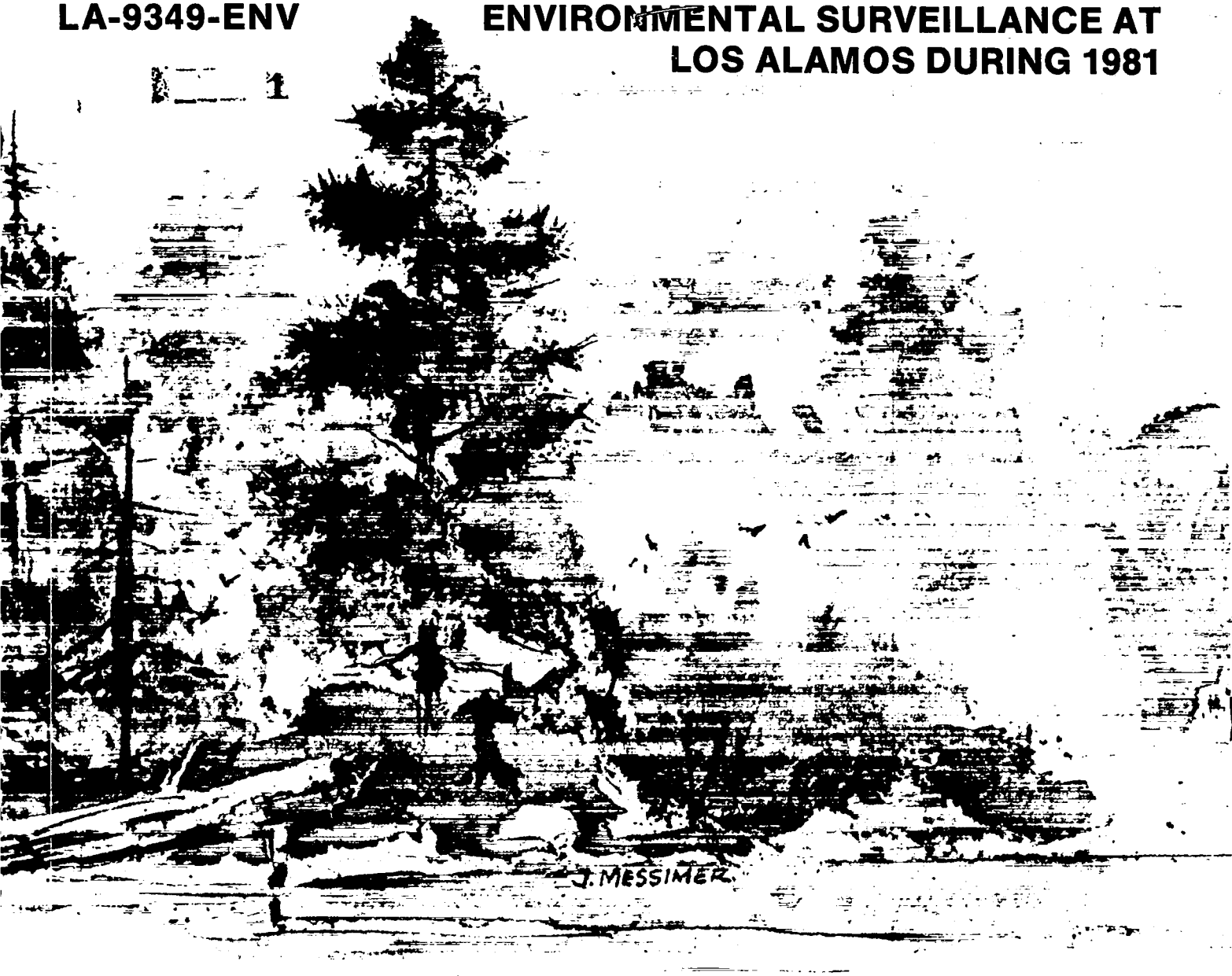
LA-9349-ENV

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1981



Los Alamos National Laboratory
Los Alamos, New Mexico, 87545

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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 LASL technical area (TA-3) is in the upper left, and the airport is at left center.

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Environmental Surveillance Group

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

The four most recent reports in this unclassified series are LA-7263-MS, LA-7800-ENV, LA-8200-ENV, and LA-8810-ENV.

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

FOREWORD

SUGGESTIONS ON HOW TO READ THIS REPORT

This report addresses a mixed audience of laypeople and scientifically oriented people. Within each of these two groups are those people with a limited interest in this report and those with a more comprehensive interest. An attempt has been made to make this report accessible to all without compromising its scientific integrity. Following are directions advising each specific audience on how best to use this document.

1. *LAYPERSON WITH LIMITED INTEREST.* Read Part I, the Environmental Monitoring Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for 1981. Emphasis is placed on significance of findings and results are explained in common language. Technical terms are avoided. A glossary, list of acronyms and abbreviations, and list of units are in the front of the report to assist you.

2. *LAYPERSON WITH COMPREHENSIVE INTEREST.* Follow directions for the "Layperson With Limited Interest" given above. Also, summaries of each section of the report are in boldface type and precede the more technically oriented text. Read summaries of those sections that interest you. Further detail can be gleaned by reading the text that follows each summary. Appendix A (Standards for Environmental Contaminants) and Appendix F (Descriptions of Technical Areas and Their Associated Programs) may also be helpful to you.

3. *SCIENTIST WITH LIMITED INTEREST.* Read Part I, the Environmental Monitoring Summary, to determine which specific parts of the Laboratory's environmental monitoring program are of interest to you. You can then read summaries and technical details of these parts in the body of the report. Also, detailed data tables are in Appendix E.

4. *SCIENTIST WITH COMPREHENSIVE INTEREST.* Read Part I, the Environmental Monitoring Summary, which describes the Laboratory's environmental monitoring operations and summarizes environmental data for 1981. Also, read the summaries (in boldface) that head each major subdivision of this report. Further detail can be gleaned from the text and appendixes.

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

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

CONTENTS

APPENDIXES

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ALARA	as low as reasonably achievable
BOD_5	5-day biochemical oxygen demand
COD	chemical oxygen demand
CG	Concentration Guide
DOE	Department of Energy
EA	environmental assessment
EEC	Environmental Evaluations Coordinator
EPA	Environmental Protection Agency
FEIS	final environmental impact statement
H-7	Waste Management Group at the Laboratory
H-8	Environmental Surveillance Group at the Laboratory
HDR	hot dry rock
HTO	tritiated water
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
Laboratory	Los Alamos National Laboratory
LAMPF	Los Alamos Meson Physics Facility
LERC	Laboratory Environmental Review Committee
LS-6	Environmental Sciences Group at the Laboratory
MAP	mixed activation products
MCL	Maximum Contaminant Level
MFP	mixed fission products
N	normal (chemical term)
NBS	National Bureau of Standards
NCRP	National Council on Radiation Protection and Measurements
NERP	National Environmental Research Park
NIPDWR	National Interim Primary Drinking Water Regulations
NMEID	New Mexico Environmental Improvement Division
NPDES	National Pollutant Discharge Elimination System
QA	quality assurance
RPS	Radiation Protection Standard
SRM	standard reference material
TA	technical area
TDS	total dissolved solids
TLD	thermoluminescent dosimeter
TRU	transuranic wastes
TSS	total suspended solids
USGS	United States Geological Survey
α	alpha
β	beta
γ	gamma
s	standard deviation
$\bar{x}$	mean

SYSTEM INTERNATIONAL PREFIXES

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

UNITS

Abbreviation	Unit
c	count
aCi	attocurie (10^{-18} curies)
Btu	British thermal unit
°C	Celsius degree
Ci	curie (unit of radioactivity)
cm	centimeter
fCi	femtocurie (10^{-15} curies)
ft	foot
g	gram
h	hour
ha	hectare
in.	inch
keV	kiloelectron volt
kg	kilogram
km	kilometer
km^2	square kilometer
ℓ	liter
m	meter
m^3	cubic meter
mCi	millicurie (10^{-3} curies)
MeV	megaelectron volt
mg	milligram (10^{-3} grams)
min	minute
mℓ	milliliter (10^{-3} liters)
mm	millimeter (10^{-3} meters)
mph	miles per hour
mR	milliroentgen (10^{-3} roentgens)
mrem	millirem (10^{-3} rems)
mS/m	milliSiemens/meter (1 mS/m = 10 μmho/cm)
MGD	million gallons per day
MT	megaton (10^6 tons)
μCi	microcurie (10^{-6} curies)
μg	microgram (10^{-6} grams)
μm	micrometer (10^{-6} meters)
nCi	nanocurie (10^{-9} curies)
ng	nanogram (10^{-9} grams)
pCi	picocurie (10^{-12} curies)
pg	picogram (10^{-12} grams)
ppb	parts per billion (1 in 1 000 000 000)
ppm	parts per million (1 in 1 000 000)
rad	62.5×10^6 MeV/g (unit of absorbed dose)
rem	roentgen equivalent man (unit of dose equivalence)
R	roentgen
sec	second
wt%	weight per cent
yr	year

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.
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 radioactivity in air or water that is determined to result in whole body or organ doses equal to the Department of Energy's Radiation Protection Standards for external and internal exposures, if the air is continuously inhaled or the water is the sole source of liquid nourishment throughout the year.
controlled area	Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and radioactive materials.
Curie (Ci)	A special unit or radioactivity. One curie equals 3.70×10^{10} nuclear transformations per second.
depleted uranium	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.
gallery	An underground collection basin for spring discharges.
gamma radiation	Short-wavelength electromagnetic radiation of nuclear origin that has no mass or charge. Because of its short wavelength, gamma radiation can cause ionization. Other electromagnetic radiation (microwaves, visible light, radio waves, 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.
Maximum Contaminat Level (MCL)	Maximum permissible level of a contaminant in water specified by the Environmental Protection Agency that is delivered to the free flowing outlet of the ultimate user of a public water system (see Appendix A and Table A-III).
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 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.
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.
roentgen	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.
Radiation Protection Standard (RPS)	Standards for external and internal exposure to radioactivity as defined in Department of Energy Order 5480.1, Chapter XI (see Appendix A and Table A-II in this report).
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.
total uranium	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).
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).

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1981

by

Environmental Surveillance Group

ABSTRACT

This report documents the environmental surveillance program conducted by the Los Alamos National Laboratory during 1981. 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 1981 are included on penetrating radiation; on the chemical and radiochemical quality of ambient air, surface and ground water, municipal water supply, soil and sediments, and food; and on the quantities of airborne emissions and liquid effluents. Comparisons with appropriate standards and regulations or with background levels from natural or other non-Laboratory sources provide a basis for concluding that environmental effects attributable to Laboratory operations are insignificant and are not considered hazardous to the population of the area. Results of several special studies describe some unique environmental conditions in the Laboratory environs.

I. ENVIRONMENTAL MONITORING SUMMARY

Los Alamos National Laboratory policy emphasizes protection of the general public and environment from any harm that could arise from Laboratory activities and mitigation of environmental impacts to the greatest degree practicable. In keeping with this policy and Department of Energy (DOE) requirements to assess and document possible influences of operations on the environment, this report provides data and interpretation of environmental conditions in the vicinity of the Laboratory during 1981.

A. Monitoring Operations

Routine monitoring for radiation, radioactive materials, and chemical substances is conducted on the Laboratory site and in the surrounding region to document compliance with appropriate standards, identify possible undesirable trends, provide information for the public, and contribute to general environmental knowledge. This monitoring in the environment is a backup to data on specific effluent releases, such as those from radioactive waste treatment plants and various stacks at nuclear research facilities.

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

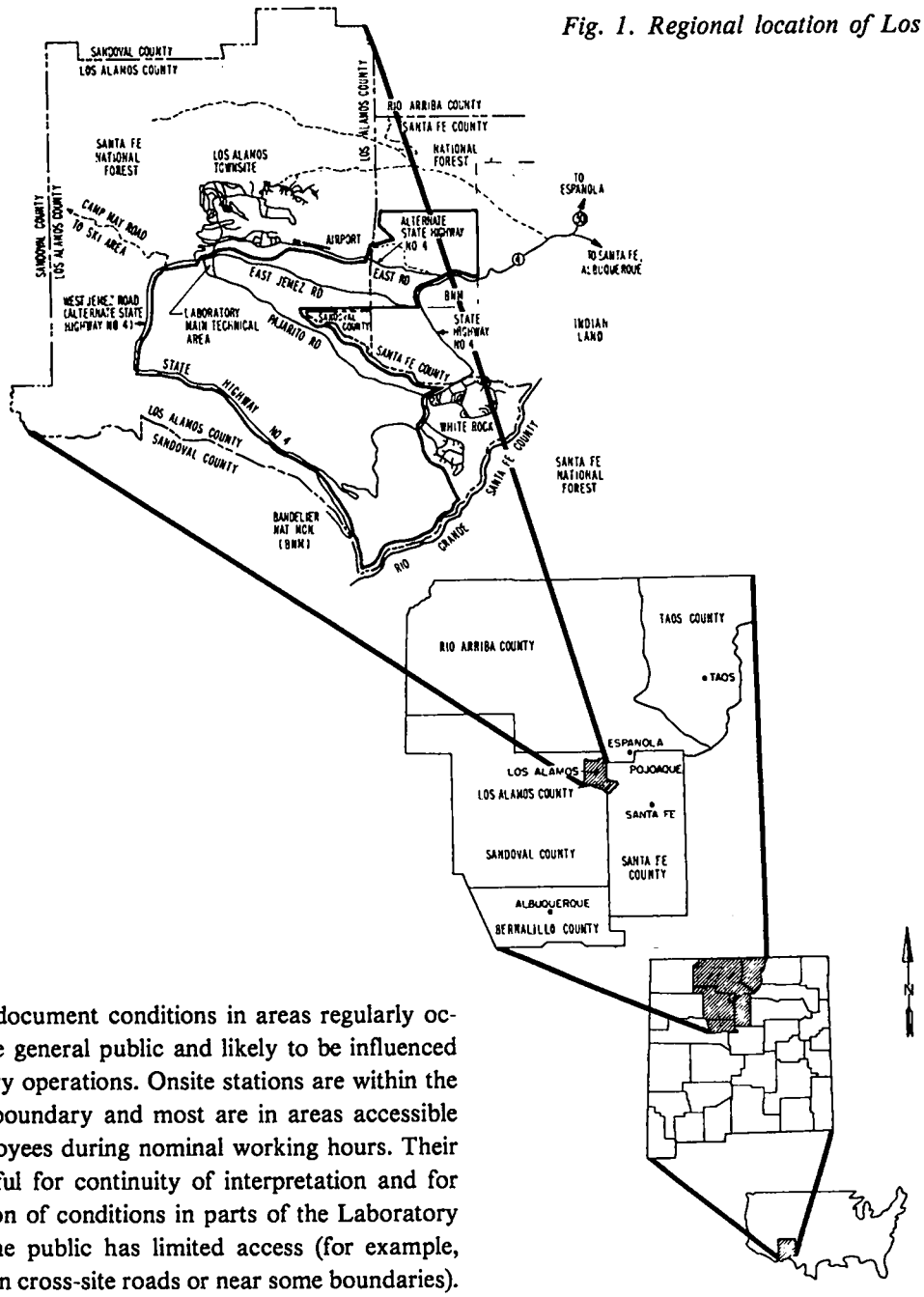


Fig. 1. Regional location of Los Alamos.

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

The types of routine monitoring conducted at these stations include measurements of radiation and collection of samples of air particulates, water, soils, and foodstuffs for subsequent analysis. External penetrating radiation (the x and gamma ray and charged particle contributions from natural, cosmic, and terrestrial sources, plus any Laboratory contributions) was measured at 61 locations by thermoluminescent dosimeters (TLDs). Airborne radioactivity samples were accumulated during monthly intervals by continuously operating samplers at 25 locations. Surface and ground water samples were collected periodically at 120 locations: 76 of which are indicated in Table I, 24 for the Department of Energy's water supply wells and distribution system, and 20 related to the Hot Dry Rock Geothermal Project at Fenton Hill.

TABLE I

NUMBER OF SAMPLING LOCATIONS

Type of Monitoring	Number of Sampling Stations in Group		
	Regional	Perimeter	Onsite
External Radiation	4	12	45
Air	3	11	11
Surface and ground water[a]	6	36	34
Soils and sediments	15	23	42
Foodstuffs	7	5	9

[a]An additional 24 stations for the water supply and 20 special stations related to the Fenton Hill Geothermal Program were also sampled.

Samples of foodstuffs, principally vegetables, fruit, and fish, were collected at 21 locations. Soil and sediment samples were collected periodically from 80 locations. Additional samples were collected at various times and locations to gain information about particular events, such as for major runoff events in intermittent streams, nonroutine releases, or special studies. During 1981, more than 13 100 analyses for chemical and radiochemical constituents were performed on these environmental samples. Resulting data were used for comparison with standards and natural background, dose calculations, and other interpretations.

B. Summary of 1981 Results

The large number of samples and wide range of purposes for which they are collected makes a brief summary difficult without leading to possible misinterpretation. Consequently, this summary presents an overview of monitoring results with selected highlights, emphasizing comparisons with standards or other bases for indicating significance. Full details of the results, their contexts, and interpretive methodology are explained in the body of the report and appendixes.

1. Radiation Doses

Individual whole body radiation doses to the public attributable to Laboratory operations are compared to applicable Radiation Protection Standards in Table II. Radiation doses for various mechanisms of exposure are expressed as a percentage of the 500 mrem/yr Radiation Protection Standard. This Radiation Protection Standard is only for doses from exposures above natural background and medical exposures. Doses presented here are those calculated to be possible doses to individuals under realistic conditions of exposure and do not include some of the maximum hypothetical exposures discussed in the body of this report that have minimal likelihood of occurring.

Another perspective is gained by comparing these estimated doses with the estimated whole body dose attributable to natural background radiation. The highest estimated dose due to Laboratory operations is about 4% of the dose attributable to naturally occurring radioactivity in Los Alamos in 1981.

The estimated maximum regional doses shown in Table II for direct external radiation and airborne radioactivity are both based on exposure to theoretically calculated concentrations of emissions from the Los

TABLE II

COMPARISON OF INDIVIDUAL WHOLE BODY RADIATION DOSES WITH RADIATION PROTECTION STANDARDS

Calculated Doses Attributable to Laboratory Operations From:	% Radiation Protection Standard[a]		
	Regional	Perimeter	Onsite
Direct external radiation	<0.001	<0.001	0.1
Airborne radioactivity	0.002	0.96	0.001
Food pathways	<0.001	0.004	0.8

[a]The Radiation Protection Standard for whole body radiation dose is 500 mrem/yr for a member of the public.

Alamos Meson Physics Facility (a linear particle accelerator) and Omega West research nuclear reactor. The maximum estimated regional dose based on a food pathway assumes consumption of liver from a steer that grazed in Los Alamos Canyon and drank water containing some radioactivity on suspended sediments during a long spring runoff.

Estimated perimeter doses from direct external radiation and airborne radioactivity occur at a commercial establishment near the boundary north of the Los Alamos Meson Physics Facility and are attributable to its operation. The perimeter food pathway is based on consumption of honey from a hive located near the Laboratory boundary.

The onsite external radiation dose is that estimated for a commuter regularly travelling past a Laboratory facility on one of the Department of Energy's roads normally open to public travel. The onsite airborne pathway was calculated for a half-day visit to the Laboratory's science museum. The onsite food pathway could occur from consumption of venison from a deer frequenting a canyon where treated liquid effluents are discharged.

2. Significance of Radiation Doses

To provide a perspective for comparing the significance of radiation exposures, estimates of the added risk of cancer were calculated. Increases in risk estimated for average individual exposures to ionizing radiation from 1981 Laboratory operations are presented in Table III, along with estimated incremental risks from natural and diagnostic medical radiation.

The maximum potential Laboratory contribution to the cancer risk is extremely small when compared to overall cancer risks. Further perspective is gained by noting the overall United States lifetime risks of contracting some form of cancer from all causes is 1 chance in 4. The lifetime risk of cancer mortality is 1 chance in 5. The Los Alamos and White Rock incremental doses attributable to 1981 Laboratory operations are equivalent to the additional exposure a person would get flying in an aircraft for 3.0 and 1.8 hours, respectively.

The factors for risk estimation are those given by the International Commission on Radiological Protection based on observed radiation damage at high doses and linearly extrapolated to effects at low doses and dose rates (that is, the injury is assumed to be directly proportional to dose). The International Commission on Radiological Protection warns that these radiation risk estimates should be used only with great caution because the factors may overestimate actual risk. The National Council on Radiation Protection and Measurements has also taken the official position that linear extrapolation methods "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." Thus, one must keep in mind that the radiation risks are likely to be less than stated in Table III.

TABLE III

ADDED INDIVIDUAL LIFETIME CANCER MORTALITY RISKS ATTRIBUTABLE TO 1981 RADIATION EXPOSURE

Exposure Source	Added Risk (Chance) to an Individual of Cancer Mortality	Dose (mrem) Used in Risk Estimate
Average Exposure from Laboratory Operations		
Los Alamos Townsite	1 in 15 000 000	0.67
White Rock Area	1 in 26 000 000	0.38
Natural Radiation		
Cosmic, Terrestrial, and Self Irradiation		
Los Alamos Townsite	1 in 86 000	116[a]
White Rock Area	1 in 93 000	108[a]
Medical X-rays (Diagnostic Procedures)		
Average Whole Body Exposure	1 in 97 000	103

[a]Based on measured dose rates for cosmic and terrestrial components with reductions made for structural and self-shielding.

3. Penetrating Radiation

Levels of 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 61 locations divided into regional, perimeter, and onsite groups. No measurements at regional or perimeter locations for any calendar quarter showed any statistically distinguishable increase in radiation levels that could be attributed to Laboratory operations (see Table IV). Apparent differences between the regional and perimeter groups are attributable to differences in the natural radioactivity content of geologic formations. Quarterly measurements at 21 onsite stations were expectably above background levels, reflecting ongoing research activities at the Laboratory. Another 24 onsite thermoluminescent dosimeter stations are specially located to monitor radioactivity from the Los Alamos Meson Physics Facility.

TABLE IV

EXTERNAL PENETRATING RADIATION DURING 1981

Group	Dose (mrem)		
	Minimum	Maximum	Average
Regional	71	96	83
Perimeter	85	113	100
Onsite	85	278	127

4. Radioactivity in Air and Water

Measurements of radioactivity in air and water are compared to standards, known as Concentration Guides, that are set by the Department of Energy (see Appendix A). The Concentration Guides are concentrations of

radioactivity in air breathed continuously or water constituting all that is ingested during a year that are determined to result in whole body or organ doses equal to the Radiation Protection Standards [standards for external or internal exposure to radioactivity (see Appendix A)]. The 1981 results for the principal isotopes (including amounts present from worldwide fallout) potentially influenced by Laboratory operations are shown in Table V as ranges of percentages of the Concentration Guides. The values shown represent a statistical range (from two standard deviations below to two standard deviations above the mean) that encompasses 90 to 95% of the individual results. All comparisons in Table V are with Concentration Guides applicable to individuals in the general public, even though the public has only restricted access to many onsite locations.

a. Radioactivity in Air. During 1981, atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranium were measured at regional, perimeter, and onsite sampling locations. For all analyses except tritium, the regional annual means were lower than the perimeter and onsite group annual means. This indicates Laboratory contributions to concentrations of these radioactive species, except tritium, were greater than regional background levels. Data in Table V show that tritium, plutonium (^{239}Pu), and uranium atmospheric concentrations were small percentages of their respective Concentration Guides. Results from only 1 of 100 plutonium (^{238}Pu) samples and 3 of 44 americium (^{241}Am) samples were above analytical detection limits and so were not included in Table V.

Atmospheric gross alpha and beta analyses serve as indicators of overall radioactivity levels. The highest gross alpha and beta concentrations were 33% and 0.2%, respectively, of the most relevant Concentration Guides. Gross beta annual means were about seven to nine times higher than last year. This increased activity was measured at all air sampling locations, so is attributable to increased worldwide radioactive fallout.

b. Radioactivity in Water. Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from Laboratory operations. Results of analyses are compared to the Concentration Guides (see Table V) as an indication of the low concentrations of radionuclides in the environment. Other radionuclides measured but not listed in this table are ^{238}Pu (most analyses were at or below analytical detection limits), gross alpha and beta (used only as

TABLE V

ANNUAL RADIONUCLIDE CONCENTRATIONS IN AIR AND WATER AS PERCENTAGES OF CONCENTRATION GUIDES

	% Concentration Guide[a]		
	Regional	Perimeter	Onsite
Air			
Tritium (^{3}H)	0.005 - 0.01	0.002 - 0.005	0.003 - 0.006
Plutonium (^{239}Pu)	0.004 - 0.02	0.02 - 0.03	0.006 - 0.02
Uranium (U)	0.0001 - 0.0003	0.0003 - 0.0004	0.0002 - 0.0004
Water			
Tritium (^{3}H)	0.0 - 0.06	0.0 - 0.14	0.0 - 0.09
Plutonium (^{239}Pu)	0.0 - 0.0002	0.0 - 0.0002	0.0 - 0.004
Cesium (^{137}Cs)	0.0 - 0.2	0.0 - 0.3	0.0 - 0.4

[a]Values in table are $(\bar{x} - 2s)$ to $(\bar{x} + 2s)$ as percent of Concentration Guide.

gross indicators of radioactivity), and uranium (concentrations low and generally indistinguishable from levels naturally in the environment). Waters in onsite liquid effluent release areas contain measurably higher concentrations of radioactivity, but at levels that are still small fractions of the Concentration Guides. These onsite waters are not a source of industrial, agricultural, or municipal water supplies.

Results of the 1981 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite noneffluent release areas indicate no significant effect from effluent releases from the Laboratory.

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

5. Radioactivity in Other Media

Measurements of radioactivity in samples of soils, sediments, and a variety of foodstuffs are made to provide information on less direct natural mechanisms that could result in exposures to people. Estimated doses potentially resulting from these mechanisms, or pathways, such as wind resuspension of dust and incorporation into food chains, are summarized in Section I.B.1 and compared to Radiation Protection Standards as an interpretation of their significance.

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

Measurements of above-background but low-level radioactivity on soils from a few locations indicate probable deposition of some airborne emissions from Laboratory facilities. Most such locations are near facilities known to have had higher emission rates in the past, especially prior to 1974.

Fruit, vegetable, fish, and honey samples analyzed in 1981 show no increments of radioactivity distinguishable from that attributable to natural sources or worldwide fallout at any offsite location. Produce collected from a garden on the Laboratory's perimeter showed slightly elevated tritium concentrations. The dose associated with this tritium is 0.004% of the Radiation Protection Standard for the public. At onsite locations near facilities emitting tritium, some elevated levels of tritiated water were found in fruit and in honey from an experimental hive.

6. Other Monitoring Results

Airborne radioactive emissions were monitored as released from 86 points at the Laboratory and were typical of releases during the past several years. The greatest increase in radioactivity released during 1981 was from 145 600 Ci (1980) to 352 340 Ci (1981) in emissions of short-lived (20 min half-life or lower) activation products (^{11}C, ^{13}N, ^{15}O) at the Los Alamos Meson Physics Facility. Laboratory-wide releases of plutonium, americium, mixed fission products, iodine, and tritium were all lower than last year. Released quantities of phosphorus, uranium, argon, and beryllium were all higher. Liquid effluents from two radioactive waste treatment plants and one sanitary sewage lagoon contained some radioactivity, all at levels well within Concentration Guides.

Nonradioactive airborne emissions from the beryllium fabrication shop, gasoline storage and combustion, power plant, gases and volatile chemicals, waste explosive burning, and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. A single National Pollutant Discharge Elimination System (NPDES) permit covers 100 industrial discharge points and 10 sanitary sewage treatment facilities. This year 9 of the 10 sanitary sewage treatment facilities exceeded one or more of the NPDES

limits (excluding flow rate limitations) in one or more months. Fewer than 7% of all samples from the 100 industrial outfalls exceeded NPDES limits.

Some special environmental research programs were conducted this year to gain a better understanding of the ecosystems at Los Alamos. Among these projects were the study of water quality, elk migration, transuranic waste management methods, hydrologic transport of sediments, and use of honeybees as biological monitors.

II. BACKGROUND ON LOS ALAMOS

A. Description of the Area

1. Geographic Setting

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

All Los Alamos County and vicinity locations referenced in this report are identified by the Laboratory cartesian coordinate system, which is based on English units of measurement. This system is standard throughout the Laboratory, but is independent of the US Geological Survey and New Mexico State Survey coordinate systems. The major coordinate markers shown on the maps are at 3.048 km (10 000 ft) intervals, but for the purpose of this report are identified to the nearest 0.30 km (1000 ft). The area within the Laboratory boundary is controlled by the Department of Energy, which has the option to completely restrict access. This control can be instituted when necessary.

2. Land Use

Most Laboratory and community developments are confined to mesa tops (see Fig. 2 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 is used to provide isolation for security and safety and as reserves for future structure locations. A comprehensive Master Plan for Laboratory lands is near completion. It will assure adequate planning for the best possible use of available land in the future.

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

3. Geology-Hydrology

Most of the finger-like mesas in the Laboratory area are formed by Bandelier Tuff (see Fig. 3, tuff). This is ashfall and ashflow 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. 3, conglomerate) in the central and eastern edge along the Rio Grande. Chino Mesa basalts (see Fig. 3, basalt) interfinger with the conglomerate along the river. These formations overlie the siltstone/sandstone Tesuque Formation (see Fig. 3, 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).

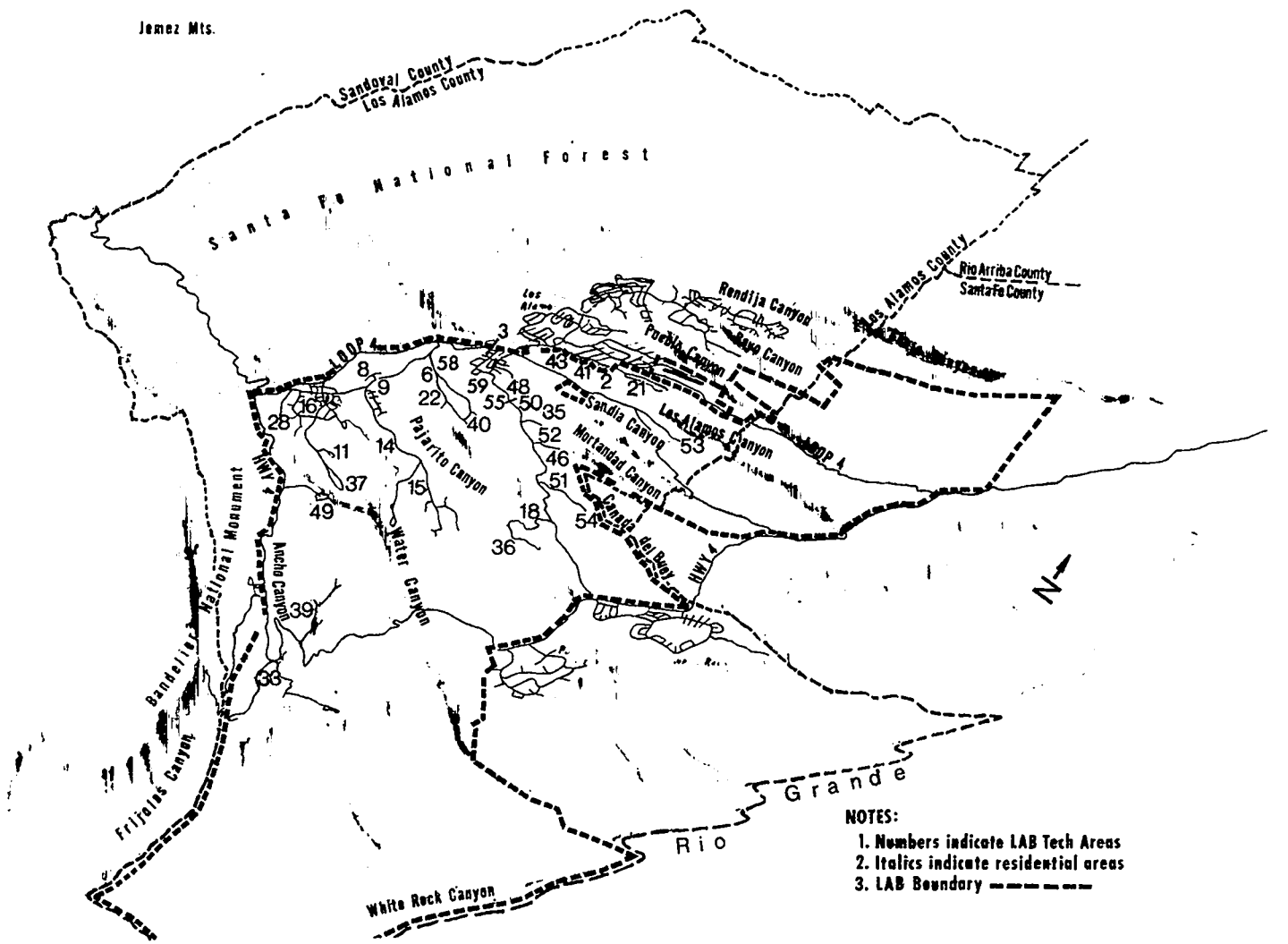


Fig. 2. Topography of the Los Alamos, New Mexico area.

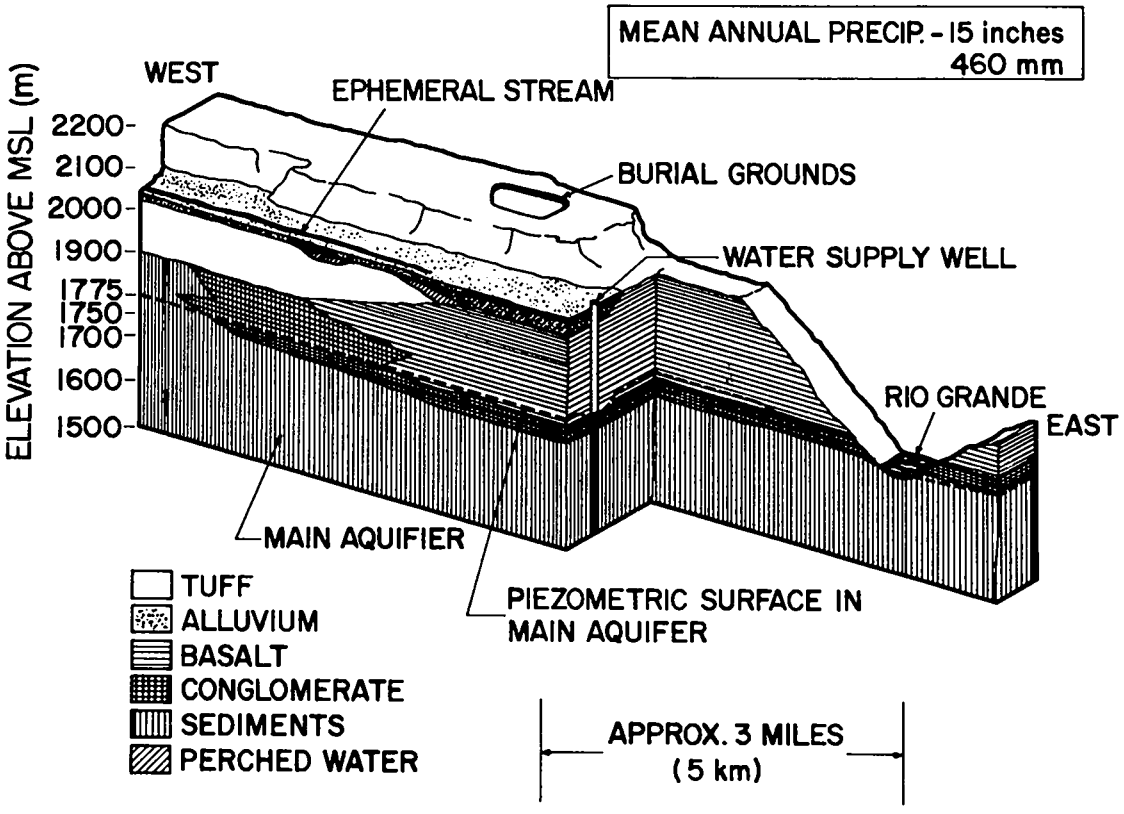


Fig. 3. Conceptual illustration of geologic-hydrologic relationships in the Los Alamos area.

Ground water occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in canyons, (2) perched water (a ground water body above an 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. 3, alluvium, perched water, and main aquifer, respectively).

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 in 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.[1].

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. 3, 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.[2] 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 $\times$ 10^6 m^3 (4300 to 5500 acre-feet) annually from the aquifer.

4. Climatology

Los Alamos has a semiarid, temperate mountain climate. The average annual precipitation of 45 cm (18 in.) is produced by warm-season showers and thundershowers and cold-season migratory storms. Forty per cent of the annual moisture total falls during July and August, primarily from afternoon thundershowers. Winter precipitation primarily falls as snow, with accumulations of about 130 cm (51 in.).

Summers are generally sunny and pleasant. Maximum temperatures are usually below 32°C (90°F). Brief afternoon thundershowers are very common, especially in July and August. The high altitude, light winds, clear skies, and dry atmosphere allow night temperatures to drop into the 12 to 15°C (54 to 59°F) range. Winter temperatures are typically in the range of −10 to 5°C (14 to 41°F). Many winter days are clear with light winds, so strong sunshine makes conditions quite comfortable even when air temperatures are cold. Occasionally, temperatures do drop to near 0°F (−17.8°C) or below.

Significant spatial and daily variations of surface winds in Los Alamos are caused by the complex terrain. With weak large-scale winds and clear skies, a distinct daily wind cycle exists: a light southeasterly upslope wind during daytime hours and a light westerly drainage wind during nighttime hours. On the east end of Pajarito Plateau, near the Rio Grande Valley, a different daily wind cycle is evident; a moderate up-valley wind during daytime hours and a light down-valley wind during nighttime hours. On the whole, the predominant winds are westerly over the Laboratory and more southwesterly nearer the Rio Grande Valley.

Historically, no tornadoes have been reported in Los Alamos County. However, strong wind gusts exceeding 20 m/sec (66 mph) are common during spring months. Lightning is very common over Pajarito Plateau. There is a high average of 58 thunderstorm days per year. Lightning protection is an important consideration applied to each facility at the Laboratory. Hailstones with diameters up to 0.6 cm (0.25 in.) are common, while 1.3 cm (0.5 in.) diameter hailstones are rather rare.

5. Population Distribution

Los Alamos County has a population estimated by the 1980 census (adjusted for 1981) at 17 929. Two residential and related commercial areas exist in the county (see Fig. 4 and inside back cover). The Los Alamos townsite, the original area of development (and now including residential areas known as the Eastern Area, the Western Area, North Community, Barranca Mesa, and North Mesa), has an estimated population of 11 012. The White Rock area (including the residential areas White Rock, La Senda, and Pajarito Acres) has about 6917 residents. About one-third of those employed in Los Alamos commute from other counties. Population estimates for 1981 place about 115 000 people within an 80 km (50 mi) radius of Los Alamos.

B. Los Alamos National Laboratory

1. Programs and Facilities

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, medicine, and magnetic and inertial fusion. In more recent years, other programs have been added in applied photochemistry, astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, computers,

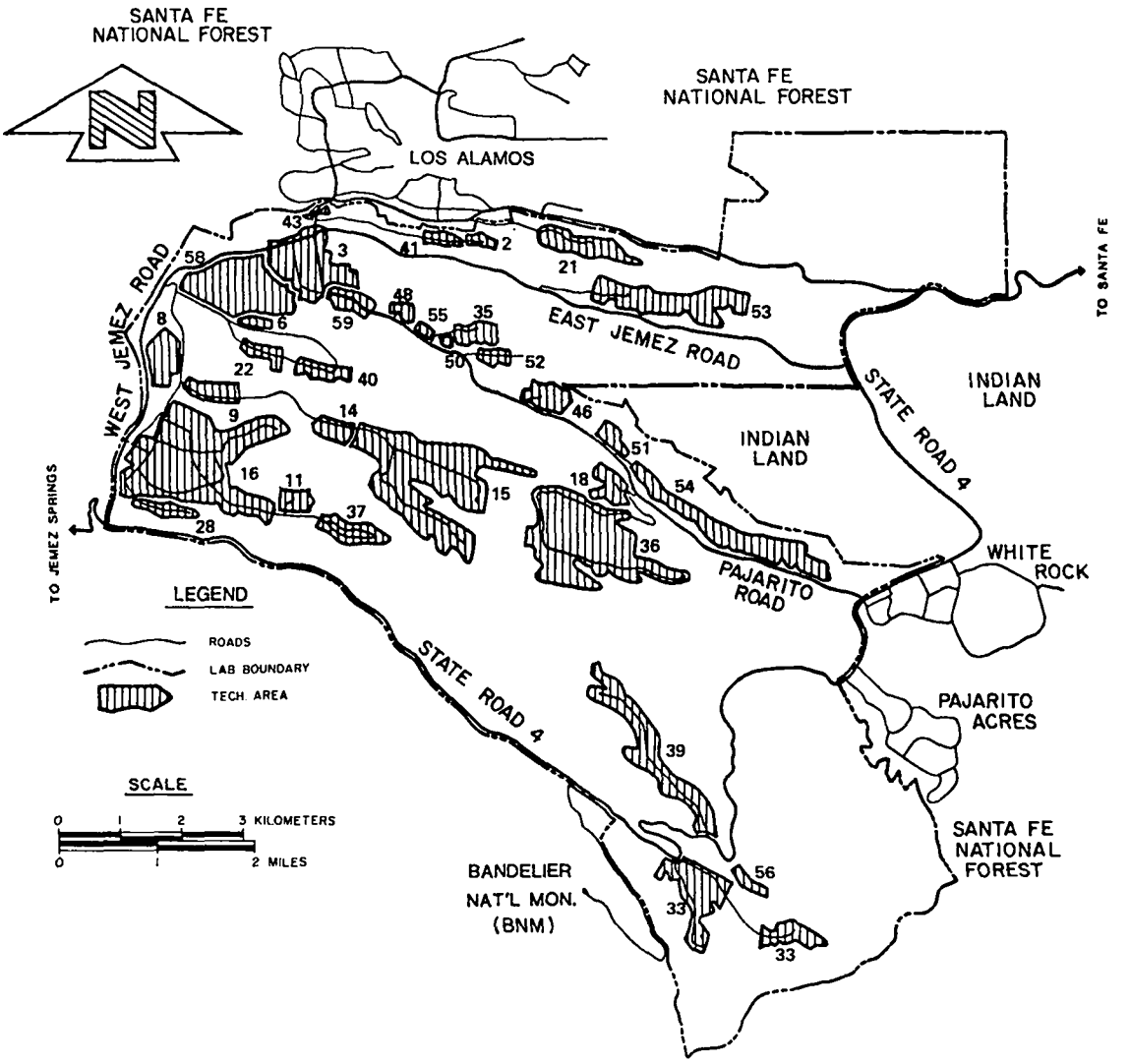


Fig. 4. Los Alamos National Laboratory's technical areas and adjacent communities.

solar energy, geothermal energy, biomedical and environmental research, and nuclear waste management research.

A unique combination of facilities that contributes to the various research programs exists at Los Alamos. These facilities include an 800 MeV linear particle accelerator, a tandem Van de Graaff accelerator, a High Energy Gas Laser Facility, and an 8 megawatt nuclear research reactor. Some of these facilities encourage participation and joint projects by researchers from other laboratories and research facilities.

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

A Final Environmental Impact Statement (FEIS)[3] that assesses potential cumulative environmental impacts associated with current, known future, and continuing activities at the Laboratory was completed in 1979. The FEIS provides environmental input for decisions

regarding continuing activities at the Laboratory. It also provides much more detailed information on the environment of the Los Alamos area.

The Laboratory is administered by the University of California for the Department of Energy under contract W-7405-ENG-36. The Laboratory's environmental program, conducted by the Environmental Surveillance Group, is part of a continuing investigation and documentation program.

2. Waste Management

The Laboratory's activities are conducted in 33 active technical areas (TAs) distributed over the site (see Fig. 4 and Appendix F for descriptions of activities at the TAs). Wastes requiring disposal are generated at virtually all these locations. Sanitary sewage is handled by a number of plants employing conventional secondary treatment processes or by septic tanks. Uncontaminated solid waste is disposed in the County-operated landfill located within the Laboratory boundary. Nonradioactive airborne emissions include combustion products from the power and steam plants, vapors or fumes from numerous local exhaust systems (such as chemistry laboratory hoods), and burning of high explosive wastes.

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

From 90 to 95% of the total volume of radioactively contaminated solid waste from the Laboratory is disposed of by burial at the waste disposal area (TA-54). The remaining 5 to 10% is classed as transuranic waste and stored retrievably. Environmental containment is provided by the dry geologic formation of the burial ground.

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

III. RADIATION DOSES

Small incremental radiation doses above those received from background levels of natural and worldwide fallout are received by Los Alamos County residents as a result of Laboratory operations. The largest estimated dose at an occupied location was 4.8 mrem or 1.0% of the Radiation Protection Standard. This estimate is based on boundary dose measurements of airborne and scattered radiation from the linear particle accelerator at TA-53. Other minor exposure pathways—direct radiation from nuclear criticality experiments at TA-18 and two unlikely food pathways—may result in several mrem/yr doses in isolated cases.

No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. Most of the radioactivity is absorbed in alluvium before leaving the Laboratory boundaries. Some is transported offsite in stream channel sediments during heavy runoff.

The total population dose received by residents of Los Alamos County was conservatively estimated to be about 10 person-rem, or about 0.5% of the 2040 person-rem received by the same population from natural radiation sources, and 0.5% of the population dose due to diagnostic medical exposure. As no significant pathways could be identified outside the County, the 10 person-rem dose also represents the population dose to inhabitants living within an 80 km radius of the Laboratory who receive an estimated 11 800 person-rem from background radiation.

The average added risk of cancer mortality to Los Alamos townsite residents from radiation from this year's Laboratory operations is 1 chance in 15 000 000. This risk is much less than the 1 chance in 86 000 from background radiation. The Environmental Protection Agency has estimated average lifetime risk for cancer incidence as 1 chance in 4 and for cancer mortality as 1 chance in 5.

A. Introduction

One means of evaluating the significance of environmental releases of radioactivity is to compare doses received by the public from exposure to these releases with appropriate standards[4] and with doses from naturally present background radiation. The principal exposure pathways considered for the Los Alamos area were atmospheric transport of airborne radioactive emissions, hydrologic transport of liquid effluents, food chains, and direct exposure to penetrating radiation. Exposures to radioactive materials or radiation in the environment were determined by direct measurements of some airborne and waterborne contaminants and of external penetrating radiation. Theoretical dose calculations based on atmospheric dispersion were made for other airborne contaminants present at levels too low for direct measurement.

Doses were calculated from measured or derived exposures utilizing models based on recommendations of the International Commission on Radiological Protection (ICRP, see Appendix D for details) for each of the following categories.[5]

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

Doses calculated for these categories are summarized in Table VI. The data on which these calculations are based are discussed in the following sections, while the calculational procedure is described in Appendix D.

In addition to compliance with dose guidelines, which define an upper limit for doses to the public, there is a

TABLE VI

SUMMARY OF ANNUAL DOSES DUE TO 1981 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	17 mrem	4.8 mrem	0.67 mrem	0.38 mrem	10 person-rem
Critical organ	Whole Body	Whole Body	Whole Body	Whole Body	Whole Body
Location	Boundary N. of TA-53	Boundary N. of TA-53	Los Alamos	White Rock	Area within 80 km of Laboratory
Radiation Protection Standard	---	500	500	500	---
Per cent of Radiation Protection Standard (%)	---	0.96	0.13	0.08	---
Natural background	116 mrem	116 mrem	116 mrem	108 mrem	11 800 person-rem
Per cent of natural background (%)	15	4	0.6	0.4	0.9

[a]Maximum boundary dose is the dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the 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.

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 airborne emission, liquid effluent, and operational controls 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. The success of the ALARA program in 1981 can be judged from the highest reported calculated dose to a member of the public (4.8 mrem to the whole body) being approximately 1% of the applicable Radiation Protection Standard.[4]

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

The maximum boundary and individual doses attributable to inhalation of and exposure to airborne releases are summarized in Table VII with a comparison to the Radiation Protection Standards for individual doses[4] (see Appendix A).

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

Exposures to ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar from the Los Alamos Meson Physics Facility (a linear particle accelerator) were inferred from direct radiation measurements (see Section IV.A.1). Exposure from ^{41}Ar released from the stack of a research nuclear reactor at TA-2 was theoretically calculated from measured stack releases and standard atmospheric dispersion models. These models used 1981 meteorological data measured at the Laboratory (see Section IV.C and Appendix D). Doses from these exposures are discussed in Section III.E.

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

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

C. Doses to Individuals from Liquid Effluents

Liquid effluents do not flow beyond the Laboratory boundary but are absorbed in alluvium of the receiving canyons. These effluents are monitored at their point of discharge and their behavior in the alluvium of the canyons below outfalls has been studied.[6-9] 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[10] indicate a maximum exposure pathway (eating liver from a steer that drinks water from and grazes in lower Los Alamos Canyon) to man from these canyon sediments results in a maximum 50-yr dose commitment of 0.0013 mrem to the bone, 0.0001% of the Radiation Protection Standard.[4]

D. Doses to Individuals from Ingestion of Foodstuffs

There are no known significant aquatic pathways or food chains to humans in the local area. Fruit, vegetable, honey, and fish sampling (see Section IV.A.5) have documented that any exposure attributable to Laboratory operations via those pathways is less than 0.02 mrem, 0.004% of the Radiation Protection Standard. A possible minor exposure pathway exists by eating venison from deer that cross into Laboratory property to graze and drink. The maximum dose calculated via this pathway is 3.9 mrem/yr and unlikely to occur.[11]

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

No measurements (see Section IV.A.1) of external penetrating radiation at regional and perimeter stations indicated any discernable increase in radiation levels attributable to Laboratory operations, except those along State Road 4 north of the Los Alamos Meson Physics Facility (TA-53). The special thermoluminescent

TABLE VII

MAXIMUM BOUNDARY AND INDIVIDUAL DOSES FROM 1981 AIRBORNE RADIOACTIVITY

Isotope	Critical Organ	Maximum Boundary Dose[a]		Maximum Individual Dose[b]		
		Location	Dose (mrem/yr)	Location	Dose (mrem/yr)	Radiation Protection Standard
^{3}H (HTO)	Whole Body	TA-54 (Station 22)[d]	0.0054	Bayo Sewage Treatment Plant (Station 9)[d]	0.0053	0.001
$^{11}C,^{13}N,^{15}O$	Whole Body	Restaurant N. of TA-53[e]	17	Restaurant N. of TA-53[e]	4.8	0.96
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack[e]	0.2	Apts. N. of TA-2 Stack[e]	0.1	0.03
^{239}Pu[c]	Lung	Booster-P2 (Station 21)[d]	0.01	48th Street (Station 7)[d]	0.006[c]	0.0004

[a]Maximum boundary dose is the dose to a hypothetical individual at the Laboratory boundary where the highest dose rate occurs. It assumes the 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.

[c]For a 50-yr dose commitment, bone is the critical organ. A maximum individual would receive a 50-yr bone dose commitment of 0.42 mrem, which is 0.03% of the Radiation Protection Standard.

[d]See Fig. 9 for station locations.

[e]See Fig. 4 for technical area (TA) locations.

dosimeter network at the Laboratory boundary north of the Los Alamos Meson Physics Facility indicated a 17.1 mrem increment above natural background as shown in Table VII. This increment is attributed to emission of air activation products from the Los Alamos Meson Physics Facility.

Based on occupancy and shielding, this 17.1 mrem increment translates to a 4.8 mrem dose to an individual working at the restaurant north of the Los Alamos Meson Physics Facility. This dose represents 0.96% of the Radiation Protection Standard for a member of the public.[4] This location north of the Los Alamos Meson Physics Facility has been the area where the highest boundary and individual doses have been measured since thermoluminescent dosimeter monitoring began there 4 years ago. The boundary doses at this location are discussed in Section IV.A.1. The increase in dose from 12.3 mrem in 1980 to 17.1 mrem in 1981 is probably mainly attributable to the increase in the Los Alamos Meson Physics Facility's airborne emissions from 145 600 Ci in 1980 to 352 340 Ci in 1981.

A maximum onsite dose to a member of the public from external radiation from all Laboratory airborne

emissions of 0.0054 mrem was estimated for a person spending 4 hours at the Laboratory's science museum.

The average annual dose to residents in Los Alamos townsite attributable to Laboratory operations was 0.67 mrem (whole body). The corresponding dose to White Rock residents was 0.38 mrem (whole body). These doses are 0.13 and 0.08%, respectively, of the Radiation Protection Standard.[4] These doses were theoretically calculated using measured stack releases (Table E-I) and 1981 meteorological data (Appendix D).

The ^{41}Ar emissions dispersed from TA-2 and TA-53 could result in a theoretically calculated annual regional dose of 0.008 mrem at Española. This dose is 0.002% of the Radiation Protection Standard.

Onsite measurements of above background doses from direct radiation were expected and do not represent potential exposure to the public except in the vicinity of TA-18 (a nuclear criticality study area) on Pajarito Road. Members of the public regularly utilizing the Department of Energy-controlled road passing by TA-18 would likely receive no more than 0.42 mrem/yr of direct gamma and neutron radiation. This value was derived from 1975 data[12] on total gamma plus neutron dose rates using 1981 gamma doses 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 station (see Section IV.A.1, Station 24 in Fig. 6) near the Laboratory boundary recorded a dose of 158 mrem/yr. The increment (about 65 mrem) of this dose above natural background is caused by a localized accumulation of ^{137}Cs on sediments transported from a treated effluent release point upstream.

F. Whole Body Cumulative Doses

Cumulative 1981 whole body doses to Los Alamos County residents attributable to Laboratory operations are compared to exposure from natural radiation and medical radiation in Table VIII. Population data are based on the US Bureau of Census count (adjusted for 1981, see Appendix D) of 11 012 residents in Los Alamos townsite and 6917 in White Rock.

The calculated 10 person-rem from 1981 Laboratory operations is probably high because of the conservative assumptions that were used (see Appendix D) to calculate the dose. The whole body population dose from Laboratory operations to the estimated 115 000 inhabitants within an 80 km radius of Los Alamos is estimated to be 10 person-rem, which is also the population dose to Los Alamos County inhabitants. This is because other population centers are far enough away that dispersion, dilution, and decay in transit (particularly for ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar) make their exposure undetectable and theoretically a very small fraction of the estimated 10 person-rem. By contrast, natural radiation exposure to the inhabitants within an 80 km radius is 11 800 per-rem.

Thus, doses potentially attributable to releases from Laboratory operations contribute about 0.5% of the total dose received by Los Alamos County residents from natural radiation, about 0.5% to the same population from diagnostic medical radiation, and about 0.09% of the dose from natural radiation received by the population within an 80 km radius of the Laboratory.

G. Estimates of Risk to an Individual from Laboratory Releases

Since there is considerable interest in possible health effects from radiation doses to the public resulting from Laboratory operations, several risk estimates have been made. However, these calculations may overestimate actual risk. The National Council on Radiation Protection and Measurements[15] has warned "risk estimates for radiogenic cancers at low doses and low dose rates derived on the basis of linear (proportional) extrapolation from the rising portions of the dose incidence curve at high doses and high dose rates... cannot be expected to provide realistic estimates of the actual risks from low level, low-LET (linear energy transfer) radiations, and have such a high probability of overestimating the actual risk as to be of only marginal value, if any, for purposes of *realistic* risk-benefit evaluation."

The International Commission on Radiological Protection[16] estimates that the total risk of cancer mortality from uniform whole body irradiation for individuals is 0.0001 per rem, that is, there is 1 chance in 10 000 that an individual exposed to 1000 mrem (1 rem) of whole body radiation would develop a cancer. In developing risk estimates, the International Commission on Radiological Protection[16] 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."

