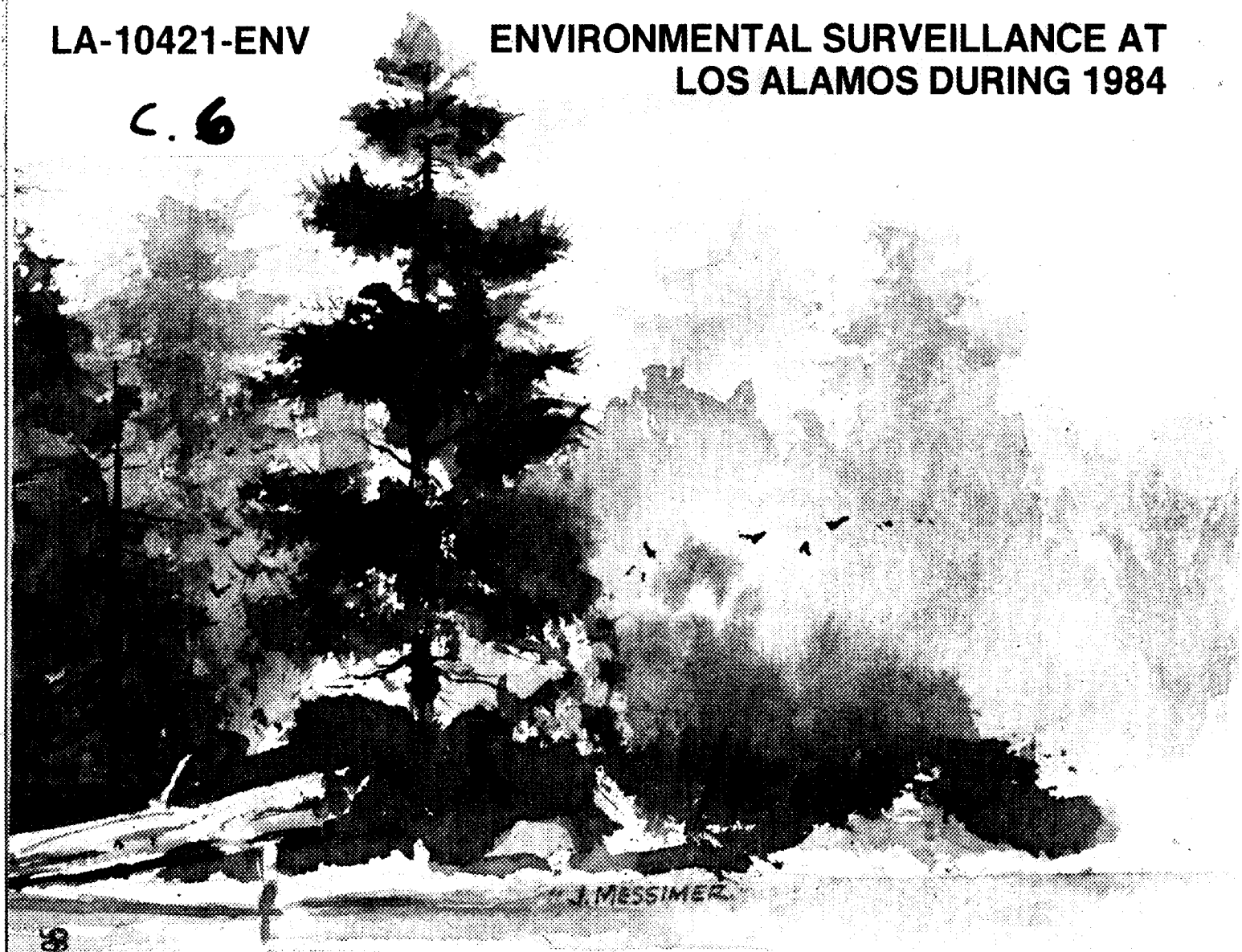
LA-10421-ENV

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1984



Los Alamos
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.

LA-10421-ENV

UC-41
Issued: April 1985

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1984

Environmental Surveillance Group

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

The four most recent reports in this unclassified series are LA-8810-ENV, LA-9349-ENV, LA-9762-ENV, and LA-10100-ENV.

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 Executive Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for this year. Emphasis is on the significance of findings and environmental regulatory compliance. A glossary is in the back.

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 (Description of technical Areas and Their Associated Programs) may also be helpful.

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

4. Scientist with Comprehensive Interest. Read Part I, the Executive Summary, which describes the Laboratory's environmental programs and summarizes environmental data for this year. 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 (HSE-8)
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 HSE-8 include:

Thomas Gunderson, Group Leader
Alan Stoker, Deputy Group Leader
Melvin McCorkle, Assistant Group Leader
John Ahlquist
Phyllis Baldwin
Naomi Becker
Brent Bowen
George Brooks
Thomas Buhl
Ili Chen
Jean Dewart
Kathy Derouin
Jane Doolen
Susan Duffy
Randy Evans
Roger Ferenbaugh
Terelene Foxx
Lynn Fritz
Anthony Gallegos
Robert Gonzales
Carla Jacquez
Keith Jacobsen
Mary Lou Keigher
Eddie Lujan
Max Maes
Maida Martinez
Donald Mayfield
Frank Montoya
David Nochumson
Colleen Olinger
William Olsen
William Purtymun
Kenneth Rea
Richard Romero
John Salazar
Diane Smith
David Snow
Charlie Steen
Daniel Talley
Gail Tierney
Michael Trujillo
Donald Van Etten
Robert Vocke
Ralph Ward
Walter Wenzel
James White

Kathy Derouin and Mary Lou Keigher did the wordprocessing and assembly of this report in a very professional manner. Environmental data was provided by the following Groups in the Laboratory's Health, Safety, and Environment Division: Radiation Protection (HSE-1), Industrial Hygiene (HSE-5), Waste Management (HSE-7), Health and Environmental Chemistry (HSE-9), Accelerator Health Protection (HSE-11), and Environmental Sciences (HSE-12).

CONTENTS

FIGURES

TABLES

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1984

by

ENVIRONMENTAL SURVEILLANCE GROUP

ABSTRACT

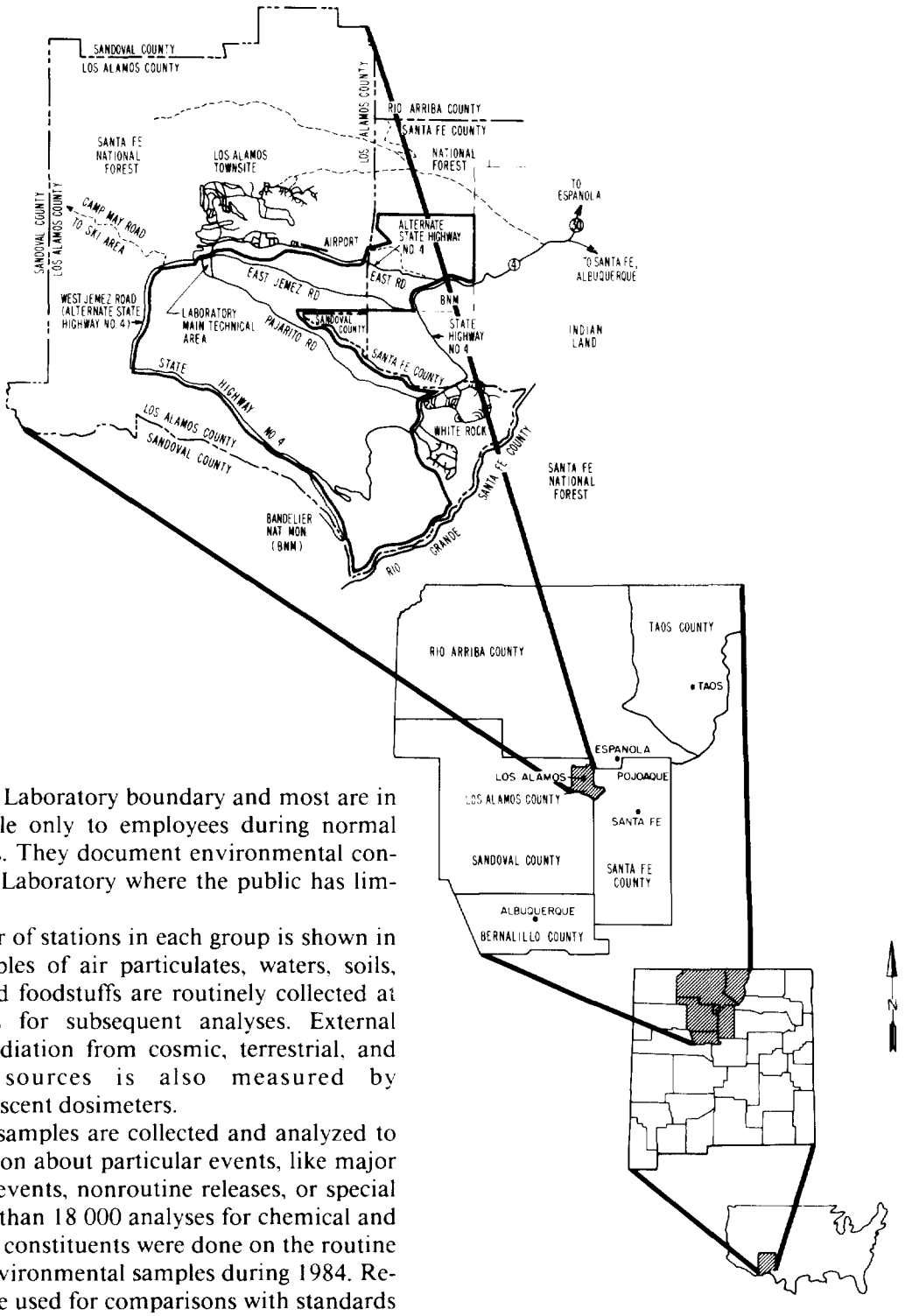
This report describes the environmental surveillance program conducted by the Los Alamos National Laboratory during 1984. Routine monitoring for radiation and radioactive or chemical substances is conducted on the Laboratory site and in the surrounding region to determine compliance with appropriate standards and permit early identification of possible undesirable trends. Results and interpretation of data for 1984 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 environemtnal 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. If an undesirable trend is discovered, then a more detailed environmental study is done to determine the extent of the problem and to provide the basis for specific remedial actions. The monitoring program also helps fulfill the Laboratory's policy to protect the public, employees, and environment from any harm that could be caused by Laboratory activities and to reduce negative environmental impacts to the greatest degree practicable. Environmental monitoring information complements data on specific releases, such as those from radioactive liquid waste treatment plants and stacks at nuclear research facilities.

Monitoring and sampling locations for various types of measurements are organized into three groups: (1) 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 of potential influence of Laboratory operations. (2) Perimeter stations are located within about 4 km (2.5 mi) of the Laboratory boundary and many are in residential and community areas. They document conditions in areas regularly occupied by the public and potentially affected by Laboratory operations. (3) Onsite stations



are within the Laboratory boundary and most are in areas accessible only to employees during normal working hours. They document environmental conditions at the Laboratory where the public has limited access.

The number of stations in each group is shown in Table I. Samples of air particulates, waters, soils, sediments, and foodstuffs are routinely collected at these stations for subsequent analyses. External penetrating radiation from cosmic, terrestrial, and Laboratory sources is also measured by thermoluminescent dosimeters.

Additional samples are collected and analyzed to gain information about particular events, like major surface unoff events, nonroutine releases, or special studies. More than 18 000 analyses for chemical and radiochemical constituents were done on the routine and special environmental samples during 1984. Resulting data are used for comparisons with standards and background levels, dose calculations, and other interpretations.

Fig. 1. Regional location of Los Alamos.

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	32	34
Soils and sediments	16	16	32
Foodstuffs	10	8	11

[a]An additional 22 stations for the water supply and 33 special surface and ground water stations related to the Fenton Hill Geothermal Program were also sampled and analyzed as part of the monitoring program.

B. Summary of Radiation Monitoring Data

1. Radiation Doses. Calculated individual whole body radiation doses to the public attributable to Laboratory operations are compared with 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 7 years are shown in Fig. 2. These estimated doses have historically been less than 4% of the 500 mrem/yr standard. In 1984 the estimated maximum individual dose was 6.2% of the Radiation Protection Standard. This dose resulted mostly from airborne emissions from the Los Alamos Meson Physics Facility (a linear particle accelerator).

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 25% of the dose from naturally occurring radioactivity in Los Alamos in 1984.

2. Significance of Radiation Doses. Estimates of the added risk of cancer were calculated to provide a perspective for comparing the significance of radiation exposures. Increases in risk estimated for average individual exposures to ionizing radiation from 1984 Laboratory operations are in Table II, along with estimated incremental risks from natural and medical diagnostic radiation. The incremental cancer risks to residents of Los Alamos townsite due to 1984 Laboratory operations was estimated to be 1 chance in 20 000 000. This risk is less than 0.6% of the 1 chance in 26 000 cancer risk from natural background radiation and the 1 chance in 110 000 risk from medical radiation.

The potential Laboratory contribution to cancer risk is small when compared with overall cancer risks. The overall lifetime risks in the United States of contracting some form of cancer is 1 chance in 4. The lifetime risk of cancer mortality is 1 chance in 5.

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

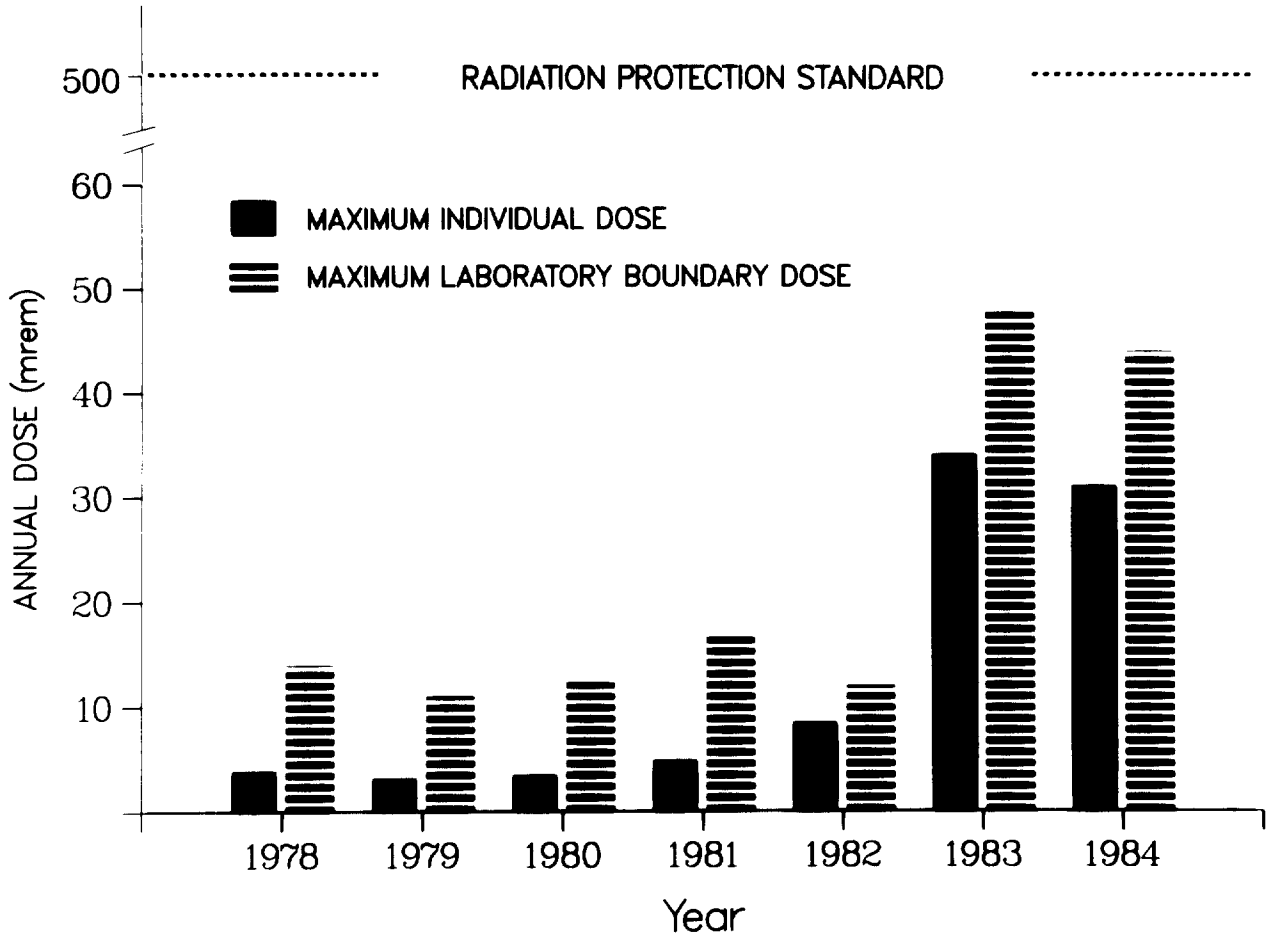


Fig. 2. Summary of estimated maximum individual and maximum Laboratory boundary doses (excluding contributions from cosmic, terrestrial, and medical diagnostic sources) from Laboratory operations.

particle accelerator) measured 44 ± 2 mrem/yr (excludes background radiation from cosmic and terrestrial sources), which is less than 10% 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 improvements to the beam stop begun in 1984 are designed to reduce the amount of airborne activation products generated by the accelerator.

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 TLD Network. No measurements at the regional or perimeter locations showed any statistically distinguishable increase in radiation that 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 ten inactive low-level radioactive 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 active site were caused by handling and storing operations.

Table II

Added Individual Lifetime Cancer Mortality Risks Attributable to 1984 Radiation Exposure

Exposure Source	Incremental Dose (mrem) Used in Risk Estimate	Added Risk (Chance) to an Individual of Cancer Mortality
Average Exposure from Laboratory Operations		
Los Alamos Townsite	0.50	1 in 20 000 000
White Rock Area	0.26	1 in 38 000 000
Natural Radiation		
Cosmic, Terrestrial, Self-Irradiation, and Radon Exposure		
Los Alamos Townsite	125[a]	1 in 26 000[b]
White Rock Area	116[a]	1 in 27 000[b]
Medical X-Rays (Diagnostic Procedures)		
Average Whole Body Exposure	92	1 in 110 000

[a]A lung exposure of 0.2 WLM was used to estimate the risk from inhaling ^{222}Rn and its decay products.
[b]The risks from whole body natural radiation were estimated to be 1 chance in 80 000 in Los Alamos and 1 chance in 86 000 in White Rock. The risk of lung cancer from radon exposure was estimated to be 1 chance in 38 000 for both locations.

4. Radioactivity in Air and Water

a. Introduction. Measurements of radioactivity in air and water are compared with the Department of Energy's Concentration Guides (see Appendix A). The Concentration Guides are concentrations of radioactivity in air breathed continuously or water that is drunk during an entire year that result in whole body or organ doses equal to the Department of Energy's Radiation Protection Standards, which are standards for external and internal exposure to radioactivity (see Appendix A). The annual averages of the radionuclides in air and water potentially affected by Laboratory operations were all less than 1% of the Concentration Guides during 1984.

b. Radioactivity in Air. Air is routinely sampled for tritium, americium, plutonium, uranium, and gross beta activity. Only the atmospheric tritium concentrations showed any measurable impact from radionuclides due to Laboratory operations. The annual average concentration of tritium, along with those of the other constituents measured, was much less than 1% of the Concentration Guides and posed no environmental or health problem in 1984.

c. Radioactivity in Water. Surface and ground waters are monitored to detect 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. These concentrations are insignificant fractions of the Concentration Guides. These onsite waters are not a source of industrial, agricultural, or municipal water supplies. The radioachemical quality of water from regional, perimeter, water supply, and onsite areas (where no effluents are or have been released) show no significant effects from effluent releases from the Laboratory.

The water supply met all applicable Environmental Protection Agency radiochemical and chemical standards. The integrity of geological formations

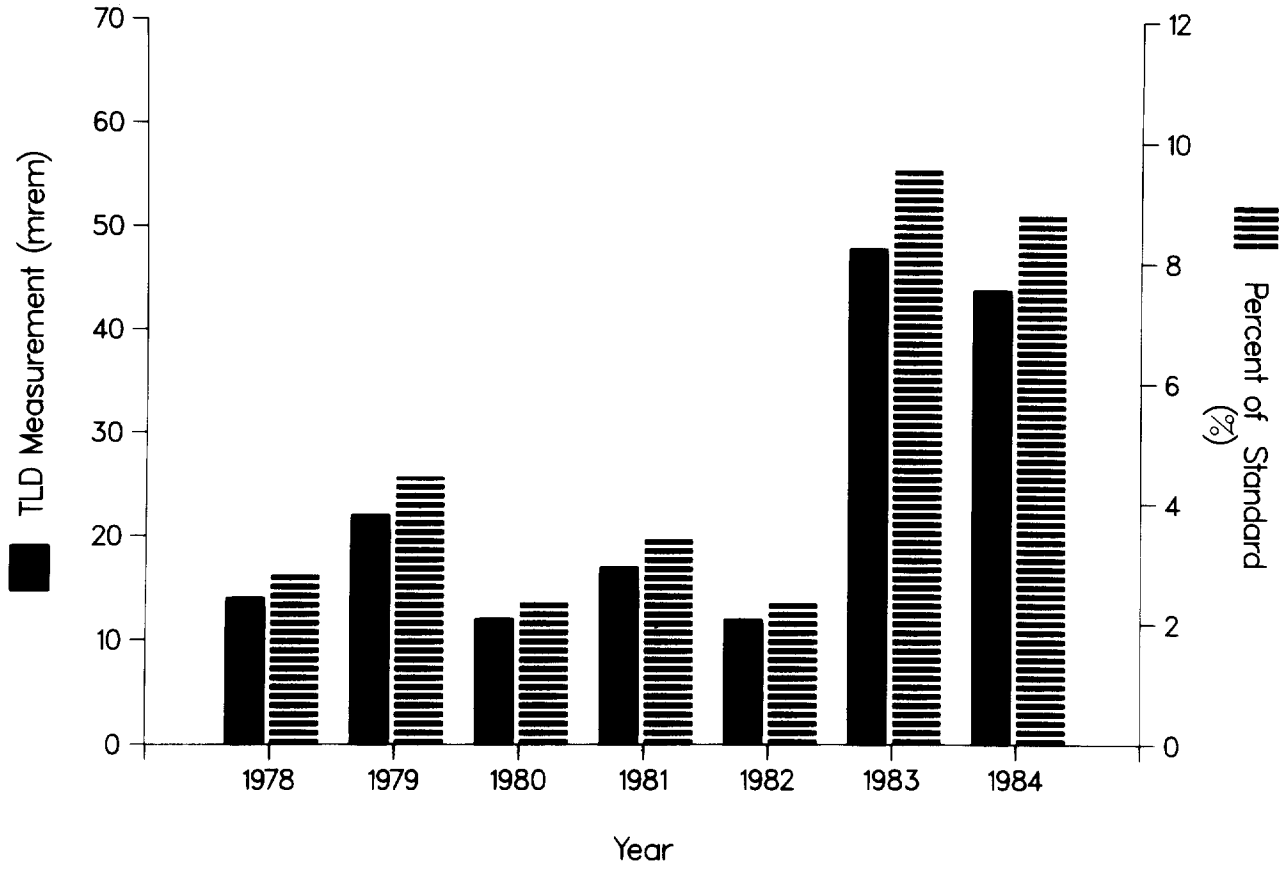


Fig. 3. Annual above-background radiation TLD measurements (and TLD measurements as per cent of standard) due to operation of the Los Alamos Meson Physics Facility.

protecting the deep ground water aquifer was confirmed by lack of any measurements indicative of radioactive 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 data on less direct natural processes that could result in exposures to people. Estimated doses potentially resulting from these processes or pathways, such as resuspension of dust by wind 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 hydrological transport of 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 sources or worldwide fallout. The low levels of cesium, plutonium, and strontium in Mortandad Canyon are from treated liquid effluents from a waste treatment plant. No radioactivity on sediments or in water has been measured in sampling locations past the Laboratory boundary.

Small amounts of radioactivity on sediments in Pueblo Canyon (from pre-1964 effluents) and upper Los Alamos Canyon (from 1952 to current treated effluents) have been transported during runoff events to the Rio Grande. Theoretical estimates, confirmed by measurements, show the incremental effect on Rio Grande sediments from this transported radioactivity is insignificant when compared with concentrations of radioactivity in soils and sediments attributable to worldwide fallout.

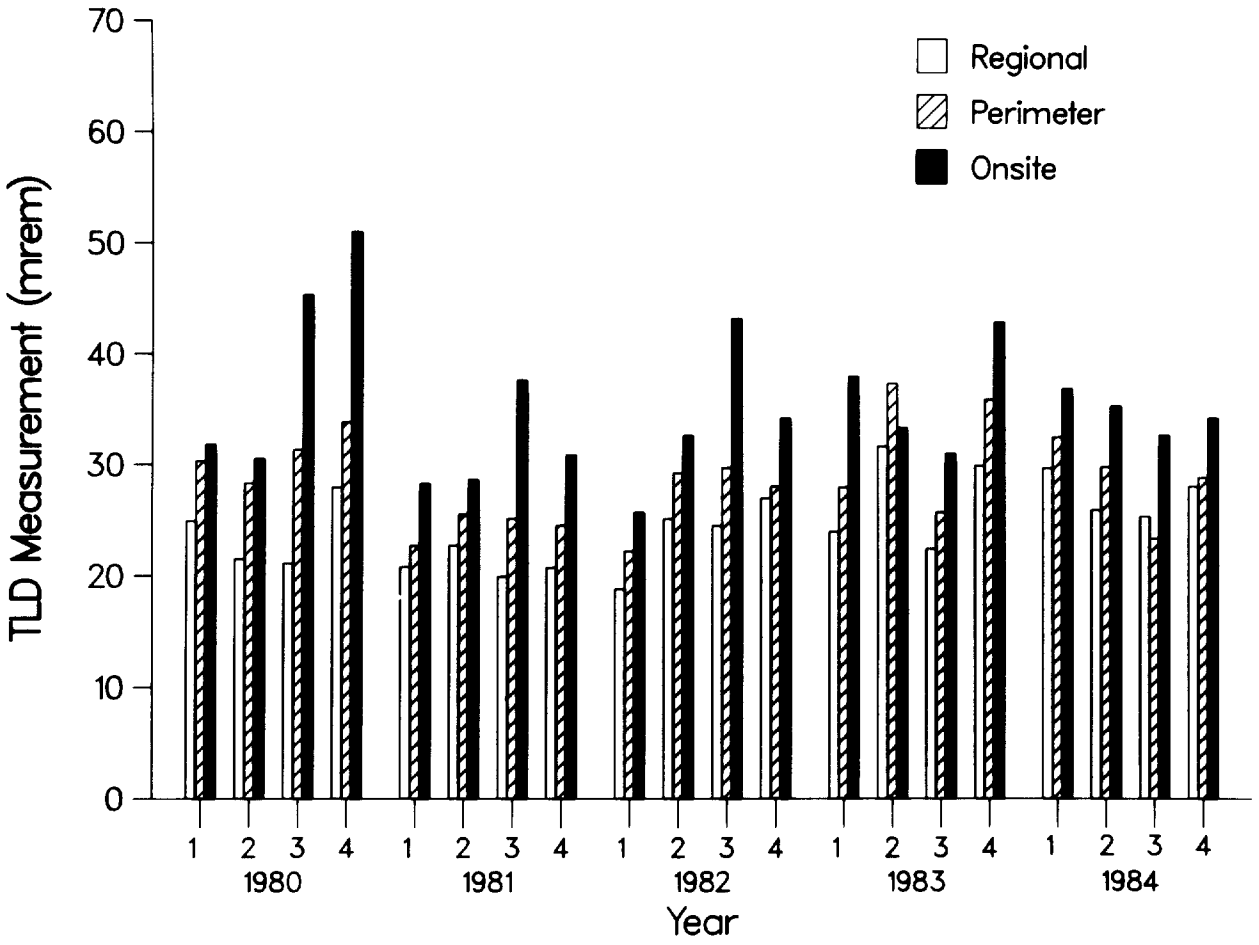


Fig. 4. Quarterly radiation TLD measurements (including contributions from cosmic, terrestrial, and Laboratory radiation sources) for regional, perimeter, and onsite locations.

Most fruit, vegetable, fish, bee, and honey samples from regional locations showed no radioactivity distinguishable from that attributable to natural sources or worldwide fallout. Some fruit samples from onsite locations had slightly elevated tritium concentrations. These levels were less than 1% of the Department of Energy's Concentration Guide for tritium in water (there are no Concentration Guides for fruits). The Laboratory released about 15 000 Ci of tritium in 1984 (see Table III).

C. Environmental Regulatory Compliance

1. Airborne Emissions

a. Radioactive. Airborne radioactive emissions were monitored as released from 86 points at the Laboratory. The results are summarized in Table III. Data for the Los Alamos Meson Physics Facility (LAMPF) show an apparent increase of about 60% (about 270 000 Ci more) in total radioactivity released during 1984 versus 1983. All but 20% of this increase is attributed to an instrument calibration error. The LAMPF stack monitor was calibrated incorrectly for an undetermined length of time and produced readings that were about 40% low in 1983. The balance of the increase was primarily due to increased operating levels and longer operating times at LAMPF. Airborne emissions from LAMPF are mostly short-lived (2 to 20 minute half-lives) activation products.

b. Nonradioactive. Operations at the Laboratory are conducted to comply with New Mexico (Air Quality Control Regulations, Source Registration,

Table III

Comparison of 1983 and 1984 Radioactive Releases from the Laboratory

Airborne Stack Emissions

Radioactive Constituent	Units	Activity Released 1983	Activity Released 1984	Ratio [1984/1983]
^{241}Am	μCi	0.095	0	0.4
^{41}Ar	Ci	418	335	0.8
^{3}H	Ci	7 847	14 869	1.9
^{131}I	μCi	83	73	0.9
^{32}P	μCi	2.7	33	12.2
$^{238,239,240}Pu$	μCi	113	140	1.2
U	μCi	888	1 205	1.4
Gaseous Mixed Activation Products	Ci	461 111	734 111	1.6
Mixed Fission Products	μCi	1 580	1 617	1.0
Particulate/Vapor Activation Products	Ci	2 640	2 500	0.9
Total	Ci	472 753	751 815	

Liquid Effluents

Radioisotopes	Activity Released (mCi) 1983	Activity Released (mCi) 1984	Ratio [1984/1983]
$^{238,239,240}Pu$	53.3	14.4	0.3
^{241}Am	38.4	9.0	0.2
$^{89,90}Sr$	59.3	269	4.5
^{3}H	10 350	46 942	4.5
^{137}Cs	45	19.7	0.4
^{234}U	2.1	7.4	3.5
Total	10 548	47 262	

Source Permitting, Emission Limits, Ambient Air Quality Standards) and federal (Clean Air Act, National Emission Standards for Hazardous Air Pollutants) air quality standards. The power plant, steam plants, beryllium shop, explosives burning and detonation, and asbestos removal operations all met the relevant regulations. Two air quality audits by the New Mexico Environmental Improvement Division and the Environmental Protection Agency in 1984 revealed no significant air pollution problems.

2. Water

a. Radioactive Effluents. Liquid effluents containing low levels of radioactivity were routinely released from two waste treatment plants and one sanitary sewage lagoon system. Effluent quality at all three discharge points was well below the Department of Energy's Concentration Guides for Controlled Areas. The only noticeable trend was higher radionuclide concentrations in the Los Alamos

Meson Physics Facility's (LAMPF, TA-53) effluent. This increase is due to higher operating levels and longer operating times at LAMPF.

b. Safe Drinking Water Act. Municipal and industrial water supply for the Laboratory and community is from 16 deep wells and 1 gallery (collection system fed by springs). The wells range in depth from 265 m to 942 m. The chemical and radiochemical quality of the water easily met the Environmental Protection Agency's National Interim Primary Drinking Water Standards (40 CFR 141) in 1984.

c. Clean Water Act. The Clean Water Act sets water quality standards and effluent limitations. The two primary programs in effect at the Laboratory to comply with the Clean Water Act are the National Pollutant Discharge Elimination System (NPDES) and the Spill Prevention, Controls and Countermeasures programs (SPCC).

The NPDES requires permits for nonradioactive constituents at all point source discharges. A single NPDES permit for the Laboratory that authorizes liquid effluent discharges from 99 industrial outfalls and 11 sanitary sewage treatment plants was issued in April 1982. It expires in September 1986. The Laboratory was in compliance with the NPDES permit in about 94% of the analyses done on samples collected for compliance monitoring.

The SPCC provides for cleanup of spills and requires preparation of a SPCC plan. The Laboratory has many elements that are required in a SPCC plan and is currently planning to assemble an official SPCC plan.

3. Solid Waste

a. Resource Conservation and Recovery Act. The Resource Conservation and Recovery Act (RCRA) is a comprehensive program to regulate hazardous wastes from generation to ultimate disposal. It regulates nonradioactive hazardous wastes and mixed wastes. Mixed wastes contain both nonradioactive hazardous materials and radioactive materials. The Environmental Protection Agency is in the process of transferring complete responsibility for RCRA to New Mexico's Environmental Improvement Division (EID). The EID cited the Laboratory with two RCRA Notices of Violation (NOVs) in 1984. The Laboratory responded to the NOVs and is preparing documentation to comply with all RCRA requirements.

b. Toxic Substances Control Act. The Toxic Substances Control Act (TSCA) regulates the manufacture, processing, distribution, use, storage, and labeling of chemical substances, including polychlorinated biphenyls (PCBs). The Laboratory has Environmental Protection Agency authorization to bury packaged PCB wastes at its Chemical Waste Landfill and burn PCB wastes at its Controlled Air Incinerator (99.9999% combustion efficiency). The Laboratory is in compliance with TSCA regulations.

c. Comprehensive Environmental Response, Compensation, and Liability Act. The Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA) manadated clean up of nonradioactive toxic and hazardous contaminants at closed and abandoned hazardous waste sites. Laboratory compliance activities related to CERCLA are being done as part of a Site Characterization Program that was begun in 1983. The Site Characterization program is evaluating all technical and waste disposal areas at the Laboratory for possible environmental contamination by radioactive and nonradioactive materials. Remedial actions will be taken where appropriate. During 1984 a CERCLA hazard ranking was done on four sites within the Laboratory. A site visit for CERCLA was made by the Environmental Protection Agency (EPA) in December. Plans to address CERCLA issues were considered to be appropriate by the EPA.

d. Federal Insecticide, Fungicide, and Rodenticide Act. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires registration of all pesticides, restricts use of certain pesticides, recommends standards for pesticide applicators, and regulates disposal and transportation of pesticides. A pesticide is defined as any substance intended to prevent, destroy, repel, or mitigate pests.

e. Environmental Monitoring at Radioactive Waste Management Areas. Environmental monitoring is done at one active and ten inactive radioactive waste management areas at the Laboratory. The general public is excluded from these areas because they are controlled-access sites. At the active disposal area there are transient elevated levels of external penetrating radiation from handling and storing the waste before burial. There also is some transport by surface runoff of low-level contamination from the active and several of the inactive disposal areas into

controlled-access canyons. The surface contamination levels are about 30 times below the Department of Energy's remedial action guidelines.

4. Environmental Evaluations

a. National Environmental Protection Act Documentation. The Laboratory Environmental Review Committee reviews environmental documentation required by National Environmental Policy Act legislation. The Committee also identifies and reviews other environmental items of interest or concern to the Laboratory. An Environmental Evaluations Coordinator assists the Committee by helping prepare the required documentation, which usually is an Action Description Memorandum (an environmental assessment document). The Laboratory Environmental Review Committee approved 49 Action Descriptions Memorandums in 1984.

b. Archaeological and Historical Protection. The Laboratory Environmental Evaluations and Quality Assurance programs provide protection as mandated by law for the over 450 archaeological and historical resources on Laboratory land. Mitigation of any unavoidable adverse effect from Laboratory activity is determined in consultation with the New Mexico State Historical Preservation Office. One mitigation effort in 1984 was approved by state and federal authorities. The Laboratory conducted salvage fieldwork of a homesteading complex (New Mexico Laboratory of Anthropology No. 16806), dismantled a homesteader's cabin (the Romero Cabin), and donated it to the Los Alamos Historical Society. It will be reconstructed near the Los Alamos County Museum. The Laboratory conducted one public archaeological tour during 1984 at the Nakemuu ruin.

II. BACKGROUND ON LOS ALAMOS

A. 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) at their eastern termination 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 Department of Energy controls the area within the Laboratory boundary and has the option to completely restrict access. This control can be instituted when necessary.

B. 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 is a reserve for future structure locations. The Long Range Site Development Plan (Engineering 1982) for Laboratory lands helps assure adequate planning for the best possible future uses of available land.

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 various cultural resource protection acts.

C. Geology-Hydrology

Most of the finger-like mesas in the Laboratory area are formed in 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 m (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

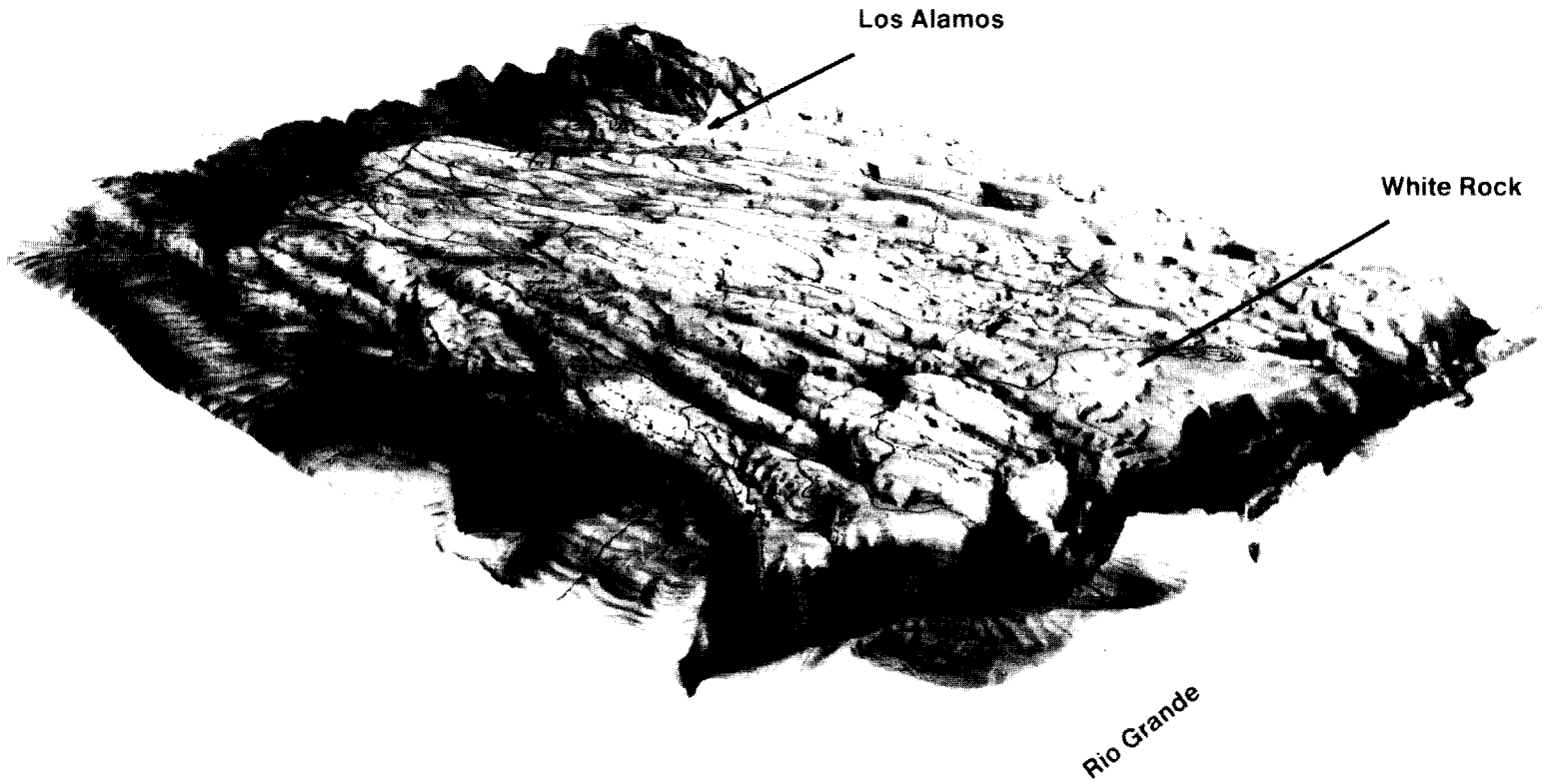


Fig. 5. Topography of the Los Alamos area.

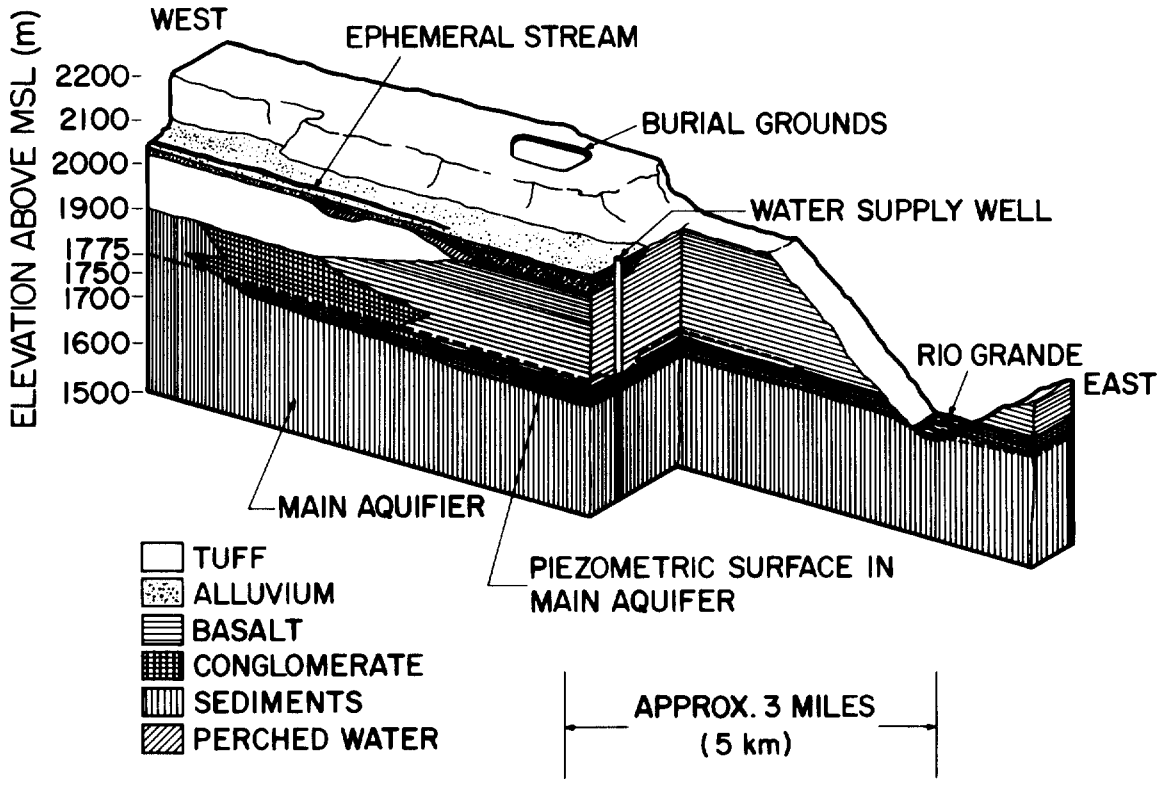


Fig. 6. Conceptual illustration of geologic-hydrologic relationships in the Los Alamos area.

an 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.

D. 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.

E. Population Distribution

Los Alamos County has an estimated 1984 population of approximately 21 400 (based on the 1980 census adjusted for 1984). 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 13 433. The White Rock area (including the residential areas of White Rock, La Senda, and Pajarito Acres) has about 7981 residents. About one-third of those employed in Los Alamos commute from other counties. Population estimates for 1984 place about 168 000 people within an 80 km (50 mi) radius of Los Alamos.

F. Programs at Los Alamos National Laboratory

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

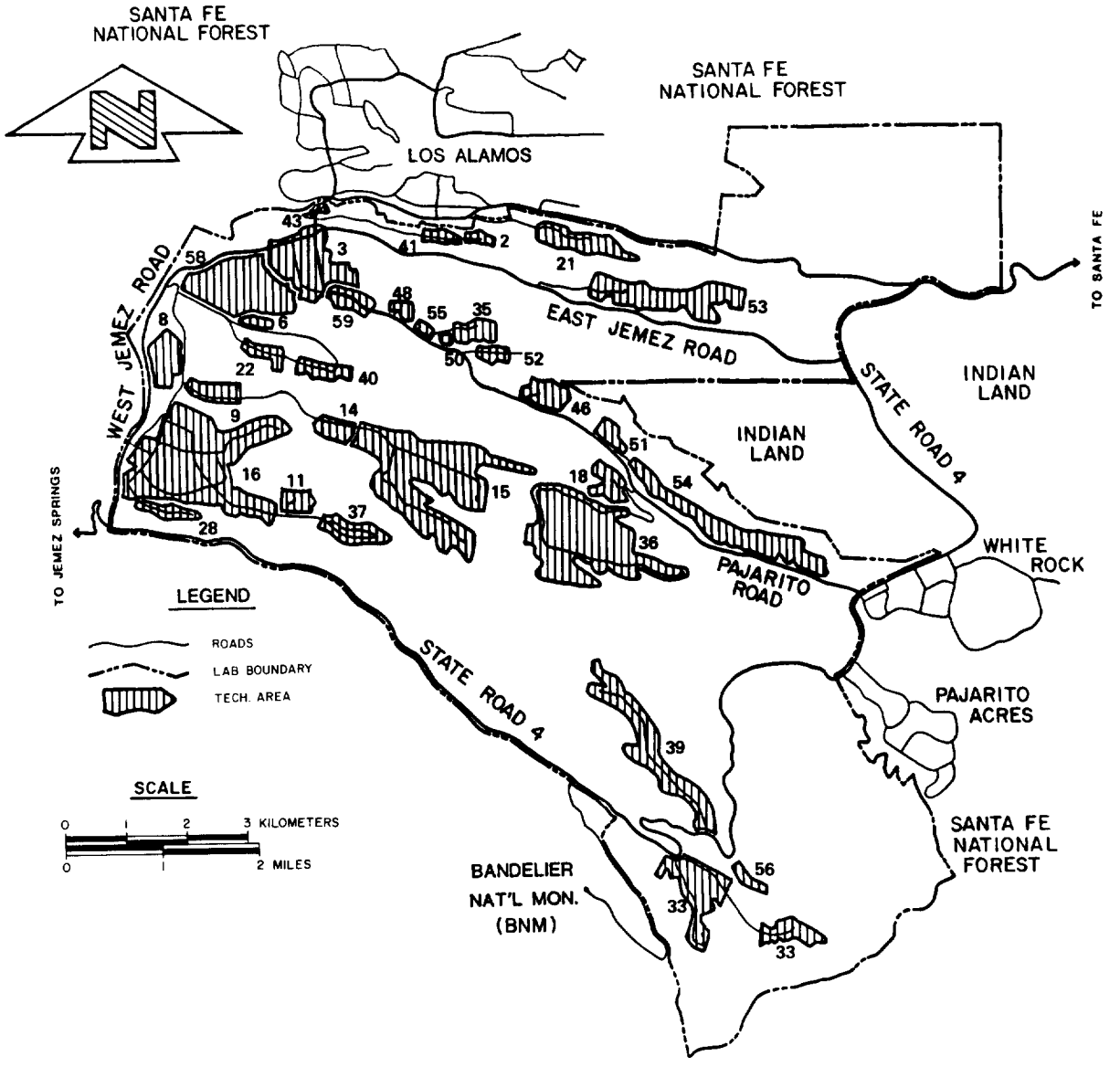


Fig. 7. Los Alamos National Laboratory's technical areas (TAs) and adjacent communities.

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.

III. RADIATION DOSES

Some incremental radiation doses—above those received from natural background, worldwide fallout, and medical and dental diagnostic procedures—are received by Los Alamos County residents as a result of Laboratory operations. The largest estimated dose at an occupied location was 31 mrem or 6.2% 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/year 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. The radioactivity levels in these sediments, however, 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 1984 was conservatively estimated to be 9.5 person-rem. This is about 0.05% of the 19 000 person-rem dose received by the same population from natural radiation sources and 0.06% of the 15 000 person-rem dose received from diagnostic medical procedures. About 90% of this dose, 8.7 person-rem, was received by persons living in Los Alamos County. This dose is 0.3% of the 2600 person-rem received by the population of Los Alamos County from natural background radiation and 0.4% of the 2000 person-rem from diagnostic medical and dental 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 26 000. This risk is much less than the 1 chance in 26 000 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

The impact of the environmental releases of radioactivity is evaluated by estimating doses received by the public from exposure to these releases. These doses are then compared with applicable standards (DOE 1981A) and with doses from background radiation and medical and dental radiation.

The principal exposure pathways considered for the Los Alamos area were atmospheric transport of airborne radioactive emissions, hydrologic transport of liquid effluents, foods 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, of contaminants in foodstuffs, and of external penetrating radiation. Theoretical dose calculations based on atmospheric dispersion modeling 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 the recommendations of the International Commission on Radiological Protection (see Appendix D for details). These doses are summarized in Table IV for the most important exposure categories, as defined in DOE Order 5484.1 (DOE 1981B) as:

1. *Maximum Boundary Dose, or "Fence-Post" Dose Rate:* Maximum dose at the Laboratory boundary where the highest dose rate occurs. This dose does not take into account shielding or occupancy and does not require that an individual actually receive this dose.
2. *Maximum Individual Dose:* Maximum dose to an individual in an offsite location where the

Table IV

Summary of Annual Doses Due to 1984 Laboratory Operations

	Maximum Dose at Laboratory Boundary[a]	Maximum Dose to an Individual[b]	Average Dose to Nearby Residents		Cumulative Dose to Population Within 80 km of the Laboratory
			Los Alamos	White Rock	
Dose	44 ± 2 mrem	31 mrem	0.50 mrem	0.26 mrem	9.5 person-rem
Critical organ	Whole Body	Whole Body	Whole Body	Whole Body	Whole Body
Location	Boundary N. of TA-53	Residence N. of TA-53	Los Alamos	White Rock	Area within 80 km of Laboratory
Radiation Protection Standard	—	500 mrem	500 mrem	500 mrem	—
% of Radiation Protection Standard	—	6.2%	0.1%	0.05%	—
Natural background	125 mrem	125 mrem	125 mrem	116 mrem	19 000 person-rem
% of natural background	35%	25%	0.4%	0.2%	0.05%

[a]Maximum boundary dose is the dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes that the hypothetical individual is at the Laboratory boundary continuously (24 hours a day, 365 days a year).

[b]Maximum individual dose is the 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.

highest dose rate occurs and where there is a person. It includes corrections for shielding (for example, for being inside a building) and occupancy (what fraction of the year the person is in the area).

3. *Average Dose:* Average doses to residents of Los Alamos and White Rock.
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 the maximum individual dose over the past 7 years are summarized in Figure 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. Estimate of Radiation Doses

1. Doses from Background, Medical and Dental Radiation. Doses from natural background and from medical and dental uses of radiation are estimated to provide a comparison with doses resulting from Laboratory operations. Health risks resulting from these doses are estimated in Section III.C. Exposure to background radiation results principally in whole body doses and in localized doses to the lung. Whole body dose is incurred from exposure to cosmic rays, external terrestrial radiation from naturally occurring radioactivity in the earth's surface and from global fallout, and internal radiation from radionuclides deposited in the body through inhalation or ingestion.

Whole body doses from background radiation in 1984, which can vary each year depending on factors such as snow cover and the solar cycle (see Section IV.A.1), were estimated to be 125 mrem at Los Alamos and 116 mrem at White Rock.

These estimates are based on measured external radiation background levels of 116 mrem (Los Alamos) and 105 mrem (White Rock) due to irradiation from charged particles, x-rays, and gamma rays. These uncorrected, measured doses were adjusted for shielding by reducing the cosmic ray component (60 mrem at Los Alamos, 52 mrem at White Rock; NCRP 1978B) by 10% to allow for shielding by structures, the terrestrial component (56 mrem at Los Alamos, 53 mrem at White Rock) by 20% to allow for shielding by structures, and 20% for self-shielding by the body (NCRP 1975B). To these estimates based on measurements were added 11 mrem from neutron cosmic radiation and 24 mrem from internal radiation, which were taken from the National Council on Radiation Protection and Measurements (NCRP 1975B).

In addition to whole body doses, a second component of background radiation is dose to the lung from inhalation of ^{222}Rn and its decay products. The ^{222}Rn is produced by the decay of ^{226}Ra, a member of the uranium series, which is naturally present in the construction materials in a building and in its underlying soil. Background exposure to ^{222}Rn and its decay products is taken to be 0.2 Working Level Month (WLM)/year (NCRP 1984B). This background estimate may be revised if a nationwide study of background levels of ^{222}Rn and its decay products in homes is undertaken as recently recommended by the National Council on Radiation Protection and Measurements (NCRP 1984A).

The use of medical and dental radiation in the United States accounts for an average annual per capita dose of 92 mrem (NRC 1980). This estimate includes doses from both x-rays and radiopharmaceuticals.

2. Doses to Individuals from Inhalation of Airborne Emissions. The maximum boundary and individual doses attributable to inhalation of airborne emissions are summarized in Table E-II and compared with the Radiation Protection Standards for individual doses (see Appendix A).

Exposures to airborne ^{3}H (as tritiated water vapor), uranium, ^{238}Pu, ^{239,240}Pu, and ^{241}Am were determined by actual measurements. A correction for background was made assuming that natural radioactivity and worldwide fallout were represented by data from the three regional sampling stations at Española, Pojoaque, and Santa Fe. Doses were calculated using the procedures described in Appendix D.

Emissions of air activation products from the Los Alamos Meson Physics Facility resulted in negligible inhalation exposures. External radiation from these emissions was detectable, however, and is discussed in Section III.B.3.

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.

3. Doses to Individuals from External Penetrating Radiation (from Airborne Emissions and Direct Radiation). The thermoluminescent dosimeter network at the Laboratory boundary north of the LAMPF indicated a 44 mrem increment above cosmic and terrestrial background radiation during 1984. This increment is attributed to emission of air activation products from LAMPF.

Based on shielding from being inside buildings (30% reduction factor; NRC 1977), this 44 mrem increment translates to an estimated 31 mrem whole body dose to an individual living on State Road 4 north of LAMPF. The 31 mrem is 6.2% of the Radiation Protection Standard for a member of the public (Appendix A). This location north of LAMPF has been the area where the highest boundary and individual doses have been measured since the dosimeter monitoring began there 7 years ago. The boundary doses at this location are discussed in Section IV.A.1.

As seen in Figure 2, the 44 mrem dose at this location during 1984 is approximately the same as the 48 mrem measured during 1983. The emissions at LAMPF increased slightly in 1984 (see Section V.A.1). The small difference in dose between the two years is due to different meteorological conditions and statistical uncertainty. To reduce exposure from airborne activation products, the beam stop area at LAMPF is being modified.

A maximum onsite dose to a member of the public from external penetrating radiation from all Laboratory airborne emissions was calculated from a Gaussian dispersion meteorological model (Slade 1968) to be 0.0042 mrem (whole body), less than 0.01% of the Radiation Protection Standard for a member of the public (DOE 1981A). This dose was calculated (using credible worst-case conditions) for a person spending 4 hours at the Laboratory's science museum, an area readily accessible to the public.

The average dose to residents in Los Alamos townsite attributable to Laboratory operations was 0.50 mrem (whole body). The corresponding dose to White Rock residents was 0.26 mrem (whole body). These doses are 0.1% and 0.05%, respectively, of the Radiation Protection Standard (DOE 1981A). They were theoretically calculated using measured stack releases (Table E-I) and 1984 meteorological data.

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 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 0.7 mrem/year of direct gamma and neutron radiation, which is 0.1% of the Radiation Protection Standard (DOE 1981A). This value was derived from 1975 data (Paxton 1975) on total gamma plus neutron dose rates using 1984 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 Figure 8) near the northeast Laboratory boundary recorded an above background dose of 77 mrem. This reflects a localized accumulation of ^{137}Cs on sediments transported from treated effluent released prior to 1964 from TA-21 (Gunderson 1983).

4. 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, Purtymum 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. This pathway could result in a maximum 50-year dose commitment of 0.0013 mrem to the bone, 0.0001% of the Radiation Protection Standard (DOE 1981A).

5. Doses to Individuals from Ingestion of Foodstuffs. Data from sampling of fruit, vegetables, fish, and honey during 1984 (see Section IV.E for a discussion of the sampling data) were used to estimate doses caused from eating these foodstuffs. All calculated doses are less than 0.003% of the Radiation Protection Standard (DOE 1981A).

The fruit and vegetable samples were analyzed for six radionuclides (^{3}H, ^{90}Sr, ^{137}Cs, total uranium, ^{238}Pu, and $^{239,240}Pu$), but only ^{3}H at onsite locations and at

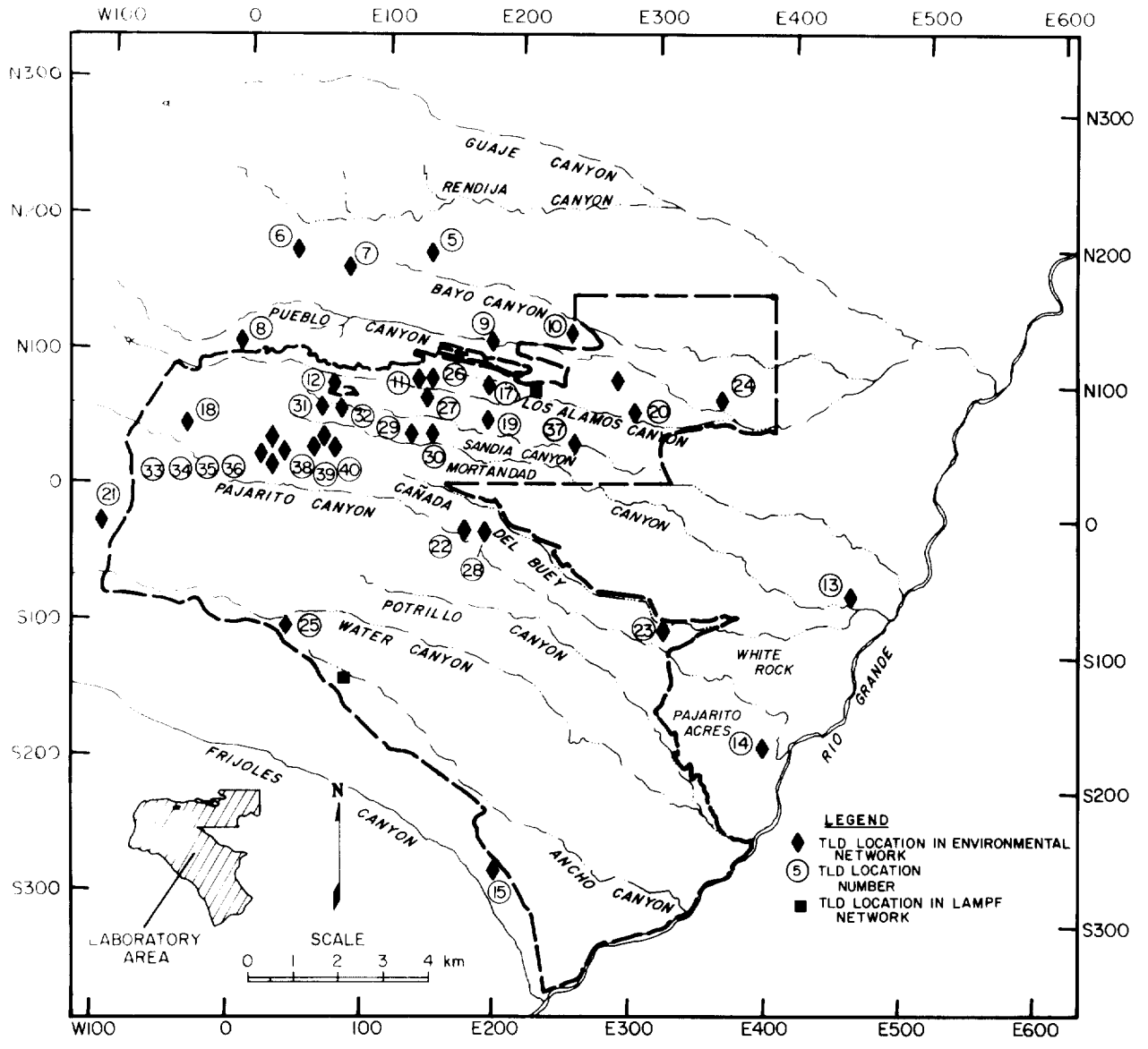


Fig. 8. Thermoluminescent dosimeter locations on or near the Laboratory site.

