste effluents are routed to either of two waste treatment facilities by a collection system that is independent from the sanitary sewage system. The balance of such wastes from remote locations is accumulated in holding tanks and periodically collected and transported to a treatment plant for processing. Radioactivity is removed by physicochemical processes that produce a concentrated sludge that is subsequently handled as solid radioactive waste. The treated effluents are released to canyons.

From 90 to 95% of the total volume of radioactively contaminated solid waste from the Laboratory is disposed of by burial at a waste disposal area (TA-54). The remaining 5 to 10% is classed as transuranic waste and stored retrievably also at TA-54. Buried wastes are confined from the environment by placing packaged wastes in pits or shafts excavated within the dry geologic formation of the burial ground. Stored wastes are packaged in steel drums or fiberglass-reinforced, plastic-coated, wooden crates. These packages are then placed in crushed tuff berms or in concrete casks, which are in turn placed in trenches.

Airborne radioactive emissions are discharged from a number of facilities after receiving appropriate treatment, such as filtration for particulates, catalytic conversion and adsorption of tritium, or temporary holdup to permit decay of short-lived activation gases.

III. RADIATION DOSES

Some incremental radiation doses—above those received from natural background, worldwide fallout, and medical diagnostic procedures— are received by Los Alamos County residents as a result of Laboratory operations. The largest estimated dose at an occupied location was 34 mrem or 6.8% of the Radiation Protection Standard. This estimate is based on boundary dose measurements of airborne and scattered radiation from the linear particle accelerator at the Los Alamos Meson Physics Facility. Other minor exposure pathways may result in several mrem/yr doses to the public.

No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. Most of the radioactivity is absorbed in alluvium inside the Laboratory boundaries. Some is transported offsite in stream channel sediments during heavy runoff. However, the radioactivity levels in these sediments are just slightly above natural background levels.

The total cumulative whole-body dose received by the population living within 80-km of the Laboratory during 1983 was conservatively estimated to be 7.3 person-rem. This is about 0.04% of the 20 000 person-rem received by the same population from natural radiation sources and 0.04% of the 17 000 person-rem dose received from diagnostic medical procedures. About 90% of this dose, 6.6 person-rem, was received by persons living in Los Alamos County. This dose is 0.3% of the 2400 person-rem received by the population of Los Alamos County from natural background radiation and 0.4% of the 1900 person-rem from diagnostic medical procedures.

The average added risk of cancer mortality to Los Alamos townsite residents from radiation from this year's Laboratory operations is 1 chance in 29 000 000. This risk is much less than the 1 chance in 76 000 from background radiation. The Environmental Protection Agency has estimated average lifetime risk for cancer incidence as 1 chance in 4 and for cancer mortality as 1 chance in 5.

A. Introduction

One way to evaluate the significance of environmental releases of radioactivity is to compare doses received by the public from exposure to these releases with appropriate standards (DOE 1981A) and with doses from background radiation (radiation from cosmic, terrestrial, global fallout, and self-irradiation sources). The principal exposure pathways considered for the Los Alamos area were atmospheric transport of airborne radioactive emissions, hydrologic transport of liquid effluents, food chains, and direct exposure to external penetrating radiation. Exposures to radioactive materials or radiation in the environment were determined by direct measurements of some airborne and waterborne contaminants and of external penetrating radiation. Theoretical dose calculations based on atmospheric dispersion were made for other airborne emissions present at levels too low for direct measurement.

Doses were calculated from measured or derived exposures using models based on recommendations of the International Commission on Radiological Protection (see Appendix D for details) for each of the following categories (DOE 1981B).

1. *Maximum Boundary Dose:* Maximum dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the individual is outdoors at the Laboratory boundary continuously (24 hours a day, 365 days a year).

2. *Maximum Individual Dose:* Maximum dose to an individual at or outside the Laboratory boundary where the highest dose rate occurs and where there is a person. It takes into account occupancy (for example, 40 hours a week) and shielding (for example, by buildings) factors.
3. *Average Dose:* Average doses to nearby residents.
4. *Whole Body Cumulative Dose:* The whole body cumulative dose for the population within an 80 km radius of the Laboratory.

The maximum boundary dose and maximum individual dose over the past 5 years are summarized in Fig. 2. Over 95% of each of these doses occurs because of emissions of air activation products from the Los Alamos Meson Physics Facility.

In addition to compliance with dose guidelines, which define an upper limit for doses to the public, there is a concurrent commitment to maintain radiation exposure to individuals and population groups to levels as low as reasonably achievable (ALARA). This policy is followed at the Laboratory by applying strict controls on airborne emissions, liquid effluents, and operations to minimize doses to the public and to limit releases of radioactive materials to the environment. Ambient monitoring described in this report documents the effectiveness of these controls.

B. Doses to Individuals from Inhalation of and Exposure to Airborne Emissions

The maximum boundary and individual doses attributable to inhalation of and exposure to airborne releases are summarized in Table IV and compared with the Radiation Protection Standards for individual doses (see Appendix A).

Exposure to airborne ^{3}H (as tritiated water vapor) was determined by actual measurements. A background correction was made assuming that natural cosmic and worldwide fallout activity was represented by data from the three regional sampling locations at Española, Pojoaque, and Santa Fe.

Exposures to ^{11}C, ^{13}N, ^{14}O, ^{15}O, and ^{41}Ar from the Los Alamos Meson Physics Facility were inferred from direct radiation measurements (see Section IV.A.1). Exposure from ^{41}Ar released from the stack of a research nuclear reactor at TA-2 was theoretically calculated from measured stack releases and standard atmospheric dispersion models. These models used 1983 meteorological data measured at the Laboratory (see Section IV.C and Appendix D). Doses from these exposures are discussed in Section III.E.

Estimates of maximum exposures (Table IV) to plutonium, americium, and uranium were calculated by subtracting the average concentration at the regional stations from the average concentration from the perimeter station with the highest measured concentration for each of these radionuclides.

All other atmospheric releases of radioactivity (Table E-I) were evaluated by theoretical calculations. All potential doses from these other releases were less than the smallest ones presented in this section and were thus considered insignificant.

C. Doses to Individuals from Liquid Effluents

Liquid effluents do not flow beyond the Laboratory boundary but are absorbed in alluvium of the receiving canyons. These effluents are monitored at their point of discharge and their behavior in the alluvium of the canyons below outfalls has been studied (Hakonson 1976A, Hakonson 1976B, Purtymun 1971A, and Purtymun 1974A).

Small quantities of radioactive contaminants transported during periods of heavy runoff have been measured in canyon sediments beyond the Laboratory boundary. Calculations made for the radiological survey of Acid, Pueblo, and Los Alamos Canyons (ESG 1981) indicate a potential exposure pathway (eating liver from a steer that drinks water from and grazes in lower Los Alamos Canyon) to man from these canyon sediments results in a maximum 50-year dose commitment of 0.0013 mrem to the bone, 0.0001% of the Radiation Protection Standard (DOE 1981A).

D. Doses to Individuals from Ingestion of Foodstuffs

Data from sampling of fruit, vegetables, fish and honey during 1983 (see Section IV.A.5 for a discussion of the sampling data) were used to estimate doses caused from eating these foodstuffs. All calculated doses are less than 0.8% of the Radiation Protection Standard (DOE 1981A).

The fruit and vegetable samples were analyzed for six radionuclides (^{3}H, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and total U), but only the tritium in fruit at the three onsite locations and the uranium in the fruit at one onsite location were significantly above background. An adult

Table IV

Estimated Maximum Boundary and Individual Doses from 1983 Airborne Radioactivity

Isotope	Critical Organ	Estimated Maximum Boundary Dose[a]		Estimated Maximum Individual Dose[b]		
		Location	Estimated Dose (mrem/yr)	Location	Estimated Dose (mrem/yr)	Percentage of Radiation Protection Standard
^{3}H	Whole Body	TA-33 (Station 24)[c]	0.03	Bandelier (Station 14)[c]	0.02	0.004
^{11}C, ^{13}N, ^{14}O, ^{15}O	Whole Body	Boundary N. of TA-53[d]	48	East Gate (Station 6)[c]	34	6.8
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack[d]	0.4	Apts. N. of TA-2 Stack[d]	0.4	0.08
U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am[e]	Lung	Booster P-2 (Station 21)[c]	0.002	48th Street (Station 7)[c]	0.01	0.0007

[a]Estimated maximum boundary dose is the dose from Laboratory operations (excluding dose contributions from cosmic, terrestrial, medical diagnostics, and other non-Laboratory sources) to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the individual is outdoors at the Laboratory boundary continuously (24 hours a day, 365 days a year).

[b]Estimated maximum individual dose is the dose from Laboratory operations (excluding dose contributions from cosmic, terrestrial, medical diagnostics, and other non-Laboratory sources) to an individual at or outside the Laboratory boundary where the highest dose rate occurs and where there is a person. It takes into account occupancy (for example, 168 hours a week) and shielding (for example, by buildings) factors.

[c]See Fig. 10 for station locations.

[d]See Fig. 7 for technical area (TA) locations.

[e]For a 50-yr dose commitment, bone is the critical organ for ^{238}Pu, $^{239,240}Pu$, and ^{241}Am. A maximum exposed individual (at Bandelier, Station 14) would receive a 50-yr bone dose commitment of 0.02 mrem, which is 0.001% of the annual Radiation Protection Standard.

getting half of his or her fruit annual consumption (57 kg) from these trees would receive a whole body dose from tritium of 0.085 mrem and a 50-year bone dose from uranium of 0.15 mrem. These doses are 0.017% and 0.010%, respectively, of the Radiation Protection Standards.

Samples of the edible portions of game fish and of the inedible portions (guts) of bottom feeders showed slightly higher uranium concentrations in samples collected at Cochiti Reservoir (Fig. 8) compared with concentrations in samples from background stations. Among the background stations, the Heron Reservoir sample showed a significantly higher uranium concentration compared with uranium levels in samples from El Vado (Fig. 8). It is believed these concentration differences are caused by natural phenomena (such as the fish living in muddy water and thereby ingesting suspended sediments that contain natural uranium). The suspended sediment concentrations are considerably higher at Cochiti than at El Vado. The maximum dose to an individual eating 21 kg of fish from Cochiti Reservoir during 1983 is a 50-year dose commitment of 0.021 mrem to the bone, which is 0.0014% of the appropriate Radiation Protection Standard.

As described in Section IV.A.6, the ^{90}Sr concentrations in fish bone or in edible flesh were higher in the background samples than at Cochiti Reservoir. Because ^{90}Sr concentrates in the bone, which is not normally eaten, and because the background stations had the highest concentrations, no dose assessment was made for ^{90}Sr.

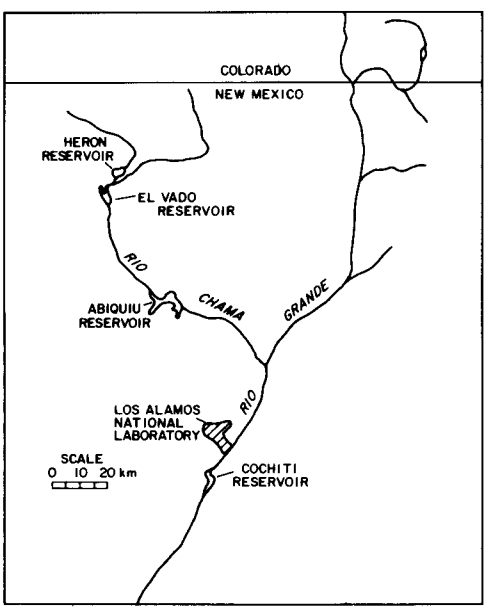


Fig. 8. Locations of reservoirs where fish samples were taken.

Trace amounts of radionuclides were found in honey collected onsite. The maximum dose one would get from eating 5 kg of this honey during 1983, if it were made available for consumption, would be 0.06 mrem, which is 0.012% of the Radiation Protection Standard.

E. Doses to Individuals from External Penetrating Radiation (from Airborne Emissions and Direct Radiation)

The special thermoluminescent dosimeter network at the Laboratory boundary north of the Los Alamos Meson Physics Facility indicated a 48 mrem increment above cosmic and terrestrial background radiation (Table IV). This increment is attributed to emission of air activation products from the Los Alamos Meson Physics Facility. Based on shielding by being inside buildings, this 48 mrem increment translates to an estimated 34 mrem whole body dose to an individual living on State Road 4 north of the Los alamos Meson Physics Facility. The 34 mrem is 6.8% of the Radiation Protection Standard for a member of the public (Appendix A). This location north of the Los Alamos Meson Physics Facility has been the area where the highest boundary and individual doses have been measured since thermoluminescent dosimeter monitoring began there 5 years ago. The boundary doses at this location are discussed in Section IV.A.1.

The increase in dose from 12 mrem in 1982 to 49 mrem in 1983 is attributed to the increase in the Los Alamos Meson Physics Facility's airborne emissions from 251 000 Ci in 1982 to 461 000 Ci in 1983, a shift in the isotopic ratio of the emissions, and a slight change in meteorological conditions. Engineering design modifications (increasing the holdup time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from airborne activation products have been conceptually designed and included in Laboratory funding requests.

A maximum onsite dose to a member of the public from external penetrating radiation from all Laboratory airborne emissions was estimated to be 0.0017 mrem. This dose was for a person spending 4 hours at the Laboratory's science museum, an area readily accessible to the public.

The average annual dose to residents in Los Alamos townsite attributable to Laboratory operations was 0.35

mrem (whole body). The corresponding dose to White Rock residents was 0.31 mrem (whole body). These doses are 0.07% and 0.06%, respectively, of the Radiation Protection Standard. They were theoretically calculated using measured stack releases (Table E-I) and 1983 meteorological data.

Emissions dispersed from the nuclear research reactor at TA-2 and the linear particle accelerator at TA-53 could result in a theoretically calculated annual regional dose of 0.005 mrem (whole body) at Española. This dose is 0.001% of the Radiation Protection Standard.

Onsite measurements of external penetrating radiation reflected Laboratory operations and do not represent potential exposure to the public except in the vicinity of TA-18 (a nuclear criticality study area) on Pajarito Road. Members of the public regularly using the Department of Energy-controlled road passing by TA-18 would likely receive no more than 0.6 mrem/yr of direct gamma and neutron radiation. This value was derived from 1975 data (Paxton 1975) on total gamma plus neutron dose rates using 1983 gamma radiation measured by thermoluminescent dosimeters. Exposure time was estimated by assuming a person made 15 round trips per week at an average speed of 65 km/h past TA-18 while tests were being conducted.

The onsite thermoluminescent dosimeter station (see Section IV.A.1, Station 24 in Fig. 8) near the northeast Laboratory boundary recorded an above background dose of 55 mrem. This reflects a localized accumulation of ^{137}Cs on sediments transported from treated effluent released prior to 1964 from TA-45 (Gunderson 1983).

F. Whole Body Cumulative Doses

Cumulative 1983 whole body doses attributable to Laboratory operations both to persons living within 80-km of the Laboratory and to Los Alamos County residents are compared to exposure from natural radiation and medical radiation in Table V. Population data are based on the 1980 US Bureau of Census count (adjusted for 1983). The calculated 7.34 person-rem from 1983 Laboratory operations to the estimated 162 000 inhabitants within the 80-km radius of the Laboratory is based on very conservative assumptions that were used to calculate the dose (see Appendix D). Approximately 90% of the total population dose is to Los Alamos County residents. The other population centers are farther away, so dispersion, dilution, and decay in transit (particularly for ^{11}C, ^{13}N, ^{14}O, ^{15}O, and ^{41}Ar) reduce their dose to theoretically less than 10% of the total. By contrast, the inhabitants in the 80-km radius receive 20 000 person-rem from natural radiation.

Thus the doses potentially attributable to releases from Laboratory operations contribute about 0.3% of the total dose received by Los Alamos County residents from natural radiation, about 0.4% to the same population from diagnostic radiation and 0.04% of the dose from natural radiation received by the population within an 80 km radius of the Laboratory.

G. Estimates of Risk to an Individual from Laboratory Releases

Risk estimates of possible health effects from radiation doses to the public resulting from Laboratory operations have been made. However, these calculations may overestimate actual risk. The National Council on Radiation Protection and Measurements (NCRP 1975B) has warned "risk estimates for radiogenic cancers at low doses and low dose rates derived on the basis of linear (proportional) extrapolation from the rising portions of the dose incidence curve at high doses and high dose rates... cannot be expected to provide realistic estimates of the actual risks from low level, low-LET (linear energy transfer) radiations, and have such a high probability of overestimating the actual risk as to be of only marginal value, if any, for purposes of *realistic* risk-benefit evaluation."

The International Commission on Radiological Protection (ICRP 1977) estimated the total risk of cancer mortality from uniform whole body irradiation for individuals is 0.0001 per rem, that is, there is 1 chance in 10 000 that an individual exposed to 1000 mrem (1 rem) of whole body radiation would develop a cancer. In developing risk estimates, the International Commission on Radiological Protection (ICRP 1977) has warned "radiation risk estimates should be used only with great caution and with explicit recognition of the possibility that the actual risk at low doses may be lower than that implied by a deliberately cautious assumption of proportionality."

During 1983, persons living in Los Alamos and White Rock received an average of 132 and 121 mrem, respectively, of whole body radiation from natural sources (including cosmic, terrestrial, and self-irradiation sources

Table V

Estimated Whole Body Population Doses During 1983

Exposure Mechanism	Estimated Los Alamos County Whole-Body Population Dose (person-rem)	Estimated 80-km Region Whole-Body Population Dose (person-rem)[c]
Atmospheric Tritium	0.06	0.06
Atmospheric ^{11}C, ^{13}N, ^{14}O, ^{15}O, ^{41}Ar	6.57	7.28
Total Due to Laboratory Releases	6.63	7.34
Total Due to Natural Sources of Radiation[a]	2400	20 000
Average Due to Airline Travel [~0.22 mrem/h at 9 km (NCRP 1975)]	18	b
Diagnostic Medical Exposure [~103 mrem/yr per person (EPA 1977)]	1900	17 000

[a]Calculations are based on thermoluminescent dosimeter measurements. They include a 10% reduction in cosmic radiation from shielding by structures and a 40% reduction in terrestrial radiation from shielding by structures and self-shielding by the body.
[b]Not estimated for the population in the 80-km region.
[c]Includes doses reported for Los Alamos County.

with allowances for shielding and cosmic neutron exposure, but excluding radiation from airline travel, luminous dial watches, building materials, and so on). Thus, the added cancer mortality risk attributable to natural whole body radiation in 1983 was 1 chance in 76 000 in Los Alamos and 1 chance in 83 000 in White Rock (Table II).

Laboratory operations contributed an average dose of 0.35 mrem to individuals in Los Alamos and 0.31 mrem to individuals in White Rock. These doses are estimated to add lifetime risks of about 1 chance in 29 000 000 in Los Alamos and 1 chance in 32 000 000 in White Rock to an individual's risk of cancer mortality because of 1983 Laboratory activities (Table II).

For Americans the average lifetime risk is a 1 in 4 chance of contracting a cancer from all causes and a 1 in 5 chance of dying from the disease (EPA 1979A). The Los Alamos incremental dose attributable to Laboratory operations is equivalent to the additional exposure from cosmic rays a person would get from flying in a commercial jet aircraft for 1.6 hours.

The exposure from Laboratory operations to Los Alamos County residents is well within variations in exposure to these people from natural cosmic and terrestrial sources and global fallout. For example, one study (Yeates 1972) showed the annual dose rate on the second floor of single-family frame dwellings was 14 mrem/yr less than the dose rate on the first floor. Energy conservation measures, such as sealing and insulating houses and installing passive solar systems, are likely to contribute much larger doses to Los Alamos County residents than Laboratory operations because of increased radon levels inside the homes. The Environmental Protection Agency has estimated the annual whole body dose to individuals from global fallout to be 4.4 mrem (Klement 1972).

IV. MONITORING RESULTS

A. Radiation and Radioactivity

1. External Penetrating Radiation. **Levels of external penetrating radiation—including x and gamma rays and charged particle contributions from cosmic, terrestrial, and manmade sources—in the Los Alamos area are monitored with thermoluminescent dosimeters. Data from regional locations for each calendar quarter did not show any statistically discernible increase in radiation levels attributable to Laboratory operations. The only boundary or perimeter measurements showing an effect attributable to Laboratory operations were those from dosimeters located north of the Los Alamos Meson Physics Facility (a linear particle accelerator). They showed an above-background radiation measurement of 48 ± 3 mrem in 1983. Some onsite measurements were expectably above background levels, reflecting research activities and waste management operations at the Laboratory.**

a. Introduction. Natural external penetrating radiation comes from natural terrestrial and cosmic sources. The natural terrestrial component results from decay of ^{40}K and from radioactive daughters in the decay chains of ^{232}Th, ^{235}U, and ^{238}U. This natural terrestrial radiation in the Los Alamos area is highly variable with time and location. Over the year these radiation levels can vary 15 to 25% at any location because of changes in soil moisture and snow cover (NCRP 1975). There are also fluctuations because of different soil and rock types in the area (ESG 1978).

The cosmic source of natural ionizing radiation increases with elevation, because there is reduced shielding by the atmosphere. At sea level it produces measurements between 25 and 30 mrem/yr. Los Alamos, with a mean elevation of about 2.2 km, receives about 60 mrem/yr from the cosmic component. This cosmic component can vary up to about ±5% (60 ± 3 mrem/yr because of solar modulations (NCRP 1975).

The fluctuations in natural background ionizing radiation make it difficult to detect any increase in radiation levels from manmade sources. This is especially true when the size of the increase is small relative to the magnitude of natural fluctuations. At Los Alamos the quarterly external penetrating radiation measurements range from 60 to 200 mrem on an annual basis. These measurements include contributions from both the terrestrial and cosmic ionizing radiation sources.

Levels of external penetrating radiation—including x and gamma rays and charged particle contributions from cosmic, terrestrial, and manmade sources—in the Los Alamos area are measured with thermoluminescent dosimeters (TLDs) deployed in three independent networks. These are the Environmental, Los Alamos Meson Physics Facility, and Low-Level Radioactive Solid Waste Management Area TLD networks. The 1983 TLD data are described in the following sections.

b. Environmental TLD Network. The environmental network consists of 40 stations divided into three groups. The regional group consists of three locations, 28 to 44 km from the Laboratory boundary in the neighboring communities of Española, Pojoaque, and Santa Fe, along with the Fenton Hill Site 30 km west of Los Alamos (Fig. 1). The perimeter group consists of 12 stations within 4 km of the boundry; 24 locations within the Laboratory boundary comprise the onsite group (Fig. 9).

Table E-II summarizes the annual measurements for the regional, perimeter, and onsite groups for 1983. Figure 4 shows a comparison of measurements for these groups for calendar quarters during the last 5 years. No measurements at regional or perimeter locations in the environmental network for any calendar quarter showed any statistically discernible increase in radiation levels attributable to Laboratory operations. As a frame of

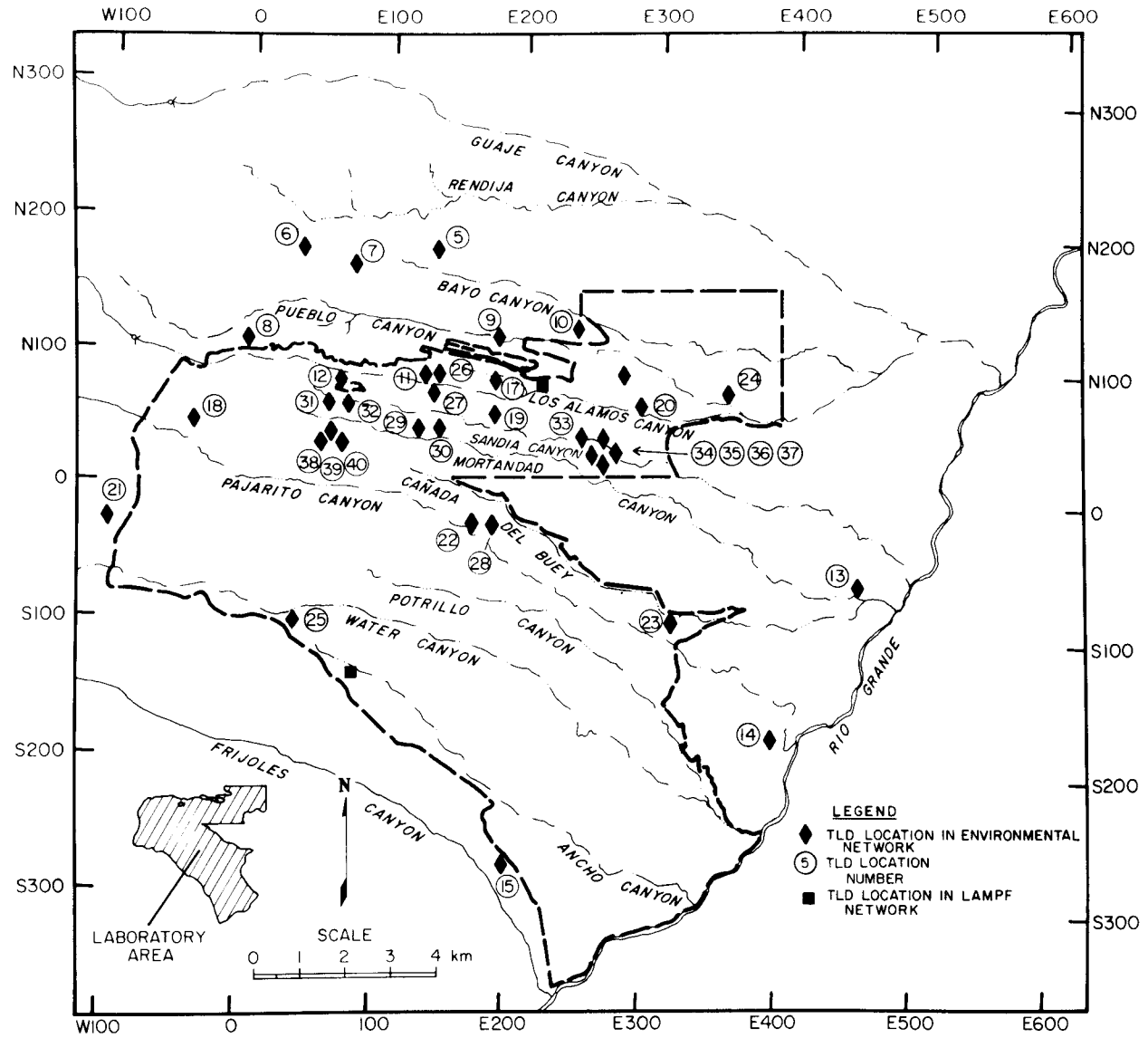


Fig. 9. Thermoluminescent dosimeter locations on or near the Laboratory site.

reference, the Department of Energy's Radiation Protection Standard is 500 mrem/yr for a whole body dose (Appendix A). This Radiation Protection Standard is for exposure (excludes contributions from cosmic, terrestrial, global fallout, self-irradiation, and medical diagnostic sources) at points of maximum probable exposure to an individual in an Uncontrolled Area. Also, the average person in the United States receives about 103 mrem/yr from medical diagnostic procedures (EPA 1977A).

c. Los Alamos Meson Physics Facility TLD Network. This network monitors radiation from airborne activation products (gases, particulates, and vapors) released by the Los Alamos Meson Physics Facility (LAMPF), TA-53. The prevailing wind is out of the south and southwest (see Section IV.C), so 12 TLD sites are located downwind at the Laboratory boundary north of LAMPF along 800 m of canyon rim. Twelve background TLD sites are about 9 km from the facility along a

canyon rim near the southern boundary of the Laboratory (Fig. 9). This background location is not influenced by any Laboratory radiation sources.

The 24 TLDs are changed in accordance with the operational schedule of LAMPF. The difference between the average TLD measurement at the north (downwind) boundary and the TLD measurement at the south (background) boundary is that attributable to operation of LAMPF. For 1983 the above-background radiation measured by the LAMPF TLD network was 48 ± 3 mrem, 9.6% of the Department of Energy's Radiation Protection Standard of 500 mrem/yr (Appendix A). It was measured at the Laboratory boundary north of LAMPF and was attributable to LAMPF's operations.

Figure 10 shows the history of TLD measurements at LAMPF. Figure 3 shows how the above-background TLD measurements from LAMPF's operations have increased over the past few years. This trend is caused by a combination of higher beam currents in the particle accelerator (which increases airborne activation product emissions), a shift in the isotoic ratio of the emissions, and changing meteorological conditions. These higher operating levels have increased the airborne activation products that are released from the LAMPF stack (Tables III and E-I). Engineering design modifications (increasing the holdup time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from the airborne activation products have been conceptually designed and included in Laboratory funding requests.

d. TLD Network for Low-Level Radioactive Solid Management Areas. This network of 91 TLD locations monitors radiation levels at one active and eight inactive low-level radioactive solid waste management areas. These waste management areas are controlled-access areas and so are not accessible to the general public. Results from this network are in Section IV.A.7 of this report.

***2. Atmospheric Radioactivity.* Worldwide background atmospheric radioactivity is composed of fallout from atmospheric nuclear weapon tests, natural radioactive constituents in dust from the earth's surface, and radioactive materials resulting from interactions with cosmic radiation. Air is routinely sampled at several locations on Laboratory land, along the Laboratory perimeter, and in distant areas to determine the existence and composition of any contributions to radionuclide levels from Laboratory operations. Atmospheric concentrations of gross beta activity, tritium, americium, plutonium, and uranium are measured. The highest measured and annual average concentrations of these radioactive materials were much less than 1% of the Department of Energy's Concentration Guides.**

a. Introduction. Atmospheric radioactivity samples are collected at 26 continuously operating air sampling stations (see Appendix B for a complete description of sampling procedures). The regional monitoring stations, located 28 to 44 km from the Laboratory at Española, Pojoaque, and Santa Fe (Fig. 1), are reference points for determining regional background levels of atmospheric radioactivity. Perimeter stations are within 4 km of the Laboratory boundary; onsite stations are within the Laboratory boundary (Fig. 11, Table E-III).

Natural atmospheric and fallout radioactivity levels fluctuate and affect the measurements made in the Laboratory's air sampling program. Worldwide background atmospheric radioactivity is largely composed of fallout from past atmospheric nuclear weapons tests, natural radioactive constituents from the decay chains of thorium and uranium in dust, and materials resulting from interactions with cosmic radiation (for example, tritiated water vapor). Background radioactivity concentrations in the atmosphere are summarized in Table E-IV and are useful in interpreting the air sampling data.

Because airborne particulates are mostly from soil resuspension, there can be large fluctuations over time (daily, seasonal) and with location in airborne radioactivity levels caused by changing meteorological conditions. Windy, dry days can result in relatively high concentrations of airborne particulates, whereas

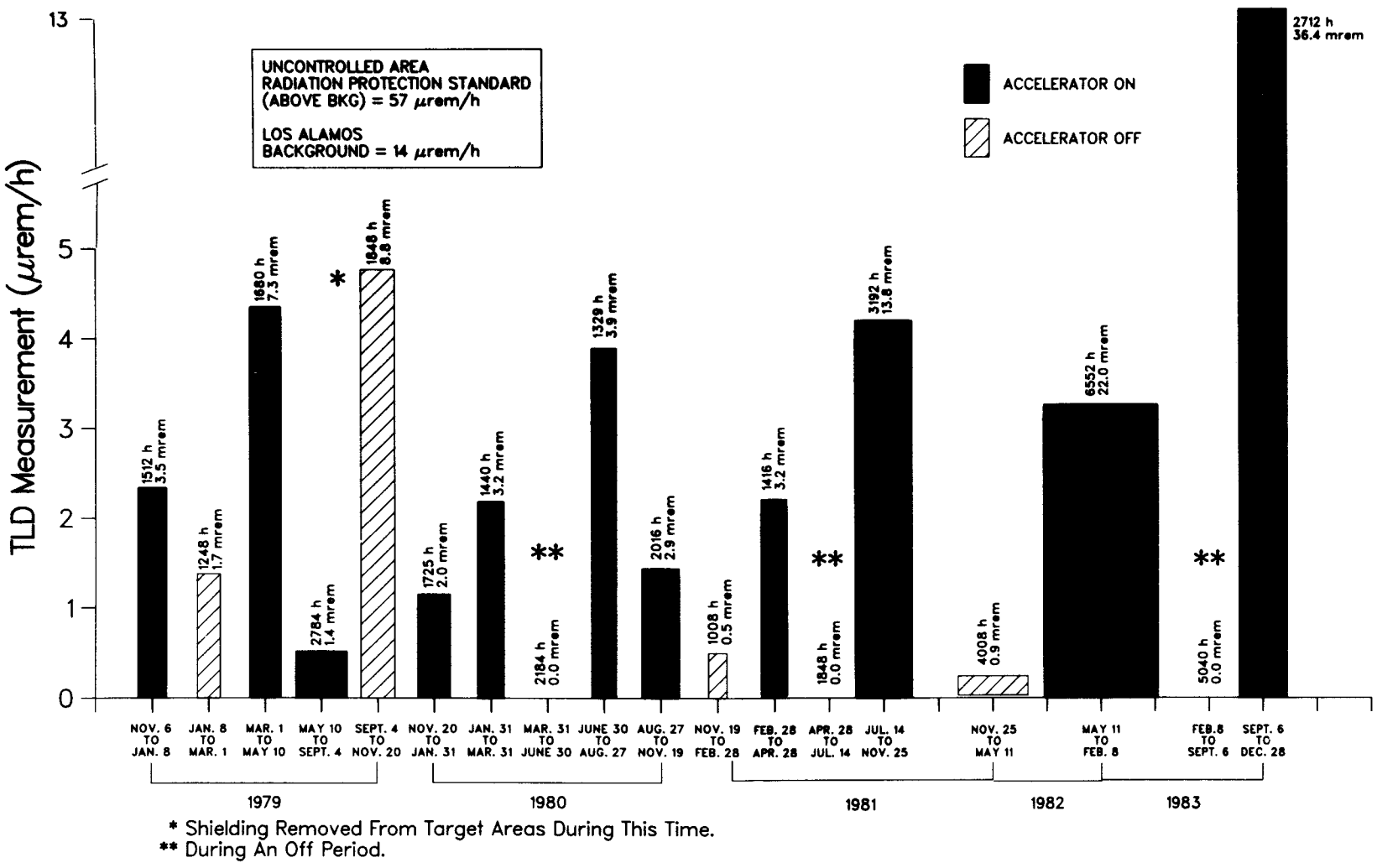


Fig. 10. Above-background TLD measurements at NE Laboratory boundary due to operations at Los Alamos Meson Physics Facility.

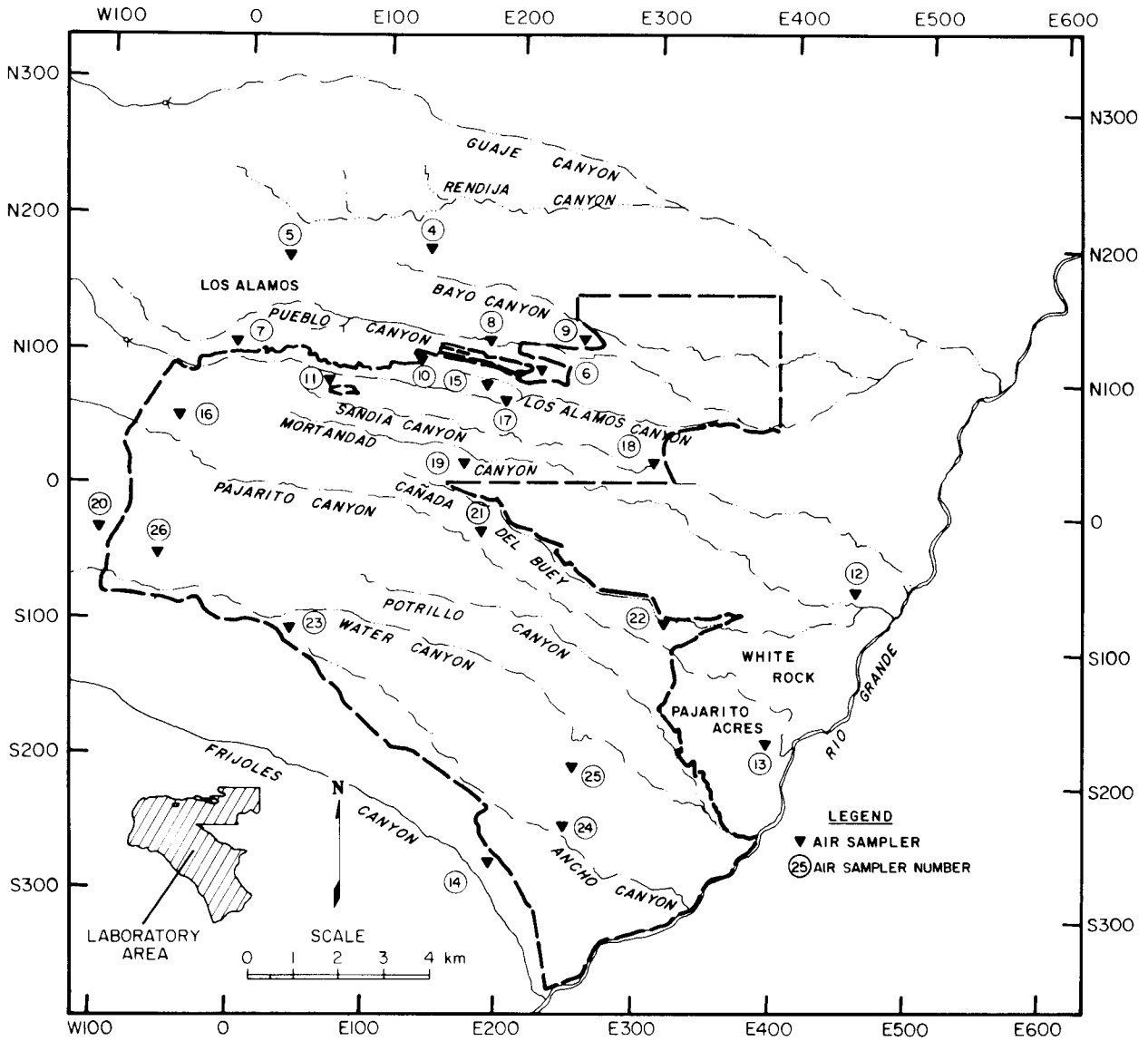


Fig. 11. Air sampler locations on or near the Laboratory site.

precipitation (rain, snow) can wash out many airborne particles.

b. Gross Beta Radioactivity. Gross beta analyses help in evaluating general radiological air quality. Figure 12 shows gross beta activity at a regional sampling location located about 30 km from the Laboratory (Española, Station 1, see Fig. 1) and at an onsite sampling location (TA-59, see Fig. 12). The plotted data show that Laboratory operations had no measurable increase in airborne gross beta concentrations over regional background levels.

c. Tritium. Atmospheric tritiated water concentrations for 1983 are in Table E-V. The regional (11×10^{-12} μCi/mℓ) and perimeter (13×10^{-12} μCi/mℓ) annual means were lower than the onsite annual mean (17×10^{-12} μCi/mℓ). This reflects the slight impact of Laboratory tritium operations. Tritium emissions from TA-33 caused the TA-33 (Station 24) annual mean (36×10^{-12}

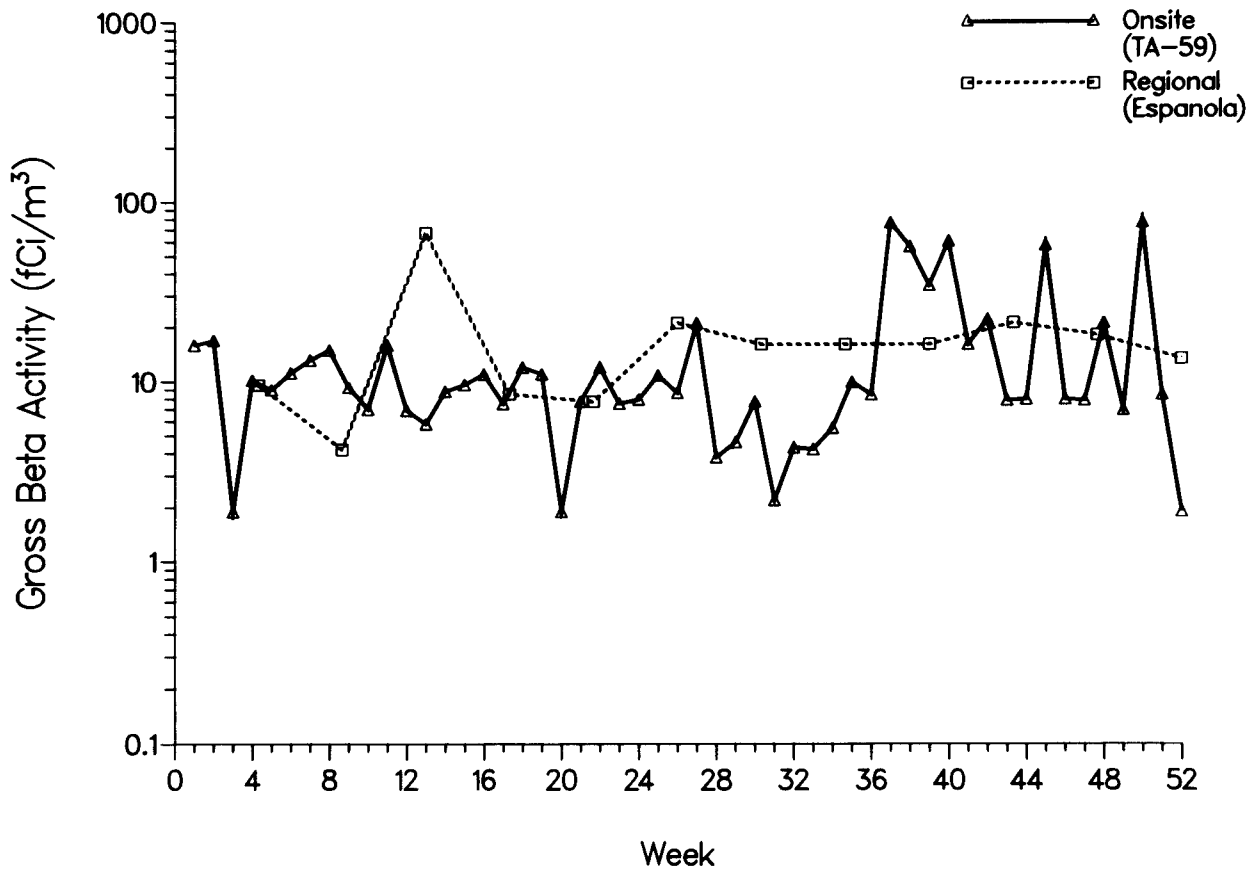


Fig. 12. Atmospheric gross-beta activity at a regional station and an onsite station during 1983.

μCi/mℓ) and the nearby TA-39 (Station 25) annual mean (31×10^{-12} μCi/mℓ) to both be higher than the other onsite station annual means. These annual mean concentrations are 0.0007% and 0.0006%, respectively, of the Department of Energy's Controlled Area Concentration Guide for tritium in air.

d. Plutonium and Americium. There was only 1 of 103 measured ^{238}Pu concentrations greater than the minimum detectable limit of 2×10^{-18} μCi/mℓ (the 102 less-than-detectable values are not tabulated in this report). This concentration was 11×10^{-18} μCi/mℓ and occurred at 48th Street (Station 7). It was 0.02% of the Department of Energy's Concentration Guide for ^{238}Pu in air for Uncontrolled Areas.

For ^{239,240}Pu in air, the regional (1.1×10^{-18} μCi/mℓ), perimeter (0.7×10^{-18} μCi/mℓ), and onsite (1.8×10^{-18} μCi/mℓ) annual means were all less than 0.002% of the Department of Energy's Concentration Guides for ^{239,240}Pu in air for Controlled and Uncontrolled Areas. The detailed results are in Table E-VI.

Analyses for ^{241}Am are done because it is a decay product (daughter) of ^{241}Pu and is much easier to detect than ^{241}Pu. Weapons-grade plutonium contains ^{241}Pu, so fallout from atmospheric nuclear tests often contain ^{241}Pu and ^{241}Am. This year only 1 of 44 analyses for ^{241}Am was above the detectable limit of 2×10^{-18} μCi/mℓ (the 43 less-than-detectable values are not tablulated in this report). The concentration was 22×10^{-18} μCi/mℓ at Booster P-2 (Station 21), which is 0.01% of the Department of Energy's Concentration Guide for ^{241}Am in air in Uncontrolled Areas.

e. Uranium. The 1983 atmospheric uranium concentrations are summarized in Table E-VII. Uranium concentrations are heavily dependent on the immediate

environment of the sampling station. Those stations with relatively higher annual averages or maximums are in dusty areas, where a higher filter dust loading accounts for collection of more natural uranium from resuspended soil particles. This year the highest annual average was at East Gate (Station 6). It was 114 pg/m^3, which is 0.002% of the Department of Energy's Concentration Guide for uranium in air in Uncontrolled Areas.

3. Radioactivity in Surface and Ground Waters. **Surface and ground waters are sampled to monitor dispersion of radionuclides from Laboratory operations. The 1983 radiochemical quality of water from regional, perimeter, and onsite areas (where there is no discharge of treated effluent) indicates no effect from the release of treated effluent at Laboratory. Water in onsite effluent release areas contain trace amounts of radionuclides that are below Department of Energy's Concentration Guides for waters in Controlled Areas. These onsite waters are not a source of industrial, municipal, or agricultural water supply. The radiochemical quality of water from supply wells, gallery, and distribution system for industrial and municipal supply for the Laboratory and community are in compliance with Environmental Protection Agency standards.**

a. Introduction. Surface and ground waters at Los Alamos are monitored to provide routine surveillance of Laboratory operations. A comparison of the maximum concentration found in these waters is made with Department of Energy's Concentration Guides for Uncontrolled and Controlled Areas (Appendix A). Water samples from regional and perimeter stations are in Uncontrolled Areas, while onsite stations are within Controlled Areas. Water supply radiochemical data are compared to the Environmental Protection Agency's Interim Drinking Water Regulations (EPA 1976).

The Concentration Guides do not account for concentration mechanisms that may exist in environmental media. Consequently, other media such as sediments, soil, and foods are monitored (see discussion in subsequent sections). Appendix B presents methods of collection, analysis, and reporting of water data.

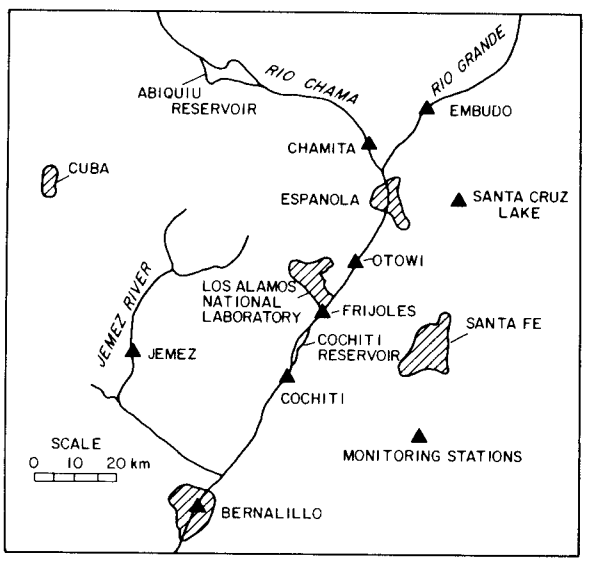


Fig. 13. Regional surface water, sediment, and soil sampling locations.

b. Regional and Perimeter Waters. Analyses of surface and ground waters from regional and perimeter stations reflect base line levels of radioactivity in areas outside the Laboratory boundary. Regional surface waters are collected within 75 km of the Laboratory from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 13, Table E-VIII). Surface waters from these rivers are used for irrigation of crops in the Rio Grande Valley, both upstream and downstream from Los Alamos. Waters of the Rio Grande are part of recreational areas on state and federal lands. Samples are also collected from six perimeter stations within about 4 km of the Laboratory boundaries. These stations include three

springs, one stream, and two reservoirs. Waters from Guaje and Los Alamos Reservoirs are used during the summer for irrigation of lawns and shrubs at the Laboratory and public schools. Water samples are also collected from 27 stations in White Rock Canyon formed by the Rio Grande. White Rock Canyon is adjacent to the eastern boundary of the Laboratory (Fig. 14). These surface and ground water sampling stations are all downgradient from the Laboratory.

Radionuclide concentrations in surface and ground waters from the six regional and six perimeter stations were low and showed no effect from release of treated liquid effluents at the Laboratory (Table VI).

Stations in White Rock Canyon are divided into four groups. Three groups are based on similar aquifer-related chemical quality, while the fourth group reflects a localized condition in the aquifer. In 1983 a spring sample was picked up near the head of Cochiti Reservoir. Three streams that enter the Rio Grande were also sampled. Treated sanitary effluent from the community of White Rock was also sampled at its confluence with

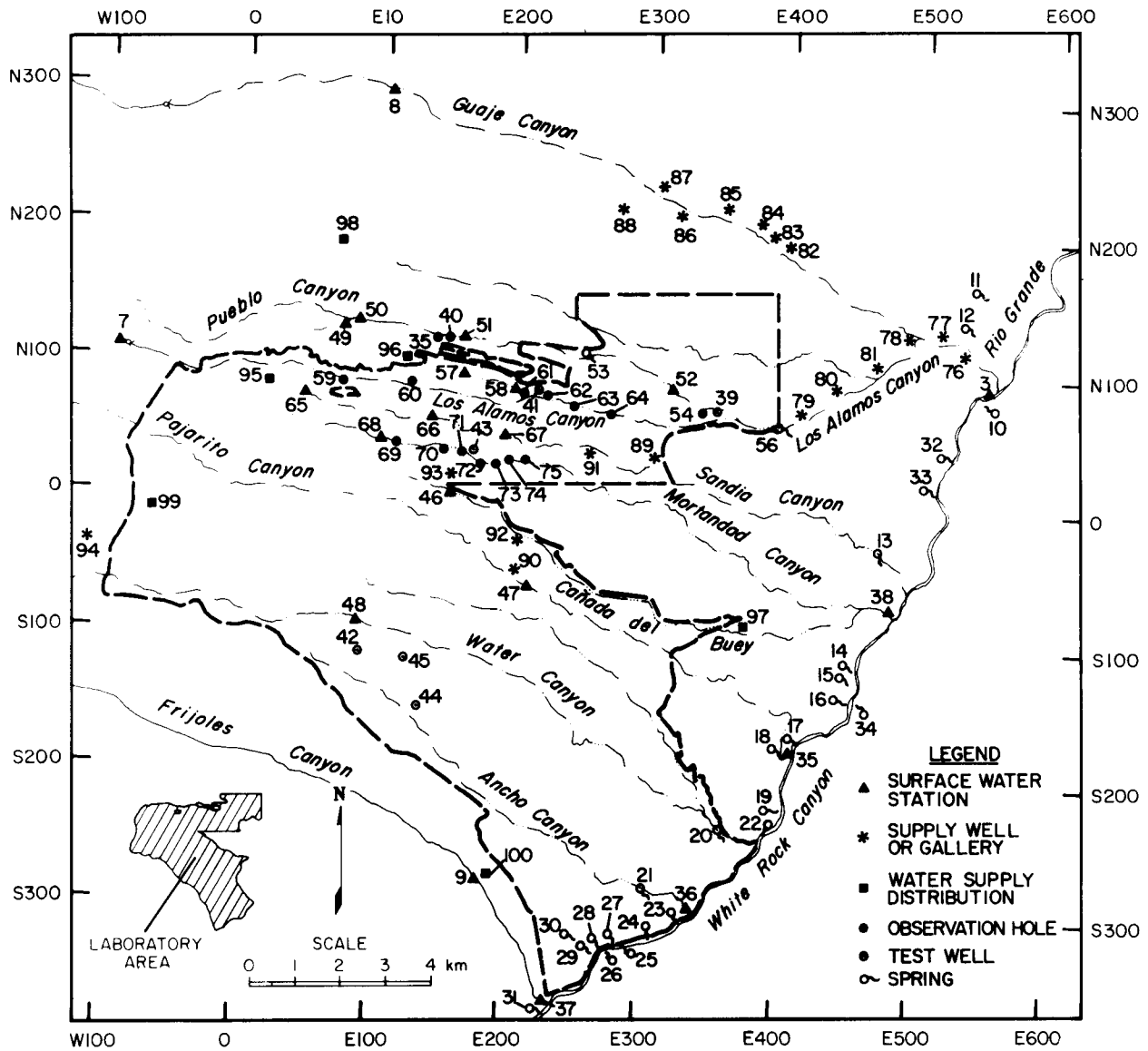


Fig. 14. Surface and ground water sampling locations on or near the Laboratory site.

Table VI

Maximum Radioactivity in Surface and Ground Water from Offsite and Onsite Stations

	Number of Stations (2 samples per station)	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U μg/ℓ)	^{241}Am (10^{-9} μCi/mℓ)	Gross Gamma (counts/min/ℓ)
Offsite Station (Uncontrolled Areas)								
Concentration Guide (CG) for Uncontrolled Areas[a]		20 000	5000	5000	3000	1800	4000	---
Regional	6	79 ± 110	0.012 ± 0.024	0.049 ± 0.034	4.2 ± 1.0	4.1 ± 1.0	---	76 ± 36
Perimeter	6	48 ± 60	0.050 ± 0.040	0.080 ± 0.040	4.5 ± 1.0	26 ± 5.2	---	88 ± 36
White Rock Canyon	27	59 ± 52	0.020 ± 0.040	0.090 ± 0.080	1.4 ± 0.4	22 ± 4.4	---	125 ± 36
Offsite Station Group Summary:								
Maximum Concentration		79 ± 110	0.050 ± 0.040	0.080 ± 0.040	4.5 ± 1.0	26 ± 5.2	---	---
Maximum Concentration as % CG for Uncontrolled Areas		<1	<1	<1	<1	1	---	---
Onsite Station (Controlled Areas)								
Concentration Guide (CG) for Controlled Areas[a]		400 000	100 000	100 000	100 000	60 000	100 000	---
Noneffluent Areas	8	96 ± 84	0.035 ± 0.034	0.070 ± 0.020	3.1 ± 0.8	2.1 ± 1.0	---	123 ± 38
Effluent Areas								
Acid-Pueblo Canyon	8	84 ± 101	0.027 ± 0.026	1.60 ± 0.16	4.9 ± 1.0	1.9 ± 0.8	0.40 ± 0.20	67 ± 36
DP-Los Alamos Canyon	8	78 ± 71	1.9 ± 0.20	2.87 ± 0.26	29 ± 6.0	208 ± 40	0.50 ± 0.12	230 ± 38
Sandia Canyon	3	66 ± 84	0.047 ± 0.032	0.029 ± 0.032	8.5 ± 1.8	2.1 ± 0.8	0.30 ± 0.10	26 ± 36
Mortandad Canyon	7	144 ± 139	3.3 ± 0.24	12 ± 0.60	103 ± 3.2	37 ± 3.7	21 ± 0.80	210 ± 38
Onsite Group Summary:								
Maximum Concentration		144 ± 139	3.3 ± 0.24	12 ± 0.60	103 ± 3.2	208 ± 40	21 ± 0.80	---
Maximum Concentration as % CG for Controlled Areas		<1	<1	<1	<1	<1	<1	---

[a]Reference (DOE 1981A).

the Rio Grande. Maximum concentrations of radioactivity in waters from White Rock Canyon are compared to Concentration Guides for Uncontrolled Areas in Table VI. Radionuclide concentrations in water from White Rock Canyon reflect naturally occurring radionuclides.

Detailed radiochemical analyses of water from regional, perimeter, and White Rock Canyon stations are reported in Tables E-IX, E-X, and E-XI, respectively.

Excluded from the discussion of perimeter stations is Acid-Pueblo Canyon, a former release area for industrial liquid wastes. Acid-Pueblo Canyon has four offsite stations and three onsite stations (Fig. 14), Table E-VIII). As a known release area and for hydrologic continuity, all monitoring results from Acid-Pueblo Canyon are discussed in the following section concerning onsite surface and ground waters.

c. Onsite Surface and Ground Waters. Onsite sampling stations are grouped according to those that are not located in effluent release areas ("noneffluent release areas") and those that are located in areas receiving or that have received treated industrial liquid effluents. Locations of these stations are shown in Fig. 14 and described in Table E-VIII.

Sampling locations in onsite effluent release areas consist of five test wells completed into the main aquifer (deep ground water body under the plateau) and three surface water sources. Maximum concentrations of radioactivity found at the eight stations are in Table VI and are compared to Concentration Guides for Controlled Areas. The concentrations are low, near or below detection limits and Concentration Guides for Controlled Areas. Results of detailed radiochemical analyses are in Table E-XII.

Onsite effluent release areas are canyons that receive or have received treated industrial effluents. These are Acid-Pueblo, DP-Los Alamos, Sandia, and Mortandad Canyons. Samples are collected from surface water stations or from shallow observation wells completed in the alluvium (Fig. 14 and Table E-VIII). Maximum concentrations of radioactivity found in each of the four canyons are in Table VI, which also includes Concentration Guide levels of radioactivity for Controlled Areas.

Radioactivity observed in waters from Acid Pueblo Canyon (Table E-XIII) is from residuals of treated and untreated radioactive liquid wastes that were released into the canyon from 1944 through 1964. Radionuclides that were absorbed by channel sediments are now being resuspended by runoff and municipal sanitary effluents. DP-Los Alamos Canyon receives treated industrial effluents that contain low levels of radionuclides and some sanitary effluents from the treatment plant at TA-21 (Table E-XIV). In the upper reaches of Los Alamos Canyon (LAO-1) there are occasional releases of cooling water from the research reactor at TA-2.

Sandia Canyon receives cooling tower blowdown from the TA-3 power plant and some treated sanitary effluent from TA-3 facilities (Table E-XV). Mortandad Canyon receives treated industrial effluent containing some radionuclides from the treatment plant at TA-50 (Table E-XVI). The plant at TA-50 processes the largest volume of liquid wastes at the Laboratory and the resulting effluents are released into Mortandad Canyon.

Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons all contain surface and shallow ground waters with measurable amounts of radioactivity. The radioactivity is well below Concentration Guides for Controlled Areas (Table VI). The surface and shallow ground waters in these canyons are not a source of municipal, industrial, or agricultural supply. Surface waters in these canyons are depleted by evapotranspiration or infiltration into the alluvium within Laboratory boundaries. Only during periods of heavy precipitation or snowmelt do waters from Acid-Pueblo, DP-Los Alamos, or Sandia Canyon reach the Rio Grande. In Mortandad Canyon there has been no surface runoff to the Laboratory's boundary since hydrologic studies were initiated in 1960. This was 3 years before the treatment plant at TA-50 began operation and effluents were released into the canyon (Purtymun 1983A).

d. Water Supply. The municipal and industrial water supply for the Laboratory and community is from 16 deep wells in 3 well fields and 1 gallery. The wells are located on Pajarito Plateau and in canyons east of the Laboratory (Fig. 14 and Table E-VIII). Water is pumped from the main aquifer, which lies about 350 m below the surface of the plateau (Purtymun 1983B). The gallery collects spring discharge from a perched water zone in the volcanics on the flanks of the mountains west of Los Alamos and the Plateau (Fig. 14). During 1983 water samples were collected from 15 supply wells (one well down for pump repairs), one standby well (LA-6), and the gallery (Table E-XVII).

Water samples were also collected at five distribution stations in the Laboratory and community and at Bandelier National Monument. Water at Bandelier is furnished by the Los Alamos system. Water from the

distribution system at TA-57, the Fenton Hill Geothermal Site, is also included as a seventh station in the distribution system. The TA-57 water is not a part of the Los Alamos supply and is from a well 133 m deep at TA-57 (Table E-XVII).

The maximum radioactive concentrations found in the supply (wells and gallery) and distribution (including Fenton Hill) systems are compared with the Environmental Protection Agency's Interim Primary Drinking Water Standards (EPA 1976) in Table VII. The radioactivity in water from the wells, gallery, and distribution system is low and at or below limits of detection. Gross alpha, gross beta, and gamma radioactivity and total uranium concentrations are low and occur naturally in the aquifer. A comparison of maximum radioactivity concentrations from supply and distribution systems with the Environmental Protection Agency's standards show that the two systems (Los Alamos and Fenton Hill) are in compliance.

4. Radioactivity in Soils and Sediments. **Soil samples are collected from 22 stations and sediment samples are collected from 42 stations in the Los Alamos area. Concentrations of ^{137}Cs, ^{238}Pu, ^{239,240}Pu, total U, ^{3}H, gross alpha activity, and gross beta activity from regional soil and sediment stations were below regional background levels. Several perimeter soil samples contained ^{137}Cs and total U in concentrations slightly above background levels. Perimeter sediment samples contained ^{137}Cs above background levels. Onsite soil samples contained concentrations of ^{137}Cs, total U, and ^{3}H above background levels. The concentrations were low, being less than twice background levels. Sediment samples from canyons that have or are now receiving treated liquid effluents contain radioactivity levels above background. Concentrations are highest near the points of effluent discharge and decrease farther from the discharge points.**

a. Background Levels of Radioactivity in Soils and Sediments. Routine samples collected and analyzed for radionuclides from regional stations from 1978 through 1982 (Purtymun 1983D) help establish background levels of ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and total U in soil and sediments in this report (Table VIII). Maximum concentrations of ^{3}H, gross alpha activity, and gross beta activity in regional soils and sediments in 1982 were used as background to compare with the 1983 analyses. These background levels of radioactivity are from natural sources or from worldwide fallout from past atmospheric nuclear weapons tests. See Appendix B for methods of collection, analyses, and reporting of soil and sediment data.

b. Regional Soils and Sediments. Regional soils are collected in the same general locations as the regional waters (Fig. 14). Regional sediments are also collected in the same general locations with additional sediment samples collected from Otowi to Cochiti on the Rio Grande. The exact locations are in Table E-XVIII and detailed results of radiochemical analyses are in Table E-XIX.

Soil samples were collected from six stations and each sample was analyzed for eight types of radioactivity (Table VIII). The maximum 1983 concentrations of radioactivity in soils were within established background levels. Sediments were collected from 10 regional stations and were analyzed for 5 types of radioactivity (Table VIII). The maximum concentrations of radioactivity in sediments in 1983 were near or within established background levels.

c. Perimeter Soils and Sediments. Six perimeter soil stations are sampled in areas within 4 km of the Laboratory. Ten sediment stations located on intermittent streams that cross Pajarito Plateau are sampled as they leave the Laboratory perimeter. The locations of the soil and sediment stations are in Table E-XVIII and Figs. 15 and 16. Detailed analyses are in Table E-XX.

Table VII

Maximum Radioactivity in Municipal Water Supply, Well, and Distribution Systems

	Number of Stations	Number of Samples	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	Gross Alpha (10^{-9} μCi/mℓ)	Gross Beta (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Water Supply										
Maximum Contaminant Level (MCL)[a]			200	15	15	15[b]	---	20	1800[c]	---
Wells										
Maximum Concentration	16	16	5 ± 44	0.060 ± 0.040	0.050 ± 0.040	7.0 ± 4.0	15 ± 3.4	0.9 ± 0.4	4.8 ± 0.8	65 ± 36
Maximum Concentration as Per Cent of MCL	16	16	2	<1	<1	47	---	5	<1	---
Distribution System (Los Alamos)										
Maximum Concentration	6	12	75 ± 82	0.029 ± 0.036	0.051 ± 0.036	2.7 ± 1.8	5.0 ± 1.4	3.7 ± 0.8	4.4 ± 1.0	43 ± 36
Maximum Concentration as Per Cent of MCL	6	12	38	<1	<1	18	---	18	<1	---
Distribution System (Fenton Hill)										
Maximum Concentration	1	2	97 ± 101	0.005 ± 0.009	0.050 ± 0.018	1.9 ± 2.0	9.7 ± 2.2	0.1 ± 0.3	1.7 ± 0.8	45 ± 36
Maximum Concentration as Per Cent of MCL	1	2	48	<1	<1	13	---	<1	<1	---

[a]Reference (EPA 1976).
[b]Environmental Protection Agency's Maximum Contaminant Level for gross alpha is 15×10^{-9} μCi/mℓ. However, gross alpha results in the distribution system that exceed EPA's screening limit of 5×10^{-9} μCi/mℓ require isotopic analysis to determine radium content.
[c]Level recommended by International Commission on Radiological Protection.