TABLE VIII

WHOLE BODY POPULATION DOSES TO RESIDENTS OF LOS ALAMOS COUNTY DURING 1981

Exposure Mechanism	Whole-Body Population Dose (person-rem)
Atmospheric Total U, ^{238}Pu, ^{239}Pu, ^{241}Am	0.06
Atmospheric Tritium (as HTO)	0.00
Atmospheric ^{11}C, ^{13}N, ^{15}O	9.51
Atmospheric ^{41}Ar	0.49
Total Due to Laboratory Atmospheric Releases	10.06
Cosmic and Terrestrial External Radiation[a]	1405
Cosmic Neutron Radiation (~11 mrem/yr per person[13])	190
Self Irradiation from Natural Isotopes in the Body (~24 mrem/yr per person[13])	430
Average Due to Airline Travel (~0.22 mrem/h at 9 km[13])	15
Total Due to Natural Sources of Radiation	2040
Diagnostic Medical Exposure (~103 mrem/yr per person[14])	1846

[a]Calculations are based on measured thermoluminescent dosimeter data. They include a 10% reduction in cosmic radiation due to shielding by structures and a 40% reduction in terrestrial radiation due to shielding by structures and self-shielding by the body.

During 1981, persons living in Los Alamos and White Rock received an average of 116 and 108 mrem, respectively, of whole body radiation from natural sources (including cosmic and terrestrial radiation with allowances for shielding, self-irradiation and cosmic neutron exposure, but excluding that radiation received from airline travel, luminous dial watches, building materials, etc.). Thus, the added cancer mortality risk attributable to natural radiation in 1981 was 1 chance in 86 000 in Los Alamos and 1 chance in 93 000 in White Rock (Table III).

Laboratory operations contributed an average dose of 0.67 mrem to individuals in Los Alamos and 0.38 mrem to individuals in White Rock. These doses are estimated to add lifetime risks of about 1 chance in 15 000 000 in Los Alamos and 1 chance in 26 000 000 in White Rock to an individual's risk of cancer mortality due to 1981 Laboratory activities (Table III).

For Americans the average lifetime risk is a 1 in 4 chance of contracting a cancer from all causes and a 1 in 5 chance of dying from the disease.[17,18] The Los Alamos and White Rock incremental doses attributable to Laboratory operations are equivalent to the additional exposure a person would get from flying in an aircraft for 3.0 and 1.7 h, respectively.

The additional exposure and subsequent risk to Los Alamos County residents are well within variations in natural exposure and risks in life that are accepted routinely by most people. For example, one study[19] showed the annual dose rate on the second floor of

single-family frame dwellings was 14 mrem/yr less than the dose rate on the first floor. Energy conservation measures, such as sealing and insulating houses and installing passive solar systems, are likely to contribute much larger doses to Los Alamos County residents than Laboratory operations because of increased radon levels inside the homes. The Environmental Protection Agency has estimated the annual whole body dose to individuals from global fallout to be 4.4 mrem.[20]

IV. MONITORING RESULTS

A. Radiation and Radioactivity

1. Penetrating Radiation

Levels of 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 and perimeter locations for each calendar quarter did not show any statistically discernible increase in radiation levels attributable to Laboratory operations. Onsite measurements were slightly above background levels, reflecting research activities at the Laboratory. A special group of dosimeters, which monitors radioactivity of gaseous emissions from the Los Alamos Meson Physics Facility, showed a small increase in radiation levels due to operation of this linear particle accelerator.

Natural penetrating radiation has two components. The natural terrestrial component results from decay of ^{40}K and of radioactive daughters from the decay chains of ^{232}Th and ^{238}U. The cosmic component includes photon radiation, charged particles, and neutrons. Thermoluminescent dosimeters (TLDs) are used at the Laboratory to measure this penetrating radiation. 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 monitoring program are insensitive to cosmic neutrons, so the neutron contribution to natural background radiation is not measured.

Cosmic ionizing radiation increases with elevation because of reduction in the shielding effect of the atmosphere. At sea level it averages 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. The regional monitoring locations, ranging from about 1.7 km elevation at Pojoaque to about 2.65 km at Fenton Hill, receive from 50 to 70 mrem/yr.[13]

In contrast to this fairly constant cosmic component, the dose from the natural terrestrial component in the Los Alamos area is highly variable. Temporal variation at any particular location (Figs. 5,6) is about 15 to 25% because of variations in soil moisture content and snow cover.[13] Figure 5, which compares all TLD locations that have been unchanged during the last 5 years, shows this temporal variation in the regional and perimeter averages. The variation in onsite averages is more influenced by changes in research programs at particular Laboratory sites than by changes in soil moisture or snow cover. There is also spatial variation because of different soil and rock types in the area.[11] These natural sources of variation make it difficult to detect any increases in the radiation level from manmade sources, especially if the magnitude of such an increase is small compared to natural fluctuations.

Levels of 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 TLDs deployed in two independent networks. The environmental network consists of 32 locations divided into three groups. Three of these locations, 28 to 44 km from the Laboratory boundary at air sampling stations in the neighboring communities of Española, Pojoaque, and Santa Fe, along with the Fenton Hill Site 30 km to the west of Los Alamos, form the regional groups (Figs. 7 and 25). The perimeter group consists of 12 dosimeters placed within 4 km of the boundary. Twenty-one locations within the Laboratory boundary comprise the onsite group. The dosimeters are changed each calendar quarter. See Appendix B for more information on handling of the TLDs.

Tables IV and E-II summarize the annual total doses by the regional, perimeter, and onsite groups for 1981. Figure 5 shows a comparison of dose averages for 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. Onsite measurements were slightly above background levels, reflecting research activities at the Laboratory.

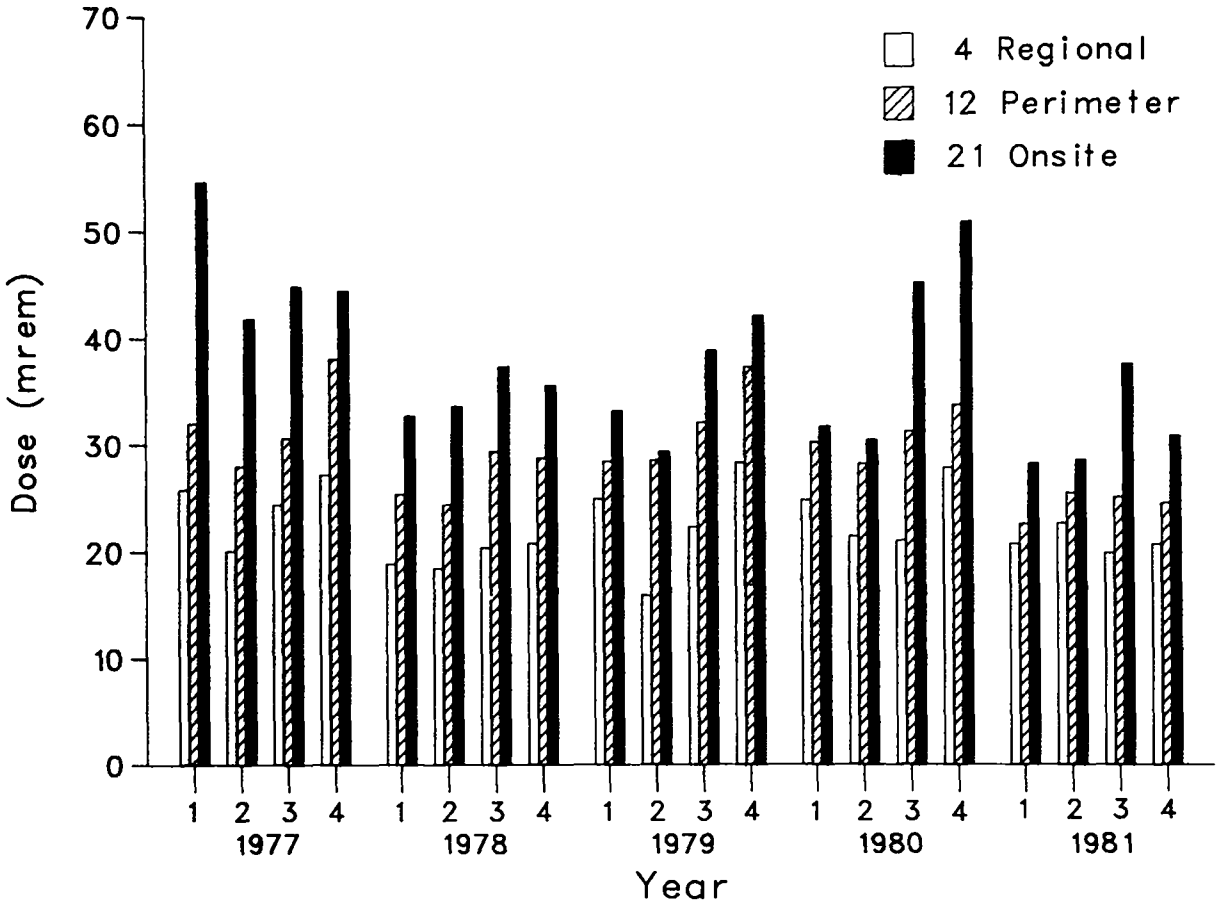


Fig. 5. Quarterly dose averages for three station groups during the last 5 years.

The second network monitors radiation from radioactive gas released by the Los Alamos Meson Physics Facility (a linear particle accelerator), TA-53. The dose contribution from the Los Alamos Meson Physics Facility's operations is very small. To improve the accuracy and decrease the uncertainty of this measurement, 12 TLD sites are located at the Laboratory boundary north of the Los Alamos Meson Physics Facility along 800 m of canyon rim. Twelve background TLD sites are similarly located about 9 km from the Facility along a canyon rim near the southern boundary of the Laboratory (Fig. 6). This background location is not influenced by any Laboratory radiation sources.

These 24 TLDs are changed in accordance with the operational schedule of the Los Alamos Meson Physics Facility. The difference between the average of the dosimeters at the north and south boundaries represents the contribution to the dose from Los Alamos Meson Physics Facility's operations and is plotted in Fig. 8. The Los Alamos Meson Physics Facility network showed an increase of 17 ± 2 mrem/yr at the Laboratory boundary north of the Los Alamos Meson Physics Facility due to its operation.

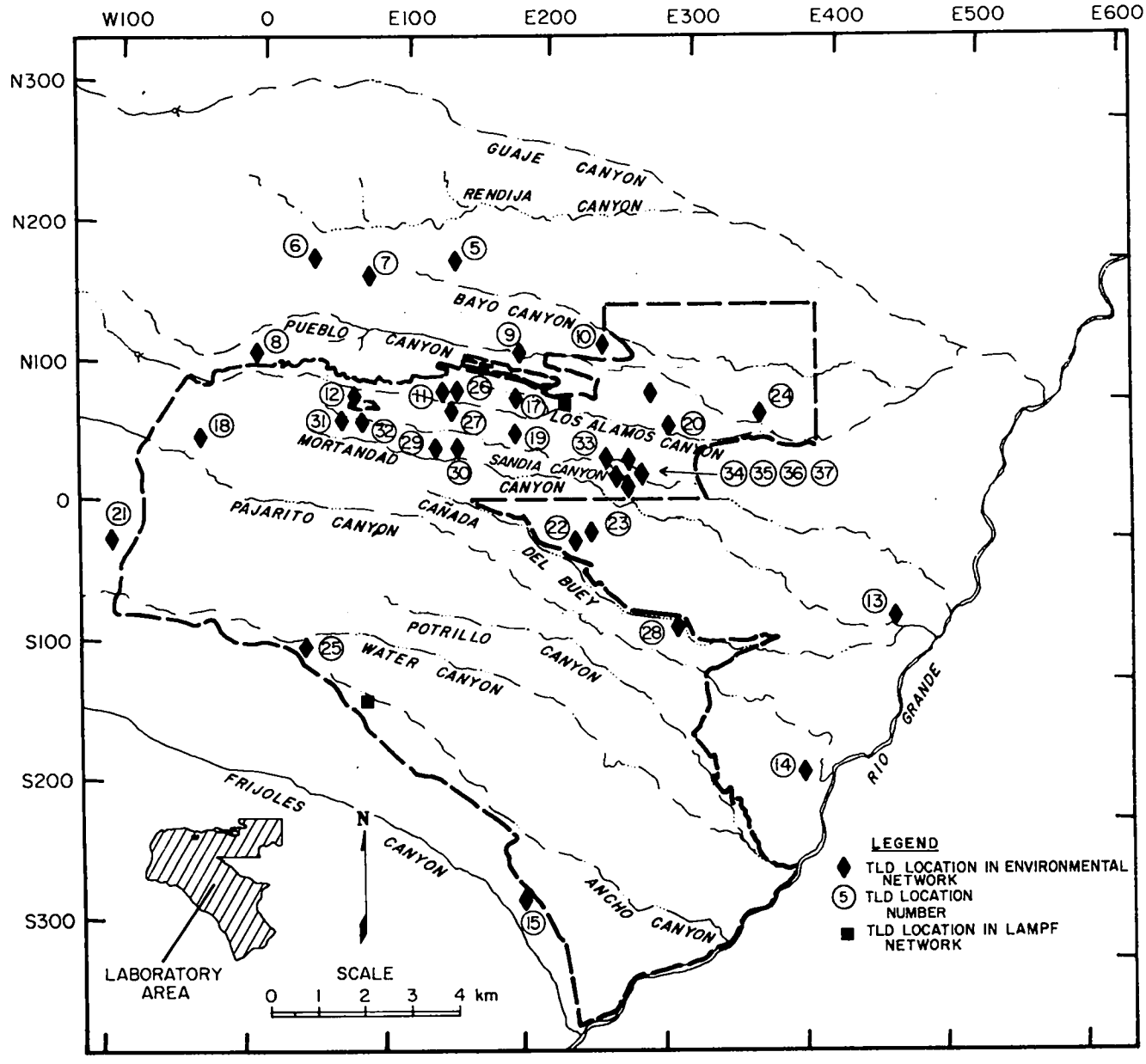


Fig. 6. Thermoluminescent dosimeter locations on or near the Laboratory site.

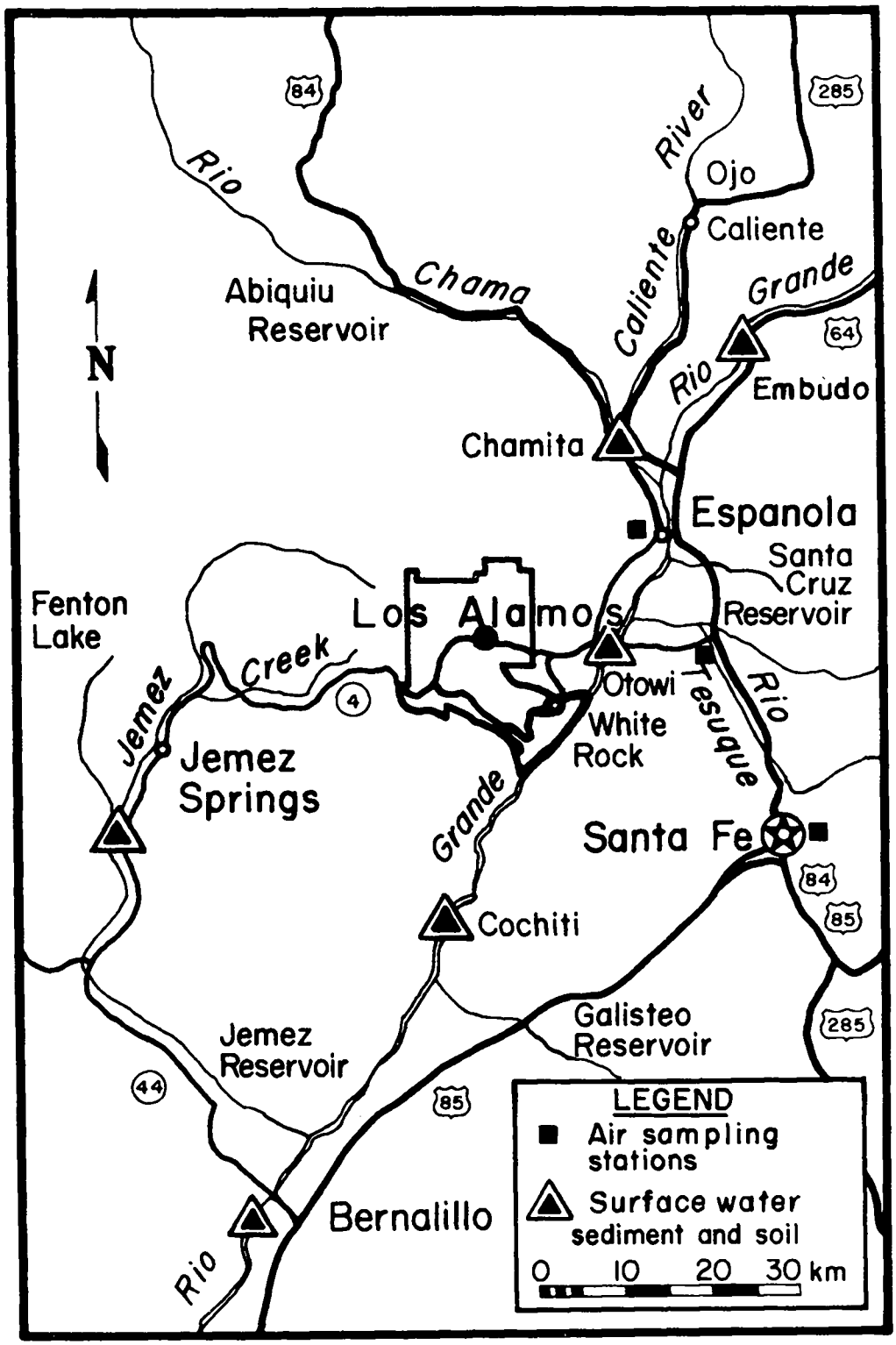


Fig. 7. Regional surface water, sediment, soil, and air sampling locations.

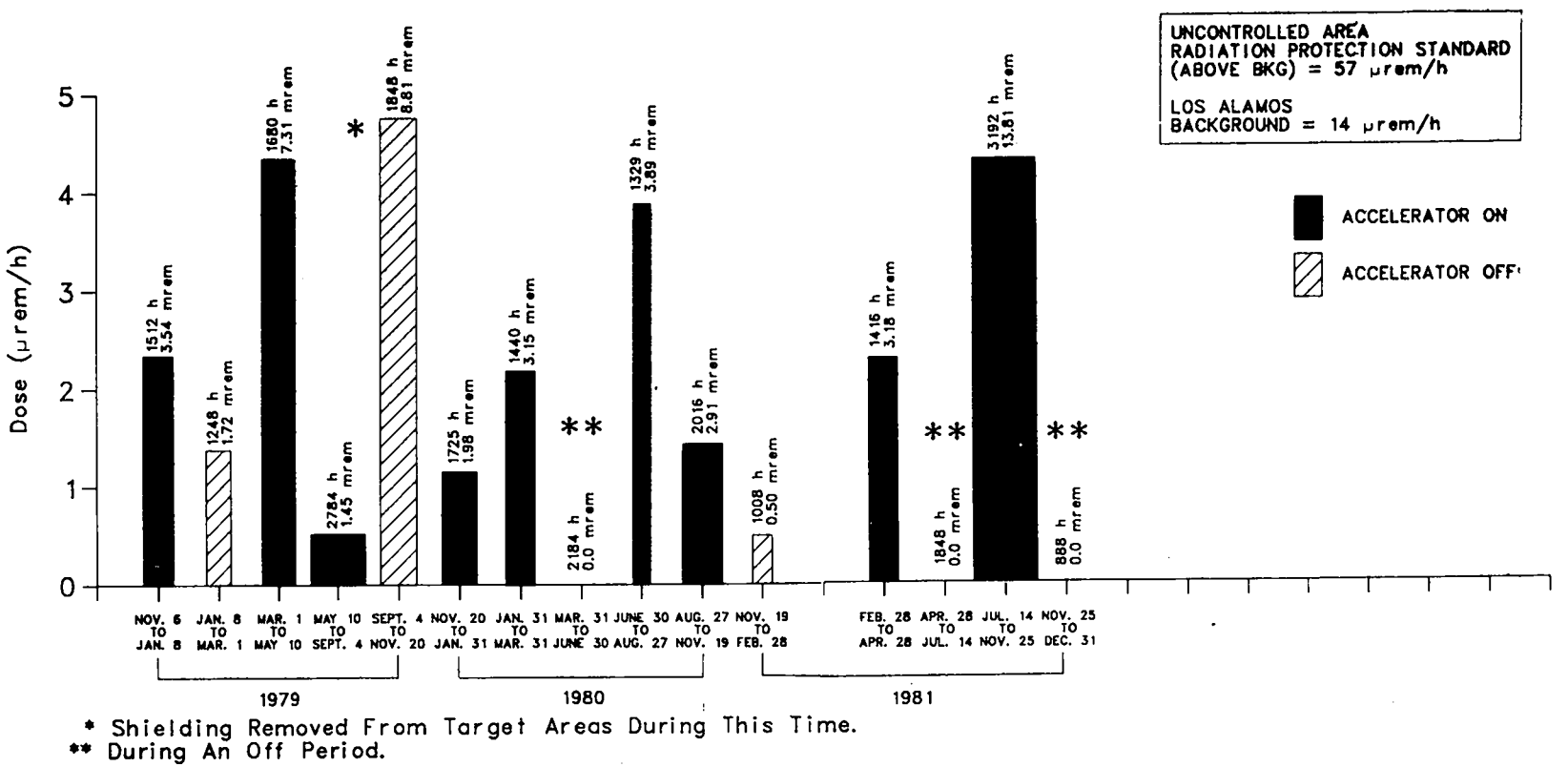


Fig. 8. Above background dose rate due to operation of the Los Alamos Meson Physics Facility.

2. Atmospheric Radioactivity

Worldwide background atmospheric radioactivity is composed of fallout from atmospheric nuclear weapon tests, natural radioactive constituents in dust from the earth's surface, and radioactive materials resulting from interactions with cosmic radiation. Air is routinely sampled at several locations on Laboratory land, along the Laboratory perimeter, and in distant areas to determine the existence and composition of any contributions to radionuclide levels from Laboratory operations. Atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranium were measured and statistically analyzed. There were some small but statistically significant differences among the regional, perimeter, and onsite groups and among stations within groups for some of these analyses.

a. Introduction. Atmospheric radioactivity samples are collected at 25 continuously operating air sampling stations in Los Alamos County and vicinity. Onsite and perimeter station locations are shown in Fig. 9 and identified by map coordinates in Table E-III. Perimeter stations are within 4 km of the Laboratory boundary. The regional monitoring stations, located 28 to 44 km from the Laboratory at Española, Pojoaque, and Santa Fe (Fig. 7), serve as reference points in determining regional background for atmospheric radioactivity. A complete description of sampling procedures and statistical treatment of data is given in Appendix B.

When interpreting data from this air sampling program, one must first be aware of natural and fallout radioactivity levels and their fluctuations. Worldwide background atmospheric radioactivity is largely composed of fallout from atmospheric nuclear weapons tests, natural radioactive constituents in dust from the decay chains of ^{232}Th and ^{238}U, and materials resulting from interactions with cosmic radiation (such as tritiated water vapor). Background radioactivity concentrations are summarized in Table E-IV and are useful in interpreting the air sampling data.

Because airborne particulates are mostly from soil resuspension, there are large temporal fluctuations in airborne radioactivity as a result of changing meteorological conditions. Periods of high winds result in relatively high suspended particulate concentrations, whereas periods of heavy precipitation remove many airborne particles. Spatial variations are dependent on these same factors.

b. Annual Gross Alpha and Beta Radioactivity. Gross alpha and beta analyses serve as indicators of overall radioactivity concentrations in the air. The annual average 4-week gross alpha and beta concentrations are summarized in Table IX and described in detail in Table E-V. Both the gross alpha and beta concentrations (Fig. 10) reached their highest levels for 1981 in May and then decreased the rest of the year. This elevated activity in the spring is due to mixing of the stratosphere with the troposphere, which increases fallout of radioactive particles.

The gross alpha data showed that the regional annual mean (1.1×10^{-15} μCi/mℓ) was statistically significantly lower (with p=0.01, which means there is a 1% probability of concluding that there is a significant difference when none exists) than the perimeter annual mean (4.0×10^{-15} μCi/mℓ) and onsite annual mean (4.4×10^{-15} μCi/mℓ). This is expected because the regional stations are 28 to 40 km distant from the Laboratory, so they are not influenced by its operation. The comparison of perimeter and onsite annual means showed no significant difference.

The gross beta data showed the regional annual mean (121×10^{-15} μCi/mℓ) to be statistically significantly lower ($p = 0.01$) than the perimeter annual mean (216×10^{-15} μCi/mℓ) and onsite annual mean (227×10^{-15} μCi/mℓ). The comparison of perimeter and onsite annual means showed no significant difference. The gross beta annual means were about 7 to 9 times higher than last year. Gross-beta activity peaked in the spring and then decreased to those levels measured in 1980 by December. This increased activity was measured at all air sampling locations, including the regional stations, so is attributable to worldwide fallout. The bulk of this fallout is probably from the atmospheric nuclear test by the People's Republic of China that was conducted on October 16, 1980.

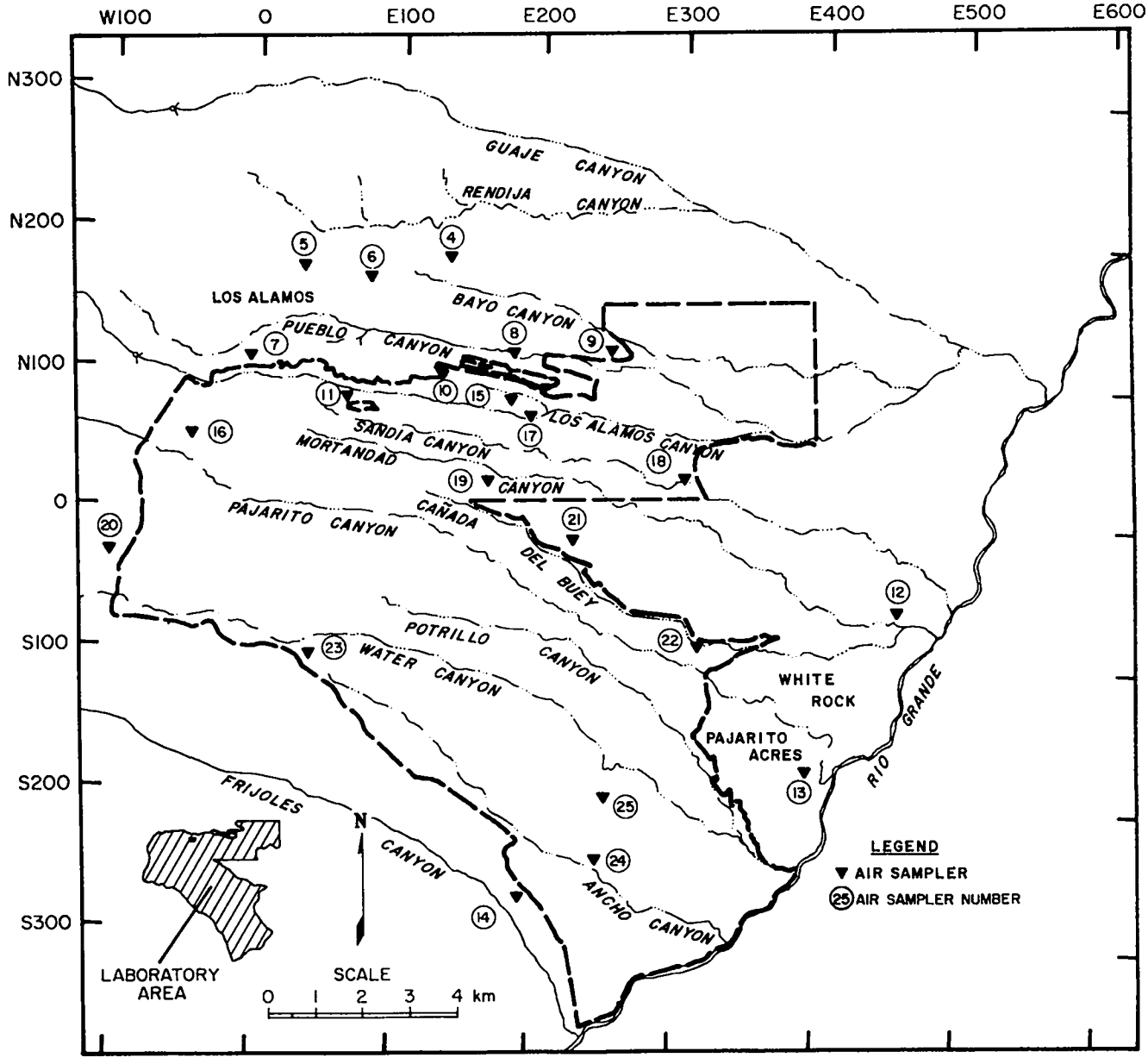


Fig. 9. Air sampler locations on or near the Laboratory site.

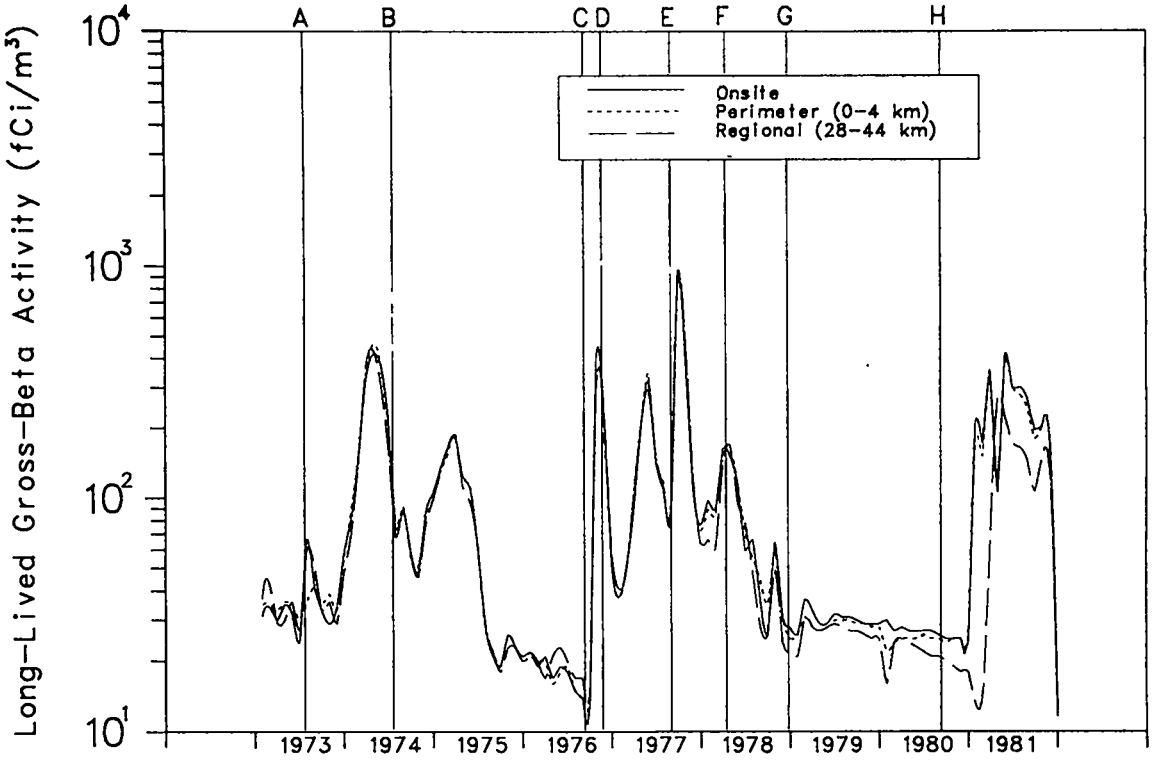
TABLE IX

SUMMARY OF ANNUAL ATMOSPHERIC RADIOACTIVITY MONITORING FOR 1981

Analysis	Group	Units	Maximum Observed	Minimum Observed	Annual Mean	Mean As % of Concentration Guide
Gross alpha	Regional	10^{-15} μCi/mℓ	3.7 ± 1.6	0.2 ± 0.1	1.1 ± 0.3	1.9
	Perimeter	10^{-15} μCi/mℓ	20 ± 8	0.1 ± 0.2	4.0 ± 0.6	6.6
	Onsite	10^{-15} μCi/mℓ	16 ± 6	0.3 ± 0.3	4.4 ± 0.5	0.22
Gross beta	Regional	10^{-15} μCi/mℓ	370 ± 100	0.5 ± 0.2	121 ± 33	0.04
	Perimeter	10^{-15} μCi/mℓ	620 ± 160	7.1 ± 1.8	216 ± 21	0.06
	Onsite	10^{-15} μCi/mℓ	550 ± 140	6.0 ± 1.6	227 ± 21	0.0014
Tritiated water vapor	Regional	10^{-12} μCi/mℓ	68 ± 22	−1.3 ± 1.0	18 ± 8	0.009
	Perimeter	10^{-12} μCi/mℓ	130 ± 40	−0.8 ± 1.0	7.6 ± 2.7	0.004
	Onsite	10^{-12} μCi/mℓ	93 ± 30	−1.6 ± 1.6	9.0 ± 2.8	0.0002
^{238}Pu	Regional	10^{-18} μCi/mℓ	0.5 ± 2.3	−3.2 ± 2.3	−1.5 ± 0.6	0.0
	Perimeter	10^{-18} μCi/mℓ	2.8 ± 3.4	−3.2 ± 1.7	−1.5 ± 0.3	0.0
	Onsite	10^{-18} μCi/mℓ	4.1 ± 2.8	−2.5 ± 1.5	0.8 ± 4.1	0.0
^{239}Pu	Regional	10^{-18} μCi/mℓ	32 ± 7	−3.3 ± 4.0	8.2 ± 5.9	0.014
	Perimeter	10^{-18} μCi/mℓ	70 ± 9	−0.5 ± 1.2	13 ± 4	0.022
	Onsite	10^{-18} μCi/mℓ	74 ± 9	−0.5 ± 1.2	8.4 ± 4.7	0.00042
^{241}Am	Regional	10^{-18} μCi/mℓ	2.8 ± 3.1	0.5 ± 3.0	1.5 ± 2.0	0.0008
	Perimeter	10^{-18} μCi/mℓ	8.7 ± 3.5	0.7 ± 3.0	2.0 ± 4.4	0.001
	Onsite	10^{-18} μCi/mℓ	450 ± 30	0.0 ± 2.5	26 ± 190	0.0004
Total U	Regional	pg/m^3	66 ± 13	−1.7 ± 18	27 ± 13	0.0005
	Perimeter	pg/m^3	168 ± 38	−2.0 ± 20	47 ± 10	0.0008
	Onsite	pg/m^3	239 ± 52	−1.9 ± 19	36 ± 11	0.00002

c. Tritium. Atmospheric tritiated water concentrations for each sampling station for 1981 are summarized in Table IX, detailed in Table E-VI, and plotted in Fig. 11. The regional annual mean (18×10^{-12} μCi/mℓ) was statistically significantly higher (p=0.01) than the perimeter annual mean (7.6×10^{-12} μCi/mℓ) and onsite annual mean (9.0×10^{-12} μCi/mℓ). In April, October, and December, measured tritium concentrations at the regional stations were higher than levels measured at perimeter and onsite stations. These higher levels could possibly be caused by fallout from the atmospheric nuclear test conducted in 1980. (Several other National Laboratories also saw unusual fluctuations in atmospheric tritium concentrations during 1981.) The relatively higher regional annual mean is 0.009% of the Department of Energy's Concentration Guide for atmospheric tritium in uncontrolled areas, so it represents no adverse health or environmental consequences.

The annual mean (22×10^{-12} μCi/mℓ) for the Bayo Sewage Treatment Plant perimeter station (Station 9)



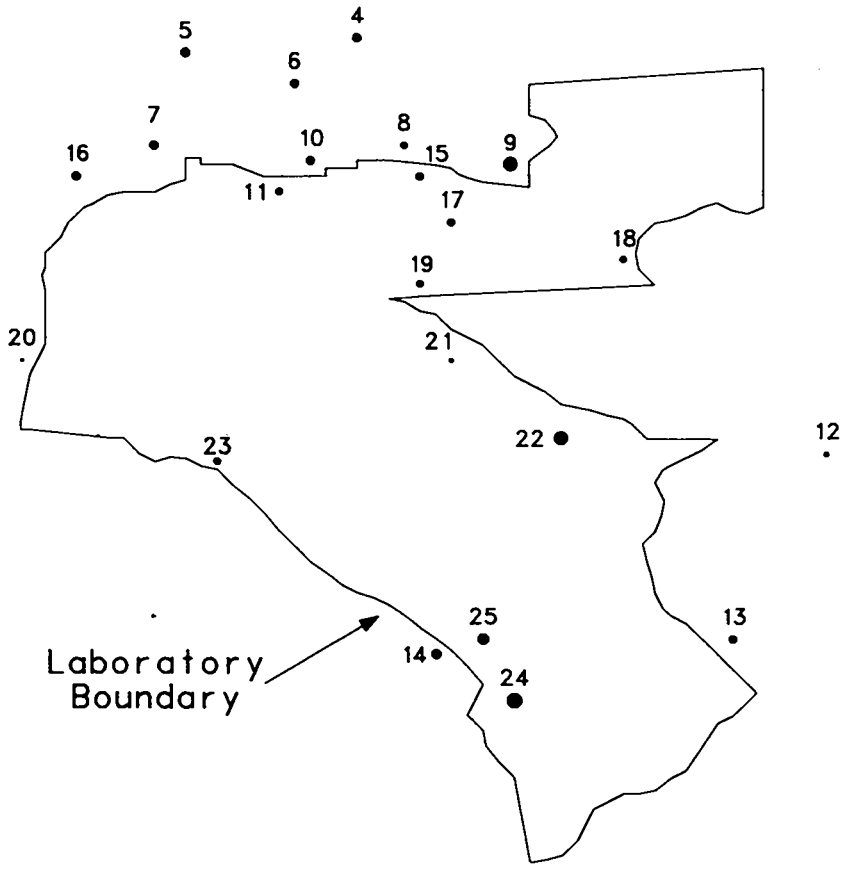
Chinese Nuclear Atmospheric Tests		
A.	26 June 1973	2–3 MT
B.	17 June 1974	0.2–1 MT
C.	26 September 1976	0.2 MT
D.	17 November 1976	4 MT
E.	17 September 1977	0.02 MT
F.	14 March 1978	0.02 MT
G.	14 December 1978	0.02 MT
H.	16 October 1980	0.2–1 MT

Fig. 10. Monthly average long-lived gross beta activity in air, 1973 through 1981, by sampling station groups.

was significantly higher (p=0.01) than the annual means for stations in the perimeter group. In October and December the measured tritium concentrations at the Bayo Sewage Treatment Plant were about 10 times higher than usual. There is no apparent explanation for these higher levels. The Bayo annual mean is 0.01% of the Department of Energy's Concentration Guide for atmospheric tritium in uncontrolled areas, so represents no adverse health or environmental consequences.

The annual mean (22×10^{-12} μCi/mℓ) for Station 22 at the radioactive solid waste disposal area (TA-54) was significantly higher (p=0.05) than annual means for the other onsite stations and resulted from evapotranspiration from buried tritium-contaminated wastes at this site.[21] Also, tritium emissions from TA-33 caused the TA-33 (Station 24) annual mean (30×10^{-15} μCi/mℓ) and the nearby TA-39 (Station 25) annual mean (12×10^{-12} μCi/mℓ) to both be higher (p=0.05) than the other onsite station annual means.

d. Plutonium. Annual average ^{238}Pu concentrations are summarized in Table IX and detailed in Table E-VII. There was just 1 of 100 measured ^{238}Pu concentrations with a detectable value. This concentration (4.1×10^{-18} μCi/mℓ) occurred at the radioactive solid waste disposal area, TA-54 (Station 22). It was 0.0002% of the Department of Energy's Concentration Guide for ^{238}Pu in air for controlled areas.



NOTE

The size of each dot is proportional to the annual atmospheric tritium concentration at a particular sampling location. The number by each dot identifies the sampling station. Table E-IV gives sampling station locations.

• – Represents 10 pCi/m^3

● – Represents 100 pCi/m^3

Fig. 11. Annual mean atmospheric tritiated water vapor concentrations on or near the Laboratory site.

For ^{239}Pu there was no statistically significant difference (p=0.05) among the regional (8.2×10^{-18} μCi/mℓ, perimeter (13.2×10^{-18} μCi/mℓ), and onsite (8.4×10^{-18} μCi/mℓ) annual means. A sample at Booster P-2 (Station 21, 74×10^{-18} μCi/mℓ) had a ^{239}Pu concentration that was about 10 times higher than the annual onsite mean for ^{239}Pu. This concentration is 0.004% of the Department of Energy's Concentration Guide for ^{239}Pu in air in controlled areas, so it did not pose a threat to public health. Almost every year there are several stations where relatively higher ^{239}Pu concentrations are measured. These isolated higher measurements are most likely caused by radioactive fallout.

e. Uranium and Americium. The 1981 atmospheric uranium concentrations are summarized in Table IX and listed in Table E-VIII. Uranium concentrations are heavily dependent on the immediate environment of the sampling station. Those stations with higher annual averages and maximums were all in dusty areas, where historically a higher filter dust loading has accounted for collection of more natural uranium from resuspended soil particles. Annual station averages were typical of regional background atmospheric uranium concentrations (see Table E-V). There were no statistically significant (p=0.05) differences among the group or station annual means.

The 1981 atmospheric ^{241}Am concentrations are summarized in Table IX and listed in Table E-IX. Analyses for ^{241}Am are done because it is a dauhter of ^{241}Pu and is much easier to detect than ^{241}Pu. Weapon-grade plutonium contains ^{241}Pu, so fallout from atmospheric nuclear tests often contain ^{241}Pu and ^{241}Am. This year only 3 of 44 analyses for ^{241}Am had detectable levels. The highest of these three concentrations was 450×10^{-18} μCi/mℓ at TA-16 (Station 20) and was 0.008% of the Department of Energy's Concentration Guide for ^{241}Am in air in controlled areas.

3. Radioactivity in Surface and Ground Waters

Surface and ground waters are monitored to provide routine surveillance of dispersion of radionuclides from Laboratory operations. Results of these analyses are compared to the Department of Energy's Concentration Guides for water. Regional background concentrations are an indication of the small amounts of radionuclides (natural and fallout) in the environment. The 1981 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite noneffluent release areas indicate no significant effect from effluent releases from the Laboratory. Waters in onsite liquid effluent release areas contain trace amounts of radioactivity. These onsite waters are not a source of industrial, agricultural, or municipal water supplies.

a. Regional and Perimeter Waters. Analyses of surface and ground waters from regional and perimeter stations reflect base line levels of radioactivity in areas outside the Laboratory boundary. Regional surface waters were collected within 75 km of the Laboratory from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 7, Table E-X). Surface water from these rivers is used for irrigation of crops in the Rio Grande Valley, both upstream and downstream from Los Alamos. Waters of the Rio Grande, Rio Chama, and Jemez River are part of recreational areas on state and federal lands. Samples were also collected from 5 perimeter stations located within about 4 km of the Laboratory boundaries and from 26 stations in White Rock Canyon of the Rio Grande (Figs. 12 and 13, Table X). Water from Los Alamos and Guaje Reservoirs is used during the summer for irrigation of lawns and shrubs at the Laboratory and public schools. These two locations are also sampled as part of the perimeter group.

A comparison of the maximum concentrations found in these waters with the Department of Energy's Concentration Guides (see Appendix A) for uncontrolled areas is given in Table X. However, the Concentration Guides do not account for concentration mechanisms that may exist in environmental media. Consequently, other media such as sediments, soils, and foods are monitored (as discussed in subsequent sections). Detailed data from regional, perimeter, and White Rock Canyon stations are in Tables E-XI, E-XII, and E-XIII, respectively. See Appendix B.3 for methods of collection, analysis, and reporting of water data.

Radionuclide concentrations in surface and ground waters from the six regional and five perimeter stations were low and showed no effect from release of liquid effluents at the Laboratory. Plutonium concentrations were near minimum detection levels and were well below Concentration Guides for uncontrolled areas.

Stations in White Rock Canyon are divided into four groups. Three groups are of similar aquifer-related chemical quality, while the fourth group reflects localized conditions in the aquifer. Radionuclide concentrations in water from the 27 stations reflect naturally occurring radionuclides (Table E-XIII).

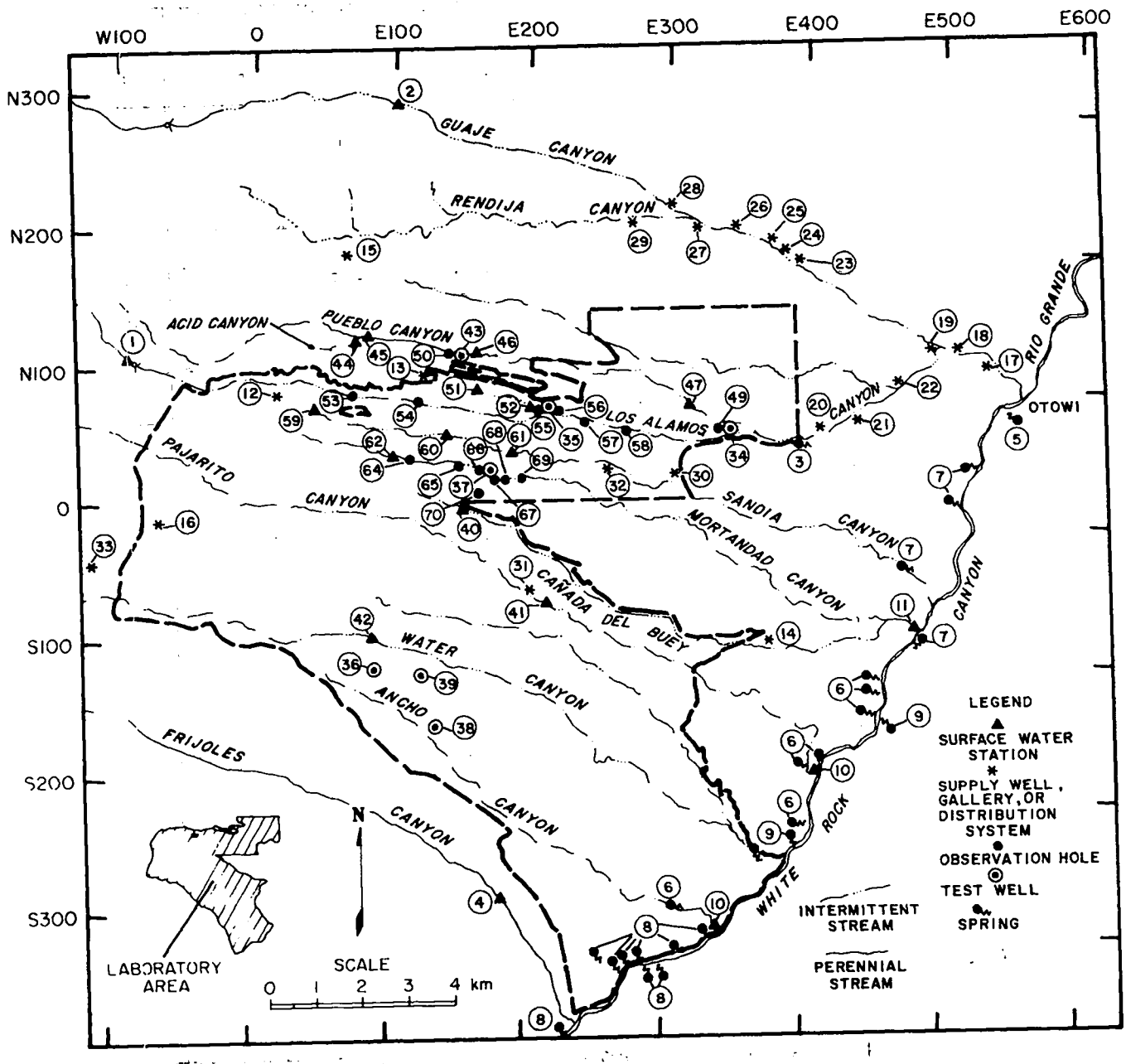


Fig. 12. Surface and ground water sampling locations on or near the Laboratory site.

Excluded from this discussion is Acid-Pueblo Canyon, a former release area for industrial liquid waste, which has four offsite stations and three onsite stations (Fig. 12). As a known release area and for hydrologic continuity, all monitoring results from Acid-Pueblo Canyon are discussed in the following section concerning onsite surface and ground waters.

b. Onsite Surface and Ground Waters. Onsite sampling stations are grouped according to those located away from effluent release areas and those located in areas that receive or have received industrial liquid effluents. Sampling locations in onsite noneffluent release areas consist of seven test wells completed into the main aquifer and three surface water sources (Fig. 12, Table E-X). Maximum concentrations of radioactivity at the ten stations are in Table X. The concentrations were low, near or below detection limits, and well below Concentration Guides for controlled areas. Detailed radiochemical analyses are shown in Table E-XIV.

Canyons that receive or have received industrial effluents are Acid-Pueblo, DP-Los Alamos, Sandia, and

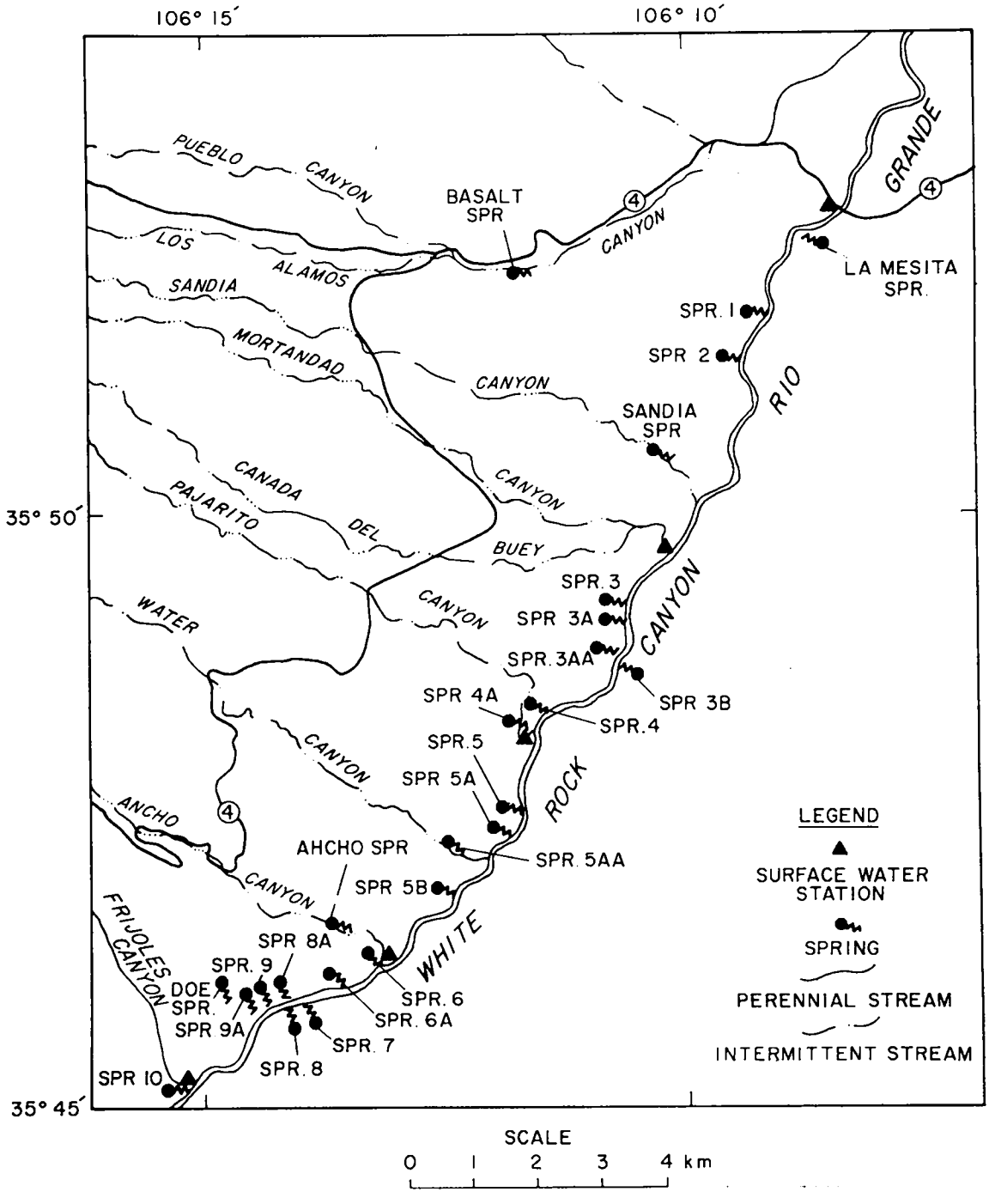


Fig. 13. Surface water sampling locations in White Rock Canyon.

TABLE X

MAXIMUM RADIOACTIVITY IN SURFACE AND GROUND WATER FROM OFFSITE, ONSITE, AND WATER SUPPLY STATIONS
(each sample result in table is the maximum concentration from a group of samples, along with ±2 standard deviations)

	Number of Stations	^{137}Cs (10^{-9} μCi/mℓ)	^{90}Sr (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Offsite Stations (Uncontrolled Areas)									
Concentration Guide (CG) for Uncontrolled Areas[a]	---	20 000	300	5 000	5 000	5 000[b]	300[c]	3 000	1 800
Regional	6	37 ± 40	---	0.019 ± 0.038	0.018 ± 0.038	5.0 ± 4.0	17 ± 4.0	1.6 ± 0.6	4.2 ± 0.8
Perimeter	5	60 ± 60	---	0.030 ± 0.020	0.050 ± 0.020	8.0 ± 4.0	21 ± 4.0	5.3 ± 0.8	11 ± 2.2
White Rock Canyon	26	60 ± 60	---	0.028 ± 0.014	0.048 ± 0.002	12 ± 3.0	12 ± 3.2	0.6 ± 0.8	19 ± 2.2
Offsite Stations Group Summary:									
Maximum Concentration	0	60 ± 60	---	0.030 ± 0.020	0.050 ± 0.020	12 ± 3.0	21 ± 4.0	5.3 ± 0.8	19 ± 2.2
Maximum Concentration as Per Cent of CG for Uncontrolled Areas	---	<1	---	<1	<1	<1	<1	<1	<1
Onsite Stations (Controlled Areas)									
Concentration Guide (CG) for Controlled Areas[a]	---	400 000	10 000	100 000	100 000	100 000	10 000	100 000	60 000
Noneffluent Areas	10	100 ± 100	---	0.090 ± 0.022	1.84 ± 0.260	4.2 ± 2.2	18 ± 3.8	3.8 ± 0.8	6.1 ± 1.2
Effluent Areas									
Acid-Pueblo	6	60 ± 100	70 ± 6.0	0.030 ± 0.060	2.15 ± 0.220	2.9 ± 2.2	210 ± 40	14 ± 1.0	0.8 ± 0.8
DP-Los Alamos	8	50 ± 60	298 ± 12	1.44 ± 0.800	4.01 ± 0.380	360 ± 140	980 ± 200	40 ± 1.6	126 ± 26
Sandia	3	50 ± 120	1.1 ± 1.0	0.050 ± 0.040	0.070 ± 0.040	14 ± 34	72 ± 16	41 ± 1.6	1.9 ± 0.8
Mortandad	7	1960 ± 300	190 ± 8.0	17.0 ± 0.800	255 ± 10	2500 ± 1000	9700 ± 2000	479 ± 8.0	8.4 ± 1.6
Onsite Stations Group Summary:									
Maximum Concentration	---	1960 ± 300	298 ± 12	17.0 ± 0.800	255 ± 10	2500 ± 1000	9700 ± 2000	479 ± 8.0	126 ± 2.6
Maximum Concentration as Per Cent of CG for Controlled Areas	---	<1	3	<1	<1	<1	97	<1	<1
Water Supply									
Maximum Contaminant Level (MCL)[d]	---	200	8	7.5	7.5	15[e]	---	20	1800[f]
Wells and Gallery									
Maximum Concentration	---	90 ± 140	---	0.066 ± 0.020	0.040 ± 0.040	14 ± 8.0	9.9 ± 2.8	7.5 ± 0.8	5.7 ± 1.2
Maximum Concentration as Per Cent of MCL	---	45	---	<1	<1	93	---	38	<1
Distribution System									
Maximum Concentration	---	70 ± 120	---	0.030 ± 0.040	0.080 ± 0.060	1.9 ± 2.0	7.6 ± 2.4	1.8 ± 0.9	3.9 ± 0.8
Maximum Concentration as Per Cent of MCL	---	35	---	<1	1	12	---	9	<1

[a]Department of Energy Order 5480.1, Chapter XI.
[b]The Concentration Guide for ^{239}Pu from the Department of Energy's Order 5480.1, Chapter XI, is used for gross alpha standard.
[c]The Concentration Guide for ^{90}Sr from the Department of Energy's Order 5480.1, Chapter XI, is used for gross beta standard.
[d]The Environmental Protection Agency's National Interim Primary Drinking Water Regulations.
[e]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.
[f]Level recommended by International Commission on Radiological Protection.