Los Alamos townsite and ^{238}Pu at onsite locations and at Cochiti were statistically distinguishable from background. The ^{238}Pu concentration at Cochiti was barely detectable, and the $^{239,240}Pu$ concentration was not detectable, suggesting that the ^{238}Pu concentration was a statistical fluctuation. The maximum doses that would result from ingesting one quarter of an annual consumption of fruits and vegetables (160 kg) from the offsite locations are a whole body dose of 0.013 mrem from ^{3}H and a 50-year dose commitment to bone of 0.004 mrem from ^{238}Pu. These doses are 0.003% and 0.0003%, respectively, of the Radiation Protection Standard for members of the public (DOE 1981A).

Ingestion of produce collected onsite is not a significant exposure pathway because of the small amount of edible material and because of the low radionuclide concentrations.

Fish samples were analyzed for ^{90}Sr, ^{137}Cs, natural uranium, ^{238}Pu, and $^{239,240}Pu$. As discussed in Section IV.E, radionuclide concentrations in fish from Cochiti Reservoir, the sampling location downstream from the Laboratory, were statistically indistinguishable from or less than concentrations in fish

taken from upstream reservoirs except for uranium in bottom feeder tissue. It is believed that these concentration differences for uranium are caused by natural phenomena, particularly ingestion of suspended sediments containing natural uranium that are higher at Cochiti than at upstream reservoirs. The maximum dose to an individual eating 21 kg of fish from Cochiti Reservoir is 0.051 mrem to bone (50-year dose commitment), which is 0.003% of the Radiation Protection Standard (DOE 1981A).

Concentrations of ^{90}Sr in bottom feeder carcass samples and ^{137}Cs in higher trophic level carcass and gut samples were statistically higher at upstream locations than at Cochiti. This difference probably reflects the greater influence of worldwide fallout at the upstream reservoirs (see Section IV.E). Because the background locations had the higher concentrations, no dose assessment was made for these radionuclides.

Trace amounts of radionuclides were found in honey. The maximum dose one would get from eating 5 kg of this honey, if it were made available for consumption, would be 0.047 mrem, which is 0.009% of the Radiation Protection Standard (DOE 1981A).

6. Whole Body Cumulative Doses. The cumulative (or population) 1984 whole body dose attributable to Laboratory operations to persons living within 80-km of the Laboratory is calculated to be 9.5 person-rem. This dose is 0.05% of the 19 000 person-rem exposure from natural background radiation (whole body) and 0.06% of the 15 000 person-rem exposure from medical radiation, as seen in Table V.

The cumulative dose from Laboratory operations was calculated from measured radionuclide emission rates (see Table E-I), atmospheric model using measured meteorological data for 1984, and population data based on the 1980 Bureau of Census count

Table V

Estimated Whole Body Population Doses During 1984

Exposure Mechanism	Estimated Los Alamos County Whole-Body Population Dose (person-rem) (21 400 persons)	Estimated 80-km Region Whole-Body Population Dose (person-rem[a] (168 000 persons)
Atmospheric Tritium	0.03	0.03
Atmospheric ^{11}C, ^{13}N, ^{15}O, ^{41}Ar	8.71	9.43
Total Due to Laboratory Releases	8.74	9.46
Total Due to Natural Sources of Radiation[b]	2600	19 000
Average Due to Airline Travel [~0.22 mrem/h at 9 km (NCRP 1975B)]	24	---[c]
Diagnostic Medical Exposure [~92 mrem/yr per person (NRC 1980)	2000	15 000

[a]Includes doses reported for Los Alamos County.
[b]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.
[c]Not estimated for the population in the 80-km region.

adjusted to 1984 (see Appendix D for the population distribution and a description of the meteorological model).

The cumulative dose from whole body natural background radiation was calculated using the background radiation levels given in Section III.B.1. The dose to the 80 km population from medical and dental radiation was calculated using a mean annual dose of 92 mrem per capita (see Section III.B.1). The population distribution in Appendix D was used in both these calculations to obtain the total cumulative dose.

Also shown in Table V is the cumulative dose in Los Alamos County from Laboratory operations, natural background radiation (whole body), and medical and dental radiation. Approximately 90% of the total cumulative dose from Laboratory operations is to Los Alamos county residents. This dose is 0.3% of the cumulative dose to the same population from natural background and 0.4% of the cumulative dose from medical and dental radiation.

The population centers outside of Los Alamos County 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 less than 10% of the total. The cumulative dose to the population outside of Los Alamos County and within 80 km of the Laboratory is 0.004% of the dose from natural background radiation and 0.005% of the dose from medical and dental radiation.

C. Estimates of Risk to an Individual from Laboratory Releases

1. Introduction. Risk estimates of possible health effects from radiation doses to the public resulting from Laboratory operations have been made to provide perspective in interpreting these radiation doses. These calculations, however, may overestimate actual risk for low-LET (linear energy transfer) radiation. The National Council on Radiation Protection and Measurements (NCRP 1975A) 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 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."

Low-LET radiation, which includes gamma rays, is the principal type of Environmental Radiation resulting from Laboratory operations. Estimated doses from high-LET radiation, such as neutron or alpha particle radiation, are less than 3% of estimated low-LET radiation doses. Consequently, risk estimates in this report may overestimate the true risks.

The International Commission on Radiological Protection (ICRP 1977) estimated that the total risk of cancer mortality from uniform whole body radiation 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 fatal cancer during his lifetime due to that radiation exposure. 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."

2. Risk from Natural Background Radiation and Medical and Dental Radiation. During 1984, persons living in Los Alamos and White Rock received an average of 125 and 116 mrem, respectively, of whole body radiation from natural sources (including cosmic, terrestrial, and self-irradiation sources 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 1984 was 1 chance in 80 000 in Los Alamos and 1 chance in 86 000 in White Rock (Table II).

Natural background radiation also includes exposure to the lung from ^{222}Rn and its decay products (see Section III.B.1), in addition to exposure to whole body radiation. This exposure to the lung also carries a chance of cancer mortality due to natural radiation sources that was not included in the estimate for whole body radiation. The National Council on Radiation Protection and Measurements has recently estimated that a 1 WLM exposure over a year would give an age-averaged risk of lung cancer of 0.00013 per WLM, or 13 chances in 100 000 for each WLM of exposure (NCRP 1984B). For the background exposure of 0.2 WLM (see Section III.B.1), the added risk due to exposure to natural ^{222}Rn and its decay products is 1 chance in 38 000.

This lung cancer risk estimate based on recommendations of the National Council on Radiation Protection and Measurements is used because it is more current than an estimate based on the lung cancer risk factor of the International Commission on Radiological Protection, and because it is meant to be used in environmental, rather than occupational, conditions.

The total cancer mortality risk from natural background radiation is 1 chance in 26 000 for Los Alamos and 1 chance in 27 000 for White Rock. The additional risk of cancer mortality from exposure to medical and dental radiation is 1 chance in 110 000.

3. Risk from Laboratory Operations. The risks calculated above from natural background radiation and medical and dental radiation can be compared to the incremental risk due to radiation from Laboratory operations. The average doses to individuals in Los Alamos and White Rock because of 1984 Laboratory activities were 0.50 mrem and 0.26 mrem, respectively. These doses are estimated to add lifetime risks of about 1 chance in 20 000 000 in Los Alamos and 1 chance in 38 000 000 in White Rock to an individual's risk of cancer mortality (Table II). These risks are less than 0.6% of the risk attributed to exposure to natural background radiation or to medical and dental radiation.

For Americans the average lifetime risk is a 1 in 4 chance of contracting a cancer and a 1 in 5 chance of dying from the desease (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 2.3 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 more to the total risk to Los Alamos County residents than Laboratory operations because of increased ^{222}Rn 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. External Penetrating Radiation

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 44 ± 2 mrem in 1984. 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. During a 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). If the measurements made at regional and perimeter locations during the four calendar quarters are used to estimate the total background radiation for the year, the range of estimates is 80 to 151 mrem.

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. However, the regional locations range in elevation from about 1.7 km at Espanola to 2.7 km at Fenton Hill, resulting in a corresponding range between 45 mrem/yr and 90 mrem/yr for the cosmic component. This cosmic component can vary up to about ±5% because of solar modulations (NCRP 1975B).

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.

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 networks are located at: (1) the Los Alamos Meson Physics Facility, (2) low-level radioactive waste management areas, and (3) the Laboratory and regional areas. The 1984 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 four 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 boundary; 24 locations within the Laboratory boundary comprise the onsite group (Fig. 8).

Table E-III summarizes the annual measurements for the regional, perimeter, and onsite groups for 1984. 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 reference, the Department of Energy's Radiation Protection Standard is 500 mrem/yr for whole body dose (Appendix A). (This

Radiation Protection Standard excludes contributions from cosmic, terrestrial, global fallout, self-irradiation, and medical diagnostic sources.The standard applies to locations 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, particles, 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.G). Twelve 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. 8). 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 attributable to operation of LAMPF. For 1984 the above background radiation measured by the LAMPF TLD Network was 44 ± 2 mrem, 8.8% of the Department of Energy's Radiation Protection Standard of 500 mrem/yr (Appendix A).

Figure 9 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, Tables III and E-I), and a shift in the isotopic ratio of the emissions. Engineering improvements to the beam stop that were begun in 1984 are designed to reduce the amount of airborne activation products that are generated by the accelerator.

d. The TLD Network for Low-Level Radioactive Waste Management Areas. This network of 91 locations monitors radiation levels at one active and ten inactive low-level radioactive 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 V.C.6 of this report.

B. 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 airborne 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.

1. 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 (Figure 10), are reference points for determining regional background levels of atmospheric radioactivity. The 11 perimeter stations are within 4 km of the Laboratory boundary; 12 onsite stations are within the Laboratory boundary (Figure 10, Table E-IV).

Natural atmospheric and fallout radioactivity levels fluctuate and affect 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

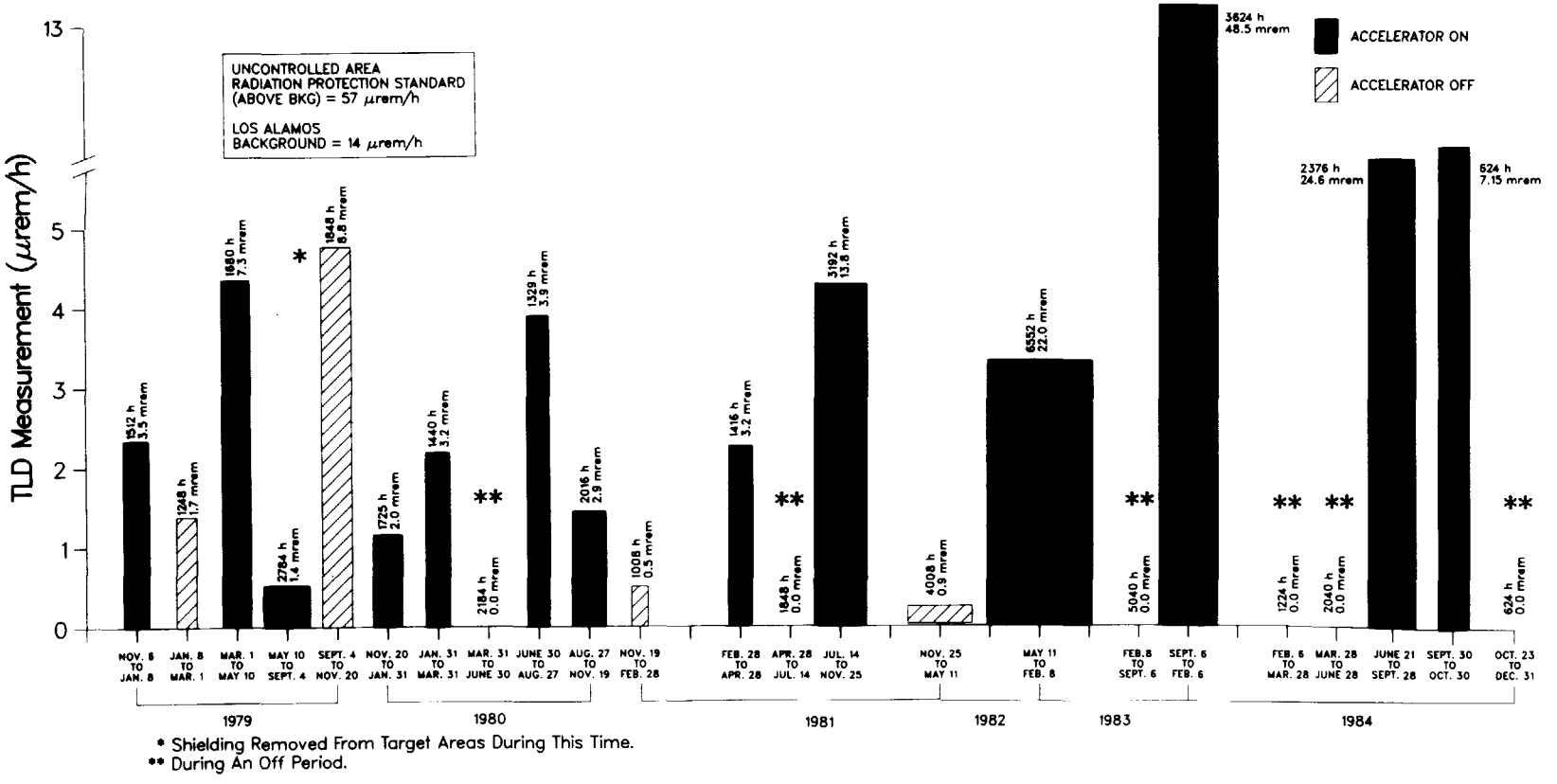


Fig. 9. Above-background TLD measurements at the northeast Laboratory boundary due to operations at the Los Alamos Meson Physic Facility (TA-53).

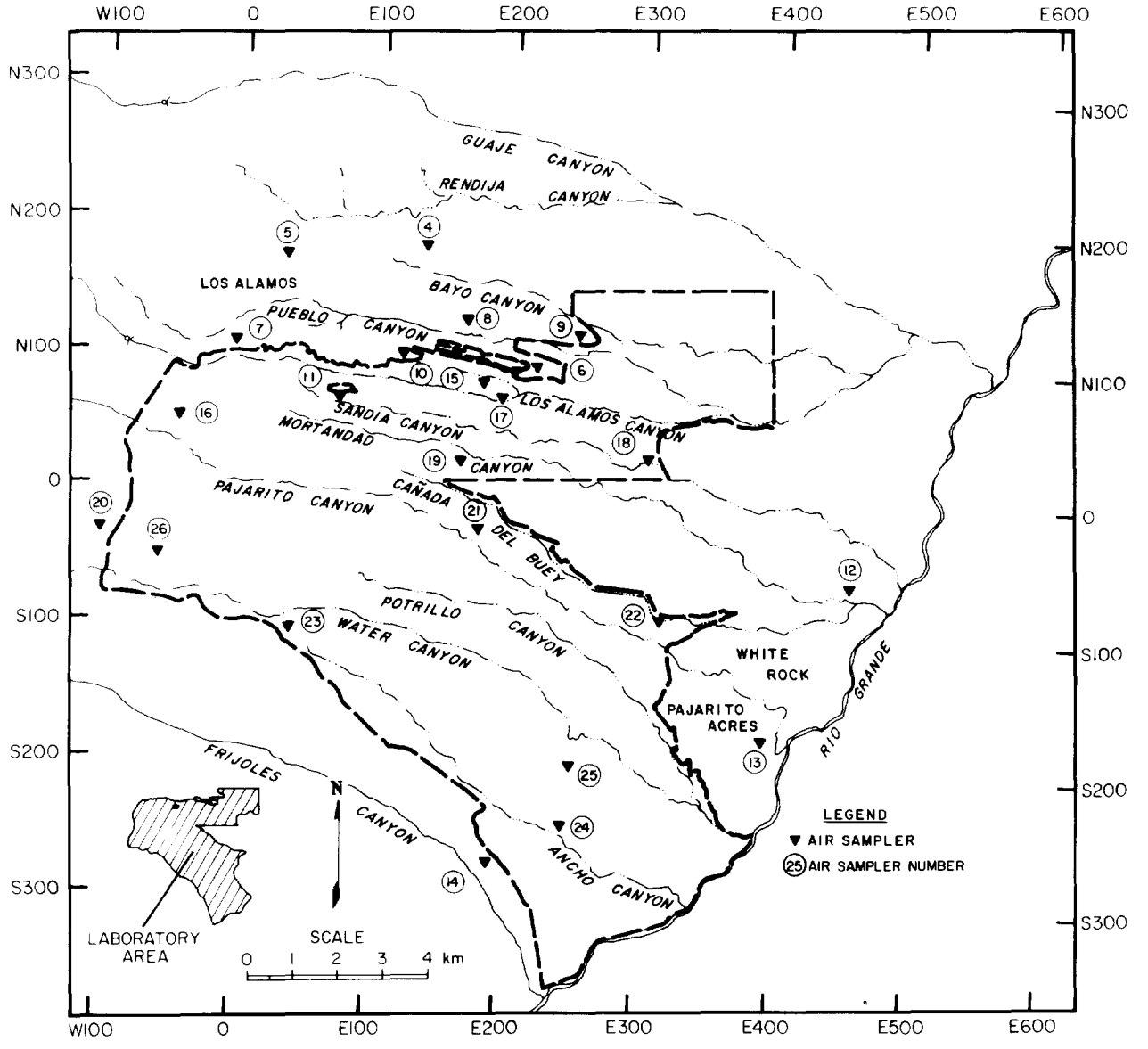


Fig. 10. Air sampler locations on or near the Laboratory site.

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-V and are useful in interpreting the air sampling data.

Atmospheric particulates result primarily from soil particles that are blown by the wind. Consequently, there are often large fluctuations with time (day-to-day or season-to-season) and location in airborne radioactivity levels caused by changing meteorological conditions. Windy, dry days can result in relatively high concentrations of airborne particulates, whereas precipitation (rain or snow) can wash out many particles from the atmosphere.

2. Gross Beta Radioactivity. Gross beta analyses help in evaluating general radiological air quality. Figure 11 shows gross beta activity at a regional sampling location (Española, Station 1, see Figure 1) about 30 km from the Laboratory and at an onsite sampling location (TA-59). The annual mean gross beta activity in 1984 was slightly but statistically significantly higher at the onsite station (16×10^{-15}

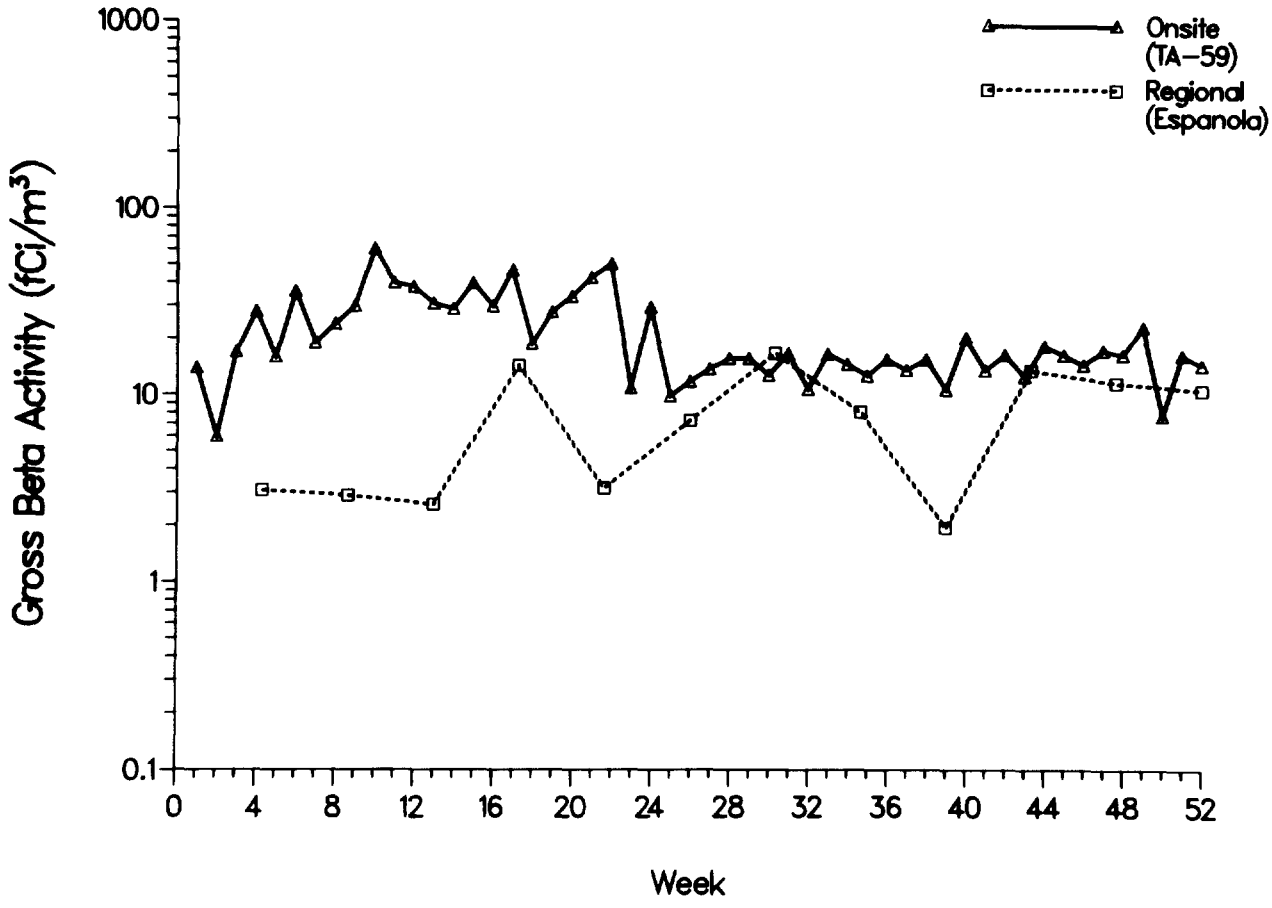


Fig. 11. Atmospheric gross-beta activity at a regional (background) station and an onsite station during 1984.

μCi/mℓ) than at the regional station (8.2×10^{-15} μCi/mℓ). These gross beta levels are less than 1% of the Department of Energy Concentration Guides for gross beta activity in Controlled or Uncontrolled Areas (see Appendix A).

3. Tritium. Atmospheric tritiated water concentrations for 1984 are in Table E-VI. The regional (9.5×10^{-12} μCi/mℓ) and perimeter (9.1×10^{-12} μCi/mℓ) annual means were lower than the onsite annual mean (19.2×10^{-12} μCi/mℓ), but the difference was not statistically significant. This reflects the slight impact of Laboratory tritium operations. The TA-54 (Station 22) annual mean (63×10^{-12} μCi/mℓ) and the TA-33 (Station 24) annual mean (56×10^{-12} μCi/mℓ) were the two highest annual means measured in 1984. Both these stations are located within the Laboratory boundary near areas where tritium is disposed or used in operations. These tritium levels are 0.0013% and 0.0011%, respectively, of the Department of Energy's Controlled Area Concentration Guide for tritium in air (see Appendix A).

4. Plutonium and Americium. Of the 104 air sample analyses performed in 1984 for ^{238}Pu, only one was above the minimum detectable limit of 2.0×10^{-18} μCi/mℓ. The concentration of airborne ^{238}Pu in the only sample having detectable activity was 4.1×10^{-18} μCi/mℓ. The sample was collected in the second quarter of 1984 at TA-54 (Station 22). The concentration is 0.0002% of the Department of Energy's Controlled Area Concentration Guide for ^{238}Pu (see Appendix A). The other 103 samples are not tabulated in this report, because they all contained less-than-detectable activity.

The 1984 annual means for $^{239,240}Pu$ concentrations in air for the regional (0.0×10^{-18} μCi/mℓ), perimeter (1.1×10^{-18} μCi/mℓ), and onsite (2.6×10^{-18} μCi/mℓ) stations were all less than 0.002% of the Department of Energy's Concentration Guides for Controlled or Uncontrolled Areas (see Appendix A). The detailed results are in Table E-VII.

Only 4 of 44 measured ^{241}Am concentrations were above the minimum detectable limit of 2.0×10^{-18} μCi/mℓ. None of the regional or perimeter air particulate samples had measurable ^{241}Am. The four onsite concentrations that were detectable were $9.2 \pm 2.2 \times 10^{-18}$ μCi/mℓ (TA 54, second quarter), $10.5 \pm 3.2 \times 10^{-18}$ μCi/mℓ (TA 54, third quarter), $7.9 \pm 2.4 \times 10^{-18}$ μCi/mℓ (TA-6, fourth quarter), and $3.6 \pm 1.7 \times 10^{-18}$ μCi/mℓ (TA-16, fourth quarter). All concentrations were less than 0.0002% of the Department of Energy's Controlled Area Concentration Guide for ^{241}Am in air (see Appendix A).

5. Uranium. The 1984 atmospheric uranium concentrations are in Table E-VIII. Because uranium is a naturally-occurring radionuclide in soil, it is found in airborne soil particles that have been resuspended by wind or mechanical forces (for example, vehicles or construction activity). As a result, uranium concentrations in air are heavily dependent on the immediate environment of the air 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.

The 1984 annual means of the regional stations (39 pg/m^3), perimeter stations (28 pg/m^3), and onsite stations (29 pg/m^3) were statistically indistinguishable. All measured annual means were less than 0.002% of the Department of Energy's Concentration Guides for uranium in Controlled or Uncontrolled Areas.

C. Radiochemical and Chemical Quality of Surface and Ground Water

Surface and ground waters are sampled to monitor dispersion of radionuclides and chemicals from Laboratory operations. The 1984 radiochemical and chemical quality of water from regional, perimeter, and onsite areas (where there is no discharge of treated effluent) indicates no observable effects of treated effluents released in other areas. Water in onsite effluent release areas contains trace amounts of radionuclides that are below the Department of Energy's Concentration Guides for waters in Controlled Areas. Results from chemical analyses of surface waters from regional, perimeter, and onsite areas (not effluent discharge areas) varied slightly from previous years, but were within the range of normal seasonal fluctuations. Chemical quality of ground water (wells and springs) from perimeter and onsite stations did not change significantly from previous years. Chemical analyses of water samples from onsite effluent release areas indicated some constituents had greater concentrations than are found in naturally-occurring waters. Although the chemical and radiochemical quality of surface and shallow ground waters in effluent release areas reflects some impact from Laboratory operations, these waters are confined within the Laboratory and are not a source of municipal, industrial, or agricultural supply.

1. Introduction. Surface and ground waters from regional, perimeter, and onsite stations are monitored to provide routine surveillance of Laboratory operations. Comparisons of maximum radiochemical concentrations in water samples from each group of stations are made with the Department of Energy's Concentration Guides (CGs) for Uncontrolled Areas (Appendix A). Regional and perimeter stations are in Uncontrolled Areas, while onsite stations are within Controlled Areas. These Concentration Guides do not account for concentration mechanisms that may exist in environmental media. Consequently, other media such as sediments, soils, and foodstuffs are monitored (see discussion in subsequent sections).

Routine chemical analyses of water samples are done for a number of constituents. These analyses have been done for a number of years and are an

excellent screening tool to detect changes in the chemical quality of water from a single source. A subset of five of these chemical constituents is compared with drinking water standards. If a sample from a particular station was not taken this year, it was because the station was dry or a water pump was broken.

Regional station locations are shown in Fig. 12. Perimeter and onsite station locations are shown in Fig. 13. Table E-IX lists the locations of surface and ground water stations. Appendix A presents standards for environmental contaminants. Appendix B describes sampling procedures and statistical treatment of data. Appendix C presents analytical chemical methodology. Results of all routine analyses are reported in Appendix E.

2. Regional Stations. Regional surface water samples are collected within 75 km of the Laboratory from 6 stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 12). The six sampling stations are at U.S. Geological Survey Gaging Stations. These waters provide baseline data for radiochemical and chemical analyses in areas beyond the Laboratory boundary. Stations on the Rio Grande are: Embudo, Otowi, Cochiti, and Bernalillo. The Rio Grande at Otowi, just east of Los Alamos, has a drainage area of 37,040 km^2 in southern Colorado and northern New Mexico. Discharge for the period of record (1895-1905, 1909-1984) has ranged from a minimum of 1.7 m^3/sec in 1902 to 691 m^3/sec in 1920. The discharge for water year 1982 ranged from 7.2 m^3/sec on September 22 to 248 m^3/sec on June 3 (USGS 1984).

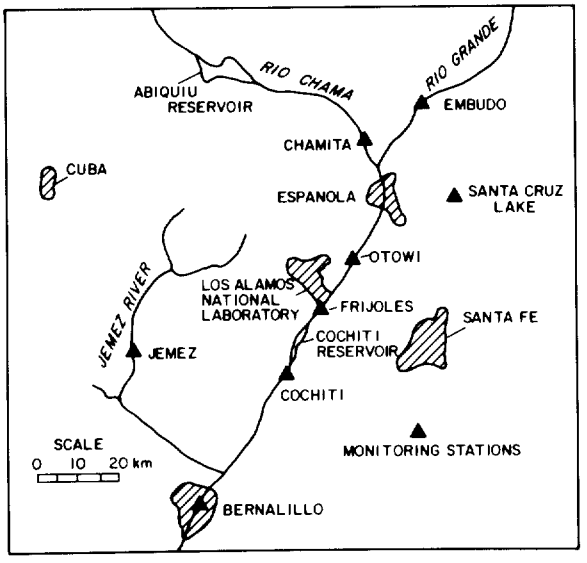


Fig. 12. Regional surface water, sediment, and soil sampling locations.

The Rio Chama is tributary to the Rio Grande north of Los Alamos (Fig. 12). At Chamita on the Rio Chama, the drainage area above the station is 8143 km^2 in northern New Mexico and a small part in southern Colorado. Since 1971, some flow has resulted from transmountain diversion water from the San Juan Drainage. Flow at the gage is governed by release from several reservoirs. Discharge during water year 1982 ranged from 0.68 m^3/sec in October to 106 m^3/sec in July.

The station at Jemez on the Jemez River drains an area of the Jemez Mountains west of Los Alamos. The drainage area is small, about 1220 km^2. During the water year 1982, the discharge ranged from 0.18 m^3/sec in December to 194 m^3/sec in April. The river is tributary to the Rio Grande below Los Alamos.

Surface water from the Rio Grande, Rio Chama, and Jemez River are used for irrigation of crops in the river valley both upstream and downstream from Los Alamos. The water from these rivers is part of recreational areas on state and federal lands.

a. Radiochemical Analyses. Surface water samples from regional stations were collected in February and August 1983. The cesium, plutonium, tritium, total uranium, and gross gamma radioactivity levels in these waters were low. Those samples collected downgradient from the Laboratory showed no effect from the Laboratory's operation (Table VI). A comparison of the 1984 analyses with previous years' results from the same stations indicated no significant changes. The maximum concentrations of radioactivity in regional surface water samples were well below the Concentration Guide for Uncontrolled Areas (Table E-X).

b. Chemical Analyses. Surface water samples from regional stations were collected in February 1983. Maximum concentrations in regional water samples were well below maximum concentrations of the same constituents in drinking water (Tables VII and E-X). There were some variations in concentrations of various constituents when compared with previous years' results. These fluctuations result from slight chemical changes that occur from variations in discharges at the various stations. This is normal and no inference should be made that the water quality at

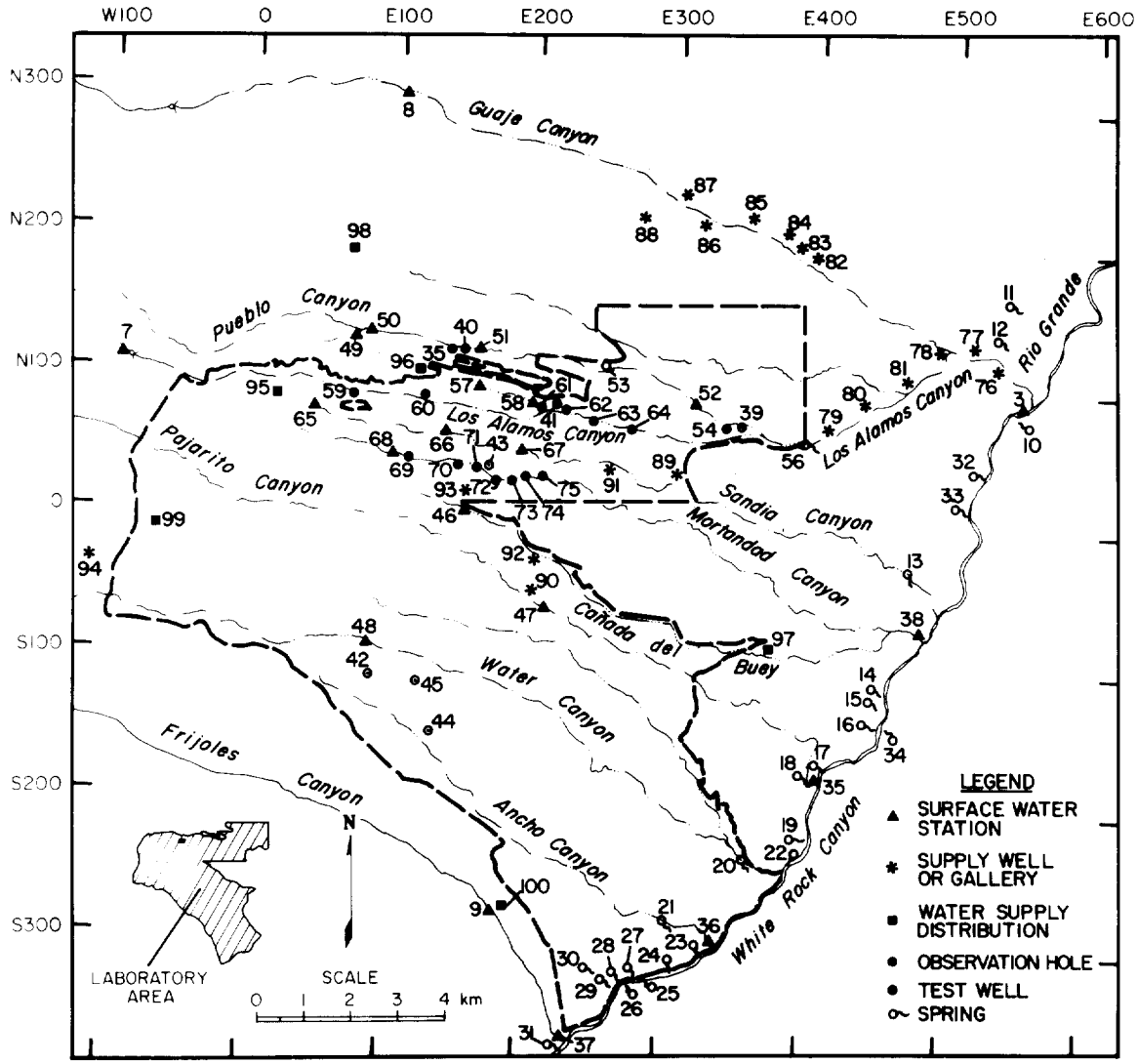


Fig. 13. Surface and ground water sampling locations on or near the Laboratory site.

these stations is deteriorating while in the water distribution system.

Surface flow in Frijoles Canyon is sampled at Bandelier National Park Headquarters. The flow in the canyon is from spring discharge in the upper reach of the canyon. It decreases in volume as it crosses Pajarito Plateau because of seepage and evapotranspiration losses. The drainage area above the Park Headquarters is about 45 km^2 (Purtymun 1980B).

La Mesita Springs is east of the Rio Grande, while Indian and Sacred Springs are west of the river in lower Los Alamos Canyon. The springs discharge from faults in the siltstones and sandstones of the Tesuque Formation. The springs form small seep areas. Total discharge at each spring is probably less than 1 ℓ/sec.

The perimeter station in White Rock Canyon is composed of four groups of springs. The springs discharge from the main aquifer. Three of the groups (Group I, II, and III) have similar aquifer-related chemical quality. Water from these springs is part of the main aquifer that moves beneath the Pajarito Plateau (Purtymun 1980C). The chemical quality of Spring 3B (Group IV) reflects a local condition in the aquifer discharging through a fault in volcanics. Three streams that flow to the Rio Grande are also sampled. Streams in Pajarito and Ancho Canyons are

Table VI

Maxiumum Concentrations of Radioactivity in Surface and Ground Waters 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)	Gross Gamma (counts/min/ℓ)
Offsite Station (Uncontrolled Areas)							
Concentration Guide (CG) for Uncontrolled Areas[a]		20 000	5000	5000	3000	1800	—
Regional	6	61 ± 82	0.09 ± 0.24	0.13 ± 0.38	3.0 ± 1.0	6.0 ± 1.2	150.±
Perimeter							
Adjacent	6	172 ± 149	0.05 ± 0.06	0.09 ± 0.06	1.4 ± 0.8	20 ± 6.0	570 ± 100
White Rock[b]	26	136 ± 135	0.097 ± 0.060	0.042 ± 0.048	1.1 ± 0.6	21 ± 4.0	71 ± 90
Offsite Station Group Summary:							
MaximumConcentration							
Maximum Concentration as % CG for Uncontrolled Areas							
Onsite Station (Controlled Areas)							
Concentration Guide (CG) for Controlled Areas[a]		400 000	100 000	100 000	100 000	60 000	—
Noneffluent Areas							
Ground Water (Main Aquifer)[b]		69 ± 176	0.022 ± 0.038	0.031 ± 0.032	2.6 ± 0.8	2.9 ± 0.4	342 ± 80
Surface Water	3	44 ± 56	0.007 ± 0.18	0.030 ± 0.030	2.4 ± 0.6	1.4 ± 0.2	299 ± 38
Effluent Areas							
Acid-Pueblo Canyon	7	163 ± 74	0.02 ± 0.02	0.389 ± 0.092	6.4 ± 1.4	13.9 ± 4.8	103 ± 30
DP-Los Alamos Canyon	8	121 ± 76	4.4 ± 0.13	8.2 ± 0.38	33 ± 6	576 ± 115	217 ± 38
Sandia Canyon	3	64 ± 133	0.28 ± 0.08	0.24 ± 0.06	7.9 ± 1.6	3.4 ± 0.6	2610 ± 60
Mortandad Canyon	7	1800 ± 396	83 ± 5.0	93 ± 6.5	75 ± 1.6	123 ± 16	—
Onsite Group Summary:							
Maximum Concentration		1800 ± 400	83 ± 5.0	93 ± 6.5	75 ± 1.6	576 ± 115	2610 ± 60
Maximum Concentration as % CG for Controlled Areas		9	2	2	3	32	—

[a]Reference (DOE 1981A).
[b]One sample per station.

Table VII

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	500	6.5 - 8.5
Offsite Stations						
Regional Stations	6	67	0.9	3.7	335	8.5
Perimeter Stations						
Adjacent	6	16	0.8	7.4	194	8.4
White Rock Canyon	26	60	1.2	48	483	8.0
Summary: Offsite Stations						
Maximum Concentration	---	67	1.2	48	483	8.4
Maximum Concentration as Per Cent of Standard	---	27	60	107	97	99
Onsite Stations						
Noneffluent Areas						
Ground Water	6	34	0.2	2.2	145	8.5
Surface Water	3	27	1.6	4.4	156	7.5
Effluent Release Areas						
Acid-Pueblo Canyon	7	300	0.8	58	506	7.9
DP-Los alamos Canyon	8	154	6.7	636	3281	12.1
Sandia Canyon	3	210	1.7	58	1277	8.2
Mortandad Canyon	7	51	5.1	650	1459	8.9
Summary: Onsite Stations						
Maximum Concentration	---	300	6.7	650	3281	12.1
Maximum Concentration as Per Cent of Standard	---	120	335	1440	656	142

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

fed from Group I springs. The stream in Frijoles Canyon is fed by a spring on the flanks of the mountains west of Pajarito Plateau and flows through Bandelier National Monument to the Rio Grande.

Treated sanitary effluent from the community of White Rock is also sampled at its confluence with the Rio Grande.

3. Perimeter Stations. Perimeter stations within 4 km of Los Alamos include surface water stations at Los Alamos Reservoir, Guaje Canyon, and Frijoles Canyon and three springs stations (La Mesita, Indian Springs, and Sacred Springs). More perimeter stations are in White Rock Canyon along the Rio Grande just east of the Laboratory. Included in this groupimg are stations at 22 springs, 3 streams, and a sanitary effluent release (Fig. 13 and Table E-IX).

Los Alamos Reservoir in upper Los Alamos Canyon on the flanks of the mountains, west of Los Alamos, has a capacity of 51×10^3 m^3 and a drainage

area of 16.6 km^2 above the intake. The reservoir is used for storage and recreation. Water flows by gravity through about 10.2 km of water lines for irrigation of lawns and shrubs at the Laboratory's Health Research Building, the Los Alamos High School, and University of New Mexico's Los Alamos Branch.

The station in Guaje Canyon is below Guaje Reservoir. Guaje Reservoir in upper Guaje Canyon has a capajcity of 0.9×10^3 m^3 and a drainage area above the intake of about 14.5 km^2. The reservoir is used for diversion rather than storage as flow in the canyon is maintained by perennial springs. Water flows by gravity through 9.0 km of water lines for irrigation of lawns and shrubs at Cumbres Junior High School and Guaje Pines Cemetery. The stream and reservoir are also used for recreation.

The waterlines from Guaje and Los Alamos Reservoirs are not a part of the municipal or industrial water supply at Los Alamos. Diversion for irrigation is usually from May through December.

a. Radiochemical Analyses. Maximum radiochemical concentrations in water samples from perimeter stations are compared to the Concentration Guides for Uncontrolled Areas in Table VI. The cesium, plutonium, tritium, total uranium, and gross gamma activity were low and well below Concentration Guides for Uncontrolled Areas. Detailed results of radiochemical and chemical analyses of samples collected from the perimeter stations are shown in Tables E-XI and E-XII.

b. Chemical Analyses. The maximum chemical concentrations (chloride, fluoride, nitrate, total dissolved solids, and pH) in samples from the perimeter stations are compared to drinking water standards. The five constituents in water from the six adjacent stations were below drinking water standards (Table VII). Concentrations in water samples from the 23 springs and 3 streams in White Rock Canyon were also below drinking water standards. However, nitrates in the sanitary effluent from the community of White Rock exceeded drinking water standards. The perimeter springs, streams, and sanitary effluents, as well as the Rio Grande, are not sources of municipal water supply downstream from Los Alamos (Tables E-XI and E-XII).

4. Onsite Stations. 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 effluents. Locations of these stations are shown in Fig. 13 and described in Table E-IX.

a. Onsite Noneffluent Release Areas. The onsite noneffluent sampling stations consist of five deep test wells and three surface water sources. The five deep test wells are completed into the main aquifer. The general movement of water in the aquifer is east to southeast toward the Rio Grande where a part of the water is discharged into the river through seeps and springs.

Test Wells 1 and 2 are in the lower and midreach of Pueblo Canyon. Depths to the top of the main aquifer are 181 m to 231 m, respectively. Test Well 23 is in the midreach of Los Alamos Canyon with a depth of 228 m to the top of the main aquifer. These wells are in canyons that have received (Pueblo Canyon) or are now receiving (Los Alamos Canyon) industrial effluents. Test Wells DT-5A and DT-10 are at the southern edge of the Laboratory. Depths to the top of the main aquifer are 359 m and 332 m, respectively. Test Well 8 is in the midreach of Mortandad Canyon, an area of industrial effluents. The top of the aquifer lies at about 295 m. These test wells are constructed to seal out all water above the main aquifer. The wells monitor any possible effect that the Laboratory's operation may have on water quality in the main aquifer.

Surface water samples are collected in Canada del Buey, Pajarito, and Water Canyons below technical areas to monitor releases of cooling water and/or sanitary effluents. Surface water in these canyons also can include runoff from snowmelt and seasonal precipitation.

(1) Radiochemical Analyses. Radiochemical concentrations from ground water (test wells completed into main aquifer) and surface water sources show no effects of Laboratory operations (Tables VI and E-XIII). The concentrations of cesium and plutonium are at or below limits of detection. The concentrations of radionuclides are well below Concentrations Guides for Controlled Areas.

(2) Chemical Analyses. Chemical quality of ground water from the test wells reflects local conditions of the aquifer around the well. The quality of surface water varies slightly and is affected by releases of cooling water or sanitary effluents from technical areas upgradient from sampling stations.

The maximum concentrations of chemical constituents (five parameters) in the onsite surface and ground water samples were within drinking water standards (Tables VII and E-XIII). Ground waters from test wells and surface water sources are not a source of municipal, industrial, or irrigation supply.

b. Onsite Effluent Release Areas. Onsite effluent release areas are canyons that receive or have received treated industrial or sanitary effluents. These are DP-Los Alamos, Sandia, and Mortandad Canyons. Also included in this discussion is Acid-Pueblo Canyon, which is a former release area for industrial effluents. Acid Pueblo Canyon received untreated and treated industrial effluents that contained residual amounts of radioactivity from 1944 to 1964 (ESG 1981). The canyon also receives treated sanitary effluents from the Los Alamos County treatment plants in the upper and middle reaches of Pueblo Canyon. The sanitary effluents form some perennial flow in the canyon, but it does not reach State Road 4.

Water occurs seasonally in the alluvium dependent on the volume of surface flow from sanitary effluents and storm runoff. Three observation wells in the alluvium of Pueblo Canyon are not used as part of the monitoring network because they are dry most of the year. Hamilton Bend Springs discharges from alluvium in the lower reach of Pueblo Canyon and is dry part of the year. The primary sampling stations are surface water stations at Acid Weir, Pueblo 1, Pueblo 2, and Pueblo 3 (Table E-IX). Other sampling stations are Test Well T-2A (drilled to a depth of 40.5 m, which penetrates the alluvium and Bandelier Tuff and is completed into the Puye Conglomerate).

Aquifer tests indicate the perched aquifer is of limited extent, while water level measurements over a period of time indicate the perched aquifer is hydrologically connected to the stream in Pueblo Canyon. Perched water in the basaltic rocks occurs in Test Well 1A in Lower Pueblo Canyon and Basalt Springs east in lower Los Alamos Canyon. Recharge to the perched aquifer in the basalt occurs near Hamilton Bend Springs and is mainly sanitary effluents from the Bayo Treatment Plant near Hamilton Bend Springs. Travel time from the recharge area near Hamilton Bend Spring to Test Well 1A is estimated to be 1 to 2 months and another 2 to 3 months to Basalt Springs.

DP-Los Alamos Canyon receives treated industrial effluents that contain some radionuclides and some sanitary effluents from treatment plants at TA-21. Industrial effluents have been released into the canyon since 1952. In the upper reaches of Los Alamos Canyon (above Station LAO-1), there are occasional releases of cooling water from the research reactor at TA-2. On the flanks of the mountains, Los Alamos Reservoir impounds runoff from snowmelt and rainfall. Stream flow from this impoundment into the canyon is intermittent, dependent on precipitation to cause runoff to reach the Laboratory boundary at State Road 4. Infiltration of effluents and natural runoff maintains a shallow body of water in the alluvium of Los Alamos Canyon. Water levels are highest in late spring from snowmelt runoff and late summer from summer thundershowers. Water levels decline during the winter and early summer as natural storm runoff is at a minimum. Sampling stations consist of two surface water stations in DP Canyon and six observations completed into alluvium (about 6 m thick) in Los Alamos Canyon (Table E-IX).

Sandia Canyon has a small drainage area that heads on Pajarito Plateau in TA-3. The canyon receives cooling tower blowdown from the TA-3 power plant and some treated sanitary effluents from TA-3 facilities. Effluents from a sanitary treatment plant form a perennial stream in a short reach of the upper canyon. Only during heavy summer thundershowers in the drainage area does stream flow reach the Laboratory boundary at State Road 4. Two monitoring holes in the lower canyon just west of State Road 4 indicate no perched water in the alluvium in this area. There are three surface water sampling stations in the reach of the canyon that contains perennial flow (Table E-IX).

Mortandad Canyon has a small drainage area that heads on the western edge of Pajarito Plateau. Industrial liquid wastes containing radionuclides are collected and processed at the Industrial Waste Treatment Plant at TA-50. After treatment that removes most of the radioactivity, the effluents are released into Mortandad Canyon. Release of effluents from TA-50 and waste water from TA-48 causes perennial flow in the upper reach of the canyon. Occasional storm runoff adds to the surface flow. The perennial surface flow and storm runoff recharge a shallow aquifer in the alluvium of the canyon that is perched (ground water separated from the main aquifer by an unsaturated zone) on the underlying tuff. As the water in the shallow aquifer moves downgradient, losses occur from evapotranspiration and infiltration into underlying tuff.

This aquifer is of limited extent and forms a shallow ground water body in the canyon within the

confines of the Laboratory. Velocity of water movement in the perched aquifer ranges from 18 m/day in the upper reach to about 2 m/day in the lower reach (Purtymun 1974C and Purtymun 1983A). The top of the main aquifer is about 290 m below the perched aquifer. Hydrologic studies in the canyon began in 1960. Since that time, there has been no surface flow beyond the Laboratory boundary from the small drainage area of the canyon and thick sections of unsaturated alluvium. Monitoring stations in the canyon are: one surface water station (Gaging Station 1, GS-1) and six observation wells completed into the shallow alluvial aquifer. At times, wells in the lower reach of the canyon are dry.

(1) Radiochemical Analyses. Acid-Pueblo (Table E-XIV), DP Los Alamos (Table E-XV), and Mortandad (Table E-XVI) 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). Radionuclide concentrations from treated effluents decrease downgradient in the canyons due to dilution with surface and shallow ground water and with their adsorption on alluvium sediments (Table E-XVI). 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 (Table E-XVII) 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).

(2) Chemical Analyses. 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 (Purtymun 1977). Mortandad Canyon receives the largest volume of industrial effluents.

Though the concentrations of some chemical constituents in the waters in these canyons are high when compared to drinking water standards (Table VII), these onsite waters are not a source of municipal, industrial, or agricultural supply. Maximum chemical concentrations are in water samples taken near effluent outfalls (Tables E-XIV through E-XVII). Chemical quality of the water improves downgradient from the outfalls. Surface flows in these canyons reach the Rio Grande only during spring snowmelt or heavy summer thunderstorms.

D. Radioactivity in Soil and Sediments

Soil and sediment samples were collected and analyzed for radioactivity to evaluate the effect of Laboratory operations on the environment. Soil samples were collected at seven regional, six perimeter, and ten onsite stations. Concentrations of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and gross gamma activity were at or below background levels. Above background concentrations of total uranium in soil samples from three perimeter and two onsite stations resulted from uranium-bearing parent rock from which the soil was derived. Low tritium concentrations in soil samples from regional and perimeter stations resulted from worldwide rainout, while relatively higher tritium concentrations in soil from onsite stations was due to Laboratory airborne tritium emissions. Sediment samples were collected from 14 regional, 9 perimeter, and 21 onsite liquid effluent stations. The concentrations of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, total uranium, and gross gamma activity in samples from regional and perimeter stations were at or below background levels. Sediment stations in onsite effluent release areas (canyons) that have received or are now receiving treated liquid effluents contain radioactivity levels above background levels. Concentrations are highest near the effluent discharge points and decrease with distance from the outfalls.

1. Background Levels of Radioactivity in Soils and Sediments. Routine samples collected and analyzed for radionuclides from regional stations from 1978 through 1982 (Purtymun 1983C) helped establish background levels of ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and total uranium in soils and sediments for this report (Table VIII). The average maximum concentration plus twice its standard deviation ($\bar{x} + 2s$) of ^{90}Sr, ^{3}H, and gross gamma activity in regional soil and sediment samples taken in 1983 were used as background to compare with analytical results from samples taken in 1984. See Appendix B for descriptions of collection methods and statistical treatment of data for soil and sediment samples.

2. Regional Soils and Sediments. Regional soil and sediment samples were collected in the same general locations as the regional water samples (Fig. 12). Additional regional sediment samples were collected from the Rio Grande and tributary streams entering the Rio Grande from Otowi Bridge to Cochiti Reservior (Fig. 6). The locations are listed in Table E-XVIII and detailed results of radiochemical analyses of the regional soils and sediments are in Table E-XIX.

Soil samples were collected from seven stations and analyzed for six types of radioactivity (Table VIII). The maximum 1984 concentrations of radioactivity in soils were within established background levels, except for tritium concentrations. Tritium levels in four of the seven samples collected exceeded 1983 background levels. The maximum concentration (at Bernalillo) of 8.8×10^{6} μCi/mℓ was about twice the maximum 1983 concentration. Sediment samples were collected from 14 regional stations and were analyzed for 5 types of radioactivity (Table VIII). Maximum concentrations of radioactivity is sediments in 1984 were near or within established background levels.

3. Perimeter Soils and Sediments. Six perimeter soil stations were sampled within 4 km of the Laboratory. Nine sediment stations near the Laboratory's boundary and on intermittent streams that cross Pajarito Plateau were sampled. The locations of the perimeter soil and sediment sampling stations are listed in Table E-XVIII and shown in Figs. 14 and 15. Detailed analytical results are in Table E-XX.

Analyses of perimeter soil samples indicated that concentrations of ^{137}Cs (one station), total uranium (three stations), and tritium (two stations) were slightly elevated when compared with background levels. Cesium and tritium levels vary with atmospheric fallout fluctuations. Uranium levels vary due to different uranium concentrations found in parent rock from which the soil was derived. Analyses of perimeter sediment samples showed that radioactivity levels in 1983 were at or near established background levels (Table VIII).

Table VIII

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

	Number of Stations	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{90}Sr (pCi/g)	Total U (μg/g)	^{3}H (10^{-6} μCi/ml)	Gross Gamma (counts/min/g)
Soils								
Background (1978-1982)[a]	—	1.32	0.006	0.081	—	3.9	4.6[b]	9.0[b]
Regional Stations	7	0.90 ± 0.30 (0)[c]	0.002 ± 0.002 (0)	0.020 ± 0.006 (0)	—	3.9 ± 0.4 (0)	8.8 ± 1.8 (4)	8.5 ± 0.6 (0)
Perimeter Stations	6	2.2 ± 0.60 (1)	0.003 ± 0.002 (0)	0.062 ± 0.010 (0)	—	5.0 ± 0.6 (3)	5.8 ± 14 (2)	9.3 ± 0.6 (1)
Onsite Stations	10	3.0 ± 0.91 (1)	0.007 ± 0.008 (1)	0.057 ± 0.010 (0)	—	5.9 ± 0.3 (2)	38 ± 8.0(6)	7.9 ± 0.6 (0)
Sediments								
Background (1978-1982)	—	0.46	0.006	0.042	1.54	4.6	—	4.8
Regional Stations	14	0.53 ± 0.30 (1)	0.005 ± 0.005 (0)	0.010 ± 0.005 (0)	—	4.9 ± 0.6 (1)	—	8.4 ± 0.6 (2)
Perimeter Stations	9	0.34 ± 0.30 (0)	0.005 ± 0.004 (0)	0.008 ± 0.004 (0)	—	2.7 ± 0.2 (0)	—	5.1 ± 0.6 (1)
Onsite Station, Effluent Release Areas								
Acid-Pueblo Canyon	3	0.79 ± 0.30 (1)	0.059 ± 0.014 (2)	7.51 ± 0.240 (2)	0.90 ± 0.12 (0)	2.4 ± 0.2 (0)	—	3.7 ± 0.6 (0)
DP-Los Alamos Canyon	11	28 ± 8.4 (8)	1.70 ± 0.08(7)	5.30 ± 0.16 (10)	12 ± 0.10 (2)	5.6 ± 0.6 (1)5	—	28 ± 0.8 (3)
Mortandad Canyon	7	90 ± 27 (5)	68 ± 0.12 (6)	235 ± 3.4 (5)	8.7 ± 0.6 (3)	4.9 ± 0.6 (1)	—	787 ± 16 (4)

[a]Average maximum value ($\bar{x}$ + 2s) (Purtymun 1983D).
[b]Average maximum ($\bar{x}$ + 2s for 1983 (ESG 1984).
[c]Number in parentheses indicates number of stations exceeding background level at stations in Northern New Mexico, 1978-1982. The ± value is twice the uncertainty for the average of the analyses.

