LA-8200-ENV
UC-41
Issued: April 1980

Environmental Surveillance at Los Alamos During 1979

Environmental Surveillance Group

10748

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UNITED STATES
DEPARTMENT OF ENERGY
CONTRACT W-7405-ENG. 36

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ACRONYMS AND ABBREVIATIONS

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
ERDA	Energy Research and Development Administration
FEIS	final environmental impact statement
H-7	Waste Management Group at LASL
H-8	Environmental Surveillance Group at LASL
HDR	hot dry rock
HT	tritium gas
HTO	tritiated water
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
LAMPF	Los Alamos Meson Physics Facility
LASL	Los Alamos Scientific Laboratory
LERC	Laboratory Environmental Review Committee
LS-6	Environmental Science Group at LASL
MAP	mixed activation products
MCL	maximum contaminant level
MFP	mixed fission products
N	normal (chemical term)
NBS	National Bureau of Standards
NEPA	National Environmental Policy Act
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
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} ℓ)
mm	millimeter (10^{-3} m)
mrem	millirem (10^{-3} rem)
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)
rad	62.5×10^6 MeV/g (unit of absorbed dose)
rem	roentgen equivalent mean (unit of dose equivalence)
s	second
yr	year

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1979

Environmental Surveillance Group

ABSTRACT

This report documents the environmental surveillance program conducted by the Los Alamos Scientific Laboratory (LASL) in 1979. 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 the data for 1979 on penetrating radiation, chemical and radiochemical quality of ambient air, surface and ground water, municipal water supply, soils and sediments, food, and airborne and liquid effluents are included. Comparisons with appropriate standards and regulations or with background levels from natural or other non-LASL sources provide a basis for concluding that environmental effects attributable to LASL operations are minor and cannot be considered likely to result in any hazard to the population of the area. Results of several special studies provide documentation of some unique environmental conditions in the LASL environs.

I. ENVIRONMENTAL MONITORING SUMMARY

Los Alamos Scientific Laboratory (LASL) policy emphasizes protection of the general public and environment from any harm which 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 LASL during 1979.

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 the 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 the various types of measurements are organized in 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 LASL. They provide a basis for determining natural conditions beyond the range for potential influence of LASL operations. Perimeter stations are located primarily within about 4 km (2.5 mi) of the LASL boundary (see Fig. 1) and emphasize locations in the adjacent

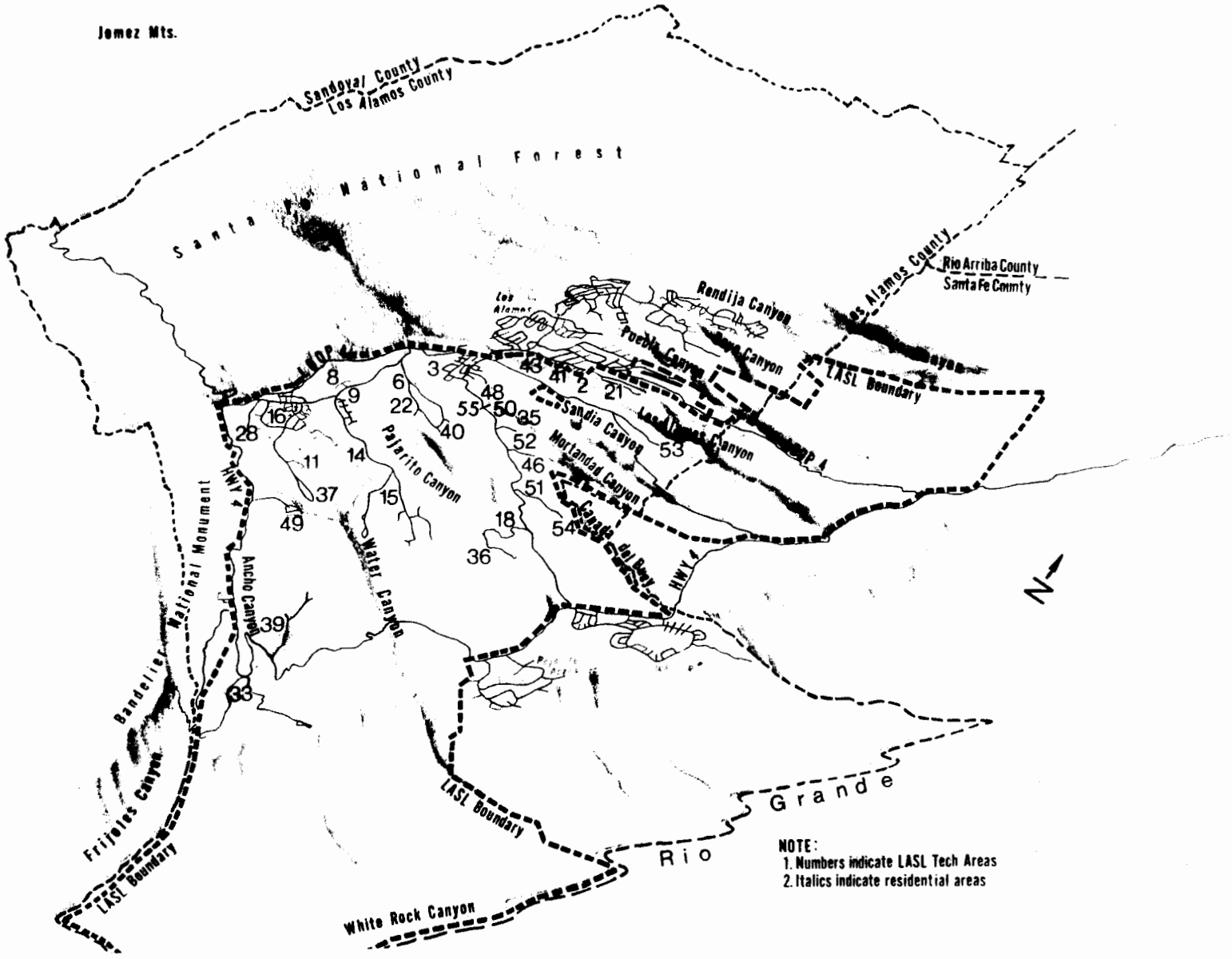


Fig. 1.
Topography of the Los Alamos, New Mexico area.

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

The types of routine monitoring conducted at these stations include measurements of radiation and collection of samples of air, water, soils, and foodstuffs for subsequent laboratory analysis. External penetrating radiation (the x and gamma ray contributions from natural cosmic and terrestrial sources, plus any Laboratory contributions) was measured at 55 locations by thermoluminescent dosimeters. Airborne radioactivity samples were accumulated during monthly intervals by continuously operating samplers at 25 locations. Surface and groundwater samples were collected periodically at 113 locations: 71 of which are indicated in Table I, 22 for the DOE water supply wells and distribution system, and 20 related to the Hot Dry Rock Geothermal Project at Fenton Hill.

Samples of foodstuffs, principally vegetables, fruit, and fish, were collected at 24 locations. Soil and sediment samples were collected periodically from 86 locations. Additional samples were collected at various times and locations to gain information on particular events such as major runoff events in intermittent streams and nonroutine releases or for special studies. During 1979, more than 17 000 analyses for chemical and radiochemical constituents were performed on these environmental samples. The resulting data were used for comparison with standards and natural background, as bases for calculations, and other interpretations.

B. Summary of 1979 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.

TABLE I

LASL MONITORING PROGRAM AND NUMBER OF SAMPLING LOCATIONS

Type of Monitoring	Number of Sampling Stations in Group		
	Regional	Perimeter	Onsite
External Radiation	3	12	40
Air	3	11	11
Surface and Ground Water[a]	6	28	37
Soils and Sediments	16	27	43
Foodstuffs	8	7	9

[a]An additional 22 stations for the water supply and 20 special stations related to the Fenton Hill Geothermal Program were also sampled.

1. Penetrating Radiation

Levels of penetrating radiation, including x and gamma rays from cosmic, terrestrial, and man-made sources in the Los Alamos area, are monitored with thermoluminescent dosimeters (TLDs) at 55 locations divided into regional, perimeter, and onsite groups. No measurements at regional or perimeter locations in the environmental network for any calendar quarter showed any statistically distinguishable increase in radiation levels that could be attributed to LASL operations (see Table II). The apparent differences between the regional and perimeter groups are attributable to differences in the natural radioactivity content of geologic formations. Quarterly measurements at the 16 onsite stations in the routine environmental network were expectably above background levels, reflecting ongoing research activities at LASL. Twenty-four of the forty onsite TLD stations are specially located to monitor radioactivity from the Los Alamos Meson Physics Facility (LAMPF).

2. Radioactivity in Air and Water

Measurements of radioactivity in air and water are compared to standards, known as Concentration Guides (CGs) that are applicable to all federal agencies (see Appendix A). CGs 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 1979 results for total measurements (that is, including the amount present from worldwide fallout) of the main isotopes potentially influenced by LASL operations are shown in Table III as ranges of percentages of the

TABLE II

EXTERNAL PENETRATING RADIATION DURING 1979

	Dose (mrem)		
Group	**Minimum**	**Maximum**	**Average**
Regional	84	97	92
Perimeter	112	147	128
Onsite	109	252	144

TABLE III

RADIONUCLIDE CONCENTRATIONS IN AIR AND WATER AS PERCENTAGES OF CONCENTRATION GUIDES[a]

	% CG		
	Regional	**Perimeter**	**Onsite**
Air			
^{3}H (as HTO)	0.0-0.006	0.0-0.01	0.0-0.03
^{239}Pu	0.0-0.03	0.0-0.06	0.0-0.07
U	0.0-0.02	0.0-0.002	0.0-0.002
Water			
^{3}H (as HTO)	0.01-0.04	0.0-0.02	0.0-0.3
^{239}Pu	0.0-0.01	0.0-0.00009	0.0-0.0005
^{137}Cs	0.0-0.3	0.0-0.2	0.0-0.2

[a]Values in tables are $(\bar{x} - 2\ s)$ to $(\bar{x} + 2\ s)$ as % CG.

CGs. The values shown represent a statistical range (from two standard deviations below to two standard deviations above the mean) that encompasses 90-95% of the individual results. All comparisons in Table III are with CGs applicable to individuals in the general public, even though many onsite locations are not accessible to the public.

During 1979, no statistically significant difference was observed between atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranium measured at sampling locations along the Laboratory perimeter and those measured in distant areas. This indicates Laboratory contributions to concentrations of these contaminants were less than local variability in background levels. Tritiated water vapor concentrations at four onsite stations were five to fifteen times higher than regional background levels and are attributable to LASL operations, whereas concentrations at the other seven onsite stations were statistically indistinguishable from regional background concentrations. The data in Table III show that tritium (^{3}H), plutonium (^{239}Pu), and uranium (U) atmospheric concentrations were only small fractions of their respective CGs. Results from only 1 of 55 ^{238}Pu samples and 1 of 44 ^{241}Am samples were above their respective analytical detection limits and were not included in Table III. Gross alpha and beta analyses serve as crude indicators of overall radioactivity levels. The highest gross alpha concentration was 3.7% of the most relevant CG and the highest gross beta concentration was 0.02% of the most relevant CG.

Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from LASL operations. Results of analyses are compared to CGs (see Table III) as an indication of the low concentrations or radionuclides in the environment. Other radioactivities 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 gross indicators of radioactivity), and uranium (concentrations low and generally indistinguishable from levels naturally in the environment). Results of the 1979 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite noneffluent release areas indicate no significant effect from effluent releases from LASL. Waters in the onsite liquid effluent release areas contain measurably higher concentrations of radioactivity, but at levels still small fractions of CGs. These onsite waters are not a source of industrial, agricultural, or municipal water supplies.

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

3. 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 the next section and compared to Radiation Protection Standards as an interpretation of their significance.

Measurements of radioactivity in soils and sediments are also useful as a means for monitoring and understanding the hydrologic transport of some radioactivity occurring in intermittent stream channels in and adjacent to the LASL site as a result of past and current liquid waste disposal operations. Pueblo, Los Alamos, and Mortandad Canyons all have concentrations of radioactivity on sediments at levels higher than 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 variability in such measurements. No radioactivity on sediments has been transported past the LASL 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 LASL 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 1979 show no increments of radioactivity distinguishable from that attributable to natural sources or worldwide fallout at any offsite location. At onsite locations near facilities emitting tritium, some elevated levels of tritiated water were found in fruit and in honey from an experimental hive.

4. Radiation Doses

Individual whole-body radiation doses to members of the public attributable to LASL operations are compared to applicable Radiation Protection Standards (RPSs) in Table IV. Radiation doses for various mechanisms of exposure are expressed as a percentage of the 500 mrem/yr RPS. This RPS 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.

The estimated maximum regional doses shown in Table IV for direct external radiation and airborne radioactivity are both based on exposure to theoretically calculated concentrations of emissions from LAMPF and the research 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 LASL boundary north of LAMPF and are attributable to its operation. The perimeter food pathway is based on consumption of honey from an experimental hive located onsite but near the LASL boundary. The onsite external radiation dose is that estimated for a commuter regularly travelling past a LASL facility on one of the DOE roads normally open to public travel. The onsite airborne pathway was calculated for a half-day visit to the science museum-personnel building area. The onsite food pathway could occur from consumption of venison from a deer frequenting a canyon where treated liquid effluents are discharged. Another perspective is provided by comparing these estimated doses with the estimated whole body dose attributable to worldwide fallout (from inhalation, ingestion of food, and external radiation) in the United States, which is about 0.9% of the RPS.

5. Interpretation of Significance

To provide a perspective for comparing the significance of radiation exposures, estimates of the added risk of cancer were calculated. The increase in risk estimated for average individual exposures to ionizing radiation from LASL operations are presented in Table V, along with estimated incremental risks from natural and diagnostic medical radiation. The factors for risk estimation are those

TABLE IV

COMPARISON OF INDIVIDUAL WHOLE BODY RADIATION DOSES WITH RADIATION PROTECTION STANDARDS
(Values are per cent of RPS. For Individual in Public: 500 mrem/yr)

Calculated Doses Attributable to LASL Operations from:	% RPS		
	Regional	Perimeter	Onsite
Direct External Radiation	<0.001	0.6	0.1
Airborne Radioactivity	<0.001	0.6	<0.001
Food Pathways	<0.001	0.005	0.8

TABLE V

ADDED INDIVIDUAL CANCER MORTALITY RISKS ATTRIBUTABLE TO RADIATION EXPOSURE

Exposure Source	Added Risk (Chance) of Cancer Mortality	Dose (mrem) Used in Risk Estimate
Average Exposure from LASL Operations		
Los Alamos Townsite	1 in 13 000 000	0.8
White Rock Area	1 in 130 000 000	0.08
Natural Radiation		
Cosmic and Terrestrial		
Los Alamos Townsite	1 in 88 000	114 [a]
White Rock Area	1 in 96 000	104 [a]
Self Irradiation	1 in 420 000	24
Medical x-rays (Diagnostic Procedures)		
Average Whole Body Exposure	1 in 97 000	103

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

given by the International Commission on Radiological Protection (ICRP) 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 ICRP 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 (NCRP) 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 V.

The maximum potential LASL contribution to the cancer risk is extremely small when compared to overall cancer risks. Further perspective is gained by noting the average risk in New Mexico of contracting a cancer from all causes is 1 chance in 405 each year. The overall United States lifetime risk of contracting some form of cancer is 1 chance in 4 and the lifetime risk of cancer mortality is 1 chance in 5.

6. Other Monitoring Results

Airborne radioactive emissions were monitored as released from 90 exhaust stacks at LASL and were typical of releases during the past several years. The greatest change during 1979 was an increase in plutonium emissions by a factor of about 10 due to problems in one experimental facility. This did not result in any increase in average ambient air concentrations offsite distinguishable from worldwide fallout. Tritium emissions decreased somewhat in spite of a release of about 3000 Ci (0.3 g) from an accident in one experimental laboratory. No measurable offsite effect resulted, and the maximum theoretically calculated dose was less than 0.05% of the RPS. Liquid effluents from two radioactive waste treatment plants and one sanitary sewage lagoon contained some radioactivity, all at levels well within CGs.

Nonradioactive effluents include airborne and liquid discharges. Airborne effluents 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 108 industrial discharge points and 10 sanitary sewage treatment facilities. This year 6 of the 10 sanitary sewage treatment facilities exceeded one or more of the NPDES limits (excluding flow rate limitations) in one or more months, and less than 1% of all samples from the 108 industrial outfalls exceeded NPDES limits.

Some special environmental research programs were conducted this year to gain a better understanding of the ecosystems at LASL. Among these projects were the study of fire ecology, flora, water quality, elk migration, climatology, transuranic waste management methods, and radionuclide detection instrumentation.