Mortandad. Samples were collected from surface water stations or shallow observation holes completed in the alluvium (Fig. 12, Tables E-XV through E-XVIII). Maximum concentrations of radioactivity in each of the four canyons are given in Table X. Radioactivity observed in Acid-Pueblo Canyon (Table E-XV) results from residuals of treated and untreated radioactive liquid waste effluents released into the canyon before 1964. Radionuclides that were absorbed by channel sediments are now being resuspended by runoff and municipal sanitary effluents.

Sandia Canyon receives cooling tower blowdown from the TA-3 power plant and some sanitary effluent from TA-3 facilities (Table E-XVI). The DP-Los Alamos Canyon receives industrial effluents that contain low levels of radionuclides and some sanitary effluents from TA-21 (Table E-XVII). Tritium concentrations above background in upper Los Alamos Canyon in shallow well LAO-1 are due to release of cooling water from the research nuclear reactor at TA-2. Mortandad Canyon receives treated industrial effluent containing radionuclides (Table E-XVIII). Water in these canyons contains radionuclides as the result of effluent from the treatment plants.

Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons all contain surface and ground water with measurable amounts of radioactivity that are well below Concentration Guides for controlled areas. Surface and ground waters of these canyons are not a source of municipal, industrial, or agricultural supply. Surface waters in these canyons normally infiltrate into alluvium of stream channels within the Laboratory's boundaries. Only during periods of heavy precipitation or snowmelt does water from Acid-Pueblo and DP-Los Alamos Canyons reach the Rio Grande. In Mortandad Canyon, there has been no surface water runoff past the Laboratory's boundary since hydrologic studies in the canyon began in 1960, 3 years before release of any industrial effluents.

c. Water Supply. The municipal and industrial water supply for the Laboratory and community is from 15 deep wells (in 3 well fields) and 1 gallery (underground collection basin for spring discharge). The wells are located on Pajarito Plateau and in canyons east of the Laboratory (Fig. 12). Water is pumped from the main aquifer, which lies about 350 m below the surface of the Plateau. The gallery discharges from a perched water zone (a ground water body above an impermeable layer that is separated from an underlying main body of ground water by an unsaturated zone) in volcanics on the flanks of the mountains west of the Plateau.

During 1981 production from the wells and gallery was about 5.8×10^6 m^3, with the wells furnishing about 97% of the total production and the gallery about 3%. Water samples were collected from the wells and gallery and at six stations in the distribution system. The five stations in the distribution system are located within the Laboratory and community, while the sixth is located at Bandelier National Monument (Fig. 12, Table E-XII). The water supply distribution system at TA-57, the Fenton Hill Geothermal Site, was also sampled.

A comparison of maximum concentrations found in these waters with the Environmental Protection Agency's National Interim Primary Drinking Water Standards[22] is given in Table X. Detailed radiochemical analyses of water from the wells, gallery, and distribution system (including Fenton Hill) are presented in Table E-XIX.

Radioactivity occurring in the water supply is low and naturally occurring. One analysis from Well G-1A contained a detectable amount of ^{238}Pu ($0.066 \pm 0.020 \times 10^{-9}$ μCi/mℓ) that is attributed to contamination of the sample during collection or processing during analysis. Water from the well has shown no previous detectable plutonium. Other plutonium analyses were at or below limits of detection. The ^{137}Cs concentration ($90 \pm 140 \times 10^{-9}$ μCi/mℓ) from Well PM-1 appears high, but is within limits set by the Environmental Protection Agency for distribution systems.

Samples from the water distribution system showed that their actual gross alpha activity was lower than the Environmental Protection Agency's screening limit (see Appendix A). Two wells (LA-1B and G-3) contained natural alpha activity greater than the screening limit. Dilution by water from the other wells results in concentrations at points of use in the distribution system that meet the Environmental Protection Agency's criteria for municipal supply. Samples taken in the distribution system (see Table E-XIX) confirm this dilution.

4. Radioactivity in Soils and Sediments

Soil samples were collected from 25 stations and sediment samples from 53 stations in and adjacent to the Los Alamos area. Concentrations of ^{137}Cs, $^{238,239}Pu$, gross alpha, gross beta, and ^{3}H from regional soil and/or sediment stations were slightly above worldwide fallout levels. The low concentrations are due to variability of worldwide fallout. Samples from 6 soil and 4 sediment perimeter stations and from 11 soil and 18 sediment onsite stations had concentrations of radioactivity in excess of normal or fallout levels. Concentrations of radioactivity from these stations are less than twice the normal or fallout levels, except in areas where treated radioactive effluents are released.

a. Regional Soil and Sediments. Regional soils are collected in the same general locations as regional waters (Fig. 7). Regional sediments are also collected at the same general locations with additional samples collected from Otowi to Cochiti on the Rio Grande. The exact locations are presented in Table E-XX and detailed results are in Table E-XXI. See Appendix B.3 for methods of collection, analysis, and reporting of soil and sediment data.

Regional and perimeter soil and sediment radiochemical data collected from 1974 through 1977 are used to distinguish background radioactivity (the result of natural and worldwide fallout) from atmospheric nuclear weapons tests.[23] These data are used for comparison with 1981 soil and sediment results (Table XI). Maximum concentrations in regional soil samples had concentrations of ^{137}Cs from one station, ^{238}Pu from one station, ^{239}Pu from two stations, and ^{3}H from two stations slightly above natural or worldwide fallout levels. Gross alpha and beta activity from several soil and sediment stations were slightly above natural or worldwide fallout levels for the period 1974 to 1977. All these concentrations were low and due to variability in worldwide fallout.

During 1981, six soil samples and three sediment samples were collected from outlying stations (Fig. 14). Special analyses for plutonium were performed using 1 kg (100 times the usual mass used for analyses) to increase the sensitivity of the analyses. Results from these 1981 analyses (Table E-XXII) approximate results from the period 1974 to 1977 (Table XI).

b. Perimeter Soils and Sediments. Six perimeter soil stations were sampled in areas within 4 km of the Laboratory. Seventeen sediment samples were collected from major intermittent streams that cross Pajarito Plateau. Locations of the stations are described in Table E-XX and are shown in Fig. 15. Detailed analyses are in Table E-XXIII.

Soil analyses from perimeter stations indicated that concentrations of ^{137}Cs at two stations, ^{90}Sr at one station, and ^{239}Pu at six stations were low but above natural background and fallout concentrations. The ^{239}Pu concentrations may be the result of airborne emissions from the Laboratory. Similar concentrations were reported during a study in 1970.[25] At a few stations, gross alpha (six stations), gross beta (six stations), and ^{3}H (two stations) slightly exceed background activity (Tables E-XXIII and XI).

Sediment analyses indicated that concentrations of ^{137}Cs from two stations, ^{90}Sr from three stations, ^{238}Pu from four stations, ^{239}Pu from four stations, and gross alpha from one station were above background in Acid-Pueblo and lower Los Alamos Canyons. Industrial effluents were released into Acid-Pueblo Canyon before 1964 and residual radionuclides remain there. Concentrations in lower Los Alamos Canyon (Totavi to the Rio Grande) reflect transport by intermittent storm runoff from Acid-Pueblo Canyon and from onsite release of industrial effluents into DP-Los Alamos Canyon. The concentrations decrease downgradient in the canyons (Table E-XXIII).

c. Onsite Soil and Sediments. Onsite soil samples were collected from 13 stations within Laboratory boundaries. Sediment samples were collected from 27 stations within the boundaries (Fig. 15, Table E-XX). Analytical results are shown in Table E-XXIV and maximum concentrations in Table XI.

Soil analyses indicated that concentrations of ^{137}Cs from 4 stations, ^{90}Sr from 2 stations, ^{238}Pu from 1 station, ^{239}Pu from 3 stations, gross alpha from 10 stations, gross beta from 11 stations, and ^{3}H from 8 stations were above normal or worldwide fallout levels.

TABLE XI

MAXIMUM RADIOACTIVITY IN SOILS AND SEDIMENTS FROM REGIONAL, PERIMETER, AND ONSITE STATIONS

	Number of Stations	pCi/g						^{3}H (10^{-6} μCi/mℓ)
		^{137}Cs	^{90}Sr	^{238}Pu	^{239}Pu	Gross Alpha	Gross Beta	
Average maximum soil or sediment concentrations at regional stations due to worldwide fallout for Northern New Mexico, 1974-77[a]	26	0.92	0.79	0.008	0.028	11	11	3
Average maximum concentrations at regional stations due to worldwide fallout for New Mexico, 1981[b]								
Soil	6	1.24	1.10	0.0090	0.0250	1.4	19	---
Sediment	3	0.61	0.68	0.0017	0.0105	1.6	26	---
Regional stations								
Soil	6	1.13 ± 0.22 (1)	0.49 ± 0.14	0.010 ± 0.012 (1)	0.075 ± 0.014 (2)	19 ± 8.0 (2)	18 ± 4.0 (3)	5.8 ± 0.8 (2)
Sediment	9	0.82 ± 0.10	0.15 ± 0.12	0.001 ± 0.002	0.015 ± 0.006	25 ± 12 (1)	19 ± 4.0 (1)	0.7 ± 0.06
Perimeter stations								
Soil	6	2.15 ± 0.18 (2)	1.9 ± 0.18 (1)	0.004 ± 0.002	0.101 ± 0.016 (6)	21 ± 10 (6)	33 ± 6 (6)	6.3 ± 0.8 (2)
Sediment	17	1.9 ± 0.22 (2)	4.6 ± 2.4 (3)	0.085 ± 0.032 (4)	14.9 ± 1.00 (4)	11 ± 4.0 (1)	6.9 ± 0.8	6.1 ± 0.8 (2)
Onsite stations								
Soil	13	3.0 ± 0.32 (4)	4.4 ± 1.6 (2)	0.011 ± 0.006 (1)	0.15 ± 0.022 (3)	40 ± 18 (10)	31 ± 3 (11)	40 ± 1.6 (4)
Sediment	---	580 ± 60 (13)	1.11 ± 0.24 (1)	60.1 ± 0.14 (15)	299 ± 6.00 (18)	230 ± 100 (5)	410 ± 80 (9)	46 ± 1.8 (8)

[a]Average maximum value ($\bar{x}$ + 2s) for regional soils and sediments 1974-77 (Ref. 23).
[b]Average maximum value ($\bar{x}$ + 2s) for regional soils and sediments, special study (Table E-XXII).
[c]Maximum value ($\bar{x}$ + 2s) for regional soils 1980 (Ref. 24).

Note: Number in parentheses indicates number of stations exceeding natural and worldwide fallout concentrations for northern New Mexico, 1974-77.

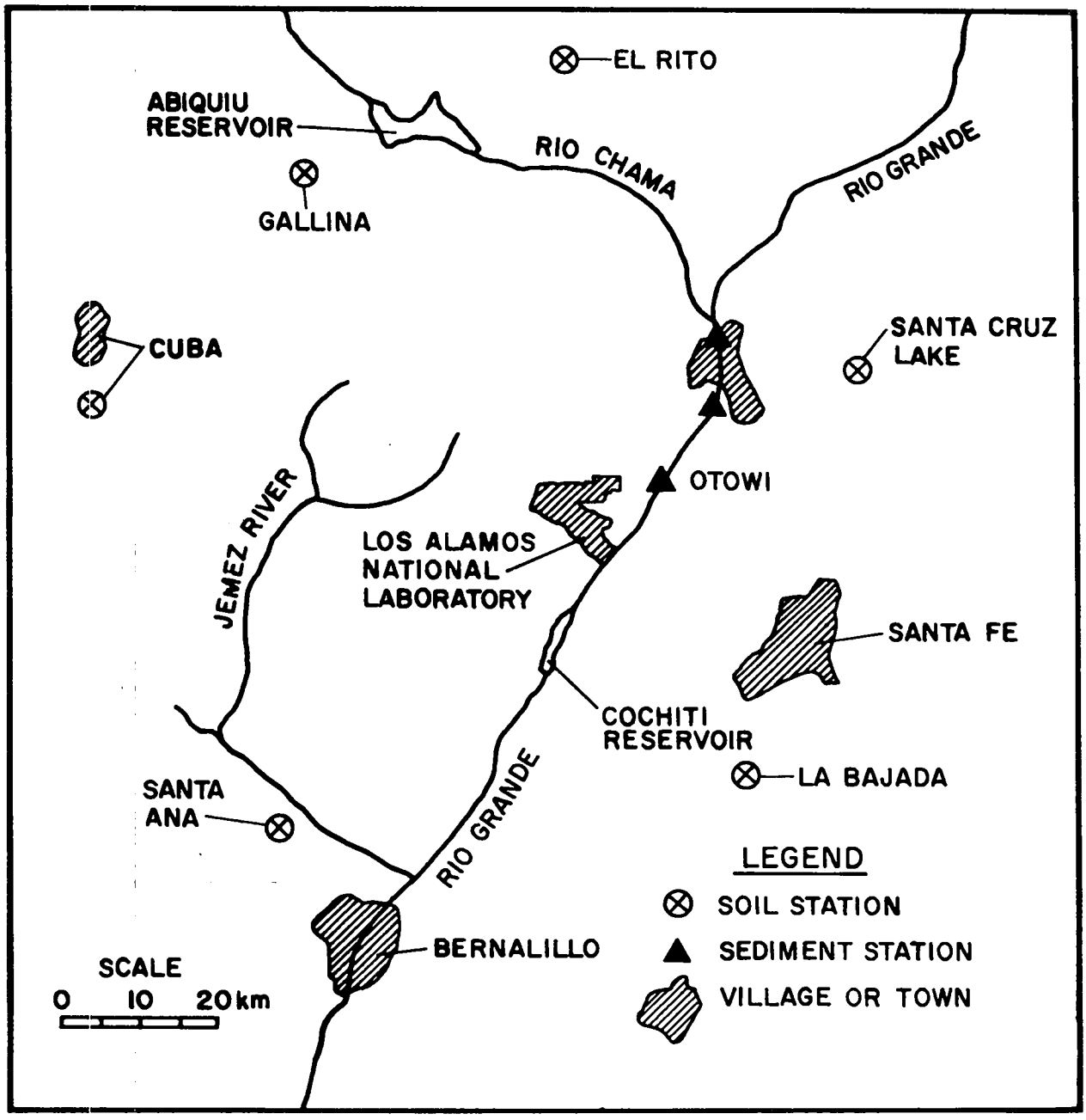


Fig. 14. Special regional soil and sediment sampling locations.

Sediment stations in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons contained radionuclide concentrations above background levels (Table E-XXIV). These canyons have or are now receiving treated industrial liquid effluents. Radionuclides in effluents are adsorbed or attached to sediment particles in the alluvium and their concentrations are highest near effluent outfalls. They generally decrease in concentration downgradient in the canyon as sediments and radionuclides are transported and dispersed by other industrial effluents, sanitary effluents, and periodic storm runoff.

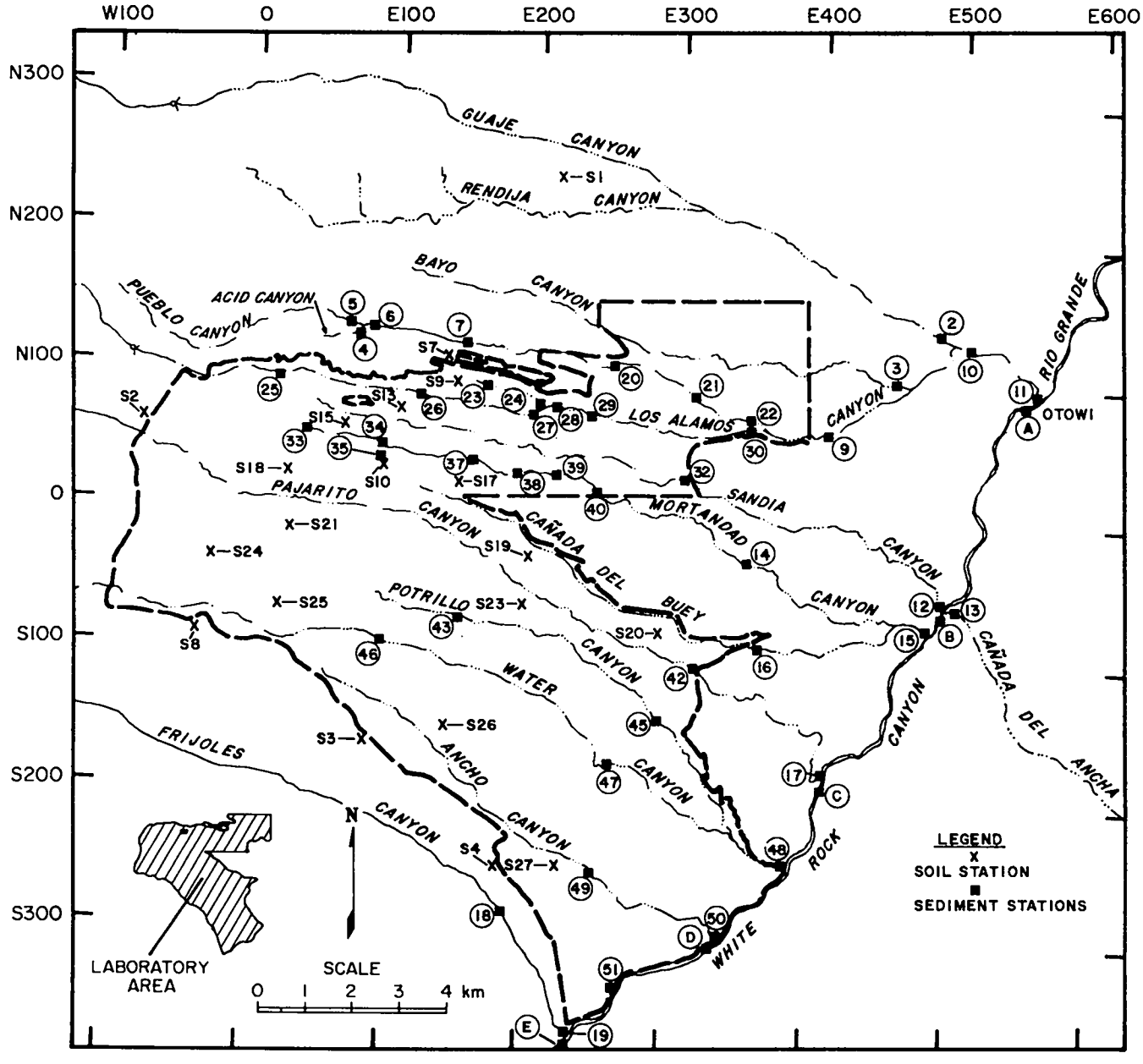


Fig. 15. Soil and sediment sampling locations on or near the Laboratory site.

5. Radioactivity in Foodstuffs

Most fruit, vegetable, fish, and honey samples collected in the vicinity of the Laboratory showed no apparent influence from Laboratory operations. However, honey from experimental hives, fruit collected onsite, and produce from a garden on the perimeter of the Laboratory had slightly elevated concentrations of tritium.

a. Introduction. Fruit, vegetable, fish, and honey samples were collected during the fall of 1981 to monitor foodstuffs for possible radioactive contamination from Laboratory operations. Fruits and vegetables were collected in the Los Alamos area and in the Rio Grande valley above and below confluences of intermittent streams that cross the Laboratory and flow into the Rio Grande (see Fig. 7). Fish were collected from locations above (Heron and El Vado reservoirs that are on the Rio Chama, a tributary of the Rio Grande) and below (Cochiti) confluences of these intermittent streams.

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

Fish samples were taken from bottom feeders, such as carp and suckers, which have a greater probability than higher tropic orders of ingesting any activity that might be associated with sediments, as well as from higher level feeders. Honey was collected from hives established in 1978 at several locations within the Laboratory boundary near waste stream outfalls and a tritium facility. Background samples came from other locations: Barranca Mesa (in Los Alamos), Pajarito Acres, and Chimayo, New Mexico.

Fruit and vegetable samples were analyzed for tritiated water, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, and total U. Fish sample analyses included ^{238}Pu, ^{239}Pu, ^{137}Cs, and total U. Honey samples were analyzed for tritiated water, ^{7}Be, ^{22}Na, and ^{137}Cs.

b. Fruits and Vegetables. Data in Tables XII, XIII, and XIV summarize fruit and vegetable sample results for tritium, strontium, cesium, uranium, and plutonium according to different water supplies. Sample moisture ranged from 60 to 97% of total sample weight.

Concentrations of tritium in water from fruits and vegetables collected offsite ranged from −0.4 to 4.9 pCi/mℓ. All offsite concentrations are within the range of values measured in local ground and surface waters (0 to 5.3 pCi/mℓ) and atmospheric water vapor at background locations (−0.4 to 20 pCi/mℓ). At Los Alamos tritium concentrations measured in produce samples were slightly higher than at background locations. However, the relatively large standard deviations associated with these sample results makes them statistically indistinguishable from background.

At White Rock, tritium concentrations in water from fruits and vegetables collected from a private garden were slightly but statistically higher than in control samples. However, fruit and vegetable samples collected in a nearby garden in Pajarito Acres had tritium concentrations among the lowest sampled. Concentrations of airborne tritium at White Rock and Pajarito Acres were approximately 25% of those at background locations for 1981. Also, White Rock tritium air concentrations were 50% lower than those at Pajarito Acres and these two communities use the same water supply. Therefore, it is not clear why the White Rock garden samples had statistically above-background tritium concentrations.

The doses associated with these tritium concentrations at White Rock are quite small. Consumption of 120 kg/yr of fruits and vegetables having the average White Rock station tritium concentration of 1.78 pCi/mℓ (which assumes that a garden supplies 25% of the 479 kg of the fruits and vegetables consumed annually by a teenager;[26] see Table D-I) would result in a whole body 50-year dose commitment of 0.02 mrem, which is 0.004% of the Radiation Protection Standard. All samples had tritium concentrations that were small fractions of the uncontrolled area Concentration Guide for water of 3000 pCi/mℓ (3000×10^{-6} μCi/mℓ).

The tritium content of nectarines at TA-35 was similar to previously reported relatively higher values at that location.[27] The TA-35 facility releases airborne tritium (see Table E-I). Elevated tritiated water concentrations were also measured in apples and peaches from trees

TABLE XII

TRITIATED WATER CONTENT OF FRUITS AND VEGETABLES

Location	Water Source	Number of Samples	Tritiated Water Concentration (10^{-6} μCi/mℓ) Average (±1s)	Range	Average Moisture (%)
Española	Rio Grande[a]	5	0.34 ± 0.52	−0.5 to 0.8	94 ± 4
Española	Rio Chama[a]	6	0.70 ± 0.83	−0.4 to 1.9	90 ± 9
Cochiti	Rio Grande[b]	9	0.98 ± 0.75	0.0 to 2.3	87 ± 14
Los Alamos	Community System	2	3.6 ± 1.9	2.2 to 4.9	83 ± 5
Pajarito Acres	Community System	5	0.48 ± 0.45	0.1 to 1.1	88 ± 11
White Rock	Community System	5	1.78 ± 0.48	1.2 to 2.5	91 ± 4
TA-35	Community System	1	8.3 ± 0.5[c]	---	85 ± 5
TA-21 (Area B)	Precipitation	2	2.8 ± 2.3	1.2 to 4.5	89 ± 1
TA-21	Precipitation	1	1.5 ± 0.4[c]	---	82 ± 5

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

located near a facility in TA-21, where airborne tritium is also released. These few nectarines, peaches, and apples do not represent a significant pathway to man because they are within a Laboratory fence, represent a very small volume of edible material, and have considerably less tritium than the uncontrolled area Concentration Guide for water (3000×10^{-6} μCi/mℓ).

Two of 37 samples analyzed had detectable ^{137}Cs. Detection of ^{137}Cs is not unusual since this radionuclide is present in surface soil due to worldwide fallout from nuclear testing. Mean ^{137}Cs concentrations at all locations, however, were statistically indistinguishable from zero.

The ^{90}Sr, ^{238}Pu, and ^{239}Pu concentrations varied. Like ^{137}Cs, these three radionuclides are commonly found in soil as a result of worldwide fallout. Samples collected at the control stations, which are not affected by Laboratory operations, had some of the highest levels of ^{90}Sr, ^{238}Pu, and ^{239}Pu. However, no statistically significant difference existed between these pooled control locations and other locations. This indicates these radionuclide concentrations are due to fallout and not Laboratory emissions.

Average total uranium concentrations in produce from all locations potentially affected by Laboratory operations were statistically indistinguishable from those at control locations, with one exception. Uranium concentrations in produce collected at Cochiti were slightly but statistically higher than those from control areas. However, these uranium concentrations were low and in good agreement with data published in previous environmental surveillance reports.[11,28]

The cause of these relatively higher uranium concentrations in produce is not known. Analysis of water, soil, and most significantly, sediment samples taken at Cochiti showed only background concentrations of uranium, similar to those found at locations upstream from the Laboratory. Thus, there is no basis for attributing the difference in produce to transport of sediment from the Laboratory.

Doses resulting from these uranium concentrations are quite low. Assuming that an individual obtains 25% of his annual intake (approximately 120 kg) of fruits and vegetables from a garden having produce at these uranium concentrations, the 50-year dose commitment to the bone, the organ receiving the highest dose, is 0.15

TABLE XIII

PLUTONIUM CONTENT OF FRUITS AND VEGETABLES

Location	Water Source	Number of Samples	^{238}Pu (pCi/g)[c] Average (±1s)	^{238}Pu (pCi/g)[c] Range	^{239}Pu (pCi/g)[c] Average (±1s)	^{239}Pu (pCi/g)[c] Range
Española	Rio Grande[a]	5,4[d]	0.00018 ± 0.00027	−0.0001 to 0.0006	0.00040 ± 0.00029	0.00011 to 0.00066
Española	Rio Chama[a]	6	0.00046 ± 0.00051	0.00003 to 1.1	0.00048 ± 0.00040	0.00004 to 0.00102
Cochiti	Rio Grande[b]	10	0.00018 ± 0.00022	−0.0001 to 0.0006	0.00021 ± 0.00048	−0.00069 to 1.24
Los Alamos	Community System	2	0.00010 ± 0.00010[e]	0.0001 to 0.0001	0.00017 ± 0.00004	0.00014 to 0.00020
Pajarito Acres	Community System	5	0.00031 ± 0.00028	0.00003 to 0.0006	0.00001 ± 0.00021	−0.00034 to 0.00024
White Rock	Community System	5	0.00020 ± 0.00017	0.0001 to 0.0005	0.00012 ± 0.00026	−0.00011 to 0.00044
TA-35	Community System	1	0.0002 ± 0.0001[e]	---	0.00006 ± 0.00007[e]	---
TA-21 (Area B)	Precipitation	2	0.00030 ± 0.00028	0.0001 to 0.0005	0.00063 ± 1.26	−0.00026 to 0.00152
TA-21	Precipitation	1	−0.00010 ± 0.0001[e]	---	0.00010 ± 0.00009[e]	---

[a]Upstream from Laboratory stream confluence.
[b]Downstream from Laboratory stream confluence.
[c]Dry weight.
[d]Five samples analyzed for ^{238}Pu and four samples analyzed for ^{239}Pu.
[e]Counting uncertainty.

TABLE XIV

URANIUM, ^{137}Cs, AND ^{90}Sr CONTENT OF FRUITS AND VEGETABLES

Location	Water Source	Number of Samples	Uranium (μg/g)[c] Average (±1s)	Uranium (μg/g)[c] Range	^{137}Cs (pCi/g)[c] Average (±1s)	^{137}Cs (pCi/g)[c] Range	^{90}Sr (pCi/g)[c] Average (±1s)	^{90}Sr (pCi/g)[c] Range
Española	Rio Grande[a]	5	0.0026 ± 0.0058	0.0000 to 0.013	−0.24 ± 0.70	−1.1 to 0.7	0.089 ± 0.063	0.022 to 0.17
Española	Rio Chama[a]	6	0.0054 ± 0.0084	0.0000 to 0.021	−0.51 ± 0.72	−1.5 to 0.13	0.055 ± 0.025[e]	---
Cochiti	Rio Grande[b]	10	0.0115 ± 0.0102	0.0000 to 0.033	0.42 ± 0.85	−0.7 to 1.7	0.063 ± 0.030[d]	0.033 to 0.090
Los Alamos	Community System	2	0.0029 ± 0.004	0.0000 to 0.0057	−0.38 ± 0.0.45	−0.7 to −0.06	0.017 ± 0.011	0.009 to 0.024
Pajarito Acres	Community System	5	0.0031 ± 0.0056	0.0000 to 0.013	−0.33 ± 0.44	−0.9 to 0.21	0.07 ± 0.10	−0.013 to 0.22
White Rock	Community System	5	0.0058 ± 0.0083	0.0000 to 0.018	0.65 ± 1.61	−0.4 to 3.5	0.047 ± 0.034	0.004 to 0.098
TA-35	Community System	1	0.0035 ± 0.0025[e]	---	0.04 ± 0.07[e]	---	---	---
TA-21 (Area B)	Precipitation	2	0.018 ± 0.015	0.0073 to 0.029	0.43 ± 0.38	0.16 to 0.7	---	---
TA-21	Precipitation	1	0.0016 ± 0.0012[e]	---	0.0 ± 0.1[e]	---	---	---

[a]Upstream from Laboratory stream confluence.
[b]Downstream from Laboratory confluence.
[c]Dry weight.
[d]Four samples analyzed.
[e]Counting uncertainty; only one sample analyzed.

mrem. This dose is 0.009% of the Radiation Protection Standard for members of the public.

c. Fish. No statistically significant differences between average concentrations in fish from control areas and from Cochiti, the area potentially affected by Laboratory operations, were found for any radionuclides monitored by the sampling program (see Table XV). The radionuclide concentrations that were measured were low and typical of worldwide fallout.

Low levels of ^{137}Cs were detected in 5 of 39 samples analyzed. Results were scattered, with mean values from areas not influenced by Laboratory operations being slightly higher than those downstream from the Laboratory for three out of four sample types.

Two samples, both from control areas not influenced by Laboratory operations, had detectable ^{238}Pu. Four samples had detectable ^{239}Pu. Two samples, including the highest which was found in a sucker gut sample, were from a control area. The other two were from Cochiti. All detectable ^{239}Pu concentrations were less than a third of ^{239}Pu levels found in sediments from background locations (see Table E-XXII). Detection of plutonium in fish is expected since plutonium is present in the environment at low levels as a result of worldwide fallout from weapon tests.

Mean concentrations of both ^{238}Pu and ^{239}Pu were generally slightly, but not statistically, higher at control areas than at Cochiti, which is downstream from the Laboratory. This indicates that the measured concentrations of ^{238}Pu and ^{239}Pu are due to worldwide fallout.

As expected, a large proportion of samples from both Cochiti and from control areas (31 of 39 samples, or 80%) had detectable levels of uranium. Uranium is present naturally in the environment and is detectable in foodstuffs at trace levels similar to those found in this sampling. No statistically significant difference was found between uranium concentrations at Cochiti and at control locations.

d. Honey. Honey samples were analyzed for tritiated water, ^{7}Be, ^{22}Na, and ^{137}Cs. Results are shown in Table E-XXV. Also shown are analytical results from previous years, which included analyses for total uranium, ^{238}Pu, ^{239}Pu, and ^{241}Am.

No samples had detectable levels of ^{7}Be and ^{137}Cs. Only one sample, at TA-33, had detectable ^{22}Na. All samples except the sample collected at TA-16 had detectable levels of tritiated water, which is expected due to the presence of tritiated water in the environment from worldwide fallout and to the location of onsite stations near facilities that release ^{3}H. The sample having the highest tritiated water concentration was collected at TA-33, the facility that emitted the most airborne tritium during 1981. Honey samples from the two offsite hives were lower in tritiated water than honey from all onsite hives except one.

The dose from consuming honey at these radionuclide levels is a small fraction of the Radiation Protection Standard. Eating 5 kg of honey at the highest tritiated water concentration of 156 pCi/mℓ and with detectable ^{22}Na would result in a dose to the whole body of 0.02 mrem, which is 0.004% of the Radiation Protection Standard for members of the public.

6. Radioactive Airborne Emissions and Liquid Effluents

Quantities of airborne radioactive emissions released from Laboratory operations in 1981 were lower for all radionuclides, except uranium, argon, phosphorus, beryllium, and activation products when compared to 1980. These increases are primarily due to programmatic activities at the Los Alamos Meson Physics Facility. Liquid effluents from two waste treatment plants contained radioactivity at levels well below the Department of Energy's controlled area Concentration Guides.

Radioactive airborne emissions are discharged at the Laboratory from 86 stacks and liquid effluents are discharged from 2 industrial waste treatment plants and 1 sanitary sewage lagoon system. The airborne emissions consist principally of filtered ventilation exhausts from gloveboxes, other experimental facilities, some process facilities such as the liquid waste treatment plants, exhausts from the research reactor, and exhausts from the

TABLE XV

RADIOACTIVITY IN FISH

Location	Type of Samples	Number of Samples	^{137}Cs (pCi/g)[c] Average (±1s)	^{137}Cs (pCi/g)[c] Range	Total Uranium (μg/g)[c] Average (±1s)	Total Uranium (μg/g)[c] Range	^{238}Pu (pCi/g)[c] Average (±1s)	^{238}Pu (pCi/g)[c] Range	^{239}Pu (pCi/g)[c] Average (±1s)	^{239}Pu (pCi/g)[c] Range
Cochiti[a]	Bottom feeders	8	0.053 ± 0.093	−0.1 to 0.17	0.066 ± 0.091	0.018 to 0.29	−0.000006 ± 0.000033	−0.00007 to 0.00003	0.00001 ± 0.00010	−0.00013 to 0.00019
	Higher level	1	−0.024 ± 0.048[f]	—	0.003 ± 0.001[f]	—	0.00001 ± 0.00002[f]	—	−0.00004 ± 0.00008[f]	—
	Bottom feeder gut	5	0.04 ± 0.55	−0.75 to 0.79	0.34 ± 0.22	0.054 to 0.66	−0.00006 ± 0.00025	−0.00050 to 0.00008	0.00018 ± 0.00063	−0.00050 to 0.00120
	Higher level gut	1	0.38 ± 0.24[f]	—	0.020 ± 0.010[f]	—	−0.00010 ± 0.00010[f]	—	−0.00010 ± 0.00010	—
El Vado[b] and Heron[b]	Bottom feeder gut	6	0.10 ± 0.10	0.01 to 0.26	0.0061 ± 0.0052	0.002 to 0.016	0.000037 ± 0.000045	−0.00002 to 0.00009	0.000030 ± 0.000032	−0.00002 to 0.00006
	Higher level	7	0.13 ± 0.17	−0.04 to 0.41	0.007 ± 0.016	0.0 to 0.042	−0.00013 ± 0.00047	−0.00120 to 0.00014	0.00040 ± 0.00097	−0.00004 to 0.00260
	Bottom feeder gut	6	0.05 ± 0.30	−0.36 to 0.52	0.28 ± 0.29	0.048 to 0.76	−0.000006 ± 0.000074[d]	−0.00010 to 0.00007	0.00055 ± 0.00056[d]	−0.00006 to 0.00126
	Higher level gut	5	−0.09 ± 0.54	−0.69 to 0.79	0.044 ± 0.041	0.007 to 0.11	−0.00006 ± 0.00069	−0.00125 to 0.00050	−0.00052 ± 0.00064[e]	−0.00140 to 0.00007

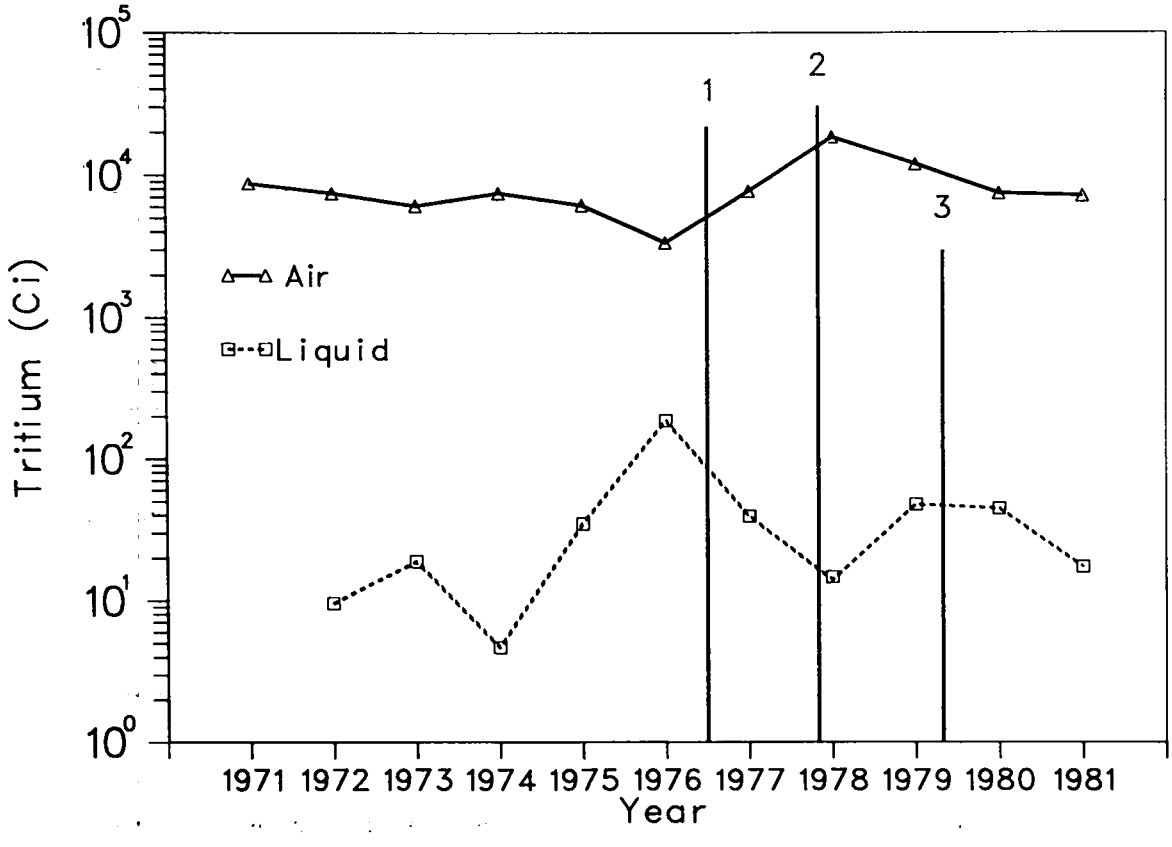
[a]Below confluence of Rio Grande with intermittent Laboratory streams.
[b]Above confluence of Rio Grande with intermittent Laboratory streams.
[c]Concentrations are based on tissue weight after oven drying.
[d]Based on five samples.
[e]Based on four samples.
[f]Counting uncertainty.

linear particle accelerator at the Los Alamos Meson Physics Facility. Releases of various isotopes from the technical areas are detailed in Table E-I. Quantities of radioactivity released depend on research programs conducted, so vary significantly from year to year (see Figs. 16-18).

Routine airborne releases of tritium (296 Ci lower, 4% lower) and plutonium (690 μCi lower, 92% lower) were both lower when compared to quantities released during 1980 (see Figs. 16 and 17). Americium releases (0.032 μCi lower, 52% lower) were also lower.

Routine airborne releases of ^{41}Ar (409 Ci higher, 43% higher), ^{7}Be (1.8 mCi higher, 15% higher), and other activation products (^{11}C, ^{13}N, ^{15}O; 206 740 Ci higher, 142% higher) were higher when compared to quantities released during 1980 (see Fig. 18). These increases are due to increased programmatic activities and changes in the ventilation systems at the Los Alamos Meson Physics Facility. The half-lives of ^{11}C, ^{13}N, and ^{15}O range from 2 to 20 minutes, so they decay very rapidly. The half-life of ^{41}Ar is 1.83 hours, so it too decays quickly. The half-life of ^{7}Be is 54 days, so persists longer in the environment.

In addition to airborne releases from facilities, some depleted uranium (uranium consisting almost entirely of ^{238}U) is dispersed by experiments employing conventional high explosives. In 1981, about 1087 kg of depleted uranium were used in such experiments. Based on known isotopic composition, this mass is estimated to contain approximately 0.38 Ci of activity. Most debris from these experiments is deposited on the ground in the vicinity of the firing point. Limited experimental information indicates that no more than about 10% of the depleted uranium becomes airborne. Approximate dispersion calculations indicate that resulting airborne concentrations would be in the same range as attributable to



1 22,000 Ci accidental release July 15, 1976
2 30,800 Ci accidental release October 6, 1977
3 3,000 Ci accidental release May 4, 1979

Fig. 16. Summary of tritium releases (air and liquid).

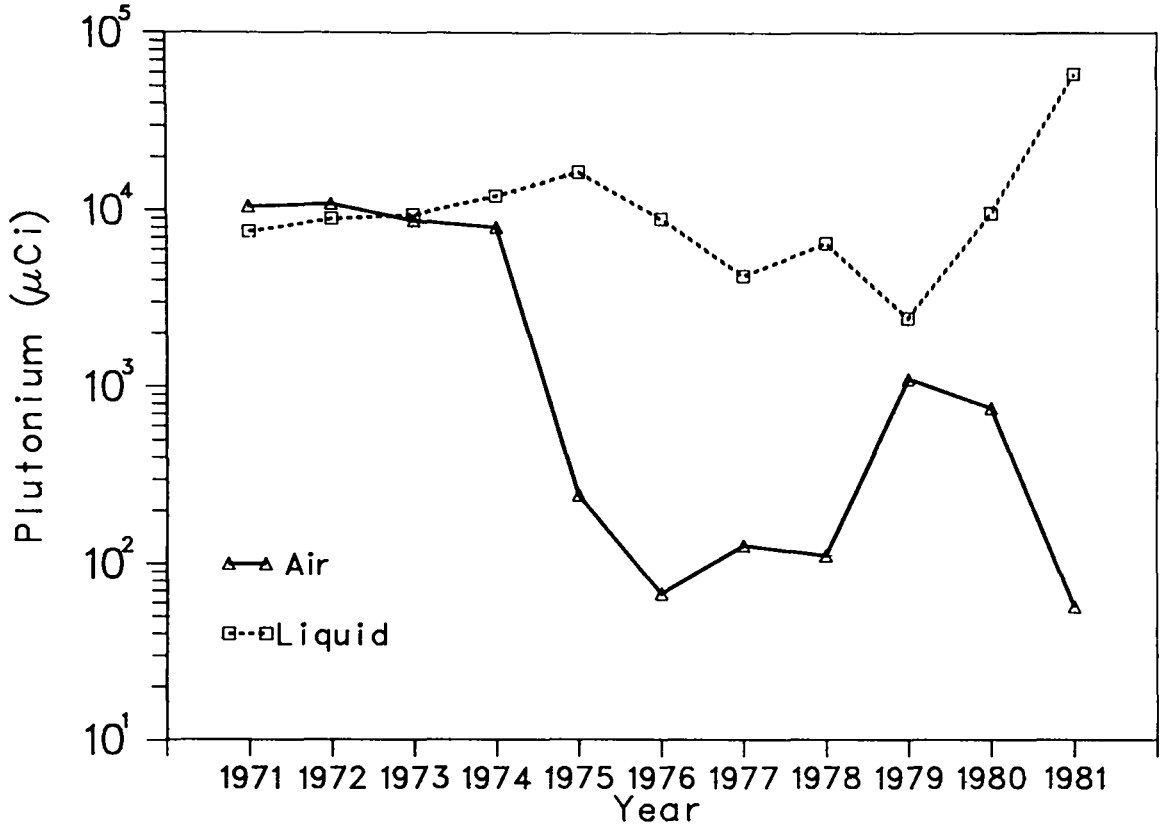


Fig. 17. Summary of plutonium releases (air and liquid).

natural crustal-abundance uranium in resuspended dust. This theoretical evaluation is compatible with the concentrations of atmospheric uranium measured by the routine air sampling network (see Section IV.A.2). Estimates of nonradioactive releases from these experiments are discussed in Section IV.B.2.

Treated liquid effluents containing low levels of radioactivity are released from the Central Liquid Waste Treatment Plant (TA-50), a smaller plant serving the old plutonium processing facility (TA-21), and a sanitary sewage lagoon system serving the Los Alamos Meson Physics Facility. Detailed results of the effluent radioactivity monitoring are in Table E-XXVI and Figs. 16, 17, and 19. Changes in total releases in 1981 compared to 1980 were as follows: plutonium (49 mCi higher, 506% higher), americium (18.6 mCi higher, 324% higher), strontium (6.21 mCi higher, 11% higher), uranium (1.01 mCi higher, 53% higher), tritium (27 541 mCi lower, 61% lower), and cesium (9.92 mCi lower, 7% lower). The increases were due mostly to higher quantities of radioactivity in process wastes from the Plutonium Processing Facility (TA-55) and were treated at the TA-50 Central Liquid Waste Treatment Plant. Design work is underway for upgrading TA-50, which will reduce the amount of contaminants in its effluent.

A total of 2.486×10^7 ℓ of effluent was discharged from the TA-53 sanitary lagoon system containing 0.49 Ci of ^{22}Na, 6.8 Ci of ^{7}Be, and 24 Ci of ^{3}H. The source of the radioactivity was activated water from beam-stop cooling systems. Samples of water, sediments, and transpirate from trees adjacent to the discharge from the lagoons have been collected this year and the results of this sampling program are discussed in Section VI.G.

Releases from the larger radioactive liquid waste treatment plant (TA-50) are discharged into a normally dry stream channel in Mortandad Canyon where surface flow has not passed beyond the Laboratory boundary since before the plant began operation (see Fig. 2). Discharges from the smaller plant (TA-21) are into DP Canyon, a tributary of Los Alamos Canyon where runoff

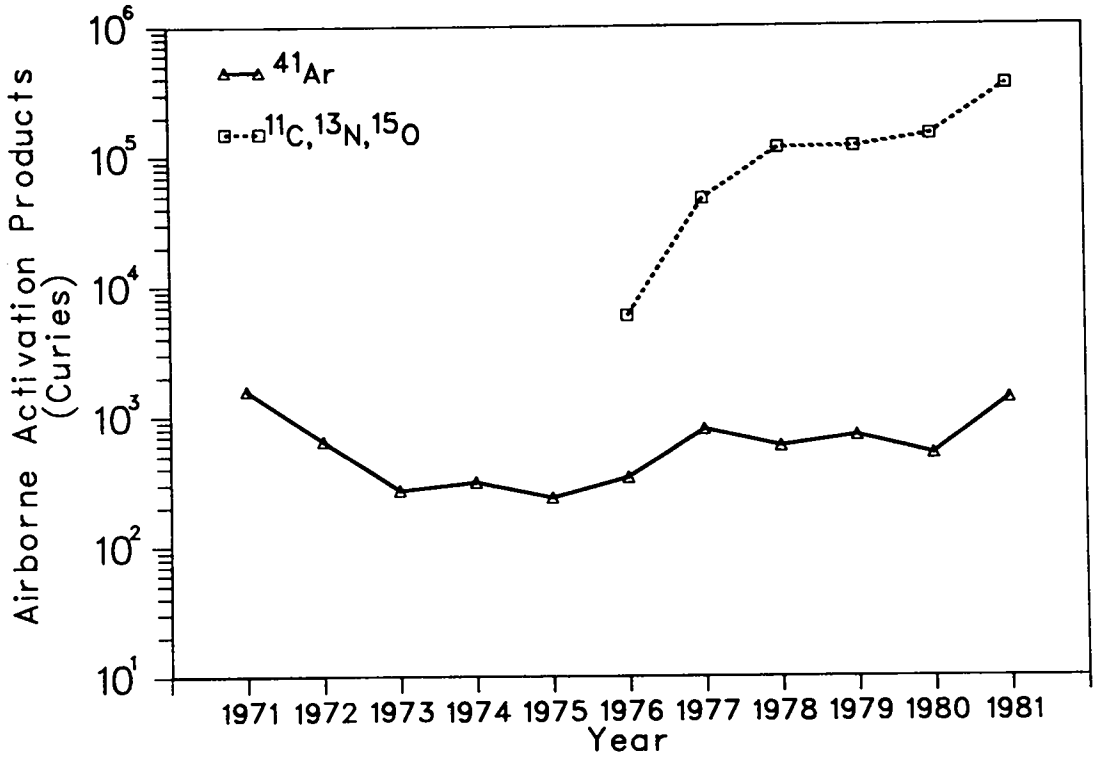


Fig. 18. Summary of ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O airborne emissions.

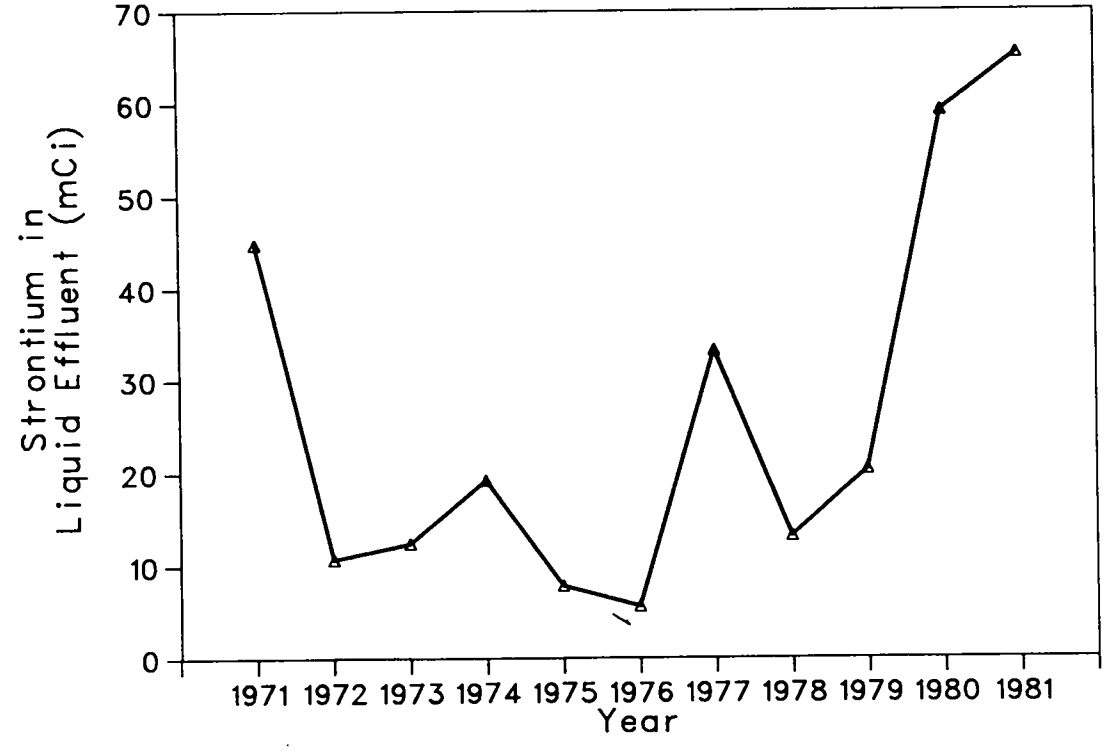


Fig. 19. Summary of strontium liquid effluents.

does at times flow past the boundary and transports some residual activity adsorbed on sediments (see Fig. 2). Effluent from the Los Alamos Meson Physics Facility's sanitary lagoons sinks into alluvium within the Laboratory boundary.

B. Chemical Constituents

1. Chemical Quality of Surface and Ground Waters

Chemical analyses of surface and ground waters from regional, perimeter, and onsite noneffluent release areas varied slightly from previous years. However, these variations in concentrations were within the normal range of seasonal fluctuations. Chemical quality of water from the municipal supply for the Laboratory and community meets standards set by the Environmental Protection Agency and New Mexico Environmental Improvement Division. Analyses from onsite effluent release areas indicated that some constituents were higher than in naturally occurring waters. However, these waters are not a source of municipal, industrial, or agricultural supply.

a. Regional and Perimeter Surface and Ground Waters. Regional and perimeter surface and ground waters were sampled at the same locations as were used for radioactivity monitoring (Table E-X). Surface waters were sampled at 6 regional stations, 5 perimeter stations, and 27 stations in White Rock Canyon (Figs. 7, 12, and 13). Maximum concentrations for seven parameters are in Table XVI. Maximum concentrations are compared to drinking water standards as a point of reference, even though the waters are not used for municipal or industrial supply. Detailed analyses from the regional, perimeter, and White Rock stations are presented in Tables E-XI, E-XII, and E-XIII, respectively. (See Appendix B.3 for methods of collection, analyses, and reporting of water data.)

The chemical quality of surface water varies at given stations during a year because of dilution of base flow with runoff from precipitation. There has been no significant change in water quality from previous years' analyses.

b. Onsite Surface and Ground Waters. Water samples were collected from three surface water stations and seven wells completed in the main aquifer (Table E-X). Maximum concentrations for selected constituents are in Table XVI. They are located in onsite areas that do not receive industrial effluents (Fig. 12). Detailed results of analyses are given in Table E-XIV. Water quality at the surface water stations varies slightly as base flow is diluted with varying amounts of storm runoff. The quality of surface and ground waters has not changed significantly from previous years' analyses.

Maximum concentrations of selected constituents found in each canyon are summarized in Table XVI. Tables E-XV through E-XVIII detail chemical quality analyses of surface and ground waters from 37 stations in canyons that receive sanitary and/or industrial effluent (Fig. 12, Table E-X). Individual analyses are shown in Tables E-XV to E-XVIII.