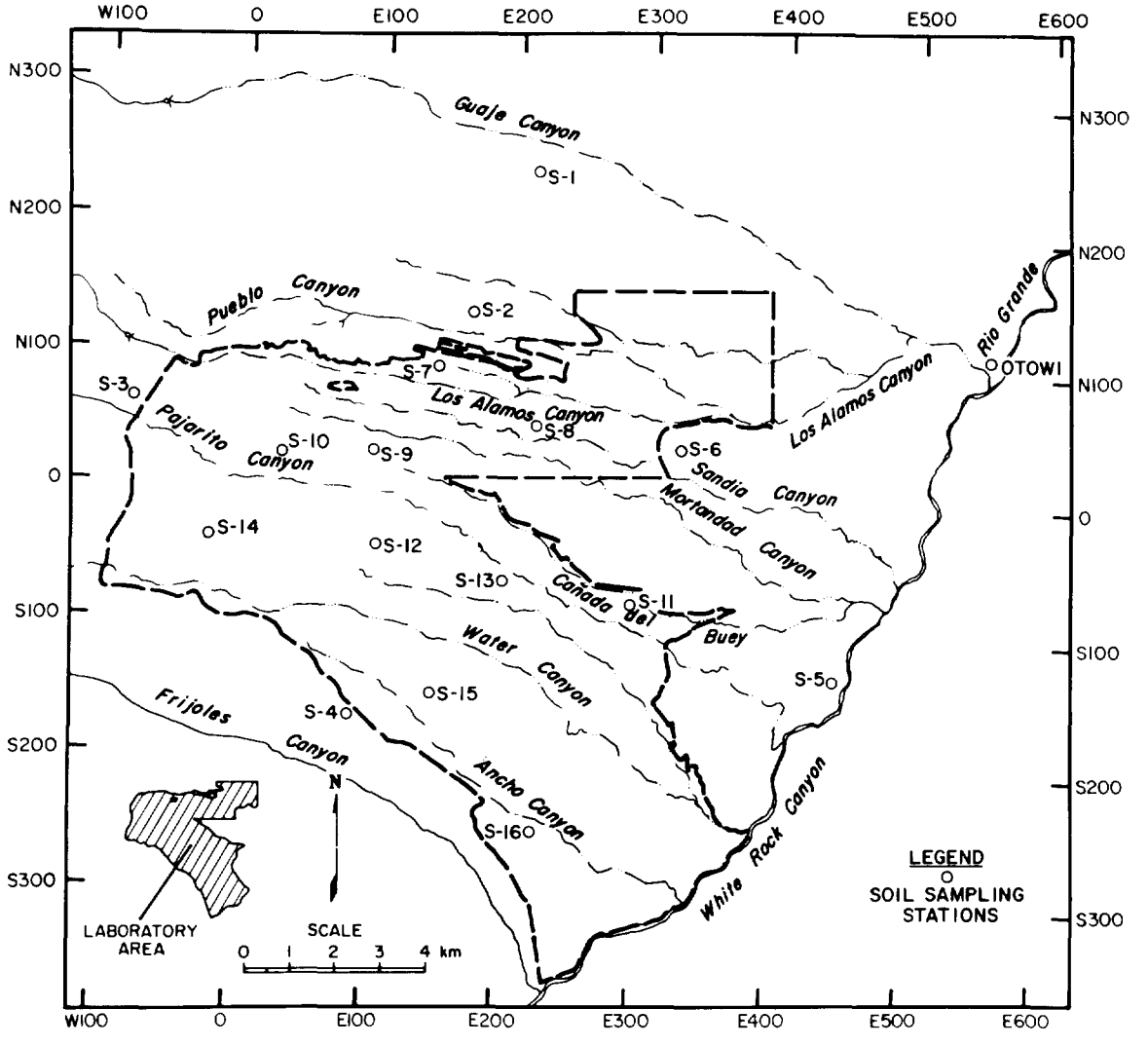


Fig. 14. Soil sampling locations on or near the Laboratory site.

4. Onsite Soils and Sediments. Onsite soil samples were collected from ten stations within the Laboratory boundaries. Onsite sediment samples were collected from 21 stations within liquid effluent release areas (Table EXVIII). Analytical results for the onsite soil and sediment samples are in Table E-XXI and maximum concentrations are in Table VIII. Locations of the soil and sediment onsite stations are shown in Figs. 15 and 16.

Soil analyses indicated that one sample contained above background concentrations of ^{137}Cs and $^{239,240}Pu$. Total uranium (two samples) and tritium (six samples) soil concentrations were above baseline levels. The uranium levels reflect fluctuations in uranium concentrations found naturally in parent rock. The relatively higher tritium concentrations probably resulted from airborne tritium emissions from the Laboratory (Table E-I). The ^{137}Cs and $^{239,240}Pu$ concentrations were near background levels.

Sediment samples 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 received or are now receiving treated industrial effluents containing trace amounts of radioactivity. Acid-Pueblo Canyon received effluents from about 1944 through 1964 and sediment samples from the canyon had relatively higher $^{239,240}Pu$ concentrations (Table VIII). DP-Los Alamos and Mortandad Canyons are now receiving treated industrial effluents.

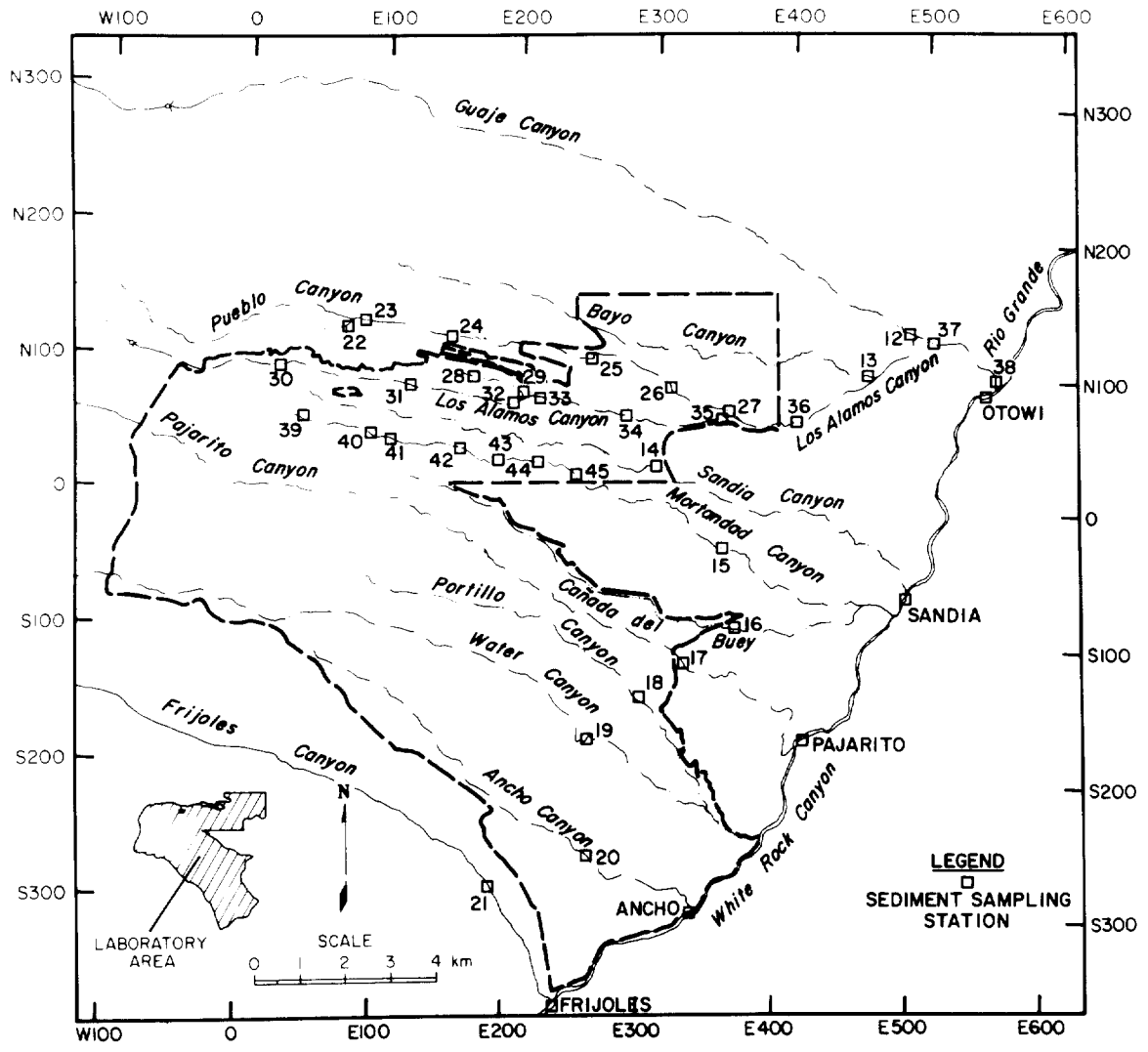


Fig. 15. Sediment sampling locations on or near the Laboratory site.

Major contaminants in these two canyons are ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and ^{90}Sr. The radionuclides are adsorbed or attached to sediment particles in the canyon stream channels (Purtymun 1971 and Purtymun 1974A). This reduces the amount of radionuclides available to be in solution. Radionuclide concentrations are generally highest near the points of effluent discharge and decrease downstream as sediments and radionuclides are dispersed by surface runoff.

5. Special Monitoring of Sediments in Regional Reservoirs. Special analyses for plutonium were performed on 1 kg samples (100 times the usual mass used for analyses) of reservior sediments. Three samples were taken from each reservior (Fig. 16). These large samples increase the sensitivity of the plutonium analyses, which is necessary to effectively evaluate background plutonium concentrations in fallout from atmospheric nuclear tests.

The reservior sediments were collected from El Vado, Heron, and Abiquiu Reserviors on the Rio Chama. Drainage occurs along the Continental Divide in southern Colorado and northern New Mexico, northwest of Los Alamos. Sediments were sampled from Cochiti Reservior, which is on the Rio Grande, below the confluence with Rio Chama, and south of Los Alamos (Fig. 16).

The sediments were collected in the upper, middle, and lower (near dam) parts of the reserviors. A boat

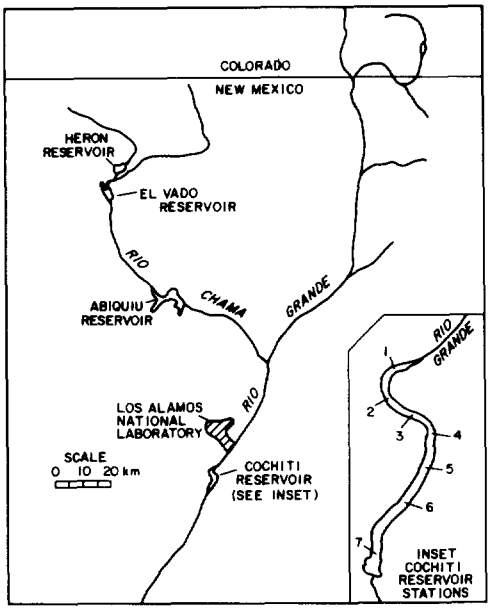


Fig. 16. Special regional soil sampling locations.

and Eckman dredge were used to collect bottom samples to a depth of about 6 cm. Samples were collected in water depths ranging from 4 to 16 m. The sediments consisted of fine-grained silts, clays, and some organic material (there were considerably more organic materials in sediments from Cochiti Reservior than from the other reserviors). The 1 kg samples were analyzed for ^{238}Pu and $^{239,240}Pu$, while ^{137}Cs, total uranium, and gross gamma activity analyses were done on standard 10 g samples (Table E-XXII).

The average concentrations of ^{238}Pu in sediments ranged from 0.00038 to 0.00070 pCi/g (Table IX). There was a slight increase in the average concentration of ^{238}Pu downgradient from Heron Reservior to Cochiservior. There was no significant difference in the average concentrations in reservior sediments when compared with the average concentrations in background soils for 1979-1982.

The average concentrations of $^{239,240}Pu$ in sediments ranged from 0.00468 to 0.01970 pCi/g. The concnetrations generally increase downgradient from Heron Reservior to Cochiti Reservior. The average $^{239,240}Pu$ concentrations were relatively higher than the ^{238}Pu concentrations (see $^{239,240}Pu/^{238}Pu$ ratios in Table IX). Ratios for reservior sediments ranged from 12 to 28, while the ratio for background sediment samples is about 20 (Table IX).

Table IX

Radiochemical Analyses of Reservoir Sediments

Reservoir	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	Ratio $[^{239,240}Pu]/[^{238}Pu]$
El Vado	0.00038 ± 0.00012	0.0047 ± 0.00722	12
Heron	0.00050 ± 0.00058	0.0093 ± 0.01551	18
Abiquiu	0.00070 ± 0.00040	0.0127 ± 0.00630	18
Cochiti	0.00070 ± 0.00108	0.0197 ± 0.01400	28
Background (1979-1982)[a]	0.001 ± 0.005	0.02 ± 0.061	20

[a]Ref. Purtymun 1983D.

E. Radioactivity in Foodstuffs

Most fruit, vegetable, and fish samples collected near the Laboratory showed no apparent influence from Laboratory operations. Some fruit collected from onsite and perimeter locations that could have been affected by Laboratory releases had slightly elevated tritium concentrations. Radiation doses from consumption of foodstuffs are discussed in Section III.D.

1. Introduction. Fruits, vegetables, fish, and honey are sampled to monitor for possible radioactive contamination from Laboratory operations. The sampling locations are shown in Fig. 17. Fruits, vegetables, and honey collected in the Rio Grande Valley and fish netted at the Abiquiu, Heron, and El Vado Reservoirs are not affected by Laboratory operations. These regional sampling locations are upstream from the confluences with the Rio Grande of intermittent streams that cross the Laboratory. They are also distant from the Laboratory and are unaffected by airborne emissions. Consequently, these regional areas are used as background sampling locations for the foodstuff sampling program. The radiological doses associated with eating these foodstuffs are discussed in Section III.D.

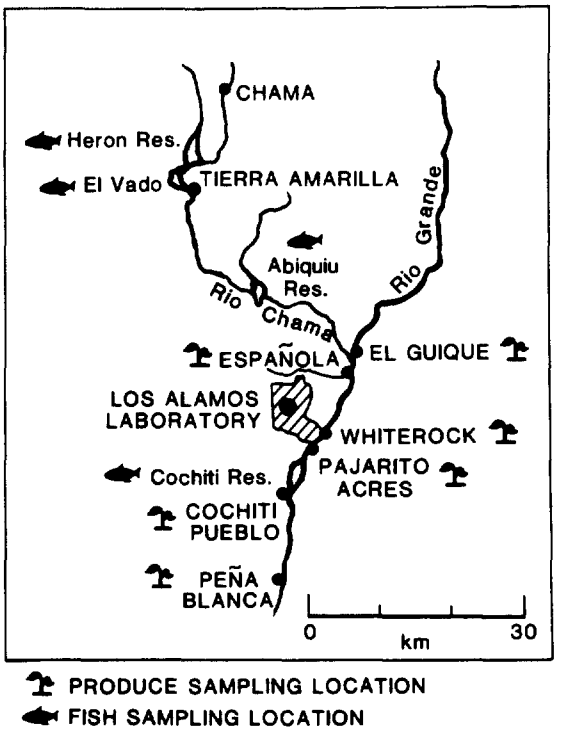


Fig. 17. Fish and produce sampling locations.

2. Fruits and Vegetables. Data in Table E-XXIII summarize fruit and vegetable sample results for ^{3}H (tritated water), ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, and total U. The sampling methods are described in another report (Salazar 1984). Concentrations of ^{238}Pu, $^{239,240}Pu$, ^{90}Sr, ^{137}Cs, and total U in fruits and vegetables from regional and perimeter sampling 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.

Tritium concentrations in water extracted from fruits and vegetables from regional locations were statistically (95% confidence level) lower that the concentrations in samples from perimeter and onsite locations. Tritium concentrations in fruits and vegetables from perimeter locations were statistically lower than concentrations in samples from onsite locations. The Laboratory releases tritium (see Section V) and the samples from the perimeter and onsite locations reflect these releases. However, these fruits and vegetables do not represent a significant pathway to humans, because of the very small amounts of edible material and the low tritium concentrations (Table E-XXIII).

The tritium levels that were measured in onsite fruits and vegetables were compared with limits for tritium concentrations in water, because there are no standards for tritium in produce. This comparison is conservative, because the limits on tritium in water are based on an annual water intake from drinking, which is much greater than the annual water intake resulting from eating produce. All the tritium maximum concentrations from the onsite produce were much less than 1% of the Department of Energy's Uncontrolled Area Concentration Guide for tritium in water.

3. Fish. Fish were sampled in four reservoirs (Fig. 17). Abiquiu, El Vado, and Heron Reservoirs are

upstream from the Laboratory on the Rio Chama and serve as background sampling locations. Cochiti Reservoir is downstream from the Laboratory on the Rio Grande. It could potentially be affected by Laboratory operations, because it is downriver from the intermittent streams that cross the Laboratory. The sampling procedures are described in another report (Salazar 1984).

Some fish samples were taken from bottom feeders (carp, catfish, suckers) that have a greater probability than higher trophic levels of ingesting any radioactivity that might be associated with sediments. Higher level feeders (bass, trout, crappie, walleye, pike, perch) were also sampled. The fish were dissected into two kinds of samples. The gut sample included the gills, major organs, and gastrointestinal tract. The carcass sample included the head, skin, fins, bones, and muscles.

The gut and carcass samples were analyzed for ^{90}Sr, ^{137}CS, ^{238}Pu, $^{239,240}Pu$, and total U. The results are in Table E-XXIV. The ^{90}Sr and ^{137}Cs levels were slightly higher in the upstream reservoirs than in the downstream reservoir. These radionuclides are in the environment mostly due to worldwide fallout from past nuclear weapons testing in the atmosphere. Fallout generally increases with altitude at the same latitude. The upstream reservoirs are at higher elevations than the downstream reservoir, so the relatively higher concentrations of ^{90}Sr and ^{137}Cs in fish from the upstream reservoir is expected.

Uranium concentrations in the fish samples showed no apparent pattern. Uranium occurs naturally in soils and sediments and has a high degree of variability. Therefore, uranium concentrations found in fish depend greatly on the concentration of natural uranium in reservoir sediments, amount of suspended sediments in reservoir water, and feeding habits of the fish.

4. Honey and Bees. During 1984, the honey bee monitoring network was expanded by three locations. Onsite hives were established at TA-9 and TA-15, and an additional regional sample was collected from San Pedro in Espanola. These new locations are identified in Table E-XXV and shown along with the old locations in Fig. 18. The honey sampling program measures the amounts of biologically available radionuclides.

The most recent data from the beehive network are shown in Table E-XXVI. The results show slightly above background uranium concentrations in bees and elevated tritium concentrations in honey from all onsite hives. There were similar uranium concentrations in bees from regional and perimeter hives. There are tritium and uranium sources at the Laboratory (see Section V) and these samples reflect those releases. Elevated ^{57}Co, ^{54}Mn, ^{83}Rb, and ^{22}Na concentrations were found in bees from the Los Alamos Meson Physics Facility's (LAMPF, TA-53) hive, but not in honey from the same hive. The LAMPF emits these isotopes.

F. Special Monitoring Studies

1. Monitoring Rain for Chemical Constituents. The National Atmospheric Deposition Program rain gauge, located at the Bandelier meteorological station at the Laboratory, continued in operation during 1984. Data obtained since publication of the last surveillance report (ESG 1984) are shown in Table E-XXVII. Rainfall acidity ranged from 4.4 to 6.5 (pH), with most measurements between 5 and 6. The low reading of 4.4 appears to be an anomaly. In general, the measured acidity is considered normal. However, rainfall in the Los Alamos area might be expected to be slightly more alkaline than normal because of the alkalinity of resuspended soil particles. Concentrations of certain chemical constituents, such as sulfate and calcium, vary widely. These may have resulted from regional aerosols transported to the Los Alamos area by changing wind patterns.

2. Monitoring Deer and Elk. As a result of road kills, poaching, and natural death, a certain number of dead deer and elk are found on Los Alamos National Laboratory property each year. Whenever possible, samples of fur from these dead animals are obtained and submitted for chemical analysis to see if elevated levels of any chemicals are present. This project was undertaken because of numerous articles in the literature indicating that many environmental contaminants tend to accumulate in human hair or animal fur. The results obtained to date are shown in Table E-XXVIII.

G. Meteorology

1. Weather Summary. Los Alamos weather during 1984 was extreme and unusual at times. Snowfall totaled nearly 113 in., the greatest amount ever recorded in a calendar year. Unusually warm weather occurred in May, while early winter weather in October produced record cold and snow. A snowstorm in December left nearly 3 ft of snow on Los Alamos,

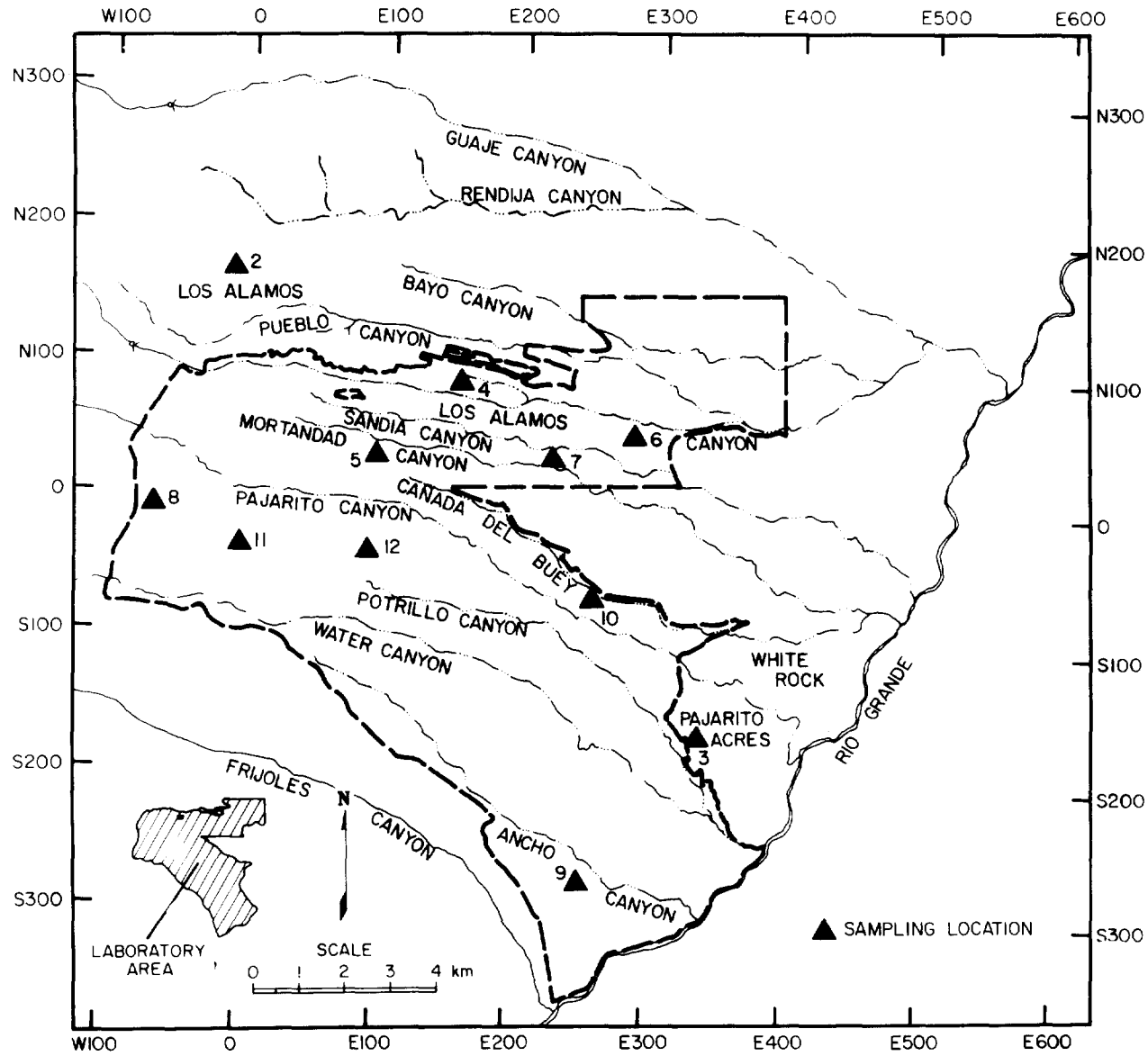


Fig. 18. Locations of beehives.

which was the largest snowfall ever recorded. Record precipitation was also recorded in December. The year as a whole was slightly cooler and wetter than normal. The 1984 weather is summarized in Fig. 19, Table E-XXIX, and Table E-XXX.

January was cool and dry. A storm on the 13th and 14th produced 14 in. of snow, which was the only measurable precipitation during the month. Low temperatures reached −2°F and −1°F on the 18th and 19th, respectively. February was dry with 0.14 in. of precipitation and 1 in. of snow. March was stormy and snowy. A total of 34 in. of snow fell, which was just shy of the record of 36 in. Precipitation of 2.04 in. was about twice the normal amount. April was cooler and drier than normal. A peak wind gust of 60 mph occurred on the 25th.

May was unusually warm with a mean temperature of 60.4°F, just below the record of 60.5°F. The normal mean is 54.9°F. There were 9 days on which records were tied or broken and 12 days on which the temperature exceeded 80°F. June, July, and August had near-normal weather conditions. September had near-normal precipitation and rainfall. The temperature reached 87°F and 88°F on the 9th and 19th, respectively, breaking records for the two dates.

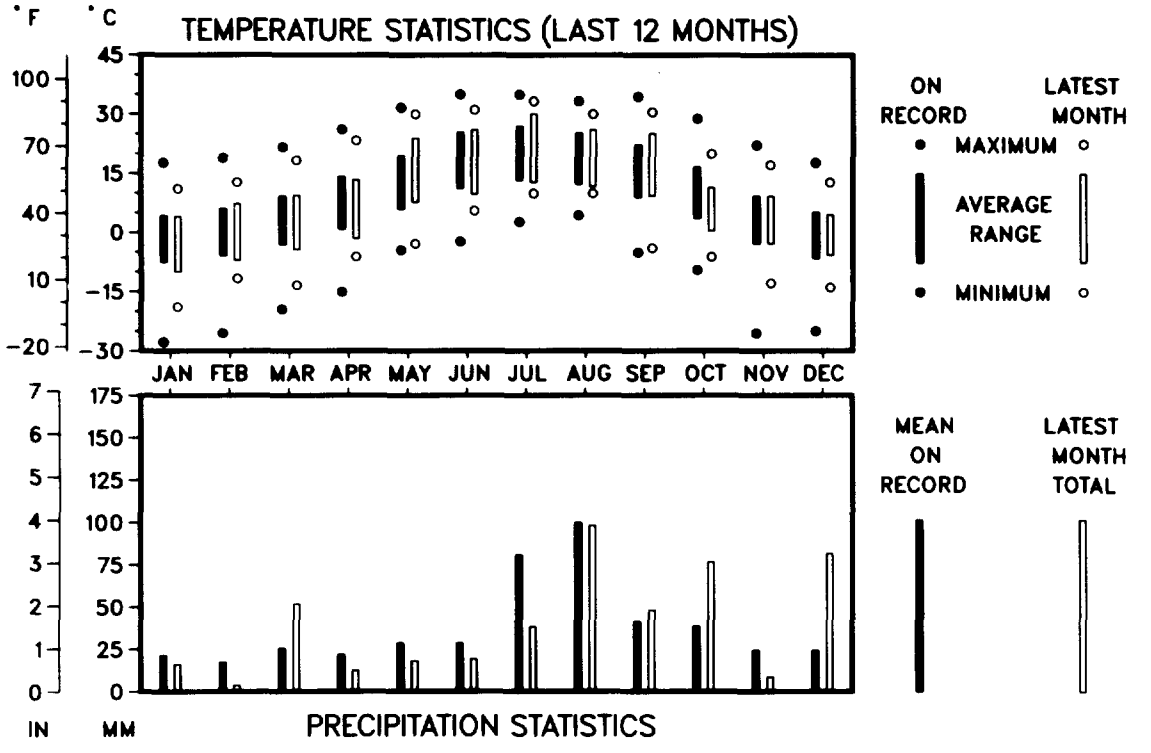


Fig. 19. Summary of 1984 weather in Los Alamos (data from Occupational Health Laboratory, OHL, TA-59).

October recorded snow and cold. A total of 20 in. of snow fell during the month, which broke the record of 9 in. The mean temperature was 42.8°F, which was significantly below the normal mean of 50.3°F and was the coldest mean temperature for October. A 21°F temperature of the 16th was the coldest temperature ever recorded for so early in the year. November had normal weather conditions. December recorded a 34.5 in. snowfall from the 12th to the 15th. This broke the largest single snowfall record of 32.1 in. The precipitation total for December was 3.21 in., which broke the previous record of 2.85 in.

2. Wind Roses. The 1984 wind speed and direction measured at the Occupational Health Laboratory (OHL, TA-59) are plotted in wind roses (Fig. 20). 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, etc.) and is centered on a 22.5° sector of the circle. The frequency of the calm winds, defined as those having wind speeds of less than 0.5 m/sec and no direction, is given in the circle's center.

The OHL wind data were measured at a height of 23 m with 89% data recovery for 1984. The wind roses in Fig. 20 include an annual summary for 1984 and summaries for daytime and nighttime hours. Los Alamos generally has light winds. The annual average wind speed is 2.6 m/sec. Only 9% of wind speeds in 1984 were greater than 5 m/sec, while 56% were less than 2.5 m/sec.

This distribution of wind directions 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. Predominant winds from NW to SW are produced by "westerlies," which are often as far south as New Mexico. The slope of the terrain fosters 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 out of the SE to SSE.

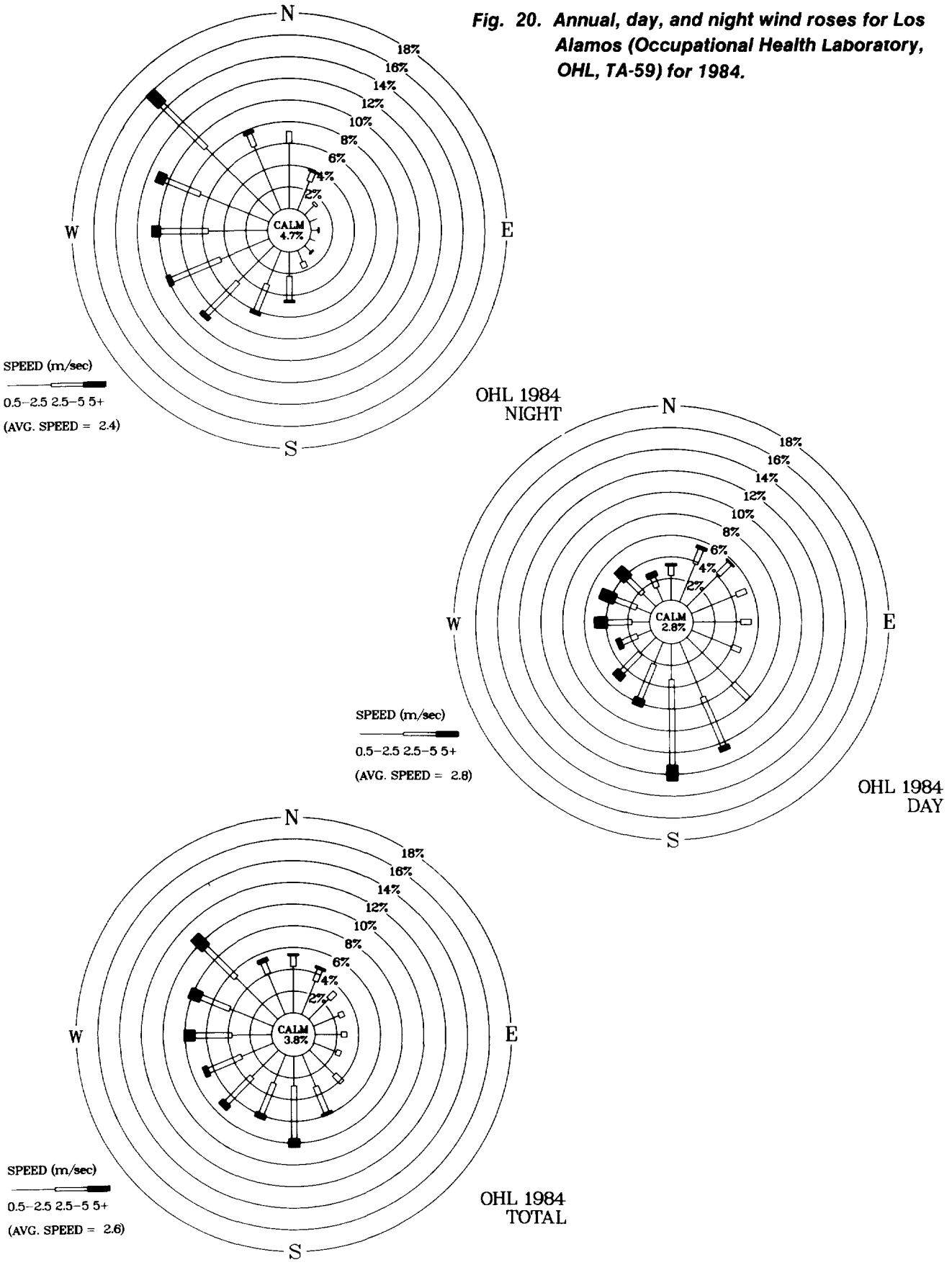


Fig. 20. Annual, day, and night wind roses for Los Alamos (Occupational Health Laboratory, OHL, TA-59) for 1984.

Wind speed and direction frequencies vary from one Laboratory site to another. These fluctuations are caused by the complex terrain of Pajarito Plateau. For example, sites located on the eastern edge of the plateau have more frequent winds from the NE and SW than do sites on the western side (e.g., Area G at TA-54, see Fig. 21). Up-valley winds, primarily from the SSW, frequently occur during the afternoon and early evening hours. These winds are often strong (greater than 5 m/sec). Down-valley winds during the night and morning hours are generally light.

3. Rainfall Summary. Above-normal amounts of precipitation fell in the Los Alamos area during 1984. Figure 22 shows 1984 quarterly and annual precipitation data from five locations in Los Alamos County. See Fig. 23 for the locations of these sites. Precipitation totals were relatively high in the fourth quarter due to unusually stormy weather in October and December. Normally only the third quarter has relatively higher precipitation totals due to summer thunderstorms. The precipitation amounts generally increase with elevation and proximity to the Jemez Mountains.

H. Unplanned Releases

1. Atmospheric Tritium Releases at TA-41. On January 4-5, 1984, approximately 790 Ci of tritium was released through a stack at TA-41. The release occurred over a 36 hour period beginning at 8:40 a.m. on January 4. Samples from three stations of the Laboratory's routine air sampling network were analyzed for tritium. In addition, a mobile tritium-in air sampler was placed near the TA-41 stack on January 5. Measured airborne concentrations of tritium were consistent with normal fluctuations in atmospheric tritium data. No measureable increase in atmospheric tritium due to the release was detected in these samples.

Doses to the public resulting from the release were estimated using meteorological modeling. The maximum potential dose that could have occurred to a member of the public from this release was estimated to be 0.1 mrem (whole body). This dose is 0.02% of the Department of Energy's 500 mrem/year Radiation Protection Standard for a member of the public (DOE 1981A).

2. ^{238}Pu Release at TA-54. On September 19, 1984, ^{238}Pu was inadvertently released from a drum at TA-54. The material was almost entirely contained in the building where the release occurred. Filter samples were taken from six air samplers in the vicinity of TA-54. In addition, two portable air samplers were placed next to the building in which the spill occurred. Air samplers were operated during the entire cleanup operation, which was completed on December 21, 1984. All air samples are being analyzed for ^{238}Pu and ^{239,240}Pu, but not all analyses have been completed.

Preliminary data show a small increase in ^{238}Pu air concentrations was detected by the two portable samplers located onsite immediately next to the building where the spill occurred. All ^{238}Pu concentrations measured by these two samplers were less than 0.1% of the Department of Energy's Concentration Guide for ^{238}Pu for Controlled Areas (DOE 1981A). These two samplers were the only ones detecting any change in ^{238}Pu concentrations in air. Measurements by air samplers farther from the building, but still in the TA-54 area, did not detect any increase in airborne radioactivity. No ^{238}Pu was detected by any offsite air samplers.

The ^{239,240}Pu air concentrations were within the normal range for airborne ^{239,240}Pu that had been previously observed at TA-54. No measureable increase in ^{239,240}Pu was detected as a result of the spill.

3. Tritium Release at TA-21. On November 19, 1985, approximately 575 Curies of tritium was released at TA-21 (DP Site). About 527 Curies was released between 10:30 a.m. and 11:15 a.m., and the remaining 48 Curies during the next 24 hours. The tritium was primarily in gaseous form as tritiated hydrogen gas, although a small fraction was believed to be present as tritiated water.

A Gaussian dispersion computer code was run to calculate ambient concentrations of tritium to estimate the potential radiation dose that might have resulted from the release. The calculated dose to a hypothetical maximally exposed individual was less than 1 mrem (whole body), or less than 0.2% of the Department of Energy's Radiation Protection Standard of 500 mrem/year for a member of the public (DOE 1981A).

Atmospheric moisture samples were collected from nine air samplers of the routine environmental air monitoring network and analyzed for tritium. All tritium concentrations measured by the air sampling network were less than 0.03% of the Department of Energy's Concentration Guide for tritium in Uncontrolled Areas (DOE 1981A).

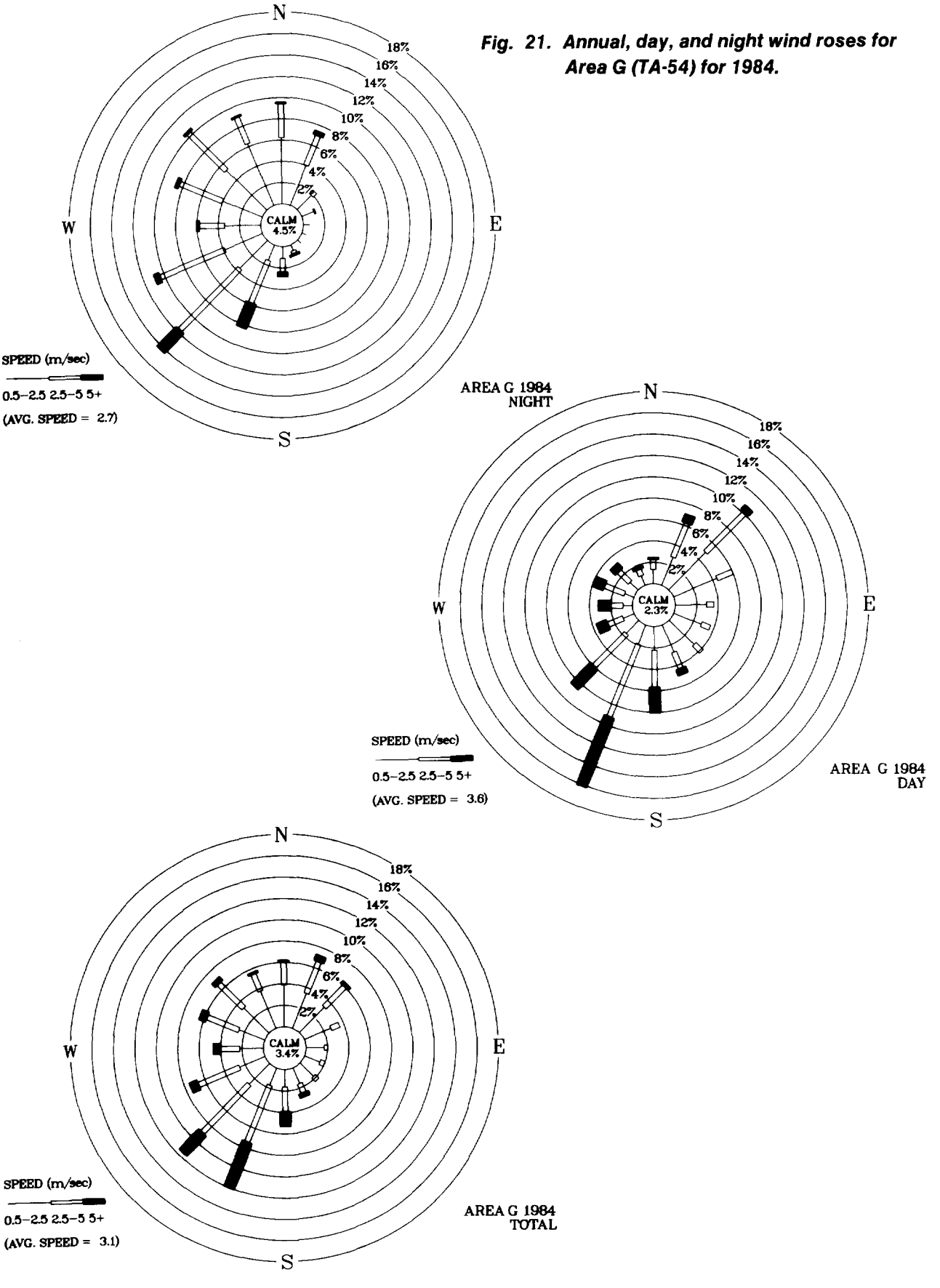


Fig. 21. Annual, day, and night wind roses for Area G (TA-54) for 1984.

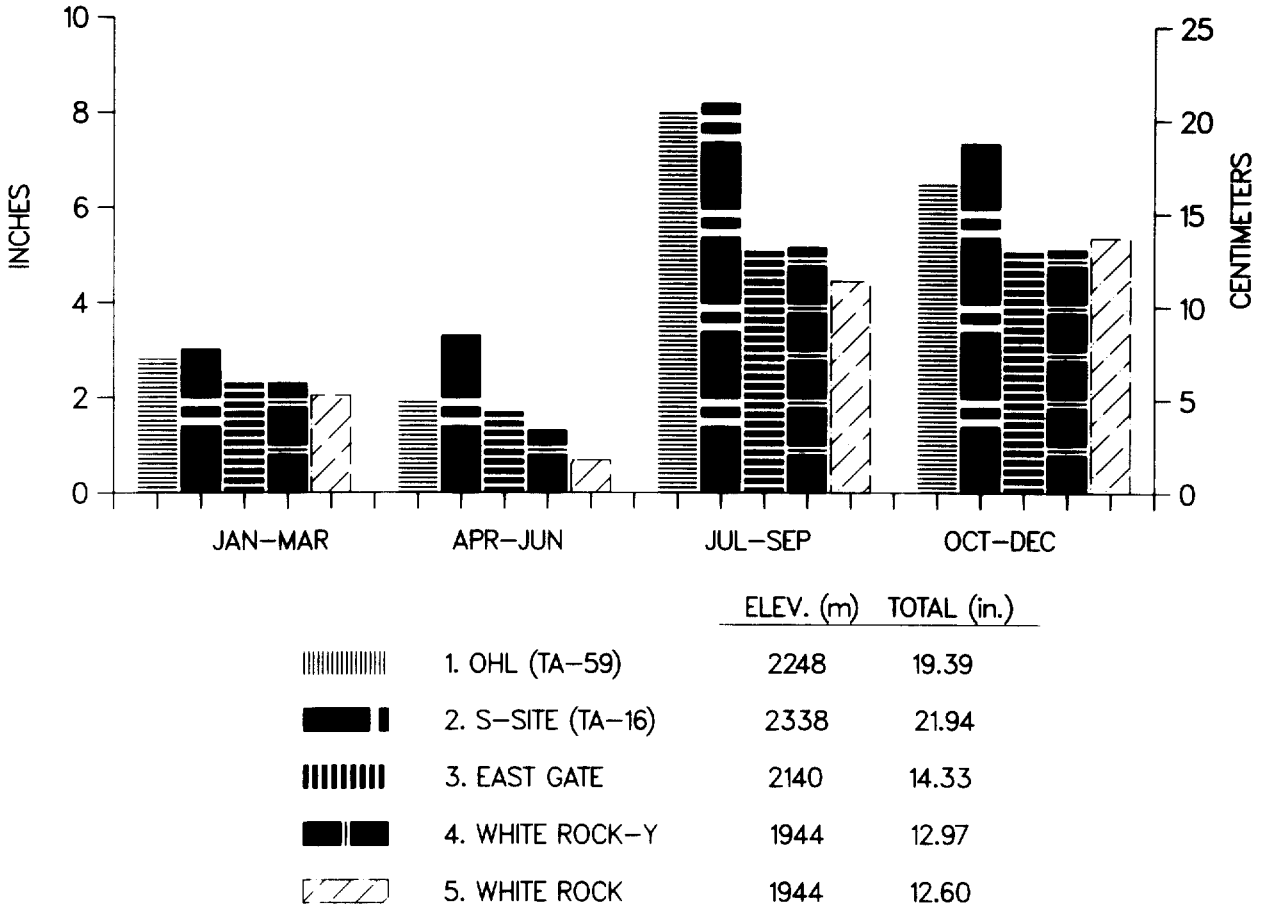


Fig. 22. Summary of precipitation in the Los Alamos area for 1984.

4. Tritium Releases at TA-33 and TA-35. A related series of tritium releases occurred at TA-33 and TA-35 from November 21 through November 24, 1985. These releases resulted from a leaking tritium container at TA-33 that was later removed to the Target Fabrication Facility at TA-35. Approximately 2000 Ci was released at TA-33, and 100 Ci at TA-35, giving a total of 2100 Ci released. The tritium was believed to be mostly in gaseous form, with a small percentage as tritiated water.

Tritium concentrations in ambient air were calculated to estimate the maximum potential dose using a Gaussian dispersion computer code, measured release rates, and local meteorology conditions. The total dose to a hypothetical maximally exposed individual was calculated to be less than 1 mrem (whole body), or less than 0.2% of the 500 mrem/year Department of Energy's Radiation Protection Standard for members of the public (DOE 1981A).

Samples to measure tritiated water vapor were collected at all stations of the routine environmental air monitoring network. The highest tritium concentration measured was 0.06% of the Department of Energy's Concentration Guide for airborne tritium in Uncontrolled Areas (DOE 1981A).

5. Fluorine Release at TA-55. On December 13, 1984, fluorine escaped from a cylinder at TA-55 and vented through a stack. There is approximately 7.3 kg of fluorine in a full cylinder, but this cylinder was not full at the time of the release. Hydrogen fluoride concentrations in air were calculated at 100 m from the stack using an atmospheric model and local meteorological conditions. These concentrations were estimated to be below the Short Term Exposure Limit for hydrogen fluoride that was adopted by the American Conference of Governmental Industrial Hygienists. Concentrations at distances greater than 100 m would be even smaller (ACGH 1983).

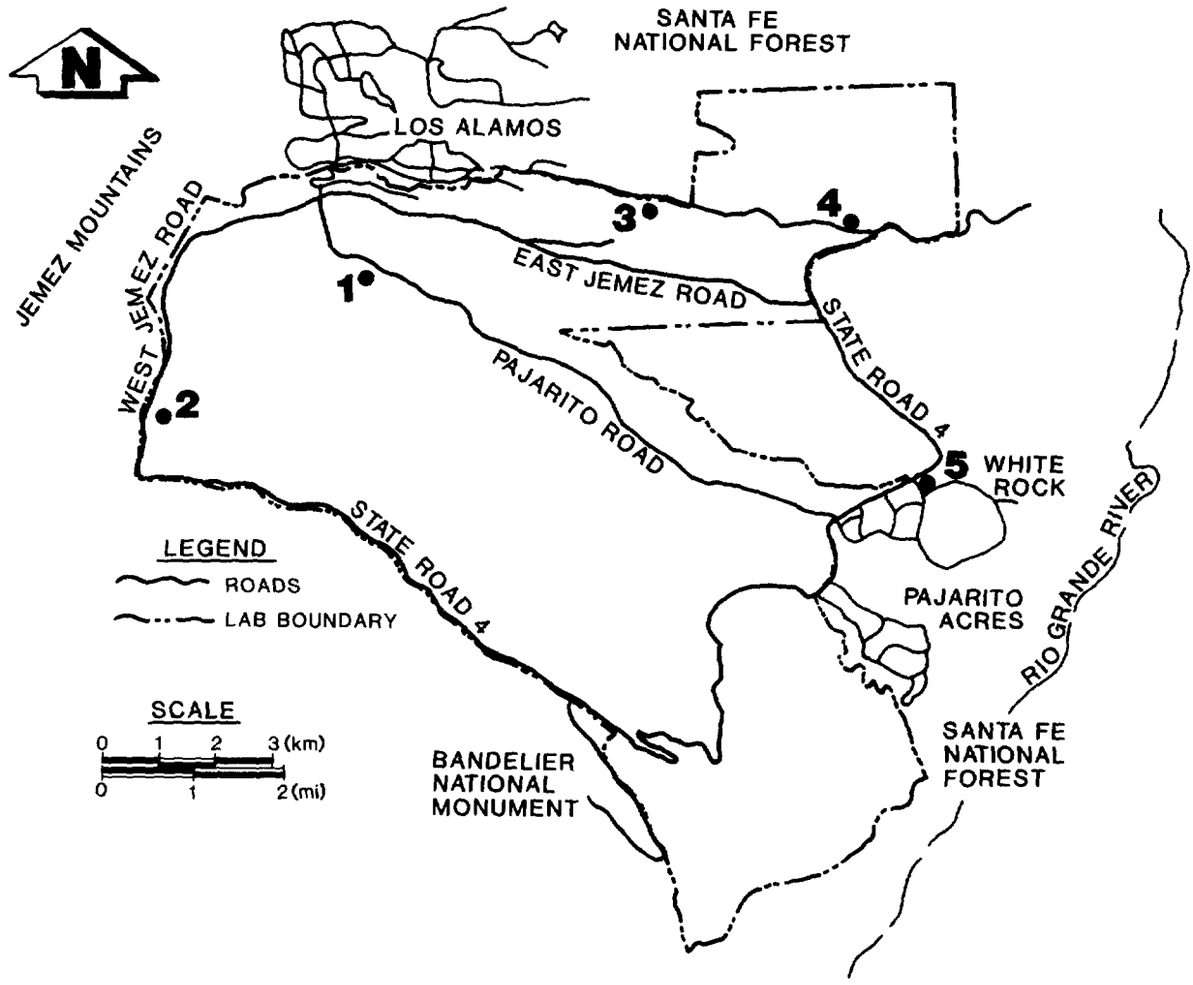


Fig. 23. Locations of rain gage stations.

V. ENVIRONMENTAL REGULATORY COMPLIANCE

A. Airborne Emissions

Airborne radioactive emissions were monitored as released from 86 points at the Laboratory. A calibration error that was discovered at the Los Alamos Meson Physics Facility (LAMPF) accounted for all but 20% of the apparent 60% increase in 1984 emissions to 736 618 Ci compared with 1983 emissions. The balance of the increase was primarily due to increased operating levels and times at LAMPF. The airborne emissions from LAMPF are mostly short-lived (2 to 20 minute half-lives) activation products.

The Laboratory's power plant, steam plants, beryllium shop, explosives burning and detonation, and asbestos operations all met the relevant federal and state air quality regulations. Two air quality audits by the New Mexico Environmental Improvement Division and the Environmental Protection Agency revealed no significant air pollution problems.

1. Radioactive. Radioactive airborne emissions are monitored and discharged at the Laboratory from 86 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). The emissions receive appropriate treatment before discharge, such as filtration for particulates, catalytic conversion and adsorption for tritium, or temporary holdup to permit decay of short-lived activation gases. Quantities of airborne radioactivity released depend on the kinds of research being done, so can vary significantly from year to year (Figs. 24-26, Tables III and E-I).

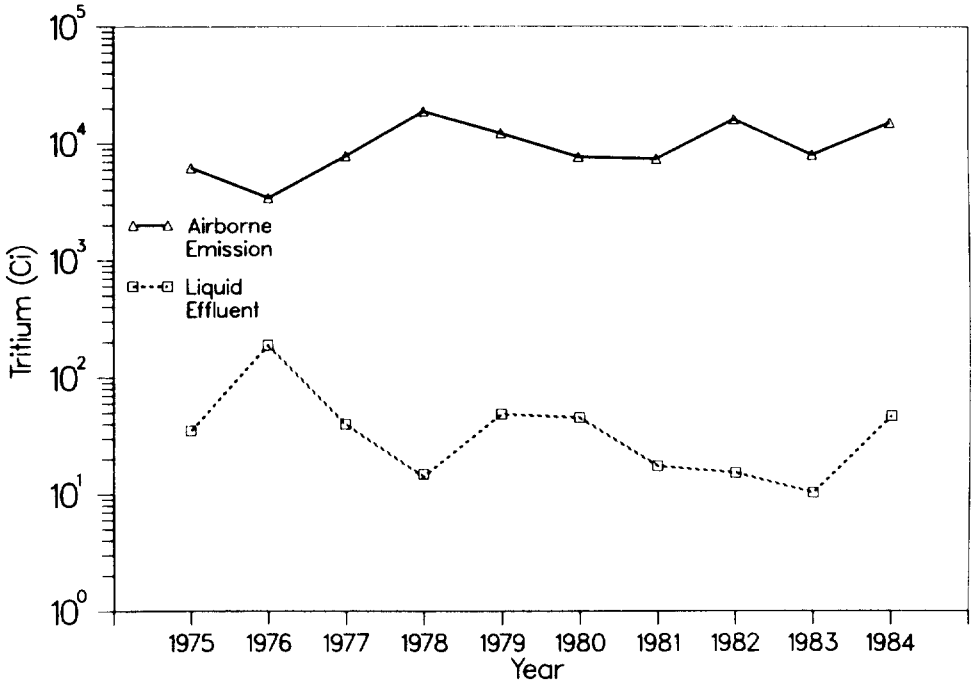


Fig. 24. Summary of tritium releases (airborne emissions and liquid effluents).

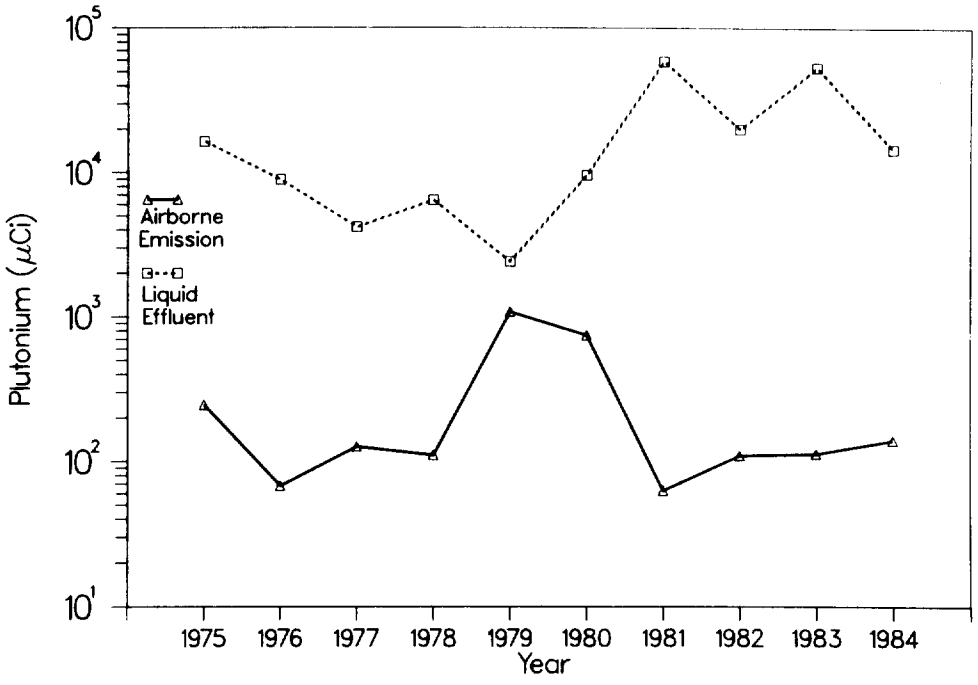


Fig. 25. Summary of plutonium releases (airborne emissions and liquid effluents).

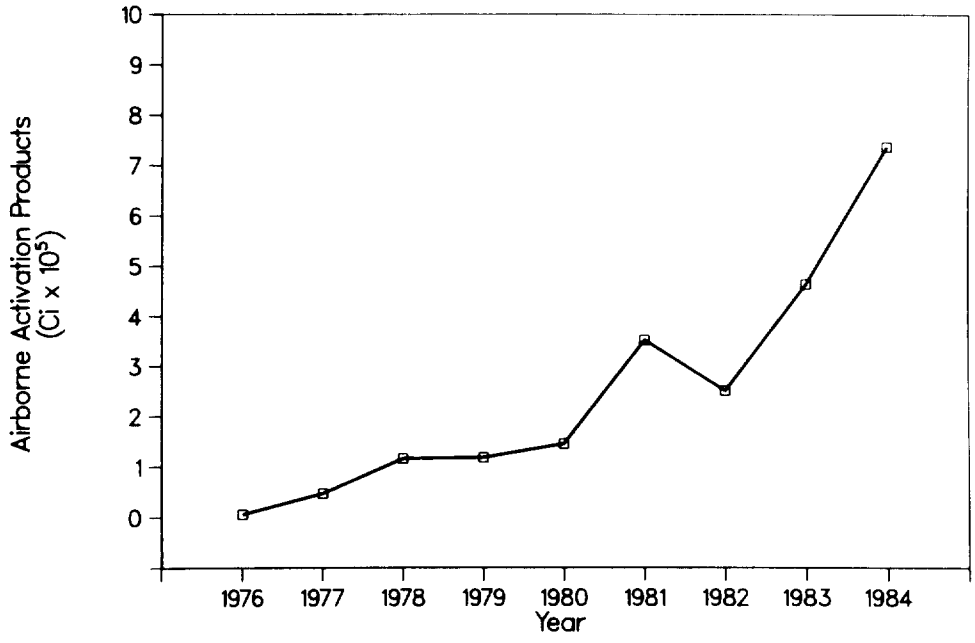


Fig. 26. Airborne activation product emissions (^{11}C, ^{13}N, ^{14}O, ^{15}O, ^{41}Ar, ^{192}Au, ^{195}Hg) from the Los Alamos Meson Physics Facility (TA-53).

During 1984, the most significant apparent increase was in airborne activation products (gases, particulates, and vapors) from the linear particle accelerator at LAMPF. A total of 463 751 Ci of activation products was reported for 1983 (ESG 1984). The total is 736 618 Ci for 1984 (Fig. 25, Table III, and Table E-I). Most of this apparent increase is due to an error in calibration of the stack sampling instrumentation at LAMPF. The instrumentation was calibrated incorrectly for an undetermined period of time, so stack emission data has been reported about 40% low. Consequently, the 1983 total should have been 40% higher or about 640 000 Ci. The real increase from 640 000 Ci (1983) to 736 618 Ci (1984) is due to increased operating levels and times at LAMPF.

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 95% of the radioactivity was from the ^{11}C, ^{13}N, ^{14}O, and ^{15}O radioisotopes, which have half lives that range from 2 to 20 minutes. Therefore, the radioactivity from these radionuclides decays very rapidly. Engineering design improvements to the beam stop area were begun in 1984 to help reduce generation of activation products.

Tritium emissions from TA-33 and TA-41 contributed to the approximate doubling of total Laboratory tritium emissions in 1984 compared with 1983 (Tables III and E-I). This increase is due primarily to changing research and development programs and operational problems (see Section IV.H).

In addition to releases from facilities, some depleted uranium (uranium consisting primarily of ^{238}U) is dispersed by experiments that use conventional high explosives. About 840 kg of depleted uranium were used in such experiments in 1984 (Table E-XXXI). This mass contains about 0.29 Ci of activity. Most debris from these experiments is deposited on the ground in the vicinity of the firing sites. Limited experimental data indicates that no more than about 10% of the depleted uranium becomes airborne. Dispersion calculations indicate that resulting airborne concentrations are in the same range as attributable to natural crustal abundance uranium in resuspended dust.