II. BACKGROUND ON LOS ALAMOS

A. Physical Characteristics of the Area

1. Geographic Setting

The Los Alamos Scientific Laboratory and associated residential areas of Los Alamos and White Rock are located in Los Alamos County in northcentral New Mexico, aproximately 100 km (60 mi.) NNE of Albuquerque and 40 km (25 mi.) NW of Santa Fe (Fig. 2). 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.

Most Laboratory and community developments are confined to mesa tops (see Fig. 1 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 U.S. Forest Service and U.S. Park Service (see land ownership map inside back cover). The Pueblo de San Ildefonso borders the Laboratory to the east.

All Los Alamos County and vicinity locations referenced in this report are identified by the LASL cartesian coordinate system, which is based on English units of measurement. This system is standard throughout the Laboratory but is independent of the U.S. Geological Survey and New Mexico State Survey coordinate sytems. 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 LASL boundary is controlled by the DOE, which has the option to completely restrict access. This control can be instituted when necessary.

2. Geology-Hydrology

Canyons and mesas in the Laboratory area are generally formed by Bandelier Tuff (see Fig. 3, tuff) composed of 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 and 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 intermittent stream flow. 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).

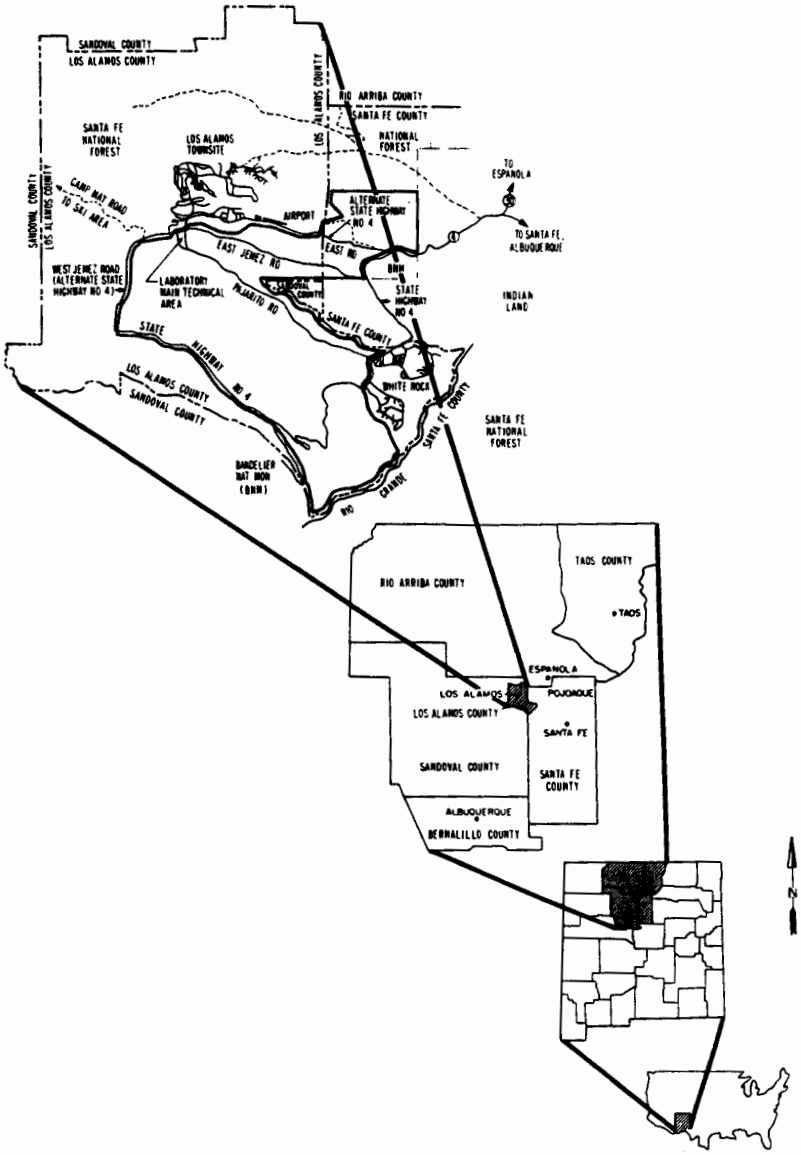


Fig. 2.
Regional location of Los Alamos.

Ground water occurs in three modes in the Los Alamos area: (1) water in shallow alluvium in canyons, (2) perched water, 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 is quite permeable in contrast to the underlying volcanic tuff and sediments. Intermittent runoff in canyons infiltrates alluvium until its downward movement is impeded by the less permeable tuff and volcanic sediment. This results in a shallow alluvial ground water body that moves downgradient in the alluvium. As water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into underlying volcanics.[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

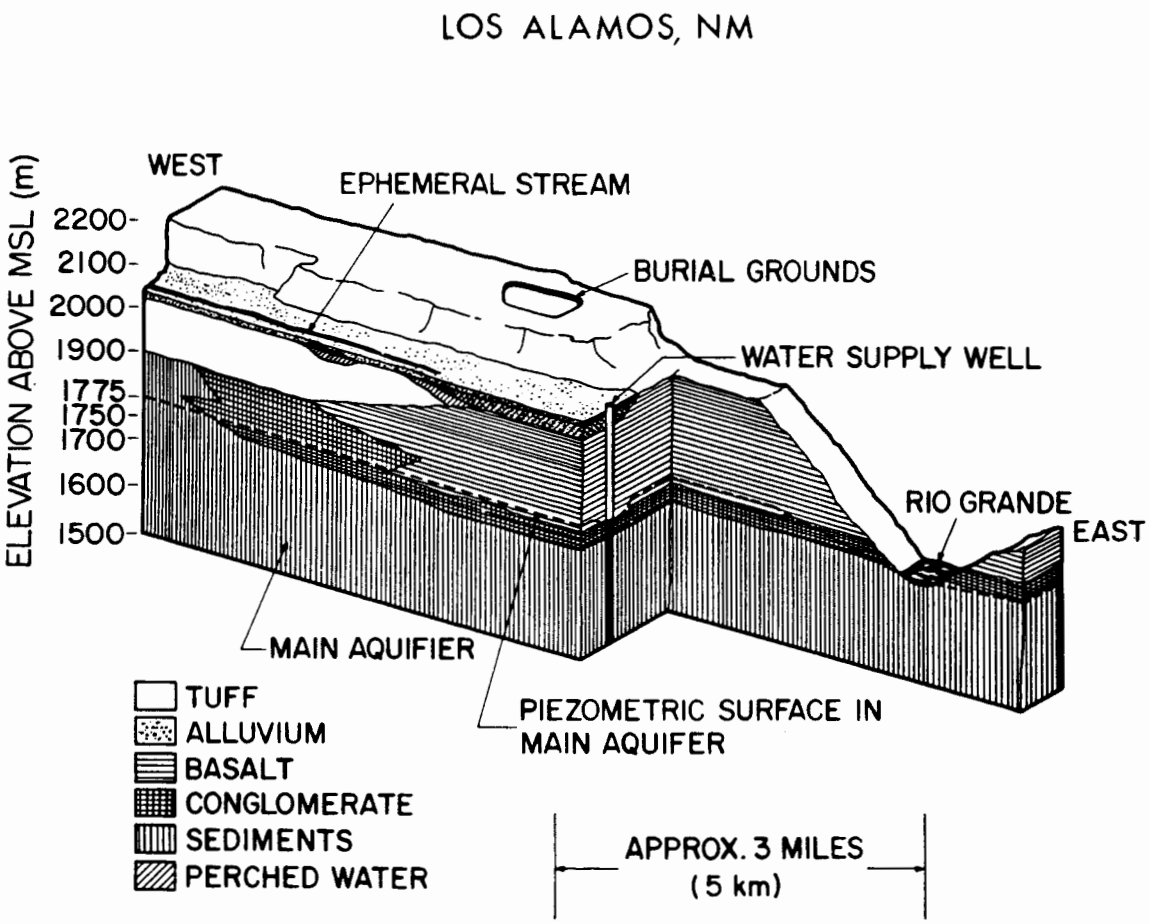


Fig. 3.
Conceptual illustration of geologic-hydrologic relationships in the Los Alamos area.

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. Perched water bodies are formed by water infiltrating from canyon alluvium into underlying volcanics until it reaches an impermeable layer that prevents further downward movement.

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 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 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 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 × 10^6 m^3 (4300 to 5500 acre-feet) annually from the aquifer.

3. Climatology

Los Alamos has a semiarid, continental mountain climate. The average annual precipitation of 46 cm (19 in) is accounted for by warm-season convective rain showers and winter migratory storms. Seventy-five per cent of the annual total moisture falls between May and October, primarily during thunderstorms. Peak shower activity is in August. Winter precipitation falls primarily as snow, with annual accumulations of about 1.3 m (4.3 ft).

Summers are cool and pleasant. Maximum temperatures are generally below 32°C (90°F) and a large diurnal variation keeps nocturnal temperatures in the 12 to 15°C (54 to 59°F) range. Winter temperatures are typically in the range from −10°C to 5°C (14 to 41°F). Many winter days are clear with light winds, and strong solar radiation makes conditions quite comfortable even when air temperatures are cold. A summary of average and 1979 weather data is presented in Fig. 4 and Table E-I.

Major spatial variation of surface winds in Los Alamos is caused by the unusual terrain. Under moderate and strong atmospheric pressure differences, flow is channeled by the major terrain features. Under weak pressure differences, a distinct daily wind cycle exists. Interaction of these two patterns gives rise to a westerly flow predominance on the western part of the Laboratory site and a southerly component at the east end of the mesas.

Historically, no tornadoes have been reported in Los Alamos County. Lightning, however, is common in the vicinity of Pajarito Plateau. Local climatological records indicate an average of 62 thunderstorm-days per year. Lightning protection is an important consideration applied to each facility at LASL.

4. Population Distribution

Los Alamos County has a population estimated at 19 600. Two residential and related commercial areas exist in the county (see Fig. 5 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, Barrance Mesa, and North Mesa), has an estimated population of 13 300. The White Rock Area (including residential areas known as White Rock, La Senda, and Pajarito Acres) has about 6300 residents. Commuting and general traffic are served by State Road 4 (SR-4), which runs through White Rock, and Loop 4, which runs through Los Alamos (see Fig. 4). Two federally owned roads, East Jemez and Pajarito Roads, cross the Laboratory site and are normally open to public use. About one third of those employed in Los Alamos commute from other counties. Population estimates for 1979 place 108 000 people within an 80 km (50 mi) radius of Los Alamos.

B. Los Alamos Scientific Laboratory

1. Programs and Facilities

Since its inception in 1943, the Laboratory's primary mission has been nuclear weapons research and development. National security programs include weapons development, laser fusion, nuclear materials research, and laser isotope separation, as well as 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 laser and magnetic fusion. In more recent years other programs have been added in applied photochemistry, astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, computers, solar energy, geothermal energy, biomedical and environmmental research, and nuclear waste management research.

A unique combination of facilities which contribute to the various research programs exists at Los Alamos. These facilities include an 800 MeV protron accelerator, a tandem Van de Graaff accelerator, a High Energy Gas Laser Facility, a Magnetic Fusion Laboratory, a flash radiographic facility, and an 8 megawatt research reactor. Some of these facilities encourage participation and joint projects by researchers from other laboratories and research facilities.

In August 1977, the LASL site, encompassing 111 km^2 (27 500 acres), was dedicated as a National Environmental Research Park. The ultimate goal of the

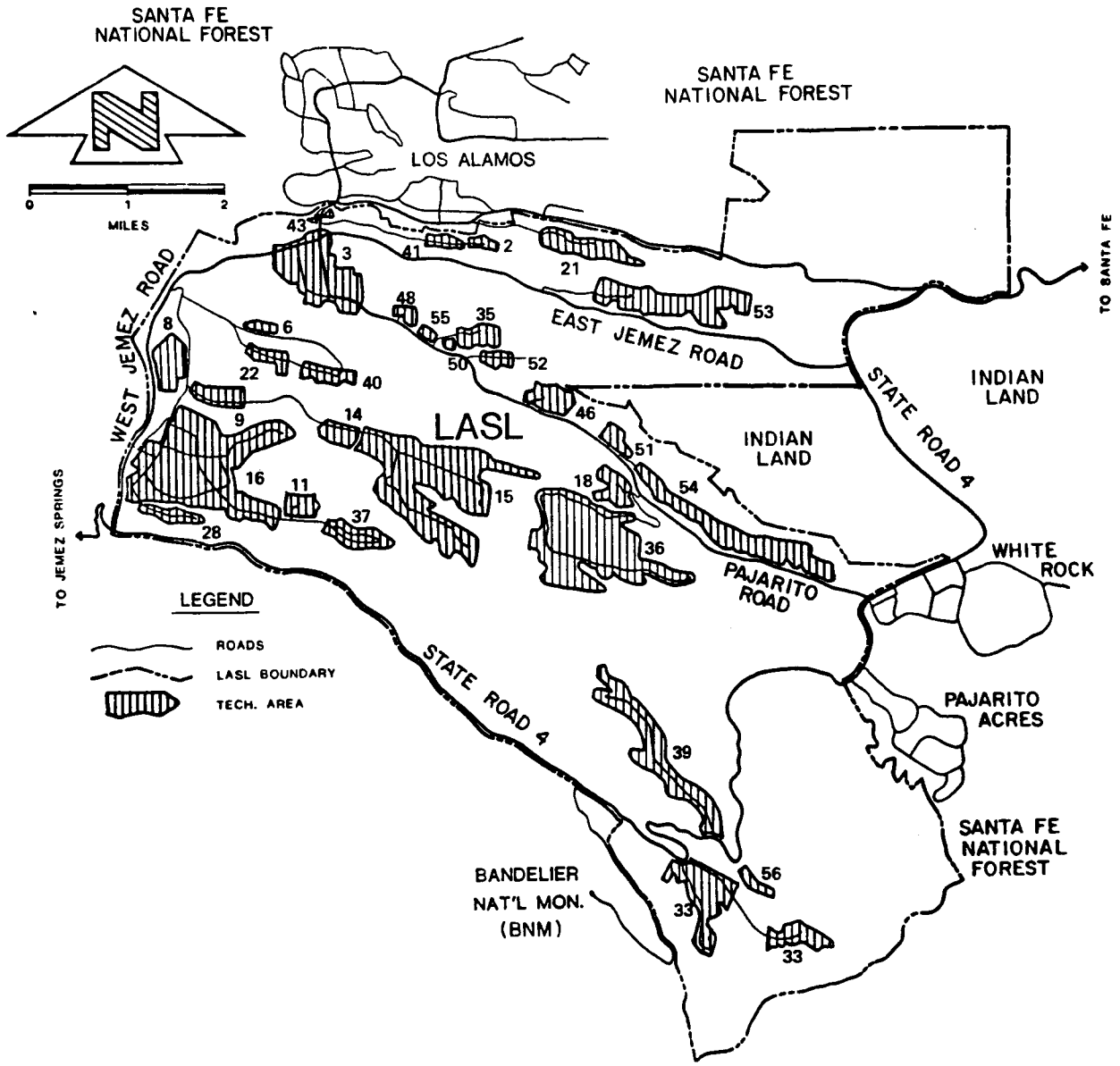


Fig. 4.
LASL technical and adjacent community areas.

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 LASL for the purpose of facilitating self-supported research on these subjects deemed compatible with the LASL programmatic mission.

A final environmental impact statement (FEIS)[8] which assesses potential cumulative environmental impacts associated with current, known future, and continuing activities at LASL was completed this year. The FEIS provides environmental input for decisions regarding continuing activities at LASL. It also provides much more detailed information on the environment of Los Alamos area.