Note: The ± value is twice the uncertainty for the average of the analyses.

Table VIII

Maximum Radioactivity in Soils and Sediments from Regional, Perimeter, and Onsite Stations

	Number of Stations (2 samples per station)	Soils							
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Total U (μg/g)	^{3}H (10^{-6} μCi/mℓ)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Gross Gamma (counts/min/g)
Background (1978-1982)[a]	---	0.59 ± 0.83	0.001 ± 0.005	0.020 ± 0.061	2.6 ± 1.3	5.0 ± 0.6[b]	11 ± 6.0[b]	11 ± 2.6[b]	---
Regional Stations	6	0.82 ± 0.18 (0)	0.006 ± 0.006 (0)	0.013 ± 0.006 (0)	3.2 ± 0.6 (0)	3.6 ± 1.0 (0)	7.9 ± 3.8 (0)	9.1 ± 2.0 (0)	8.8 ± 0.28
Perimeter Stations	6	1.1 ± 0.24 (0)	0.002 ± 0.002 (0)	0.029 ± 0.008 (0)	5.9 ± 1.2 (2)	2.3 ± 0.6 (0)	15 ± 6.0 (0)	10 ± 2.2 (0)	14 ± 0.36
Onsite Stations	10	1.5 ± 0.32 (1)	0.004 ± 0.004 (0)	0.044 ± 0.010 (0)	6.5 ± 1.4 (7)	13 ± 2.6 (3)	14 ± 6.0 (0)	12 ± 26 (0)	13 ± 0.36

	Number of Stations (2 samples) (per station)	Sediments								
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{90}Sr (pCi/g)	Total U (μg/g)	^{241}Am (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Gross Gamma (counts/min/g)
Background (1978-1982)	---	0.19 ± 0.27	0.000 ± 0.006	0.007 ± 0.036	0.34 ± 1.2	2.7 ± 1.9	---	16 ± 8.0[b]	18 ± 3.8[b]	---
Regional Stations	10	0.22 ± 0.10 (0)	0.007 ± 0.002 (1)	0.013 ± 0.002 (0)	---	2.3 ± 1.0 (0)	---	---		2.7 ± 2.1
Perimeter Stations	10	0.74 ± 0.18 (2)	0.003 ± 0.002 (0)	0.031 ± 0.002 (0)	---	3.9 ± 0.6 (0)	---	14 ± 6.0 (0)	13 ± 3.8 (0)	6.2 ± 0.26
Onsite Station, Effluent Release Areas										
Acid-Pueblo Canyon	6	0.99 ± 0.20 (1)	0.016 ± 0.006 (1)	7.37 ± 0.260 (4)	0.89 ± 0.12 (0)	2.7 ± 0.6 (0)	0.40 ± 0.02	17 ± 3.0 (0)	9.3 ± 2.0 (0)	9.0 ± 0.30
DP-Los Alamos Canyon	9	24 ± 4.8 (6)	1.47 ± 0.060 (5)	3.78 ± 0.140 (4)	14 ± 0.80 (1)	3.3 ± 0.6 (0)	24 ± 9.6	33 ± 7.0 (1)	74 ± 14 (1)	35 ± 0.80
Mortandad Canyon	7	107 ± 11 (6)	27.9 ± 0.600 (5)	181 ± 3.40 (3)	2.04 ± 0.16 (3)	---	150 ± 60	620 ± 260 (3)	165 ± 34 (3)	303 ± 6.0

[a]Average maximum value ($\bar{x}$ ± 2s) (Ref. Purtymun 1983D).
[b]Average maximum ($\bar{x}$ ± 2s) 1982 (Ref. ESG 1983).

Note: Number in parentheses indicates number of stations exceeding background from stations in Northern New Mexico, 1978-1982. The ± value is twice the uncertainty for the average of the analyses.

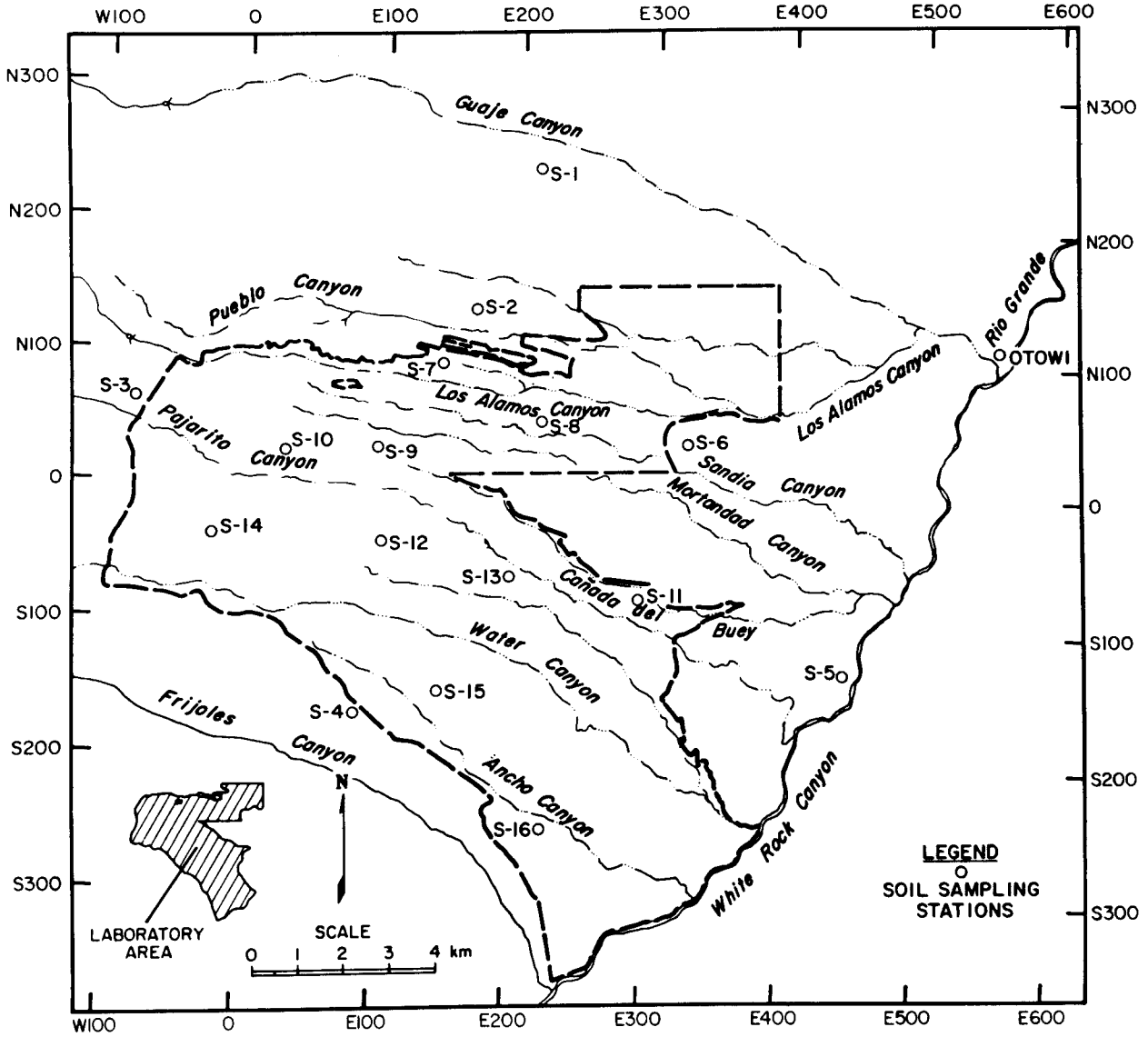


Fig. 15. Soil sampling locations on or adjacent to the Laboratory site.

Perimeter soil analyses indicate the maximum concentrations of radioactivity were within established background concentrations except for the total uranium concentrations from two stations (North Mesa and Sportsman Club). Uranium concentrations vary because of different concentrations formed in the parent rock from which the soil was derived. The total U concentrations at the two stations were from naturally occurring uranium in soils. The perimeter sediment analyses show that the maximum concentration of radioactivity in 1983 were within established background levels (Table VIII).

d. Onsite Soils and Sediments. Onsite soils are collected from 10 stations within the Laboratory boundaries. Sediment samples are collected from 22 stations within the boundaries (Table E-XVIII). Analytical results are in Table E-XXI and maximum concentrations in Table VII. The locations of soil and sediment stations are in Figs. 15 and 16.

Soil analyses indicate that some concentrations of ^{137}Cs (one station), ^{3}H (three stations), and total uranium (seven stations) were above background levels of 1978-1982 (Table VIII). The concentrations are low, with

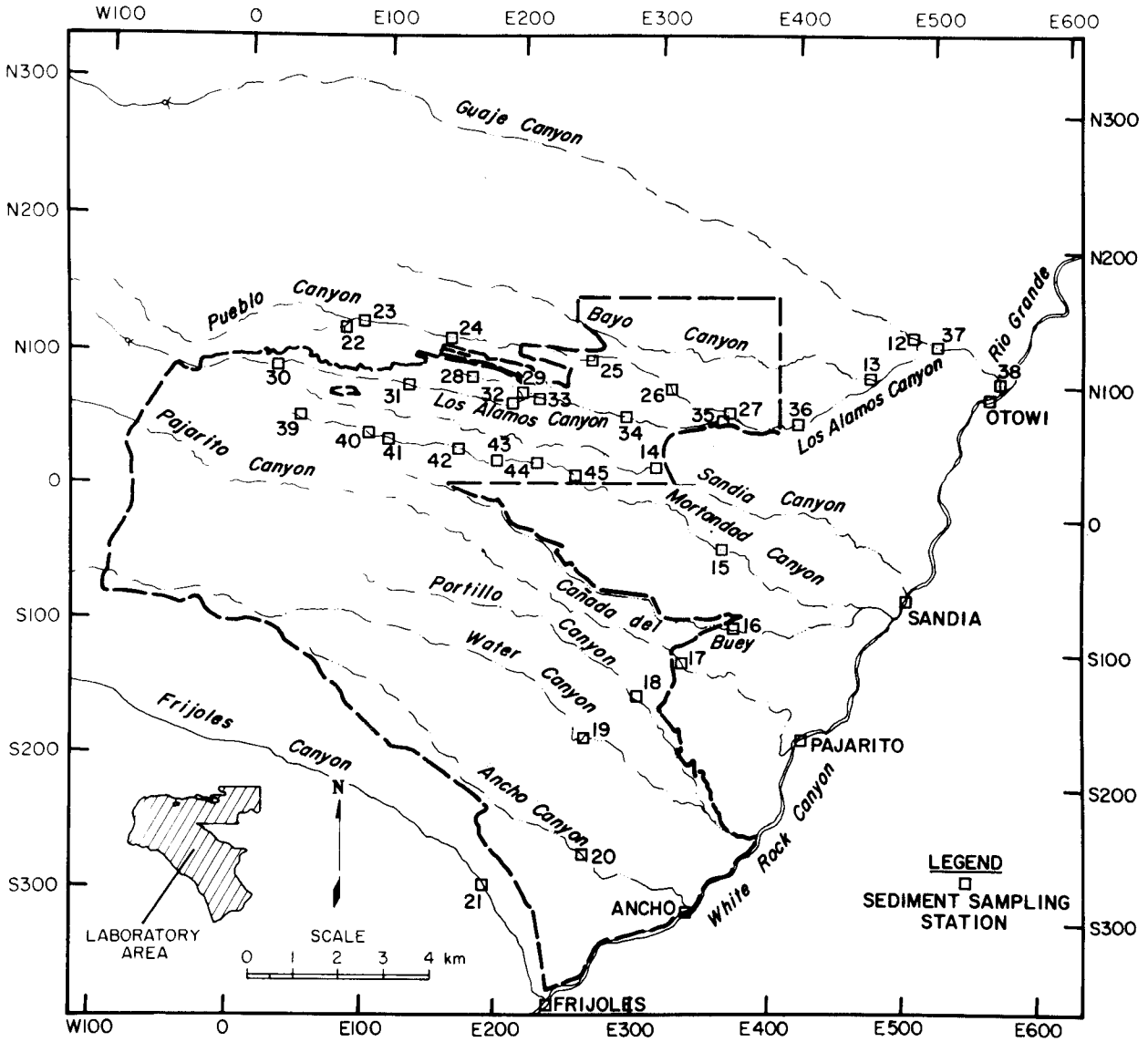


Fig. 16. Sediment sampling locations on or adjacent to the Laboratory site.

the ^{137}Cs concentration near background levels and the maximum ^{3}H and total uranium concentrations about twice background levels. The ^{3}H level may reflect some airborne tritium emissions from the Laboratory, while the total uranium concentration reflects naturally occurring uranium in the parent soil material.

Sediments from stations in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons had radionuclide concentrations above background levels (Tables VIII and E-XXI). These canyons have or are now receiving treated industrial effluents. Acid-Pueblo Canyon received effluents from about 1944 through 1964. The major radionuclide found in the sediments is $^{239,240}Pu$. DP-Los Alamos and Mortandad Canyons are now receiving treated effluents. Major contaminants in DP-Los Alamos and Mortandad Canyons are ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am. The radionuclides are adsorbed or attached to sediment particles in the stream channel alluvium. These concentrations are generally highest near the point of effluent discharge from the treatment plant. The concentrations decrease downgradient in the canyon as the sediments and radionuclides are transported and dispersed by effluents and periodic storm runoff.

e. Radiological Soil Survey Adjacent to TA-35, TA-48, TA-50, and TA-55. Preoperational radionuclide soil concentrations were established around the Laboratory site TA-55 (Plutonium Processing Facilities) in 1977. Soil samples were collected and analyzed from nine locations around TA-55. A resurvey was made in 1983. However, the original sampling locations had been disturbed by construction, so five new locations in undisturbed soil were established in the areas around TA-35, TA-48, TA-50, and TA-55 (Fig. 17). Each of these technical areas has or is now processing radioactive materials and can release trace amounts to the atmosphere through filters in the ventilation system. This could result in deposition of radionuclides on the soil.

The ^{137}Cs concentrations in soil from the five new locations are at or below the maximum levels (1.4 pCi/g) found in regional soils (Table IX). The ^{238}Pu and $^{239,240}Pu$

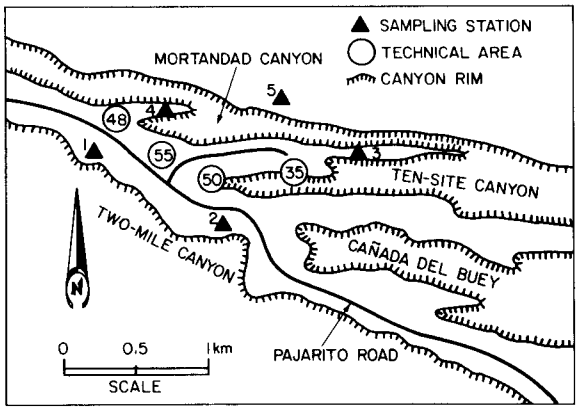


Fig. 17. Soil sampling locations near TA-35, TA-48, TA-50, and TA-55.

Table IX

Radiochemical Resurvey of Technical Areas 35, 48, 50, and 55
(July 6, 1983)

Station	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Total U (μg/g)	Gross Gamma (counts/min/g)
1	0.34 ± 0.15	−0.002 ± 0.004	0.019 ± 0.004	4.5 ± 1.0	6.6 ± 0.26
2	0.54 ± 0.23	0.011 ± 0.006	0.420 ± 0.040	5.4 ± 1.0	6.4 ± 0.26
3	0.97 ± 0.40	0.001 ± 0.004	0.049 ± 0.012	7.2 ± 1.4	7.4 ± 0.26
4	1.4 ± 0.58	−0.002 ± 0.010	0.058 ± 0.026	8.4 ± 1.6	7.6 ± 0.28
5	0.31 ± 0.14	0.002 ± 0.004	0.050 ± 0.020	4.7 ± 1.0	6.3 ± 0.26
Summary for 1983:					
No. of Analyses	5	5	5	5	5
Minimum	0.31 ± 0.14	−0.002 ± 0.004	0.019 ± 0.004	4.5 ± 1.0	6.3 ± 0.26
Maximum	1.4 ± 0.58	0.011 ± 0.006	0.420 ± 0.040	8.0 ± 1.6	7.6 ± 0.26
$\bar{x} \pm 2s$	0.71 ± 0.93	0.002 ± 0.011	0.12 ± 0.34	6.1 ± 3.4	6.9 ± 1.2
Summary for 1977:					
No. of Analyses	9	9	9	9	9
$\bar{x} \pm 2s$	0.31 ± 0.50	0.003 ± 0.004	0.030 ± 0.060	5.1 ± 3.4	6.6 ± 0.76
Regional Background					
Average Minimum for 1978-1982 ($\bar{x} \pm 2s$) (Purtymun 1983D)	0.59 ± 0.83	0.001 ± 0.005	0.020 ± 0.061	2.6 ± 1.3	---

soil concentrations at Station 2 were greater than found in regional soils (Table IX, 1977 and 1978-1982 Summaries). Station 2 is located south of TA-50 (Fig. 17). The total uranium soil concentrations exceed regional background concentrations at all stations. However, these levels do not indicate contamination, but reflect natural uranium leached from soil derived from the tuff. These concentrations are similar to the data collected in 1977 (Table IX). Uranium concentrations in soils vary and depend on the rock type that has weathered to form the soil. A comparison of the averages and standard deviations of radiochemical analyses collected in 1977 and 1983 indicate only slight variations between the 2 years.

The five new stations established in 1983 are to provide long-term monitoring of the possible airborne deposition of contaminants in the area around TA-35, TA-48, TA-50, and TA-55. Comparing 1977 with 1983 data indicates no significant increase in radioactivity of the soil adjacent to these technical areas.

f. Special Regional Soil Analyses. Special analyses for plutonium were performed on 1 kg (100 times the usual mass used for analyses) soil samples from six regional stations (Fig. 18). These larger samples increase the sensitivity of the plutonium analyses, which is necessary to evaluate background plutonium concentrations in fallout from atmospheric nuclear weapons tests. The samples at each station were collected by taking 5 plugs, 75 mm diameter and 50 mm deep, at the center and corners of a square area 10 m on a side. The five plugs were combined into one sample for radiochemical analyses. (One set of samples from Santa Cruz Lake consisted of 1 kg plugs at the four corners and center and were taken to determine variability in radionuclide concentrations within a sampling grid.) The 1 kg samples were analyzed for ^{238}Pu and ^{239,240}Pu, while ^{137}Cs, ^{90}Sr, total U, and gross gamma (Table E-XXII) analyses were done on standard size samples.

In Table X the analytical results from the six stations in 1983 are compared to similar data from 1981. There is no significant difference in the concentrations of ^{137}Cs, ^{238}Pu, ^{239,240}Pu, or ^{90}Sr between the 1983 and 1981 results. The average ^{239,240}Pu/^{238}Pu ratios for both sets of samples are similar at 23 (1981) and 15 (1983).

There were no significant differences in the concentrations of ^{137}Cs, total U, and gross gamma within the set of five samples taken at Santa Cruz Lake (Table E-XXII). There was a slight but also insignificant difference in the concentrations of ^{238}Pu (range 0.0006 to 0.0023 pCi/g) and ^{239,240}Pu (range 0.0088 to 0.026 pCi/g) within the five samples.

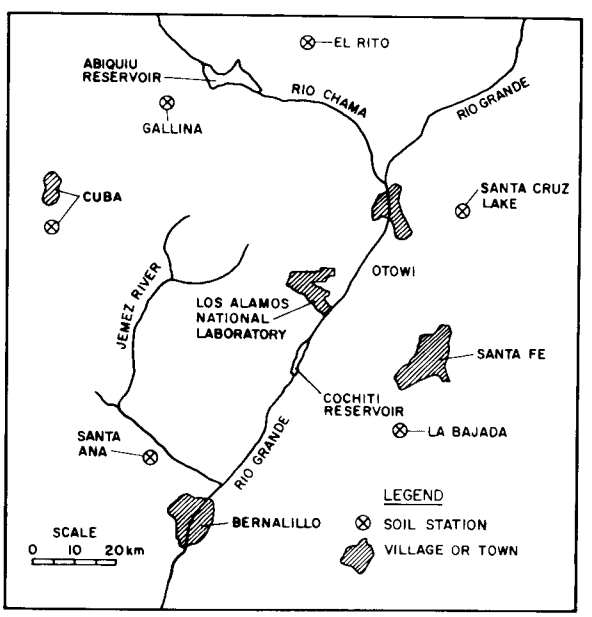


Fig. 18. Special regional soil sampling locations.

Table X

Radiochemical Analyses of Special Regional Soils

Analysis	Units	No. of Samples	1981 ($\bar{x} \pm 2s$)	1983 ($\bar{x} \pm 2s$)
^{137}Cs	(pCi/g)	6	0.68 ± 0.80	0.55 ± 0.68
^{238}Pu	(pCi/g)	6	0.00040 ± 0.00049	0.00054 ± 0.00090
$^{239,240}Pu$	(pCi/g)	6	0.0091 ± 0.0098	0.00819 ± 0.01105
^{90}Sr	(pCi/g)	6	0.49 ± 0.50	0.32 ± 0.22
Total U	(μg/g)	6	---	2.4 ± 1.2
Gross gamma	(counts/min/g)	6	---	3.0 ± 2.8
$^{239,240}Pu/^{238}Pu$	---	6	23	15

5. *Transport of Radionuclides in Surface Runoff.* The major transport of radionuclides from canyons that have received or are now receiving treated low-level radioactive effluents is by surface runoff. Runoff samples from these canyons were analyzed for radionuclides in solution and on suspended sediments. The runoff in Los Alamos Canyon was found to carry trace amounts of plutonium to the Rio Grande in silts and clays (suspended sediments).

a. Introduction. The major transport of radionuclides from canyons that have received or are now receiving treated low-level radioactive effluents is by surface runoff (solution and sediments). Radionuclides in the effluents become adsorbed or attached to sediment particles in the stream channels. The concentration of radioactivity in the alluvium is highest near the effluent outfall and decreases in concentration downgradient in the canyon as the sediments and radionuclides are transported and dispersed by other industrial effluents, sanitary effluents, and surface runoff.

Surface runoff, the major transport mechanism, occurs in two modes. Spring snowmelt runoff occurs over a long period of time (days) at a low discharge rate and sediment load. Summer runoff from thunderstorms occurs over a short period of time (hours) at a high discharge rate and sediment load.

Samples of the runoff were collected and analyzed for radionuclides in solution and suspended sediments (Table E-XXIII). Radioactivity in solution is defined as the filtrate passing through a 0.45 μm pore-size filter, while radioactivity in suspended sediments is defined as the residue on the filter. The solution was analyzed for ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{3}H, total U, and gross gamma, while suspended sediments were analyzed for ^{238}Pu and $^{239,240}Pu$.

b. Snowmelt Runoff. During 1983 snowmelt runoff was monitored at Los Alamos Canyon at State Road 4 (SR-4) and at Otowi near the Rio Grande (Fig. 19). Los Alamos Canyon and tributary Pueblo Canyon have received low-level radioactive effluents from treatment plants, so the channel sediments contain radionuclides that are subject to transport in surface runoff.

Snowmelt runoff was also monitored in Pajarito Canyon at SR-4. State Road 4 forms the eastern boundary of the Laboratory. There are no industrial effluents released into Pajarito Canyon. Runoff was also monitored as it drained several of the Laboratory's technical areas, one

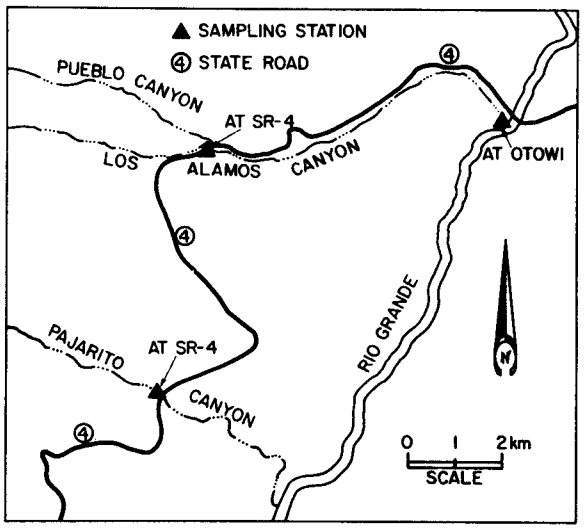


Fig. 19. Locations of surface runoff sampling stations.

of which is used for the disposal and storage area for low-level solid radioactive wastes.

The runoff samples from Pajarito Canyon are compared with samples from Los Alamos Canyon in Tables XI and E-XXIII. The concentrations of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{3}H, total U, and gross gamma activity in solution samples from Los Alamos Canyon at SR-4 and Otowi were indistinguishable from radioactivity concentrations in solution samples from Pajarito Canyon.

There was no significant difference in concentrations of ^{238}Pu in suspended sediment in Los Alamos Canyon at SR-4 and at Otowi when compared to those ^{238}Pu concentrations in Pajarito Canyon (Table XI). There was, however, a significant difference in the $^{239,240}Pu$ concentrations in suspended sediments in Los Alamos Canyon when compared to those concentrations in Pajarito Canyon. The average concentrations of $^{239,240}Pu$ in suspended sediments in Los Alamos Canyon ranged

Table XI

Average Radiochemical and Chemical Concentrations in Snowmelt Runoff

Solution	Units	Los Alamos Canyon SR-4	Los Alamos Canyon Otowi	Pajarito Canyon
Radiochemical				
^{137}Cs	10^{-9} μCi/mℓ	20 ± 65	16 ± 44	4 ± 60
^{238}Pu	10^{-9} μCi/mℓ	0.003 ± 0.018	−0.001 ± 0.008	−0.005 ± 0.019
$^{239,240}Pu$	10^{-9} μCi/mℓ	0.014 ± 0.021	0.008 ± 0.008	0.007 ± 0.005
^{3}H	10^{-6} μCi/mℓ	2.4 ± 1.1	2.4 ± 1.0	3.1 ± 1.4
Total U	μg/ℓ	0.1 ± 0.7	0.6 ± 1.1	0.3 ± 0.8
Gross gamma	counts/min/ℓ	49 ± 67	33 ± 47	41 ± 56
Chemical				
Cl	mg/ℓ	11	13	31
F	mg/ℓ	0.1	0.2	0.1
NO_3	mg/ℓ	1.5	1.0	0.9
TDS	mg/ℓ	118	131	192
pH	No units	7.5	7.8	7.7
Suspended Sediments				
^{238}Pu	pCi/g	0.27 ± 0.40	0.15 ± 0.24	0.20 ± 0.59
$^{239,240}Pu$	pCi/g	4.7 ± 6.4	2.3 ± 3.0	0.18 ± 0.53

from 4.7 pCi/g at SR-4 to 2.3 pCi/g at Otowi. These were about 26 and 13 times greater than the average background $^{239,240}Pu$ concentrations in Pajarito Canyon. The concentrations of $^{239,240}Pu$ in sediments declined downstream in Los Alamos Canyon as the sediments dispersed and mixed with uncontaminated sediments in the channel.

The average chemical concentrations of the runoff at each of the three stations are also shown in Table XI. The chloride and total dissolved solids concentrations in runoff in Pajarito Canyon were higher than those in Los Alamos Canyon. This was probably caused by the smaller drainage area of Pajarito Canyon. This resulted in smaller volume of runoff in Pajarito Canyon at SR-4 (about 11×10^4 m^3) compared with that in Los Alamos Canyon at SR-4 (52×10^4 m^3).

c. Summer Runoff. One summer thunderstorm runoff event was sampled in Los Alamos Canyon at SR-4 and at Otowi (Table XII). There were no unusually high concentrations of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{3}H, total U, or gross gamma radioactivity in solution at either SR-4 or Otowi. However, the ^{238}Pu and $^{239,240}Pu$ concentrations in the suspended sediments were above normal levels at SR-4. As with snowmelt runoff, the plutonium concentrations decreased downgradient in the Canyon.

d. Runoff in the Rio Grande. Analyses were performed on two samples, one snowmelt runoff and the other summer runoff in the Rio Grande. Except for total U levels, the concentrations of radionuclides in solution and suspended sediments were at background levels. The total U concentration in the snowmelt runoff was 1.4 μg/ℓ, while the summer runoff had a concentration of 4.4 μg/ℓ. These levels do not reflect contamination, but are caused by natural uranium leached from soil.

e. Summary. There was little, if any, transport during 1983 of radionuclides in solution surface runoff in Los Alamos Canyon, which has received treated low level radioactive effluents. There is little, if any, transport of ^{238}Pu in suspended sediments. The major transport of radioactivity in the suspended sediments was of $^{239,240}Pu$. This was the major isotope of plutonium released by the treatment plants released into DP and Pueblo Canyons, which are tributaries to Los Alamos Canyon. The runoff in Los Alamos Canyon carries trace amounts of plutonium to the Rio Grande in silts and clays (suspended sediments).

Table XII

Summer Runoff, Los Alamos Canyon and Rio Grande

		Solution						Suspended Sediments	
Location	Date (month-day)	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)
Los Alamos Canyon									
SR-4	08-02	6 ± 33	0.001 ± 0.002	0.002 ± 0.002	36 ± 8.0	1.4 ± 0.8	49 ± 36	0.463 ± 0.038	3.08 ± 0.160
Otowi	08-02	4 ± 42	0.000 ± 0.004	0.001 ± 0.004	21 ± 4.0	2.0 ± 0.8	69 ± 36	0.160 ± 0.018	1.31 ± 0.080
Rio Grande									
Otowi	05-29	---	−0.004 ± 0.018	−0.012 ± 0.018	1.6 ± 0.6	1.4 ± 0.8	30 ± 36	0.014 ± 0.012	0.014 ± 0.012
Otowi	08-02	43 ± 42	0.001 ± 0.001	0.002 ± 0.002	1.5 ± 0.4	4.4 ± 0.8	36 ± 36	0.002 ± 0.005	0.020 ± 0.008

6. *Radioactivity in Foodstuffs.* Most fruit, vegetable, and fish samples collected in the vicinity of the Laboratory showed no apparent influence from Laboratory operations. Some fruit collected onsite from locations that could have been affected by Laboratory releases had slightly elevated tritium concentrations. Slightly elevated uranium concentrations were in fruit from one onsite location. Some fish samples from Cochiti Reservoir showed higher uranium concentrations than fish samples from background locations. Several fish samples from background locations had higher ^{90}*Sr concentrations than fish samples from Cochiti Reservoir. Honey samples collected on or near the Laboratory showed trace amounts of radionuclides primarily associated with liquid effluent discharges. Radiation doses from the consumption of foodstuffs are discussed in Section III.D.*

a. Introduction. Fruit, vegetable, fish, and honey samples are collectd to monitor foodstuffs for possible radioactive contamination from Laboratory operations. Fruits and vegetables are collected in the Los Alamos area and in the Rio Grande Valley above and below confluences of intermittent streams that cross the Laboratory and flow into the Rio Grande (Fig. 8). Fish are collected from locations above (Abiquiu, Heron, and El Vado Reservoirs that are on the Rio Chama, a tributary of the Rio Grande) and below (Cochiti Rservoir) confluences of these intermittent streams (Fig. 8).

Fruit and vegetables collected in the Rio Grande Valley in the Española area and fish collected at the Abiquiu, Heron, and El Vado Reservoirs would be unaffected by Laboratory operations. These locations are upstream from the confluences with the Rio Grande of intermittent streams crossing the Laboratory. They are also distant from the Laboratory so are unaffected by airborne emissions. These areas are used as control locations for fruit, vegetable, and fish sampling programs.

Some fish samples are taken from bottom feeders, such as carp and suckers, which have a greater probability than higher tropic orders of ingesting any activity that might be associated with sediments. Higher level feeders are also sampled. Honey is collected from hives at several locations within the Laboratory boundary near waste stream outfalls and a tritium facility. Background honey samples come from the residential areas of Barranca Mesa and Pajarito Acres, respectively in and near Los Alamos.

Fruit, vegetable, and fish samples are analyzed for ^{90}Sr, ^{137}Cs, total U, ^{238}Pu, and ^{239,240}Pu. Fruit and vegetable samples are also analyzed for ^{3}H (tritiated water). Honey samples are analyzed for ^{3}H (tritiated water), ^{7}Be, ^{22}Na, ^{54}Mn, ^{57}Co, ^{83}Rb, ^{134}Cs, and ^{137}Cs.

b. Fruits and Vegetables. Data in Tables XIII and E-XXIV summarize fruit and vegetable sample results for ^{3}H (tritiated water) ^{90}Sr, ^{137}Cs, total U, ^{238}Pu, and ^{239,240}Pu. Concentrations of ^{238}Pu, ^{239,240}Pu, ^{90}Sr, ^{137}Cs, and total U in fruits and vegetables at offsite locations potentially affected by Laboratory activities were statistically indistinguishable from concentrations in samples taken in background areas. Concentrations for these radionuclides were low and typical of values expected from natural background or worldwide fallout.

Total U, while very low, was significantly higher in the TA-3 samples. This was the only onsite location that had significantly higher than background uranium concentrations.

Tritium concentrations in water extracted from fruits and vegetables were not significantly different from background levels for the offsite locations. However, they were significantly higher for the three onsite locations, as has been noted in a previous report (ESG 1983). These samples do not represent a significant pathway to man because of the very small amount of edible material and the low concentrations.

Because there are no concentration standards for tritium in produce, the tritium levels that were measured

Table XIII

Tritiated Water Content of Fruits and Vegetables

Location	Water Source	Number of Samples	Tritiated Water Concentration (10^{-6} μCi/mℓ) Average (±1s)[a]	Range	Average Moisture (%)
Española	Rio Grande[b]	10	2.3 ± 0.6	1.8 - 2.7	87 ± 10
Española	Rio Chama[b]	5	3.1 ± 0.8	2.0 - 4.1	80 ± 21
Cochiti	Rio Grande[c]	15	5.3 ± 4.9	1.7 - 20	90 ± 6
Los Alamos	Community System	3	3.3 ± 2.4	1.6 - 6.0	83 ± 2
White Rock/Pajarito Acres	Community System	10	2.4 ± 0.9	1.3 - 3.5	90 ± 8
TA-35	Community System	1	16	---	87
TA-21	Precipitation	2	9.9 ± 2.0	8.5 - 11	87 ± 9
TA-3	Community System	3	19 ± 3.5	16 - 23	85 ± 4

[a]Counting uncertainty.
[b]Upstream from Laboratory stream confluence.
[c]Downstream from Laboratory stream confluence.

in onsite produce were compared to limits for tritium concentrations in water. This comparison is conservative, because the limits on tritium in water are based on an annual water intake from drinking, which is much larger than the annual water intake resulting from eating produce. All the tritium concentrations from the onsite produce were less than 0.7% of the Department of Energy's Uncontrolled Area Concentration Guide for tritium in water. See Section III.D for a discussion of the radiation dose that could result from eating this produce.

c. Fish. Concentrations of ^{238}Pu, ^{239,240}Pu, and ^{137}Cs in fish were statistically indistinguishable between the samples from Cochiti Reservoir and background stations (Table E-XXV). Cochiti Reservoir is an area that could potentially be affected by Laboratory operations, because it is downriver from the intermittent streams that traverse the Labortory (Fig. 8). Four kinds of fish samples were taken: bottom feeder (edible tissue), bottom feeder (gut), higher trophic level feeder (edible tissue), and higher trophic level feeder (gut).

Uranium concentrations in the bottom feeder (gut) and higher trophic level feeder (edible tissue) samples were statistically higher at Cochiti Reservoir (Fig. 8), when compared to the concentrations in similar samples from the background locations (Abiquiu, El Vado, and Heron Reservoirs). These relatively higher uranium concentrations probably reflect the relatively greater concentrations of suspended sediments in Cochiti Reservoir. Uranium naturally occurs in soils and sediments. Fish living in turbid water are more likely to ingest suspended sediments (that contain natural uranium) than are fish living in clearer water, so they are also more likely to have higher concentrations of uranium in their bodies. The uranium concentrations in the Cochiti Reservoir fish samples were low and in the range of levels normally found in sediments from natural background (Table E-XIX). The radiation dose assessment for these samples is in Section III.D.

The radioisotope ^{90}Sr is present in the environment due to worldwide fallout from nuclear weapons testing. The ^{90}Sr concentrations in bottom feeder (edible tissue) samples from the background locations (Abiquiu, El Vado, and Heron Reservoirs) were statistically higher than similar samples from Cochiti Reservoir. Fallout patterns vary with latitude (more fallout as latitude increases northward) and meteorological conditions, so variation in ^{90}Sr levels is quite normal. Because ^{90}Sr resides in bone

(the fish samples included bone), which is not usually consumed by people, and because the ^{90}Sr concentrations were relatively low, no radiation dose assessment was made.

d. **Honey.** Honey samples were analyzed for ^{3}H (tritiated water), ^{7}Be, ^{22}Na, ^{54}Mn, ^{57}Co, ^{83}Rb, ^{134}Cs, ^{137}Cs, and total U. Results are shown in Table E-XXVI. Also shown are analytical results from previous years for ^{3}H (tritiated water), ^{7}Be, ^{22}Na, ^{137}Cs, and total U.

The honey sampling program serves as an indicator of biologically available radionuclides. It can be seen from Table E-XXVI that honey samples collected from onsite hives were generally higher in most radionuclides than the offsite honey samples from Chimayo, Barranca Mesa, and Pajarito Acres. The radiological doses associated with consumption of honey are discussed in Section III.D.

7. Environmental Surveillance of Low-Level Radioactive Solid Waste Management Facilities. Environmental surveillance of one active and eight inactive radioactive solid waste management sites at Los Alamos documents compliance with appropriate standards, identifies undesirable trends, and monitors the adequacy of disposal practices. The general public is excluded from these sites because they are controlled-access areas. At the active disposal area there are transient elevated levels of external penetrating radiation from waste management operations (handling and storing) before waste burial. There also is some transport by surface runoff of low-level surface contamination from the active disposal area into controlled-access canyons.

a. **Introduction.** Environmental surveillance of radioactive solid waste management facilities at Los Alamos documents compliance with appropriate standards, identifies undesirable trends, and monitors the adequacy of disposal practices. Radioactivity concentrations in air (particulates and moisture), water, soil, and sediment samples are measured, along with the levels of penetrating radiation. Nine radioactive solid waste management sites are monitored; one is currently active (Area G) and the remainder are closed or decommissioned (Areas A, B, C, E, F, T, U, and V). The general public is excluded from these waste management sites because they are controlled-access areas.

b. **External Penetrating Radiation Measurements.** Levels of external penetrating radiation (including x and gamma rays and charged particle contributions from cosmic, terrestrial, and manmade sources) are measured at the nine waste management sites. Thermoluminescent dosimeters (TLDs) attached to the site perimeter fences measure radiation from both natural background and manmade sources (see Section IV.A.1).

The annual TLD measurements doses for the waste management areas are in Table XIV. A holding tank for radioactive liquid wastes from current operations and buried wastes from past operations at Area T caused this area's relatively higher measurement. Buried radioactive wastes at Area C near the exclusion fence were removed and buried at Area G during 1983. The relatively higher 265 mrem measurement at Area C occurred before that waste was removed. Several transient elevated TLD measurements at Area G were due to the waste management operations (handling and storing) before waste burial.

c. **Radionuclide Concentrations in Soils and Bedrock.** During 1983, 207 surface soil samples (top 30 cm, Table XV) and 209 bedrock and subsurface samples (below 30 cm, Table XV) were taken at eight inactive low-level radioactive waste management areas. These samples were analyzed for ^{3}H, ^{137}Cs, $^{239,240}Pu$, and total U, because these radionuclides are good indicators of migration. Gamma spectra analyses are also done on the samples to identify other radionuclides.

Table XIV

External Penetrating Radiation at
Waste Management Areas During 1983

Area	No. of Sampling Locations	No. of Quarterly Measurements	Annual Measurements (mrem) Maximum ($\bar{x} \pm 2s$)	Minimum ($\bar{x} \pm 2s$)	Average ($\bar{x} \pm 2s$)
Inactive Area					
A	5	20	138.2 ± 5.2	126.7 ± 5.2	131.6 ± 9.2
B	23	92	164.9 ± 5.2	120.6 ± 5.1	138.1 ± 17.0
C	18	71	265.0 ± 5.5	123.0 ± 5.1	143.0 ± 63.3
E	4	8	157.7 ± 5.4	148.5 ± 5.2	153.6 ± 7.6
F	2	3	152.0 ± 5.4	123.3 ± 5.1	137.6 ± 40.5
T	7	28	287.8 ± 5.6	134.6 ± 5.1	165.7 ± 108.2
U	2	8	140.7 ± 5.1	137.8 ± 5.1	139.2 ± 4.1
V	3	12	147.1 ± 5.2	139.4 ± 5.1	142.3 ± 8.2
Active Area					
G	27	108	219.5 ± 5.4	136.0 ± 5.1	157.4 ± 33.0

The uranium sampling data show adequate containment of uranium in the wastes. The ^{3}H data show there is some migration from buried wastes. However, better packaging procedures have greatly improved containment (Wheeler 1975). The ^{137}Cs data are marginally above detectable concentrations in subsurface samples from a few sites. Further ^{137}Cs data are being collected and evaluated.

The $^{239,240}Pu$ data show there is some contamination from liquid waste storage and disposal operations that were begun in the 1940s and 1950s. There is downward migration of plutonium below Area T, but there is little lateral movement (Nyhan 1983). This contamination was caused by intentional experimental flooding of plutonium absorption beds in 1961. There is presently no water in the beds. The plutonium soil concentrations may not prove extensive enough to warrant remedial action, although further evaluations are being done.

There also are low levels of plutonium contamination at Area A (apparently from leaks in liquid waste storage tanks that have been emptied) and at Area V (from migration of plutonium in laundry waste water that was discharged into a former lagoon system). These plutonium concentrations are several orders of magnitude below published guidance for remedial action (DOE 1983 and Gilbert 1983).

Waste management practices at Los Alamos are continually being improved. Better treatment, handling, packaging, storage, and disposal methods help ensure containment of low-level radioactive wastes. For example, liquid wastes that contain plutonium are treated and reduced to solid wastes for disposal. This practice precludes liquid wastes leaking from their packages into the environment.

d. Air Sampling Results. At the end of 1983 four new air sampling stations were placed around the perimeter of TA-54 (Area G) to supplement the existing air sampler at the site. Area G is the only active radioactive solid waste management site at the Laboratory. Air particulate and moisture samples from these stations are analyzed for ^{3}H, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and total U. The air sampling data for the existing air sampler (Station 22, see Section IV.A.2) showed no unusual data during 1983.

Table XV

Radionuclide Concentrations in Soils
and Bedrock at the Low-Level
Radioactive Waste Management Areas

Surface Soils

	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	$^{239,240}Pu$ (pCi/g)
Depth 0-1 cm			
Range	5.1 - 81	3.0 - 4.1	0.02 - 0.07
$\bar{x} \pm 2s$	24 ± 30	3.6 ± 0.7	0.04 ± 0.04
No. of Samples	86	6	5
Depth 1-10 cm			
Range	6.2 - 115	3.3 - 3.7	0.002 - 0.04
$\bar{x} \pm 2s$	22 ± 37	3.6 ± 0.4	0.02 ± 0.03
No. of Samples	83	6	6
Depth 10-30			
Range	3.1 - 66	2.9 - 3.3	0.001 - 0.02
$\bar{x} \pm 2s$	12 ± 20	3.2 ± 0.4	0.007 ± 0.02
No. of Samples	38	4	4

Subsurface Soils and Bedrock

	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (pCi/g)	Total U (μg/g)	$^{239,240}Pu$ (pCi/g)
Depth 0.0-0.9 m				
Range	4.5 - 29	0.01 - 0.46	3.0 - 4.8	---
$\bar{x} \pm 2s$	12 ± 13	0.19 ± 0.30	3.8 ± 1.1	---
No. of Samples	12	11	11	---
Depth >0.9 m				
Range	7.1 - 90	0.00 - 0.72	2.7 - 62	0.000 - 2.2
$\bar{x} \pm 2s$	30 ± 44	0.08 ± 0.23	4.3 - 11	0.06 ± 0.51
No. of Samples	88	121	122	118

All airborne radionuclide concentration were well less than 1% of the Department of Energy's Concentration Guides.

e. Radionuclide Transport in Sediments and Runoff. Radionuclides transported by surface runoff have an affinity for attachment to sediment particles by ion exchange or adsorption. Thus, radionuclides in surface runoff tend to concentrate on sediments in the stream channels that drain Area G. Nine sampling stations are located outside the perimeter fence at Area G to collect sediments that are transported from Area G by surface runoff (Fig. 20).

The sediments analyzed for ^{137}Cs and total U in 1983 were within or below concentrations found in the natural environment at all nine stations (Tables XVI and E-XXVII). The ^{238}Pu concentrations in sediments at Stations 4 and 6 through 9 and ^{239,240}Pu concentrations in sediments at Stations 6 and 7 were above regional levels (^{238}Pu regional sediment concentration is 0.006 pCi/g and ^{239,240}Pu regional sediment concentration is 0.042 pCi/g). This indicates some transport of surface contamination by runoff from Area G. The maximum ^{238}Pu sediment concentration was 0.16 pCi/g or about 27 times greater than the regional concentration. The maximum ^{239,240}Pu sediment concentration was 2.4 pCi/g or about 57 times greater than the regional concentration. These above-background concentrations are not considered significant, because Area G is several kilometers from the Laboratory boundary (which restricts public access) and additional sampling of storm runoff at the Laboratory boundary did not detect any contamination (see Section IV.A.5, Pajarito Canyon).

The average concentrations of ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and total U in sediments for 1982 and 1983 from the nine stations are compared to average regional levels in Table XVI. The 1983 mean concentrations of ^{238}Pu and ^{239,240}Pu in sediments from the nine stations have increased slightly over the 1982 concentrations.

Only one runoff event at the gaging station occurred during the summer. A sample collected at the station was analyzed for plutonium in solution and in suspended sediments (Tables XVI and E-XXVII). Radioactivity in

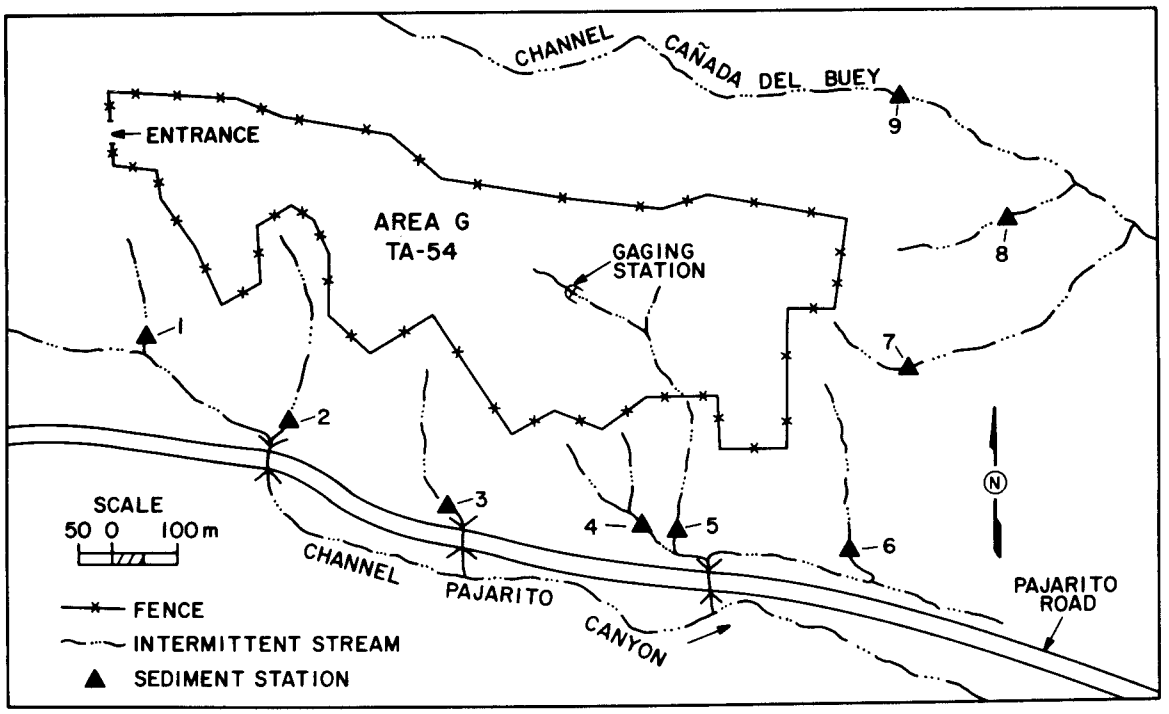


Fig. 20. Surface water gaging station in Area G (TA-54) and sediment sampling stations adjacent to Area G.

Table XVI

Radiochemical Analyses of Sediments and Runoff at TA-54 (Area G)

Analyses	Units	1982 ($\bar{x} \pm 2s$)	1983 $\bar{x} \pm 2s$)	1978-1982[a] Regional Stations ($\bar{x} \pm 2s$)
Nine Sediment Stations				
^{137}Cs	pCi/g	0.30 ± 0.41	0.23 ± 0.20	0.19 ± 0.27
^{238}Pu	pCi/g	0.11 ± 0.025	0.033 ± 0.107	0.000 ± 0.006
$^{239,240}Pu$	pCi/g	0.032 ± 0.104	0.0340 ± 1.60	0.007 ± 0.036
Total U	μg/g	3.2 ± 1.9	3.7 ± 2.3	2.7 ± 1.9
Runoff at Gaging Station				
Solution				1983 Pajarito Canyon ($\bar{x} \pm 2s$)
^{238}Pu	10^{-9} μCi/mℓ	0.027 ± 0.051	0.001 ± 0.001	−0.005 ± 0.019
$^{239,240}Pu$	10^{-9} μCi/mℓ	0.013 ± 0.056	0.002 ± 0.002	−0.007 ± 0.005
Suspended Sediments				
^{238}Pu	pCi/g	1.1 ± 0.28	3.2 ± 0.32	0.20 ± 0.59
$^{239,240}Pu$	pCi/g	1.3 ± 0.24	5. ± 0.12	0.18 ± 0.53

[a]Reference (Purtymun 1983D).

solution is defined as the filtrate passing through a 0.45-μm pore-size filter, while radioactivity in suspended sediments is defined as residue on the filter. This runoff event contained little if any ^{238}Pu or $^{239,240}Pu$ in solution. The suspended sediments, however, transported both ^{238}Pu and $^{239,240}Pu$ during the runoff event. The average concentrations ^{238}Pu and $^{239,240}Pu$ in the suspended sediments in 1983 were higher when compared with the concentrations of ^{238}Pu and $^{239,240}Pu$ in 1982 (Table XVI).

8. Radioactive Airborne Emissions and Liquid Effluents. **The quantity of airborne radioactive emissions released by Laboratory operations in 1983 were about 77% higher (about 205 000 Ci more) than in 1982. Almost all this increase was caused by higher operating levels of the linear particle accelerator at the Los Alamos Meson Physics Facility. This significantly increased the quantities of short-lived (2 to 20 minute half-lives) airborne activation product emissions. Liquid effluents from two waste treatment plants and one sanitary sewage lagoon system contained radioactivity levels well below the Department of Energy's Controlled Area Concentration Guides. Overall, the 1983 radioactive liquid effluents contained about 32% (about 5100 Ci) less radioactivity than in 1982.**

a. Radioactive Airborne Emissions. Radioactive airborne emissions are monitored and discharged at the Laboratory from 84 stacks. These emissions consist principally of filtered exhausts from gloveboxes, experimental facilities, operational facilities (such as liquid waste treatment plants), a research nuclear reactor, and a linear particle accelerator at the Los Alamos Meson Physics Facility (LAMPF). Quantities of airborne radioactivity released depend on the kinds of research being done, so they vary significantly from year to year (Figs. 21-23, Table III, and Table E-I).

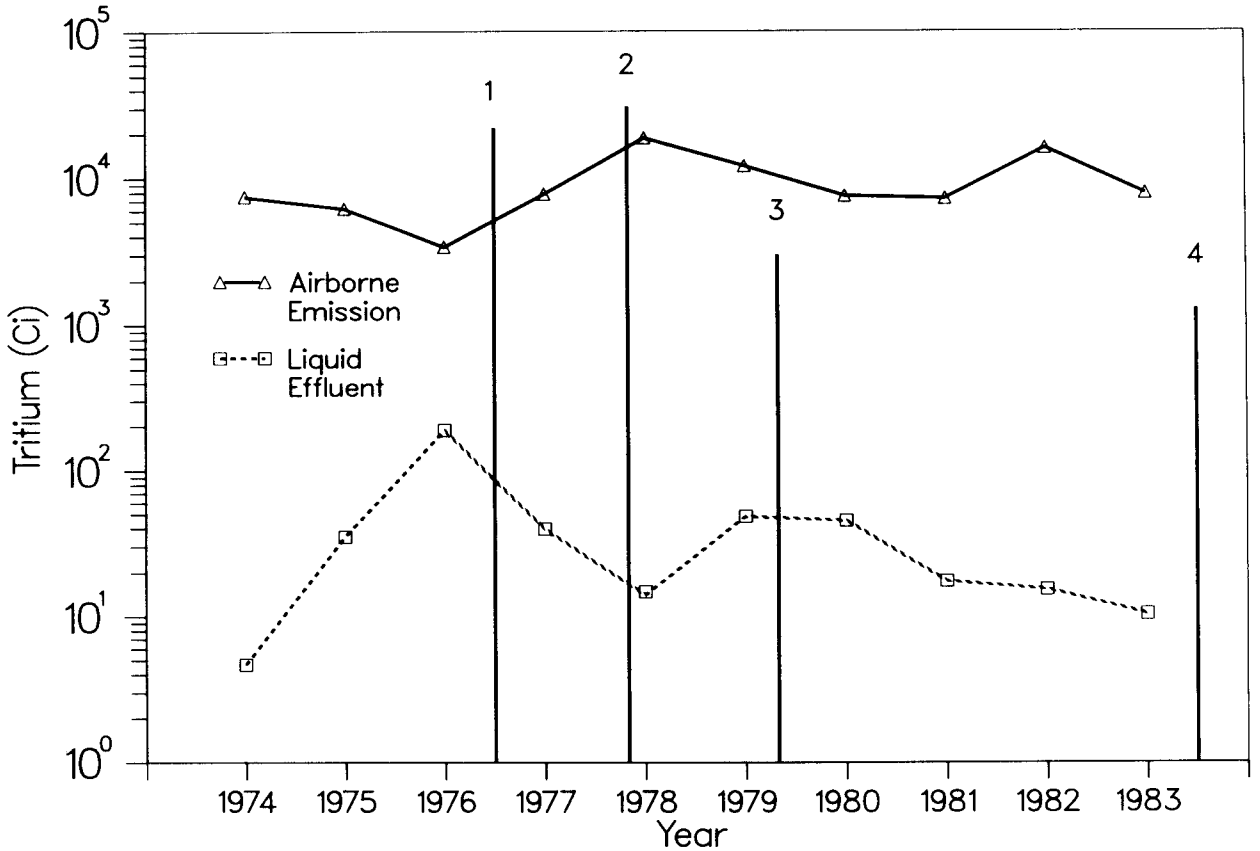
During 1983, the most significant increase was in the airborne activation products (gases, particulates, and vapors) from higher operating levels of the linear particle accelerator at LAMPF. In 1983 the quantity of activation products was about 85% higher (about 213 000 Ci more) than in 1982 (Fig. 23, Table III, and Table E-I). The principal airborne activation products (half-lives in parentheses) were ^{11}C (20 min), ^{13}N (10 min), ^{14}O (71 sec), ^{15}O (123 sec), ^{41}Ar (1.83 h), ^{192}Au (4.1 h), and ^{195}Hg (9.5 h). Over 98% of the radioactivity was associated with the ^{11}C, ^{13}N, ^{14}O, and ^{15}O radioisotopes, which have half-lives that range from about 2 to 20 minutes. Consequently, the radioactivity from these radionuclides decays very rapidly. Engineering design modifications (increasing the holdup time of the airborne emissions, moving the stack, and improving the beam stop) to reduce exposure from airborne activation products are through the conceptual design phase and have been included in Laboratory funding requests.

In addition to airborne releases from facilities, some depleted uranium (uranium consisting primarily of ^{238}U) is dispersed by experiments employing conventional high explosives. In 1983, about 830 kg of depleted uranium were used in such experiments. This mass contains approximately 0.29 Ci of activity. Most debris from these experiments is deposited on the ground in the vicinity of the firing sites. Limited experimental information indicates that no more than about 10% of the depleted uranium (83 kg or 0.03 Ci in 1983) becomes airborne. Approximate dispersion calculations indicate that resulting airborne concentrations are in the same range as attributable to natural crustal-abundance uranium in resuspended dust. This theoretical evaluation is compatible with the atmospheric uranium concentrations measured by the routine air sampling program (see Section IV.A.2). Estimates of nonradioactive releases from experiments are discussed in Section IV.B.2.

b. Radioactive Liquid Effluents. Treated liquid effluents containing low levels or radioactivity are released from the Central Liquid Waste Treatment Plant (TA-50), a smaller plant serving a uranium processing facility (TA-21), and a sanitary sewage lagoon system serving the Los Alamos Meson Physics Facility (TA-53). Detailed results of the effluent radioactivity monitoring are in Table III, Table E-XXVIII, and Figs. 21, 22, and 24.

A total of 1.7×10^7 ℓ of effluent was discharged from the TA-53 sanitary lagoon system containing ^{22}Na (0.11 Ci), ^{7}Be (2.8 Ci), ^{3}H (16 Ci), ^{57}Co (0.22 Ci), ^{60}Co (0.027 Ci), ^{134}Cs (0.087 Ci), and ^{54}Mn (0.076 Ci). The source of the radioactivity was activated water from beam-stop cooling systems. Samples of water, sediments, and transpirate from trees adjacent to the discharge from the lagoons have been collected this year and the results of this sampling program are discussed in Section VI.F.

Releases from the larger radioactive liquid waste treatment plant (TA-50) are discharged into a normally dry stream channel in Mortandad Canyon where surface flow has not passed beyond the Laboratory boundary since



Unplanned Releases:
1 22,000 Ci on July 15, 1976.
2 30,800 Ci on October 6, 1977.
3 3,000 Ci on May 4, 1979.
4 1,300 Ci on May 12, 1983.

Fig. 21. Summary of tritium releases (airborne emissions and liquid effluents).

before the plant began operation. Discharges from the smaller plant (TA-21) are into DP Canyon, a tributary of Los Alamos Canyon, where runoff does at times flow past the boundary and transports some residual radioactivity adsorbed on sediments. Effluent from the Los Alamos Meson Physics Facility's sanitary lagoon system sinks into alluvium of Los Alamos Canyon within the Laboratory's boundary.

9. Unplanned Releases

a. Atmospheric Tritium Releases at TA-33. On May 12, 1983, approximatley 1300 Ci of tritium was released from the Building 86 stack at TA-33. The release lasted for several minutes, beginning at about 2:42 p.m. It was almost all gaseous tritium.

Samples from eight air samplers from the Laboratory's routine air sampling network were analyzed for tritium. These samples were of tritiated water vapor, not of gaseous tritium. Six soil and six vegetation samples were collected downwind of the stack in the area expected to be most impacted by the release. Moisture was extracted from the samples and analyzed for tritium.

Doses to the public resulting from the release were estimated using meteorological modeling, air sampling results, vegetation sampling results, and soil sampling data. The maximum potential whole body dose by inhalation of tritium from the release to a member of the public (Bandelier National Monument) was estimated to be 0.02 mrem. This dose is 0.004% of the Department of Energy's 500 mrem/yr Radiation Protection Standard for individuals in the public. The maximum whole body

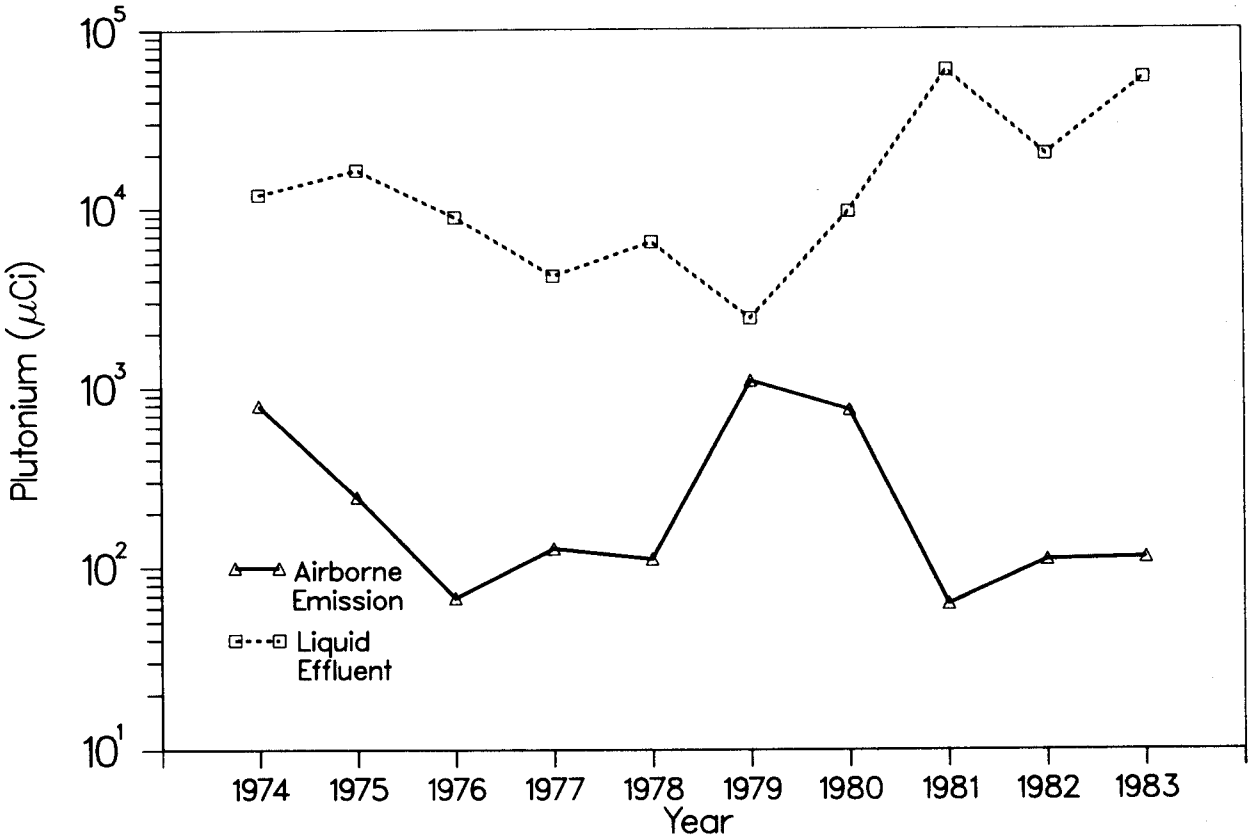


Fig. 22. Summary of plutonium releases (airborne emissions and liquid effluents).

dose through an ingestion pathway was estimated to be 0.2 mrem or 0.04% of the Radiation Protection Standard.