2. Nonradioactive

a. Particulate Air Quality. Total suspended particulate (TSP) concentrations in the communities of Los Alamos and White Rock are routinely measured by the New Mexico State Environmental Improvement Division. Table E-XXXII summarizes these data for 1984 and the applicable state and federal standards. The primary standards are designed to protect human health and the secondary standards are designed to protect general welfare (for example, preventing soiling).

The New Mexico standard and federal secondary 24-hour standard were exceeded once in White Rock on May 6. High winds on this day caused an excessive amount of wind blown dust of natural origin. The highest TSP concentrations were measured in the spring (Table E-XXXII), which is the windiest season of the year.

b. TA-21 Steam Plant. New Mexico Air Quality Control Regulation (AQCR) 703 requires registration of emission sources that emit greater than 2000 pounds of any air contaminant per year. The purpose of this regulation is to allow for development and maintenance of a state air quality emission inventory. Prior to construction, emissions from the new steam plant at TA-21 were estimated to be greater than 2000 lb/yr for nitrogen oxides and carbon monoxide. Therefore, it was registered with the State of New Mexico in 1984. Emissions from the plant during 1984 were estimated using the Environmental Protection Agency's emission factors (EPA 1981, EPA 1984) and are shown in Table X.

c. TA-3 Power Plant. The TA-3 power plant was not required to meet New Mexico AQCR 604 in 1984 because each of its boilers consumed less than 1×10^{12} Btu/yr of natural gas. Boilers 1, 2 and 3 consumed 0.544, 0.612, and 0.533×10^{12} Btu of natural gas in 1984, respectively.

The AQCR 604 requires gas burning equipment built before January 10, 1973, like the TA-3 plant, to meet an emission standard for nitrogen oxides of 0.3 lb/10^6 Btu if its natural gas consumption exceeds 1×10^{12} Btu/yr/unit. This emission standard is equivalent to a flue gas concentration of 248 ppm. The TA-3 boilers meet this standard with measured flue gas concentrations from 14 to 45 ppm.

Sulfur dioxide analyses of the flue gas indicate that sulfur dioxide emissions are negligible. Estimated emissions from the plant for 1984 are in Table X. The nitrogen oxides emissions were estimated based on exhaust gas measurements. The Environmental Protection Agency's emission factors were used in estimating the other emission quantities (EPA 1984).

d. Asphalt Plant. The asphalt plant easily meets the stack emission requirements for

Table X

Estimated Emissions and Fuel Consumption for the TA-3 Power Plant and Steam Plants for 1984

Pollutant	TA-3	TA-16	TA-21
Particulates (tons)	2.4	0.4	0.2
Oxides of nitrogen (tons)	31.2	20.3	8.1
Carbon monoxide (tons)	31.4	5.1	2.0
Hydrocarbons (tons)	1.3	0.8	0.3
Fuel consumption (1000 ft^3)	1 571 634	290 613	116 124

particulates as specified in New Mexico AQCR 501. According to AQCR 501, the asphalt plant, which has a 75 ton/h capacity, is required to meet a particulate emission limit of 35 lb/h. A stack test of the asphalt plant in 1977 indicated an average emission rate of 1.8 lb/h and a maximum rate of 2.2 lb/h over 3 tests (Kramer 1977).

Though the plant is an old plant and it is not required to meet the federal New Source Performance Standards for asphalt plants, it could also easily meet these standards (Kramer 1977). The plant was found to have fugitive emission problems from leaks at six locations on the equipment. These leaks will be repaired as soon as possible. In 1984 the plant produced 13,773 tons of asphalt (12,171 tons in 1983) and emitted 458 lb of particulates (405 lbs in 1983).

e. Environmental Audits. There were two air quality audits in 1984. The first was done by the State of New Mexico's Environmental Improvement Division (EID) on October 2, 1984. The second was a joint audit by the EID and the Environmental Protection Agency (EPA), Region 6, on November 14, 1984. Normally, only an annual audit is conducted by the EID. However, the Laboratory was EPA's "targeted federal facility" in New Mexico for fiscal year 1985. This designation caused the second audit. No significant air pollution problems were found during the audits.

f. Beryllium Shop. The Laboratory's beryllium shop is required to comply with the New Mexico Ambient Air Quality Standard (AAQS) for Be of 0.01 $\mu g/m^3$ averaged over 30 days (AQCR 201). Under the National Emission Standards for Hazardous Air Pollutants (NESHAP), beryllium shops are required to meet either an emission standard of 10 gm/day or an AAQS of 10 $\mu g/m^3$ averaged over 30 days. The beryllium shop easily meets all these requirements with emissions of less than 2 gm for a period exceeding 9 months and stack concentrations of between 0.00016 to 0.0016 $\mu g/m^3$ (Table E-XXXIII).

g. Asbestos. The National Emission Standards for Hazardous Air Pollutants (NESHAP) have notification, emission control and disposal requirements for friable asbestos renovation/demolition activites. The New Mexico Environmental Improvement Division (EID) was delegated authority by the Environmental Protection Agency (EPA) for the New Mexico NESHAP program. Friable asbestos material means any material containing more than 1 % asbestos by weight that hand pressure can crumble, pulverize or reduce to powder when dry.

Friable asbestos wastes are buried at TA-54 (Area G) and the disposal practices meet NESHAP requirements. The notification requirements are shown in Table XI. Nine notifications were made to the EID in 1984 (Table E-XXXIV). One of these was a blanket estimate for small renovation jobs for 1985.

One late notification was made when it was discovered at TA 21 that an outside contractor was not meeting NESHAP emission control and disposal requirements. The contractor corrected his removal procedures to comply with the regulations. One of the buildings the contractor demolished still contained friable asbestos when it was demolished. In addition, the debris from this demolition were improperly disposed of at San Ildefonso Pueblo. The demolition debris was removed from the Pueblo land and buried at TA-54 (Area G). The Pueblo land and TA-21 demolition site were cleaned of asbestos contamination. The cleanup was verified by analysis of soil samples. Air sampling during removal operations at the two sites showed very low levels, less than 0.01 fibers/cm^3.

Table XI

Asbestos Notification Times

Limit Exceeded[a]	Activity	
	Renovation	Demolition[b]
Yes	As early as possible	10 days
No	Notification not[c] required on an individual basis	20 days

[a]Limit is 260 feet on pipe or 160 square feet on other components of friable asbestos material.
[b]Demolition means the wrecking or taking out of any load supporting structural member of a facility together with any related handling operations.
[c]For small jobs, a prediction of the total friable asbestos material to be removed over a maximum period of 1 year is required.

h. Burning and Detonation of Explosives. A total of 19 045 kg of high-explosive wastes was disposed of by open burning at the Laboratory during 1984. This reduced the 1984 estimated airborne emissions by about 9% when compared with 1983. The 1984 emissions were 149 kg of carbon monoxide, 343 kg of particulates, 1.9 kg of hydrocarbons, and 575 kg of nitrogen oxides. These estimates were made by using data from previous experimental work (MHSM 1976). Open burning of high-explosive wastes is permitted under New Mexico Air Quality Control Regulations 301.

Dynamic tests using conventional explosives are routinely conducted at the Laboratory and may contain quantities of potentially toxic metals, including beryllium, lead, and uranium. Estimates of average concentrations of these toxic metals downwind fromthe detonations are reported in Table E-XXXI. These estimates are based upon information concerning the proportion of material aerosolized provided from limited field experiments involving aircraft sampling and the amounts of toxic metals used in the 1984 experiments. The estimated average concentrations of uranium, beryllium, and lead are all less than 0.006% of applicable standards.

i. Emissions from Vehicles. A large fleet of cars and trucks is maintained for the Laboratory complex by the Zia Company. A total of 3.2×10^6 ℓ of gasoline was used by this fleet to cover 10.4×10^6 km during 1984.

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 fueling. Air emissions from operation of this fleet during 1984 were estimated using the appropriate Environmental Protection Agency emission factors (EPA 1984) and are shown in Table XII.

j. Chemical Usage. 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 chemical usage over the years has been compiled (Table E-XXXV).

Table XII

Estimates of Air Pollutant Emissions Associated with the Operation of the Vehicle Fleet (metric tons)

Fuel storage evaporative losses	5.7
Hydrocarbons	16
Carbon monoxide	197
Nitrogen oxides	24
Sulfur oxides	2.3
Particulates	
Exhaust	1.0
Tire Wear	1.4

B. Water

Liquid effluents containing low levels of radioactivity were routinely released from two waste treatment plants and one sanitary sewage lagoon system. Effluent quality at all three discharge points was less than 5% of the Department of Energy's Concentration Guides for Controlled Areas. Municipal and industrial water supply for the Laboratory and community is from 16 deep wells and 1 gallery. The chemical and radiochemical quality of this water easily met the Environmental Protection Agency's National Interim Primary Drinking Water Standards. A single National Pollutant Discharge Elimination System (NPDES) permit authorizes discharge of nonradioactive liquid effluents from 99 industrial outfalls and 11 sanitary sewage treatment plants. The Laboratory was in compliance with the NPDES permit for 94% of the analyses done on samples collected for compliance monitoring.

1. Radioactive Effluents. Treated liquid effluents containing low levels of 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 Tables III, E-XXXVI, E-XXXVII, and Figs. 24, 25, and 27.

The quality of effluents from the larger radioactive liquid waste treatment plant (TA-50) was well below the Department of Energy's Concentration Guides for onsite releases (Table E-XXXVI). There was no significant trend in the comparison of the 1983 and 1984 data. The effluents are discharged into a normally dry stream channel in Mortandad Canyon where surface flow has not passed beyond the Laboratory boundary since before the plant began operation.

All radionuclide concentrations in effluents from the smaller plant (TA-21) were well within the Department of Energy's Concentration Guides for onsite releases (Table E XXXVI). No significant trends were noted when radionuclide releases for 1984 were compared with those for 1983. Discharges from TA-21 are into DP Canyon, a tributary of Los Alamos Canyon. Runoff in DP Canyon does at times flow past the Laboratory boundary and transports some residual radionuclides that have adsorbed on sediments.

All radionuclide concentrations found in the TA-53 lagoon effluent in 1984 were higher than those found in 1983. This is due to the increase in radionuclide production, because of higher accelerator beam strength. The source of the radioactivity was activated water from the beam-stop cooling systems. All radionuclide concentrations were well below the Department of Energy's Concentration Guides for

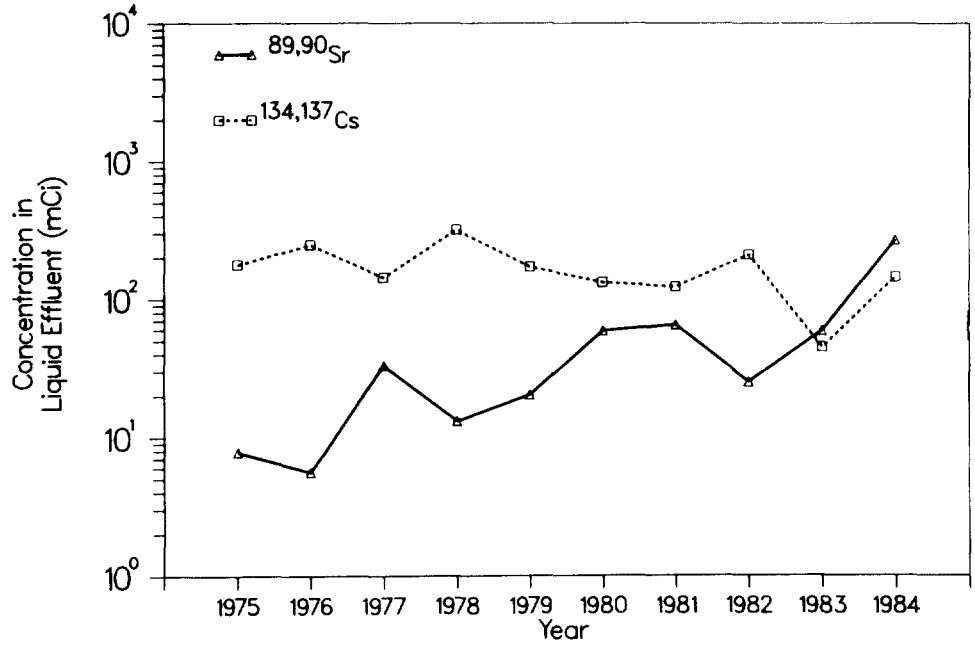


Fig. 27. Summary of strontium and cesium liquid effluent releases.

onsite effluents (Table E-XXXVII). The effluent sinks into alluvium of Los Alamos Canyon within the Laboratory's boundary.

2. Safe Drinking Water Act (Municipal and Industrial Water Supply)

a. Introduction. Municipal and industrial water supply for the Laboratory and community is from 16 deep wells in 3 well fields and 1 gallery. The well fields are on Pajarito Plateau and in canyons east of the Laboratory. The gallery is west of the Laboratory on the flanks of the mountains (Fig. 28). Production from the wells and gallery for 1984 was 6×10^9 ℓ.

The main aquifer is the only aquifer in the area capable of municipal and industrial water supply. The upper surface of the aquifer rises westward from the Rio Grande beneath Pajarito Plateau with depths ranging from about 180 m along the eastern edge of the plateau to about 365 m along the western edge of the plateau. The water in the aquifer moves from the major recharge area in the Valles Caldera (west of Los Alamos) eastward to the Rio Grande where part is discharged into the river through seep and springs.

The Los Alamos field is composed of five producing wells and one standby well. During 1984, Well LA-3 was down for repairs for part of the year. Well LA-6 is on standby status, to be used only in case of emergency. The water from Well LA-6 contains excessive amounts of natural arsenic (up to 0.200 mg/ℓ) that cannot be reduced to acceptable limits by mixing in the system (Purtymun 1977). The wells in the field range in depth from 265 to 600 m. Movement of water in the upper 411 m of the main aquifer in this area is eastward at about 6.1 m/yr (Purtymun 1984).

The Guaje well field is composed of seven producing wells. The wells in the field range in depth from 463 to 610 m. Movement of water in the upper 430 m of the aquifer is southeastward at about 10.7 m/yr (Purtymun 1984).

The Pajarito well field is composed of five wells. During 1984 production was from four of the wells. Well PM-5, a new well, has not been placed in service at this time. The wells range in depth from 701 to 942 m. Movement of water in the upper 535 m of the aquifer is eastward at 29 m/yr.

The Water Canyon gallery collects spring discharge from a perched water zone in the volcanics on the flanks of the mountains west of Los Alamos and Pajarito Plateau (Fig. 28). The canyon supplies a small but important part of the production with use of very little energy.

Water for drinking water and industrial use is also obtained from a well at the Laboratory's experimental geothermal site (Fenton Hill, TA-57) about 45 km west of Los Alamos. The TA-57 water is not a part of

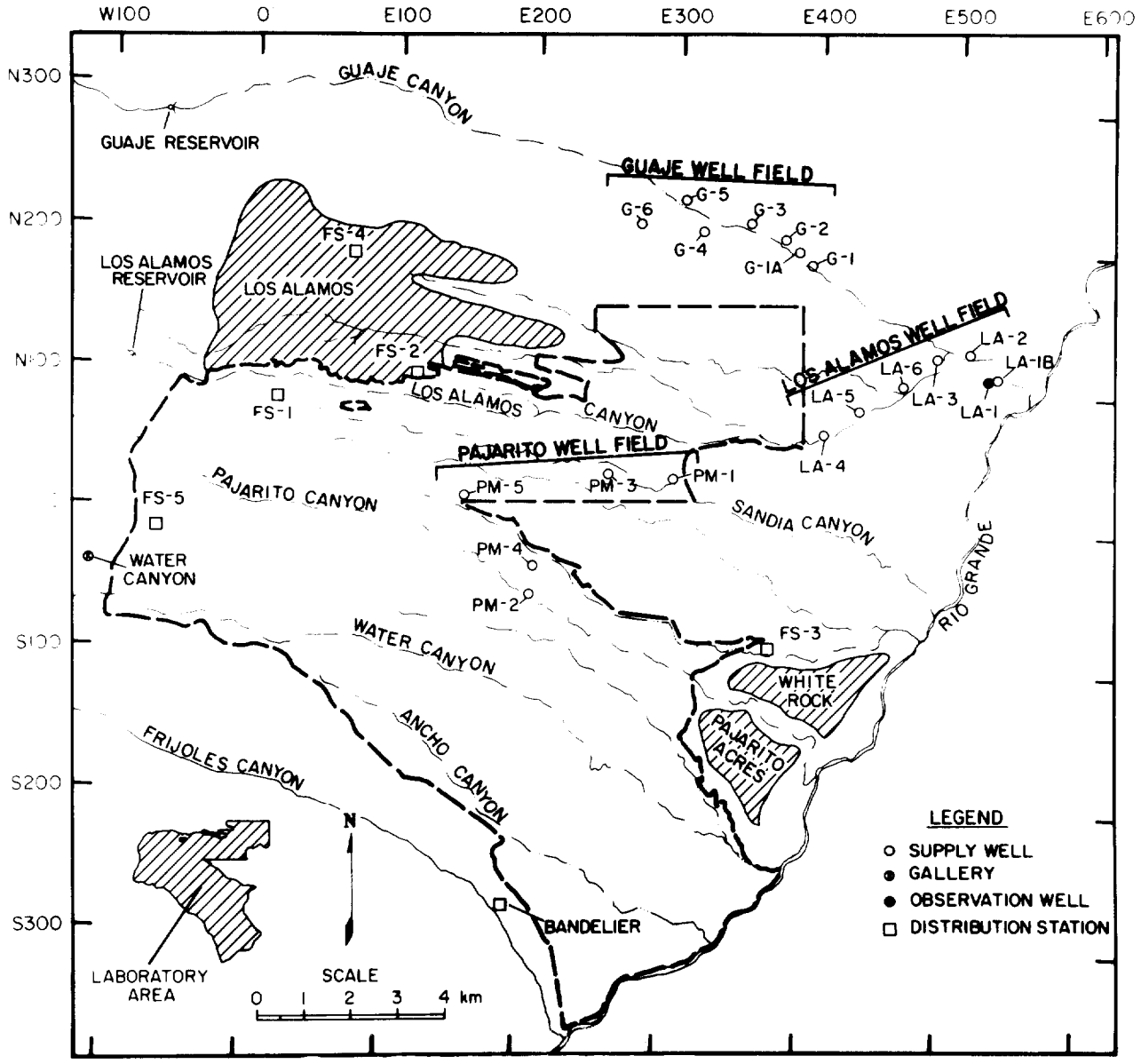


Fig. 28. Locations of reservoirs, well fields, supply wells, and gallery water supply.

the Los Alamos supply but is from a well about 133 m deep completed in volcanics. During 1984 the well produced about 21.9×10^6 ℓ.

All water comprising the municipal and industrial supply is pumped from wells, piped through transmission lines, and lifted by booster pumps into reservoirs for destribution to the community and Laboratory areas. Water from the gallery flows by gravity through a microfilter station and is pumped into one of the reservoirs for distribution. All supply water is chlorinated prior to entering the distribution system.

Water in the distribution systems is sampled at five community and Laboratory locations (fire stations), Bandelier National Monument, and Fenton Hill (TA-57). Water at Bandelier is part of the Los Alamos water supply. Locations of the gallery, supply wells, and distribution systems are shown in Fig. 28 and described in Table E-IX. Individual radionuclides, primary and secondary chemical parameters, and miscellaneous chemical parameters from wells, gallery, and distribution systems are presented in Table E-XXXVIII. Appendix A gives

federal and state standards and criteria for municipal water supply.

b. Radioactivity in Municipal and Industrial Water Supply. 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 National Interim Primary Drinking Water Standards (EPA 1976) in Table XIII. The radioactivity in water from the distribution systems, wells, and gallery is low and at or below limits of detection. A comparison of the maximum radioactive concentrations from the supply and distribution system with the Environmental Protection Agency's standards shows that the two systems (Los Alamos and Fenton Hill) comply with federal standards.

c. Chemical Quality of Municipal and Industrial Water Supply. The maximum concentrations of chemical constituents in water from the distribution systems, wells, and gallery are compared to primary and secondary standards in Table XIV. The primary maximum contaminant level (MCL) is the maximum permissible level of a contaminant in water that may be delivered into a free-flowing outlet of the ultimate user of a public water supply system (EPA 1976). The secondary drinking water levels for contaminants are primarily related to the aesthetic qualities of the drinking water and its public acceptance (EPA 1979B). At very high concentrations, secondary contaminants may have negative health implications as well as aesthetic degradations. Water from wells, gallery, and the distribution systems comply with primary and secondary standards (Table XIV).

Chemical constituents in water from the distribution systems (Los Alamos, Bandelier National Monument, and Fenton Hill Site) comply with primary standards (Table XIV). Maximum concentrations of arsenic in water from Well G-2 and fluoride from Well LA-1B) are above primary standards as shown in Table XIV. However, mixing in the distribution system reduces the concentrations to acceptable levels. Arsenic and fluoride occur naturally in the aquifer. The chemical quality of water from each well reflects nearby aquifer characteristics. The chemistry of the water in Wells LA-1B and G-2 changes slightly with increased pumping. Fluoride concentrations in water from Well LA-1B decreases slightly with pumpage, while arsenic concentrations in Well G-2 increases slightly with pumpage. Mixing of water from Wells LA-1B and G-2 with other wells in the fields reduces the concentrations to acceptable levels in the distribution system.

Water from Well LA-6 (Los Alamos field) is not used as part of the water supply for Los Alamos. In 1984 tests indicated that arsenic concentrations in water from the well were about twice the standard at 0.11 mg/ℓ. The arsenic concentrations tend to increase with increased pumpage up to about 0.20 mg/ℓ. At this higher concentration, dilution of Well LA-6 water with water from other wells will not reduce the concentrations to acceptable levels (Purtymun 1977).

Concentrations of miscellaneous chemical constituents from individual wells are shown in Table E-XXXVIII. As shown by these concentrations, the quality of water from the wells varies because of local conditions within the same aquifer. The quality depends on well depth, lithology of aquifer adjacent to well, and yield from beds within the aquifer.

3. Clean Water Act

a. National Pollutant Discharge Elimination System. The National Pollutant Elimination System (NPDES) requires permits for nonradioactive constituents at all point source discharges. A single NPDES permit (NM 0028355) for the Laboratory sets liquid effluent limits at 99 industrial outfalls in 10 categories and at 11 sanitary sewage treatment plant outfalls. The permit was issued in April 1982 and it expires in September 1986. The industrial categories are: power plant effluent (1 location), boiler blowdown (1), treated cooling water (30), noncontact cooling water (30), industrial waste treatment plant effluent (2), high explosive waste effluent (20), photo waste effluent (14), and printed circuit board waste effluent (1).

Tables E-XXXIX and E-XL summarize the effluent quality of the industrial and sanitary outfalls. The Laboratory was in compliance with the NPDES permit in about 94% of all samples collected for compliance monitoring (Table XV).

The two radioactive waste treatment plants have the largest number of NPDES limits. About 99% of all analyses done on samples collected for compliance monitoring were in compliance. Details of the effluent quality from these two plants are in Table E-XXXVI.

b. Federal Facility Compliance Agreement. In March 1983 the Los Alamos Area Office of the

Table XIII

Maximum Concentrations of 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	15	31	89 ± 138	0.050 ± 0.040	0.160 ± 0.100	6.7 ± 3.8	37 ± 80	1.0 ± 0.8	7.3 ± 1.4	120 ± 200
Maximum Concentration as Per Cent of MCL	—	—	45	<1	1	45	—	5	<1	—
Distribution System (Los Alamos)										
Maximum Concentration	6	11	91 ± 138	0.040 ± 0.040	0.04 ± 0.060	6.2 ± 3.6	6.4 ± 1.6	1.2 ± 0.8	4.7 ± 0.5	130 ± 100
Maximum Concentration as Per Cent of MCL	—	—	45	<1	<1	41	—	6	<1	—
Distribution System (Fenton Hill)										
Maximum Concentration	1	2	44 ± 138	−0.030 ± 0.060	0.010 ± 0.020	1.5 ± 1.8	5.8 ± 1.6	0.7 ± 0.8	2.5 ± 0.6	186 ± 60
Maximum Concentration as Per Cent of MCL	—	—	22	<1	<1	10	—	4	<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 XIV

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

Inorganic Chemical Contaminant	Standards	Supply		Distribution	
		Well and Gallery	Per Cent of Standard	Los Alamos Bandelier TA-57	Per Cent of Standard
Primary[a]					
Ag	0.05	<0.001	<2	<0.001	<2
As	0.05	0.110	220	0.022	44
Ba	1.0	0.09	9	0.07	7
Cd	0.01	<0.0002	<2	<0.0002	<2
Cr	0.05	0.020	40	0.015	30
F	2.0	3.2	160	1.5	75
Hg	0.002	<0.0001	<5	<0.0001	<5
NO_3	45	2.1	5	2.1	5
Pb	0.05	0.016	32	<0.004	8
Se	0.01	<0.003	<30	<0.003	<30
Secondary[b]					
Cl	250	17	7	20	8
Cu	1.0	0.08	8	<0.01	<1
Fe	0.3	0.047	16	0.012	4
Mn	0.05	0.003	6	<0.001	2
SO_4	250	39	16	8	3
Zn	5.0	0.06	1	0.27	5
TDS	500	461	92	246	49
pH	6.5 - 8.5	8.5	100	8.2	9.6

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

Department of Energy signed a Federal Facility Compliance Agreement (FFCA) that contained an abatement schedule with compliance dates ranging from 1983 to 1985. The FFCA called for abatement efforts to be completed at three high explosive treatment plants and one sanitary sewage treatment plant in 1984. Improved administrative procedures at two of the high explosive waste treatment plants were responsible for achieving compliance. Compliance at the third location was achieved by constructing a lined evaporation pit. Reconstruction of a sand filter at the TA-35 sanitary sewage treatment plant was to put the plant in compliance in 1984. The schedule was set back several months and the sand filter is now slated for completion in early 1985.

c. Clean Water Act Audits. The Environmental Protection Agency (EPA) conducted three audits under the Clean Water Act in 1984. A compliance inspection reviewed the status of the Federal Facility Compliance Agreement (FFCA) and the National Pollutant Discharge Elimination System (NPDES)

Table XV

Summary of National Pollutant Discharge Elimination System (NPDES) Compliance in 1984

Parameter Measured	Number of Samples	
	Domestic Discharges	Industrial Discharges
pH		
Taken	228	275
Out of compliance	24	15
Per cent compliance	89.5	94.5
Other[a]		
Taken	511	1383
Out of compliance	51	54
Per cent compliance	90.0	96.1
Flow[b]		
Taken	2573	275
Summary: Domestic and Industrial		
Taken	2397	
Out of compliance	144	
Per cent compliance	94.0	

[a]Chemical parameters such as chemical oxygen demand (COD), total suspended solids (TSS), etc.

[b]Flow is monitored but there is not limit under the Laboratory's NPDES permit.

permit. All schedules calling for compliance in 1984 or later were reviewed. Slippage of the compliance date for reconstruction of a sand filter at the TA-35 sanitary sewage treatment plant was discussed. Two more sanitary sewage treatment plants at TA-8 and TA-41 that do not meet NPDES permit limits were discussed as possible FFCA candidate projects for the fiscal year 1988.

A second inspection by the EPA focused primarily on analytical procedures. The inspector noted some minor deficiencies that have been corrected or are scheduled for correction by April 1, 1985.

The last inspection by the EPA covered the Spill Prevention, Controls and Countermeasures (SPCC) part of the Clean Water Act. The SPCC provides for cleanup of spills and requires preparation of a SPCC plan. The Laboratory has many elements that are required in a SPCC plan and is currently planning to assemble an official SPCC plan.

C. Solid Waste

The Laboratory complies or is working to comply with several regulations that govern handling, storage, and disposal of solid waste. These regulations include the: Resource Conservation and Recovery Act; Toxic Substances Control Act; and Comprehensive Environmental Response, Compensation, and Liability Act. The Laboratory also complies with the Federal Insecticide, Fungicide, and Rodenticide Act. Environmental surveillance is done at the one active and ten inactive low level radioactive waste management areas at the Laboratory.

1. Resource Conservation and Recovery Act

a. Introduction. The Resource Conservation and Recovery Act (RCRA) is a comprehensive program to regulate hazardous wastes from generation to ultimate disposal. It regulates nonradioactive hazardous wastes and mixed wastes. Mixed wastes contain both nonradioactive hazardous materials and radioactive materials. The Environmental Protection Agency (EPA) granted the state of New Mexico an interim RCRA authorization on September 30, 1983. The authorization transferred regulatory control of hazardous wastes from the EPA to the state of New Mexico's Environmental Improvement Division (EID). The authorization is being transferred in two phases.

The first phase enables the EID to administer a hazardous waste program that includes identifying and listing such wastes; regulating generators and transporters; and enforcing preliminary standards for treatment, storage, and disposal facilities.

The second phase consists of Parts A, B, and C. Part A includes permitting of tanks and container facilities. Part B includes permitting of incinerators. Part C includes permitting of land disposal facilities (landfills, land treatment units, waste piles, surface impoundments). The EID did not initially apply for Part C.

Application for Part C is included in New Mexico's complete application for Final Authorization, which was submitted to the EPA on July 26, 1984. The EPA has stated that it intends to grant this Final Authorization, but has not done so to date (February 1985).

b. Laboratory Interactions with the Environmental Protection Agency and New Mexico's Environmental Improvement Division. There were a number of significant interactions among the Laboratory, Environmental Protection Agency (EPA), and New Mexico's Environmental Improvement Divisiom (EID) concerning the Resource Conservation and Recovery Act (RCRA) in 1984. They are listed in Table E-XLI. The most significant interactions are described in the following paragraphs. On February 22, 1984, the EPA requested that the Laboratory submit a RCRA Part B application. This request was repeated by the EID on April 23, 1984. An extension to submit the RCRA Part B was granted by the EID on August 23, 1984. The extension was to May 1, 1985 and it added the requirement that the RCRA Part B application address mixed wastes. Mixed wastes are wastes that contain both hazardous and radioactive materials.

On May 23 and 25, 1984, the EID performed a RCRA compliance inspection of TA-3, TA-50, and TA-54. This audit resulted in the Laboratory receiving a Notice of Violation (NOV) on June 22, 1984. The NOV was issued for inadequacies in closure and post-closure plans at waste disposal areas, waste analysis plans, personnel training, a contingency plan, and ground water monitoring at the waste disposal sites (failure to perform). The Laboratory's responses to the NOV were submitted on November 1 and December 1, 1984.

The Laboratory received a second NOV on October 26, 1984, for an inadequate RCRA Part A application, lack of water run-on control at the waste disposal sites, and failure to supply information to an inspector. The Laboratory responded to this second NOV on November 14, 1984.

2. Toxic Substances Control Act

a. Toxic Substances Control Act and Polychlorinated Biphenyls. The Toxic Substances Control Act (TSCA) was signed into law in October

1976. It regulates the manufacture, processing, distribution, use, storage, and labeling of existing and new chemical substances. Polychlorinated biphenyls (PCBs) are regulated by TSCA. The TSCA banned manufacturing and processing of PCBs and placed limitations on their use. It also designated the Environmental Protection Agency (EPA) to promulgate regulations relating to PCB disposal. These regulations establish three categories of PCB wastes: (1) less than 50 ppm of PCBs (PCB content by weight), not regulated except for a few cases; (2) 50 to 500 ppm PCBs, minimal regulation, "PCB Contaminated" label is required; (3) greater than 500 ppm, most restrictive controls, "PCBs" label is required.

b. Laboratory Permits

(1) Chemical Waste Landfill. A request was made to the EPA, Region 6, in January 1979 to dispose of Laboratory PCBs at the Laboratory's Waste Disposal Site (TA-54, Area G). Authorization was received from the EPA Region 6 Administrator in June 1980. Conditions on the approval stipulated that the Laboratory maintain disposal records, monitor designated springs and onsite cumulative water samplers, and submit a semi-annual report describing the PCB activities during the reporting period. Furthermore, disposal of PCBs was limited to (1) liquids containing less than 500 ppm of PCBs, (2) capacitors until March 1, 1981, (3) transformers that had been properly drained and flushed, (4) PCB-contaminated soil, clothing, and other debris.

The two springs and three cumulative water samplers are sampled for PCBs, pH, specific conductance, and designated chlorinated organics. Analytical results from these samples are submitted in the semi-annual report. There are no limits for these parameters, but detection of PCBs or chlorinated organics would trigger further action. The springs are sampled once per year. The cumulative samplers are sampled and emptied when they have accumulated runoff water.

(2) Controlled Air Incinerator. A request was made to the EPA, Region 6, in February 1982 to conduct a trial burn of PCBs as a research and development project. The objective of the project was to demonstrate that the Laboratory's Controlled Air Incinerator (CAI) could destroy PCBs at the required combustion efficiency. The CAI was originally designed and built to thermally treat radioactive wastes. Consequently, it has more pollution abatement controls than would normally be installed on PCB incinerators.

The trial burn was done in June 1982. It demonstrated to the EPA that the CAI could achieve a combustion efficiency of 99.9999% and comply with TSCA regulations. The EPA approved CAI operation for PCB disposal on May 21, 1984. Combustion temperatures, PCB feed rates, and gases (CO, CO_2, O_2) are monitored during CAI operation and retained in permanent files.

(3) Compliance Activities. The only PCB inspection of Laboratory facilities to date was done by the EPA on November 7, 1984. Several items cited for which the Laboratory was in only partial compliance were:

(1) The PCB inventroy of in-service items was not complete.
(2) The PCB labels were not regulation size (4 in. by 4 in. instead of 6 in. by 6 in.).
(3) While all data was available, it was not in a format readily accessible by the EPA. This is not a violation. However, the format will be changed to ease EPA review.
(4) Quarterly inspection reports filed by the Zia Company for PCB transformers were incomplete (no signature by the inspector).

These items were considered minor and corrective actions have been or are being taken.

3. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was enacted by Congress in 1980. It mandated clean up of nonradioactive toxic and hazardous contaminants at closed and abandoned hazardous waste sites. The federal government is permitted to recover cost of this cleanup and associated damages by suing the responsible parties. Cleanup monies come out of a "Superfund" created by taxes on chemicals and hazardous wastes.

The CERCLA required the Environmental Protection Agency to establish a National Priorities List (NPL) to identify former disposal sites that may require remedial action. A Hazard Ranking System (HRS) was developed to provide a common basis for site evaluations. Non-federal sites that scored high under the HRS would be (after additional considerations) eligible for CERCLA funds (Superfund) for remedial actions. Cleanup of dioxin contamination

in Times Beach, Missouri, is an example of use of the Superfund.

Compliance with CERCLA by the Laboratory is being effected partly through a Site Characterization Program. This program was started in 1983 to identify all radioactive and nonradioactive contamination that might be present at the Laboratory. The environmental surveillance program has documented that there is no present hazard to the public from present and past Laboratory practices.

The Site Characterization Program will identify sources of contamination that might remain from the early days of the Laboratory to insure there is no contamination that might cause a future problem. If problems are identified, appropriate remedial actions will be taken. Portions of Laboratory land that were released to the public in the past were characterized through special programs that began in 1972. Identified remedial actions have been completed.

As part of the Site Characterization Program, the HRS was applied to four sites that are catergorized as nonradioactive sites. These were disposal areas M and W, a chemical pit at Area C, and surface contamination at E-F Site at TA-15 (where uranium was considered to be nonradioactive contaminant). The scores for these sites ranged from 0 to 14.2. The HRS score must be 28.5 or higher to be considered for the NPL.

Two representatives from the Environmental Protection Agency, Region 6, visited Los Alamos on December 18 and 19, 1984. They learned about the Site Characterization Program and how it applies to CERCLA. This was the first visit of an anticipated series of inspections to determine the Laboratory's compliace with CERCLA.

4. Federal Insecticide, Fungicide, and Rodenticide Act. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) requires registration of all pesticides, restricts use of certain pesticides, recommends standards for pesticide applicators, and regulates disposal and transportation of pesticides. A pesticide is defined as any substance intended to prevent, destroy, repel, or mitigate pests.

A new Pest Control Policy, which will help comply with FIFRA, was implemented at the Laboratory in 1984. It includes policies and procedures for pesticide use, as well as for others types of pest control (controlled burning, live-trapping, etc.).

A FIFRA audit was done for the Environmental Protection Agency, Region 6, by the state of New Mexico's Department of Agriculture in December, 1984. The inspectors found no major deficiencies in the Laboratory's pesticide use procedures. They commended many of the Laboratory's pesticide policies and procedures. New temporary pesticide storage facilities were built in 1984 and were approved during the audit. These facilities will be used until new facilities are available from the Zia Company.

5. Operational Improvements. Improvement in the control, treatment, and disposal of hazardous materials is a continuing goal of the Laboratory (Balo 1984 and Los Alamos 1984). Major efforts were expended in several areas in 1984.

Construction of a chemical batch treatment system was completed in 1984. Minor modifications and writing of operational procedures will delay start-up until the middle of 1985. This system will increase chemical treatment capacity and produce a stable waste form for burial.

Three alternatives to land disposal were explored in 1984. Work continued on developing a comprehensive waste oil recycling program for the Laboratory. Secondly, design work was started on an above-ground treatment and evaporation tank system to replace a surface impoundment at Area L. The system will become operational in early 1985. Finally, a plan to incinerate essentially all organic wastes generated at the Laboratory was begun. A trial burn, as required by Environmental Protection Agency regulations, is tentatively scheduled for the latter half of 1985 in an existing controlled air incinerator at TA-50.

6. ***Environmental Surveillance of Low-Level Radioactive Waste Management Areas.*** **Environmental surveillance of one active and ten inactive radioactive waste management areas at Los Alamos documents compliance with appropriate standards, identifies undesirable trends that may require remedial actions, and monitors the performance of waste confinement. The general public is excluded from these areas because they are controlled-access sites. At the active disposal area there are transient elevated levels of external penetrating radiation from handling and storing the waste before burial. There also is some transport by surface runoff of low-level contamination from the active and several of the inactive disposal areas into controlled-access canyons. The surface contamination levels are about 30 times below the Department of Energy's remedial action guidelines.**

a. Introduction. Environmental surveillance of radioactive waste management areas at Los Alamos documents compliance with appropriate standards, identifies undesirable trends that may require remedial actions, and monitors the performance of waste confinement. Radioactivity concentrations in air (particulates and moisture), water, soil, and sediment samples are measured, along with the levels of external penetrating radiation. Eleven radioactive waste management sites are monitored (Fig. 29). The general public is excluded from these waste management areas because they are controlled-access areas. One (Area G at TA-54) is currently active and the remainder (Areas A, B, C, E, F, T, U, V, W, and X) are closed or decommissioned. They are described in the next paragraphs.

b. Descriptions of Active and Inactive Radioactive Waste Disposal Areas

(1) Area A. Area A was used from 1945 to 1946. It is on the north side of TA-21 between DP-East and DP-West and covers 5000 m^2. Pits were excavated in volcanic tuff for burial of polonium contaminated wastes, which has now almost completely decayed, and possibly plutonium, uranium, and thorium contaminated wastes from TA-21. Two tanks designated the "General's tanks" are buried on the west side of Area A. These tanks were used for storing plutonium solutions. Liquids from the tanks have been pumped to a nearby liquid waste plant for treatment. However, a thin layer (several centimeters) of gelatinous residue still remains in each tank.

Area A was reactivated in April 1969. An additional pit was excavated for disposal of low-level radioactively contaminated debris from demolition work at TA-21. This pit remained active thru September 1977 and was backfilled in May 1978.

(2) Area B. Area B is on the south side of DP Road, about 490 m east of the intersection of DP Road and Trinity Drive and about 130 m west of TA-21. It covers 24 000 m^2 and is divided into three sections. The larger section is paved with asphalt and is leased by Los Alamos County for storing privately-owned boats and trailers.

Area B was used from 1946 through 1948 for disposal of wastes contaminated with radioactive materials used at Los Alamos. It is estimated to contain no more than 100 g of ^{239}Pu. The ground surface of the eastern section (about one third of the total area) was decontaminated and stabilized during fiscal year 1982. New cover material was compacted over the section and topsoil seeded with a mixture of native grasses placed over the cover layer. In September 1984, the smaller southwest corner section received the same remedial treatment.

(3) Area C. Area C, near Pajarito Road and south of TA-50, covers 48 000 m^2. It contains 7 pits, one of which has been designated a hazardous chemical waste pit, and 108 disposal shafts. These pits and shafts contain alpha and beta-gamma contaminated wastes. Wastes with relatively higher concentrations of radioactivity were disposed in the vertical shafts. Some of the shafts were lined with corrugated metal pipe or cement. One of the shafts has been used for disposal of ^{90}Sr waste.

In fiscal year 1983 a remedial action was started at Area C to stabilize and cover surface contamination, remove debris, modify the fence line, and add drainage channels for preventing soil erosion. In September 1983, a can containing ^{137}Cs was removed from Area C and disposed at Area G. In November 1983, nine gas cylinders found at the site were vented and detonated. In early Jannuary 1984, the nine cylinders were removed from Area C and disposed at

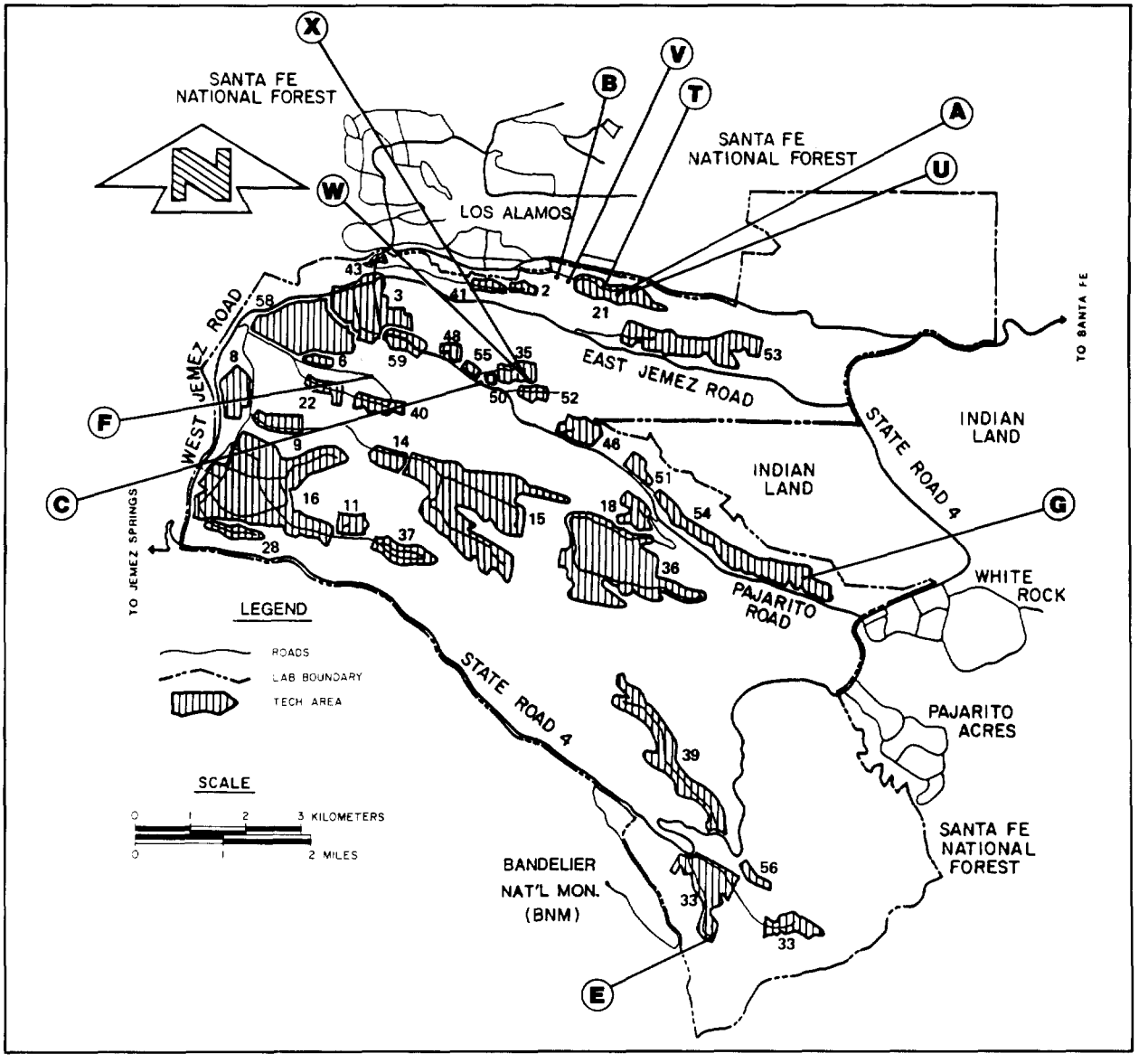


Fig. 29. Locations of active (Area G) and inactive radioactive waste disposal areas.

Area L. Remedial work on the eastern end of the site was completed in early 1984.

(4) Area E. Area E is on the extreme south end of TA-33. It covers about 307 m^2 and contains six pits and an underground chamber. The underground chamber was destroyed by experimentation in 1950 and was probably contaminated with polonium (now decayed) and perhaps uranium. This site was used from 1951 through the middle 1960s for disposal of waste contaminated with polonium, uranium, and beryllium. In October 1983 an old barbed-wire fence was replaced with a chain link fence.

(5) Area F. Area F is on Two-Mile Mesa east of TA-6 and was used from 1946 through the early 1950s for disposal of Laboratory wastes. It consists of two burial pits. The smaller pit has an estimated volume of 740 m^3. It may contain wastes contaminated with ^{90}Sr, ^{137}Cs, alpha emitters, and high explosives. The larger waste pit has an estimated volume of 2020 m^3 and contains only high explosive

wastes. In September 1983 a chain-link fence was installed around both disposal pits.

(6) Area G. Area G is the primary radioactive solid waste disposal and storage facility for the Laboratory. It is on Mesita del Buey at TA-54 and occupies an area of 2.55×10^5 m^2 and consists of pits, shafts, trenches, and storage pads. This facility started operation in 1957 and is expected to remain active into the forseeable future.

From 90 to 95% of the total volume of radioactively contaminated solid waste from the Laboratory is disposed of by burial at Area G. The remaining 5 to 10% is classed as transuranic waste and is stored retrievably at Area G. The pits, shafts, and trenches contain mixed fission products, tritium, uranium, activation products, small amounts of transuranic elements, and a few grams of ^{238}Pu. Other types of radioactive waste materials buried at this facility include: contaminated demolition debris, process waste, paper, plastic, clothing, and equipment. The main ground water aquifer is about 260 m below the ground surface of Area G.

Buried wastes are confined from the environment by placing packaged wastes in pits or shafts excavated in the dry geologic formation of Area G. Burial pits range in size from 9 to 30 m wide, 45 to 180 m long, and 4 to 10 m deep. Packaged wastes are disposed of in layers 1 to 2 m deep and each layer is covered with about 0.5 m of crushed volcanic tuff. Filled burial pits are covered with top soil that is slightly mounded to encourage surface runoff. Packaged wastes are also disposed of in vertical shafts that range from 0.6 to 1.8 m in diameter and up to 20 m deep. The layering and mounded cover techniques are again used.

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 in turn are placed in trenches.

Guidelines for pit construction were specified in 1965 by the US Geological Survey (USGS 1965). These specifications were revised and reissued in 1980 by the Laboratory's Waste Management Group (HSE-7) and the Environmental Surveillance Group (HSE-8) (Purtymun 1980). Each newly constructed pit is in spected to assure it complies with the Laboratory's guidelines.

(7) Area T. Area T is on the north side of TA-21 and west of Area A. From 1945 to 1967 absorption beds were used for subsurface disposal of liquid wastes generated from the recovery process of plutonium. The absorption beds consisted of trenches excavated into volcanic tuff and backfilled with three different layers of materials (from bottom to top: about 20-cm diameter boulders, gravel, fine sand). Liquid wastes containing plutonium and americium from the recovery process were discharged into the beds. This practice was done from 1945 to 1952. The absorption beds also recieved effluent from the Laboratory's liquid waste treatment facility from the early 1950s to 1967.

Operation of the TA-21 liquid waste treatment facility generated sludge residue contaminated with plutonium and americium. For years the residue was placed in steel drums and the drums buried at Areas C and G. Then in 1968, a pug mill operation was started to mix the sludge with cement. The resulting cement paste was pumped directly into asphalt coated vertical shafts augered between the absorption beds. This procedure continued through 1975.

In late 1974 a new disposal technique was implemented. A storage pit was dug beyond the shaft field area. Corrugated metal pipes were filled with transuranic cement paste and placed in the pit.

In August 1984, 74 corrugated metal pipes were relocated from Area T to Area G.

(8) Area U. Area U is on the northeast side of DP-East at TA-21. It covers an area of 1200 m^2 and contains two absorption beds excavated in volcanic tuff. These beds were used for subsurface disposal of radioactively contaminated liquid wastes from 1948 to 1968. The amounts of liquid wastes discharged are unknown, because documentation is lacking. However, there are records that indicate about 2.5 Ci of ^{227}Ac were discharged into these beds in 1953. In December 1984 a gate was installed in the west fence of the site.

(9) Area V. Area V is southwest of TA-21 and east of Area B and covers about 4000 m^2. Its primary purpose was for disposal of liquid wastes from laundry operations. It consists of three absorption beds excavated into volcanic tuff. They were used from 1945 to 1964. The beds received wastes containing an estimated total of 3 Ci (^{89}Sr, ^{140}Ba, and ^{140}La), which have decayed over the years. In addition, small quantities of ^{90}Sr and ^{239}Pu were contained in the liquid wastes. In January 1984 a chain-link fence was constructed around the waste area.

(10) Area W. Area W is at TA-35, southwest of Building TSL-116, and about 5 m north of the rim of a tributary canyon to Mortandad Canyon. This site consists of two stainless steel tanks encased in carbon steel sleeves. The tanks are in separate vertical shafadiated sodium contaminated with ^{137}Cs, ^{22}Na, and ^{239}Pu. In 1979 the tops of the tanks, which are at ground level, were entombed in a reinforced concrete structure.

(11) Area X. Area X is at TA-35 north of Building TSL-110 and was used for subsurface storage of the Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) reactor vessel. The vessel was buried in 1964. It contains some of the longer-lived activation products and some residual ^{235}U. This site has now been paved with asphalt.

c. 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 9 of the 11 waste management areas. Areas W and X were not monitored with thermoluminescent dosimeters (TLDs), because they consist only of buried vessels that offer little opportunity for radiation exposure at the ground surface. Surface measurements with field instruments have confirmed this fact. The TLDs are attached to the areas' perimeter fences measure radiation from both natural background and manmade sources (see Section IV.A.1).

The annual TLD measurements for the waste management areas are in Table E-XLII. For comparison, natural background radiation varied from 80 to 151 mrem/yr (see Table E-III, regional and perimeter stations) during 1984 in the Los Alamos region. 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. Several transient elevated TLD measurements at Area G were due to handling and storing of the wastes before their burial.

d. Air Sampling Results. Air sampling is done at the one active waste management area, Area G at TA-54. During the later part of 1984 four new air sampling stations were placed around the perimeter of Area G to supplement the existing air sampler there (see Fig. 30). Moisture samples from these stations are analyzed for ^{3}H (monthly) and air particulate samples for $^{239,240}Pu$ (quarterly) and total U (quarterly).

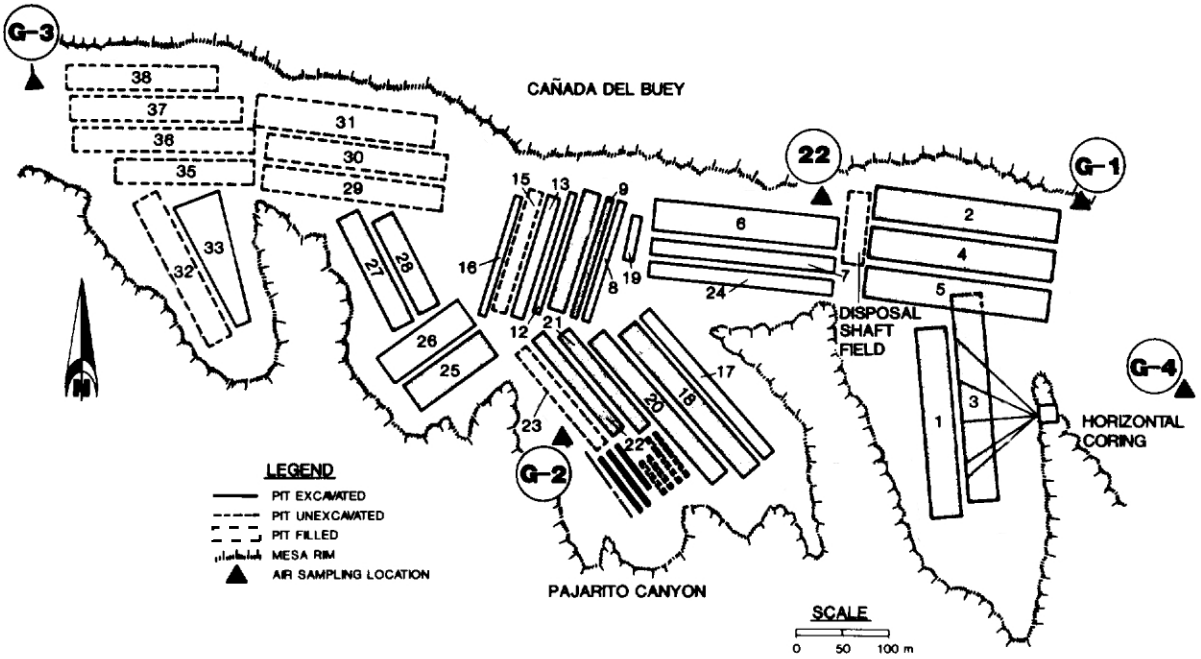


Fig. 30. Air sampler locations at Area G.

Air sampling data for the last quarter of 1984 are in Table E-XLIII. The highest mean tritium concentration of 1290×10^{-12} μCi/mℓ (0.03% of Department of Energy's Concentration Guide for Controlled Areas) occurred at Station G-2. This station is near burial shafts that are used for disposal of liquid scintillation vials, which contain trace amounts of tritium. The uranium concentrations were at background levels. Only one ^{239,240}Pu concentration was above the minimum detectable limit of 3×10^{-18} μCi/mℓ. A concentration of 7.7×10^{-18} μCi/mℓ (0.0004% of the Department of Energy's Concentration Guide for Controlled Areas) was measured at Station G-1. This station is downwind from handling and storing operations at the transuranic waste storage pads.

e. Monitoring Results for Areas B and C. Environmental monitoring of Areas B and C was completed during 1984. Soil and vegetation samples were collected from three perimeter locations around Area B and four perimeter locations around Area C. Samples were taken in surface runoff areas around the perimeters of the areas to monitor transport of radionuclides from the waste areas, should transport occur. The samples were analyzed for ^{3}H, ^{238}Pu, ^{239,240}Pu, and total U, because these radionuclides are likely to be in the buried wastes. Gamma spectra analyses were also done to identify other radionuclides that might be present.

Results of the sampling are in Table E-XLIV. For comparison, concentrations in regional (background) soil samples range from about 1 to 4×10^{-6} μCi/mℓ for ^{3}H, about 2 to 3 μg/g for total U, and about 0.000 to 0.015 pCi/g for ^{239,240}Pu (see Section IV.D.2). Although prior years' samples contained traces of ^{3}H, these samples showed no evidence of ^{3}H contamination at Area B and little at Area C. Uranium concentrations in the Area B and C soil samples, although slightly higher than regional values, were within the range of variability in the natural crustal abundance of uranium.

Plutonium concentrations in the soil samples from Areas B and C evidenced low level contamination. This contamination is about 30 times below the Department of Energy's remedial action guidelines (DOE 1983). Surface runoff from Area B empties into Small Canyon, a tributary to Los Alamos Canyon. Soil and sediment samples from these two canyons do not show any evidence of plutonium contamination from Area B (see Section IV.D).

Surface runoff from Area C flows into Mortandad Canyon, which receives effluents from a radioactive waste liquid treatment plant at TA-50. Therefore, any contamination from Area C that might have been transported into the canyon is not distinguishable from contamination from TA-50 operations.

f. Radionuclide Transport in Sediments and Runoff at Area G. 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 stream channels. Nine sampling stations were established in 1982 outside the perimeter fence at Area G to monitor any possible transport of radionuclides by storm runoff (Fig. 31). These stations are sampled annually.

The average concentrations of ^{137}Cs (0.46 pCi/g) and total uranium (4.6 μg/g) in sediments from the nine sediment stations were below regional background levels from 1978 through 1982 (Tables XVI and E-XLV). Additional analyses of the sediments for ^{3}H and gross gamma in 1984 indicated these concentrations were low when compared to the regional sediments in 1984 (^{3}H regional, 3.9×10^{-6} μCi/ℓ; gross gamma regional, 9.0 counts/min/g).

The average concentrations of ^{238}Pu at Stations 3, 4, 6, 7, 8, and 9 were above regional background concentrations. The average ^{238}Pu and ^{239,240}Pu concentrations at Stations 6, 7, and 8 also exceeded regional background concentrations (^{238}Pu regional, 0.006 pCi/g; ^{239,240}Pu regional, 0.042 pCi/g). These above background concentrations of ^{238}Pu and ^{239,240}Pu in the sediments are similar to what was found in 1982 and 1983 and indicates some transport of surface contamination by runoff from Area G. Any contaminated sediments transported into adjacent canyons are dispersed by storm runoff transport.

The maximum concentration of ^{238}Pu was 0.73 pCi/g or about 12 times greater than regional background concentrations or fallout levels. The ^{239,240}Pu maximum concentration was 0.44 pCi/g or about 10 times greater than regional background concentrations. Sampling in Canada del Buey at State Road-4 (SR-4) below Stations 7, 8, and 9 and in Pajarito Canyon at SR-4 below Stations 1 through 6 (Area G) detected no concentrations above regional background levels (see Stations 16 and 17 in Figs. 15 and 32).