The Laboratory is administered by the University of California for DOE, under contract W-7405-ENG-36. The LASL environmental program, conducted by the Environmental Surveillance Group, is part of

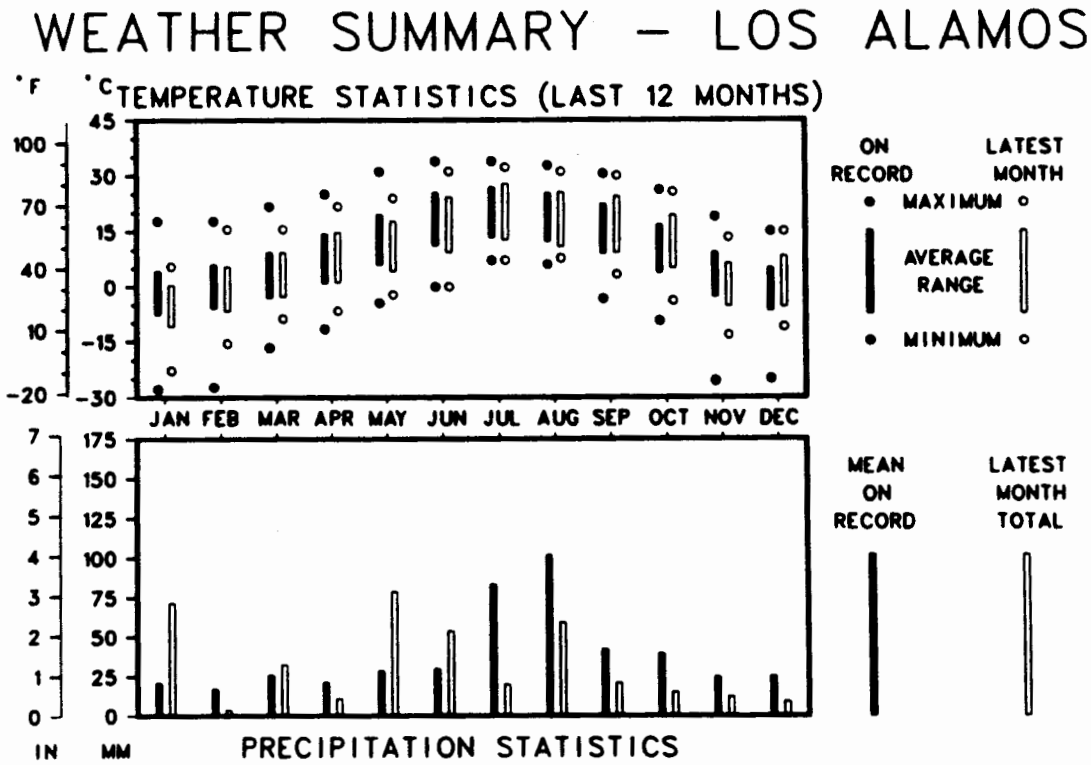


Fig. 5.
Summary of 1979 weather in Los Alamos.

a continuing investigation and documentation program.

2. Waste Management

LASL's activities are carried out in 31 active technical areas (TA) distributed over the site (see Fig. 4). 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 tank installations. Uncontaminated solid waste is disposed in a County-operated landfill located within the Laboratory boundary. Nonradioactive airborne effluents 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 explosives wastes.

Most liquid radioactive or chemical laboratory waste is 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 subsequently handled as solid radioactive waste. The treated effluents are released to canyons.

Between 90% and 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 5-10% is classed as tranuranic waste and stored retrievably. Environmental containment is provided by the dry geologic formation of the burial ground.

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

III. MONITORING RESULTS

A. Radiation and Radioactivity

1. Penetrating Radiation

Levels of penetrating radiation, including x and gamma rays from cosmic, terrestrial, and man-made sources in the Los Alamos area are monitored with thermoluminescent dosimeters deployed in two independent networks. The environmental network consists of 31 locations divided into three groups (Fig. 6). Three of these locations are 28 to 44 km from the Laboratory boundaries in the neighboring communities of Española, Pojoaque, and Santa Fe, and form the regional group (Fig. 7). The perimeter group consists of 12 dosimeters placed within 4 km of the boundary. Sixteen locations within LASL boundaries are classed as the onsite group. The dosimeters are changed each calendar quarter. The second network consists of 24 locations, all within LASL boundaries. This network was established to monitor radioactivity of the gaseous effluent from the Los Alamos Meson Physics Facility (LAMPF) at ground level approximately 1 km from the stack. Twelve of the 24 locations are along an 800 m segment of the LASL boundary directly north of LAMPF. The dosimeters are changed in accordance with the operating schedule of LAMPF. No measurements at regional or perimeter locations in the environmental network for any calendar quarter showed any statistically discernible increase in radiation levels that could be attributed to LASL operations; onsite measurements were slightly above background levels, reflecting research activities at LASL. The LAMPF network showed an increase of 21.7 ± 2.2 mrem/yr at the LASL boundary north of the LAMPF facility. Tables II and E-II summarize the annual total doses by the regional, perimeter, and onsite groups for 1979. Figure 8 shows a comparison of dose averages for the last four years.

Natural penetrating radiation background has two components. The natural terrestrial component results from the decay of ^{40}K and the radioactive daughters from the decay chains of ^{232}Th and ^{238}U. The cosmic component includes both photon radiation and neutrons. The thermoluminescent dosimeters (TLDs) used in the LASL monitoring program are insensitive to neutrons so neutron contribution to natural background radiation was not measured and, therefore, will be excluded from this discussion. The cosmic ionizing radiation level 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 2.1 km at Santa Fe, receive from 50-60 mrem/yr.[4]

In contrast to this fairly constant cosmic component, the dose from the natural terrestrial component in the Los Alamos area is highly variable. The temporal variation at any particular location (Fig. 8) is about 15-25% because of variations in soil moisture content and snow cover.[4] Figure 7, which compares all TLD locations that have been unchanged during the last four years, shows this temporal variation in the offsite and perimeter averages. The variation in the onsite averages is more influenced by changes in the research programs at particular LASL 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.[5] These natural sources of variation make it difficult to detect any increases in the radiation level from man-made sources, especially if the magnitude of such an increase is small compared to natural fluctuations.

In order to discriminate between these man-made and natural components of variation, data were used from two different dosimeter configurations at each LAMPF network location. One measures total

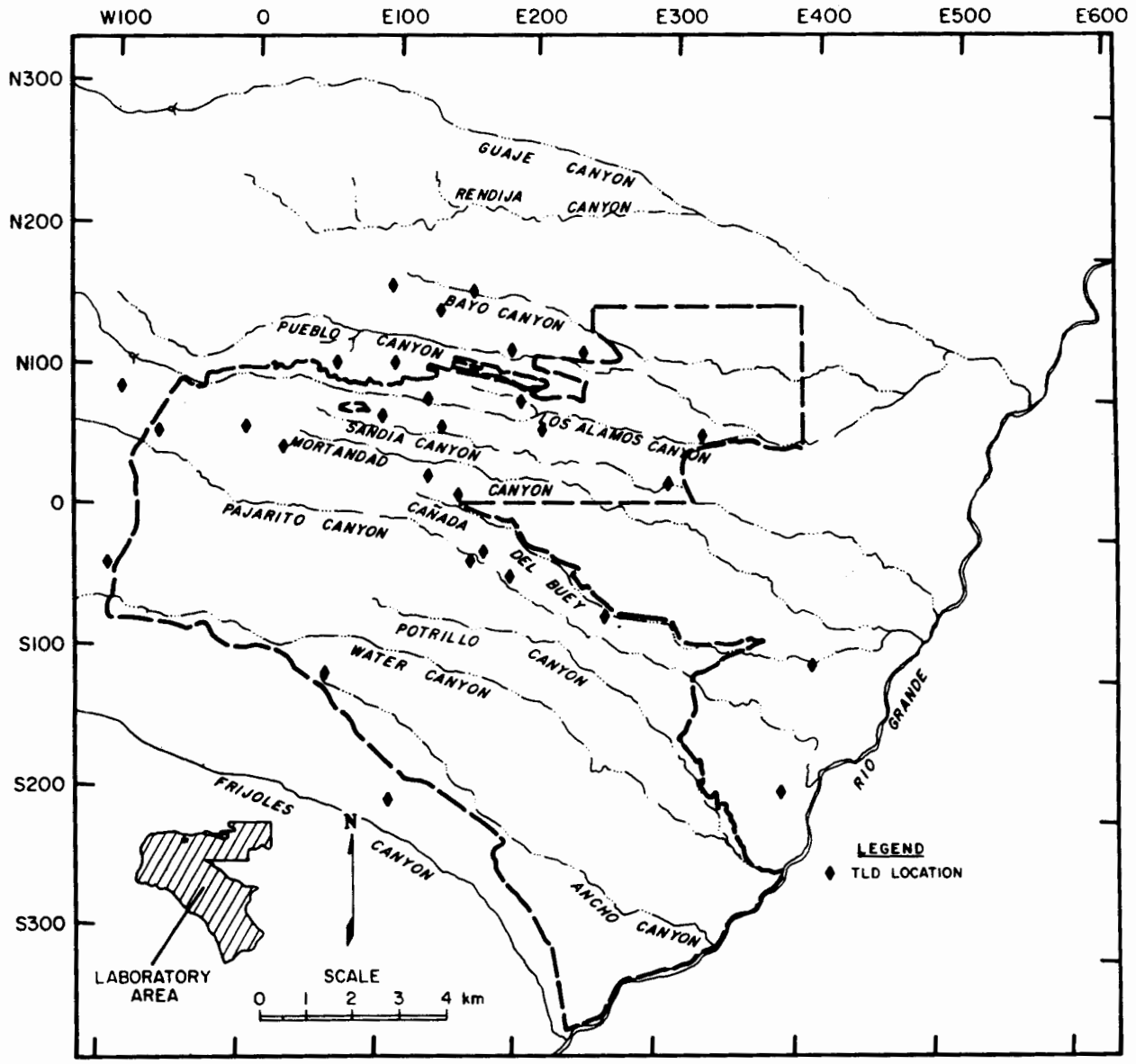


Fig. 6.
TLD locations on or near the LASL Site.

penetrating radiation, both cosmic and terrestrial. The second is shielded from below with enough lead to eliminate about 90% of the direct terrestrial gamma-ray component and from above by enough Lucite® to eliminate virtually all beta particles and positrons (whether from natural sources or from LAMPF operations). Gamma rays from annihilation of positrons and electrons can penetrate the Lucite.

Three of the locations in the LAMPF TLD network are 7.5 to 9 km from LAMPF in similar terrain. These three locations are not influenced by any laboratory radiation sources and are used as background locations. By comparing ratios of unshielded to shielded doses recorded during the same period at the background locations and at each field location in the LAMPF network, the component of the total penetrating dose due to LAMPF operations can be determined for each field location.

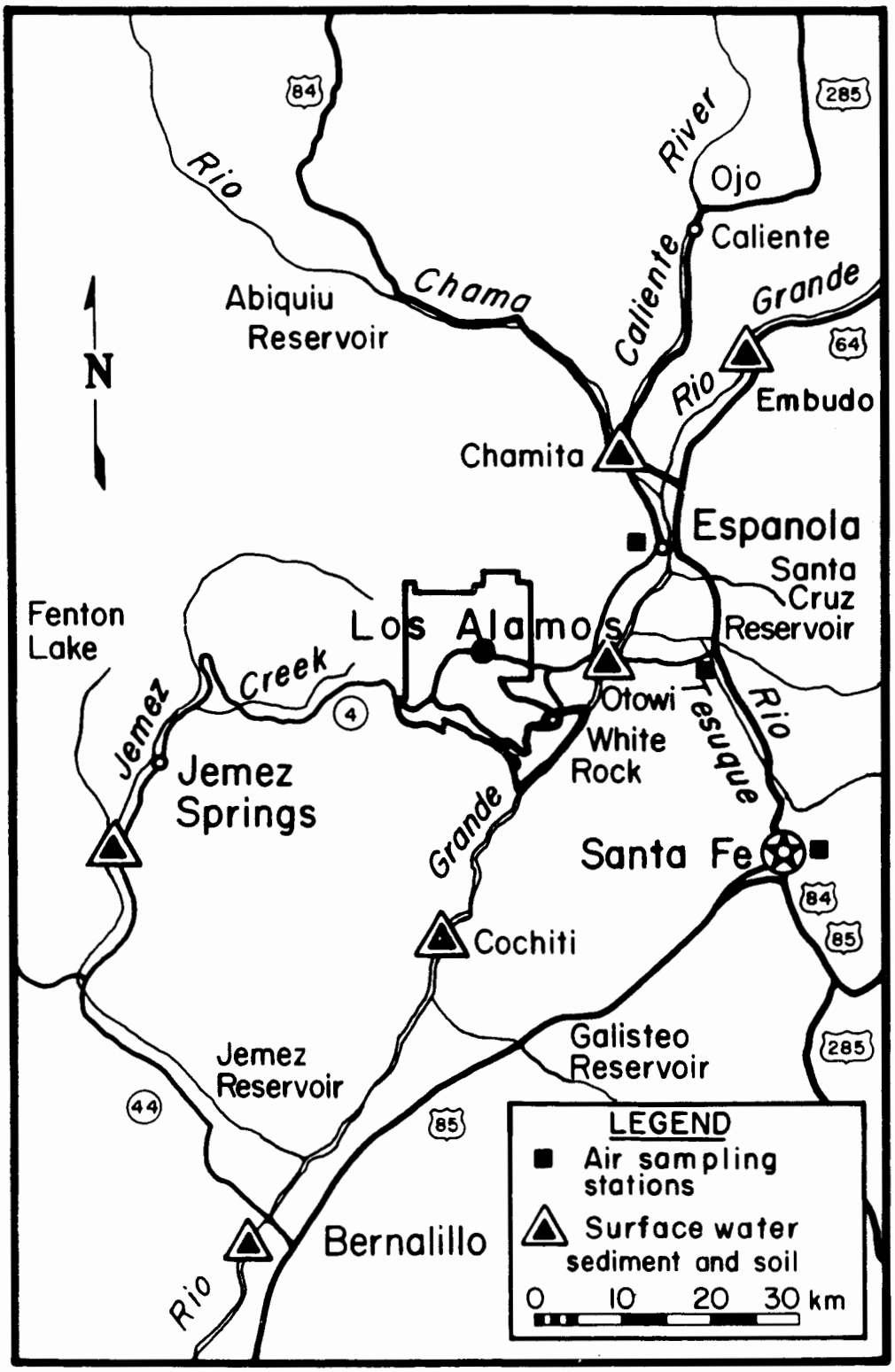


Fig. 7.
Regional surface water, sediments, soil and air sampling locations.

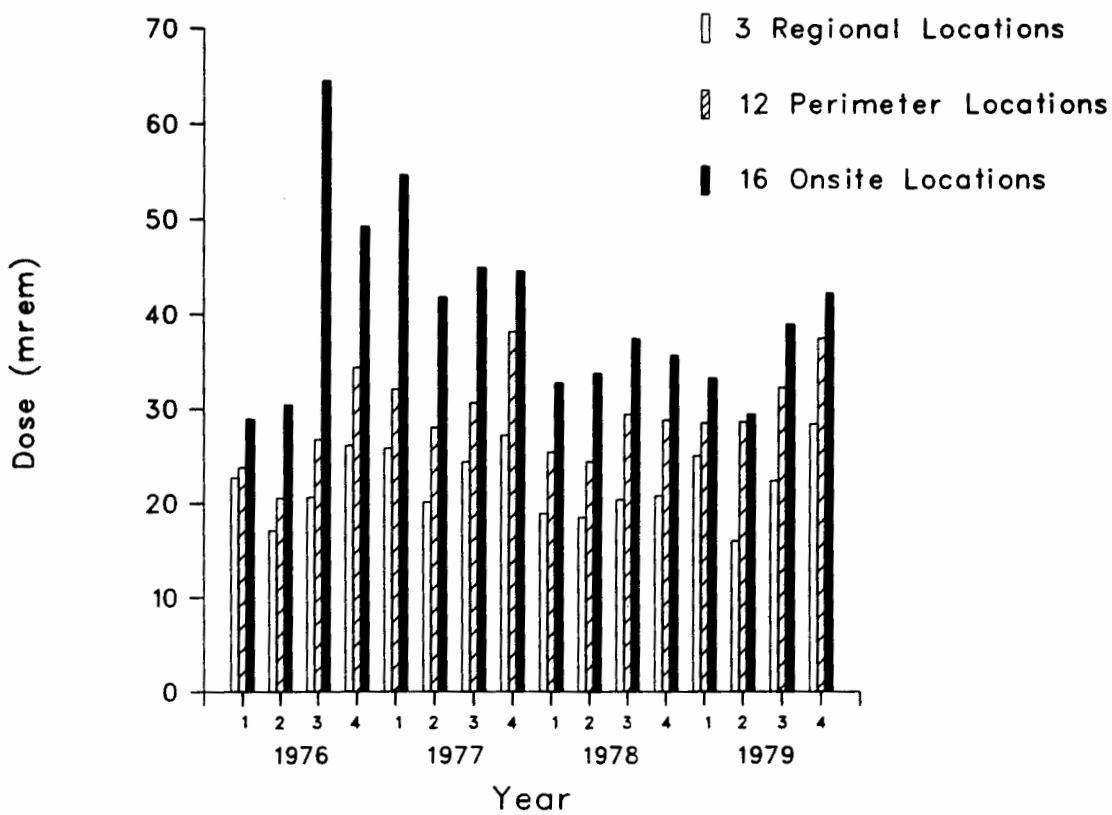


Fig. 8.
Quarterly dose averages for three station groups during the last four years.

2. Atmospheric Radioactivity

Worldwide background atmospheric radioactivity is composed of fallout from atmospheric nuclear weapons 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. During 1979, no statistically significant difference was observed between atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranium measured at sampling locations along the Laboratory perimeter and those measured in distant areas. This indicates Laboratory contributions to concentrations of these contaminants were less than local variability in background levels. Tritiated water vapor concentrations at 4 onsite stations were 5 to 15 times higher than regional background levels and are attributable to LASL operations, whereas concentrations at the other 7 onsite stations were statistically indistinguishable from regional background concentrations.