Acid-Pueblo Canyon received industrial effluents from 1943 to 1964. Currently it is receiving 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 and Mortandad Canyons receive treated industrial effluents that contain some radionuclides and residual chemicals used in the waste treatment processes. The high total dissolved solids (TDS) and chlorides result from effluents released into each of these canyons. The maximum concentration of sodium occurs in Sandia and Mortandad Canyons; fluoride in DP-Los Alamos and Mortandad Canyons; nitrate in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons; and total dissolved solids in Sandia Canyon. All of these concentrations were above drinking water standards. However, these onsite waters are not a source of municipal, industrial, or agricultural supply. Maximum concentrations occurred near effluent outfalls. The chemical quality of the water improves downgradient from the outfalls. There is no surface flow

TABLE XVI

MAXIMUM CHEMICAL CONCENTRATIONS IN SURFACE AND GROUND WATERS

	Number of Stations	mg/ℓ						
		Ca	Mg	Na	Cℓ	F	NO_3	TDS
Standard or Criteria[a]	---	---	---	250	250	2.0	45	1 000
Regional Stations	6	51	13	85	162	1.1	6	418
Perimeter Stations	5	31	7	30	14	0.7	13	180
White Rock Canyon	27	38	9	139	49	1.1	15	438
Maximum Concentration	---	51	13	139	162	2.0	15	438
Maximum Concentration as Per Cent of Standard or Criteria	---	---	---	56	53	100	33	44
Onsite Stations								
Noneffluent Stations	10	46	13	37	130	2.8	16	304
Effluent Release Stations								
Acid-Pueblo Canyon	9	32	5	108	65	0.9	60	406
DP-Los Alamos Canyon	8	42	8	250	206	13	186	902
Sandia Canyon	3	132	19	381	117	1.3	17	1 930
Mortandad Canyon	7	31	8	812	78	4.2	1 610	2 632
Maximum Concentration	---	132	19	812	206	13	1 610	2 632
Maximum Concentration as Per Cent of Standard or Criteria	---	---	---	325	82	650	3 600	263
Water Supply								
Supply Wells and Gallery	14	28	8	162	16	3.0	4.9	390
Distribution								
Los Alamos	5	25	7	74	5	1.4	3.5	224
Bandelier	1	9	2	42	17	0.4	1.3	114
Fenton Hill (Well)	1	52	6	14	44	0.1	1.1	272
Maximum Concentration	---	52	7	162	44	3.0	4.9	390
Maximum Concentration as Per Cent of Standard or Criteria	---	---	---	65	18	150	11	39

[a]The Environmental Protection Agency's National Interim Primary Drinking Water Standards and New Mexico's Environmental Improvement Division's maximum contaminant levels.

to the Rio Grande in these canyons except during periods of heavy precipitation or spring snowmelt.

c. Water Supply. Municipal and industrial water supplies for the Laboratory and community were sampled at 13 deep wells, 1 gallery (an underground collection basin for spring discharges), 5 stations in the distribution system, and at Bandelier National Monument (Table E-X, Fig. 12). Maximum concentrations of chemical constituents from well, gallery, and distribution system stations are compared to criteria in Table XVII. Detailed analyses are in Table E-XIX. Also, shown in Table E-XXVII is the chemical quality of water used from a supply at Fenton Hill (TA-57). This site is located about 30 km west of Los Alamos. Appendix A gives federal and state standards and criteria for municipal water supplies.

Concentrations of fluoride in water from well LA-1B were above standards for drinking water.[22] However, mixing with water from other wells reduces the concentrations at points of use to levels that are well within standards. The fluoride in water from well LA-1B is naturally occurring in the aquifer. Comparison of quality of water in the distribution systems at Los Alamos, Bandelier National Monument, and Fenton Hill with Environmental Protection Agency standards shows that all three systems are in compliance.

2. Nonradioactive Airborne Emissions and Liquid Effluents

Nonradioactive airborne emissions from the beryllium fabrication shop, gasoline storage and combustion, power plant, gases and volatile chemicals, waste explosive burning, and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. Particulate concentrations in the Los Alamos area exceeded state standards on one day when the state was sampling.

A single National Pollutant Discharge Elimination System permit covers nonradioactive liquid effluents from 100 industrial discharge points and 10 sanitary treatment facilities. This year 9 of 10 sanitary sewage treatment facilities exceeded 1 or more of the National Pollutant Discharge Elimination System limits (excluding flow rate limitations) in 1 or more months. Fewer than 7% of all samples from the industrial outfalls exceeded National Pollutant Discharge Elimination System limits.

a. Particulate Air Quality. Airborne particulate concentrations in the Los Alamos and White Rock areas are routinely measured by the New Mexico State Environmental Improvement Division. The highest 24 h averages and annual averages are compared to the New Mexico Ambient Air Quality Standards for particulates in Table XVIII. Table E-XXVIII summarizes these data for 1981. One 24-h average of 167 $\mu g/m^3$ in White Rock was unusually high and exceeded the state standard. The next highest 24-h average was 96 $\mu g/m^3$. The annual geometric means for Los Alamos and White Rock were well within state standards. Although true 7-day and 30-day averages cannot be calculated, there is no indication that they would exceed state standards.

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

Beryllium concentrations in stack gases from the beryllium shop during 1981 ranged from 0.004 to 0.008 $\mu g/m^3$. The state ambient air quality standard for beryllium is 0.01 $\mu g/m^3$, as a 30-day average, which was not exceeded. Total beryllium emissions for the year were about 1.9 mg. This is down somewhat from 1980 and down significantly from years prior to 1980 when total emissions were 15 to 20 mg/yr. The reason is that the beryllium shop is not being used as much as in previous years. The sampling pump for the beryllium shop exhaust stack was inoperative during July and part of August. This did not significantly affect 1981 data, because the shop use during that period was negligible.

TABLE XVII

MAXIMUM CHEMICAL CONCENTRATIONS IN WATER SUPPLY

	Number of Analyses	mg/ℓ									
		Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pd	Se
Standard or Criteria	---	0.05	0.05	1.0	0.010	0.05	2.0	0.002	45	0.05	0.01
Supply Wells and Gallery											
Maximum Concentration	14	<0.0003	0.038	0.15	<0.002	0.039	3.0	<0.0002	4.9	0.009	<0.005
Maximum Concentration as Per Cent of Standard or Criteria	---	<1	76	15	<2	78	150	<10	11	18	<50
Distribution											
Los Alamos	5	<0.0003	0.026	0.080	<0.0002	0.046	1.4	---	3.5	0.004	<0.005
Bandelier	1	<0.0003	0.009	0.048	<0.0002	0.004	0.4	---	1.3	<0.003	<0.005
Fenton Hill (Well)	1	<0.0003	<0.005	0.320	<0.0002	<0.002	0.1	---	1.1	<0.003	<0.005
Maximum Concentration	---	<0.0003	0.026	0.320	<0.0002	0.046	1.4	---	3.5	0.004	<0.005
Maximum Concentration as Per Cent of Standard or Criteria	---	<1	52	32	<2	92	70	---	7	8	<50

TABLE XVIII

SUMMARY OF ATMOSPHERIC PARTICULATE CONCENTRATIONS IN LOS ALAMOS AND WHITE ROCK DURING 1981

	New Mexico Ambient Air Quality Standards for Particulates ($\mu g/m^3$)	Los Alamos ($\mu g/m^3$)	White Rock ($\mu g/m^3$)
Maximum 24 h average	150	96	167
Maximum 7 day average	110	---	---
Maximum 30 day average	90	---	---
Annual geometric mean	60	38	40

A large fleet of cars and trucks is maintained for the Laboratory complex by the Zia Company. During fiscal year 1981, a total of 2.2×10^6 ℓ of gasoline were used by this fleet to cover 9.1×10^6 km. These figures are nearly identical to those for fiscal year 1980.

Carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and particulates are emitted during vehicle operation. There are also gasoline evaporative losses associated with gasoline storage and vehicle refueling. By breaking down total gasoline usage among the size classes of vehicles and by applying the most appropriate Environmental Protection Agency emission factors[29,30] to these data, air emissions associated with maintenance and operation of the vehicle fleet (Table XIX) were estimated. The gasoline evaporative losses and carbon monoxide, hydrocarbon, and nitrogen oxide emissions are quite different from previous years because of the use

TABLE XIX

ESTIMATES OF AIR POLLUTANT EMISSIONS ASSOCIATED WITH MAINTENANCE AND OPERATION OF THE VEHICLE FLEET

Pollutant	Estimated Amount (metric tons)	Change From 1980 (%)
Gasoline evaporative losses	6.5	---
Carbon monoxide	339	---
Hydrocarbons	15.5	---
Nitrogen oxides	9.4	---
Sulfur oxides	1.1	0
Particulates, exhaust	0.7	0
Particulates, tires	1.2	–0.1

of new Environmental Protection Agency emission factors.

The TA-3 power plant is fueled with natural gas and thus comes under state regulations for gas burning equipment. These regulations specify maximum allowable nitrogen oxide emissions but also contain a provision exempting facilities that have a heat input of less than 1×10^{12} Btu/yr/unit. Heat inputs for the TA-3 power plant individual boilers during 1981 were 0.70×10^{12} Btu, 0.67×10^{12} Btu, and 0.34×10^{12} Btu. Total heat input for the power plant was 1.71×10^{12} Btu (about 10% less than last year), but inputs for the individual boilers were below the 1×10^{12} Btu/yr exemption threshold.

Measured concentrations of nitrogen oxides (NO_x) in the power plant stack gas ranged from 24 to 48 ppm, which is about 20% of the standard that would apply if the heat input threshold was exceeded. Sulfur dioxide (SO_2) analyses of the stack gas are not performed routinely, but the sulfur content of the natural gas fed to the boilers is so low that it precludes any significant SO_2 emissions. Table XX shows estimated total power plant emissions for 1981, based on Environmental Protection Agency emission factors[29] for natural gas burning facilities.

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

During 1981 a total of 16 907 kg of high-explosive wastes was disposed by open burning at the Laboratory.

TABLE XX

ESTIMATES OF STACK GAS EMISSIONS FROM THE TA-3 POWER PLANT

Pollutant	Estimated Amount (metric tons)
Sulfur oxides	0.45
Hydrocarbons	0.74
Carbon monoxide	12.7
Particulates	7.5
Nitrogen oxides	234

Estimates of emissions (Table XXI) were made by using data from experimental work carried out by Mason & Hangar-Silas Mason Co., Inc.[31] Open burning of high-explosive wastes is permitted by New Mexico Air Quality Control regulations.

Dynamic experiments employing conventional explosives are routinely conducted in certain test areas at the Laboratory and may contain quantities of potentially toxic metals, including beryllium, lead, and uranium. Some limited field experiments, based on aircraft sampling of debris clouds, provided information on the proportion of such materials aerosolized. This information was employed to prepare estimates of airborne concentrations at the Laboratory boundary based on the amounts of explosives used during 1981. The results are presented in Table E-XXX along with comparisons to applicable air quality regulations. The average concentrations of uranium, beryllium, and lead are all less than 0.004% of applicable standards.

c. Liquid Effluents. Nonradioactive liquid waste discharges are authorized by National Pollutant Discharge Elimination System (NPDES) permit number NM 0028355 issued by the Environmental Protection Agency effective October 16, 1978. The permit authorizes discharges from 100 industrial outfalls in 10 industrial categories and 10 domestic waste outfalls. Tables E-XXXI and E-XXXII summarize the effluent quality of the domestic and industrial waste outfalls, respectively.

The current NPDES permit was scheduled to expire on June 30, 1981, but was extended by the Environmental Protection Agency. A new NPDES application required under the Environmental Protection Agency's Consolidated Permit Regulation was submitted in April

TABLE XXI

ESTIMATED EMISSIONS FROM BURNING OF EXPLOSIVE WASTES

Pollutant	Estimated Amount (kg)
Carbon monoxide	132
Particulates	304
Nitrogen oxides	510

1981. On August 14, 1981, the Environmental Protection Agency issued for the Laboratory a public notice, fact sheet, and proposed NPDES permit. The final NPDES permit was scheduled for issuance in September 1981, but has been delayed pending resolution of certain issues regarding state certification by New Mexico. Until the new permit is issued, the Laboratory will continue to operate under the original permit. The major changes in the proposed new permit are elimination of flow as an effluent limit at all domestic waste outfalls and elimination of fecal coliform as an effluent limit at one domestic waste outfall.

In 1981 corrective action was undertaken at two domestic waste treatment plants. At one location, a chlorination chamber was installed and at a second location construction was started on intermittent sand filters. The filters are scheduled for completion in 1982.

For industrial discharges in 1981, as in past years, the main emphasis regarding corrective action has been elimination of discharges. Since the NPDES permit was issued in 1978, a total of 19 outfalls have been eliminated. During 1981 a solids removal system and pH adjustment station were installed at the Laboratory's steam plant. At another facility, a manifold system reduced six outfalls to two.

This year one of the domestic waste treatment plants met all limits and one lagoon exceeded only flow limits. Fewer than 7% of the samples from the industrial outfalls exceeded permit limits during 1981.

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

C. Meteorology

Weather during 1981 for Los Alamos was unusually warm and precipitation was near normal. It was the second consecutive very warm year and the warmest since 1956. Normal rainfall returned in March, ending the severe drought that began in June 1980. It was marked by many high temperature records and unusually warm temperatures in January, February, April, June, November, and December.

1. Summary of 1981 Weather

Los Alamos experienced a very warm 1981 but had near normal precipitation, breaking the long drought extending from 1980. The 1981 weather is summarized in Fig. 20, Table E-XXXIII, and Table E-XXXIV. Again, the past year continued the trend of extreme weather that began in the latter half of the 1970s. The past year became the fourth warmest year on record, slightly exceeding the very warm 1980. A total of 35 days or almost 10% of the days in the year tied or exceeded daily maximum temperature records. Most importantly, the severe drought that began in June 1980 ended in March 1981. Total precipitation for 1981 was near normal.

The year started out very warm and dry with January and February 1981 and December 1980 comprising the warmest winter on record with an average temperature of 1.4°C (36.3°F). Previously, the warmest winters were 1979 to 1980 and 1953 to 1954. It was also the driest winter on record with only 11.9 mm (0.47 in.) of precipitation. Only 24.1 cm (9.5 in.) of snow fell during the 3-month period, accumulating the fourth lowest amount of snow for any winter on record. Eight days in January and February tied or set maximum temperature records.

A strong high pressure ridge anchored over the western United States finally yielded to intense storms in March, allowing heavy precipitation to fall. A total of 69.3 mm (2.73 in.) of precipitation fell during the month with 747 mm (29.4 in.) of snow. A locally heavy snowstorm produced 38.1 cm (15.0 in.) of snow on the eleventh. Until March of 1981, only 144.6 mm (5.69 in.) of precipitation had fallen during the previous 9 months, representing about less than a third of the normal amount for that period.

Another high pressure ridge developed over the Rocky Mountains in April causing warm and dry conditions for much of the month. Daily maximum temperature

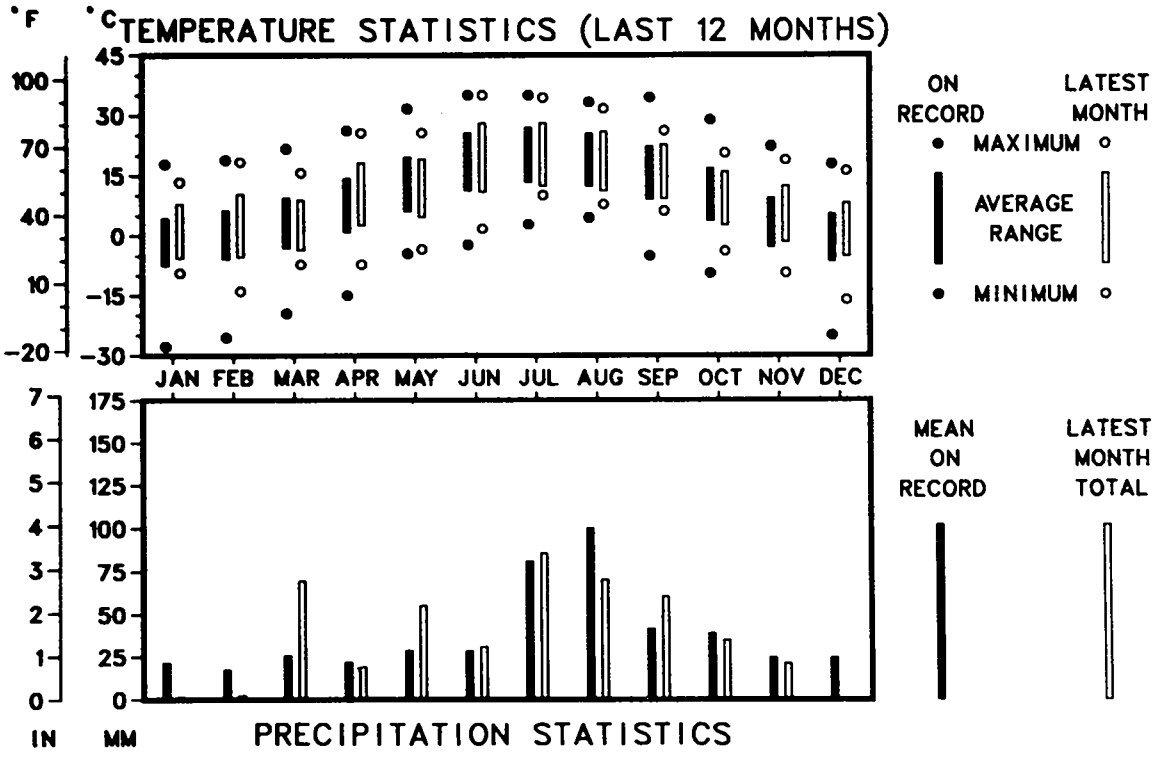


Fig. 20. Summary of 1981 weather in Los Alamos (Data from Occupational Health Laboratory, OHL, at TA-59).

records were set in the final 6 days of the month. The month became the third warmest April on record. An intense storm produced wind gusts as strong as 35.5 m/sec (78 mph) on April 3.

The ridge weakened in May but reintensified during June causing high daytime temperatures. The average maximum temperature for June was the second highest on record, next to that of June 1980. Ten days in June set record daily maximum temperatures, including a temperature of 35.0°C (95°F) on June 22, equaling the all-time maximum temperature for any day set on July 11, 1935. There were 8 days with temperatures of at least 32.2°C (90°F), the most in a month on record except for 9 in June 1980 and 11 in July 1980. The normal for June is less than 1 day.

Several more high temperature records were set in July and August, although these months had near-normal temperatures. Both temperature and rainfall remained near normal through October. However, another strong ridge formed over the Rocky Mountain states in November, causing warm weather over New Mexico and Los Alamos for the remainder of the year. Nine maximum daily temperature records were set in the last 2 months of the year. December 1981 was the driest December on record with only 0.25 mm (0.01 in.) of precipitation. The month also tied for the least amount of snow for December with 0.5 cm (0.2 in.).

2. Wind Roses for 1981

The 1981 wind speed and direction measured at the Occupational Health Laboratory (OHL, TA-59) are plotted in wind roses (see Fig. 21). 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 speed of less than 1 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 over 99% data recovery for 1981. The wind roses

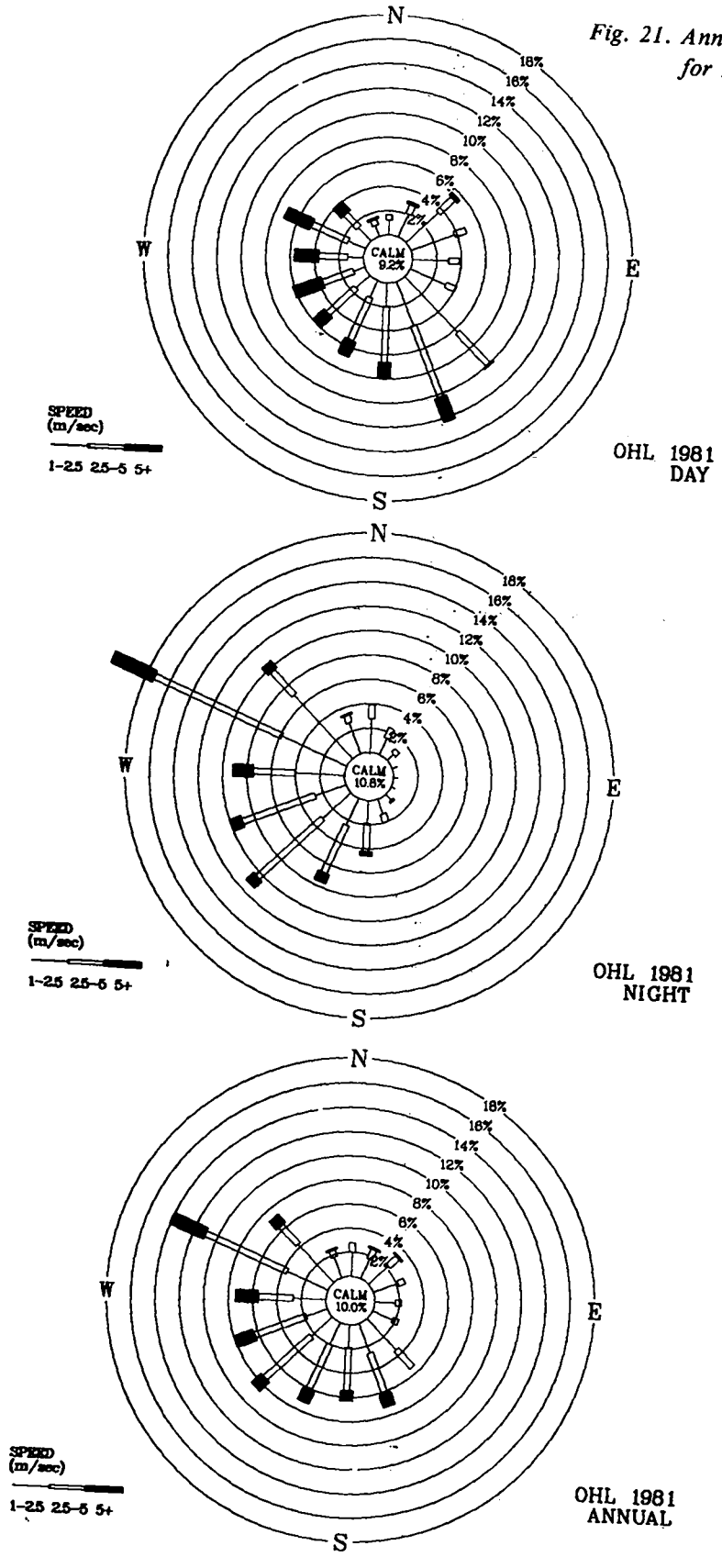


Fig. 21. Annual, day, and night wind roses for Los Alamos for 1981.

in Fig. 21 include an annual summary for 1981 and summaries for daytime and nighttime hours. Daylight hours were defined as the hours when measured solar insolation was less than 0.01 langleys/min. Los Alamos is a generally light wind site with an annual average wind speed of 3.0 m/sec. Only 12% of wind speeds in 1981 were greater than 5 m/sec, while almost 50% were less than 2.5 m/sec.

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

3. Rainfall Summary for 1981

Near-normal amounts of precipitation returned to the Los Alamos area in 1981 after the very dry previous year. Figure 22 shows 1981 quarterly and annual precipitation for four sites. See Figs. 2 and 4 for locations of the sites. The four sites—TA-16 (S-Site), TA-59 (Occupational Health Laboratory), TA-54 (Area G), and White Rock—have elevations of 2338, 2249, 2039, and 1944 m, respectively. Note that precipitation increases with higher elevation. TA-16, the highest site, received the most precipitation and White Rock, the lowest, received the least. About half of the precipitation fell during the period July-September at all sites.

A brief, very heavy rainfall of 44.5 mm (1.75 in.) occurred on July 27 at TA-16. The line of thundershowers only produced about 16.5 mm (0.65 in.) of rain at each of the other three sites. The rainfall at TA-16 equaled the 35-year rain for a 15-minute period with a total of 25.4 mm (1.00 in.). Table XXII shows rainfall amounts during this rainstorm and the expected return periods for several elapsed times.

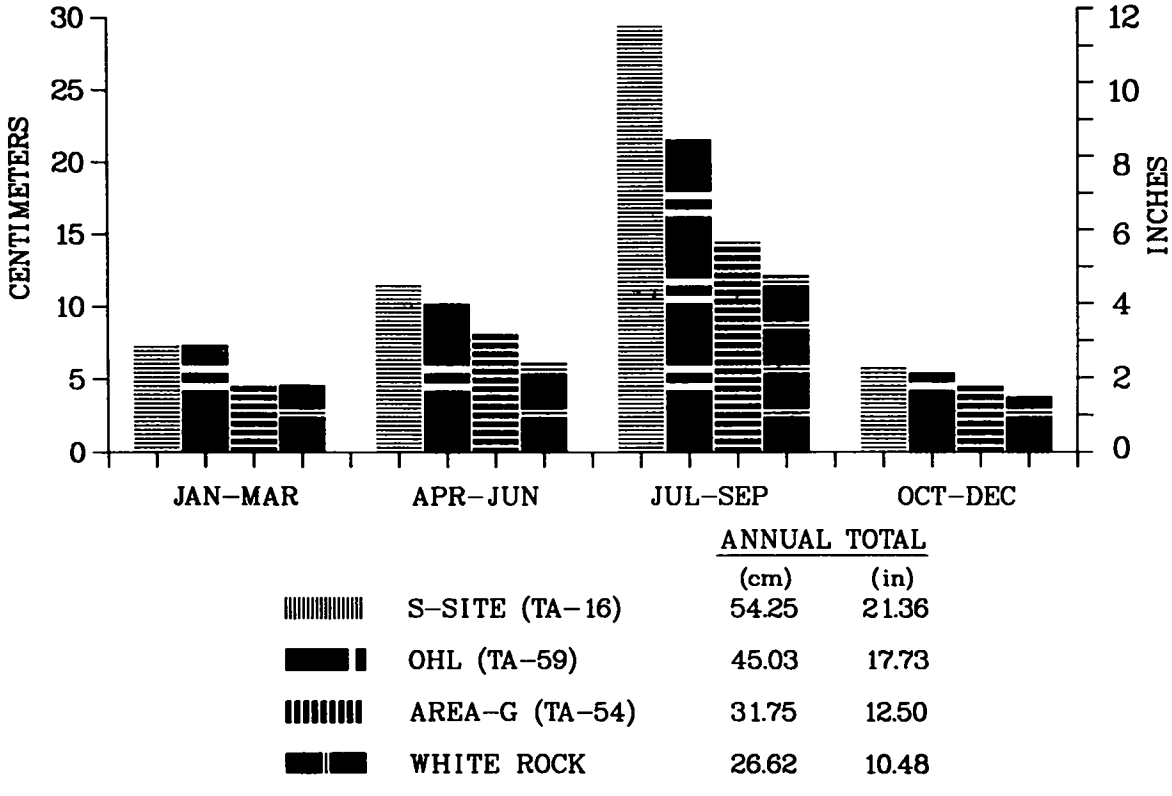


Fig. 22. Summary of 1981 precipitation at four sites at the Laboratory.

TABLE XXII

RAINFALL INTENSITIES AND EXPECTED RETURN PERIODS FOR THE JULY 27, 1981 RAINSTORM AT TA-16

Elapsed Time	Cumulative Amount of Precipitation (mm)	Cumulative Amount of Precipitation (in.)	Return[a] (years)
15 min	25.4	1.00	35
30 min	31.8	1.25	25
60 min	40.1	1.58	25
2 h	43.4	1.71	15
3 h	44.5	1.75	10
6 h	44.5	1.75	5
24 h	44.5	1.75	<2

[a]Return periods based on memorandum dated August 11, 1981, from Leonard Lane (LS-6) to Brent Bowen (H-8). A return period is the number of years that would normally pass before a rainfall of equal intensity would likely occur.

V. ENVIRONMENTAL PROTECTION PROGRAMS AT LOS ALAMOS

A. Laboratory Environmental Review Committee

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

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

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

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

B. Quality Assurance

The Laboratory has a Quality Assurance program[32] for engineering, construction, modification, and maintenance of Department of Energy facilities and installations. The purpose of the program is not only to minimize chance of deficiencies in construction, but also to improve cost effectiveness of facilities' design, construction, and operation, and to protect the environment. The Quality Assurance program is implemented from inception of design through completion of construction by a project team approach. The project team consists of individuals from the Department of Energy's program division, Department of Energy's Albuquerque Operations and Los Alamos Area Offices, Laboratory operating group(s), Laboratory Engineering Division, design contractor, inspection organization, and construction contractor.

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

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

C. Archeological and Historical Protection

Protection of archeological sites at the Laboratory (mandated by several Congressional Acts and Executive

Order 11593) is also part of the Environmental Evaluations Coordinator and Quality Assurance programs. A proposed location for a new facility is surveyed for archeological and historical features. If a feature is found, then an attempt is made to adjust siting to preserve it. If alternative siting is not feasible, then the feature is documented and excavated to gain knowledge about it and recover artifacts. The decision as to which course to follow (excavation or moving the facility) is based on the value of the archeological or historical feature, availability of alternative locations for the new facility, and the programmatic impact if the new facility was not relocated.

The Laboratory has a contract with the Museum of New Mexico to provide archeological surveys and make evaluations of archeologic or historic features. When a decision has been made to excavate a site, the State Historic Preservation Officer is notified and with his concurrence a request for a determination of eligibility is made with the National Register of Historic Places. If a site is determined to be ineligible, excavation proceeds. Otherwise, the Advisory Council on Historic Preservation is contacted to request approval of excavation procedures prior to salvage operations.

The Laboratory is currently drafting a Cultural Resources Management Plan to streamline the above process. The State Historic Preservation Officer and Laboratory have agreed that a blanket detemination for all archeological and historic sites within Laboratory boundaries should be made. Necessary excavations could then be made under this blanket determination with concurrence of the Advisory Council on Historic Preservation.

A survey of more than 450 archeological sites at the Laboratory was made between March 1973 and July 1975. This survey of the pre-Columbian Indian ruins is summarized in a Laboratory report.[33] The survey is used during construction planning to avoid damage to such sites or to provide the lead time necessary to conduct required salvage archeology (contacting the State Historic Preservation Officer, National Register of Historic Places, and Advisory Council on Historic Preservation as previously outlined). Several unique sites were recommended for registration as national historic sites and formal nomination procedures are underway. This will ensure their preservation for future generations by establishing formal responsibility for their protection. Nine new sites, both pre-Columbian and historic, were located this year and added to the inventory of sites.

Two public tours of archeological sites within the Laboratory's boundary were conducted in 1981. These tours allow the public to see archeological sites that are normally inaccessible to them due to security restrictions for the surrounding Laboratory land. This year the tours included Tshirege, the largest pre-Columbian community on Pajarito Plateau, and Nakemuu, an excellently preserved pre-Columbian village. Nakemuu has a unique configuration of a plaza village and several stone shrines. These tours were extremely popular, with more than 500 Laboratory employees and visitors participating in each of the 1981 tours.

VI. RELATED ENVIRONMENTAL STUDIES

The Environmental Sciences Group (LS-6) at the Laboratory conducts research and experimental studies under auspices of the Department of Energy. Some of the research programs conducted by LS-6 complement routine monitoring and research (see Appendix G for list of publications) conducted by the Environmental Surveillance Group (H-8) by providing a better understanding of the ecosystem surrounding the Laboratory in relation to its operations. Following are highlights of several of these research programs.

A. Preliminary Assessment of Geologic Materials to Minimize Biological Intrusion of Low-Level Waste Trench Covers and Plans for the Future [T. E. Hakonson, G. C. White (LS-6); E. S. Gladney, M. Muller (H-8)]

1. Introduction

Low activity wastes and wastes suspected of being contaminated are generally buried in shallow trenches (1.5 to 45 m wide, 2 to 11 m deep, 6 to 300 m long) that are covered with less than 1.0 to 2.5 m of material when the trenches are full.[34] Most waste burial facilities attempt to revegetate the trench covers to minimize soil loss and to increase the aesthetic appearance of the site. Although it has been recognized[35,36] that biological intrusion of low-level waste trenches can lead to transport of radionuclides from a burial site, little has been done to quantify the magnitude of the problem and to develop measures, when needed, to prevent the intrusion.

The stability of low-level waste trench covers is a function of physical, chemical, biological, and climatological factors that interact in both obvious and subtle ways. The importance of biological factors in altering the integrity of trench covers is often overlooked, despite evidence that plants and animals can influence trench cover stability and mobilize radionuclides buried in the trench.[35,36] Biological interactions with trench covers can be direct, as in the case of radionuclide uptake by plant roots. They can also be indirect, such as when tunnel systems created by burrowing animals increase the rates and depths of rain water penetration into the trench cover profile.

2. Methods and Materials

A series of experiments was initiated at Los Alamos in the Experimental Engineered Test Facility to determine the effectiveness of several natural geologic materials as barriers that inhibit plant intrusion into low-level waste cover profiles. Initial experiments employed 288 lysimeters consisting of 25-cm-diameter plastic pipe ranging from 105 to 210 cm in length. Cover profiles were constructed in the lysimeters to evaluate the effect of four different variables on plant root penetration with depth (Table XXIII). The profiles consist of a simulated waste (CsCl) at the bottom of the profile. The waste layer was covered by a barrier layer consisting of four different types of natural geologic materials (cobble, cobble-gravel, bentonite clay, and crushed tuff) at three different depths. Top soil was applied at two different depths as an overburden to complete the profile. Three species of fast-growing, deep-rooted plants (alfalfa, barley, yellow sweet clover) were seeded into the lysimeters to produce the biological stress for evaluating the barrier systems. Success or failure of the barriers was evaluated by analyzing plant tissue for stable cesium using neutron activation analysis.

TABLE XXIII

EXPERIMENTAL DESIGN OF PLANT ROOT INTRUSION STUDY

Variable	Number	Remarks
Plant species	3	Barley, clover, alfalfa
Top soil depth	2	30 cm, 60 cm
Barrier type	4	Crushed tuff
		Bentonite clay
		Cobble
		Cobble-gravel
Barrier depth	3	Clay: 15 cm, 30 cm, 45 cm
		Others: 30 cm, 60 cm, 90 cm
Replications	4	
Total	288	

3. Preliminary Results

Initial results from sampling vegetation for cesium tracers indicate that 126 of the 288 cover profiles had been completely penetrated by plant roots in a 102-day period. Analyses of these data show that about 50% of the penetration through the barrier materials were caused by barley, whereas clover and alfalfa were each associated with about 25% of the penetrations. These initial differences in the rate of root penetration between plant species indicate the need to carefully consider rooting characteristics of species used to stabilize low-level waste covers. Consideration should also be given to rooting characteristics of successional species that eventually replace the species initially used to reclaim low-level waste sites.

All of the profiles containing a sandy backfill material (crushed tuff) had been penetrated by plant roots after 102 days, regardless of barrier or soil depth. About 30% of the cobble barrier systems and about 22% of the clay and cobble-gravel systems had been penetrated after 102 days. Increasing soil and barrier depth substantially reduced barrier penetrations. Minimum barrier and soil depth combinations were associated with the highest rate of root penetrations through the clay, cobble, and gravel. The most effective depth combination at this stage of the study appears to be 60 cm of soil and 90 cm of barrier.

While bentonite clay and cobble-gravel performed equally well in preventing plant root intrusion, plant roots greatly altered the integrity of the clay barrier system. During the course of the study it was noted, by visual observation through clear plastic lysimeters, that the integrity of the clay layer changed through time. A gradual, but continual, shrinkage of the clay layer occurred as a result of depletion of moisture from the clay by invading plant roots. This observation, if confirmed by further data, has significant implications on the use of bentonite clay as a moisture, gas, and/or biological barrier.

4. Summary

Small-scale, short-term biological intrusion studies at the Los Alamos Experimental Engineered Test Facility show that typical sandy backfill material is readily penetrated by invading plant roots and animals. Bentonite clay, cobble, and cobble-gravel combinations reduce the rate of root and animal intrusion through experimental waste cover profiles compared to sandy backfill. Intermediate scale studies with proposed barrier materials will provide further technical support for selecting effective biological intrusion barriers. Current data suggest that cobble-gravel combinations offer the most resistance to biological intrusion when all factors are considered.

B. Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers [T. E. Hakonson, J. L. Martinez, and G. C. White (LS-6)]

1. Introduction

A study has been done at Los Alamos to characterize the amount of disturbance of a low-level waste cover resulting from the burrowing activities of pocket gophers (*Thomomys bottae*). Data are presented on the amount of soil excavated from the cover profile, amount of tunnel system created by these soil activities, and particle size distribution and radionuclide content of cast soil.

2. Methods and Materials

A 0.95-ha study area was established on a low-level waste burial site that was decommissioned in 1977. The plot was positioned over trenches that were covered with 1 m of crushed tuff (the material excavated from the trenches) and about 0.25 m of topsoil. A mixture of native grasses and forbs (sweet clover and alfalfa) was seeded into the topsoil in 1977.

A sampling grid with 7.5- by 7.5-m cells was established over the covered trenches in August 1979. All soil excavated by pocket gophers within each grid cell was collected and weighed at 2- to 11-week intervals over a 1-year period. Subsamples of the soil were screened to determine the amount of soil in the less than 2-mm diameter size class versus gravel and rock (greater than 2 mm diameter). The soil fraction (less than 2 mm diameter) was also analyzed for gamma emitting radionuclides.

3. Results and Discussion

Total vegetation cover of the plot was estimated as about 23% with sand dropseed *(Sporobolus cryptandrus)*, sweet clover *(Melilotus officinalis)*, alfalfa *(Medicago sativa)* and fescue *(Festuca* spp.) contributing

the most to the cover estimate. Of the 25 species recorded on the plot, most were not present in the original seed mixture applied to the cover in 1977 due to natural invasion of the plot with forb species. Grasses, forbs, and shrubs comprised 24, 72, and 4% of the species present. About 40% of the forb species were from the sunflower family (*Compositae*).

In a 401-day period, 1998 separate mounds were created by pocket gophers on the 0.95-ha study area for an average of about 5 mounds day^{-1} ha^{-1}. Total mass of the soil in these mounds was 11 255-kg oven dry weight, for an average excavation rate of about 30 kg day^{-1} ha^{-1}. Mound building activity was greatest in late summer and fall when a total of about 60 kg ha^{-1} of soil was brought to the surface of the waste burial pit each day.

Composition of mound soils was almost exclusively the crushed tuff directly overlying the waste. An average of about 33% of the mound soil was tuff particles in the gravel and rock size range (greater than 2 mm diameter), while the remaining 67% was soil particles (less than 2 mm in diameter). Rock-sized particles were often up to 6 cm in diameter, indicating the ability of the gophers to move relatively large chunks of backfill material. The ratio of gravel and rock to soil in the mound samples was significantly different (p less than 0.05) from the corresponding ratio in the tuff backfill material. The percentage of particles greater than 2 mm in the mound soil was 33%, whereas the corresponding percentage in the tuff backfill was 48%.

Digging activity of pocket gophers on the study plot turned over less than 0.1% of the waste cover during the 1-yr observation period. However, the 11 255 kg of material brought to the soil surface represents a volume of about 8.3 m^3; presumably about 8.3 m^3 of void space was created within the cover profile. Based on an average tunnel cross-sectional area of 30 cm^2, as measured in the field, 8.3 m^3 of void space was created within the cover represents about 2800 m of pocket gopher tunnel system.

Based on the total number and dimension of individual mounds, the soil in the mounds covered about 1% of the ground surface to a depth of 12.5 cm on the study plot. Soil mounding by the gophers was observed in 76% of the grid cells in the plot.

Gamma emitting radionuclides, at levels exceeding worldwide fallout, were not detected in any of the mound soil samples. The lack of waste radionuclides in the mound samples would suggest that gophers have not penetrated into the waste trench in the 4 yr subsequent to closure of the site.

4. Summary

Pocket gophers modify the soil matrix in many ways. Perturbations to the soil profile that may be detrimental to low-level waste containment systems include excavation of soil from within the cover profile to the ground surface,[37,38] increasing water infiltration rates into the soil profile,[39-41] displacing chemicals vertically within the profile, altering rates of soil erosion,[38] and penetrating into waste burial tenches and mobilizing radionuclides.[42] The results of this study indicate that the amount of soil brought to the surface of low-level waste site is small relative to the volume of cover material. However, the void space created by their burrowing activity represents a substantial network of tunnel system within the waste cover profile.

The effects plants and animals have in altering the soil profile must be considered in developing reclamation procedures that have long-term effectiveness. Burrowing animals not only directly alter the soil profile through digging activities but also change the physical and chemical processes within the profile that can mobilize buried contaminants.

C. Mapping Pocket Gopher Burrow Systems with Expanding Polyurethane Foam [M. Felthauser and D. McInroy (LS-6)]

1. Introduction

In a Los Alamos study of barrier materials that inhibit burrowing by pocket gophers (*Thomomys* spp.) into waste material, it was necessary to map tunnel systems as a function of depth and soil profile type. A method of mapping burrow systems was needed that would be economical (in money and labor), portable, useful in a variety of soil types, and give accurate, permanent records of burrow configurations. A method for injecting an expanding polyurethane foam to map burrow systems *in situ* was chosen.

2. Injection Apparatus

A device used to map burrow systems was developed for injecting insulating foam into closed building spaces. The foam is initially in two components: an isocyanate and a resin. Freon added to the components causes the foam to expand when mixed and exposed to air. Pressurized nitrogen is used to force the two components

into a gun assembly where mixing takes place. The resulting foam is shot out in a stream that, depending on the nitrogen pressure, can travel several meters in air.

3. Field Testing

The foam injection apparatus was tested under a variety of natural and experimental conditions involving several soil profile types. Fifteen pocket gopher tunnel systems occurring under natural conditions were injected with foam to determine applicability of the technique to different soil types. Those types were: a sandy alluvial soil, a sandy-loam disturbed by heavy equipment, an undisturbed sandy-loam, and a gravel.

The apparatus was also tested under experimental conditions in four different soil profiles that were created in four metal culverts (1.8-m diam, 2.1-m ht). One pocket gopher was placed in each culvert; the gophers were maintained for 4 months and then were removed. The burrow system that had been constructed by each gopher was injected with foam.

The injection procedure that provided the best results consisted of attaching a 2.5-cm diam plastic hose about 45-cm long to the gun nozzle. The hose was then inserted into an exposed tunnel entrance; the area around the entry point of the hose into the tunnel was tamped with soil to prevent backflow of the foam. Foaming of the tunnel system was continued until backflow or foam eruptions at remote tunnel entrances prevented further flow. When tunnel systems branched near the entrance point, each branch was injected separately to facilitate the foam's travel into both branches.

After the foam was injected, it expanded into an exact cast of the tunnel system and hardened in about 15 minutes. The foam was then excavated manually with a shovel and trowel. Four to eight hours were required to inject, excavate, and reassemble each tunnel system. Occasionally, a tunnel cast could be removed intact although breakage of a cast occurred frequently. Broken casts were easily reassembled on the ground surface (using wire rods for support) to provide a three-dimensional model of the tunnel system.

Maximum length of a single branch of a burrow mapped by the foaming technique was 15 m. Maximum volume of an injected burrow system was 0.15 m^3; maximum depth of a burrow, as measured by the foam cast, was 1.5 m.

Factors that limited the amount of tunnel system that was mapped by a single injection included: (1) a plugged tunnel resulting from a cave-in or from the digging by a gopher and (2) increased viscosity of the foam as the expanding and hardening process began. Both of these problems were eliminated by reinjecting the continuation of the tunnel beyond the plug or point where flow of the foam had ceased. It was discovered that reinjecting a continuing tunnel system should be done as soon as possible after the first injection to reduce the chance of further tunnel plugs created by the gopher or cave-ins.

Performance of the foaming apparatus in creating tunnel casts in sand alluvial soil, disturbed sandy-loam, and undisturbed sandy-loam was excellent as judged by the ease of tunnel cast excavation and reassembly. The technique did not perform well in the gravel soil type, because the relatively large amount of pour space between gravel particles often filled with foam. Thus, exact dimensions of the pocket gopher burrows were obscured.

Burrow systems created by pocket gophers confined to the metal culverts were completely mapped in three dimensions by the foam. All features of the burrows were apparent from the cast, including food storage and nest chambers.

4. Summary

The polyurethane foam injection technique provided a relatively easy, accurate method of mapping pocket gopher burrow systems. Features of the burrows that were readily identified or measured included the length, depth, and volume of the tunnel system as well as food storage and nesting chambers.

Labor required to map a burrow system in detail was minimal over conventional excavation methods that employ archeological procedures. The foam injection method was particularly appropriate for cohesive soil types with limited pore space. The method did not work well in loosely structured gravel or cobble soil profiles. Although this technique was tested only on tunnel systems, it could be adapted to map tunnel systems from a wide array of burrowing organisms.

D. Development of a Simplified Model to Predict Runoff, Sediment Yield, and Contaminant Transport in Mortandad Canyon [L. J. Lane, T. E. Hakonson, and G. C. White (LS-6)]

1. Introduction

Contaminants associated with large volume wastes may be transported from waste disposal sites with eroding soils. Soil erosion and subsequent sediment transport are of particular concern in the semiarid western United States where much of the annual precipitation occurs during intense summer thunderstorms. Runoff from such storms can result in accelerated loss of soil and associated contaminants from a disposal site. Once the contaminants enter a stream channel system, the stream bed sediments are often the major repository of radioactive and stable elements released to the environment. Subsequent storms produce runoff which can result in offsite transport of the sediment and contaminants in the channel system.

Differential erosion, transportation, and deposition result in sediment particle sorting. As these processes are selective, as a function of particle characteristics, the result is that transported sediment is usually enriched in the finer particles. Because of physiochemical processes, again as a function of particle characteristics, contaminants can be more strongly associated with the smaller sediment particles. The combined processes of particle sorting during erosion, transportation, and deposition and the differential association of contaminants by sediment particle size produce complex relations between runoff, sediment transport, and associated contaminant transport. Because knowledge of contaminant transport is important in designing monitoring systems, in estimating contaminant inventories, and in contaminant-risk assessments, there is a need to determine the influence of particle sorting on contaminant transport rates.

2. Model Development

Models or procedures used to predict particle transport should be conceptually and operationally simple. The procedures should not be oversimplified, but they should require a minimum amount of calibration data, they should be able to make predictions without extensive parameter optimization, and the information they provide should be useful in decision making.

Toward this end, a procedure was developed to predict runoff from upland areas using precipitation, soils, and vegetation data. The runoff is then routed through stream channel systems to compute sediment transport by particle size classes. The runoff and sediment particle transport data are then used to compute contaminant transport rates and amounts. The hydrologic model was developed using data from 65 experimental watersheds operated by the US Department of Agriculture. Data from these 81 experimental watersheds in 12 areas of the US represent several hundred runoff events. Sediment data from eight US Department of Agriculture and US Geological Survey watersheds were used to develop the sediment transport equations.[43] Based on analysis of these data, the hydrologic model and sediment transport equations were deemed sufficiently tested and accurate to use in predicting particle-contaminant transport at Los Alamos.

A method was developed to predict sediment transport by particle size classes in alluvial streams with noncohesive sediments. Based on a knowledge of contaminant concentrations in the bed sediments, procedures were developed to predict the transport rate of contaminants traveling in association with sediment particles. Runoff, sediment, and contaminant rates were integrated over a given period of runoff (the runoff hydrograph) to estimate water, sediment, and contaminant yields. Results of this routing procedure were compared with empirical methods, such as loading functions and enrichment ratios, that are commonly used to predict contaminant yields. The routing method includes the influence of particle sorting and thus represents an improvement over the loading function-enrichment ratio approach.

3. Applications of the Model

An example application of this method is for plutonium transport in an effluent-receiving canyon at Los Alamos. Plutonium concentrations in bed sediments of an alluvial stream channel were found to vary by an order of magnitude as a function of particle size.[44] Errors in computed plutonium transport rates as a result of ignoring sediment particle sorting ranged from less than 10% for large runoff events to near 100% for very small runoff events. For flood events smaller than the average annual flood, plutonium yields predicted by ignoring particle sorting differed by over a factor of two from yields computed using the routing procedure. Moreover, the routing procedure accurately predicted measured

plutonium transport rates during a flood event. This illustrated the importance of particle sorting on plutonium transport in Mortandad Canyon at Los Alamos.

A second example application involved developing frequency distributions for runoff, sediment yield, and contaminant yield. Procedures were developed to predict the distance a contaminant will travel as a function of storm size and to determine the probability distribution for travel distances. This application for contaminant transport in ephemeral streams illustrated the importance of accurately predicting transport and deposition of sediments by particle size classes.

E. An Update on Biotelemetry Studies of Elk [G. C. White and D. K. Thiel (LS-6)]

The movements of Rocky Mountain elk (*Cervus elaphus nelsoni*) in the eastern Jemez Mountains of northcentral New Mexico have been studied from 1978 to 1981. Seventy elk have been trapped, marked, and released; 60 of these animals were radio collared. The results of the study through 1980 are published in "Biotelemetry Studies on Elk" (Los Alamos National Labortory report, LA-8529-NERP, 1981). A movie based on the study, "Elk Biotelemetry at the Los Alamos Environmental Research Park," was also produced.

As of October 1981, 24-collared animals were being monitored. The others have been hunter-killed, been poached, had radio-failures, or disappeared because of unknown causes. Two significant occurrences during 1981 were an outbreak of the disease *Elaeophora schneideri* and, due to a timber sale on the eastern slopes of Cerro Grande and Pajarito Mountain, a shift in migration routes (see Fig. 23).

F. Sulphlex Environmental Studies [R. W. Ferenbaugh, K. A. Knight, M. K. Wallwork (H-8); L. Hersman (LS-6)]

1. Introduction

As part of a Laboratory investigation into the feasibility of using Sulphlex pavement, a copolymer of sulfur and organic compounds, as an asphalt substitute at Los Alamos, an investigation of the environmental interactions of Sulphlex was undertaken. This investigation consisted of two sets of experiments. One set dealt with microbial degradation of Sulphlex, and the other with growth of plants in Sulphlex-amended soil.

2. Microbial Degradation Study

Because of the sulfur constituent of Sulphlex, the question arose as to whether sulfur-metabolizing microorganisms in the environment would cause premature degradation and weakening of the Sulphlex pavement.

To investigate this possibility, a series of experiments was undertaken in which sterile culture media containing either sulfur or Sulphlex as a sulfur source were inoculated with a sulfur-oxidizing bacterium (*Thiobacillus* spp.). Growth of the bacterium was measured by monitoring the pH drop of the cultures. The pH drops because the bacterium produce sulfuric acid as they metabolize sulfur. The sulfur-containing medium served as the control for the experiment, which was designed to determine if the *Thiobacillus* bacterium could, indeed, use the Sulphlex as a sulfur source.

Initial results of the experiments indicated that the pH of the Sulphlex medium did not drop as fast as that of the sulfur medium, indicating that the Sulphlex was not as available a sulfur source. However, subsequent investigation showed that the Sulphlex medium had a higher buffering capacity. When the data were normalized to eliminate confounding effects of the difference in buffering capacity, the bacterium was found to use both the sulfur and Sulphlex media equally as efficiently as a sulfur source. Such microbial activity and concomitant acid production could result in premature weakening of this paving.

3. Plant Growth Study

Plants were grown in Sulphlex-amended soil to determine if Sulphlex would have either a detrimental or beneficial (because sulfur is a nutrient) effect on plants. Both unamended soil and asphalt-amended soil were used as controls. Bush bean and barley were used as experimental subjects.

The first experiment used soils amended at both the 1 and 5% levels by mass. Plant growth at the 5% level of both Sulphlex and asphalt was so poor that only the 1% level was used in subsequent experiments. Growth responses were mixed. In most trials, plants grew decidedly poorer in Sulphlex-amended soil. In two trials, however, there were no apparent differences. Plants

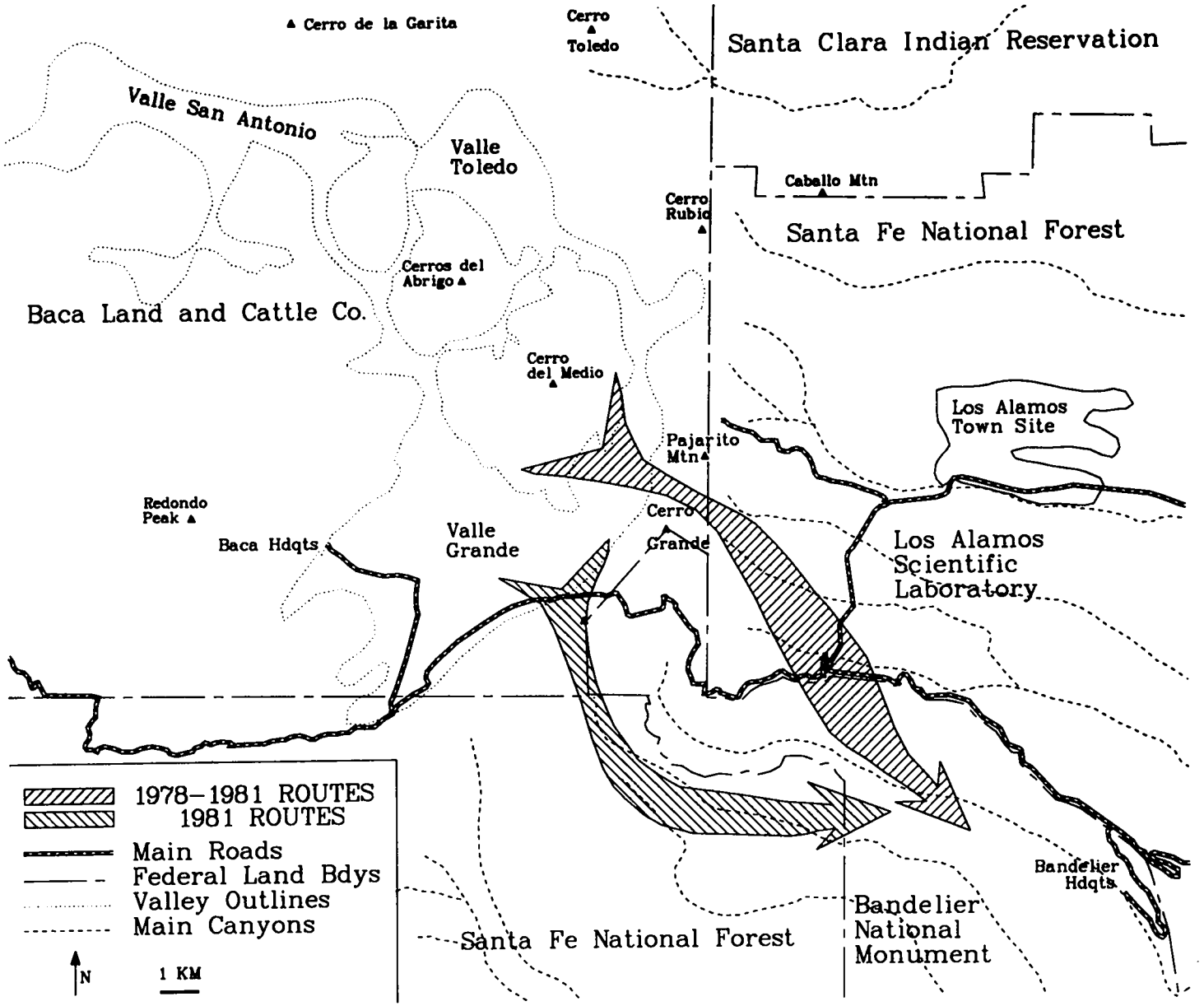


Fig. 23. Elk migration route change from 1978 to 1981.

grown in asphalt-amended soil gave variable results. Seed production by plants grown in Sulphlex-amended soil was definitely poorer. Chlorophyll content also was affected. Results are summarized in Table E-XXXV.

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

Cooling system leaks at the Los Alamos Meson Physics Facility (LAMPF) discharge water with activation product radionuclides into lagoons below the facility. Samples of water, sediments, and transpirate from trees adjacent to the effluent stream from the lagoons have been collected approximately every 2 months since effluent began flowing in the spring of 1979. The purpose of this sampling program is to ascertain the extent to which radionuclides are dispersed from the lagoons. Figure 24 shows locations of the sampling sites relative to the lagoons and Los Alamos Canyon. Between Sites 2 and 3, the discharge stream drops from the plateau, on which the lagoons are located, into a side canyon that eventually enters Los Alamos Canyon between Sites 6 and 7. Surface water is found in the side canyon below Site 4 only during heavy runoff events.

A summary of the sampling results from 1979, 1980, and 1981 is shown in Table E-XXXVI. These data show that radionuclide concentrations decrease with progression down the canyon and fall off past sampling Site 4. Transpirates from piñon and juniper trees located immediately adjacent to the stream show elevated tritium concentrations (as HTO) above Site 4. Tritium in transpirates collected below Site 4 also are lower.

Given the uncertainty of the analytical results, as high as 100% in some cases, the data in Table E-XXXVI are difficult to interpret. The ^{7}Be and ^{22}Na data seem to indicate that the concentrations of these radionuclides are increasing below the lagoons, but this trend is not apparent in the tritium data. There also is an indication that the radionuclides are beginning to move down the canyon, past the point where the effluent sinks into the alluvium. This probably is a result of movement during heavy runoff events.