One sample was collected of runoff in the center of Area G during 1984 (Fig. 31). The sample was analyzed for plutonium in solution and in suspended sediments (Tables XVI and E-XLV). Radioactivity in solution is defined as filtrate passing through a 0.45 μ pore-size filter, while radioactivity in

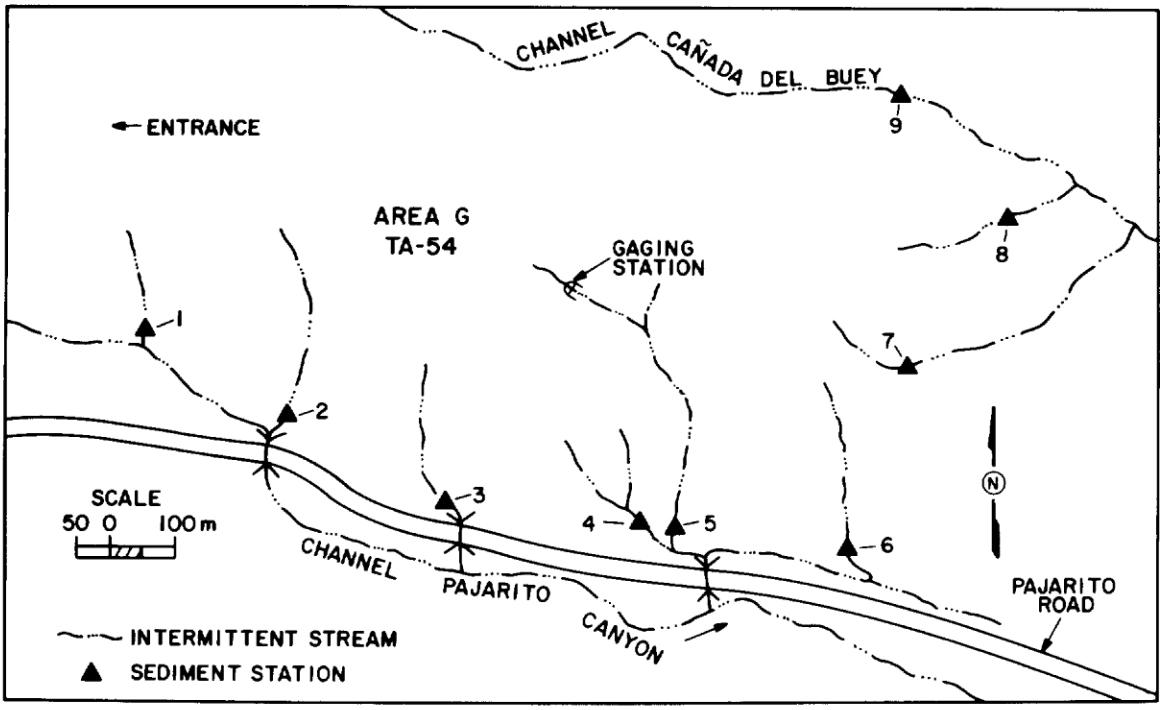


Fig. 31. Surface water gaging station in Area G (TA-54) and sediment sampling stations adjacent to Area G.

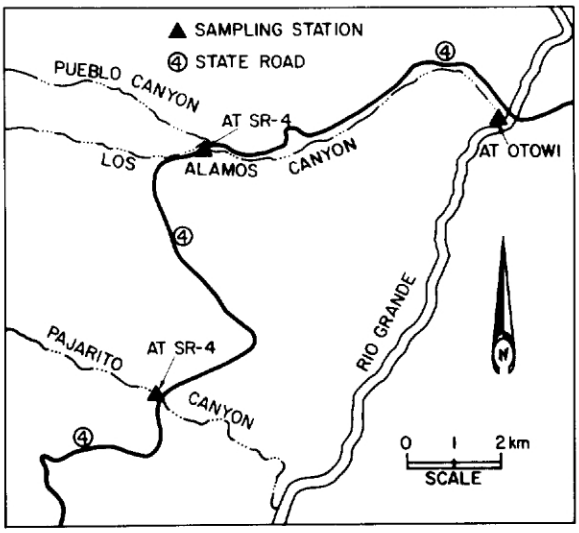


Fig. 32. Locations of surface runoff sampling stations at State Road 4 (SR-4).

suspended sediments is defined as the residue on the filter. The single runoff event contained no plutonium in solution or in suspended sediments when compared to snowmelt runoff for 1983 (ESG 1984). During 1984 there was no snowmelt runoff at SR-4 in Pajarito Canyon.

D. Environmental Evaluations

1. National Environmental Policy Act Documentation. The Laboratory has a Laboratory Environmental Review Committee (LERC) that reviews environmental documents required by National Environmental Policy Act legislation. These documents are prepared by the Laboratory for the Department of Energy. The LERC consists of representatives from the Associate Director for Technical Support; Associate Director for Legal Counsel; Associate Director for Planning and Analysis; Facilities Engineering Division; Budget Division; and Health, Safety, and Environment Division. It also provides a critical management overview of environmental issues by identifying and reviewing items of environmental concern that are generated by Laboratory activities or that affect Laboratory programs and property.

An Environmental Evaluations Coordinator (EEC), based in the Environmental Surveillance Group, assists the LERC by (a) coordinating with

Table XVI

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

Analysis	Units	1982 ($\bar{x} \pm 2s$)	1983 ($\bar{x} \pm 2s$)	1984 ($\bar{x} \pm 2s$)	Regional Stations 1978-1982 ($\bar{x} + 2s$)[a]
		Sediment Stations			
^{137}Cs	pCi/g	0.30 ± 0.41	0.23 ± 0.20	0.2 ± 21	0.46
^{238}Pu	pCi/g	0.110 ± 0.025	0.033 ± 0.107	0.023 ± 0.016	0.006
$^{239,240}Pu$	pCi/g	0.032 ± 0.104	0.034 ± 0.160	0.088 ± 0.295	0.042
^{3}H	10^{-6} μCi/mℓ	---	---	2.9 ± 2.1	3.9[b]
Total U	μg/g	3.2 ± 1.9	3.7 ± 2.3	3.3 ± 1.7	4.6
Gross gamma	counts/min/g	---	5.9 ± 4.1	6.8 ± 3.9	9.0[b]
		Runoff at Gaging Station			
					Pajarito Canyon 1983 ($\bar{x} + 2s$)[c]
Solution					
^{238}Pu	10^{-9} μCi/mℓ	0.027 ± 0.051	0.001 ± 0.001	–0.012 ± 0.024	0.014
$^{239,240}Pu$	10^{-9} μCi/mℓ	0.013 ± 0.056	0.002 ± 0.002	0.012 ± 0.024	–0.002
Suspended Sediments					
^{238}Pu	pCi/g	1.1 ± 0.28	3.2 ± 0.32	–0.008 ± 0.010	0.79
$^{239,240}Pu$	pCi/g	1.3 ± 0.24	5.0 ± 0.12	–0.003 ± 0.012	0.71

[a]Reference (Purtymun 1983D).
[b]Regional sediments (1984).
[c]Pajarito Canyon snowmelt (1983).

user groups; Health, Safety, and Environment Division; and Facilities Engineering Division on environmental documentation and (b) providing input to construction or programmatic project design at the earliest stage for appropriate environmental and safety decision making.

The EEC personnel assisted in preparing 46 new Action Description Memorandums (ADMs) and 4 ADM revisions in 1984. The LERC approved 49 and chose not to review one ADM for a postponed project. Table E-XLVI lists all ADMs reviewed by the LERC during 1984.

The EEC also coordinates input on environmental matters for the Quality Assurance program (see Section V.D.3). The EEC 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 environmental considerations are incorporated into project design. The EEC also is an environmental consultant for activities affecting Laboratory biotic or cultural resources.

2. Archaeological and Historical Protection. Protection of archaeological 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 archaeological 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 pursued in consultation with the New Mexico State Historical Preservation Office.

The Laboratory employs a professional archaeologist to provide archaeological surveys, make evaluations of archaeologic or historic features, implement appropriate adverse mitigation, and provide professional expertise for cultural resource management.

More than 450 archaeological sites at the Laboratory were surveyed 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 later (Steen 1982). These surveys are used during construction planning to avoid damage to archaeologic or historic sites. Additional surveys of proposed construction sites routinely reveal new undocumented sites.

One public tour of an archaeological site within the Laboratory's boundary was conducted in 1984. These tours are conducted annually to allow the public to view archaeological and historical sites that are normally inaccessible because of security restrictions for the surrounding Laboratory land. This year the public visited Nakemuu, one of the best preserved and most remote prehistoric ruins on Pajarito Plateau.

The Laboratory initiated a major cultural resource research and reconstruction project in 1984. Approval was obtained from the New Mexico State Historical Preservation Office and the National Advisory Council on Historic Preservation to document and research several historical and archaeological resources on the construction site of a new Laboratory project, the Nuclear Materials Storage Facility. The Laboratory donated an onsite homesteader's cabin, the Romero Cabin, to the Los Alamos Historical Society. A historical architect was employed to dismantle and store the structure for reconstruction at the Los Alamos County Historical Museum.

The Laboratory's archaeologist has begun field surveys of associated outlying features (a dugout, shed, corral, cistern, and prehistoric lithic scatter) and analysis of recovered artifacts. Certain site features will be excavated. Botanical analysis of vegetation patterns has also been started. This project is the first professional investigation of homesteading on Pajarito Plateau. It also marks a cooperative research effort between the Laboratory, which is doing field investigations, and the Los Alamos Historical Society, which is conducting interviews of people who lived on Pajarito Plateau during the homesteading period.

3. Engineering Quality Assurance. The Laboratory has a Quality Assurance program (Facilities 1983) for engineering, construction, modification, installation, and maintenance of Department of Energy facilities. The purpose of the program is to minimize the chance of deficiencies in construction; 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's operationing group(s), Laboratory's Facility 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 environmental degradation. Consideration is given to the present condition of the site (soils, geology, ground water, surface water, air quality, archaeology, 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.).

VI. RELATED ENVIRONMENTAL STUDIES

The Environmental Surveillance Group (HSE-8) and the Environmental Sciences Group (HSE-12) 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. Movement of Depleted Uranium by Storm Runoff [N. M. Becker, W. D. Purtymun, and M. Maes (HSE-8)]

Field studies were begun in the spring of 1983 to determine the extent of movement of depleted uranium from test firings at some of the Laboratory's dynamic testing areas. Airborne depleted uranium from test shots settles on the ground surface and is washed into onsite stream channels by precipitation and snowmelt. Onsite channels and alluvium were sampled for uranium to help trace its movement by storm runoff processes.

Background uranium levels were measured in Pajarito Plateau stream channels in the vicinity of the Laboratory that are not in the drainage area of the firing sites (Fig. 33) and in sediments collected in the Rio Grande (Fig. 34). Alluvium on Pajarito Plateau is derived from weathered Bandelier Tuff. Consequently, uranium samples and analyses were made on the different units that make up Bandelier Tuff. Results of these samples are in Tables XVII, XVIII, and XIX. Uranium concentrations in stream channel deposits and river sediments ranged from 1.6 to 4.4 parts per million (ppm). Background uranium levels in the Bandelier Tuff units tended to be slightly higher, ranging from 3.8 ppm in Unit 3 to 11 ppm in the Guaje Member.

Onsite studies were concentrated on stream channel sediments in Potrillo Canyon, which drains four firing sites. The sampling locations are shown in Fig. 35. Samples collected in channel alluvium in Potrillo Canyon had relatively higher uranium concentrations near the main sources of uranium at Firing Sites E-F and I-J and the levels decreased with distance from the firing sites. The concentrations ranged from 112 ppm below Firing Site E-F to 2.5 ppm at the intersection of Potrillo Canyon and New Mexico State Road 4 (Table XX). A background stream channel sample in a side canyon to Mortandad Canyon had 4.6 ppm uranium. Channel bank samples showed the same uranium distribution pattern as the sediment samples. They ranged from 275 ppm below E-F Firing Site to 4.2 ppm at the intersection of Potrillo Canyon and New Mexico State Road 4 (Table XX).

The sediment samples were sieved into sand (larger particles) and silt-clay fractions (smaller particles). The silt-clay fractions were consistently greater in uranium content than the sand fractions (Table XX). The uranium appears to have a greater affinity for smaller-sized particles. Storm runoff, which carrys a high suspended sediment load (silt-clay fraction), deposits some suspended sediments on channel banks during receding flow. This deposition accounts for relatively higher uranium concentrations in channel bank samples versus concentrations in channel sediments.

Cumulative samplers, which collect storm runoff, were installed in Potrillo Canyon and a side canyon to Mortandad Canyon. The sample locations B, D, M, G, J, and L are shown in Fig. 35. In every runoff sample, uranium concentrations in solution and suspended sediments were inversely proportional to the distance between the sampling location and the source firing site (Table XXI).

Leach tests were done on selected channel sediment samples. These samples were from runoff samples that contained relatively low levels of uranium in solution when compared to the uranium levels in suspended sediments. Twenty-five grams of channel sediment were leached in 1 liter of distilled water and agitated for 6 hours. The liquid and sediment portions of the resulting mixture were then analyzed (Table XXII). In general, most of the uranium remained in the sediment fraction. This indicates that uranium binds closely with some minerals and does not readily leach out.

B. Rooting Depths of Plants Relative to Biological and Environmental Factors [T. S. Foxx, G. D. Tierney (HSE-8/HSE-12), and J. M. Williams (HSE-12)]

In 1981-1982 an extensive bibliographic study was completed to document rooting depths of native plants in the United States. The data base currently contains 1034 citations and approximately 12 000 data elements. The data were analyzed for rooting depths as related to life form, soil type, geographical region, root type, family, root depth to shoot height ratios, and root depth to root lateral ratios. Average rooting depths and frequencies were determined and

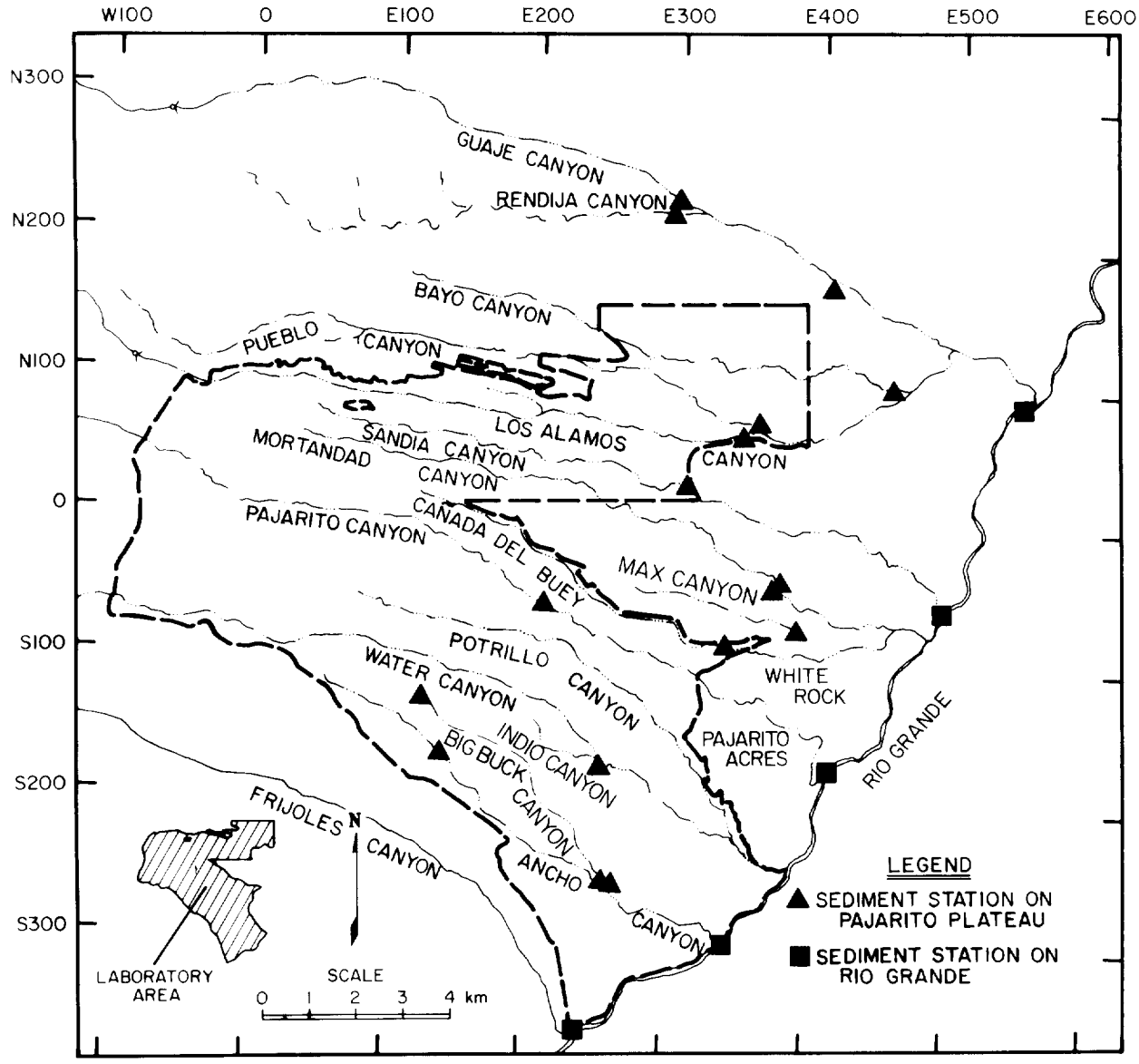


Fig. 33. Locations of sediment sampling stations for depleted uranium study.

related to present low-level radioactive waste site maintenance (Foxx 1984A).

There are 11 low-level radioactive waste sites in the United States, 6 of which are in semiarid or arid regions. Overburdens at most of these sites are 0.3 to 1 m deep. The shallowness of the cover almost assures penetration by the roots of all but the shallowest rooting plants. In this study only annual grasses root entirely within 1 m and only half of these root within 0.3 m. Median rooting depths of other life forms are up to 1.95 m with maximum rooting depths to 61 m: annual forbs (median of 0.61 m: annual forbs (median of 0.61 m, maximum of 3.0 m); biennial forbs (0.76 m, 1.5 m); perennial grasses (1.06 m, 8.2 m); perennial forbs (1.14 m, 39 m); subshrubs and vines (1.16 m, 6.4 m); trees (3.34, 61 m); and shrubs (1.95 m, 17 m). Without effective biobarriers, approximately 1.5 m of cover is sufficient to prevent root entry into the waste, provided the deep-rooting plants are kept cleared.

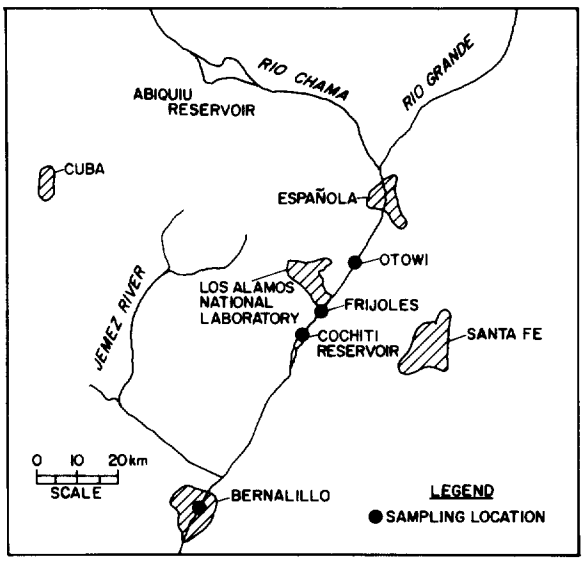


Fig. 34. Locations of sediment sampling stations on the Rio Grande.

Table XVIII

Total Uranium in Samples from Ephemeral Streams at the Rio Grande

Location on Rio Grande	Total Uranium (ppm)
Otowi	3.0 ± 0.6
Sandia Canyon	2.9 ± 1.0
Pajarito Canyon	2.8 ± 1.0
Ancho Canyon	1.6 ± 1.0
Frijoles Canyon	2.0 ± 1.0
Head of Cochiti Reservoir	1.8 ± 1.0
Bernalillo	2.8 ± 0.6

Table XVII

Total Uranium in Samples from Ephemeral Streams That Cross Pajarito Plateau

Location	Total Uranium (ppm)
Rendija Canyon at Guaje Canyon	2.9 ± 1.0
Guaje Canyon at Well 5	2.8 ± 1.0
Barrancas Canyon at Guaje Canyon	2.9 ± 1.0
Pueblo Canyon at the "Y"	1.7 ± 1.0
Los Alamos Canyon at the "Y"	1.8 ± 1.0
Sandia Canyon at State Road 4	3.4 ± 1.0
Mortandad Canyon at State Road 4	2.6 ± 1.0
Cedro Canyon at State Road 4	2.8 ± 1.0
Max Canyon at State Road 4	2.9 ± 1.0
Cañada del Buey at State Road 4	2.1 ± 1.0
Pajarito Canyon below Area G	2.4 ± 1.0
Indio Canyon at State Road 4	3.3 ± 1.0
Big Buck Canyon at State Road 4	4.4 ± 1.0
Ancho Canyon at State Road 4	1.6 ± 1.0
Ancho Canyon below DT-9	1.9 ± 1.0
Big Buck Canyon below DT-10	1.9 ± 1.0
Bayo Canyon at State Road 4	2.4 ± 1.0

Table XIX

Total Uranium in Outcrop Samples

Bandelier Tuff Unit	Total Uranium (ppm)
Guaje	11.0 ± 2.2
Otowi A	6.0 ± 1.2
Otowi B	6.7 ± 1.4
Unit 1A	8.1 ± 1.6
Unit 1B	7.9 ± 1.6
Unit 2A	8.5 ± 1.6
Unit 2B	4.7 ± 1.0
Unit 3	3.8 ± 1.2
Pumice Fragment 1 (Otowi)	5.9 ± 1.2
Pumice Fragment 2 (Ancho Canyon)	6.1 ± 1.2

Cover type strongly affects root penetration and hence the amount of cover needed. Adobe clay affords the shallowest rooting system (median root depth of all plants is 0.4 m; 99% of all plants have root depths less than 2.7 m); sandy soil (0.75m, 4.5 m); loam (0.85 m, 3.0 m), clay loam (1.3 m, 4.5 m); and silt (1.6 m, gretaer than 4.5 m). Soil effects on lateral

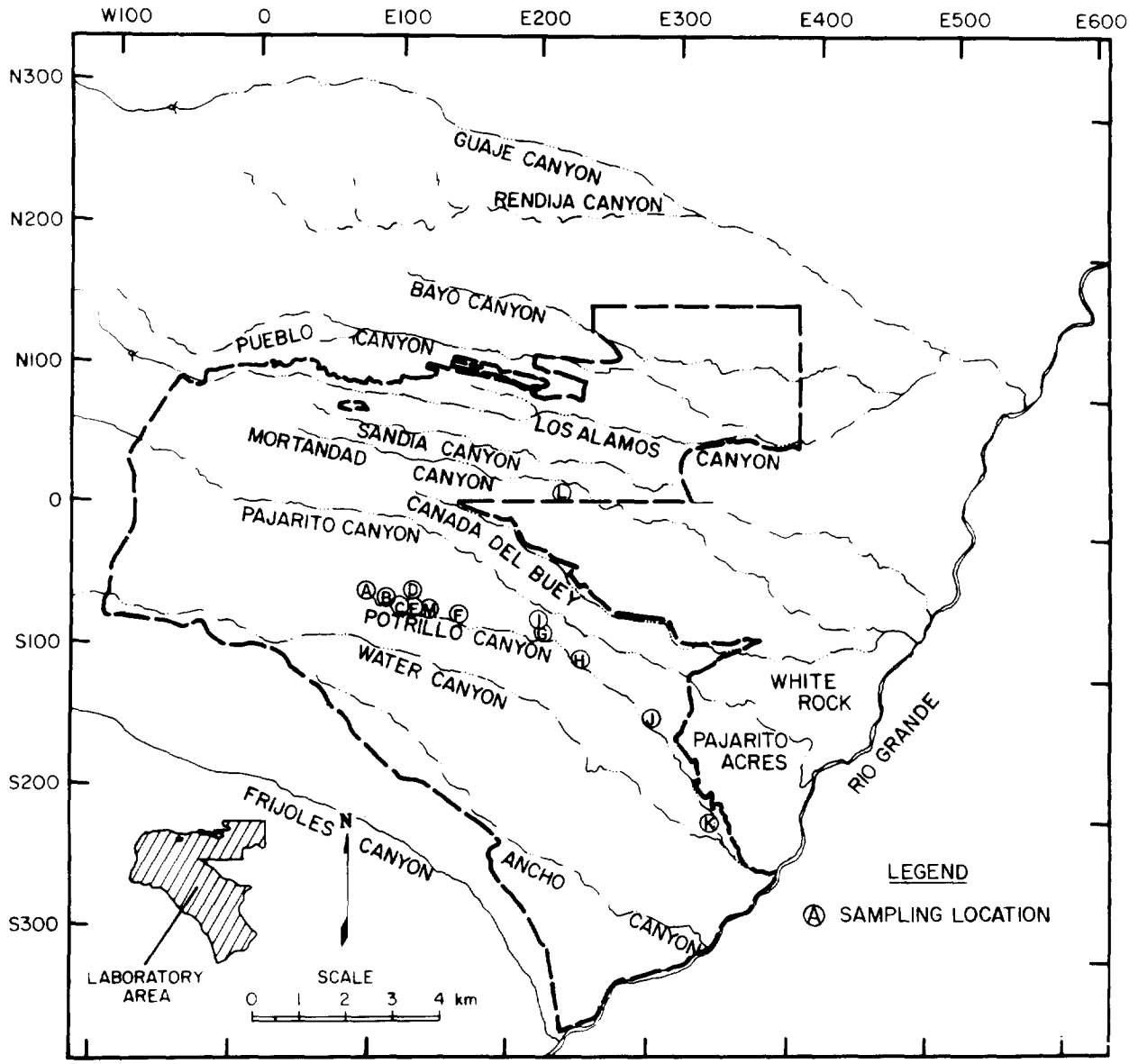


Fig. 35. Locations of sediment sampling stations in stream channels.

root growth are similar, except that sandy soils are less restrictive and more like silts. Adobe clay retards root growth by physical restraint, but roots can penetrate through cracks. Sand retards root growth by acting as a sieve to conduct water away before the plants can use it.

Root type plays a major role in a plant's ability to penetrate into a soil. Bulb-type roots are the least penetrating (average depth of 0.12 m); corm roots (0.24 m); rhizome roots (0.80 m); fibrous roots (1.3 m); and taproots (2.4 m).

Plant height can give a rough estimate of root penetration. In most cases, the depth to height (d/h) ratio for trees was less than 1.1. Trees that were less than 305 cm tall had a 0.22 ratio. Shrubs had a d/h ratio of 1.2; forbs, 1.7; and grasses, 2.0. In some cases, lateral spread may be important, particularly for species on waste site perimeters. With sufficient lateral extensions, species may penetrate wastes from the waste pit exterior. Ratios indicate that the lateral spread of trees will vary with age of the trees.

Table XX

Total Uranium in Samples from Potrillo Canyon
(concentrations in ppm)

Station	Bank		Channel Sediments		Sand Fraction		Silt/Clay Fraction	
	Number of Samples	$\bar{x} \pm 2s$	Number of Samples	$\bar{x} \pm 2s$	Number of Samples	$\bar{x} \pm 2s$	Number of Samples	$\bar{x} \pm 2s$
A	1	13 ± 1.3	1	6.5 ± 1.4	---	---	---	—
B	5	270 ± 42	1	112 ± 22	1	270 ± 54	1	260 ± 52
C	1	32 ± 3.0	1	12 ± 2.4	---	---	---	---
D	1	7.0 ± 0.7	2	4.8 ± 3.2	1	2.8 ± 0.6	1	18 ± 3.6
E	1	25 ± 2.5	1	6.2 ± 1.2	---	---	---	—
F	1	8.1 ± 0.8	1	3.9 ± 0.8	---	---	---	---
G	---	---	2	5.8 ± 2.2	---	---	---	---
H	1	4.4 ± 0.4	1	2.3 ± 0.4	---	---	---	---
I	---	---	---	5.0 ± 1.0	---	---	---	---
J	1	4.2 ± 0.4	3	2.5 ± 4.1	1	2.6 ± 0.8	1	4.7 ± 1.0
K	---	---	1	1.5 ± 1.0	1	1.4 ± 1.0	1	4.6 ± 1.0
L	---	---	1	4.6 ± 1.0	1	3.6 ± 0.8	1	6.9 ± 1.4

Table XXI

Total Uranium in 1983 and 1984 Runoff Samples in Potrillo Canyon

Station	Water (ppb)		Suspended Sediment[a] (ppm)	
	Number of Samples	$\bar{x} \pm 2s$	Number of Samples	$\bar{x} \pm 2s$
B	3	26 ± 34	2	185 ± 4.0
M	13	0.9 ± 1.8	9	12 ± 4.0
G	4	5.8 ± 16	4	4.5 ± 4.6
J	4	-0.1 ± 1.2	5	4.0 ± 0.6
L (background)	2	0.8 ± 2.2	2	3.2 ± 3.6

[a]Obtained by passing runoff liquid through a 45-μm filter.

Table XXII

Results of Leaching of Channel Sediments

Station	Total Uranium in Sample (ppm)	Total Uranium in Fractions		Ratio (Amount of Leachate in Sediment)/ (Total Uranium)
		Water (ppb)	Sediment (ppm)	
B	204 ± 40	6.5 ± 1.4	230 ± 46	1.1
D	5.9 ± 1.2	3.9 ± 1.0	1.8 ± 0.4	0.30
J	2.7 ± 0.6	0.0 ± 1.0	2.6 ± 0.6	0.96
L	4.6 ± 1.0	0.0 ± 1.0	3.8 ± 0.8	0.83

Younger trees will have lower depth to lateral distance (d/l) ratios than will older trees. Shrubs have d/l ratios of less than 1, forbs and grasses greater than 2. The highest d/l ratios were found for subshrubs.

C. Rooting Depths of Plants on Low-Level Radioactive Waste Sites [T. S. Foxx, G. D. Tierney (HSE-8/HSE-12), and J. M. Williams (HSE-12)]

An extensive bibliographic study was done on rooting depths of 53 plant species found on low-level radioactive waste sites at Los Alamos National Laboratory (Foxx 1984B). The plants are rooted in surface materials composing the waste site covers that include weathered tuff, silty clay, sand, and gravel. Presently, most sites have overburdens of 30 to 90 cm. The study indicates that regardless of soil type, most grass species will root to depths greater than 90 cm, the exception being Junegrass (*Koeleria cristata*). The shallowest rooting grasses were found to be bluegrass (*Poa* spp.), fescue (*Festuca* spp.), three-awn (*Aristida* spp.), and needle-and-thread grass (*Stipa*

comata). Side-oats grama (*Bouteloua curtipendula*) and alkali sacaton (*Sporobolus arioides*) were found to root to depths greater than 457 cm. The majority of the grass species studied root within the first 275 cm.

Forb species were more variable in depths. Species such as alfalfa (*Medicago sativa*), gayfeather (*Liatris punctata*), and golden-weed (*Haplopappus* spp.) root below 460 cm, while roots of species such as yucca (*Yucca* spp.) and groundsel (*Senecio* spp.) are within the first 180 cm. Buckwheat (*Eriogonum* spp.), wormwood (*Artemisia* spp.), cinquefoil (*Potentilla* spp.), and goldenrod (*Solidago* spp.) do not root deeper than the first 270 cm.

Trees and shrubs commonly root deeper than 460 cm. Roots of shrubs and tree species such as one-seed juniper (*Juniperus monosperma*) have been found at great depths.

When three families of plants—the grass family, sunflower family, and pea family—were compared, it was found that the grass family rooted the shallowest and the pea family the deepest. Rooting depth varies with biological and environmental factors. These should be considered when selection of specific species is made for site stabilization.

D. Status of the Flora of the Los Alamos National Research Park [T. S. Foxx and G. D. Tierney (HSE-8/HSE-12)]

The flora of the Los Alamos National Research Park (LA/NERP) and surrounding area is diverse but not entirely unpatterned (Foxx 1984C). Six distinct plant communities are encountered as one travels from the eastern boundaries of the LA/NERP near White Rock Canyon, across Pajarito Plateau, to points beyond the western boundaries and near the summit of Pajarito Mountain. The six plant communities are named by the predominant vegetation types. In order of increasing elevation, they are the juniper grassland. piñon-juniper, ponderosa pine, mixed conifer, spruce-fir, and subalpine meadow communities.

Inhomogeneities within the six communities may occur when deep canyons cross a community's elevational domain, leading to an inversion of the order of the communities. Other, more localized differences in the vegetation pattern occur when special circumstances of exposure, water availability, substrate (soils), and/or anthropogenic disturbance combine to create special habitats that are reflected by unusual associations of plant species. There are many kinds of special habitats and unusual associations of plants within the LA/NERP and its surrounding terrain.

Approximately 436 vascular plant species representing 67 families have been found in the plant community sections that are cut by Water and Pajarito Canyons. Very few of these species are presently regarded as endangered, threatened, or even rare. However, 39 of them receive limited protection under New Mexico laws.

Vegetation patterns of the LA/NERP and its immediate surroundings have been affected by former patterns of use on Pajarito Plateau. Some evidence of disturbance dates to the pre-Spanish period (archeological ruins and agricultural areas). Subsequent grazing, homesteading, and logging have extensively disturbed the three plant communities (juniper grassland, piñon-juniper, and ponderosa pine) that occupy the lower elevations. From 1940 to the present, recreational and road development have minimally disturbed the upper two plant communities (mixed conifer and spruce-fir). The strongest agents of disturbance in recent times have been fires, logging, and insect pests.

E. Estimating the Risks of Cancer Mortality and Genetic Defects Resulting from Exposures to Low Levels of Ionizing Radiation [T. E. Buhl and W. R. Hansen (HSE-8)]

Estimators for calculating the risk of cancer and genetic disorders induced by exposure to ionizing radiation have been recommended by the US National Academy of Sciences Committee on the Biological Effects of Ionizing Radiations, the United Nations Scientific Committee on the Effects of Atomic Radiation, and the International Committee on Radiological Protection. These groups have also considered the risks of somatic effects other than cancer. The US National Council on Radiation Protection and Measurements has discussed risk estimate procedures for radiation-induced health effects.

The recommendations of these national and international advisory committees have been summarized in a report (Buhl 1984). In this report, two procedures for risk estimation are presented for use by the Department of Energy under the National Environmental Policy Act of 1969 (NEPA). In the first procedure, age- and sex-averaged risk estimators calculated with United States average demographic statistics would be used with estimates of radiation dose to calculate the projected risk of cancer and genetic disorders that would result from the operation being reviewed under NEPA. If more site-specific risk estimators are needed, and the demographic

information is available, a second procedure is described that would involve direct calculation of the risk estimators using recommended risk-rate factors. A computer program (REPCAL) was written to perform this calculation and is described in the report.

F. HUMTRN: Documentation and Verification for an ICRP Based Age- and Sex-Specific Human Simulation Model for Radionuclide Dose Assessment [A. F. Gallegos and W. J. Wenzel (HSE-8)]

A dynamic human simulation model HUMTRN has been designed specifically as a major module to BIOTRAN (an environmental simulation model). It integrates climatic, hydrologic, atmospheric, food crop, and herbivore simulation, human dietary and physiological characteristics, and metabolism of radionuclides to predict radiation doses to selected organs of both sexes in different age groups (Gallegos 1984). The model is based on age- and sex-specific equations developed for predicting human radionuclide transport from metabolic and physical characteristics. These characteristics are modeled from studies documented by the International Commission on Radiological Protection (ICRP Report 23).

The HUMTRN module allows cumulative doses from uranium or plutonium radionuclides to be predicted by modeling age specific anatomical, physiological, and metabolic characteristics of individuals between 1 and 70 years of age. It can track radiation exposure and radionuclide metabolism for any age group for specified daily or yearly time periods. The simulated daily dose integration of eight or more simultaneous air, water, and food intakes gives a new, comprehensive, dynamic picture of radionuclide intake, uptake, and hazard analysis of complex scenarios.

G. Silver Transport in Cañon de Valle [Claudine A. Kasunic, Roger W. Ferenbaugh (HSE-8), and Ernest S. Gladney (HSE-9)]

Beginning in the 1940's, the Los Alamos National Laboratory began discharging spent photographic solutions into a small canyon tributary to Canon de Valle. These solutions consisted of untreated spent x-ray fixing baths that contained silver (silver thiosulfate). There are no records of the total volume of discharges over the years. However, operations at the photographic laboratory ran 24 hours a day until the mid-1960s, when operations dropped to 16 hours a day, and ultimately to 8 hours a day (5 days a week). In the late 1970s, silver recovery from the x-ray fixing baths by use of ion exchange columns was implemented.

The purpose of this study was to determine the extent of silver contamination in the canyon receiving the silver solution discharge. Samples of water, vegetation, sediment, and soil were collected along the canyon channel and analyzed for silver.

As might be expected, silver concentrations decreased with progression down the canyon. At approximately 300 m distance from the discharge point, the silver levels in vegetation approached background concentrations. Silver concentrations in sediments and soils, however, remained significantly higher than background for about 420 m. The small tributary into which the photographic waste solution is discharged converges with Cañon de Valle at a distance of about 90 m, so above-background silver concentrations are detectable in Cañon de Valle.

Near the mouth of the waste outfall, the soil and rocks were stained black with silver oxide. Waste discharge is not continuous, and apparently in this area, which is devoid of vegetation, silver solutions evaporated and oxidation of silver occurred. Farther down the canyon, the surface flow infiltrates into alluvium and no surface deposits of silver are evident. The maximum silver concentrations detected were 20,000-25,000 ppm in sediment, 10,000-15,000 ppm in soil, and 8-10 ppm in grass and trees. In the area of highest silver concentrations in soil, above-background silver concentrations were found to a depth of about 1 m.

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

The effluent release area near the Los Alamos Meson Physics Facility's (LAMPF's) lagoons was sampled for ^{7}Be, ^{57}Co, ^{3}H, ^{54}Mn, ^{22}Na, and ^{83}Rb twice during 1984 (June and December). The sampling locations are shown in Fig. 36 and results in Table E-XLVII. The quality of the effluent is detailed in Table E-XXXVII. The following observations can be made from examining these data:

1. The concentration of each radionuclide in samples of LAMPF's effluent was less than 1% of the Department of Energy's Concentration Guide for Controlled Areas.

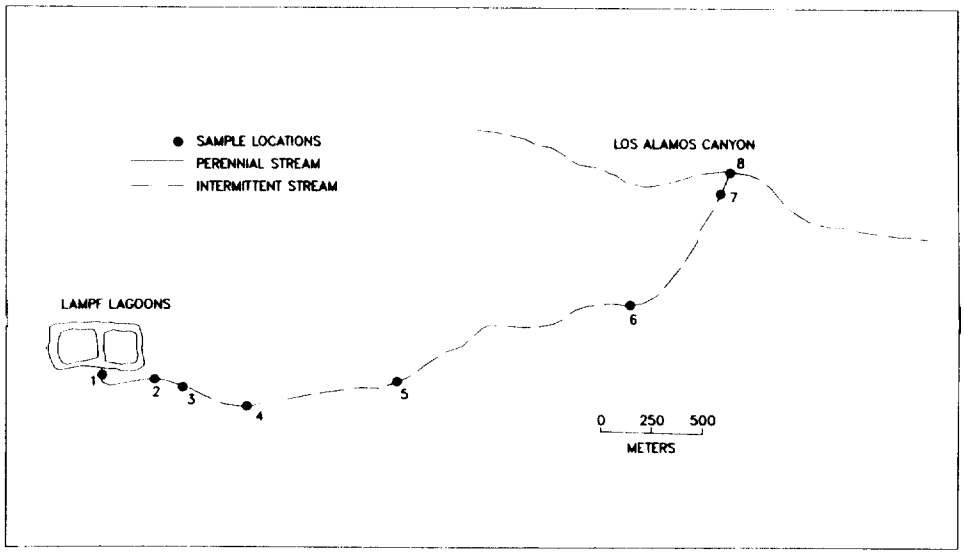


Fig. 36. Sampling locations in the effluent discharge path from the Los Alamos Meson Physics Facility's lagoons.

2. The concentrations of ^{7}Be, ^{57}Co, ^{134}Cs, ^{54}Mn, and ^{22}Na in water and sediment samples were similar to those found in previous years (ESG 1983 and ESG 1984).
3. The concentrations of ^{3}H in water and sediment samples were slightly higher than in previous years (ESG 1983 and ESG 1984). These relatively higher levels most likely resulted from LAMPF's higher beam currents and longer operating times during 1984.
4. The levels of ^{83}Rb in water and sediment samples were substantially higher at sampling locations nearest the lagoons (Stations 1, 2, and 3) when compared with data from previous years (ESG 1983 and ESG 1984). These relatively higher concentrations are due to increased use of stable ^{85}Rb in experimental targets.

Surface concentrations of all the radionuclides sampled decreased precipitously beyond Station 4, where the effluent sinks into the alluvium. All the stations were dry, except for Station 8, for the June sampling period. The last four stations were dry for the December sampling period.

All the radionuclide concentrations (except for ^{7}Be) in water and sediment samples were higher in winter than summer. Greater uptake of radionuclides by increased plant and algae growth in summer reduces radioactivity in the water and sediments. This is a commonly observed ecological phenomenon (Odum 1971, Menzel 1965, and Woodwell 1967).

I. BIOTRAN Models [W. J. Wenzel, A. F. Gallegos, G. H. Brooks, Jr., D. L. Mayfield (HSE-8) and J. C. Rodgers (HSE-12)]

1. Introduction. The BIOTRAN computer model was developed by the Laboratory over the past 11 years to predict and assess the impact to people from acute and chronic releases of pollutants. Thirteen modules have been developed and integrated to simulate soils, plants, animals, humans, and population dynamics. The modules are driven by a Monte Carlo climate simulator. Each module is coupled with two- and three dimensional color graphics that allow rapid verification of complex scenario simulations.

The BIOTRAN code is a dynamic, mechanistic model that realistically simulates environmental processes for daily and yearly time periods. It is used to simulate radionuclide and nutrient transport at Los Alamos to help interpret environmental surveillance data. It is also used for special studies and for environmental training courses.

2. User's Manual. A BIOTRAN User's Manual was developed in 1984 to document each module on various computer systems (VAX, CDC 7600, CRAY). The manual has four parts for each module: a description of the module, a description of the input requirements, examples, and the code and its flow chart.

3. Recent Developments. After development of a human metabolic model, HUMTRN (Gallegos 1984), a cancer risk prediction model was developed based on work by Buhl and Hansen (Buhl 1984). The cancer risk model called EFFECTS calculates the number of cancer mortalities as a function of age and sex for a dynamic population.

The BIOTRAN model was also expanded to simulate environmental transport of stable elements. For example, transport of the major nutrients nitrogen, phosphorus, and potassium can now be simulated. This development of nutrient cycling extends BIOTRAN capabilities into new areas such as hazardous chemical risk assessment, watershed management, and farm and range management.

J. Measurement and Modeling of Gamma Doses from LAMPF Emissions [B. M. Bowen, D. M. Van Etten, A. I. Chen, and W. A. Olsen (HSE-8)]

1. Introduction. Portable, high pressure ionization chambers (HPICs) were used to measure short-term gamma radiation levels produced by air activation products from LAMPF. These measurements were in addition to those made by the thermoluminescent dosimeter (TLD) network that measures long-term gamma radiation levels. A Gaussian-type atmospheric dispersion model that assumes an infinite plume (that is, uniform radionuclide concentrations are assumed around receptor point) was used to predict absorbed gamma dose. Onsite meteorological and stack release data were inputs to the model.

Short-term gamma absorbed doses were measured by HPICs at azimuths of 0° (north), 22° (north-northeast), and 45° (northeast) from the LAMPF stack during the year. Daily contributions of gamma levels by LAMPF were determined by subtracting background levels at all three sites. The background was estimated by the total gamma levels during periods when the LAMPF plume was not affecting the sites.

2. Results. Daily model predictions, based on integration of 15-minute period predictions, were made and compared with measured values. There were 49 days during the summer in which all three HPICs were operating and when at least one recorded a daily gamma level of at least 100 μRad. Figure 37 shows the wind rose for this period. Note that the predominant winds are typically SSW and SW over LAMPF. The high frequency of SSW and SW winds

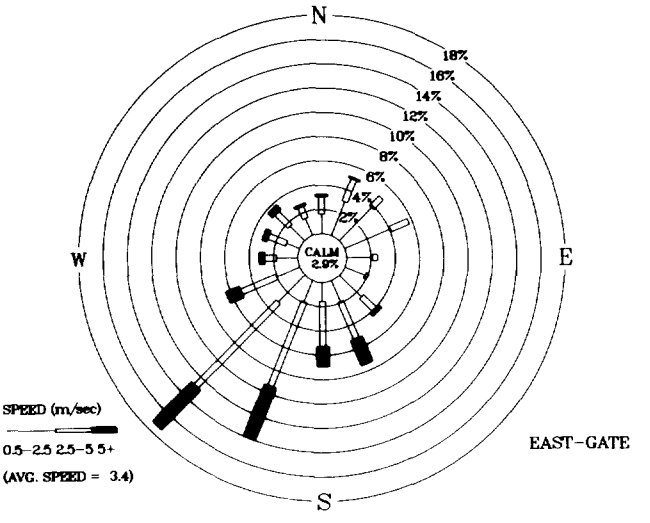


Fig. 37. Wind rose for nearest offsite location from LAMPF (TA-53) during a 49-day modeling study.

is due in large part to the afternoon and evening up-valley winds. These predominant winds transport the LAMPF stack emissions toward East Gate (Station 6 in Fig. 11), the nearest fence line location.

Comparison of the predicted and measured daily gamma doses due to LAMPF emissions at three sites is shown in Fig. 38. There is very good correlation between the predicted and measured data. Correlation is strongest at the NNE site and weakest at the NE site. Note that the model over the entire 49-day period closely predicts the gamma levels (108% at HPIC NO. 2 and 96% at HPIC No. 3, while it only predicts 61% of the gamma levels at HPIC No. 1. This rather large difference of slope of HPIC No. 1 data may be related to the large difference of wind frequency in S and SSW winds.

The model was also used to predict annual gamma levels on State Road 4 during 1984 due to LAMPF emissions. Predicted gamma absorbed doses ranged from approximately 90 mrad to the NNE of LAMPF, 75 mrad to the NE, and 17 mrad to the NW. An average of nearly 50 mrad was predicted in the sector that is NW to NE of LAMPF. This compares favorably with the 44 mrad as measured by the TLD network (see Section IV.A).

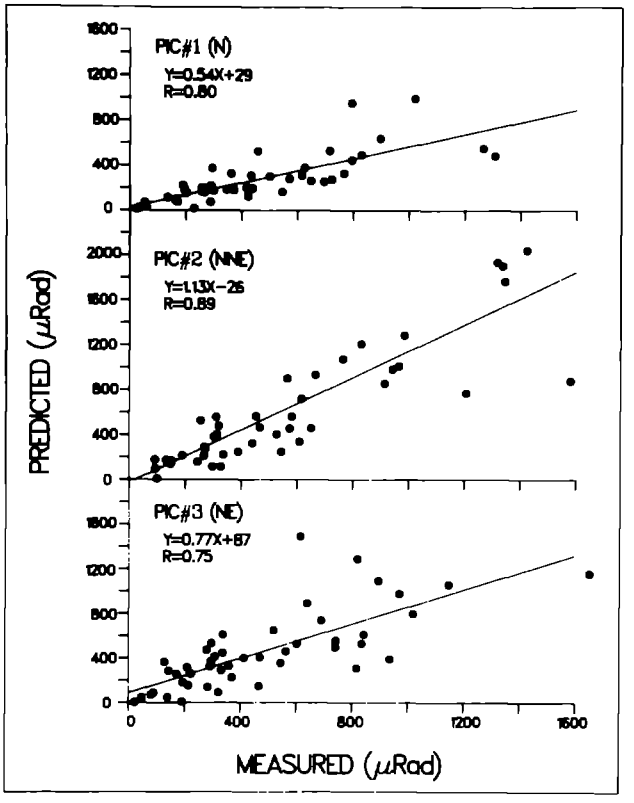


Fig. 38. Predicted versus measured daily gamma doses due to LAMPF emissions at sites N, NNE, and NE of LAMPF on State Road 4.

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).

Balo 1984: K. A. Balo and J. L. Warren, "Waste Management Site Plan, Los Alamos National Laboratory, December 1984," Los Alamos National Laboratory report LA-UR-85-336 (December 1984).

Buhl 1984: 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 LA-9893-MS (May 1984).

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/EIS0018 (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," US Department of Energy report ORO-831 (1983).

Engineering 1982: Engineering Division, "Los Alamos National Laboratory Long-Range Site Development Plan," for Los Alamos National Laboratory (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 1977: 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 1979A: US Environmental Protection Agency, "National Emission Standards for Identifying, Assessing, and Regulating Airborne Substances Posing a Risk of Cancer," Federal Register **44** (197), October 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).

EPA 1984: US Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," US Environmental Protection Agency report AP-42, Supplement 15, Third Edition (January 1984).

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).

ESG 1984: Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1983," Los Alamos National Laboratory report LA-10100-ENV (April 1984).

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

Foxx 1984A: T. S. Foxx, G. D. Tierney, and J. M. Williams, "Rooting Depths of Plants Relative to Biological and Environmental Factors," Los Alamos National Laboratory report LA-10254-MS (November 1984).

Foxx 1984B: T. S. Foxx, G. D. Tierney, and J. M. Williams, "Rooting Depths of Plants on Low-Level Waste Disposal Sites," Los Alamos National Laboratory report LA-10253-MS (November 1984).

Foxx 1984C: T. S. Foxx and G. D. Tierney, "Status of the Flora of the Los Alamos National Environmental Research Park," Los Alamos National Laboratory report LA-8050-NERP (September 1984).

Gallegos 1984: A. F. Gallegos and W. J. Wenzel, "HUMTRN: Documentation and Verification for an ICRP-Baed Age- and Sex-Specific Human Simulation Model for Radionuclide Dose Assessment," Los Alamos National Laboratory report LA-9994-MS (June 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," US Department of Energy report ORO-832 (1983).

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 Resources* (Dowden, Hutchinson, and 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. Transuranium Nuclides in the Environment, International Atomic Energy Agency report IAEA-SM-199/99 (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), ICRP Publication No. 26.

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).

Kramer 1977: Kramer, Callahan, and Associates, "Particulate Analyses of Drier Exhaust Emissions at the Zia Company Asphalt Plant, Los Alamos, New Mexico" (September 1977).

Los Alamos 1984: Los Alamos National Laboratory, "Implementation Plan for Radioactive Waste Management at Los Alamos National Laboratory" (October 1984).

Menzel 1965: R. G. Menzel, "Soil-Plant Relationships of Radioactive Elements," Health Physics 11, 1325-1332 (1965).

MHSM 1976: Mason and Hanger-Silas Mason Co., Inc., "Disposal of Waste or Excess High Explosives," MHSM quarterly progress reports (January 1971 through March 1976).

NCRP 1975A: National Council on Radiation Protection and Measurements, "Review of the Current State of Radiation Protection Philosophy," National Council on Radiation Protection and Measurements report No. 43 (1975).

NCRP 1975B: 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).

NCRP 1984A: National Council on Radiation Protection and Measurements, "Exposures from the Uranium Series with Emphasis on Radon and its Daughters," National Council on Radiation Protection and Measurements report No. 77 (1984).

NCRP 1984B: National Council on Radiation Protection and Measurements, "Evaluation of Occupational and Environmental Exposures to Radon and Radon Daughters in the United States," National Council on Radiation Protection and Measuremnts report No. 78 (May 1984).

NRC 1977: US Nuclear Regulatory Commission, "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).

NRC 1980: National Research Council, Committee on the Biological Effects of Ionizing Radiations, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980," National Academy Press, Washington, D.C. (1980).

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).

Odum 1971: E. P. Odum, *Fundamentals of Ecology* (W. B. Saunders Co., Philadelphia, 1971), pp. 86-99.

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 1971 (was 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 1974A: W. D. Purtymun, "Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County, New Mexico," Los Alamos Scientific Laboratory report LA-5744 (1974).

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

Purtymun 1974C: W. D. Purtymun, "Dispersion and Movement of Tritium in a Shallow Aquifer in Mortandad Canyon," Los Alamos Scientific Laboratory report LA-5716-MS (September 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 1980A: 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 1980B: W. D. Purtymun and H. Adams, "Geohydrology of Bandelier National Monument," Los Alamos Scientific Laboratory report LA-8461-MS (July 1980).

Purtymun 1980C: W. D. Purtymun, R. J. Peters, and J. W. Owens, "Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon," Los Alamos Scientific Laboratory report LA-8635-MS (December 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. 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, "Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies," Los Alamos National Laboratory report LA-9957-MS (January 1984).

Salazar 1984: J. G. Salazar, "Produce and Fish Sampling Program of Los Alamos National Laboratory's Environmental Surveillance Group," Los Alamos National laboratory report LA-10186-MS (September 1984).

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

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 Archaelogical Survey and Excavations, Vol. II," Los Alamos National Laboratory report LA-8860-NERP (April 1982).

USGS 1965: U. S. 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.

USGS 1984: U. S. Geological Survey, "Water Resource Data for New Mexico Water Year 1983," U. S. Geological Survey water data report NM-83-1 (1984).

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

Woodwell 1967: G. M. Woodwell, "Toxic Substances and Ecological Cycles," Scientific American 216 (3), 24-31 (1967).

Yeates 1972: D. B. Yeates, A. S. Gilden, 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 XI (Requirements for Radiation Protection), DOE Order 5484.1 (Environmental Radiation Protection, Safety, and Health Protection Information Reporting Requirements), Chapter III (Effluent and Environmental Monitoring Program Requirements), and DOE Order 5480.4 (Environmental Protection, Safety, and Health Protection Standards).

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.[A2] 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) and 40CFR141.

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

PROCEDURES FOR SAMPLING AND DATA HANDLING

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,B2] 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).[B3]

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.[B4] 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 collectded monthly at 26 continuously operating stations.[B5] Air pumps with flow rates of about 3 ℓ/sec are used. Atmospheric aerosols are collected on 79 mm diameter polystyrene filters. Each filter is mounted on a cartridge that contains charcoal. This charcoal is not routinely analyzed for radioactivity. 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 to 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 data.

At one onsite location (N050-E040) atmospheric radioactivity samples are collected weekly. Atmospheric particulate matter on each weekly filter is counted for gross alpha and gross beta activities, which help trace temporal variations in atmospheric radioactivity concentrations. The same measurements are made on a monthly filter from the Española (Station 1) regional air sampler.

On a quarterly basis, the monthly filters for each station are cut in half. The filter halves are combined to produce two quarterly composite samples for each station. The first group is analyzed for ^{238}Pu, $^{239,240}Pu$, and ^{241}Am (on selected filters). The second group of filter halves is saved for uranium analyses.

Filters from the first composite group are ignited in platinum dishes, treated with $HF\text{-}HNO_3$ to dissolve silica, wet ashed with $HNO_3\text{-}H_2O_2$ 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 resulting 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, $^{239,240}Pu$, and ^{241}Am are integrated and the concentration of each radionuclide in its respective filter 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 the degree of dessicant saturation. During cold months of low absolute humidity, sampling flow rates are increased to ensure collection of enough water vapor for analysis. Water is distilled from each silica gel cartridge and an aliquot of the distillate is analyzed for tritium by liquid scintillation counting.

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

2. Statistical Analysis. Measurements of the air particulate samples require that analytical or instrumental backgrounds be subtracted to obtain net values. Thus, net values that are lower than the minimum detection limit of an analytical technique (see Appendix C) are sometimes obtained. Consequently, individual measurements can result in values of zero or negative numbers. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values are included in the population.[B6]

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

Standard errors for the 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).

Twice this value is reported as the uncertainty for the station and group means.

C. Water Sampling

Surface and ground water sampling stations are grouped by location (regional, perimeter, onsite) and hydrologic similarity. Water samples are taken once or twice a year. Samples from wells are collected after sufficient pumpage or bailing to ensure that the sample is representative of the aquifer. Spring samples (ground water) are collected at the discharge point.

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 of sample collection for filtration through a 0.45 μm pore membrane filter.

The samples are analyzed radiochemically ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{3}H and total U, as well as for gross alpha, gross beta, and gamma activities. Water samples for chemical analyses are handled similarly.

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

D. Soil and Sediment Sampling

Two soil sampling procedures are used. The first procedure is used to take surface composite samples. Soils samples are collected by taking 5 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 analysis.

The second procedure is used to take surface and subsurface samples at one sampling location. Samples are collected from three layers in the top 30 cm of soil. A steel ring is placed on the surface of the soil at the sampling point. The soil enclosed by the ring is then collected by under-cutting the ring with a metal spatula. A second spatula is then placed on top of the ring and the sample is transfered into a plastic bag. The plastic bag is then marked with identifying information: collection date, location, initials of collector, and depth of soil collected.

The second step is to use a stainless steel core to collect a sample from the 1-10 cm layer. The core is placed directly on the surface cleared by the first sample and driven into the ground. When the core is at surface level, the surounding soil is cleared away from the core to avoid cross contamination of the sample. Next a shovel or spatula is driven horizontally under the core and the sample is transfered into a plastic bag. The bag is labelled as described in the previous paragraph.

A scoop or shovel is driven vertically downward from the bottom of the 1-10 cm sample cavity to collect a sample from the 10-30 cm layer. Care is exercised to prevent cross contamination from surrounding soil. The collected sample is transfered into a plastic bag and labelled.

All three layers are preserved by freezing. All equipment used for collection of these samples is washed with a soap and water solution and dried with paper towels. This is done before each sample is taken to reduce the potential for cross contamination.

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 in the main channel.

Depending on the reason for taking a particular soil or sediment sample, it may be analyzed to detect any of the following: gross alpha and gross beta activities, total uranium, ^{90}Sr, ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$. Moisture distilled from soil samples may be analyzed for ^{3}H.

E. Meteorological Monitoring

Meteorological data are continuously monitored on instrumented towers at five Laboratory locations. Measurements include wind speed and direction, standard deviations of wind speed and direction, vertical wind speed and its standard deviation, air temperature, dewpoint temperature, relative humidity, solar radiation, and precipitation.

These parameters are measured at discrete levels on the towers at heights ranging from ground level to 91 m. Each parameter is measured every 3 to 5 sec and averaged or summed over 15 min intervals. Data are recorded on digital cassettee tape or transmitted by phone line to a microcomputer at the Occupational Health Laboratory at TA-59.

Data validation is accomplished with automated and manual screening techniques. One computer code compares measured data with expected ranges and makes comparisons based known meteorological relationships. Another code produces daily plots of data from each tower. These graphics are reviewed to provide another check of the data. This screening also helps to detect problems with the instrumentation that might develop between the annual or semiannual (depending upon the instrument) calibrations.

REFERENCES

B1. H. E. John and J. R. Cunningham, *The Physics of Radiobiology*, 3rd Edition (C. C. Thomas, Springfield, Illinois, 1974).

B2. International Commission on Radiological Protection, "Protection Against Ionizing Radiation from External Sources," International Commission on Radiological Protection report no. 15 (Pergamon Press, New York, 1970).

B3. P. R. Bevington, *Data Reduction and Error Analysis for the Physical Sciences* (McGraw-Hill, New York, 1969).

B4. M. G. Natrella, *Experimental Statistics* (National Bureau of Standards Handbook 91, Washington, D.C., 1963).

B5. 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).

B6. R. O. Gilbert, *Recommendations Concerning the Computation and Reporting of Counting Statistics for the Nevada Applied Ecology Group*, Battelle Pacific Northwest Laboratories report BNWL-B-368 (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 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-C62]

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 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. The DOE's Environmental Measurements Laboratory also provides quality assurance samples.

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.[C63] 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-C62]

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 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.