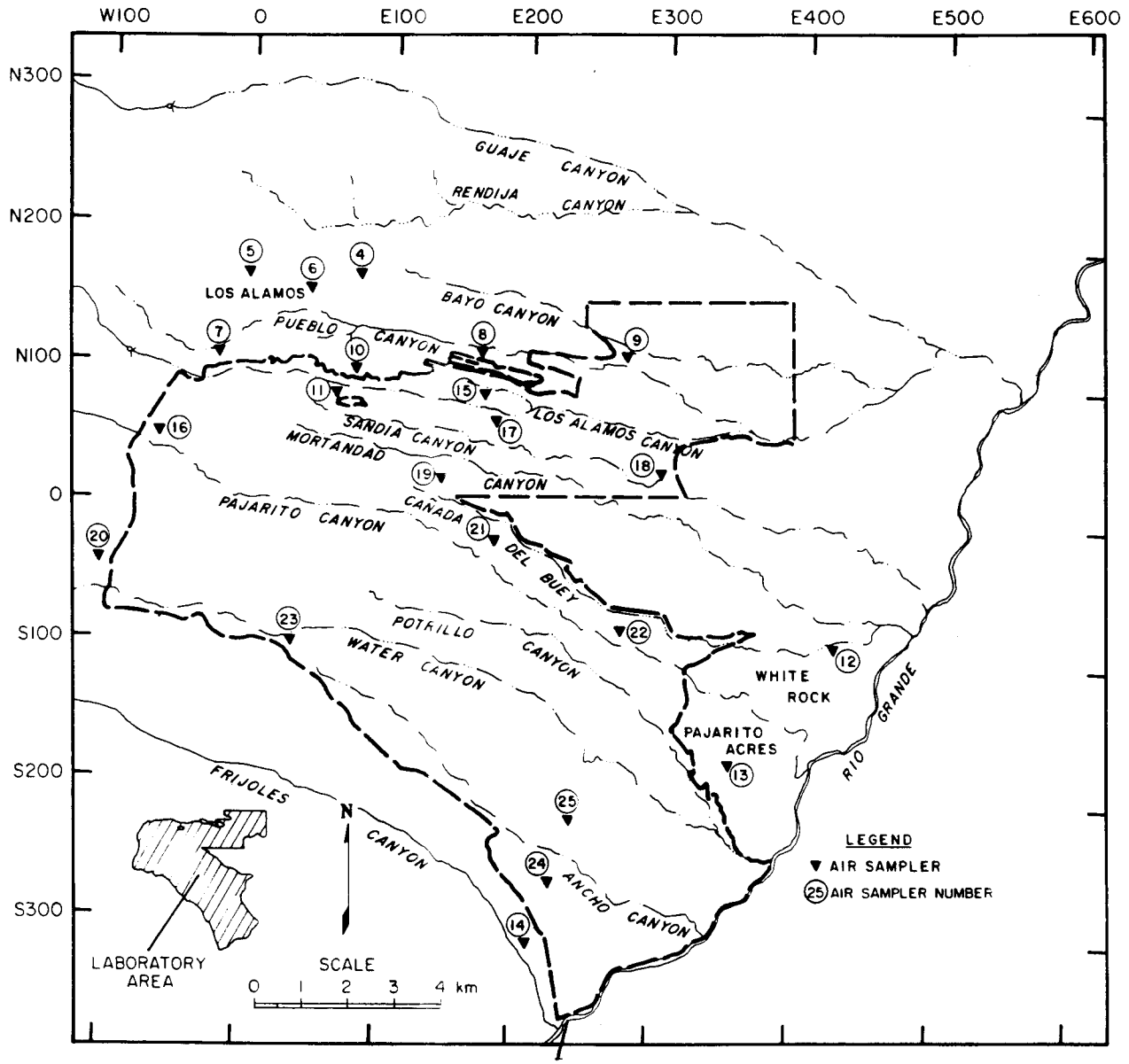


Fig. 9.
Air sampler locations on or near the LASL site.

a. Introduction

Atmospheric radioactivity samples were 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 the 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, ^{238}U,

and materials resulting from interactions with cosmic radiation, such as tritiated water vapor. Because suspended particulates are mostly from soil resuspension, there are large temporal fluctuations in radioactivity concentrations as a result of changing meteorological conditions. Periods of high winds, resulting in relatively high suspended particulate concentrations, contrast with periods of heavy precipitation, which remove much of the suspended mass. Spatial variations may be dependent on these same factors. Previous measurements of background atmospheric radioactivity concentrations are summarized in Table E-IV and are useful in interpreting the air sampling data.

b. Annual Gross Alpha and Gross Beta Radioactivity

Gross alpha and beta analyses serve as crude indicators of overall radioactivity levels. The annual average 4-wk gross alpha and gross beta concentrations are summarized in Table VI and shown in detail in Table E-V. There was a very slight increase in long-lived gross beta concentrations (see Fig. 10) during the spring. This elevated activity was small this spring in comparison with maxima observed in other years when mixing of the stratosphere with the troposphere causes increased fallout of radioactive particulates.

Data plotted in Fig. 10 also show that there were no significant differences in atmospheric gross beta concentrations among regional, perimeter, and onsite sampling stations this year. There have been no statistically significant differences over the past seven years. This lack of statistically significant differences in concentrations indicates that Laboratory operations have negligible influence on the ambient atmospheric radioactivity in the Los Alamos vicinity and suggests that this radioactivity originates from widespread sources—fallout from nuclear test detonations and naturally occurring materials—and not from a localized source such as the Laboratory.

c. Tritium

Atmospheric tritiated water concentrations for each station for 1979 are summarized in Table VI, detailed in Table E-VI, and plotted in Fig. 11. The highest annual mean of 40 (±42) pCi/m^3 at TA-33 is attributable to tritium stack effluents from the site. A total of 10 470 Ci of tritium was released from TA-33 during the year, about 70% of the total from all technical areas at LASL (see Table E-XX). The relatively higher concentrations at TA-54 (station 22) result from evapotranspiration of buried tritium-contaminated wastes at this site. Also, tritium effluents from stacks near sampling stations at TA-52 (station 19) and TA-39 (station 25) cause their annual means to be relatively higher than the other stations.

d. Plutonium

Annual average ^{238}Pu and ^{239}Pu concentrations are summarized in Table VI and detailed in Table E-VII. All ^{238}Pu concentrations, except for one at TA-16 (station 20), had no detectable (i.e., where the 2 s measurement error was less than the measured value) values. The annual ^{239}Pu means were lower than last year because of an apparently small input from worldwide fallout (see Fig. 10), although maximum values at several stations were slightly higher than in 1979. These maximum concentrations occurred during the first and third quarters. The maxima during the first quarter could be related to increased ^{239}Pu airborne emissions from one LASL facility, however, the third quarter maxima occurred when releases from that facility were relatively low (see Section III.A.6). Regional, perimeter, and onsite group ^{239}Pu means are statistically indistinguishable from one another, indicating Laboratory contributions of ^{239}Pu to the atmosphere are negligible.

e. Uranium and Americium

The 1979 atmospheric uranium concentrations are summarized in Table VI 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 located in dusty areas where historically a higher filter dust loading has accounted for collection of more natural uranium. Annual station averages are typical of regional background atmospheric uranium concentrations

TABLE VI

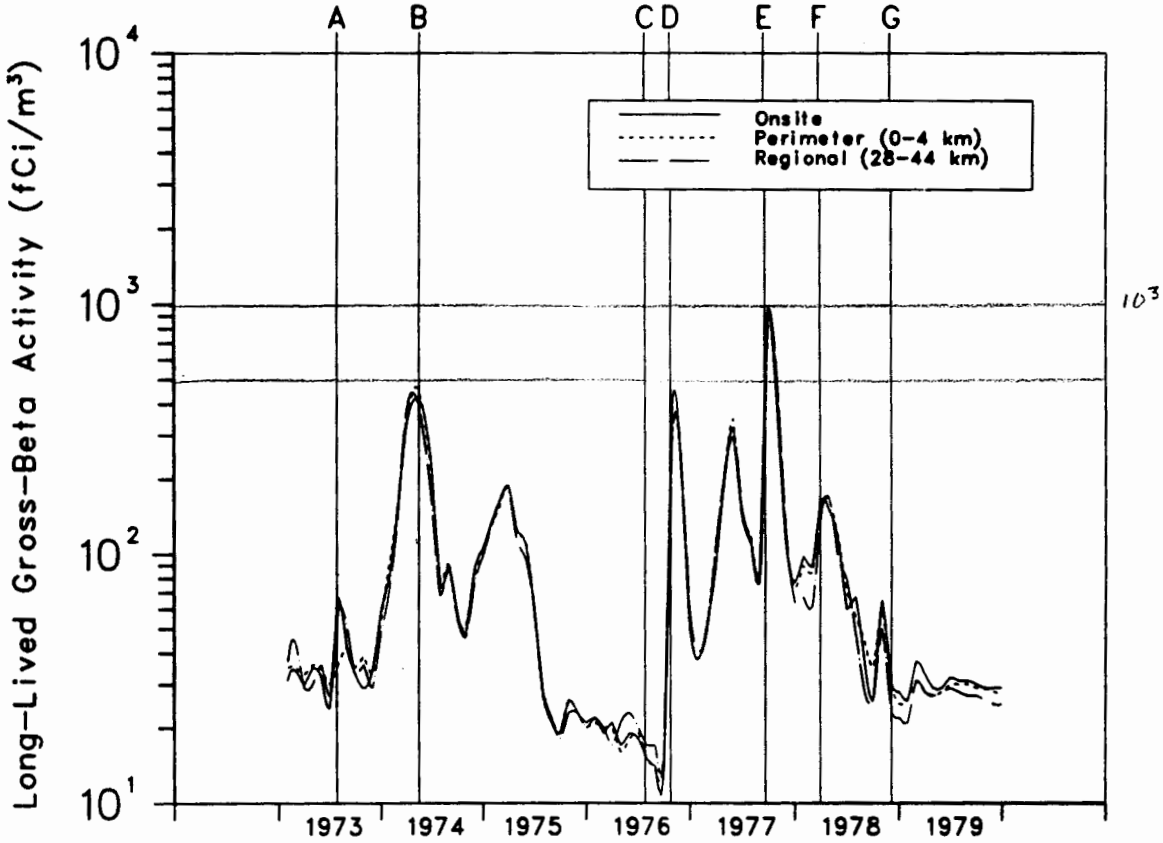
SUMMARY OF ANNUAL ATMOSPHERIC RADIOACTIVITY MONITORING FOR 1979[a]

Analysis	Composite Group	Units	Maximum Observed	Minimum Observed	Annual Mean	Mean As % CG
Gross alpha	Regional	10^{-15} μCi/mℓ	5.9 ± 2.6	0.3 ± 0.2	1.4 ± 1.5	1.3
	Perimeter	10^{-15} μCi/mℓ	7.4 ± 3.2	0.0 ± 0.1	2.2 ± 2.8	3.7
	Onsite	10^{-15} μCi/mℓ	6.2 ± 2.8	0.0 ± 0.0	2.3 ± 2.7	0.1
Gross beta	Regional	10^{-15} μCi/mℓ	132 ± 34	8.5 ± 2.2	25 ± 17	0.03
	Perimeter	10^{-15} μCi/mℓ	62 ± 16	0.0 ± 0.1	28 ± 23	0.03
	Onsite	10^{-15} μCi/mℓ	58 ± 14	0.0 ± 0.1	29 ± 26	0.0007
Tritiated Water vapor	Regional	10^{-12} μCi/mℓ	20 ± 10	−1.4 ± 1	2.7 ± 8.7	0.001
	Perimeter	10^{-12} μCi/mℓ	65 ± 22	0.1 ± 0.6	4.9 ± 15	0.002
	Onsite	10^{-12} μCi/mℓ	130 ± 40	−3.0 ± 1.2	12 ± 42	0.0002
^{238}Pu	Regional	10^{-18} μCi/mℓ	1.5 ± 22	−6.2 ± 4.5	−2.6 ± 3.2	0.0
	Perimeter	10^{-18} μCi/mℓ	1.6 ± 2.9	−14 ± 15	−2.3 ± 2.9	0.0
	Onsite	10^{-18} μCi/mℓ	20 ± 6.9	−8 ± 5	−2.1 ± 3.8	0.0
^{239}Pu	Regional	10^{-18} μCi/mℓ	25 ± 4.8	−0.9 ± 1.8	5 ± 15	0.008
	Perimeter	10^{-18} μCi/mℓ	83 ± 11	−7 ± 25	8.1 ± 30	0.013
	Onsite	10^{-18} μCi/mℓ	242 ± 20	−1.8 ± 2.5	8.3 ± 33	0.0004
^{241}Am	Regional	10^{-18} μCi/mℓ	−1.1 ± 4.6	−6 ± 10	−3.1 ± 4.7	0.0
	Perimeter	10^{-18} μCi/mℓ	1.2 ± 6.8	−4.6 ± 5.2	−1 ± 2.6	0.0
	Onsite	10^{-18} μCi/mℓ	37 ± 10	−5.1 ± 7.6	−0.1 ± 9.4	0.0
Total Uranium	Regional	pg/m^3	116 ± 18	15 ± 17	62 ± 75	0.0007
	Perimeter	pg/m^3	190 ± 32	8 ± 21	54 ± 73	0.0006
	Onsite	pg/m^3	251 ± 55	−1.8 ± 18	50 ± 64	0.00002

[a]See footnotes in Table E-V (gross alpha and beta), E-VI (tritiated water vapor), E-VII (^{238}Pu and ^{239}Pu), E-VIII (uranium), and E-IX (^{241}Am) for minimum detectable limits, Concentration Guide values, and other pertinent information.

(see Table E-IV). There were no statistically significant (at a >99% confidence level) temporal or geographical differences among regional, perimeter, and onsite station groups.

The 1979 atmospheric ^{241}Am concentrations are summarized in Table II and listed in Table E-IX. Just one quarterly sample (37 ± 10 aCi/m^3 at station 22, TA-54) was above the analytical detection limit. Only 0.019 μCi of ^{241}Am was released to the atmosphere from LASL during 1979.



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

Fig. 10.
Monthly average long-lived gross beta activity in air, 1973 to 1979, by sampling station groups.

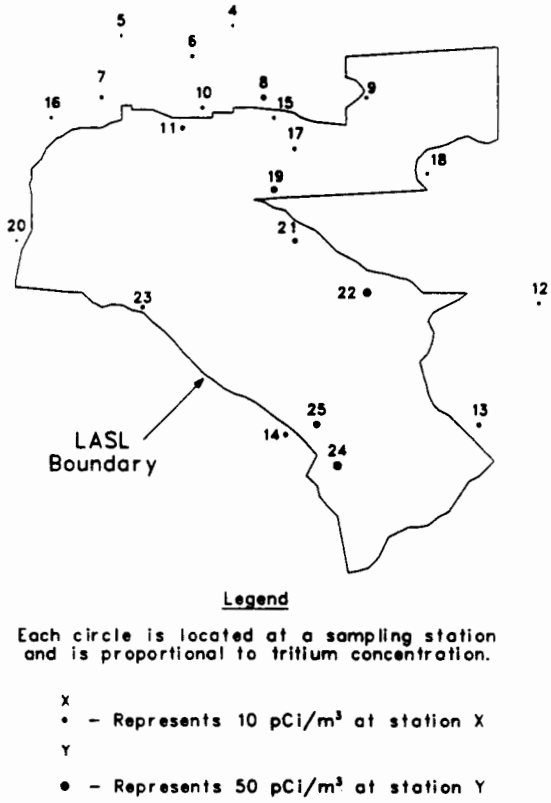


Fig. 11.
Annual mean atmospheric tritiated water vapor concentrations on or near the LASL site.