On August 25, 1983, at about 4:30 p.m., a puff release of 104 Ci of tritium (believed to be in the form of water vapor) occurred at TA-33. This was followed by a slow release of an additional 45 Ci in the next 24 hours. At the time of the puff and for the next 2 hours, winds were from the SW to SSW. This made the nearest downwind population the residents of Pajarito Acres and White Rock. The maximum calculated dose to a person in Pajarito Acres was less than 1 mrem. If someone had been along State Road 4 near Ancho Canyon during the release, that person's maximum dose would also have been less than 1 mrem or less than 0.2% of the Radiation Protection Standard. Tritium measurements from the air sampling network supported these calculations.

b. Fluoride Gas Release. An old gas cylinder at TA-50 (Area C) was accidentally ruptured on December 1, 1983. There were two separate releases (at 11:00 a.m. and 12:15 p.m.). Measurements indicated the liquid and gas contents of the cylinder contained fluorides [most likely hydrofluoric acid (HF)]. Atmospheric dispersion analyses made for the two separate releases estimated the worst-case airborne HF concentrations. Concentrations of HF from the 11:00 a.m. release were at least 10 times the Threshold Limit Value—Short Term Exposure Limit of 5 mg/m^3 (ACGIH 1983) up to 1000 m downwind and over the limit up to 2500 m downwind. Concentrations from the 12:15 p.m. release were estimated to be 75% less, with concentrations at 10 times the limit up to 500 m downwind and exceeding the limit up to 1300 m downwind.

The 11:00 a.m. release initially crossed adjacent Pajarito Road (Fig. 5) and then most likely traveled across the western Laboratory boundary toward the Jemez Mountains. The 12:15 p.m. release traveled NNW, initially over TA-50 and then possibly over a trailer park and the Los Alamos townsite. The maximum HF concentrations would have been slightly below the Threshold Limit Value—Short Term Exposure Limit at the trailer park and townsite.

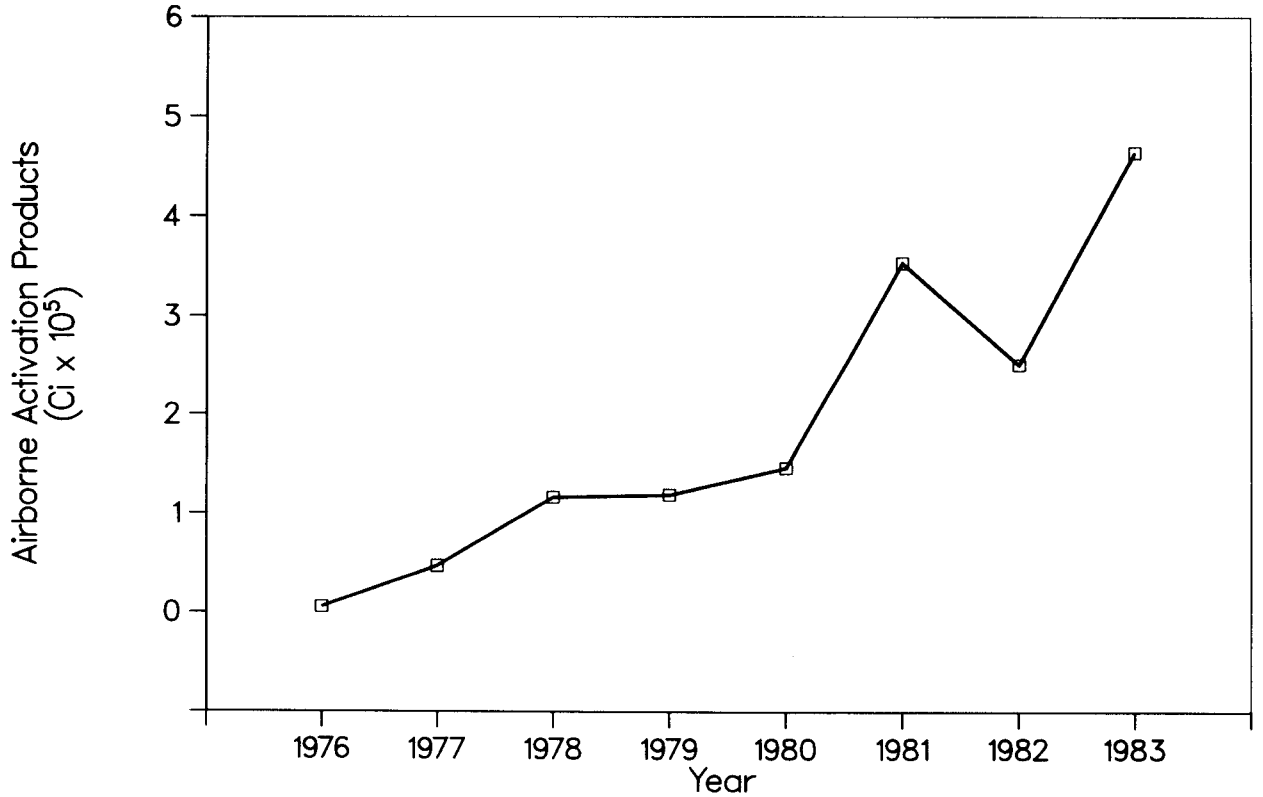


Fig. 23. Airborne activation product releases (^{11}C, ^{13}N, ^{14}O, ^{15}O, ^{41}Ar, ^{192}Au, ^{195}Hg) from the Los Alamos Meson Physics Facility (TA-53).

B. Chemical Constituents

1. Chemical Quality of Water. **Chemical analyses of surface waters from regional, perimeter, and onsite (areas where there are no effluent releases) areas varied slightly from previous years. However, these variations in concentrations are within normal range of seasonal fluctuations. Chemical quality of ground waters (wells and springs) from perimeter and onsite stations did not change significantly from previous years. Chemical quality of water from the municipal supply for the Laboratory and community met standards set by the Environmental Protection Agency. Analyses of water from onsite effluent release areas indicate some constituents were at greater concentrations than they are in naturally occurring waters. However, these waters are not a source of municipal, industrial, or agricultural supply.**

a. **Introduction.** Regional, perimeter, White Rock Canyon (perimeter), onsite noneffluent areas (areas where there are no effluent releases), and onsite effluent release areas are sampled at the same locations that are used for radioactive monitoring of surface and ground waters (Table E-VIII). Maximum concentrations for five chemical constituents are shown in Table XVII. These maximum concentrations are compared to drinking

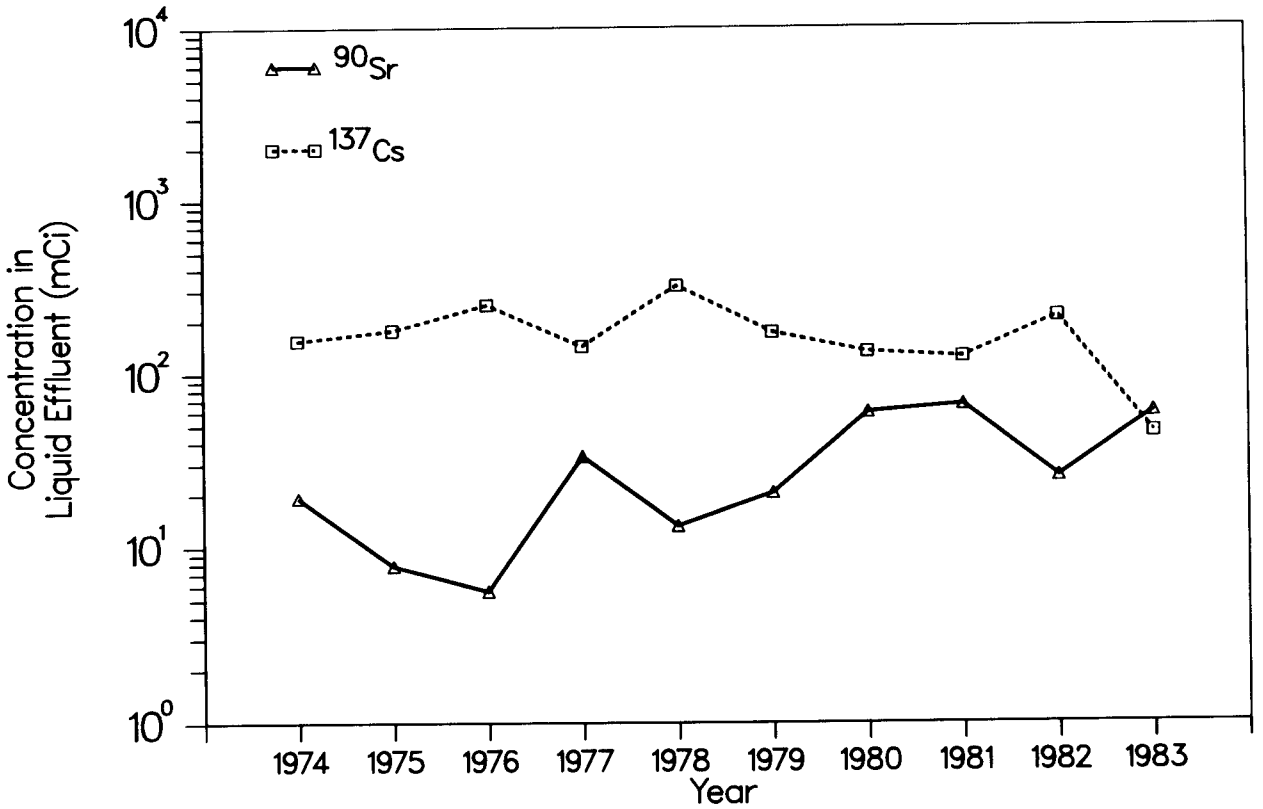


Fig. 24. Summary of strontium and cesium liquid effluent releases.

water standards for reference, even though the waters are not used for municipal or industrial supply. Regional stations are shown in Fig. 13, while perimeter and onsite stations are shown in Fig. 14. Methods of collection, analyses, and reporting of water data are described in Appendix B.

b. Regional and Perimeter Surface and Ground Waters. Regional stations consist of six surface water stations on the Rio Chama, Rio Grande, and Jemez River (Fig. 13). A comparison with drinking water standards of maximum concentrations for five chemical constituents in the regional surface waters shows these concentrations are below maximum concentrations allowed for drinking water (Table XVII). There has been no significant change from previous years in the chemical quality of regional surface waters. The quality of surface waters will vary slightly during the year because of dilution of base flow with storm runoff. Detailed analyses of regional surface waters are in Table E-IX.

Perimeter stations are composed of three surface water stations and three springs. Sampling stations in White Rock Canyon consist of 23 springs, 3 streams, and effluent from 1 Los Alamos County sanitary treatment plant (Table XVII). The levels of the chemical constituents analyzed in samples from these stations are low compared with drinking water standards (with the exception of pH from one spring in White Rock Canyon). There was no significant change in chemical quality of ground water from the springs. Detailed chemical analyses are in Tables E-X (perimeter) and E-XI (White Rock Canyon).

c. Onsite Surface and Ground Waters. Onsite noneffluent area (an area where there is no effluent discharge) water samples are collected from three surface water stations and five wells completed in the main aquifer (Fig. 14). Maximum concentrations for select constituents in the noneffluent areas are in Table XVII.

Table XVII

Maximum Chemical Concentrations in Surface and Ground Waters

	Number of Stations	mg/ℓ				
		Cl	F	NO_3	TDS	pH
Standard[a]		250	2.0	45	1000	6.5 - 8.5
Offsite Stations						
Regional Stations	6	78	1.0	3.9	255	8.3
Perimeter Stations	6	16	0.7	10	214	8.3
White Rock Canyon	27	49	0.6	3.9	458	9.4
Summary:						
Maximum Concentration		78	1.0	10	458	9.4
Maximum Concentration as Per Cent of Standard		31	50	22	46	111
Onsite Stations						
Noneffluent Areas	8	155	0.7	43	404	7.9
Effluent Release Areas						
Acid-Pueblo Canyon	8	85	0.9	52	329	7.8
DP-Los Alamos Canyon	8	78	1.6	89	499	7.8
Sandia Canyon	3	124	1.6	20	771	8.0
Mortandad Canyon	7	30	6.3	440	899	8.3
Summary:						
Maximum Concentration		155	6.3	440	899	8.3
Maximum Concentration as Per Cent of Standard		62	315	978	90	98

[a](EPA 1976) and (EPA 1979).

The quality of surface water varies slightly but insignificantly. The quality of water from the wells has not changed from previous years. Detailed results of the chemical analyses are in Table E-XII.

Water samples are collected from 36 stations in 4 canyons that receive sanitary and/or industrial effluents (Fig. 14, Table E-VIII). Maximum concentrations of selected constituents in water from each canyon are summarized in Table XVII. Tables E-XIII through E-XVI detail individual chemical constituents from the stations in the four canyons. Additional chemical quality results (metal ions and organics) from selected stations in the four canyons are in Table E-XXIX.

Acid-Pueblo Canyon received treated industrial effluents from 1943 to 1964. Currently, it receives treated sanitary effluents, which are now the major part of the flow. The effluents are from a Los Alamos County operated plant. Sandia Canyon receives cooling tower blowdown and some treated sanitary effluents. DP-Los Alamos Canyon and Mortandad Canyons receive treated

industrial effluents that contain radionuclides and residual chemicals used in waste treatment processes. The relatively high chlorides, nitrates, and total dissolved solids result from effluents released into the canyons. Relatively high fluoride and nitrate concentrations are in waters from Mortandad Canyon. Mortandad Canyon receives the largest volume of industrial effluents.

Though the concentrations of some chemical constituents in the water in these canyons are high when compared to drinking water standards, these onsite waters are not a source of municipal, industrial, or agricultural supply. Maximum chemical concentrations are in water samples taken near the effluent outfalls. The chemical quality of the water improves downgradient from the outfall. Surface flow in these canyons reaches the Rio Grande only during spring snowmelt or heavy summer thunderstorms.

d. Water Supply. Municipal and industrial water supplies for the Laboratory and community were sampled at 15 deep wells, 1 gallery (underground basin for spring discharge), and 5 stations in the distribution system (Table E-VIII, Fig. 14). Water at Bandelier National Monument is from the Los Alamos distribution system. Also shown as part of the distribution system is Fenton Hill Geothermal Site (TA-57), which has its own water supply furnished by a deep well. The Fenton Hill Geothermal Site is located about 30 km west of Los Alamos.

Appendix A gives federal and state standards and criteria for municipal water supply. Maximum concentrations of chemical constituents from wells, gallery, and distribution system stations are compared to primary and secondary standards in Table XVII. Detailed chemical analyses for water supply and distribution are in Table E-XVII. The primary maximum contaminant level (MCL) is the maximum permissible level of a contaminant in water that may be delivered to a free-flowing outlet of the ultimate user of a public water supply system. The secondary drinking water levels for contaminants are primarily related to the aesthetic qualities of the drinking water and its public acceptance. At very high concentrations, secondary contaminants may have negative health implications as well as aesthetic degradations.

Chemical constituents in waters from the wells, gallery, and distribution system (Los Alamos, Bandelier National Monument, and Fenton Hill Geothermal Site) are in compliance with the primary standards (Table XVIII). Waters from the wells, gallery, and distribution system meet all secondary standards, except for the iron concentration from the gallery water, which is about four times the secondary standard (Table E-XVII). However, mixing of water from the gallery with well water reduced the iron concentration in the distribution system to acceptable levels.

Water from Well LA-6 (Los Alamos well field) is not used as part of the water supply for Los Alamos. Water from the well contains arsenic at concentrations (0.11 mg/ℓ, Table E-XVII) that are about twice the primary standard. The water cannot be mixed with water from the other wells to reduce the concentrations below the primary standard of 0.05 mg/ℓ.

Table XVIII

Maximum Chemical Concentrations in
Water Supply and Distribution System
(results in mg/ℓ)

Inorganic Chemical Contaminant	Standards	Supply: Well and Gallery	Supply: Per Cent of Standard	Distribution: Los Alamos Bandelier TA-57	Distribution: Per Cent of Standard
Primary[a]					
Ag	0.05	<0.005	<10	<0.005	<10
As	0.05	0.009	18	0.007	14
Ba	1.0	0.06	6	0.04	4
Cd	0.01	<0.002	<20	<0.002	<20
Cr	0.05	0.025	50	0.020	36
F	2.0	1.8	90	1.0	50
Hg	0.002	<0.002	<10	<0.0002	<10
NO_3	45	4.0	9	3.3	7
Pb	0.05	<0.003	<6	0.003	6
Se	0.01	<0.003	<30	<0.003	<30
Secondary[b]					
Cl	250	14	6	32	13
Cu	1.0	0.01	1	<0.01	<1
Fe	0.3	1.48	493	0.045	15
Mn	0.05	0.006	12	<0.001	<2
SO_4	250	14	6	10	4
Zn	5.0	0.02	<1	0.30	6
TDS	500	229	46	263	53
pH	6.5 - 8.5	8.4	99	8.4	99

[a](EPA 1976).
[b](EPA 1979B).

2. *Nonradioactive Airborne Emissions and Liquid Effluents.* Nonradioactive airborne emissions from the beryllium fabrication shop, gasoline storage and combustion, power plant, waste explosive burning, and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality.

A single National Pollutant Discharge Elimination System permit covers nonradioactive liquid effluents from 103 industrial discharge points and 11 sanitary treatment facilities. This year 9 of 11 sanitary sewage treatment facilities exceeded one or more of the National Pollutant Discharge Elimination System permit limits (biochemical oxygen demand, total suspended solids, fecal coliform, and/or pH) in one or more months. Since April 1983, fewer than 4% of all samples from the domestic and industrial outfalls exceeded National Pollutant Discharge Elimination System permit limits.

a. Particulate Air Quality. Airborne particulate concentrations in the Los Alamos and White Rock areas are routinely measured by the New Mexico State Environmental Improvement Division. The highest 24 h averages and annual averages are compared to the New Mexico Ambient Air Quality Standards for particulates in Table XIX, Table E-XXX summarizes these data for 1983. The annual geometric means for Los Alamos and White Rock are well within state standards. Although true 7-day and 30-day averages cannot be calculated, there is no indication that they would exceed state standards. In 1983 there were several exceedingly windy, dusty days during which the 24-h average New Mexico State Standard was exceeded. Most of this dust was of natural origin.

b. Airborne Emissions. Airborne emission sources at the Laboratory that are routinely assayed include the beryllium shop, gasoline storage and combustion, the TA-3 power plant, gas and volatile chemical usage, waste explosive burning, and dynamic testing operations. These sources are discussed separately in the following paragraphs.

Beryllium concentrations in stack gases from the beryllium shop during 1983 ranged from 0.0003 to 0.009 $\mu g/m^3$. The state ambient air quality standard for beryllium is 0.01 $\mu g/m^3$, as a 30-day average. Thus, the standard was not exceeded even in the stack gas. Total beryllium emission for the year was about 7 mg, which is about half of the 1982 emission.

Table XIX

Summary of Atmospheric Particulate Concentrations in Los alamos and White Rock During 1983

	National Secondary and New Mexico Ambient Air Quality Standards for Particulates ($\mu g/m^3$)	Los Alamos ($\mu g/m^3$)	White Rock ($\mu g/m^3$)
Maximum 24 h average	150	353	253
Maximum 7 day average	110	---	---
Maximum 30 day average	90	---	---
Annual geometric mean	60	33	34

Table XX

Estimates of Air Pollutant Emissions Associated with Maintenance and Operation of the Vehicle Fleet

Pollutant	Estimated Amount (metric tons)	Change From 1982 (%)
Gasoline evaporative losses	7.7	+12
Carbon monoxide	291	−18
Organics	19.0	+14
Nitrogen oxides	25.9	+167
Sulfur oxides	3.5	+192
Particulates, exhaust	9.8	+1300
Particulates, tires	1.6	+23

A large fleet of cars and trucks is maintained for the Laboratory complex by the Zia Company. During fiscal year 1983, a total of 1.9×10^6 ℓ of gasoline was used by this fleet to cover 11.2×10^6 km.

Carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and particulates are emitted during vehicle operations. There also are gasoline evaporative losses associated with gasoline storage and vehicle refueling. By breaking down total gasoline usage among the size classes of vehicles and by applying the most appropriate Environmental Protection Agency emission factors (EPA 1977B, EPA 1981) to these data, air emissions associated with maintenance and operation of the vehicle fleet were estimated (Table XX). These estimates are based on a new set of Environmental Protection Agency emission factors and more accurately represent the age structure and mixture of gasoline and diesel vehicles in the fleet. This has resulted in estimates that, in some cases, differ greatly from previous years' estimates.

The TA-3 power plant is fueled with natural gas and thus comes under State of New Mexico regulations for gas burning equipment. These regulations specify maximum allowable nitrogen oxide emissions, but also contain a provision exempting facilities that have a heat input of less than 1×10^{12} Btu/yr/unit. Heat inputs for the TA-3 power plant individual boilers during 1983 were 0.63×10^{12} Btu, 0.54×10^{12} Btu, and 0.58×10^{12} Btu. Total heat input for the power plant was 1.75×10^{12} Btu, but inputs for the individual boilers were below the 1×10^{12} Btu/yr exemption threshold.

Measured concentrations of nitrogen oxides (NO_x) in the power plant stack gas ranged from 20 to 47 ppm and averaged 39 ppm, which is about 23% of the standard that would apply if the heat input threshold was exceeded. The NO_x analyser was not operating for about 6 months because it had to be repaired. Sulfur dioxide (SO_2) analyses of the stack gas are not performed routinely, but the sulfur content of the natural gas fed to the boilers is so low that it precludes any significant SO_2 emissions.

The following estimates of stack gas emissions from the TA-3 power plant for 1983 were made using Environmental Protection Agency emission factors (EPA 1981) for natural gas burning facilities: 0.45 metric tons of sulfur oxides (−6% versus 1982 emissions), 1.29 metric tons of organics (+61%), 30.3 metric tons of carbon monoxide (+124%), 1.90 metric tons of particulates (−76%), and 134 metric tons of nitrogen oxides (−31%) Changes in carbon monoxide and nitrogen oxide emissions estimates from 1982 are due to use of revised emission factors of the Environmental Protection Agency (EPA 1981).

The Laboratory complex uses large quantities of various volatile chemicals and gases, some of which are released into the atmosphere by evaporation or exhaust. Using data from stock records, a table of patterns of chemical usage over past years has been compiled (Table E-XXXI).

During 1983 a total of 21 044 kg of high-explosive wastes was disposed of by open burning at the Laboratory. This resulted in estimated airborne emissions of 164 kg of carbon monoxide (+29% versus 1982 emissions), 379 kg of particulates (+30%), and 636 kg of nitrogen oxides (+30%). These estimates were made by using data from experimental work carried out by Mason & Hanger-Silas Mason Co., Inc. (MHSM 1976). Open burning of high-explosive wastes is permitted by New Mexico Air Quality Control regulations.

Dynamic experiments employing conventional explosives are routinely conducted in certain test areas at the Laboratory and may contain quantities of potentially toxic metals, including beryllium, lead, and uranium. Some limited field experiments, based on aircraft sampling of debris
clouds, provided information on the proportion of such materials aerosolized. This information was employed to prepare estimates of airborne concentrations at the Laboratory boundary based on the amounts of explosives used

during 1983. The results are presented in Table E-XXXII along with comparisons to applicable air quality regulations. The average concentrations of uranium, beryllium, and lead are all less than 0.003% of applicable standards.

c. Liquid Effluents. Nonradioactive liquid waste discharges are authorized by National Pollutant Discharge Elimination System (NPDES) permit number NM 0028355 issued by the Environmental Protection Agency. The NPDES permit authorizes discharges from 103 industrial outfalls in 10 categories and 11 domestic waste outfalls. Tables E-XXXIII and E-XXXIV summarize the effluent quality of the domestic and industrial outfalls.

This year 9 of 11 sewage treatment facilities exceeded one or more of the NPDES permit limits (biochemical oxygen demand, total suspended solids, fecal coliform, and/or pH) in one or more months. Since April 1983, fewer than 4% of all samples from the domestic and industrial outfalls exceeded NPDES limits.

In 1983 the Los Alamos Area Office of the Department of Energy (with Laboratory input) and the Environmental Protection Agency signed a Federal Facility Compliance Agreement (FFCA), which contains an abatement schedule for two domestic waste locations and seven industrial waste locations. Compliance dates range from 1983 to 1985. The 1983 compliance date was extended to June 1984 to allow additional time for construction of a sand filter with more stringent specifications. Although not a part of the FFCA, a new chlorination chamber at the TA-3 domestic waste treatment plant to accommodate increased flows and a new contact cooling water tower at TA-41 will also be built.

The two radioactive waste treatment plants have the largest number of limits with which to comply, and those plants exceeded one or more limits in fewer than 1% of the samples taken. Details of the effluent quality from these two plants are given in Table E-XXVIII for nonradioactive (including several not regulated by the NPDES permit) and radioactive constituents.

d. Monitoring Rain for Chemical Constituents. A National Atmospheric Deposition Program (NADP) rain gauging station at Bandelier National Monument has continued operation through 1983. The purpose of the NADP network is to provide background data on the chemical composition of rain throughout the United States and to monitor trends in chemical composition. The Bandelier station provides local information on rainfall composition. The station started operation in June of 1982 and the data obtained to date are in Table E-XXXV.

e. Monitoring Honey Bee Hives. Honey bee hives continue to be used as biological monitors of environmental contaminants at Los Alamos. These hives are located throughout Laboratory property at sites where there is potential for environmental contamination. The locations of the hives are in Table E-XXXVI and Fig. 25. The data obtained to date from honey and bee analyses are in Table E-XXVI.

There have been some slightly elevated tritium concentrations in the bees and honey from hives located near Laboratory facilities that release airborne tritium. Also, ^{7}Be, ^{22}Na, ^{54}Mn, ^{57}Co, ^{83}Rb, and ^{134}Cs were found in bees from the hive at the Los Alamos Meson Physics Facility (TA-53). However, correspondingly higher concentrations were not found in honey from the same hive.

C. Meteorology

1. Weather Summary. Los Alamos weather during 1983 was slightly cooler and drier than normal. However, there were occurrences of extreme and unusual weather during the year. Snowfall was heavy and totalled 72 in. The spring was snowy and the second coldest on record. A rare funnel cloud was reported near the community of White Rock in the summer. Also, during the summer, a thunderstorm produced heavy rains that caused the collapse of a store roof in the Los Alamos Business District. A very early hard freeze on September 21 gave Los Alamos its shortest growing season on record. The 1983 weather is summarized in Fig. 26, Table E-XXXVII, and Table E-XXXVIII.

The year began with dry and pleasant weather for most of January. Then, a snowstorm on the 30th and 31st dumped over 14 in. of snow on Los Alamos. Another snowstorm quickly followed on February 3 and 4, producing another 9 in. of snow. The remainder of February and the first half of March were dry and warm, with the storm track shifting to the north of New Mexico. A series of three storms passed through New Mexico during the third week of March, producing 14 in. of snow. Several more storms moved across Colorado during the last week of March, producing strong winds in Los Alamos. The strongest wind gust of the spring season, 56 mph, was recorded on March 31.

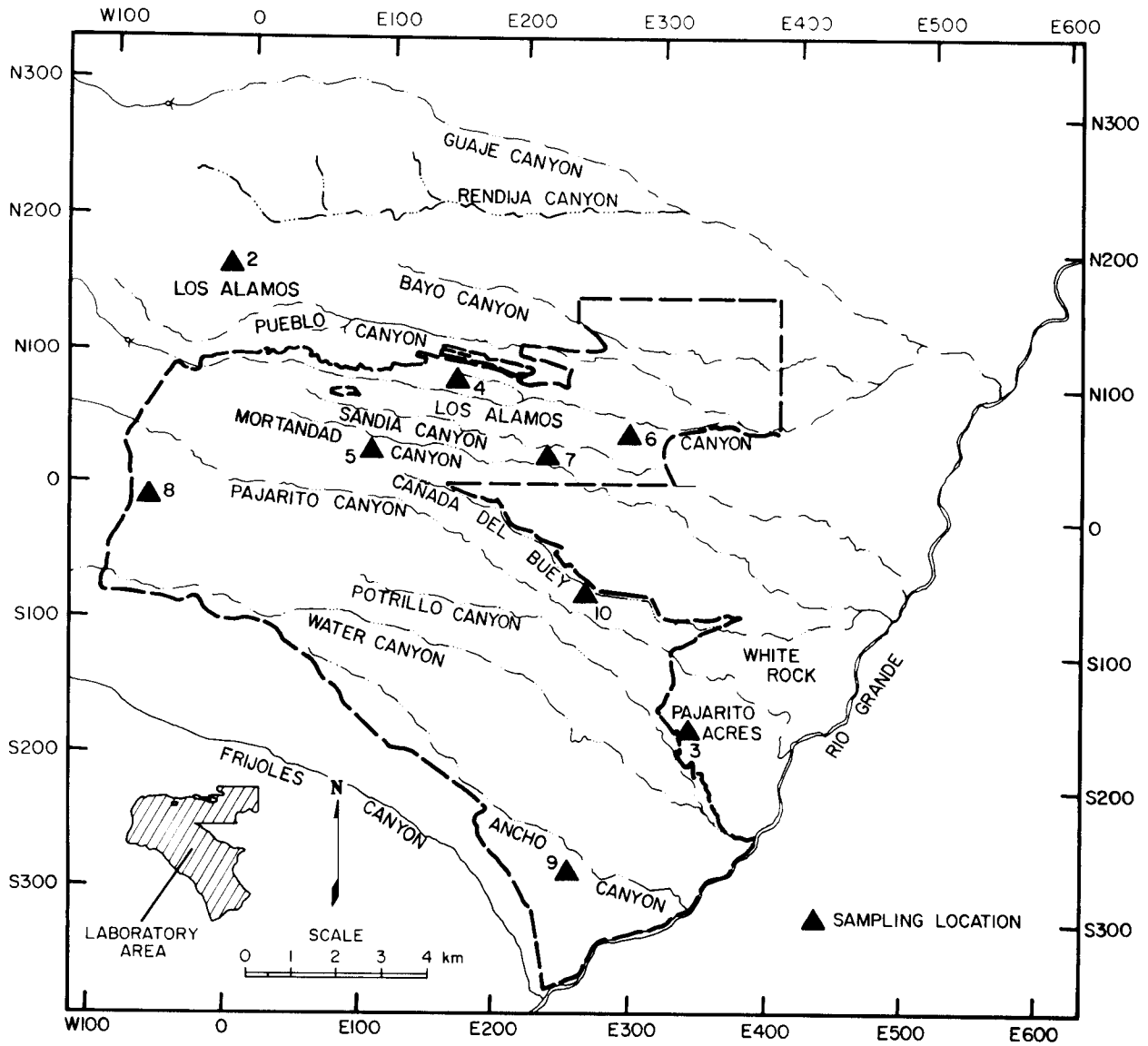


Fig. 25. Locations of bee hives at Los Alamos.

Another storm, in combination with upslope winds, locally produced 10 in. of snow in Los Alamos on April 4. On the same day, the temperature reached only 26°F for a high, setting a record for the lowest high temperature for so late in the season. Also, low temperature records were set on April 4 and 5, with readings of 10° and 8°F, respectively. Cool and unsettled weather persisted until the middle of April. The last half of the month was dry but cool. April of 1983 became the third coldest April on record.

Northwesternly upper winds persisted throughout most of May, making it a cold and dry month. Three daily low temperature records were set during the month, with the latest freeze (31°F) occurring on May 21. It was the third coldest May on record and the coldest since 1957. The months of March, April,and May of 1983 combined for the second coldest spring on record, with the spring of 1973 the only one colder. Also, the average minimum temperature for spring 1983, 30.7°F, set a record for the lowest on record.

The cool and dry conditions extended into June. The temperature did, however, reach 90°F on June 18 for the only time during the summer. The rainy season began during the second week of July, with the occurrence of

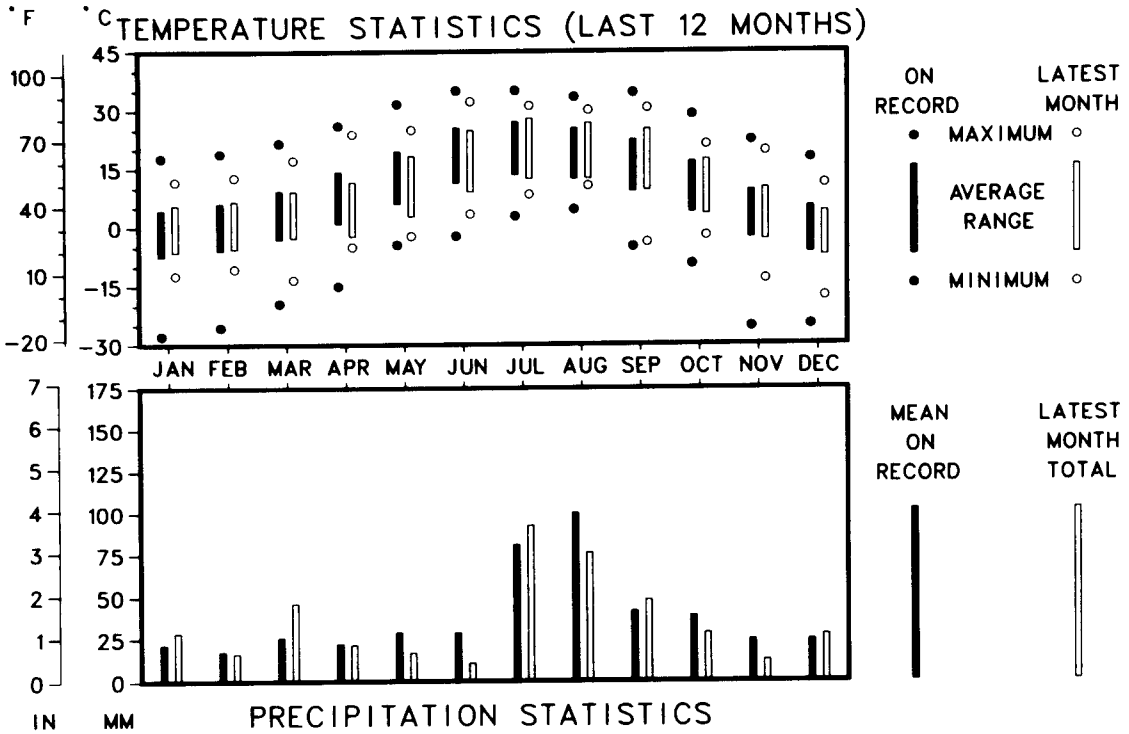


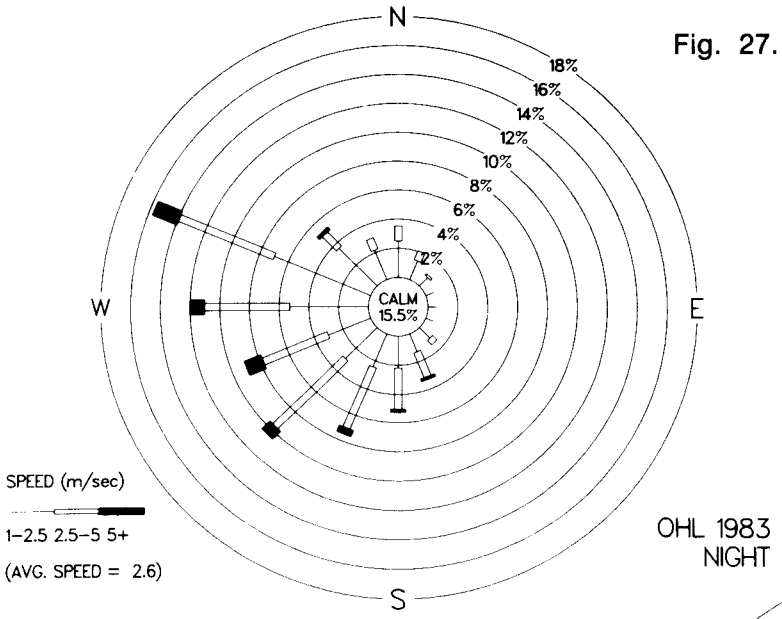
Fig. 26. Summary of 1983 weather in Los Alamos (data from Occupational Health Laboratory, OHL, TA-59).

afternoon and evening thundershowers. A heavy thundershower on the afternoon of July 23 produced 1.56 in. of rain in less than 2 hours. The showery weather continued through August, although the monthly total (2.99 in.) was below normal. On the afternoon of August 23, a rare funnel cloud located about 10 miles southeast of the community of White Rock was sighted by the public. This funnel was a local phenomena and was not associated with severe weather. It extended from a cloud, reached about halfway to the ground (elevation about 2000 m), and lasted about 10 minutes.

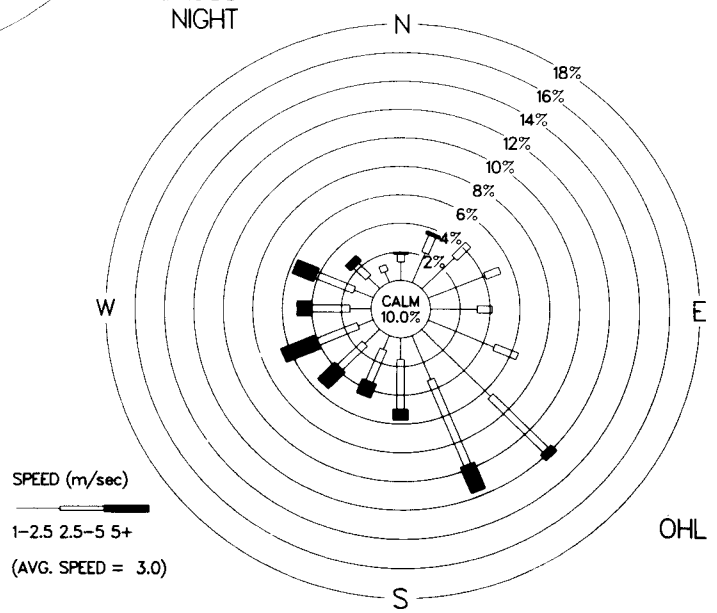
Autumn began with above-normal temperatures in September. Maximum temperatures averaged 77.2°F, almost 5°F above normal. Two high temperature records were set in the beginning of the month. In contrast, a very early hard freeze occurred on September 21, when the temperature dipped to 25°F. This gave 1983 a growing season (number of consecutive days with no temperature lower than 28°F) of only 125 days, the shortest ever on record. Temperatures returned to near-normal in October, with precipitation below normal. November had very warm and dry weather during the first half of the month, and cold and snowy conditions during the last half. The year ended with a slightly cooler than normal December. A snowstorm dropped 6.5 in. of snow on December 27 and 28, with temperatures dropping to 0°F on the mornings of the 28th and 29th, setting and tying, respectively, daily low temperatures.

2. **Wind Roses.** The 1983 wind speed and direction measured at the Occupational Health Laboratory (OHL, TA-59) are plotted in wind roses (see Fig. 27). A wind rose is a circle from the center of which emanate lines representing the direction *from* which the wind blows. The length of each line is proportional to the frequency of the wind speed interval from that particular direction. Each direction is one of the 16 major compass points (N, NNE, and so on) and is centered on a 22.5° sector of the circle. The frequency of the calm winds, defined as those having wind speed of less than 1 m/sec and no direction, is given in the circle's center.

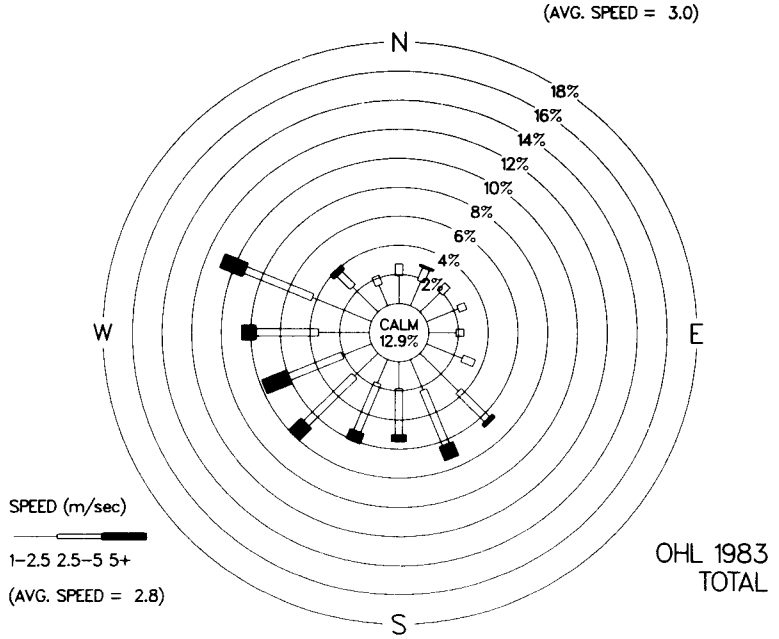
Fig. 27. Annual, day, and night wind roses for Los Alamos for 1983.



OHL 1983
NIGHT



OHL 1983
DAY



OHL 1983
TOTAL

The OHL wind data were measured at a height of 23 m with 99% data recovery for 1983. The wind roses in Fig. 27 include an annual summary for 1983 and summaries for daytime and nighttime hours. Los Alamos is a generally light wind site with an annual average wind speed of 2.8 m/sec. Only 12% of wind speeds in 1983 were greater than 5 m/sec, while 38% were less than 2.5 m/sec.

The distribution of wind direction reflects (1) the location of Los Alamos on the southern side of the midlatitude westerlies, and (2) the northwest-southeast slope of the Jemez Mountains and Pajarito Plateau. Predominance of winds from NW to SW is produced by "westerlies," which are often as far south as New Mexico. The slope of the terrain produces a distinct daily pattern under weak atmospheric pressure gradients. At night, drainage winds (less than 2.5 m/sec) flow down from the Jemez Mountains out of the NW and WNW. During the day, light upslope winds come up out of the SE to SSE.

3. Rainfall Summary. Slightly below-normal amounts of precipitation fell in the Los Alamos area in 1983. Figure 28 shows 1983 quarterly and annual precipitation at four sites in Los Alamos County. See Figs. 1 and 7 for locations of the sites. Note that the precipitation generally increased with elevation for the sites. Almost half of the precipitation for the sites fell during the period July-August-September, coinciding with the thundershower season.

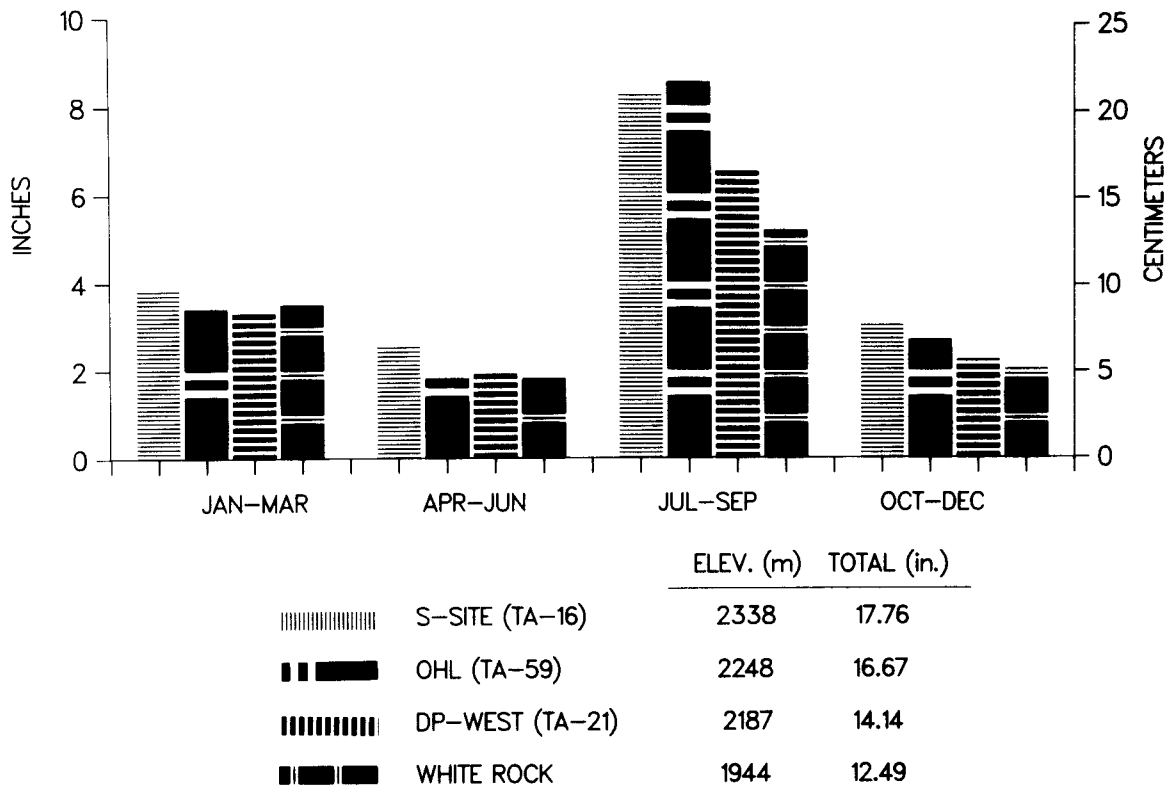


Fig. 28. Survey of 1983 precipitation in the Los Alamos area.

V. ENVIRONMENTAL PROTECTION PROGRAMS AT LOS ALAMOS

A. Laboratory Environmental Review Committee

The Laboratory has a Laboratory Environmental Review Committee to provide a critical management overview of environmental concerns. The Laboratory Environmental Review Committee membership consists of representatives from the Associate Director for Technical Support; Legal Affairs Office; Facilities Engineering Division; Budget Division; and Health, Safety, and Environment Division. The Laboratory Environmental Review Committee has responsibility to review environmental documents prepared for the Department of Energy by the Laboratory. Additionally, the Laboratory Environmental Review Committee identifies and reviews items of environmental interest that are generated by Laboratory activities or that affect Laboratory programs and property.

An Environmental Evaluations Coordinator, based in the Environmental Surveillance Group, assists the Laboratory Environmental Review Committee by (a) coordinating with user groups; Health, Safety, and Environment Division; and Facilities Engineering Division on enviromental documentation and (b) providing input to construction or programmatic project design at the earliest stage for appropriate environmental decision making.

Projects that may require an environmental assessment or environmental impact statement are screened by the Environmental Evaluations Coordinator to determine the necessary preliminary environmental documentation. When needed, various resource people are identified by the Environmental Evaluations Coordinator to assist in preparation of the draft environmental document.

The Environmental Evaluations Coordinator also coordinates input on environmental matters for other official documents and the Quality Assurance program (see next section). The Environmental Evaluations Coordinator and the Environmental Surveillance Group's representative to the Quality Assurance program work with those responsible for construction and/or programmatic activities to assure that proper environmental considerations are made during project design and that they are implemented in the Quality Assurance program.

B. Quality Assurance

The Laboratory has a Quality Assurance program (Facilities 1983) for engineering, construction, modification, and maintenance of Department of Energy facilities and installation. The purpose of the program is not only to minimize the chance of deficiencies in construction, but also to improve the cost effectiveness of facility design, construction, and operation, and to protect the environment. The Quality Assurance program is implemented from inception of design through completion of construction by a project team approach. The project team consists of individuals from the Department of Energy's program division, Department of Energy's Albuquerque Operations and Los Alamos Area Offices, Laboratory operating group(s), Laboratory Engineering Division, design contractor, inspection organization, and construction contractor.

Under the project team approach, each organization having responsibility for some facet of the project is likewise responsible for its respective aspects of the overall Quality Assurance program. For example, it is the inspection organization's responsibility to provide assurance that the structures, systems, and components have been constructed or fabricated in accordance with the approved drawings and specifications.

Laboratory representatives are responsible for coordinating reviews and comments from all groups with a vested interest in the project. In particular, the Environmental Surveillance Group reviews proposed new construction, maintenance activities, and modifications to existing facilities to minimize any environmental degradation. Consideration is given to the present condition of the site (soils, geology, ground water, surface water, air quality, archeology, flora, fauna, drainage features, etc.), environmental consequences of the proposed project (airborne emissions, liquid effluents, industrial waste, solid waste, noise levels, traffic patterns, etc.), and environmental impact assessment (air, water, land, visual, noise, odor, biota, etc.).

C. Archeological and Historical Protection

Protection of archeological and historical sites at the Laboratory (mandated by several Congressional Acts and Executive Order 11593) is also part of the Environmental Evaluations and Quality Assurance programs. A proposed location for a new facility is surveyed for

archeological and historical features. If a feature is found, siting is adjusted to preserve it. If that is not possible, documentation, excavation, or other mitigation measures are carried out in consultation with the New Mexico State Historical Preservation Office.

The Laboratory has a contract with a professional archeologist to provide archeological surveys, make evaluations of archeologic or historic features, and provide professional expertise for cultural resource management. The Laboratory is drafting a Cultural Resources Management Plan to guide protection efforts.

A survey of more than 450 archeological sites at the Laboratory was made between March 1973 and July 1975. This survey of the pre-Columbian Indian ruins is summarized in a Laboratory report (Steen 1977). A further report summarizing excavations on the Laboratory between 1975 and 1978 was issued this year (Steen 1982). These surveys are used during construction planning to avoid damage to archeologic or historic sites. Additional surveys of proposed construction sites routinely reveal new undocumented sites.

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Two public tours of archeological sites within the Laboratory's boundary were conducted in 1983. These tours allowed the public to view archeological sites that are normally inaccessible because of security restrictions for the surrounding Laboratory land. This year the tours included Otowi (one of the largest pre-Columbian communities on Pajarito Plateau) and for, the first time, a historical site—the Gomez Ranch Complex at TA-15 (the best preserved homestead site on Laboratory land).

D. Toxic and Hazardous Waste Management Program

Improvements in the control, treatment and disposal of hazardous materials is a continuing goal of the Laboratory. Major efforts were expended in several areas during 1983.

An extensive endeavor to upgrade Polychlorinated Biphenyl (PCB) Inventory Control to a computerized record system was initiated. As a result, each PCB item is assigned a unique identification number for future traceability. A PCB incineration permit was applied for during the year. This permit would allow the Los Alamos incinerator to burn radioactively contaminated PCBs.

Approval and funding were received, design completed, and construction begun for a new chemical batch treatment plant. This will enhance the Laboratory's waste treatment capability and produce a stable waste form for burial.

Alternatives to land disposal of hazardous chemicals resulted in two changes in 1983. An extensive search located a commercial facility capable of treating lithium hydride waste, a reactive substance that cannot be landfilled. The second area of concern is the relatively large amount of recyclable oil being landfilled. Efforts to start a recycling program were initiated in 1983 with plans to begin in 1984.

VI. RELATED ENVIRONMENTAL STUDIES

The Environmental Surveillance Group (HSE-8) and the Environmental Sciences Group (LS-6) at the Laboratory do some environmental research to complement the routine monitoring program. These studies help provide a better understanding of the ecosystem surrounding the Laboratory in relation to its operations.

A. Delta-Count Rate-Monitoring System [D. Van Etten and W. Olsen (HSE-8)]

Detection of radioactive contaminants in the environment often requires surveying large areas. A need for a more effective way to rapidly search for gamma-ray contamination over large areas led to the design and construction of a very sensitive gamma detection system (Van Etten 1983). This system alerts the user to small changes in the count rate, or delta, which can locate areas of potential radioactive contamination.

Environmental surveys are frequently done in areas with rugged off-road conditions in adverse weather. For this reason, the delta-count rate-monitoring system was installed in a four-wheel-drive van instrumented for environmental surveillance and accident response.

The system consists of four main sections: (a) two scintillation detectors; (b) high-voltage power supply amplifier, and single-channel analyzer; (c) delta-count rate monitor; and (d) count rate meter and recorder. The van's 6.5-kW generator powers the standard nuclear instrument module modular design system. The two detectors are mounted in the rear corners of the van and can be run singly or jointly. A solid-state bar-graph count rate meter mounted on the dashboard can be read easily by both the driver and passenger. Mounted just to the right of the driver is a solid-state strip chart recorder, which shows trends and provides a permanent record of the data. An audible alarm is sounded at the delta monitor and at the dashboard count rate meter if a detected radiation level exceeds the set background level by a predetermined amount.

B. Development of Water Supply Well PM-5 [W. D. Purtymun, N. M. Becker, and M. N. Maes (HSE-8)]

Construction of water supply Well PM-5 began in December 1981 with the drilling of the pilot hole and was completed in September 1982 when the well was test pumped. The well is located about 3.4 km northwest of Well PM-4 on the Pajarito Plateau at an elevation of 2162 m. The pilot hole was drilled to a depth of 948 m. Stratigraphic units (Griggs 1964) penetrated by the well in descending order are the Bandelier Tuff, Basaltic Rocks of Chino Mesa, Puye Conglomerate, and Tesuque Formation (Table XXI).

The top of the main aquifer of the Los Alamos area (only aquifer capable of municipal and industrial water supply) was encountered at a depth of about 368 m in the fanglomerate member of the Puye Conglomerate. The lower member of the Puye Conglomerate, the Totavi Lentil, and Tesuque Formation are within the main zone of saturation at the well.

A step test to determine the size (pumping rate) of the permanent pump was made at rates of 48 ℓ/sec to 79 ℓ/sec. The tests were made over about a 11-h period with the higher pumping rate at the start of the test. At a pumping rate of about 79 ℓ/sec for about 3 h the drawdown was 44 m with a specific capabity of 1.8 ℓ/sec of draindown. Based on the step test, the contractor recommended a pump that will produce about 76 ℓ/sec.

The well is in an area where a better yield was expected. The contractor used a large quantity of drilling mud and lost circulation material from a depth of about 368 to 732 m. It is quite possible that the aquifer still contains significant amounts of drilling mud and lost circulation material. When the well is put into service, the specific capacities may improve as some of the material plugging the aquifer is removed. This has occurred in Well PM-4 and other wells on the Pajarito Plateau.

Water from Well PM-5 is a sodium and bicarbonate type and is similar to water from Well PM-4. Water from Well PM-5 has a hardness of 52 mg/ℓ and total dissolved solids of 211 mg/ℓ. The concentrations of constituents in water samples collected during the aquifer test are below Primary, Secondary, and Radiochemical Standards of the Environmental Protection Agency (Appendix A).

The well will not be added to the system until mid-1984 after completion of the pump station, transmission lines, and a storage tank, which are currently being built. Specific details of the well construction and testing are found in a Laboratory report (Purtymun 1984).

C. Geohydrological Investigations at TA-54 (Area G) [W. D. Purtymun, N. M. Becker, and M. N. Maes (HSE-8)]

1. Introduction. Technical Area 54 (TA-54), Area G, is used for disposal of solid low-level radioactive wastes. Area G is located on a mesa named Mesita del Buey.

Table XXI

Generalized Geologic Log of Supply Well PM-4

	Thickness (m)	Depth (m)
Bandelier Tuff	225	225
Basalt (Rocks of Chino Mesa)	6	231
Puye Conglomerate		
Fanglomerate Member	14	245
Basalt (Rocks of Chino Mesa)	38	283
Puye Conglomerate		
Fanglomerate Member	11	294
Basalt (Rocks of Chino Mesa)	55	349
Puye Conglomerate		
Fanglomerate Member	99	448
Totavi Lentil	24	472
Tesuque Formation		
Sandstone	66	538
Basalt	12	550
Sandstone	24	574
Basalt	3	577
Sandstone	14	591
Basalt and breccias	41	632
Sandstone	20	652
Basalt and breccias	59	711
Siltstone, claystone	14	725
Basalt and breccias	110	835
Siltstone, claystone, and sandstone	113	948

Note: Top of main aquifer at 368 m.

Mesita del Buey trends southeast and is about 3.2 km long and 0.4 km wide. The surface slopes from an elevation of about 2100 m near its western end to about 2010 m at its eastern end of Area G. It is bounded on the north and south by canyons cut 15 to 30 m below the mesa surface, and several small side drainages serrate the edge of the mesa.

The surface and underlying rocks of Mesita del Buey are ash flows and ash flows of rhyolite tuff that are underlain by volcanic basalts and interbedded with sediments. The tuff is about 75 m thick. There is no known perched water at Area G between the surface of the mesa and the main aquifer of the Los Alamos area. The main aquifer (capable of municipal and industrial water supply) lies at a depth of 250 m below the surface of Mesita del Buey. Movement of water in the aquifer is to the east and southeast where a part is discharged into the Rio Grande (Purtymun 1971B).

In 1956, Area G was designated for the disposal of solid radioactive waste (Fig. 20). The wastes range from potentially contaminated rubber gloves and glassware to parts of obsolete buildings and equipment that cannot be decontaminated. They are buried in pits ranging in size from 9 to 30 m wide, 45 to 180 m long, and 4 to 10 m deep. The waste is placed in layers 1 to 2 m deep and each layer is covered with approximately 0.5 m of crushed tuff. The pits are filled to within 1 m of the land surface and covered with 1.5 to 2 m of crushed tuff. This final cover is

slightly mounded above the original grade to encourage surface runoff. Some wastes are placed in vertical shafts, which range from 0.6 to 1.8 m in diameter and up to 20 m deep. Wastes in the shafts are layered with crushed tuff, the same practice used for the pits, and the final cover is about 1 m thick.

Guidelines for the construction of pits were issued by the US Geological Survey in 1965 (USGS 1965). These were revised and reissued in 1980 by the Waste Management Group (HSE-7) and Environmental Surveillance Group (HSE-8) of the Los Alamos National Laboratory (Purtymun 1980). The pits are inspected and photographs taken to determine if they comply with the guidelines.

2. Construction of Pit 26. Pit 26 was constructed in Area G during 1983 using heavy earthmoving equipment. It is about 95 m long, 15 m wide, with a maximum depth of 10 m. The floor of the pit is ramped at the long dimension to allow construction and vehicle access during disposal operations. The total volume of tuff excavated was 17 000 m^3. The long dimension of the pit is northeast-southwest. The "spill point" or lowest area is the southwest corner of the pit.

Pit 26 is dug into Unit 2b of the Tshirege Member of the Bandelier Tuff (Griggs 1964). The unit in the pit consists of two ash flows. Contact between the two flows occurs about 6 m below land surface. The contact is shown by an increase in the amount and size of dark gray devitrified pumice fragments in the top of the ash flow. The contact is nearly horizontal, though in places becomes indistinct. The tuff in both flows is a gray moderately welded tuff, consisting of quartz and sanidine crystals and crystal fragments with a few rock fragments of rhyolite, latite, and pumice in a gray ash matrix.

The tuff in the walls of the pit is broken by joints that formed as the ash flows cooled. Most of the major joints are vertical or nearly vertical. They range from closed to open. Beneath the thin soil zone (less than 0.5 m thick), the joints are filled with clay. At depth the joints may also be filled with clay or be slightly open. The joint face may be weathered with a thin layer of clay. The new joint faces exposed in the pit walls are the result of excavation of the pit. The frequency of the joints is about one master joint for every 2 to 3 m of wall of the pit. This frequency is normal at Area G. The floor of the pit is covered with a layer of crushed tuff. The joint openings in the walls or joint systems in the floor (filled with tuff) are small and do not require remedial action.

The inspection and documentation in November 1983 of Pit 26 indicate that the pit is in compliance with the guidelines and is suitable for disposal of wastes.

D. Environmental Monitoring at the Fenton Hill Site [W. D. Purtymun, N. M. Becker, R. W. Ferenbaugh, M. N. Maes (HSE-8), and H. Adams (HSE-7)]

1. Introduction. The Los Alamos National Laboratory is currently evaluating the feasibility of extracting thermal energy from the hot dry rock geothermal reservoir at the Fenton Hill Geothermal Site (TA-57). The site is located about 45 km west of Los Alamos on the southwestern edge of the Valles Caldera. The hot dry rock energy concept involves drilling two deep holes, connecting these holes by hydraulic fracturing, and bringing the thermal energy to the surface by circulating water through the system. Environmental monitoring is done at the site to assess any impacts of the geothermal operations.

2. Chemical Quality of Surface and Ground Water. The chemical quality of surface and ground water in the vicinity of TA-57 (Fig. 29) has been determined for use in geohydrologic and environmental studies. These water quality studies began before construction and testing of the hot dry rock system. Results of the studies and detailed data are published elsewhere (Purtymun 1983C).

Surface water stations (12 on the Jemez River, the Rio Guadalupe, and their tributaries) are divided into four general groups based on common chemical properties of predominate ions and TDS (Table E-XXXIX). The predominate ions are (1) sodium and chloride, (2) calcium and bicarbonate, (3) calcium and sulfate, and (4) sodium and bicarbonate.

Ground water stations (five mineral and hot springs, one well, and five springs) are grouped with predominate ions: (1) sodium and chloride, (2) calcium and bicarbonate, and (3) sodium and bicarbonate (Table E-XXXIX).

There was no significant change in the chemical quality of surface and ground water at the individual stations in 1983 when compared to previous years' chemical analyses. Some slight variations are caused by normal seasonal variations.

The ponds at the Fenton Hill Geothermal Site contain water used in drilling operations and in the hydraulic fracturing operations. The water (November 1983) was

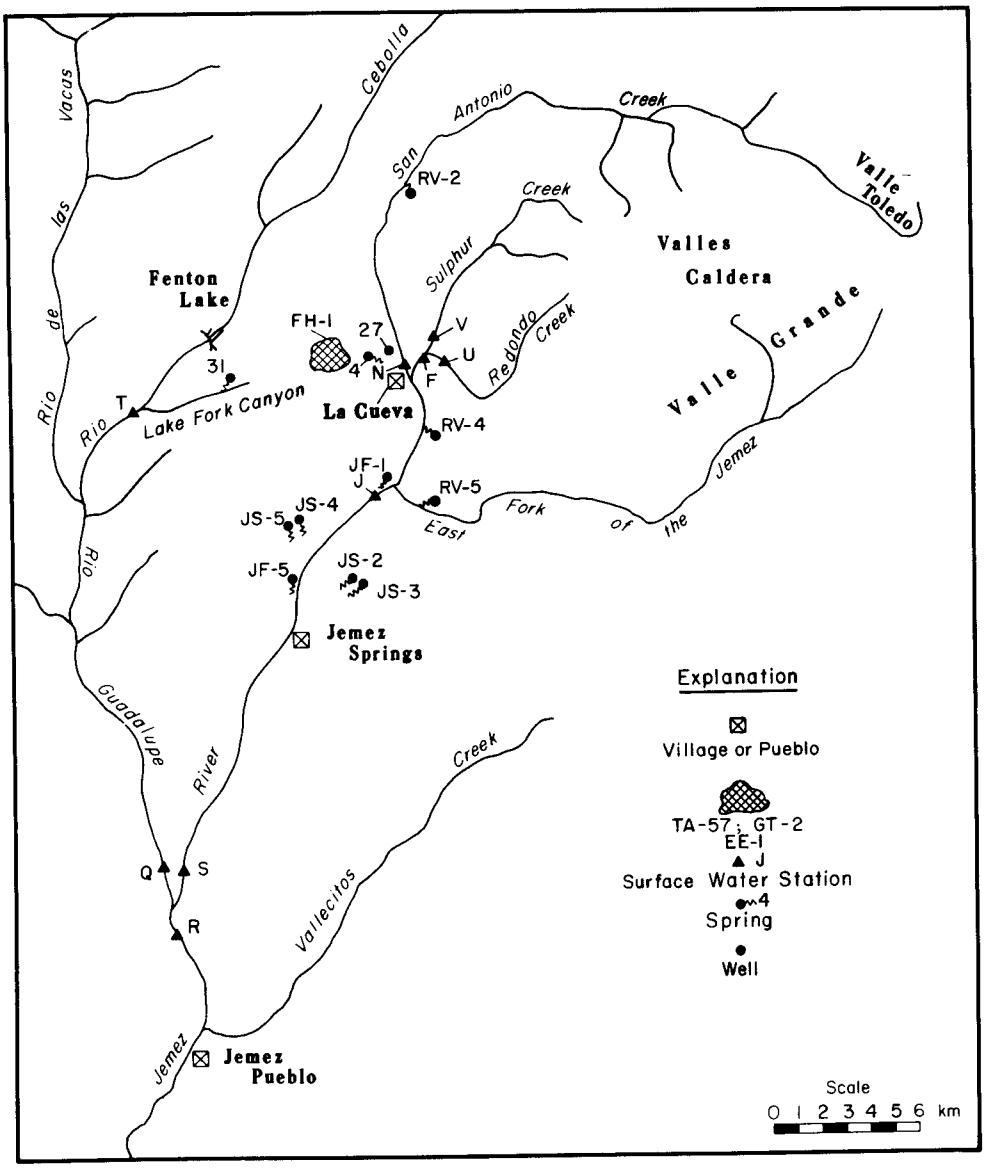


Fig. 29. Water sampling locations in the vicinity of Fenton Hill Geothermal Site (TA-57).

highly mineralized in Pond GTP-1 (TDS was 3488 mg/ℓ) adjacent to the deep wells. Certain elements in the ponds (SO_4, Cl, and TDS) are of interest in monitoring the quality of adjacent waters, while other elements (As, B, Cd, F, and Li) must be monitored as specified in the National Pollutant Discharge Elimination System Permits (NPDES) for the site. Water in the ponds is sometimes released into a dry canyon adjacent to the site. Release is at a rate that allows the water to infiltrate into the alluvium and underlying rock of the canyon floor within 100 m from point of effluent discharge. The water from the ponds does not reach surface water in the area. Monitoring of the surface water (Stations LF-1, 2, 3, and 4) and ground water (Stations 31 and 39) below the site failed to detect any change in chemical constituents that could be related to release of water from the ponds.