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):

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

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 Table C-II. 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:

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

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 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,C62]

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

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

Table C-II

Summary of Analytical Quality Assurance Results for Radiochemical and Stable Element Analyses Completed in HSE-9 During CY 1984 by Matrix

Analysis	Silicates [R ± s (N)]	Waters and Urines [R ± s (N)]	Biologicals [R ± s (N)]	Air Filters and Swipe Filters
Gross alpha	—	1.28 ± 0.32 (16)	—	1.06 ± 0.10 (9)
Gross beta	—	1.47 ± 0.35 (16)	—	0.96 ± 0.02 (9)
^{3}H	—	0.93 ± 0.09 (264)	—	—
^{22}Na	0.88 ± 0.03 (3)	1.03 (2)	—	—
^{40}K	1.16 ± 0.04 (3)	—	0.96 ± 0.06 (3)	—
^{60}Co	—	—	0.99 ± 0.05 (3)	—
^{90}Sr	0.96 ± 0.34 (3)	1.06 ± 0.24 (12)	0.88 ± 0.21 (12)	—
^{137}Cs	1.05 ± 0.13 (45)	1.04 ± 0.24 (60)	1.04 ± 0.34 (6)	—
^{226}Ra	—	0.94 ± 0.14 (9)	—	—
^{238}Pu	0.86 ± 0.16 (3)	0.87 ± 0.12 (36)	—	—
$^{239,240}Pu$	0.87 ± 0.13 (3)	0.96 ± 0.14 (62)	0.90 ± 0.02 (3)	—
Ag	—	1.01 ± 0.07 (35)	—	1.13 (2)
Al	1.03 (2)	1.20 ± 0.12 (7)	0.98 ± 0.09 (10)	1.02 (1)
As	—	1.01 ± 0.08 (22)	0.96 ± 0.14 (84)	1.10 ± 0.23 (25)
B	0.99 ± 0.06 (7)	—	1.02 (1)	—
Ba	1.22 (1)	1.08 ± 0.09 (19)	1.27 ± 0.49 (19)	1.06 (1)
Be	0.94 ± 0.07 (15)	—	—	1.10 ± 0.15 (70)
Bi	—	—	—	0.95 (1)
Br	—	—	0.89 ± 0.24 (32)	—
Ca	1.03 ± 0.08 (4)	0.99 ± 0.04 (17)	0.98 ± 0.03 (6)	1.02 (1)
Cd	0.72 (1)	0.96 ± 0.09 (48)	—	1.03 ± 0.07 (40)
Ce	1.01 ± 0.07 (8)	—	0.89 ± 0.24 (19)	—
Cl	—	0.97 ± 0.05 (15)	0.95 ± 0.14 (14)	—
Co	0.96 ± 0.01 (4)	—	1.03 ± 0.08 (16)	1.10 ± 0.11 (16)
Conductivity	—	1.01 ± 0.02 (15)	—	—
Cr	1.00 ± 0.14 (3)	1.03 ± 0.10 (21)	1.15 ± 0.35 (27)	1.12 ± 0.05 (3)
Cs	1.09 ± 0.23 (42)	—	1.24 ± 0.22 (56)	1.09 ± 0.10 (35)
Cu	0.74 ± 0.03 (3)	1.02 ± 0.13 (16)	—	1.03 (2)
Dy	0.96 ± 0.12 (16)	—	—	—
Eu	0.96 ± 0.06 (12)	—	1.42 ± 0.59 (19)	—
F	0.98 ± 0.24 (19)	0.99 ± 0.06 (4)	0.96 ± 0.22 (12)	—
Fe	1.03 ± 0.02 (5)	1.01 ± 0.02 (3)	1.00 ± 0.04 (19)	1.06 (1)
Gd	0.99 (1)	—	—	—
Hardness	—	0.99 ± 0.03 (7)	—	—
Hf	1.07 ± 0.04 (4)	—	—	1.05 (2)
Hg	—	0.94 ± 0.15 (15)	—	—
HNO_3	—	0.97 ± 0.08 (3)	—	—
I	—	—	1.01 (1)	—

Table C-II (cont)

Analysis	Silicates [R ± s (N)]	Waters and urines [R ± s (N)]	Biologicals [R ± s (N)]	Air Filters and Swipe Filters
In	—	—	—	1.04 ± 0.07 (18)
K	0.90 ± 0.07 (4)	1.04 ± 0.06 (16)	0.82 ± 0.19 (3)	—
La	1.02 ± 0.05 (15)	—	1.03 ± 0.11 (22)	—
Li	0.93 (2)	—	1.18 (2)	—
Lu	—	—	1.06 ± 0.53 (18)	—
Mg	1.02 ± 0.18 (6)	0.98 ± 0.04 (15)	—	—
Mn	0.93 ± 0.05 (8)	1.07 ± 0.12 (12)	0.96 ± 0.07 (12)	1.10 ± 0.14 (16)
Na	0.99 ± 0.05 (22)	1.00 ± 0.03 (16)	1.06 ± 0.34 (32)	—
Nd	1.14 ± 0.26 (4)	—	—	—
Ni	1.02 ± 0.05 (4)	0.96 (2)	—	1.00 ± 0.07 (4)
NO_3-N	—	1.00 ± 0.10 (21)	—	—
Os	—	—	—	1.03 (2)
P	1.61 (2)	—	—	—
Pb	1.04 ± 0.03 (3)	0.98 ± 0.10 (62)	1.13 ± 0.34 (7)	1.03 ± 0.09 (45)
PO_4	—	1.08 (2)	—	—
Rb	—	—	1.04 ± 0.27 (18)	—
Re	—	—	—	0.83 (2)
Sb	—	—	1.04 ± 0.13 (18)	1.09 ± 0.07 (30)
Sc	1.00 ± 0.04 (9)	—	1.01 ± 0.09 (27)	—
Se	—	1.03 ± 0.15 (47)	—	—
Si	1.02 ± 0.07 (15)	—	—	—
Sm	0.98 ± 0.10 (10)	—	0.74 ± 0.26 (25)	—
SO_4	—	0.95 ± 0.05 (16)	—	—
Sr	0.95 ± 0.03 (6)	—	0.94 ± 0.11 (33)	—
Ta	—	—	1.01 ± 0.17 (12)	1.06 ± 0.10 (39)
Tb	1.14 (2)	—	—	—
TDS	—	1.13 ± 0.16 (14)	—	—
Th	0.90 ± 0.15 (6)	—	1.14 ± 0.22 (19)	—
Ti	—	—	—	0.96 (1)
Total alkalinity	—	0.95 ± 0.02 (12)	—	—
U	0.99 ± 0.08 (193)	1.00 ± 0.07 (164)	1.02 ± 0.11 (72)	0.97 ± 0.10 (13)
^{235}U	—	0.99 ± 0.12 (62)	—	—
^{238}U	—	1.00 ± 0.24 (66)	—	—
$^{235}U/^{238}U$	1.01 ± 0.05 (6)	—	—	—
V	1.01 ± 0.07 (3)	—	0.98 ± 0.11 (10)	1.04 ± 0.08 (11)
W	—	—	—	1.16 (2)
Yb	—	—	1.02 ± 0.05 (12)	—
Zn	1.31 (2)	0.93 ± 0.08 (11)	—	0.99 ± 0.07 (39)

Table C-III

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

D. Organizational Change

There has been a major change in the organizational structure within the Health, Safety, and Environment Division for analytical chemistry support of the environmental surveillance program. On January 1, 1984, chemistry functions in the Division were combined into an independent group (HSE-9, Health and Environmental Chemistry). This reorganization is expected to increase the quality of data by providing greater depth and access to analytical resources.

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).

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 LA-10115-MS (1984).

C62. M. A. Gautier, E. S. Gladney, and D. R. Perrin, "Quality Assurance for Health and Environmental Chemistry: 1984," Los alamos National Laboratory report (in press).

C63. 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).

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 the year. 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 network, 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 because of formation of two 0.511-MeV photons through positron-electron annihilation. The ^{14}O emits a 2.3 MeV gamma with a 99% yield. 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 162 059 to 167 856 persons within 80 km of the boundary) to account for population changes between 1983 and 1984.

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[D7]) and the source term Q. Source terms, obtained by stack measurements, are in Table E-I.

The dispersion factors were calculated from 1984 meteorological data collected near LAMPF during the actual time periods when radionuclides were being released from the stacks. Dispersion coefficients used to calculate the χ/Q's were determined from measurements of the standard deviations of wind direction. 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, $\gamma_{\chi}(r,\theta,t)$, can be represented by the equation[D7]

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

where

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

$\bar{E}_{\theta}$ = average gamma energy per decay (MeV) (1.02 MeV for pure 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

1984 Population 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	—	—	—	—	—	—	1020	—	330
NNE	—	—	—	508	—	487	1555	1615	198
NE	3	—	—	—	285	13 525	907	1020	3453
ENE	—	—	—	1579	1405	2210	2364	1067	2098
E	—	—	68	20	453	932	566	—	1463
ESE	—	—	—	—	—	238	18 843	1084	1500
SE	—	—	7981	—	—	—	43 560	1988	6
SSE	—	—	—	—	—	—	346	3539	77
S	—	—	—	55	—	178	344	3927	—
SSW	—	—	—	30	—	457	112	4609	18 733
SW	—	—	—	—	—	—	176	2326	—
WSW	—	—	—	—	—	176	175	1424	116
W	—	—	—	—	—	—	—	92	74
WNW	—	1695	7718	—	—	—	—	—	1724
NW	—	618	2033	—	—	—	—	1292	—
NNW	—	682	684	—	—	—	—	57	56

[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 167 856.

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 Emission Totals

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	---	---	---	---	---	335	---	---	---	---
TA-3	114	---	214	42	73	---	---	1 792	---	---
TA-9	---	---	---	---	---	---	---	---	---	---
TA-15	---	---	---	---	---	---	---	---	---	---
TA-18	---	---	---	---	---	---	---	---	---	---
TA-21	17	---	990	0.3	---	---	---	802	---	---
TA-33	---	---	---	---	---	---	---	7 110	---	---
TA-35	0.4	---	---	---	---	---	---	206	---	---
TA-41	---	---	---	---	---	---	---	4 780	---	---
TA-43	1.0	--	---	---	---	---	33	---	---	---
TA-46	---	---	0.05	---	---	---	---	---	---	---
TA-48	2.6	---	1.3	1566	---	---	---	---	---	---
TA-50	3.7	---	---	8.9	---	---	---	---	---	---
TA-53	---	---	---	---	---	---	---	27	734 118	2500
TA-54	0.02	---	---	---	---	---	---	---	---	---
TA-55	1.0	---	---	---	---	---	---	152	---	---
Totals	140	---	1205	1617	73	335	33	14 869	734 118	2500

[a]Does not include aerosolized uranium from explosives testing. See Table E-XXXII.
[b]Mixed fission products.
[c]Another source of ^{41}Ar (3080 Ci) is the G/MAP from TA-53.
[d]G/MAP = Gaseous Mixed Activation Products. Main contaminants are ^{11}C (16%), ^{13}N (4.2%), ^{14}O (2.1%), ^{15}O (71.8%), and ^{41}Ar (0.42%). 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

Estimated Maximum Boundary and Individual Doses from 1984 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-54 (Station 22)[c]	0.07	Royal Crest (Station 11)[c]	0.02	0.004%
^{11}C, ^{13}N, ^{14}O, ^{15}O	Whole Body	Boundary N. of TA-53[d]	44	East Gate (Station 6)[c]	31	6.2%
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack[d]	0.3	Apts. N. of TA-2 Stack[d]	0.2	0.04%
U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am[e]	Lung	TA-54 (Station 22)[c]	0.01	LA Airport (Station 8)[c]	0.004	0.003%

[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 Gulf/Exxon, Station 10) would receive a 50-yr bone dose commitment of 0.11 mrem, which is 0.007% of the annual Radiation Protection Standard.

Table E-III

Thermoluminescent Dosimeter Measurements

Station Location	Coordinates	Annual Measurement (mrem)
Regional Stations (28-44 km)—Uncontrolled Areas		
1. Espanõla	---	80 ± 4
2. Pojoaque	---	122 ± 4
3. Santa Fe	---	90 ± 4
4. Fenton Hill	---	118 ± 4
Perimeter Stations (0-4)—Uncontrolled Areas		
5. Barranca School	N180 E130	103 ± 4
6. Arkansas Avenue	N170 E030	103 ± 4
7. Cumbres School	N150 E090	114 ± 4
8. 48th Street	N110 W010	125 ± 4
9. LA Airport	N110 E170	135 ± 4
10. Bayo Canyon	N120 E250	151 ± 5
11. Gulf Station	N090 E120	115 ± 4
12. Royal Crest	N080 E080	117 ± 5
13. White Rock	S080 E420	113 ± 4
14. Pajarito Acres	S210 E380	97 ± 4
15. Bandelier	S280 E200	130 ± 4
16. Pajarito Ski Area	N150 W200	115 ± 4
Onsite Stations—Controlled Areas		
17. TA-21 (DP West)	N095 E140	140 ± 4
18. TA-6 (Two-Mile Mesa)	N025 E030	121 ± 4
19. TA-53 (LAMPF)	N070 E090	161 ± 4
20. Well PM-1	N030 E305	135 ± 4
21. TA-16 (S-Site)	S035 W025	122 ± 4
22. Booster P-2	S030 E220	135 ± 4
23. TA-54 (Area G)	S080 E290	135 ± 5
24. State Hwy 4	N070 E350	182 ± 4
25. TA-49 (Frijoles Mesa)	S165 E085	119 ± 4
26. TA-2 (Omega Stack)	N075 E120	127 ± 4
27. TA-2 (Omega Canyon)	N085 E120	157 ± 4
28. TA-18 (Pajarito Site)	S040 E205	183 ± 4
29. TA-35 (Ten Site A)	N040 E105	128 ± 4
30. TA-35 (Ten Site B)	N040 E110	128 ± 4
31. TA-59 (Occupational Health Lab)	N050 E040	137 ± 5
32. TA-3 (Van de Graaff)	N050 E020	130 ± 4
33. TA-3 (Guard Station)	N050 E020	138 ± 4
34. TA-3 (Alarm Building)	N050 E020	189 ± 4
35. TA-3 (Guard Building)	N050 E020	118 ± 5
36. TA-3 (Shops)	N050 E020	119 ± 4
37. Pistol Range	N040 E240	127 ± 4
38. TA-55 (Plutonium Facility South)	N040 E240	127 ± 4
39. TA-55 (Plutonium Facility West)	N040 E080	136 ± 5
40. TA-55 (Plutonium Facility North)	N040 E080	145 ± 5

Table E-IV

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	N090	E210
7. 48th Street	N110	W010
8. LA Airport	N110	E170
9. Bayo STP	N120	E250
10. Gulf/Exxon 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

Table E-V

Average Background Concentrations of Radioactivity in the Atmosphere

Radioactive Constituent	Units	EPA[a] 1982 - 1984	Laboratory[b] 1984	Uncontrolled Area Concentration Guide
Gross beta	10^{-15} μCi/mℓ	10 ± 10	8.2 ± 11	3×10^3
^{3}H	10^{-12} μCi/mℓ	Not reported	9.5 ± 6.0	2×10^5
U (natural)	10^{-18} μCi/mℓ	20 ± 11	12 ± 7	2×10^6
U (natural)	pg/m^3	61 ± 32	39 ± 21	6×10^6
^{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
^{241}Am	10^{-18} μCi/mℓ	Not reported	<2 [c]	2×10^{11}

[a]Environmental Protection Agency, "Environmental Radiation Data," Reports 31, 32, 33, 34, 35, 36, 37, and 38. Data are from Santa Fe, New Mexico sampling location and were taken from August 1982 through June 1984, excluding the period from May 1983 through February 1984 for which data were not available.

[b]Data annual averages are from the regional stations (Española, Pojoaque, Santa Fe) and were taken during calendar year 1984.

[c]Minimum detectable limit.

Table E-VI

Annual Atmospheric Tritiated Vapor Concentrations for 1984

Station Location[a]	Total Air Volume (m^3)	Number of Quarterly Samples	Number of Samples <MDL[b]	Concentrations—pCi/m^3 (10^{-12} $\mu Ci/m\ell$) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (24-44 km)—Uncontrolled Areas							
1. Española	125	12	2	69 ± 26	1.0 ± 2.0	10 ± 11	0.005
2. Pojoaque	126	12	4	81 ± 30	1.0 ± 2.0	12 ± 13	0.006
3. Santa Fe	125	12	4	38 ± 14	0.0 ± 2.0	6.5 ± 6.1	0.003
Regional Group Summary	376	36	10	81 ± 30	0.0 ± 2.0	9.5 ± 3.1	0.005
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	119	12	0	14 ± 6.0	1.8 ± 1.0	6.5 ± 2.6	0.003
5. Arkansas Avenue	119	12	1	20 ± 8.0	0.0 ± 6.0	5.3 ± 3.1	0.003
6. East Gate	126	12	2	18 ± 6.0	0.4 ± 0.2	6.9 ± 3.0	0.003
7. 48th Street	126	12	0	15 ± 6.0	2.5 ± 1.0	6.6 ± 1.9	0.003
8. LA Airport	119	12	1	20 ± 8.0	0.5 ± 0.2	9.0 ± 3.9	0.004
9. Bayo Canyon	126	12	0	15 ± 6.0	1.9 ± 1.0	5.9 ± 2.3	0.003
10. Gulf/Exxon Station	119	12	1	22 ± 8.0	2.0 ± 1.0	9.7 ± 3.5	0.005
11. Royal Crest	118	12	0	130 ± 60	1.1 ± 0.6	22 ± 21	0.011
12. White Rock	126	12	0	45 ± 18	1.7 ± 0.8	9.1 ± 6.7	0.005
13. Pajarito Acres	125	12	0	20 ± 10	1.6 ± 0.8	8.6 ± 3.2	0.004
14. Bandelier	126	12	0	26 ± 10	4.9 ± 2.0	9.9 ± 3.2	0.005
Perimeter Group Summary	1347	132	5	130 ± 60	0.0 ± 6.0	9.1 ± 2.8	0.005
Onsite Stations—Controlled Areas							
15. TA-21	119	12	1	31 ± 12	0.8 ± 0.4	8.8 ± 4.6	0.0002
16. TA-6	119	12	1	8.2 ± 3.6	2.6 ± 1.2	4.4 ± 1.0	0.0001
17. TA-53 (LAMPF)	126	12	0	24 ± 10	2.9 ± 1.2	8.9 ± 3.6	0.0002
18. Well PM-1	126	12	0	27 ± 10	3.4 ± 1.4	9.7 ± 3.8	0.0002
19. TA-52	127	12	0	44 ± 16	2.9 ± 1.2	18 ± 6.0	0.0003
20. TA-16	126	12	1	49 ± 18	0.7 ± 0.4	12 ± 8.1	0.0002
21. Booster P-2	119	12	0	45 ± 18	1.3 ± 0.4	11 ± 7.0	0.0002
22. TA-54	127	12	0	270 ± 100	1.7 ± 0.8	63 ± 43	0.0013
23. TA-49	126	12	1	85 ± 32	2.8 ± 1.2	13 ± 14	0.0003
24. TA-33	126	12	0	220 ± 80	2.0 ± 0.8	56 ± 36	0.0011
25. TA-39	122	12	0	25 ± 10	6.0 ± 2.4	14 ± 3.6	0.0003
26. TA-16-450	107	12	0	47 ± 20	1.8 ± 1.6	14 ± 7.6	0.0003
Onsite Group Summary	1468	144	4	270 ± 100	0.7 ± 0.4	19 ± 11	0.0004

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

Table E-VII

Atmospheric $^{239,240}Pu$ Concentrations

Station Location[a]	Total Air Volume (m^3)	Number of Quarterly Samples	Number of Samples <MDL[b]	Concentrations—aCi/m^3 (10^{-18} μCi/mℓ) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (24-44 km)—Uncontrolled Areas							
1. Española	89 722	4	4	1.8 ± 3.6	−1.9 ± 3.6	−0.2 ± 2.0	−0.0000
2. Pojoaque	74 970	4	4	1.2 ± 5.5	−1.2 ± 1.5	−0.3 ± 1.0	−0.0000
3. Santa Fe	74 600	4	4	1.9 ± 1.9	−0.6 ± 1.1	0.6 ± 1.2	0.0010
Regional Group Summary	239 292	12	12	1.9 ± 1.9	−1.9 ± 3.6	0.0 ± 0.6	−0.0001
Perimeter Stations (0-40 km)—Uncontrolled Areas							
4. Barranca School	83 269	4	4	1.8 ± 1.7	−0.9 ± 1.0	0.4 ± 1.2	0.0006
5. Arkansas Avenue	57 311	4	4	1.4 ± 1.7	−1.4 ± 2.5	−0.4 ± 1.2	−0.0000
6. East Gate	82 623	4	4	1.3 ± 1.8	−0.2 ± 1.7	0.5 ± 0.7	0.0008
7. 48th Street	87 484	4	3	4.0 ± 3.8	−0.4 ± 0.8	1.4 ± 1.8	0.0023
8. LA Airport	84 811	4	4	1.7 ± 5.9	−0.2 ± 1.7	1.0 ± 0.8	0.0017
9. Bayo Canyon	81 939	4	4	1.8 ± 3.9	−0.1 ± 1.3	0.6 ± 0.9	0.0010
10. Gulf/Exxon Station	92 571	4	3	11.7 ± 2.9	0.9 ± 1.5	4.1 ± 5.1	0.0069
11. Royal Crest	49 341	4	4	1.1 ± 1.5	−2.8 ± 3.3	−0.7 ± 1.8	−0.0000
12. White Rock	66 731	4	3	4.8 ± 2.4	0.1 ± 1.6	2.4 ± 2.5	0.0029
13. Pajarito Acres	93 995	4	4	2.6 ± 6.9	−0.6 ± 1.0	1.1 ± 1.7	0.0018
14. Bandelier	92 259	4	3	7.4 ± 3.5	−1.7 ± 6.1	1.8 ± 4.0	0.0031
Perimeter Group Summary	872 334	44	40	11.7 ± 2.9	−2.8 ± 3.3	1.11 ± 0.81	0.0018
Onsite Stations—Controlled Areas							
15. TA-21	77 554	4	2	3.5 ± 2.6	−0.4 ± 2.0	1.5 ± 2.0	0.00007
16. TA-6	80 936	4	3	3.2 ± 2.0	−0.2 ± 2.2	1.2 ± 1.5	0.00006
17. TA-53 (LAMPF)	93 019	4	4	2.3 ± 3.6	−1.2 ± 2.3	0.6 ± 1.5	0.00003
18. Well PM-1	97 077	4	4	0.9 ± 1.5	−0.3 ± 0.9	0.0 ± 0.6	0.00000
19. TA-52	88 323	4	4	2.9 ± 2.3	−0.4 ± 0.8	1.3 ± 1.3	0.00007
20. TA-16	82 558	4	4	1.3 ± 3.4	−0.8 ± 1.4	0.0 ± 0.9	0.00000
21. Booster P-2	82 968	4	3	4.2 ± 2.5	−0.4 ± 1.1	1.4 ± 2.0	0.00007
22. TA-54	99 531	4	1	48.3 ± 5.4	2.9 ± 1.6	18.1 ± 21.2	0.00091
23. TA-49	94 495	4	4	2.3 ± 2.3	−0.4 ± 0.9	0.8 ± 1.2	0.00004
24. TA-33	90 860	4	3	26.3 ± 5.6	−0.2 ± 0.7	7.0 ± 12.9	0.00035
25. TA-39	82 019	4	4	1.6 ± 3.1	−1.7 ± 1.5	−0.2 ± 1.4	−0.00000
26. TA-16-450	79 646	4	4	1.3 ± 2.4	−4.0 ± 6.9	−0.5 ± 2.5	0.00002
Onsite Group Summary	1 048 986	48	40	48.3 ± 5.4	−4.0 ± 6.9	2.6 ± 3.0	0.00013

[a]See Fig. 10 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/ℓ.
Uncontrolled Area Concentration Guide = 6×10^{-14} μCi/mℓ.

Table E-VIII

Atmospheric Uranium Concentrations
(concentrations in pg/m³)

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 % CG[d]
Regional Stations (24-44 km)—Uncontrolled Areas							
1. Española	89 722	4	0	34 ± 7.6	11 ± 4.3	24 ± 12	0.0004
2. Pojoaque	74 970	4	0	138 ± 28	37 ± 8.3	74 ± 47	0.0012
3. Santa Fe	74 600	4	0	28 ± 6.8	15 ± 4.0	20 ± 6.1	0.0003
Regional Group Summary	239 292	12	0	138 ± 28	11 ± 4.3	39 ± 35	0.0007
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	83 269	4	0	66 ± 14	16 ± 4.8	34 ± 22	0.0006
5. Arkansas Avenue	57 311	4	0	25 ± 6.4	7.1 ± 5.6	15 ± 7.9	0.0002
6. East Gate	82 623	4	0	82 ± 17	11 ± 3.4	34 ± 33	0.0006
7. 48th Street	87 484	4	0	31 ± 6.8	6.6 ± 2.7	16 ± 11	0.0003
8. LA Airport	84 811	4	0	136 ± 28	18 ± 4.9	64 ± 55	0.0011
9. Bayo Canyon	81 939	4	0	50 ± 11	5.7 ± 2.5	23 ± 19	0.0004
10. Gulf/Exxon Station	92 571	4	0	63 ± 13	30 ± 9.8	44 ± 15	0.0007
11. Royal Crest	49 341	4	0	16 ± 4.4	5.3 ± 2.9	11 ± 4.3	0.0002
12. White Rock	66 731	4	0	61 ± 13	9.3 ± 3.9	29 ± 23	0.0005
13. Pajarito Acres	93 993	4	0	33 ± 7.2	5.2 ± 2.2	19 ± 14	0.0003
14. Bandelier	92 259	4	0	39 ± 8.4	4.8 ± 2.0	18 ± 15	0.0003
Perimeter Group Summary	872 334	44	0	136 ± 28	4.8 ± 2.0	28 ± 9.4	0.0005
Onsite Stations—Controlled Areas							
15. TA-21	77 554	4	0	163 ± 33	16 ± 4.7	65 ± 67	0.00004
16. TA-6	80 936	4	0	34 ± 7.4	11 ± 3.9	20 ± 10	0.00001
17. TA-53 (LAMPF)	93 019	4	0	74 ± 15	9.9 ± 3.2	33 ± 28	0.00002
18. Well PM-1	97 077	4	1	48 ± 10	1.3 ± 2.0	18 ± 21	0.00001
19. TA-52	88 323	4	0	106 ± 22	9.7 ± 3.1	37 ± 46	0.00002
20. TA-16	82 558	4	0	21 ± 7.3	2.2 ± 1.9	13 ± 8.9	0.00001
21. Booster P-2	82 968	4	0	40 ± 8.5	8.7 ± 3.4	23 ± 15	0.00001
22. TA-54	99 531	4	0	190 ± 38	20 ± 4.9	67 ± 82	0.00004
23. TA-49	94 495	4	0	27 ± 6.0	5.5 ± 2.3	16 ± 11	0.00001
24. TA-33	90 860	4	0	42 ± 9.0	4.2 ± 1.9	18 ± 17	0.00001
25. TA-39	82 019	4	0	46 ± 9.8	6.5 ± 3.0	23 ± 17	0.00001
26. TA-16-450	79 646	4	0	22 ± 7.5	2.3 ± 2.1	13 ± 11	0.00001
Onsite Group Summary	1 048 986	48	1	190 ± 38	1.3 ± 2.0	29 ± 11	0.00002

[a]See Fig. 10 for map of sampling locations.
[b]Minimum detectable limit = 1 pg/m^3.
[c]Uncertainties are ±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-IX

Locations of Surface and Ground Water Sampling 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. 12; 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-IX (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-IX (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-IX (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-X

Radiochemical and Chemical Quality of Surface Water from Regional Stations

Station	1984 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	Radiochemical ^{238}Pu (10^{-9} μCi/mℓ)	Radiochemical $^{239,240}Pu$ (10^{-9} μCi/mℓ)	Radiochemical ^{3}H (10^{-6} μCi/mℓ)	Total U μg/ℓ	Gross Gamma (counts/min/ℓ)
Rio Chama at Chamita	02-22	34 ± 57	0.016 ± 0.026	0.020 ± 0.011	0.2 ± 0.4	4.6 ± 2.0	246 ± 38
Rio Chama at Chamita	08-07	−30 ± 82	0.010 ± 0.040	0.070 ± 0.080	1.3 ± 0.8	1.6 ± 3.2	150 ± 100
Rio Grande at Embudo	02-22	32 ± 78	0.014 ± 0.028	0.009 ± 0.028	0.7 ± 9.4	3.6 ± 1.6	100 ± 38
Rio Grande at Embudo	08-07	61 ± 82	0.090 ± 0.240	0.130 ± 0.280	0.5 ± 0.8	1.6 ± 3.2	110 ± 80
Rio Grande at Otowi	02-22	0 ± 34	0.016 ± 0.032	0.019 ± 0.028	0.4 ± 0.4	3.6 ± 1.6	20 ± 38
Rio Grande at Otowi	08-07	−48 ± 64	−0.006 ± 0.034	0.023 ± 0.038	1.1 ± 0.8	1.6 ± 3.2	140 ± 100
Rio Grande at Cochiti	02-23	16 ± 36	0.060 ± 0.060	0.020 ± 0.040	0.2 ± 0.4	4.4 ± 1.8	−64 ± 36
Rio Grande at Cochiti	08-08	25 ± 96	0.004 ± 0.038	0.017 ± 0.034	2.6 ± 0.8	1.6 ± 3.2	0 ± 200
Rio Grande at Bernalillo	02-23	32 ± 33	0.015 ± 0.024	0.007 ± 0.020	1.0 ± 0.4	4.0 ± 1.6	46 ± 38
Rio Grande at Bernalillo	08-08	2 ± 94	0.004 ± 0.028	0.039 ± 0.038	3.0 ± 1.0	6.0 ± 1.2	100 ± 80
Jemez River at Jemez	02-23	10 ± 42	−0.036 ± 0.016	0.004 ± 0.022	0.7 ± 0.4	1.5 ± 3.0	−52 ± 36
Jemez River at Jemez	08-08	−25 ± 100	0.009 ± 0.026	0.050 ± 0.060	1.5 ± 0.8	1.6 ± 3.2	0 ± 200
No. of Analyses		12	12	12	12	12	12
Minimum		−48 ± 64	−0.036 ± 0.016	0.004 ± 0.022	0.2 ± 0.4	1.5 ± 3.0	−64 ± 36
Maximum		61 ± 82	0.090 ± 0.240	0.130 ± 0.280	3.0 ± 1.0	6.0 ± 1.2	246 ± 38
Average		9	0.016	0.034	1.1	2.9	66
2s		62	0.063	0.072	1.8	3.1	182

Table E-X (cont)

Station	1984 (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)
Rio Chama at Chamita	02-22	15	51	10	2.6	30	0	163	<0.1	74	12	0.3	0.1	289	166	8.2	450
Rio Grande at Embudo	02-22	32	31	5	2.3	14	0	115	<0.1	26	4	0.4	1.4	164	101	8.2	260
Rio Grande at Otowi	02-22	24	36	6	2.4	17	0	127	<0.1	34	6	0.4	3.7	203	113	7.9	310
Rio Grande at Cochiti	02-23	23	40	6	2.4	18	0	137	0.1	36	6	0.4	0.9	210	122	8.2	320
Rio Grande at Bernalillo	02-23	22	37	7	3.0	25	0	153	<0.1	50	15	0.4	0.3	239	131	8.1	400
Jemez River at Jemez	02-23	46	36	4	0.9	60	5	155	<0.1	16	67	0.9	0.0	335	111	8.5	505
No. of Analyses		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum		15	31	4	2.3	14	0	115	<0.1	26	4	0.4	0.1	164	101	7.9	260
Maximum		46	51	10	3.0	60	5	155	0.1	74	67	0.9	3.7	335	166	8.5	505
Average		27	38	6	2.2	27	0	141	0.1	39	18	0.4	1.0	240	124	8.1	374
2s		21	13	4	1.4	34	4	37	0.0	40	48	0.4	2.8	124	46	0.4	186

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 Waters from Perimeter Stations

Station	1984 (month-day)	Radiochemical ^{137}Cs (10^{-9} μg/mℓ)	Radiochemical ^{238}Pu (10^{-9} μg/mℓ)	Radiochemical $^{239,240}Pu$ (10^{-9} μg/mℓ)	Radiochemical ^{3}H (10^{-6} μCi/mℓ)	Total U μg/ℓ	Gross Gamma (counts/min/ℓ)
Los Alamos Reservoirs	03-12	8 ± 37	−0.012 ± 0.020	0.004 ± 0.028	−1 ± 0.4	6.0 ± 12	−52 ± 36
Los Alamos Reservoirs	08-13	172 ± 149	0.050 ± 0.060	0.020 ± 0.060	0.1 ± 0.6	1.6 ± 3.2	0 ± 200
Guaje Canyon	06-14	0 ± 176	0.008 ± 0.028	0.008 ± 0.022	0.4 ± 2.4	1.6 ± 3.2	0 ± 200
Guaje Canyon	08-13	115 ± 138	−0.050 ± 0.060	0.040 ± 0.060	1.4 ± 0.8	1.6 ± 3.2	100 ± 80
Frijoles Canyon	03-12	−14 ± 47	0.004 ± 0.028	0.004 ± 0.022	−0.9 ± 0.4	6.0 ± 12	−26 ± 36
Frijoles Canyon	08-16	136 ± 143	0.020 ± 0.032	0.090 ± 0.060	0.5 ± 0.6	1.6 ± 3.2	0 ± 200
La Mesita Spring	03-12	−16 ± 38	0.008 ± 0.024	0.015 ± 0.020	0.9 ± 0.4	6.0 ± 12	−48 ± 36
La Mesita Spring	08-13	−21 ± 129	0.031 ± 0.036	0.015 ± 0.032	0.2 ± 0.6	16.9 ± 3.4	0 ± 200
Indian Spring	03-12	6 ± 40	0.011 ± 0.024	0.004 ± 0.022	−0.3 ± 0.4	6.0 ± 12	−29 ± 36
Indian Spring	08-16	25 ± 132	0.004 ± 0.028	0.004 ± 0.024	0.3 ± 0.6	13 ± 2.6	570 ± 100
Sacred Spring	03-12	−1 ± 23	0.011 ± 0.028	−0.004 ± 0.020	−0.7 ± 0.4	20 ± 6.0	−16 ± 36
Sacred Spring	08-13	44 ± 104	0.018 ± 0.030	0.011 ± 0.026	0.2 ± 0.6	1.6 ± 3.2	0 ± 200
No. of Analyses		12	12	12	12	12	12
Minimum		−21 ± 129	−0.050 ± 0.060	−0.004 ± 0.024	−1 ± 0.4	1.6 ± 3.2	−52 ± 36
Maximum		172 ± 149	0.050 ± 0.060	0.090 ± 0.060	1.4 ± 0.8	20 ± 6.0	570 ± 100
Average		37	0.009	0.018	0.0	6.7	41
2s		131	0.048	0.051	1.4	12.6	341

Table E-XI (cont)

Station	1984 (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)
Los Alamos Reservoir	3-12	43	6	2	2.2	5	0	45	0.1	1.8	1	0.0	0.8	86	26	7.8	86
Guaje Canyon	6-14	52	7	2	2.7	7	0	48	<0.1	8.0	1	0.0	0.0	105	30	7.4	91
Frijoles Canyon	3-12	56	6	2	1.6	9	0	54	0.1	2.5	2	0.8	0.1	110	29	7.9	97
La Mesita Spring	3-12	38	27	6	3.0	16	0	103	<0.1	19.0	16	0.5	7.4	194	91	7.7	275
Indian Spring	3-12	34	22	0	3.0	22	0	121	<0.1	7.2	2	0.4	0.1	158	62	7.6	210
Sacred Spring	3-12	47	26	2	3.1	20	3	125	<0.1	2.2	8	0.5	1.2	182	73	8.4	245
No. of Analyses		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum		34	6	0	1.6	5	0	45	<0.1	1.8	1	0.0	0.0	86	26	7.4	86
Maximum		56	27	2	3.0	22	3	125	<0.1	19.0	16	0.8	7.4	194	91	8.4	275
Average		45	15	2	2.6	13	0	82	<0.1	6.7	5	0.3	1.5	139	51	7.8	167
2s		16	20	3	1.1	14	2	75	0.0	13.1	12	0.6	5.7	89	54	0.6	171

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-XII

Radiochemical and Chemical Quality of Surface and Ground Waters from White Rock Canyon

Station	1984 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	Radiochemical ^{238}Pu (10^{-9} μCi/mℓ)	Radiochemical $^{239,240}Pu$ (10^{-9} μCi/mℓ)	Radiochemical ^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
Group I							
Sandia Spring	9-24	136 ± 135	−0.017 ± 0.019	−0.011 ± 0.022	0.3 ± 0.6	1.2 ± 0.6	10 ± 90
Spring 3	9-24	−10 ± 71	−0.005 ± 0.023	−0.016 ± 0.018	−0.3 ± 0.6	1.9 ± 0.8	50 ± 90
Spring 3A	9-24	34 ± 79	0.097 ± 0.060	−0.013 ± 0.026	0.0 ± 0.6	1.3 ± 0.6	39 ± 90
Spring 3AA	9-24	39 ± 65	−0.014 ± 0.028	−0.014 ± 0.028	0.0 ± 0.6	2.3 ± 0.8	0 ± 90
Spring 4	9-25	48 ± 79	−0.013 ± 0.025	−0.013 ± 0.026	0.2 ± 0.6	2.4 ± 0.8	9 ± 90
Spring 4A	9-24	4 ± 121	−0.018 ± 0.021	−0.012 ± 0.024	0.2 ± 0.6	1.4 ± 0.6	36 ± 90
Spring 5	9-25	0 ± 74	−0.020 ± 0.027	−0.005 ± 0.022	−0.4 ± 0.6	0.8 ± 0.4	50 ± 90
Spring 5AA	9-25	−34 ± 79	−0.006 ± 0.025	−0.022 ± 0.022	0.6 ± 0.6	0.7 ± 0.4	32 ± 90
Ancho Spring	9-25	−0 ± 61	−0.006 ± 0.024	0.008 ± 0.022	0.1 ± 0.6	1.1 ± 0.6	0 ± 90
Group II							
Spring 5A	9-25	42 ± 73	0.005 ± 0.030	0.011 ± 0.022	−0.2 ± 0.6	2.6 ± 0.8	28 ± 90
Spring 6	9-25	32 ± 69	0.013 ± 0.026	0.013 ± 0.026	0.0 ± 0.6	1.2 ± 0.8	8 ± 90
Spring 6A	9-25	23 ± 76	0.013 ± 0.026	0.020 ± 0.022	−0.2 ± 0.6	1.0 ± 0.6	9 ± 90
Spring 7	9-25	−18 ± 58	0.040 ± 0.049	0.000 ± 0.020	−0.4 ± 0.6	1.2 ± 0.6	22 ± 90
Spring 8	9-25	9 ± 71	0.007 ± 0.037	0.007 ± 0.031	0.0 ± 0.6	1.8 ± 0.8	1 ± 90
Spring 8A	9-25	68 ± 108	0.012 ± 0.024	0.000 ± 0.020	−0.3 ± 0.6	0.6 ± 0.4	3 ± 90
Spring 9	9-25	38 ± 57	0.005 ± 0.022	0.015 ± 0.017	1.1 ± 0.6	1.2 ± 0.6	30 ± 90
Spring 9A	9-25	−29 ± 52	0.006 ± 0.027	0.000 ± 0.020	0.6 ± 0.6	1.2 ± 0.6	9 ± 90
Doe Spring	9-25	32 ± 64	0.063 ± 0.047	0.006 ± 0.030	0.8 ± 0.6	0.2 ± 0.4	24 ± 90
Spring 10	9-25	8 ± 69	0.015 ± 0.017	0.005 ± 0.022	0.2 ± 0.6	1.2 ± 0.6	20 ± 90
Group III							
Spring 1	9-25	0 ± 73	0.057 ± 0.046	0.023 ± 0.036	−0.1 ± 0.6	2.2 ± 0.8	43 ± 90
Spring 2	9-25	−7 ± 87	0.015 ± 0.030	0.022 ± 0.026	−0.3 ± 0.6	2.9 ± 1.0	31 ± 90
Group IV							
Spring 3B	9-24	9 ± 56	0.042 ± 0.049	0.042 ± 0.048	0.1 ± 0.6	21.4 ± 4.0	32 ± 90
Streams							
Pajarito	9-25	37 ± 80	0.006 ± 0.026	0.012 ± 0.024	−0.2 ± 0.6	1.6 ± 0.8	59 ± 90
Ancho	9-25	94 ± 87	0.005 ± 0.030	0.012 ± 0.024	0.0 ± 0.6	0.7 ± 0.4	71 ± 90
Frijoles	9-25	−17 ± 68	−0.006 ± 0.028	0.019 ± 0.038	0.1 ± 0.6	0.9 ± 0.6	47 ± 90
Sanitary Effluent							
Mordandad	9-24	11 ± 57	−0.009 ± 0.018	−0.009 ± 0.018	0.6 ± 0.6	0.7 ± 0.4	1 ± 45
No. of Analyses		26	26	26	26	26	26
Minimum		−34 ± 79	−0.020 ± 0.027	−0.022 ± 0.022	−0.4 ± 0.6	0.6 ± 0.4	0 ± 90
Maximum		136 ± 135	0.097 ± 0.060	0.042 ± 0.048	1.1 ± 0.6	21 ± 4.0	71 ± 90
Average		21	−0.013	−0.005	0.1	2.1	25
2s		75	0.056	0.030	0.7	7.9	40

Table E-XII (cont)

Station	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)
Group I																
Sandia Spring	44	40	3.5	3.2	17	0	166	<0.1	4	3	1.2	1.4	213	117	7.5	30
Spring 3	47	19	1.6	2.9	15	0	95	<0.1	4	3	0.6	3.5	154	59	7.8	17
Spring 3A	48	19	1.6	2.9	15	0	94	<0.1	4	3	0.6	2.8	143	58	7.6	17
Spring 3AA	34	23	0.6	2.6	27	0	132	<0.1	4	3	1.2	0.4	162	63	7.2	24
Spring 4	48	21	4.1	2.7	14	0	95	<0.1	9	5	0.7	4.9	165	72	7.4	22
Spring 4A	62	20	4.4	2.2	12	0	94	<0.1	6	5	0.8	4/4	182	71	7.6	18
Spring 5	60	20	4.6	2.1	12	0	103	<0.1	4	4	0.8	0.7	175	71	7.9	19
Spring 5AA	38	29	5.6	2.8	14	0	141	<0.1	3	5	1.2	0.1	206	103	7.1	26
Ancho Spring	59	12	2.8	2.2	10	0	70	<0.1	2	2	0.4	1.2	149	44	7.2	13
Group II																
Spring 5	49	22	2.6	3.1	23	0	124	<0.1	8	4	0.5	2.0	178	70	7.4	25
Spring 6	65	12	3.5	2.0	10	0	74	<0.1	2	2	0.5	2.1	141	48	7.6	13
Spring 6A	70	10	2.6	2.1	10	0	62	<0.1	2	2	0.3	2.2	134	38	7.8	11
Spring 7	75	12	2.8	2.2	13	0	75	<0.1	3	2	0.3	1.2	146	42	7.2	14
Spring 8	67	20	4.2	3.0	22	0	124	<0.1	7	2	0.5	1.2	192	68	6.8	24
Spring 8A	66	9	2.2	1.9	11	9	42	<0.1	2	2	0.5	0.0	137	33	7.9	11
Spring 9	70	11	2.8	1.7	12	0	70	<0.1	2	2	0.5	0.0	142	39	7.9	12
Spring 9A	67	9	2.9	0.1	11	0	69	<0.1	2	2	0.5	0.9	127	39	7.7	12
Doe Spring	64	12	3.4	1.8	11	0	71	<0.1	1	2	0.4	0.0	140	46	7.1	13
Spring 10	63	11	2.9	1.6	11	0	72	<0.1	2	1	0.5	0.0	128	42	7.6	13
Group III																
Spring 1	31	17	1.2	2.1	33	0	130	<0.1	7	3	0.8	0.3	168	53	7.8	24
Spring 2	29	16	0.7	1.5	50	0	163	<0.1	6	3	2.2	0.0	200	45	7.8	24
Group 4																
Spring 3B	41	22	2.0	4.9	133	0	38	<0.1	5	5	0.8	8.3	434	37	7.5	65
Streams																
Pajarito	62	19	4.5	2.6	13	0	99	<0.1	5	5	0.5	3.3	178	70	8.0	19
Ancho	65	13	3.2	2.0	11	5	74	<0.1	3	2	0.4	0.0	159	49	8.4	14
Frijoles	56	10	3.1	2.2	11	0	64	<0.1	2	2	0.2	0.0	130	39	8.0	11
Sanitary Effluent																
Mortandad	86	20	6.1	13.5	99	0	141	35.4	39	60	0.6	48	483	80	7.8	65
No. of Analyses	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Minimum	31	9	0.6	0.1	10	0	38	<0.1	1	1	0.2	0.0	128	33	7.1	11
Maximum	75	40	6.1	13.5	133	9	166	35.4	9	60	1.2	48	483	117	8.0	30
Average	56	17	3.0	2.8	23	0	95	<1.4	5	5	0.6	3.4	183	57	7.6	21
2s	28	14	2.7	4.6	58	4	70	<13.8	14	22	0.8	18.5	169	41	0.8	28

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 Onsite Stations

Location	1984 (month-day)	Radiochemical					
		^{137}Cs (10^{-9} μCi/mℓ)	^{238} (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	03-20	20 ± 37	0.005 ± 0.040	0.005 ± 0.020	2.0 ± 0.6	2.0 ± 0.4	3 ± 36
Test Well 1	08-02	68 ± 131	0.022 ± 0.038	0.004 ± 0.030	1.0 ± 0.8	1.0 ± 0.8	0 ± 200
Test Well 2	05-02	0 ± 176	0.017 ± 0.028	0.013 ± 0.028	1.9 ± 0.6	2.0 ± 4.0	−3 ± 36
Test Well 2	08-24	69 ± 116	−0.009 ± 0.032	0.031 ± 0.032	0.8 ± 0.6	0.7 ± 0.4	0 ± 200
Test Well 3	05-02	0 ± 176	0.015 ± 0.028	0.004 ± 0.020	1.2 ± 0.6	2.9 ± 0.4	21 ± 36
Test Well 3	08-24	16 ± 70	---	−0.011 ± 0.046	0.4 ± 0.6	0.2 ± 0.4	0 ± 200
Test Well DT-5A	03-20	38 ± 36	0.004 ± 0.016	0.004 ± 0.026	−0.1 ± 0.4	<0.7 ± 1.4	−9 ± 36
Test Well DT-5A	09-06	−4 ± 116	−0.006 ± 0.024	−0.011 ± 0.022	1.8 ± 0.8	0.4 ± 0.4	0 ± 200
Test Well 8	03-20	42 ± 42	0.006 ± 0.038	0.017 ± 0.034	0.9 ± 0.4	0.7 ± 1.4	3420 ± 80
Test Well 8	09-18	26 ± 98	−0.013 ± 0.025	−0.013 ± 0.025	0.7 ± 0.6	1.2 ± 0.6	28 ± 90
Test Well DT-10	06-14	0 ± 176	0.010 ± 0.040	0.027 ± 0.038	0.7 ± 0.4	2.0 ± 4.0	0 ± 200
Test Well DT-10	09-17	−18 ± 109	−0.011 ± 0.022	−0.011 ± 0.022	2.6 ± 0.8	0.6 ± 0.4	22 ± 90
Cañada del Buey	03-15	36 ± 48	0.007 ± 0.018	0.004 ± 0.024	2.4 ± 0.6	1.4 ± 0.2	299 ± 38
Pajarito	03-15	44 ± 56	0.004 ± 0.030	0.030 ± 0.030	0.2 ± 0.6	1.1 ± 0.2	113 ± 38
Water at Beta Hole	05-07	0 ± 176	−0.013 ± 0.018	0.022 ± 0.030	2.0 ± 0.6	0.2 ± 0.4	75 ± 36
No. of Analyses		15	14	15	15	15	15
Minimum		−18 ± 109	−0.013 ± 0.025	−0.013 ± 0.025	−0.1 ± 0.4	<0.7 ± 1.4	−9 ± 36
Maximum		69 ± 116	0.022 ± 0.038	0.031 ± 0.032	2.6 ± 0.8	2.9 ± 0.4	3420 ± 80
Average		22	0.003	0.008	0.9	1.1	293
2s		53	0.023	0.031	2.4	1.5	1886

Table E-XIII (cont)

Station	1984 (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	03-20	21	11	3	3.6	25	0	46	1.6	8	34	0.1	0.9	145	41	7.3	196
Test Well 2	05-02	40	16	4	1.6	11	0	94	0.9	4	4	0.0	0.3	129	59	7.8	162
Test Well 3	05-02	10	17	5	3.0	16	0	113	<0.1	5	6	0.0	0.0	112	66	7.9	215
Test Well DF-5A	03-20	68	8	2	1.8	10	0	64	1.7	1	2	0.2	2.2	122	34	7.8	110
Test Well 8	03-20	2	9	2	1.8	10	3	62	<0.1	2	2	0.1	<0.1	60	33	8.5	115
Test Well DT-10	06-14	54	12	3	1.3	11	0	80	<0.1	2	1	0.0	0.7	116	46	8.0	132
Cañada del Buey	03-15	26	6	1	0.0	16	0	39	<0.1	8	16	1.6	0.2	93	24	7.5	134
Pajarito	03-15	19	18	5	5.2	18	0	77	<0.1	10	27	0.1	4.4	156	66	7.4	240
Water at Beta	05-07	32	9	2	3.5	23	0	74	<0.1	8	11	0.0	0.8	122	37	7.3	173
No. of Analyses		9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Minimum		2	6	1	0.0	10	0	39	<0.1	1	1	0.0	<0.1	60	33	7.3	110
Maximum		68	18	5	5.2	23	3	113	1.7	10	27	1.6	4.4	156	66	8.5	240
Average		30	12	3	2.4	15	0	72	<0.5	5	11	0.2	<1.0	117	45	7.7	164
2s		42	9	2	3.1	11	2	45	1.3	6	24	1.0	2.8	56	30	0.7	91

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 Acid Pueblo Canyon, A Former Effluent Release Area

Station	1984 (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)
Acid Weir	04-03	29 ± 51	0.020 ± 0.020	0.035 ± 0.060	1.4 ± 0.6	<0.7 ± 1.4	103 ± 38
Acid Weir	09-12	69 ± 83	0.015 ± 0.028	0.005 ± 0.026	2.4 ± 0.8	0.4 ± 0.4	0 ± 200
Pueblo 1	04-03	52 ± 49	0.013 ± 0.022	0.160 ± 0.080	1.0 ± 0.4	0.7 ± 1.4	67 ± 38
Pueblo 1	09-12	47 ± 78	–0.020 ± 0.023	–0.013 ± 0.027	6.4 ± 1.4	0.2 ± 0.4	0 ± 200
Pueblo 2	04-03	53 ± 48	0.004 ± 0.024	0.071 ± 0.060	1.0 ± 0.4	<0.7 ± 1.4	71 ± 38
Pueblo 2	09-12	57 ± 97	–0.014 ± 0.016	0.389 ± 0.092	--	<0.1 ± 0.0	–30 ± 100
Pueblo 3	04-03	30 ± 60	–0.008 ± 0.014	0.120 ± 0.060	4.0 ± 0.5	1.4 ± 0.2	95 ± 38
Pueblo 3	09-12	61 ± 111	0.006 ± 0.029	0.089 ± 0.052	---	3.0 ± 1.0	10 ± 100
Test Well 1A	03-20	73 ± 69	0.005 ± 0.034	0.019 ± 0.030	2.0 ± 0.6	<0.7 ± 1.4	2 ± 36
Test Well 1A	08-14	163 ± 74	0.013 ± 0.018	0.013 ± 0.026	0.2 ± 0.6	<1.6 ± 3.2	0 ± 200
Test Well 2A	05-03	0 ± 176	–0.020 ± 0.040	0.008 ± 0.022	3.8 ± 1.0	2.0 ± 4.0	2 ± 36
Test Well 2A	08-14	96 ± 120	–0.010 ± 0.018	0.007 ± 0.022	1.2 ± 0.6	0.2 ± 0.4	0 ± 200
Basalt Spring	05-03	0 ± 176	–0.020 ± 0.040	0.020 ± 0.060	1.4 ± 0.6	13.9 ± 4.8	–16 ± 36
Basalt Spring	08-15	0 ± 160	–0.018 ± 0.036	0.018 ± 0.054	1.1 ± 0.6	11.4 ± 4.4	12 ± 36
No. of Analyses		14	14	14	12	14	14
Minimum		0 ± 176	–0.020 ± 0.0023	–0.013 ± 0.027	0.2 ± 0.6	<0.1 ± 1.4	–30 ± 100
Maximum		163 ± 74	0.020 ± 0.020	0.389 ± 0.092	6.4 ± 1.4	13.9 ± 4.8	103 ± 30
Average		52	–0.002	0.067	2.1	<2.6	22
2s		86	0.030	0.210	3.5	<8.6	85

Table E-XIV (cont)

Station	1984 (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	04-03	17	50	7	8.1	153	0	32	1.6	50	300	0.2	6.8	621	161	7.0	118
Pueblo 1	04-03	43	24	11	11.8	92	0	141	20	31	83	0.4	54	43	77	7.5	65
Pueblo 2	04-03	42	28	5	10.5	96	0	105	24	32	148	0.5	58	506	100	7.1	70
Pueblo 3	04-03	50	17	3	13.2	99	0	140	13	41	54	0.8	28	378	55	7.2	55
Test Well 1A	03-20	51	20	4	7.5	64	0	121	16	31	41	0.6	44	332	69	7.9	50
Test Well 2A	04-03	150	32	6	3.9	21	0	75	0.1	24	42	0.0	14	239	102	7.5	34
Basalt Spring	04-03	40	27	6	3.2	19	0	102	<0.1	23	12	0.6	6	169	92	7.9	30
No. of Analyses		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum		17	17	3	3.2	19	0	32	<0.1	24	12	0.0	6	43	55	7.0	34
Maximum		150	50	11	13.2	153	0	140	24	50	300	0.8	58	506	161	7.9	118
Average		56	28	6	8.3	77	0	102	<10.6	33	97	0.4	30	326	93	7.4	60
2s		86	21	5	7.6	95	0	77	<20	19	198	0.5	44	395	68	0.7	58

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 and Ground Waters from DP-Los Alamos Canyon, An Active Effluent Release Area

Station	1984 (month-day)	Radiochemical				Total U ($\mu g/\ell$)	Gross Gamma (counts/min/ℓ)
		^{137}Cs (10^{-9} $\mu Ci/m\ell$)	^{238}Pu (10^{-9} $\mu Ci/m\ell$)	$^{239,240}Pu$ (10^{-9} $\mu Ci/m\ell$)	^{3}H (10^{-6} $\mu Ci/m\ell$)		
DPS-1	04-09	121 ± 76	4.4 ± 0.13	8.2 ± 0.38	0.3 ± 0.0	576 ± 115	217 ± 38
DPS-1	09-10	34 ± 65	0.229 ± 0.084	0.438 ± 0.116	4.5 ± 1.2	209 ± 30	0 ± 200
DPS-4	04-09	0 ± 176	0.230 ± 0.060	0.110 ± 0.020	0.2 ± 0.0	12 ± 2.6	49 ± 38
LAO-C	04-09	0 ± 176	0.013 ± 0.026	0.004 ± 0.030	0.1 ± 0.2	2 ± 0.0	49 ± 38
LAO-C	09-10	33 ± 70	–0.012 ± 0.023	–0.017 ± 0.020	1.6 ± 0.8	0.3 ± 0.4	0 ± 200
LAO-1	04-09	0 ± 176	–0.004 ± 0.024	0.010 ± 0.060	7.6 ± 1.6	1.9 ± 0.4	55 ± 38
LAO-2	04-09	0 ± 176	0.005 ± 0.034	0.210 ± 0.060	33 ± 6	2.0 ± 0.4	174 ± 38
LAO-2	09-10	–1 ± 50	0.021 ± 0.041	0.097 ± 0.062	2.4 ± 0.8	1.7 ± 0.8	0 ± 200
LAO-3	04-09	0 ± 176	0.011 ± 0.022	0.040 ± 0.040	32 ± 6	4.7 ± 1.0	–45 ± 36
LAO-3	09-10	–75 ± 114	0.000 ± 0.020	0.152 ± 0.074	4.4 ± 1.2	0.8 ± 0.4	0 ± 200
LAO-4	04-09	0 ± 176	0.020 ± 0.060	0.030 ± 0.120	14.3 ± 3.0	3.0 ± 0.6	–79 ± 36
LAO-4	09-10	–3 ± 93	0.051 ± 0.047	0.134 ± 0.067	4.7 ± 1.2	1.1 ± 0.6	0 ± 200
LAO-4.5	04-09	0 ± 176	0.008 ± 0.022	0.060 ± 0.060	14.5 ± 3.0	2.6 ± 0.6	–71 ± 36
LAO-4.5	09-10	–53 ± 61	0.006 ± 0.034	0.045 ± 0.046	5.3 ± 1.2	0.1 ± 0.0	0 ± 200
No. of Analyses		14	14	14	14	14	14
Minimum		–75 ± 114	–0.012 ± 0.023	–0.017 ± 0.020	0.1 ± 0.2	0.1 ± 0.0	–79 ± 36
Maximum		121 ± 76	4.4 ± 0.13	8.2 ± 0.38	33 ± 6	576 ± 115	217 ± 38
Average		4	0.356	0.680	4.7	58.4	25
2s		88	2.3	4.3	9.2	317.6	166

Table E-XV (cont)

Station	1984 (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)
DPS-1	04-09	22	5	0	142.0	1057	1027	0	2.0	0	116	56	636	3281	18	12.1	800
DPS-4	04-09	14	26	21	21	181	0	154	<0.1	42	154	6.7	120	644	82	7.5	112
LAO-C	04-09	51	38	8	3.4	11	0	113	<0.1	22	25	0.3	27	242	135	8.0	35
LAO-1	04-09	40	16	4	4.1	52	0	90	0.1	11	67	0.4	7.6	242	62	7.4	40
LAO-2	04-09	14	27	5	9.7	68	0	95	0.2	22	80	1.1	57	378	96	7.0	62
LAO-3	04-09	44	30	5	20.2	70	0	96	0.3	30	81	1.0	59	401	98	7.1	62
LAO-4	04-09	42	9	3	4.1	35	0	85	<0.1	11	25	0.5	1.6	179	39	7.2	25
LAO-4.5	04-09	58	10	3	3.8	34	0	83	3.1	11	23	0.5	7.6	178	39	7.0	25
No. of Analyses		8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Minimum		14	5	0	3.4	11	0	0	<0.1	0	23	0.3	1.6	178	18	7.0	25
Maximum		58	38	21	142.0	1057	1027	154	2.0	42	154	6.7	636	3281	135	12.1	800
Average		35	20	6	26.0	188	128	89	<0.7	18	71	8.3	114.4	693	71	7.9	145
2s		33	23	12	94.8	709	726	85	<2.3	26	94	38.7	428.7	2114	77	3.4	532

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 Waters from Mortandad Canyon, An Active Effluent Release Area

Station	1984 (month-day)	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	Radiochemical ^{238}Pu (10^{-9} μCi/mℓ)	Radiochemical $^{239,240}Pu$ (10^{-9} μCi/mℓ)	Radiochemical ^{3}H (10^{-6} μCi/mℓ)	Total U (μg/ℓ)	Gross Gamma (counts/min/ℓ)
GS-1	04-10	0 ± 176	1.4 ± 0.016	4.37 ± 0.30	5.8 ± 1.2	2.9 ± 0.6	680 ± 40
GS-1	09-19	1610 ± 358	81 ± 5.2	93 ± 6.5	6.5 ± 1.4	1.6 ± 0.4	910 ± 380
MCO-3	04-10	0 ± 176	4.3 ± 0.028	10.3 ± 0.400	6.2 ± 1.4	123 ± 16	890 ± 40
MCO-3	09-19	1800 ± 396	83 ± 5.0	90 ± 5.4	6.6 ± 1.4	123 ± 16	948 ± 380
MCO-4	04-10	0 ± 176	4.3 ± 0.026	18.9 ± 0.300	41 ± 8.0	11.5 ± 2.4	1370 ± 40
MCO-4	09-19	−19 ± 91	0.510 ± 0.126	1.76 ± 0.260	29 ± 6.0	15.9 ± 3.2	246 ± 232
MCO-5	04-10	0 ± 176	3.2 ± 0.022	17.1 ± 0.600	75 ± 16	9.2 ± 1.8	149 ± 38
MCO-5	09-19	19 ± 93	0.675 ± 0.142	2.73 ± 0.320	32 ± 6.0	22.0 ± 4.0	526 ± 336
MCO-6	04-10	0 ± 176	0.230 ± 0.060	0.470 ± 0.100	72 ± 14	21.2 ± 4.2	331 ± 38
MCO-6	09-19	−25 ± 50	0.130 ± 0.066	0.337 ± 0.102	35 ± 8.0	13.0 ± 3.0	178 ± 94
MCO-7	04-10	0 ± 176	0.021 ± 0.024	0.053 ± 0.032	6.8 ± 1.4	1.1 ± 0.2	14 ± 36
MCO-7	09-19	10 ± 80	0.038 ± 0.040	0.098 ± 0.054	---	2.5 ± 0.8	30 ± 90
MCO-7.5	04-10	0 ± 176	0.070 ± 0.040	0.090 ± 0.080	54 ± 10	5.7 ± 1.2	87 ± 38
No. of Analyses		13	13	13	12	13	13
Minimum		−25 ± 50	0.021 ± 0.024	0.053 ± 0.032	5.8 ± 1.2	1.1 ± 0.2	14 ± 36
Maximum		1800 ± 396	83 ± 5.0	93 ± 6.5	75 ± 16	123 ± 16	1370 ± 40
Average		261	13.8	18.4	30.8	27.1	489
2s		1284	60.7	66.2	51.5	86.2	867

Table E-XVI (cont)

Station	1984 (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)
GS-1	04-10	53	22	5	6.8	54	0	128	<0.1	14	16	0.4	83	318	75	8.1	45
MCO-3	04-10	38	22	5	7.1	63	0	126	1.3	15	1	0.4	110	345	75	7.7	47
MCO-4	04-10	16	7	0	22.8	284	29	231	2.3	61	34	3.2	460	1067	23	8.9	154
MCO-5	04-10	19	21	4	5.1	322	0	305	2.1	79	39	4.2	510	1190	71	7.7	171
MCO-6	04-10	16	22	4	5.4	412	0	372	2.1	94	51	5.1	650	1459	73	7.9	220
MCO-7	04-10	32	21	5	4.4	88	0	102	2.2	42	44	0.4	110	422	76	6.8	61
MCO-7.5	04-10	13	26	6	5.8	248	0	228	1.8	42	42	0.8	340	959	94	7.5	139
No. of Analyses		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum		13	7	0	4.4	63	0	102	<0.1	14	1	0.4	83	345	23	6.8	45
Maximum		53	26	6	22.8	412	29	372	2.3	94	51	5.1	650	1459	94	8.9	220
Average		26	20	4	8.2	210	4	213	1.7	49	32	2.0	323	822	69	7.8	119
2s		29	12	3	13.0	284	21	202	1.5	60	35	4.0	454	917	43	1.2	138

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 Surface Water from Sandia Canyon, an Active Effluent Release Area

Station	1984 (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)
SCS-1	04-02	54 ± 43	0.021 ± 0.030	0.090 ± 0.040	4.6 ± 1.0	3.4 ± 0.6	2610 ± 60
SCS-2	04-02	3 ± 17	0.280 ± 0.036	0.070 ± 0.040	7.9 ± 1.6	2.2 ± 0.4	2280 ± 60
SCS-2	08-27	64 ± 133	0.020 ± 0.038	0.010 ± 0.020	3.9 ± 1.0	0.8 ± 0.4	0 ± 200
SCS-3	04-02	27 ± 33	0.012 ± 0.028	0.240 ± 0.060	7.3 ± 1.6	2.0 ± 0.4	2110 ± 60
SCS-3	08-27	40 ± 139	0.013 ± 0.034	0.018 ± 0.032	4.3 ± 1.2	1.1 ± 0.6	0 ± 200
No. of Analyses		5	5	5	5	5	5
Minimum		3 ± 17	0.012 ± 0.028	0.010 ± 0.020	3.9 ± 1.0	0.8 ± 0.4	0 ± 200
Maximum		64 ± 133	0.280 ± 0.036	0.240 ± 0.060	7.9 ± 1.6	3.4 ± 0.6	2610 ± 60
Average		37	0.069	0.086	5.6	1.9	1400
2s		47	0.236	0.185	3.7	2.0	2581

Table E-XVII (cont)

Station	1984 (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	04-02	103	66	11	20.6	328	0	331	4.8	499	96	1.3	13	1277	201	8.0	180
SCS-2	04-02	77	43	9	16.3	240	0	197	5.0	228	210	1.7	10	998	152	8.2	140
SCS-3	04-02	58	44	8	13.9	212	0	191	4.4	180	140	1.5	58	874	140	8.0	132
No. of Analyses		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Minimum		58	43	8	13.9	212	0	191	4.4	180	96	1.3	10	874	152	8.0	132
Maximum		103	66	11	20.6	328	0	331	5.0	499	210	1.7	58	1277	201	8.2	180
Average		79	51	9	16.9	260	0	239	4.7	302	148	1.5	27	1049	164	8.0	150
2s		45	26	3	6.7	121	0	158	0.6	344	115	0.4	53	412	64	0.2	51

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-XVIII

Locations of Soil and Sediment Sampling Stations

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]
Regional Soils			
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 sampling locations in Figs. 12 and 14; sediment sampling locations in Figs. 12 and 15.