3. Radioactivity in Surface and Ground Waters

Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from LASL operations. Results of these analyses are compared to CGs (see Appendix A) and regional background concentrations as an indication of the small amounts of radionuclides in the environment. Results of 1979 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite noneffluent release areas indicate no significant effect from effluent releases from LASL. 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 the areas outside the LASL boundaries. Regional surface waters were collected within 75 km of LASL from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 7, Table E-X). Samples were also collected from five perimeter stations located within about 4 km of the LASL boundaries and from 23 stations in White Rock Canyon of the Rio Grande (Fig. 12, Table E-X). Excluded from this discussion is Acid-Pueblo Canyon, a former

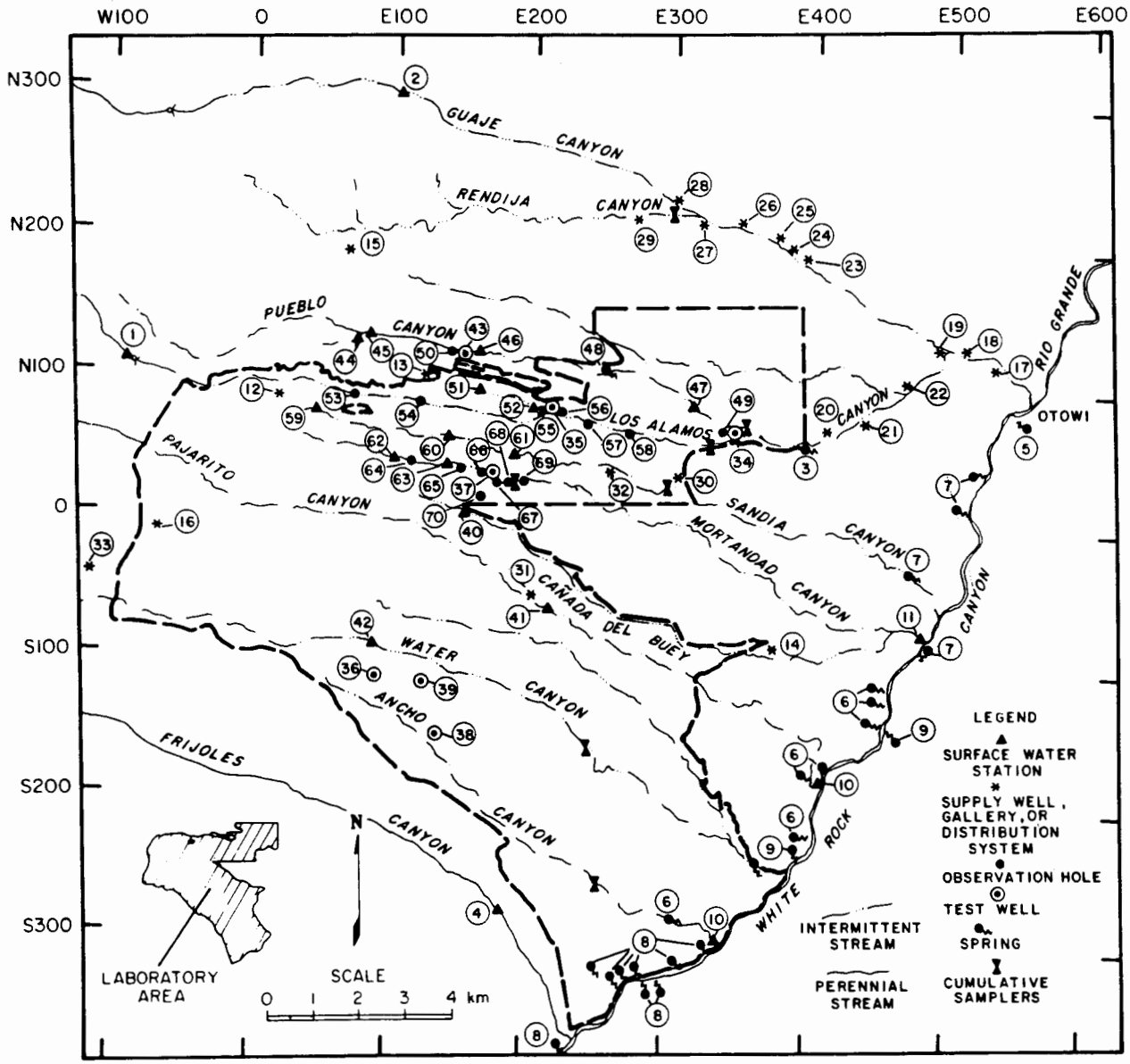


Fig. 12.
Surface and ground water sampling locations on or near the LASL site.

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 of the monitoring results in Acid-Pueblo Canyon are discussed in the following section concerning onsite surface and ground waters. Detailed data from regional and perimeter stations are in Table E-XI and E-XII, respectively (see Appendix B.3 for methods of collection, analyses, and reporting of water data). A comparison of the maximum concentrations found in these waters with CGs for uncontrolled areas is given in Table VII. However, the CGs 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).

Radionuclide concentrations in surface and ground waters from the six regional and five perimeter stations are low and have shown no effect

TABLE VII

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN REGIONAL AND PERIMETER WATERS

Analysis	Units (μCi/mℓ)	Regional	Perimeter: Five Stations	Perimeter: White Rock Canyon	CG for Uncontrolled Areas
^{3}H	10^{-6}	1.2	0.8	0.7	3 000
^{137}Cs	10^{-9}	<120	<60	110	30 000
^{238}Pu	10^{-9}	<0.02	<0.07	<0.26	5 000
^{239}Pu	10^{-9}	<0.04	<0.08	<0.06	5 000
Gross alpha	10^{-9}	5	5.8	4.9	5 000
Gross beta	10^{-9}	16	8.9	16	300
Total U	μg/ℓ	5.1	14	23	1 800

Note: < value represents analytical value plus twice the uncertainty term for that analysis.

from release of liquid effluents at LASL. Plutonium concentrations are near detection and are well below CGs for uncontrolled areas.

b. Water Supply. The municipal and industrial water supply for the Laboratory and community is from 15 deep wells (in 3 well fields) and one gallery (underground collection basin for spring discharge). The wells are located on Pajarito Plateau and in canyons east of the Laboratory (Fig. 12). The water is pumped from the main aquifer, which lies at a depth of about 350 m below the surface of the plateau. The gallery discharges from a perched water zone in the volcanics west of the plateau. During 1979, production from the wells and gallery was about 5.5×10^{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 5 stations on the distribution system. The 5 stations on the distribution system are located within the Laboratory and community (Fig. 12, Table E-X).

Detailed radiochemical analyses from the wells, gallery, and distribution system are presented in Table E-XIII. A comparison of maximum concentrations found in these waters with the EPA National Interim Primary Drinking Water Standards[6] is given in Table VIII.

Radioactivity occurring in the water supply is low and naturally occurring. Plutonium is below detection limits. Samples from the water distribution system showed gross alpha activity lower than the EPA screening limit (see Appendix A) even though one well (LA-1B, Los Alamos field) contained natural alpha activity about 80% greater than the screening limit. Dilution by water from the wells results in concentrations at points of use (distribution system) that meet the EPAs criteria for municipal supply.

c. Onsite Surface and Ground Waters. Onsite sampling stations are grouped according to areas that are not located in 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). Detailed radiochemical analyses are shown in Table E-XIV. The maximum concentration of radioactivity at the ten stations is in Table IX. The concentrations were

TABLE VIII

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATER SUPPLY

Analysis	Units (μCi/mℓ)	Wells and Gallery	Distribution System	EPA NIPDWR[a]
^{3}H	10^{-6}	0.8	1.0	20
^{137}Cs	10^{-9}	<100	<90	200
^{238}Pu	10^{-9}	<0.04	<0.03	7.5
^{239}Pu	10^{-9}	<0.02	<0.04	7.5
Gross alpha	10^{-9}	9.0	1.2	5
Gross beta	10^{-9}	5.8	5.5	---
Total U	μg/ℓ	6.2	3.3	1800

[a]Environmental Protection Agency's National Interim Primary Drinking Water Regulations.

Note: < value represents analytical value plus twice the uncertainty term for that analysis.

TABLE IX

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN ONSITE WATER IN AREAS NOT RECEIVING EFFLUENTS

Analysis	Units (μCi/mℓ)	Onsite Non-Effluent Areas	CG for Controlled Areas
^{3}H	10^{-6}	3.3	100 000
^{137}Cs	10^{-9}	<100	400 000
^{238}Pu	10^{-9}	<0.07	100 000
^{239}Pu	10^{-9}	<0.08	100 000
Gross alpha	10^{-9}	2.3	100 000
Gross beta	10^{-9}	16	10 000
Total U	μg/ℓ	2.3	60 000

Note: < value represents analytical value plus twice the uncertainty term for that analysis.

low, near or below detection limits, and well below CGs for controlled areas.

Canyons that receive or have received industrial effluents are Acid-Pueblo, DP-Los Alamos, Sandia, and Mortandad. Samples were collected from surface water stations or shallow observation holes completed in the alluvium. (Fig. 12, Table E-XIV). The maximum concentration of radioactivity in each of the four canyons is given in Table X. Radioactivity observed in Acid-Pueblo Canyon (7 stations) results from residuals of treated and untreated radioactive liquid waste effluents released into the canyon before 1964 (Table E-XIV).

TABLE X

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATERS IN AREAS RECEIVING EFFLUENTS

Analysis	Units (μCi/mℓ)	Acid—Pueblo	DP—Los Alamos	Sandia	Mortandad	CG for Controlled Areas
^{3}H	10^{-6}	20	11	7.5	650	100 000
^{137}Cs	10^{-9}	<100	<110	27	210	400 000
^{238}Pu	10^{-9}	<0.05	0.11	0.07	4.6	100 000
^{239}Pu	10^{-9}	0.50	0.64	<0.03	2.5	100 000
^{241}Am	10^{-9}	---	7.6	<0.11	5.6	100 000
Gross alpha	10^{-9}	2.6	30	<1.5	46	100 000
Gross beta	10^{-9}	97	380	26	340	10 000
Total U	μg/ℓ	3.0	77	2.0	4.3	60 000

Note: < value represents analytical value plus twice the uncertainty term for that analysis.

Radionuclides that were adsorbed by channel sediments are now being resuspended by runoff and municipal sanitary effluents.

Sandia Canyon (3 stations) receives cooling tower blowdown from the TA-3 power plant and some sanitary effluent from the TA-3 areas. Analyses of samples from this canyon show ^{137}Cs and ^{238}Pu at detection limits, in one sample (Table E-XIV).

DP-Los Alamos Canyon (8 stations) receives industrial effluents that contain low levels of radionuclides and some sanitary effluents from TA-21. Mortandad Canyon (8 stations) receives treated industrial effluent containing radionuclides (Table E-XIV). Water in these canyons contain radionuclides as the result of effluent from the treatment plants.

The three areas, Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons, contain surface and ground water with measurable amounts of radioactivity that are well below CGs 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 the alluvium of the stream channel within LASL 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 LASL boundary since hydrologic studies in the canyon began in 1960, 3 yr before release of any industrial effluents.

4. Radioactivity in Soil and Sediment

Soil samples were collected from 37 stations and sediment samples from 59 stations in and adjacent to the Los Alamos area. Concentrations of ^{239}Pu from one regional soil station and ^{90}Sr from one regional sediment station were about three times worldwide fallout levels. Seven soil and nine sediment perimeter stations, and twelve soil and twenty sediment onsite stations contained concentrations of radioactivity in excess of normal or fallout levels. The concentrations of radioactivity from these stations are less than three times 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 from the Rio Grande. The exact locations are presented in Table E-XV (see Appendix B.3 for methods of collection, analysis, and reporting of soil and sediment data) and detailed results are in Table E-XVI.

Regional and perimeter soil and sediment radiochemical data collected from 1974 through 1978 are used to distinguish background radioactivity (from natural and worldwide fallout) from atmospheric nuclear weapons tests.[7] This criteria is used for comparison using the mean plus twice the standard deviation for a number of analyses for a certain radionuclide from 1974 through 1977 (Table XI). The mean plus twice the standard deviation includes approximately 95% of the population of the samples.

Maximum concentrations of radionuclides in the regional samples were near or below maximum concentration for natural and worldwide fallout except for samples from Chamita and from the Rio Grande at Ancho. The soil sample from Chamita contained about 0.14 pCi/g of ^{239}Pu or three times the criteria. Chamita is about 30 km NE of Los Alamos up hydrologic gradient and beyond the influence of airborne emissions. The sediment sample from the Rio Grande at Ancho contained about 2.5 pCi/g of ^{90}Sr or about three times the criteria. The station is located in the drainage from Los Alamos, so may represent transport by storm runoff into the river. Both the ^{239}Pu and ^{90}Sr concentrations are apparently due to variability in fallout, since none of the other regional stations showed anomalous results.

b. Perimeter Soils and Sediments. Eight perimeter soil stations were sampled in areas within 4 km of the Laboratory. Nineteen sediment samples were collected from major intermittent streams that cross Pajarito Plateau. Locations of the stations are described in Table E-XV and are shown on Fig. 13. Detailed analyses are shown on Table E-XVII.

Soil analyses indicate that ^{3}H from one station, ^{137}Cs from five stations, ^{90}Sr from one station, ^{239}Pu and gross beta from two stations, and total U from three stations were slightly above maximum background (x + 2s) criteria (Table XII) based on 1974-1977 data. The ^{90}Sr and ^{239}Pu concentrations are at locations adjacent to TA-21 and are due to deposition from stack emission at the site. Similar concentrations were reported during a study in 1970.[6]

Sediment analyses indicated that ^{137}Cs and ^{238}Pu from two stations, ^{90}Sr from three stations, and ^{239}Pu from six stations 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-XVII).

c. Onsite Soil and Sediments. Onsite soil samples were collected from 19 stations within Laboratory boundaries. Sediment samples were collected from 31 stations within the boundaries (Fig. 13, Table E-XV). Analytical results are shown on Table E-XVIII and maximum concentrations in Table XIII.

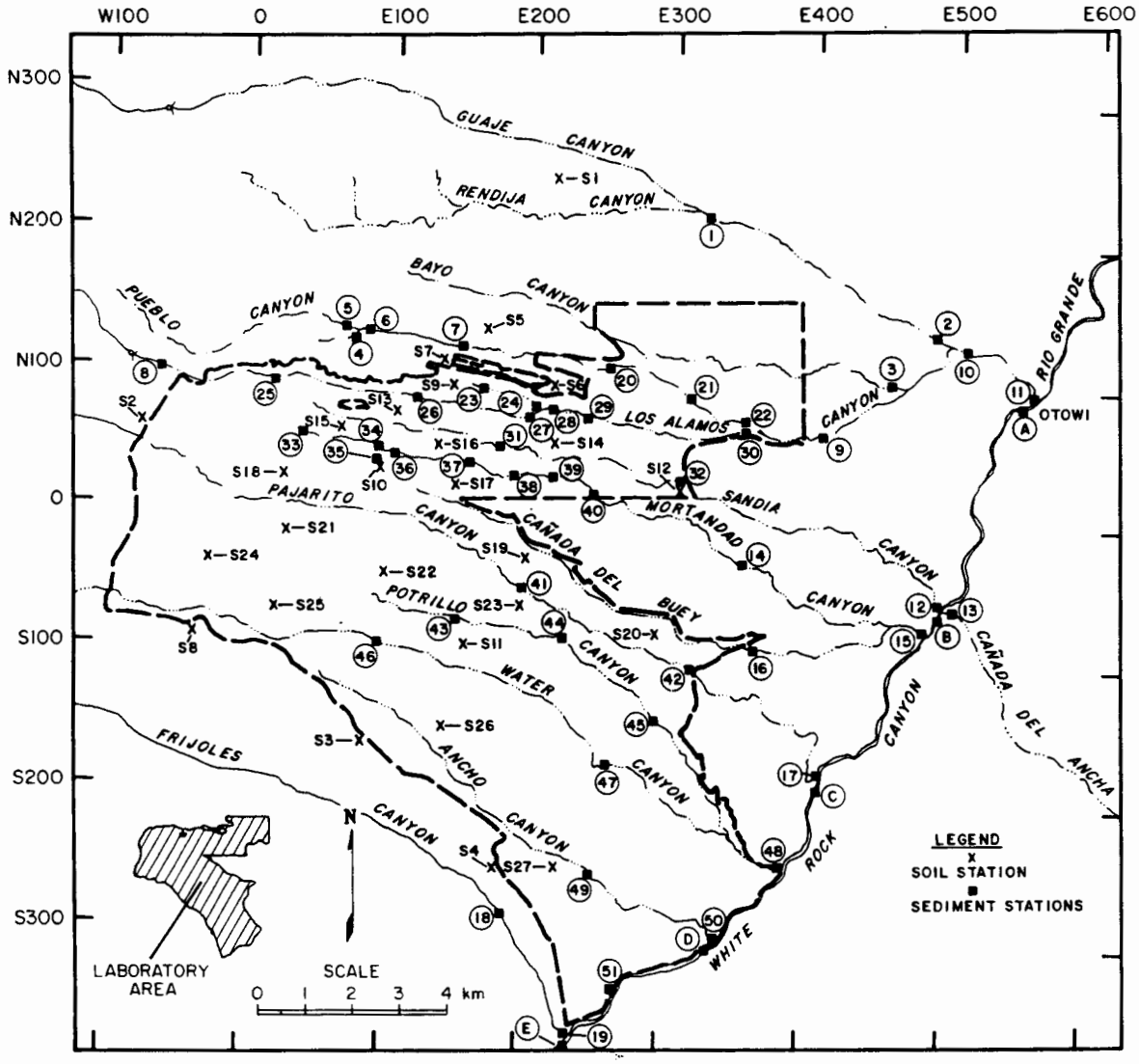


Fig. 13.
Soil and sediment sampling locations on or near the LASL site.