3. **Soil and Vegetation Samples.** Samples of vegetation and soil from the channel bottom and the canyon bank below Pond GTP-3 have been collected semiannually since 1978. The collected samples are analyzed for arsenic, boron, cadmium, fluorine, and lithium. The sampling locations are at distances of about 100, 200, 400, and 1000 m down canyon from the Pond GTP-3 discharge point. An additional sample is collected from the canyon bottom far down the canyon at its junction with Lake Fork Canyon. The data obtained to date from these samples are in Table E-XL.

The behavior in the environment of each of the five elements monitored reflects its varying soil physicochemical and plant biophysiological properties. Each element is discussed separately in the following paragraphs.

The data indicate that there is a slight arsenic accumulation in plant roots (Table E-XL). This agrees with published information (Leibig 1966), which notes that arsenic accumulates in much larger amounts in or on plant roots than in foliage. Foliar content is low (0.5 ppm), which also agrees with the literature. Leibig notes that arsenic toxicity limits plant growth before large amounts of arsenic are absorbed and translocated to the foliage. The foliar arsenic level at which toxicity occurs apparently varies widely, being reported at 0.05 to 250 ppm, depending on plant species, arsenic source, soil type, and other factors. Natural foliar arsenic levels range up to about 10 ppm (SHM 1978). The measured soil concentrations are well within the normal range of 0.3 to 38 ppm (Leibig 1966).

Boron shows a definite accumulation pattern in soil, plant roots, and plant folige (Table E-XL), although the accumulation in plant foliage is the most pronounced. Excess foliar boron levels are generally considered to be anything above 200 ppm, although tissue levels may reach 1000 ppm without visible damage symptoms (Bradford 1966A). Recent foliar boron levels at the Fenton Hill Site have exceeded 200 ppm in portions of the canyon within 200 m of Pond GTP-3, although there is no visual evidence of foliar damage. Soil boron content is within the normal range of 2 to 100 ppm, although soils in the upper end of this range may cause plant damage under appropriate conditions. There is evidence that plant damage may occur as a result of a boron-fluoride synergistic effect (Temple 1978), which is a consideration because fluoride is also present in the effluent discharged from Pond GTP-3.

The data received to date on cadmium are scanty and insufficient to make any statement as to whether there is any accumulation (Table E-XL). The single set of foliage data from 1981 indicates that some foliar accumulation might be occurring. However, the levels are still well below critical levels of 10 to 15 ppm (Becket 1977).

The data for fluoride show some evidence that there is a slight accumulation in soils, but no trends are apparent in root and foliar analyses (Table E-XL). Soil buildup is to be expected because nearly all fluoride compounds are relatively insoluble. However, all measured soil concentrations are still within the normal range of 20 to 500 ppm. With the exception of the fall 1981 root samples, the vegetation analyses all fall into the normal fluoride content range of up to 20 ppm (Weinstein 1977 and Brewer 1966). Toxic levels vary widely among species, ranging from about 30 to several hundred ppm (CBEAP 1971). Also, as mentioned previously, there is the possibility of a detrimental fluoride-boron synergistic effect.

Lithium data also are rather scanty. There does appear to be some accumulation in soils and roots and there is a definite accumulation in plant foliage (Table E-XL). Soil concentrations are well within the normal range of 10 to 100 ppm, but foliage analyses of plants from that portion of the canyon affected by the Pond GTP-3 effluent are considerably above the normal range of 0.5 to 1.5 ppm (Bradford 1966B). Lithium toxicity symptoms have been reported at as low as 13 ppm for sensitive species, although critical levels for a grass (barley) were reported in the range of 22 to 60 ppm (Davis 1978). In spite of the fact that measured foliar lithium concentrations in the canyon are potentially in the toxic range, no apparent damage is evident on the grasses or aspen growing there.

E. Distribution of Moisture, Tritium, and Plutonium in the Alluvium, Aquifer, and Underlying Tuff in Mortandad Canyon [W. D. Purtymun, M. N. Maes (HSE-8) and R. Peters (HSE-9)]

1. Introduction. Mortandad Canyon received industrial effluents containing trace amounts of radionuclides from the treatment plant at TA-50 (Fig. 13). The effluents and surface runoff recharge a shallow aquifer in the canyon. The shallow aquifer in the alluvium is perched (separated by about 290 m of unsaturated volcanics and sediments from the main aquifer) on the underlying tuff (Purtymun 1983A). The aquifer is of limited extent, as

water in the aquifer is depleted by evapotranspiration and infiltration into the underlying tuff. This investigation was made to determine the distribution of infiltration (moisture) and radionuclides in the alluvium and underlying tuff in a section of Mortandad Canyon.

Concentrations of radionuclides in water of the shallow aquifer decrease downgradient in the canyon from the effluent outfall. This reduction is caused by adsorption or ion exchange of the radionuclides with silt or clay minerals in the alluvium or dilution of the effluent by storm runoff. The distribution of the radionuclides in the aquifer is monitored by seven observation wells (Purtymun 1977).

At observation Well MCO-6, three core holes were drilled at right angles to the stream channel. Two other holes were cored to obtain background information. Cores taken from five holes were analyzed to determine moisture content and concentrations of tritium and plutonium (Table E-XLI).

The alluvium in the canyon is derived from the weathering of the Bandelier Tuff. At Well MCO-6, the alluvium is thickest beneath the stream channel and thins away from channel (Fig. 30). The alluvium is a silty sand that includes a thin layer of silty clay of weathered tuff at the base. The tuff is a light pinkish gray moderately welded tuff composed of quartz and sanidine crystals and crystal fragments, small rock fragments of rhyolite, latite, and pumice in an ash matrix. The tuff beneath the aquifer is weathered; the ash matrix contains some light brown silts and clays. The amount of silt and clays (degree of weathering) decrease at depth and with distance from the aquifer.

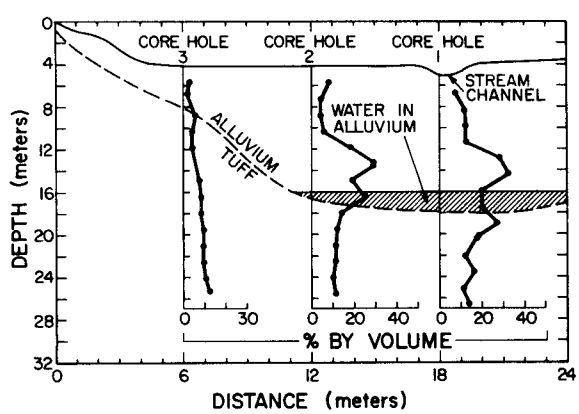


Fig. 30. Distribution of moisture in alluvium and tuff in Mortandad Canyon.

*2. **Moisture Distribution.*** The distribution of moisture in the alluvium and tuff is shown in Fig. 30. In core holes 1 and 2 the moisture content approaches 30% by volume from 1 to 3 m above the top of the aquifer. This anomaly above the aquifer is in a silty clay unit within the alluvium. The water table fluctuates twice a year because of seasonal runoff from snowmelt and summer precipitation. At the time the holes were cored, the water table was declining.

The moisture content of the aquifer material ranged from 20 to 25% by volume. There is some infiltration of water into the tuff beneath the aquifer. At core hole 1 the moisture content ranges from about 10 to 27% to a depth of 8 m below the base of the aquifer. At core hole 2 the moisture content is lower, ranging from 10 to 18% to a depth of 8 m below the aquifer. Core hole 3 indicates some horizontal component of movement of moisture from the aquifer only in the low moisture range, greater than 5% by volume below a depth of 13 m (Fig. 30). Natural moisture content of the tuff is about 5% by volume (Table E-XLI).

*3. **Tritium Distribution.*** Water distilled from the cores was analyzed for tritium (^3H). Tritium, a part of the water molecule, moves with the water and is not affected by adsorption or ion exchange with clay minerals. The average ^3H concentration in water in the aquifer (1978 when core was taken) at Well MCO-6 was 303×10^{-6} $\mu Ci/m\ell$, having declined from a high of 1760×10^{-6} $\mu Ci/m\ell$ in 1976. The core from hole 1 contained a high of 400×10^{-6} $\mu Ci/m\ell$ about 1 m below the aquifer, and was about 550×10^{-6} $\mu Ci/m\ell$ at the same depth below the aquifer in core hole 2 (Fig. 31). The ^3H concentrations generally decline with depth below aquifer. The high concentrations in the tuff below the aquifer probably reflect the movement of tritium beneath the aquifer in the tuff, possibly from the high concentration that occurred in 1976. At core hole 2 a high concentration of ^3H (290×10^{-6} $\mu Ci/m\ell$) occurred in the silt and clay base alluvium at a depth of about 10 m. This is above the aquifer. The ^3H in core hole 3 increases slightly with depth and is above background (Table E-XLI). The concentrations are low, less than 50×10^{-6} $\mu Ci/m\ell$, but the ^3H concentrations reflect the same pattern of the movement of moisture from the aquifer (Figs. 30 and 31).

*4. **Plutonium Distribution.*** Samples of water taken from observation wells were filtered through a 45-μm pore membrane filter to remove fine sediments. The

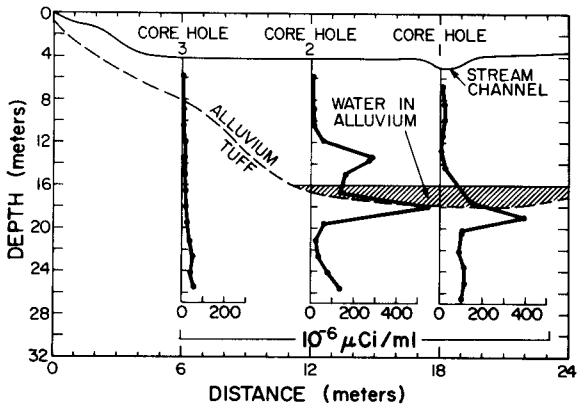


Fig. 31. Distribution of tritium in alluvium and tuff in Mortandad Canyon.

Table XXII

Average Plutonium Concentrations in Soil Cores from Mortandad Canyon

Location	$\bar{x} \pm 2s$ ^{238}Pu (pCi/g)	$\bar{x} \pm 2s$ ^{239,240}Pu (pCi/g)
Core Hole 1	0.001 ± 0.005	0.004 ± 0.009
Core Hole 2	0.000 ± 0.003	0.011 ± 0.025
Core Hole 3	−0.001 ± 0.003	0.006 ± 0.015
Core Hole 4 (control)	−0.001 ± 0.002	0.000 ± 0.006
Core Hole 5 (control)	−0.001 ± 0.002	−0.002 ± 0.003

filtrate and the filter were analyzed for ^{238}Pu and ^{239,240}Pu. The data indicated little, if any, plutonium was retained on the filter and most, if not all, of the plutonium was in solution. This is in direct contrast with what occurs in the channel when the effluent is released from the treatment plant. The plutonium in the effluent is readily adsorbed or attached to silt and clays in the alluvium in the channel (Section VI.F). Concentrations in solution and on sediments decrease downgradient in the canyon.

Cores taken through the alluvium, aquifer, and into the underlying tuff were analyzed for plutonium to determine if there was any transport or buildup of plutonium in silts and clays beneath the channel in the alluvium, aquifer, or tuff. When the cores were taken in 1978, the alluvium in the channel contained about 2.7 pCi/g of ^{238}Pu and 4.0 pCi/g of ^{239,240}Pu. Water in the aquifer contained an average of 2.2×10^{-6} μCi/mℓ of ^{238}Pu and 0.28×10^{-6} μCi/mℓ of ^{239,240}Pu at Well MCO-6. Results of the analyses of cores indicate no significant concentrations of ^{238}Pu in silts and clay of the alluvium, aquifer, or underlying tuff (Table XXII). A comparison of the ^{239,240}Pu concentrations in cores with the control core concentrations indicate some high concentrations from core holes 1 and 2 and perhaps from core hole 3. However, the ^{239,240}Pu concentrations are low, being much lower than those found in solution in the aquifer or attached to sediments in the stream channel.

5. Summary. In summary, a study of the distribution of moisture, tritium, and plutonium in the Mortandad Canyon aquifer indicates some infiltration of water into the underlying tuff. This infiltration was accompanied by similar movement of tritium. The concentrations of plutonium on the sediments in the aquifer were low when compared to the high concentrations in solution in the aquifer or on sediments in the stream channel. It appears that most of the plutonium in the aquifer is in solution, in an ionic complex that does not readily exchange or is adsorbed by clay minerals in the alluvium.

F. Geochemical Mechanisms of Contaminant Transport [W. L. Polzer, E. H. Essington, E. J. Cokal (LS-6), and D. M. Nelson (Argonne National Laboratories)]

Complimentary to research in the general area of hydrologic mechanisms of contaminant transport is the research that deals with geochemical mechanisms. It appears that, if the hydrology can be controlled at a waste disposal site, it is not critical to understand all chemical reactions that could occur between contaminant species and the surrounding geologic media. However, it is not possible at this stage of waste disposal site technology development to assure complete control of the hydrology for long periods of time. There are also countless disposal sites in this country where state-of-the-art technology has not been employed. In these situations it would be useful to be able to predict potentially hazardous conditions of contaminant transport before they occur and to use research data to aid in any clean-up strategy necessary. Another general area of concern that

necessitates an understanding of the geochemistry as well as the hydrology addresses the fate of liquid waste streams, which although treated, contain trace contaminants when released to the environment. It is this particular situation that directed this research to describe the mobility of waste actinides in a shallow aquifer of a Los Alamos canyon.

Treated waste effluent at Los Alamos has been released to the environment in Mortandad Canyon since 1963. This study was initiated to investigate (1) the relative mobilities of the actinides in the shallow aquifer of Mortandad Canyon and (2) the influence of physicochemical characteristics of those mobilities. The study is of significance because it will extend the understanding of processes controlling actinide mobility, which will provide a broader technical basis for predicting and controlling actinide mobility in the environment.

Some important results follow.

1. Mobility is inversely related to concentration ratio (K_D). Based on that relationship the mobility of americium (Am) and plutonium (Pu) are similar in the upper reaches of the canyon ($K_D = 10^4$ mℓ/g). However, the mobility of americium ($K_D = 10^2$ mℓ/g) is much greater than that for plutonium ($K_D = 10^4$ mℓ/g) in the lower reaches of the canyon.

2. The distribution of charges associated with plutonium is relatively constant throughout the canyon; >90%, <10%, and <2% of the plutonium behave as neutral, anionic, and cationic species, respectively. In the upper reaches of the canyon americium appears to have a charge distribution similar to plutonium. However, in the lower reaches the proportion of anionic species increases to about 40% from about 10% in the upper reaches of the canyon.

3. Approximately 87% of the plutonium and 27% of the americium in the aquifer water were associated with a colloidal size fraction of 25 nm to 450 nm. About 7% of the plutonium and 61% of the americium were associated with the <10k MW (molecular weight) size fraction.

4. Plutonium and americium tracers did not equilibrate readily with the ambient plutonium and americium. For example, only 16% of the plutonium tracer was associated with the 25 nm to 450 nm size fraction and only 28% of the americium tracer was associated with the <10k MW size fraction.

5. The ambient americium in the <10k MW size fraction adsorbed to sedient to a lesser extent then did plutonium and the tracer americium.

The above results suggest the following tentative conclusions. Plutonium is associated with mobile colloidal material and americium is associated with both mobile colloidal and low molecular weight materials; neither species equilibrates readily with its aqueous environment. As the effluent moves through the aquifer, the colloidal material is removed from "solution." In the lower reaches of the canyon the low molecular weight americium complex becomes the predominant americium species and it is not adsorbed readily by sediment.

G. Transport of Radionuclides from the LAMPF Lagoons [R. W. Ferenbaugh and W. D. Purtymun (HSE-8)]

Monitoring of the discharge water from the Los Alamos Meson Physics Facility lagoons continued during 1983. Sampling frequency has been reduced to twice a year, in June and December. The list of radionuclides being monitored has been expanded so that it now includes ^{7}Be, ^{57}Co, ^{134}Cs, ^{3}H, ^{54}Mn, ^{22}Na, and ^{83}Rb. The sampling locations are shown in Figure 32 and the data obtained to date are shown in Table E-XLII. Movement of radionuclides around the lagoons has been described in a previous report (ESG 1983).

H. BIOTRAN Model [W. J. Wenzel, A. F. Gallegos (HSE-8), and J. C. Rodgers (LS-6)]

The BIOTRAN (Gallegos 1980) model was developed at Los Alamos to help predict short- and long-term consequences to man from releases of radionuclides into the environment. It is a dynamic simulation model that simulates on a daily and yearly basis the flux of biomass, water, and radionuclides through terrestrial and aquatic ecosystems. Biomass, water, and radionuclides are driven within the ecosystems by climate variables stochastically generated by BIOTRAN each simulation day. The climate variables influence soil hydraulics, plant growth,

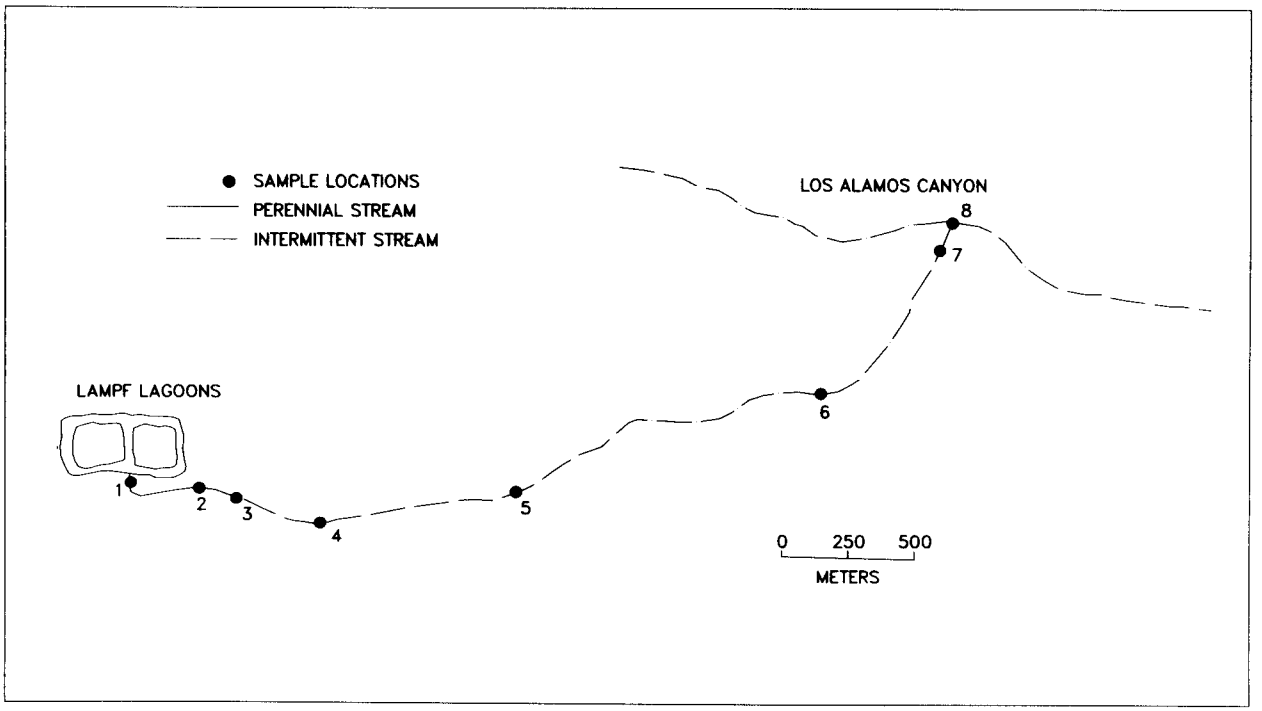


Fig. 32. Sampling locations in vicinity of the Los Alamos Meson Physics Facility's lagoons.

evapotranspiration, and particle suspension and deposition. BIOTRAN has 22 different plant growth strategies for simulating various grasses, shrubs, trees, and crops. Ruminants and humans are also dynamically simulated using the simulated crops and forage as intake for user specified diets. BIOTRAN has been used at Los Alamos for long-term prediction of health effects to populations following potential accidental releases of uranium (Wenzel 1983A) and plutonium (Walker 1981 and Wenzel 1983).

BIOTRAN has been restructured into manageable structured subroutines. All variables and their units have been defined and code logic charts have been made. Graphical output for each subroutine both during and after an execution has greatly increased the efficiency of using BIOTRAN. The streamlined graphical output allows the user to scan output quickly, instead of reviewing long tables of numbers. This is particularly useful for three-dimensional analysis of radionuclide flow in soils and between lake water layers.

Three new subroutines have recently been developed for BIOTRAN. HUMTRN (Gallegos 1984) is a human dynamic physiological and metabolic model that simulates male and female intake, organ uptake, and radiation doses in age groups. Simulated crops, meat, and daily air radionuclide concentrations from BIOTRAN become intake to humans on a user-specified diet. Daily intakes of food and water are adjusted by HUMTRN based on amount of physical activity, growth, age, sex, and food availability from BIOTRAN.

The soil hydrology and irrigation model, WATFLX, was developed based on Hillel's Darcy equation (Hillel 1976) for movement of water in silt, sand, and clay. Soil is modeled as layers. Each layer is considered a unit contributing to the evapotranspiration losses for the plant in the soil profile. Uptake is simulated to occur as a function of the root biomass in each soil layer simulated.

Limnetic nutrient and radionuclide cycling in multiple fresh water lake layers is modeled in the AQUAT subroutine as a function of daily solar radiation intensity and plankton kinetics. AQUAT will later be coupled with a shoreline (littoral) model to develop the transition terrestrial-aquatic coupling needed for BIOTRAN.

Several areas of BIOTRAN development are in progress. The Los Alamos health effects model, REPCAL (Buhl 1983, is being analyzed for addition to

HUMTRN/BIOTRAN. It will allow age- and sex-specific cancer mortality to be simulated dynamically. At present BIOTRAN predicts uranium and plutonium transport and consequences to humans. BIOTRAN is being changed to follow cesium as well as strontium environmental transport. With the addition of these elements a major addition to BIOTRAN will be required: mineral cycling. Once mineral and nutrient cycling for Ca, K, P, N, and Si are complete, then extensions to more elements and even organic compounds could be rapidly developed as the need arises.

I. Measurement and Modeling of Gamma Absorbed Doses Due to Atmospheric Releases from Los Alamos Meson Physics Facility [B. M. Bowen, A. I. Chen, W. A. Olsen, and D. M. Van Etten (HSE-8)]

1. Introduction. Portable, high-pressure ionization chambers (HPICs) measure short-term gamma radiation levels caused by air activation products from the Los Alamos Meson Physics Facility's emissions. The HPICs are situated at the nearest (~800 m) offsite location from Los Alamos Meson Physics Facility (Fig. 10, Station 6, East Gate). These measurements were in addition to those made by the thermoluminescent dosimeter network that routinely measures long-term gamma radiation levels. A Gaussian-type atmospheric dispersion model, which accounts for gamma radiation from various radioisotopes in the Los Alamos Meson Physics Facility plume, was used to predict absorbed gamma dose.

Short-term gamma absorbed doses were measured by one HPIC at an azimuth of 12° from the Los Alamos Meson Physics Facility stack during the January 1 through February 8 operating cycle. Two HPIC's were in the field during the September 8 through December 31 operating cycle, one north and the other north-northeast of the Los Alamos Meson Physics Facility stack, but they did not provide reliable data. Meteorological data were also measured at both East Gate and Los Alamos Meson Physics Facility. Airborne emission data were taken at the stack.

2. Results. The predominant winds are typically south-southwesterly and southweaterly over Los Alamos Meson Physics Facility. Figure 33 shows the wind rose for the periods in 1983 when Los Alamos Meson Physics Facility was operating. The high frequency of SSW and SW winds is due in large part to the afternoon, up-Rio Grande Valley wind. These predominant winds blow toward East Gate.

Daily model predictions, based on the integration of modeled 15-minute periods, were made for the first Los Alamos Meson Physics Facility operating cycle and were compared with the measured data. Figure 34 shows the comparison of the predicted and measured daily gamma doses due to Los Alamos Meson Physics Facility emissions. There is very good correlation between measured and predicted values. The model overpredicts an average of 17%. During 39-day operating cycles, the model predicted an absorbed dose of 10.3 mrad compared with the 8.8 mrad that was measured.

3. Further Study. Three portable HPICs will be used during the next Los Alamos Meson Physics Facility operating cycle. The instruments will be placed in the directional sectors of N, NNW, and NE from the Los Alamos Meson Physics Facility stack toward East Gate. A TLD will also be placed by each HPIC. It is hoped that the dimensions of the plume can be better defined over short-time periods. Also, the short-term model's accuracy and precision can be tested further. Finally, comparisons of HPIC data with TLD data of model predictions will be made.

J. The Los Alamos National Environmental Research Park [K. W. Bostick (LS-6)]

The Los Alamos National Environmental Research Park (LA/NERP) was established in 1976 as a field laboratory for ecological research, to study the environmental impacts of energy development, and as a source of public information on environmental issues. This is one of five NERPs at Department of Energy facilities throughout the country. The emphasis of research on the park is to develop criteria that facilitate energy development in ways that are least harmful to the environment.

The LA/NERP encompasses approximately 111 square kilometers of Department of Energy land at Los Alamos. The steep elevation gradient (1500 m in 25 km) and canyon/mesa terrain give the LA/NERP a wide spectrum of southwestern habitat types in a compact area. A unique feature of the LA/NERP is that some areas within the park have been protected from activities such as agriculture, lumbering, or mining for nearly 40 years. The presence of trace levels of both radioactive and nonradioactive materials that result from technology development at Los Alamos National Laboratory, the

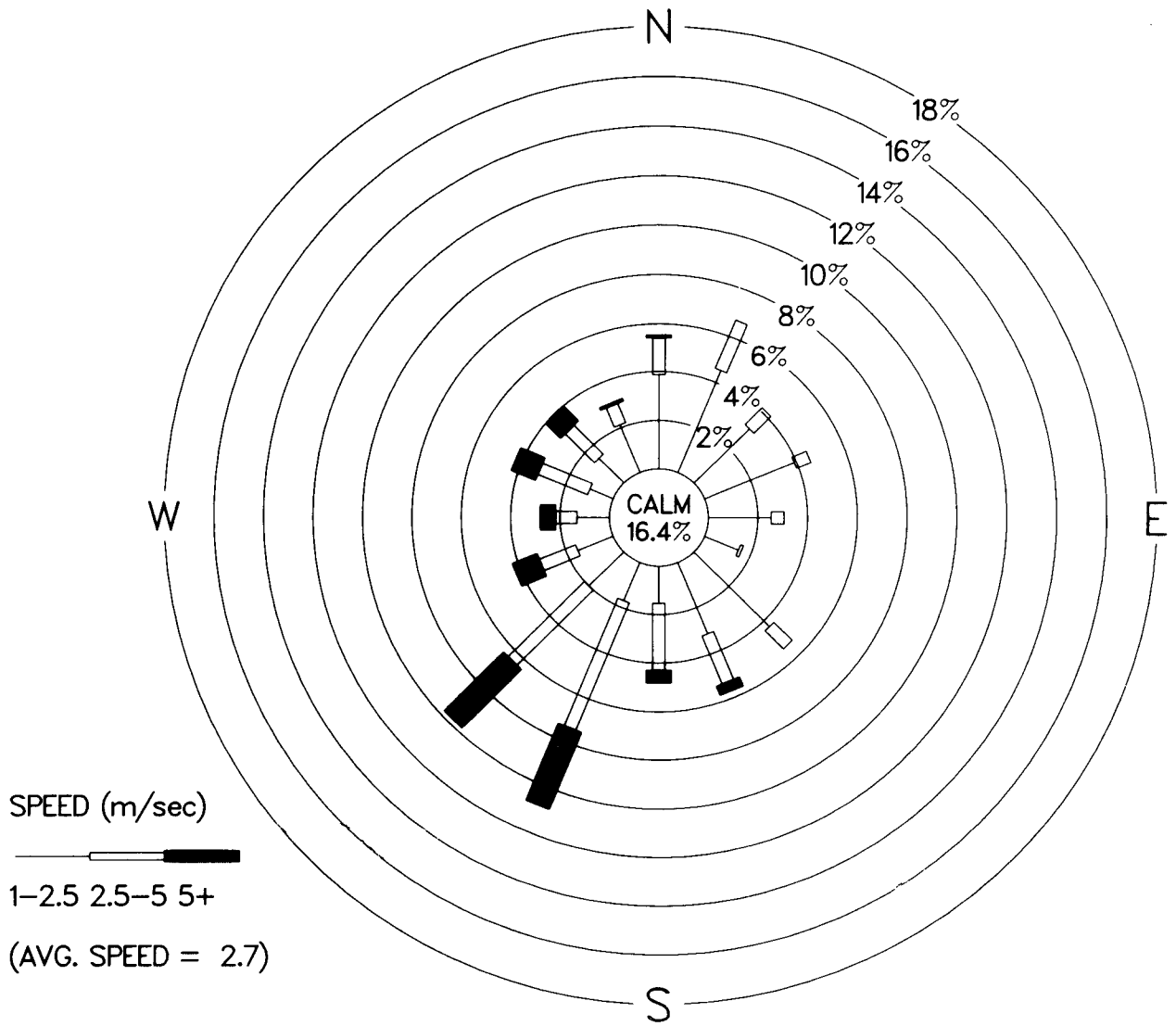


Fig. 33. Wind rose for nearest offsite location from LAMPF's 1983 operating cycles (January 1 to February 8 and September 8 to December 31).

appreciable technical resources of the Laboratory, and the physical security of outdoor study areas also make the LA/NERP a unique and valuable research resource.

While the term Park generally implies a physical area, it is more accurate to think of the LA/NERP as a resource and as a research program. The LA/NERP is an outdoor laboratory for conducting environmental research. This resource is available to researchers from outside the Laboratory as well as Laboratory staff. Much of the research conducted on the LA/NERP is performed by graduate and undergraduate students from regional universities. LA/NERP management encourages this use as much as possible. Universities using the Park include New Mexico Stte University, Colorado State University, University of New Mexico, Alma College, Utah State University, and University of California-Los Angeles. Some of the work ont he Park is conducted in cooperation with federal and state agencies such as the National Park Service and the New Mexico Department of Game and Fish. Use of the LA/NERP by researchers with independent funding sources is also encouraged.

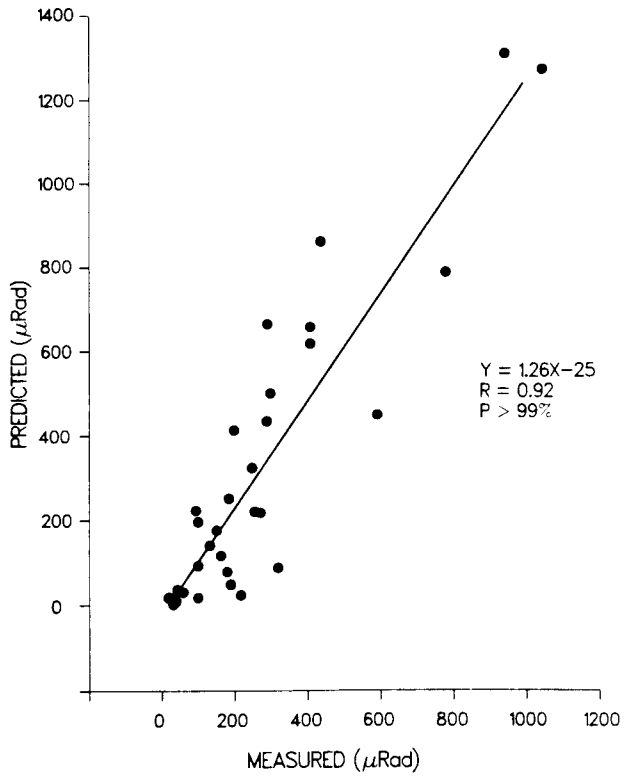


Fig. 34. Predicted versus measured daily gamma doses.

Current research activities include plant habitat characterization, rodent impacts on waste management practices, lizard physiology, and work with endangered species.

In keeping with the NERP charter to promote public understanding of environmental issues, a significant effort of the LA/NERP staff is devoted to public presentations. During 1983, 21 talks or presentations were given, primarily to schools and educational organizations.

K. Rooting Depths of Vascular Plants [T. S. Foxx, G. D. Tierney (LS-6), and J. M. Williams (ADPA)]

Appropriate management of waste disposal sites requires knowledge of the complex interactions among the physical, chemical, and biological processes occurring on the site. The extent to which vascular plants perturb or stabilize waste disposal sites has become of interest in recent years. Design and maintenance of such sites to prevent escape of contaminants into the environment requires knowledge of the potential rooting depth of plants. Such information can be used to select optimum species for controlling root intrusion, seepage, and percolation below the trench cover. There is no known summary of the literature concerning depth of rooting of vascular plants. Thus, in 1981-1983, an extensive bibliographic study was done to document rooting depths of native plants in the United States. The data base presently contains 1034 citations with approximately 12 000 data elements. All references were searched for information concerning family, species, common names, root depth, root lateral extension, root type, shoot height, life form, substrate, and geographical location.

There were three separate aspects of the study on rooting depths of vascular plants. First, the data were analyzed for rooting depths as related to life form, soil type, geographic region, root type, family, root depth to shoot height, and root depth to root lateral ratios. Average rooting depth and rooting frequencies were determined and related to present low-level waste site maintenance. Secondly, the data were analyzed for rooting depths of species known to occur on waste disposal sites. Average rooting depth and frequencies were determined for 53 species found on disposal sites at Los Alamos National Labortory. The third aspect of the study was to summarize the literature concerning factors influencing rooting depth and affecting root growth.

Overburdens on disposal sites in arid to semiarid regions have ranged from 0.3 to 1 m deep. In this study only annual grasses were found to root within 1 m and only half of these root within 0.3 m. This means that even shallow overburdens will be penetrated by roots unless a biobarrrier is used. Median rooting depths of life forms were as follows: annual forbs (0.61 m); biennial forbs (0.76 m); perennial grasses (1.06 m); perennial forbs (1.14 m); subshrubs and vines (1.16 m); trees (1.58 m); and shrubs (1.95 m).

REFERENCES

ACGIH 1983: American Conference of Governmental Industrial Hygienists, "Threshold Limit Values for Chemical Substances in the Work Environment," adopted by ACGIH for 1983-1984 (1983).

Becket 1977: P. H. T. Becket and R. D. Davis, "Upper Critical Levels of Toxic Elements in Plants," New Phytol. **79**, 96-106 (1977).

Bradford 1966A: G. D. Bradford, "Boron," in *Diagnostic Criteria for Plants and Soils*, H. D. Chapman, Ed. (University of California, Riverside 1966), pp. 33-61.

Bradford 1966B: G. R. Bradford, "Lithium," in *Diagnostic Criteria for Plants and Soils*, H. D. Chapman, Ed. (University of California, Riverside, 1966), pp. 218-224.

Brewer 1966: R. F. Brewer, "Fluorine," in *Diagnostic Criteria for Plants and Soils*, H. D. Chapman, Ed. (University of California, Riverside, 1966), pp. 180-196.

Buhl 1983: T. E. Buhl and W. R. Hansen, "Estimating the Risks of Cancer Mortality and Genetic Defects Resulting from Exposure to Low Levels of Ionizing Radiation" Environmental Surveillance Group of Los Alamos National Laboratory internal report (October 1983).

CBEAP 1971: Committee on Biological Effects of Atmospheric Pollutants, "Fluorides," National Academy of Sciences, Washington, DC (1971).

Davis 1978: R. D. Davis, P. H. T. Beckett, and E. Wellan, "Critical Levels of Twenty Potentially Toxic Elements in Young Spring Barley," Plant and Soil **49**, 395-408 (1978).

DOE 1979: US Department of Energy, "Final Environmental Impact Statement: Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico," US Department of Energy report DOE/EIS-0018 (December 1979).

DOE 1981A: US Department of Energy Order 5480.1A, Chapter XI, "Requirements for Radiation Protection" (April 1981).

DOE 1981B: US Department of Energy Order 5484.1, Chapter III, "Effluent and Environmental Monitoring Program Requirements" (February 1981).

DOE 1983: US Department of Energy, "Radiological Guidelines for Application to DOE's Formerly Utilized Sites Remedial Action Program," Department of Energy report ORO-831 (1983).

Engineering 1982: Engineering Division, "Los Alamos National Laboratory Long-Range Site Development Plan," Los Alamos National Laboratory report (September 1982).

EPA 1976: US Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," US Environmental Protection Agency report EPA-570/9-76-0033 (1976).

EPA 1977A: US Environmental Protection Agency, "Radiological Quality of the Environment in the United States, 1977," US Environmental Protection Agency report EPA-520/1-77-009 (September 1977).

EPA 1977B: US Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," US Environmental Protectio Agency report AP-42, Supplement 107, Third Edition (1977).

EPA 1979A: US Environmental Protection Agency, "National Emission Standards for Identifying, assessing and Regulating Airborne Substances Posing a Risk of Cancer," Federal Register **44** (197), Oct. 10, 1979, p. 58643.

EPA 1979B: US Environmental Protection Agency, "National Secondary Drinking Water Regulations," Federal Register **44** (140) (July 19, 1979).

EPA 1981: US Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors: Highway Mobile Sources," US Environmental Protection Agency report EPA-460/3-81-005 (1981).

ESG 1978: Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1977," Los Alamos Scientific Laboratory report LA-7263-MS (April 1978).

ESG 1981: Environmental Surveillance Group, "Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico, Final Report," Los Alamos National Laboratory report LA-8890-ENV/US Department of Energy report DOE/EV-0005/30 (May 1981).

ESG 1983: Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1982," Los Alamos National Laboratory report LA-9762-ENV (April 1983).

Facilities 1983: Facilities Engineering Division, "Laboratory Quality Assurance Manual for Engineering and Construction," Los Alamos National Laboratory Manual (September 1983, Revision 5).

Gallegos 1980: A. F. Gallegos, B. J. Garcia, and C. M. Sutton, "Documentation of TRU Biological Transport Model (BIOTRAN)," Los Alamos National Laboratory report LA-8213-MS (January 1980).

Gallegos 1984: A. F. Gallegos and W. J. Wenzel, "HUMTRN: Documentation and Verification for an ICRP Based Age and Sex Specific Human Simulation Model for Radionuclide Dose Assessment," Los Alamos National Laboratory report LA-9994-MS (1984).

Gilbert 1983: T. L. Gilbert, P. C. Chee, M. J. Knight, J. M. Peterson, C. J. Roberts, J. E. Robinson, S. Y. H. Tsai, and Y. Yoan, "Pathways Analysis and Radiation Dose Estimates for Radioactive Residues at Formerly Utilized MED/AEC Sites," Department of Energy report ORO-832 (1983).

Griggs 1964: R. L. Griggs, "Geology and Ground-Water Resources of the Los Alamos Area New Mexico," US Geology Survey Water Supply Paper 1753 (1964).

Gunderson 1983: T. Gunderson, T. Buhl, R. Romero, and J. Salazar, "Radiological Survey Following Decontamination Activities Near the TA-45 Site," Los Alamos National Laboratory report LA-9831-MS (July 1983).

Hakonson 1976A: T. E. Hakonson and K. V. Bostick, "Cesium-137 and Plutonium in Liquid Waste Discharge Areas at Los Alamos," F. R. Miera, Jr. and R. J. Peters, "The Distribution of Plutonium and Cesium of Alluvial Soils in the Los Alamos Environs," both in *Radioecology and Energy Resorces* (Dowden, Hutchinson, & Ross, Inc., Stroudsburg, Pennsylvania, 1976).

Hakonson 1976B: T. E. Hakonson, J. W. Nyhan, and W. D. Purtymun, "Accumulation and Transport of Soil Plutonium in Liquid Waste Discharge Areas at Los Alamos," Proc. Tranuranium Nuclides in the Environment, International Atomic Energy Agency report, IAEA-SM-199/99 (1976).

Hillel 1976: D. Hillel and C. H. M. Von Bavel, "Simulation of Profile Water Storage as Related to Soil Hydraulic Properties," Soil Science Journal **40**:6 (1976).

ICRP 1977: International Commission on Radiological Protection, "Recommendations of the International Commission on Radiological Protection," adopted January 17, 1977, Annals of the ICRP 1 (3) (1977).

Klement 1972: A. W. Klement, Jr., C. R. Miller, R. P. Minx, and B. Shleien, "Estimates of Ionizing Radiation Doses in the United States 1960-2000," US Environmental Protection Agency report ORP/CSD 72-1 (August 1972).

Liebig 1966: G. F. Liebig, Jr., "Arsenic," in *Diagnostic Criteria for Plants and Soils*, H. D. Chapman, Ed. (University of Califronia, Riverside, 1966), pp. 13-23.

MHSM 1976: Mason and Hanger-Silas Mason Co., Inc., "Disposal of Waste or Excess High Explosives," Quarterly Progress Reports from January 1971 through March 1976.

Nyhan 1983: J. W. Nyhan, B. J. Drennon, M. L. Wheeler, W. D. Purtymun, G. Trujillo, W. J. Herrera, and J. W. Booth, "Environmental Migration of Long-Lived Radionuclides Beneath A Former Los Alamos Liquid Waste Disposal Site After 33 Years," Los Alamos National Laboratory report LA-UR-83-1199 (1983).

NCRP 1975: National Council on Radiation Protection and Measurements, "Natural Background Radiation in the United States," National Council on Radiation Protection and Measurements report No. 45 (November 1975).

Paxton 1975: H. C. Paxton, "Safety and Analysis of the Los Alamos Critical Experiments Facility," Los Alamos Scientific Laboratory report LA-6206, Vol. II (October 1975).

Purtymun 1971A: W. D. Purtymun, "Plutonium in Stream Channel Alluvium in the Los Alamos Area, New Mexico," Los Alamos Scientific Laboratory report LA-4561 (1971).

Purtymun 1971B: W. D. Purtymun and W. R. Kennedy, "Geology and Hydrology of Mesita del Buey," Los Alamos Scientific Laboratory report LA-4660 (1971).

Purtymun 1974A: W. D. Purtymun, "Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County, New Mexico," Los Alamos Scientific Labortory report LA-5744 (1974).

Purtymun 1974B: W. D. Purtymun and S. Johansen, "General Geohydrology of the Pajarito Plateau," N. M. Geological Society Guidebook, 25th Field Conference, Ghost Ranch, New Mexico (1974).

Purtymun 1977: W. D. Purtymun, J. R. Buchholz, and T. E. Hakonson, "Chemical Quality of Effluents and Their Influence on Water Quality in a Shallow Aquifer," J. of Environmental Quality 6 (1) (January-March 1977).

Purtymun 1980: W. D. Purtymun, M. Wheeler, and J. L. Warren, "Guidelines for Construction and Use of Solid Waste Disposal Facilities at Area G, TA-54," Memorandum H-7-8-660 to members of Operational Waste Management Committee (December 10, 1980).

Purtymun 1983A: W. D. Purtymun, W. R. Hansen, and R. J. Peters, "Radiochemical Quality of Water in the Shallow Aquifer in Mortandad Canyon 1967-1978," Los Alamos National Laboratory report LA-9675-MS (March 1983).

Purtymun 1983B: W. D. Purtymun, N. M. Becker, and M. Maes, "Water Supply at Los Alamos During 1981," Los Alamos National Laboratory report LA-9734-PR (May 1983).

Purtymun 1983C: W. D. Purtymun, R. W. Ferenbaugh, N. M. Becker, W. H. Adams, and M. N. Maes, "Water Quality in the Vicinity of Fenton Hill, 1981 and 1982," Los Alamos National Laboratory report LA-9857-PR (1983).

Purtymun 1983D: W. D. Purtymun, R. J. Peters, T. H. Buhl, and M. Maes, "Recap of Radionuclides in Soils and Sediments from Regional Stations, 1978-82," Los Alamos National Laboratory report (in preparation).

Purtymun 1984: W. D. Purtymun, N. M. Becker, and M. N. Maes, "Water Supply at Los Alamos During 1983," Los Alamos National Laboratory report (in preparation).

SHM 1978: Subcommittee on Heavy Metals, "Effects of Arsenic in the Canadian Environment," National Research Council of Canada report No. 15391 (1978).

Steen 1977: C. R. Steen, "Pajarito Plateau Archaeological Survey and Excavations," Los Alamos Scientific Laboratory report LASL-77-4 (May 1977).

Steen 1982: C. R. Steen, "Pajarito Plateau Archaeological Survey and Excavations, Vol. II," Los Alamos National Laboratory report LA-8860-NERP (April 1982).

Temple 1978: P. J. Temple, S. N. Linzon, and M. L. Smith, "Fluorine and Boron Effects on Vegetation in the Vicinity of a Fiberglass Plant," Water, Air, and Soil Pollution **10**, 163-174 (1978).

USGS 1965: US Geological Survey, "Guides for Construction of Pits on Mesita del Buey," correspondence from F. C. Koopman (USGS) to S. E. Russo (Los Alamos Scientific Laboratory, ENG-3), June 30, 1965.

Van Etten 1983: D. Van Etten and W. Olsen, "Delta-Count Rate-Monitoring System," Los Alamos National Laboratory report L-9855-M (September 1983).

Walker 1981: L. J. Walker, W. R. Hansen, D. C. Nelson, G. Maestas, W. J. Wenzel, F. A. Guavara, Jr., L. Warren, J. C. Rodgers, and J. M. Graf, "Alternate Transuranic Waste Management Strategies at Los Alamos National Laboratory," Los Alamos National Laboratory report LA-8982-MS (September 1981).

Weinstein 1977: L. H. Weinstein, "Fluoride and Plant Life," J. of Occupational Medicine **19**, 48-78 (1977).

Wenzel 1983A: W. J. Wenzel, K. M. Wallwork-Barber, J. C. Rodgers, and A. F. Gallegos, "The Texas Panhandle Soil-Crop-Beef Food Chain for Uranium: A Dynamic Model Validated by Experimental Data," in Fourth DOE Environmental Protection Information Meeting, CONF-821215, Paper 6D (August 1983).

Wenzel 1983B: W. J. Wenzel and A. F. Gallegos, "Supplementary Documentation for an Environmental Impact Statement Regarding the Pantex Plant: Long-Term Radiological Risk Assessment for Postulated Accidents," Los Alamos National Laboratory report LA-9445-PNTX-O (1983).

Wheeler 1975: M. L. Wheeler and J. L. Warren, "Tritium Containment After Burial of Contaminated Solid Waste," in *Proceedings of the 23rd Conference on Remote Systems Technology*, (American Nuclear Society, San Francisco, California, 1975).

Yeates 1972: D. B. Yeates, A. S. Gildin, and D. W. Moeller, "Natural Radiation in the Urban Environments," Nuclear Safety **13** (4), 2754 (July-August 1972).

APPENDIX A

STANDARDS FOR ENVIRONMENTAL CONTAMINANTS

The concentrations of radioactive and chemical contaminants in air and water samples are compared with pertinent standards in regulations of several federal and state agencies to verify the Laboratory's compliance. Laboratory operations are conducted in accordance with directives and procedures contained in DOE Order 5480.1A (Environmental Protection, Safety, and Health Protection Program for DOE Operations), Chapter I (Environmental Protection, Safety, and Health Protection Standards) and Chapter XI (Requirements for Radiation Protection); and DOE Order 5484.1 (Environmental Radiation Protection, Safety, and Health Protection Information Reporting Requirements), Chapter III (Effluent and Environmental Monitoring Program Requirements).

In the case of radioactive materials in the environment, guides contained in Chapter XI are used as a basis for evaluation. The standards are listed in Table A-I as Concentration Guides (CGs). A CG is the concentration of radioactivity in air breathed continuously or water constituting all that ingested during 50 years that will result in whole body or organ doses equal to the Radiation Protection Standards in the fiftieth year (RPSs, listed in Table A-II) for internal and external exposures.

Obviously, there are uncertainties in relating CGs to RPSs. Uncontrolled Area CGs correspond to RPSs for the general public, whereas Controlled Area CGs correspond to RPSs for workers. Thus, common practice and stated DOE policy in Chapter XI are that operations shall be "conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels reasonably achievable."

Because some radioisotopes remain in the body and cause exposure long after intake has occurred, the RPSs require consideration of dose commitment caused by inhalation, ingestion, or absorption of such isotopes. For purposes of this report, 50-yr dose commitments were calculated where appropriate using dose factors from Reference A1.

For chemical pollutants in water supply, the controlling standards are those promulgated by either the Environmental Protection Agency (EPA) or the New Mexico Environmental Improvement Division (NMEID, see Table A-III). EPA's primary maximum contaminant level (MCL) is the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system.[A2]

The EPA's secondary drinking water regulations control contaminants in drinking water that primarily affect aesthetic qualities relating to public acceptance of drinking water. At considerably higher concentrations of these contaminants, health implications may also exist as well as aesthetic degradations.[A3]

Radioactivity in public water supply is governed by EPA regulations contained in 40CFR141. These regulations provide that combined ^{226}Ra and ^{228}Ra shall not exceed 5×10^{-9} μCi/mℓ (5 pCi/ℓ) and gross alpha activity (including ^{226}Ra, but excluding radon and uranium) shall not exceed 15×10^{-9} μCi/mℓ (15 pCi/ℓ). A screening level of 5×10^{-9} μCi/mℓ (5 pCi/ℓ) is established as part of the monitoring requirements to determine whether specific radium analyses must be performed. Plutonium concentrations are compared to the EPA gross alpha MCL of 15×10^{-9} μCi/mℓ (15 pCi/ℓ).[A2]

For manmade beta and photon emitting radionuclides, the EPA drinking water regulations specify that a concentration be limited to a level that would result in a dose of 4 mrem/yr calculated according to a specified procedure. The EPA calculated value for tritium (^{3}H) is 20×10^{-6} μCi/mℓ and for cesium (^{137}Cs) is 200×10^{-9} μCi/mℓ.[A2]

Table A-I

DOE Concentration Guides (CGs)

Concentration Guides for Uncontrolled Areas[a,b]			Concentration Guides for Controlled Areas[a,b]		
Nuclide	CG for Air (μCi/mℓ)	CG for Water (μCi/mℓ)	Nuclide	CG for Air (μCi/mℓ)	CG for Water (μCi/mℓ)
^{3}H	2×10^{-7}	3×10^{-3}	^{3}H	5×10^{-6}	1×10^{-1}
^{7}Be	---	2×10^{-3}	^{7}Be	---	5×10^{-2}
$^{11}C, ^{13}N, ^{15}O$	3×10^{-8}	---	$^{11}C, ^{13}N, ^{15}O$	1×10^{-6}	---
^{41}Ar	4×10^{-8}	---	^{41}Ar	2×10^{-6}	---
^{89}Sr	3×10^{-10}	3×10^{-6}	^{89}Sr	3×10^{-8}	3×10^{-4}
^{90}Sr[d]	3×10^{-11}	3×10^{-7}	^{90}Sr	1×10^{-9}	1×10^{-5}
^{131}I[d]	1×10^{-10}	3×10^{-7}	^{131}I[d]	4×10^{-9}	3×10^{-5}
^{137}Cs	5×10^{-10}	2×10^{-5}	^{137}Cs	1×10^{-8}	4×10^{-4}
^{238}Pu	7×10^{-14}	5×10^{-6}	^{238}Pu	2×10^{-12}	1×10^{-4}
^{239}Pu[d]	6×10^{-14}	5×10^{-6}	^{239}Pu[d]	2×10^{-12}	1×10^{-4}
^{241}Am	2×10^{-13}	4×10^{-6}	^{241}Am	6×10^{-12}	1×10^{-4}
	(pg/m^3)[c]			(pg/m^3)[c]	
U, natural[c]	6×10^{6}	6×10^{-7}	U, natural[c]	1.8×10^{8}	2×10^{-5}

[a]This table contains the most restrictive CGs for nuclides of major interest at the Laboratory (DOE Order 5480.1A, Chapter XI).

[b]CGs apply to radionuclide concentrations in excess of that occurring naturally or due to fallout.

[c]One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses may be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

[d]The CGs of ^{239}Pu and ^{90}Sr are the most appropriate to use for gross alpha and gross beta CGs, respectively.

Table A-II

DOE Radiation Protection Standards for
External and Internal Exposures

Individuals and Population Groups in Uncontrolled Areas

Type of Exposure	Annual Dose Equivalent or Dose Commitment[a] (mrem)	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population[b]
Whole body, gonads, or bone marrow	500	170
Other organs	1500	500

Individuals in Controlled Areas

Type of Exposure	Exposure Period	Dose Equivalent [Dose or Dose Commitment[a] (mrem)]
Whole body, head and trunk, gonads, lens of the eyes,[c] red bone marrow, active blood forming organs.	Year	5 000[d]
	Calendar Quarter	3 000
Unlimited areas of the skin (except hands and forearms). Other organs, tissues, and organ systems (except bone).	Year	15 000
	Calendar Quarter	5 000
Bone	Year	30 000
	Calendar Quarter	10 000
Forearms[e]	Year	30 000
	Calendar Year	10 000
Hands[e] and feet	Year	75 000
	Calendar Year	25 000

[a]In keeping with the DOE policy on lowest practicable exposure, exposures to the public shall be limited to as small a fraction of the respective annual dose limits as is practicable. These Radiation Protection Standards apply to exposures from Laboratory operations, so exclude contributions from cosmic, terrestrial, global fallout, self-irradiation, and medical diagnostic radiation sources. They are from DOE Order 5480.1A, Chapter XI.

[b]See Paragraph 5.4, FRC Report No. 1 (Reference A4) for discussion on concept of suitable sample of exposed population.

[c]A beta exposure below a maximum energy of 700 keV will not penetrate the lens of the eye; therefore, the applicable limit for these energies would be that for the skin (15 000 mrem)/year).

[d]In special cases with the approval of the Deputy Assistant Secretary for Environmental Safety and Health, a worker may exceed 5000 mrem/year provided his or her average exposure per year since age 18 will not exceed 5000 mrem/year. This does not apply to emergency situations.

[e]All reasonable effort shall be made to keep exposure of forearms and hands to the general limit for the skin.

Table A-III

Maximum Contaminant Level (MCL) in Water Supply for Inorganic Chemicals and Radiochemicals[a]

Inorganic Chemical Contaminant	MCL (mg/ℓ)	Radiochemical Contaminant	MCL (μCi/mℓ)
	Primary Standard[a]		
Ag	0.05	^{137}Cs	200×10^{-9}
As	0.05	Gross alpha[d]	5×10^{-9}
Ba	1.0	^{3}H	20×10^{-6}
Cd	0.010	^{238}Pu	15×10^{-9}
Cr	0.05	^{239}Pu	15×10^{-9}
F[b]	2.0		
Hg	0.002		
NO_3	45		
Pb	0.05		
Se	0.01		
	Secondary Standards[c]		
Cℓ	250		
Cu	1.0		
Fe	0.3		
Mn	0.05		
SO_4	250		
Zn	5.0		
TDS	500		
pH	6.5 - 8.5		

[a]Reference A2.
[b]Based on annual average of the maximum daily air temperature of 14.6 to 17.7°C.
[c]Reference A3.
[d]See text for discussion of application of gross alpha MCL and gross alpha screening level of 5×10^{-9} μCi/mℓ.

REFERENCES

A1. US Department of Energy, "A Guide for Environmental Radiological Surveillance at U.S. Department of Energy Installations," US Department of Energy report DOE/EP-0023 (July 1981).

A2. US Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," US Environmental Protection Agency report EPA-570/9-76-003 (1976).

A3. US Environmental Protection Agency, "National Secondary Drinking Water Regulations," Federal Register **44** (140) (July 19, 1979).

A4. Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards," Federal Radiation Council Report No. 1 (1960).

APPENDIX B

SAMPLING PROCEDURES AND STATISTICAL TREATMENT OF DATA

A. Thermoluminescent Dosimeters

The thermoluminescent dosimeters (TLDs) used at the Laboratory are lithium fluoride (LiF) chips, 6.4 mm square by 0.9 mm thick. The TLDs, after being exposed to radiation, emit light upon being heated. The amount of light is proportional to the amount of radiation to which the TLD was exposed. The TLDs used in the Laboratory's environmental monitoring program are insensitive to neutrons, so the contribution of cosmic neutrons to natural background radiation is not measured.

The chips are annealed at 400°C for 1 h and then cooled rapidly to room temperature. This is followed by annealing at 100°C for 1 h and again cooling rapidly to room temperature. In order for the annealing conditions to be repeatable, the chips are put into rectangular borosilicate glass vials that hold 48 LiF chips each. These vials are slipped into a borosilicate glass rack so they all can be placed at once into the ovens maintained at 400°C and 100°C.

Four LiF chips constitute a dosimeter. The LiF chips are contained in a two part threaded assembly made of an opaque yellow acetate plastic. A calibration set is prepared each time chips are annealed. The calibration set is read at the start of the dosimetry cycle. The number of dosimeters and exposure levels are determined for each calibration in order to efficiently use available TLD chips and personnel. Each set contains from 20 to 50 dosimeters. These are irradiated at levels in the range between 0 mR and 80 mR using an 8.5 mCi ^{137}Cs source calibrated by the National Bureau of Standards.

A factor of 1 rem (tissue) = 1.050 mR is used in evaluating the dosimeter data. This factor is the reciprocal of the product of the roentgen to rad conversion factor of 0.958 for muscle for ^{137}Cs and the factor 0.994, which corrects for attenuation of the primary radiation beam at electronic equilibrium thickness. A rad-to-rem conversion factor of 1.0 for gamma rays is used as recommended by the International Commission on Radiation Protection.[B1] A method of weighted least squares linear regression is used to determine the relationship between TLD reader response and dose (weighting factor is the variance).[B2]

The TLD chips used are all from the same production batch and were selected by the manufacturer so that the measured standard deviation in TL sensitivity is 2.0 to 4.0% of the mean at a 10 R exposure. At the end of each field cycle, whether calendar quarter or the Los Alamos Meson Physics Facility operation cycle, the dose at each network location is calculated along with the upper and lower limits at the 95% confidence level.[B3] At the end of the calendar year, individual field cycle doses are summed for each location. Uncertainty is calculated as summation in quadrature of the individual uncertainties.

B. Air Sampling

1. Sampling Procedures. Samples are collected monthly at 26 continuously operating stations.[B4] Air pumps with flow rates of approximately 3 ℓ/sec are used. Atmospheric aerosols are collected on 79 mm diameter polystyrene filters. The filters are mounted on a cartridge that contains charcoal. This charcoal is not routinely analyzed for radionuclies. However, if an unplanned release occurs, the charcoal can be analyzed for any ^{131}I it may have collected. Part of the total air flow (2.4 - 3.1 mℓ/sec) is passed through a cartridge containing silica gel to adsorb atmospheric water vapor for tritium analyses. Air flow rates through both sampling cartridges are measured with rotameters and sampling times recorded. The entire air sampling train at each station is cleaned, repaired, and calibrated on an as-needed basis.

Two clean, control filters are used to detect any possible contamination of the 26 sampling filters while they are in transit. The control filters accompany the 26 sampling filters when they are placed in the air samplers and when they are retrieved. Then the control filters are analyzed for radioactivity just like the 26 sampling filters. Analytical results for the control filters are subtracted

from the appropriate gross analytical results to obtain net analytical results.

At one onsite location (N050-E040) atmospheric radioactivity samples are collected daily (Monday through Friday). Atmospheric particulate matter on each daily filter is counted for gross alpha and gross beta activities on collection day and again 7 to 10 days after collection. The first measurement provides an early indication of any major change in atmospheric radioactivity. The second measurements (made after absorbed, naturally occurring, radon-thoron daughters had reached equilibrium with their long-lived parents) are used to observe temporal variations in long-lived atmospheric radioactivity. Gross alpha and gross beta activities are also measured in the same manner on the monthly filter from the Española (Station 1) regional air sampling station.

On a quarterly basis, the monthly filters for each station are cut in half. The first group of filter halves is combined and disssolved to produce quarterly composite samples for each station. The second group of filter halves is saved for uranium analysis.

The filters are ignited in platinum dishes, treated with HF-HNO_3 to dissolve silica, wet ashed with HNO_3-H_2O_2 to decompose organic residue, and treated with HNO_3-HCl to ensure isotopic equilibrium. Plutonium is separated from the resulting solution by anion exchange. For 11 selected stations, americium is separated by cation exchange from the eluent solutions from the plutonium separation process. The purified plutonium and americium samples are separately electrodeposited and measured for alpha-particle emission with a solid-state alpha detection system. Alpha-particle energy groups associated with the decay of ^{238}Pu, ^{239}Pu, and ^{241}Am are integrated, and the concentration of each radionuclide in its respective air sample calculated. This technique does not differentiate between ^{239}Pu and ^{240}Pu. Uranium analyses by neutron activation analysis (see Appendix C) are done on the second group of filter halves.

Silica gel cartridges from the 26 air sampling stations are analyzed monthly for tritiated water. The cartridges contain a small amount of blue "indicating" gel at each end to indicate a desiccant oversaturation. During cold months of low absolute humidity, sampling flow rates are increased to ensure collection of enough water vapor for analysis. To avoid sample preservation problems, water is distilled from each silica gel sample immediately upon being retrieved from the field. This distillation yields a monthly average atmospheric water vapor sample. An aliquot of the distillate is then analyzed for tritium by liquid scintillation counting.

Analytical quality control and quality assurance for analysis done in the air sampling program are described in Appendix C (Part C). In brief, both blanks and standards are analyzed in conjunction with normal analytical procedures. About 10% of the analyses are devoted to the quality control and assurance program.

2. Statistical Analysis. Measurements of the air particulate samples require that chemical or instrumental backgrounds be subtracted to obtain net values. Thus, net values lower than the minimum detection limit (MDL, Table C-IV) of an analytical technique are sometimes obtained. Consequently, individual measurements can result in values of zero or negative numbers because of statistical fluctuations in the measurements. Although a negative value does not represent a physical reality, a valid long-term averge of many measurements can be obtained only if the very small and negative values[B5] are included in the population.

Uncertainties reported for maximum and minimum concentrations reflect uncertainties introduced both in the field (flow rate and time determinatins) and laboratory (counting, pipetting, and so on). These values indicate the precision of the maximums and minimums and are twice the measurement uncertainties.

Standard deviations for station and group (regional, perimeter, onsite) means are calculated using the following equation:

$$s_{\bar{c}} = \sqrt{\frac{\sum_{i=1}^{N} (\bar{c} - c_i)^2}{N(N-1)}}$$

where

$s_{\bar{c}}$ = standard deviation of c,
$\bar{c}$ = annual mean of a station or group of stations,
c_i = concentration for station i, and
N = number of concentrations (sampling periods).