Gamma ray spectroscopy of water samples from the lagoons have identified a variety of radionuclides in the water. A list of those isotopes whose presence is certain is given in Table XXIV. Other isotopes may be present. Analyses of copepods and salamanders from the lagoons and insects, lizards, snakes, and small rodents from the surrounding mesa tops show that radionuclides are being dispersed from the lagoons and the effluent stream. Birds that use the lagoons and adjacent area for food and water undoubtedly also pick up some radioactivity. The degree of biological dispersal is being investigated in a study that will continue during 1981.

H. Environmental Surveillance of Radioactive Waste Disposal Areas [D. L. Mayfield (H-8)]

In 1980, an environmental surveillance plan[45] tailored to specific radioactive waste disposal sites was developed to supplement the Laboratory's general environmental

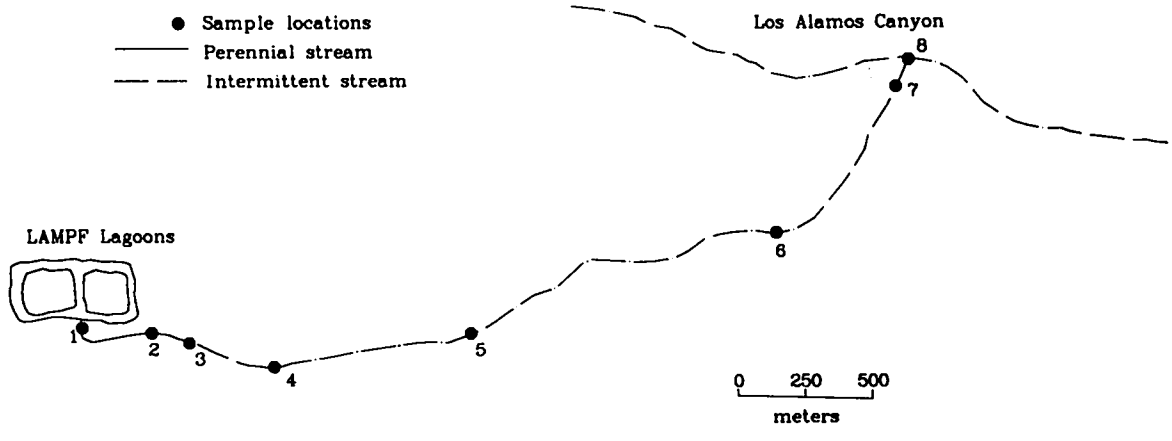


Fig. 24. Sampling locations in vicinity of the Los Alamos Meson Physics Facility's lagoons.

TABLE XXIV

RADIONUCLIDES IN LAMPF SEWAGE SYSTEM

Isotope	Half Life
^{7}Be	53.4 d
^{22}Na	2.60 y
^{46}Sc	83.9 d
^{48}V	16.1 d
^{51}Cr	27.7 d
^{52}Mn	5.7 d
^{54}Mn	312 d
^{59}Fe	45.1 d
^{56}Co	77.3 d
^{57}Co	270 d
^{58}Co	70.8 d
^{60}Co	5.3 y
^{65}Zn	244 d
^{75}Se	120 d
^{83}Rb	86.2 d
^{85}Sr	64.7 d
^{88}Y	107 d
^{105}Ag	41.0 d
^{110m}Ag	250 d
^{124}Sb	60.2 d
^{134}Cs	2.06 y

surveillance effort. The plan, which is for both active and retired disposal areas, specifies a brief annual survey for most disposal areas and a comprehensive survey for each disposal area every fifth year. The annual surveys are designed to monitor changes on the surface of each disposal area. Fifth year comprehensive surveys will disclose more subtle trends, both on and below the surface.

The survey plan also provides guidance in designing sampling grids and transects, using field instruments for radioactivity measurements, taking soil and biota samples, and applying Laboratory analytical techniques to soil and biota specimens. Several areas were surveyed during the annual survey in 1980; however, special studies during 1981 prevented their completion.

New sampling techniques were conceived especially for this program in 1981. One technique uses a circular saw fitted with a masonry blade to cut cylinders of tuff from trench walls. Another technique, still conceptual, would fill test holes with native materials that could be withdrawn as a sampling medium. This concept would minimize potential physical transport of buried waste materials across test holes, reduce the number of test holes required, and reduce percolation of surface water into the test well array. The major benefit of this concept is that nearly uniform transport properties across a test well improves the quality of collected data and makes the data easier to interpret.

I. Honeybees as Biological Monitors [R. W. Ferenbaugh, M. K. Wallwork-Barber, and E. S. Gladney (H-8)]

Several studies[46-48] have demonstrated that honeybees can be used as indicators of environmental pollution. Use of honeybees for biological monitoring is presently being investigated by the US Environmental Protection Agency. This investigation is based on the premise that honeybees pick up contaminants present in the environment and may concentrate them in their bodies and/or honey.

At the Los Alamos National Laboratory, use of honeybees as environmental biomonitors for radionuclides was investigated[49] in the early 1970s. This work showed that honeybees could be used for this purpose, particularly for detection of tritium in the environment. More recently, a network of beehives has been established near waste disposal sites and waste stream outfalls throughout the Laboratory reservation. Bee and honey samples are collected each fall from these hives and from control hives at various locations away from the Laboratory. These samples are analyzed for both radioactive and nonradioactive constituents. Table E-XXV shows analytical results that have been obtained to date. As further data are accumulated, they will provide monitoring information and possibly information on movement of pollutants in the environment and food chains.

Two large mesh cages have been constructed in which small bee colonies can be maintained with artificial food sources. By spiking the food sources with tracers, information on the uptake of elements and their movement within the hive can be obtained.

J. Evaluation of Transuranic Waste Management Methods [L. J. Walker and W. R. Hansen (H-8)]

An in-depth evaluation of several possible strategies for long-term management of transuranic (TRU) wastes has been completed and published as "Alternative Transuranic Waste Management Strategies at Los Alamos National Laboratory," issued September 1981 (LA-8982-MS). This study was part of the Laboratory's ongoing waste management program and involved identification of various strategies for long-term management of TRU wastes currently buried and stored at Los Alamos. Fourteen alternatives were selected for thorough analysis. These alternatives included maintenance of current practices, engineering improvements at the current waste areas, and exhumation of buried TRU wastes.

The TRU wastes at Los Alamos are in six disposal areas. The total estimated volume of wastes, backfill materials, and projected accumulations to the year 1990 total about 330 000 m^3. Estimated long-term environmental impacts after the first few hundred years were found to be dependent upon potential uses of the land and to be highly dependent upon man-caused changes in surface erosion rates. Estimated dollar cost of the various alternatives were found to be generally proportional to the amount of handling and processing.

K. Fenton Hill Site (TA-57) Surface and Ground Water Quality [W. D. Purtymun and R. W. Ferenbaugh (H-8)]

Los Alamos National Laboratory is currently evaluating the feasibility of extracting thermal energy from hot dry rock geothermal reservoirs at this Fenton Hill Site (TA-57). The concept involves drilling two deep holes, connecting these holes by hydraulic fracturing, and bringing thermal energy to the surface by circulating water through the system.

The chemical quality of surface and ground waters in the vicinity of TA-57, about 30-km west of Los Alamos (Fig. 25), has been determined for use in geohydrologic and environmental studies. Results of past studies and detailed data have been reported elsewhere.[50] Table E-XXVII summarizes the chemical quality of water for nine surface water stations, four water supply locations, two springs along the Jemez Fault, one spring discharging from recent volcanics, and three hot springs. Water quality has varied slightly, mainly due to normal seasonal fluctuations.

Ponds at the site contain water used in drilling operations and water used in the experimental loop in the dry hot rocks about 3000 m below land surface. The water in the ponds is highly mineralized (5874 ± 602 mg/ℓ of TDS). Certain elements present in the ponds are of interest because of monitoring requirements specified in the National Pollutant Discharge Elimination System permit. These are arsenic, boron, cadmium, fluoride, and lithium.

Discharges from the ponds into the canyon began about 1974. Samples of vegetation and soil from the canyon bottom and bank of the channel have been collected semiannually since 1978. These samples are analyzed for the five elements previously mentioned. Sample locations are about 100, 200, 400, and 1000 m down canyon. An additional sample is collected at the lower end of the canyon, far beyond the section of the canyon reached by the holding pond discharges. These sample collections are designed to indicate if there is any accumulation of the elements of interest with time and with progression down the canyon.

Results obtained to date are shown in Table E-XXXVII. Although these data are scanty, there is some indication that there might be elevated concentrations of certain elements in vegetation in the stream channel in the upper part of the canyon. This is consistent with the preliminary conclusion, using chloride as a tracer, that the discharge from the holding ponds sinks into the canyon alluvium before it reaches 400 m down the canyon.

During the summer of 1981, problems were encountered with the holding ponds, particularly the upper pond at the Fenton Hill Site. Because of drilling mud, surfactants, other additives, and sulfur-containing cuttings added to the ponds, anaerobic microbial action in the sediments produced significant quantities of hydrogen sulfide. The odor in the vicinity of the ponds was quite offensive.

Measurements taken with a portable sampling instrument in July indicated air concentrations ranging from 0 to 1.15 ppm. The state standard for hydrogen sulfide is 0.01 ppm, and the odor threshold is about 0.003 ppm. However, even though high levels of hydrogen sulfide were measured around the ponds, the state standard

technically was not violated since hydrogen sulfide concentrations in excess of 0.01 ppm did not exist at the site boundary.

After unsuccessful attempts to treat the ponds by aeration and with biocides, an elaborate chemical treatment followed by flocculation and sedimentation was undertaken. The relatively uncontaminated supernatant liquid resulting from the process was discharged down the canyon, and the precipitated material was buried.

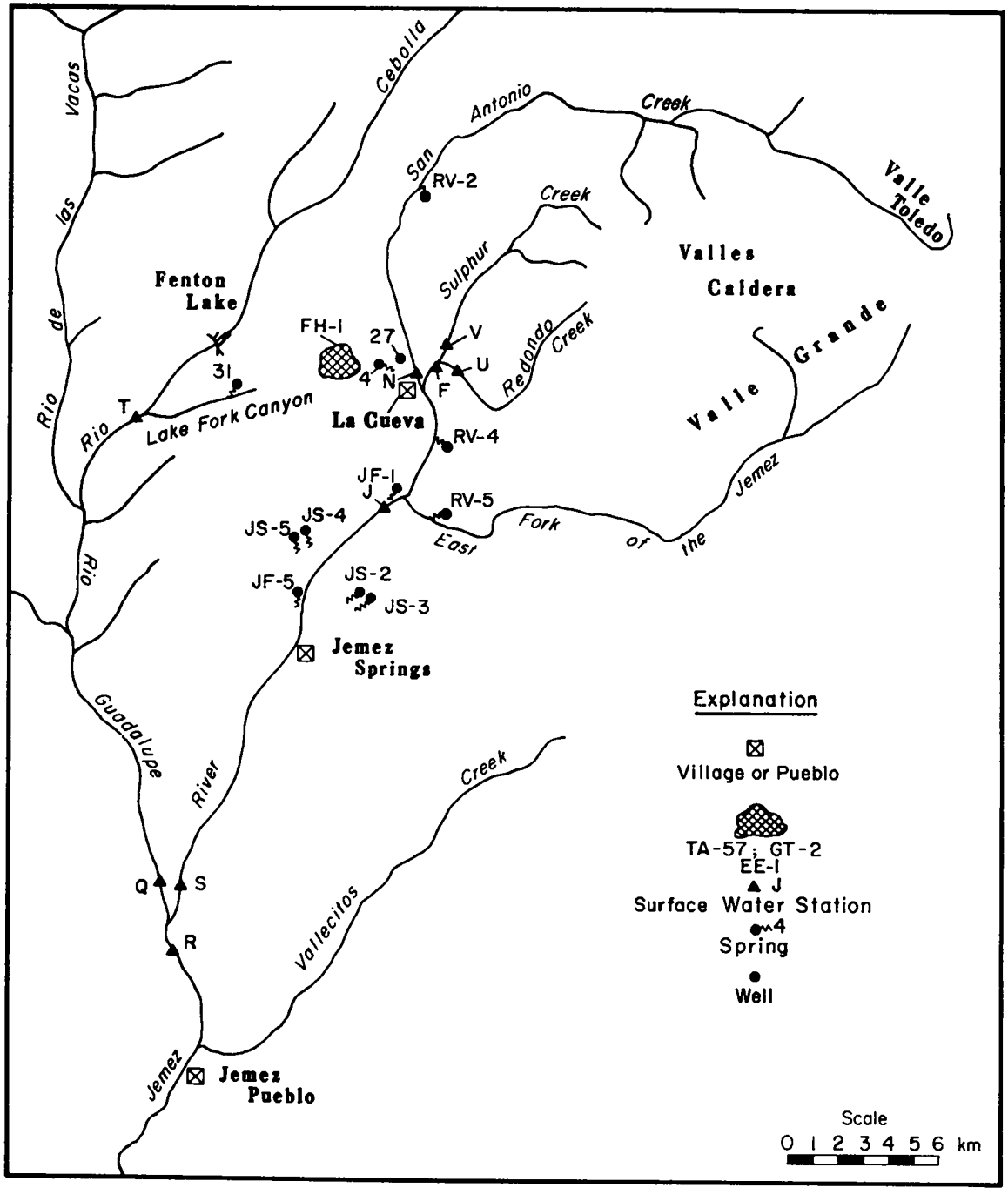


Fig. 25. Water sampling locations in vicinity of Fenton Hill Geothermal Site (TA-57).

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APPENDIX A

STANDARDS FOR ENVIRONMENTAL CONTAMINANTS

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

In the case of radioactive materials in the environment, guides contained in Chapter XI are used as a basis for evaluation. However, the DOE standard for uranium in water (1500 and 60 mg/ℓ for controlled and uncontrolled areas, respectively) does not consider chemical toxicity. Therefore, for the purposes of this report, the more restrictive standards[A1] of the International Commission on Radiological Protection (ICRP) for uranium in water (60 mg/ℓ for an occupational 40-h week) are used as a point of comparison. For atmospheric uranium, the DOE and ICRP standards are in agreement. The standards are listed in Table A-I as Radioactivity Concentration Guides (CGs). A CG is the concentration of radioactivity in air breathed continuously or water constituting all that ingested during a year that is determined to result in whole body or organ doses equal to the Radiation Protection Standards (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 achieveable."

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 A-2.

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 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]

Radioactivity in public water supply is governed by EPA regulations contained in 40CFR141. These regulations provide that combined ^{226}Ra and ^{228}Ra shall not exceed 5×10^{-9} μCi/mℓ (5 pCi/ℓ) and gross alpha activity (including ^{226}Ra, but excluding radon and uranium) shall not exceed 15×10^{-9} μCi/mℓ (15 pCi/ℓ). A screening level of 5×10^{-9} μCi/mℓ (5 pCi/ℓ) is established as part of the monitoring requirements to determine whether specific radium analyses must be performed. Plutonium concentrations are compared to the EPA gross alpha MCL of 15×10^{-9} μCi/mℓ (15 pCi/ℓ).[A3]

For man-made 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.[A3]

TABLE A-I

DOE RADIOACTIVITY 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} 1.8×10^{-6}[e]	U, natural[c]	1.8×10^{8}	2×10^{-5} 6×10^{-5}[e]

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

[e]For purposes of this report, concentrations of total uranium in water are compared to the ICRP recommended values that consider chemical toxicity.

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] (rem)	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population
Whole body, gonads, or bone marrow	0.5	0.17
Other organs	1.5	0.5

Individuals in Controlled Areas

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

[a]To meet the above dose commitment standards, operations must be conducted in such a manner that it would be unlikely that an individual would assimilate in a critical organ, by inhalation, ingestion, or absorption, a quantity of a radionuclide or mixture of radionuclides that would commit the individual to an organ dose that exceeds the limits specified in the above table.

[b]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 rem/year).

[c]In special cases with the approval of the Director, Division of Operational and Environmental Safety, a worker may exceed 5 rem/year provided his or her average exposure per year since age 18 will not exceed 5 rem/year. This does not apply to emergency situations.

[d]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)
As	0.05
Ba	1.0
Cd	0.010
Cl	250
Cr	0.05
F[b]	2.0
Pb	0.05
Hg	0.002
Na	250
NO_3	45
Se	0.01
Ag	0.05
TDS	1000

Radiochemical Contaminant	MCL (μCi/mℓ)
^{137}Cs	200×10^{-9}
Gross alpha[c]	5×10^{-9}
^{3}H	20×10^{-6}
^{238}Pu	15×10^{-9}
^{239}Pu	15×10^{-9}

[a]EPA's National Interim Primary Drinking Water Regulations (EPA-570/9-76-003), EPA, Office of Water Supply (1976) and NMEID Water Supply Regulations (Regulations Governing Water Supply, N.M. Environmental Improvement Agency, Santa Fe, N.M., Dec. 9, 1977).
[b]Based on annual average of the maximum daily air temperature of 14.6 to 17.7°C.
[c]See text for discussion of application of gross alpha MCL and gross alpha screening level of 5×10^{-9} μCi/mℓ.

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APPENDIX B

SAMPLING PROCEDURES AND STATISTICAL TREATMENT OF DATA

A. Thermoluminescent Dosimeters

Lithium fluoride (LiF) chips, 6.4 mm square by 0.9 mm thick, are used in the environmental and Los Alamos Meson Physics Facility (LAMPF) networks. 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 rectangular holes formed by stacking machined stainless steel blocks inside the ovens maintained at 400°C and 100°C. After 1 h the vials are removed from the ovens and placed between massive copper blocks at room temperature.

Incandescent lighting is used exclusively during all phases of annealing, dosimeter preparation, and readout to prevent ultraviolet-induced spurious thermoluminescence (TL). Four chips are placed in a molded snap-top polyethylene vial measuring 1 cm diameter by 1.5 cm high. This assembly constitutes one dosimeter. 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 160 mR. using an 8.5 mCi ^{137}Cs source calibrated by the National Bureau of Standards.

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

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

B. Air Sampling

1. Sampling Procedures

Samples are collected monthly at 25 continuously operating stations. Positive displacement air pumps with flow rates of approximately 3 ℓ/sec are used. Atmospheric aerosols are collected on 79 mm diameter polystyrene filters. Part of the total air flow (2.4 — 3.1 mℓ/sec) is passed through a cartridge containing silica gel to adsorb atmospheric water vapor for tritium analyses. Air flow rates through both sampling cartridges are measured with variable-area flow meters, and sampling times recorded. The entire air sampling train at each station is cleaned, repaired, and calibrated on an as-needed basis.

Gross alpha and gross beta activities on the monthly air filters are measured with a gas-flow proportional counter on collection day and again 7 to 10 days after collection. The first count is used to screen samples for inordinate activity levels. The second count (made after absorbed, naturally-occurring, radon-thoron daughters had reached equilibrium with their long-lived parents)

provides a record of long-lived atmospheric radioactivity. Immediately upon being retrieved from the field, the filters are mounted on counting planchets and covered with mylar. This insures adequate sample preservation.

Two clean, control filters are used to detect any possible contamination of the 25 sampling filters while they are in transit. The control filters accompany the 25 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 25 sampling filters. Analytical results for the control filters are subtracted from the appropriate gross analytical results to obtain net analytical results.

At one location (N050-E040) atmospheric radioactivity samples are collected daily (Monday through Friday). Atmospheric particulate matter on each daily filter is counted for gross alpha and gross beta activities on collection day and again 7 to 10 days after collection. The first measurement provides an early indication of any major change in atmospheric radioactivity. The second measurements are used to observe temporal variations in long-lived atmospheric radioactivity.

After being measured for gross alpha and gross beta activities, the monthly filters for each station are cut in half. The first group of filter halves is then combined and dissolved to produce quarterly composite samples for each station. The second group of filter halves is saved for uranium analysis.

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

Silica gel cartridges from the 25 air sampling stations are analyzed monthly for tritiated water. The cartridges contain a small amount of blue "indicating" gel at each end to indicate a desiccant over-saturation. During cold months of low absolute humidity, sampling flow rates are increased to ensure collection of enough water vapor for analysis. To avoid sample preservation problems, water is distilled from each silica gel sample immediately upon being retrieved from the field. This distillation yields a monthly average atmospheric water vapor sample. An aliquot of the distillate is then analyzed for tritium by liquid scintillation counting.

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

2. Statistical Analysis

Measurements of the air particulate samples require that chemical or instrumental backgrounds be subtracted to obtain net values. Thus, net values lower than the minimum detection limit (MDL, Table C-IV) of an analytical technique are sometimes obtained. Consequently, individual measurements result in values of zero or negative numbers because of statistical fluctuations in the measurements. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small and negative values[B4] are included in the population.

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

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

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

where

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

An analysis of variance was done with groups (regional, perimeter, onsite) and sampling period (month or quarter) as sources of variation. A commercially available software package[B5] is used for this analysis. The purpose of the analysis is to detect significant differences among regional, perimeter, and onsite means. Differences are declared significant at various confidence levels. For example, with a confidence level of $P = 0.05$ there is a 5% probability of concluding a difference exists when there is none.

Next, all radioactive constituents that exhibited significant differences among regional, perimeter, and onsite annual means are analyzed using a modified t-test for unpaired observations and unequal variances.[B6] The t-test is used to compare regional-perimeter, onsite-perimeter, and regional-onsite group annual means and specifically determine if a particular group differed from the other two groups.

Finally for each radioactive constituent, the Student-Newman-Keuls and Tukey procedures[B6] are used to determine which stations within a group are significantly different. These procedures were chosen because they mitigate a problem that arises with multiple comparisons. Namely, there is almost a certainty that some differences will be falsely declared significant. The 5% test level used in this procedure means that 5% of the comparisons will give false significant differenes.

C. Water, Soil, and Sediment Sampling

Surface and ground water sampling points are grouped (regional, perimeter, and onsite) according to location and hydrologic similarity. Surface and ground water grab samples are taken one to two times annually. Samples from wells are collected after sufficient pumpage or bailing to ensure that the sample is representative of the water in the aquifer. Spring samples (ground water) are collected at point of discharge.

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

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

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

The average concentrations of radionuclides and chemical constituents are reported for a number of individual analyses in Tables E-XI through E-XIX and Tables E-XXI through E-XXIV. The minimum and maximum values reported are individual analyses in the groups, while the average is computed from all of the individual analyses in the group. The uncertainty following the primary value represents twice the standard deviation of the distribution of observed values, or the analytical variation for individual results.

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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, 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]

Recently a method for measuring the $^{235}U/^{238}U$ ratio in large numbers of samples via neutron activation was developed. Details of this new procedure are being prepared for publication.[C5]

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, ion selective electrodes, and combustion analysis. The methods used and references for determination of the various chemical constituents are summarized in Table C-I. Standard chemical methods are also used for many of the common water quality tests.[C6] Atomic absorption capabilities include flame, graphite, mercury cold vapor, and hydride generation, as well as flame emission spectrophotometry.

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 the analytical procedures so that problems that might occur can be identified and corrected. Secondly, data obtained from the 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 one of analytical control; the latter is called quality assurance.

No attempt is made to make control samples unknown to the analyst. However, they are submitted to the laboratory at regular intervals and analyzed in association with other samples; that is, they are not normally handled as a unique set of samples. We feel that it would be difficult for the analysts to give the samples special attention, even if they were so inclined. We endeavor to run at least 10% of the 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.[C55,C56,C57]

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

TABLE C-I

ANALYTICAL METHODS FOR VARIOUS STABLE CONSTITUENTS

Technique	Stable Constituents Measured	References
Standard Chemical Methods	pH, Total Alkalinity, Hardness, $SO_4^=$, TDS, Conductivity,COD	C6
Color Spectrophotometry	NO_3^-,PO_4^{-2}	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,$^{235}U/^{238}U$	C5,6,30,31,32,33,34,35,36, 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_3^{-2},SO_4^{-2}, PO_4^{-3}	C49
Ion Selective Electrodes	F^-,NH_4^+	C50
Combustion	C,N,H,S	C29

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}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}U, ^{226}Ra, ^{228}Ra, and ^{210}Pb. Recently two new environmental radioactivity soil and sediment Standard Reference Materials (SRMs) have been certified by the National Bureau of Standards (NBS) for ^{60}Co, ^{90}Sr, ^{137}Cs, ^{226}Ra, ^{230}Th, ^{238}Pu, $^{239+240}Pu$, ^{241}Am, and several other nuclides.

The Department of Energy's (DOE) Environmental Measurements Laboratory (EML) provided soil, water, bone, tissue, vegetation, and air filter samples each containing many of the same radionuclides. These were part of a laboratory intercomparison of DOE-supported facilities, which is being discontinued. Uranium standards obtained from the Canadian Geological Survey (CGS) and the International Atomic Energy Agency (IAEA) are used to evaluate the uranium analysis procedures. Internal standards are prepared by adding known quantities of analyte 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 certified standards have been obtained from the CGS and the United States Geological Survey (USGS).

A program for evaluation of the quality of results for a specific water sample has been recently initiated. It is anticipated that the criteria of acceptance will tighten with continued monitoring of these parameters. The parameters are the ratio of the sum of milliequivalent (meq) cations to the sum of meq anions, and the ratio of meq hardness to the sum of meq of Ca^{++} and Mg^{++}. A comparison of the sum of ions, total dissolved solids, and conductivity values is also being made.

A summary of these ratios is given for 1981 waters by sample set in Table C-II. Reanalysis of a sample for one or more chemical constituents will be based on sample quality parameters, historical considerations, and the presence of constituents not requested by the investigator. Evaluation of the quality of a specific batch of samples is a 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.

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 standards. These results are normalized to the known quantity in the standard to permit comparison between standards containing different quantities 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 by weighting each normalized value (r_i) by the uncertainty associated with it (s_i).

$$R = \frac{\Sigma_i \, (r_i/s_i^2)}{\Sigma_i \, (1/s_i^2)}$$

The standard deviation (s) of R is calculated assuming a normal distribution of the population of samples (N).

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

These calculated values are presented in Tables C-III and C-IV. The weighted mean 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 quantity of analyte; that is, as the absolute quantity 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. Conversely, precision of uranium analyses is unrealistically small because

TABLE C-II

WATER SAMPLE QUALITY PARAMETERS

[Cation/Anion] Ratios

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	67	0.978	0.094	14
2	2	0.960	0.042	0
3	27	0.999	0.046	1
4	16	1.04	0.046	2

[meq Hardness/Sum meq Ca + Mg] Ratios

Sample Set	Number of Samples	Average Ratio	s	Number of Outliers[a]
1	66	1.03	0.12	13
2	2	0.98	0.035	0
3	27	0.97	0.029	0
4	16	0.96	0.044	0

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

standards contained quantities of uranium significantly above detection limits.

Analysis of blanks provide a criterion to judge the probability that samples were contaminated during the analysis. Table C-V presents weighted means and standard deviations of the absolute quantity of analyte reported in blank materials analyzed during 1981.

D. Limits of Detection

Data from analysis of blanks also provide a means of calculating limits of detection for various procedures. Table C-VI presents detection limits for analyses of various constituents in several environmental matrices. The limits for $^{238+239}Pu$, ^{241}Am, ^{137}Cs, and U are calculated from the weighted mean plus two standard deviations of the analyses of blanks (Table C-V). For tritium, the detection limit is merely 2s of repetitive determinations of the instrumental blank.

Detection limits for gross alpha and gross beta in Table C-VI are calculated assuming that counting rates for both are at background levels. Gross alpha and gross beta are measured simultaneously by counting on a gas proportional counter and electronically discriminating the output pulses. As there is crosstalk generated by detection of the two types of emissions, the detection limit of one is a function of the counting rate of the other. The detection limit for alpha increases 10% above the limit for every count per minute (cpm) of beta activity emitted by the sample. Similarly, the detection limit for beta increases 40% for every 10 cpm of alpha.

Results greater than a defined detection limit indicate the presence of a constituent at the 95% confidence level. However, results less than a detection limit do not necessarily indicate its absence.

TABLE C-III

SUMMARY OF ANALYTICAL QUALITY ASSURANCE RESULTS FOR STABLE CONSTITUENTS AND SELECTED RADIOACTIVE CONSTITUENTS

Analysis	Soil		Water		Biological		Air Particulates	
	R ± s	Number of Samples	R ± s	Number of Samples	R ± s	Number of Samples	R ± s	Number of Samples
Ag			0.96	1				
Al	1.01 ± 0.05	5	1.05 ± 0.10	4	1.07	1		
As	1.00 ± 0.11	84	1.01 ± 0.10	9	1.09 ± 0.22	35		
B	1.09 ± 0.16	21			1.07 ± 0.15	19		
Ba	0.85 ± 0.19	7	1.03 ± 0.06	6				
Be	0.82	1						
^{7}Be			0.98 ± 0.006	18				
C					0.99 ± 0.01	13		
Ca	1.01 ± 0.04	17	1.07 ± 0.02	7	1.03	2		
Cd	0.78 ± 0.15	4	0.97 ± 0.12	8			0.85 ± 0.10	9
Ce	1.01 ± 0.09	27						
Cl			0.98	2				
Co	0.90	2						
Conductivity			0.97 ± 0.08	8				
Cr	1.05 ± 0.13	83	1.05 ± 0.10	7	0.95 ± 0.12	20	0.95	1
Cs	0.95 ± 0.15	97			[a]	200		
^{137}Cs	1.12 ± 0.06	8	1.03 ± 0.08	51				
Cu	1.14 ± 0.28	3	1.03 ± 0.09	4			0.98 ± 0.04	8
Dy	0.65 ± 0.06	9						
Eu	0.96 ± 0.11	30						
F					1.01 ± 0.08	10		
Fe	1.00	2	1.06 ± 0.08	5			0.95	2
Gd	0.94 ± 0.04	3						
H					1.00 ± 0.05	8		
Hardness			1.04 ± 0.03	6				
Hf	0.87	1						
Hg	0.93 ± 0.09	16	1.00 ± 0.12	21	0.97 ± 0.12	37		
^{3}H (<2000 pCi/ℓ)			1.05 ± 0.33	31				
^{3}H (>2000 pCi/ℓ)			0.96 ± 0.07	28				
K	1.02 ± 0.02	19	0.98 ± 0.04	10				
La	0.96 ± 0.07	30						
Lu	0.98 ± 0.16	7						
Mg	0.94 ± 0.07	17	1.02 ± 0.05	10			0.91 ± 0.07	6
Mn	1.03 ± 0.04	5	0.98 ± 0.05	3	1.12	1	1.02 ± 0.09	3
N					0.97 ± 0.07	20		
Na	1.05 ± 0.07	6	1.04 ± 0.02	8				
^{22}Na	1.05 ± 0.08	12	1.22 ± 0.10	5				
Nd	1.04 ± 0.06	3						
Ni			1.00 ± 0.09	5			0.88 ± 0.18	3
NO_3			1.02 ± 0.06	7				
Pb	0.82 ± 0.06	3	0.96 ± 0.06	5			0.93 ± 0.04	9
pH			0.95 ± 0.03	12				
PO_4			1.00 ± 0.11	4				
Pr	1.04 ± 0.07	3						
^{226}Ra	0.95 ± 0.08	89						
Sb	0.94	1						
Sc	0.90	1						
Se			0.99	1				
Si	1.01 ± 0.04	17						
Sm	1.00 ± 0.05	29						
SO_4			0.95	2				
Ta	0.92	1						
Total dissolved solids			1.00 ± 0.05	16				
Th	0.91	1						
Ti							1.04 ± 0.09	10
Tl			1.30 ± 0.46	3				
Total alkalinity			1.07 ± 0.10	15				
U	1.00 ± 0.02	59	1.01 ± 0.04	34	1.02 ± 0.05	8		
$^{235,238}U$ (natural)	1.01 ± 0.04	18						
$^{235,238}U$ (depleted)	0.92 ± 0.05	5						
V			1.02 ± 0.09	3				
W	1.14 ± 0.19	72						
Yb	0.96 ± 0.07	16						
Zn	1.02 ± 0.18	17	1.04	2			1.01	1

[a] All determinations were at or below detection limits, in agreement with certified values.

TABLE C-IV

SUMMARY OF RADIOACTIVE CONSTITUENT QUALITY ASSURANCE RESULTS ON EPA AND EML PROGRAMS

Analysis[a]	Number of Samples	R ± s
Gross alpha	24	0.96 ± 0.21
Gross beta	24	1.20 ± 0.25
^{3}H	15	1.05 ± 0.32
^{40}K	6	1.07 ± 0.12
^{90}Sr	21	1.13 ± 0.21
^{131}I	3	0.87 ± 0.05
^{137}Cs	3	0.88 ± 0.11
^{226}Ra	3	0.85 ± 0.02
^{239}Pu	6	0.79 ± 0.20
U (natural)	6	0.98 ± 0.09

[a]Most samples for ^{51}Cr, ^{60}Co, ^{65}Zn, ^{106}Ru, ^{134}Cs, and ^{140}Ba were below our detection limits.

TABLE C-V

QUANTITY OF CONSTITUENT REPORTED IN BLANKS

Analysis	Number of Samples	Quantity ($\bar{x}$ ± s)	Units
^{90}Sr	18	−0.029 ± 0.26	pCi
^{238}Pu	14	0.010 ± 0.011	pCi
^{239}Pu	18	0.014 ± 0.022	pCi
^{241}Am	5	0.019 ± 0.015	pCi
Uranium (Delayed neutron)	25	15 ± 10	ng
Uranium (Epithermal activation)	8	10 ± 8	ng
^{137}Cs	50	5 ± 4	pCi
Grass gamma	50	1600 ± 100	counts/min

TABLE C-VI

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	100 min	1×10^{-12} μCi/mℓ
^{238}Pu	2.0×10^4 m^3	8×10^4 sec	2×10^{-18} μCi/mℓ
^{239}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	3×10^{-16} μCi/mℓ
Gross beta	6.5×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Uranium (Delayed neutron)	2.0×10^4 m^3	60 sec	1 pg/m^3
Water Sample			
Tritium	0.005 ℓ	100 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}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	1×10^{-9} μCi/mℓ
Gross beta	0.9 ℓ	100 min	5×10^{-9} μCi/mℓ
Uranium (Delayed neutron)	0.025 ℓ	50 sec	1 μg/ℓ
Soil Sample			
Tritium	1 kg	100 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}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	0.8 pCi/g
Gross beta	2 g	100 min	0.003 pCi/g
Uranium (Delayed neutron)	2 g	20 sec	0.03 μg/g

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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 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 site.

Four age groups are considered: infant, child, teen, and adult. Dose calculations utilize parameters such as annual food consumption and breathing rates specific to each age group. Values[D2,D3] provided for these and other parameters used in the calculations are in Table D-I.

Age specific dose conversion factors[D4] used for inhalation and ingestion calculations are in Table D-II. These factors give total dose received (in mrem) by an organ during the 50-yr period following intake of a radionuclide (the 50-yr dose commitment) per amount of radionuclide (in pCi) either inhaled or ingested.[D5]

Table D-III also lists a second set of dose conversion factors based on the dose (in mrem) received in the first year, rather than the 50-yr dose commitment. Procedures for calculating doses using these two sets of dose conversion factors are identical. The first set gives total dose incurred during the 50-yr following intake; the second gives dose received in the first year. Dose estimates in the text are identified as to which type of dose they represent.

B. Inhalation Dose

Annual average air concentrations of ^{3}H, ^{238}Pu, ^{239}Pu, ^{241}Am, and total U, determined by H-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 50-yr dose commitments for bone, liver, total body, thyroid, kidney, lung, and gastrointestinal (GI) tract. First year dose is estimated for bone, total body, thyroid, lung, and GI tract. Organs chosen for dose calculations include those expected to receive the largest dose from the radionuclides being considered. Parameters used in the calculations are in Tables D-I, D-II, and D-III. As noted in Tables D-II and D-III, 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 (8736 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.

TABLE D-I

PARAMETERS USED IN DOSE ASSESSMENT

Parameter	Infant	Child	Teenager	Adult
Annual breathing rate (m^3/yr)	1400	3700	8000	8000
Food consumption rate				
Fish (kg/yr)	---	6.9	16	21
Fruits (kg/yr)	---	114	139	114
Vegetables (kg/yr)	---	281	340	281
Grain (kg/yr)	---	125	151	125
Meat and poultry (kg/yr)	---	41	65	110
Milk (ℓ/yr)	330	330	400	310
Honey (kg/yr)	---	3	5	5
Shielding factor for residential structures				0.7
Occupancy Factor				
Restaurant north of TA-53				0.4
All other locations, except where noted				1.0
Solubility of inhaled radionuclides				
^{3}H				Soluble
Total U				Insoluble
^{238}Pu				Insoluble
$^{239,240}Pu$				Insoluble
^{241}Am				Insoluble
Number of trips, longer than one day, taken by Laboratory personnel in 1981				15 798

TABLE D-II

AGE SPECIFIC DOSE CONVERSION FACTORS FOR 50-YR DOSE COMMITMENT

Infant Dose Conversion Factors
(mrem/50-yr per pCi intake in first year)

Radio-nuclide	Pathway	Organ						
		Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI[b]
^{3}H	Inhalation[a]	0.0	4.62×10^{-7}	4.62×10^{-7}	4.62×10^{-7}	4.62×10^{-7}	4.62×10^{-7}	4.62×10^{-7}
	Ingestion	0.0	3.08×10^{-7}	3.08×10^{-7}	3.08×10^{-7}	3.08×10^{-7}	3.08×10^{-7}	3.08×10^{-7}
^{137}Cs	Ingestion	5.22×10^{-4}	6.11×10^{-4}	4.33×10^{-5}	0.0	1.64×10^{-4}	6.64×10^{-5}	1.91×10^{-6}
Total U	Inhalation	5.00×10^{-2}	0.0	3.52×10^{-3}	0.0	1.00×10^{-2}	3.27×10^{-1}	3.77×10^{-5}
	Ingestion	4.67×10^{-3}	0.0	3.56×10^{-4}	0.0	9.93×10^{-4}	0.0	6.08×10^{-5}
^{238}Pu	Inhalation	5.02	6.33×10^{-1}	1.27×10^{-1}	0.0	4.64×10^{-1}	9.03×10^{-1}	4.69×10^{-5}
	Ingestion	1.34×10^{-3}	1.69×10^{-4}	3.40×10^{-5}	0.0	1.21×10^{-4}	0.0	7.57×10^{-5}
^{239}Pu	Inhalation	5.50	6.72×10^{-1}	1.34×10^{-1}	0.0	4.95×10^{-1}	8.47×10^{-1}	4.28×10^{-5}
	Ingestion	1.45×10^{-3}	1.77×10^{-4}	3.54×10^{-5}	0.0	1.28×10^{-4}	0.0	6.91×10^{-5}
^{241}Am	Inhalation	1.84	8.44×10^{-1}	1.31×10^{-1}	0.0	7.94×10^{-1}	4.06×10^{-1}	4.78×10^{-5}
	Ingestion	1.53×10^{-3}	7.18×10^{-4}	1.09×10^{-4}	0.0	6.55×10^{-4}	0.0	7.70×10^{-5}

Child Dose Conversion Factors
(mrem/50-yr per pCi intake in first year)

^{3}H	Inhalation[a]	0.0	3.04×10^{-7}	3.04×10^{-7}	3.04×10^{-7}	3.04×10^{-7}	3.04×10^{-7}	3.04×10^{-7}
	Ingestion	0.0	2.03×10^{-7}	2.03×10^{-7}	2.03×10^{-7}	2.03×10^{-7}	2.03×10^{-7}	2.03×10^{-7}
^{137}Cs	Ingestion	3.27×10^{-4}	3.13×10^{-4}	4.62×10^{-5}	0.0	1.02×10^{-4}	3.67×10^{-5}	1.96×10^{-6}
Total U	Inhalation	4.27×10^{-2}	0.0	2.59×10^{-3}	0.0	7.00×10^{-3}	1.63×10^{-1}	3.74×10^{-5}
	Ingestion	3.42×10^{-3}	0.0	2.07×10^{-4}	0.0	5.60×10^{-4}	0.0	6.03×10^{-5}
^{238}Pu	Inhalation	4.74	6.05×10^{-1}	1.21×10^{-1}	0.0	4.47×10^{-1}	6.08×10^{-1}	4.65×10^{-5}
	Ingestion	1.25×10^{-3}	1.56×10^{-4}	3.16×10^{-5}	0.0	1.15×10^{-4}	0.0	7.50×10^{-5}
^{239}Pu	Inhalation	5.24	6.44×10^{-1}	1.28×10^{-1}	0.0	4.78×10^{-1}	5.72×10^{-1}	4.24×10^{-5}
	Ingestion	1.36×10^{-3}	1.65×10^{-4}	3.31×10^{-5}	0.0	1.22×10^{-4}	0.0	6.85×10^{-5}
^{241}Am	Inhalation	1.74	7.85×10^{-1}	1.24×10^{-1}	0.0	7.63×10^{-1}	2.02×10^{-1}	4.73×10^{-5}
	Ingestion	1.43×10^{-3}	6.40×10^{-4}	1.02×10^{-4}	0.0	6.03×10^{-4}	0.0	7.64×10^{-5}

[a]Includes an increase of 50% to account for skin absorption.
[b]Gastrointestinal—Lower large intestine.

TABLE D-II (Continued)

Teen Dose Conversion Factors
(mrem/50-yr per pCi intake in first year)

Radionuclide	Pathway	Organ						
		Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI[b]
^{3}H	Inhalation[a]	0.0	1.59×10^{-7}	1.59×10^{-7}	1.59×10^{-7}	1.59×10^{-7}	1.59×10^{-7}	1.59×10^{-7}
	Ingestion	0.0	1.06×10^{-7}	1.06×10^{-7}	1.06×10^{-7}	1.06×10^{-7}	1.06×10^{-7}	1.06×10^{-7}
^{137}Cs	Ingestion	1.12×10^{-4}	1.49×10^{-4}	5.19×10^{-5}	0.0	5.07×10^{-5}	1.97×10^{-5}	2.12×10^{-6}
Total U	Inhalation	1.42×10^{-2}	0.0	8.66×10^{-4}	0.0	3.33×10^{-3}	8.43×10^{-2}	3.85×10^{-5}
	Ingestion	1.14×10^{-3}	0.0	6.93×10^{-5}	0.0	2.67×10^{-4}	0.0	6.21×10^{-5}
^{238}Pu	Inhalation	2.86	4.06×10^{-1}	7.22×10^{-2}	0.0	3.10×10^{-1}	3.12×10^{-1}	4.37×10^{-5}
	Ingestion	7.12×10^{-4}	1.02×10^{-4}	1.82×10^{-5}	0.0	7.80×10^{-5}	0.0	7.73×10^{-5}
^{239}Pu	Inhalation	3.31	4.50×10^{-1}	8.05×10^{-2}	0.0	3.44×10^{-1}	2.93×10^{-1}	4.46×10^{-5}
	Ingestion	8.27×10^{-4}	1.12×10^{-4}	2.01×10^{-5}	0.0	8.57×10^{-5}	0.0	7.06×10^{-5}
^{241}Am	Inhalation	1.06	4.07×10^{-1}	7.10×10^{-2}	0.0	5.32×10^{-1}	1.05×10^{-1}	4.88×10^{-5}
	Ingestion	8.62×10^{-4}	3.29×10^{-4}	5.75×10^{-5}	0.0	4.31×10^{-4}	0.0	7.87×10^{-5}

Adult Dose Conversion Factors
(mrem/50-yr per pCi intake in first year)

^{3}H	Inhalation[a]	0.0	1.58×10^{-7}	1.58×10^{-7}	1.58×10^{-7}	1.58×10^{-7}	1.58×10^{-7}	1.58×10^{-7}
	Ingestion	0.0	1.05×10^{-7}	1.05×10^{-7}	1.05×10^{-7}	1.05×10^{-7}	1.05×10^{-7}	1.05×10^{-7}
^{137}Cs	Ingestion	7.97×10^{-5}	1.09×10^{-4}	7.14×10^{-5}	0.0	3.70×10^{-5}	1.23×10^{-5}	2.11×10^{-6}
Total U	Inhalation	9.93×10^{-3}	0.0	6.06×10^{-4}	0.0	2.33×10^{-3}	4.90×10^{-2}	3.63×10^{-5}
	Ingestion	8.01×10^{-4}	0.0	4.85×10^{-5}	0.0	1.87×10^{-4}	0.0	5.86×10^{-5}
^{238}Pu	Inhalation	2.74	3.87×10^{-1}	6.90×10^{-2}	0.0	2.96×10^{-1}	1.82×10^{-1}	4.52×10^{-5}
	Ingestion	6.80×10^{-4}	9.58×10^{-5}	1.71×10^{-5}	0.0	7.32×10^{-5}	0.0	7.30×10^{-5}
^{239}Pu	Inhalation	3.19	4.31×10^{-1}	7.75×10^{-2}	0.0	3.30×10^{-1}	1.72×10^{-1}	4.13×10^{-5}
	Ingestion	7.87×10^{-4}	1.06×10^{-4}	1.91×10^{-5}	0.0	8.11×10^{-5}	0.0	6.66×10^{-5}
^{241}Am	Inhalation	1.01	3.59×10^{-1}	6.71×10^{-2}	0.0	5.04×10^{-1}	6.06×10^{-2}	4.60×10^{-5}
	Ingestion	8.19×10^{-4}	2.88×10^{-4}	5.41×10^{-5}	0.0	4.07×10^{-4}	0.0	7.42×10^{-5}

[a]Includes an increase of 50% to account for skin absorption.
[b]Gastrointestinal—Lower large intestine.

TABLE D-III

DOSE CONVERSION FACTORS FOR FIRST YEAR DOSE

Adult Dose Conversion Factors
(mrem/first year per pCi intake)

Radio-nuclide	Pathway	Organ						
		Bone	Liver	Total Body	Thyroid	Kidney	Lung	GI-LLI[a]
^{3}H	Inhalation[a]	0.0	---	1.5×10^{-7}	1.5×10^{-7}	---	1.5×10^{-7}	1.5×10^{-7}
	Ingestion	0.0	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	1.0×10^{-7}	---	1.0×10^{-7}
^{137}Cs	Ingestion	4.3×10^{-5}	7.3×10^{-5}	4.3×10^{-5}	0.0	3.1×10^{-5}	---	2.1×10^{-6}
Total U	Inhalation	1.5×10^{-3}	---	1.9×10^{-4}	0.0	---	2.8×10^{-2}	3.6×10^{-5}
	Ingestion	2.6×10^{-4}	0.0	3.1×10^{-5}	0.0	7.8×10^{-5}	---	5.8×10^{-5}
^{238}Pu	Inhalation	7.3×10^{-3}	---	1.9×10^{-4}	0.0	---	5.1×10^{-2}	4.5×10^{-5}
	Ingestion	8.9×10^{-6}	1.4×10^{-6}	2.3×10^{-7}	0.0	1.1×10^{-6}	---	7.3×10^{-5}
^{239}Pu	Inhalation	7.1×10^{-3}	---	1.7×10^{-4}	0.0	---	4.8×10^{-2}	4.1×10^{-5}
	Ingestion	8.6×10^{-6}	1.3×10^{-6}	2.1×10^{-7}	0.0	9.9×10^{-7}	---	6.7×10^{-5}
^{241}Am	Inhalation	5.2×10^{-3}	---	4.2×10^{-4}	0.0	---	3.5×10^{-2}	4.6×10^{-5}
	Ingestion	9.3×10^{-6}	1.1×10^{-5}	7.6×10^{-7}	0.0	5.3×10^{-6}	---	7.4×10^{-5}

[a]Gastointestinal—Lower large intestine.

C. Ingestion Dose

Results from foodstuff sampling, described in Section IV.A.5, 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. 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 50-yr dose commitment and first year dose to the organ. Consumption rates and dose conversion factors used in the calculations are in Tables D-I, D-II, and D-III.

Doses are evaluated for ingestion of ^{3}H, ^{90}Sr, ^{137}Cs, total U, ^{238}Pu, and ^{239}Pu in fruits and vegetables; ^{3}H, ^{7}Be, ^{22}Na, ^{137}Cs, and total U in honey; and ^{137}Cs, total U, ^{238}Pu, and ^{239}Pu in fish.

Consumption rates in Table D-I correspond to values recommended by the Nuclear Regulatory Commission[D2] for calculation of dose to the maximum exposed individual. The single exception is the honey consumption rate, which, since it has no recommended value, was based on professional judgment.

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, and ^{15}O to be formed. These isotopes are all positron emitters and have 20.4-min, 10-min, 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, and ^{15}O are sources of gamma radiation that are due to formation of two 0.511-MeV photons through positron-electron annihilation. The ^{41}Ar emits a 1.29 MeV gamma with a 99% yield.

External radiation doses are monitored with H-8's thermoluminescent dosimeter network. Measured doses, considered as whole body doses 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 due to 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.

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[D6] (see Table E-I). Procedures used in making the calculations are described in the following section. A dose rate correction for plume size is taken from standard graphical compilations[D6] in making this dose estimate.

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).

There doses are multiplied by population data incorporating results of the 1980 census, which is summarized in Table D-IV. The population data has been slightly modified to account for population changes between 1980 and 1981. The modification is based on an extrapolation of the 1970-1980 growth rates.

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

Dispersion factors for the LAMPF and Omega West Reactor are given in Table D-V. The dispersion factors were calculated from 1981 meteorological data collected at Los Alamos during the actual time periods when radionuclides were being released from the stacks. The

TABLE D-IV

ESTIMATES OF NUMBER OF PEOPLE LIVING WITHIN 80 km OF LABORATORY

A. Cities and towns included in 1980 census results[a]

Town	No. of People	Town	No. of People
Alcalde	432	San Felipe	1 940
Bernalillo	3 135	San Felipe/Santo Domingo Joint Area	393
Chama	1 111	San Ildefonso	1 492
Chimayo	2 477	San Ysidro	199
Cochiti	804	Sandia	239
Cuba	633	Santa Ana	395
Española	6 897	Santa Clara	2 448
Jemez	1 542	Santa Fe	49 808
Jemez Springs	312	Santo Domingo	2 054
Los Alamos	11 012	Tesuque (Pueblo)	362
Nambe	1 124	Tesuque	1 032
Pecos	920	White Rock	6 917
Ranchos de Taos	1 455	Zia	517
		Total	99 650

B. Estimate of number of people not included in 1980 census results. 15 368

C. Estimate of total number of people living within 80 km of Laboratory. 115 018

[a]1980 census counts. Source: U.S. Bureau of the Census.

χ/Q includes the reduction of the source term due to radioactive decay. The annual average wind data for 1981 is represented in Fig. 20. These dispersion factors differ somewhat from those used in previous reports in that the latter did not include a correction for radioactive decay (decay corrections were calculated separately in determining the air concentrations) and were calculated from meteorological data from a different year.

The gamma dose rate in a semi-infinite cloud at time t, γ_∞ (r,θ,t), can be represented by the equation[D6]

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

where

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

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

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

TABLE D-V

DISPERSION FACTOR (χ/Q) USED FOR POPULATION DOSE ESTIMATES[a]

Source	Location	Radionuclide	Half-Life (min)	χ/Q (sec/m^3)
TA-2	Boundary	^{41}Ar	109.8	2.4×10^{-6}
TA-2	Maximum individual	^{41}Ar	109.8	2.0×10^{-6}
TA-2	Los Alamos	^{41}Ar	109.8	2.0×10^{-7}
TA-2	White Rock	^{41}Ar	109.8	6.7×10^{-9}
TA-53	Boundary	^{15}O	2.07	1.8×10^{-7}
		^{13}N	10.0	5.5×10^{-7}
		^{11}C	20.4	6.6×10^{-7}
		^{41}Ar	109.8	7.8×10^{-7}
TA-53	Los Alamos	^{15}O	2.07	5.8×10^{-11}
		^{13}N	10.0	9.4×10^{-9}
		^{11}C	20.4	2.6×10^{-8}
		^{41}Ar	109.8	7.6×10^{-8}
TA-53	White Rock	^{15}O	2.07	1.1×10^{-11}
		^{13}N	10.0	2.9×10^{-9}
		^{11}C	20.4	1.5×10^{-8}
		^{41}Ar	109.8	8.3×10^{-8}

[a]Includes correction for radioactive decay.

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 due to 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.[D7]

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APPENDIX E

ENVIRONMENTAL DATA TABLES

TABLE E-I

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTALS FOR 1981

Location	^{238}Pu ^{239}Pu (μCi)	^{241}Am (μCi)	^{235}U ^{238}U (μCi)	MFP[a] (μCi)	^{131}I (μCi)	^{41}Ar (Ci)	^{32}P (μCi)	^{3}H (Ci)	$^{11}C,^{13}N,^{15}O$[b] (Ci)	^{7}Be (mCi)
TA-2	---	---	---	---	---	300	---	---	---	---
TA-3	40	---	236	172	44	---	---	899	---	---
TA-9	---	---	---	---	---	---	---	---	---	---
TA-15	---	---	---	---	---	---	---	---	---	---
TA-18	---	---	---	---	---	---	---	---	---	---
TA-21	13	0.029	1 021	2.8	---	---	---	108	---	---
TA-33	---	---	---	---	---	---	---	6 085	---	---
TA-35	0.27	---	---	---	---	---	---	---	---	---
TA-41	---	---	---	---	---	---	---	126	---	---
TA-43	0.37	---	---	---	---	---	20	---	---	---
TA-46	---	---	14	---	---	---	---	---	---	---
TA-48	1.3	---	2.3	1 367	---	---	---	---	---	---
TA-50	1.8	---	---	2.4	---	---	---	---	---	---
TA-53	---	---	---	---	---	1 060	---	6.6	352 340	14
TA-54	0.01	---	---	---	---	---	---	---	---	---
TA-55	0.10	---	---	---	---	---	---	---	---	---

[a]Mixed fission products.

[b]The half-lives of ^{11}C, ^{13}N, and ^{15}O range from about 2 to 20 minutes, so these nuclides decay rapidly.