TABLE XI

MAXIMUM RADIOACTIVITY IN REGIONAL SOILS AND SEDIMENTS
(Concentrations in pCi/g, except as noted)

Analysis	Soil	Sediments	Maximum Natural and Worldwide Fallout for Northern New Mexico[a]
^{3}H[b]	1.9	---	27[c]
^{137}Cs	0.96	0.32	0.92
^{90}Sr	0.44	0.12[d]	0.79
^{241}Am	0.011	---	---
^{238}Pu	<0.004	<0.005	0.008
^{239}Pu	0.023[e]	0.039	0.028
Gross alpha	11	13	10.4
Gross beta	13	15	11.2
Total U[f]	4.1	3.2	4.4

[a]Maximum value ($\bar{x}$ + 2 s) for soil and sediments 1974-77 (Ref. 7).
[b]10^{-6} μCi/mℓ.
[c]($\bar{x}$ + 2 s) for regional soils 1978.
[d]Maximum value except for sample Rio Grande at Ancho of 2.5 pCi/g ^{90}Sr.
[e]Maximum value except for sample from Chamita of 0.14 pCi/g ^{239}Pu.
[f]μg/g.

Note: < value represents analytical value plus twice the uncertainty term for that analysis.

In areas that have not received industrial effluents, concentrations of ^{137}Cs from seven stations, ^{90}Sr from one station, ^{238}Pu from two stations, ^{239}Pu and gross alpha from seven stations, gross beta from eight stations, and total U from five stations in on-site soils were above background levels (Table XIII). These levels may be due to deposition of airborne effluents from Laboratory operations either from TA-21 or TA-50.[5,8]

Sediment stations in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons contained radionuclides above background levels. These canyons have or are now receiving treated industrial liquid effluents (Table E-XVIII). Radionuclides in effluents are adsorbed or attached to sediment particles in the alluvium and their concentrations are highest near effluent outfalls. They 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.

Other samples containing above background levels of radionuclides were in Mortandad Canyon near the CMR Facility (station 33, Fig. 12), ^{238}Pu, and ^{239}Pu; Pajarito Canyon at TA-18 (station 41), total U; Potrillo Canyon at TA-36 (station 43), total U; and Potrillo Canyon east of TA-36 (station 44) ^{90}Sr. The concentrations range from slightly above background levels to a factor of three above background levels (Table E-XVIII).

d. Radionuclide Transport in Snowmelt Runoff, Spring 1979. The major transport of radionuclides from canyons receiving treated liquid radioactive effluents is in storm runoff (solution and suspended sediments). During the spring of 1979, snowmelt runoff samples were collected in Guaje,

TABLE XII

MAXIMUM RADIOACTIVITY IN PERIMETER SOILS AND SEDIMENTS[a]
(Concentrations in pCi/g, except as noted)

	Soil		Sediments	
Analysis	Above Background	Background	Above Background	Background
^{3}H[b]	96. (1)	3. (7)	---	---
^{137}Cs	1.29 (5)	0.90 (3)	1.39 (2)	0.52 (17)
^{90}Sr	1.1 (1)	0.79 (7)	2.25 (3)	0.68 (12)
^{238}Pu	.---	<0.004 (8)	0.68 (2)	0.006 (17)
^{239}Pu	0.066 (2)	0.026 (6)	10.6 (6)	0.004 (13)
Gross alpha	.---	10. (8)	12. (1)	6.8 (18)
Gross beta	14. (2)	9.5 (6)	12. (1)	5.6 (18)
Total U[c]	5.3 (3)	4.7 (5)	4.8 (2)	3.9 (17)

[a]Parentheses indicate number of stations in group with maximum value noted. Background criteria is that given for natural and worldwide fallout as shown in Table XI.
[b]10^{-6} μCi/mℓ of moisture distilled from soil sample.
[c]μg/g.

TABLE XIII

MAXIMUM RADIOACTIVITY IN ONSITE SOILS AND SEDIMENTS[a]
(Concentrations in pCi/g, except as noted)

	Soils		Sediments	
Analysis	Above Background	Background	Above Background	Background
^{3}H[b]	---	26 (19)	---	---
^{137}Cs	3.1 (7)	0.77 (12)	360 (8)	0.89 (23)
^{90}Sr	0.90 (1)	0.56 (6)	3.47 (7)	0.52 (9)
^{238}Pu	0.234 (2)	0.003 (17)	5.75 (9)	0.004 (22)
^{239}Pu	0.127 (7)	0.023 (12)	2.38 (15)	0.035 (16)
Gross alpha	18 (7)	10 (12)	14 (1)	8.3 (24)
Gross beta	19 (8)	11 (11)	32 (4)	11 (21)
Total U[c]	7.1 (5)	4.4 (14)	15 (3)	4.3 (22)

[a]Parentheses indicate number of stations in group with maximum value noted. Background criteria is that given for natural and worldwide fallout as shown in Table XI.
[b]10^{-6} μCi/mℓ of moisture distilled from soil sample.
[c]μg/g.

Rendija, Pueblo, Los Alamos (3 stations), Mortandad, Pajarito, Water, and Ancho Canyons (Table E-XIX). Analyses of dissolved commitments were performed for ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, ^{90}Sr, and total U. Also chemical analyses were made for SO_4, $C\ell$, F, NO_3, and TDS. Suspended sediments were analyzed for ^{238}Pu and ^{239}Pu. Analyses from Guaje and Rendija Canyons were used for controls (background) as these stations are about 6 km north of the Laboratory.

A number of samples were collected during spring runoff. Analyses of individual samples varied considerably as shown by the standard deviation of the distribution of the observed values. Tritium in solution was above normal levels and occurred at times in Los Alamos Canyon at SR-4, Totavi, and Otowi, as well as in Pajarito, Mortandad, and Ancho Canyons.

Cesium-137 in solution was near or below normal levels at all stations. The ^{238}Pu concentrations were above normal concentrations in Mortandad Canyon, whereas ^{239}Pu exceeded normal levels in one out of five analyses in Pueblo Canyon and in the five analyses in Mortandad Canyon. The ^{90}Sr in solution occurred in Los Alamos Canyon at SR-4, Totavi, and Otowi and in Mortandad Canyon. Total U in solution was high in Mortandad Canyon.

Concentrations of radioactivity in suspended sediments cannot be compared directly to concentrations found in the bed sediments discussed in Sections III.A.4.b and III.A.4.c. The silt and clay fraction makes up almost all of suspended sediment while the silt and clay fraction comprises only about 5% (by weight) of the bed sediments. As expected, the concentrations of ^{238}Pu in suspended sediments were elevated in Mortandad Canyon, while the concentrations of ^{239}Pu were elevated in Mortandad Canyon, Pueblo Canyon, and Los Alamos Canyon at SR-4, Totavi, and Otowi (Table E-XIX).

In summary, most of the concentrations of radioactivity above background found in solution and suspended sediments occurred in Pueblo, Los Alamos, and Mortandad Canyons. These three canyons have or are now receiving treated radioactive effluents. Some snowmelt and thunderstorm runoff from Pueblo and Los Alamos Canyons reaches the Rio Grande. Runoff in Mortandad Canyon infiltrates alluvium within Laboratory boundaries. Liquid effluents are released after treatment to reduce radioactivity levels well below CGs for controlled areas. Transport of radionuclides occurs from adsorption or retention of radionuclides in effluents on bed sediments in effluent release areas.

The chemical quality of selected constituents in snowmelt runoff follows the same general pattern as radionuclides (Table E-XIX). Sulfates show no particular trends. Chlorides were high in runoff from Pueblo, Los Alamos, Mortandad, and Pajarito Canyons from perturbances of man, industrial effluent, sanitary effluent or possible from salt-sand mixture used for snow removal. Fluoride and nitrates in Mortandad Canyon are from release of industrial effluents, whereas nitrates in Pueblo Canyon reflect release of sanitary effluents.

e. Plutonium in Bed Sediments from the Rio Chama and Rio Grande. Seven samples of bed sediments from the Rio Chama and Rio Grande were collected in August. Special analyses were performed using 1 kg (100 times the mass normally used for analysis) of sediment to increase sensitivity of the analyses (Table XIV). The concentrations fall within the range observed for worldwide fallout on sediments in Northern New Mexico of <0.008 pCi/g for ^{238}Pu and <0.028 pCi/g for ^{239}Pu.[7] The average for the five stations in White Rock Canyon (below drainage from LASL) is identical with that obtained from the four years of analyses in northern New Mexico. The slight variability in concentrations of plutonium between individual stations is attributable to the fact that the samples were not separated by particle size and to different degrees of mixing between freshly eroded sediments and older sediments which had been exposed to worldwide fallout.

TABLE XIV

PLUTONIUM IN BED SEDIMENTS FROM THE RIO CHAMA AND RIO GRANDE
(Concentrations in pCi/g)

Location	^{238}Pu	^{239}Pu
Rio Chama		
At Chamita	0.0000 ± 0.0000	0.0003 ± 0.0000
Rio Grande		
At Embudo	0.0001 ± 0.0000	0.0017 ± 0.0002
Below Otowi	0.0002 ± 0.0000	0.0073 ± 0.0004
At Sandia Canyon	0.0001 ± 0.0000	0.0043 ± 0.0004
At Pajarito Canyon	0.0001 ± 0.0002	0.0010 ± 0.0004
At Ancho Canyon	0.0005 ± 0.0000	0.0088 ± 0.0004
At Frijoles Canyon	0.0000 ± 0.0000	0.0023 ± 0.0004

Note: ± value represents twice the analytical uncertainty associated with that analysis.

5. Radioactivity in Foodstuffs

Fruit, vegetable, fish, and honey samples collected in the vicinity of LASL showed no apparent influence from Laboratory operations, except for apricots and peaches collected onsite and honey collected near facilities that emit tritium.

Fruit, vegetable, fish, and honey samples were collected during the fall 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 the intermittent streams which cross the Laboratory and flow into the Rio Grande (see Fig. 7). Fish were collected from locations above (Abiquiu, El Vado, and Heron reservoirs which are on the Rio Chama, a tributary of the Rio Grande) and below (Cochiti) confluences of these streams. Fish samples were taken from bottom feeders, such as carp and suckers, which have a greater probability than higher trophic orders of ingesting any activity that might be associated with sediments. Honey was collected from hives established in 1978 at several locations within the LASL boundary near waste stream outfalls and a tritium facility. Background samples came from other LASL locations, Barranca Mesa (in Los Alamos), Pajarito Acres (in White Rock), and Chimayo, New Mexico.

Fruit and vegetable samples were analyzed for tritiated water (HTO), ^{238}Pu, and ^{239}Pu. Fish sample analyses included gross gamma, ^{238}Pu, ^{239}Pu, ^{90}Sr, and total uranium. Honey samples were analyzed for HTO and ^{137}Cs.

Data presented in Tables XV and XVI summarize fruit and vegetable sample results for tritium and plutonium according to different water supplies. Sample moisture ranged from 47% to 96% of total sample weight. With the exception of onsite samples (TA-35 and TA-21) there is no significant difference in HTO content between any batches of samples analyzed. Observed concentrations are within the range of values measured in local surface water and atmospheric water vapor. Thus, there is no indication of any measurable offsite contribution from Laboratory operations. The tritium content of

TABLE XV

TRITIATED WATER CONTENT OF FRUITS AND VEGETABLES

Location	Water Source	No. of Samples	Tritiated Water Concentration (pCi/mℓ) Average (±1 s)	Range
Espanola	Rio Grande[a]	5	0.90 ± 0.45	0.40 to 1.5
Espanola	Rio Chama[a]	5	0.96 ± 0.18	0.80 to 1.2
Cochiti	Rio Grande[b]	5	0.86 ± 0.21	0.60 to 1.1
Los Alamos	Community System	4	1.13 ± 0.61	0.40 to 1.8
Pajarito Acres	Community System	5	1.00 ± 0.29	0.80 to 1.5
White Rock	Community System	3	1.03 ± 0.23	0.90 to 1.3
TA-35	Community System	1	15.7	
TA-21	Precipitation	2	9.7 ± 11.8	1.4 to 18

[a]Upstream from Laboratory stream confluence.
[b]Downstream from Laboratory stream confluence.

TABLE XVI

PLUTONIUM CONTENT OF FRUITS AND VEGETABLES

Location	Water Source	No. of Samples	^{239}Pu (fCi/g)[c] Average (±1 s)	^{239}Pu (fCi/g)[c] Range	^{238}Pu (fCi/g)[c] Average (±1 s)	^{238}Pu (fCi/g)[c] Range
Espanola	Rio Grande[a]	5	−0.4 ± 0.3	−0.7 to −0.07	0.08 ± 0.3	−0.3 to 0.5
Espanola	Rio Chama[a]	5	−0.07 ± 0.2	−0.3 to 0.2	−0.2 ± 0.1	−0.4 to −0.09
Cochiti	Rio Grande[b]	5	−0.2 ± 0.4	−0.6 to 0.3	−0.1 ± 1.0	−0.8 to 1.6
Los Alamos	Community System	4	−0.6 ± 0.3	−1. to 0.4	−0.5 ± 0.2	−0.7 to −0.3
Pajarito Acres	Community System	5	0.02 ± 0.3	−0.7 to 0.1	0.06 ± 0.2	−0.3 to 0.08
White Rock	Community System	3	−0.07 ± 0.2	−0.1 to 0.3	0.07 ± 0.2	−0.1 to 0.2
TA-35	Community System	1	−0.1		1.6	
TA-21	Precipitation	2	0.04 ± 0.05	0. to 0.07	0.8 ± 0.1	0.7 to 0.9

[a]Upstream from Laboratory stream confluence.
[b]Downstream from Laboratory stream confluence.
[c]Dry weight.

peaches at TA-35 was similar to previously reported relatively higher values at that location.[9] A major source of tritium at TA-35 (tritium-contaminated gloveboxes which off-gassed through a 23 m stack) was removed and disposed during 1979. The elevated HTO concentrations in apricots were from a tree located near a facility in TA-21 where tritium operations are conducted and where some tritium is released. The few peaches and apricots do not represent a significant pathway to man because they are within a Laboratory fence, represent a very small volume of ingestible water, and have considerably less tritium than the uncontrolled area CG for water (3000 pCi/mℓ) and less than the EPA's drinking water standard (20 pCi/mℓ).

None of the samples collected had measurable ^{238}Pu (i.e., where the 2s measurement error was less than the measured value). Only five samples had detectable ^{239}Pu activity. Results are summarized in Table XVI. Ingestion of 3.0 kg of fresh carrots (annual per capita consumption of carrots)[10] contaminated to 1.6×10^{-3} pCi/g (dry weight) of ^{239}Pu (the maximum value which was in a sample of carrots) would result in a 50 yr dose commitment of 2.1×10^{-4} mrem to the critical organ (bone). The magnitude of the contamination and doses indicate they are due to fallout or soil contamination on plant surfaces and not to Laboratory related effluents.

Data on radioactivity in fish are presented in Table XVII. For all determinations, the fish flesh was analyzed so some bone was included in the samples. Uranium content is elevated in the gut indicating sediment ingestion. Uranium in fish samples from Cochiti is statistically higher than in the background samples. Rio Grande sediment samples (above and below the Laboratory) have statistically higher uranium concentrations (see Table E-XVI) than the Rio Chama station at Chamita, but the uranium in water is higher at Chamita than along the Rio Grande (see Table E-XI). More significantly, sediment from Los Alamos Canyon has uranium concentrations (Table E-XVI) virtually the same as sediments from the Rio Grande (Table E-XVII) above and below their confluence. Thus, there is no basis for attributing the difference in fish to transport of sediments from Los Alamos Canyon. Whatever the cause, a person eating 18 kg of fish from Cochiti would get a 50 yr dose commitment of 0.03 mrem to the bone and 0.007 mrem to the kidney over what he would get if the fish came from the Rio Chama. All ^{238}Pu data are less than detection limits. The two positive ^{239}Pu samples are in the gut which indicates the material was ingested. The largest of these two positive values is from Abiquiu which is not influenced by Laboratory operations. Strontium-90 values are low and vary widely, with values from Cochiti not statistically different from levels at background locations.

The 1979 honey samples and library of honey samples collected in 1977 by LASL's Environmental Studies Group were analyzed for ^{137}Cs and HTO. In all cases ^{137}Cs results were less than detection limits (the measured value was ≤ the 2s of the measurement). Results of the HTO measurements are given in Table XVIII and are consistent with previously measured values.[11] If a person ate 5 kg of honey from the hive with the maximum HTO concentration (579 pCi/mℓ at TA-33), the whole body dose would be 0.024 mrem which is 0.005% of the Radiation Protection Standard for members of the public.