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 Sediments

Location[a]	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)
Regional Soils						
Chamita	0.80 ± 0.10	0.001 ± 0.002	0.020 ± 0.006	1.5 ± 0.6	3.9 ± 0.4	3.7 ± 0.6
Embudo	0.90 ± 0.30	−0.000 ± 0.002	0.016 ± 0.006	5.4 ± 1.2	2.2 ± 0.2	8.5 ± 0.6
Otowi	0.20 ± 0.20	0.000 ± 0.002	0.003 ± 0.004	4.2 ± 1.0	3.0 ± 0.1	4.6 ± 0.6
Near Santa Cruz Lake	0.00 ± 0.20	0.000 ± 0.002	0.001 ± 0.002	1.6 ± 0.6	2.8 ± 0.2	5.0 ± 0.6
Cochiti	0.40 ± 0.30	0.000 ± 0.002	0.012 ± 0.006	5.3 ± 1.2	2.7 ± 0.2	3.8 ± 0.6
Bernalillo	0.30 ± 0.20	0.000 ± 0.001	0.002 ± 0.001	8.8 ± 1.8	1.9 ± 0.2	2.0 ± 0.6
Jemez	0.00 ± 0.20	0.002 ± 0.002	−0.001 ± 0.001	7.0 ± 1.6	2.1 ± 0.4	3.5 ± 0.6
No. of Analyses	7	7	7	7	7	7
Minimum	0.00 ± 0.20	0.000 ± 0.002	−0.001 ± 0.001	1.5 ± 0.6	1.9 ± 0.2	2.0 ± 0.6
Maximum	0.90 ± 0.30	0.002 ± 0.002	0.020 ± 0.006	8.8 ± 1.8	3.9 ± 0.4	8.5 ± 0.6
Average	0.30	0.000	0.008	4.8	2.6	4.4
2s	0.70	0.000	0.017	5.3	1.3	4.0
Regional Sediments						
Rio Chama at Chamita	0.27 ± 0.30	0.000 ± 0.001	0.000 ± 0.002	0.8 ± 0.6	1.3 ± 0.2	2.0 ± 0.2
Rio Grande at Embudo	0.27 ± 0.30	0.001 ± 0.004	0.002 ± 0.004	2.7 ± 0.8	2.7 ± 0.4	4.6 ± 0.6
Rio Grande at Otowi	0.18 ± 0.30	−0.001 ± 0.004	0.002 ± 0.004	3.1 ± 0.8	2.7 ± 0.2	4.3 ± 0.6
Rio Grande at Sandia	0.09 ± 0.12	−0.006 ± 0.007	−0.002 ± 0.008	---	2.9 ± 0.4	4.1 ± 0.6
Cañada del Ancho at Rio Grande	0.09 ± 0.12	−0.001 ± 0.006	−0.004 ± 0.004	---	1.3 ± 0.2	0.4 ± 0.6
Rio Grande at Pajarito	0.09 ± 0.12	−0.002 ± 0.002	0.000 ± 0.001	---	4.9 ± 0.6	6.9 ± 0.6
Pajarito at Rio Grande	0.24 ± 0.18	−0.002 ± 0.003	0.000 ± 0.001	---	2.6 ± 0.4	3.1 ± 0.6
Water at Rio Grande	0.05 ± 0.08	−0.001 ± 0.002	0.001 ± 0.002	---	1.1 ± 0.2	1.4 ± 0.6
Rio Grande at Ancho	0.26 ± 0.10	0.003 ± 0.003	0.005 ± 0.006	---	1.7 ± 0.2	1.6 ± 0.6
Chaquihui at Rio Grande	0.32 ± 0.18	−0.002 ± 0.004	0.004 ± 0.005	---	3.0 ± 0.4	4.8 ± 0.6
Rio Grande at Frijoles	0.04 ± 0.08	−0.003 ± 0.003	0.000 ± 0.001	---	1.9 ± 0.2	1.5 ± 0.6
Frijoles at Rio Grande	0.14 ± 0.14	−0.002 ± 0.004	−0.003 ± 0.004	---	3.3 ± 0.4	4.3 ± 0.6
Rio Grande at Bernalillo	0.25 ± 0.30	−0.001 ± 0.004	0.004 ± 0.004	1.3 ± 0.6	2.7 ± 0.2	4.2 ± 0.6
Jemez River at Jemez	0.53 ± 0.30	0.005 ± 0.005	0.010 ± 0.005	0.7 ± 0.6	4.1 ± 0.4	8.4 ± 0.6
No. of Analyses	14	14	14	5	14	14
Minimum	0.04 ± 0.08	−0.006 ± 0.007	−0.004 ± 0.004	0.7 ± 0.6	1.1 ± 0.2	0.4 ± 0.6
Maximum	0.53 ± 0.30	0.005 ± 0.005	0.010 ± 0.005	3.1 ± 0.8	4.9 ± 0.6	8.4 ± 0.6
Average	0.20	−0.001	0.001	1.7	26	3.7
2s	0.27	0.005	0.007	2.2	2.2	4.4

[a]Locations shown in Fig. 12 and described in Table E-XVIII.

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-XX

Radiochemical Analyses of Perimeter Soils and Sediments

Locations[a]	Sampling Station Number	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)
Perimeter Soil							
Sportsman's Club	S-1	0.60 ± 0.20	0.002 ± 0.002	0.020 ± 0.006	1.5 ± 0.6	3.8 ± 0.2	6.0 ± 0.6
North Mesa	S-2	0.40 ± 0.20	0.000 ± 0.002	0.014 ± 0.006	2.0 ± 0.6	3.6 ± 0.2	5.8 ± 0.6
TA-8	S-3	2.2 ± 0.60	0.003 ± 0.002	0.062 ± 0.010	5.0 ± 1.2	4.0 ± 0.2	7.2 ± 0.6
TA-49	S-4	1.0 ± 0.20	0.000 ± 0.002	0.024 ± 0.006	2.9 ± 0.8	4.5 ± 0.4	7.1 ± 0.6
White Rock (East)	S-5	0.30 ± 0.20	0.000 ± 0.000	0.010 ± 0.004	4.3 ± 1.0	3.1 ± 0.2	6.2 ± 0.6
Tsankawi	S-6	0.40 ± 0.20	0.000 ± 0.000	0.006 ± 0.002	5.8 ± 1.4	5.0 ± 0.6	9.3 ± 0.6
No. of Analyses		6	6	6	6	6	6
Minimum		0.3 ± 0.20	0.000 ± 0.002	.006 ± 0.002	1.5 ± 0.6	3.6 ± 0.2	5.8 ± 0.6
Maximum		2.2 ± 0.60	0.003 ± 0.002	0.062 ± 0.010	5.8 ± 1.4	5.0 ± 0.6	9.3 ± 0.6
Average		0.8	0.001	0.023	3.5	4.0	6.9
2s		1.4	0.003	0.041	3.4	1.3	2.6
Perimeter Sediments							
Guaje at SR-4	12	0.00 ± 0.30	0.004 ± 0.008	0.002 ± 0.004	2.6 ± 0.8	2.2 ± 0.2	4.5 ± 0.6
Bayo at SR-4	13	0.20 ± 0.30	0.005 ± 0.004	0.003 ± 0.003	–0.8 ± 0.6	2.0 ± 0.2	4.0 ± 0.6
Sandia at SR-4	14	0.00 ± 0.30	0.001 ± 0.003	0.000 ± 0.002	0.7 ± 0.6	1.7 ± 0.2	4.4 ± 0.6
Mortandad at SR-4	15	0.00 ± 0.30	–0.002 ± 0.006	0.003 ± 0.003	4.0 ± 1.0	2.0 ± 0.2	5.1 ± 0.6
Cañada del Buey at SR-4	16	0.00 ± 0.30	–0.00 ± 0.002	0.002 ± 0.002	5.9 ± 1.4	1.0 ± 0.2	3.3 ± 0.6
Pajarito at SR-4	17	0.34 ± 0.30	–0.001 ± 0.003	–0.001 ± 0.003	40 ± 8.0	2.5 ± 0.2	4.7 ± 0.6
Potrillo at SR-4	18	0.00 ± 0.30	0.003 ± 0.004	0.000 ± 0.003	49 ± 10	2.4 ± 0.2	4.6 ± 0.6
Water at SR-4	19	0.17 ± 0.30	0.002 ± 0.003	0.003 ± 0.004	3.9 ± 1.0	2.3 ± 0.2	3.4 ± 0.6
Ancho at SR-4	20	0.29 ± 0.30	0.003 ± 0.003	0.008 ± 0.004	8.9 ± 20	2.7 ± 0.2	4.4 ± 0.6
No. of Analyses		9	9	9	9	9	9
Minimum		0.00 ± 0.30	–0.002 ± 0.006	–0.001.±0.003	–0.8 ± 0.6	1.0 ± 0.2	3.3 ± 0.6
Maximum		0.34 ± 0.30	0.005 ± 0.004	0.008 ± 0.004	49 ± 10	2.7 ± 0.2	5.1 ± 0.6
Average	0.11	0.002	0.002	0.002	13	2.1	4.3
2s		0.28	0.005	0.005	37	1.0	1.2

[a]Locations shown in Figs. 14 and 15 and described in Table E-XVIII.

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-XXI

Radiochemical Analyses of Onsite Soils and Sediments
from Effluent Release Areas

Location[a]	Sampling Station Number	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)	^{241}Am (pCi/g)	^{90}Sr (pCi/g)
Onsite Soils									
TA-21	S-7	0.00 ± 0.30	0.007 + 0.008	0.027 ± 0.010	2.0 ± 0.6	3.6 ± 0.2	5.5 ± 0.6	---	---
East of TA 53	S-8	1.0 ± 0.34	0.002 ± 0.002	0.048 ± 0.010	3.0 ± 0.8	5.9 ± 0.3	7.5 ± 0.6	---	---
TA 50	S-9	0.00 ± 0.30	0.000 ± 0.002	0.008 ± 0.004	26 ± 6.0	3.5 ± 0.2	6.4 ± 0.6	---	---
Two Mile Mesa	S-10	0.47 ± 0.30	0.000 ± 0.002	0.010 ± 0.004	5.7 ± 1.2	3.8 ± 0.2	4.4 ± 0.6	--	---
East of TA-54	S-11	0.28 ± 0.30	0.003 ± 0.004	0.008 ± 0.004	3.8 ± 1.0	3.2 ± 0.2	5.6 ± 0.6	---	---
R-Site Road East	S-12	3.0 ± 0.91	0.003 ± 0.002	0.057 ± 0.010	10 ± 1.1	5.8 ± 0.6	7.8 ± 0.6	---	---
Potrillo Drive	S-13	0.37 ± 0.30	-0.005 + 0.004	0.005 ± 0.005	5.1 ± 1.2	3.7 ± 0.2	5.9 ± 0.6	---	--
S-Site	S 14	0.99 ± 0.32	0.001 ± 0.005	0.021 ± 0.008	11 ± 1.1	3.6 ± 0.2	7.5 ± 0.6	---	---
Near DT-9	S-15	1.1 ± 0.36	-0.006 + 0.010	0.035 ± 0.010	1.7 ± 0.6	3.6 ± 0.2	7.9 ± 0.6	---	---
Near TA-33	S 16	0.28 ± 0.30	0.001 + 0.003	0.005 + 0.004	38 ± 8.0	3.5 ± 0.2	7.9 ± 0.6	---	---
No. of Analyses		10	10	10	10	10	10	---	---
Minimum		0.00 ± 0.30	-0.006 ± 0.010	0.005 ± 0.005	1.7 ± 0.6	3.2 ± 0.2	4.4 ± 0.6	---	---
Maximum		3.0 ± 0.91	0.007 ± 0.008	0.057 ± 0.010	38 ± 8.0	5.9 ± 0.3	7.9 ± 0.6	---	---
Average		0.75	0.001	0.022	11	4.0	6.6	---	---
2s		1.8	0.008	0.038	24	1.9	2.5	---	---
Sediments Effluent Release Area, Pueblo Canyon									
Acid Weir	22	0.9 ± 0.30	0.059 ± 0.0014	7.51 ± 0.240	1.7 ± 0.6	1.9 ± 0.38	3.7 + 0.6	0.01 ± 0.00	0.90 ± 0.12
Pueblo 1	23	0.00 ± 0.30	0.002 ± 0.002	0.010 ± 0.004	0.9 ± 0.6	1.8 ± 0.36	2.0 ± 0.6	-0.01 ± 0.00	0.50 ± 0.08
Pueblo at SR-4	27	0.00 ± 0.30	0.016 ± 0.006	3.17 ± 0.100	5.8 ± 1.4	2.4 ± 0.24	2.6 ± 0.6	0.00 ± 0.00	0.36 ± 0.08
No. of Analyses		3	3	3	3	3	3	3	3
Minimum		0.00 ± 0.30	0.002 ± 0.002	0.010 ± 0.004	0.9 ± 0.6	1.8 ± 0.2	2.0 ± 0.6	-0.01 ± 0.00	0.36 ± 0.8
Maximum		0.79 ± 0.30	0.059 + 0.014	7.51 ± 0.240	5.8 + 1.4	2.4 ± 0.2	3.7 ± 0.6	0.01 ± 0.00	0.90 ± 0.12
Average		0.26	0.030	3.56	2.8	2.0	2.8	0.00	0.59
2s		0.91	0.060	7.53	5.3	0.6	1.7	0.00	0.56

Table E-XXI (cont)

Location[a]	Sampling Station Number	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	Gross Gamma (counts/min/g)	^{241}Am (pCi/g)	^{90}Sr (pCi/g)
Sediments, Effluent Release Area, DP-Los Alamos Canyon									
DP Canyon at DPS-1	28	16 ± 4.8	1.7 ± 0.080	5.3 ± 0.16	18 ± 3.6	5.6 ± 0.6	25 ± 0.8	0.84 ± 0.04	12 ± 0.10
DP Canyon at DPS-4	29	17 ± 2.6	0.161 ± 0.018	0.474 ± 0.032	2.4 ± 0.8	1.5 ± 0.1	15 ± 0.6	0.03 ± 0.00	2.1 ± 0.28
Los Alamos at Bridge	30	0.16 ± 0.30	0.001 ± 0.018	0.004 ± 0.003	2.4 ± 0.8	1.6 ± 0.2	1.3 ± 0.6	0.00 ± 0.00	0.40 ± 0.10
Los Alamos at LAO-1	31	0.39 ± 0.30	0.008 ± 0.004	0.484 ± 0.052	2.6 ± 0.8	2.7 ± 0.2	4.7 ± 0.6	0.00 ± 0.00	0.42 ± 0.80
Los Alamos at GS-1	32	15 ± 4.4	0.164 ± 0.024	0.611 ± 0.062	5.2 ± 1.2	2.3 ± 0.2	15 ± 0.6	0.02 ± 0.00	0.86 ± 0.10
Los Alamos at LAO-3	33	0.0 ± 0.30	0.000 ± 0.000	0.122 ± 0.025	2.6 ± 0.8	1.6 ± 0.2	1.1 ± 0.6	0.00 ± 0.00	0.32 ± 0.16
Los Alamos at LAO-4.5	34	28 ± 8.4	0.291 ± 0.036	1.06 ± 0.102	2.7 ± 0.8	3.6 ± 0.2	28 ± 0.8	0.06 ± 0.00	1.38 ± 0.30
Los Alamos at SR-4	35	1.2 ± 0.40	0.110 ± 0.052	0.080 ± 0.010	3.4 ± 0.8	2.5 ± 0.2	4.8 ± 0.6	0.00 ± 0.00	0.65 ± 0.22
Los Alamos at Totavi	36	0.76 ± 0.30	0.011 ± 0.007	0.389 ± 0.064	2.5 ± 0.8	2.1 ± 0.2	3.4 ± 0.6	0.00 ± 0.00	0.59 ± 0.10
Los Alamos at LA-2	37	0.69 ± 0.30	−0.002 ± 0.004	0.151 ± 0.022	2.9 ± 0.8	1.4 ± 0.2	2.5 ± 0.6	0.00 ± 0.00	0.46 ± 0.010
Los Alamos at Otowi	38	0.49 ± 0.30	0.006 ± 0.004	0.096 ± 0.014	2.1 ± 0.6	2.2 ± 0.2	3.1 ± 0.6	0.00 ± 0.00	0.41 ± 0.16
No. of Analyses		11	11	11	11	11	11	11	11
Minimum		0.00 ± 0.30	−0.002 ± 0.004	0.004 ± 0.003	2.1 ± 0.6	1.4 ± 0.2	1.1 ± 0.6	0.00 ± 0.00	0.32 ± 0.16
Maximum		28 ± 8.4	1.7 ± 0.080	5.3 ± 0.16	18 ± 3.6	5.6 ± 0.6	28 ± 0.8	0.84 ± 0.04	12 ± 0.10
Average		7.2	0.223	0.798	4.2	2.5	9.4	0.09	1.8
2s		20	0.999	3.05	9.3	2.4	20	0.50	6.9
Sediment Effluent Release Area, Mortandad Canyon									
Mortandad at CMR	39	0.00 ± 0.30	0.136 ± 0.016	0.451 ± 0.032	78 ± 16	1.9 ± 0.1	1.6 ± 0.6	0.02 ± 0.00	0.12 ± 0.14
Mortandad West of GS-1	40	0.00 ± 0.30	0.017 ± 0.006	0.033 ± 0.008	63 ± 14	1.3 ± 0.2	0.8 ± 0.6	0.00 ± 0.00	8.7 ± 0.6
Mortandad at GS-1	41	90 ± 27	68 ± 0.12	235 ± 3.4	61 ± 12	4.9 ± 0.6	787 ± 16	2.6 ± 0.8	2.6 ± 2.6
Mortandad at MCO-5	42	55 ± 16	10.9 ± 0.130	72 ± 1.4	32 ± 6	2.4 ± 0.2	121 ± 2.6	0.15 ± 0.00	5.7 ± 0.6
Mortandad at MCO-7	43	46 ± 14	1.90 ± 0.060	5.5 ± 1.4	12 ± 1.6	2.2 ± 0.4	38 ± 1.0	0.03 ± 0.00	0.93 ± 0.09
Mortandad at MCO-9	44	1.3 ± 0.40	0.009 ± 0.004	0.077 ± 0.010	9.7 ± 3.4	3.9 ± 0.4	7.5 ± 0.6	0.00 ± 0.00	0.15 ± 0.16
Mortandad at MCO-13	45	0.69 ± 0.30	0.002 ± 0.002	0.031 ± 0.008	12 ± 3.6	2.9 ± 0.2	4.5 ± 0.6	0.00 ± 0.00	0.12 ± 0.10
No. of Analyses		7	7	7	7	7	7	7	7
Minimum		0.00 ± 0.30	0.002 ± 0.002	0.031 ± 0.008	9.7 ± 3.4	1.3 ± 0.2	0.8 ± 0.6	0.00 ± 0.00	0.12 ± 0.14
Maximum		90 ± 27	68 ± 0.12	235 ± 3.4	78 ± 16	4.9 ± 0.6	787 ± 16	2.6 ± 0.08	8.7 ± 0.6
Average		28	12	45	38	2.8	137	0.40	2.6
2s		73	51	176	57	2.5	580	1.9	6.7

[a]Location shown in Figs. 14 and 15 and described in Table E-XVIII.

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

Radiochemical Analyses of Sediments from Reservoirs

Reservoir Station	1984 (Month-Day)	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Total Uranium (μg/g)	Gross Gamma (counts/min/g)
El Vado (South)	6-14	0.70 ± 0.34	0.00045 ± 0.00006	0.00675 ± 0.00036	4.6 ± 0.4	6.7 ± 0.6
El Vado (Middle)	6-14	0.57 ± 0.30	0.00034 ± 0.00005	0.00678 ± 0.00084	3.5 ± 0.4	4.8 ± 0.6
El Vado (North)	6-14	0.35 ± 0.23	0.00036 ± 0.00005	0.00051 ± 0.00028	4.2 ± 0.4	5.1 ± 0.6
Summary: $\bar{x} \pm 2s$	---	0.54 ± 0.35	0.00038 ± 0.00012	0.00468 ± 0.00722	4.1 ± 1.1	5.5 ± 2.0
Heron (South)	6-13	1.1 ± 0.48	0.00083 ± 0.00008	0.01810 ± 0.00087	3.8 ± 0.8	5.1 ± 0.6
Heron (Middle)	6-13	0.52 ± 0.28	0.00032 ± 0.00006	0.00655 ± 0.00042	4.5 ± 0.4	4.7 ± 0.6
Heron (North)	6-13	0.59 ± 0.30	0.00034 ± 0.00005	0.00336 ± 0.00022	5.3 ± 0.6	7.0 ± 0.6
Summary: $\bar{x} \pm 2s$	---	0.74 ± 0.63	0.00050 ± 0.00058	0.00934 ± 0.01551	4.5 ± 1.5	5.6 ± 2.5
Abiquiu (Upper)	7-25	1.0 ± 0.46	0.0007 ± 0.0002	0.0163 ± 0.0012	3.6 ± 0.6	6.3 ± 0.6
Abiquiu (Middle)	7-25	0.78 ± 0.32	0.0005 ± 0.0002	0.0110 ± 0.0012	3.9 ± 0.4	6.2 ± 0.6
Abiquiu (Lower)	7-25	0.89 ± 0.42	0.0009 ± 0.0002	0.0107 ± 0.0008	3.1 ± 0.6	5.0 ± 0.6
Summary: $\bar{x} \pm 2s$	---	0.89 ± 0.22	0.0007 ± 0.0004	0.0127 ± 0.0063	3.5 ± 0.8	5.8 ± 1.5
Cochiti (North)	6-04	0.58 ± 0.30	0.00008 ± 0.00008	0.01470 ± 0.00072	4.1 ± 0.4	---
Cochiti (Middle)	6-04	0.90 ± 0.30	0.00105 ± 0.00009	0.01670 ± 0.00080	4.6 ± 0.4	---
Cochiti (South)	6-04	0.81 ± 0.30	0.00098 ± 0.00009	0.02770 ± 0.00134	3.6 ± 0.4	—
Summary: $\bar{x} \pm 2s$	—	0.76 ± 0.33	0.00070 ± 0.00108	0.01970 ± 0.01400	4.1 ± 1.0	—

Notes:

1. El Vado, Heron, and Abiquiu Reservoirs are in Rio Chama drainage; Cochiti Reservoir is in Rio Grande drainage below confluence with Rio Chama and Los Alamos.
2. 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

Radionuclide Concentrations in Fruits and Vegetables

Location:	Background		Offsite			Onsite	
Water Source:	Espanola (Rio Chama)	Espanola (Rio Grande)	Cochiti (Rio Grande)	Los Alamos (Community System)	White Rock/ Pajarito Acres (Community System)	TA-3	TA-21
Radionuclide:							
^{238}Pu (pCi/g dry weight)							
No. of Samples	4	5	15	10	9	4	
Minimum	−0.00023 ± 0.00028	−0.00085 ± 0.00090	−0.0013 ± 0.00068	−0.0042 ± 0.0050	−0.0067 ± 0.0024	−0.000041 ± 0.00018	—
Maximum	−0.00011 ± 0.00048	−0.00015 ± 0.00068	0.00072 ± 0.00074	0.00027 ± 0.00030	0.000067 ± 0.00036	0.00019 ± 0.00038	—
x̄ ± 2s	−0.00012 ± 0.000072	−0.00038 ± 0.00028	0.000028 ± 0.00045	−0.00078 ± 0.0014	−0.00088 ± 0.0022	0.000053 ± 0.00010	—
$^{239,240}Pu$ (pCi/g dry weight)							
No. of Samples	4	5	15	10	9	4	—
Minimum	−0.00032 ± 0.00036	−0.00051 ± 0.00058	−0.00031 ± 0.00034	−0.0025 ± 0.0020	−0.00075 ± 0.0010	−0.00012 ± 0.00014	—
Maximum	0.0020 ± 0.00090	0.00014 ± 0.00076	0.00051 ± 0.0010	0.00017 ± 0.00034	0.0000 ± 0.00020	0.00031 ± 0.00042	—
x̄ ± 2s	0.00050 ± 0.0010	−0.00024 ± 0.00026	0.000013 ± 0.00026	−0.00031 ± 0.00080	0.00027 ± 0.00023	0.00010 ± 0.00024	—
Uranium (µg/g dry weight)							
No. of Samples	4	5	15	10	9	4	1
Minimum	0.00038 ± 0.00030	0.00016 ± 0.00032	0.00028 ± 0.00056	0.0015 ± 0.00042	0.00035 ± 0.00070	0.0014 ± 0.00038	—
Maximum	0.0024 ± 0.0011	0.016 ± 0.0028	0.011 ± 0.0020	0.0290 ± 0.0042	0.0540 ± 0.0090	0.0066 ± 0.0013	—
x̄ ± 2s	0.00094 ± 0.00098	0.0061 ± 0.0066	0.0035 ± 0.0014	0.0096 ± 0.0081	0.0086 ± 0.017	0.0034 ± 0.0023	0.0076 ± 0.0015
^{137}Cs (pCi/g dry weight)							
No. of Samples	4	5	15	10	9	4	1
Minimum	−0.15 ± 0.58	−1.045 ± 1.5	−0.53 ± 1.9	−0.88 ± 1.9	−1.62 ± 2.4	−0.15 ± 0.72	—
Maximum	1.14 ± 0.91	1.16 ± 2.4	1.70 ± 2.2	1.94 ± 1.7	3.01 ± 2.2	0.65 ± 0.78	—
x̄ ± 2s	0.39 ± 0.56	0.57 ± 0.93	0.35 ± 0.56	0.19 ± 0.92	0.70 ± 1.4	0.14 ± 0.36	−0.017 ± 0.94
^{90}Sr (pCi/g dry weight)							
No. of Samples	4	5	15	10	9	4	1
Minimum	−0.019 ± 0.0036	0.0067 ± 0.0054	−0.0047 ± 0.0026	−0.0039 ± 0.0018	0.0015 ± 0.0018	0.0043 ± 0.0048	—
Maximum	0.0085 ± 0.0017	0.087 ± 0.011	0.060 ± 0.078	0.13 ± 0.018	0.043 ± 0.015	0.024 ± 0.0024	—
x̄ ± 2s	−0.0030 ± 0.013	0.035 ± 0.034	0.016 ± 0.020	0.044 ± 0.055	0.018 ± 0.0078	0.012 ± 0.0086	0.025 ± 0.0076
^{3}H (10^{-6} µCi/ml)							
No. of Samples	4	5	15	10	9	4	1
Minimum	−0.9 ± 0.6	0.7 ± 0.6	−0.2 ± 0.6	0.9 ± 0.6	0.7 ± 0.6	1.6 ± 0.8	—
Maximum	1.5 ± 0.8	1.4 ± 0.8	2.1 ± 0.8	2.7 ± 0.8	2.8 ± 0.8	16.1 ± 3.4	—
x̄ ± 2s	0.73 ± 1.2	0.96 ± 0.32	1.1 ± 0.57	2.0 ± 0.62	1.5 ± 0.59	8.7 ± 6.0	5.8 ± 1.4

Table E-XXIV

Radionuclide Content of Fish

Location	Alligator, El Vado, and Heron Reservoirs				Cochiti Reservoir			
	Bottom Feeder (carcass)[a]	Bottom Feeder (gut)[b]	Higher Level (carcass)[a]	Higher Level (gut)[b]	Bottom Feeder (carcass)[a]	Bottom Feeder (gut)[b]	Higher Level (carcass)[a]	Higher Level (gut)[b]
Radionuclide:								
^{238}Pu (pCi/g dry weight)								
No. of Samples	21	15	15	9	21	12	9	4
Minimum	−0.00013 ± 0.00016	−0.00056 ± 0.0011	−0.0023 ± 0.00026	−0.0015 ± 0.0022	−0.00042 ± 0.0018	−0.011 ± 0.050	−0.000045 ± 0.00022	0.000049 ± 0.00013
Maximum	0.00075 ± 0.00044	0.00088 ± 0.0016	0.0014 ± 0.00042	0.00043 ± 0.00058	0.00058 ± 0.0012	0.0012 ± 0.0066	0.00014 ± 0.00064	0.00045 ± 0.00090
$\bar{x} \pm 2s$	0.000042 ± 0.00036	0.000047 ± 0.00090	0.00014 ± 0.00086	−0.00022 ± 0.0011	0.000031 ± 0.00034	−0.00099 ± 0.0066	0.053 ± 0.061	0.00019 ± 0.00036
$^{239,240}Pu$ (pCi/g dry weight)								
No. of Samples	21	15	15	9	21	12	9	4
Minimum	−0.00013 ± 0.00016	−0.00071 ± 0.0018	−0.00015 ± 0.00030	0.00051 ± 0.0010	−0.0013 ± 0.0014	−0.0038 ± 0.0054	0.0000 ± 0.090	0.0002 ± 0.00013
Maximum	0.00078 ± 0.0019	0.0035 ± 0.0024	0.00027 ± 0.00026	−0.00077 ± 0.0021	0.00039 ± 0.0012	0.012 ± 0.0066	0.00014 ± 0.00074	0.00016 ± 0.00080
$\bar{x} \pm 2s$	0.000037 ± 0.00036	0.00067 ± 0.00094	0.000020 ± 0.00022	0.00027 ± 0.00076	−0.0000 ± 0.00062	0.0016 ± 0.0074	0.000080 ± 0.000848	0.000082 ± 0.00012
Uranium (pg/g dry weight)								
No. of Samples	21	16	15	9	21	12	10	4
Minimum	0.0031 ± 0.00062	0.030 ± 0.0042	0.0006 ± 0.0002	0.0088 ± 0.0018	0.0059 ± 0.0016	0.007 ± 0.0002	0.0028 ± 0.012	0.0014 ± 0.0096
Maximum	0.018 ± 0.0036	0.94 ± 0.092	0.0073 ± 0.0026	0.080 ± 0.012	0.075 ± 0.14	0.70 ± 0.072	0.040 ± 0.0082	0.067 ± 0.0096
$\bar{x} \pm 2s$	0.0097 ± 0.0044	0.28 ± 0.23	0.0046 ± 0.0020	0.032 ± 0.026	0.027 ± 0.020	0.21 ± 0.27	0.010 ± 0.011	0.026 ± 0.031
^{137}Cs (pCi/g dry weight)								
No. of Samples	19	13	14	9	21	12	10	4
Minimum	−0.15 ± 0.38	−0.16 ± 0.68	0.023 ± 0.34	−0.18 ± 1.4	−0.23 ± 0.38	0.070 ± 0.24	−0.29 ± 0.84	−0.23 ± 0.34
Maximum	0.56 ± 0.64	1.8 ± 1.9	1.1 ± 0.60	3.7 ± 3.8	0.77 ± 0.60	1.0 ± 1.4	0.39 ± 0.36	0.54 ± 0.80
$\bar{x} \pm 2s$	0.19 ± 0.18	0.54 ± 0.53	0.34 ± 0.30	1.6 ± 1.1	0.15 ± 0.21	0.36 ± 0.28	0.076 ± 0.21	0.099 ± 0.33
^{90}Sr (pCi/g dry weight)								
No. of Samples	21	14	15	9	21	12	10	4
Minimum	0.041 ± 0.0048	0.0015 ± 0.0036	0.0064 ± 0.0016	0.012 ± 0.0064	0.059 ± 0.0034	0.0008 ± 0.0006	−0.0010 ± 0.0070	−0.0001 ± 0.0010
Maximum	0.17 ± 0.0078	0.038 ± 0.0036	0.18 ± 0.0096	0.086 ± 0.0072	0.095 ± 0.0076	0.075 ± 0.0058	0.14 ± 0.012	0.16 ± 0.0090
$\bar{x} \pm 2s$	0.092 ± 0.058	0.012 ± 0.020	0.060 ± 0.11	0.026 ± 0.046	0.064 ± 0.048	0.017 ± 0.050	0.067 ± 0.096	0.050 ± 0.15

[a]Sample consists of fish carcass (head, skin, fins, bones, and muscles).
[b]Sample consists of fish gut (gills, major organs, gastrointestinal tract).

Table E-XXV

Locations of Beehives

Station	N-S Coordinate	E-W Coordinate
Regional Station (28-44 km)—Uncontrolled Area		
1. Chimayo	---	---
13. San Pedro	---	---
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
11. TA-9	S045	E010
12. TA-15	S040	E100

Table E-XXVI

Radiochemical and Chemical Analyses of Bees and Honey

Analysis	Units	Year	Sample Location[a,b] Chimayo	San Pedro	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	1981	---	---	0.18	0.02	0.07	0.06	0.02	0.03	0.12	0.02	---
B	ppm	1980	19	---	14	18	15	13	---	17	11	17	20
^{7}Be	pCi/g	1983	0.11	0.17	0.52	0.51	0.61	<0.17	1.82	---	<0.33	0.49	0.93
^{57}Co	pCi/g	1983	0.06	0	<0.011	0.05	0.09	0.01	12.8	---	0.05	<0.023	<0.036
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	1983	0	0.05	0.12	0.17	0.09	0.05	1.43	---	0.07	0.05	0.13
^{137}Cs	pCi/g	1983	0.11	0.02	0.12	0.10	0.11	0.01	0.07	---	0.001	0.08	0.15
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	1983	0.14	0.04	0.11	0.03	0.01	0.06	10.5	---	0.07	0.11	0.04
^{22}Na	pCi/g	1983	0.08	0.06	0.08	0.08	0.02	0.04	16.2	---	<0.034	0.12	0.09
Pb	ppm	1981	---	---	<3	0.60	2.20	0.60	0.30	0.50	<5	0.30	---
^{83}Rb	pCi/g	1983	<0.077	0.04	0.13	<0.026	0.11	0.13	6.1	---	0.17	0.004	0.41
U	ppb	1983	44	<6	36	68	248	44	39	---	21	17	66
Honey Analyses													
As	ppb	1981	1.7	---	1.5	---	2.4	22.1	---	10.5	3.4	2.5	4.7
^{7}Be	pCi/g	1983	<0.03	0	<0.06	0.01	<0.11	<0.08	<0.07	---	<0.01	0	0.12
Cd	ppb	1981	1.4	---	12	---	3.1	9.0	---	2.8	13	0.9	16
^{57}Co	pCi/g	1983	0.004	<0.004	<0.011	0.01	0	0.02	0	---	<0.008	0.01	<0.001
^{134}Cs	pCi/g	1983	0.01	0.003	0.01	0.01	0.02	0.003	0.05	---	0.02	<0.002	0.01
^{137}Cs	pCi/g	1983	0.02	0	0	0.002	0.01	0.04	0.02	---	<0.013	0	<0.008
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	1983	4.80	3.10	0.22	4.90	81	31	9.80	---	7.70	73	29
^{54}Mn	pCi/g	1983	0.02	0.002	0.01	0	0.03	0.004	0.02	---	0.03	0	<0.011
^{22}Na	pCi/g	1983	0.01	0.003	0.001	<0.007	0.002	<0.014	0.32	---	0.03	0	<0.014
Pb	ppm	1981	0.08	---	0.02	---	0.09	<0.03	---	0.04	0.05	0.07	0.16
^{83}Rb	pCi/g	1983	<0.006	0.02	<0.007	0	<0.001	0.002	0.09	---	0	0.02	<0.027
U	ppb	1983	<6	<6	9.2	<6	9.2	6.5	<6	---	<6	<6	<6

[a]One sample per location per year.
[b]See Fig. 18. and Table E-XXV for sample locations.

Table E-XXVII

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
1983											
08/16 - 08/22	4.9	12.1	0.34	0.02	0.04	0.06	0.15	0.67	0.13	1.25	<0.003
08/22 - 8/30	4.8	15.8	0.27	0.03	0.15	0.25	0.31	1.63	0.38	1.15	<0.003
08/30 - 09/06	5.0	34.2	2.62	0.38	0.36	0.94	0.36	4.26	0.21	5.91	<0.003
09/06 - 09/13	4.8	17.6	1.19	0.07	0.11	0.16	0.40	1.94	0.23	2.82	<0.003
09/13 - 09/20	Dry										
09/20 - 09/27	5.4	5.3	0.14	0.02	0.05	0.08	0.08	0.58	0.14	0.58	<0.003
09/27 - 10/04	5.1	5.2	0.07	0.01	0.02	0.04	0.06	0.38	0.10	0.53	<0.003
10/04 - 10/11	5.0	10.0	0.12	0.02	0.07	0.09	0.09	0.56	0.13	1.28	<0.003
10/11 - 20/18	Dry										
10/18 - 10/25	6.5	14.3	0.10	0.10	3.88	0.15	<0.02	<0.02	0.43	0.56	0.02
10/25 - 11/01	Dry										
11/01 - 11/08	5.8	3.2	0.02	0.01	0.01	0.02	0.07	0.07	0.07	<0.10	<0.003
11/08 - 11/15	6.2	14.3	2.06	0.07	0.05	0.38	<0.02	0.96	0.22	1.49	<0.003
11/15 - 11/22	5.6	6.0	0.25	0.03	0.04	0.12	0.08	0.59	0.15	0.82	<0.003
11/22 - 11/29	6.2	8.1	0.06	0.34	0.35	0.34	<0.02	1.20	0.39	0.71	<0.003
11/29 - 12/06	6/1	4.9	0.07	0.02	0.05	0.09	0.06	0.19	0.12	0.76	<0.003
12/06 - 12/13	Dry										
12/13 - 12/20	5.8	8.8	0.35	0.07	0.28	0.38	0.15	1.23	0.53	0.68	<0.003
12/20 - 12/27	6.0	5.5	0.28	0.06	0.15	0.23	0.10	0.50	0.23	0.74	<0.003
1984											
12/27 - 01/03	6.0	4.3	0.08	0.02	0.08	0.20	0.05	0.34	0.24	<0.10	<0.003
01/03 - 01/10	Dry										
01/10 - 01/17	4.9	8.8	0.16	0.02	0.03	0.06	0.17	1.20	0.11	0.78	<0.003
01/17 - 01/24	6.1	16.0	0.57	0.18	0.16	0.58	<0.09	2.35	0.56	2.68	<0.014
01/24 - 01/31	6.1	3.3	0.04	0.02	0.04	0.09	<0.02	<0.02	0.12	<0.10	<0.003
01/31 - 02/07	6.0	2.1	0.07	0.03	0.04	0.14	0.07	0.04	0.15	0.23	<0.003
02/07 - 02/14	6.0	2.6	0.03	0.01	0.01	0.02	0.08	0.06	0.07	<0.10	<0.003
02/14 - 02/21	5.9	11.2	0.72	0.09	0.07	0.22	<0.02	1.32	0.29	0.91	<0.003
02/21 - 02/28	6.2	2.0	0.07	0.02	0.03	0.04	0.06	<0.02	0.08	<0.10	<0.003
02/28 - 03/06	5.9	6.2	0.38	0.05	0.11	0.13	0.11	0.84	0.17	0.81	<0.003
03/06 - 03/13	Dry										
03/13 - 03/20	6.7	19.6	2.27	0.24	0.14	0.46	0.24	1.69	0.36	2.26	<0.003
03/20 - 03/27	5.4	3.4	0.08	0.01	0.01	0.02	0.03	0.42	<0.02	0.34	<0.003
03/27 - 04/03	6.2	12.8	1.28	0.10	0.06	0.26	0.28	1.58	0.34	2.02	0.01
04/03 - 04/10	6.3	11.5	1.06	0.12	0.13	0.38	0.09	1.04	0.41	2.06	<0.003
04/10 - 04/17	Dry										
04/17 - 04/24	6.6	23.4	1.55	0.47	0.15	1.03	0.33	1.38	1.05	2.10	<0.020
04/24 - 05/01	6.6	10.2	1.14	0.12	0.07	0.33	0.03	0.81	0.39	1.02	<0.003
05/01 - 05/08	Dry										
05/08 - 05/15	Dry										
05/15 - 05/22	6.2	9.1	0.48	0.08	0.08	0.29	0.46	1.03	0.28	1.07	<0.003
05/22 - 05/29	Dry										
05/29 - 06/05	6.2	14.7	1.28	0.19	0.17	0.30	0.16	1.76	0.33	2.32	<0.003
06/05 - 06/12	Dry										
06/12 - 06/19	5.6	7.5	0.53	0.06	0.04	0.10	0.23	0.88	0.13	0.23	<0.003
06/19 - 06/26	5.3	10.7	0.54	0.07	0.05	0.12	0.32	1.46	0.16	1.67	<0.003
06/26 - 07/03	4.9	11.6	0.26	0.05	0.05	0.08	0.24	1.07	0.14	1.27	<0.003
07/03 - 07/10	5.4	17.2	1.36	0.10	0.13	0.20	0.46	3.08	0.28	2.34	<0.003
07/10 - 07/17	4.4	23.7	0.35	0.06	0.07	0.11	0.21	2.19	0.16	2.03	<0.003
07/17 - 07/24	Dry										
07/24 - 07/31	4.8	19.2	0.84	0.07	0.05	0.08	0.69	2.64	0.17	2.54	<0.003
07/31 - 08/07	4.7	13.1	0.19	0.02	0.02	0.04	0.25	1.14	0.11	1.24	<0.003
08/07 - 08/14	4.9	10.6	0.27	0.04	0.10	0.11	0.32	1.19	0.17	1.14	<0.003

Table E-XXVIII

Analyses of Deer and Elk Hair

	Date Animal Found							
	11/81	11/81	12/81	12/81	6/82	12/82	5/83	5/84
Type of Animal	Elk	Deer	Deer	Deer	Deer	Deer	Deer	Elk
Location	TA-15	Ponderosa Campground	TA-16	Pajarito Road by TA-46	TA-37	TA-39	Pajarito Road 2 km east of TA-18	TA-16
Cause of Death	Road Kill	Poached	Shot	Road Kill	Road Kill	Found Dead	Road Kill	Found Dead
Concentration in Hair Samples								
U (ppb)	41 ± 8	130 ± 26	360 ± 80	20 ± 20	18 ± 10	370 ± 80	230 ± 50	<144
Hg (ppb)	44 ± 16	21 ± 24	---	150 ± 20	---	---	---	
Zn (ppm)	73 ± 14	101	±.20	143 ± 28	5 ± 1.0	115 ± 46	54 ± 22	117 ± 48
Ba (ppm)	18 ± 24	36 ± 8	74 ± 16	6 ± 1.8	16 ± 5.4	7.2 ± 2.6	41 ± 12	---
Cr (ppm)	3.5 ± 0.8	6.8 ± 1.4	19.6 ± 3.8	3.9 ± 0.8	3.5 ± 0.8	1.3 ± 0.2	7.6 ± 1.6	---
As (ppm)	<0.04	0.12 ± 0.12	0.54 ± 0.36	<0.07	---	---	---	---
F (ppm)	---	8.9 ± 1.8	---	---	4.1 ± 0.8	4.8 ± 0.8	17 ± 2.0	---
^{137}Cs (pCi/g)	-3 ± 7.8	0.8 ± 3.8	---	-0.2 ± 0.2	0.15 ± 1.4	0 ± 1.0		
Pb (ppm)	---	---	---	---	1.9 ± 0.4	1.6 ± 0.2	37 ± 6.0	---

Table E-XXIX

Climatological Summary (1911-1984) for Los Alamos, New Mexico: Means[a] and Extremes of Temperature and Precipitation[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	69.4	1980	60.4	1965	95	6/22/81	28	6/3/19
Jul	80.4	56.1	68.2	71.4	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	42.8	1984	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	20.0	1984	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	3.21	1984	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	112.8	1984	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-XXIX (cont)

Climatological Summary for 1984

Month	Temperature (°F)						
	Means			Extremes			
	Mean Max	Mean Min	Avg	High	Date	Low	Date
Jan	39.2	14.3	26.7	52	5,6	−2	18
Feb	45.2	19.4	32.3	55	29	11	12
Mar	49.0	24.3	36.7	65	21	8	6
Apr	56.2	29.4	42.8	74	17	21	3
May	74.9	45.9	60.4	86	22,24	27	8
Jun	78.9	49.6	64.2	88	23,28	42	3,4
Jul	83.5	54.6	69.0	90	19,20	51	17,18
Aug	78.9	53.1	66.0	86	29	50	21
Sept	73.1	47.0	60.1	87	9	31	29
Oct	52.7	33.0	42.8	68	10,11	21	16
Nov	48.7	27.1	37.9	63	7	9	27
Dec	40.2	21.8	31.0	55	7	7	22
Annual	60.0	35.0	47.5	90	7/19,20	−2	1/18

Month	Precipitation(in.)						Number of Days		
	Rain[a]			Snow					
	Total	Daily Max	Date	Total	Daily Max	Date	Precip ≥0.10 in.	Max Temp ≥90°F	Min Temp ≤32°F
Jan	0.63	0.39	14	14.2	8.5	14	2	0	31
Feb	0.14	0.11	17	1.0	0.7	17	1	0	29
Mar	2.04	0.60	26	34.0	10.0	26	5	0	28
Apr	0.49	0.19	20	2.2	0.9	26	1	0	24
May	0.71	0.56	15	0	0	---	2	0	1
Jun	0.76	0.15	19,30	0	0	---	2	0	0
Jul	2.50	0.69	1	0	0	---	7	2	0
Aug	3.86	1.04	20	0	0	---	8	0	0
Sept	1.69	0.54	21	0	0	---	4	0	1
Oct	3.02	0.60	21	20.0	6.0	21	8	0	13
Nov	0.34	0.10	23	3.3	1.0	23,24	1	0	23
Dec	3.21	1.09	14	38.1	21.0	14	5	0	30
Annual	19.39	1.09	12/14	112.8	21.0	12/14	46	2	180

Table E-XXX

Weather Highlights of 1984

January	Cool. Mean temperature = 26.7°F (Normal = 29.1°F). Mean low temperature = 14.3°F (Normal = 18.5°F). Snowstorm on 13th-14th: 14.0 in. SMDS on the 13th: 5.5 in. SMDS on the 14th: 8.5 in.
February	Very dry: 0.14 in. precipitation (Normal = 0.68 in.). Only 1.0 in. snowfall (Normal = 7.3 in.). Windstorms on the 10th and 14th: peak winds of 55 and 51 mph, respectively.
March	Very snowy and wet. Snowfall = 34.0 in. (Normal = 9.7 in.). 4th snowiest March on record (most was 36.0 in. in 1973). Precipitation = 2.04 in. (Normal = 1.01 in.). Snowstorm during 26th-28th drops 20.5 in. SMDH on the 21st: 65°F. SMDP on the 26th: 0.60 in. SMDS on the 26th: 10.0 in. SMDS on the 27th: 5.0 in. SMDS on the 28th: 5.5 in.
April	Cool. Mean temperature = 42.8°F (Normal = 45.6°F). Strong winds with peak winds ≥ 50 mph on 2nd, 9th, 11th, 13th, and 25th. Highest peak wind was 60 mph on the 25th. Very cold on 26th: only reached 34°F for high temperature.
May	Very warm. Mean temperature = 60.4°F (Normal = 54.9°F). 2nd warmest May on record (Warmest was 1956 with 60.5°F). Highest average temperature for May on record: 74.9°F (previous highest was in 1974: 72.7°F). There were 12 days in month with high temperatures ≥ 80°F. SMDH on the 10th: 79°F. SMDH on the 11th: 82°F (Also warmest for so early in the year). SMDH on the 12th: 83°F (Also warmest for so early in the year). TMDH on the 20th: 81°F. SMDH on the 22nd: 86°F. TMDH on the 23rd: 81°F. SMDH on the 24th: 86°F. SMDH on the 25th: 82°F. TMDH on the 26th: 82°F.
June	Near normal temperatures and rainfall.

Table E-XXX (cont)

July	Warm daytime temperatures. Mean high temperature = 83.5°F (Normal = 80.4°F). SMDP on the 1st: 0.69 in. TMDH on the 20th: 90°F. Haze on 25th-27th with visibility ≤20 miles at times.
August	Near normal temperatures and rainfall.
September	Near-normal temperatures and precipitation. SMDH on the 9th: 87°F. SMDH on the 19th: 83°F. Very cold on 26th: high temperature of 41°F. Snow in the mountains on the 26th.
October	Record cold and snow. Mean temperature = 42.8°F (Normal = 50.3°F). Coldest October on record (Previous coldest was in 1976: 44.4°F). Mean high temperature = 52.7°F (Normal = 62.0°F). Coldest mean high temperature on record for October (previous: 55.0°F—1970). Snowfall = 20.0 in. (Normal = 1.7 in.). Snowiest October on record (Previous: 9.0 in.—1972). Precipitation = 3.02 in. (Normal = 1.52 in.). TMDP on the 3rd: 0.59 in. SMDP on the 15th: 0.59 in. TMDS on the 15th: 4.0 in. TMDL on the 15th: 25°F. SMDL on the 16th: 21°F (also coldest for so early in the season). Windy on the 16th: peak gust = 62 mph. SMDS on the 21st: 6.0 in. SMDS on the 22nd: 1.5 in. SMDS on the 23rd: 3.5 in. SMDS on the 24th: 4.0 in. There were 6 days (3rd, 15th, 20th-23rd) in month thad had lowest high temperatures for date.
November	Near normal temperatures. Dry: 0.34 in. precipitation.
December	Wet and snowy. Precipitation = 3.21 in. (Normal = 0.96 in.). Wettest December on record (previous wettest was 1965: 2.85 in.). Snowfall = 38.1 in. (Normal = 11.4 in.). Second snowiest December on record (snowiest was in 1967: 41.3 in.). Third snowiest month on record. SMDP on the 14th: 1.09 in. SMDS on the 14th: 21.0 in. Also second largest snowfall in a day on record (Most: 22.0 in. on 12/6/78). Most snow from single snowstorm on record (previous greatest was 32.1 in. during 4/10-4/13 1975). SMDP on the 27th: 0.74 in.

Table E-XXX (cont)

Annual	1984 mean temperature = 47.5°F (Normal = 48.1°F). 1984 precipitation = 19.39 in. (Normal = 17.83 in.). 1984 snowfall = 112.8 in. (Normal = 50.8 in.). Snowiest calendar year on record (previous snowiest: 1958 at 100.0 in. and 1982 at 99.4 in.).

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 Maximum Daily Snowfall Record

Table E-XXXI

Estimated Concentrations of Toxic Elements Aerosolized by Dynamic Experiments

Element	1984 Total Usage (kg)	Fraction Aerosolized (%)	Annual Average Concentration (ng/m^3) 4 km	Annual Average Concentration (ng/m^3) 8 km	Applicable Standard (ng/m^3)
Uranium	840.5	10	0.08	0.03	9000[a]
Be	17.5	2	0.0005	0.0001	10[b]
Pb	81.8	100[c]	0.09	0.04	1500[d]

[a]Reference (DOE 1981).
[b]Thirty-day average. New Mexico Air Quality Control Regulation 201.
[c]Assumed percentage aerosolized.
[d]Three-month average. 40 CFR 50.12.

Table E-XXXII

Particulate Air Quality ($\mu g/m^3$)

Federal and State Ambient Air Quality Standards		Measurements	
Type	**Concentration**	**Los Alamos**	**White Rock**
24-hour average[a]			
State[b]	150	69[c] (72)[d]	157[c] (202)[d]
Federal			
Primary	260		
Secondary	150		
7-day average[b]	110		
30-day average[b]	90		
Annual geometric mean		31	36
Primary	75		
Secondary[b]	60		
Seasonal arithmetic mean			
Winter		36	34
Spring		41	84
Summer		28	36
Fall		31	28

[a]Not to be exceeded more than once per year.
[b]New Mexico State standard only.
[c]Second highest.
[d]Highest.