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

TABLE E-II

ANNUAL THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station Location	Coordinates	Annual Dose: Dose (mrem)	Annual Dose: 95% Conf Interval (mrem)	Annual Dose: 95% Conf Interval (per cent)
Regional Stations (28-44 km)		**Uncontrolled Areas**		
1. Española	---	70.9	± 4.0	± 5.6
2. Pojoaque	---	86.4	± 4.0	± 4.6
3. Santa Fe	---	79.3	± 4.0	± 5.0
4. Fenton Hill	---	96.0	± 4.0	± 4.2
Perimeter Stations (0-4 km)		**Uncontrolled Areas**		
5. Barranca School	N180 E130	93.7	± 4.9	± 5.2
6. Arkansas Avenue	N170 E030	85.5	± 4.0	± 4.7
7. Cumbres School	N150 E090	90.5	± 4.0	± 4.4
8. 48th Street	N110 W010	110.3	± 4.0	± 3.6
9. LA Airport	N110 E170	101.4	± 4.0	± 3.9
10. Bayo Canyon S.T.P.	N120 E250	113.2	± 4.0	± 3.5
11. Gulf Station	N090 E120	116.2	± 4.0	± 3.4
12. Royal Crest	N080 E080	105.1	± 4.0	± 3.8
13. White Rock S.T.P.	S080 E420	92.6	± 4.0	± 4.3
14. Pajarito Acres	N130 W180	86.8	± 4.0	± 4.6
15. Bandelier Lookout	S280 E200	105.7	± 4.0	± 3.8
16. Pajarito Ski Area	N130 W180	99.5	± 4.0	± 4.0

Station Location	Coordinates	Annual Dose: Dose (mrem)	Annual Dose: 95% Conf Interval (mrem)	Annual Dose: 95% Conf Interval (per cent)
Onsite Stations		**Controlled Areas**		
17. TA-21	N095 E140	92.7	± 4.0	± 4.3
18. TA-6	N025 E030	102.4	± 4.0	± 3.9
19. TA-53	N070 E090	122.6	± 4.0	± 3.3
20. Well PM-1	N030 E305	102.8	± 4.0	± 3.9
21. TA-16	S035 W025	93.0	± 4.0	± 4.3
22. Booster-P-2	S030 E220	119.5	± 4.0	± 3.3
23. TA-54	S080 E290	91.0	± 4.0	± 4.4
24. State Hwy 4	N070 E350	157.8	± 4.0	± 2.5
25. TA-49	S165 E085	90.9	± 4.0	± 4.4
26. TA-2	N075 E120	96.5	± 4.0	± 4.1
27. TA-2	N085 E120	119.6	± 4.0	± 3.3
28. TA-18	S040 E205	175.3	± 4.0	± 2.3
29. TA-35	N040 E105	92.9	± 4.0	± 4.3
30. TA-36	N040 E110	178.9	± 4.0	± 2.2
31. TA-3	N050 E020	178.1	± 4.0	± 2.2
32. TA-3	N050 E020	128.7	± 4.5	± 3.5
33. TA-3	N050 E020	144.6	± 4.5	± 3.1
34. TA-3	N050 E020	278.2	± 4.5	± 1.6
35. TA-3	N050 E020	120.5	± 5.0	± 4.1
36. TA-3	N050 E040	85.7	± 4.0	± 4.7
37. Pistol Range	N040 E240	95.2	± 4.0	± 4.2

TABLE E-III

LOCATIONS OF AIR SAMPLING STATIONS

Station	Latitude or N-S Coord	Longitude or E-W Coord
Regional (28-44 km)		
1. Española	36°00′	106°06′
2. Pojoaque	35°52′	106°02′
3. Santa Fe	35°40′	106°56′
Perimeter (0-4 km)		
4. Barranca School	N180	E130
5. Arkansas Avenue	N170	E030
6. Cumbres School	N150	E090
7. 48th Street	N110	W010
8. LA Airport	N110	E170
9. Bayo STP	N120	E250
10. Gulf Station	N090	E120
11. Royal Crest	N080	E080
12. White Rock	S080	E420
13. Pajarito Acres	S210	E380
14. Bandelier	S280	E200
Onsite		
15. TA-21	N095	E140
16. TA-6	N025	E030
17. TA-53 (LAMPF)	N070	E090
18. Well PM-1	N030	E305
19. TA-52	N020	E155
20. TA-16	S035	W025
21. Booster P-2	S030	E220
22. TA-54	S080	E290
23. TA-49	S165	E085
24. TA-33	S245	E225
25. TA-39	S190	E230

TABLE E-IV

REGIONAL AVERAGE BACKGROUND ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS

Radioactive Constituent	Units	EPA[a] 1980	Laboratory[b] 1981	Uncontrolled Area Concentration Guide
Gross alpha	10^{-15} μCi/mℓ	Not reported	1.1 ± 0.3	6×10^{1}
Gross beta	10^{-15} μCi/mℓ	10	121 ± 33	3×10^{4}
^{241}Am	10^{-18} μCi/mℓ	Not reported	1.5 ± 2.0	2×10^{11}
^{238}Pu	10^{-18} μCi/mℓ	3.1 ± 1.2	−1.5 ± 0.6	7×10^{4}
^{239}Pu	10^{-18} μCi/mℓ	8.2 ± 1.7	8.2 ± 5.9	6×10^{4}
^{3}H	10^{-12} μCi/mℓ	Not reported	18 ± 8	2×10^{5}
U	10^{-18} μCi/mℓ	34 ± 4	8.9 ± 4.3	2×10^{6}
U	pg/m^3	103 ± 12	27 ± 13	6×10^{6}

[a]US Environmental Protection Agency, "Environmental Radiation Data," Report 21-22 (December 1980). Data are from the Santa Fe, New Mexico sampling location and were taken from January through June 1980.

[b]Data annual averages are from the regional stations (Española, Pojoaque, Santa Fe) and were takeh during calendar year 1981.

TABLE E-V

ANNUAL ATMOSPHERIC LONG-LIVED
GROSS ALPHA AND GROSS BETA ACTIVITY CONCENTRATIONS[a]

Station Location	Gross Alpha Concentrations—fCi/m³ (10^{-15} μCi/mℓ)							Gross Beta Concentrations—fCi/m³ (10^{-15} μCi/mℓ)					
	Total Air Volume[b] (m^3)	Number of Monthly Samples	Number of Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]	Number of Monthly Samples	Number of Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]
Regional Stations (28-44 km)—Uncontrolled Areas													
1. Española	53 826	12	0	1.6 ± 0.8	0.4 ± 0.2	0.9 ± 0.2	1.4	12	0	210 ± 60	5.0 ± 1.2	109 ± 42	0.03
2. Pojoaque	43 323	12	3	3.7 ± 1.6	0.2 ± 0.1	1.4 ± 0.7	2.3	12	0	290 ± 80	0.7 ± 0.2	129 ± 62	0.03
3. Santa Fe	55 059	12	3	2.6 ± 1.2	0.2 ± 0.1	1.2 ± 0.5	2.0	12	0	370 ± 100	0.5 ± 0.2	126 ± 68	0.04
Regional Group Summary	152 208	36	6	3.7 ± 1.6	0.2 ± 0.1	1.1 ± 0.3	1.9	36	0	370 ± 100	0.5 ± 0.2	121 ± 33	0.04
Perimeter Stations (0-4 km)—Uncontrolled Areas													
4. Barranca School	52 311	12	0	11 ± 4	0.7 ± 0.3	4.3 ± 1.7	7.2	12	0	450 ± 120	7.1 ± 1.8	256 ± 71	0.08
5. Arkansas School	46 779	12	0	16 ± 6	0.7 ± 0.3	3.9 ± 2.4	6.5	12	0	390 ± 100	8.4 ± 2.2	205 ± 56	0.06
6. Cumbres School	42 892	12	0	13 ± 6	0.8 ± 0.4	5.0 ± 2.3	8.3	12	0	470 ± 120	7.1 ± 1.8	258 ± 74	0.08
7. 48th Street	49 163	12	0	9 ± 4	0.8 ± 0.4	4.4 ± 1.4	7.4	12	0	500 ± 120	21 ± 6	252 ± 78	0.08
8. LA Airport	55 406	12	0	7.5 ± 3.2	0.5 ± 0.3	2.9 ± 1.3	4.9	12	0	360 ± 100	15 ± 4	184 ± 62	0.06
9. Bayo STP	48 713	12	1	8.2 ± 3.6	0.1 ± 0.2	3.5 ± 1.3	5.8	12	0	360 ± 100	9.2 ± 2.4	209 ± 59	0.06
10. Gulf Station	51 834	12	1	5.8 ± 2.6	0.2 ± 0.2	2.4 ± 0.9	4.0	12	0	410 ± 100	20 ± 6	198 ± 70	0.06
11. Royal Crest	49 135	12	0	10 ± 4	0.6 ± 0.3	3.8 ± 1.3	6.3	12	0	370 ± 100	9.6 ± 2,4	198 ± 59	0.06
12. White Rock	49 552	12	0	16 ± 8	0.5 ± 0.4	3.1 ± 2.4	5.2	12	0	360 ± 100	12 ± 3	154 ± 49	0.05
13. Pajarito Acres	37 783	12	0	20 ± 8	1.3 ± 0.6	5.1 ± 3.0	8.5	12	0	320 ± 80	21 ± 6	190 ± 44	0.06
14. Bandelier	43 426	12	0	10 ± 4	0.7 ± 0.3	5.2 ± 1.9	8.6	12	0	620 ± 160	7.2 ± 1.8	277 ± 100	0.08
Perimeter Group Summary	526 994	132	2	20 ± 8	0.1 ± 0.2	4.0 ± 0.6	6.6	132	0	620 ± 160	7.1 ± 1.8	216 ± 21	0.06
Onsite Stations—Controlled Areas													
15. TA-21	48 499	12	0	13 ± 6	0.7 ± 0.3	4.4 ± 2.3	0.22	12	0	410 ± 100	6.0 ± 1.8	217 ± 63	0.0014
16. TA-6	49 103	12	0	16 ± 6	0.8 ± 0.4	5.2 ± 2.2	0.26	12	0	520 ± 140	8.6 ± 2.2	271 ± 82	0.0017
17. TA-53 (LAMPF)	49 899	12	0	7.8 ± 3.4	1.0 ± 0.4	4.8 ± 1.3	0.24	12	0	550 ± 140	7.4 ± 2.2	261 ± 90	0.0016
18. Well PM-1	49 020	12	0	10 ± 4	0.9 ± 0.4	5.1 ± 1.5	0.25	12	0	400 ± 100	7.4 ± 2.2	188 ± 73	0.0012
19. TA-52	51 804	12	0	15 ± 6	1.3 ± 0.6	5.6 ± 2.1	0.28	12	0	460 ± 120	15 ± 4	262 ± 73	0.0016
20. TA-16	48 139	12	0	10 ± 4	0.9 ± 0.4	4.2 ± 1.4	0.21	12	0	370 ± 100	15 ± 4	205 ± 51	0.0013
21. Booster P-2	53 640	12	0	7.5 ± 3.2	0.3 ± 0.3	3.2 ± 1.1	0.16	12	0	320 ± 80	13 ± 3	187 ± 48	0.0012
22. TA-54	55 666	12	0	12 ± 6	1.1 ± 0.4	4.5 ± 1.8	0.23	12	0	480 ± 120	15 ± 4	262 ± 78	0.0016
23. TA-49	52 769	12	0	15 ± 6	1.2 ± 0.6	5.4 ± 2.2	0.27	12	0	520 ± 140	16 ± 4	287 ± 84	0.0018
24. TA-33	51 544	12	0	8.4 ± 3.6	1.1 ± 0.4	2.9 ± 1.2	0.15	12	0	340 ± 80	19 ± 4	147 ± 46	0.0009
25. TA-39	54 166	12	0	8.8 ± 3.8	0.9 ± 0.4	3.5 ± 1.3	0.18	12	0	390 ± 100	6.8 ± 1.8	213 ± 59	0.0013
Onsite Group Summary	564 199	132	0	16 ± 6	0.3 ± 0.3	4.4 ± 0.5	0.22	132	0	550 ± 140	6.0 ± 1.6	227 ± 21	0.0014

[a]The filters are held 7-10 days before analysis to allow naturally-occurring radon-thoron daughters to reach equilibrium with their long-lived parents.

[b]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.

[c]Minimum detectable limit = 0.3×10^{-15} μCi/mℓ (α).
= 0.3×10^{-15} μCi/mℓ (β).

[d]Uncertainties are ±2 standard deviations (see Appendix B.2).

[e]The CGs of ^{239}Pu and ^{90}Sr are the most appropriate to use for the gross alpha and gross beta CGs, respectively.
Controlled area radioactivity concentration guide = 2×10^{-12} μCi/mℓ (α)
1×10^{-9} μCi/mℓ (β)
Uncontrolled area radioactivity concentration guide = 6×10^{-14} μCi/mℓ (α).
3×10^{-11} μCi/mℓ (β).

TABLE E-VI

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR CONCENTRATIONS

Station Location	Total Air Volume[a] (m^3)	Number of Monthly 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 (28-44 km)—Uncontrolled Areas							
1. Española	78	12	4	55 ± 18	−0.4 ± 1.8	17 ± 13	0.008
2. Pojoaque	78	12	4	62 ± 20	0.3 ± 1.0	17 ± 14	0.009
3. Santa Fe	78	12	6	68 ± 22	−1.3 ± 1.0	18 ± 16	0.009
Regional Group Summary	234	36	14	68 ± 22	−1.3 ± 1.0	18 ± 8	0.009
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	78	12	4	29 ± 10	−0.5 ± 0.8	6.8 ± 5.8	0.003
5. Arkansas Ave	78	12	3	30 ± 10	−0.8 ± 1.0	7.9 ± 6.5	0.004
6. Cumbres School	78	12	4	22 ± 8	1.1 ± 0.8	6.4 ± 4.2	0.003
7. 48th Street	78	12	2	32 ± 10	0.5 ± 0.8	7.7 ± 6.1	0.004
8. LA Airport	78	12	0	13 ± 4	0.5 ± 0.8	4.5 ± 2.4	0.002
9. Bayo STP	78	12	3	130 ± 40	0.3 ± 0.6	22 ± 26	0.011
10. Gulf Station	78	12	4	9.8 ± 3.4	2.4 ± 1.2	6.1 ± 1.6	0.003
11. Royal Crest	78	12	0	16 ± 6	1.2 ± 0.8	4.7 ± 2.3	0.002
12. White Rock	78	12	1	11 ± 4	0.7 ± 0.8	2.9 ± 1.6	0.001
13. Pajarito Acres	78	12	0	22 ± 8	1.1 ± 1.0	5.7 ± 3.5	0.003
14. Bandelier	78	12	0	31 ± 10	2.5 ± 1.2	8.5 ± 4.6	0.004
Perimeter Group Summary	858	132	21	130 ± 40	−0.8 ± 1.0	7.6 ± 2.7	0.004
Onsite Stations—Controlled Areas							
15. TA-21	78	12	0	18 ± 6	0.9 ± 1.4	5.6 ± 3.1	0.0001
16. TA-6	78	12	4	35 ± 12	0.2 ± 1.0	6.7 ± 5.3	0.0001
17. TA-53 (LAMPF)	78	12	0	31 ± 10	0.1 ± 0.4	5.4 ± 4.9	0.0001
18. Well PM-1	78	12	0	11 ± 4	0.5 ± 1.0	4.1 ± 1.8	0.0001
19. TA-52	78	12	1	17 ± 6	0.1 ± 0.8	4.4 ± 3.1	0.0001
20. TA-16	78	12	3	4.5 ± 1.6	−0.3 ± 0.8	1.9 ± 1.1	0.0000
21. Booster P-2	78	12	3	14 ± 4	−1.6 ± 1.6	2.5 ± 2.5	0.0001
22. TA-54	78	12	0	93 ± 30	0.7 ± 0.8	22 ± 17	0.0004
23. TA-49	78	12	7	14 ± 4	−0.2 ± 0.4	4.4 ± 2.9	0.0001
24. TA-33	78	12	0	85 ± 28	0.7 ± 0.8	30 ± 17	0.0006
25. TA-39	78	12	0	49 ± 16	0.4 ± 0.8	12 ± 8	0.0002
On-Site Group Summary	858	132	18	93 ± 30	−1.6 ± 1.6	9.0 ± 2.8	0.0002

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 1×10^{-12} $\mu Ci/m\ell$.
[c]Uncertainties are ±2 standard deviations (see Appendix B.2).
[d]Controlled area radioactivity concentration guide = 5×10^{-6} $\mu Ci/m\ell$.
Uncontrolled area radioactivity concentration guide = 2×10^{-7} $\mu Ci/m\ell$.

TABLE E-VII

ANNUAL ATMOSPHERIC ^{238}Pu AND ^{239}Pu CONCENTRATIONS

Station Location	Total Air Volume[a] (m^3)	^{238}Pu aCi/m^3 (10^{-18} μCi/m*l*) Number of Samples	Number <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]	^{239}Pu aCi/m^3 (10^{-18} μCi/m*l*) Number of Samples	Number <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas													
1. Española	53 826	4	4	−1.0 ± 1.6	−1.8 ± 1.6	−1.3 ± 0.3	0.0	4	1	11 ± 3	0.4 ± 1.4	5.7 ± 4.3	0.01
2. Pojoaque	43 323	4	4	0.5 ± 2.3	−3.2 ± 2.3	−2.0 ± 1.7	0.0	4	2	32 ± 7	−3.3 ± 4.0	12 ± 16	0.02
3. Santa Fe	55 059	4	4	−0.2 ± 1.9	−1.9 ± 1.4	−1.3 ± 0.8	0.0	4	2	18 ± 4	−2.5 ± 2.2	7.2 ± 9.6	0.01
Regional Group Summary	152 208	12	12	0.5 ± 2.3	−3.2 ± 2.3	−1.5 ± 0.6	0.0	12	5	32 ± 7	−3.3 ± 4.0	8.2 ± 5.9	0.01
Perimeter Stations (0-4 km)—Uncontrolled Areas													
4. Barranca School	52 311	4	4	−1.2 ± 1.6	−1.6 ± 1.5	−1.4 ± 0.2	0.0	4	1	35 ± 7	−0.3 ± 1.2	13 ± 15	0.02
5. Arkansas Ave	46 779	4	4	−1.0 ± 2.0	−1.7 ± 1.7	−1.3 ± 0.3	0.0	4	1	20 ± 6	1.9 ± 1.8	8.3 ± 7.9	0.01
6. Cumbres School	42 892	4	4	−1.1 ± 1.9	−2.6 ± 2.4	−1.7 ± 0.6	0.0	4	1	32 ± 6	0.2 ± 1.4	14 ± 15	0.02
7. 48th Street	49 163	4	4	−1.2 ± 1.8	−3.2 ± 1.7	−1.9 ± 0.9	0.0	4	2	70 ± 9	1.0 ± 2.1	24 ± 32	0.04
8. LA Airport	55 406	4	4	−0.7 ± 1.7	−3.0 ± 1.4	−1.7 ± 1.0	0.0	4	0	23 ± 4	4.1 ± 2.3	14 ± 8	0.02
9. Bayo STP	48 713	4	4	−0.4 ± 1.8	−1.6 ± 1.6	−1.1 ± 0.5	0.0	4	1	30 ± 6	0.4 ± 1.4	12 ± 13	0.02
10. Gulf Station	51 834	4	4	−0.4 ± 1.9	−1.6 ± 1.5	−1.2 ± 0.6	0.0	4	2	23 ± 4	−0.5 ± 1.2	10 ± 11	0.02
11. Royal Crest	49 135	4	4	−0.9 ± 2.1	−1.6 ± 1.5	−1.4 ± 0.4	0.0	4	2	17 ± 4	0.0 ± 1.4	8.0 ± 8.2	0.01
12. White Rock	49 552	4	4	−0.6 ± 1.8	−1.7 ± 1.5	−1.3 ± 0.5	0.0	4	1	22 ± 6	0.7 ± 1.5	11 ± 9	0.02
13. Pajarito Acres	37 783	4	4	2.8 ± 3.4	−2.9 ± 2.3	−1.0 ± 2.6	0.0	4	1	27 ± 5	−0.1 ± 1.7	13 ± 11	0.02
14. Bandelier	43 426	4	4	−1.4 ± 2.0	−2.9 ± 1.9	−2.3 ± 0.7	0.0	4	0	38 ± 7	6.4 ± 3.0	19 ± 14	0.03
Perimeter Group Summary	526 994	44	44	2.8 ± 3.4	−3.2 ± 1.7	−1.5 ± 0.3	0.0	44	12	70 ± 9	−0.5 ± 1.2	13 ± 4	0.02
Onsite Stations—Controlled Areas													
15. TA-21	48 499	4	4	−1.0 ± 2.4	−2.2 ± 1.3	−1.5 ± 0.5	0.0	4	1	10 ± 3	−0.5 ± 1.2	4.6 ± 4.2	0.0002
16. TA-6	48 103	4	4	−1.2 ± 1.5	−2.0 ± 1.4	−1.6 ± 0.3	0.0	4	1	15 ± 3	0.3 ± 1.4	5.7 ± 6.1	0.0003
17. TA-53 (LAMPF)	49 899	4	4	0.8 ± 1.5	−2.0 ± 1.5	−1.2 ± 0.4	0.0	4	1	18 ± 4	0.4 ± 1.4	6.3 ± 7.7	0.0003
18. Well PM-1	49 020	4	4	−1.0 ± 1.8	−2.0 ± 2.0	−1.5 ± 0.4	0.0	4	3	12 ± 4	−0.5 ± 1.2	4.4 ± 5.4	0.0002
19. TA-52	51 804	4	4	−0.9 ± 1.7	−2.2 ± 1.3	−1.4 ± 0.6	0.0	4	3	18 ± 4	0.8 ± 1.4	6.1 ± 8.0	0.0003
20. TA-16	48 139	4	4	−1.3 ± 1.6	−2.3 ± 1.8	−1.6 ± 0.5	0.0	4	1	7.1 ± 3.3	0.8 ± 1.5	3.6 ± 2.6	0.0002
21. Booster P-2	53 640	4	4	0.4 ± 2.5	−2.1 ± 1.4	−1.2 ± 1.1	0.0	4	1	74 ± 9	0.8 ± 1.6	40 ± 40	0.0020
22. TA-54	55 666	4	3	4.1 ± 2.8	−2.2 ± 1.2	0.9 ± 2.7	0.00005	4	1	17 ± 5	1.0 ± 1.2	10 ± 7	0.0005
23. TA-49	52 769	4	4	−0.8 ± 1.9	−2.5 ± 1.5	−1.4 ± 0.8	0.0	4	1	16 ± 4	1.0 ± 1.5	5.9 ± 6.8	0.0003
24. TA-23	51 544	4	4	−1.3 ± 1.8	−2.5 ± 1.2	−1.8 ± 0.5	0.0	4	3	11 ± 3	0.5 ± 1.3	3.9 ± 5.0	0.0002
25. TA-39	54 166	4	4	−0.4 ± 1.6	−1.6 ± 1.4	−1.0 ± 0.6	0.0	4	4	4.5 ± 5.2	−0.3 ± 1.1	2.0 ± 2.0	0.0001
Onsite Group Summary	564 199	44	43	4.1 ± 2.8	−2.5 ± 1.5	0.8 ± 4.1	0.00004	44	20	74 ± 9	−0.5 ± 1.2	8.4 ± 4.7	0.0004

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.

[b]Minimum detectable limits = 2×10^{-10} μCi/m*l* (^{238}Pu).
= 3×10^{-18} μCi/m*l* (^{239}Pu).

[c]Uncertainties are ±2 sample standard deviations (see Appendix B.2).

[d]Controlled area radioactivity concentration guide = 2×10^{-12} μCi/m*l* (^{238}Pu).
= 2×10^{-12} μCi/m*l* (^{239}Pu).
Uncontrolled area radioactivity concentration guide = 7×10^{-14} μCi/m*l* (^{238}Pu).
= 6×10^{-14} μCi/m*l* (^{239}Pu).

TABLE E-VIII

ANNUAL ATMOSPHERIC URANIUM CONCENTRATIONS
(concentrations in pg/m^3)

Station Location	Total Air Volume[a] (m^3)	Number of Quarterly Samples	Number of Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
1. Española	53 826	4	3	31 ± 7	−1.7 ± 18	19 ± 14	0.0003
2. Pojoaque	43 323	4	2	66 ± 13	3.2 ± 3.0	38 ± 31	0.0006
3. Santa Fe	55 059	4	3	39 ± 9	3.2 ± 2.3	23 ± 16	0.0004
Regional Group Summary	152 208	12	8	66 ± 13	−1.7 ± 18	27 ± 13	0.0005
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	52 311	4	1	78 ± 36	−1.9 ± 19	42 ± 33	0.0007
5. Arkansas Ave	46 779	4	2	57 ± 39	18 ± 20	36 ± 16	0.0006
6. Cumbres School	42 892	4	2	139 ± 40	−2.0 ± 20	51 ± 61	0.0009
7. 48th Street	49 163	4	0	82 ± 38	21 ± 4	46 ± 28	0.0008
8. LA Airport	55 406	4	1	64 ± 33	16 ± 18	42 ± 23	0.0007
9. Bayo STP	48 713	4	1	66 ± 39	17 ± 19	40 ± 24	0.0007
10. Gulf Station	51 834	4	0	98 ± 18	26 ± 19	59 ± 30	0.0010
11. Royal Crest	49 135	4	1	47 ± 39	27 ± 38	34 ± 10	0.0006
12. White Rock	49 552	4	3	43 ± 10	18 ± 20	31 ± 11	0.0005
13. Pajarito Acres	37 783	4	2	97 ± 50	21 ± 24	62 ± 40	0.0010
14. Bandelier	43 426	4	1	168 ± 38	21 ± 23	74 ± 66	0.0012
Perimeter Group Summary	526 994	44	14	168 ± 38	−2.0 ± 20	47 ± 10	0.0008
Onsite Stations—Controlled Areas							
15. TA-21	48 499	4	3	74 ± 38	13 ± 4	36 ± 28	0.00002
16. TA-6	49 103	4	3	55 ± 38	17 ± 19	32 ± 18	0.00002
17. TA-53 (LAMPF)	49 899	4	2	53 ± 37	−1.9 ± 19	26 ± 22	0.00001
18. Well PM-1	49 020	4	2	45 ± 38	−1.9 ± 19	17 ± 23	0.00001
19. TA-52	51 804	4	1	71 ± 36	17 ± 19	42 ± 24	0.00002
20. TA-16	48 139	4	4	37 ± 39	13 ± 4	23 ± 11	0.00001
21. Booster P-2	53 640	4	2	42 ± 35	18 ± 20	30 ± 14	0.00002
22. TA-54	55 666	4	1	239 ± 52	16 ± 17	86 ± 103	0.00005
23. TA-49	52 769	4	0	43 ± 36	24 ± 17	33 ± 10	0.00002
24. TA-33	51 544	4	0	51 ± 35	25 ± 18	36 ± 13	0.00002
25. TA-39	54 166	4	2	50 ± 35	16 ± 4	31 ± 17	0.00002
Onsite Group Summary	564 199	44	20	239 ± 52	−1.9 ± 20	36 ± 11	0.00002

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 1 pg/m^3.
[c]Uncertainties ±2 sample standard deviations (see Appendix B.2).
[d]Controlled area radioactivity concentration guide = 1.8 × 10^8 pg/m^3.
Uncontrolled area radioactivity 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

ANNUAL ATMOSPHERIC ^{241}Am CONCENTRATIONS

Station Location	Total Air Volume (m^3)[a]	Number of Quarterly Samples	Number of Samples <MDL[b]	aCi/m^3 (10^{-18} μCi/mℓ) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
3. Santa Fe	55 059	4	4	2.8 ± 3.1	0.5 ± 3.0	1.5 ± 2.0	0.0008
Regional Group Summary	55 059	4	4	2.8 ± 3.1	0.5 ± 3.0	1.5 ± 2.0	0.0008
Perimeter Stations (0-4 km)—Uncontrolled Areas							
6. Cumbres	42 892	4	4	3.0 ± 3.0	0.7 ± 3.0	1.1 ± 0.7	0.0006
8. LA Airport	55 406	4	3	8.7 ± 3.5	0.9 ± 3.0	3.3 ± 7.3	0.0017
9. Bayo STP	48 713	4	4	1.4 ± 3.0	0.8 ± 3.0	1.1 ± 0.5	0.0006
12. White Rock	49 552	4	3	6.1 ± 5.2	1.1 ± 3.1	2.6 ± 4.7	0.0013
Perimeter Group Summary	196 563	16	14	8.7 ± 3.5	0.7 ± 3.0	2.0 ± 4.4	0.0010
Onsite Stations—Controlled Areas							
16. TA-6	49 103	4	3	174 ± 16	1.0 ± 2.9	45 ± 172	0.00075
17. TA-53 (LAMPF)	49 899	4	4	3.0 ± 3.1	0.1 ± 2.8	1.3 ± 2.8	0.00002
20. TA-16	48 139	4	4	5.2 ± 3.3	0.0 ± 2.5	1.9 ± 4.6	0.00003
21. Booster P-2	53 640	4	3	450 ± 30	0.4 ± 3.0	110 ± 450	0.0018
22. TA-54	55 666	4	4	3.2 ± 3.0	0.3 ± 3.1	1.6 ± 3.1	0.00003
23. TA-39	52 769	4	4	2.3 ± 3.0	0.0 ± 2.5	0.9 ± 2.2	0.00002
Onsite Group Summary	309 216	24	22	450 ± 30	0.0 ± 2.5	26 ± 190	0.00043

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 2×10^{-18} μCi/mℓ.
[c]Uncertainties are ±2 sample deviations (see Appendix B.2).
[d]Controlled area radioactivity concentration guide = 6×10^{-12} μCi/mℓ.
Uncontrolled area radioactivity concentration guide = 2×10^{-13} μCii/mℓ.

TABLE E-X

LOCATIONS OF SURFACE AND GROUND WATER STATIONS

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Regional[c]				
Chamita—Rio Chama	36°05'	106°07'	---	SW
Embudo—Rio Grande	36°12'	105°58'	---	SW
Otowi—Rio Grande	35°52'	106°08'	---	SW
Cochiti—Rio Grande	35°37'	106°19'	---	SW
Bernalillo—Rio Grande	35°17'	106°36'	---	SW
Jemez River	35°40'	106°44'	---	SW
Perimeter				
Los Alamos Reservoir	N105	W090	1	SW
Guaje Canyon	N300	E100	2	SW
Basalt Spring	N060	E395	3	GWS
Frijoles Canyon	S280	E180	4	SW
La Mesita Spring	N080	E550	5	GWD
White Rock Canyon[d]				
Puye Formation	---	---	---	GWD
Tesuque Fm (F.G. Sed)	---	---	---	GWD
Tesuque Fm (F.G. Sed)	---	---	---	GWD
Tesuque Fm (Basalts)		---	---	GWD
Surface Water	---	---	---	SW
Surface Water (Sanitary Effluents)	---	---	---	SW
Water Supply				
Distribution				
Fire Station 1	N080	E015	12	D
Fire Station 2	N100	E120	13	D
Fire Station 3	S085	E375	14	D
Fire Station 4	N185	E070	15	D
Fire Station 5	S010	W065	16	D
Los Alamos Field				
LA-1B	N115	E530	17	GWD
LA-2	N125	E505	18	GWD
LA-3	N130	E490	19	GWD
LA-4	N070	E405	20	GWD
LA-5	N076	E435	21	GWD
LA-6	N105	E465	22	GWD
Guaje Field				
G-1	N190	E385	23	GWD
G-1A	N197	E380	24	GWD
G-2	N205	E365	25	GWD
G-3	N215	E350	26	GWD
G-4	N213	E315	27	GWD
G-5	N228	E295	28	GWD
G-6	N215	E270	29	GWD

TABLE E-X (Continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Pajarito Field				
PM-1	N030	E305	30	GWD
PM-2	S055	E202	31	GWD
PM-3	N040	E255	32	GWD
Water Canyon Gallery	S040	W125	33	GWD
Noneffluent Areas				
Test Well 1	N070	E345	34	GWD
Test Well 3	N080	E215	35	GWD
Deep Test-5A	S110	E090	36	GWD
Test Well-8	N035	E170	37	GWD
Deep Test-9	S155	E140	38	GWD
Deep Test-10	S120	E125	39	GWD
Canada del Buey	N010	E150	40	SW
Pajarito Canyon	S060	E215	41	SW
Water Canyon	S090	E090	42	SW
Test Well 2	N120	E150	43	GWD
Effluent Release Area				
Acid-Pueblo Canyon (Former Release Area)				
Acid Weir	N125	E070	44	SW
Pueblo 1	N130	E080	45	SW
Pueblo 2	N120	E155	46	SW
Pueblo 3	N085	E315	47	SW
Test Well 1A	N070	E335	49	GWS
Test Well 2A	N120	E140	50	GWS
DP —Los Alamos Canyon				
DPS-1	N090	E160	51	SW
DPS-4	N080	E200	52	SW
Obs: Hole LAO-C	N085	E070	53	GWS
Obs: Hole LAO-1	N080	E120	54	GWS
Obs: Hole LAO-2	N080	E210	55	GWS
Obs: Hole LAO-3	N080	E220	56	GWS
Obs: Hole LAO-4	N070	E245	57	GWS
Obs: Hole LAO-4.5	N065	E270	58	GWS
Sandia Canyon				
SCS-1	N080	E040	59	SW
SCS-2	N060	E140	60	SW
SCS-3	N050	E185	61	SW

TABLE E-X (Continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Mortandad Canyon				
GS-1	N040	E100	62	SW
Obs. Hole MCO-3	N040	E110	64	GWS
Obs. Hole MCO-4	N035	E150	65	GWS
Obs. Hole MCO-5	N030	E160	66	GWS
Obs. Hole MCO-6	N030	E175	67	GWS
Obs. Hole MCO-7	N025	E180	68	GWS
Obs. Hole MCO-7.5	N030	E190	69	GWS

[a]See Fig. 12 for numbered locations.
[b]SW = surface water; GWD = deep or main aquifer; GWS = shallow or alluvial aquifer; D = water supply distribution system.
[c]See Fig. 6 for regional locations.
[d]Puye Formation 9 stations; Tesuque Fm (F. G. Sed) 2 stations; Tesuque Fm (C. G. Sed) 11 stations; Tesuque (basalts) 3 stations; surface water 2 stations; surface water (sanitary effluents) 1 station.

TABLE E-XI

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE WATER FROM REGIONAL STATIONS

Station	1981 Sampling Date	Radiochemical						
		^{137}Cs (10^{-9} µCi/mℓ)	^{238}Pu (10^{-9} µCi/mℓ)	^{239}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)
Chamita	3-16	0 ± 34	−0.014 ± 0.028	0.018 ± 0.038	1.7 ± 2.6	9.7 ± 2.8	0.5 ± 0.6	4.9 ± 1.0
Chamita	9-3	20 ± 80	0.011 ± 0.022	0.000 ± 0.020	1.2 ± 2.6	5.9 ± 2.2	0.9 ± 0.8	---
Embudo	3-16	23 ± 34	0.013 ± 0.030	−0.010 ± 0.040	1.3 ± 1.6	5.4 ± 2.0	0.2 ± 0.6	1.6 ± 0.8
Embudo	9-3	30 ± 40	0.007 ± 0.014	0.010 ± 0.020	−0.7 ± 1.4	3.9 ± 1.8	1.6 ± 0.6	---
Otowi	3-16	15 ± 20	−0.005 ± 0.018	0.005 ± 0.018	1.9 ± 2.0	6.2 ± 2.2	0.9 ± 0.6	3.7 ± 0.8
Otowi	9-3	30 ± 80	0.019 ± 0.038	0.010 ± 0.020	−0.6 ± 2.2	7.7 ± 2.4	1.3 ± 0.6	---
Cochiti	3-17	0 ± 100	−0.004 ± 0.036	−0.070 ± 0.060	1.3 ± 1.8	5.7 ± 2.2	0.1 ± 0.6	3.5 ± 0.8
Cochiti	9-14	20 ± 40	0.014 ± 0.030	0.000 ± 0.020	−0.7 ± 1.6	5.4 ± 2.0	0.3 ± 0.8	—
Bernalillo	3-17	37 ± 40	−0.008 ± 0.022	−0.050 ± 0.060	2.0 ± 2.4	8.4 ± 2.6	1.2 ± 0.6	4.2 ± 0.8
Bernalillo	9-14	10 ± 60	0.008 ± 0.028	0.010 ± 0.020	−0.1 ± 2.6	9.0 ± 2.6	0.4 ± 0.8	—
Jemez	3-17	30 ± 100	−0.008 ± 0.020	−0.012 ± 0.030	5.0 ± 4.0	17 ± 4.0	0.1 ± 0.6	0.0 ± 0.8
Jemez	9-14	23 ± 30	0.011 ± 0.022	0.000 ± 0.000	1.2 ± 2.8	15 ± 3.8	0.5 ± 0.8	---
No. of Analyses		12	12	12	12	12	12	6
Minimum		0 ± 34	−0.014 ± 0.028	−0.070 ± 0.060	−0.7 ± 1.6	3.9 ± 1.8	0.1 ± 0.6	0.0 ± 0.8
Maximum		37 ± 40	0.019 ± 0.038	0.018 ± 0.038	5.0 ± 4.0	17 ± 4.0	1.6 ± 0.6	4.2 ± 0.8
Average		20	0.004	−0.007	1.1	8.3	0.7	2.9
2s		24	0.022	0.053	3.2	8.1	1.0	3.6

Station	Chemical (average of a number of analyses, concentrations in mg/ℓ)															Cond (mS/m)
	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cℓ	F	NO_3	TDS	Hard	pH	
Chamita	15	51	13	2.4	37	3	151	<0.1	136	12	0.3	6.4	330	192	8.4	45
Embudo	27	36	6.5	2.7	18	0	117	0.2	36	4	0.5	2.2	196	108	8.2	27
Otowi	24	42	8.0	2.7	24	0	137	0.3	59	2	0.4	3.5	220	130	8.2	34
Cochiti	23	40	7.7	4.3	22	0	139	0.2	59	7	0.5	7.5	212	126	8.3	30
Bernalillo	25	44	8.5	4.3	62	5	139	<0.1	99	9	0.5	4.7	342	154	8.7	47
Jemez	49	45	5.7	12	85	9	177	<0.1	57	162	1.1	2.5	418	131	8.6	58
No. of Analyses	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	15	36	5.7	2.4	18	0	117	<0.1	36	2	0.3	2.2	196	108	8.2	27
Maximum	49	51	13	12	85	9	177	0.3	136	162	1.1	6.4	418	192	8.6	58
Average	27	43	8.2	4.7	41	3	143	0.2	74	33	0.6	4.5	286	140	8.4	40
2s	23	10	5.1	7.3	53	7	40	0.2	73	127	0.6	4.3	180	59	0.4	24

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 WATER FROM PERIMETER STATIONS

Station	1981 Sampling Date	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Los Alamos Reservoir	3-19	20 ± 40	−0.018 ± 0.034	0.012 ± 0.006	1.0 ± 1.2	12 ± 3.0	0.4 ± 0.6	0.0 ± 0.8
Los Alamos Reservoir	9-9	20 ± 60	0.010 ± 0.020	0.040 ± 0.020	0.3 ± 0.8	2.3 ± 1.6	0.2 ± 0.8	--
Guaje Canyon	3-26	20 ± 40	−0.010 ± 0.028	0.040 ± 0.040	−0.3 ± 0.8	4.0 ± 1.4	0.1 ± 0.6	0.0 ± 0.8
Guaje Canyon	9-10	15 ± 36	0.030 ± 0.020	0.010 ± 0.000	−0.4 ± 0.8	4.5 ± 1.8	1.0 ± 0.8	--
Basalt Spring	3-26	60 ± 60	−0.015 ± 0.018	−0.027 ± 0.028	0.5 ± 1.4	6.1 ± 2.0	0.8 ± 0.6	1.6 ± 0.8
Basalt Spring	9-15	30 ± 100	0.030 ± 0.020	0.050 ± 0.020	3.2 ± 2.2	21 ± 4.0	5.3 ± 0.8	--
Frijoles Canyon	3-19	5 ± 60	0.004 ± 0.024	0.020 ± 0.030	0.7 ± 1.0	2.5 ± 1.4	0.4 ± 0.6	0.0 ± 0.8
Frijoles Canyon	9-9	20 ± 60	0.020 ± 0.000	0.030 ± 0.080	−0.2 ± 0.8	2.6 ± 1.6	1.0 ± 0.8	--
La Mesita Spring	3-19	10 ± 20	−0.004 ± 0.018	0.007 ± 0.020	4.2 ± 2.4	6.0 ± 2.0	0.1 ± 0.6	11 ± 2.2
La Mesita Spring	9-15	29 ± 32	0.022 ± 0.016	0.011 ± 0.016	8.0 ± 4.0	14 ± 3.4	1.3 ± 0.8	--
No. of Analyses		10	10	10	10	10	10	5
Minimum		5 ± 60	−0.018 ± 0.034	−0.027 ± 0.028	−0.4 ± 0.8	2.3 ± 1.6	0.1 ± 0.6	0.0 ± 0.8
Maximum		60 ± 60	0.030 ± 0.020	0.050 ± 0.020	8.0 ± 4.0	21 ± 4.0	5.3 ± 0.8	11 ± 2.2
Average		23	0.010	0.019	1.7	7.5	1.1	2.5
2s		30	0.040	0.044	5.4	12	3.1	9.6

Station	Chemical (concentrations in mg/ℓ, one analysis) 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	31	5	2.0	1.9	5	0	34	<1	3	2	0.7	<0.4	56	20	7.2	7
Guaje Canyon	51	6	2.3	2.2	6	0	40	<1	4	<1	0.2	0.4	72	24	7.8	8
Basalt Spring	41	28	6.9	3.0	17	0	106	<1	22	14	0.6	6.2	162	94	7.9	26
Frijoles Canyon	61	7	2.6	1.5	10	0	54	<1	2	2	0.2	0.8	86	30	8.1	11
La Mesa Spring	31	31	0.8	2.7	30	0	133	<1	17	10	0.3	13	180	87	8.2	30
No. of Analyses	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Minimum	31	5	0.8	1.5	5	0	34	--	3	1	0.2	<0.4	56	20	7.2	7
Maximum	51	31	6.9	2.7	30	0	133	<1	22	14	0.7	13	180	87	8.2	30
Average	43	15	2.9	2.2	13.6	0	73	--	10	6	0.4	<4.2	111	51	7.8	16
2s	26	26	4.6	1.2	20.6	0	88	--	18	12	0.5	11	112	73	0.8	22

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 WATER FROM WHITE ROCK CANYON, OCTOBER 1981

Station	Radiochemical						
	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Group I—Totavi Lentil							
Sandia Spring	30 ± 70	0.019 ± 0.014	0.010 ± 0.020	0.4 ± 1.2	3.0 ± 1.6	−1.4 ± 0.6	2.3 ± 0.8
Spring 3	20 ± 80	0.004 ± 0.018	0.009 ± 0.008	0.9 ± 1.2	4.2 ± 1.8	−1.4 ± 0.6	2.3 ± 0.8
Spring 3A	6 ± 20	0.006 ± 0.012	0.017 ± 0.008	0.7 ± 1.2	6.4 ± 2.2	−1.0 ± 0.8	2.0 ± 0.8
Spring 3AA	25 ± 38	0.004 ± 0.008	0.004 ± 0.012	1.1 ± 1.2	2.9 ± 1.6	−1.6 ± 0.6	2.1 ± 0.8
Spring 4	60 ± 80	0.016 ± 0.016	0.048 ± 0.002	1.7 ± 1.6	2.9 ± 1.8	−1.4 ± 0.6	1.5 ± 0.8
Spring 4A	20 ± 60	0.028 ± 0.014	0.010 ± 0.014	0.8 ± 1.0	2.0 ± 1.6	−1.1 ± 0.8	1.9 ± 0.8
Spring 5	20 ± 70	0.009 ± 0.024	0.009 ± 0.018	0.5 ± 1.0	3.9 ± 1.8	−1.1 ± 0.8	1.7 ± 0.8
Spring 5AA	50 ± 80	0.004 ± 0.000	0.010 ± 0.014	0.8 ± 1.2	3.1 ± 1.6	−1.1 ± 0.8	0.9 ± 0.8
Ancho Spring	8 ± 24	0.013 ± 0.014	0.033 ± 0.024	0.7 ± 1.0	1.9 ± 1.4	−1.1 ± 0.6	1.2 ± 0.8
Group II—Tesuque Fm Coursed-Grained							
Spring 5A	10 ± 60	0.006 ± 0.016	0.016 ± 0.000	1.7 ± 1.6	3.0 ± 1.8	−1.0 ± 0.8	2.2 ± 0.8
Spring 5B	20 ± 60	0.013 ± 0.018	0.004 ± 0.012	0.6 ± 1.0	2.0 ± 1.4	0.6 ± 0.8	1.9 ± 0.8
Spring 6	20 ± 80	0.005 ± 0.010	0.014 ± 0.000	0.7 ± 1.0	3.9 ± 1.6	−1.3 ± 0.6	1.0 ± 0.8
Spring 6A	19 ± 38	0.009 ± 0.012	0.013 ± 0.008	0.1 ± 0.8	3.3 ± 1.6	−0.3 ± 0.8	1.4 ± 0.8
Spring 7	40 ± 40	0.005 ± 0.014	0.005 ± 0.018	0.6 ± 1.0	3.2 ± 1.6	−0.9 ± 0.6	1.3 ± 0.8
Spring 8	3 ± 36	0.004 ± 0.012	0.031 ± 0.008	1.4 ± 1.4	2.3 ± 1.6	−0.8 ± 0.8	2.7 ± 0.8
Spring 8A	2 ± 38	0.008 ± 0.000	0.012 ± 0.008	0.8 ± 1.2	2.1 ± 1.6	−0.8 ± 0.8	1.7 ± 0.8
Spring 9	6 ± 34	0.005 ± 0.016	0.005 ± 0.018	1.8 ± 1.4	4.0 ± 1.6	−0.8 ± 0.6	1.9 ± 0.8
Spring 9A	10 ± 40	0.007 ± 0.026	0.015 ± 0.026	0.4 ± 1.0	1.7 ± 1.6	−1.3 ± 0.8	1.4 ± 0.8
Doe Spring	60 ± 60	0.005 ± 0.010	0.005 ± 0.016	0.5 ± 0.8	1.3 ± 1.8	−0.9 ± 0.8	1.7 ± 0.8
Spring 10	20 ± 38	0.028 ± 0.028	0.006 ± 0.020	−0.1 ± 0.8	1.5 ± 1.4	−0.9 ± 0.8	1.7 ± 0.8
Group III—Tesuque Fm Fine-Grained							
Spring 1	20 ± 80	0.013 ± 0.016	0.009 ± 0.012	4.1 ± 2.4	4.6 ± 1.8	−1.2 ± 0.6	3.3 ± 0.8
Spring 2	0 ± 36	0.005 ± 0.018	0.005 ± 0.010	2.1 ± 1.8	3.8 ± 1.8	−1.4 ± 0.6	5.4 ± 1.0
Group IV—Tesuque Fm Fine-Grained; Basalt Intrusion							
Spring 3B	20 ± 80	0.005 ± 0.000	0.040 ± 0.040	12 ± 3.0	12 ± 3.2	−1.1 ± 0.6	19 ± 4.0
Streams into Rio Grande							
Pajarito	26 ± 28	0.006 ± 0.016	0.006 ± 0.016	0.3 ± 1.0	4.2 ± 1.8	−1.0 ± 0.8	2.0 ± 0.8
Ancho	28 ± 26	0.011 ± 0.018	0.007 ± 0.012	0.6 ± 1.0	1.9 ± 1.6	−0.9 ± 0.8	1.9 ± 0.8
Frijoles	50 ± 50	0.005 ± 0.014	0.005 ± 0.020	0.7 ± 1.0	3.8 ± 1.6	−1.4 ± 0.6	1.2 ± 0.8
No. of Analyses	26	26	26	26	26	26	26
Minimum	0 ± 36	0.004 ± 0.018	0.004 ± 0.012	−0.1 ± 0.8	1.3 ± 1.8	−1.6 ± 0.6	0.9 ± 0.8
Maximum	60 ± 60	0.028 ± 0.014	0.048 ± 0.002	12 ± 3.0	12 ± 3.2	0.6 ± 0.8	19 ± 4.0
Average	23	0.009	0.013	1.4	3.4	−1.0	2.6
2s	34	0.014	0.023	4.6	4.2	0.9	6.9
Sanitary Effluent into Rio Grande							
Mortandad	20 ± 32	0.019 ± 0.020	0.004 ± 0.010	1.3 ± 2.4	34 ± 0.4	−0.3 ± 0.8	2.0 ± 0.8

TABLE E-XIII (Continued)

Station	Chemical (concentrations in mg/l, one analysis)														pH	Cond (mS/m)
	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard		
Group I—Totavi Lentil																
Sandia Spring	47	38	2.9	2.6	18	0	168	<0.3	6	5	0.6	<0.4	170	110	7.7	26
Spring 3	52	20	1.6	2.8	16	0	99	<0.3	4	5	0.4	2.6	125	56	8.1	21
Spring 3A	52	20	1.7	2.8	16	0	98	<0.3	4	4	0.4	1.8	120	56	7.9	19
Spring 3AA	45	20	0.3	3.1	18	0	101	<0.3	4	4	0.4	<0.4	126	51	7.7	20
Spring 4	60	28	5.7	2.7	15	0	132	<0.3	6	8	0.5	<0.4	168	92	7.0	22
Spring 4A	68	22	4.8	2.0	13	0	97	<0.3	5	7	0.5	3.8	148	70	7.2	21
Spring 5	57	21	4.8	1.9	13	0	110	<0.3	4	6	0.4	<0.4	148	68	7.5	18
Spring 5AA	55	25	4.4	2.4	13	0	114	<0.3	3	6	0.5	<0.4	156	76	6.9	24
Ancho Spring	75	13	3.2	1.8	11	0	72	<0.3	3	6	0.3	1.2	130	44	6.5	15
Group II—Tesuque Fm Course-Grained																
Spring 5A	60	24	2.7	2.9	22	0	124	<0.3	7	6	0.3	1.7	186	69	7.4	24
Spring 5B	64	17	4.4	1.9	12	0	87	<0.3	2	4	0.5	2.0	152	56	7.4	15
Spring 6	74	12	3.6	1.9	11	0	74	<0.3	2	4	0.3	<0.4	134	44	7.0	14
Spring 6A	75	10	2.8	1.9	10	0	64	<0.2	<1	3	0.3	2.2	138	36	8.0	13
Spring 7	79	12	3.0	2.1	14	0	80	<0.2	2	6	0.3	1.7	136	44	6.9	13
Spring 8	76	27	4.4	3.0	24	0	153	<0.2	8	6	0.4	1.6	200	80	6.8	25
Spring 8A	75	11	2.8	2.1	13	0	56	<0.2	3	5	0.4	<0.4	152	39	9.0	13
Spring 9	75	13	3.2	1.7	12	0	82	<0.2	2	4	0.4	1.1	152	43	8.0	12
Spring 9A	73	12	3.3	1.5	12	0	74	<0.2	1	5	0.5	<0.4	150	42	8.1	12
Doe Spring	76	14	3.6	1.5	13	0	86	<0.2	2	5	0.5	<0.4	170	48	7.7	13
Spring 10	69	12	3.2	1.6	13	0	80	<0.2	3	4	0.4	1.7	146	42	7.8	12
Group III—Tesuque Fm Fine-Grained																
Spring 1	33	20	1.3	2.0	33	0	139	<0.3	17	4	0.5	<0.9	140	56	7.6	23
Spring 2	34	22	1.1	1.6	54	0	201	<0.3	11	7	1.1	<0.9	208	58	8.3	32
Group IV—Tesuque Fm Fine-Grained; Basalt Intrusion																
Spring 3B	46	24	2.0	4.8	139	0	392	<0.3	4	6	0.6	8.4	374	64	7.5	61
Streams into Rio Grande																
Pajarito	68	23	4.7	2.5	12	0	107	<0.2	7	7	0.4	3.4	176	72	7.9	22
Ancho	69	13	3.3	1.8	12	0	51	<0.2	3	5	0.4	0.9	156	46	9.0	12
Frijoles	64	2	3.2	2.1	13	0	71	<0.2	2	4	0.2	<0.9	132	39	7.7	11
No. of Analyses	26	26	26	26	26	0	26	26	26	26	26	26	26	26	26	26
Minimum	33	2	0.3	1.5	10	0	51	—	<1	3	0.2	0.4	120	36	6.5	11
Maximum	79	38	5.7	4.8	139	0	392	<0.2	17	8	1.1	8.4	374	110	9.0	61
Average	62	18	3.2	2.3	21	0	112	—	<4	5	0.4	<1.5	161	58	7.6	20
2s	27	15	2.6	1.4	51	0	134	—	7	2	0.3	3.4	98	36	1.2	20
Sanitary Effluent into Rio Grande																
Mortandad Canyon	94	31	8.9	14	13	0	213	46	16	49	0.9	15	438	108	7.5	57

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 WATER FROM ONSITE STATIONS

Station	1981 Sampling Date	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Test Well 1	2-28	0 ± 40	0.090 ± 0.022	0.230 ± 0.280	4.2 ± 2.2	6.8 ± 1.8	1.1 ± 0.6	6.1 ± 1.2
Test Well 1	9-15	20 ± 20	0.000 ± 0.020	0.006 ± 0.020	0.5 ± 1.6	7.3 ± 2.4	3.8 ± 0.8	—
Test Well 3	3-31	0 ± 100	0.020 ± 0.040	0.060 ± 0.060	−0.8 ± 0.8	2.6 ± 1.2	0.4 ± 0.6	0.7 ± 0.8
Deep Test 5A	3-30	40 ± 100	0.007 ± 0.028	0.010 ± 0.040	−0.1 ± 0.8	2.3 ± 1.0	0.4 ± 0.6	—
Deep Test 5A	9-16	8 ± 30	0.026 ± 0.018	0.006 ± 0.022	0.1 ± 0.8	0.9 ± 1.4	0.6 ± 0.8	0.0 ± 0.8
Test Well 8	4-6	0 ± 40	−0.020 ± 0.040	0.050 ± 0.180	−0.2 ± 0.8	3.8 ± 1.4	0.1 ± 0.6	—
Test Well 8	9-21	100 ± 100	0.020 ± 0.020	0.010 ± 0.040	0.1 ± 0.8	1.1 ± 1.4	0.0 ± 0.8	0.0 ± 0.8
Test Well 9	4-10	12 ± 38	−0.020 ± 0.040	−0.010 ± 0.080	1.1 ± 0.8	6.5 ± 1.8	0.8 ± 0.6	—
Test Well 10	4-2	0 ± 100	−0.012 ± 0.038	0.090 ± 0.040	−0.6 ± 0.8	1.3 ± 1.0	0.3 ± 0.6	0.8 ± 0.8
Test Well 10	9-21	20 ± 60	0.010 ± 0.000	0.030 ± 0.080	0.2 ± 0.8	0.3 ± 1.4	0.8 ± 0.8	—
Cañada del Buey	3-26	0 ± 80	0.010 ± 0.040	0.010 ± 0.040	0.1 ± 0.8	6.4 ± 1.8	0.8 ± 0.6	0.0 ± 0.8
Cañada del Buey	9-21	—	0.014 ± 0.008	0.012 ± 0.020	0.1 ± 0.8	6.1 ± 1.8	0.7 ± 0.4	0.1 ± 0.8
Pajarito Canyon	3-26	0 ± 80	0.005 ± 0.034	0.010 ± 0.060	−0.3 ± 1.8	18 ± 3.8	0.5 ± 0.6	0.0 ± 0.8
Water at Beta	4-8	30 ± 100	0.080 ± 0.022	1.84 ± 0.260	0.9 ± 0.8	6.7 ± 1.8	0.0 ± 0.6	0.0 ± 0.8
Test Well 2	3-30	60 ± 120	0.010 ± 0.060	−0.080 ± 0.080	0.3 ± 0.8	2.1 ± 1.0	0.6 ± 0.6	0.0 ± 0.8
Test Well 2	9-17	—	0.013 ± 0.060	0.060 ± 0.044	0.3 ± 0.8	2.4 ± 1.0	0.7 ± 0.4	0.1 ± 0.8
No. of Analyses		14	14	14	16	16	17	11
Minimum		0 ± 80	−0.020 ± 0.040	−0.080 ± 0.080	−0.8 ± 0.8	0.3 ± 1.4	0.0 ± 0.6	0.0 ± 0.8
Maximum		100 ± 100	0.090 ± 0.022	1.84 ± 0.260	4.2 ± 2.2	18 ± 3.8	3.8 ± 0.8	6.1 ± 1.2
Average		19	0.016	0.146	0.4	4.6	0.8	0.7
2s		54	0.060	0.913	2.3	8.6	1.8	3.6

Station	Chemical (concentrations in mg/ℓ, one analysis)															Cond (mS/m)
	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cℓ	F	NO_3	TDS	Hard	pH	
Test Well 1	49	43	7.7	3.4	12	0	121	<3	3	7	0.4	2.4	220	128	8.0	32
Test Well 3	84	17	6.0	2.2	13	0	104	<3	3	4	0.4	4.1	168	64	7.9	19
Deep Test 5A	72	8	2.5	1.7	11	0	65	<3	1	2	0.2	3.9	124	38	7.9	12
Test Well 8	50	4	0.9	1.6	11	7	22	<3	<1	3	0.2	4.4	52	16	9.8	9
Deep Test 9	72	9	3.1	8.9	12	0	69	<3	2	4	<0.2	4.3	142	35	8.0	15
Deep Test 10	58	10	3.5	1.3	11	0	81	<3	1	3	0.3	<0.4	124	42	8.3	13
Cañada del Buey	42	10	3.0	2.7	17	0	44	<3	13	14	2.8	16	146	40	6.9	17
Pajarito Canyon	30	46	13	7.0	37	0	49	<3	15	130	<0.2	1.5	304	152	6.5	53
Water at Beta	36	9	4.1	4.0	16	0	65	<3	11	10	0.2	6.6	180	42	7.9	16
Test Well 2	79	13	3.8	0.9	9	0	79	<3	3	3	0.5	6.2	150	51	8.0	15
No. of Analyses	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Minimum	30	4	0.9	0.9	9	0	22	—	1	2	0.2	0.4	52	16	6.5	9
Maximum	84	46	13	8.9	37	7	104	<3	15	130	2.8	16	304	152	8.3	53
Average	57	17	4.8	3.4	15	7	70	—	5	18	0.5	4.9	161	61	7.9	20
2s	38	30	6.9	5.3	16	4.4	57	—	11	79	1.6	8.6	133	88	1.7	26