6. Radioactive Effluents

Airborne radioactive effluents released from LASL operations in 1979 were typical of releases during the past several years. The greatest change was about a tenfold increase in plutonium effluents due to problems caused by aging equipment in one facility. Liquid effluents from three waste treatment plants contained radioactivity at levels well below controlled area Concentration Guides.

TABLE XVII

RADIOACTIVITY IN FISH

Location	Type of Sample	No. of Samples	Data Range[c] Total Uranium (ng/g)	Gross Gamma (net c/min/g)	^{239}Pu (fCi/g)	^{240}Pu (fCi/g)	^{90}Sr (pCi/g)
Cochiti[a]	Carp Guts	2	67 to 105 (2)[d]	0.08 to 0.30 (0)	−0.06 to 0.1(0)	0.1 to 0.47(1)	0.01 to 0.011(0)
	Bottom Feeders	4	5.9 to 23 (4)	0.15 to 0.54 (4)	−0.27 to −0.05(0)	−0.2 to −0.04(0)	0.08 to 0.18 (4)
	Higher Level	4	1.5 to 9.1 (3)	0.43 to 0.97 (4)	−0.23 to 0.1 (0)	−0.3 to 0.1 (0)	0.02 to 0.078 (1)
Abiquiu[b]	Sucker Guts	2	39 to 74 (2)	0.30 to 0.38 (0)	−1.2 to −0.5 (0)	−0.90 to 2.8 (1)	−0.10 to 0.11 (0)
	Bottom Feeders	2	2.8 to 3.7 (2)	0.18 to 0.59 (1)	−0.19 to 0.08 (0)	−0.23 to 0.10 (0)	0.08 to 0.09 (2)
	Higher Level	2	2.6 to 3.0 (2)	0.24 to 0.47 (2)	−0.09 to 0.01 (0)	0.03 to 0.07 (0)	0.012 to 0.022 (0)
El Vado[b]	Sucker Guts	2	21 to 63 (2)	0.62 to 1.36 (2)	−0.7 to −0.05 (0)	0.01 to 1.2 (0)	−0.02 to 0.64 (1)
	Bottom Feeders	2	3.1 to 5.1 (2)	0.49 to 0.69 (2)	−0.16 to −0.05 (2)	−0.19 to −0.04 (0)	0.10 to 0.17 (2)
	Higher Level	2	0 to 1.6 (1)	0.025 to 0.08 (0)	−0.17 to −0.10 (0)	0.03 to 0.05 (0)	0.023 to 0.031 (1)
Heron[b]	Sucker Guts	2	30 to 78 (2)	0.23 to 0.42 (0)	−2.8 to 0 (0)	0.3 to 1.2 (0)	0.01 to 0.09 (0)
	Bottom Feeders	2	2.6 to 2.8 (2)	0.12 to 0.29 (2)	−0.1 to −0.04 (0)	−0.09 to 0 (0)	0.16 to 0.19 (2)
	Higher Level	2	0 to 4.4 (1)	0.32 to 0.39 (2)	−0.2 to −0.09 (0)	−0.13 to −0.1 (0)	0.054 to 0.08 (2)

[a]Below confluence of the 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]Number in parentheses indicates number of samples >MDL.

TABLE XVIII

HTO CONCENTRATION IN HONEY SAMPLES

Location	HTO Concentration (pCi/mℓ)[a,b] 1977	1979
Mortandad	55.7 ± 1.1	11.8 ± 0.5
Effluent	115 ± 1.9	26.7 ± 0.7
DP	39.5 ± 0.8	5.8 ± 0.4
TA-33	85.2 ± 1.5	579 ± 9
Area G	---	9.6 ± 0.4
S-Site	8.4 ± 0.4	2.8 ± 0.4
Pajarito Acres	7.3 ± 0.4	10.5 ± 0.4
Barranca Mesa	---	3.6 ± 0.4
Chimayo	---	0.6 ± 0.3

[a]pCi/mℓ of water in the honey. Honey is ~17.2% water.[12]
[b]Data is formatted $\bar{x} \pm 1$ s.

Effluents containing radioactivity are discharged at LASL as airborne materials in stack exhausts at 12 of the technical areas and as liquid discharges from 2 industrial waste treatment plants and 1 sanitary sewage lagoon system. The airborne effluents 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 linear accelerator at LAMPF. Releases of various isotopes from the technical areas are detailed in Table E-XX. Quantities of radioactivity released depend on research programs conducted, so vary significantly from year-to-year (see Figs. 14-16).

Routine airborne tritium effluents were down by about 35% this year compared with 1978 (see Fig. 14). However, there was an accidental release of 3000 Ci on May 4 (see Section III.A.7). This 3000 Ci is about 25% of the 12 026 Ci routinely released during 1979.

Airborne plutonium effluents were higher by a factor of about 10 in 1979 compared to 1978 (see Fig. 16). Almost all of the increase was due to problems caused by aging equipment in one wing of an experimental building in the main technical area (TA-3). The majority (~90%) of releases from this source occurred during the first and fourth quarters. This source contributed 1060 μCi (about 98%) out of the annual total plutonium emissions of 1086 μCi for the entire LASL site, indicating all other facilities have achieved better control than in the past. Large filters were replaced in March and engineering studies were initiated for refurbishing and installation of new High Efficiency Particulate Air filters. During the fourth quarter, emissions again increased because of further equipment deterioration. Corrective measures have been implemented to control a major source of the release. Total correction of the problem will involve major capital expenditures.

In addition to airborne releases from stacks, some depleted uranium (uranium consisting almost entirely of ^{238}U) is dispersed by experiments employing conventional high explosives. In 1979 about 568 kg of depleted uranium were used in such experiments. Based on known isotopic composition, this mass is estimated to contain approximately 0.20 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

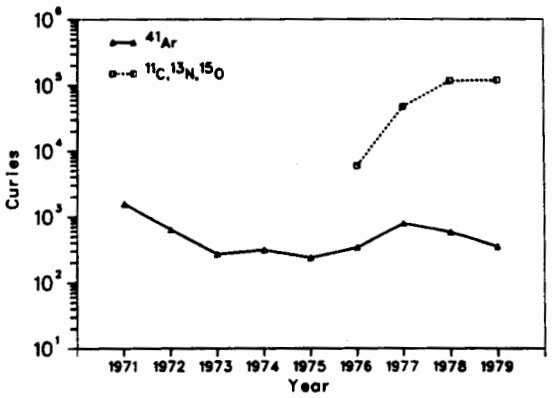


Fig. 14.
Summary of atmospheric releases of ^{41}Ar, ^{11}C, ^{13}N and ^{15}O.

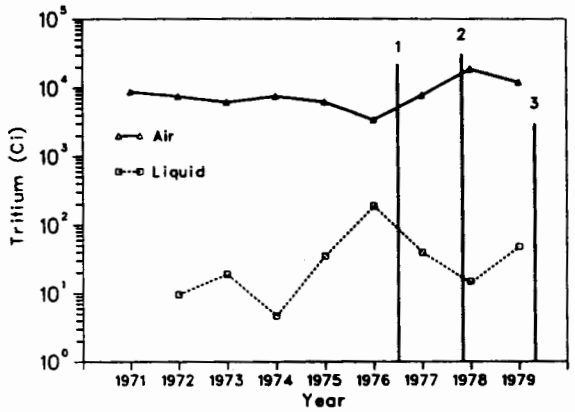


Fig. 15.
Summary of tritium effluents (air and liquid).

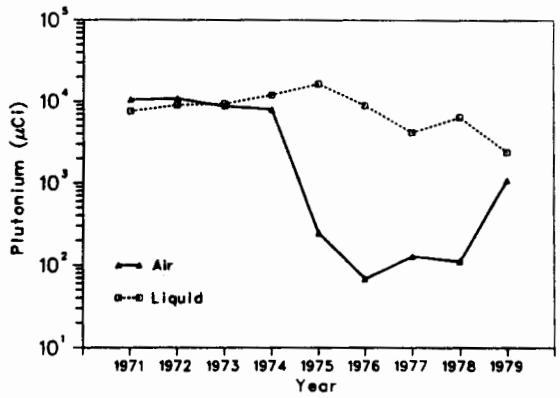


Fig. 16.
Summary of plutonium effluents (air and liquid).

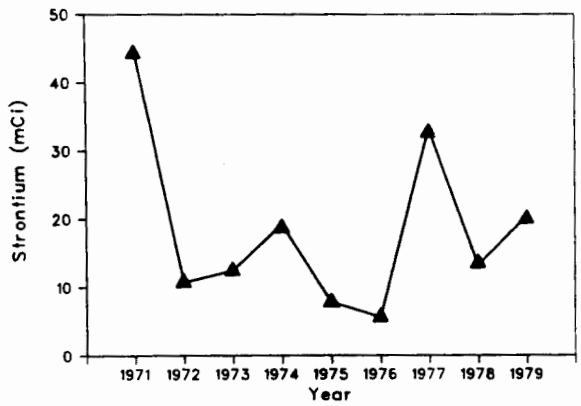


Fig. 17.
Summary of strontium liquid effluents.

calculations indicate that resulting airborne concentrations would be in the same range as attributable to 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 III.A.2). Estimates of nonradioactive releases from these experiments are discussed in Section III.B.3.

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 two sanitary sewage lagoons serving LAMPF. Detailed results of the effluent radioactivity monitoring are in Table E-XX and Figs. 15-17. Plutonium and cesium releases in 1979 were lower by factors of two to three, whereas americium, strontium, and tritium were higher by as much as 2.7 in comparison with 1978. Design work is underway for upgrading TA-50, which will further reduce the amount of contaminants in the effluent. Activity released from TA-21 is down by a factor of two for some isotopes and by a factor of four or more for the remainder of the radionuclides. Plutonium operations were moved from TA-21 in 1978 to TA-55. Remaining effluents at TA-21 are from decontamination operations. TA-55 liquid wastes are

treated at TA-50. A total of 1.7×10^7 ℓ of effluent was discharged from the TA-53 sanitary lagoons containing 0.021 Ci of ^{22}Na, 0.86 Ci of ^{7}Be, and 15 Ci of ^{3}H. The source of the radioactivity was activated water from beam stop cooling systems. None of the concentrations were at concentrations higher than about 0.9% of CGs for water in controlled areas. 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 IV.C.9.

Releases from the larger plant (TA-50) are discharged into a normally dry stream channel (Mortandad Canyon) in which surface flow has not passed beyond the Laboratory boundary since before the plant began operation. Discharges from the smaller plant (TA-21) are into DP Canyon, a tributary of Los Alamos Canyon where runoff does at times flow past the boundary and transports some residual activity adsorbed on sediments. Effluent from the LAMPF lagoons sinks into alluvium within the Laboratory boundary.

7. Unplanned Releases

On May 4, 1979, up to 0.31 g (3000 Ci) of tritium (probably as tritium gas and oxide) were released to the environment from an accidental overheating of a stainless steel pot containing uranium tritide at the Cryogenics Building (SM-34). Had the release been all tritium oxide (HTO) it would have been measured by the air sampling network, however, it was not detected. To estimate upper bound doses from the release, standard diffusion models were used and the entire release was conservatively assumed to be HTO. This estimate gives a maximum boundary dose (near the Omega Bridge) of 0.27 mrem which is 0.05% of the annual dose limit to members of the public. Since we were not able to measure in the atmosphere the release, it is likely that actual doses would probably be 10 to 100 times lower than those calculated. Although Royal Crest Mobile Home Park, the nearest offsite location, was not downwind from the release, the HTO concentration at the Park was somewhat higher (16 pCi/m^3) than perimeter (average 2.9 pCi/m^3, maximum 5.3 pCi/m^3) and regional (average 3.6 pCi/m^3, maximum 8 pCi/m^3) stations for this period, but was well within expected values for this station (1978 average 16 pCi/m^3, maximum 67 pCi/m^3).

On Oct. 31, 1979, a small amount of activated soil was released as airborne emissions from the Omega West Reactor Facility located in Los Alamos Canyon. A soil sample stuck in a sample irradiation port at the reactor. During attempts to remove the stuck sample, the sample container broke spreading activated soil throughout the sample handling room. Some of this activity (principally ^{152m}Eu, ^{116m}In, ^{140}La, and ^{24}Na) escaped to the environment through an unfiltered air exhaust in the room. Samples were collected from five routine air monitoring stations (TA-53, TA-21, Gulf Station, Royal Crest, and 48th Street) near Los Alamos Canyon and at two background locations (Well PM-1 and Espanola). None of the samples had detectable activity. Detection limits for these short-lived isotopes (maximum half life was 40 h) were between 100 and 10 000 times below the uncontrolled area CGs (which apply to continuous exposure) for those isotopes.

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. The chemical quality of water from the municipal supply for the Laboratory and community meets the standards set by the EPA 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.

TABLE XIX

MAXIMUM CHEMICAL CONCENTRATIONS IN REGIONAL AND PERIMETER WATERS
(concentrations in mg/ℓ)

Analysis	Regional	Perimeter: Four Stations	Perimeter: White Rock Canyon	Standard or Criteria
Ca	49	31	29	---
Mg	12	8	9	---
Na	45	32	116	---
Cl	52	29	44	250
F	0.8	0.6	1.0	2.0
NO_3	1.4	16	32	45
TDS	444	266	528	1000.

a. Regional and Perimeter. Regional and perimeter surface and ground waters were sampled at the same locations as were used for radioactivity monitoring (Table E-X). The regional surface waters were sampled at six stations, with perimeter waters sampled at four stations plus 23 stations in White Rock Canyon (Figs. 7 and 12). Detailed analyses from the regional and perimeter stations are presented in Tables E-XI and E-XII, respectively. (See Appendix B.3 for methods of collection, analyses, and reporting of water data.) The maximum concentrations for seven parameters are in Table XIX.

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 the quality of water from previous analyses.

b. Onsite Surface and Ground Waters. Water samples were collected from two surface water stations and six wells completed in the main aquifer (Table E-XIII). They are located in onsite areas that do not receive industrial effluents (Fig. 12). Detailed results of analyses are given in Table E-XIV. The maximum concentrations for selected constituents are in Table XX. 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 analyses.

Table E-XIV details the chemical quality analyses of surface and ground water from 26 stations located in canyons that receive sanitary and/or industrial effluent (Fig. 12, Table E-X). The maximum concentrations of selected constituents found in each canyon are summarized in Table XXI.

Acid-Pueblo Canyon received industrial effluents from 1943 to 1964 and currently is receiving treated sanitary effluents, which are now the major part of the flow. 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 process. The high TDS and chlorides reflect effluents released into the canyons. Fluorides and nitrates in DP-Los Alamos and Mortandad canyons were above drinking water standards;[6] however, these onsite waters are not a source of municipal, industrial, or agricultural supply (Table XXI). The maximum concentrations occurred near the effluent outfalls. The chemical quality of the water improves downgradient from the outfall. There is no surface flow to the Rio Grande in these canyons except during periods of heavy precipitation.

TABLE XX

MAXIMUM CHEMICAL CONCENTRATIONS IN ONSITE NONEFFLUENT WATER
(concentrations in mg/ℓ)

Analysis	Surface Water	Ground Water	Standard or Criteria
Ca	7	32	---
Mg	4	3	---
Na	15	21	---
Cl	17	13	250
F	0.7	0.5	2
NO_3	3	3	45
TDS	192	186	1000

TABLE XXI

MAXIMUM CHEMICAL CONCENTRATIONS IN EFFLUENT AREA WATERS
(concentrations in mg/ℓ)

Analysis	Acid—Pueblo	DP—Los Alamos	Sandia	Mortandad	Standard or Criteria
Ca	16	43	16	16	---
Mg	4	6	6	5	---
Na	69	130	128	146	---
Cl	61	127	93	22	250
F	0.9	10	1.6	3.1	2
NO_3	31	98	30	140	45
TDS	370	580	690	680	1000

2. Water Supply

The federally-owned well field produced water for the Laboratory and County water samples from the distribution system met all applicable EPA standards.

Municipal and industrial water supplies for the Laboratory and community were sampled at 15 deep wells, one gallery, and at five stations on the distribution system (Table E-X, Fig. 12). Detailed analyses are in Table E-XIII. Appendix A gives the federal and state standards and criteria for municipal water supplies. The maximum concentrations of chemical constituents from wells, gallery, and distribution system stations are compared to criteria in Table XXII.

Concentrations of arsenic (0.5 mg/ℓ) and fluoride (2.8 mg/ℓ) in water from well LA-1B and lead (0.19 mg/ℓ) in water from well G-6 were at or above standards for drinking water;[6] however, mixing with water from other wells reduces the concentrations to levels well within standards at points of use. Arsenic and fluoride in water from well LA-1B is naturally occurring in the aquifer. The high lead concentration in well G-6 is from wear on the pump resulting in finely divided particles of lead-containing brass in the water. The well was taken out of service in November 1978 and returned to service in June 1979. The well was taken out of service again in August as the well was pumping sand and the pump could not be adjusted to operate properly. It has since been removed for repairs.