Table E-XXXIII

Stack Gas Sampling Results from Beryllium Shop for 1984

Sample Date	Be on Filter (μg)	Hours Operated	Stack Concentration (μg/m³)	Emissions (g)
01-20-84	0.23	51.7	0.00119	0.185
01-30-84	0.17	36.9	0.00123	0.137
02-15-84	0.24	51.2	0.00125	0.193
02-3-84	0.06	43.3	0.00037	0.048
03-20-84	0.05	61.0	0.00022	0.040
03-30-84	0.21	52.4	0.00107	0.169
07-06-84	0.11	68.0	0.00043	0.089
08-07-84	0.32	137.5	0.00062	0.258
08-24-84	0.12	57.4	0.00056	0.097
09-21-84	0.42	72.0	0.00156	0.338
10-05-84	0.07	60.2	0.00031	0.056
10-26-84	0.07	53.7	0.00035	0.056
11-08-84	0.03	50.0	0.00016	0.024
12-05-84	0.05	45.7	0.00029	0.040
12-28-84	0.18	49.1	0.00098	0.145
			Total	1.877

Table E-XXXIV

Asbestos Removal Notifications

Facility	Dates			Amount	
	Notice	Start	Completion	Pipe Components (ft)	Other (ft²)
TA-22-5, -34, -52	01-26-84	01-23-84	02-17-84	---	---
Small renovation jobs, 1984	06-14-84	07-01-84	12-30-84	1410	404
TA-9-21	07-30-84	08-06-84	08-17-84	300	640
TA-16-207	08-13-84	09-10-84	11-02-84	660	0
TA-22-1	09-17-84	10-09-84	11-09-84	3100	0
TA-3-34	09-20-84	09-19-84	09-30-84	300	100 valves
Small renovation jobs, 1985	12-10-84	01-02-85	12-31-85	2620	810
TA-21-46	12-12-84	03-04-85	03-15-85	300	0
TA-21-14	12-12-84	03-04-85	03-15-85	300	0
TA-15-20	12-19-84	12-20-84	12-23-84	380	0

Table E-XXXV

Quantities of Volatile Chemicals and Compressed Gases Used at Los Alamos[a] (all amounts in kg)

	1982	1983	1984
Acids			
Acetic Acid	170	---	99
Hydrochloric Acid	6 000	1 400	1 655
Hydrofluoric Acid	270	640	191
Nitric Acid	70 500	52 100	55 976
Perchloric Acid	180	60	321
Phosphoric Acid	490	30	111
Sulfuric Acid	2 200	2 600	692
Gases			
Ammonia	1 800	2 400	2 177
Carbon Monoxide	9 600	---	2 965
Chlorine	610	140	1 238
Freon 12	1 600	2 600	4 137
Hydrogen Fluoride	1 600	1 600	1 134
Nitrogen Oxides	330	410	354
Sulfur Dioxide	210	30	0
Sulfur Hexafluroide	8 800	14 200	9 507
Inorganic Chemicals			
Ammonium Hydroxide	1 200	2 100	797
Mercury	210	60	24
Sodium Hydroxide	---	39 500	73 539
Organic Chemicals			
Acetone	10 700	10 900	10 118
Benzene	---	70	12
Carbon Tetrachloride	190	60	103
Chloroform	320	500	177
Ethanol	12 800	13 500	7 024
Freons	32 200	28 400	22 006
Kerosene	5 500	2 800	1 315
Methanol	3 100	730	3 298
Methylene Chloride	430	100	1 876
Methyl Ethyl Ketone	400	6 200	5 805
Perchloroethylene	340	---	2
Tetrahydrofuran	---	---	30
Toluene	60	190	337
Trichloroethane	25 600	31 100	27 674
Trichloroethylene	390	4 200	2 204
Xylene	---	70	59

[a]This table does not include chemicals received under special orders.

Table E-XXXVI

Quality of Effluents from Liquid Radioactive Waste Treatment Plants for 1984

Radioactive Isotopes	Waste Treatment Plant Location: TA-50 Activity Released (mCi)	TA-50 Mean Concentration (μCi/mℓ)	TA-50 Mean as % CG[a]	TA-21 Activity Released (mCi)	TA-21 Mean Concentration (μCi/mℓ)	TA-21 Mean as %CG[a]
^{238}Pu	6.1	1.7×10^{-7}	0.17	0.09	2.1×10^{-8}	0.02
$^{239,240}Pu$	8.1	2.3×10^{-7}	0.23	0.13	3.1×10^{-8}	0.03
^{241}Am	8.2	2.3×10^{-7}	0.23	0.84	2.0×10^{-7}	0.20
^{89}Sr	262	7.5×10^{-6}	2.5	0.16	3.8×10^{-8}	0.01
^{90}Fr	6.8	1.9×10^{-7}	1.9	0.23	5.5×10^{-8}	0.55
^{3}H	12,700	3.6×10^{-4}	0.36	542	1.3×10^{-4}	0.13
^{137}Cs	19.5	5.6×10^{-7}	0.14	0.16	3.8×10^{-8}	0.01
^{234}U	3.8	1.1×10^{-7}	0.11	3.6	8.6×10^{-7}	0.86
Total Effluent Volume:	3.503×10^{7} ℓ			4.198×10^{6} ℓ		

Nonradioactive Constituent	Waste Treatment Plant Location: TA-50 Mean Concentration (mg/ℓ)	TA-21 Mean Concentration (mg/ℓ)
Cd[b]	0.003	0.005
Ca	120	16
Cl	84	27
Cr (total)[b]	0.13	0.07
Cu[b]	0.44	0.022
F	12	79
Hg[b]	0.0013	0.0006
Mg	4	3.6
Na	972	908
Pb[b]	0.029	0.03
Zn[b]	0.24	0.25
CN	0.082	0.022
COD[b]	73	60
$NO_3(N)$	331	159
PO_4	0.62	0.86
TDS	3400	2820
pH[b]	7.0-12.8	8.6-12.5
Total Effluent Volume	3.5×10^{7} ℓ	4.2×10^{6} ℓ

[a]Department of Energy's Concentration Guide for Controlled Areas.
[b]Constituents regulated by National Pollutant Discharge Elimination System permit.

Table E-XXXVII

Quality of Effluent from the Los Alamos Meson Physics Facility's (TA-53) Lagoons

Radioactive Isotope	Activity Released (mCi)	Mean Concentration (μCi/mℓ)	Mean as % CG[a]
^{7}Be	7630	4.3×10^{-4}	0.86
^{57}Co	258	1.5×10^{-5}	0.15
^{60}Co	36	2.0×10^{-6}	0.20
^{134}Cs	125	7.1×10^{-6}	2.4
^{3}H	33,700	1.9×10^{-3}	1.9
^{54}Mn	80	4.5×10^{-6}	0.15
^{22}Na	170	9.6×10^{-6}	1.1
Total Effluent Volume Released	1.77×10^{7} ℓ		

[a]Department of Energy's Concentration Guide for Controlled Areas.

Table E-XXXVIII

Radiochemical and Chemical Quality of Water from Municipal Supply and Distribution Systems

		Radiochemical							
	1984 (month-day)	^{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)
Well Field and Gallery									
Los Alamos Field									
Well LA-1B	2-23	-16 ± 26	0.005 ± 0.034	0.010 ± 0.026	5.0 ± 4.0	7.5 ± 1.8	0.3 ± 0.4	6.7 ± 2.6	-55 ± 36
Well LA-1B	8-14	53 ± 98	0.030 ± 0.080	0.030 ± 0.060	2.0 ± 4.0	3.5 ± 1.2	0.7 ± 0.8	7.0 ± 1.4	0 ± 200
Well LA-2	2-23	-21 ± 46	0.004 ± 0.022	0.070 ± 0.080	6.7 ± 3.8	6.2 ± 1.6	0.6 ± 0.4	6.1 ± 2.4	-73 ± 36
Well LA-2	8-14	61 ± 108	-0.018 ± 0.026	0.018 ± 0.038	3.6 ± 2.8	2.9 ± 1.0	0.9 ± 0.8	7.3 ± 1.4	0 ± 200
Well LA-4	2-23	0 ± 176	0.014 ± 0.030	0.005 ± 0.026	1.7 ± 1.2	5.9 ± 1.6	0.7 ± 0.4	2.0 ± 0.4	81 ± 36
Well LA-4	8-14	49 ± 82	-0.013 ± 0.024	0.013 ± 0.024	0.1 ± 1.0	3.0 ± 1.0	0.5 ± 0.6	2.0 ± 0.4	0 ± 200
Well LA-5	2-23	-17 ± 34	0.014 ± 0.016	0.050 ± 0.040	2.5 ± 1.8	4.6 ± 1.4	0.0 ± 0.4	1.5 ± 3.0	-69 ± 36
Well LA-5	8-14	51 ± 86	0.020 ± 0.040	0.030 ± 0.040	2.4 ± 2.0	2.6 ± 1.0	0.4 ± 0.6	6.6 ± 1.4	0 ± 200
Guaje Field									
Well G-1	2-23	17 ± 30	0.000 ± 0.000	-0.004 ± 0.000	0.4 ± 1.0	5.4 ± 1.4	0.1 ± 0.4	1.5 ± 3.0	-83 ± 36
Well G-1	8-14	16 ± 86	0.004 ± 0.022	0.004 ± 0.022	-0.3 ± 1.0	4.3 ± 1.2	0.9 ± 0.8	1.6 ± 3.2	0 ± 200
Well G-1A	2-23	54 ± 47	0.028 ± 0.026	0.012 ± 0.028	0.2 ± 1.0	4.0 ± 1.2	0.2 ± 0.4	1.5 ± 3.0	-83 ± 36
Well G-1A	8-14	1 ± 32	0.004 ± 0.028	0.008 ± 0.024	0.5 ± 1.2	2.9 ± 1.0	0.7 ± 0.8	0.9 ± 0.6	0 ± 200
Well G-2	2-23	11 ± 37	0.018 ± 0.028	0.026 ± 0.026	0.7 ± 1.6	5.7 ± 1.6	-0.1 ± 0.4	2.4 ± 1.8	-74 ± 36
Well G-2	8-14	-19 ± 88	-0.030 ± 0.080	0.008 ± 0.024	0.8 ± 1.2	2.7 ± 1.0	0.3 ± 0.6	2.5 ± 0.6	0 ± 200
Well G-3	8-14	19 ± 101	0.020 ± 0.060	0.160 ± 0.100	0.9 ± 1.2	2.9 ± 1.0	0.9 ± 0.8	1.8 ± 0.4	0 ± 200
Well G-4	2-23	15 ± 40	0.022 ± 0.032	0.016 ± 0.038	0.3 ± 1.0	5.1 ± 1.4	0.5 ± 0.4	1.5 ± 3.0	-75 ± 36
Well G-4	8-14	67 ± 88	0.050 ± 0.040	0.220 ± 0.080	0.9 ± 1.6	3.1 ± 1.0	-01 ± 0.6	2.0 ± 0.4	0 ± 200
Well G-5	2-23	17 ± 34	0.013 ± 0.030	0.033 ± 0.028	1.2 ± 1.4	6.4 ± 1.6	0.4 ± 0.4	1.8 ± 0.8	-82 ± 36
Well G-5	8-14	3 ± 102	0.006 ± 0.028	0.006 ± 0.036	0.9 ± 1.2	2.8 ± 1.0	0.4 ± 0.6	1.8 ± 0.4	0 ± 200
Well G-6	2-23	30 ± 48	0.004 ± 0.016	0.004 ± 0.022	1.0 ± 1.4	3.5 ± 1.2	-0.1 ± 0.4	1.6 ± 0.6	-55 ± 36
Well G-6	8-14	37 ± 101	-0.040 ± 0.060	-0.080 ± 0.016	1.3 ± 1.3	3.8 ± 1.0	0.7 ± 0.8	1.6 ± 3.2	0 ± 200
Pajarito Field									
Well PM-1	2-23	27 ± 39	0.015 ± 0.020	0.100 ± 0.060	1.2 ± 1.6	6.5 ± 1.6	0.7 ± 0.4	2.8 ± 2.0	-76 ± 36
Well PM-1	8-14	32 ± 92	0.004 ± 0.018	0.056 ± 0.038	1.4 ± 1.6	5.8 ± 1.6	0.3 ± 0.6	2.5 ± 0.6	0 ± 200
Well PM-2	5-16	0 ± 176	-0.009 ± 0.026	-0.004 ± 0.018	1.3 ± 1.0	37 ± 8.0	0.9 ± 0.4	2.0 ± 4.0	90 ± 36
Well PM-2	8-14	49 ± 92	-0.010 ± 0.060	0.010 ± 0.060	0.5 ± 1.2	2.9 ± 1.0	0.4 ± 0.6	1.6 ± 3.2	120 ± 200
Well PM-3	2-23	-28 ± 41	0.004 ± 0.026	0.050 ± 0.060	0.6 ± 1.4	4.6 ± 1.4	0.7 ± 0.4	1.5 ± 3.0	-86 ± 36
Well PM-3	8-14	57 ± 82	-0.010 ± 0.060	0.010 ± 0.060	0.0 ± 1.2	5.0 ± 1.4	0.5 ± 0.8	2.2 ± 0.4	0 ± 200
Well PM-4	2-23	0 ± 176	0.002 ± 0.026	0.042 ± 0.008	0.5 ± 1.4	3.8 ± 1.2	0.4 ± 0.4	1.5 ± 3.0	-47 ± 36
Well PM-4	8-14	89 ± 138	-0.004 ± 0.026	-0.004 ± 0.011	0.9 ± 1.4	2.7 ± 1.0	1.0 ± 0.8	1.6 ± 3.2	0 ± 200

Table E-XXXVIII (cont)

	1984 (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)
Gallery									
Water Canyon	2-23	1 ± 33	-0.010 ± 0.016	0.014 ± 0.022	0.6 ± 1.0	5.2 ± 1.4	0.4 ± 0.4	1.5 ± 3.0	48 ± 36
Water Canyon	8-15	-30 ± 82	0.033 ± 0.038	0.012 ± 0.028	0.0 ± 1.0	2.5 ± 1.0	0.2 ± 0.6	2.5 ± 0.6	0 ± 200
No. of Analyses		31	31	31	31	31	31	31	31
Minimum		-30 ± 82	-0.040 ± 0.060	-0.080 ± 0.016	-0.3 ± 1.0	2.5 ± 1.0	-0.1 ± 0.4	0.9 ± 0.6	-86 ± 36
Maximum		89 ± 138	0.050 ± 0.040	0.160 ± 0.100	6.7 ± 3.8	37 ± 80	1.0 ± 0.8	7.3 ± 1.4	120 ± 200
Average		20	0.006	0.030	1.3	5.2	0.4	2.6	-17
2s		62	0.037	0.105	3.0	12.2	0.6	3.8	107
Distribution									
Fire Station 1	3-6	18 ± 47	0.004 ± 0.032	0.033 ± 0.038	2.0 ± 2.0	5.1 ± 1.4	0.4 ± 0.4	---	6 ± 36
Fire Station 1	8-9	-4 ± 72	-0.009 ± 0.028	0.013 ± 0.032	0.4 ± 0.1	3.6 ± 1.2	0.8 ± 0.8	1.6 ± 3.2	110 ± 80
Fire Station 2	3-6	2 ± 36	0.004 ± 0.032	0.004 ± 0.028	6.2.±3.6	4.3 ± 1.4	0.0 ± 0.4	---	-24 ± 36
Fire Station 2	8-9	-33 ± 98	0.010 ± 0.032	-0.015 ± 0.020	2.1 ± 2.2	4.0 ± 1.2	0.1 ± 0.6	4.7 ± 0.5	130 ± 100
Fire Station 3	3-6	13 ± 38	0.040 ± 0.040	0.040 ± 0.060	3.9 ± 2.6	6.4 ± 1.6	0.5 ± 0.4	---	-36 ± 36
Fire Station 3	8-9	8 ± 94	0.014 ± 0.038	0.019 ± 0.036	2.7 ± 2.2	3.6 ± 1.2	0.2 ± 0.6	3.5 ± 0.8	0 ± 200
Fire Station 4	3-6	36 ± 35	-0.004 ± 0.024	0.026 ± 0.026	3.8 ± 2.6	5.3 ± 1.4	0.5 ± 0.4	---	-64 ± 36
Fire Station 4	8-9	-27 ± 78	-0.004 ± 0.028	0.004 ± 0.020	0.3 ± 1.0	2.9 ± 1.0	0.8 ± 0.4	2.1 ± 0.4	0 ± 200
Fire Station 5	3-6	9 ± 45	-0.008 ± 0.013	0.033 ± 0.034	2.8 ± 1.8	3.5 ± 1.2	0.0 ± 0.4	---	-26 ± 36
Fire Station 5	8-9	67 ± 100	-0.015 ± 0.024	0.005 ± 0.030	1.0 ± 1.2	2.8 ± 1.0	0.6 ± 0.8	1.6 ± 3.2	0 ± 200
Bandelier National Monument	8-20	91 ± 138	-0.030 ± 0.060	0.030 ± 0.060	1.2 ± 1.6	3.1 ± 1.0	1.2 ± 0.8	2.1 ± 0.8	0 ± 200
Fenton Hill (TA-57)	3-13	20 ± 42	-0.021 ± 0.032	0.040 ± 0.060	---	---	0.6 ± 0.4	---	1860 ± 60
Fenton Hill (TA-57)	8-16	44 ± 138	-0.003 ± 0.022	0.010 ± 0.020	1.5 ± 1.8	5.8 ± 1.6	0.7 ± 0.8	2.5 ± 0.6	220 ± 100
No. of Analyses		13	13	13	12	12	13	7	13
Minimum		-33 ± 98	-0.030 ± 0.060	-0.015 ± 0.020	0.3 ± 1.0	2.8 ± 1.0	0.0 ± 0.4	1.6 ± 3.2	-64 ± 36
Maximum		91 ± 138	0.040 ± 0.040	0.040 ± 0.060	6.2 ± 3.6	6.4 ± 1.6	1.2 ± 0.8	4.7 ± 0.5	1860 ± 60
Average		19	-0.002	0.020	2.3	4.2	0.5	2.6	167
2s		69	0.035	0.030	3.4	2.4	0.7	2.3	1029
Maximum Contaminant Level[a]		200	15	15	15[b]	---	20	1800	---
Standby Well (not part of water supply)									
Well LA-6	2-23	9 ± 15	0.005 ± 0.032	0.018 ± 0.032	2.7 ± 2.4	3.8 ± 1.6	-0.3 ± 0.4	1.7 ± 0.8	-100 ± 36

Table E-XXXVIII (cont)

Well Fields and Gallery	1984 (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-1B	02-23	<0.001	0.043	0.05	<0.0002	0.020	3.2	<0.0001	1.6	0.016	<0.003
Well LA-2	02-23	<0.001	0.013	0.09	<0.0002	0.020	1.6	<0.0001	1.8	<0.002	<0.003
Well LA-3	05-15	<0.001	0.008	0.04	<0.0002	0.009	0.6	<0.0001	1.1	<0.002	<0.003
Well LA-4	05-16	<0.001	0.003	0.03	<0.0002	0.003	1.8	<0.0001	1.9	<0.002	<0.003
Well LA-5	02-23	<0.001	0.011	0.06	<0.0002	0.005	0.3	<0.0001	1.1	<0.002	<0.003
Guaje Field											
Well G-1	02-23	<0.001	<0.003	0.06	<0.0002	0.004	0.4	<0.0001	1.5	<0.002	<0.003
Well G-1A	02-23	<0.001	0.004	0.05	<0.0002	0.005	0.4	<0.0001	0.9	<0.002	<0.003
Well G-2	02-23	<0.001	0.110	0.03	<0.0002	0.020	1.6	<0.0001	1.0	<0.002	<0.003
Well G-3	09-24	<0.001	<0.003	0.01	<0.0002	0.007	0.3	<0.0001	1.9	<0.002	<0.003
Well G-4	02-23	<0.001	<0.003	0.02	<0.0002	0.003	0.3	<0.0001	1.5	<0.002	<0.003
Well G-5	02-23	<0.001	<0.003	0.01	<0.0002	0.002	0.3	<0.0001	2.0	<0.002	<0.003
Well G-6	02-23	<0.001	<0.003	0.01	--	0.003	0.3	<0.0001	1.7	<0.002	<0.003
Pajarito Field											
Well PM-1	02-23	<0.001	<0.003	0.07	<0.0002	0.004	0.3	<0.0001	1.6	<0.002	<0.003
Well PM-2	05-16	<0.001	<0.003	0.03	<0.0002	0.004	0.0	<0.0001	2.1	<0.002	<0.003
Well PM-3	02-23	<0.001	<0.003	0.05	<0.0002	0.005	0.3	<0.0001	1.1	<0.002	<0.003
Well PM-4	08-24	<0.001	<0.003	0.02	<0.0002	0.008	0.3	<0.0001	1.3	<0.002	<0.003
Water Canyon											
Gallery	02-23	<0.001	<0.003	0.01	<0.0002	0.001	0.1	<0.0001	1.1	<0.002	<0.003
Summary of Well and Gallery											
No. of Analyses		17	17	17	16	17	17	17	17	17	17
Minimum		<0.001	<0.003	0.01	<0.002	0.001	0.3	<0.0001	0.9	<0.002	<0.003
Maximum		--	0.110	0.09	--	0.020	3.2	--	2.1	0.016	--
Average		<0.001	<0.010	0.04	<0.0002	0.01	0.7	<0.0001	1.5	<0.003	<0.003
2s		--	0.050	0.05	--	0.01	1.7	--	0.8	<0.007	--
Distribution											
Fire Station 1	03-06	<0.001	<0.003	0.06	<0.0002	0.004	0.3	<0.0001	2.1	<0.002	<0.003
Fire Station 2	03-06	<0.001	0.022	0.07	<0.0002	0.015	1.5	<0.0001	1.8	<0.002	<0.003
Fire Station 3	03-06	<0.001	0.003	0.03	<0.0002	0.005	0.3	<0.0001	1.8	<0.004	<0.003
Fire Station 4	03-06	<0.001	<0.003	0.03	<0.0002	0.005	0.3	<0.0001	1.5	<0.002	<0.003
Fire Station 5	03-06	<0.001	0.004	0.02	<0.0002	0.004	0.3	<0.0001	1.6	<0.002	<0.003
Bandelier National Monument	03-09	<0.001	<0.003	0.02	<0.0002	0.001	0.3	<0.0001	1.4	<0.002	<0.003
Fenton Hill (TA-57)	03-13	<0.001	<0.003	0.07	<0.0002	0.001	0.1	<0.0001	0.9	<0.002	<0.003
Summary of Distribution											
No. of Analyses		7	7	7	7	7	7	7	7	7	7
Minimum		<0.001	<0.001	0.02	<0.0002	0.001	0.1	<0.0001	0.9	<0.002	<0.003
Maximum		--	0.022	0.07	--	0.015	1.5	--	2.1	<0.004	--
Average		<0.001	<0.010	0.04	0.0002	0.010	0.4	<0.0001	1.6	<0.002	<0.003
2s		--	0.150	0.05	--	0.005	0.9	--	0.7	0.002	--
Primary Maximum Contaminant Level		0.05	0.05	1.0	0.01	0.05	2.0	0.002	45	0.05	0.01
Standby Well (Not part of Water Supply)											
Well LA-6	02-23	<0.001	0.116	0.02	<0.0002	0.008	1.6	<0.0001	0.9	<0.003	<0.003

Table E-XXXVIII (cont)

	1984 (month-day)	Cl	Cu	Fe	Mn	SO_4	Zn	TDS	pH
Well Field and Gallery									
Los Alamos Field					z				
Well LA-1B	02-23	17	0.08	0.080	0.003	39	0.01	461	8.0
Well LA-2	02-23	16	<0.01	0.003	<0.001	14	<0.01	215	8.4
Well LA-4	05-16	2	<0.01	0.006	<0.001	3	<0.01	113	8.1
Well LA-5	02-23	3	<0.01	0.006	<0.001	3	<0.01	123	8.5
Guaje Field									
Well G-1	02-23	3	<0.01	<0.003	<0.001	4	<0.01	172	8.3
Well G-1A	02-23	3	<0.01	0.009	<0.001	4	0.01	164	8.3
Well G-2	02-23	4	<0.01	0.007	<0.001	6	0.01	212	8.5
Well G-4	02-23	3	<0.01	0.012	<0.001	4	<0.01	144	8.0
Well G-5	02-23	3	<0.01	0.007	<0.001	4	0.06	153	8.2
Well G-6	02-23	3	<0.01	0.008	<0.001	3	<0.01	154	8.2
Pajarito Field									
Well PM-1	02-23	7	<0.01	0.003	<0.001	5	<0.01	217	8.0
Well PM-2	05-16	2	<0.01	0.004	<0.001	1	0.01	142	7.8
Well PM-3	02-23	8	<0.01	<0.003	<0.001	5	<0.01	222	7.9
Water Canyon									
Gallery	02-23	<1	<0.01	0.047	<0.001	1	<0.01	89	7.8
No. of analyses		14	14	14	14	14	14	14	14
Minimum		<1	<0.01	<0.003	<0.001	1	<0.01	89	7.8
Maximum		17	0.08	0.047	0.003	39	0.06	461	8.5
Average		<5	<0.02	<0.010	<0.001	7	<0.01	184	8.1
2s		10	0.04	0.04	0.001	19	0.03	179	0.5
Distribution									
Fire Station 1	03-06	8	<0.01	<0.003	<0.001	5	0.07	211	7.8
Fire Station 2	03-06	8	<0.01	0.012	<0.001	4	<0.01	246	8.1
Fire Station 3	03-06	3	<0.01	0.005	<0.001	4	<0.01	153	7.9
Fire Station 4	03-06	3	<0.01	0.011	<0.001	4	<0.01	156	7.9
Fire Station 5	03-06	3	<0.01	0.007	<0.001	4	0.05	122	7.7
Fenton Hill (TA-57)	03-13	20	<0.01	0.011	<0.001	8	0.27	245	8.2
No. of Analyses		6	6	6	6	6	6	6	6
Minimum		3	<0.1	<0.003	<0.001	4	<0.01	122	7.7
Maximum		20	---	0.012	---	8	0.27	246	8.2
Average		8	<0.1	<0.010	<0.001	5	<0.07	189	7.9
2s		13	---	0.007	---	3	0.20	105	0.4
Secondary Maximum Contaminant Level		250	1.0	0.3	0.05	250	5.0	500	6.5 - 8.5
Standby Well (not part of Water Supply)									
Well LA-6	02-23	3	<0.01	0.300	0.002	5	0.01	199	8.7

Table E-XXXVIII (cont)

Station	1984 (month-day)	SiO_2	Ca	Mg	K	Na	CO_4	HCO_3	PO_4	Total Hard	Cond (mS/m)
		Miscellaneous Chemical Analyses (concentrations in mg/ℓ)									
Well Field and Gallery											
Los Alamos Field											
Well 1B	02-23	40	7	0.3	2	157	0	382	<0.1	19	74
Well 2	02-23	31	7	0.1	1	69	1	156	<0.1	19	35
Well 3	05-15	32	11	0.3	1	37	2	108	<0.1	38	22
Well 4	02-23	40	13	0.4	2	19	0	86	<0.1	33	14
Well 5	02-23	41	8	0.0	1	24	2	84	0.2	20	16
Guaje Field											
Well G-1	02-23	79	11	0.5	3	20	0	88	0.4	32	16
Well G-1A	02-23	80	11	0.5	2	22	0	89	<0.1	30	16
Well G-2	02-23	53	9	0.6	1	60	4	157	0.1	25	14
Well G-3	08-14	58	11	1.4	2	23	0	89	<0.1	36	15
Well G-4	02-23	53	17	2.8	2	12	0	90	0.1	53	16
Well G-5	02-23	59	17	3.5	2	11	0	90	<0.1	56	16
Well G-6	02-23	60	17	2.7	2	12	0	94	<0.1	52	16
Pajarito Field											
Well PM-1	02-23	73	25	6.0	3	18	0	138	<0.1	87	27
Well PM-2	05-16	77	9	3.1	2	10	0	66	<0.5	37	11
Well PM-3	02-23	87	24	7.8	3	16	0	141	<0.1	90	27
Gallery											
Water Canyon	02-23	32	6	3.0	1	5	0	47	0.6	28	8
No. of Analyses		16	16	16	16	16	16	16	16	16	16
Minimum		31	6	0.0	1	5	0	47	<0.1	19	8
Maximum		80	25	7.8	3	157	4	382	0.6	90	74
Average		56	12	2.0	2	32	0	119	<0.2	41	21
2s		37	11	4.5	1	75	2	153	<0.3	43	31
Distribution											
Fire Station 1	03-06	90	24	6.8	3	17	0	142	<0.1	90	27
Fire Station 2	03-06	44	8	0.3	1	71	0	189	<0.1	22	37
Fire Station 3	03-06	73	12	1.8	2	19	0	90	<0.1	40	16
Fire Station 4	03-06	73	13	1.8	2	19	0	89	<0.1	43	16
Fire Station 5	03-06	50	7	2.5	1	20	0	78	<0.1	30	14
Fenton Hill (TA-57)	03-13	68	42	3.9	4	13	0	140	<0.1	113	30
No. of Analyses		6	6	6	6	6	6	6	6	6	6
Minimum		50	8	0.3	1	13	0	78	<0.1	22	14
Maximum		90	42	3.9	4	71	0	189	<0.1	113	37
Average		66	17	2.8	2	26	0	121	<0.1	56	23
2s		33	26	4.5	2	43	0	86	<0.0	73	18
Standby Well (not part of Water Supply)											
Well LA-6		29	2	<1	1	68	7	160	<0.1	6	31

[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-XXXIX

Effluent Quality Summary of Sanitary Sewage Treatment Facilities

Discharge Location	Permit Constituents	Number of Deviations	Range of: [Deviation / Limiting Standard] or pH
TA-3	BOD[b]	4	1.0 - 3.4
	TSS[c]	2	1.06 - 1.13
	Fecal Coliform[d]	4	1.1 - 2.5
	pH[e]	1	3.2
TA-8	BOD	3	1.1
	TSS (90)[c]	1	1.2
	pH	3	9.4 - 9.9
TA-9	BOD	0	---
	TSS	0	---
	pH	0	---
TA-16	BOD	1	1.1
	TSS	1	1.2
	pH	0	---
TA-18	BOD	0	---
	TSS (90)[c]	0	---
	pH	0	---
TA-21	BOD	3	1.0 - 2.1
	TSS	3	1.1 - 2.28
	pH	5	9.2 - 10.9
TA-35	BOD	13	1.0- 3.6
	TSS (90)[c]	0	---
	pH	2	9.1 - 10.0
TA-41	BOD	0	---
	TSS	0	---
	Fecal Coliform[d]	8	1.1 - 25.0
	pH	0	---
TA-46	BOD	0	---
	TSS	0	---
	pH	0	---
TA-48	BOD	0	---
	TSS	1	---
	pH	0	---
TA-53	BOD	3	1.2 - 1.3
	TSS (90)[c]	3	1.2 - 1.5
	pH	13	9.1 - 10.1

[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 mgℓ (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.

Table E-XL

Effluent Quality Summary of Industrial Outfalls[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	1	TSS	0	---	0
		Free Cl	0	---	0
		pH	0	---	1
Blower Blowdown	1	TSS	2	1.0 - 455.0	1
		Fe	0	---	0
		Cu	3	1.8 - 4.3	1
		P	1	1.0	1
		pH	4	9.8 - 10.8	1
Treated Cooling Water	30	TSS	3	1.2 - 1.8	3
		Free Cl	7	1.8 - 22.8	5
		P	0	---	0
		pH	2	9.18 - 9.31	1
Noncontact Cooling Water	30	pH	0	---	0
Radioactive Waste Treatment Plant Discharges	2	H_3	0	---	0
		COD	0	---	0
		TSS	0	---	0
		Cd	0	---	0
		Cr	3	1.5 - 2.8	2
		Cu	1	2.1	1
		Fe	6	1.1 - 9.5	1
		Pb	4	1.1 - 1.9	2
		Hg	0	---	0
		Zn	0	---	0
		pH	0	---	0
High Explosives Waste Discharges	20	COD	19	1.0 - 8.1	7
		TSS	3	1.4 - 2.4	3
		pH	8	2.0 - 9.5	5
Photo Waste Discharges	14	Cn	0	---	0
		TSS	0	---	0
		pH	1	5.5	1
		Ag	2	1.1 - 3.2	2
Printed Circuit Board Development Wastes	1	COD	0	---	0
		Cu	0	---	0
		Fe	0	---	0
		Ni	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-XLI

Interactions Among the Laboratory, Environmental Protection Agency, and New Mexico's Environmental Improvement Division Concerning the Resource Conservation and Recovery Act

Date (1984)	Initiator	Action
February 22	EPA	Request for the Resource Conservation and Recovery Act (RCRA) Part B permit is issued to the Laboratory.
April 4	Laboratory	The Laboratory submits the 1983 biannual operators and hazardous waste facilities reports and a revised Part A application to the Environmental Protection Agency (EPA) with a copy to New Mexico's Environmental Improvement Division (EID).
April 23	EID	A request is issued to the Laboratory for a joint calling of the Part B permit.
May 23,25	EID	A RCRA compliance inspection occurs at TA-3, TA-50, and TA-54.
June 22	EID	The Laboratory receives a Notice of Violation (NOV). Major violations include inadequacies in closure/post closure plans at waste disposal areas, waste analyses plans, personnel training, contingency plan, and ground water monitoring at waste disposal areas (failure to perform).
July 26	Laboratory	Responses to the major issues of the NOV are submitted, along with a ground water monitoring waiver request.
August 7	EPA/EID	The Laboratory receives an extension on RCRA Part B to May 1, 1985, and notification that the RCRA Part B is to include mixed waste.
September 7	Laboratory	A meeting is held at the EID to discuss the July 26 submittal. Comments of inadequacies are transmitted.
September 26	Laboratory	A meeting is held at the Laboratory to discuss additional information that might satisfy issues of the NOV.
October 31	EID	The Laboratory receives a second NOV for lacking run-on control, an inadequate RCRA Part A permit, and failure to supply information to an inspector.
November 1	Laboratory	A revised RCRA Part A permit, ground water monitoring waiver request, waste characteristics and analysis plan, personnel training matrix table, and additional requested supporting documentation are submitted to the EID.
November 14	Laboratory	The Laboratory responds to the October 31 NOV issue-by-issue.
December 1	Laboratory	The Laboratory submits a revised closure/post closure plan, Area L disposal information, and other requested information to the EID.

Table E-XLII

External Penetrating Radiation Measurements at Waste Management Areas During 1984

Area	No. of Sampling Locations	No. of Quarterly Measurements	Annual Measurement (mrem)		
			Maximum	Minimum	Mean
Inactive					
A	5	20	133.1 ± 9.3	127.1 ± 9.3	130.6 ± 4.7
B	23	88	138.4 ± 9.3	117.5 ± 9.3	127.6 ± 12.5
C	18	64	145.9 ± 9.4	116.1 ± 9.4	131.1 ± 19.0
E	4	0	---	---	---
F	2	4	114.1 ± 9.3	114.1 ± 9.3	114.1 ± 9.3
T	7	20	280.9 ± 10.1	135.8 ± 9.3	167.9 ± 126.6
U	2	8	151.5 ± 9.3	148.5 ± 9.3	150.0 ± 4.2
V	4	0	---	---	---
Active					
G	27	92	246.8 ± 8.8	130.7 ± 8.4	158.9 ± 49.1

Table E-XLIII

Air Sampling Results for Fourth Quarter at Area G (TA-54)

Station Location[a]	^{3}H pCi/m^3 (10^{-12} µCi/mℓ)					Total U (pg/m^3)			$^{239,240}Pu$ aCi/m^3 (10^{-18} µCi/mℓ)		
	Number of Samples	Max	Min	Mean	Mean as % CG[b]	Number of Samples	Mean	Mean as % CG[b]	Number of Samples	Mean	Mean as % CG[b]
Station 22	3	80 ± 20	25 ± 5	62 ± 64	0.0012	1	12 ± 1.3	0.00001	1	0.5 ± 0.3	0.00005
G-1	3	80 ± 10	17 ± 3	45 ± 64	0.0009	1	24 ± 2.7	0.00001	1	7.7 ± 1.0	0.0004
G-2	3	2100 ± 400	280 ± 50	1290 ± 1850	0.03	1	6.4 ± 0.7	0.00000	1	0.2 ± 0.2	0.00001
G-3	3	21 ± 4	6 ± 1	13 ± 15	0.0003	1	12 ± 1.2	0.00001	1	0.3 ± 0.2	0.00002
G-4	3	34 ± 7	15 ± 3	24 ± 19	0.0005	1	5.0 ± 0.6	0.00000	1	0.1 ± 0.2	0.00000

[a]See Fig. 10 for map of station locations.
[b]Controlled Area Concentration Guides: $^{3}H = 2 \times 10^{-6}$ µCi/mℓ, Total U = 1.8×10^{8} pg/m^3, and $^{239,240}Pu = 2 \times 10^{-12}$ µCi/mℓ.

Table E-XLIV

Radionuclide Concentrations in Soil Samples from Waste Management Areas B and C

	Area B		
	^{3}H (10^{-6} μCi/mℓ)	Total U (μg/g)	$^{239,240}Pu$ (pCi/g)
Depth: 0-1 cm			
Range	2.4 - 4.8	4.9 - 5.7	0.5 - 3.1
$\bar{x} \pm 2s$	3.2 ± 2.7	5.3 ± 0.7	1.7 ± 2.6
No. of Samples	3	3	3
Depth: 1-10 cm			
Range	1.8 - 2.7	5.2 - 6.0	0.6 - 7.4
$\bar{x} \pm 2s$	2.3 ± 0.9	5.5 ± 0.9	3.0 ± 7.6
No. of Samples	3	3	3
Depth: 10-30 cm			
Range	1.8 - 2.4	4.0 - 4.8	0.39 - 1.2
$\bar{x} \pm 2s$	2.2 ± 0.7	4.5 ± 0.8	0.65 ± 0.91
No. of Samples	3	3	3
	Area C		
Depth 0-1 cm			
Range	9.9 - 20	3.7 - 5.6	0.05 - 5.9
$\bar{x} \pm 2s$	15 ± 8.3	4.4 ± 1.9	1.8 ± 5.6
No. of Samples	4	4	4
Depth: 1-10 cm			
Range	6.6 - 11	3.6 - 6.1	0.09 - 2.6
$\bar{x} \pm 2s$	9.2 ± 3.9	4.7 ± 2.4	0.99 ± 2.2
No. of Samples		4	4
Depth: 10-30			
Range	7.9 - 22	3.6 - 5.6	0.33 - 8.5
$\bar{x} \pm 2s$	14 ± 13	4.4 ± 1.8	2.5 ± 8.1
No. of Samples	4	4	4

Table E-XLV

Radiochemical Analyses of Sediment and Runoff Samples from Area G (TA-54)

	Sediments (October 1, 1984)					
Station	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)	^{3}H (pCi/g)	Total Uranium (μg/g)	Gross Gamma (counts/min/g)
1	0.10 ± 0.16	0.002 ± 0.004	0.004 ± 0.004	1.9 ± 0.8	4.1 ± 0.6	8.2 ± 0.6
2	0.17 ± 0.13	0.004 ± 0.004	0.005 ± 0.003	2.1 ± 0.8	2.7 ± 0.4	5.9 ± 0.6
3	0.34 ± 0.18	0.014 ± 0.007	0.011 ± 0.006	2.1 ± 0.8	3.5 ± 0.5	8.0 ± 0.6
4	0.42 ± 0.26	0.015 ± 0.006	0.037 ± 0.009	3.8 ± 1.0	4.2 ± 0.6	9.0 ± 0.6
5	0.16 ± 0.18	0.002 ± 0.005	0.002 ± 0.003	4.7 ± 1.2	2.2 ± 0.4	3.9 ± 0.3
6	0.23 ± 0.15	0.029 ± 0.010	0.440 ± 0.045	3.0 ± 1.0	4.2 ± 0.6	8.9 ± 0.3
7	0.21 ± 0.14	0.073 ± 0.007	0.214 ± 0.024	4.1 ± 1.0	2.2 ± 0.4	5.4 ± 0.6
8	0.17 ± 0.14	0.036 ± 0.009	0.051 ± 0.005	1.8 ± 0.8	3.9 ± 0.5	7.9 ± 0.6
9	0.11 ± 0.18	0.032 ± 0.008	0.030 ± 0.007	2.7 ± 0.8	2.8 ± 0.4	4.4 ± 0.6
$\bar{x} \pm 2s$	0.21 ± 0.21	0.023 ± 0.046	0.088 ± 0.295	2.9 ± 2.1	3.3 ± 1.7	6.8 ± 3.9

	Runoff in Area G at Gaging Station (August 24, 1984)			
	Solution		Suspended Sediments	
	^{238}Pu (10^{-9} μCi/mℓ)	$^{239,240}Pu$ (10^{-9} μCi/mℓ)	^{238}Pu (pCi/g)	$^{239,240}Pu$ (pCi/g)
	−0.012 ± 0.024	0.012 ± 0.024	−0.008 ± 0.010	−0.003 ± 0.012

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-XLVI

Action Description Memorandums Approved by the Laboratory Environmental Review Committee During 1984

Laboratory-wide

Device Fabrication Research and Development Projects (February)
115 kV Power Line, Los Alamos Meson Physics Facility to TA-3/Two Mile Mesa Power Line (May)
Los Alamos Airport Improvements, Revised (April)
Scientific Shallow Core Hole Drilling on Santa Fe National Forest (June)
Central Guard Facility, East of TA-59 (June)
Electrical System Upgrade: Replacement of Equipment Containing Polychlorinated Biphenyl Fluids (October)
Mitigation of Cultural Resources LA-16806 and LA-22766, Romero Cabin Relocation (October)
345 kV Power Line: Public Service Company of New Mexico Ojo Extension, Draft (October)

TA-3

Laboratory Construction, TA-3-141 (October)
Staging Area for Strategic Defensive Projects, TA-3-40 (October)
Metal Shears Building, TA-3-39 (October)
Classified Laboratory and Office Complex, West Bay, TA-3-40 (October)
Compressed Gas Facility Renovation, TA-3-170 (February)
X-ray Scanner Support, TA-3-66 (March)
Mg Set Facility (March)
Consolidation of E Division (June)
Electronics Laboratory (July)
Ventilation and Humidity Control Improvements, TA-3-43 (November)
High Energy Density Physics Facility, TA-3-316 (November)
Telephone Duct Bank Addition (December)

TA-15

Explosive Physics Experimental Facility (March)
Dual Axis Radiograph Hydrotest Facility (March)

TA-16

Solid Waste Reduction Facility (March)
WX-10 Office and Laboratory Building (December)

TA-21

Laboratory Conversion of TA-21-152 (February)

TA-22

Demolition of TA-22-1 (July)

Table E-XLVI (cont)

TA-35

Advanced Laser Addition, TA-35-128 (October)

TA-39

Branch Shop Building, TA-39-98 (February)

TA-41

Ice House Upgrade, TA-41-4 (July)

TA-43

Replacement of 600 kVA Substation, TA-43-1 (February)
Microbiology Facility (February)
Microbiology Facility, Revised (May)
Modular Biochemical Laboratory (June)
Life Sciences Facility Improvements (December)

TA-46

Fourier Transform Spectrometer Facility (December)

TA-48

Weapons Diagnostic Instrument Building (January)
Addendum to Action Description Memorandum for Weapons Diagnostic Instrument Building (October)
Addendum to Action Description Memorandum for Advanced Radiochemical Weapons Diagnostic Facilities (October)

TA-50

Building Addition to WM-1 (July)

TA-53

Helium Liquifier Building (February)
Los Alamos Meson Physics Facility Line E Neutrino Facility (March)
Beam Stop Neutrino Facility (March)
Neutron Scattering Experimental Hall (March)
Accelerator Test Stand Upgrade (October)
Experimental Area Office Building (October)

Table E-XLVI (cont)

TA-55

MST Training Center (February)
Process Support Building (February)
Special Nuclear Materials Research and Development Laboratory (May)
Warehouse Facility Expansion (October)

A total of 49 Action Description Memorandums were approved by the Laboratory Environmental Review Committee during 1984.

Note: Month of approval is in parentheses.

Table E-XLVII

Results for Samples Taken Below the Los Alamos Meson Physics Facility's (TA-53) Lagoons

Analysis	Units	1984 Sampling Month	Sampling Location 1	2	3	4	5	6	7	8
					Sediments					
^{7}Be	pCi/g	June	9600 ± 1900	28 000 ± 5600	22 000 ± 4300	11 000 ± 2200	100 ± 21	13 ± 3.4	0.91 ± 0.92	0.41 ± 0.87
^{7}Be	pCi/g	December	2900 ± 440	11 000 ± 1700	5700 ± 860	8200 ± 1200	50.0 ± 7.8	6.6 ± 1.3	0.50 ± 0.30	0.80 ± 0.40
^{57}Co	pCi/g	June	400 ± 82	1600 ± 320	1100 ± 220	800 ± 160	120 ± 24	26 ± 5.2	2.3 ± 0.5	0.08 ± 0.05
^{57}Co	pCi/g	December	120 ± 18	810 ± 120	580 ± 86	600 ± 90	100 ± 15	14 ± 2.1	0.10 ± 0.00	0.00 ± 0.00
^{134}Cs	pCi/g	June	1100 ± 220	2000 ± 400	1000 ± 200	1100 ± 230	350 ± 69	43 ± 8.6	2.90 ± 0.59	0.03 ± 0.06
^{134}Cs	pCi/g	December	200 ± 29	3400 ± 520	1200 ± 190	1500 ± 230	280 ± 41	45 ± 6.8	0.50 ± 0.10	0.20 ± 0.10
^{3}H	10^{-4} μCi/mℓ	June	7.9 ± 0.8	8.3 ± 0.8	9.3 ± 0.9	8.0 ± 0.8	0.38 ± 0.04	0.08 ± 0.01	0.04 ± 0.005	0.06 ± 0.006
^{3}H	10^{-4} μCi/mℓ	December	13 ± 1.0	14 ± 1.0	14 ± 1.0	14 ± 1.0	0.14 ± 0.01	0.02 ± 0.004	0.02 ± 0.004	0.02 ± 0.004
^{54}Mn	pCi/g	June	400 ± 80	1300 ± 260	880 ± 180	380 ± 75	61 ± 12	35 ± 6.9	1.9 ± 0.38	0.04 ± 0.050
^{54}Mn	pCi/g	December	52 ± 7.9	1300 ± 190	330 ± 49	690 ± 100	150 ± 22	28 ± 4.3	0.20 ± 0.10	0.10 ± 0.10
^{22}Na	pCi/g	June	11 ± 2	14 ± 3	7 ± 1	6 ± 1	1.5 ± 0.3	2.3 ± 0.5	0.42 ± 0.10	0.007 ± 0.047
^{22}Na	pCi/g	December	18 ± 3	34 ± 5	18 ± 2.7	64 ± 9	1.9 ± 0.3	1.9 ± 0.3	0.10 ± 0.10	0.10 ± 0.10
^{83}Rb	pCi/g	June	110 ± 22	110 ± 22	46 ± 9	47 ± 9	18 ± 3.7	5.4 ± 1.2	0.37 ± 0.14	0.06 ± 0.13
^{83}Rb	pCi/g	December	1100 ± 170	1900 ± 280	1500 ± 220	1200 ± 170	2.3 ± 0.6	1.0 ± 0.2	0.1 ± 0.1	0.1 ± 0.1
					Water					
^{7}Be	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.045 ± 0.085
^{7}Be	10^{-6} μCi/mℓ	December	350 ± 70	840 ± 170	300 ± 59	550 ± 110	Dry	Dry	Dry	Dry
^{57}Co	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.008 ± 0.008
^{57}Co	10^{-6} μCi/mℓ	December	14 ± 2.8	32 ± 6.4	14 ± 2.7	30 ± 5.9	Dry	Dry	Dry	Dry
^{134}Cs	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.021 ± 0.011
^{134}Cs	10^{-6} μCi/mℓ	December	5.8 ± 1.2	10 ± 2.1	3.9 ± 0.78	4.7 ± 0.94	Dry	Dry	Dry	Dry
^{3}H	10^{-4} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.055 ± 0.006
^{3}H	10^{-4} μCi/mℓ	December	13 ± 1.0	14 ± 1.0	14 ± 1.0	14 ± 1.0	Dry	Dry	Dry	Dry
^{54}Mn	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.021 ± 0.009
^{54}Mn	10^{-6} μCi/mℓ	December	9.3 ± 1.9	21.±4.2	5.8 ± 1.2	13 ± 2.5	Dry	Dry	Dry	Dry
^{22}Na	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.005 ± 0.007
^{22}Na	10^{-6} μCi/mℓ	December	15 ± 3.0	16 ± 3.1	15 ± 3.0	15 ± 2.9	Dry	Dry	Dry	Dry
^{83}Rb	10^{-6} μCi/mℓ	June	Dry	Dry	Dry	Dry	Dry	Dry	Dry	-0.003 ± 0.013
^{83}Rb	10^{-6} μCi/mℓ	December	39 ± 7.8	44 ± 8.8	31 ± 6.2	26 ± 5.3	Dry	Dry	Dry	Dry

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 1984

N. M. Becker, "Prediction of Soil Loss with CREAMS Model," Los Alamos National Laboratory report LA-UR-84-1399 (July 1984).

N. M. Becker, "Prediction of Soil Loss with the CREAMS Model," in *Water Today and Tomorrow*, J. A. Replogle and K. G. Renard, Eds. (American Society of Civil Engineers, 1984), pp. 544-551.

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 LA-9893-MS (May 1984).

T. S. Foxx, G. D. Tierney, and J. M. Williams, "Rooting Depths of Plants Relative to Biological and Environmental Factors," Los Alamos National Laboratory report LA-10254-MS (November 1984).

T. S. Foxx, G. D. Tierney, and J. M. Williams, "Rooting Depths of Plants on Low-Level Waste Disposal Sites," Los Alamos National Laboratory report LA-10253-MS (November 1984).

T. S. Foxx and G. D. Tierney, "Status of the Flora of the Los Alamos National Laboratory Research Park," Los Alamos National Laboratory report LA-8050-NERP, Vol. II (September 1984).

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

C. Olinger and K. Rea, "Los Alamos National Laboratory Compliance with Cultural Resource Management Legislation," Los Alamos National Laboratory report LA-UR-3529 (November 1984).

W. D. Purtymun, N. M. Becker, and M. Maes, "Water Supply at Los Alamos During 1982," Los Alamos National laboratory report LA-9896-PR (January 1984).

W. D. Purtymun, "Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies," Los Alamos National Laboratory report LA-9957-MS (January 1984).

A. J. Ruttenber, Jr., K. Keriss, R. L. Douglas, T. E. Buhl, and J. Millard, "The Assessment of Human Exposure to Radionuclides from a Uranium Mill Tailings Release and Mine Dewatering Effluent," Health Physics **47** (1), 21-35 (July 1984).

J. G. Salazar, "Produce and Fish Sampling Program of Los Alamos National Laboratory's Environmental Surveillance Group," Los Alamos National Laboratory report LA-10186-MS (September 1984).

D. M. Van Etten, A. J. Ahlquist, and W. R. Hansen, "Los Alamos National Laboratory's Environmental Surveillance and Radiological Emergency Vehicle and the ^{60}Co Incident," Los Alamos National Laboratory report LA-UR-84-1823 (November 1984).

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).

Working Level Month (WLM)	A unit of exposure to ^{222}Rn and its decay products. A Working Level (WL) is any combination of the short-lived ^{222}Rn decay products in 1 liter of air that will result in the emission of 1.3×10^5 MeV potential alpha energy. At equilibrium, 100 pCi/ℓ of ^{222}Rn corresponds to one WL. Cumulative exposure is measured in Working Level Months, which is 170 WL-hours.

DISTRIBUTION LIST

STANDARD UC-41 (HEALTH AND SAFETY DISTRIBUTION)

DEPARTMENT OF ENERGY

Office of Military Applications (2)
  General G. Whithers
Technical Information Center
  D. Bost
Albuquerque Operations Office (20)
  C. Garcia
  R. Miller
  C. Soden
Los Alamos Area Office (3)
  H. Valencia
  D. Gallegos
Environmental Measurements Laboratory
  H. Volchok
  E. Hardy, Jr.
Idaho Operations Office
  M. Williamson
Nevada Operations Office
  B. Church
Oak Ridge Operations Office
  R. Sleeman
Savannah River Operations Office
  S. Wright

Department of Energy Contractors

Argonne National Laboratory
  N. Golchert
Battelle, Pacific Northwest Laboratories
  K. Price
Brookhaven National Laboratory
  L. Day
Rockwell International - Rocky Flats Plant
  D. Gray
Lawrence Livermore National Laboratory
  K. Griggs
Mound Laboratory
  D. Carfagno
Oak Ridge National Laboratory
  D. Parzyck
Pantex Plant
  W. Laseter
Sandia National Laboratories, Albuquerque
  G. Millard
Savannah River Laboratory
  H. McLearen

Other External

University of California
  Environmental, Health, and Safety Office
Environmental Protection Agency
  G. Sjoblum, ORP, Washington, DC
  C. Costa, EMSL, Las Vegas, NV
  D. Whittington, Region 6, Dallas, TX
  A. Davis, Region 6, Dallas, TX
  J. Highland, Region 6, Dallas, TX
New Mexico Health and Environment Dept.,
Environmental Improvement Division
  D. Fort, Director
  S. Hill
  R. Holland
  L. Lockie
  F. Miera
  J. Millard
  C. Nylander
  P. Pache
  J. Thompson
New Mexico Energy and Minerals Department
  D. Stamets
US Forest Service
  E. Collins
Zia Company
  K. Jones
  G Vavra
Individuals
  J. White, Army Corps of Engineers
  J. Daniel, US Geological Survey, Albuquerque, NM
  New Mexico State Engineer, Santa Fe, NM
  Superintendent, Bandelier National Monument, Los Alamos, NM
  R. 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, Espanola, NM
Albuquerque Journal, Albuquerque, NM
Albuquerque Tribune, Albuquerque, NM
New Mexico Independent, Albuquerque, NM
KRSN Radio, Los Alamos, NM
New Mexico Congressional Delegation
Senator P. Domenici
Senator J. Bingaman
Representative M. Lujan, Jr.
Representative J. Skeen
Representative W. Richardson
Elected Officials
City of Espanola
C. Thompson, Mayor
City of Santa Fe
L. Montano, Mayor
County of Los Alamos
M. Pongrantz, Chairman of Los Alamos Council
S. Stoddard, State Senator
V. Kerr, State Representative
New Mexico Office of Indian Affairs
Bureau of Indian Affairs
Administrative Manager
Eight Northern Pueblos
Governor D. Perez, Nambe Pueblo
Governor G. Nailor, PicurisPueblo
Governor J. Viarrial, Pojoaque Pueblo
Governor J. Sanchez, San Ildefonso Pueblo
Governor J. Trujillo, San Juan Pueblo
Governor L. Singer, Santa Clara Pueblo
Governor J. Sandoval, Taos Pueblo
Governor J. Padilla, Tesuque Pueblo
Mesa Public Library, Los Alamos, NM

Internal Distribution

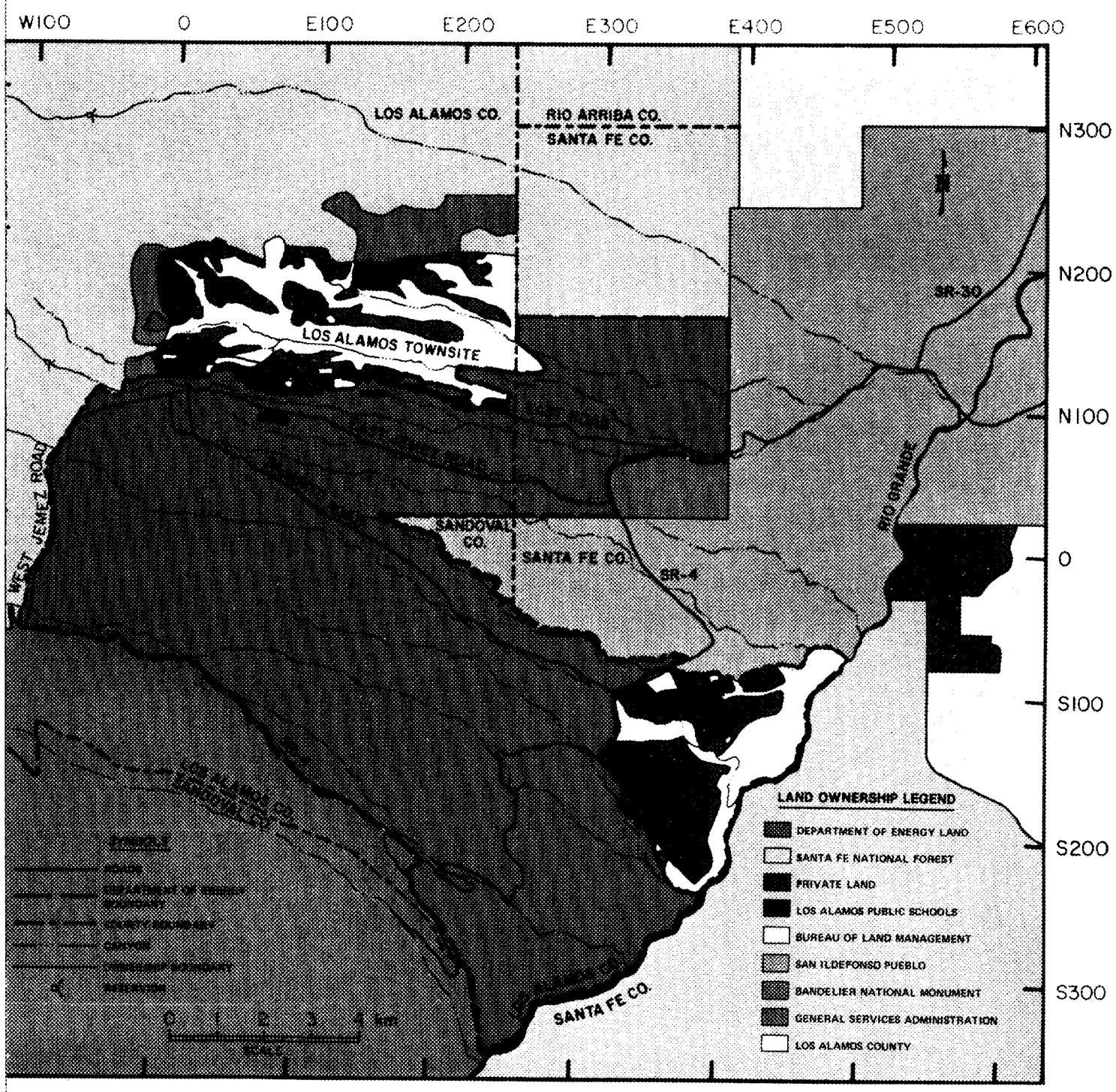
Director's Office
D. Kerr, Director
C. Adams, Associate Director for Technical Support
J. Breen, Public Affairs Officer (2)
Health, Safety, and Environment Division Office (10)
J. Aragon
J. Dummer
W. Hansen
G. Voelz
Group HSE-1, Radiation Protection
A. Valentine
J. Graf
F. Guevara
R. Jalbert
Group HSE-3, Safety
W. Courtright
Group HSE-5, Industrial Hygiene
J. Jackson
Group HSE-7, Waste Management
R. Garde
K. Balo
J. Buchholz
L. Emelity
J. Warren
Group HSE-8, Environmental Surveillance
T. Gunderson
M. McCorkle
A. Stoker
Group HSE-9, Health and Environmental Chemistry
R. Gooley
E. Gladney
Group HSE-10, Chemistry Health Protection
R. Stafford
Group HSE-11, Accelerator Health Protection
J. Miller
Group HSE-12, Environmental Sciences
T. Hakonson
C. Reynolds
Group IS-1, Publicatons
C. Rodriguez
Group IS-4, Library Services (15)
Group IS-10, Technical Information (2)
Group ENG-11, Long Range Facilities Planning
D. Sneesby
Laboratory Environmental Review Committee
A. Tiedman
E. Arntzen
G. Bergman
W. Brown
W. Hansen
D. Houck
C. Olinger

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.