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 WATER FROM ACID PUEBLO CANYON, FORMER EFFLUENT RELEASE AREA

Station	1981 Sampling Date	Radiochemical							
		^{137}Cs (10^{-9} µCi/mℓ)	^{90}Sr (10^{-9} µCi/mℓ)	^{238}Pu (10^{-9} µCi/mℓ)	^{239}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)
Acid Weir	4-1	0 ± 40	70 ± 6.0	−0.013 ± 0.020	0.010 ± 0.060	−0.3 ± 2.8	210 ± 40	1.5 ± 0.6	0.8 ± 0.8
Acid Weir	9-28	30 ± 120	---	0.030 ± 0.020	2.15 ± 0.220	2.9 ± 2.2	51 ± 10	0.8 ± 0.8	---
Pueblo 1	4-1	50 ± 100	1.5 ± 0.4	0.018 ± 0.030	−0.014 ± 0.032	−0.5 ± 1.2	13 ± 3.0	0.1 ± 0.6	0.0 ± 0.8
Pueblo 1	9-28	30 ± 80	---	0.010 ± 0.020	0.000 ± 0.040	−0.5 ± 1.4	7.2 ± 2.2	3.6 ± 0.8	---
Pueblo 2	4-1	30 ± 100	3.2 ± 0.4	0.008 ± 0.026	0.160 ± 0.060	−0.2 ± 1.4	21 ± 4.0	0.3 ± 0.6	0.0 ± 0.8
Pueblo 2	9-28	40 ± 60	---	0.000 ± 0.000	0.230 ± 0.080	0.8 ± 2.2	19 ± 4.0	1.4 ± 0.8	---
Pueblo 3	4-1	0 ± 80	---	−0.004 ± 0.016	0.018 ± 0.038	−0.5 ± 1.4	14 ± 3.2	0.1 ± 0.6	0.0 ± 0.8
Test Well 1A	3-30	29 ± 36	3.3 ± 0.8	−0.018 ± 0.030	−0.014 ± 0.030	−0.7 ± 1.4	8.5 ± 2.2	0.4 ± 0.6	0.0 ± 0.8
Test Well 1A	9-17	6 ± 36	---	0.005 ± 0.026	0.014 ± 0.034	1.5 ± 1.6	3.6 ± 1.8	6.6 ± 0.8	---
Test Well 2A	4-6	60 ± 100	−0.1 ± 0.6	−0.030 ± 0.060	−0.030 ± 0.060	−0.2 ± 1.2	2.8 ± 1.2	1.1 ± 0.8	0.0 ± 0.8
Test Well 2A	9-17	10 ± 60	---	0.030 ± 0.060	0.011 ± 0.040	−0.5 ± 1.6	−0.4 ± 0.8	14 ± 1.0	---
No. of Analyses		11	5	11	11	11	11	11	6
Minimum		0 ± 40	−0.1 ± 0.6	−0.030 ± 0.060	−0.030 ± 0.060	−0.7 ± 1.4	0.4 ± 0.8	0.1 ± 0.6	0.0 ± 0.8
Maximum		60 ± 100	70 ± 6.0	0.030 ± 0.060	2.15 ± 0.220	2.9 ± 2.2	210 ± 40	14 ± 1.0	0.8 ± 0.8
Average		26	15	0.000	0.230	0.2	32	3.6	0.1
2s		40	61	0.039	1.28	2.2	121	9.7	0.6

Station	1981 Date	Chemical (average of a number of analyses, concentrations in mg/ℓ)														pH	Cond (mS/m)
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cℓ	F	NO_3	TDS	Hard		
Acid Weir	4-1	21	32	4.3	6.1	108	0	61	<3	16	64	0.4	15	406	88	6.9	69
Acid Weir	9-28	29	12	1.7	4.7	62	0	124	4	2	39	0.4	2.4	226	38	6.9	36
Pueblo 1	4-1	64	14	2.7	9.2	71	0	84	28	13	65	0.5	33	356	51	7.5	49
Pueblo 1	9-28	59	13	2.2	11	83	0	75	27	32	64	0.4	45	386	41	7.3	52
Pueblo 2	4-1	59	17	3.5	10	76	0	137	16	42	38	0.5	42	324	62	8.0	49
Pueblo 2	9-28	53	16	2.7	10	82	0	115	24	31	43	0.5	47	330	48	8.0	44
Pueblo 3	4-1	54	13	2.4	10	76	0	89	27	27	44	0.9	60	334	42	7.5	45
Test Well TW-1A	4-1	50	18	5.1	7.0	74	0	104	16	32	40	0.8	53	314	64	7.7	46
Test Well TW-2A	4-1	6	18	3.5	2.0	17	0	61	<3	5	33	0.2	0.5	114	64	7.6	22
No. of Analyses		9	9	9	9	9	0	9	9	9	9	9	9	9	9	9	9
Minimum		6	12	1.7	2.0	17	0	61	<3	5	33	0.2	0.5	114	38	6.9	22
Maximum		64	32	5.1	11	108	0	137	28	42	65	0.9	60	406	88	8.0	69
Average		44	17	3.1	7.8	72	0	94	<16	22	48	0.5	33	310	55	7.5	46
2s		40	12	2.2	6	48	0	55	22	27	26	0.4	44	179	32	0.8	25

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 ANALYSES OF SURFACE WATER FROM SANDIA CANYON, ACTIVE EFFLUENT RELEASE AREA

Station	1981 Sampling Date	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{90}Sr (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
SCS-1	3-30	10 ± 100	1.1 ± 1.0	−0.008 ± 0.028	0.011 ± 0.028	−4.0 ± 14	53 ± 12	41.1 ± 1.6	1.9 ± 0.8
SCS-1	9-24	50 ± 120	---	0.050 ± 0.040	0.070 ± 0.040	14 ± 34	72 ± 16	6.8 ± 0.8	---
SCS-2	3-30	10 ± 20	0.2 ± 0.8	−0.008 ± 0.020	0.004 ± 0.022	−1.8 ± 3.6	21 ± 4.0	25.4 ± 1.2	0.0 ± 0.8
SCS-2	9-24	20 ± 40	---	0.020 ± 0.020	0.000 ± 0.000	0.4 ± 2.2	15 ± 3.6	10.9 ± 1.0	---
SCS-3	3-30	20 ± 60	0.4 ± 0.6	0.040 ± 0.038	0.040 ± 0.020	−3.0 ± 4.0	27 ± 6.0	26.9 ± 1.2	0.8 ± 0.8
SCS-3	9-24	8 ± 26	---	0.000 ± 0.000	0.000 ± 0.020	1.2 ± 1.6	8.9 ± 2.6	4.4 ± 0.8	---
No. of Analyses		6	3	6	6	6	6	6	3
Minimum		8 ± 26	0.2 ± 0.8	−0.008 ± 0.020	0.000 ± 0.020	−4.0 ± 14	8.9 ± 2.6	4.4 ± 0.8	0.0 ± 0.8
Maximum		50 ± 120	1.1 ± 1.0	0.050 ± 0.040	0.070 ± 0.040	14 ± 34	72 ± 16	41 ± 1.6	1.9 ± 0.8
Average		20	0.6	0.016	0.020	1.1	33	19	0.9
2s		32	0.9	0.050	0.060	13	49	29	1.9

Station	1981 Date	Chemical (average of a number of analyses, 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	3-30	99	33	6.6	13	268	0	120	<3	247	117	1.3	8.4	762	112	8.4	116
SCS-1	9-24	115	132	19	31	381	0	0	12	1070	54	0.7	17	1930	420	3.4	218
SCS-2	3-30	85	31	6.6	11	166	0	126	8	189	108	1.1	14	690	102	7.7	102
SCS-2	9-24	74	20	4.1	6.3	74	0	114	4	58	41	0.8	3.5	322	66	7.0	47
SCS-3	3-30	84	33	6.7	12	175	0	128	9	226	98	1.2	16	712	102	8.1	107
SCS-3	9-24	71	25	4.6	8.4	113	0	134	9	108	41	1.1	4.1	454	80	6.9	82
No. of Analyses		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum		71	20	4.1	6.3	74	---	0	<3	58	41	0.7	3.5	322	66	3.4	47
Maximum		115	132	19	31	381	0	134	12	1070	117	1.3	17	1930	420	8.4	218
Average		88	46	7.9	14	196	---	104	8	316	77	1.0	11	812	147	6.9	112
2s		33	85	11	18	224	---	102	7	752	70	0.47	12	1147	270	3.6	115

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 AND GROUND WATER
FROM DP—LOS ALAMOS CANYON, ACTIVE EFFLUENT RELEASE AREA

Station	1981 Sampling Date	Radiochemical ^{137}Cs (10^{-9} μCi/mℓ)	^{90}Sr (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
DPS-1	3-31	30 ± 40	298 ± 12	1.44 ± 0.180	2.38 ± 0.240	360 ± 140	980 ± 200	1.3 ± 0.6	126 ± 26
DPS-1	9-29	23 ± 38	---	0.280 ± 0.080	0.720 ± 0.140	53 ± 22	370 ± 80	5.1 ± 0.8	---
DPS-4	3-31	50 ± 80	---	0.170 ± 0.060	0.340 ± 0.080	8.0 ± 3.8	66 ± 14	0.6 ± 0.6	5.2 ± 1.0
LAO-C	3-31	10 ± 40	1.5 ± 0.6	−0.110 ± 0.300	−0.500 ± 0.300	2.1 ± 2.6	13 ± 3.0	0.6 ± 0.6	1.6 ± 0.8
LAO-C	9-29	20 ± 60	---	0.000 ± 0.020	0.010 ± 0.020	−0.4 ± 1.2	4.8 ± 2.0	0.8 ± 0.8	---
LAO-1	3-31	30 ± 80	1.6 ± 2.8	0.008 ± 0.024	0.023 ± 0.026	1.0 ± 1.8	68 ± 14	39.5 ± 1.6	0.0 ± 0.8
LAO-1	9-29	0 ± 60	---	0.000 ± 0.020	0.040 ± 0.020	−0.9 ± 1.8	75 ± 16	9.1 ± 1.0	---
LAO-2	3-31	50 ± 60	35 ± 2.2	0.010 ± 0.040	1.54 ± 0.240	5.8 ± 3.0	128 ± 2.6	0.2 ± 0.6	2.5 ± 0.8
LAO-2	9-29	24 ± 32	---	0.000 ± 0.020	0.050 ± 0.020	−0.4 ± 2.2	122 ± 24	1.2 ± 0.8	---
LAO-3	3-31	0 ± 40	14 ± 1.4	0.010 ± 0.040	0.090 ± 0.080	4.1 ± 2.4	52 ± 10	0.4 ± 0.6	1.8 ± 0.8
LAO-3	9-29	30 ± 100	---	0.020 ± 0.020	0.080 ± 0.040	0.4 ± 2.2	57 ± 12	1.8 ± 0.8	---
LAO-4	3-31	30 ± 80	4.4 ± 1.0	0.024 ± 0.032	0.070 ± 0.040	1.4 ± 1.4	21 ± 4.0	0.5 ± 0.6	1.2 ± 0.8
LAO-4	9-29	30 ± 40	---	0.020 ± 0.020	0.050 ± 0.040	6.0 ± 3.4	23 ± 6.0	6.1 ± 0.8	---
LAO-4.5	3-31	40 ± 100	2.9 ± 0.8	−0.020 ± 0.032	0.020 ± 0.040	0.6 ± 1.2	12 ± 2.6	1.1 ± 0.6	1.0 ± 0.8
LAO-4.5	9-29	30 ± 60	---	0.030 ± 0.040	4.01 ± 0.380	0.6 ± 1.6	11 ± 3.0	4.2 ± 0.8	---
No. of Analyses		15	7	15	15	15	15	15	8
Minimum		0 ± 60	1.5 ± 0.6	−0.11 ± 0.300	−0.500 ± 0.300	−0.9 ± 1.8	4.8 ± 2.0	0.2 ± 0.6	0.0 ± 0.8
Maximum		50 ± 60	298 ± 12	1.44 ± 0.800	4.01 ± 0.380	360 ± 140	980 ± 200	39.5 ± 1.6	126 ± 26
Average		26	51	0.125	0.593	29	134	4.8	17
2s		30	219	0.748	2.37	185	502	20	44

Station	1981 Date	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	3-31	15	42	3.1	52	250	19	168	<3	38	206	13	186	902	100	9.0	137
DPS-1	9-29	15	25	2.3	13	145	30	215	<3	26	33	8.9	64	400	64	9.3	64
DPS-4	3-31	48	8	0.6	5.4	56	4	139	<3	22	9	1.8	17	190	25	8.4	29
DPS-4	9-29	21	20	2.0	15	85	0	210	<3	20	19	2.5	39	290	55	7.6	41
LAO-C	3-31	33	30	8.2	4.9	69	0	55	<3	11	147	0.1	1.1	342	110	7.0	56
LAO-1	3-31	40	22	4.9	5.3	68	0	109	<3	16	57	0.8	7.9	278	74	7.2	46
LAO-2	3-31	44	33	1.3	12	63	0	159	<3	10	11	3.4	7.1	258	22	7.6	30
LAO-2	9-29	47	12	2.0	19	78	0	194	<3	17	19	2.3	21	469	38	7.0	47
LAO-3	3-31	48	5	1.7	11	64	0	149	<3	9	19	5.6	12	260	22	7.5	39
LAO-4	3-31	38	3	3.1	7.4	51	0	139	<3	10	19	2.3	19	200	38	7.4	32
LAO-4	9-29	42	20	1.9	8.8	63	0	138	<3	7	23	1.9	15	216	51	6.9	34
LAO-4.5	3-31	40	13	4.9	4.6	43	0	122	<3	7	19	0.7	8.9	192	52	7.2	30
LAO-4.5	9-29	62	8	1.5	15	70	0	175	<3	9	17	2.9	12	226	27	7.0	37
No. of Analyses		13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Minimum		15	3	1.3	4.6	43	0	122	---	7	9	0.1	1.1	190	22	6.9	29
Maximum		62	42	8.2	52	250	34	215	<3	38	206	13	186	902	100	8.0	137
Average		38	19	2.9	13	85	4	152	---	16	46	3.6	32	325	52	7.6	48
2s		28	24	4.1	25	111	19	87	—	18	121	7.3	98	385	57	1.6	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-XVIII

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE AND GROUND WATER
FROM MORTANDAD CANYON, ACTIVE EFFLUENT RELEASE AREA

Station	1981 Sampling Date	Radiochemical							
		^{137}Cs (10^{-9} μCi/mℓ)	^{90}Sr (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
GS-1	4-2	1220 ± 160	85 ± 4.0	17.1 ± 0.800	255 ± 10	2500 ± 1000	2000 ± 400	427 ± 4	3.0 ± 0.8
GS-1	10-26	---	---	1.28 ± 0.180	12.2 ± 0.600	15 ± 6.0	220 ± 40	4.4 ± 0.8	--
MCO-3	4-2	1960 ± 300	190 ± 8.0	2.71 ± 0.040	24.4 ± 0.200	1000 ± 400	9700 ± 2000	47.9 ± 8	4.1 ± 0.8
MCO-3	10-26	---	---	1.30 ± 0.160	12.4 ± 0.600	13 ± 6.0	250 ± 60	4.2 ± 0.8	--
MCO-4	4-2	1 ± 22	5.8 ± 0.8	0.030 ± 0.080	0.110 ± 0.120	1200 ± 600	230 ± 40	335 ± 10	8.4 ± 1.6
MCO-4	10-26	---	---	1.17 ± 0.160	3.40 ± 0.280	60 ± 40	760 ± 160	160 ± 6	--
MCO-5	4-2	60 ± 100	5.2 ± 0.8	0.350 ± 0.080	0.080 ± 0.040	41 ± 20	74 ± 16	346 ± 12	7.9 ± 1.6
MCO-5	10-26	---	---	0.280 ± 0.080	0.690 ± 0.060	8 ± 8	55 ± 12	207 ± 6	--
MCO-6	4-2	10 ± 40	4.4 ± 0.6	0.180 ± 0.060	0.100 ± 0.060	49 ± 24	81 ± 16	350 ± 12	7.5 ± 1.6
MCO-6	10-26	---	---	0.280 ± 0.080	0.570 ± 0.010	67 ± 32	78 ± 16	723 ± 4	--
MCO-7	4-2	10 ± 60	0.3 ± 0.6	0.019 ± 0.030	0.056 ± 0.036	3.9 ± 2.6	22 ± 4.0	29.2 ± 1.4	2.1 ± 0.8
MCO-7	10-26	---	---	0.140 ± 0.060	0.390 ± 0.120	9.0 ± 6.0	20 ± 4.0	60.8 ± 2.2	---
MCO-7.5	4-2	20 ± 40	0.7 ± 0.6	0.100 ± 0.040	0.200 ± 0.080	3.3 ± 2.0	11 ± 2.4	16.8 ± 1.0	1.2 ± 0.8
MCO-7.5	10-26	19 ± 38	0.5 ± 0.6	0.140 ± 0.020	0.260 ± 0.020	2.8 ± 1.8	9.8 ± 2.0	14.9 ± 3.0	1.1 ± 0.8
No. of Analyses		8	8	14	14	14	14	14	8
Minimum		1 ± 22	0.3 ± 0.6	0.019 ± 0.030	0.056 ± 0.036	2.8 ± 1.8	9.8 ± 2.0	4.2 ± 0.8	1.1 ± 0.8
Maximum		1960 ± 300	190 ± 8.0	17.0 ± 0.800	255 ± 10	2500 ± 1000	9700 ± 2000	479 ± 8.0	8.4 ± 1.6
Average		419	36	1.79	22.1	355	965	183	4.4
2s		1522	137	8.94	134	1460	5140	345	6.2

Station	1981 Date	Chemical (average of a number of analyses, concentrations in mg/ℓ)															Cond (mS/m)
		SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	
GS-1	4-2	61	17	2.2	5.6	61	2	170	<3	17	17	1.1	58	293	50	8.5	41
GS-1	10-26	46	24	1.7	35	170	96	160	<3	28	20	3.5	276	656	62	10.1	81
MCO-3	4-2	40	15	1.1	27	812	29	63	<3	128	78	3.8	1610	2632	34	9.0	329
MCO-3	10-26	43	23	0.9	45	196	0	117	<3	36	22	3.9	304	732	62	10.2	109
MCO-4	4-2	34	25	6.6	7.3	312	0	320	<3	73	50	3.2	452	1100	88	8.2	158
MCO-4	10-26	35	31	2.9	18	403	0	305	<3	78	36	4.2	832	1444	91	8.1	169
MCO-5	4-2	26	26	6.4	6.5	305	0	320	<3	72	49	1.9	456	1066	88	8.3	154
MCO-6	4-2	28	27	6.5	6.8	317	0	330	<3	69	45	2.4	518	1192	98	7.8	163
MCO-6	10-26	41	25	6.1	6.1	323	0	305	<3	72	32	2.2	476	1090	86	7.2	131
MCO-7	4-2	48	17	5.5	5.8	66	0	92	<3	38	30	0.8	102	354	62	7.1	47
MCO-7	10-26	56	30	7.5	6.9	78	0	117	<3	40	29	0.4	133	406	117	6.7	62
MCO-7.5	4-2	44	18	5.0	4.4	59	0	83	<3	23	30	0.7	71	268	60	7.1	44
No. of Analyses		12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Minimum		26	15	0.9	4.4	59	0	63	---	17	17	0.4	71	268	34	6.7	44
Maximum		61	31	7.5	45	812	96	330	<3	128	78	4.2	1610	2632	117	10.2	329
Average		42	23	4.4	14.5	259	11	199	---	56	37	2.3	441	936	75	8.2	124
2s		21	11	4.8	27.5	426	56	216	---	63	34	2.7	867	1330	47	2.3	163

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-XIX

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

Station	1981 Sampling Date	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Los Alamos Well Field								
Well LA-1B	3-18	20 ± 60	−0.003 ± 0.018	0.003 ± 0.018	14 ± 8.0	9.9 ± 2.8	0.5 ± 0.6	5.7 ± 1.2
Well LA-1B	9-10	30 ± 40	0.004 ± 0.012	0.010 ± 0.000	9.0 ± 6.0	4.9 ± 2.0	0.1 ± 0.8	---
Well LA-2	3-18	0 ± 20	−0.010 ± 0.024	−0.010 ± 0.030	3.5 ± 2.6	7.7 ± 2.4	0.4 ± 0.6	4.5 ± 1.0
Well LA-2	9-10	15 ± 30	0.005 ± 0.014	0.000 ± 0.000	0.3 ± 1.6	0.8 ± 1.6	0.1 ± 0.8	—
Well LA-3	3-18	50 ± 60	0.017 ± 0.026	−0.008 ± 0.018	1.4 ± 1.4	2.0 ± 1.4	0.1 ± 0.6	3.5 ± 0.8
Well LA-3	9-10	20 ± 60	0.025 ± 0.028	0.040 ± 0.040	−0.1 ± 1.2	1.9 ± 1.6	0.7 ± 0.8	---
Well LA-4	3-18	0 ± 40	−0.004 ± 0.018	−0.008 ± 0.010	−0.3 ± 1.0	4.5 ± 1.8	0.2 ± 0.6	0.9 ± 0.8
Well LA-5	9-10	20 ± 140	−0.019 ± 0.030	−0.009 ± 0.030	2.2 ± 1.6	4.0 ± 1.8	0.1 ± 0.6	4.8 ± 0.8
Well LA-5	3-18	30 ± 20	0.004 ± 0.014	0.000 ± 0.000	−0.4 ± 1.2	1.4 ± 1.4	0.2 ± 0.8	---
Guaje Well Field								
Well G-1	3-18	50 ± 100	−0.021 ± 0.032	−0.150 ± 0.060	1.3 ± 1.4	4.8 ± 1.8	0.4 ± 0.6	1.0 ± 0.8
Well G-1	9-10	20 ± 60	0.011 ± 0.024	0.000 ± 0.000	2.3 ± 1.8	5.8 ± 2.0	7.5 ± 0.8	---
Well G-1A	3-18	80 ± 100	−0.010 ± 0.032	−0.015 ± 0.032	2.1 ± 1.6	4.1 ± 1.8	0.4 ± 0.6	0.7 ± 0.8
Well G-1A	9-10	5 ± 100	0.066 ± 0.020	0.040 ± 0.020	−0.9 ± 1.2	2.7 ± 1.6	2.0 ± 0.8	---
Well G-2	3-18	3 ± 20	−0.005 ± 0.026	0.010 ± 0.060	1.2 ± 1.4	3.6 ± 1.6	0.2 ± 0.6	0.9 ± 0.8
Well G-3	3-18	0 ± 20	−0.005 ± 0.020	−0.005 ± 0.014	0.9 ± 1.2	6.4 ± 2.0	0.1 ± 0.6	0.8 ± 0.8
Well G-3	9-10	0 ± 60	0.006 ± 0.018	0.010 ± 0.000	7.4 ± 1.5	−2.0 ± 1.6	0.1 ± 0.8	---
Well G-5	3-18	10 ± 80	---	---	1.5 ± 2.0	4.6 ± 2.0	2.0 ± 0.8	---
Well G-6	3-18	50 ± 120	−0.010 ± 0.040	−0.070 ± 0.080	0.3 ± 1.4	7.2 ± 2.2	0.1 ± 0.6	2.4 ± 0.8
Well G-6	9-10	30 ± 30	0.015 ± 0.020	0.010 ± 0.000	−0.8 ± 1.2	2.1 ± 1.6	3.9 ± 0.8	—
Pajarito Well Field								
Well PM-1	3-18	90 ± 140	−0.016 ± 0.024	−0.050 ± 0.060	1.4 ± 1.6	3.2 ± 1.6	0.2 ± 0.6	2.4 ± 0.8
Well PM-1	9-10	10 ± 60	0.006 ± 0.020	0.010 ± 0.020	0.0 ± 1.6	5.2 ± 2.0	5.9 ± 0.8	---
Well PM-2	3-18	40 ± 60	−0.004 ± 0.024	−0.017 ± 0.032	1.2 ± 1.4	5.3 ± 1.8	0.1 ± 0.6	0.0 ± 0.8
Well PM-2	9-10	23 ± 34	0.005 ± 0.012	0.000 ± 0.020	−0.5 ± 1.2	1.6 ± 1.6	0.5 ± 0.8	---
Well PM-3	3-18	0 ± 60	0.004 ± 0.018	−0.028 ± 0.024	0.8 ± 1.6	3.9 ± 1.8	0.1 ± 0.6	1.0 ± 0.8
Well PM-3	9-10	70 ± 120	0.027 ± 0.026	0.060 ± 0.020	0.2 ± 1.6	2.4 ± 1.6	0.2 ± 0.8	—
Water Canyon								
Gallery	3-18	0 ± 20	−0.015 ± 0.022	0.004 ± 0.024	0.5 ± 1.0	0.6 ± 1.4	0.2 ± 0.6	0.0 ± 0.8
Gallery	9-10	20 ± 60	---	---	0.5 ± 1.0	0.6 ± 1.4	4.6 ± 0.8	---
No. of Analyses		27	25	25	27	27	27	14
Minimum		0 ± 20	−0.021 ± 0.032	−0.150 ± 0.060	−0.9 ± 1.2	−2.0 ± 1.6	0.1 ± 0.8	0.0 ± 0.8
Maximum		90 ± 140	0.066 ± 0.020	0.040 ± 0.040	14 ± 8.0	9.9 ± 2.8	7.5 ± 0.8	5.7 ± 1.2
Average		25	0.003	−0.003	1.8	3.7	1.1	2.0
2s		50	0.036	0.063	6.6	5.1	4.0	1.9

TABLE E-XIX (Continued)

Station	1981 Sampling Date	Radiochemical						
		^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}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)
Distribution								
Fire Station 1	3-16	0 ± 80	0.004 ± 0.018	−0.023 ± 0.022	0.1 ± 1.0	2.1 ± 1.4	0.2 ± 0.6	0.0 ± 0.8
Fire Station 1	9-4	20 ± 100	---	---	1.9 ± 1.6	2.8 ± 1.6	1.1 ± 0.8	---
Fire Station 2	3-16	50 ± 140	0.012 ± 0.026	−0.008 ± 0.022	0.9 ± 1.6	3.5 ± 1.8	0.0 ± 0.6	3.9 ± 0.8
Fire Station 2	9-4	30 ± 60	0.013 ± 0.014	0.030 ± 0.000	1.2 ± 1.8	2.5 ± 1.6	0.6 ± 0.8	---
Fire Station 3	3-17	40 ± 60	−0.009 ± 0.034	0.080 ± 0.060	0.1 ± 1.4	5.0 ± 1.8	0.5 ± 0.6	1.5 ± 0.8
Fire Station 3	9-4	10 ± 100	0.026 ± 0.012	0010 ± 0.000	−1.4 ± 1.4	3.4 ± 1.8	0.1 ± 0.8	---
Fire Station 4	3-17	70 ± 120	−0.004 ± 0.026	0.031 ± 0.032	−0.5 ± 1.0	4.1 ± 1.8	0.5 ± 0.6	1.1 ± 0.8
Fire Station 4	9-4	5 ± 60	0.011 ± 0.020	0.000 ± 0.000	−0.9 ± 1.2	1.4 ± 1.4	1.8 ± 0.6	---
Fire Station 5	3-17	0 ± 100	−0.009 ± 0.020	0.048 ± 0.038	0.1 ± 1.0	2.4 ± 1.6	0.8 ± 0.6	0.9 ± 0.8
Fire Station 5	9-4	15 ± 36	0.030 ± 0.040	0.000 ± 0.020	−0.2 ± 1.0	1.4 ± 1.4	1.4 ± 0.6	---
Bandelier National Monument	4-18	10 ± 60	---	---	0.6 ± 1.2	5.8 ± 2.0	0.8 ± 0.6	1.3 ± 0.8
Fenton Hill (TA-57)	4-18	40 ± 60	---	---	1.9 ± 2.0	7.6 ± 2.4	0.6 ± 0.6	2.1 ± 0.8
No. of Analyses		12	9	9	12	12	13	7
Minimum		0 ± 80	−0.009 ± 0.020	−0.023 ± 0.022	−0.9 ± 1.2	1.4 ± 1.4	0.0 ± 0.6	0.0 ± 0.8
Maximum		70 ± 120	0.030 ± 0.040	0.080 ± 0.060	1.9 ± 2.0	7.6 ± 2.4	1.8 ± 0.6	3.9 ± 0.8
Average		24	0.008	0.019	0.3	3.5	0.6	1.5
2s		44	0.014	0.032	2.1	3.7	1.1	2.4
Los Alamos Well LA-6[a]	3-17	0 ± 40	---	---	2.1 ± 2.2	9.3 ± 2.6	0.5 ± 0.6	3.1 ± 0.8
Los Alamos Well LA-6[a]	9-4	---	0.004 ± 0.014	0.010 ± 0.000	0.9 ± 2.0	3.7 ± 1.8	0.4 ± 0.8	---

TABLE E-XIX (Continued)

Chemical Quality of Water Required for Municipal Use
(concentrations in mg/ℓ, one analysis)

	Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pd	Se
Los Alamos Well Field										
Well LA-1B	<0.0003	0.038	0.090	<0.0002	0.039	3.0	<0.0002	1.3	<0.003	<0.005
Well LA-2	<0.0003	0.010	0.110	<0.0002	0.009	1.6	<0.0002	1.1	<0.003	<0.005
Well LA-3	<0.0003	<0.005	0.090	<0.0002	0.038	0.6	<0.0002	1.6	<0.003	<0.005
Well LA-4	<0.0003	<0.005	<0.020	<0.0002	0.004	0.4	<0.0002	0.4	0.009	<0.005
Well LA-5	<0.0003	0.028	0.110	<0.0002	0.011	1.2	<0.0002	0.8	<0.003	<0.005
Guaje Well Field										
Well G-1	<0.0003	<0.005	0.025	<0.0002	<0.002	0.6	<0.0002	1.0	<0.003	<0.005
Well G-1A	<0.0003	0.006	0.054	<0.0002	0.008	0.4	<0.0002	2.2	<0.003	<0.005
Well G-2	<0.0003	0.050	<0.020	<0.0002	<0.002	0.8	<0.0002	1.8	<0.003	<0.005
Well G-3	<0.0003	<0.005	<0.020	<0.0002	0.005	0.4	<0.0002	4.9	<0.003	<0.005
Well G-6	<0.0003	<0.005	<0.020	<0.0002	0.003	0.3	<0.0002	2.3	<0.003	<0.005
Pajarito Well Field										
Well PM-1	<0.0003	0.005	0.150	<0.0002	<0.002	0.3	<0.0002	2.0	<0.003	<0.005
Well PM-2	<0.0003	<0.005	0.054	<0.0002	0.004	0.3	<0.0002	<0.1	<0.003	<0.005
Well PM-3	<0.0003	<0.005	0.120	<0.0002	0.005	0.4	<0.0002	1.8	<0.003	<0.005
Water Canyon										
Gallery	<0.0003	<0.005	0.051	<0.0002	<0.002	0.1	---	4.4	<0.003	<0.005
No. of Analyses	14	14	14	14	14	14	13	14	14	14
Minimum	---	<0.005	<0.020	---	<0.002	0.1	---	<0.1	<0.003	---
Maximum	<0.0003	0.038	0.150	<0.0002	0.039	3.0	<0.0002	4.9	0.009	<0.005
Average	---	<0.010	<0.060	---	<0.010	0.7	---	<1.8	<0.003	---
2s	---	0.030	0.080	---	0.030	1.5	---	2.7	0.002	---
Distribution										
Fire Station 1	<0.0003	<0.005	0.060	<0.0002	0.046	0.3	---	1.1	<0.003	<0.005
Fire Station 2	<0.0003	0.026	0.080	<0.0002	0.018	1.4	---	2.0	0.004	<0.005
Fire Station 3	<0.0003	<0.005	0.080	<0.0002	0.005	1.0	---	3.5	<0.003	<0.005
Fire Station 4	<0.0003	0.012	0.070	<0.0002	0.032	0.5	---	2.3	<0.003	<0.005
Fire Station 5	<0.0003	0.007	0.040	<0.0002	0.012	0.4	---	1.0	<0.003	<0.005
Bandelier National Monument	<0.0003	0.009	0.048	<0.0002	0.004	0.4	---	1.3	<0.003	<0.005
Fenton Hill (TA-57)	<0.0003	<0.005	0.320	<0.0002	<0.002	0.1	---	1.1	<0.003	<0.005
No. of Analyses	7	7	7	7	7	7	---	7	7	7
Minimum	---	<0.005	0.040	---	<0.002	0.1	---	1.0	<0.003	---
Maximum	<0.0003	0.026	0.320	<0.002	0.046	1.4	---	3.5	0.004	<0.005
Average	---	<0.010	0.010	---	<0.016	0.6	---	1.6	<0.003	---
2s	---	0.020	0.197	---	0.034	0.9	---	2.2	0.001	---
USEPA and NMEID MCL	0.05	0.05	1.0	0.01	0.05	2.0	0.002	45	0.05	0.01
Los Alamos Well LA 6[a]	<0.0002	0.274	0.030	<0.0002	0.019		<0.0002	21	<0.003	<0.005

TABLE E-XIX (Continued)

Chemical Quality of Water from Municipal Wells and Distribution
(concentrations in mg/ℓ, one analysis)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cℓ	TDS	Hard	pH	Cond (mS/m)
Los Alamos Well Field														
Well LA-1B	36	7	0.3	2.2	162	2	362	<1	36	11	390	18	8.4	64
Well LA-2	30	6	<0.1	0.9	72	5	137	<1	14	16	176	18	8.6	32
Well LA-3	33	12	0.3	1.4	36	3	107	<1	8	6	127	41	8.5	24
Well LA-4	36	10	0.3	1.7	20	3	75	<1	3	4	118	40	8.6	17
Well LA-5	36	7	<0.1	1.5	57	5	138	<1	6	4	154	20	8.8	28
Guaje Well Field														
Well G-1	82	10	0.6	3.3	25	3	86	<1	5	13	174	32	8.6	18
Well G-1A	76	9	0.5	3.1	28	4	87	<1	4	11	164	33	8.5	21
Well G-2	74	10	0.5	3.1	33	3	107	<1	5	6	174	30	8.6	21
Well G-3	58	12	1.4	2.1	20	3	82	<1	4	8	126	36	8.5	15
Well G-6	54	14	2.5	2.3	16	2	87	<1	4	2	130	50	8.4	16
Pajarito Well Field														
Well PM-1	77	28	6.9	4.2	18	0	144	<1	5	4	212	90	8.0	26
Well PM-2	81	8	3.1	2.0	10	0	65	<1	3	9	140	36	7.8	13
Well PM-3	88	24	8.4	3.0	18	0	148	<1	7	10	216	90	8.3	25
Water Canyon														
Gallery	43	6	3.4	1.4	6	0	50	<1	3	2	88	30	8.1	8
No. of Analyses	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Minimum	30	6	<0.1	0.9	6	0	50	<1	3	2	88	18	7.8	8
Maximum	88	28	8.4	4.2	162	5	362	---	36	16	390	90	8.8	64
Average	57	12	<2.0	2.3	37	2	120	---	8	8	171	40	8.4	23
2s	43	13	5.3	1.8	80	4	153	---	17	9	145	46	0.6	27
Distribution														
Fire Station 1	84	9	3.1	1.8	11	0	69	<1	2	2	142	38	7.8	13
Fire Station 2	40	9	0.4	1.7	74	4	153	<1	15	5	224	26	8.5	33
Fire Station 3	84	25	7.3	3.2	20	0	150	<1	7	4	206	92	8.2	26
Fire Station 4	67	11	1.0	2.3	26	3	92	<1	5	2	162	34	8.4	18
Fire Station 5	51	8	2.2	1.6	21	0	84	<1	5	3	120	34	8.2	13
Bandelier National Monument	50	9	2.0	2.0	42	0	96	<1	<1	17	114	30	7.4	19
Fenton Hill (TA-57)	68	52	6.1	5.6	14	0	128	<1	13	44	272	150	8.0	38
No. of Analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum	40	8	0.4	1.6	11	0	69	<1	<1	2	114	26	7.4	13
Maximum	84	52	7.3	5.6	74	4	153	---	15	44	272	150	8.5	38
Average	63	18	3.2	2.6	30	1	110	---	<7	11	177	58	81	23
2s	34	33	5.2	2.9	44	3	67	---	11	31	118	93	0.8	20
Los Alamos Well LA-6[a]	35	3	<01	1.3	88	10	168	<1	6	6	214	16	8.6	40

[a]Los Alamos Well LA-6 on standby; not used (see LA-7012-MS).

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

TABLE E-XX

LOCATIONS OF SOIL AND SEDIMENT STATIONS

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 15)[a]
Regional Soils[b]			
Regional Sediments			
Rio Chama			
Chamita	36°05'	106°07'	---
Rio Grande			
Embudo	36°12'	105°58'	---
Otowi	N085	E550	A
Sandia	S060	E490	B
Pajarito	S185	E410	C
Ancho	S305	E335	D
Frijoles	S375	E235	E
Bernalillo	35°17'	106°36'	---
Jemez River	35°40'	106°44'	---
Perimeter Soils			
Sportsman's Club	N240	E215	S1
TA-8	N060	W075	S2
TA-49	S165	E085	S3
Frijoles	S245	E180	S4
West of Airport	N115	E135	S7
South SR-4 near S-Site	S085	W035	S8
Perimeter Sediments			
Guaje at SR-4	N135	E480	2
Bayo at SR-4	N100	E455	3
Pueblo at Acid Weir	N125	E070	4
Pueblo at PC-1	N130	E070	5
Pueblo at Pueblo 1	N130	E085	6
Pueblo at Pueblo 2	N120	E145	7
Los Alamos at Totavi	N065	E405	9
Los Alamos at LA-2	N125	E510	10
Los Alamos at Rio Grande	N095	E555	11
Sandia at Rio Grande	S055	E490	12
Canada del Ancha	S060	E505	13
Mortandad at SR-4	S030	E350	14
Mortandad at Rio Grande	S075	E480	15
Canada del Buey at SR-4	S090	E360	16
Pajarito at Rio Grande	S175	E410	17
Frijoles at Park Hdq	S280	E185	18
Frijoles at Rio Grande	S365	E235	19

TABLE E-XX (Continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 15)[a]
Onsite Soils			
TA-21	N095	E140	S9
TA-50	N035	E095	S10
West of TA-53	N070	E105	S13
Sigma Mesa	N050	E135	S16
East of TA-52	N020	E145	S17
2-Mile Mesa	N025	E030	S18
Near TA-51	S030	E200	S19
East of TA-54	S080	E295	S20
R-Site Road	S015	E030	S21
Potrillo Drive	S065	E195	S23
S-Site	S035	W025	S24
Near TA-11	S070	E020	S25
Near DT-9	S150	E140	S26
TA-33	S245	E225	S27
Onsite Sediments			
Pueblo at Hamilton Bend Spr	N105	E255	20
Pueblo at Pueblo 3	N090	E315	21
Pueblo at SR-4	N070	E350	22
DP Canyon at DPS-1	N090	E160	23
DP Canyon at DPS-4	N075	E205	24
Los Alamos Canyon at Bridge	N095	E020	25
Los Alamos at LAO-1	N080	E120	26
Los Alamos at GS-1	N075	E200	27
Los Alamos at TW-3	N075	E215	28
Los Alamos at LAO-4	N075	E240	29
Los Alamos at SR-4	N065	E355	30
Sandia at SR-4	N025	E315	32
Mortandad near CMR	N060	E036	33
Mortandad West of GS-1	N045	E095	34
Mortandad Near MCO-2	N035	E090	35
Mortandad at GS-1	N040	E105	36
Mortandad at MCO-5	N035	E155	37
Mortandad at MCO-7	N025	E190	38
Mortandad at MCO-9	N030	E215	39
Mortandad at MCO-13	N015	E250	40

TABLE E-XX (Continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 15)[a]
Pajarito at SR-4	S105	E320	42
Potrillo at TA-36	S075	E150	43
Potrillo at SR-4	S145	E295	45
Water at Beta Hole	S090	E095	46
Water at SR-4	S170	E260	47
Water at Rio Grande	S240	E385	48
Ancho at SR-4	S255	E250	49
Ancho at Rio Grande	S295	E340	50
Chaquihui at Rio Grande	S335	E265	51

[a]See Fig. 15 for numbered locations.
[b]Locations are the same as for surface water stations (Table E-X).

TABLE E-XXI

RADIOCHEMICAL ANALYSES OF REGIONAL SOILS AND SEDIMENTS

Location	Map Designation[a]	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)
Regional Soils								
Chamita	---	0.69 ± 0.12	0.45 ± 0.10	0.010 ± 0.012	0.013 ± 0.006	5.5 ± 2.8	9.1 ± 2.2	0.2 ± 0.6
Embudo	---	1.13 ± 0.22	0.30 ± 0.12	0.001 ± 0.002	0.021 ± 0.008	9.0 ± 4.0	13 ± 2.8	1.2 ± 0.6
Otowi	---	0.57 ± 0.16	0.15 ± 0.08	0.004 ± 0.002	0.075 ± 0.014	5.1 ± 2.4	10 ± 2.4	0.2 ± 0.6
Cochiti	---	0.00 ± 0.12	0.29 ± 0.08	0.001 ± 0.000	0.052 ± 0.012	19 ± 8.0	17 ± 3.8	3.0 ± 0.6
Bernalillo	---	0.00 ± 0.10	0.49 ± 0.14	0.001 ± 0.000	0.006 ± 0.004	4.5 ± 2.2	5.6 ± 1.4	4.9 ± 0.6
Jemez	---	0.23 ± 0.10	0.07 ± 0.22	0.001 ± 0.002	0.002 ± 0.002	18 ± 8.0	18 ± 4.0	5.8 ± 0.8
No. of Analyses		6	6	6	6	6	6	6
Minimum		0.00 ± 0.12	0.07 ± 0.22	0.001 ± 0.000	0.002 ± 0.002	4.5 ± 2.2	5.6 ± 1.4	0.2 ± 0.6
Maximum		1.13 ± 0.22	0.49 ± 0.14	0.010 ± 0.012	0.075 ± 0.014	19 ± 8.0	18 ± 4.0	5.8 ± 0.8
Average		0.44	0.29	0.003	0.028	10	12	2.5
2s		0.89	0.33	0.007	0.058	13	10	4.8
Regional Sediments								
Rio Chama at:								
Chamita	---	0.15 ± 0.32	−0.10 ± 0.18	−0.000 ± 0.000	0.002 ± 0.002	3.5 ± 2.0	5.7 ± 1.4	0.3 ± 0.6
Rio Grande at:								
Embudo	---	0.14 ± 0.10	0.06 ± 0.12	0.000 ± 0.000	0.002 ± 0.002	8.0 ± 3.8	7.2 ± 1.8	0.7 ± 0.6
Otowi	A	0.14 ± 0.10	0.15 ± 0.12	0.001 ± 0.002	0.000 ± 0.002	6.7 ± 3.2	8.9 ± 2.0	−0.5 ± 0.6
Sandia	B	0.21 ± 0.06	---	---	---	3.5 ± 1.8	6.9 ± 1.6	---
Pajarito	C	0.16 ± 0.08	---	---	---	3.4 ± 1.8	7.6 ± 1.8	---
Ancho	D	0.23 ± 0.14	---	---	---	5.5 ± 0.8	8.5 ± 2.0	---
Frijoles	E	0.20 ± 0.14	---	---	---	2.1 ± 1.2	4.1 ± 1.2	---
Bernalillo	---	0.20 ± 0.00	−1.0 ± −18	0.000 ± 0.000	0.001 ± 0.002	1.4 ± 1.0	1.4 ± 0.8	0.4 ± 0.6
Jemez	---	0.82 ± 0.16	0.52 ± 0.12	0.001 ± 0.002	0.015 ± 0.006	25 ± 12	19 ± 4.0	0.2 ± 0.6
No. of Analyses		9	5	5	5	9	9	5
Minimum		0.14 ± 0.10	−0.10 ± 0.18	−0.000 ± 0.000	0.000 ± 0.002	1.4 ± 1.0	1.4 ± 0.8	−0.5 ± 0.6
Maximum		0.82 ± 0.16	0.15 ± 0.12	0.001 ± 0.002	0.015 ± 0.006	25 ± 12	19 ± 4.0	0.7 ± 0.6
Average		0.25	−0.07	0.000	0.004	6.6	7.7	0.2
2s		0.43	1.13	0.001	0.012	15	9.7	0.9

[a]See Fig. 15.

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

TABLE E-XXII

SPECIAL RADIOCHEMICAL ANALYSES OF SOIL AND SEDIMENTS FROM OTHER REGIONAL STATIONS

	pCi/g					
	^{137}Cs	^{90}Sr	^{238}Pu[a]	^{239}Pu[a]	Gross Alpha	Gross Beta
Soils						
Cuba	1.1 ± 0.14	0.86 ± 0.24	0.0079 ± 0.0010	0.0170 ± 0.0080	0.6 ± 0.6	4.5 ± 1.2
Santa Ana Pueblo	0.06 ± 0.10	0.14 ± 0.12	0.0013 ± 0.0004	0.0026 ± 0.0020	0.3 ± 0.6	4.9 ± 1.2
Gallina	0.38 ± 0.10	0.65 ± 0.18	0.0020 ± 0.0004	0.0054 ± 0.0034	0.4 ± 2.8	8.3 ± 2.0
La Bajada	0.98 ± 0.16	0.37 ± 0.10	0.0057 ± 0.0030	0.0100 ± 0.0200	0.5 ± 0.6	5.7 ± 1.4
El Rito	0.66 ± 0.12	0.39 ± 0.12	0.0034 ± 0.0008	0.0103 ± 0.0060	0.6 ± 0.8	16 ± 3.4
Santa Cruz Lake	0.92 ± 0.12	0.51 ± 0.20	0.0038 ± 0.0016	0.0103 ± 0.0140	0.2 ± 0.6	4.0 ± 1.2
Minimum	0.06 ± 0.10	0.14 ± 0.12	0.0013 ± 0.0004	0.0026 ± 0.0020	0.2 ± 0.6	4.0 ± 1.2
Maximum	1.1 ± 0.14	0.86 ± 0.24	0.0079 ± 0.0010	0.0170 ± 0.0080	0.6 ± 0.8	16 ± 3.4
$\bar{x}$ ± 2s	0.68 ± 0.80	0.49 ± 0.50	0.0040 ± 0.0049	0.0093 ± 0.0099	0.5 ± 0.3	7.2 ± 9.1
Sediments						
Rio Grande above Española	0.32 ± 0.18	0.42 ± 0.26	0.0011 ± 0.0004	0.0023 ± 0.0020	0.4 ± 1.2	22 ± 4
Rio Grande at Española	0.11 ± 0.18	0.28 ± 0.12	0.0000 ± 0.0000	0.0071 ± 0.0034	0.4 ± 1.4	12 ± 2.8
Rio Grande at Otowi	0.43 ± 0.18	0.12 ± 0.12	0.0011 ± 0.0006	0.0028 ± 0.0036	0.1 ± 1.4	11 ± 2.4
Minimum	0.11 ± 0.18	0.12 ± 0.12	0.0000 ± 0.0000	0.0023 ± 0.0020	0.1 ± 1.4	11 ± 2.8
Maximum	0.43 ± 0.18	0.42 ± 0.26	0.0011 ± 0.0006	0.0071 ± 0.0034	0.4 ± 1.2	22 ± 4
$\bar{x}$ ± 2s	0.29 ± 0.33	0.27 ± 0.30	0.0007 ± 0.0013	0.0041 ± 0.0053	0.3 ± 0.3	15 ± 12

[a]Mass of 1 kg used for each analysis (100 times usual mass).