C. Water, Soil, and Sediment Sampling

Surface and ground water sampling points are grouped (regional, perimeter, and onsite) according to location and hydrologic similarity. Surface and ground water grab

samples are taken one to two times annually. Samples from wells are collected after sufficient pumpage or bailing to ensure that the sample is representative of the water in the aquifer. Spring samples (ground water) are collected at point of discharge.

The water samples are collected in 4 ℓ (for radiochemical) and 1 ℓ (for chemical) polyethylene bottles. The 4 ℓ bottles are acidified in the field with 5 mℓ of concentrated nitric acid and returned to the laboratory within a few hours for filtration through a 0.45 μm pore membrane filter. The samples are analyzed radiochemically for dissolved cesium (^{137}Cs), plutonium (^{238}Pu and $^{239,\ 240}Pu$), and tritium (as HTO), as well as for total dissolved gross alpha, beta, and gamma activities. Total uranium is measured using the neutron activation method (see Appendix C).

Water is collected for chemical analyses at the same time as for radiochemical analysis and returned to the laboratory for filtration. Samples for trace constituents in the water supply are collected and acidified in the field and returned immediately to the laboratory for filtration.

Storm runoff samples are analyzed for radionuclides in solution and suspended sediments. The samples are filtered through a 0.45 μm filter. The radioactivity composition of the solution is defined as filtrate passing through the filters, while the suspended sediment radioactivity is defined as the residue on the filter.

Soil samples are collected by taking five plugs, 75 mm in diameter and 50 mm deep, at the center and corners of a square area 10 m on a side. The five plugs are combined to form a composite sample for radiochemical analyses. Sediment samples are collected from dune buildup behind boulders in the main channels of perenially flowing streams. Samples from the beds of intermittently flowing streams are collected across the main channel. The soil an sediment samples are analyzed for gross alpha and gross beta activities, ^{137}Cs and ^{238}Pu and ^{239}Pu. Moisture distilled from soil samples is analyzed for ^{3}H. A few select samples are analyzed for ^{90}Sr.

The average concentrations of radionuclides and chemical constituents are reported for a number of individual analyses in tables in this report. The minimum and majximum values reported are individual analyses in the groups, while the average is computed from all of the individual analyses in the group. The uncertainty following the primary value represents twice the standard deviation of the distribution of observed values, or the analytical variationfor individual results.

REFERENCES

B1. H. E. John and J. R. Cunningham, *The Physics of Radiobiology*, 3rd edition. (C. C. Thomas, Springfield, Illinois 1974) and International Commission on Radiological Protection (ICRP), "Protection Against Ionizing Radiation from External Sources," ICRP Report No. 15 (Pergamon Press, New York 1970).

B2. P. R. Bevington, *Data Reduction and Error Analysis for the Physical Sciences* (McGraw-Hill, New York 1969).

B3. National Bureau of Standards Handbook 91, *Experimental Statistics* (National Bureau of Standards, August 1, 1963).

B4. T. C. Gunderson, "Environmental and Emergency Response Capabilities of Los Alamos Scientific Laboratory's Radiological Air Sampling Program," Los Alamos Scientific Laboratory report LA-8379-MS (May 1980).

B5. R. O. Gilbert, *Recommendations Concerning the Computation and Reporting of Counting Statistics for the Nevada Applied Ecology Group*, BNWL-B-368, Battelle, Pacific Northwest Laboratories, Richland, Washington, September 1975.

APPENDIX C

ANALYTICAL CHEMISTRY METHODOLOGY

A. Radioactive Constituents

Environmental samples are routinely analyzed for the following radioactive constituents: gross alpha, gross beta, gross gamma, isotopic plutonium, americium, uranium, cesium, tritium, and strontium. The detailed procedures have been published in this appendix in previous years.[C1,C2] Occasionally other radionuclides from specific sources are determined: ^{7}Be, ^{22}Na, ^{40}K, ^{51}Cr, ^{60}Co, ^{65}Zn, ^{83}Rb, ^{106}Ru, ^{134}Cs, ^{140}Ba, ^{152}Eu, ^{154}Eu, and ^{226}Ra. All but ^{226}Ra are determined by gamma-ray spectrometry on large Ge(Li) detectors. Depending upon the concentration and matrix, ^{226}Ra is measured by emanation[C3] or by gamma-ray spectrometry of its ^{214}Bi decay product.[C4] Uranium isotopic ratios (^{235}U/^{238}U) are measured by neutron activation analysis where precisions of $\pm 5\%$ are adequate.[C5] More precise work still requires mass spectrometry.

B. Stable Constituents

A number of analytical methods are used for various stable elements. The choice of method is based on many criteria, including the operational state of the instruments, expected concentrations in samples, quantity of sample available, sample matrix, and Environmental Protection Agency (EPA) regulations.

Instrumental techniques available include neutron activation, atomic absorption, ion chromatography, color spectrophotometry, potentiometry, and combustion analysis. Standard chemical methods are also used for many of the common water quality tests. Atomic absorption capabilities include flame, furnace, mercury cold vapor, and hydride generation, as well as flame emission spectophotometry. The methods used and references for determination of various chemical constituents are summarized in Table C-I.

C. Analytical Chemistry Quality Evaluation Program

1. Introduction. Control samples are analyzed in conjunction with the normal analytical chemistry work load. Such samples consist of several general types: calibration standards, reagent blanks, process blanks, matrix blanks, duplicates, and standard reference materials. Analysis of control samples fill two needs in the analytical work. First, they provide quality control over analytical procedures so that problems that might occur can be identified and corrected. Secondly, data obtained from analysis of control samples permit evaluation of the capabilities of a particular analytical technique for determination of a given element or constituent under a certain set of circumstances. The former function is analytical quality control; the latter is quality assurance.

No attempt is made to conceal the identity of control samples from the analyst. They are submitted to the laboratory at regular intervals and analyzed in association with other samples; that is, they are not normally handled as a unique set of samples. We feel it would be difficult for analysts to give the samples special attention, even if they are so inclined. We endeavor to run at least 10% of stable constituent analyses and selected radioactive constituent analyses as quality assurance samples using the materials described above. A detailed description of our Quality Assurance program and a complete listing of our annual results have been published.[C56-C61]

2. Radioactive Constituents. Quality control and quality assurance samples for radioactive constituents are obtained from outside agencies as well as prepared internally. The Quality Assurance Division of the Environmental Monitoring Systems Laboratory (EPA—Las Vegas) provides water, foodstuff, and air filter standards for analysis of gross alpha, gross beta, ^{3}H, ^{40}K, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{106}Ru, ^{134}Cs, ^{137}Cs, ^{226}Ra, and ^{239,240}Pu as part

Table C-I

Analytical Methods for Various Stable Constituents

Technique	Stable Constituents Measured	References
Standard Chemical Methods	Total Alkalinity, Hardness, $SO_4^{=}$, TDS, Conductivity	C6
Color Spectrophotometry	NO_3^-,$PO_4^{=}$,Si,Pb,Ti	C6
Neutron Activation		
Instrumental Thermal	Al,Sb,As,Ba,Br,Ca,Ce,Cs,Cl,Cr, Co,Dy,Eu,Au,Hf,In,I,Fe,La,Lu, Mg,Mn,K,Rb,Sm,Sc,Se,Na,Sr,S, Ta,Tb,Th,Ti,W,V,Yb,Zn	C7,12,13,14,15
Instrumental Epithermal	Al,Sb,As,Ba,Br,Cs,Cr,F,Ga,Au, In,I.La,Mg,Mn,Mo,Ni,K,Sm,Se, Si,Na,Sr,Th,Ti,W,U,Zn,Zr	C7,9,16,17,18,19,20,21
Thermal Neutron Capture Gamma Ray	Al,B,Ca,Cd,C,Gd,H,Fe,Mg N,P,K,Si,Na,S,Ti	C7,22,23,24,25,26,27,28,29
Radiochemical	Sb,As,Cu,Au,Ir,Hg,Mo,Os,Pd Pt,Ru,Se,Ag,Te,Th,W,U,La,Ce, Pr,Nd,Sm,Eu,Gd,Tb,Dy,Ho,Er, Yb,Lu,$^{235}U/^{238}U$, ^{238}Pu, ^{239}Pu	C5,6,7,30,31,32,33,34,35,36, 37,38,51
Delayed Neutron Assay	U	C7,8,10,11,39,40
Atomic Absorption	Sb,As,Ba,Be,Bi,Cd,Ca,Cr,Co,Cu Ga,In,Fe,Pb,Li,Mg,Mn,Hg,Mo, Ni,K,Se,Si,Ag,Na,Sr,Te,Tl,Sn, Ti,V,Zn	C6,41,43,44,45,46,47,48,52, 53,54
Ion Chromatography	F^-,Cl^-,Br^-,NO_2^-, NO_3^-,SO_4^{-2}, PO_4^{-3}	C49
Potentiometric	F^-,NH_4^+,pH	C50,C55
Combustion	C,N,H,S	C29

of an ongoing laboratory intercomparison program. They also distribute reference soil samples that have been characterized for ^{235}U, ^{238}U, ^{228}Th, ^{230}Th, ^{232}Th, ^{226}Ra, ^{228}Ra, and ^{210}Pb. The National Bureau of Standards (NBS) provides two soil and sediment Standard Reference Materials (SRM) for environmental radioactivity. These SRMs are certified for ^{60}Co, ^{90}Sr, ^{137}Cs, ^{226}Ra, ^{230}Th, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and several other nuclides.

Soil, rock, and ore samples obtained from the Canadian Geological Survey (CGS) are used for quality assurance of uranium and thorium determinations in silicate matrices.[C62] Our own "in-house" standards are prepared by adding known quantities of liquid NBS radioactivity SRMs to blank matrix materials.

3. Stable Constituents. Quality assurance for the stable constituent analysis program is maintained by analysis of certified or well-characterized environmental materials. The NBS has a large set of silicate, water, and biological SRMs. The EPA distributes mineral analysis and trace analysis water standards. Rock and soil reference materials have been obtained from the CGS and the United States Geological Survey (USGS). Details of this program have also been published.[C56-C61]

The analytical quality control program for a specific batch of samples is the combination of many factors. These include the "fit of the calibration curve," instrument drift, calibration of the instrument and/or reagents, recovery for SRMs, and precision of results. In addition, there is a need for a program for evaluation of the quality of results for an individual water sample. These individual water sample quality ratios are the sum of the milliequivalent (meq) cations to the sum of meq anions, the meq hardness to the sum of meq Ca^{+2} and Mg^{+2}, the observed total dissolved solids (TDS) to the sum of solids, the observed conductivity to the sum of contributing conductivities, as well as the two ratios obtained by multiplying (0.01) × (conductivity) and dividing by the meq cations, and the meq anions. A summary of these ratios is given for 1983 waters by sample set in Table C-II.

A detailed investigation of these individual quality assurance ratios can be suggestive of the need for reanalysis of specific constituents. However, one must realize that obtaining a ratio of 1.00 is not always possible. Reanalysis of a sample is based on these ratios, the presence of constituents not requested, and historical considerations. The details of our approach are being prepared for publication.[C63]

4. Indicators of Accuracy and Precision. Accuracy is the degree of difference between average test results and true results, when the latter are known or assumed. Precision is the degree of mutual agreement among replicate measurements (frequently assessed by calculating the standard deviation of a set of data points). Accuracy and precision are evaluated from results of analysis of reference materials. These results are normalized to the known quantity in the reference material to permit comparison among reference materials of similar matrix containing different concentrations of the analyte:

$$r = \frac{\text{Reported Quantity}}{\text{Known Quantity}}$$

A mean value (R) for all normalized analyses of a given type is calculated as follows for a given matrix type (N is total number of analytical determinations):

$$R = \frac{\Sigma_i r_i}{N}$$

The standard deviation (s) of R is calculated assuming a normal distribution of the population of analytical determinations (N):

$$s = \sqrt{\frac{\Sigma_i (R - r_i)^2}{(N - 1)}}$$

These calculated values are presented in Tables C-III and C-IV. The mean value of R is a measure of the accuracy of a procedure. Values of R greater than unity indicate a positive bias and values less than unity a negative bias in the analysis.

The standard deviation is a measure of precision. Precision is a function of the concentration of analyte; that is, as the absolute concentration approaches the limit of detection, precision deteriorates. For instance, the precision for some ^{3}H determinations is quite large because many standards approached the limits of detection of a measurement. We are attempting to address this issue by calculating a new quality assurance parameter:

$$|\bar{X}_E - \bar{X}_c| < \sqrt{(S_E)^2 + (S_c)}$$

where $\bar{X}_E$ and $\bar{X}_c$ are the experimentally determined and certified/consensus mean elemental concentrations, respectively. The S_E and S_c parameters are the standard

Table C-II

Individual Sample Water Quality Assurance Ratios

[meq Cation/meq Anion] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	33	1.001	0.0685	1
2	21	0.958	0.0340	0
3	27	1.003	0.1080	2
Annual	81	0.990	0.0800	3

[Conductivity/Sum of Contributing Conductivities] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	34	0.943	0.0423	5
2	21	0.953	0.0356	2
3	27	0.994	0.0570	3
Annual	82	0.962	0.0510	10

[meq Hardness/Sum meq Ca + Mg] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	34	1.002	0.0429	1
2	21	1.039	0.0804	1
3	27	0.985	0.0550	2
Annual	82	1.006	0.0614	4

[0.01 Conductivity/meq Cations] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	34	1.031	0.0747	8
2	21	0.952	0.0400	1
3	27	0.981	0.0390	1
Annual	82	0.994	0.0652	10

[TDS/Sum of Solids] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	34	1.000	0.0786	6
2	21	0.965	0.0532	3
3	27	0.981	0.107	3
Annual	82	0.985	0.084	12

[0.01 Conductivity/meq Anions] Ratio

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	34	1.019	0.100	13
2	21	0.912	0.041	7
3	27	0.983	0.116	4
Annual	82	0.980	0.103	24

[a]Outliers are defined as having a ratio outside 1.00 ± 0.10.

Table C-III

Summary of Analytical Quality Assurance Results for Stable Constituents and Selected Radioactive Constituents

Analysis	Silicates [R ± s (N)]	Waters [R ± s (N)]	Biologicals and Air Particulates [R ± s (N)]
Ag	---	1.10 ± 0.28 (19)	---
Al	---	---	0.98 ± 0.03 (5)
As	0.98 ± 0.09 (9)	0.90 ± 0.12 (6)	1.03 ± 0.02 (4)
B	0.90 ± 0.10 (5)	---	1.09 ± 0.08 (7)
Ba	1.16 (1)	0.99 ± 0.14 (8)	---
Br	---	---	0.96 ± 0.12 (50)
Ca	---	0.98 ± 0.03 (10)	1.26 ± 0.31 (5)
Cd	1.11 ± 0.08 (9)	---	1.00 ± 0.14 (14)
Ce	1.21 ± 0.11 (5)	---	---
Cl	---	1.00 ± 0.05 (16)	1.02 ± 0.18 (36)
Co	1.00 ± 0.11 (93)	---	---
Cond	---	1.01 ± 0.01 (18)	---
Cr	1.05 (1)	1.07 ± 0.12 (14)	---
Cs	0.95 ± 0.16 (183)	---	1.02 ± 0.19 (49)
Cu	---	1.14 ± 0.16 (5)	1.00 ± 0.05 (4)
Eu	0.96 ± 0.04 (13)	---	---
F	---	1.04 ± 0.24 (24)	---
Fe	1.02 (2)	1.10 ± 0.13 (5)	---
Hardness	---	0.97 ± 0.01 (4)	---
Hg	---	1.12 (2)	---
I	---	---	0.94 ± 0.19 (13)
K	0.94 (1)	0.98 ± 0.03 (12)	1.03 ± 0.16 (6)
Li	1.08 (2)	---	0.70 ± 0.10 (4)
Lu	1.04 ± 0.16 (35)	---	---
Mg	0.93 (1)	1.01 ± 0.03 (12)	1.03 ± 0.09 (9)
Mn	---	1.08 ± 0.09 (6)	---
Na	0.93 (1)	1.03 ± 0.03 (12)	1.10 ± 0.12 (11)
Ni	---	1.00 ± 0.10 (6)	---
NO_3	---	1.05 ± 0.23 (29)	---
Pb	0.97 ± 0.17 (23)	1.02 ± 0.08 (6)	0.96 ± 0.10 (8)
pH	---	1.00 ± 0.02 (31)	---
PO_4	---	1.00 ± 0.08 (12)	---
Rb	0.95 (1)	---	---
S	---	---	1.03 ± 0.17 (184)
Sc	0.98 ± 0.04 (20)	---	0.97 ± 0.16 (44)
Se	---	0.98 ± 0.07 (4)	---
Si	1.00 ± 0.04 (10)	---	---
Sm	1.23 ± 0.07 (4)	---	---
SO_4	---	0.89 ± 0.11 (4)	---
Sr	1.02 ± 0.10 (37)	---	---

Table C-III (cont)

Analysis	Silicates [R ± s (N)]	Waters [R ± s (N)]	Biologicals and Air Particulates [R ± s (N)]
Tb	1.19 ± 0.04 (4)	---	---
TDS	---	0.92 ± 0.10 (32)	---
Th	0.96 (1)	---	---
Ti	0.99 ± 0.03 (8)	---	1.31 ± 0.10 (4)
Tot alk	---	1.05 (2)	---
U	1.00 ± 0.07 (102)	1.00 ± 0.05 (22)	1.06 ± 0.16 (18)
$^{235/238}U$	1.03 ± 0.02 (4)	---	---
V	0.92 ± 0.07 (11)	---	---
Yb	0.96 ± 0.12 (48)	---	---
^{3}H	---	0.93 ± 0.10 (213)	---
^{22}Na	0.92 (1)	---	---
^{137}Cs	1.23 ± 0.21 (30)	1.05 ± 0.10 (34)	---
^{152}Eu	1.30 ± 0.18 (6)	---	---
^{154}Eu	0.84 (2)	---	---
^{226}Ra	1.01 ± 0.01 (4)	---	---
^{238}Pu	0.90 ± 0.40 (7)	---	---
$^{239,240}Pu$	1.02 ± 0.07 (7)	---	---
^{241}Am	1.18 ± 0.10 (4)	---	---

Table C-IV

Summary of Radioactive Constituent Quality Assurance Results on EPA Programs

Constituent	Number of Samples	R ± s
Gross alpha	24	1.21 ± 0.40
Gross beta	24	1.30 ± 0.20
^{3}H (<4000 pCi/ℓ)	15	0.97 ± 0.15
^{90}Sr	15	0.92 ± 0.10
^{137}Cs	12	1.49 ± 0.63
^{226}Ra	18	0.81 ± 0.09
$^{239,240}Pu$	6	0.92 ± 0.05
U (natural)	12	0.93 ± 0.13

deviations associated with $\bar{X}_E$ and $\bar{X}_c$, respectively. An analysis will be considered under control when this condition is satisfied for a certain element in a given matrix. Details on this approach are presented elsewhere.[C60]

Data on analytical detection limits are in Table C-V.

Table C-V

Detection Limits for Analyses of Typical Environmental Samples

Parameter	Approximate Sample Volume or Weight	Count Time	Detection Limit Concentration
Air Sample			
Tritium	3 m^3	50 min	1×10^{-12} μCi/mℓ
^{238}Pu	2.0×10^4 m^3	8×10^4 sec	2×10^{-18} μCi/mℓ
$^{239,240}Pu$	2.0×10^4 m^3	8×10^4 sec	3×10^{-18} μCi/mℓ
^{241}Am	2.0×10^4 m^3	8×10^4 sec	2×10^{-18} μCi/mℓ
Gross alpha	6.5×10^3 m^3	100 min	4×10^{-16} μCi/mℓ
Gross beta	6.5×10^3 m^3	100 min	4×10^{-16} μCi/mℓ
Uranium (Delayed neutron)	2.0×10^4 m^3	60 sec	1 pg/m^3
Water Sample			
Tritium	0.005 ℓ	50 min	7×10^{-7} μCi/mℓ
^{137}Cs	0.5 ℓ	5×10^4 sec	4×10^{-8} μCi/mℓ
^{238}Pu	0.5 ℓ	8×10^4 sec	9×10^{-12} μCi/mℓ
$^{239,240}Pu$	0.5 ℓ	8×10^4 sec	3×10^{-11} μCi/mℓ
^{241}Am	0.5 ℓ	8×10^4 sec	2×10^{-10} μCi/mℓ
Gross alpha	0.9 ℓ	100 min	3×10^{-9} μCi/mℓ
Gross beta	0.9 ℓ	100 min	3×10^{-9} μCi/mℓ
Uranium (Delayed neutron)	0.025 ℓ	50 sec	1 μg/ℓ
Soil Sample			
Tritium	1 kg	50 min	0.003 pCi/g
^{137}Cs	100 g	5×10^4 sec	10^{-1} pCi/g
^{238}Pu	10 g	8×10^4 sec	0.003 pCi/g
$^{239,240}Pu$	10 g	8×10^4 sec	0.002 pCi/g
^{241}Am	10 g	8×10^4 sec	0.01 pCi/g
Gross alpha	2 g	100 min	1.4 pCi/g
Gross beta	2 g	100 min	1.3 pCi/g
Uranium (Delayed neutron)	2 g	20 sec	0.03 μg/g

REFERENCES

C1. Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1979," Los Alamos Scientific Laboratory report LA-8200-ENV (April 1980).

C2. Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1980," Los Alamos National Laboratory report LA-8810-ENV (April 1981).

C3. J. H. Harley, Ed. (1972 annual supplements), Environmental Measurements Laboratory Procedures Manual HASL-300.

C4. E. S. Gladney, W. Eberhardt, and R. J. Peters, "The Determination of Radium-226 in CCRMP Reference Samples by Independent Nuclear Methods," Geostandards Newsletter **6**, 5-6 (1982).

C5. E. S. Gladney, D. R. Perrin, and R. J. Peters, "The Determination of U-235/U-238 Ratio in Natural Waters by Chelex-100 Ion Exchange and Neutron Activation Analysis. Anal. Chem. 55: 976-977 (1983).

C6. American Public Health Association, American Water Works Association, and the Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater*, 15th edition (1980).

C7. E. S. Gladney, D. B. Curtis, D. R. Perrin, J. W. Owens, and W. E. Goode, "Nuclear Techniques for the Chemical Analysis of Environmental Materials," Los Alamos National Laboratory report LA-8192-MS (1980).

C8. E. S. Gladney, J. W. Owens, and J. W. Starner, "Simultaneous Determination of Uranium and Thorium in Ores by Instrumental Epithermal Neutron Activation Analysis," Anal. Chim. Acta **104**, 121 (1979).

C9. E. S. Gladney, D. R. Perrin, J. P. Balagna, and C. L. Warner, "Evaluation of a Boron Filtered Epithermal Neutron Irradiation Facility," Anal. Chem. **52**, 2128 (1980).

C10. B. A. Amiel, "Analytical Applications of Delayed Neutron Emission in Fissionable Elements," Anal. Chem. **34**, 1683 (1962).

C11. E. S. Gladney, W. K. Hensley, and M. M. Minor, "Comparison of Three Techniques for the Measurement of Depleted Uranium in Soils," Anal. Chem. **50**, 652 (1978).

C12. G. E. Gordon, K. Randle, G. G. Goles, J. B. Corliss, M. H. Beeson, and S. S. Oxley, "Instrumental Activation Analysis of Standard Rocks with High Resolution γ-Ray Detectors," Geochim. et Cosmochim. Acta **32**, 369 (1968).

C13. R. Dams, J. A. Robbins, K. A. Rahn, and J. W. Winchester, "Nondestructive Neutron Activation Analysis of Air Pollution Particulates," Anal. Chem. **42**, 861 (1970).

C14. B. Salbu, E. Steinnes, and A. C. Pappas, "Multielement Neutron Activation of Fresh Water Using Ge(Li) Gamma Spectrometry," Anal. Chem. **47**, 1011 (1975).

C15. G. R. Van der Linden, F. DeCorte, and J. Hoste, "Activation Analysis of Biological Materials with Ruthenium as a Multi-Isotopic Comparator," Anal. Chem. Acta **71**, 263 (1974).

C16. E. Steinnes, "Epithermal Neutron Activation Analysis of Geological Materials," in *Activation Analysis in Geochemistry and Cosmochemistry*, A. O. Brumfelt and E. Steinnes, Eds., UNIVERSITETSFORLAGET, Oslo, Norway, pp. 113-128 (1971).

C17. E. S. Gladney, L. E. Wangen, and R. D. Aguilar, "Comparison of Three Techniques for Rapid Determination of Sr in Soils and Vegetation," Anal. Lett. **10**, 1083 (1977).

C18. L. E. Wangen and E. S. Gladney, "Determination of As and Ga in Standard Materials by Instrumental and Epithermal Neutron Activation Analysis," Anal. Chim. Acta **96**, 271 (1978).

C19. E. S. Gladney, J. W. Owens, M. L. Marple, and D. L. Dreesen, "A Comparison of Thermal and Epithermal Neutron Activation for the Measurement of Se in Vegetation," Anal. Lett. **A11**, 1001 (1978).

C20. E. S. Gladeny and D. R. Perrin, "Quantitative Analysis of Silicates by Instrumental Epithermal Neutron Activation Using (n,p) Reactions," Anal. Chem. **51**, 2297 (1979).

C21. E. S. Gladney and D. R. Perrin, "Determination of Bromine in Biological, Soil, and Geological Standard Reference Materials by Instrumental Epithermal Neutron Activation Analysis," Anal. Chem. **51**, 2015 (1979).

C22. E. S. Gladney, E. T. Jurney, and D. B. Curtis, "Nondestructive Determination of Boron and Cadmium in Environmental Materials by Thermal Neutron Prompt Gamma-Ray Spectrometry," Anal. Chem. **48**, 2139 (1976).

C23. E. T. Jurney, D. B. Curtis, and E. S. Gladney, "Nondestructive Determination of Sulfur in Environmental Materials by Thermal Neutron Prompt Gamma-Ray Spectroscopy," Anal. Chem. **49**, 1741 (1977).

C24. E. S. Gladney, D. B. Curtis, and E. T. Jurney, "Multielement Analysis of Major and Minor Elements by Thermal Neutron Capture Gamma-Ray Spectrometry," J. Radioanal. Chem. **46**, 299 (1978).

C25. D. B. Curtis, E. S. Gladney, and E. T. Jurney, "Potential Interference in the Determination of Sulfur by Thermal Neutron Induced Prompt Gamma-Ray Spectrometry," Anal. Chem. **51**, 158 (1979).

C26. E. S. Gladney, D. B. Curtis, and E. T. Jurney, "Simultaneous Determination of Nitrogen, Carbon, and Hydrogen Using Thermal Neutron Prompt Gamma-Ray Spectrometry," Anal. Chim. Acta **110**, 339 (1979).

C27. E. S. Gladney, "A Literature Survey of Chemical Analysis by Thermal Neutron Induced Capture Gamma-Ray Spectrometry," Los Alamos National Laboratory report LA-8028-MS (Sept. 1979).

C28. M. P. Failey, D. L. Anderson, W. H. Zoller, G. E. Gordon, and R. M. Lindstrom, "Neutron Capture Prompt Gamma-Ray Activation Analysis for Multielement Determination in Complex Samples," Anal. Chem. **51**, 2209 (1979).

C29. T. G. Schofield, E. S. Gladney, F. R. Miera, and P. E. Trujillo, "Comparative Determination of Carbon, Nitrogen, and Hydrogen in Environmental Standard Reference Materials by Instrumental Combustion Analysis and Thermal Neutron Capture Gamma Ray Spectrometry," Anal. Lett. **A13**, 75 (1980).

C30. E. S. Gladney and H. L. Rook, "Determination of Tellurium and Uranium in Environmental Materials," Anal. Chem. **47**, 1554 (1975).

C31. E. S. Gladney, J. W. Owens, and J. W. Starner, "The Determination of Uranium in Natural Waters by Neutron Activation Analysis," Anal. Chem. **48**, 973 (1976).

C32. E. S. Gladney, "Copper Determination in Standard Materials Using Neutron Activation and Srafion NMRR Anion Exchange Resin," Anal. Chim. Acta **91**, 353 (1977).

C33. E. S. Gladney, "Determination of As, Sb, Mo, Th, and W in Silicates by Thermal Neutron Activation and Inorganic Ion Exchange," Anal. Lett. **A11**, 429 (1978).

C34. E. S. Gladney and J. W. Owens, "Determination of As, W, and Sb in Natural Waters by Neutron Activation and Inorganic Ion Exchange," Anal. Chem. **48**, 2220 (1976).

C35. R. A. Nadkarni and G. H. Morrison, "Determination of the Noble Metals in Geological Materials by Neutron Activation Analysis," Anal. Chem. **46**, 232 (1974).

C36. R. A. Nadkarni and G. H. Morrison, "Determination of Molybdenum by Neutron Activation and Srafion NMRR Ion Exchange Resin Separation," Anal. Chem. **50**, 294 (1978).

C37. R. A. Nadkarni and G. H. Morrison, "Determination of Silver in Rocks by Neutron Activation Analysis," Anal. Chem. **47**, 2285 (1975).

C38. D. Knab and E. S. Gladney, "Determination of Selenium in Environmental Materials by Neutron Activation and Inorganic Ion Exchange," Anal. Chem. **52**, 825 (1980).

C39. E. S. Gladney, D. R. Perrin, W. K. Hensley, and M. E. Bunker, "Uranium Content of 25 Silicate Standard Materials," Geostandards Newsletter **4**, 243 (1980).

C40. E. S. Gladney, D. R. Perrin, and W. K. Hensley, "Determination of Uranium in NBS Biological Standard Reference Materials by Delayed Neutron Assay," J. Radioanal. Chem. **59**, 249 (1980).

C41. Perkin-Elmer Corporation, "Analytical Methods Using the HGA Graphite Furnace," Perkin-Elmer, Norwalk, Connecticut (1977).

C42. R. D. Ediger, "Atomic Absorption Analysis with the Graphite Furnace Using Matrix Modification," Atomic Absorption Newslett. **14**, 127 (1975).

C43. J. W. Owens and E. S. Gladney, "Determination of Beryllium in Environmental Materials by Flameless Atomic Absorption Spectrometry," Atomic Absorption Newslett. **15**, 95 (1976).

C44. J. W. Owens and E. S. Gladney, "Lithium Metaborate Fusion and the Determination of Trace Metals in Fly Ash by Flameless Atomic Absorption," Atomic Absorption Newslett. **15**, 95 (1976).

C45. J. W. Owens and E. S. Gladney, "The Determination of Arsenic in Natural Waters by Flameless Atomic Absorption," Atomic Absorption Newslett. **15**, 47 (1976).

C46. E. S. Gladney, "Matrix Modification for the Determination of Bi by Flameless Atomic Absorption," Atomic Absorption Newslett. **16**, 114 (1977).

C47. E. S. Gladney and J. W. Owens, "Determination of Hg Using a Carrier-Free Combustion Separation and Flameless Atomic Absorption," Anal. Chim. Acta **90**, 271 (1977).

C48. E. S. Gladney, J. W. Owens, and D. R. Perrin, "The Determination of Mercury in Environmental Materials," Los Alamos National Laboratory report LA-7865-MS (June 1979).

C49. F. C. Smith and R. A. Wetzel, "Operation and Maintenance Manual for Dionex Model 10 and Model 14 Ion Chromatographs," Dionex Corp., Sunnyvale, California (1978).

C50. American Society for Testing and Materials, *1977 Annual Book of ASTM Standards: Part 31: Water*, ASTM, Philadelphia, Pennsylvania (1977).

C51. E. S. Gladney and D. Knab, "Determination of 13 Rare Earth Elements in Geological Materials via Thermal and Epithermal Neutron Activation with Pre-irradiation Chemical Separation," (in preparation).

C52. F. J. Fernandez, M. M. Beaty, and W. B. Barnett, "Use of L'Vov Platform for Furnace Atomic Absorption Applications," Atomic Spectroscopy **2**, 16 (1981).

C53. T. C. Rains, M. S. Epstein, and S. R. Koirtyohann, "Atomic Absorption Spectroscopy," American Chemical Society—A Short Course.

C54. C. R. Parker, "Water Analysis by Atomic Spectroscopy," Varian Techtron Ltd, Springvale, Australia (1972).

C55. D. Knab, "An Investigation of the Analysis of Environmental Samples for Fluoride" (in preparation, 1984).

C56. E. S. Gladney, J. W. Owens, T. C. Gunderson, and W. E. Goode, "Quality Assurance for Environmental Analytical Chemistry: 1976-1979," Los Alamos Scientific Laboratory report LA-8730-MS (1981).

C57. E. S. Gladney, W. E. Goode, D. R. Perrin, and C. E. Burns, "Quality Assurance for Environmental Analytical Chemistry: 1980," Los Alamos National Laboratory report LA-8966-MS (1981).

C58. E. S. Gladney, C. E. Burns, D. R. Perrin, and R. D. Robinson, "Quality Assurance for Environmental Analytical Chemistry: 1981," Los Alamos National Laboratory report LA-9579-MS (1982).

C59. E. S. Gladney, C. E. Burns, D. R. Perrin, R. D. Robinson, and D. Knab, "Quality Assurance for Environmental Analytical Chemistry: 1982," Los Alamos National Laboratory report LA-9950-MS (1984).

C60. E. S. Gladney, D. R. Perrin, and W. E. Goode, "Quality Assurance for Environmental Analytical Chemistry at Los Alamos," Proceedings of the 4th DOE Environmental Protection Information Meeting, Denver, Co., Dec. 7-9, 1982, CONF-821215, pp. 107-118 (1983).

C61. E. S. Gladney, C. E. Burns, D. R. Perrin, R. D. Robinson, and N. A. Raybold, "Quality Assurance for Environmental Analytical Chemistry: 1983," Los Alamos National Laboratory report (in press).

C62. E. S. Gladney, "Compilation of Elemental Concentration Data for Fourteen Canadian Certified Reference Materials Project Standards," Los Alamos Scientific Laboratory report LA-8382-MS (1980).

C63. R. D. Robinson, D. Knab, and D. Perrin, "An Individual Water Sample Quality Assurance Program," Los Alamos National Laboratory report (in preparation).

APPENDIX D

METHODS FOR DOSE CALCULATIONS

A. Introduction

Annual radiation doses are evaluated for three principal exposure pathways: inhalation, ingestion, and external exposure (which includes exposure from immersion in air containing radionuclides and direct and scattered penetrating radiation). Results of environmental measurements are used as much as possible. Calculations based on these measurements follow procedures recommended by federal agencies to determine radiation doses.[D1,D2]

Estimates are made of the:

1. Maximum boundary dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the individual is outside at the Laboratory boundary continuously (24 hours a day, 365 days a year).
2. Maximum individual dose to an individual at or outside the Laboratory boundary where the highest dose rate occurs and where there is a person. It takes into account occupancy (for example, 40 hours a week) and shielding (for example, by buildings) factors.
3. Average doses to nearby residents.
4. Whole body person-rem dose for the population living within an 80-km radius of the Laboratory.

Four age groups are considered: infant, child, teen, and adult. Dose calculations utilize parameters[D2,D3,D4] such as annual food consumption and breathing rates specific to each age group.

Age specific dose conversion factors used for inhalation and ingestion calculations are also in Reference D4. Doses are calculated for the first year dose and the 50-yr dose commitment per amount of radionuclide inhaled or ingested during 1983. The 50-yr dose commitment is the total dose received by an organ during the 50-yr period following the intake of a radionuclide.

All dose conversion factors (except those for ^{7}Be) were taken from Hoenes and Soldat.[D5] The ^{7}Be dose conversion factors, which were not published by Hoenes and Soldat,[D5] were taken from values recommended by the International Commission on Radiological Protection.[D6]

B. Inhalation Dose

Annual average air concentrations of ^{3}H, ^{238}Pu, ^{239,240}Pu, ^{241}Am, and total U, determined by HSE-8's air monitoring netwok, are corrected for background by subtracting the average concentrations measured at regional stations. These net concentrations are then multiplied by standard breathing rates for the four age groups to determine total annual intake via inhalation, in pCi/yr, for each radionuclide. Each intake is multiplied by appropriate dose conversion factors to convert intake into first year dose and 50-yr dose commitments. Organs chosen for dose calculations, bone, liver, total body, kidney, lungs, and gastrointestinal tract (GI) include those expected to receive the largest dose from the radionuclides being considered. Dose conversion factors for ^{3}H include an increase of 1.5 over inhalation intake to account for skin absorption.

This procedure for dose calculation conservatively assumes that a hypothetical individual is exposed to the measured air concentration continuously throughout the entire year (8760 h). This assumption is made for the boundary dose, dose to the maximum exposed individual, and dose to the population living within 80 km of the site.

Organ doses are determined at sampling sites for each radionuclide. A final calculation estimates the total inhalation dose to an organ by summing doses to that organ from each radionuclide.

C. Ingestion Dose

Results from foodstuff sampling, described in Section IV.A.6 are used to calculate doses to the same organs as considered for the inhalation dose. The procedure is similar to that used in the previous section. Corrections for background are made by subtracting the average

concentrations from stations not influenced by Laboratory operations. The radionuclide concentration in a particular foodstuff is multiplied by the annual consumption rate[D2] to obtain total annual intake of that radionuclide. Multiplication of the annual intake by the radionuclide's ingestion dose conversion factor for a particular organ gives the estimated dose to the organ. Consumption rates and dose conversion factors used in the calculations are in Reference D4.

Doses are evaluated for ingestion of ^{3}H, ^{90}Sr, ^{137}Cs, total U, ^{238}Pu, and $^{239,240}Pu$ in fruits and vegetables; ^{3}H, ^{7}Be, ^{22}Na, ^{54}Mn, ^{57}Co, ^{83}Rb, ^{134}Cs, ^{137}Cs, and total U in honey; and ^{90}Sr, ^{137}Cs, total U, ^{238}Pu, and $^{239,240}Pu$ in fish.

D. External Radiation

Nuclear reactions with air in the target areas at the Los Alamos Meson Physics Facility (LAMPF, TA-53) cause the air activation products ^{11}C, ^{13}N, ^{14}O, and ^{15}O to be formed. These isotopes are all positron emitters and have 20.4-min, 10-min, 71-sec, and 122-sec half-lives, respectively. Neutron reactions with air at the Omega West Reactor (TA-2) and the LAMPF form ^{41}Ar (1.8 h half-life).

The radioisotopes ^{11}C, ^{13}N, ^{14}O, and ^{15}O are sources of gamma radiation that are because of formation of two 0.511-MeV photons through positron-electron annihilation. The ^{41}Ar emits a 1.29 MeV gamma with a 99% yield.

External radiation doses are monitored with HSE-8's thermoluminescent dosimeter network. Measured exposures, considered as whole body exposures in this report, are in Table E-II. Background estimates at each site, based on historical data, consideration of possible nonbackground contributions, and, if possible, values measured at locations of similar geology and topography, are then subtracted from each measured value. This net dose is assumed to represent the dose from Laboratory activities that an individual would receive if he or she were to spend 100% of his or her time during an entire year at the monitoring location. These measured values are used where possible to give dose estimates.

Boundary and maximum individual doses from ^{41}Ar releases from the Omega West Reactor (TA-2) are estimated using standard meteorological models and measured stack releases[D7] (see Table E-I). Procedures used in making the calculations are described in the following section.

At onsite locations at which above background doses were measured, but at which public access is limited, doses based on a more realistic estimate of exposure time are also presented. Assumptions used in these estimates are in the text.

E. Population Dose

Calculation of whole body population dose estimates (in person-rem) are based on measured data to the extent possible. For background radiation, average measured background doses for Los Alamos, White Rock, and regional stations are multiplied by the appropriate population number. Tritium average doses are calculated from average measured concentrations in Los Alamos and White Rock above background (as measured by regional stations).

These doses are multiplied by population data incorporating results of the 1980 census, which is summarized in Table D-I. The population data has been slightly modified (increased from 125 068 to 162 059 persons within 80 km of the boundary) to account for population changes between 1982 and 1983.

Radionuclides emitted by Los Alamos Meson Physics Facility and, to a lesser extent, by the Omega West Reactor contribute over 95% of the population dose.

For ^{41}Ar, ^{11}C, ^{13}N, ^{14}O, and ^{15}O, atmospheric dispersion models are used to calculate an average dose to individuals living in the area in question. The air concentration of the isotope $[\chi(r,\theta)]$ at a location (r,θ) due to its emission from a particular source is found using the annual average meteorological dispersion coefficient $[\chi(r,\theta)/Q]$ (based on Gaussian plume dispersion models) and the source term Q. Source terms, obtained by stack measurements, are in Table E-I.

The dispersion factors were calculated from 1983 meteorological data collected near LAMPF during the actual time periods when radionuclides were being released from the stacks. The χ/Q includes the reduction of the source term due to radioactive decay.

The gamma dose rate in a semi-infinite cloud at time t, $\gamma_{\infty}(r,\theta,t)$, can be represented by the equation[D7]

$$\gamma_{\infty}(r,\theta,t) = 0.25\ \overline{E}_{\gamma}\ \chi(r,\theta t)$$

where

$\gamma_{\infty}(r,\theta,t)$ = gamma dose rate (rad/sec) at time t, at a distance r, and angle θ,

$\bar{E}_{\gamma}$ = average gamma energy per decay (MeV) (1.02 MeV for position emitters and 1.29 MeV for ^{41}Ar), and

$\chi(r,\theta,t)$ = plume concentration in Ci/m^3 at time t, at a distance r, and angle θ.

The annual dose is calculated from the dose rate and then multiplied by the appropriate population figure to give the estimated population dose.

Background radiation doses because of airline travel are based on the number of trips taken by Laboratory personnel. It was assumed that 85% of these trips were taken by Laboratory personnel residing in Los Alamos County and that non-Laboratory travel was 10% of the Laboratory trips. Average air time at altitude for each trip was estimated to be 4.5 h, where the average dose rate is 0.22 mrem/h.[D8]

Table D-I

1983 Population Distribution Within 80 km of Los Alamos[a,b]

Direction	1-2	2-4	4-8	8-15	15-20	20-30	30-40	40-60	60-80
N	---	---	---	---	---	---	988	---	320
NNE	---	---	---	492	---	471	1505	1565	192
NE	1	---	---	---	276	13 147	878	1003	3409
ENE	---	---	---	1562	1360	2187	2306	1033	2062
E	---	---	67	20	448	922	560	---	1401
ESE	---	---	---	---	---	236	18 671	1039	1438
SE	---	---	6896	---	---	---	43 094	1967	6
SSE	---	---	---	---	---	---	343	3500	76
S	---	---	---	---	---	173	334	3822	---
SSW	---	---	---	---	---	444	109	4476	18 195
SW	---	---	---	---	---	---	171	2259	---
WSW	---	---	---	---	---	171	170	1383	112
W	---	---	---	---	---	---	---	89	72
WNW	---	1464	6669	---	---	---	---	---	1674
NW	---	534	1756	---	---	---	---	1251	---
NNW	---	590	591	---	---	---	---	55	54

[a]This distribution represents the resident population with respect to the Los Alamos Meson Physics Facility's stack at TA-53. A slightly different distribution for Los Alamos County was used to model releases from the TA-2 stack, which is located closer to Los Alamos.
[b]Total population within 80 km of Los Alamos is 162 059.

REFERENCES

D1. US Department of Energy, "A Guide for Environmental Radiological Surveillance at U.S. Department of Energy Installations," US Department of Energy report DOE/EP-0023 (July 1981).

D2. "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," US Nuclear Regulatory Commission Regulatory Guide 1.109 (1977).

D3. International Commission on Radiological Protection, "Report of the Task Group on Reference Man," ICRP Publication 23 (1974).

D4. Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1982," Los Alamos National Laboratory report LA-9762-ENV (April 1983).

D5. G. R. Hoenes and J. K. Soldat, "Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake," US Nuclear Regulatory Commission report NUREG-0172 (1977).

D6. International Commission on Radiological Protection, "Report of Committee II on Permissible Dose for Internal Radiation," International Commission on Radiological Protection Publication 2 (1959).

D7. D. H. Slade, Ed., "Meteorology and Atomic Energy 1967," US Atomic Energy Commission document TID-24190 (1968).

D8. National Council on Radiation Protection and Measurements, "Natural Background Radiation in the United States," National Council on Radiation Protection and Measurements report No. 45 (November 1975).

APPENDIX E

ENVIRONMENTAL DATA TABLES

Table E-I

Atmospheric Radioactive Effluent Totals for 1983

Location	^{238}Pu $^{239,240}Pu$ (μCi)	^{241}Am (μCi)	^{235}U ^{238}U[a] (μCi)	MFP[b] (μCi)	^{131}I (μCi)	^{41}Ar[c] (Ci)	^{32}P (μCi)	^{3}H (Ci)	G/MAP (Ci)[d]	P/VAP (Ci)[e]
TA-2	---	---	---	---	---	418	---	---	---	--
TA-3	89	---	887	17	83	---	---	2457	---	---
TA-9	---	---	---	---	---	---	---	---	---	---
TA-15	---	---	---	---	---	---	---	---	---	---
TA-18	---	---	---	---	---	---	---	---	---	---
TA-21	9.9	0.095	---	0.79	---	---	---	---	---	---
TA-33	---	---	---	---	---	---	---	4410	---	---
TA-35	0.9	---	---	---	---	---	---	6	---	---
TA-41	---	---	---	---	---	---	---	974	---	---
TA-43	6.6	---	---	---	---	---	2.7	---	---	---
TA-46	---	---	0.04	---	---	---	---	---	---	---
TA-48	---	---	0.51	816	---	---	---	---	---	---
TA-50	5.5	---	---	9.1	---	---	---	---	---	---
TA-53	---	---	---	---	---	---	---	---	461 111	2640
TA-54	0.002	---	---	---	---	---	---	---	---	---
TA-55	1.1	---	---	---	---	---	---	44	---	---
Totals	113	0.095	888	843	83	418	2.7	7891	461 111	2640

[a]Does not include aerosolized uranium from explosives testing. See Table E-XXXII.
[b]Mixed fission products.
[c]Another source of ^{41}Ar (1844 Ci) is the G/MAP at TA-53.
[d]G/MAP = Gaseous Mixed Activation Products. Main contaminants are ^{11}C (16.4%), ^{13}N (4.3%), ^{14}O (2.3%), ^{15}O (76.6%), and ^{41}Ar (0.4%). The half-lives of ^{11}C, ^{13}N, ^{14}O, and ^{15}O range from about 2 to 20 minutes; the half-life of ^{41}Ar is 1.83 hours.
[e]P/VAP = Particulate or Vapor Activation Products. Main contaminants are ^{195}Hg for vapor and ^{192}Au for particulates.

Note: --- means no discharge of that radionuclide at that location.

Table E-II

Annual Thermoluminescent Dosimeter Measurements

Station Location	Coordinates	Annual Measurement (mrem)
Regional Stations (28-44 km)—Uncontrolled Areas		
1. Española	---	92 ± 5
2. Pojoaque	---	101 ± 5
3. Santa Fe	---	104 ± 5
4. Fenton Hill	---	139 ± 5
Perimeter Stations (0-4 km)—Uncontrolled Areas		
5. Barranca School	N180 E130	121 ± 5
6. Arkansas Avenue	N170 E030	110 ± 5
7. Cumbres School	N150 E090	127 ± 5
8. 48th Street	N110 W010	149 ± 5
9. LA Airport	N110 E170	147 ± 5
10. Bayo Canyon	N120 E250	171 ± 7
11. Gulf Station	N090 E120	130 ± 7
12. Royal Crest	N080 E080	136 ± 7
13. White Rock	S080 E420	130 ± 5
14. Pajarito Acres	S210 E380	108 ± 5
15. Bandelier	S280 E200	136 ± 5
16. Pajarito Ski Area	N150 W200	123 ± 5
Onsite Stations—Controlled Areas		
17. TA-21	N095 E140	135 ± 7
18. TA-6	N025 E030	135 ± 5
19. TA-53	N070 E090	163 ± 5
20. Well PM-1	N030 E305	158 ± 5
21. TA-16	S035 W025	122 ± 5
22. Booster P-2	S030 E220	158 ± 5
23. TA-54	S080 E290	143 ± 5
24. State Hwy 4	N070 E350	187 ± 5
25. TA-49	S165 E085	125 ± 5
26. TA-2	N075 E120	141 ± 5
27. TA-2	N085 E120	159 ± 5
28. TA-18	S040 E205	188 ± 5
29. TA-35	N040 E105	140 ± 5
30. TA-36	N040 E110	140 ± 5
31. TA-3	N050 E020	142 ± 5
32. TA-3	N050 E020	187 ± 5
33. TA-3	N050 E020	167 ± 5
34. TA-3	N050 E020	141 ± 7
35. TA-3	N050 E020	121 ± 7
36. TA-3	N050 E040	140 ± 5
37. Pistol Range	N040 E240	127 ± 5
38. TA-55	N040 E080	128 ± 7
39. TA-55	N040 E080	110 ± 7
40. TA-55	N040 E080	137 ± 7

Table E-III

Locations of Air Sampling Stations

Station	Latitude or N-S Coord	Longitude or E-W Coord
Regional (28-44 km)		
1. Española	36°00′	106°06′
2. Pojoaque	35°52′	106°02′
3. Santa Fe	35°40′	106°56′
Perimeter (0-4 km)		
4. Barranca School	N180	E130
5. Arkansas Avenue	N170	E030
6. East Gate[a]	N090	E210
7. 48th Street	N110	W010
8. LA Airport	N110	E170
9. Bayo STP	N120	E250
10. Gulf Station	N090	E120
11. Royal Crest	N080	E080
12. White Rock	S080	E420
13. Pajarito Acres	S210	E380
14. Bandelier	S280	E200
Onsite		
15. TA-21	N095	E140
16. TA-6	N025	E030
17. TA-53 (LAMPF)	N070	E090
18. Well PM-1	N030	E305
19. TA-52	N020	E155
20. TA-16	S035	W025
21. Booster P-2	S030	E180
22. TA-54	S080	E290
23. TA-49	S165	E085
24. TA-33	S245	E225
25. TA-39	S190	E230
26. TA-16-450[b]	S055	W070

[a]New station started December 27, 1982 (replaces Cumbres School).
[b]New station started June 29, 1983.

Table E-IV

Regional Average Background Atmospheric Radioactive Concentrations

Radioactive Constituent	Units	EPA[a] 1982-1983	Laboratory[b] 1983	Uncontrolled Area Concentration Guide
Gross beta	10^{-15} μCi/mℓ	10 ± 10	19 ± 32	3×10^4
^{241}Am	10^{-18} μCi/mℓ	Not reported	<2 [c]	2×10^{11}
^{238}Pu	10^{-18} μCi/mℓ	0.2 ± 0.6	<2 [c]	7×10^4
^{239,240}Pu	10^{-18} μCi/mℓ	1.8 ± 1.0	<3 [c]	6×10^4
^{3}H	10^{-12} μCi/mℓ	Not reported	11 ± 2.7	2×10^5
U	10^{-18} μCi/mℓ	41 ± 10	39 ± 15	2×10^6
U	pg/m^3	124 ± 31	118 ± 45	6×10^6

[a]US Environmental Protection Agency, "Environmental Radiation Data," Reports 31, 32, 33, and 34. Data are from the Santa Fe, New Mexico sampling location and were taken from July 1982 through June 1983.

[b]Data annual averages are from the regional stations (Española, Pojoaque, Santa Fe) and were taken during calendar year 1983.

[c]Minimum detectable limit.

Table E-V

Annual Atmospheric Tritiated Vapor Concentrations for 1983

Station Location[a]	Total Air Volume (m^3)	Number of Monthly Samples	Number of Samples <MDL[b]	Concentrations—pCi/m^3 (10^{-12} μCi/mℓ) Max[c]	Min[c]	Mean[c]	Mean as % CD[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
1. Española	122	12	3	23 ± 8	−1.4 ± 0.8	12 ± 5.3	0.006
2. Pojoaque	122	12	2	22 ± 8	−1.3 ± 0.6	12 ± 4.9	0.006
3. Santa Fe	122	12	3	21 ± 8	−2.3 ± 1.0	10 ± 4.1	0.005
Regional Group Summary	366	36	8	23 ± 8	−2.3 ± 1.0	11 ± 2.7	0.006
Perimeter Stations (0-4 km)— Uncontrolled Areas							
4. Barranca School	122	12	1	23 ± 8	0.8 ± 0.6	13 ± 4.1	0.006
5. Arkansas Avenue	122	12	2	18 ± 6	−1.5 ± 0.8	8.3 ± 3.6	0.004
6. East Gate	122	12	1	20 ± 8	−1.7 ± 0.8	8.9 ± 3.3	0.004
7. 48th Street	122	12	1	15 ± 6	0.7 ± 0.8	8.8 ± 2.2	0.004
8. LA Airport	122	12	0	21 ± 8	1.2 ± 0.8	13 ± 3.3	0.007
9. Bayo Canyon	122	12	1	23 ± 8	0.1 ± 0.4	12 ± 0.4	0.006
10. Gulf Station	122	12	0	16 ± 6	1.5 ± 0.8	11 ± 2.4	0.005
11. Royal Crest	122	12	0	17 ± 6	1.2 ± 0.6	9.6 ± 2.3	0.005
12. White Rock	122	12	1	46 ± 18	1.0 ± 0.6	17 ± 7.5	0.008
13. Pajarito Acres	122	12	2	31 ± 12	−1.0 ± 0.6	18 ± 7.2	0.009
14. Bandelier	122	12	2	52 ± 16	−1.2 ± 0.6	28 ± 12	0.014
Perimeter Group Summary	1342	132	11	52 ± 16	−1.7 ± 0.8	13 ± 1.9	0.007
Onsite Stations—Controlled Areas							
15. TA-21	122	12	1	36 ± 14	−0.2 ± 0.4	20 ± 7.6	0.0004
16. TA-6	122	12	1	20 ± 6	0.2 ± 0.8	11 ± 3.5	0.0002
17. TA-53 (LAMPF)	122	12	1	16 ± 6	−1.1 ± 0.6	11 ± 2.9	0.0002
18. Well PM-1	122	12	0	74 ± 28	3.7 ± 1.6	16 ± 11	0.0003
19. TA-52	122	12	0	30 ± 12	3.2 ± 1.4	17 ± 5.2	0.0003
20. TA-16	122	12	1	34 ± 12	0.2 ± 0.4	18 ± 6.5	0.0004
21. Booster P-2	122	12	2	15 ± 6	−0.5 ± 0.4	9.8 ± 2.9	0.0002
22. TA-54	122	12	1	34 ± 12	−0.1 ± 0.4	18 ± 5.3	0.0004
23. TA-49	122	12	1	21 ± 6	−2.1 ± 1.0	11 ± 4.4	0.0002
24. TA-33	122	12	1	110 ± 40	−0.1 ± 0.6	36 ± 22	0.0007
25. TA-39	122	12	1	75 ± 28	0.0 ± 0.4	31 ± 16	0.0006
26. TA-16-450	61	6	0	17 ± 3	0.6 ± 0.4	4.2 ± 12	0.0001
Onsite Group Summary	1403	138	10	110 ± 40	−2.1 ± 1.0	17 ± 3.3	0.0004

[a]See Fig. 11 for map of station locations.
[b]Minimum detectable limit = 1×10^{-12} μCi/mℓ.
[c]Uncertainties are ±2s (see Appendix B).
[d]Controlled Area Concentration Guide = 5×10^{-6} μCi/mℓ.
Uncontrolled Area Concentration Guide = 2×10^{-7} μCi/mℓ.

Table E-VI

Annual Atmospheric $^{239,240}Pu$ Concentrations for 1983

Station Location[a]	Total Air Volume (m^3)	$^{239,240}Pu$ aCi/m^3 (10^{-18} μCi/mℓ) Number of Samples	Number <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
1. Española	93 227	4	4	6.0 ± 2.3	0.4 ± 2.7	2.2 ± 2.6	0.004
2. Pojoaque	79 869	4	4	0.6 ± 2.0	−1.2 ± 2.5	0.1 ± 0.9	0.0002
3. Santa Fe	92 131	4	4	1.7 ± 1.5	−0.3 ± 1.4	0.9 ± 0.9	0.002
Regional Group Summary	265 227	12	12	6.0 ± 2.3	−1.2 ± 2.5	1.1 ± 1.0	0.002
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	94 636	4	4	0.8 ± 1.4	0.1 ± 1.3	0.4 ± 0.3	0.0007
5. Arkansas Avenue	77 525	4	4	1.3 ± 2.8	−0.1 ± 1.7	0.6 ± 0.7	0.0010
6. East Gate	81 613	4	4	1.4 ± 1.8	0.2 ± 2.8	0.5 ± 0.6	0.0009
7. 48th Street	83 091	4	3	3.2 ± 1.9	−1.0 ± 1.9	1.2 ± 1.7	0.0020
8. LA Airport	91 518	4	4	0.6 ± 1.4	−0.2 ± 1.3	0.3 ± 0.4	0.0005
9. Bayo Canyon	85 343	4	4	1.3 ± 3.1	−0.2 ± 1.1	0.3 ± 0.7	0.0005
10. Gulf Station	89 319	4	4	0.3 ± 1.1	−1.0 ± 2.1	−0.2 ± 0.6	0.0000
11. Royal Crest	92 368	4	3	5.2 ± 2.6	−0.7 ± 1.0	0.9 ± 2.8	0.0016
12. White Rock	81 891	4	4	1.8 ± 2.1	0.2 ± 2.6	0.8 ± 0.7	0.0014
13. Pajarito Acres	81 535	4	4	1.1 ± 1.6	0.3 ± 1.7	0.7 ± 0.4	0.0012
14. Bandelier	78 744	4	4	2.2 ± 3.0	1.1 ± 1.5	1.9 ± 0.6	0.0032
Perimeter Group Summary	937 583	44	42	5.2 ± 2.6	−1.0 ± 2.1	0.7 ± 0.3	0.0011
Onsite Stations—Controlled Areas							
15. TA-21	83 860	4	3	3.0 ± 2.1	−0.2 ± 1.8	0.9 ± 1.5	0.00005
16. TA-6	83 230	3	2	1.6 ± 1.6	0.7 ± 1.5	1.2 ± 0.9	0.00006
17. TA-53 (LAMPF)	86 289	4	4	1.6 ± 1.6	0.6 ± 1.4	1.0 ± 0.5	0.00005
18. Well PM-1	89 712	4	4	3.6 ± 2.1	−1.1 ± 1.5	1.1 ± 1.9	0.00006
19. TA-52	87 797	4	3	13 ± 3.2	−1.1 ± 2.2	3.1 ± 6.6	0.00015
20. TA-16	79 223	4	4	1.4 ± 2.1	0.0 ± 1.7	0.7 ± 0.6	0.00004
21. Booster P-2	81 864	4	3	23 ± 4.7	0.2 ± 1.3	6.7 ± 11	0.00033
22. TA-54	92 561	4	4	1.1 ± 1.5	0.2 ± 1.7	0.7 ± 0.4	0.00004
23. TA-49	96 754	4	4	0.7 ± 1.3	−0.7 ± 1.1	0.1 ± 0.6	0.00001
24. TA-33	89 603	4	4	0.9 ± 1.1	−1.0 ± 1.8	−0.1 ± 0.8	0.00000
25. TA-39	94 657	4	4	4.8 ± 11	0.6 ± 1.3	1.8 ± 2.0	0.00009
26. TA-16-450	42 713	3	3	0.8 ± 1.5	0.1 ± 1.2	0.4 ± 0.8	0.00002
Onsite Group Summary	1 008 263	47	43	23 ± 4.7	−1.1 ± 2.2	1.8 ± 2.0	0.00009

[a]See Fig. 11 for map of station locations
[b]Minimum detectable limit = 3×10^{-18} μCi/mℓ.
[c]Uncertainties are ±2s (see Appendix B).
[d]Controlled Area Concentration Guide = 2×10^{-12} μCi/mℓ.
Uncontrolled Area Concentration Guide = 6×10^{-14} μCi/mℓ.

Table E-VII

Annual Atmospheric Uranium Concentrations for 1983 (concentrations in pg/m^3

Station Location[a]	Total Air Volume (m^3)	Number of Quarterly Samples	Number of Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CD[d]
Regional Stations (24-44 km)—Uncontrolled Areas							
1. Española	93 227	4	0	94 ± 19	9.6 ± 4.2	43 ± 36	0.0007
2. Pojoaque	79 869	4	1	64 ± 13	5.1 ± 5.3	43 ± 26	0.0007
3. Santa Fe	92 131	4	0	49 ± 10	17 ± 4.4	30 ± 14	0.0005
Regional Group Summary	265 227	12	1	94 ± 19	5.1 ± 5.3	39 ± 15	0.0006
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	94 636	4	0	61 ± 13	12 ± 4.6	36 ± 23	0.0006
5. Arkansas Avenue	77 525	4	0	64 ± 13	24 ± 5.7	31 ± 24	0.0005
6. East Gate	81 613	4	0	44 ± 9.4	6.5 ± 4.8	17 ± 18	0.0003
7. 48th Street	83 091	4	0	190 ± 38	6.2 ± 4.6	114 ± 85	0.0019
8. LA Airport	91 518	4	0	64 ± 13	12 ± 4.6	41 ± 23	0.0007
9. Bayo Canyon	85 343	4	0	24 ± 5.5	2.5 ± 2.3	15 ± 13	0.0003
10. Gulf Station	89 319	4	2	40 ± 8.1	−0.2 ± 1.9	11 ± 19	0.0002
11. Royal Crest	92 368	4	1	51 ± 10	1.3 ± 1.8	22 ± 21	0.0004
12. White Rock	81 891	4	0	45 ± 9.7	14 ± 4.6	27 ± 13	0.0004
13. Pajarito Acres	81 535	4	0	150 ± 31	20 ± 6.9	55 ± 64	0.0009
14. Bandelier	78 744	4	1	85 ± 26	11 ± 6.1	35 ± 39	0.0006
Perimeter Group Summary	937 583	44	4	190 ± 38	−0.2 ± 1.9	37 ± 13	0.0006
Onsite Stations—Controlled Areas							
15. TA-21	83 860	4	0	53 ± 11	7.3 ± 4.6	31 ± 25	0.00002
16. TA-6	83 230	4	0	72 ± 23	23 ± 5.0	34 ± 26	0.00002
17. TA-53 (LAMPF)	86 289	4	0	23 ± 7.6	12 ± 4.6	25 ± 14	0.00001
18. Well PM-1	89 712	4	0	45 ± 10	24 ± 5.4	26 ± 17	0.00002
19. TA-52	87 797	4	1	160 ± 33	1.1 ± 4.6	48 ± 76	0.00003
20. TA-16	79 223	4	1	63 ± 14	31 ± 10	32 ± 25	0.00002
21. Booster P-2	81 864	4	0	64 ± 14	6.3 ± 4.7	26 ± 28	0.00001
22. TA-54	92 561	4	0	50 ± 11	17 ± 6.0	30 ± 16	0.00002
23. TA-49	96 754	4	1	11 ± 4.1	0.8 ± 4.1	6.5 ± 4.2	0.00001
24. TA-33	89 603	4	0	41 ± 8.0	12 ± 4.3	21 ± 13	0.00001
25. TA-39	94 657	4	1	20 ± 6.6	3.0 ± 4.5	10 ± 7.1	0.00001
26. TA-16-450	42 713	2	0	17 ± 6.6	10 ± 4.2	14 ± 9.2	0.00001
Onsite Group Summary	1 008 263	46	4	160 ± 33	0.8 ± 4.1	26 ± 8.4	0.00002

[a]See Fig. 11 for map of sampling locations.
[b]Minimum detectable limit = 1 pg/m^3.
[c]Uncertainties ±2s (see Appendix B).
[d]Controlled Area Concentration Guide = 1.8×10^8 pg/m^3.
Uncontrolled Area Concentration Guide = 6×10^6 pg/m^3.

Note: One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses can be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

Table E-VIII

Locations of Surface and Ground Water Stations

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Regional Surface Water				
Rio Chama at Chamita	36°05′	106°07′	---	SW
Rio Grande at Embudo	36°12′	105°58′	---	SW
Rio Grande at Otowi	35°52′	106°08′	---	SW
Rio Grande at Cochiti	35°37′	106°19′	---	SW
Rio Grande at Bernalillo	35°17′	106°36′	---	SW
Jemez River	35°40′	106°44′	---	SW
Perimeter Stations				
Los Alamos Reservoir	N105°	W090	7	SW
Guaje Canyon	N300	E100	8	SW
Frijoles	S280	E180	9	SW
La Mesita Spring	N080	E550	10	GWD
Sacred Spring	N170	E540	11	GWD
Indian Spring	N140	E530	12	GWD
White Rock Canyon				
Group I				
Sandia Spring	S030	E470	13	SWR
Spring 3	S110	E450	14	SWR
Spring 3A	S120	E445	15	SWR
Spring 3AA	S140	E440	16	SWR
Spring 4	S170	E110	17	SWR
Spring 4A	S150	E395	18	SWR
Spring 5	S220	E390	19	SWR
Spring 5AA	S240	E360	20	SWR
Ancho Spring	S280	E305	21	SWR
Group II				
Spring 5A	S230	E390	22	SWR
Spring 6	S300	E330	23	SWR
Spring 6A	S310	E310	24	SWR
Spring 7	S330	E295	25	SWR
Spring 8	S335	E285	26	SWR

[a]Regional Surface Water sampling locations in Fig. 13, Perimeter, White Rock Canyon, Onsite, and Effluent Release Area sampling locations in Fig. 13.

[b]SW = surface water, GWD = deep or main aquifer, GWS = shallow or alluvial aquifer, SWR = spring at White Rock Canyon, and D = water supply distribution system.

Table E-VIII (cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Spring 8A	S315	E280	27	SWR
Spring 9	S270	E270	28	SWR
Spring 9A	S325	E265	29	SWR
Doe Spring	S320	E250	30	SWR
Spring 10	S370	E230	31	SWR
White Rock Canyon Stations				
Group III				
Spring 1	N040	E520	32	SWR
Spring 2	N015	E505	33	SWR
Group IV				
Spring 3B	S150	E465	34	SWR
Streams				
Pajarito	S180	E410	35	SWR
Ancho	S295	E340	36	SWR
Frijoles	S365	E235	37	SWR
Sanitary Effluent				
Mortandad	S070	E480	38	SWR
Onsite				
Test Well 1	N070	E345	39	GWD
Test Well 2	N120	E150	40	GWD
Test Well 3	N080	E215	41	GWD
Test Well DT-5A	S110	E090	42	GWD
Test Well 8	N035	E170	43	GWD
Test Well DT-9	S155	E140	44	GWD
Test Well DT-10	S120	E125	45	GWD
Cañada del Buey	N010	E150	46	SW
Pajarito	S060	E215	47	SW
Water Canyon at Beta	S090	E090	48	SW
Effluent Release Areas				
Acid-Pueblo Canyon				
Acid Weir	N125	E070	49	SW
Pueblo 1	N130	E080	50	SW
Pueblo 2	N120	E155	51	SW
Pueblo 3	N085	E315	52	SW

Table E-VIII (cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Hamilton Bend Springs	N110	E250	53	S
Test Well 1A	N070	E335	54	GWS
Test Well 2A	N120	E140	55	GWS
Basalt Spring	N065	E395	56	S
DP-Los Alamos Canyon				
DPS-1	N090	E160	57	SW
DPS-4	N080	E200	58	SW
LAO-C	N085	E070	59	GWS
LAO-1	N080	E120	60	GWS
LAO-2	N080	E210	61	GWS
LAO-3	N080	E220	62	GWS
LAO-4	N070	E245	63	GWS
LAO-4.5	N065	E270	64	GWS
Sandia Canyon				
SCS-1	N080	E040	65	SW
SCS-2	N060	E140	66	SW
SCS-3	N050	E185	67	SW
Mortandad Canyon				
GS-1	N040	E100	68	SW
MCO-3	N040	E110	69	GWS
MCO-4	N035	E150	70	GWS
MCO-5	N030	E160	71	GWS
MCO-6	N030	E175	72	GWS
MCO-7	N025	E180	73	GWS
MCO-7.5	N030	E190	74	GWS
MCO-8				
Water Supply and Distribution				
Los Alamos Well Field				
Well LA-1B	N115	E530	76	GWD
Well LA-2	N125	E505	77	GWD
Well LA-3	N130	E490	78	GWD
Well LA-4	N070	E405	79	GWD
Well LA-5	N076	E435	80	GWD
Well LA-6	N105	E465	81	GWD

Table E-VIII (cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Guaje Well Field				
Well G-1	N190	E385	82	GWD
Well G-1A	N197	E380	83	GWD
Well G-2	N205	E365	84	GWD
Well G-3	N215	E350	85	GWD
Well G-4	N213	E315	86	GWD
Well G-5	N228	E295	87	GWD
Well G-6	N215	E270	88	GWD
Pajarito Well Field				
Well PM-1	N030	E305	89	GWD
Well PM-2	S055	E202	90	GWD
Well PM-3	N040	E255	91	GWD
Well PM-4	S030	E205	92	GWD
Well PM-5	N015	E155	93	GWD
Water Canyon Gallery	S040	W125	94	GWD
Fire Station 1	N080	E015	95	D
Fire Station 2	N100	E120	96	D
Fire Station 3	S085	E375	97	D
Fire Station 4	N185	E070	98	D
Fire Station 5	S010	W065	99	D
Bandelier National Monument Headquarters	S270	E190	100	D
Fenton Hill (TA-57)	35°53′	106°40′	101	D

Table E-IX

Radiochemical and Chemical Quality of Surface Water from Regional Stations

Station	1983 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Chamita	2-24	7 ± 51	---	---	1.4 ± 0.6	2.3 ± 0.8	27 ± 36
Chamita	10-3	4 ± 84	-0.010 ± 0.034	0.005 ± 0.020	4.1 ± 1.0	2.9 ± 1.0	-71 ± 36
Embudo	2-24	5 ± 30	0.005 ± 0.026	0.049 ± 0.034	2.2 ± 0.6	2.1 ± 0.8	-11 ± 36
Embudo	10-3	79 ± 110	0.004 ± 0.022	0.004 ± 0.012	2.5 ± 0.6	3.8 ± 1.0	-54 ± 36
Otowi	2-24	-20 ± 8	-0.005 ± 0.014	0.010 ± 0.016	2.2 ± 0.6	2.8 ± 0.8	21 ± 36
Otowi	10-3	68 ± 66	-0.006 ± 0.030	0.006 ± 0.030	4.2 ± 1.0	4.1 ± 1.0	-75 ± 36
Cochiti	2-28	-21 ± 24	-0.010 ± 0.000	0.005 ± 0.020	3.6 ± 0.6	3.1 ± 0.8	28 ± 36
Cochiti	10-4	52 ± 92	0.005 ± 0.028	0.005 ± 0.024	2.4 ± 0.6	3.9 ± 1.0	-25 ± 36
Bernalillo	2-28	-5 ± 49	0.011 ± 0.016	0.004 ± 0.016	4.1 ± 0.6	3.6 ± 0.8	54 ± 36
Bernalillo	10-4	21 ± 30	0.012 ± 0.024	0.025 ± 0.030	3.4 ± 0.8	1.0 ± 1.0	-37 ± 36
Jemez	2-28	39 ± 30	0.004 ± 0.005	0.007 ± 0.014	3.3 ± 0.6	1.5 ± 0.8	76 ± 36
Jemez	10-4	-5 ± 76	-0.024 ± 0.026	0.006 ± 0.030	2.9 ± 0.6	4.0 ± 1.0	-60 ± 36
No. of Analyses		12	11	11	12	12	12
Minimum		-21 ± 24	-0.024 ± 0.026	0.004 ± 0.016	1.4 ± 0.6	1.0 ± 1.0	-75 ± 36
Maximum		79 ± 110	0.012 ± 0.024	0.049 ± 0.034	4.2 ± 1.0	4.1 ± 1.0	76 ± 36
Average		18	-0.001	0.011	3.0	2.9	-10
2s		67	0.022	0.028	1.8	2.0	102

Station	1983 (month-day)	Chemical (concentrations in mg/ℓ) Cl	F	NO_3	TDS	pH
Chamita	2-24	6	0.3	3.9	229	8.2
Embudo	2-24	4	0.3	1.4	148	8.2
Otowi	2-24	4	0.3	0.8	249	8.0
Cochiti	2-28	5	0.4	1.2	246	8.1
Bernalillo	2-28	15	0.4	0.7	212	8.1
Jemez	2-28	78	1.0	1.8	255	8.3
No. of Analyses		6	6	6	6	6
Minimum		4	0.3	0.7	148	8.0
Maximum		78	1.0	3.9	255	8.3
Average		19	0.4	1.6	223	8.1
2s		58	0.5	2.4	80	0.2

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-X

Radiochemical and Chemical Quality of Surface and Ground Waters from Perimeter Stations

Station	1983 (month-day)	Radiochemical ^{137}Cs (10^{-9} μg/mℓ)	^{238}Pu (10^{-9} μg/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U μg/ℓ)	Gross Gamma (counts/min/ℓ)
Los Alamos Reservoir	3-14	8 ± 50	0.050 ± 0.040	0.080 ± 0.040	1.3 ± 0.6	0.0 ± 0.8	47 ± 36
Los Alamos Reservoir	10-5	0 ± 46	0.010 ± 0.040	0.007 ± 0.024	2.3 ± 0.6	0.0 ± 1.0	−52 ± 36
Guaje Canyon	3-14	−29 ± 40	−0.004 ± 0.000	0.013 ± 0.022	1.9 ± 0.6	0.0 ± 0.8	80 ± 36
Guaje Canyon	10-5	−11 ± 18	0.005 ± 0.014	0.010 ± 0.022	4.5 ± 1.0	0.6 ± 1.0	−85 ± 36
Frijoles Canyon	3-14	48 ± 60	0.020 ± 0.032	0.040 ± 0.038	0.7 ± 0.6	0.9 ± 0.8	88 ± 36
Frijoles Canyon	10-5	24 ± 82	0.007 ± 0.028	0.004 ± 0.012	3.9 ± 0.8	0.0 ± 1.0	−50 ± 36
La Mesita Spring	3-14	−17 ± 13	0.005 ± 0.034	−0.020 ± 0.022	0.0 ± 0.6	11 ± 2.0	64 ± 36
La Mesita Spring	10-5	41 ± 26	0.027 ± 0.024	0.004 ± 0.016	2.1 ± 0.6	26 ± 5.2	−26 ± 36
Indian Spring	3-14	−29 ± 45	−0.010 ± 0.040	0.025 ± 0.036	0.7 ± 0.6	3.0 ± 0.4	76 ± 36
Indian Spring	10-5	16 ± 102	0.025 ± 0.038	0.070 ± 0.040	2.4 ± 0.6	6.9 ± 1.2	−24 ± 36
Sacred Spring	3-14	17 ± 42	0.005 ± 0.022	0.019 ± 0.026	0.7 ± 0.6	0.9 ± 0.4	51 ± 36
Sacred Spring	10-5	31 ± 52	0.006 ± 0.016	−0.006 ± 0.016	3.3 ± 0.8	2.1 ± 1.0	−3 ± 36
No. of Analyses		12	12	12	12	12	12
Minimum		−29 ± 40	−0.010 ± 0.040	−0.020 ± 0.022	0.0 ± 0.6	0.0 ± 0.8	−85 ± 36
Maximum		48 ± 60	0.050 ± 0.040	0.080 ± 0.040	4.5 ± 1.0	26 ± 5.2	88 ± 36
Average		8	0.012	0.021	1.9	4.2	13
2s		52	0.032	0.059	2.8	15.2	121

Table E-X (cont)

Station	1983 Date	Chemical Concentrations in mg/ℓ)															
		SiO_2	Ca	Mg	K	NO	Co_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
Los Alamos Reservoir	3-14	34	6	2	2.0	4	0	32	<0.1	7	1	0.7	0.5	80	24	7.6	7
Guaje Canyon	3-14	36	12	4	4.6	10	0	73	0.4	13	3	0.2	0.8	137	51	7.9	15
Frijoles at National Monument	3-14	53	9	3	2.3	9	0	45	<0.1	13	4	0.1	0.6	129	34	7.5	11
La Mesita Spring	3-14	29	38	1	2.8	34	2	175	<0.1	15	7	0.3	10	214	102	8.3	34
Indian Springs	3-14	72	30	2	2.6	22	0	131	<0.1	6	16	0.4	3.4	195	83	7.5	28
Sacred Springs	3-14	44	23	0	2.7	22	0	124	<0.1	7	2	0.5	0.5	157	59	7.5	22
No. of Analyses		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum		34	6	0	2.0	4	0	32	<0.1	6	1	0.1	0.5	80	24	7.5	7
Maximum		72	38	4	4.6	34	2	175	<0.1	15	16	0.7	10	214	102	8.3	34
Average		44	19	2	2.8	16	0	96	0.1	10	5	0.3	2.6	152	58	7.7	19
2s		31	25	2	1.8	22	1	111	0.2	7	11	0.4	7.5	96	59	0.6	21

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XI

Radiochemical and Chemical Quality of Surface and Ground Water from White Rock Canyon, September 1982

Station	1983 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Group I							
Sandia Spring	9-20	88 ± 38	0.012 ± 0.038	0.006 ± 0.032	0.6 ± 0.2	1.5 ± 0.8	81 ± 36
Spring 3	9-20	-30 ± 42	0.004 ± 0.022	0.004 ± 0.018	0.6 ± 0.6	2.2 ± 0.8	71 ± 36
Spring 3A	9-20	23 ± 48	0.020 ± 0.024	0.005 ± 0.018	0.7 ± 0.6	1.6 ± 0.8	79 ± 36
Spring 3AA	9-20	24 ± 30	0.010 ± 0.040	-0.007 ± 0.028	0.6 ± 0.6	0.6 ± 0.8	44 ± 36
Spring 4	9-20	-0 ± 34	0.004 ± 0.022	0.004 ± 0.014	1.0 ± 0.8	1.6 ± 0.8	77 ± 36
Spring 4A	9-20	13 ± 36	-0.012 ± 0.030	-0.006 ± 0.030	0.6 ± 0.3	2.0 ± 0.8	119 ± 36
Spring 5	9-21	-9 ± 60	0.004 ± 0.012	0.008 ± 0.018	0.9 ± 0.4	1.2 ± 0.8	34 ± 36
Spring 5AA	9-21	-50 ± 91	0.020 ± 0.040	0.020 ± 0.024	1.0 ± 0.4	0.6 ± 0.8	41 ± 36
Ancho Spring	9-21	8 ± 52	0.006 ± 0.018	0.006 ± 0.022	0.7 ± 0.6	0.9 ± 0.8	30 ± 36
Group II							
Spring 5A	9-21	42 ± 62	-0.030 ± 0.040	0.090 ± 0.080	0.5 ± 0.6	2.8 ± 0.8	55 ± 36
Spring 5B	9-21	22 ± 36	-0.020 ± 0.040	0.010 ± 0.060	0.7 ± 0.3	2.0 ± 0.8	100 ± 36
Spring 6	9-21	5 ± 105	0.005 ± 0.012	0.018 ± 0.024	0.7 ± 0.6	0.9 ± 0.8	62 ± 36
Spring 6A	9-21	20 ± 48	0.009 ± 0.030	0.005 ± 0.026	0.6 ± 0.6	1.0 ± 0.8	78 ± 36
Spring 7	9-21	-9 ± 29	-0.013 ± 0.022	0.007 ± 0.018	0.5 ± 0.6	1.0 ± 0.8	125 ± 36
Spring 8	9-21	21 ± 35	0.012 ± 0.030	0.006 ± 0.030	0.7 ± 0.6	1.9 ± 0.8	13 ± 36
Spring 8A	9-21	31 ± 62	-0.015 ± 0.040	-0.015 ± 0.040	0.8 ± 0.6	0.0 ± 0.8	17 ± 36
Spring 9	9-21	-5 ± 38	0.009 ± 0.016	-0.009 ± 0.020	0.9 ± 0.8	0.0 ± 0.8	19 ± 36
Spring 9A	9-21	-22 ± 50	-0.040 ± 0.100	-0.020 ± 0.060	0.4 ± 0.6	0.7 ± 0.8	-2 ± 36
Doe Spring	9-21	8 ± 56	0.018 ± 0.038	0.006 ± 0.030	0.6 ± 0.6	1.0 ± 0.8	27 ± 36
Spring 10	9-22	4 ± 33	0.010 ± 0.060	0.014 ± 0.038	0.7 ± 0.8	1.9 ± 0.8	21 ± 36
Group III							
Spring 1	9-20	-7 ± 73	0.007 ± 0.036	0.007 ± 0.024	1.0 ± 0.8	2.2 ± 0.8	-19 ± 36
Spring 2	9-20	59 ± 92	0.014 ± 0.020	0.040 ± 0.030	0.9 ± 0.8	0.9 ± 0.8	23 ± 36
Group IV							
Spring 3B	9-20	-7 ± 52	-0.017 ± 0.036	0.035 ± 0.030	0.9 ± 0.4	22 ± 4.4	0 ± 36
Group V							
Spring 11	9-23	---	---	---	---	13 ± 2.6	---
Streams							
Ancho	9-20	4 ± 7	0.004 ± 0.032	0.008 ± 0.020	0.7 ± 0.3	1.0 ± 0.8	57 ± 36
Frijoles	9-21	3 ± 21	-0.020 ± 0.040	-0.015 ± 0.022	0.9 ± 0.4	1.1 ± 0.8	45 ± 36
Sanitary Effluent							
Mortandad	9-20	-20 ± 27	0.005 ± 0.022	0.010 ± 0.020	1.4 ± 0.4	1.7 ± 0.8	21 ± 36
No. of Analyses		26	26	26	26	27	26
Minimum		-50 ± 91	-0.040 ± 0.100	-0.020 ± 0.060	0.4 ± 0.6	0.0 ± 0.8	-19 ± 36
Maximum		59 ± 52	0.020 ± 0.040	0.090 ± 0.080	1.4 ± 0.4	22 ± 4.4	125 ± 36
Average		8	-0.042	0.009	0.8	2.5	47
2s		56	0.032	0.043	0.4	9.1	73

Table E-XI (cont)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
	Chemical Concentrations in mg/ℓ															
Group I																
Sandia Spring	48	34	30	3.1	15	0	157	<0.1	4	3	0.2	<0.3	186	103	8.0	27
Spring 3	52	20	1	3.2	14	0	101	<0.1	3	3	0.2	2.0	139	58	7.8	18
Spring 3A	51	18	1	3.1	14	0	96	<0.1	5	3	0.2	1.7	146	55	7.8	18
Spring 3AA	38	14	0	3.0	18	7	24	<0.1	3	3	0.2	<0.3	143	37	9.4	15
Spring 4	55	21	4	3.1	12	0	99	<0.1	11	6	0.2	3.9	158	71	7.5	19
Spring 4A	67	21	4	2.2	11	0	102	<0.1	11	6	0.2	0.4	171	69	7.6	22
Spring 5	65	18	4	2.3	12	0	97	<0.1	5	4	0.2	1.3	156	65	7.7	18
Spring 5AA	59	20	3	2.7	11	0	101	<0.1	6	5	0.3	1.3	158	68	7.2	19
Ancho Spring	73	12	3	2.1	10	0	73	<0.1	2	2	0.2	1.0	122	42	7.5	13
Group II																
Spring 5A	53	24	2	3.4	23	0	131	<0.1	8	5	0.1	1.6	186	71	7.5	25
Spring 5B	62	16	3	2.4	10	0	93	0.1	3	5	0.3	1.8	149	56	7.9	16
Spring 6	73	11	3	2.3	10	0	75	<0.1	2	2	0.1	1.2	140	43	7.5	13
Spring 6A	74	9	2	2.3	10	0	64	0.1	2	2	0.1	1.2	129	35	7.6	12
Spring 7	76	12	3	2.6	13	0	81	<0.1	2	2	0.2	1.2	149	42	7.3	15
Spring 8	73	20	4	3.4	21	0	131	0.1	6	3	0.1	1.2	187	67	7.0	24
Spring 8A	79	9	2	2.2	11	0	66	<0.1	0	2	0.2	<0.3	118	32	8.3	11
Spring 9	74	11	3	2.2	11	0	77	<0.1	1	2	0.2	<0.3	145	41	7.6	13
Spring 9A	74	10	2	1.8	10	0	69	<0.1	2	2	0.2	0.9	126	37	7.6	13
Doe Spring	74	11	3	1.7	11	0	75	<0.1	6	0	0.3	<0.3	139	40	7.7	13
Spring 10	66	12	2	1.7	11	0	74	<0.1	6	2	0.2	1.0	129	41	7.8	13
Group III																
Spring 1	35	19	1	2.3	30	0	134	<0.1	9	4	0.3	<0.3	158	54	8.0	24
Spring 2	33	17	0	1.8	50	0	178	<0.1	10	4	0.6	<0.2	192	46	8.0	30
Group IV																
Spring 3B	49	25	2	8.9	12	0	402	<0.1	18	4	0.3	1.9	435	63	6.1	66
Group V																
Spring 11	55	77	20	7.9	44	0	397	<0.1	43	13	0.2	0.7	458	68	6.8	68
Streams																
Ancho	72	14	3	2.2	10	1	82	<0.1	8	3	0.2	<0.3	154	48	8.3	14
Frijoles	63	9	2	2.2	9	0	64	<0.1	6	3	0.1	<0.3	126	35	7.6	12
Sanitary Effluent																
Mortandad	89	25	7	17.4	87	0	167	28	46	49	0.1	<0.3	455	94	7.6	62
No. of Analyses	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Minimum	33	9	0	1.7	9	0	24	<0.1	0	0	0.1	<0.3	118	32	6.1	27
Maximum	89	77	20	17.4	87	7	397	28	46	49	0.6	3.9	458	103	9.4	68
Average	62	19	4	3.4	18	0	119	1.1	8	5	0.2	1.0	183	54	7.6	22
2s	28	26	12	6.5	34	2	176	10.7	22	18	0.2	1.6	196	36	1.1	33

Note: The ± value represents twice deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XII

Radiochemical and Chemical Quality of Surface and Ground Waters from Onsite Stations

Station	1983 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Test Well 1	03-17	−8 ± 29	0.010 ± 0.040	0.008 ± 0.038	1.8 ± 0.6	2.0 ± 0.8	39 ± 36
Test Well 1	10-14	93 ± 74	0.010 ± 0.040	0.030 ± 0.040	1.1 ± 0.4	2.1 ± 1.0	−2 ± 36
Test Well 2	03-17	18 ± 49	−0.025 ± 0.018	−0.019 ± 0.022	0.0 ± 0.6	0.7 ± 0.8	74 ± 36
Test Well 2	10-07	33 ± 58	−0.007 ± 0.028	0.070 ± 0.020	2.7 ± 0.6	0.0 ± 1.0	55 ± 36
Test Well DT-5A	03-17	37 ± 42	−0.010 ± 0.040	0.021 ± 0.032	1.3 ± 0.6	1.1 ± 0.8	60 ± 36
Test Well DT-5A	10-13	−8 ± 48	0.035 ± 0.034	0.005 ± 0.024	1.5 ± 0.4	0.5 ± 1.0	66 ± 36
Test Well 8	05-26	15 ± 46	−0.013 ± 0.026	−0.007 ± 0.020	2.0 ± 0.6	0.7 ± 0.8	14 ± 36
Test Well 8	10-13	−1 ± 100	0.023 ± 0.028	0.028 ± 0.030	1.4 ± 0.4	0.0 ± 1.0	28 ± 36
Test Well DT-9	11-07	−27 ± 38	0.006 ± 0.028	0.040 ± 0.032	0.3 ± 0.2	0.0 ± 1.0	123 ± 38
Cañon	10-11	96 ± 84	0.014 ± 0.024	−0.007 ± 0.034	3.1 ± 0.8	2.1 ± 1.0	26 ± 36
Pajarito	03-16	−25 ± 58	0.010 ± 0.024	0.005 ± 0.014	2.2 ± 0.6	0.5 ± 0.8	83 ± 36
Pajarito	10-11	10 ± 64	0.006 ± 0.036	0.006 ± 0.024	3.1 ± 0.8	0.8 ± 1.0	4 ± 36
Water at Beta	04-13	6 ± 100	---	---	1.2 ± 0.6	0.5 ± 0.8	58 ± 36
No. of Analyses		13	12	12	13	13	13
Minimum		−27 ± 38	−0.025 ± 0.018	−0.019 ± 0.022	0.0 ± 0.6	0.0 ± 1.0	−2 ± 36
Maximum		96 ± 84	0.035 ± 0.034	0.070 ± 0.020	3.1 ± 0.8	2.1 ± 1.0	123 ± 38
Average		18	−0.005	0.015	1.7	0.8	48
2s		78	0.033	0.049	1.9	1.5	70

Table E-XII (cont)

Station	1983 (month-day)	Chemical (concentrations in mg/ℓ)																
		SiO_2	Ca	Mg	K	Na	Co_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
Test Well 1	03-17	50	37	8	2.5	12	0	116	<0.1	17	20	0.4	25	235	129	7.8	33
Test Well 2	03-17	74	14	4	1.1	9	0	81	<0.1	1	2	0.4	5.1	147	51	7.9	18
Test Well DT-5A	03-17	71	8	2	1.8	11	0	66	<0.1	1	1	0.2	0.9	131	31	7.8	11
Test Well 8	05-26	56	9	3	1.9	11	0	76	<0.1	2	2	0.2	0.4	124	40	7.6	12
Test Well 9	11-07	56	---	---	---	---	---	---	---	0	---	0.7	1.2	116	---	7.9	11
Cañada del Buey	10-11	50	10	2	4.2	23	0	60	0.2	4	3	2	2.7	226	40	7.6	19
Pajarito	03-16	30	55	16	7.3	51	0	75	<0.1	21	155	0.0	31	404	202	6.2	74
Water at Beta	04-13	48	22	6	7.7	67	0	126	17.0	30	40	0.6	43	335	77	7.5	48
No. of Analyses		8	7	7	7	7	7	7	7	8	7	8	8	8	7	8	8
Minimum		19	8	2	1.1	9	0	60	<0.1	0	1	0.0	0.4	116	31	6.2	11
Maximum		74	55	16	7.7	67	0	126	17.0	30	155	0.7	43	404	202	7.9	74
Average		54	22	6	3.8	26	0	86	2.5	9	32	0.5	13.6	214	81	7.5	28
2s		27	35	10	5.4	46	0	50	12.8	23	112	1.2	33.6	214	126	1.1	45

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XIII

Radiochemical and Chemical Quality of Surface and Ground Waters from Acid Pueblo Canyon, Former Effluent Release Area

Station	1983 (month-day)	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	^{241}Am (10^{-9} μCi/mℓ)	Gross Gamma (counts/min/ℓ)
Acid Weir	03-24	-4 ± 71	0.006 ± 0.038	-0.012 ± 0.024	1.9 ± 0.6	0.0 ± 0.8	0.16 ± 0.10	32 ± 36
Acid Weir	10-18	66 ± 84	0.011 ± 0.022	1.60 ± 0.160	3.9 ± 0.8	1.6 ± 1.0	---	54 ± 36
Pueblo 1	03-24	67 ± 56	0.006 ± 0.032	-0.006 ± 0.028	1.7 ± 0.6	0.0 ± 0.8	0.06 ± 0.08	45 ± 36
Pueblo 1	10-18	-2 ± 84	0.010 ± 0.022	0.005 ± 0.018	2.8 ± 0.6	0.0 ± 1.0	---	16 ± 36
Pueblo 2	03-24	15 ± 93	0.006 ± 0.016	0.070 ± 0.040	1.3 ± 0.6	0.8 ± 0.8	0.07 ± 0.08	40 ± 36
Pueblo 2	10-18	-26 ± 82	0.011 ± 0.032	0.051 ± 0.038	1.1 ± 0.4	0.0 ± 1.0	---	-28 ± 36
Pueblo 3	03-24	84 ± 101	-0.015 ± 0.020	0.020 ± 0.030	1.0 ± 0.6	1.1 ± 0.8	0.04 ± 0.08	66 ± 36
Pueblo 3	10-18	29 ± 48	0.027 ± 0.026	0.130 ± 0.060	2.5 ± 0.6	0.5 ± 1.0	---	1 ± 36
Hamilton Bend Spring	03-24	44 ± 70	0.006 ± 0.034	0.030 ± 0.040	2.1 ± 0.6	1.9 ± 0.8	0.05 ± 0.08	48 ± 36
Test Well 1A	03-17	64 ± 73	-0.006 ± 0.000	0.006 ± 0.026	1.1 ± 0.6	0.7 ± 0.8	0.09 ± 0.08	67 ± 36
Test Well 1A	10-17	20 ± 35	0.008 ± 0.024	0.023 ± 0.020	1.7 ± 0.6	0.0 ± 1.0	---	32 ± 36
Test Well 2A	10-17	12 ± 106	-0.005 ± 0.028	-0.021 ± 0.018	4.9 ± 1.0	0.7 ± 1.0	---	-47 ± 36
Basalt Spring	03-28	25 ± 55	-0.021 ± 0.036	0.021 ± 0.030	1.8 ± 0.6	1.6 ± 0.8	0.40 ± 0.20	35 ± 36
Basalt Spring	10-07	9 ± 24	-0.016 ± 0.008	0.017 ± 0.021	1.3 ± 0.6	1.4 ± 0.6	---	29 ± 32
No. of Anayses		14	14	14	14	14	7	14
Minimum		-26 ± 82	-0.016 ± 0.008	0.021 ± 0.018	1.0 ± 0.6	0.0 ± 0.8	0.04 ± 0.08	-47 ± 36
Maximum		84 ± 101	0.027 ± 0.026	1.60 ± 0.160	4.9 ± 1.0	1.9 ± 0.8	0.40 ± 0.20	67 ± 36
Average		28	0.002	0.140	2.1	0.6	0.12	27
2s		64	0.026	0.844	2.3	1.2	0.26	66

Table E-XIII (cont)

Station	1983 (month-day)	Chemical (concentrations in mg/ℓ)															
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
Acid Weir	03-24	54	20	4	8.9	74	0	86	19	24	83	0.3	24	329	64	7.2	12
Pueblo 1	03-24	55	19	4	8.9	66	0	86	18	25	79	0.3	25	324	64	7.5	52
Pueblo 2	03-24	46	21	4	8.5	75	0	95	13	20	85	0.3	14	318	66	7.6	49
Pueblo 3	03-24	60	18	3	10.4	74	0	105	21	24	54	0.6	50	325	57	7.5	48
Hamilton Bend Spring	03-24	52	14	4	8.4	75	0	114	23	26	48	0.9	17	315	53	7.3	45
Test Well 1A	03-24	50	16	5	7	74	0	108	17	32	35	0.8	52	318	64	7.7	45
Test Well 2A	03-24	8	18	3	2	18	0	63	3	6	34	0.3	0	116	68	7.5	22
Basalt Spring	03-24	40	27	5	5	19	0	122	1	18	14	0.3	6	168	94	7.8	---
No. of Analyses		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	7
Minimum		8	14	3	2.0	18	0	86	1	6	14	0.3	0	116	53	7.2	12
Maximum		60	27	5	10.4	75	0	122	23	32	85	0.9	52	329	94	7.8	52
Average		45	19	4	7.3	59	0	97	14	21	54	0.4	23	276	66	7.5	39
2s		32	7	1	5.4	50	0	37	16	15	52	0.5	37	168	24	0.4	31

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XIV

Radiochemical and Chemical Quality of Surface and Ground Waters from DP-Los Alamos Canyon, Active Effluent Release Areas

		Radiochemical						
Station	1983 Date	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	^{241}Am (10^{-9} μCi/mℓ)	Gross Gamma counts/min/ℓ)
DPS-1	10-20	−15 ± 48	1.91 ± 0.200	2.87 ± 0.260	29 ± 6.0	208 ± 40	---	51 ± 36
DPS-4	03-29	68 ± 94	0.024 ± 0.026	0.066 ± 0.038	4.1 ± 0.6	0.0 ± 0.8	0.50 ± 0.12	60 ± 36
DPS-4	10-20	8 ± 44	−0.009 ± 0.024	0.120 ± 0.060	0.1 ± 0.2	2.8 ± 1.0	---	37 ± 36
LAO-C	03-29	36 ± 76	−0.020 ± 0.018	0.007 ± 0.026	1.8 ± 0.6	6.1 ± 0.6	0.02 ± 0.08	33 ± 36
LAO-C	10-20	18 ± 27	−0.009 ± 0.016	0.014 ± 0.018	3.7 ± 0.8	2.0 ± 1.0	---	−3 ± 36
LAO-1	03-29	8 ± 119	0.005 ± 0.014	0.026 ± 0.028	4.3 ± 0.6	0.0 ± 0.8	0.06 ± 0.08	58 ± 36
LAO-1	10-20	11 ± 25	0.018 ± 0.026	0.046 ± 0.036	7.6 ± 1.6	1.2 ± 1.0	---	53 ± 36
LAO-2	03-24	69 ± 108	−0.007 ± 0.038	0.030 ± 0.060	4.7 ± 0.6	2.0 ± 0.8	0.08 ± 0.08	39 ± 36
LAO-2	10-20	−20 ± 46	0.022 ± 0.032	0.090 ± 0.040	5.8 ± 1.2	2.0 ± 1.0	---	135 ± 38
LAO-3	03-29	70 ± 140	0.005 ± 0.026	0.063 ± 0.038	5.5 ± 0.6	1.7 ± 0.8	0.14 ± 0.08	58 ± 36
LAO-3	10-20	1 ± 49	0.019 ± 0.022	0.009 ± 0.028	26 ± 6.0	2.3 ± 1.0	---	230 ± 38
LAO-4	03-29	19 ± 41	0.017 ± 0.030	0.023 ± 0.034	3.2 ± 0.6	1.4 ± 0.8	0.05 ± 0.08	2 ± 36
LAO-4	10-20	78 ± 71	0.004 ± 0.028	0.013 ± 0.022	17.6 ± 3.6	0.7 ± 1.0	---	24 ± 36
LAO-4.5	03-29	−8 ± 31	−0.015 ± 0.016	0.029 ± 0.026	3.2 ± 0.6	0.8 ± 0.8	0.03 ± 0.08	−3 ± 36
LAO-4.5	10-20	15 ± 85	0.005 ± 0.028	0.046 ± 0.038	11.9 ± 2.4	1.4 ± 1.0	---	−49 ± 36
No. of Analyses		15	15	15	15	15	7	15
Minimum		−20 ± 46	−0.015 ± 0.016	0.007 ± 0.026	0.1 ± 0.2	0.0 ± 0.8	0.02 ± 0.08	−49 ± 36
Maximum		78 ± 71	1.91 ± 0.200	2.87 ± 0.260	29 ± 6.0	208.0 ± 40	0.50 ± 0.12	230 ± 38
Average		23	0.031	0.230	7.0	15.4	0.13	48
2s		65	0.985	1.46	14.9	106.5	0.34	129

Table E-XIV (cont)

Station	1983 (month-day)	Chemical (concentration in mg/ℓ)															
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
DPS-4	03-29	24	22	3	18.6	164	0	142	0.8	17	167	4.5	75	560	69	7.8	95
LAO-C	03-29	35	13	3	2.9	27	0	37	<0.1	9	43	0.1	0.8	161	48	7.4	25
LAO-1	03-29	36	14	4	3.4	33	0	50	<0.1	10	48	0.2	1.6	196	52	7.8	28
LAO-2	03-29	34	28	5	25.8	122	0	136	0.4	22	119	1.6	89	468	93	7.0	80
LAO-3	03-29	73	28	5	25.1	122	0	135	0.3	22	118	1.6	89	499	97	6.9	80
LAO-4	03-29	36	14	5	4.6	41	0	105	0.1	10	28	0.6	3.1	211	54	7.0	30
LAO-4.5	03-29	37	13	4	4.6	41	0	107	<0.1	11	29	0.6	3.4	200	53	6.9	30
No. of Analyses		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum		24	13	3	2.9	33	0	37	<0.1	10	28	0.1	0.8	161	48	6.9	25
Maximum		73	28	5	25.8	164	0	136	0.4	22	119	1.6	89	499	97	7.8	95
Average		39	18	4	12.1	78	0	101	0.2	14	78	1.3	37.4	327	66	7.2	53
2s		31	14	1	21.1	111	0	84	0.5	11	110	3.0	88.3	344	41	0.8	61

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XV

Radiochemical and Chemical Quality of Surface Water from Sandia Canyon Active Effluent Release Area

Station	1983 (month-day)	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	^{241}Am (10^{-9} μCi/mℓ)	Gross Gamma (counts/min/ℓ)
SCS-1	03-21	0 ± 53	0.047 ± 0.032	0.009 ± 0.030	3.3 ± 0.6	2.1 ± 0.8	0.07 ± 0.08	4 ± 36
SCS-1	10-18	3 ± 29	0.038 ± 0.024	0.006 ± 0.032	3.9 ± 0.8	1.9 ± 1.0	---	---
SCS-2	03-21	63 ± 93	-0.015 ± 0.028	0.005 ± 0.020	5.3 ± 0.6	0.6 ± 0.8	0.16 ± 0.10	-11 ± 36
SCS-2	10-18	66 ± 84	-0.006 ± 0.016	0.028 ± 0.030	7.8 ± 1.6	0.7 ± 1.0	---	-78 ± 36
SCS-3	03-21	37 ± 70	0.015 ± 0.030	0.029 ± 0.032	5.7 ± 0.6	0.9 ± 0.8	0.30 ± 0.10	26 ± 36
SCS-3	10-18	-23 ± 48	0.005 ± 0.024	0.005 ± 0.008	8.5 ± 1.8	1.2 ± 1.0	---	-72 ± 36
No. of Analyses		6	6	6	6	6	3	5
Minimum		-23 ± 48	-0.015 ± 0.028	0.005 ± 0.020	3.3 ± 0.6	0.6 ± 0.8	0.07 ± 0.08	-78 ± 36
Maximum		66 ± 84	0.047 ± 0.032	0.029 ± 0.032	8.5 ± 1.8	2.1 ± 0.8	0.30 ± 0.10	26 ± 36
Average		24	0.014	0.014	5.7	1.2	0.18	-26
2s		73	0.049	0.023	4.1	1.2	0.23	93

Table E-XV (cont)

Station	1983 (month-day)	Chemical (concentrations in mg/ℓ)															
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
SCS-1	03-21	130	34	7	20.4	138	0	89	12	220	98	1.6	4.4	771	114	6.8	99
SCS-2	03-21	74	29	5	13.5	163	0	125	11	144	124	1.3	9.9	651	94	7.9	95
SCS-3	03-21	78	27	5	13.4	163	0	126	11	164	123	1.2	20	649	95	8.0	97
No. of Analyses		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Minimum		74	27	5	13.4	138	0	89	11	144	98	1.2	4.4	649	94	6.8	99
Maximum		130	34	7	20.4	163	0	126	12	220	124	1.6	20	771	114	8.0	95
Average		94	30	6	15.8	155	0	113	11	176	115	1.3	11.4	690	101	7.5	97
2s		62	7	2	8.0	29	0	42	1	79	29	0.4	15.8	139	22	1.3	4

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XVI

Radiochemical and Chemical Quality of Surface and Ground Water from Mortandad Canyon, Active Effluent Release Area

Station	1983 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	^{241}Am (10^{-9} μCi/mℓ)	Gross Gamma (counts/min/ℓ)
GS-1	03-29	−25 ± 100	0.800 ± 0.120	7.14 ± 0.360	10 ± 0.8	0.8 ± 0.8	21 ± 0.80	30 ± 36
GS-1	10-31	2 ± 38	0.800 ± 0.140	5.42 ± 0.340	61 ± 1.2	1.6 ± 1.0	---	56 ± 36
MCO-3	03-30	113 ± 105	3.27 ± 0.240	9.40 ± 0.400	45 ± 1.6	1.0 ± 0.8	14 ± 0.60	13 ± 36
MCO-3	10-31	6 ± 23	1.25 ± 0.140	3.18 ± 0.220	80 ± 16	20.6 ± 4.2	---	210 ± 38
MCO-4	03-24	144 ± 139	2.04 ± 0.200	12.0 ± 0.600	86 ± 2.8	2.3 ± 0.8	21 ± 0.80	148 ± 36
MCO-4	10-31	9 ± 42	0.770 ± 0.120	3.2 ± 0.240	96 ± 20	37.1 ± 3.7	---	188 ± 38
MCO-5	03-29	−17 ± 44	0.690 ± 0.100	2.17 ± 0.200	69 ± 2.2	3.3 ± 0.8	4.6 ± 0.36	76 ± 36
MCO-5	10-31	−5 ± 28	0.760 ± 0.120	4.72 ± 0.280	70 ± 14	3.8 ± 1.0	---	123 ± 38
MCO-6	03-29	−8 ± 30	0.520 ± 0.100	0.850 ± 0.140	66 ± 2.2	3.7 ± 0.8	0.57 ± 0.12	95 ± 36
MCO-6	10-31	−33 ± 46	0.340 ± 0.080	0.880 ± 0.120	48 ± 10	7.0 ± 1.4	---	50 ± 36
MCO-7	03-29	−3 ± 47	0.039 ± 0.028	0.030 ± 0.024	63 ± 2.2	2.2 ± 0.8	1.5 ± 0.18	92 ± 36
MCO-7	10-31	−18 ± 50	0.120 ± 0.060	0.080 ± 0.040	74 ± 14	3.2 ± 1.0	---	102 ± 38
MCO-7.5	03-29	13 ± 38	0.070 ± 0.040	0.039 ± 0.030	103 ± 3.2	3.2 ± 0.8	2.2 ± 0.60	117 ± 36
MCO-7.5	10-31	−18 ± 34	0.039 ± 0.028	0.030 ± 0.040	19 ± 3.8	2.3 ± 1.0	---	62 ± 36
No. of Analyses		14	14	14	14	14	7	14
Minimum		−33 ± 46	0.039 ± 0.028	0.030 ± 0.024	10 ± 0.8	0.8 ± 0.8	0.57 ± 0.12	13 ± 36
Maximum		144 ± 139	3.27 ± 0.240	12.0 ± 0.600	103 ± 3.2	37.1 ± 3.7	21 ± 0.80	210 ± 38
Average		−11	0.822	3.51	63	6.6	9.2	97
2s		103	1.78	7.65	53	20.1	18	113

Table E-XVI (cont)

Station	1983 (month-day)	Chemical (concentration in mg/ℓ) Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond (mS/m)
GS-1	03-21	14	3	5.7	33	0	69.6	0.1	6	14	0.6	35	199	44	7.6	25
MCO-3	03-21	4	0	11.6	141	78	22.8	0.9	14	17	3.1	130	468	12	7.9	64
MCO-4	03-21	5	0	10.3	244	72	97.6	2.1	33	27	6.3	330	788	14	7.5	111
MCO-5	03-21	11	2	3.9	278	0	203	0.9	42	28	6.1	440	874	37	8.3	126
MCO-6	03-21	13	2	4.6	282	0	233	0.6	44	25	5.1	440	899	46	7.5	125
MCO-7	03-21	22	6	6.3	188	0	193	0.4	39	30	0.6	300	688	81	7.5	96
MCO-7.5	03-21	32	9	6.8	252	0	227	0.2	51	30	0.6	480	964	115	7.8	135
No. of Samples		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum		4	0	3.9	33	0	22.8	0.1	6	17	0.6	35	199	12	7.5	25
Maximum		32	9	11.6	282	78	233	0.9	44	30	6.3	440	899	115	8.3	135
Average		14	3	7.0	202	21	149	0.7	32	24	3.2	307	697	49	7.7	97
2s		19	6	5.7	180	73	169	1.3	33	12	5.3	337	549	73	0.6	80

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XVII

Radiochemical and Chemical Quality of Water from Municipal Supply and Distribution

Station	1983 (month-day)	Radiochemical							
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	Gross Alpha (10^{-9} μCi/mℓ)	Gross Beta (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Los Alamos Field									
Well LA-2	03-08	41 ± 64	−0.018 ± 0.034	−0.024 ± 0.028	7.0 ± 4.0	15 ± 3.4	0.2 ± 0.6	4.8 ± 0.8	14 ± 36
Well LA-3	03-08	−4 ± 118	0.060 ± 0.040	0.050 ± 0.040	1.5 ± 1.2	2.3 ± 1.0	0.1 ± 0.6	1.8 ± 0.8	40 ± 36
Well LA-4	11-07	−6 ± 21	−0.006 ± 0.034	0.006 ± 0.036	---	---	0.5 ± 0.2	0.9 ± 1.0	52 ± 36
Well LA-5	03-08	37 ± 71	−0.017 ± 0.032	−0.011 ± 0.030	0.3 ± 0.8	2.3 ± 1.0	0.3 ± 0.6	1.0 ± 0.8	9 ± 36
Guaje Field									
Well G-1	03-08	−47 ± 85	−0.011 ± 0.016	−0.011 ± 0.012	1.7 ± 1.2	4.1 ± 1.2	0.6 ± 0.6	0.6 ± 0.8	6 ± 36
Well G-1A	03-08	58 ± 44	−0.015 ± 0.018	−0.010 ± 0.018	1.0 ± 1.2	5.1 ± 1.4	−0.1 ± 0.6	0.6 ± 0.8	2 ± 36
Well G-2	11-17	−25 ± 54	0.005 ± 0.032	0.005 ± 0.032	---	---	0.9 ± 0.4	0.9 ± 1.0	65 ± 36
Well G-3	03-08	−21 ± 29	−0.019 ± 0.014	−0.009 ± 0.018	0.8 ± 1.0	3.1 ± 1.0	0.4 ± 0.6	1.1 ± 0.8	39 ± 36
Well G-4	03-08	−17 ± 50	−0.030 ± 0.060	0.040 ± 0.040	0.9 ± 1.0	2.5 ± 1.0	0.2 ± 0.6	1.1 ± 0.8	17 ± 36
Well G-5	03-08	−29 ± 42	0.005 ± 0.018	0.005 ± 0.014	0.6 ± 1.0	3.0 ± 1.0	0.6 ± 0.6	1.4 ± 0.8	9 ± 36
Well G-6	11-17	−27 ± 43	0.015 ± 0.022	0.005 ± 0.024	---	---	0.6 ± 0.2	0.8 ± 1.0	42 ± 36
Pajarito Field									
Well PM-1	03-08	−60 ± 64	−0.025 ± 0.032	0.006 ± 0.034	1.6 ± 1.6	5.1 ± 1.4	0.4 ± 0.6	1.6 ± 0.8	−7 ± 36
Well PM-2	03-08	−6 ± 30	0.005 ± 0.026	−0.009 ± 0.020	0.5 ± 0.8	7.8 ± 1.8	0.3 ± 0.6	0.6 ± 0.8	−7 ± 36
Well PM-3	03-08	−7 ± 23	0.004 ± 0.012	0.004 ± 0.020	1.0 ± 1.4	5.1 ± 1.4	0.3 ± 0.6	1.4 ± 0.8	0 ± 36
Well PM-4	03-08	6 ± 39	0.004 ± 0.012	0.009 ± 0.020	0.0 ± 0.8	6.5 ± 1.6	0.6 ± 0.6	0.0 ± 0.8	−18 ± 36
Gallery									
Water Canyon	03-08	29 ± 40	−0.026 ± 0.030	0.004 ± 0.020	2.0 ± 1.4	4.1 ± 1.2	1.8 ± 0.6	0.0 ± 0.8	23 ± 36
No. of Analyses		16	16	16	13	13	16	16	16
Minimum		−60 ± 64	−0.030 ± 0.060	−0.024 ± 0.078	0.0 ± 0.8	2.3 ± 1.0	−0.1 ± 0.6	0.0 ± 0.8	−18 ± 36
Maximum		58 ± 44	0.060 ± 0.040	0.050 ± 9.040	7.0 ± 4.0	15 ± 3.4	0.9 ± 0.4	4.8 ± 0.8	65 ± 36
Average		−4	−0.004	−0.004	1.4	5.1	0.4	1.1	18
2s		65	0.044	0.037	3.5	6.8	0.8	2.2	47

Table E-XVII (cont)

Station	1983 (month-day)	Radiochemical							
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	Gross Alpha (10^{-9} μCi/mℓ)	Gross Beta (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Distribution									
Fire Station 1	03-01	−7 ± 50	−0.004 ± 0.008	0.004 ± 0.012	0.2 ± 0.8	2.7 ± 1.0	1.5 ± 0.6	0.0 ± 0.8	−1 ± 36
Fire Station 1	10-03	43 ± 78	−0.006 ± 0.036	0.050 ± 0.040	---	---	3.7 ± 0.8	1.1 ± 1.0	−65 ± 36
Fire Station 2	03-01	10 ± 36	−0.014 ± 0.010	−0.009 ± 0.014	0.5 ± 1.0	3.0 ± 1.0	1.0 ± 0.6	2.1 ± 0.8	3 ± 36
Fire Station 2	10-03	75 ± 82	−0.009 ± 0.018	0.004 ± 0.012	---	---	2.3 ± 0.6	4.4 ± 1.0	−79 ± 36
Fire Station 3	03-01	−24 ± 25	−0.008 ± 0.014	−0.008 ± 0.016	0.7 ± 1.0	3.1 ± 1.0	1.0 ± 0.6	0.8 ± 0.8	10 ± 36
Fire Station 3	10-03	−2 ± 108	0.029 ± 0.036	0.015 ± 0.028	---	---	0.6 ± 0.4	1.5 ± 1.0	−57 ± 36
Fire Station 4	03-01	−17 ± 42	0.012 ± 0.020	0.016 ± 0.020	1.3 ± 1.2	3.5 ± 1.2	1.4 ± 0.6	2.4 ± 0.8	44 ± 36
Fire Station 4	10-03	−10 ± 66	0.005 ± 0.032	0.051 ± 0.036	---	---	2.6 ± 0.6	2.0 ± 1.0	−64 ± 36
Fire Station 5	03-01	20 ± 36	−0.007 ± 0.000	−0.003 ± 0.000	2.1 ± 1.6	3.4 ± 1.2	1.4 ± 0.6	2.7 ± 0.8	43 ± 36
Fire Station 5	10-03	1 ± 36	0.026 ± 0.022	0.022 ± 0.030	---	---	3.4 ± 0.8	1.0 ± 1.0	−65 ± 36
Bandelier National Monument	03-07	−25 ± 54	0.012 ± 0.010	0.004 ± 0.014	2.7 ± 1.8	5.0 ± 1.4	0.4 ± 0.6	2.1 ± 0.8	33 ± 36
Bandelier National Monument	10-17	−8 ± 57	0.004 ± 0.030	0.012 ± 0.016	---	---	0.2 ± 0.4	0.8 ± 1.0	−90 ± 36
Fenton Hill (TA-57)	03-08	97 ± 1.1	0.005 ± 0.009	0.050 ± 0.018	1.9 ± 2.0	9.7 ± 2.2	0.1 ± 0.3	1.7 ± 0.8	45 ± 36
Fenton Hill (TA-57)	10-18	−9 ± 56	0.004 ± 0.030	0.012 ± 0.016	---	---	1.2 ± 0.6	0.8 ± 1.0	−90 ± 36
No. of Analyses		14	14	14	7	7	14	14	14
Minimum		−25 ± 54	−0.001 ± 0.008	−0.009 ± 0.014	0.2 ± 0.8	2.7 ± 1.0	0.1 ± 0.3	0.0 ± 0.8	−90 ± 36
Maximum		97 ± 101	0.029 ± 0.036	0.051 ± 0.036	2.7 ± 1.8	9.7 ± 2.2	3.7 ± 0.8	4.4 ± 1.0	45 ± 36
Average		10	0.004	0.016	1.3	4.3	1.5	1.7	−24
2s		73	0.026	0.042	1.8	4.9	2.3	2.2	107
Stand By Well									
Well LA-6	03-08	11 ± 50	0.005 ± 0.036	0.005 ± 0.011	1.1 ± 1.6	2.8 ± 1.0	0.1 ± 0.6	2.4 ± 0.8	22 ± 36
Maximum Contaminant Level[a]		200	15	15	15[b]	---	20	1800[c]	---

Table E-XVII (cont)

Station	1983 (month-day)	Primary Chemical Quality Required for Municipal Use (concentrations in mg/ℓ) Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pb	Se
Los Alamos Field											
Well LA-2	03-08	<0.005	0.009	0.05	<0.007	0.025	1.8	<0.0002	3.0	<0.003	<0.003
Well LA-3	03-08	<0.005	0.005	0.03	<0.002	0.014	0.7	<0.0002	3.0	<0.003	<0.003
Well LA-4		---	---	---	---	0.003	---	---	---	---	---
Well LA-5	03-08	<0.005	0.005	0.05	<0.007	0.009	0.5	<0.0002	3.1	<0.003	<0.003
Guaje Field											
Well G-1	03-08	<0.005	0.004	0.05	<0.002	0.007	0.3	<0.0002	2.1	<0.003	<0.003
Well G-1A	03-08	<0.005	0.003	0.04	<0.002	0.008	0.5	<0.0002	2.8	<0.003	<0.003
Well G-2		---	---	0.02	---	0.012	---	---	---	---	---
Well G-3	03-08	<0.005	0.002	<0.01	<0.002	0.007	0.3	<0.0002	2.6	<0.003	<0.003
Well G-4	03-08	<0.005	<0.001	<0.01	<0.002	0.006	0.2	<0.0002	2.6	<0.003	<0.003
Well G-5	03-08	<0.005	<0.001	<0.08	<0.002	0.005	0.2	<0.0002	3.6	<0.003	<0.003
Well G-6	11-07	---	---	---	---	0.007	---	<0.0002	1.8	---	---
Pajarito Field											
Well PM-1	03-08	<0.005	<0.001	0.06	<0.002	0.007	0.2	<0.0002	4.0	<0.003	<0.003
Well PM-2	03-08	<0.005	<0.001	<0.01	<0.002	0.008	0.3	<0.0002	1.2	<0.003	<0.003
Well PM-3	03-08	<0.005	<0.001	0.04	<0.002	0.006	0.2	<0.0002	2.5	<0.003	<0.003
Well PM-4	03-08	<0.005	<0.001	0.02	<0.002	0.007	0.2	<0.0002	2.8	<0.003	<0.003
Gallery											
Water Canyon	03-08	<0.005	<0.001	0.02	<0.002	0.005	<0.1	<0.0002	0.8	<0.003	<0.003
No. of Analyses		13	13	13	13	16	13	14	14	13	13
Minimum		<0.005	<0.001	<0.08	<0.002	0.005	<0.1	<0.002	0.8	<0.003	<0.003
Maximum		<0.005	0.009	0.06	<0.002	0.025	1.8	<0.002	4.0	<0.003	<0.003
Average		<0.005	<0.003	<0.04	<0.002	0.009	<0.4	<0.002	2.5	<0.003	<0.003
2s		0.000	0.005	0.04	0.000	0.010	0.9	0.000	1.7	0.000	0.000
Distribution											
Fire Station 1	03-01	<0.005	<0.001	0.03	<0.002	0.020	0.2	<0.0002	2.1	<0.003	<0.003
Fire Station 2	03-01	<0.005	0.006	0.04	<0.002	0.013	0.8	<0.0002	3.0	<0.003	<0.003
Fire Station 3	03-01	<0.005	<0.001	<0.01	<0.002	<0.007	0.7	<0.0002	3.0	<0.003	<0.003
Fire Station 4	03-01	<0.005	0.003	0.01	<0.002	0.004	0.3	<0.0002	3.1	<0.003	<0.003
Fire Station 5	03-01	<0.005	0.005	0.01	<0.002	0.012	1.0	<0.0002	2.7	<0.003	<0.003
Bandelier National Monument	03-07	<0.005	0.007	0.02	<0.002	0.012	1.0	<0.0002	3.3	<0.003	<0.003
Fenton Hill (TA-57)	03-08	<0.005	<0.001	0.02	<0.002	0.003	<0.1	<0.0002	1.7	<0.003	<0.003
No. of Analyses		7	7	7	7	7	7	7	7	7	7
Minimum		<0.005	<0.001	<0.01	<0.002	0.004	<0.1	<0.0002	1.7	<0.003	<0.003
Maximum		<0.005	0.007	0.04	<0.002	0.020	1.0	<0.0002	3.3	<0.003	<0.003
Average		<0.005	<0.003	<0.02	<0.002	0.010	<0.6	<0.0002	2.7	<0.003	<0.003
2s		0.000	0.005	0.02	0.000	0.012	0.7	0.0000	1.1	0.000	0.000
Standby Well											
Well LA-6	03-08	<0.005	0.110	0.02	<0.002	0.008	2.5	<0.0002	1.1	0.005	<0.003
Primary Maximum Contaminated Level[a]		0.05	0.05	1.0	0.01	0.05	2.0	0.002	45	0.05	0.01

Table E-XVII (cont)

Station	1983 (month-day)	Secondary Chemical Quality for Municipal Use (concentrations in mg/ℓ)							
		Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Los Alamos Field									
Well LA-2	03-08	14	<0.01	0.008	<0.001	14	<0.01	223	8.4
Well LA-3	03-08	3	<0.01	0.051	0.001	5	<0.01	127	8.3
Well LA-4	11-07	---	---	0.007	---	---	---	---	---
Well LA-5	03-08	2	<0.01	0.011	0.001	4	<0.01	122	8.3
Guaje Field									
Well G-1	03-08	2	<0.01	0.013	<0.001	3	<0.01	161	8.3
Well G-1A	03-08	2	<0.01	0.053	<0.001	5	<0.01	165	8.3
Well G-2	11-07	---	---	---	---	---	---	---	---
Well G-3	03-08	2	<0.01	0.006	0.002	2	<0.01	127	8.4
Well G-4	03-08	3	<0.01	0.012	0.001	3	<0.01	145	7.8
Well G-5	03-08	3	<0.01	0.004	<0.001	6	<0.01	147	8.2
Well G-6	11-07	---	---	---	---	---	---	---	---
Pajarito Field									
Well PM-1	03-08	11	<0.01	0.016	<0.001	5	<0.01	214	8.3
Well PM-2	03-08	13	<0.01	0.004	<0.001	3	<0.01	138	7.9
Well PM-3	03-08	7	<0.01	0.002	<0.001	5	<0.01	229	7.7
Well PM-4	03-08	11	<0.01	0.004	<0.001	<1	<0.01	144	8.0
Gallery									
Water Canyon	03-08	12	<0.01	1.48	0.006	6	0.02	86	7.6
No. of Analyses		13	13	14	13	13	13	13	13
Minimum		2	<0.01	0.002	<0.001	<1	<0.01	122	7.7
Maximum		14	0.01	1.48	0.006	14	0.02	229	8.4
Average		6	<0.01	0.119	<0.001	<4	<0.01	156	8.1
2s		10	0.00	0.784	0.003	6	0.01	85	0.5
Distribution									
Fire Station 1	03-01	4	<0.01	0.031	<0.001	4	0.04	159	8.3
Fire Station 2	03-01	3	<0.01	0.016	<0.001	6	<0.01	151	7.7
Fire Station 3	03-01	7	<0.01	0.004	<0.001	6	<0.01	197	7.7
Fire Station 4	03-01	2	<0.01	0.006	<0.001	5	<0.01	151	8.3
Fire Station 5	03-01	4	<0.01	0.033	<0.001	7	0.04	174	8.1
Bandelier National Monument	03-07	5	<0.01	0.045	<0.001	8	0.05	175	8.4
Fenton Hill (TA-57)	03-08	32	<0.01	0.007	<0.001	10	0.30	263	8.0
No. of Analyses		7	7	7	7	7	7	7	7
Minimum		2	<0.01	0.004	<0.001	4	<0.01	151	7.7
Maximum		32	<0.01	0.045	<0.001	10	0.30	263	8.4
Average		8	<0.01	0.020	<0.001	6	<0.07	181	8.0
2s		21	0.00	0.032	0.000	4	0.21	79	0.6
Standby Well									
Well LA-6	03-08	3	0.02	1.0	0.031	8	0.02	230	7.8
Secondary Maximum Contaminant Level[d]		250	1.0	0.3	0.05	250	5.0	500	6.5 - 8.5

Table E-XVII (cont)

Station	1983 (month-day)	Miscellaneous Chemical Analyses (concentrations in mg/ℓ)									
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_4	PO_4	Total Hard	Cond (mS/m)
Los Alamos Field											
Well 2	03-08	31	7	<0.1	1.2	70	4	158	<0.1	18	34
Well 3	03-08	33	13	0.3	1.7	29	2	103	<0.1	33	18
Well 4	11-07	37	---	---	---	---	---	---	---	---	14
Well 5	03-08	36	9	<0.1	1.4	26	5	87	<0.1	25	15
Guaje Field											
Well G-1	03-08	76	12	0.6	3.0	20	0	92	<0.1	34	16
Well G-1A	03-08	61	12	0.5	3.1	22	0	90	<0.1	32	15
Well G-2	11-07	50	---	---	---	---	---	---	---	---	28
Well G-3	03-08	54	12	1.5	1.9	19	1	88	<0.1	38	15
Well G-4	03-08	54	17	3.3	2.0	12	0	96	<0.1	57	16
Well G-5	03-08	59	18	3.9	2.0	12	0	95	<0.1	59	16
Well G-6	11-07	57	---	---	---	---	---	---	---	---	16
Pajarito Field											
Well PM-1	03-08	77	22	6.4	3.5	20	0	152	<0.1	87	25
Well PM-2	03-08	73	8	2.7	1.8	10	0	66	<0.1	34	11
Well PM-3	03-08	81	22	8.1	3.6	18	0	148	<0.1	94	27
Well PM-4	03-08	77	9	3.6	2.2	12	0	79	<0.1	41	13
Gallery											
Water Canyon	03-08	39	6	2.8	1.9	5	0	41	<0.1	28	10
No. of Analyses		16	13	13	13	13	13	13	13	13	16
Minimum		31	6	<0.1	1.2	10	0	66	<0.1	18	10
Maximum		81	22	8.1	3.6	70	4	158	<0.1	94	34
Average		56	13	<2.6	2.2	21	0	99	<0.1	44	18
2s		34	11	5.0	1.6	32	3	68	0.0	47	13
Distribution											
Fire Station 1	03-01	82	9	3.5	2.3	12	0	79	<0.1	41	16
Fire Station 2	03-01	54	10	1.3	1.9	34	0	115	<0.1	32	21
Fire Station 3	03-01	75	27	7.2	3.5	20	0	142	<0.1	93	27
Fire Station 4	03-01	65	13	1.7	2.4	18	0	92	<0.1	42	16
Fire Station 5	03-01	57	10	1.8	2.0	33	0	117	<0.1	34	22
Bandelier National Monument	03-07	50	9	1.6	2.0	38	3	120	<0.1	33	24
Fenton Hill (TA-57)	03-08	72	43	5.2	2.5	15	0	148	<0.1	263	35
No. of Analyses		7	7	7	7	7	7	7	7	7	7
Minimum		50	6	1.3	1.9	12	0	92	<0.1	32	16
Maximum		82	43	7.2	3.5	34	3	148	<0.1	263	35
Average		65	17	3.2	2.3	24	0	116	<0.1	76	23
2s		24	26	4.5	1.1	21	2	49	0.0	170	13
Standby Well											
Well LA-6	03-08	29	3	<0.1	1.1	82	0	215	<0.1	13	36

[a]Reference (EPA 1976).