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

TABLE E-XXIII

RADIOCHEMICAL ANALYSES OF PERIMETER SOILS AND SEDIMENTS

Location	Map Designation	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)
Soils								
Sportsman Club	S1	0.05 ± 0.12	0.71 ± 0.12	0.000 ± 0.002	0.048 ± 0.014	21 ± 10	25 ± 6	6.3 ± 0.8
TA-8	S2	0.00 ± 0.14	1.9 ± 0.18	0.004 ± 0.002	0.101 ± 0.014	21 ± 6	33 ± 6	0.3 ± 0.6
TA-49	S3	2.15 ± 0.18	0.64 ± 0.10	0.003 ± 0.002	0.051 ± 0.012	21 ± 10	27 ± 6	2.0 ± 0.6
Frijoles	S4	0.77 ± 0.12	0.75 ± 0.12	0.002 ± 0.006	0.035 ± 0.014	17 ± 8	22 ± 4	0.4 ± 0.6
West of Airport	S7	0.70 ± 0.10	0.36 ± 0.14	0.001 ± 0.002	0.061 ± 0.012	12 ± 6	14 ± 3	3.8 ± 0.6
South of SR-4 Near S-Site	S8	2.0 ± 0.20	0.71 ± 0.18	0.003 ± 0.002	0.029 ± 0.008	17 ± 8	17 ± 4	0.1 ± 0.6
No. of Analyses		6	6	6	6	6	6	6
Minimum		0.00 ± 0.14	0.36 ± 0.14	0.000 ± 0.002	0.029	12 ± 6	14 ± 3	0.1 ± 0.6
Maximum		2.15 ± 0.18	1.9 ± 0.18	0.004 ± 0.002	0.101	21 ± 10	33 ± 6	6.3 ± 0.8
Average		0.95	0.85	0.002	0.054	18	23	2.1
2s		1.87	1.07	0.003	0.051	7	14	4.9
Sediments								
Guaje at SR-4	2	0.08 ± 0.02	0.97 ± 0.16	0.001 ± 0.002	0.003 ± 0.002	2.7 ± 1.4	2.4 ± 0.8	−0.3 ± 0.6
Bayo at SR-4	3	0.04 ± 0.10	−0.02 ± 0.14	0.001 ± 0.002	0.000 ± 0.002	3.0 ± 1.6	3.3 ± 1.0	1.6 ± 0.6
Acid Weir	4	1.0 ± 0.12	---	0.085 ± 0.032	14.9 ± 1.00	11 ± 4.0	3.9 ± 1.0	0.2 ± 0.6
Pueblo at PC-1	5	0.10 ± 0.00	---	0.005 ± 0.006	0.037 ± 0.014	1.3 ± 0.8	1.7 ± 0.8	−1.0 ± 0.6
Pueblo at Pueblo 1	6	0.50 ± 0.10	---	0.030 ± 0.008	3.93 ± 0.120	10 ± 4.0	2.3 ± 0.8	−0.4 ± 0.6
Pueblo at Pueblo 2	7	0.29 ± 0.08	---	0.011 ± 0.006	2.77 ± 0.120	5.3 ± 2.4	2.8 ± 1.0	−0.8 ± 0.6
Los Alamos at Totavi	9	1.9 ± 0.22	0.32 ± 0.12	0.010 ± 0.004	0.012 ± 0.016	2.5 ± 1.2	4.1 ± 1.0	3.2 ± 0.8
Los Alamos at LA-2	10	0.09 ± 0.04	3.2 ± 1.4	0.000 ± 0.000	0.002 ± 0.002	1.9 ± 1.0	1.6 ± 0.8	0.1 ± 0.6
Los Alamos at Rio Grande	11	0.18 ± 0.08	0.07 ± 0.18	0.000 ± 0.002	0.002 ± 0.002	6.6 ± 3.2	6.9 ± 1.8	0.6 ± 0.6
Sandia at Rio Grande	12	0.18 ± 0.06	---	---	---	4.3 ± 1.0	4.5 ± 1.2	---
Cañada del Ancha	13	0.06 ± 0.06	---	0.000 ± 0.000	0.000 ± 0.002	2.1 ± 1.0	1.4 ± 0.8	---
Mortandad at SR-4	14	0.02 ± 0.08	4.6 ± 2.4	0.000 ± 0.002	0.003 ± 0.002	3.8 ± 1.8	2.2 ± 0.8	2.3 ± 0.8
Mortandad at Rio Grande	15	0.04 ± 0.10	---	---	---	3.3 ± 1.6	3.8 ± 1.0	---
Cañada del Buey at SR-4	16	0.20 ± 0.00	0.06 ± 0.16	0.003 ± 0.002	0.009 ± 0.006	5.9 ± 2.6	5.3 ± 1.4	6.1 ± 0.8
Pajarito at Rio Grande	17	0.19 ± 0.06	---	---	---	2.2 ± 1.2	2.8 ± 1.0	---
Frijoles at Park Hdq.	18	0.16 ± 0.06	0.73 ± 0.34	0.000 ± 0.000	0.003 ± 0.002	2.1 ± 1.0	1.3 ± 0.6	0.1 ± 0.6
Frijoles at Rio Grande	19	0.23 ± 0.12	---	0.000 ± 0.002	0.001 ± 0.002	1.4 ± 0.8	1.4 ± 0.4	---
No. of Analyses		17	8	14	14	17	17	12
Minimum		0.02 ± 0.08	−0.02 ± 0.14	0.000 ± 0.000	0.000 ± 0.002	1.3 ± 0.8	1.3 ± 0.6	−0.3 ± 0.6
Maximum		1.9 ± 0.22	4.6 ± 2.4	0.085 ± 0.032	14.9 ± 1.00	11 ± 4.0	6.9 ± 0.8	6.1 ± 0.8
Average		0.31	1.24	0.010	1.5	4.0	3.0	0.9
2s		0.95	3.44	0.046	8.1	5.7	3.1	4.1

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

TABLE E-XXIV

RADIOCHEMICAL ANALYSES OF ONSITE SOIL AND SEDIMENTS

Location	Map Designation	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)
Soils								
TA-21	S9	0.47 ± 0.10	4.4 ± 1.6	0.001 ± 0.002	0.151 ± 0.022	17 ± 8	17 ± 4	3.3 ± 0.6
TA-50	S10	0.08 ± 0.12	−1.4 ± 1.6	0.003 ± 0.002	0.010 ± 0.006	15 ± 6	14 ± 3	8.3 ± 0.8
West of TA-53	S13	0.85 ± 0.14	0.52 ± 0.32	0.000 ± 0.002	0.025 ± 0.008	18 ± 8	25 ± 6	12 ± 0.8
East of TA-52	S17	2.2 ± 0.20	0.39 ± 0.16	0.000 ± 0.002	0.009 ± 0.004	27 ± 12	21 ± 4	1.4 ± 0.6
Two Mile Mesa	S18	--	0.43 ± 0.28	0.002 ± 0.002	0.030 ± 0.012	29 ± 14	30 ± 6	1.0 ± 0.6
Near TA-51	S19	0.37 ± 0.12	−0.08 ± 0.18	0.001 ± 0.002	0.000 ± 0.000	40 ± 18	31 ± 3	1.4 ± 0.6
East of TA-54	S20	0.10 ± 0.40	−0.87 ± 0.38	0.003 ± 0.002	0.018 ± 0.006	10 ± 4	10 ± 8	2.8 ± 0.6
R-Site Road East	S22	0.31 ± 0.10	0.34 ± 0.10	0.002 ± 0.002	0.005 ± 0.004	12 ± 6	13 ± 3	0.3 ± 0.6
Potrillo Drive	S23	0.40 ± 0.12	0.21 ± 0.12	0.000 ± 0.000	0.008 ± 0.004	9 ± 4	8 ± 2	0.4 ± 0.6
S-Site	S24	3.0 ± 0.32	0.69 ± 0.16	0.003 ± 0.002	0.006 ± 0.004	13 ± 6	18 ± 4	0.5 ± 0.6
Near TA-11	S25	2.9 ± 0.24	1.43 ± 0.22	0.011 ± 0.006	0.076 ± 0.018	13 ± 6	20 ± 4	0.5 ± 0.6
Near DT-9	S26	1.0 ± 0.12	0.35 ± 0.18	0.001 ± 0.002	0.028 ± 0.008	18 ± 8	17 ± 4	0.4 ± 0.6
Near TA-33	S27	0.73 ± 0.12	0.01 ± 0.16	0.007 ± 0.002	0.025 ± 0.008	11 ± 2	12 ± 3	40 ± 1.6
No. of Analyses		12	13	13	13	13	13	13
Minimum		0.10 ± 0.40	−1.4 ± 1.6	0.000 ± 0.000	0.000 ± 0.000	9 ± 4	8 ± 2	0.3 ± 0.6
Maximum		3.0 ± 0.32	4.4 ± 1.6	0.011 ± 0.006	0.151 ± 0.022	40 ± 18	31 ± 3	40 ± 1.6
Average		1.0	0.49	0.003	0.030	18	18	5.6
2s		2.1	2.73	0.006	0.082	18	14	22

TABLE E-XXIV (Continued)

Location	Map Designation	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	^{3}H (10^{-6} μCi/mℓ)
Sediments								
Pueblo at Hamilton Bend Springs	20	0.12 ± 0.08	---	0.013 ± 0.006	0.700 ± 0.000	2.1 ± 1.2	64 ± 12	−0.4 ± 0.6
Pueblo at SR-4	22	0.14 ± 0.06	0.10 ± 0.12	0.001 ± 0.002	0.600 ± 0.000	11 ± 4.0	3.5 ± 1.0	7.5 ± 1.6
DP Canyon at DPS-1	23	18 ± 1.2	---	2.11 ± 0.140	4.40 ± 0.200	2.6 ± 1.2	3.5 ± 1.0	2.2 ± 0.6
DP Canyon at DPS-4	24	16 ± 1.2	---	0.169 ± 0.018	0.460 ± 0.020	3.0 ± 1.4	5.2 ± 1.2	14 ± 3.2
Los Alamos at Bridge	25	0.02 ± 0.08	−0.07 ± 0.10	0.005 ± 0.000	0.000 ± 0.000	3.4 ± 1.6	2.1 ± 0.8	0.0 ± 0.6
Los Alamos at LAO-1	26	0.16 ± 0.10	0.52 ± 0.12	0.000 ± 0.000	0.010 ± 0.000	3.8 ± 1.8	7.1 ± 1.6	3.0 ± 0.6
Los Alamos at GS-1	27	8.3 ± 0.80	1.11 ± 0.24	0.149 ± 0.036	0.440 ± 0.080	5.1 ± 2.2	11 ± 2.2	2.0 ± 0.6
Los Alamos at TW-3	28	7.1 ± 0.60	0.29 ± 0.14	0.081 ± 0.017	0.280 ± 0.240	3.3 ± 1.6	8.1 ± 1.8	2.7 ± 0.6
Los Alamos at LAO-4	29	6.2 ± 0.60	0.66 ± 0.20	0.102 ± 0.016	0.360 ± 0.360	4.7 ± 2.0	7.4 ± 1.6	3.0 ± 0.6
Los Alamos at SR-4	30	2.6 ± 0.20	0.43 ± 0.16	0.063 ± 0012	0.280 ± 0.020	2.9 ± 1.4	5.1 ± 1.2	---
Sandia at SR-4	32	0.03 ± 0.04	0.06 ± 0.16	0.000 ± 0.002	0.004 ± 0.004	3.4 ± 1.6	3.4 ± 1.0	4.9 ± 3.0
Mortandad at CMR	33	0.10 ± 0.16	---	0.084 ± 0.014	0.063 ± 0.000	3.7 ± 1.6	16 ± 3.4	2.1 ± 0.6
Mortandad at GS-1	34	73 ± 6.0	---	3.48 ± 0.020	18.4 ± 1.00	33 ± 14	46 ± 10	2.1 ± 0.6
Mortandad at MCO-2	35	116 ± 8.0	---	15.9 ± 0.600	68.1 ± 2.20	1.9 ± 1.2	1.8 ± 0.8	2.6 ± 0.6
Mortandad at GS-1	36	580 ± 60	---	60.1 ± 0.140	299 ± 6.00	33 ± 14	41 ± 8.0	46 ± 1.8
Mortandad at MCO-5	37	67 ± 4.0	---	3.36 ± 0.100	1.36 ± 0.060	230 ± 100	410 ± 80	3.3 ± 0.6
Mortandad at MCO-7	38	33 ± 3.0	---	1.43 ± 0.040	0.384 ± 0.024	13 ± 2.8	38 ± 8.0	2.1 ± 0.6
Mortandad at MCO-9	39	1.0 ± 0.10	---	0.012 ± 0.006	0.123 ± 0.018	9 ± 4.0	32 ± 4.0	1.3 ± 0.6
Mortandad at MCO-13	40	1.1 ± 0.14	---	0.018 ± 0.006	0.128 ± 0.016	5.1 ± 2.2	30 ± 3.2	1.5 ± 0.6
Pajarito at SR-4	42	0.44 ± 0.12	0.50 ± 0.18	0.001 ± 0.002	0.020 ± 0.006	16 ± 8.0	14 ± 3.2	1.8 ± 0.6
Potrillo at SR-4	45	0.10 ± 0.60	−0.04 ± 0.20	0.000 ± 0.002	0.035 ± 0.008	2.2 ± 1.2	1.2 ± 0.6	8.1 ± 3.0
Water at Beta Hole	46	0.17 ± 0.10	0.06 ± 0.14	0.000 ± 0.000	0.003 ± 0.002	1.7 ± 1.0	1.3 ± 0.6	0.3 ± 0.6
Water at SR-4	47	0.07 ± 0.16	0.10 ± 0.16	0.004 ± 0.002	0.002 ± 0.002	3.6 ± 1.8	4.6 ± 1.2	4.7 ± 0.6
Water at Rio Grande	48	0.20 ± 0.18	---	---	---	1.6 - 0.8	2.2 ± 0.8	---
Ancho at SR-4	49	0.18 ± 0.14	0.26 ± 0.18	0.000 ± 0.000	0.007 ± 0.004	2.5 ± 1.2	3.7 ± 1.0	29 ± 1.4
Ancho at Rio Grande	50	0.10 ± 0.10	---	---	---	1.8 ± 0.8	2.7 ± 0.8	---
Chaquihui at Rio Grande	51	0.04 ± 0.20	---	0.007 ± 0.000	0.058 ± 0.014	4.4 ± 1.0	7.7 ± 1.8	---
No. of Analyses		27	13	25	25	27	27	23
Minimum		0.02 ± 0.08	−0.07 ± 0.010	0.000 ± 0.000	0.000 ± 000	1.6 ± 0.8	1.2 ± 0.6	−0.4 ± 0.6
Maximum		580 ± 60	1.11 ± 0.24	60.1 ± 0.14	299 ± 6.00	230 ± 100	410 ± 80	46 ± 1.8
Average		34	0.31	3.48	15.8	15	29	6.3
2s		225	0.67	24.5	121	87	156	21

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

E-XXV

ELEMENTAL ANALYSES OF BEES AND HONEY

Honey Analyses

Sample Location	^{7}Be (pCi/ℓ)		^{137}Cs (pCi/ℓ)			^{3}H (pCi/mℓ)			^{22}Na (pCi/ℓ)		U (ppb)		^{238,239}Pu (pCi/g)	^{241}Am (pCi/g)	F (ppm)	Hg (ppb)
	1980	1981	1979	1980	1981	1979	1980	1981	1980	1981	1979	1980	1980	1980	1980	1980
Area G	136	93	<43	<28	93	9.6	21.4	27.0	24	32	0	0	0	0	0.2	<1
DP Canyon	<266	74	<29	16	13	5.8	5.6	18.2	<34	15	0	0	0	0	0.4	<1
Effluent Canyon	<156	112	10	14	41	26.7	17.9	63.5	26	22	0	0	0	0	<0.1	<1
Mortandad Canyon	206	149	<29	4	19	11.8	27.4	13.6	<16	17	0	0.9	0	0	0.1	<1
TA-33	<94	186	<26	30	19	579	207	156	4	37	0	0	0	0	---	---
TA-16	<196	37	1	62	26	2.8	5.2	3.1	28	15	0	0	0	0	<0.1	<1
Pajarito Acres	<176	---	0	6	---	10.5	7.9	6.3	<20	---	0	0	0	0	0.4	<1
Barranca Mesa	<266	186	<9	6	93	3.6	4.0	12.7	12	47	0	0	0	0	0.1	<1
Chimayo	92	---	<11	<42	---	0.6	3.0	---	82	---	0	0	0	0	0.2	<1

Bee Analyses

Sample Location	U (ppb)		B (ppm)		As (ppm)		Cr (ppm)		F (ppm)
	1979	1980	1979	1980	1979	1980	1979	1980	1979
Area G	23	14	25	20	0.07	0.00	1.22	5.22	2.9
DP Canyon	57	99	20	15	0.00	0.00	1.33	4.43	18.0
Effluent Canyon	15	47	11	13	0.00	0.25	0.96	2.25	2.6
Mortandad Canyon	36	96	24	17	0.21	0.00	1.57	1.08	3.9
TA-33	7	44	15	17	0.00	0.12	1.45	2.52	3.9
TA-16	18	31	11	11	0.07	0.07	1.04	1.75	2.0
Pajarito Acres	---	0	---	18	---	0.00	---	2.68	---
Barranca Mesa	---	59	---	14	---	0.07	---	3.91	---
Chimayo	---	20	---	19	---	0.00	---	0.83	---

TABLE E-XXVI

QUALITY OF EFFLUENTS FROM LIQUID RADIOACTIVE WASTE TREATMENT PLANTS FOR 1981

Radioactive Isotopes	Waste Treatment Plant Location: TA-50 Activity Released (mCi)	TA-50 Average Concentration (μCi/mℓ)	TA-21 Activity Released (mCi)	TA-21 Average Concentration (μCi/mℓ)
^{238}Pu	2.9	5.2×10^{-8}	0.45	1.0×10^{-7}
^{239}Pu	54.7	9.9×10^{-7}	0.70	1.6×10^{-7}
^{241}Am	22.7	4.1×10^{-7}	1.7	3.8×10^{-7}
^{89}Sr	41.5	7.5×10^{-7}	0.12	2.7×10^{-8}
^{90}Sr	22.8	4.1×10^{-7}	0.87	2.0×10^{-7}
^{3}H	17 000	3.1×10^{-4}	436	9.9×10^{-5}
^{137}Cs	122	2.2×10^{-6}	0.55	1.2×10^{-7}
^{234}U	0.95	1.7×10^{-8}	0.95	2.1×10^{-7}

Nonradioactive Constituent	Waste Treatment Plant Location: TA-50 Average Concentration (mg/ℓ)	TA-21 Average Concentration (mg/ℓ)
Cd[a]	0.0003	0.318
Ca	85	25
Cl	57	33
Cr (Total)[a]	0.037	0.092
Cu[a]	0.23	0.099
F	15.1	110.5
Hg[a]	0.0006	0.0007
Mg	4.8	5
Na	645	766
Pb[a]	0.025	0.017
Zn[a]	0.258	0.247
CN	0.032	---
COD[a]	44	61
$NO_3(N)$	262	277
PO_4	1.5	0.93
TDS	2625	2649
pH[a]	6.9 - 12.6	7.9 - 12.4
Total Effluent Volume	5.533×10^7 ℓ	4.425×10^6 ℓ

[a]Constituents regulated by National Pollutant Discharge Elimination System permit.

TABLE E-XXVII

CHEMICAL QUALITY OF WATER IN THE VICINITY OF FENTON HILL
(average of a number of analyses)

	Surface Water	Water Supply	Springs (Jemez Fault)	Springs (Volcanics)	Springs (Hot Springs)	Fenton Hill Pond Fluids
Number of Stations[a]	9	4	2	1	3	2
Number of Analyses	16	7	3	2	3	3
Chemical (mg/ℓ)						
SiO_2	46 ± 11	71 ± 9	49 ± 7	55 ± 12	77 ± 8	117 ± 84
Ca	35 ± 19	21 ± 15	229 ± 109	14 ± 0	7 ± 2	25 ± 24
Mg	6 ± 4	4 ± 1	22 ± 2	3 ± 0	3 ± 2	2 ± 0.6
Na	37 ± 32	15 ± 3	628 ± 233	10 ± 2	31 ± 17	1 388 ± 174
CO_3	2 ± 4	0 ± 0	0 ± 0	0 ± 0	0 ± 0	507 ± 638
HCO_3	87 ± 74	85 ± 19	1 035 ± 328	65 ± 1	79 ± 34	1 847 ± 849
SO_4	62 ± 103	5 ± 4	60 ± 57	3 ± 0	9 ± 6	896 ± 855
Cl	40 ± 49	10 ± 18	1 230 ± 520	2 ± 1	6 ± 2	157 ± 84
F	1.0 ± 0.6	0.7 ± 0.2	3.8 ± 0.2	1.4 ± 0.1	1.3 ± 0.2	1.3 ± 0.1
NO_3	0.2 ± 0.2	1.4 ± 0.3	1.5 ± 1.5	1.6 ± 0.0	3.1 ± 2.2	<0.4 ± 0.0
TDS	295 ± 177	189 ± 57	3 292 ± 1 188	139 ± 10	170 ± 51	5 847 ± 602
Hard	113 ± 61	70 ± 42	497 ± 175	47 ± 0.7	27 ± 14	72 ± 63
pH	6.9 ± 1.4	7.2 ± 0.4	6.5 ± 0.4	6.7 ± 0.1	7.6 ± 0.4	9.6 ± 1.4
Conductance (mS/m)	42.5 ± 28.2	21.5 ± 9.7	510 ± 185	15.5 ± 7	17 ± 7.8	630 ± 105

[a]Sample locations key in Fig. 22 as follows:
Surface water—Locations F, J, N, Q, R, S, T, U, and V.
Water supply—Locations JS-2, JS-3, JS-4, JS-5, FH-1, and FH-4.
Springs (Jemez Fault)—Locations JF-1 and JF-5.
Springs (Volcanic)—Location 31.
Springs (Hot Spring)—RV-2, RV-4, and RV-5.
Fenton Hill (pond fluids)—Drilling fluids and circulation fluids from tests.

TABLE E-XXVIII

TOTAL SUSPENDED PARTICULATES IN AIR AT LOS ALAMOS AND WHITE ROCK DURING 1981

(Data from New Mexico Environmental Improvement Division. All concentrations in $\mu g/m^3$.)

Los Alamos (Annual Geometric Mean = 38)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Number of Samples	5	5	5	5	4	5	5	5	5	6	5	5
Maximum	53	47	48	53	40	59	47	62	61	66	96	48
Minimum	29	21	18	25	27	37	31	22	14	49	58	29
Mean	41	35	30	39	34	46	38	42	39	60	81	39
±1s	10	12	13	10	5	8	7	16	19	6	15	7

White Rock (Annual Geometric Mean = 40)

Number of Samples	5	5	5	5	4	5	5	3	6	6	5	5
Maximum	58	82	41	65	56	80	167	32	35	85	72	52
Minimum	26	27	12	14	38	37	19	25	12	37	47	28
Mean	40	50	31	39	45	60	55	29	27	59	60	42
±1s	12	21	12	21	8	20	63	4	9	15	11	9

TABLE E-XXIX

QUANTITIES OF VOLATILE CHEMICALS AND COMPRESSED GASES USED AT LOS ALAMOS
(all amounts in kg)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Acids										
Acetic Acid	---	---	---	---	---	---	410	220	190	230
Hydrochloric Acid	---	---	---	---	---	---	3 700	4 200	5 400	6 500
Hydrofluoric Acid	---	---	---	---	---	---	8 100	6 400	170	420
Nitric Acid	---	---	---	---	---	---	80 000	58 100	71 900	99 500
Perchloric Acid	---	---	---	---	---	---	390	140	290	230
Phosphoric Acid	---	---	---	---	---	---	710	450	320	480
Sulfuric Acid	---	---	---	---	---	---	1 700	2 300	1 800	2 200
Gases										
Ammonia	4 200	2 700	3 200	2 600	2 600	2 900	3 000	2 500	2 600	2 900
Carbon Monoxide	---	---	---	---	4 900	6 200	9 300	5 500	4 800	6 200
Chlorine	---	---	---	---	500	680	500	640	1 100	1 200
Freon 12	---	---	---	---	2 500	3 400	2 800	2 000	2 100	3 300
Hydrogen Fluoride	---	---	---	---	1 300	950	360	500	1 300	1 000
Nitrogen Oxides	---	---	---	---	7 800	6 700	640	1 200	350	440
Sulfur Dioxide	---	---	---	---	120	290	160	110	150	370
Sulfur Hexafluoride	17 400	6 700	10 300	11 400	12 200	13 700	9 200	11 400	6 900	10 600
Inorganic Chemicals										
Ammonium Hydroxide	---	---	---	---	---	---	---	2 200	1 600	1 900
Mercury	---	---	---	---	500	290	180	140	140	200
Organic Chemicals										
Acetone	18 800	9 200	12 400	16 100	15 500	12 700	10 600	8 300	7 900	10 200
Carbon Tetrachloride	300	290	250	100	250	230	200	280	100	180
Chloroform	360	250	500	380	370	190	160	200	310	250
Ethanol	---	---	---	---	---	9 200	10 900	9 900	9 400	11 800
Freons	10 900	13 300	15 000	10 200	12 400	13 800	8 200	9 200	12 800	12 500
Kerosene	8 100	5 000	5 900	4 800	4 600	4 400	3 800	4 100	5 800	5 300
Methanol	590	540	1 500	1 700	6 600	4 300	2 600	3 300	2 400	3 400
Methylene Chloride	820	820	310	1 000	820	2 200	250	170	180	230
Methyl Ethyl Ketone	---	---	---	2 300	9 400	10 600	14 300	22 000	11 400	21 000
Perchloroethylene	3 400	680	1 000	820	680	1 000	1 400	340	1 400	9 100
Toluene	2 300	2 100	1 200	2 700	3 300	1 600	2 100	2 100	650	60
Trichloroethane	25 600	18 300	25 800	22 900	34 000	28 300	24 100	23 800	28 200	39 300
Trichloroethylene	20 400	15 500	16 200	9 400	13 200	10 200	7 400	6 900	3 400	3 200

TABLE E-XXX

ESTIMATED CONCENTRATIONS OF TOXIC ELEMENTS
AEROSOLIZED BY DYNAMIC EXPERIMENTS

Element	1981 Total Usage (kg)	Per Cent Aerosolized (%)	Annual Average Concentration (ng/m^3) 4 km	8 km	Applicable Standard (ng/m^3)
Uranium	1087	10	0.11	0.04	9000[a]
Be	10.6	2	0.0003	0.0001	10[b] (30 day av)
Pb	57.6	100[c]	0.06	0.025	1500[d] (3 month av)

[a]Department of Energy Order 5480.1, Chapter XI.
[b]Section 201 of the Ambient Air Quality Standards and Air Quality Control Regulations adopted by the New Mexico Health and Social Services Board, April 19, 1974.
[c]Assumed percentage aerosolization.
[d]40 CFR 50.12.

TABLE E-XXXI

SANITARY SEWAGE TREATMENT FACILITIES EFFLUENT QUALITY SUMMARY[a]

Discharge Location	Permit Constituents	Number of Deviations	Range of: Deviation / Limiting Standard or pH
TA-3	BOD[b]	3	1.02 - 1.18
	TSS[c]	1	1.16
	Fecal Coliform[d]	4	73 - 184
	Flow (MGD)[e]	0	---
	pH[f]	0	---
TA-9	BOD	0	---
	TSS	0	---
	Flow (MGD)	218	1.04 - 4.56
	pH	0	---
TA-16	BOD	0	---
	TSS	1	1.06
	Flow (MGD)	0	---
	pH	0	---
TA-18	BOD	3	1.02 - 1.19
	TSS	14	1.04 - 13.2
	Flow (MGD)	6	1.4 - 4.56
	pH	13	9.1 - 9.7
TA-21	BOD	0	---
	TSS	0	---
	Fecal Coliform[d]	8	1.2 - 73
	Flow (MGD)	0	---
	pH	0	---
TA-41	BOD	2	1.06 - 1.15
	TSS	1	4.03
	Fecal Coliform[d]	2	7.0 - 8.5
	Flow (MGD)	53	1.02 - 1.49
	pH	0	---
TA-46	BOD	0	---
	TSS	0	---
	Flow (MGD0	128	1.008 - 2.12
	pH	0	---
TA-48	BOD	0	---
	TSS	0	---
	Flow	0	---
	pH	0	---
TA-53	BOD	0	---
	TSS	7	1.06 - 2.28
	Flow (MGD)	97	0.56 - 1.66
	pH	9	9.3 - 10.3
TA-35	BOD	8	1.06 - 2.85
	TSS	12	1.006 - 5.24
	Flow (MGD)	0	---
	pH	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 mg/ℓ (20-day avg), 45 mg/ℓ (7 day avg).
[d]Fecal coliform limits are 2000/100 mℓ (daily max) and 1000/100 mℓ (geometric mean).
[e]Flow effluent limit will be removed when permit is reissued.
[f]The pH range limit is not less than 6.0 or greater than 9.0 standard units.

TABLE E-XXXII

INDUSTRIAL LIQUID EFFLUENT QUALITY SUMMARY[a]

Discharge Category	Number of Outfalls	Permit Constituents	Number of Deviations	Range of: Deviation / Limiting Standards or pH[b]	Number of Outfalls Causing Deviations
Power Plant	2 [c]	TSS	11	1.08 - 1030	3
		Free Cl	0	---	0
		pH	14	1.9 - 11.9	2
Boiler Blowdown	1 [d]	TSS	1	2.67	1
		Fe	0	---	0
		Cu	3	1.31 - 2.32	1
		P	0	---	0
		pH	9	9.5 - 11.9	1
Treated Cooling Water	30 [e]	TSS	2	1.13 - 3.41	1
		Free Cl	0	---	0
		P	0	---	0
		pH	3	9.1 - 9.4	1
Noncontact Cooling Water	30 [f]	pH	0	---	0
Radioactive Waste Treatment Plant Discharges	2	NH_3	0	---	0
		COD	0	---	0
		TSS	1	1.001	1
		Cd	0	---	0
		Cr	1	1.46	1
		Cu	0	---	0
		Fe	2	1.08 - 2.1	1
		Pb	0	---	0
		Hg	0	---	0
		Zr	0	---	0
		pH	0	---	0
High Explosives Waste Discharges	20 [g]	COD	9	1.06 - 9.68	6
		TSS	8	1.15 - 29.98	3
		pH	1	9.2	1

TABLE E-XXXII (Continued)

Discharge Category	Number of Outfalls	Permit Constituents	Number of Deviations	Range of: [Deviation / Limiting Standards] or pH[b]	Number of Outfalls Causing Deviations
Photo Waste Discharges	14 [h]	Cn	0	---	0
		TSS	0	---	0
		pH	0	---	0
		Ag	4	2.42 - 22.5	3
Printed Circuit Board Development Wastes	1	COD	0	---	0
		Cu	6	2.5 - 14.6	1
		Fe	5	6.1 - 42.75	1
		Ni	0	---	0
		P	0	---	0
		pH	6	2.8 - 3.6	1
Acid Dip Tank Rinse	1 [i]	Cu	0	---	0
		pH	0	---	0
Gas Cylinder Cleaning Waste	1 [j]	TSS	0	---	0
		P	0	---	0
		pH	0	---	0

[a]Summary of reports to EPA or NPDES Permit NM 0028355.
[b]The pH range limit on all outfalls is not less than 6.0 or greater than 9.0 standard units.
[c]Reduced from 6 outfalls to 2 outfalls in 1981.
[d]Reduced from 3 outfalls to 1 outfall in 1981.
[e]Reduced from 35 outfalls to 30 outfalls in 1981.
[f]Reduced from 33 outfalls to 30 outfalls in 1981.
[g]Reduced from 22 outfalls to 20 outfalls in 1981.
[h]Reduced from 15 outfalls to 14 outfalls in 1981.
[i]Eliminated in 1981.
[j]Use discontinued in 1981.

TABLE E-XXXIII

MEANS[a] AND EXTREMES OF TEMPERATURE AND PRECIPITATION— CLIMATOLOGICAL SUMMARY (1911-1981) FOR LOS ALAMOS, NEW MEXICO[b]

	Temperature (°C)										
	Means			Extremes							
				High Monthly		Low Monthly		High Daily		Low Daily	
Month	Mean Max	Mean Min	Avg	Mean	Year	Mean	Year	Max	Date	Min	Date
Jan	4.3	−7.5	−1.6	3.1	1953	−6.2	1930	17.8	1/12/53	−27.8	1/13/63
Feb	6.1	−5.8	0.2	3.0	1934	−5.0	1939	18.9	2/24/36	−25.6	2/1/51
											2/8/33
March	9.3	−3.0	3.2	7.7	1972	0.0	1948	21.7	3/26/71	−19.4	3/11/48
									3/30/76		
April	14.2	1.0	7.6	12.4	1954	4.3	1973	26.1	4/23/38	−15.0	4/9/28
May	19.4	6.0	12.7	15.8	1956	10.1	1957	31.7	5/29/35	−4.4	4 Dates
June	25.4	11.3	18.4	20.8	1980	15.8	1965	35.0	6/22/81	−2.2	6/3/19
July	26.9	13.4	20.2	21.9	1980	17.4	1926	35.0	7/11/35	2.8	7/7/24
Aug	25.2	12.4	18.8	21.3	1936	16.1	1929	33.3	8/10/37	4.4	8/16/47
Sept	22.3	9.1	15.7	18.8	1956	13.4	1965	34.4	9/11/34	−5.0	9/29/36
Oct	16.7	3.7	10.2	12.6	1963	6.9	1976	28.9	10/1/80	−9.4	10/19/76
Nov	9.3	−2.7	3.3	6.9	1949	−0.8	1972	22.2	11/1/50	−25.6	1/28/76
Dec	5.2	−6.5	−0.6	10.1	1980	−4.1	1931	17.8	12/27/80	−25.0	12/9/78
Annual	15.3	2.6	9.0	11.1	1954	6.8	1932	35.0	7/11/35	−27.8	1/13/63
									6/22/81		

	Precipitation (mm)										Mean Number of Days		
	Rain[c]					Snow							
Month	Mean	Mo. Max	Year	Daily Max	Date	Mean	Mo. Max	Year	Daily Max	Date	Precip ≥2.5 mm	Max Temp >32°C	Min Temp <0°C
Jan	21.6	171.5	1916	64.5	1/27/16	246	998	1949	381	1/5/13	2	0	30
Feb	17.3	62.0	1948	26.7	2/20/15	186	605	1948	330	2/20/15	2	0	26
March	25.7	104.4	1973	57.2	3/30/16	247	914	1973	457	3/30/16	3	0	24
April	21.8	117.9	1915	50.8	4/12/75	129	853	1958	508	4/12/75	2	0	13
May	28.7	113.5	1929	45.7	5/21/29	21	432	1917	305	5/2/78	3	0	2
June	28.5	141.5	1913	63.8	6/10/13	0	---	---	---	---	3	1	0
July	80.8	202.7	1919	62.7	7/31/68	0	---	---	---	---	8	1	0
Aug	99.8	284.0	1952	57.4	8/1/51	0	---	---	---	---	9	0	0
Sept	41.4	147.1	1941	56.1	9/22/29	2	152	1913	152	9/25/13	4	0	0
Oct	38.6	172.0	1957	88.4	10/5/11	42	229	1972	229	10/31/72	3	0	7
Nov	24.4	167.6	1978	45.0	11/25/78	128	665	1931	356	11/22/31	2	0	22
Dec	24.9	72.4	1965	40.6	12/6/78	293	1049	1967	559	12/6/78	3	0	30
Annual	453.4	770.6	1941	88.4	10/5/11	1295	2540	1958	559	12/6/78	43	2	154

TABLE E-XXXIII (Continued)

CLIMATOLOGICAL SUMMARY 1981

	Temperature (°C)						
	Means			Extremes			
Month	Mean Max	Mean Min	Avg	High	Date	Low	Date
Jan	7.8	−5.5	1.2	13.3	5	−5.5	17
Feb	10.2	−5.3	2.4	18.3	19	−13.9	11
March	8.7	−3.5	2.6	15.6	26	−7.2	7
April	18.1	2.6	10.4	25.6	30	−7.2	5
May	19.0	4.6	11.8	25.6	27	−3.3	9
June	28.1	11.0	19.5	35.0	22	1.7	4
July	28.1	12.4	20.3	34.4	21	10.0	2
Aug	25.8	11.1	18.4	31.7	5	7.8	28
Sept	22.6	9.2	15.9	26.1	2	6.1	24
Oct	15.8	2.7	9.3	20.6	5	−3.9	31
Nov	12.4	−1.6	5.4	18.9	16	−9.4	26
Dec	8.0	−5.2	1.4	16.1	7	−16.1	24
Annual	17.1	2.7	9.9	35.0	6/22	−16.1	12/24

	Precipitation (mm)						Number of Days		
	Rain[b]			Snow					
Month	Total	Daily Max	Date	Total	Daily Max	Date	Precip ≥2.5 mm	Max Temp >32°C	Min Temp <0°C
Jan	1.3	1.3	18	30	30	18	0	0	31
Feb	2.3	1.5	10	33	25	10	0	0	27
March	69.3	25.4	11	747	381	11	5	0	31
April	19.0	9.4	14	25	25	15	3	0	8
May	55.1	15.2	1	0	0	---	6	0	2
June	31.0	9.4	23	0	0	---	3	8	0
July	85.3	19.0	1	0	0	---	10	6	0
Aug	70.1	16.8	31	0	0	---	9	0	0
Sept	60.2	15.2	4	0	0	---	8	0	0
Oct	34.8	21.6	2	0	0	---	3	0	8
Nov	21.1	19.0	29	38	31	29	1	0	23
Dec	0.3	0.3	31	5	5	31	0	0	30
Annual	449.8	25.4	3/11	879	381	3/11	47	14	160

[a]Means based on standard 30-year period: 1951-1980.
[b]Latitude 35° 32' north, longitude 106° 19' west; elevation 2260 m.
[c]Includes liquid water equivalent of frozen precipitation.

TABLE E-XXXIV

HIGHLIGHTS OF WEATHER DURING 1981

January	Average temperature = 1.2°C (34.1°F). Warmest since 1956. 3rd warmest January. 4th driest January: 1.3 mm (0.05 in.). Only 30 mm (1.2 in.) of snow. TMDH on the 1st: 11.1°C (52°F). TMDH on the 5th: 12.2°C (54°F). TMDH on the 9th: 11.7°C (53°F). Windstorm on 31st: gust of 29 m/sec (65 mph).
February	Average temperature = 2.4°C (36.4°F). 5th warmest February. Dry: only 2.3 mm (0.09 in.) precipitation and 33 mm (1.3 in.) snow. SMDH on the 15th: 13.9°C (57°F). SMDH on the 16th: 15.0°C (59°F). SMDH on the 18th: 15.6°C (60°F). SMDH on he 19th: 18.3°C (65°F). SMDH on the 25th: 16.1°C (61°F).
Winter 80-81 (Dec. 80-Feb. 81)	Average temperature = 2.4°C (36.3°F). Warmest winter on record (Previous warmest: 1953-1954 and 1979-1980). Driest winter on record: 11.9 mm (0.47 in.) precipitation (Previous record: 26.9 mm (1.06 in. for 1957-1958). 4th least snowfall: 241 mm (9.5 in.).
March	4th wettest March: 69.3 mm (2.73 in.) precipitation. 4th snowiest March: 747 mm (29.4 in.) snow. SMDP on the 2nd: 15.2 mm (0.60 in.) precipitation. Snowstorm on the 11th. SMDP on the 11th: 25.4 mm (1.00 in.) precipitation. SMDS on the 11th: 381 mm (15.0 in.) snow. Windstorm on the 21st: gusts to 33 m/sec (73 mph).

TABLE E-XXXIV (Continued)

April	Average temperature = 10.4°C (50.7°F). 3rd warmest April. Windstorm/duststorm on the 3rd: gusts to 36 m/sec (78 mph). SMDH on the 25th: 24.4°C (76°F). SMDH on the 26th: 24.4° (76°F). SMDH on the 27th: 23.3°C (74°F). SMDH on the 28th: 23.3°C (74°F). SMDH on the 29th: 23.3°C (74°F). SMDH on the 30th: 25.6°C (78°F).
June	Warm June. Average maximum temperature = 28.1°C (82.6°F). Second highest average maximum temperature for June. SMDH on the 7th: 30.6°C (87°F). SMDH on the 8th: 31.7°C (89°F). SMDH on the 9th: 32.2°C (90°F). SMDH on the 10th: 32.2°C (90°F). SMDH on the 11th: 32.2°C (90°F). TMDH on the 18th: 32.2°C (90°F). SMDH on the 20th: 33.3°C (92°F). SMDH on the 21st: 34.4°C (94°F). SMDH on the 22nd: 35.0°C (95°F). TMDH on the 24th: 32.2°C (90°F).
July	SMDP on the 1st: 19.0 mm (0.75 in.). SMDH on the 20th: 33.3°C (92°F). SMDH on the 21st: 34.4°C (94°F).
August	SMDH on the 5th: 31.7°C (89°F).
November	4th warmest November on record. Warmest since 1966. SMDH on the 16th: 18.9°C (66°F). TMDH on the 17th: 17.8°C (64°F). TMDH on the 23rd: 15.6°C (60°F). SMDH on the 24th: 18.9°C (66°F). SMDP on the 29th: 19.0 mm (0.75 in.).
December	Driest December on record: 0.25 mm (0.01 in.) precipitation. Tied record for least snow in December: 5.1 mm (0.2 in.). Very warm December. SMDH on the 7th: 16.1°C (61°F). SMDH on the 8th: 15.6°C (60°F). SMDH on the 9th: 15.6°C (60°F). SMDH on the 10th: 14.4°C (58°F).

TABLE E-XXXIV (Continued)

Annual	Average temperature = 9.88°C (49.78°F). Mean annual temperature (1951-1980) = 8.97°C (48.14°F). 4th warmest year on record. Warmest since 1956. 1981 precipitation = 449.8 mm (17.71 in.). Mean annual precipitation (1951-1980) = 453.4 mm (17.85 in.). 1981 snowfall = 879 mm (34.6 in.). Mean annual snowfall (1951-1980) = 1295 mm (51.0 in.).

Key for Abbreviations

SMDH: Set Maximum Daily High Temperature Record
SMDL: Set Minimum Daily Low Temperature Record
SMDP: Set Maximum Daily Precipitation Record
SMDS: Set Maximum Daily Snowfall Record
TMDH: Tied Maximum Daily High Temperature Record
TMDL: Tied Minimum Daily Low Temperature Record

TABLE E-XXXV

RESULTS FROM SULPHLEX EXPERIMENTS

Plant	Control	1% Asphalt	1% Sulphlex
	Chlorophyll (mg/g tissue)		
Beans (Exp. 2)	0.82 ± 0.17	0.95 ± 0.16	1.06 ± 0.22
Beans (Exp. 4)	1.31 ± 0.19	1.68 ± 0.42	1.47 ± 0.31
Grass (Exp. 5)	1.53 ± 0.37	1.59 ± 0.30	1.73 ± 0.13
Beans (Exp. 5)	1.11 ± 0.32	1.23 ± 0.28	1.24 ± 0.31
Barley (Exp. 5)	1.13 ± 0.46	1.14 ± 0.27	1.23 ± 0.26
Beans (Exp. 6)	1.00 ± 0.46	0.83 ± 0.21	1.12 ± 0.33
Barley (Exp. 6)	1.27 ± 0.29	1.32 ± 0.29	1.51 ± 0.22
	Dry Plant Weight (g)		
Beans (Exp. 1)	3.52 ± 0.98	3.41 ± 1.92	2.94 ± 1.20
Grass (Exp. 3)	0.39 ± 0.14	0.47 ± 0.09	0.45 ± 0.16
Beans (Exp. 4)	2.24 ± 0.42	1.21 ± 0.54	1.65 ± 0.59
Beans (Exp. 5)	1.16 ± 0.28	1.90 ± 0.91	0.96 ± 0.23
Barley (Exp. 5)	0.63 ± 0.17	0.54 ± 0.21	0.69 ± 0.13
Beans (Exp. 5)	1.16 ± 0.35	1.41 ± 0.38	1.48 ± 0.42
Barley (Exp. 6)	0.75 ± 0.19	0.52 ± 0.12	0.54 ± 0.14
	Dry Weight Bean Pods (g)		
Exp. 2	0.64 ± 0.15	0.54 ± 0.20	0.15 ± 0.07
Exp. 4	1.09 ± 0.55	0.70 ± 0.46	0.12 ± 0.15
Exp. 5	0.93 ± 0.26	1.08 ± 0.48	0.64 ± 0.25
Exp. 6	0.63 ± 0.26	0.57 ± 0.20	0.40 ± 0.22
	Average Number of Seeds per Plant		
Exp. 2	0.65 ± 0.90	0.90 ± 0.55	0
Exp. 4	1.60 ± 1.23	1.79 ± 1.47	0.13 ± 0.35
Exp. 5	2.00 ± 0.82	1.89 ± 1.36	1.33 ± 0.87

TABLE E-XXXVI

ANALYTICAL RESULTS OF SAMPLES TAKEN BELOW LAMPF LAGOONS

	^3H ($\times 10^5$)					
	1979		1980		1981	
	Low	High	Low	High	Low	High
Water (pCi/ℓ)						
Loc. 1	4.00 ± 0.20	11.8 ± 0.19	5.55 ± 0.09	9.47 ± 0.15	3.62 ± 0.06	6.68 ± 0.10
Loc. 2	3.90 ± 0.20	11.5 ± 0.18	5.53 ± 0.09	8.30 ± 0.13	3.52 ± 0.06	6.79 ± 0.10
Loc. 3	4.20 ± 0.20	10.8 ± 0.17	5.49 ± 0.09	9.77 ± 0.15	3.60 ± 0.06	6.70 ± 0.10
Loc. 4	4.60 ± 0.20	8.01 ± 0.13	5.05 ± 0.03	9.65 ± 0.15	3.60 ± 0.06	6.47 ± 0.09
Loc. 8	0.004 ± 0.003	0.029 ± 0.004	0.02 ± 0.003	0.05 ± 0.004	0.004 ± 0.003	0.14 ± 0.003
Sediment (pCi/g)						
Loc. 1	5.64 ± 0.09	9.57 ± 0.15	5.87 ± 0.09	9.65 ± 0.15	3.82 ± 0.06	6.41 ± 0.09
Loc. 2	4.63 ± 0.07	10.4 ± 0.2	2.01 ± 0.03	9.61 ± 0.15	3.72 ± 0.06	6.30 ± 0.09
Loc. 3	4.85 ± 0.08	10.5 ± 0.2	3.49 ± 0.06	9.61 ± 0.15	3.59 ± 0.06	6.97 ± 0.09
Loc. 4	1.38 ± 0.03	8.47 ± 0.13	4.29 ± 0.07	8.31 ± 0.13	3.70 ± 0.06	6.54 ± 0.09
Loc. 5	0.076 ± 0.004	3.27 ± 0.05	0.008 ± 0.0003	0.102 ± 0.006	0.04 ± 0.004	2.43 ± 0.17
Loc. 6	0	0.062 ± 0.004	0.006 ± 0.0003	0.079 ± 0.002	0.02 ± 0.004	1.04 ± 0.912
Loc. 7	0	0.055 ± 0.004	0.011 ± 0.003	0.102 ± 0.016	0.007 ± 0.004	0.280 ± 0.004
Loc. 8	1.131 ± 0.005	0.140 ± 0.020	0.016 ± 0.003	0.120 ± 0.01	0 ± 0.003	0.209 ± 0.008
Transpirate (pCi/ℓ)						
Loc. 2	0.012 ± 0.003	6.60 ± 0.40	0.016 ± 0.003	6.30 ± 0.10	1.21 ± 0.02	5.62 ± 0.09
Loc. 3	0.042 ± 0.004	3.97 ± 0.06	0.04 ± 0.004	5.71 ± 0.09	1.80 ± 0.03	4.00 ± 0.06
Loc. 4	0.007 ± 0.003	2.28 ± 0.04	0.019 ± 0.004	4.15 ± 0.07	1.34 ± 0.02	4.05 ± 0.06
Loc. 5	0.003 ± 0.003	0.007 ± 0.003	0.004 ± 0.003	0.054 ± 0.004	0.013 ± 0.003	0.038 ± 0.003
Loc. 6	0.003 ± 0.004	0.011 ± 0.003	0.014 ± 0.003	0.018 ± 0.003	0.009 ± 0.004	0.022 ± 0.003
Loc. 7	0.007 ± 0.004	0.012 ± 0.003	0.010 ± 0.003	0.034 ± 0.003	0.016 ± 0.004	0.030 ± 0.003
Loc. 8	0.004 ± 0.003	0.015 ± 0.003	0.024 ± 0.004	0.033 ± 0.003	0.042 ± 0.003	0.014 ± 0.003

TABLE E-XXXVI (Continued)

	^{7}Be					
	1979		1980		1981	
	Low	High	Low	High	Low	High
Water (pCi/ℓ)						
Loc. 1	11 100 ± 1100	$3.4 \pm 0.1 \times 10^{5}$	40 000 ± 3000	$2.7 \pm 0.1 \times 10^{5}$	220 ± 50	$1.09 \pm 0.06 \times 10^{6}$
Loc. 2	1050 ± 110	$6.9 \pm 0.2 \times 10^{5}$	37 000 ± 3000	$4.9 \pm 0.3 \times 10^{5}$	590 ± 70	$5.80 \pm 0.30 \times 10^{6}$
Loc. 3	140 ± 160	$1.0 \pm 0.03 \times 10^{5}$	32 000 ± 2000	$2.2 \pm 0.2 \times 10^{5}$	890 ± 50	$7.1 \pm 0.4 \times 10^{5}$
Loc. 4	16 600 ± 600	$6.0 \pm 0.2 \times 10^{4}$	13 000 ± 1100	$2.9 \pm 0.2 \times 10^{5}$	719 ± 19	$4.3 \pm 0.1 \times 10^{5}$
Loc. 8	60 ± 50	90 ± 120	<150	900 ± 500	0 ± 160	<500
Sediment (pCi/g)						
Loc. 1	148 ± 15	5900 ± 600	1180 ± 70	3370 ± 170	950 ± 30	30 000 ± 1600
Loc. 2	340 ± 30	10 200 ± 1000	3.4 ± 1.4	7000 ± 400	5000 ± 300	20 700 ± 900
Loc. 3	134 ± 4	12 200 ± 1200	2470 ± 100	9000 ± 400	300 ± 10	13 500 ± 600
Loc. 4	21.5 ± 0.7	1180 ± 130	33 ± 3	5700 ± 300	2720 ± 130	50 000 ± 3000
Loc. 5	0.07 ± 0.02	740 ± 70	0 ± 1.3	1.7 ± 0.8	0.7 ± 0.7	460 ± 20
Loc. 6	0.04 ± 0.02	1.8 ± 1.7	0.2 ± 0.3	1.1 ± 0.6	0.1 ± 0.7	51.8 ± 1.8
Loc. 7	0.05 ± 0.03	1.3 ± 0.8	0.3 ± 0.5	1.1 ± 0.6	0 ± 0.3	0.7 ± 0.3
Loc. 8	0.05 ± 0.02	1.6 ± 0.9	0.2 ± 0.5	2.1 ± 0.8	0 ± 1.17	3.0 ± 0.8
Transpirate (pCi/ℓ)						
Loc. 2	0 ± 700	2000 ± 5000	0	2200 ± 1700	0 ± 300	800 ± 1700
Loc. 3	0	3000 ± 3000	0	200 ± 700	0 ± 300	900 ± 400
Loc. 4	0 ± 400	800 ± 600	<90	2000 ± 3000	0 ± 18	1700 ± 1200
Loc. 5	<200	5000 ± 2000	0	800 ± 500	0 ± 500	1400 ± 130
Loc. 6	<80	900 ± 400	0	1000 ± 600	10 ± 19	700 ± 400
Loc. 7	30 ± 60	500 ± 300	0	900 ± 600	0 ± 30	50 ± 1000
Loc. 8	0	2000 ± 3000	<200	<200	0 ± 16	400 ± 300

TABLE E-XXXVI (Continued)

	^{22}Na					
	1979		1980		1981	
	Low	High	Low	High	Low	High
Water (pCi/ℓ)						
Loc. 1	1060 ± 50	3360 ± 150	2550 ± 90	6000 ± 400	530 ± 60	9200 ± 200
Loc. 2	930 ± 40	3270 ± 140	2600 ± 190	5700 ± 400	400 ± 60	5000 ± 300
Loc. 3	970 ± 50	3010 ± 110	2490 ± 160	6500 ± 400	3080 ± 170	7500 ± 400
Loc. 4	870 ± 40	1940 ± 70	2420 ± 160	5200 ± 400	3340 ± 190	8900 ± 200
Loc. 8	3 ± 6	3 ± 6	<3	80 ± 40	12 ± 20	12 ± 20
Sediment (pCi/g)						
Loc. 1	1.55 ± 0.17	2.8 ± 1.5	1.57 ± 0.11	8.1 ± 0.4	4.5 ± 0.3	8.4 ± 0.6
Loc. 2	2.00 ± 0.20	8.3 ± 1.3	4.2 ± 0.3	17.1 ± 1.1	11.9 ± 0.6	26 ± 1
Loc. 3	0.40 ± 0.06	1.73 ± 0.18	3.4 ± 0.3	4.6 ± 0.4	2.7 ± 0.1	13.3 ± 0.7
Loc. 4	0.81 ± 0.10	2.6 ± 0.3	4.0 ± 0.3	7.3 ± 0.3	8.5 ± 0.5	52 ± 4
Loc. 5	0.04 ± 0.04	1.55 ± 0.19	0.03 ± 0.19	0.14 ± 0.06	0 ± 0.08	2.19 ± 0.12
Loc. 6	0	0.07 ± 0.05	<0.01	0.07 ± 0.09	0 ± 0.04	0.47 ± 0.05
Loc. 7	0.01 ± 0.04	0.06 ± 0.05	<0.01	0.05 ± 0.06	0.05 ± 0.07	0.1 ± 0.04
Loc. 8	0.01 ± 0.04	0.07 ± 0.11	0.04 ± 0.06	0.13 ± 0.06	0 ± 0.03	0.14 ± 0.06
Transpirate (pCi/ℓ)						
Loc. 2	0	50 ± 40	20 ± 20	70 ± 60	0 ± 10	130 ± 200
Loc. 3	<8	500 ± 300	10 ± 30	50 ± 40	0 ± 30	170 ± 30
Loc. 4	0	90 ± 40	20 ± 40	400 ± 300	0 ± 10	15 ± 20
Loc. 5	11 ± 18	60 ± 30	<10	50 ± 60	0 ± 70	90 ± 50
Loc. 6	9 ± 23	80 ± 100	10 ± 50	40 ± 17	0 ± 20	20 ± 40
Loc. 7	<2	80 ± 70	60 ± 30	90 ± 50	0 ± 30	80 ± 100
Loc. 8	0	20 ± 70	60 ± 40	60 ± 40	0 ± 17	80 ± 60

TABLE E-XXXVII

METAL ION ANALYSES OF VEGETATION AND SOILS IN POND RELEASE AREA AT FENTON HILL
(all values in ppm)

Sample Type	Channel											
	100 m			200 m			400 m			1000 m		
	Vegetation	Roots	Soil	Vegetation	Roots	Soil	Vegetation	Roots	Soil	Vegetation	Roots	Soil
Fall 78												
As	0.22	---	---	0	---	---	0.12	---	---	0.34	---	---
Cd	0	---	---	0	---	---	0	---	---	0	---	---
Li	3.5	---	---	9.1	---	---	12.9	---	---	1.93	---	---
Spring 79												
As	0.44	---	---	0.21	---	---	0	---	---	0	---	---
B	150	---	---	286	---	---	350	---	---	26	---	---
Cd	0.17	---	---	0.15	---	---	0.15	---	---	0.19	---	---
Li	46	---	---	109	---	---	239	---	---	2.6	---	---
Fall 79												
As	---	0.97	---	---	5.39	---	---	1.86	---	---	1.60	---
B	---	13	---	---	21	---	---	28	---	---	20	---
F	---	50	---	---	34	---	---	78	---	---	47	---
Spring 80												
As	0	8.37	10	0.31	5.86	43	0.12	2.13	12	0	0.31	2
B	236	56	22	245	64	44	237	34	25	21	9	18
F	---	---	380	---	---	290	---	---	160	---	---	110
Fall 80												
As	0	---	8.4	0	---	3.4	0	---	5.7	0	---	2.4
B	173	---	31	182	---	42	113	---	36	18	---	18
F	---	---	420	---	---	140	---	---	180	---	---	105
Spring 81												
As	0	7.17	6.1	0	1.23	7.3	0	1.79	5.7	---	0.16	3.2
B	1390	78	33	1270	95	120	182	30	11	---	14	12
F	5	39	---	1.8	32	---	---	3.2	6.4	---	6.3	---
Fall 81												
B	210	73	38	110	140	51	130	61	17	13	36	15

TABLE E-XXXVII (Continued)

Sample Type	Bank														
	100 m			200 m			400 m			1000 m			Lower Canyon		
	Vegetation	Roots	Soil	Vegetation	Roots	Soil	Vegetation	Roots	Soil	Vegetation	Roots	Soil	Vegettion	Roots	Soil
Fall 78															
As	0.13	---	---	0.14	---	---	0.06	---	---	0	---	---	0.08	---	---
Cd	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Li	1.93	---	---	1.93	---	---	0.69	---	---	1.00	---	---	1.00	---	---
Spring 79															
As	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
B	0	---	---	0	---	---	0	---	---	0	---	---	0	---	---
Cd	0.27	---	---	0.19	---	---	0.14	---	---	0.27	---	---	0.15	---	---
Li	0.8	---	---	0.8	---	---	3.3	---	---	0.8	---	---	2.6	---	---
Fall 79															
As	---	2.24	---	---	0.67	---	---	0.45	---	---	0.78	---	---	0.41	---
B	---	14	---	---	0	---	---	9	---	---	8	---	---	0	---
F	---	66	---	---	28	---	---	25	---	---	23	---	---	14	---
Spring 80															
As	0.07	0.41	12	0.08	0.12	10	0	0.76	3	0	0.35	5	0.06	0.27	3
B	21	9	16	14	0	19	13	13	15	11	0	25	10	0	14
F	---	---	100	---	---	110	---	---	100	---	---	200	---	---	220
Fall 80															
As	0	---	---	0	---	4.2	0	---	3.3	0.15	---	4.8	0	---	3.2
B	32	---	---	30	---	13	9	---	19	9	---	23	10	---	20
F	---	---	---	---	---	80	---	---	95	---	---	160	---	---	210
Spring 81															
As	0.26	0.34	0.5	0	0.45	7.3	26.3	0.36	3.1	0.09	0.10	3.3	1.8	0.09	4.9
B	18	22	15	24	18	16	20	19	20	27	15	23	66	10	16
F	2.9	19	---	2.3	21	---	7.8	22	---	13	11.2	---	10.5	9	---
Fall 81															
B	15	42	16	14	29	16	20	28	15	12	35	15	15	21	19

APPENDIX F

DESCRIPTIONS OF TECHNICAL AREAS AND THEIR ASSOCIATED PROGRAMS

Locations of the 31 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, Personnel Administration Department offices, Materials Department, the science museum, Chemistry and Metallurgy Division, Physics Division, 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 tritium research. DP East is the high temperature chemistry site where studies are conducted on the chemical stability and interaction of materials at temperatures up to and exceeding 3300°C.

TA-22, TD Site: See TA-6.

TA-28, Magazine Area "A": Explosives storage area.

TA-33, HP-Site: Design and development of nuclear and other components of weapon systems are conducted here. A major 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. Also located here is an underground laboratory that is used for physics experiments.

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 contaminated liquid waste received from Laboratory technical areas, for development of improved methods of waste treatment, and for containment of radioactivity removed by treatment. Radioactive waste is piped to this site for treatment from many of the technical areas.

TA-51, Radiation Exposure Facility: Here animals are irradiated 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 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

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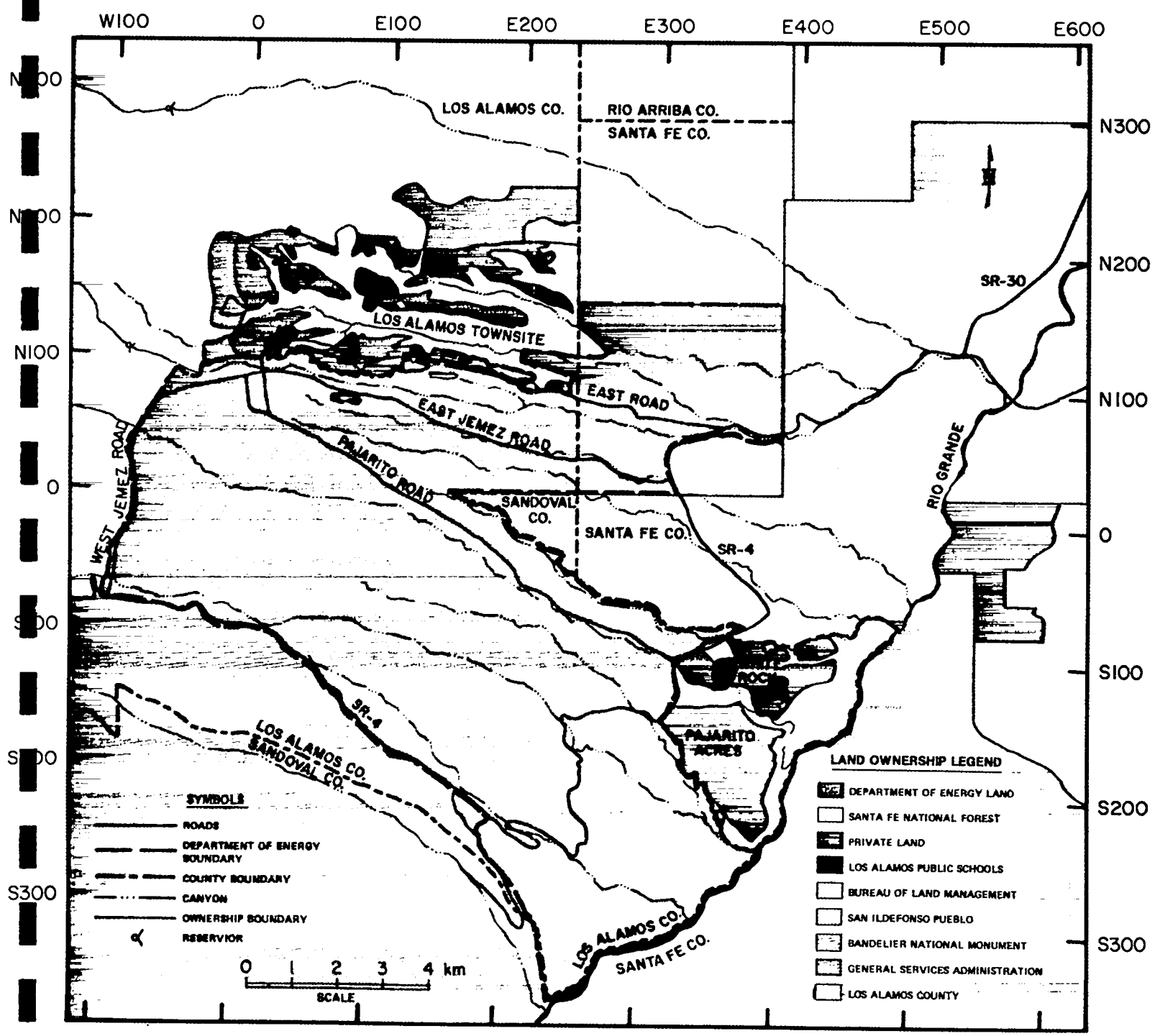

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