[b]The Environmental Protection Agency's MCL for gross alpha is 15×10^{-9} μCi/mℓ. However, gross alpha results from the distribution system that exceed EPA's screening limit of 5×10^{-9} μCi/mℓ require isotopic analysis to determine radium content.

[c]Level recommended by International Commission on Radiological Protection.

[d]Reference (EPA 1979B).

Note: The ± value represents twice the standard deviation of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XVIII

Locations of Soil and Sediment Stations

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]
Regional Soils[b]			
Rio Chama at Chamita	36°05′	106°07′	---
Embudo	36°12′	105°58′	---
Otowi	35°52′	106°08′	---
Near Santa Cruz	35°59′	105°54′	---
Cochiti	35°37′	106°19′	---
Bernalillo	35°17′	106°36′	---
Jemez	35°40′	106°44′	---
Perimeter Soils			
Sportsman's Club	N240	E215	S1
North Mesa	N134	E168	S2
TA-8	N060	W075	S3
TA-49	S165	E085	S4
White Rock (east)	N051	E218	S5
Tsankawi	N020	E310	S6
Onsite Soils			
TA-21	N095	E140	S7
East of TA-53	N051	E218	S8
TA-50	N035	E095	S9
Two Mile Mesa	N025	E030	S10
East of TA-54	S080	E295	S11
R-Site Road East	S042	E103	S12
Potrillo Drive	S065	E195	S13
S-Site	S035	W025	S14
Near Test Well DT-9	S150	E140	S15
Near TA-33	S245	E225	S16

[a]Soil samplig locations in Fig. 15; sediment sampling locations in Fig. 16.

Table E-XVIII (cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]
Regional Sediments			
Chamita	36°05′	106°07′	---
Embudo	36°12′	105°58′	---
Otowi	35°52′	106°08′	---
Sandia	S060	E490	---
Pajarito	S185	E410	---
Ancho	S305	E335	---
Frijoles	S375	E235	---
Cochiti	35°37′	106°19′	---
Bernalillo	35°17′	106°36′	---
Jemez River	35°40′	106°44′	---
Perimeter Sediments			
Guaje at SR-4	N135	E480	12
Bayo at SR-4	N100	E455	13
Sandia at SR-4	N025	E315	14
Mortandad at SR-4	S030	E350	15
Cañada del Buey at SR-4	S090	E360	16
Pajarito at SR-4	S105	E320	17
Potrillo at SR-4	S145	E295	18
Water at SR-4	S170	E260	19
Ancho at SR-4	S255	E250	20
Frijoles at National Monument Headquarters	S280	E185	21
Effluent Release Area Sediments			
Acid Pueblo Canyon			
Acid Weir	N125	E070	22
Pueblo 1	N130	E085	23
Pueblo 2	N120	E145	24
Hamilton Bend Spring	N105	E255	25
Pueblo 3	N090	E315	26
Pueblo at SR-4	N070	E350	27

Table E-XVIII (cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]
Sediments (cont)			
DP-Los Alamos Canyon			
DPS-1	N090	E160	28
DPS-4	N075	E205	29
Los Alamos at Bridge	N095	E020	30
Los Alamos at LAO-1	N080	E120	31
Los Alamos at GS-1	N075	E200	32
Los Alamos at LAO-3	N075	E215	33
Los Alamos at LAO-4.5	N065	E270	34
Los Alamos at SR-4	N065	E355	35
Los Alamos at Totavi	N065	E405	36
Los Alamos at LA-2	N125	E510	37
Los Alamos at Otowi	N100	E560	38
Mortandad Canyon			
Mortandad near CMR	N060	E036	39
Mortandad West of GS-1	N045	E095	40
Mortandad at GS-1	N040	E105	41
Mortandad at MCO-5	N035	E155	42
Mortandad at MCO-7	N025	E190	43
Mortandad at MCO-9	N030	E215	44
Mortandad at MCO-13	N015	E250	45

Table E-XIX

Radiochemical Analyses of Regional Soils and Sediment

Location	Map Designation	Regional Soils, May 1983							
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)
Chamita	Fig. 12	0.14 ± 0.06	0.003 ± 0.000	0.000 ± 0.000	3.5 ± 1.8	3.3 ± 0.8	1.4 ± 0.6	3.2 ± 0.6	1.6 ± 0.20
Embudo	Fig. 12	0.04 ± 0.08	0.006 ± 0.006	0.001 ± 0.002	4.5 ± 2.2	3.4 ± 0.8	1.4 ± 0.6	2.6 ± 0.6	7.9 ± 0.28
Near Santa Cruz Lake	Fig. 12	0.82 ± 0.18	0.000 ± 0.002	0.013 ± 0.006	7.9 ± 3.8	9.1 ± 2.0	1.1 ± 0.6	3.2 ± 0.6	8.8 ± 0.28
Cochiti	Fig. 12	0.23 ± 0.06	0.000 ± 0.002	0.002 ± 0.002	4.7 ± 2.8	8.1 ± 1.8	2.8 ± 0.8	2.6 ± 0.6	4.0 ± 0.24
Bernalillo	Fig. 12	0.08 ± 0.06	0.001 ± 0.000	0.000 ± 0.002	4.1 ± 2.2	4.9 ± 1.2	3.6 ± 1.0	2.2 ± 0.4	2.8 ± 0.22
Jemez	Fig. 12	0.32 ± 0.09	0.000 ± 0.000	0.003 ± 0.002	3.0 ± 1.8	7.2 ± 1.6	1.3 ± 0.6	2.4 ± 0.4	3.8 ± 0.22
No. of Analyses		6	6	6	6	6	6	6	6
Minimum		0.04 ± 0.08	0.000 ± 0.002	0.000 ± 0.000	3.0 ± 1.8	3.3 ± 0.8	1.1 ± 0.6	2.2 ± 0.4	1.6 ± 0.20
Maximum		0.82 ± 0.18	0.006 ± 0.006	0.013 ± 0.006	7.9 ± 3.8	9.1 ± 2.0	3.6 ± 1.0	3.2 ± 0.6	8.8 ± 0.28
Average		0.27	0.002	0.003	4.6	6.0	1.9	2.7	4.9
2s		0.57	0.005	0.010	3.4	4.9	1.9	0.8	5.7

Table E-XIX (cont)

Location	Map Designation	Regional Sediments, February 1983				
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Total U μg/g)	Gross Gamma (counts/min/g)
Chamita	Fig. 12	0.10 ± 0.06	0.003 ± 0.002	0.011 ± 0.004	1.9 ± 0.2	2.2 ± 0.22
Embudo	Fig. 12	0.12 ± 0.44	0.000 ± 0.002	0.002 ± 0.002	2.3 ± 0.2	2.4 ± 0.22
Otowi	Fig. 12	0.20 ± 0.10	0.003 ± 0.002	0.002 ± 0.002	3.0 ± 0.3	3.9 ± 0.24
Sandia	Fig. 15	0.15 ± 0.10	0.001 ± 0.006	0.006 ± 0.006	2.8 ± 1.0	3.4 ± 0.22
Pajarito	Fig. 15	0.13 ± 0.06	−0.002 ± 0.004	0.001 ± 0.006	2.8 ± 1.0	3.5 ± 0.22
Ancho	Fig. 15	0.04 ± 0.06	−0.003 ± 0.008	−0.001 ± 0.004	1.6 ± 1.0	1.3 ± 0.20
Frijoles	Fig. 15	0.09 ± 0.04	−0.003 ± 0.006	0.003 ± 0.006	2.0 ± 1.0	2.2 ± 0.22
Cochiti	Fig. 12	0.06 ± 0.06	0.007 ± 0.002	0.013 ± 0.002	1.8 ± 1.0	1.1 ± 0.20
Bernalillo	Fig. 12	0.22 ± 0.10	0.000 ± 0.000	0.005 ± 0.002	2.8 ± 0.6	4.0 ± 0.24
Jemez		0.16 ± 0.12	0.001 ± 0.000	0.003 ± 0.002	2.3 ± 0.4	3.8 ± 0.22
No. of Analyses		10	10	10	10	10
Minimum		0.04 ± 0.06	−0.003 ± 0.008	−0.001 ± 0.004	1.6 ± 1.0	1.1 ± 0.20
Maximum		0.22 ± 0.10	0.002 ± 0.002	0.013 ± 0.002	3.0 ± 0.3	4.0 ± 0.24
Average		0.13	0.001	0.005	2.3	2.7
2s		0.12	0.006	0.009	1.0	2.1

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XX

Radiochemical Analyses of Perimeter Soils and Sediments

Location	Map Designation	Perimeter Soils, May 1983							
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)
Sportsman's Club	S1	0.91 ± 0.18	0.000 ± 0.002	0.024 ± 0.004	11 ± 4.0	9.7 ± 2.0	2.3 ± 0.6	3.7 ± 0.8	6.2 ± 0.26
North Mesa	S2	1.11 ± 0.24	0.000 ± 0.000	0.029 ± 0.008	6.9 ± 3.2	10 ± 2.2	1.9 ± 0.6	4.2 ± 0.8	6.1 ± 0.26
TA-8	S3	0.25 ± 0.10	0.001 ± 0.000	0.002 ± 0.002	3.8 ± 1.8	4.4 ± 1.0	2.1 ± 0.6	2.5 ± 0.6	4.1 ± 0.24
TA-49	S4	0.06 ± 0.90	0.000 ± 0.002	−0.001 ± 0.002	9.0 ± 4.0	7.5 ± 1.6	1.3 ± 0.6	3.2 ± 0.6	7.3 ± 0.26
White Rock (East)	S5	0.55 ± 0.16	0.002 ± 0.002	0.005 ± 0.002	15 ± 6.0	9.3 ± 2.0	1.3 ± 0.6	3.7 ± 0.8	14 ± 0.36
Tsankawi	S6	0.86 ± 0.23	0.002 ± 0.002	0.008 ± 0.004	6.0 ± 2.6	9.7 ± 2.0	1.4 ± 0.6	5.9 ± 1.2	10 ± 0.36
No. of Analyses		6	6	6	6	6	6	6	6
Minimum		0.06 ± 0.90	0.000 ± 0.000	−0.001 ± 0.007	3.8 ± 1.8	4.4 ± 1.0	1.3 ± 0.6	2.5 ± 0.6	4.1 ± 0.24
Maximum		1.1 ± 0.24	0.002 ± 0.002	0.029 ± 0.008	15 ± 6.0	10 ± 2.2	2.3 ± 0.6	5.9 ± 1.2	14 ± 0.36
Average		0.62	0.001	0.011	8.6	8.4	1.7	3.9	7.9
2s		0.82	0.002	0.025	7.9	4.3	0.8	2.3	7.1

Table E-XX (cont)

Location	Map Designation	Perimeter Sediments, May 1983						
		^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total U (μg/g	Gross Gamma (counts/min/g)
Guaje at SR-4	12	0.11 ± 0.06	0.001 ± 0.002	0.003 ± 0.002	2.5 ± 1.2	2.2 ± 0.6	2.8 ± 0.6	4.9 ± 0.24
Bayo at SR-4	13	0.10 ± 0.04	0.000 ± 0.000	0.003 ± 0.002	2.2 ± 1.2	1.7 ± 0.6	2.5 ± 0.6	3.2 ± 0.22
Sandia at SR-4	14	0.00 ± 0.06	0.000 ± 0.000	0.003 ± 0.004	2.8 ± 1.4	2.0 ± 0.6	2.9 ± 0.6	4.4 ± 0.24
Mortandad at SR-4	15	0.06 ± 0.07	0.003 ± 0.002	0.004 ± 0.002	2.5 ± 1.2	2.4 ± 0.6	2.4 ± 0.6	5.2 ± 0.24
Cañada del Buey at SR-4	16	0.07 ± 0.08	0.002 ± 0.002	0.031 ± 0.002	2.8 ± 1.4	2.6 ± 0.6	2.4 ± 0.4	3.2 ± 0.22
Pajarito at SR-4	17	0.74 ± 0.18	0.002 ± 0.002	0.011 ± 0.004	14 ± 6.0	13 ± 2.8	2.9 ± 0.6	5.0 ± 0.24
Potrillo at SR-4	18	0.22 ± 0.12	0.001 ± 0.001	0.005 ± 0.002	3.5 ± 1.6	4.6 ± 1.0	1.9 ± 0.4	3.4 ± 0.22
Water at SR-4	19	0.26 ± 0.10	–0.001 ± 0.002	0.004 ± 0.002	4.3 ± 2.0	5.0 ± 1.2	2.6 ± 0.6	3.9 ± 0.22
Ancho at SR-4	20	0.07 ± 0.10	0.000 ± 0.000	0.003 ± 0.002	6.4 ± 2.8	5.4 ± 1.2	3.9 ± 0.6	6.2 ± 0.26
Frijoles	21	0.09 ± 0.08	0.001 ± 0.000	0.011 ± 0.000	1.8 ± 0.8	1.3 ± 0.4	1.8 ± 0.4	2.8 ± 0.22
No. of Analyses		10	10	10	10	10	10	10
Minimum		0.00 ± 0.06	0.000	0.003 ± 0.003	1.8 ± 0.8	1.3 ± 0.4	1.8 ± 0.4	2.8 ± 0.22
Maximum		0.74 ± 0.18	–0.001 ± 0.002	0.031 ± 0.002	14 ± 6.0	13 ± 2.8	3.9 ± 0.6	6.2 ± 0.26
Average		0.17	0.003 ± 0.002	0.008	4.2	4.0	2.6	4.2
2s		0.43	0.002	0.017	7.3	6.9	1.1	2.2

Note: The ± value is twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value is twice the uncertainty term for the analysis.

Table E-XXI

Radiochemical Analyses of Onsite Soils and Sediments from Effluent Release Areas

Location	Map Designation	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)
				Onsite Soil (May 1983)					
TA-21	S7	0.16 ± 0.06	0.002 ± 0.002	0.020 ± 0.006	10 ± 4.0	9.3 ± 2.0	2.7 ± 0.8	3.7 ± 0.8	5.6 ± 0.24
East of TA-53	S8	0.46 ± 0.06	0.002 ± 0.002	0.008 ± 0.004	9.0 ± 4.0	10 ± 2.2	2.3 ± 0.6	4.1 ± 0.8	6.2 ± 0.26
TA-50	S9	0.09 ± 0.08	0.004 ± 0.001	0.044 ± 0.010	7.8 ± 3.6	6.5 ± 1.4	4.0 ± 1.0	4.0 ± 0.8	6.1 ± 0.26
Two Mile Mesa	S10	0.46 ± 0.06	0.004 ± 0.004	0.006 ± 0.004	11 ± 2.0	7.6 ± 1.6	1.9 ± 0.6	3.6 ± 0.8	7.5 ± 0.28
East of TA-54	S11	0.58 ± 0.07	0.003 ± 0.002	0.009 ± 0.004	10 ± 4.0	9.8 ± 2.0	13 ± 2.6	6.5 ± 1.4	1.3 ± 0.36
R-Site Road East	S12	0.46 ± 0.07	0.001 ± 0.002	0.034 ± 0.008	10 ± 4.0	7.1 ± 1.6	9.2 ± 2.0	3.7 ± 0.8	6.1 ± 0.26
Potrillo Drive	S13	1.5 ± 0.32	0.001 ± 0.000	0.007 ± 0.002	9.0 ± 4.0	12 ± 2.6	1.1 ± 0.6	5.1 ± 1.0	6.4 ± 0.26
S-Site	S14	0.15 ± 0.10	0.000 ± 0.002	0.012 ± 0.006	5.9 ± 2.6	6.6 ± 1.4	1.3 ± 0.6	4.0 ± 1.0	5.8 ± 0.24
Near Test Well DP-9	S15	0.69 ± 0.18	0.001 ± 0.001	0.036 ± 0.008	7.3 ± 3.2	8.1 ± 1.8	9.6 ± 2.0	4.6 ± 1.0	6.0 ± 0.26
Near TA-33	S16	0.45 ± 0.16	0.000 ± 0.001	0.003 ± 0.002	14 ± 6.0	11 ± 2.2	4.7 ± 1.0	4.0 ± 1.0	7.4 ± 0.26
No. of Analyses		10	10	10	10	10	10	10	10
Minimum		0.09 ± 0.08	0.000 ± 0.000	0.003 ± 0.002	5.9 ± 2.6	6.5 ± 1.4	1.1 ± 0.6	3.7 ± 0.8	5.6 ± 0.24
Maximum		1.5 ± 0.32	0.004 ± 0.004	0.044 ± 0.010	14 ± 6.0	12 ± 2.6	13 ± 2.6	6.5 ± 1.4	13 ± 0.36
Average		0.50	0.002	0.018	9.4	8.8	4.9	4.3	7.0
2s		0.83	0.003	0.030	4.4	3.7	8.3	1.8	4.4

Table E-XXI (cont)

	Map Designation	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Total U (μg/g)	^{241}Am (pCi/g)	^{90}Sr (pCi/g)	Gross Gamma (counts/min/g)
Sediments, Effluent Release Area, Acid Pueblo Canyon, May 1983										
Acid Weir	22	0.99 ± 0.20	0.005 ± 0.014	7.39 ± 0.260	17 ± 3.0	9.3 ± 2.0	0.9 ± 0.8	0.40 ± 0.02	0.89 ± 0.12	3.5 ± 0.22
Pueblo 1	23	0.25 ± 0.12	0.002 ± 0.006	0.006 ± 0.004	5.8 ± 2.8	5.1 ± 1.2	---	0.14 ± 0.01	0.13 ± 0.08	5.8 ± 0.26
Pueblo 2	24	0.16 ± 0.10	0.016 ± 0.006	4.39 ± 0.120	9.0 ± 2.0	4.4 ± 1.0	---	---	0.18 ± 0.14	9.0 ± 0.30
Hamilton Bend Spring	25	0.05 ± 0.04	0.008 ± 0.006	0.740 ± 0.040	5.3 ± 1.2	1.9 ± 0.6	---	0.05 ± 0.01	0.30 ± 0.18	3.9 ± 0.22
Pueblo 3	26	0.13 ± 0.08	0.004 ± 0.002	0.006 ± 0.006	4.7 ± 2.2	3.1 ± 0.8	---	0.03 ± 0.01	0.21 ± 0.18	4.1 ± 0.24
Pueblo at SR-4	27	0.10 ± 0.06	0.002 ± 0.002	0.065 ± 0.040	2.8 ± 1.2	1.8 ± 0.6	2.7 ± 0.6	0.02 ± 0.00	0.08 ± 0.08	3.3 ± 0.22
No. of Analyses		6	6	6	6	6	2	5	6	6
Minimum		0.05 ± 0.04	0.002 ± 0.006	0.006 ± 0.006	2.8 ± 1.2	1.8 ± 0.6	0.9 ± 0.8	0.02 ± 0.00	0.08 ± 0.08	3.3 ± 0.22
Maximum		0.99 ± 0.20	0.016 ± 0.006	7.39 ± 0.260	17 ± 3.0	9.3 ± 2.0	2.7 ± 0.6	0.40 ± 0.02	0.89 ± 0.12	9.0 ± 0.30
Average		0.28	0.006	2.10	7.4	4.2	1.8	0.13	0.30	4.9
2s		0.71	0.011	6.20	10.2	5.6	2.6	0.32	0.60	4.3

Table E-XXI (cont)

Location	Map Designation	^{137}Cs (pCi/g)	^{238}Pu (pCi/g	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{241}Am (pCi/g)	Total U (μg/g)	^{90}Sr (pCi/g)	Gross Gamma (counts/min/g)
Sediment, Effluent Release Area, DP-Los Alamos Canyons, May 1983										
DPS-1	28	24 ± 4.8	1.47 ± 0.060	3.78 ± 0.140	33 ± 7.0	74 ± 14	24 ± 9.6	---	14 ± 0.80	35 ± 0.80
Los Alamos at Bridge	30	0.09 ± 0.08	0.000 ± 0.000	0.002 ± 0.000	1.7 ± 0.8	1.3 ± 0.4	0.00 ± 0.00	1.5 ± 0.4	0.02 ± 0.16	0.92 ± 0.20
LAO-1	31	0.16 ± 0.06	0.001 ± 0.002	0.001 ± 0.002	1.7 ± 0.8	2.2 ± 0.6	0.00 ± 0.00	1.7 ± 0.4	-0.02 ± 0.14	1.7 ± 0.22
Los Alamos GS-1	32	0.06 ± 0.04	0.000 ± 0.000	0.002 ± 0.002	1.8 ± 1.0	1.5 ± 0.4	0.00 ± 0.00	1.6 ± 0.4	-0.06 ± 0.08	1.2 ± 0.20
Los Alamos at LAO-3	33	1.8 ± 0.36	0.002 ± 0.000	0.002 ± 0.000	1.7 ± 0.8	1.4 ± 0.4	0.00 ± 0.00	1.5 ± 0.4	-0.01 ± 0.08	0.96 ± 0.20
Los Alamos at LAO-4.5	34	1.8 ± 0.19	0.018 ± 0.006	0.038 ± 0.032	3.0 ± 1.4	4.1 ± 1.0	0.22 ± 0.26	3.3 ± 0.6	-0.01 ± 0.14	4.9 ± 0.24
Los Alamos at SR-4	35	4.3 ± 0.84	0.035 ± 0.006	0.201 ± 0.018	3.4 ± 1.6	6.7 ± 1.4	0.38 ± 0.34	1.7 ± 0.4	0.07 ± 0.16	2.7 ± 0.22
Los Alamos at LA-2	37	1.5 ± 0.30	0.017 ± 0.006	0.990 ± 0.060	2.8 ± 1.2	4.4 ± 1.0	0.20 ± 0.26	2.4 ± 0.4	0.11 ± 0.08	5.6 ± 0.24
Los Alamos at Otowi	38	1.2 ± 0.26	0.015 ± 0.006	0.314 ± 0.026	2.8 ± 1.4	3.2 ± 0.8	0.17 ± 0.20	1.5 ± 0.4	0.06 ± 0.10	5.0 ± 0.24
No. of Analyses		9	9	9	9	9	9	8	9	9
Minimum		0.09 ± 0.08	0.000 ± 0.000	0.001 ± 0.002	1.7 ± 0.8	1.3 ± 0.4	0.00 ± 0.00	1.5 ± 0.4	-0.06 ± 0.08	0.92 ± 0.20
Maximum		24 ± 4.8	1.47 ± 0.060	3.78 ± 0.140	33 ± 7.0	74 ± 14	24 ± 9.6	3.3 ± 0.6	14 ± 0.80	35 ± 0.80
Average		3.9	0.173	0.592	5.7	10.9	2.7	1.9	1.57	6.4
2s		15	0.973	2.475	20.4	47.4	15.9	1.2	9.32	21.7

Table E-XXI (cont)

Location	Map Designation	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{241}Am (pCi/g)	Total U (μg/g)	^{90}Sr (pCi/g)	Gross Gamma (counts/min/g)
				Sediment, Effluent Release Area, Mortandad Canyon, May 1983						
Mortandad at CMR	39	0.14 ± 0.03	0.040 ± 0.010	0.036 ± 0.010	5.7 ± 2.6	4.3 ± 1.0	0.20 ± 0.02	---	0.16 ± 0.08	3.0 ± 0.2
Mortandad West of GS-1	40	107 ± 11	27.9 ± 0.600	181 ± 3.40	620 ± 260	165 ± 34	150 ± 60	---	2.04 ± 0.16	303 ± 6.0
Mortandad at GS-1	41	0.48 ± 0.07	0.007 ± 0.004	0.027 ± 0.008	9 ± 4	8.9 ± 2.0	0.05 ± 0.02	---	0.05 ± 0.14	6.2 ± 0.26
Mortandad at MCO-5	42	72 ± 7.2	5.58 ± 0.160	36.3 ± 0.800	160 ± 60	102 ± 10	0.04 ± 0.02	---	3.02 ± 0.16	75 ± 1.6
Mortandad at MCO-7	43	60 ± 6.0	2.68 ± 0.080	10.0 ± 0.220	29 ± 12	91 ± 18	6.9 ± 0.18	---	1.89 ± 0.32	4.8 ± 1.0
Mortandad at MCO-9	44	0.78 ± 0.11	0.003 ± 0.004	0.022 ± 0.004	10 ± 4	10 ± 2.2	0.08 ± 0.02	---	0.15 ± 0.08	5.2 ± 0.24
Mortandad at MCO-13	45	0.97 ± 0.14	0.003 ± 0.002	0.029 ± 0.008	8.3 ± 3.8	10 ± 2.2	0.04 ± 0.08	---	0.78 ± 0.14	5.5 ± 0.24
No. of Analyses		7	7	7	7	7	7	---	7	7
Minimum		0.1 ± 0.03	0.003 ± 0.004	0.022 ± 0.04	5.7 ± 2.6	4.3 ± 1.0	0.04 ± 0.02	---	0.05 ± 0.14	3.0 ± 0.2
Maximum		107 ± 11	27.9 ± 0.600	181 ± 3.40	620 ± 260	165 ± 34	150 ± 60	---	2.04 ± 0.16	303 ± 6.0
Average		35	1.17	32.5	120	56	22	---	1.16	63.7
2s		89	20.5	134	454	127	1.2	---	2.35	218

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XXII

Special Regional Soils
(May 7-10, 1983)

Location (1 sample per location)	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{90}Sr (pCi/g)	Total Uranium (μg/g)	Gross Gamma (counts/min/g)
La Bajada	0.85 ± 0.35	0.00066 ± 0.00012	0.01340 ± 0.00100	0.38 ± 0.10	3.0 ± 0.6	4.2 ± 0.24
Cuba	0.13 ± 0.12	0.00012 ± 0.00006	0.00260 ± 0.00028	0.21 ± 0.08	2.0 ± 0.4	1.7 ± 0.24
El Rito	0.36 ± 0.20	0.00021 ± 0.00004	0.00320 ± 0.00022	0.21 ± 0.16	1.8 ± 0.4	1.5 ± 0.22
Santa Cruz Lake	0.72 ± 49	0.00135 ± 0.00164	0.01306 ± 0.01498	0.36 ± 0.18	2.8 ± 0.2	4.8 ± 0.56
Santa Ana Pueblo	0.26 ± 0.16	0.00032 ± 0.00010	0.00367 ± 0.00036	0.46 ± 0.10	1.8 ± 0.4	1.8 ± 0.22
Gallina	0.96 ± 0.40	0.00058 ± 0.00010	0.01320 ± 0.00100	---	3.1 ± 0.6	4.2 ± 0.24
Summary: $\bar{x}$ ± 2s	0.55 ± 0.68	0.00054 ± 0.00090	0.00819 ± 0.01105	0.32 ± 0.22	2.4 ± 1.2	3.0 ± 28
Santa Cruz Lake						
Center	1.15 ± 0.48	0.00225 ± 0.00026	0.02640 ± 0.00180	0.36 ± 0.18	2.7 ± 0.6	5.2 ± 0.24
Northeast Corner	0.52 ± 0.22	0.00109 ± 0.00018	0.00940 ± 0.00080	---	2.8 ± 0.6	4.6 ± 0.24
Southwest Corner	0.62 ± 0.27	0.00062 ± 0.00010	0.01010 ± 0.00060	---	2.9 ± 0.6	5.0 ± 0.24
Southeast Corner	0.70 ± 0.30	0.00060 ± 0.00017	0.00880 ± 0.00140	---	2.8 ± 0.6	4.6 ± 0.24
Northeast Corner	0.63 ± 0.26	0.00220 ± 0.00028	0.01060 ± 0.00080	---	2.9 ± 0.6	4.6 ± 0.24
Summary: $\bar{x}$ ± 2s	0.72 ± 0.49	0.00135 ± 0.00164	0.01306 ± 0.01998	0.36 ± 0.18	2.8 ± 0.2	4.8 ± 0.56

Note: The ± value represents twice the standard deviation of the distribution of observed values. If only one analysis is reported, then the value represents twice the uncertainty term for the analysis.

Table E-XXIII

Snowmelt Runoff, Spring 1983

1983 (month-day)	Solution: ^{137}Cs (10^{-9} μCi/mℓ)	Solution: ^{238}Pu (10^{-9} μCi/mℓ)	Solution: $^{239,240}Pu$ (10^{-9} μCi/mℓ)	Solution: ^{3}H (10^{-6} μCi/mℓ)	Solution: Total U (μg/ℓ)	Solution: Gross Gamma (counts/min/ℓ)	Suspended Sediments: ^{238}Pu (pCi/g)	Suspended Sediments: $^{239,240}Pu$ (pCi/g)
Pajarito Canyon								
04-12	−7 ± 20	0.005 ± 0.038	0.005 ± 0.024	---	---	−4 ± 35	0.60 ± 0.60	0.40 ± 0.40
04-22	8 ± 42	−0.006 ± 0.026	0.006 ± 0.030	3.1 ± 0.8	0.0 ± 0.8	70 ± 36	−0.10 ± 0.36	0.20 ± 0.40
04-27	−4 ± 30	0.005 ± 0.030	0.011 ± 0.032	4.1 ± 1.0	0.0 ± 0.8	58 ± 36	0.10 ± 0.40	−0.20 ± 0.60
05-02	−29 ± 10	−0.020 ± 0.022	0.005 ± 0.026	3.7 ± 1.0	0.0 ± 0.8	36 ± 36	---	---
05-05	52 ± 44	−0.004 ± 0.024	0.008 ± 0.018	2.5 ± 0.8	0.9 ± 0.8	45 ± 0.8	0.20 ± 0.60	0.30 ± 0.60
05-09	---	−0.008 ± 0.012	0.004 ± 0.014	2.6 ± 0.8	0.4 ± 0.8	---	---	---
$\bar{x}$ ± 2s	4 ± 60	−0.005 ± 0.019	0.007 ± 0.005	3.2 ± 1.4	0.3 ± 0.8	41 ± 56	0.20 ± 0.59	0.18 ± 0.53
Los Alamos Canyon at SR-4								
03-23	118 ± 142	0.005 ± 0.024	0.024 ± 0.028	---	---	96 ± 36	0.45 ± 0.12	1.7 ± 0.24
04-07	30 ± 65	−0.016 ± 0.024	−0.005 ± 0.026	---	---	114 ± 36	0.06 ± 0.01	0.22 ± 0.02
04-12	2 ± 30	−0.005 ± 0.030	0.005 ± 0.026	---	---	59 ± 36	0.54 ± 0.32	4.1 ± 0.80
04-22	3 ± 27	0.004 ± 0.020	0.026 ± 0.026	2.3 ± 0.8	0.0 ± 0.8	52 ± 36	0.78 ± 0.06	11 ± 0.60
04-27	18 ± 46	−0.005 ± 0.032	0.032 ± 0.015	2.5 ± 0.8	0.0 ± 0.8	69 ± 36	0.25 ± 0.04	3.2 ± 0.22
04-28	37 ± 37	−0.005 ± 0.016	0.005 ± 0.026	1.8 ± 0.6	0.0 ± 0.8	49 ± 36	0.37 ± 0.10	6.5 ± 0.60
04-28	14 ± 26	0.022 ± 0.030	0.009 ± 0.026	2.1 ± 0.6	0.0 ± 0.8	63 ± 36	0.37 ± 0.06	13 ± 0.60
05-02	−13 ± 44	0.005 ± 0.022	0.018 ± 0.024	2.3 ± 0.8	1.0 ± 0.8	23 ± 36	0.22 ± 0.08	4.9 ± 0.40
05-05	6 ± 70	0.004 ± 0.010	0.004 ± 0.018	1.6 ± 0.6	0.0 ± 0.8	65 ± 36	0.21 ± 0.08	3.3 ± 0.34
05-09	10 ± 33	0.009 ± 0.016	0.028 ± 0.028	2.5 ± 0.8	0.0 ± 0.8	---	0.12 ± 0.04	4.3 ± 0.32
05-13	18 ± 43	0.009 ± 0.022	0.018 ± 0.024	2.5 ± 0.8	0.0 ± 0.8	29 ± 36	0.13 ± 0.04	5.5 ± 0.34
05-16	−12 ± 68	0.012 ± 0.024	0.017 ± 0.026	2.8 ± 0.8	0.0 ± 0.8	24 ± 36	0.06 ± 0.10	3.3 ± 0.40
05-20	0 ± 16	−0.004 ± 0.016	0.011 ± 0.016	3.7 ± 1.0	0.7 ± 0.8	10 ± 36	0.11 ± 0.10	2.9 ± 0.38
05-23	13 ± 56	0.004 ± 0.022	0.004 ± 0.012	2.2 ± 0.6	0.0 ± 0.8	−13 ± 36	0.16 ± 0.16	4.0 ± 0.60
05-31	54 ± 52	0.004 ± 0.018	0.007 ± 0.016	3.1 ± 0.8	0.0 ± 0.8	47 ± 36	0.18 ± 0.16	3.8 ± 0.60
$\bar{x}$ ± 2s	20 ± 65	0.003 ± 0.018	0.014 ± 0.021	2.4 ± 1.1	0.1 ± 0.7	49 ± 67	0.27 ± 0.40	4.7 ± 6.4
Los Alamos Canyon at Otowi								
04-27	2 ± 28	−0.004 ± 0.012	0.013 ± 0.016	2.4 ± 0.8	0.7 ± 0.8	59 ± 36	0.42 ± 0.06	4.85 ± 0.30
04-28	15 ± 44	−0.004 ± 0.008	0.004 ± 0.020	2.1 ± 0.6	0.0 ± 0.8	16 ± 36	0.24 ± 0.04	3.5 ± 0.11
05-02	42 ± 50	0.004 ± 0.010	0.015 ± 0.018	2.0 ± 0.6	0.8 ± 0.8	39 ± 36	0.12 ± 0.02	2.4 ± 0.10
05-05	35 ± 43	---	---	1.9 ± 0.6	0.8 ± 0.8	54 ± 36	0.08 ± 0.02	1.2 ± 0.10
05-09	6 ± 49	0.004 ± 0.026	−0.004 ± 0.023	2.4 ± 0.8	0.0 ± 0.8	---	0.16 ± 0.02	2.6 ± 0.16
05-13	7 ± 30	−0.005 ± 0.020	−0.010 ± 0.037	2.3 ± 0.8	0.7 ± 0.8	69 ± 36	0.10 ± 0.02	1.9 ± 0.12
05-16	37 ± 51	−0.004 ± 0.018	0.013 ± 0.018	3.4 ± 0.8	0.5 ± 0.8	62 ± 18	0.06 ± 0.01	1.2 ± 0.08
05-20	−6 ± 56	0.004 ± 0.013	0.027 ± 0.024	2.2 ± 0.8	0.5 ± 0.8	20 ± 36	0.21 ± 0.02	3.2 ± 0.20
05-23	41 ± 51	−0.004 ± 0.018	0.004 ± 0.022	1.9 ± 0.6	1.9 ± 0.8	4 ± 36	0.01 ± 0.01	0.18 ± 0.03
05-31	−22 ± 78	−0.004 ± 0.000	0.011 ± 0.018	3.0 ± 0.8	0.0 ± 0.8	−22 ± 36	0.12 ± 0.03	0.18 ± 0.01
$\bar{x}$ ± 2s	16 ± 44	−0.001 ± 0.008	0.008 ± 0.022	2.4 ± 1.0	0.6 ± 1.1	33 ± 47	0.15 ± 0.23	2.1 ± 3.0

Table E-XXIV

Radionuclide Content of Fruits and Vegetables

Location:	Background		Offsite			Onsite		
Water Source:	Española Rio Chama	Española Rio Grande	Cochiti Rio Grande	Los Alamos Community System	White Rock/ Pajarito Acres Community System	TA-3	TA-21	TA-35
Radionuclide:								
^{238}Pu (pCi/g dry weight)								
No. of Samples	5	10	15	3	10	3	2	1
Maximum[a]	0.00075 ± 0.00050	0.00043 ± 0.00043	0.0024 ± 0.0014	0.00031 ± 0.00027	0.00083 ± 0.00067	0.00071 ± 0.00024	0.00049 ± 0.00081	---
Minimum[a]	-0.00012 ± 0.00035	-0.00030 ± 0.00030	0.00044 ± 0.00044	-0.00006 ± 0.00019	-0.00011 ± 0.00004	0.00013 ± 0.00020	0.00010 ± 0.00015	---
$\bar{x} \pm s$	0.00020 ± 0.00033	0.00005 ± 0.00022	0.00027 ± 0.00071	0.00009 ± 0.00019	0.00029 ± 0.00028	0.00032 ± 0.00033	0.00030 ± 0.00028	0.00020 ± 0.00039
^{239,240}Pu (pCi/g dry weight)								
No. of Samples	5	10	15	3	10	3	2	1
Maximum[a]	0.00033 ± 0.00010	0.0012 ± 0.00092	0.0033 ± 0.00100	0.00027 ± 0.00011	0.0033 ± 0.0010	0.00051 ± 0.00020	0.00049 ± 0.00049	---
Minimum[a]	-0.00035 ± 0.00059	-0.00083 ± 0.00050	0.00008 ± 0.00010	-0.00031 ± 0.00016	0.00014 ± 0.00029	0.00020 ± 0.00013	0.00005 ± 0.00010	---
$\bar{x} \pm s$	0.00009 ± 0.00026	0.00016 ± 0.00053	0.00044 ± 0.00081	0.00005 ± 0.00031	0.00069 ± 0.00096	0.00037 ± 0.00016	0.00027 ± 0.00031	-0.00020 ± 0.00039
Uranium (μg/g dry weight)								
No. of Samples	5	9	15	3	10	3	2	1
Maximum[a]	0.022 ± 0.005	0.012 ± 0.0033	0.024 ± 0.0048	0.011 ± 0.0021	0.15 ± 0.027	0.059 ± 0.0083	0.042 ± 0.006	---
Minimum[a]	0.0005 ± 0.0006	0.0000 ± 0.0009	0.00083 ± 0.00058	0.0010 ± 0.0008	0.00008 ± 0.00072	0.0088 ± 0.0030	0.0045 ± 0.0024	---
$\bar{x} \pm s$	0.0084 ± 0.0085	0.0057 ± 0.0048	0.0076 ± 0.0068	0.0047 ± 0.0053	0.0018 ± 0.047	0.040 ± 0.028	0.023 ± 0.026	0.0045 ± 0.0018
^{137}Cs (pCi/g dry weight)								
No. of Samples	5	10	15	3	10	3	2	1
Maximum[a]	0.97 ± 1.46	1.83 ± 0.92	1.24 ± 1.21	0.46 ± 0.63	2.07 ± 0.90	0.41 ± 0.19	0.37 ± 0.31	---
Minimum[a]	-1.39 ± 1.68	-1.11 ± 0.65	-1.07 ± 1.02	-0.63 ± 1.01	-1.16 ± 0.82	-0.18 ± 0.13	0.18 ± 0.23	---
$\bar{x} \pm s$	-0.082 ± 0.91	0.067 ± 0.72	-0.053 ± 0.60	0.05 ± 0.59	0.39 ± 1.06	0.17 ± 0.31	0.28 ± 0.13	-0.44 ± 0.41
^{90}Sr (pCi/g dry weight)								
No. of Samples	5	10	11	1	8	2	1	1
Maximum[a]	0.052 ± 0.0071	0.10 ± 0.011	0.29 ± 0.020	---	0.076 ± 0.0071	0.070 ± 0.0031	---	---
Minimum[a]	-0.0016 ± 0.0048	0.0012 ± 0.0012	0.0063 ± 0.0013	---	0.0022 ± 0.0015	0.011 ± 0.0035	---	---
$\bar{x} \pm s$	0.025 ± 0.025	0.029 ± 0.034	0.056 ± 0.081	0.0089 ± 0.0089	0.027 ± 0.023	0.040 ± 0.042	0.0031 ± 0.0031	0.028 ± 0.0073

[a]Counting uncertainty.

Table E-XXV

Radionuclide Content of Fish

Location	Abiquiu, El Vado, and Heron Reservoirs				Cochiti Reservoir			
	Bottom Feeder[a]	Bottom Feeder (gut)[b]	Higher Level[a]	Higher Level (gut)[b]	Bottom Feeder[a]	Bottom Feeder (gut)[b]	Higher Level[a]	Higher Level (gut)[b]
Radionuclide:								
^{238}Pu (pCi/g dry weight)								
No. of Samples	10	8	8	6	13	10	8	5
Maximum[c]	0.00004 ± 0.00011	0.0017 ± 0.0007	0.00006 ± 0.00003	0.00058 ± 0.00033	0.00056 ± 0.00022	0.0064 ± 0.0038	0.00006 ± 0.00000	0.00028 ± 0.0000
Minimum[c]	−0.00002 ± 0.00004	−0.00063 ± 0.0019	−0.00006 ± 0.00005	−0.00009 ± 0.00027	−0.00005 ± 0.00001	−0.00029 ± 0.00078	−0.00014 ± 0.00007	−0.00004 ± 0.00009
$\bar{x} \pm s$	0.00001 ± 0.00002	0.00029 ± 0.00075	0.00000 ± 0.00005	0.00016 ± 0.00023	0.00007 ± 0.00015	0.00085 ± 0.00017	−0.00003 ± 0.00008	0.00013 ± 0.00012
^{239,240}Pu (pCi/g dry weight)								
No. of Samples	10	8	8	6	13	10	8	5
Maximum[c]	0.00011 ± 0.00006	0.0044 ± 0.0010	0.00006 ± 0.00005	0.001 ± 0.0003	0.00078 ± 0.00022	0.0059 ± 0.0011	0.00021 ± 0.00000	0.0023 ± 0.0020
Minimum[c]	−0.00009 ± 0.00010	0.00011 ± 0.00011	−0.00012 ± 0.00005	0.00007 ± 0.00008	−0.00018 ± 0.00002	−0.00058 ± 0.00068	−0.00011 ± 0.00009	0.00002 ± 0.00005
$\bar{x} \pm s$	0.00003 ± 0.00006	0.0011 ± 0.0014	0.00002 ± 0.00006	0.00041 ± 0.00040	0.00011 ± 0.00029	0.0020 ± 0.0019	0.00006 ± 0.00009	0.00052 ± 0.00102
Uranium (μg/g dry weight)								
No. of Samples	10	9	8	6	13	10	8	5
Maximum[c]	0.0507 ± 0.0051	0.33 ± 0.03	0.0061 ± 0.0010	0.084 ± 0.008	0.056 ± 0.057	1.35 ± 0.14	0.021 ± 0.005	0.54 ± 0.007
Minimum[c]	0.0079 ± 0.0010	0.058 ± 0.006	0.0000 ± 0.0019	0.0046 ± 0.0007	0.0079 ± 0.0001	0.075 ± 0.0075	0.0053 ± 0.0018	0.007 ± 0.0007
$\bar{x} \pm s$	0.020 ± 0.014	0.18 ± 0.11	0.0018 ± 0.0024	0.028 ± 0.031	0.027 ± 0.014	0.49 ± 0.38	0.0088 ± 0.0051	0.12 ± 0.24
^{137}Cs (pCi/g dry weight)								
No. of Samples	10	9	8	5	13	10	8	5
Maximum[c]	0.39 ± 0.28	0.45 ± 0.14	0.10 ± 0.06	0.33 ± 0.28	0.17 ± 0.10	0.58 ± 0.66	0.15 ± 0.07	0.43 ± 0.22
Minimum[c]	−1.4 ± 1.2	−1.4 ± 2.5	−0.061 ± 0.050	−1.3 ± 0.5	−0.19 ± 0.076	0.16 ± 0.15	−0.58 ± 0.54	−0.022 ± 0.11
$\bar{x} \pm s$	−0.076 ± 0.49	−0.0002 ± 0.57	0.038 ± 0.055	−0.23 ± 0.76	0.043 ± 0.11	0.20 ± 0.24	−0.063 ± 0.25	0.21 ± 0.22
^{90}Sr (pCi/g dry weight)								
No. of Samples	10	8	5	4	12	10	6	2
Maximum[c]	0.23 ± 0.009	0.082 ± 0.006	0.11 ± 0.01	0.056 ± 0.005	0.11 ± 0.005	0.36 ± 0.02	0.18 ± 0.007	0.034 ± 0.002
Minimum[c]	0.069 ± 0.004	0.0044 ± 0.0044	0.0098 ± 0.0006	−0.0011 ± 0.007	0.035 ± 0.003	0.0018 ± 0.0018	0.049 ± 0.002	0.032 ± 0.002
$\bar{x} \pm s$	0.14 ± 0.050	0.027 ± 0.024	0.043 ± 0.040	0.023 ± 0.026	0.076 ± 0.025	0.05 ± 0.11	0.093 ± 0.046	0.033 ± 0.001

[a]Samples consisted of fish less digestive system (gut).
[b]Samples consisted of gut only.
[c]Counting uncertainty.

Table E-XXVI

Most Recent Available Data on Analyses of Bees and Honey

Analysis	Units	Year	Sample Location[a,b] Chimayo	N. Los Alamos County	Pajarito Acres	TA-21 (DP Canyon)	TA-50 (Effluent Canyon)	TA-53 (LAMPF)	Mortandad Canyon	TA-8	TA-33	TA-54 (Area G)
Bee Analyses												
As	ppm	1980	<0.02	0.07	<0.02	<0.02	0.25	---	<0.02	0.07	0.12	<0.03
B	ppm	1980	19	14	18	15	13	---	17	11	17	20
^{7}Be	pCi/g	1982	<0.26	0.59	0.29	0.03	1.06	0.41	<0.26	0.44	<0.45	1.43
^{57}Co	pCi/g	1982	0.07	<0.06	0.04	0.18	1.4	0.09	<0.02	<0.05	0.003	0.20
Cr	ppm	1980	0.83	3.9	2.7	4.4	2.3	---	1.1	1.8	2.5	5.2
^{134}Cs	pCi/g	1982	0.05	0.15	0.13	0.10	0.11	0.10	0.08	0.16	0.06	0.23
^{137}Cs	pCi/g	1982	<0.03	0.11	0.05	0.09	0.03	0.07	0.03	0.09	0.04	0.05
F	ppm	1981	---	1.1	4.1	2.8	1.2	0.9	1.5	0.3	0.4	1.3
Hg	ppb	1982	4	4	3	<1	2	<1	<1	3	35	<1
^{3}H	pCi/mℓ	1982	0.7	1.8	11	3.6	---	15	4.5	1.8	35	38
^{54}Mn	pCi/g	1982	<0.03	0.07	0.03	0.04	1.1	<0.04	0.002	0.02	0.06	0.09
^{22}Na	pCi/g	1982	0.09	<0.06	0.06	0.003	11	<0.03	0.04	0.07	0.005	0.001
^{83}Rb	pCi/g	1982	0.17	0.04	<0.07	0.11	<0.05	0.04	0.006	0.04	0.008	0.18
U	ppb	1982	5.5	5.5	6.5	20	---	76	9.0	5.5	4.0	6.0
Honey Analyses												
^{7}Be	pCi/g	1982	<0.064	0.05	0.16	0.02	0.15	0.20	<0.08	<0.07	0.12	0.12
Cd	ppb	1981	1.4	12	---	3.1	9.0	---	2.8	13	0.9	16
^{57}Co	pCi/g	1982	0.03	<0.01	0.03	0.03	0.06	<0.01	0.03	0.02	0.04	0.002
^{134}Cs	pCi/g	1982	0.002	0.02	0.004	0.03	0.05	0.02	0.02	0.02	0.006	0.04
^{137}Cs	pCi/g	1982	0.009	0.003	<0.02	0.02	0.03	0.02	0.02	0.007	0.005	0.03
F	ppm	1982	0.1	0.2	0.2	0.4	0.5	0.1	0.1	0.1	0.1	0.1
Hg	ppb	1982	1	2	1	2	<0.5	<0.5	1	<0.5	0.5	3
^{3}H	pCi/mℓ	1982	1.3	12	3.2	9	18	11	7	11	93	29
^{54}Mn	pci/g	1982	<0.007	0.007	0.04	0.001	0.03	<0.01	0.009	0.001	0.03	0.02
^{22}Na	pCi/g	1982	<0.01	0.03	0.007	0.06	0.21	0.01	0.03	<0.007	0.10	0.007
^{83}Rb	pCi/g	1982	0.04	0.01	0.02	0.02	0.04	<0.02	0.03	0.03	<0.01	0.03
U	ppb	1982	2.4	1.9	<0.5	4.0	4.4	3.3	4.4	2.8	2.6	3.5

[a]One sample per location per year.
[b]See Figure 25 and Table E-XXXVI for sample locations.

Table E-XXVII

Radiochemical Analyses of Sediments and Runoff at TA-54 (Area G)

	Sediments (June 28, 1983)				
Station	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Total Uranium (μg/g)	Gross Gamma (counts/min/g)
1	0.07 ± 0.05	0.000 ± 0.000	0.000 ± 0.000	2.1 ± 0.4	3.4 ± 0.22
2	0.14 ± 0.07	0.000 ± 0.000	0.000 ± 0.000	3.2 ± 0.6	4.4 ± 0.24
3	0.40 ± 0.18	0.001 ± 0.004	0.013 ± 0.006	3.3 ± 0.6	5.9 ± 0.24
4	0.27 ± 0.14	0.031 ± 0.010	0.038 ± 0.010	5.4 ± 1.0	10 ± 0.30
5	0.15 ± 0.14	0.002 ± 0.004	0.007 ± 0.006	5.6 ± 1.2	7.7 ± 0.28
6	0.24 ± 0.14	0.017 ± 0.008	0.500 ± 0.040	3.0 ± 0.6	4.7 ± 0.24
7	0.24 ± 0.12	0.164 ± 0.022	2.44 ± 0.180	3.0 ± 0.6	4.8 ± 0.24
8	0.34 ± 0.16	0.018 ± 0.006	0.036 ± 0.010	3.7 ± 0.8	7.2 ± 0.26
9	0.25 ± 0.11	0.064 ± 0.014	0.028 ± 0.010	4.0 ± 0.8	5.5 ± 0.24
$\bar{x} \pm 2s$	0.23 ± 0.20	0.033 ± 0.107	0.340 ± 1.60	3.7 ± 2.3	5.9 ± 4.1

Runoff Area G at Gaging Station (August 2, 1983)							
Solution						Suspended Sediments	
^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{3}H (10^{-6} μCi/mℓ)	Total Uranium (μg/ℓ)	Gross Gamma (counts/min/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)
14 ± 40	0.001 ± 0.001	0.002 ± 0.002	2.5 ± 0.6	0.0 ± 0.8	70 ± 36	3.2 ± 0.32	0.50 ± 0.12

Table E-XXVIII

Quality of Effluents from Liquid
Radioactive Waste Treatment Plants for 1983

Radioactive Isotopes	Waste Treatment Plant Location: TA-50 Activity Released (mCi)	TA-50 Average Concentration (μCi/mℓ)	TA-21 Activity Released (mCi)	TA-21 Average Concentration (μCi/mℓ)
^{238}Pu	11.0	3.8×10^{-7}	0.04	1.1×10^{-8}
$^{239,240}Pu$	42.2	1.5×10^{-6}	0.09	2.5×10^{-8}
^{241}Am	37.7	1.3×10^{-6}	0.71	2.0×10^{-7}
^{89}Sr	56.7	2.0×10^{-6}	0.09	2.5×10^{-9}
^{90}Sr	2.3	8.0×10^{-8}	0.24	6.7×10^{-8}
^{3}H	8690	3.0×10^{-4}	1660	4.7×10^{-4}
^{137}Cs	44.7	1.6×10^{-6}	0.27	7.6×10^{-8}
^{234}U	0.6	2.1×10^{-8}	1.54	4.3×10^{-7}

Nonradioactive Constituent	Waste Treatment Plant Location: TA-50 Average Concentration (mg/ℓ)	TA-21 Average Concentration (mg/ℓ)
Cd[a]	0.007	0.32
Ca	47	16.4
Cl	90	59.5
Cr (Total)[a]	0.05	0.16
Cu[a]	0.41	0.17
F	15.8	197
Hg[a]	0.0008	0.0004
Mg	3.3	2.0
Na	1063	1120
Pb[a]	0.03	0.03
Zn[a]	0.13	1.5
CN	0.02	---
COD[a]	75	71
$NO_3(N)$	384	62
PO_4	2.2	0.87
TDS	4060	2950
pH[a]	7.0 - 12.8	10.0 - 12.6
Total Effluent Volume	2.873×10^7 ℓ	3.566×10^7 ℓ

[a]Constituents regulated by National Pollutant Discharge Elimination System permit.

Table E-XXIX

Chemical Quality of Surface and Ground Waters
from Effluent Release Areas

Analyses (mg/ℓ) (1 sample per location)	Acid-Pueblo Canyon				DP-Los Alamos Canyon			Sandia Canyon		Mortandad Canyon		
	Acid Weir	Pueblo 1	Pueblo 2	Pueblo 3	DPS-4	LAO-2	LAO-4.5	SCS-1	SCS-3	GS-1	MCO-4	MCO-7.5
Boron	<0.05	0.28	0.15	0.22	0.12	0.14	<0.05	0.28	0.23	0.12	0.10	0.09
Lithium	0.02	0.02	0.02	0.01	0.04	0.02	0.01	0.10	0.07	0.03	0.03	0.01
Cadmium	0.01	0.03	0.03	0.01	0.01	0.01	0.33	0.24	0.04	0.13	0.05	0.09
Copper	<0.001	0.002	0.002	0.001	0.005	0.007	0.008	0.008	0.004	<0.001	<0.001	0.007
Chromium	<0.01	<0.01	0.05	0.04	0.05	<0.01	<0.01	0.12	0.05	<0.01	<0.01	<0.01
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Lead	<0.01	<0.01	<0.01	0.02	0.17	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01
Zinc	0.05	0.80	0.14	0.11	0.17	0.32	0.30	0.19	0.15	0.05	0.07	0.25
Ammonia	0.24	5.0	1.5	2.9	1.2	0.58	0.06	9.1	1.7	<0.05	0.09	0.06
COD	42	59	62	48	34	20	22	73	42	22	42	36
Suspended Solids	2	20	72	73	69	95	1253	89	7	179	271	156

Table E-XXX

Total Suspended Particulates in Air at
Los Alamos and White Rock During 1983
(Data from New Mexico Environmental Improvement Division. All concentrations in $\mu g/m^3$.)

	Los Alamos (Annual Geometric Mean = 33)											
	Jan	Fed	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Number of Samples	5	4	6	5	5	5	5	5	5	5	5	5
Maximum	90	96	353	61	52	50	65	37	49	30	39	34
Minimum	18	27	15	19	13	31	23	16	25	11	14	16
Mean	48	63	91	41	32	39	36	28	34	22	24	26
± 1s	27	35	130	18	16	9	18	8	9	8	11	7
	White Rock (Annual Geometric Mean = 34)											
Number of Samples	5	3	6	6	5	5	5	6	4	4	5	6
Maximum	25	27	228	253	200	97	86	51	86	28	64	47
Minimum	8	18	11	19	20	50	19	19	16	16	12	16
Mean	19	23	55	94	79	71	46	31	39	21	40	26
± 1s	10	5	85	83	75	20	28	13	32	5	22	12

Table E-XXXI

Quantities of Volatile Chemicals and Compressed Gases Used at Los Alamos
(all amounts in kg)

	1980	1981	1982	1983
Acids				
Acetic Acid	190	230	170	---
Hydrochloric Acid	5 400	6 500	6 000	1 400
Hydrofluoric Acid	170	420	270	640
Nitric Acid	71 900	99 500	70 500	52 100
Perchloric Acid	290	230	180	60
Phosphoric Acid	320	480	490	30
Sulfuric Acid	1 800	2 200	2 200	2 600
Gases				
Ammonia	2 600	2 900	1 800	2 400
Carbon Monoxide	4 800	6 200	9 600	---
Chlorine	1 100	1 200	610	140
Freon 12	2 100	3 300	1 600	2 600
Hydrogen Fluoride	1 300	1 000	1 600	1 600
Nitrogen Oxides	350	440	330	410
Sulfur Dioxide	150	370	210	30
Sulfur Hexafluoride	6 900	10 600	8 800	14 200
Inorganic Chemicals				
Ammonium Hydroxide	1 600	1 900	1 200	2 100
Mercury	140	200	210	60
Sodium Hydroxide	---	---	---	39 500
Organic Chemicals				
Acetone	7 900	10 200	10 700	10 900
Benzene	---	---	---	70
Carbon Tetrachloride	100	180	190	60
Chloroform	310	250	320	500
Ethanol	9 400	11 800	12 800	13 500
Freons	12 800	12 500	32 200	28 400
Kerosene	5 800	5 300	5 500	2 800
Methanol	2 400	3 400	3 100	730
Methylene Chloride	180	230	430	100
Methyl Ethyl Ketone	11 400	21 000	400	6 200
Perchloroethylene	1 400	9 100	340	---
Toluene	650	60	60	190
Trichloroethane	28 200	39 300	25 600	31 100
Trichloroethylene	3 400	3 200	390	4 200
Xylene	---	---	---	70

[a]Does not include chemicals received under special orders.

Table E-XXXII

Estimated Concentrations of Toxic Elements
Aerosolized by Dynamic Experiments

Element	1983 Total Usage (kg)	Fraction Aerosolized (%)	Annual Average Concentration (ng/m^3)		Applicable Standard (ng/m^3)
			4 km	8 km	
Uranium	830	10	0.08	0.03	9000[a]
Be	7.7	2	0.0002	0.0001	10[b] (30 day av)
Pb	48.5	100 [c]	0.05	0.02	1500[d] (3 month av)

[a]Reference (DOE 1981A).
[b]Section 201 of the Ambient Air Quality Standards and Air Quality Control Regulations adopted by the New Mexico Health and Social Services Board, April 19, 1974.
[c]Assumed percentage aerosolization.
[d]40 CFR 50.12.

Table E-XXXIII

Sanitary Sewage Treatment Facilities Effluent Quality Summary[a]

Discharge Location	Permit Constituents	Number of Deviations	Range of: Deviation / Limiting Standard or pH	Location	Constituents	Number of Deviations	Range of: Deviation / Limiting Standard or pH
TA-3	BOD[b]	33	1.1 - 8.1	TA-41	BOD	10	1.1 - 2.6
	TSS[c]	3	1.2 - 1.7		TSS	2	1.2 - 14.3
	Fecal Coliform[d]	6	26 - 450		Fecal Coliform[d]	20	1.1 - 48
	pH[e]	0	---		pH	0	---
TA-8	BOD	6	1.0 - 13.2	TA-46	BOD	0	---
	TSS (90)[c]	1	1.0		TSS	0	---
	pH	3	9.3 - 9.8		pH	2	5.9 - 5.9
TA-9	BOD	0	---	TA-48	BOD	0	---
	TSS	1	1.4		TSS	0	---
	pH	0	---		pH	0	---
TA-16	BOD	0	---	TA-53	BOD	8	3.2 - 6.3
	TSS	0	---		TSS (90)[c]	1	1.6
	pH	0	---		pH	19	9.4 - 10.7
TA-18	BOD	3	1.1 - 2.3	TA-35	BOD	11	1.4 - 11.1
	TSS (90)[c]	1	2.2		TSS (90)[c]	3	1.0 - 1.5
	pH	7	9.8 ± 10.6		pH	5	9.2 - 9.6
TA-21	BOD	4	1.0 - 2.1				
	TSS	1	1.2				
	pH	0	---				

[a]Single NPDES Permit NM 0028355.
[b]The BOD_5 limits are 30 mg/ℓ (20-day avg), 45 mg/ℓ (7-day avg).
[c]The TSS limits are 30 mg/ℓ (20-day avg), 45 mg/ℓ (7-day avg) at some outfalls and 90 mg/ℓ (7-day avg) at other outfalls.
[d]Fecal coliform limits are 2000/100 mℓ (daily max) and 1000/100 mℓ (geometric mean).
[e]The pH range limit is not less than 6.0 or greater than 9.0 standard units.
[f]TNTC = Too numerous to count.

Table E-XXXIV

Industrial Liquid Effluent Quality Summary[a]

Discharge Category	Number of Outfalls	Permit Constituents	Number of Deviations	Range of: Deviation / Limiting Standards or pH[b]	Number of Outfalls Causing Deviations
Power Plant	12	TSS	0	---	0
		Free Cl	0	---	0
		pH	1	9.2	1
Blower Blowdown	1	TSS	1	1.7	1
		Fe	1	1.2	1
		Cu	7	1.3 - 27	1
		P	0	---	0
		pH	10	9.4 - 11.7	1
Treated Cooling Water	30	TSS	2	1.3 - 8.9	2
		Free Cl	1	6.0	1
		P	0	---	0
		pH	1	9.1	1
Noncontact Cooling Water	30	pH	1	3.5	1
Radioactive Waste Treatment Plant Discharges 606	2	NH_3	0	---	0
		COD	0	---	0
		TSS	1	1.6	1
		Cd	0	---	0
		Cr	4	1.3 - 2.8	1
		Cu	0	---	0
		Fe	2	1.0 - 2.4	1
		Pb	0	---	0
		Hg	0	---	0
		Zn	0	---	0
		pH	0	---	0
High Explosives Waste Discharges	20	COD	9	1.2 - 50	6
		TSS	5	1.1 - 1.8	3
		pH	4	2.9 - 9.7	4
Photo Waste Discharges	15	Cn	0	---	0
		TSS	0	---	0
		pH	2	5.6 - 5.9	2
		Ag	3	1.8 - 3.07	2
Printed Circuit Board Development Wastes	1	COD	1	6.9	1
		Cu	3	1.5 - 4.6	1
		Fe	3	2.2 - 13	1
		Ni	0	---	0
		P	0	---	0
		pH	3	4.1 - 5.5	0
Acid Dip Tank Rinse	1	Cu	0	---	0
		pH	0	---	0
Gas Cylinder Cleaning Waste	1	TSS	0	---	0
		P	0	---	0
		pH	0	---	0

[a]Summary of reports to EPA or NPDES Permit NM 0028355.
[b]The pH range limit on all outfalls is not less than 6.0 or greater than 9.0 standard units.

Table E-XXXV

Acid Rain Gauge Results
(all results in ppm)

Month-Day	pH	Conductivity (μmho/cm)	Ca	Mg	K	Na	NH_4	NO_3	Cl	SO_4	PO_4
1982											
10/05 - 10/13	5.0	7.6	0.19	0.01	0.02	0.04	0.11	0.56	0.08	0.85	<0.003
10/13 - 10/19	Dry										
10/19 - 10/26	Dry										
10/26 - 11/02	6.7	15.2	0.80	0.17	0.13	0.33	0.63	2.22	0.57	1.90	<0.003
11/02 - 11/09	5.6	13.2	0.62	0.05	0.05	0.11	0.29	1.21	0.19	1.52	<0.003
11/09 - 11/16	5.7	5.2	0.19	0.02	0.02	0.04	0.20	0.37	0.08	0.65	<0.003
11/16 - 11/23	6.3	6.8	0.10	0.01	0.02	0.39	<0.02	0.59	0.21	0.40	<0.003
11/23 - 11/30	5.4	6.5	0.06	0.01	0.03	0.05	0.09	0.38	0.10	0.19	<0.003
11/30 - 12/07	5.1	9.6	0.30	0.04	0.11	0.20	0.29	0.46	0.31	1.91	<0.003
12/07 - 12/14	5.1	7.3	0.10	0.01	0.02	0.03	0.20	0.40	0.09	0.99	<0.003
12/14 - 12/21	6.1										
12/21 - 12/28	4.9	9.4	0.11	0.02	0.01	0.04	0.20	0.49	0.06	1.14	<0.003
1983											
12/28 - 1/04	5.2	13.3	0.68	0.14	0.06	0.12	0.24	0.78	0.27	1.48	<0.009
01/04 - 01/11	Dry										
01/11 - 01/17	6.0	14.0	0.60	0.31	0.11	0.77	0.28	0.99	0.32	1.85	<0.012
01/17 - 01/25	5.8	5.0	0.21	0.05	0.02	0.07	0.09	0.98	0.10	0.39	<0.003
01/25 - 01/01	5.1	5.4	0.08	0.10	0.01	0.05	0.07	0.44	0.05	0.45	<0.003
02/01 - 02/04	5.2	4.5	0.04	0.01	0.01	0.02	0.04	0.29	0.04	0.38	0.014
02/04 - 01/08	5.9	3.4	0.14	0.04	0.02	0.06	0.07	0.25	0.07	0.28	<0.003
02/08 - 02/15	Dry										
02/15 - 02/22	3.7	119.5	1.71	0.43	1.86	0.72	<0.02	1.67	0.34	2.84	0.28
02/22 - 3/01	5.3	27.8	2.18	0.15	0.15	0.27	0.71	3.61	0.45	5.55	<0.003
03/01 - 03/08	5.8	4.0	0.23	0.02	0.02	0.27	<0.02	0.35	0.06	0.49	<0.003
03/08 - 03/16	4.9	13.0	0.25	0.07	0.07	0.09	0.12	1.13	0.12	1.25	<0.003
03/16 - 03/22	4.8	10.2	0.12	0.02	0.02	0.06	0.13	0.50	0.07	1.17	<0.003
03/22 - 3/29	6.0	3.5	0.15	0.03	0.03	0.08	<0.02	0.13	0.09	0.51	<0.003
03/29 - 04/05	5.9	3.8	0.29	0.03	0.02	0.14	<0.02	0.47	0.12	0.45	<0.003
04/05 - 04/12	5.5	4.8	0.16	0.04	0.06	0.16	0.05	0.78	0.28	0.39	<0.003
04/12 - 04/19	5.4	6.0	0.25	0.04	0.02	0.08	0.11	0.71	0.09	0.81	<0.003
04/19 - 04/26	6.9	28.9	0.64	0.07	0.05	4.80	<0.02	0.13	0.97	1.27	<0.003
04/26 - 05/03	5.6	42.3									
05/03 - 05/10	Dry										
05/10 - 05/17	6.3	36.6	4.00	0.27	0.29	0.87	0.67	7.51	1.07	3.96	<0.003
05/17 - 05/14	5.0	11.0	0.38	0.09	0.05	0.15	0.14	1.19	0.22	1.28	<0.003
05/24 - 05/31	4.9	19.1	0.81	0.10	0.12	0.20	0.40	2.02	0.23	2.55	<0.003
05/31 - 06/07	5.9	41.4	3.78	0.37	0.54	1.14	0.67	5.66	1.51	5.74	<0.003
06/07 - 06/14	5.6	44.5	3.21	0.31	0.87	1.18	1.30	5.35	1.72	7.75	<0.003
06/14 - 06/21	Dry										
06/21 - 06/28	4.7	16.7	0.60	0.07	0.18	0.17	0.49	1.77	0.24	2.32	<0.003
06/28 - 07/05	Dry										
07/05 - 07/12	5.3	7.5	0.44	0.03	0.03	0.04	0.15	0.97	0.07	0.92	<0.003
07/12 - 07/19	5.0	23.2	2.47	0.21	0.30	0.40	0.07	2.81	0.62	2.98	<0.003
07/19 - 07/26	5.1	5.9	0.20	0.02	0.02	0.04	0.09	0.81	0.06	0.58	<0.003
07/26 - 08/02	4.9	8.1	0.16	0.02	0.05	0.08	0.22	0.98	0.08	0.85	<0.003
08/02 - 08/09	5.2	11.1	0.49	0.04	0.14	0.19	0.42	1.73	0.46	1.49	<0.003
08/09 - 08/16	Dry										

Table E-XXXVI

Locations of Beehives

Station	N-S Coordinate	E-W Coordinate
Regional Station (28-44 km)—Uncontrolled Area		
1. Chimayo	---	---
Perimeter Stations (0-4 km)—Uncontrolled Areas		
2. Northern Los Alamos County	N190	W020
3. Pajarito Acres	S210	E380
Onsite Stations—Controlled Areas		
4. TA-21 (DP Canyon)	N095	E140
5. TA-50 (Effluent Canyon)	N040	E080
6. TA-53 (LAMPF)	N070	E090
7. Mortandad Canyon	N020	E220
8. TA-8	S020	W080
9. TA-33	S245	E225
10. TA-54 (Area G)	S080	E290

Table E-XXXVII

Means[a] and Extremes of Temperature and Precipitation— Climatological Summary (1911-1983) for Los Alamos, New Mexico[b]

	Temperature (°F)										
	Means			Extremes							
Month	Mean Max	Mean Min	Avg	High Avg	Year	Low Avg	Year	High Daily Max	Date	Low Daily Min	Date
Jan	39.7	18.5	29.1	37.5	1953	20.9	1930	64	1/12/53	-18	1/13/63
Feb	43.0	21.5	32.2	37.4	1934	23.0	1939	66	2/24/36	-14	2/1/51 2/8/33
Mar	48.7	26.5	37.6	45.8	1972	32.1	1948	71	3/26/71 3/30/46	-3	3/11/48
Apr	57.6	33.7	45.6	54.3	1954	39.7	1973	79	4/23/38	5	4/9/28
May	67.0	42.8	54.9	60.5	1956	50.1	1957	89	5/29/35	24	4 Dates
Jun	77.8	52.4	65.1	84.5	1980	60.4	1965	95	6/22/81	28	6/3/19
Jul	80.4	56.1	68.2	87.3	1980	63.3	1926	95	7/11/35	37	7/7/24
Aug	77.4	54.3	65.8	70.3	1936	60.9	1929	92	8/10/37	40	8/16/47
Sept	72.1	48.4	60.2	65.8	1956	56.2	1965	94	9/11/34	23	9/29/36
Oct	62.0	38.7	50.3	54.7	1963	44.4	1976	84	10/1/80	15	10/19/76
Nov	48.7	27.1	37.9	44.4	1949	30.5	1972	72	11/1/50	-14	1/28/76
Dec	41.4	20.3	30.8	38.4	1980	24.6	1931	64	12/27/80	-13	12/9/78
Annual	59.6	36.7	48.1	52.0	1954	46.2	1932	95	7/11/35 6/22/81	-18	1/13/63

	Precipitation (in.)											Mean Number of Days		
	Rain[c]					Snow								
Month	Mean	Mo. Max	Year	Daily Max	Date	Mean	Mo. Max	Year	Daily Max	Date		Precip ≥0.10 in.	Max Temp ≥90°F	Min Temp ≤32°F
Jan	0.85	6.75	1916	2.45	1/27/16	9.7	39.3	1949	15.0	1/5/13		2	0	30
Feb	0.68	2.44	1948	1.05	2/20/15	7.3	36.4	1982	19.0	2/4/82		2	0	26
Mar	1.01	4.11	1973	2.25	3/30/16	9.7	36.0	1973	18.0	3/30/16		3	0	24
Apr	0.86	4.64	1915	2.00	4/12/75	5.1	33.6	1958	20.0	4/12/75		2	0	13
May	1.13	4.47	1929	1.80	5/21/29	0.8	17.0	1917	12.0	5/2/78		3	0	2
Jun	1.12	5.57	1913	2.51	6/10/13	0	---	---	---	---		3	1	0
Jul	3.18	7.98	1919	2.47	7/31/68	0	---	---	---	---		8	1	0
Aug	3.93	11.18	1952	2.26	8/1/51	0	---	---	---	---		9	0	0
Sept	1.63	5.79	1941	2.21	9/22/29	0.1	6.0	1913	6.0	9/25/13		4	0	0
Oct	1.52	6.77	1957	3.48	10/5/11	1.7	9.0	1972	9.0	10/31/72		3	0	7
Nov	0.96	6.60	1978	1.77	11/25/78	5.0	26.2	1931	14.0	11/22/31		2	0	22
Dec	0.96	2.85	1965	1.60	12/6/78	11.4	41.3	1967	22.0	12/6/78		3	0	30
Annual	17.83	30.34	1941	3.48	10/5/11	50.8	100.0	1958	22.0	12/6/78		43	2	154

[a]Means based on standard 30-year period: 1951-1980.
[b]Latitude 35° 32' north, longitude 106° 19' west; elevation 2249 m.
[c]Includes liquid water equivalent of frozen precipitation.

Table E-XXXVII (cont)

Climatological Summary 1983

	Temperature (°F)						
	Means			Extremes			
Month	Mean Max	Mean Min	Avg	High	Date	Low	Date
Jan	41.9	20.7	31.3	53	13	10	10
Feb	43.9	22.3	33.1	55	18	13	2
Mar	48.5	27.2	37.8	63	31	14	21
Apr	52.8	27.9	40.3	70	25	8	5
May	64.8	36.9	50.9	79	24	27	2
Jun	76.7	48.3	62.5	90	18	38	13,14
Jul	82.1	54.3	68.2	88	7,9	47	14
Aug	80.0	54.4	67.1	86	17	51	23,26
Sept	77.2	49.0	63.1	87	6	25	21
Oct	63.1	39.8	50.4	70	18	28	25
Nov	49.8	26.1	37.9	67	3	8	27,28
Dec	39.1	18.9	29.0	52	8	0	28,29
Annual	60.0	35.3	47.6	90	6/18	0	12/28

	Precipitation(in.)						Number of Days		
	Rain[a]			Snow					
Month	Total	Daily Max	Date	Total	Daily Max	Date	Precip ≥ 0.10 in.	Max Temp ≥90°F	Min Temp ≤32°F
Jan	1.12	0.80	31	17.9	12.0	31	2	0	31
Feb	0.63	0.28	4	9.8	5.0	4	2	0	28
Mar	1.82	0.54	18	16.3	5.3	18	6	0	27
Apr	0.84	0.65	4	11.5	10.0	4	1	0	18
May	0.65	0.21	20	T	T	20	3	0	11
Jun	0.41	0.19	27	0	0	---	1	1	0
Jul	3.64	1.56	23	0	0	---	7	0	0
Aug	2.99	0.54	11	0	0	---	9	0	0
Sept	1.89	0.67	11	0	0	---	6	0	1
Oct	1.12	0.45	1	0	0	---	4	0	4
Nov	0.48	0.19	26	5.2	3.3	26	1	0	21
Dec	1.08	0.36	28	11.7	4.5	28	3	0	31
Annual	16.67	1.56	7/23	72.4	12.0	1/31	45	1	172

Table E-XXXVIII

Highlights of Weather During 1983

January	Snowstorm on the 31st. Snowy: 17.9 in. SMDP on the 31st: 0.80 in. SMDS on the 31st: 12.0 in.
February	Near normal temperatures and precipitation.
March	Wet: 1.82 in. precipitation. Snowy: 16.3 in. Windstorm during 4th to 6th; 50 mph peak gusts. SMDP on the 18th: 0.54 in. SMDS on the 18th: 5.3 in. Windstorm and blowing dust on the 31st; 56 mph peak gusts.
April	Very cold and snowy. Mean temperature = 40.3°F (Normal = 45.6°F). 3rd coldest April on record. Mean low temperature = 27.9°F (Normal = 33.7°F). Second lowest monthly mean low temperature on record for April. Snowfall = 11.5 in. (Normal = 5.1 in.) Windstorm on 1st; 51 mph peak gust. SMDL on the 4th = 10°F. Coldest high temperature for so late in the season on the 4th: 26°F. SMDP on the 4th = 0.65 in. SMDS on the 4th = 10.0 in. SMDL on the 5th = 8°F.
May	Very cold and dry. Mean temperature = 50.9°F (Normal = 54.9°F). 3rd coldest May on record; coldest since 1957. Mean low temperature = 36.9°F (Normal = 42.8°F). Coldest mean low temperature for May on record. SMDL on the 17th: 30°F. SMDL on the 18th: 28°F. SMDL on the 21st: 31°F.
(Spring 1983) (March-May)	Mean temperature = 43.0°F (Average = 46.0 °F). 2nd coldest spring on record (1973 spring mean = 42.1°F). Mean minimum temperature = 30.7°F (Average = 34.3°F). Coldest mean minimum temperature for spring (previous coldest = 30.9°F in 1941).

Table E-XXXVIII (cont)

June	Cool and dry. Mean temperature = 62.5°F (Normal = 65.1°F). Precipitation = 0.41 in. (Normal = 1.12 in.). TMDL on the 14th: 38°F. TMDH on the 18th: 90°F. TMDL on the 28th: 46°F.
July	Thunderstorms with heavy rain in Los Alamos on 23rd; Store roof collapses due to rains in Los Alamos Business District. SMDP on the 23rd: 1.56 in.
August	Temperatures near normal. Precipitation below normal: 2.99 in. (Normal = 3.93 in.). Funnel cloud was reported by public several miles SE of White Rock on afternoon of the 23rd.
September	Warm. Mean temperature = 63.1°F (Normal = 60.2°F). Very warm daytime temperatures. Mean daily high temperature = 77.2°F (Normal = 72.1°F). SMDH on the 2nd: 84°F. SMDH on the 9th: 84°F. Extremely early hard freeze on the 21st: 25°F. Set record for coldest for so early in season. SMDL on the 21st: 25°F.
October	Temperatures near normal. Precipitation below normal: 1.12 in. (Normal = 1.52 in.).
November	Month of extremes: First 17 days were very warm and dry, while the end of the month was cold and snowy. Month as a whole had normal temperatures. Dry: 0.48 in. precipitation (Normal = 0.96 in.). SMDH on the 3rd: 67°F. TMDH on the 7th: 66°F. Windstorm on the 8th and 9th; maximum gusts of 49 and 43 mph, respectively. Windstorm on the 14th; 51 mph peak gust.
December	Cool. Mean temperature = 29.0°F (Normal = 30.8°F). SMDL on the 6th: 5°F. SMDL on the 28th: 0°F. TMDL on the 29th: 0°F.

Table E-XXXVIII (cont)

Annual	1983 mean temperature = 48.1°F (Normal = 47.6°F). 1983 precipitation = 16.67 in. (Normal = 17.83 in.). 1983 snowfall = 72.4 in. (Normal = 50.8 in.). 1983 growing season was shortest on record (125 consecutive days with no minimum temperatures below 28°F).

Key for Abbreviations

SMDH: Set Maximum Daily High Temperature Record
TMDH: Tied Maximum Daily High Temperature Record
SMDL: Set Minimum Daily Low Temperature Record
TMDL: Tied Minimum Daily Low Temperature Record
SMDP: Set Maximum Daily Precipitation Record
SMDS: Set Minimum Daily Snowfall Record

Table E-XXXIX

Predominate Ions in Surface and Ground Waters and Ponds at Fenton Hill Geothermal Site (concentrations in mg/ℓ)

Surface Water

	Na	Cl	TDS
Sodium Chloride			
Redondo Creek (U)	13	8	77
Jemez River (R)	78	102	428
Jemez River (S)	78	102	380

	Ca	HCO_3	TDS
Calcium Bicarbonate			
San Antonio Creek (N)	16	60	139
Rio Cebolla (T)	20	75	102
Rio Guadalupe (Q)	49	150	207
Lake Fork 1 (LF-1)	14	45	89
Lake Fork 2 (LF-2)	16	55	116
Lake Fork 3 (LF-3)	14	65	133
Lake Fork 4 (LF-4)	16	70	142

	Ca	SO_4	TDS
Calcium Sulfate			
Sulphur Creek (V)	60	325	442
Sulphur Creek (F)	25	62	150

	Na	HCO_3	TDS
Sodium Bicarbonate			
Jemez River (J)	20	60	131

Ground Water

	Na	Cl	TDS
Sodium Chloride			
Loc. JF-1 (Hot Spr)	500	690	1902
Loc. JF-5 (Hot Spr)	925	1400	3876

	Ca	HCO_3	TDS
Calcium Bicarbonate			
FH-1 (Supply Well)	41	115	236
Loc. 39 (Spr)	17	50	106

	Na	HCO_3	TDS
Sodium Bicarbonate			
JS-2, 3 (Spr)	23	97	151
JS-4, 5 (Spr)	20	85	164
Loc. 4 (Spr)	38	130	190
Loc. 31 (Spr)	17	60	97
RV-2 (Hot Spr)	26	50	154
RV-4 (Hot Spr)	53	115	231
RV-5 (Hot Spr)	23	75	137

Ponds—Fenton Hill

	SO_4	Cl	F	TDS	As	B	Cd	Li
Upper GTP-1	84	1250	4.3	3488	0.065	40	<0.001	18
Lower GTP-3	40	46	0.6	202	0.200	1.3	0.002	0.7

Notes: 1. See Figure 29 for sampling locations indicated in parentheses.
2. One sample taken at each location.

Table E-XL

Most Recent Available Data on Environmental Samples
from Fenton Hill Geothermal Site

	As		B		Cd		F		Li	
Location[a]	Date	Concentration (ppm)	Date	Concentration (ppm)	Date	Concentration (ppb)	Date	Concentration (ppm)	Date	Concentration (ppm)
Roots (Bank)										
100 m[b]	Fall 1981	3.8	Fall 1982	29	Spring 1982	740	Fall 1982	45	Spring 1982	1.4
200 m	Fall 1981	2.2	Fall 1982	37	Spring 1982	200	Fall 1982	52	Spring 1982	1.9
400 m	Fall 1981	2.9	Fall 1982	30	Spring 1982	120	Fall 1982	40	Spring 1982	42
1000 m	Fall 1981	5.7	Fall 1982	34	Spring 1982	250	Fall 1982	43	Spring 1982	1.3
Roots (Channel)										
100 m	Fall 1981	13	Fall 1982	114	Spring 1982	260	Fall 1982	78	Spring 1982	3.4
200 m	Fall 1981	5.7	Fall 1982	139	Spring 1982	220	Fall 1982	170	Spring 1982	13
400 m	Fall 1981	6.5	Fall 1982	130	Spring 1982	270	Fall 1982	61	Spring 1982	1.6
1000 m	Fall 1981	1.9	Fall 1982	30	Spring 1982	280	Fall 1982	37	Spring 1982	1.2
Lower Canyon	Fall 1981	1.1	Fall 1982	32	Spring 1982	350	Fall 1982	77	Spring 1982	19
Foliage (Bank)										
100 m	Fall 1981	0.11	Fall 1982	11	Spring 1982	28	Fall 1982	12	Spring 1982	0.5
200 m	Fall 1981	0.08	Fall 1982	13	Spring 2982	43	Fall 1982	170	Spring 1982	1.3
400 m	Fall 1981	0.35	Fall 1982	32	Spring 1982	19	Fall 1982	10	Spring 1982	0.5
1000 m	Fall 1981	<0.06	Fall 1982	9	Spring 1982	22	Fall 1982	2	Spring 1982	2.4
Foliage (Channel										
100 m	Fall 1981	<0.11	Fall 1982	188	Spring 1982	44	Fall 1982	70	Spring 1982	89
200 m	Fall 1981	0.09	Fall 1982	434	Spring 1982	31	Fall 1982	84	Spring 1982	126
400 m	Fall 1981	0.45	Fall 1982	110	Spring 1982	65	Fall 1982	8	Spring 1982	15
1000 m	Fall 1981	0.24	Fall 1982	12	Spring 1982	38	Fall 1982	19	Spring 1982	0.5
Lower Canyon	Fall 1981	0.30	Fall 1982	13	Spring 1982	44	Fall 1982	28	Spring 1982	1.1
Soil (Bank)										
100 m	Fall 1982	3.1	Fall 1982	14	Fall 1982	80	Spring 1982	80	Spring 1982	31
200 m	Fall 1982	3.1	Fall 1982	23	Fall 1982	160	Spring 1982	130	Spring 1982	26
400 m	Fall 1982	3.9	Fall 1982	17	Fall 1982	80	Spring 1982	200	Spring 1982	32
1000 m	Fall 1982	5.4	Fall 1982	31	Fall 1982	510	Spring 1982	220	Spring 1982	33
Soil (Channel)										
100 m	Fall 1982	12	Fall 1982	49	Fall 1982	210	Spring 1982	240	Spring 1982	44
200 m	Fall 1982	17	Fall 1982	104	Fall 1982	440	Spring 1982	200	Spring 1982	48
400 m	Fall 1982	12	Fall 1982	54	Fall 1982	220	Spring 1982	150	Spring 1982	31
1000 m	Fall 1982	2.9	Fall 1982	18	Fall 1982	210	Spring 1982	190	Spring 1982	30
Lower Canyon	Fall 1982	2.8	Fall 1982	15	Fall 1982	140	Spring 1982	200	Spring 1982	46

[a]One sample per location.
[b]Distance downstream channel from Fenton Hill Geothermal Site.

Table E XLI

Distribution of Moisture, Tritium, and Plutonium
from Core Holes in Mortandad Canyon

	Depth (m)	Per Cent Moisture by Volume	^{3}H (10^{-6} μCi/mℓ)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)
Core Hole 1					
(In channel)	1.8	7	10 ± 0.8	0.001 ± 0.002	0.000 ± 0.003
	3.4	12	29 ± 1.4	−0.003 ± 0.004	0.016 ± 0.008
	4.9	12	21 ± 1.2	0.001 ± 0.002	0.004 ± 0.003
	6.4	12	14 ± 1.0	−0.001 ± 0.002	0.008 ± 0.006
	7.9	28	8.5 ± 0.8	0.006 ± 0.003	0.010 ± 0.004
	9.4	32	23 ± 1.2	0.000 ± 0.003	0.003 ± 0.004
	11.0	19	---	---	---
	12.5	20	150 ± 4.0	0.003 ± 0.003	0.002 ± 0.002
	14.0	27	391 ± 12	0.003 ± 0.003	0.004 ± 0.003
	15.2	18	106 ± 3.6	0.005 ± 0.003	0.000 ± 0.002
	15.5	17	101 ± 3.4	−0.001 ± 0.002	0.002 ± 0.002
	17.1	12	91 ± 3.0	0.003 ± 0.003	0.002 ± 0.003
	18.6	16	118 ± 3.8	0.001 ± 0.003	0.001 ± 0.002
	20.1	11	115 ± 3.8	−0.001 ± 0.001	0.004 ± 0.003
	21.6	14	107 ± 3.6	0.000 ± 0.002	0.000 ± 0.002
Summary: $\bar{x}$ ± 2s		17 ± 14	92 ± 198	0.001 ± 0.005	0.004 ± 0.009
Core Hole 2					
(6 m south of channel)	1.8	8	7.9 ± 0.8	−0.001 ± 0.000	0.010 ± 0.004
	3.4	4	---	0.002 ± 0.002	0.043 ± 0.008
	4.9	4	11 ± 1.0	−0.002 ± 0.004	0.020 ± 0.006
	6.4	6	16 ± 1.0	−0.001 ± 0.003	0.001 ± 0.003
	7.9	18	62 ± 2.2	0.001 ± 0.002	0.008 ± 0.004
	9.3	29	291 ± 10	0.000 ± 0.002	0.010 ± 0.004
	9.4	29	277 ± 8.0	−0.001 ± 0.002	0.035 ± 0.008
	11.0	19	169 ± 6.0	0.002 ± 0.004	0.006 ± 0.004
	12.5	25	138 ± 4.0	0.003 ± 0.003	0.010 ± 0.004
	14.0	14	541 ± 18	−0.001 ± 0.002	0.005 ± 0.003
	15.5	12	60 ± 2.2	−0.001 ± 0.002	0.004 ± 0.004
	17.1	11	34 ± 14	−0.001 ± 0.003	0.000 ± 0.002
	18.6	11	65 ± 2.4	−0.001 ± 0.002	0.002 ± 0.002
	20.1	10	80 ± 2.8	−0.001 ± 0.002	0.002 ± 0.003
	21.6	11	139 ± 4.0	−0.001 ± 0.003	0.002 ± 0.002
Summary: $\bar{x}$ ± 2s		14 ± 17	135 ± 296	0.000 ± 0.003	0.011 ± 0.025
Core Hole 3					
(12 m south of channel)	1.8	3	18 ± 1.0	0.004 ± 0.004	0.000 ± 0.004
	2.9	2	---	−0.002 ± 0.002	0.003 ± 0.003
	4.9	6	2.4 ± 0.8	−0.003 ± 0.003	−0.002 ± 0.003
	6.4	4	6.0 ± 1.2	−0.001 ± 0.002	−0.001 ± 0.003
	7.9	4	17 ± 1.0	0.000 ± 0.003	0.000 ± 0.003
	9.4	---	14 ± 1.0	0.000 ± 0.001	−0.001 ± 0.002
	11.0	7	13 ± 1.0	0.000 ± 0.004	0.017 ± 0.006
	12.5	8	13 ± 1.0	−0.002 ± 0.003	0.002 ± 0.004
	14.0	8	16 ± 1.0	0.000 ± 0.002	0.003 ± 0.004
	15.5	9	25 ± 1.2	−0.002 ± 0.001	0.015 ± 0.004
	17.1	9	35 ± 1.6	−0.003 ± 0.002	0.003 ± 0.004
	18.6	9	50 ± 2.0	−0.001 ± 0.001	0.010 ± 0.004
	20.1	10	44 ± 1.8	−0.001 ± 0.003	0.010 ± 0.004
	21.6	12	53 ± 2.0	−0.001 ± 0.001	0.022 ± 0.006
Summary: $\bar{x}$ ± 2s		7 ± 6	28 ± 39	−0.001 ± 0.003	0.006 ± 0.015
Core Hole 4					
(control)	1.8	5	4.5 ± 0.8	−0.002 ± 0.002	−0.002 ± 0.003
	3.4	5	1.6 ± 0.8	0.000 ± 0.003	−0.001 ± 0.003
	4.9	5	1.3 ± 0.6	---	---
	6.4	3	---	−0.001 ± 0.002	0.004 ± 0.003
Summary: $\bar{x}$ ± 2s		4 ± 2	2.5 ± 3.5	−0.001 ± 0.002	0.000 ± 0.006
Core Hole 5					
(Control)	1.8	3	6.0 ± 0.8	−0.002 ± 0.004	−0.004 ± 0.003
	3.4	3	1.7 ± 0.4	−0.002 ± 0.002	−0.001 ± 0.002
	4.9	2	---	0.000 ± 0.002	−0.001 ± 0.004
	6.4	5	3.8 ± 0.8	−0.001 ± 0.002	−0.003 ± 0.002
Summary: $\bar{x}$ ± 2s		3 ± 2	3.8 ± 4.3	−0.001 ± 0.002	−0.002 ± 0.003
Core Holes 4 and 5 (Control)					
Summary: $\bar{x}$ ± 2s		4 ± 2	3.0 ± 3.5	−0.001 ± 0.002	−0.001 ± 0.005

Notes: 1. One sample taken at each depth.
2. The ± value is twice the uncertainty for that analysis.

Table E-XLII

Most Recent Available Data from Samples Taken
Below Los Alamos Meson Physics' (TA-53) Lagoons

Analysis	Units	1983 Sampling Date	Sampling Location[a] 1	2	3	4	5	6	7	8
					Sediment					
^{7}Be	pCi/g	June	1500 ± 150	3100 ± 310	14 000 ± 1400	660 ± 70	1700 ± 170	560 ± 60	11 ± 1.2	-0.10 ± 0.25
^{7}Be	pCi/g	December	1900 ± 190	2700 ± 270	4300 ± 430	1700 ± 170	180 ± 18	40 ± 4	7.5 ± 0.8	0.59 ± 0.06
^{57}Co	pCi/g	June	97 ± 10	460 ± 46	450 ± 46	13 ± 1.3	110 ± 11	96 ± 10	3.7 ± 0.4	0.03 ± 0.02
^{57}Co	pCi/g	December	300 ± 30	550 ± 55	680 ± 68	250 ± 25	120 ± 12	30 ± 3.0	7.9 ± 0.8	0.14 ± 0.01
^{134}Cs	pCi/g	June	330 ± 32	470 ± 48	1220 ± 120	150 ± 15	550 ± 55	180 ± 18	8.0 ± 0.8	0.03 ± 0.03
^{134}Cs	pCi/g	December	340 ± 34	580 ± 58	1100 ± 110	180 ± 18	270 ± 27	67 ± 6.7	5.5 ± 0.6	0.18 ± 0.02
^{3}H	10^{-4} μCi/mℓ	June	4.3 ± 0.4	4.2 ± 0.4	4.3 ± 0.4	4.2 ± 0.4	2.4 ± 0.2	0.88 ± 0.09	0.18 ± 0.02	0.028 ± 0.004
^{3}H	10^{-4} μCi/mℓ	December	11 ± 1.1	10 ± 1.0	11 ± 1.1	9.7 ± 1.0	1.5 ± 0.2	0.035 ± 0.004	0.03 ± 0.004	0.042 ± 0.005
^{54}Mn	pCi/g	June	110 ± 11	240 ± 24	730 ± 73	150 ± 15	340 ± 34	86 ± 8.7	3.3 ± 0.3	0.061 ± 0.028
^{54}Mn	pCi/g	December	190 ± 19	350 ± 35	320 ± 32	82 ± 8.2	91 ± 9.1	32 ± 3.2	6.2 ± 0.6	0.19 ± 0.02
^{22}Na	pCi/g	June	5.4 ± 0.5	15 ± 1.6	5.5 ± 0.6	3.5 ± 0.4	6.7 ± 0.7	2.7 ± 0.3	0.92 ± 0.10	-0.22 ± 0.03
^{22}Na	pCi/g	December	4.4 ± 0.4	15 ± 1.5	4.8 ± 0.5	8.1 ± 0.8	7.4 ± 0.7	1.0 ± 0.1	1.1 ± 0.1	0.095 ± 0.010
^{83}Rb	pCi/g	June	200 ± 20	360 ± 36	230 ± 23	160 ± 16	350 ± 35	80 ± 8.0	2.0 ± 0.2	0.082 ± 0.040
^{83}Rb	pCi/g	December	43 ± 4.3	100 ± 10	52 ± 5.2	57 ± 5.7	55 ± 5.5	14 ± 1.4	6.3 ± 0.6	0.31 ± 0.03
					Water					
^{7}Be	10^{-6} μCi/mℓ	June	160 ± 16	1600 ± 160	460 ± 46	Dry	Dry	Dry	Dry	-0.043 ± 0.004
^{7}Be	10^{-6} μCi/mℓ	December	510 ± 51	520 ± 52	440 ± 44	420 ± 42	Dry	Dry	Dry	Dry
^{57}Co	10^{-6} μCi/mℓ	June	24 ± 2.4	130 ± 13	59 ± 6	Dry	Dry	Dry	Dry	-0.012 ± 0.001
^{57}Co	10^{-6} μCi/mℓ	December	15 ± 1.5	15 ± 1.6	14 ± 1.4	11 ± 1.1	Dry	Dry	Dry	Dry
^{134}Cs	10^{-6} μCi/mℓ	June	13 ± 1	100 ± 10	120 ± 12	Dry	Dry	Dry	Dry	-0.008 ± 0.001
^{134}Cs	10^{-6} μCi/mℓ	December	6.7 ± 0.7	9.5 ± 1.0	5.0 ± 0.5	3.1 ± 0.3	Dry	Dry	Dry	Dry
^{3}H	10^{-4} μCi/mℓ	June	4.3 ± 0.4	4.3 ± 0.4	4.3 ± 0.4	Dry	Dry	Dry	Dry	0.026 ± 0.004
^{3}H	10^{-4} μCi/mℓ	December	11 ± 1.1	11 ± 1.1	11 ± 1.1	11 ± 1.1	Dry	Dry	Dry	Dry
^{54}Mn	10^{-6} μCi/mℓ	June	24 ± 2.4	150 ± 15	60 ± 6	Dry	Dry	Dry	Dry	0.045 ± 0.005
^{54}Mn	10^{-6} μCi/mℓ	December	2.7 ± 0.3	3.7 ± 0.4	2.6 ± 0.3	2.2 ± 0.2	Dry	Dry	Dry	Dry
^{22}Na	10^{-6} μCi/mℓ	June	7.7 ± 0.8	8.3 ± 0.8	8.9 ± 0.9	Dry	Dry	Dry	Dry	0.001 ± 0.0001
^{22}Na	10^{-6} μCi/mℓ	December	6.5 ± 0.7	5.5 ± 0.6	5.9 ± 0.6	5.6 ± 0.6	Dry	Dry	Dry	Dry
^{83}Rb	10^{-6} μCi/mℓ	June	9.9 ± 1.0	50 ± 5	10 ± 1	Dry	Dry	Dry	Dry	0.010 ± 0.001
^{83}Rb	10^{-6} μCi/mℓ	December	2.0 ± 0.2	1.8 ± 0.2	1.8 ± 0.2	1.5 ± 0.2	Dry	Dry	Dry	Dry

[a]See Figure 31 for map of sampling locations. One sample per location.
[b]The ± value is the uncertainty (10%) of the analytical result.

APPENDIX F

DESCRIPTIONS OF TECHNICAL AREAS AND THEIR ASSOCIATED PROGRAMS

Locations of the 32 active technical areas (TA's) operated by the Laboratory are shown in Fig. 4. The main programs conducted at each are listed in this appendix.

TA-2, Omega Site: Omega West Reactor, an 8 megawatt nuclear research reactor, is located here. It serves as a research tool in providing a source of neutrons for fundamental studies in nuclear physics and associated fields.

TA-3, South Mesa Site: In this main technical area of the Laboratory is the Administration Building that contains the Director's office and administrative offices and laboratories for several divisions. Other buildings house the Central Computing Facility, Administration offices, Materials Department, the science museum, Chemistry and Materials Science Laboratories, Physics Laboratories, technical shops, cryogenics laboratories, a Van de Graaff accelerator, and cafeteria.

TA-6, Two Mile Mesa Site: This is one of three sites (TA-22 and TA-40 are the other two sites) used in development of special detonators for initiation of high explosive systems. Fundamental and applied research in support of this activity includes investigation of phenomena associated with initiation of high explosives, and research in rapid shock-induced reactions with shock tubes.

TA-8, GT Site (or Anchor Site West): This is a nondestructive testing site operated as a service facility for the entire Laboratory, It maintains capability in all modern nondestructive testing techniques for insuring quality of materials, ranging from test weapon components to checking of high pressure dies and molds. Principal tools include radiographic techniques (x-ray machines to 1 million volts, a 24-MeV betatron), radioactive isotopes, ultrasonic testing, penetrant testing, and electromagnetic methods.

TA-9, Anchor Site East: At this site fabrication feasibility and physical properties of explosives are explored. New organic compounds are investigated for possible use as explosives. Storage and stability problems are also studied.

TA-11, K-Site: Facilities are located here for testing explosive components and systems under a variety of extreme physical environments. The facilities are arranged so testing may be controlled and observed remotely, and so devices containing explosives or radioactive materials, as well as those containing nonhazardous materials, may be tested.

TA-14, Q-Site: This firing site is used for running various tests on relatively small explosive charges and for fragment impact tests.

TA-15, R-Site: This is the home of PHERMEX—a multiple cavity electron accelerator capable of producing a very large flux of x-rays for certain weapons development problems and tests. This site is also used for the investigation of weapon functioning and weapon system behavior in nonnuclear tests, principally by electronic recording means.

TA-16, S-Site: Investigations at this site include development, engineering design, pilot manufacture, environmental testing, and stockpile production liaison for nuclear weapon warhead systems. Development and testing of high explosives, plastics and adhesives, and process development for manufacture of items using these and other materials are accomplished in extensive facilities.

TA-18, Pajarito Laboratory Site: The fundamental behavior of nuclear chain reactions with simple, low-power reactors called "critical assemblies" is studied here. Experiments are operated by remote control and observed by closed circuit television. The machines are housed in buildings known as "kivas" and are used primarily to provide a controlled means of assembling a critical amount of fissionable materials. This is done to study the effects of various shapes, sizes, and configurations. These machines are also used as sources of fission neutrons in large quantities for experimental purposes.

TA-21, DP-Site: This site has two primary research areas, DP West and DP East. DP West is concerned with chemistry research. DP East is the high temperature chemistry and tritium site.

TA-22, TD Site: See TA-6.

TA-28, Magazine Area "A": Explosives storage area.

TA-33, HP-Site: A major high-pressure tritium handling facility is located here. Laboratory and office space for Geosciences Division related to the Hot Dry Rock Geothermal Project are also here.

TA-35, Ten Site: Nuclear safeguards research and development, which is conducted here, is concerned with techniques for nondestructive detection, identification, and analysis of fissionable isotopes. Research in reactor safety and laser fusion is also done here.

TA-36, Kappa Site: Various explosive phenomena, such as detonation velocity, are investigated here.

TA-37, Magazine Area "C": Explosives storage area.

TA-39, Ancho Canyon Site: Nonnuclear weapon behavior is studied here, primarily by photographic techniques. Investigations are also made into various phenomenological aspects of explosives, interaction of explosives, and explosions with other materials.

TA-40, DF-Site: See TA-6.

TA-41, W-Site: Personnel at this site are engaged primarily in engineering design and development of nuclear components, including fabrication and evaluation of test materials for weapons.

TA-43, Health Research Laboratory: The Biomedical Research Group does research here in cellular radiobiology, molecular radiobiology, biophysics, mammalian radiobiology, and mammalian metabolism. A large medical library, special counters used to measure radioactivity in humans and animals, and animal quarters for dogs, mice and monkeys are also located in this building.

TA-46, WA Site: Here applied photochemistry, which includes development of technology for laser isotope separation and laser-enchancement of chemical processes, is investigated. Solar energy research, particularly in the area of passive solar heating for residences, is done.

TA-48, Radiochemistry Site: Laboratory scientists and technicians at this site study nuclear properties of radioactive materials by using analytical and physical chemistry. Measurements of radioactive substances are made and "hot cells" are used for remote handling of radioactive materials.

TA-50, Waste Management Site: Personnel at this site have responsibility for treating and disposing of most industrial liquid waste received from Laboratory technical areas, for development of improved methods of folid waste treatment, and for containment of radioactivity removed by treatment. Radioactive liquid waste is piped to this site for treatment from many of the technical areas.

TA-51, Animal Exposure Facility: Here animals are exposed to nonradioactive toxic materials to determine biological effects of high and low exposures.

TA-52, Reactor Development Site: A wide variety of activities related to nuclear reactor performance and safety are done here.

TA-53, Meson Physics Facility: The Los Alamos Meson Physics Facility (LAMPF), a linear particle accelerator, is used to conduct research in the areas of basic physics, cancer treatment, materials studies, and isotope production.

TA-54, Waste Disposal Site: This is a disposal area for solid radioactive and toxic wastes.

TA-55, Plutonium Processing Facilities: Processing of plutonium and research in plutonium metallurgy are done here.

TA-57, Fenton Hill Site: This is the location of the Laboratory's Hot Dry Rock geothermal project. Here scientists are studying the possibility of producing energy by circulating water through hot, dry rock located hundreds of meters below the earth's surface. The water is heated and then brought to the surface to drive electric generators.

TA-58, Two Mile Mesa. Undeveloped technical area.

TA-59, Occupational Health Site: Occupational health and environmental science activities are conducted here.

APPENDIX G

PUBLICATIONS OF THE ENVIRONMENTAL SURVEILLANCE GROUP DURING 1983

N. Becker and R. Pettitt, "How to Improve Conventions and Oral Presentations," Civil Engineering **53** (12), 6 (December 1983).

W. W. Berg, P. D. Sperry, K. H. Rahn, and E. S. Gladney, "Atmospheric Bromine in the Arctic," Journal of Geophysical Research **88**, 6719-6736 (1983).

B. Bowen, J. Dewart, and I. Chen, "Stability Class Determination: A Comparison for One Site," in Proceedings of the Sixth Symposium on Turbulence and Diffusion, Massachusetts, March 22-25, 1983 (American Meteorological Society).

B. M. Bowen, T. E. Buhl, J. M. Dewart, W. R. Hansen, D. Talley, A. I. Chen, W. A. Olsen, and D. M. Van Etten, "Measurements and Modeling of Gamma Absorbed Doses Due to Releases from a Linear Proton Accelerator: Experimental Design and Preliminary Results," Proceedings of the Fourth DOE Environmental Protection Information Meeting, Denver, Colorado, December 7-9, 1982, CONF-821215, pp. 447-456.

T. E. Buhl and W. R. Hansen, "Estimating the Risks of Cancer Mortality and Genetic Defects Resulting from Exposures to Low Levels of Ionizing Radiation," Los Alamos National Laboratory report (in press).

Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1982," Los Alamos National Laboratory report LA9762-ENV (April 1983).

E. S. Gladney, M. K. Wallwork-Barber, and R. W. Ferenbaugh, "Enriched Uranium as an Activatable Tracer in Environmental Research," Journal of Radioanalytical Chemistry **78**, 209-212 (1983).

E. S. Gladney, C. E. Burns, and I. Roelandts, "1982 Compilation of Elemental Concentrations in Eleven USGS Rock Standards," Geostandards Newsletter **7**, 3-226 (1983).

E. S. Gladney, W. A. Sedlacek, and W. W. Berg, "Comparative Determination of Bromine and Iodine in Three Air Sampling Media Via Instrumental Thermal and Epithermal Neutron Activation Analysis," Journal of Radioanalytical Chemistry **78** (1), 213-225 (1983).

E. S. Gladney, D. R. Perrin, and W. E. Goode, "Quality Assurance for Environmental Analytical Chemistry at Los Alamos," Proceedings of the Fourth DOE Environmental Protection Information Meeting, Denver, Colorado, December 7-9, 1982, in CONF-821215, pp. 107-118.

T. C. Gunderson, T. E Buhl, R. Romero, and D. M. Van Etten, "An Environmental Study of Emissions from Testing of Shaped-Charge, Depleted Uranium Munitions," Los Alamos National Laboratory report LA-UR-83-373 (February 1983).

T. Gunderson, T. Buhl, R. Romero, and J. Salazar, "Radiological Survey Following Decontamination Activities Near the TA-45 Site," Los Alamos National Laboratory report LA-9831-MS (July 1983).

W. R. Hansen and J. C. Rodgers, "Risk Analyses for Shallow Land Burial and Greater Confinement of Alpha Contaminated Wastes," Nuclear and Chemical Waste Management **4**, 81-94 (1983).

D. L. Mayfield and W. R. Hansen, "Surface Reconnaissance Through 1980 for Radioactivity at Radioactive Waste Disposal Area G at the Los Alamos National Laboratory," Los Alamos National Laboratory report LA-9656-MS (March 1983).

R. J. Peters and E. S. Gladney, "Determination of Thorium-230 in CCRMP Reference Samples by Alpha Spectroscopy," Geostandards Newsletter **7**, 319-320 (1983).

R. Pettitt and N. Becker, "Mining Earth's Heat: Development of Hot Dry Rock Geothermal Reservoirs," in Innovations in Energy Development Related to Underground Mining, American Society of Civil Engineers preprint 83-034 (May 1983).

W. D. Purtymun, N. M. Becker, and M. Maes, "Water Supply at Los Alamos During 1981," Los Alamos National Laboratory report LA-9734-PR (May 1983).

W. D. Purtymun, R. W. Ferenbaugh, N. M. Becker, W. H. Adams, and M. Maes, "Water Quality in the Vicinity of Fenton Hill, 1981 and 1982," Los Alamos National Laboratory report LA-9854-PR (September 1983).

W. D. Purtymun, W. R. Hansen, and R. J. Peters, "Radiochemical Quality of Water in the Shallow Aquifer in Mortandad Canyon, 1967-1978," Los Alamos National Laboratory report LA-9675-MS (1983).

D. Van Etten and W. Olsen, "Delta-Count Rate-Monitoring System," Los Alamos National Laboratory report LA-9855-M (September 1983).

D. M. Van Etten, D. Talley, T. E. Buhl, and W. R. Hansen, "Capabilities of the Los Alamos National Laboratory's Environmental Emergency Response Vehicle," Proceedings of the Fourth DOE Environmental Protection Information Meeting, Denver, Colorado, December 7-9, 1982, CONF-821215, pp. 573-576.

GLOSSARY

alpha particle	A charged particle (identical to the helium nucleus) composed of two protons and two neutrons that is emitted during decay of certain radioactive atoms. Alpha particles are stopped by several centimeters of air or a sheet of paper.
activation products	In nuclear reactors and some high energy research facilities, neutrons and other subatomic particles that are being generated can produce radioactive species through interaction with materials such as air, construction materials, or impurities in cooling water. These "activation products" are usually distinguished, for reporting purposes, from "fission products."
background radiation	Ionizing radiation from sources other than the Laboratory. It may include cosmic radiation; external radiation from naturally occurring radioactivity in the earth (terrestrial radiation), air, and water; internal radiation from naturally occurring radioactive elements in the human body; and radiation from medical diagnostic procedures.
beta particle	A charged particle (identical to the electron) that is emitted during decay of certain radioactive atoms. Most beta particles are stopped by 0.6 cm of aluminum or less.
Concentration Guide (CG)	The concentration of a radionuclide in air or water that results in a whole body or organ dose in the 50th year of exposure equal to the Department of Enrgy's Radiation Protection Standard for external and internal exposures. This dose is calculated assuming the air is continuously inhaled or the water is the sole source of liquid nourishment for 50 years.
Controlled Area	Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and radioactive materials.
cosmic radiation	High energy particulate and electromagnetic radiations that originate outside the earth's atmosphere. Cosmic radiation is part of natural background radiation
curie (Ci)	A special unit of radioactivity. One curie equals 3.70×10^{10} nuclear transformations per second.

dose	A term denoting the quantity of radiation energy absorbed.
dose, absorbed	The energy imparted to matter by ionizing radiation per unit mass of irradiated material. (The unit of absorbed dose is the rad.)
dose, equivalent	A term used in radiation protection that expresses all types of radiation (alpha, beta, and so on) on a common scale for calculating the effective absorbed dose. It is the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)
dose, maximum boundary	The greatest dose commitment, considering all potential routes of exposure from a facility's operation, to a hypothetical individual who is in an Uncontrolled Area where the highest dose rate occurs. It assumes that the hypothetical individual is present for 100% of the time (full occupancy) and does not take into account shielding (for example, by buildings).
dose, maximum individual	The greatest dose commitment, considering all potential routes of exposure from a facility's operation, to an individual at or outside the Laboratory boundary where the highest dose rate occurs. It takes into account shielding and occupancy factors that would apply to a real individual.
dose, population	The sum of the radiation doses to individuals of a population. It is expressed in units of person-rem (for example, if 1000 people each received a radiation dose of 1 rem, their population dose would be 1000 person-rem.
dose, whole body	A radiation dose commitment that involves exposure of the entire body (as opposed to an organ dose that involves exposure to a single organ or set of organs).
exposure	A measure of the ionization produced in air by x or gamma radiation. (The unit of exposure is the roentgen.)
external radiation	Radiation originating from a source outside the body.
fission products	Those atoms created through the splitting of larger atoms into smaller ones, accompanied by release of energy.
gallery	An underground collection basin for spring discharges.

gamma radiation	Short-wavelength electomagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength (high energy), gamma radiation can cause ionization. Other electromagnetic radiation (microwaves, visible light, radiowaves, etc.) have longer wavelengths (lower energy) and cannot cause ionization.
gross alpha	The total amount of measured alpha activity without identification of specific radionuclides.
gross beta	The total amount of measured beta activity without identification of specific radionuclides.
ground water	A subsurface body of water in the zone of saturation.
half-life, radioactive	The time required for the activity of a radioactive substance to decrease to half its value by inherent radioactive decay. After two half-lives, one-fourth of the original activity remains ($1/2 \times 1/2$), after three half-lives, one-eighth ($1/2 \times 1/2 \times 1/2$), and so on.
internal radiation	Radiation from a source within the body as a result of deposition of radionuclides in body tissues by processes such as ingestion, inhalation, or implantation. Potassium-40, a naturally occurring radionuclide, is a major source of internal radiation in living organisms.
Laboratory	Los Alamos National Laboratory.
Maximum Contaminant Level (MCL)	Maximum permissible level of a contaminant in water that is delivered to the free flowing outlet of the ultimate user of a public water system (see Appendix A and Table A-III). The MCLs are specified by the Environmental Protection Agency.
mrem	Millirem (10^{-3} rem). See rem definition.
perched water	A ground water body above an impermeable layer that is separated from an underlying main body of ground water by an unsaturated zone.
person-rem	The unit of population dose, it expresses the sum of radiation exposures received by a population. For example, two persons each with a 0.5 rem exposure have received 1 person-rem. Also, 500 people each with an exposure of 0.002 rem have received 1 person-rem.
rad	A special unit of absorbed dose from ionizing radiation. A dose of 1 rad equals the absorption of 100 ergs of radiation energy per gram of absorbing material.

radiation	The emission of particles or energy as a result of an atomic or nuclear process.
Radiation Protection Standard	A standard for external and internal exposure to radioactivity as defined in Department of Energy Order 5480.1A, Chapter XI (see Appendix A and Table A-II in this report).
rem	The unit of radiation dose equivalent that takes into account different kinds of ionizing radiation and permits them to be expressed on a common basis. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the necessary modifying factors.
roentgen (R)	A unit of radiation exposure that expresses exposure in terms of the amount of ionization produced by x rays in a volume of air. One roentgen (R) is 2.58×10^{-4} coulombs per kilogram of air.
terrestrial radiation	Radiation emitted by naturally occurring radionuclides, such as ^{40}K, the natural decay chains ^{235}U, ^{238}U, or ^{232}Th, or from cosmic-ray induced radionuclides in the soil.
thermoluminescent dosimeter (TLD)	A material (the Laboratory uses lithium fluoride) that, after being exposed to radiation, luminesces upon being heated. The amount of light the material emits is proportional to the amount of radiation (dose) to which it was exposed.
tritium	A radionuclide of hydrogen with a half-life of 12.3 years. The very low energy of its radioactive decay makes it one of the least hazardous radionuclides.
tuff	Rock of compacted volcanic ash and dust.
Uncontrolled Area	An area beyond the boundaries of a Controlled Area (see definition of "Controlled Area" in this Glossary).
uranium, depleted	Uranium consisting primarily of ^{238}U and having less than 0.72 wt% ^{235}U. Depleted uranium generally contains less than 0.2 wt% ^{235}U. Except in rare cases occurring in nature, depleted uranium is manmade.
uranium, total	The amount of uranium in a sample assuming the uranium has the isotopic content of uranium in nature (99.27 wt% ^{238}U 0.72 wt% ^{235}U, 0.0057 wt% ^{234}U).

DISTRIBUTION LIST

Standard UC-41 (Health and Safety Distribution)
Department of Energy
Assistant Secretary for Policy, Environment, and Safety
J. W. Mares
Director of Operational Safety
D. Patterson
Director of Nuclear Safety
J. Maher
Group Leader of Environmental Protection
C. Welty
Office of Health and Environmental Research
C. W. Edington, Acting Associate Director
Office of Military Applications (2)
Major General W. W. Hoover, USAF
Technical InformationCenter
D. E. Bost
Albuquerque Operations Office (19)
P. M. Ramey
R. L. Miller
Los Alamos Area Office (3)
H. E. Valencia
W. Crismon, Jr.
Environmental Measurements Laboratory, New York
H. L. Volchok
E. P. Hardy, Jr.
Idaho Operations Office
M. M. Williamson
Nevada Operations Office
B. Church
Oak Ridge Operations Office
Robert Sleeman
Savannah River Operations Office
S. R. Wright
Department of Energy Contractors
Argonne National Laboratory
J. Sedlet
D. P. O'Neil
Battelle, Pacific Northwest Laboratories
J. P. Corley (2)
C. M. Unruh
E. C. Watson
Rockwell Hanford Operations
D. L. Uhl
Brookhaven National Laboratory
A. P. Hull
Rockwell International—Rocky Flats Plant
D. Hunt
D. Hornbacher
D. Bokowski
GE—Pinellas Plant
E. P. Forest
Lawrence Livermore National Laboratory
W. J. Silver
M. Gonzales
V. Noshkin
R. W. Buddemeier
Mound Laboratory
A. G. Barnett
D. G. Carfagno
H. E. Meyer
C. T. Bishop
Oak Ridge National Laboratory
J. A. Auxier
Pantex Plant
R. E. Alexander
Sandia National Laboratories, Albuquerque
L. W. Brewer
W. D. Burnett
G. Millard
Savannah River Laboratory
J. L. Crandall
J. E. Johnson
J. A. Harper

Other External

University of California
Environmental, Health, and Safety Office
Environmental Protection Agency
G. Sjoblum, ORP, Washington, DC
C. F. Costa, EMSL, Las Vegas, NV
D. Whittington, Region 6, Dallas, TX
New Mexico Health and Environment Dept.,
Environmental Improvement Division
S. Asher, Director
J. Millard
L. Lockie
F. Miera
C. Nylander
S. Hill
R. Holland
T. Buhl
New Mexico Energy and Minerals Department
O. A. Simpson III
U.S. Forest Service
E. Collins
Individuals
K. Schiager, University of Utah
J. White, Army Corps of Engineers
J. F. Daniel, US Geological Survey,
Albuquerque, NM
W. Schwarts, LFE, Richmond, CA
J. Mueller, CEP, Santa Fe, NM
New Mexico State Engineer, Santa Fe, NM
Ed Collins, Santa Fe National Forest
Los Alamos, NM
Superintendent, Bandelier National
Monument, Los Alamos, NM
T. K.Vosniakos, Physics Laboratory,
Institute of Technology, Greece
Robert Faus, TP Pump and Pipe Co.
Albuquerque, NM
Media
The Monitor, Los Alamos, NM
The Chronicle, Los Alamos, NM
The New Mexican, Santa Fe, NM
The Reporter, Santa Fe, NM
The Rio Grande Sun, Española, NM
Albuquerque Journal, Albuquerque, NM
Albuquerque Tribune, Albuquerque, NM
New Mexico Independent, Albuquerque, NM
KRSN Radio, Los Alamos, NM
New Mexico Congressional Delegation
Senator Pete V. Domenici
Senator J. Bingaman
Representative Manuel Lujan, Jr.
Representative Joseph Skeen
Representative William Richardson
Elected Officials
City of Española
C. Thompson, Major
City of Santa Fe
L. Montano, Mayor
County of Los Alamos
Sidney Singer, Chairman of Los Alamos Council
Stephen Stoddard, State Senator
Vernon Kerr, State Representative
New Mexico Office of Indian Affairs
Bureau of Indian Affairs
Administrative Manager
Eight Northern Pueblos
Governor C. Vigil, Nambe Pueblo
Governor B. Duran, Picuris Pueblo
Governor T. Talachy, Pojoaque Pueblo
Governor J. Mountain, San Ildefonso Pueblo
Governor R. Martinez, San Juan Pueblo
Governor J. Tafoya, Santa Clara Pueblo
Governor B. Mondragon, Taos Pueblo
Governor J. Hena, Tesuque Pueblo
Mesa Public Library, Los Alamos

Internal Distribution

Director's Office
D. M. Kerr, Director
C. Adams, Associate Director for Technical Support
J. H. Breen, Public Affairs Officer (2)
Health, Safety, and Environment Division Office (10)
J. Aragon
L. Backwell
J. Dummer
G. Voelz
D. Lee
Group HSE-1, Health Physics (6)
A. Valentine
J. M. Graf
R. A. Jalbert
Group HSE-3, Safety
W. Courtright

Group HSE-5, Industrial Hygiene
J. O. Jackson
Group HSE-7, Waste Management
L. C. Borduin
L. A. Emelity
J. R. Buchholz
M. L. McCorkle
J. Warren
Group HSE-8, Environmental Surveillance Group (20)
W. R. Hansen
A. K. Stoker
Group HSE-9, Health and Environmetnal Chemistry
E. Gladney
Group HSE-10, Chemistry Health Protection
R. Stafford
Group HSE-11, Accelerator Health Protection
J. Miller

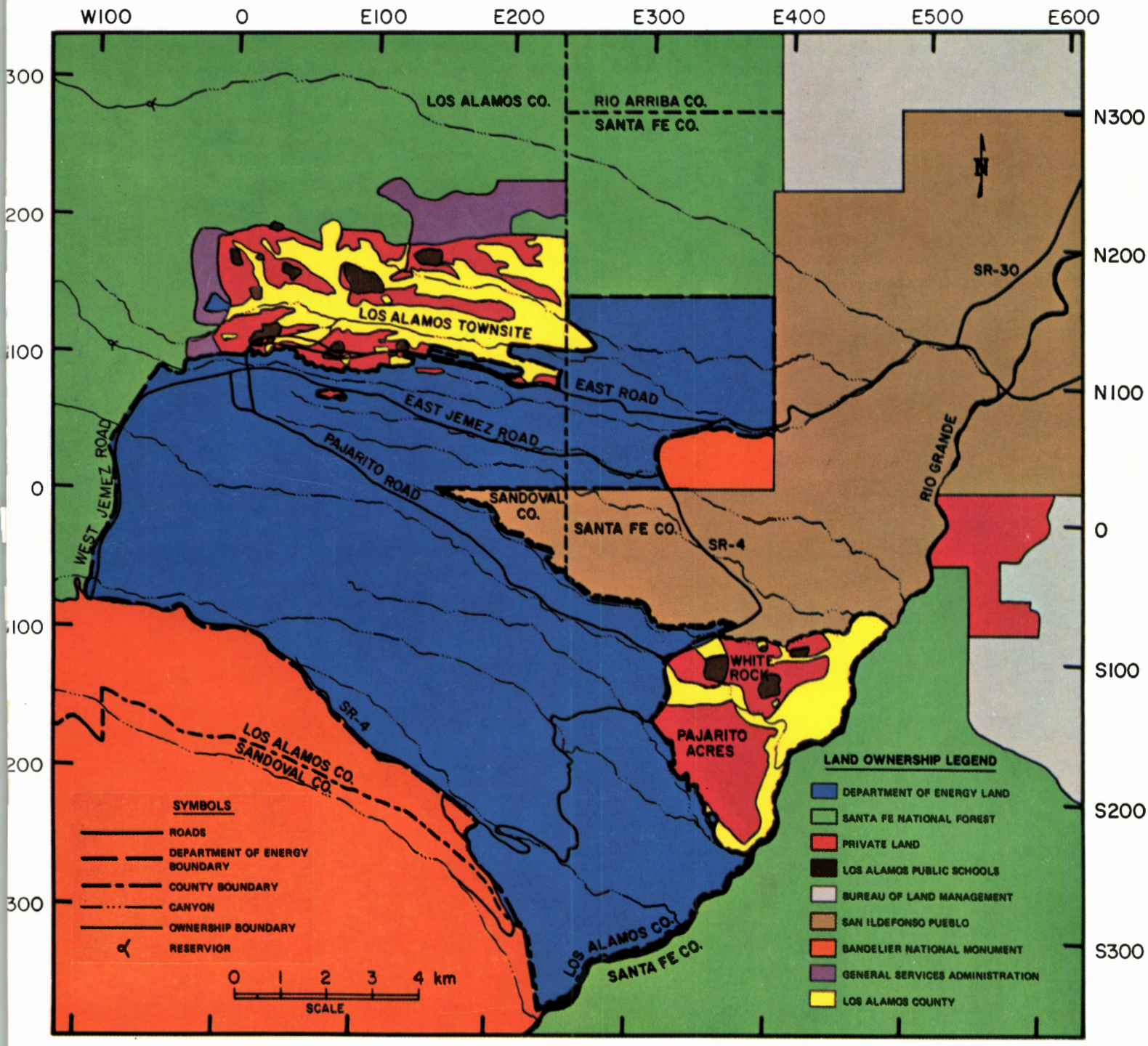
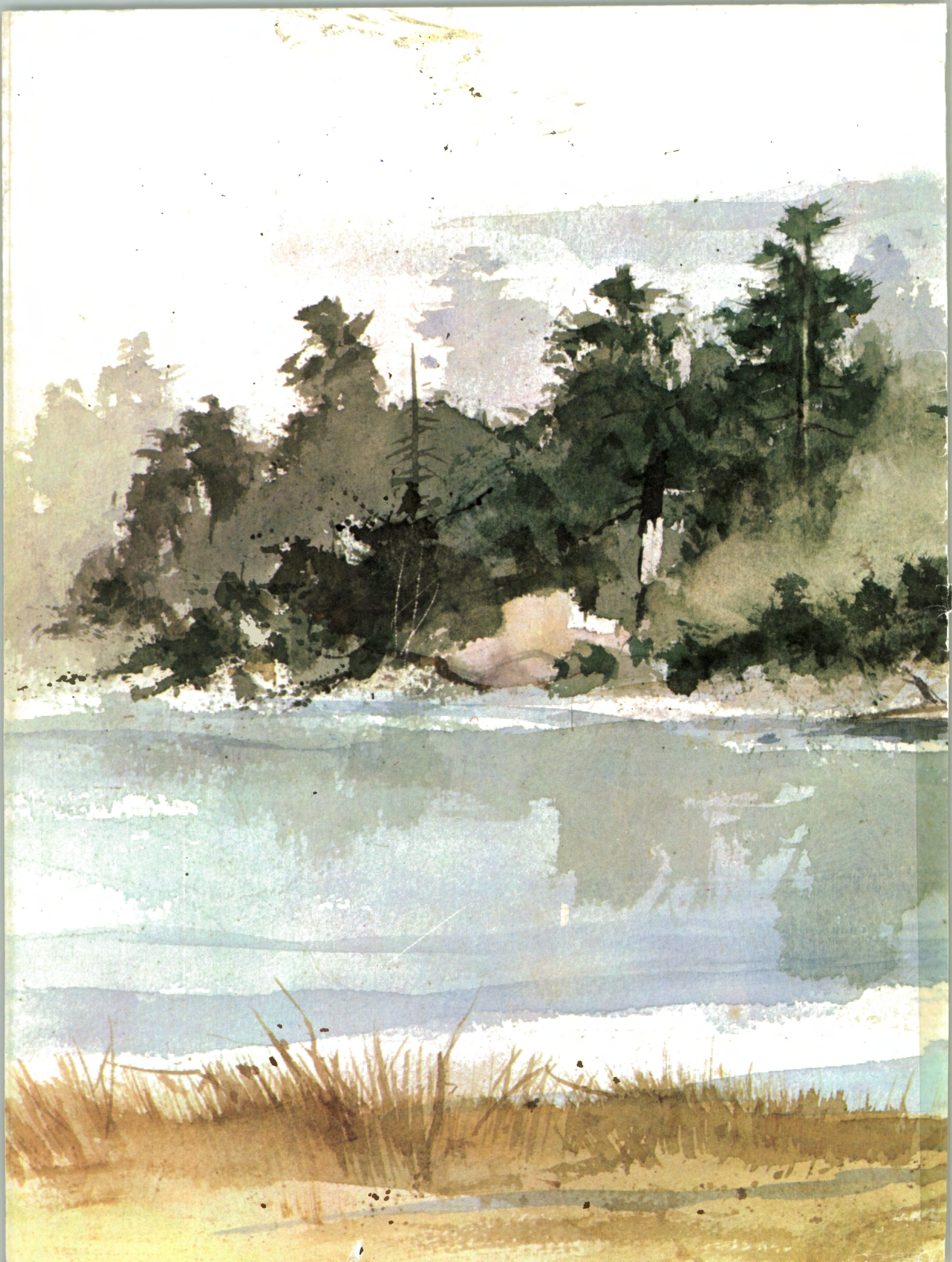
Group IS-1, Publications
C. Rodriguez
Group IS-4, Library Services (15)
Group IS-6, Technical Information (2)
Group LS-6, Life Science (8)
J. G. Steger
C. L. Reynolds
Group ENG-11
R. Crombie
D. Sneesby
Laboratory Environmental Review Committee (LERC)
F. L. Menlove
R. H. Miller
W. Hansen
D. L. Houck
W. Pelzer
G. L. Bergman

Printed in the United States of America
Available from
National Technical Information Service
US Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Microfiche (A01)

Page Range	NTIS Price Code	Page Range	NTIS Price Code	Page Range	NTIS Price Code	Page Range	NTIS Price Code
001-025	A02	151-175	A08	301-325	A14	451-475	A20
026-050	A03	176-200	A09	326-350	A15	476-500	A21
051-075	A04	201-225	A10	351-375	A16	501-525	A22
076-100	A05	226-250	A11	376-400	A17	526-550	A23
101-125	A06	251-275	A12	401-425	A18	551-575	A24
126-150	A07	276-300	A13	426-450	A19	576-600	A25
						601-up*	A99

*Contact NTIS for a price quote.



Land ownership in Los Alamos vicinity.