TABLE XXII

MAXIMUM CHEMICAL CONCENTRATIONS IN WATER SUPPLY
(concentrations in mg/ℓ)

Analysis	Supply Wells and Gallery	Distribution	Standard or Criteria
Ag	<0.001	<0.001	0.05
As	0.05	0.01	0.05
Ba	<0.5	<0.5	1.0
Cd	<0.01	<0.01	0.010
Cl	15	8	250
Cr	0.02	0.008	0.05
F	2.8	1.0	2.0
Hg	<0.0005	<0.0005	0.002
NO_3	<2	<2	45
Pb	0.19	<0.01	0.05
Se	<0.005	<0.005	0.01
TDS	588	262	1000

3. Nonradioactive Effluents

Nonradioactive effluents include airborne and liquid discharges. Airborne effluents from the beryllium fabrication shop; gasoline storage and combustion; power plant; gases and volatile chemicals; waste explosive burning; lead pouring operations; and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. A single NPDES permit covers 108 industrial discharge points and 10 sanitary sewage treatment facilities. This year 6 of the 10 sanitary sewage treatment facilities exceeded one or more of the NPDES limits (excluding flow rate limitations) in one or more months and less than 1% of all samples from the 108 industrial outfalls exceeded NPDES limits.

a. Airborne Discharges. Airborne particulate concentrations in the Los Alamos and White Rock areas are routinely measured by the New Mexico State Environmental Improvement Division. Table E-XXI summarizes these data for 1979. The highest 24 h averages and annual averages are compared to the New Mexico Ambient Air Quality Standards for particulates in Table XXIII. Both the 24 h averages and annual geometric means are well within state standards. Although true 7 day and 30 day averages cannot be calculated, there is no indication that they would exceed state standards.

Particulate samples from samplers located throughout and adjacent to Laboratory property have been collected monthly since June of 1979 for heavy metal analyses. Samplers are located at the Fenton Hill Geothermal Site, the LASL Administration Building (TA-3), Santa Fe, Bandelier National Monument, White Rock, TA-49, and TA-54. This sampling program was initiated primarily to measure concentrations of nonradioactive elements in air for comparison with standards and to determine whether LASL emissions are making any contribution. The project will also provide background data on concentrations of nonradioactive elements in the Los Alamos area. Some difficulty in sample analysis has been encountered, so that no results from this program are yet available.

TABLE XXIII

SUMMARY OF ATMOSPHERIC PARTICULATE CONCENTRATIONS IN LOS ALAMOS AND WHITE ROCK DURING 1979

	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	77	113
Maximum 7 day average	110	---	---
Maximum 30 day average	90	---	---
Annual geometric mean	60	35	35

The samples will be analyzed for Al, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Si, Ti, and Zn.

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

Beryllium concentrations in the stack gases from the beryllium shop are monitored by the Industrial Hygiene Group. However, for a large part of 1979 the stack gas sampling apparatus was broken, so no data are available on beryllium emissions for last year. In past years, stack gas concentrations have always been below the state ambient air standard of 0.01 $\mu g/m^3$, and total annual beryllium emissions have been about 20 mg. There is no reason to believe that there were substantial changes in emissions during 1979. The sampler is back in operation now, so data should be collected during 1980.

A large fleet of cars and trucks is maintained for the Laboratory complex by the Zia Company. During fiscal year 1979, a total of 2.4×10^6 ℓ of gasoline were used by this fleet to cover 3.6×10^6 km. These figures represent changes of −0.5% and +1.7%, respectively, indicating a slightly greater fuel economy than last year. Carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and particulates are emitted during automobile 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 EPA emissions factors[13] to these data, air pollution emissions associated with maintenance and operation of the vehicle fleet (Table XXIV) were estimated. Estimated vehicle emissions are down drastically from last year because of reduced EPA emission factors for 1978 and 1979 vehicles.

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 input for the TA-3 power plant individual boilers during 1979 were 0.67×10^{12} Btu, 0.66×10^{12} Btu, and 0.77×10^{12} Btu. Total heat input for the power plant was 2.1×10^{12} Btu (about 14% less than last year), but inputs for the individual boilers were below the 1×10^{12} Btu/yr exemption threshold.

Measured NO_x (nitrogen oxides) concentrations in the power plant stack gas ranged from 36 to 46 ppm, which is about 20% of the standard that would apply if the heat input threshold were exceeded. Sulfur dioxide (SO_2) analyses of the stack gas are

TABLE XXIV

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

Pollutant	Estimated Amount (metric tons)	Change From 1978 (%)
Gasoline Evaporative Losses	29	+2.5
Carbon Monoxide	108	−49
Hydrocarbons	9	−57
Nitrogen Oxides	17	−41
Sulfur Oxides	1.2	+8.3
Particulates, Exhaust	0.7	+17
Particulates, Tires	1.4	+17

TABLE XXV

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

Pollutant	Estimated Amount (metric tons)
Sulfur oxides	0.55
Hydrocarbons	0.91
Carbon monoxide	15.5
Particulates	9.1
Nitrogen oxides	319

TABLE XXVI

ESTIMATED EMISSIONS FROM BURNING OF EXPLOSIVE WASTES (Using Data from Mason and Hanger—Silas Mason Co., Inc.[13])

Pollutant	Estimated Amount (kg)
Carbon Monoxide	155
Particulates	358
Nitrogen Oxides	600

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 XXV shows estimated total power plant emissions for 1979, based on EPA emission factors[13] for natural gas burning facilities. The apparent decrease in NO_x emissions from previous years' estimates is because the earlier estimates did not incorporate a load reduction factor to account for operation of the boilers at about 60% of their design capacity.

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 has been compiled (Table E-XXII). On the basis of actual release data obtained from compressed gas and volatile chemical users throughout the Laboratory, estimates of emissions are in preparation.

During 1979 a total of 19 865 kg of high explosives wastes were disposed by open burning at the Laboratory. Estimates of emissions (Table XXVI) were made by using data from experimental work carried out by Mason & Hangar-Silar Mason Co., Inc.[14] Open burning of high explosives wastes is permitted by the New Mexico Air Quality Control regulations.

Dynamic experiments employing conventional explosives are routinely conducted in certain test areas at LASL 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 concentrations at the LASL boundary based on the current year's utilization of the elements of interest. The results are presented in Table E-XXIII along with comparisons to applicable air quality regulations. The average concentrations are all less than 0.01% of applicable standards. The amount of material used in testing operations during 1979 was less than 50% of that used during the previous year.

b. Liquid Discharges

Nonradioactive liquid wastes are released from 108 industrial discharge points and 10 sanitary sewage treatment facilities subject to National Pollutant Discharge Elimination System (NPDES) requirements. The single NPDES permit for LASL issued by the EPA places specific effluent limits on 10 categories of industrial waste outfalls and 10 sanitary sewage treatment facilities. Tables E-XXIV and E-XXV summarize the effluent quality and compliance status of the sanitary and industrial waste outfalls, respectively.

This year two of the sanitary sewage outfalls met all limits, and two others (lagoons) exceeded only flow rate limits during winter months when they were frozen. The industrial outfalls exceeded one or more limit during 1979 less than 7% of the time. Eight of those responsible for the largest number of deviations are scheduled for already-funded corrective measures to be carried out in 1980-81.

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 less than 3% 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.

IV. ENVIRONMENTAL EVALUATION

A. Radiation Doses

Small incremental radiation doses above those recieved from natural and worldwide fallout background are received by Los Alamos County residents as a result of LASL operations. The largest estimated dose at an occupied location was 6.1 mrem or 1.2% of the Radiation Protection Standard. This estimate is based on boundary dose measurements of airborne and scattered radiation from the accelerator at TA-53. Other minor exposure pathways, direct radiation from TA-18 and two unlikely food pathways may result in several mrem/yr in isolated cases. No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. The radioactivity is absorbed in alluvium before leaving LASL boundaries and 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 10.86 man-rem or about 0.41% of the 2665 man-rem received by the same population from natural radiation sources, and 0.54% of the population dose due to diagnostic medical exposure. As no significant pathways could be identified outside the County, the 10.86 man-rem dose also represents the population dose to inhabitants living within an 80 km radius of LASL who receive an estimated 13 000 man-rem from background radiation. The average added risk of cancer mortality to Los Alamos residents from radiation from this year's LASL operations is 1 chance in 13 000 000. This risk is much less than the 1 chance in 72 000 from background radiation, which in turn is very small compared to the average annual New Mexico cancer incidence risk rate of 1 chance in 405. The EPA has estimated average lifetime risk for cancer incidence as 1 chance in 4 and for cancer mortality as 1 chance in 5.

One means of evaluating the significance of environmental releases of radioactivity is to interpret the exposures received by the public in terms of doses that can be compared to appropriate standards and naturally present background. The critical exposure pathways considered for the Los Alamos area were atmospheric transport of airborne radioactive effluents, 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 for some airborne and waterborne contaminants and external penetrating radiation, and by theoretical calculation based on atmospheric dispersion for other airborne contaminants. Doses were calculated from measured or derived exposures utilizing models based on recommendations of the International Council on Radiation Protection (ICRP, see Appendix D for details) for each of the three following categories:

1. Maximum dose at a site boundary,
2. Dose to individual or population groups where highest dose rates occur, and

3. The whole body cumulative dose for the population within an 80 km radius of the site.

Exposure to airborne ^{3}H (as HTO) was determined by actual measurements with background correction based on the assumption that natural and worldwide fallout activity was represented by the average 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 LAMPF were inferred from direct radiation measurements (see Sec. III.A.1). Exposure from ^{41}Ar released from the TA-2 stack was theoretically calculated from measured stack releases and standard atmospheric dispersion models.

Estimates of a maximum lung exposure to plutonium were calculated by subtracting the average concentration at the regional stations from the average concentration from the perimeter station with the highest measured plutonium concentration (Table XXVII).

The maximum boundary and individual doses attributable to these exposures are summarized in Table XXVII with a comparison to the Radiation Protection Standards (RPS) for individual doses (see Appendix A).

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

Liquid effluents, as such, do not flow beyond the LASL boundary but are absorbed in alluvium of the receiving canyons; excess moisture is lost primarily by evapotranspiration. These effluents are monitored at their point of discharge and their behavior in the alluvium of the canyons below outfalls has been studied.[17-20] Small quantities of radioactive contaminants transported during periods of heavy runoff have been measured in canyon sediments beyond the LASL boundary. Calculations made for the Final Environmental Impact Statement[3] 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.

There are no known significant aquatic pathways or food chains to humans in the local area. Fruit, vegetable, honey, and fish sampling (see Sec. III.A.5) has documented that any exposure attributable to LASL operations via those pathways is insignificant. A possible minor exposure pathway exists by eating venison from deer who cross into Laboratory property to graze and drink. The maximum dose calculated via this pathway is 3.9 mrem/yr[3] and is unlikely to occur.

As was stated in Sec. III.A.1, no measurements of external penetrating radiation at regional and perimeter stations in the environmental network indicated any discernable increase in radiation levels that could be attributed to LASL operations except those along State Road 4 north of LAMPF. The special TLD network at the Laboratory boundary north of TA-53 indicated a 21.7 mrem increase above natural background. Of this increase, 10.7 mrem was attributed to direct and scattered radiation from stored shield components and an opened beam stop area during accelerator maintenance in the fall at LAMPF. Based on occupancy and shielding, this would contribute a 3.0 mrem dose to an individual working at the restaurant north of LAMPF. The other 11.0 mrem are attributed to activated air emissions from LAMPF. These airborne emissions would contribute a 3.1 mrem dose to an individual working in the restaurant north of LAMPF for a total dose of 6.1 mrem which is 1.2% of the RPS for a member of the public.

Onsite measurements of above background doses were expected and do not represent potential exposure to the public except in the vicinity of TA-18 on Pajarito Road. Members of the public regularly utilizing the DOE-controlled road passing by TA-18 would likely receive no more than 0.5 mrem/yr of direct gamma and neutron radiation. This value was derived from 1975 data[21] on total dose rates using 1979 gamma doses measured by TLDs and estimating exposure time by assuming a person made 15 round trips per week at an average speed of 40 mph past TA-18 while tests were being conducted. The onsite station near the Laboratory boundary at State Road 4 recorded a dose of 187 mrem/yr. This is caused by a localized accumulation of ^{137}Cs on sediments transported from a treated effluent release point upstream. A maximum onsite dose to a member of the public from airborne effluents of 0.00055 mrem was estimated for a person spending 4 h at the Laboratory Museum while ^{41}Ar effluent dispersed from TA-2 passed over the Museum. The ^{41}Ar emissions from TA-2 and TA-53 could result in a

TABLE XXVII

BOUNDARY AND MAXIMUM INDIVIDUAL DOSES FROM AIRBORNE RADIOACTIVITY

Isotope	Critical Organ	Maximum Boundary Dose		Maximum Individual Dose		% RPS
		Location	Dose (mrem/yr)	Location	Dose (mrem/yr)	
^{3}H(HTO)	Whole Body	TA-54	0.043	Airport	0.0084	0.0017
^{11}C, ^{13}N, ^{15}O	Whole Body	Restaurant N. of TA-53	11.0	Restaurant N. of TA-53	3.1	0.62
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack	1.8	Apts. N. of TA-2 Stack	1.0	0.2
^{239}Pu	Lung	TA-54	0.008	Cumbres School	0.008[a]	0.00053

[a]For a 50-yr dose commitment, bone is the critical organ. A maximum individual would receive a 50-yr bone dose commitment of 0.51 mrem, which is 0.035% of RPS.

TABLE XXVIII

1979 WHOLE BODY POPULATION DOSES TO RESIDENTS OF LOS ALAMOS COUNTY

Explosure Mechanism	Whole-Body Population Dose (man-rem)
Atmospheric Tritium (as HTO)	0.06
Atmospheric ^{11}C, ^{13}N, ^{15}O	8.6
Atmospheric ^{41}Ar	2.2
Total Due to LASL Atmospheric Releases	10.86
Cosmic and Terrestial Gamma Radiation[a]	1850
Cosmic Neutron Radiation (~17 mrem/yr per person[15])	330
Self Irradiation from Natural Isotopes in the Body (~24 mrem/yr per person[4])	470
Average Due to Airline Travel (~0.22 mrem/h at 9 km[4])	15
Total Due to Natural Sources of Radiation	2665
Diagnostic Medical Exposure (~103 mrem/yr per person[16])	2020

[a]Calculations are based on measured TLD 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.

theoretically calculated annual regional (at Espanola) dose of 0.004 mrem.

Cumulative 1979 whole body doses to Los Alamos County residents attributable to LASL operations are compared to exposure from natural radiation and medical radiation in Table XXVIII. Population data are based on a Los Alamos County Planning Department estimate of 13 300 residents in the Los Alamos townsite and 6300 in White Rock.

The calculated 8.6 man-rem from atmospheric ^{11}C, ^{13}N, and ^{15}O is probably high because it is subject to many of the same uncertainties that caused boundary dose calculations to overestimate actual doses.[9] The whole-body population dose to the estimated 108 000 inhabitants[22] of the 80 km circle around Los Alamos because of LASL operations is estimated to be 10.86 man-rem, which is the population dose to Los Alamos County inhabitants. That 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 exposure undetectable and theoretically a very small fraction of the estimated 10.86 man-rem. By contrast, natural radiation exposure to the inhabitants within the 80 km circle is 12 800 man-rem.

Thus, doses potentially attributable to releases of effluents contribute about 0.41% of the total dose received by Los Alamos County residents from natural radiation, about 0.54% to the same population from diagnostic medical radiation, and about 0.008% of the dose from natural radiation received by the population within an 80 km radius of the Laboratory.

Since there is considerable interest in possible health effects from radiation doses to the public resulting from LASL operations, several risk estimates have been made. However, these calculations may overestimate actual risk as the NCRP[23] 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 ICRP estimates that the total stochastic risk of cancer mortality from uniform whole body irradiation for individuals is 1×10^{-4} per rem, i.e., there is 1 chance in 10 000 that an individual exposed to 1000 mrem of whole body radiation would develop a cancer. In developing risk estimates the ICRP 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."[24] Persons living in Los Alamos and White Rock received an average of 138 mrem and 128 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 due to natural radiation in 1979 was 1 chance in 72 000 in Los Alamos and 1 chance in 78 000 in White Rock. LASL operations contributed an average dose of 0.78 mrem to individuals in Los Alamos and 0.08 mrem to individuals in White Rock. These added risks amount to a conservative 1 chance in 13 000 000 in Los Alamos and 1 chance in 130 000 000 in White Rock of a cancer mortality due to LASL activities. The average incidence is 1 chance in 405 each year that a person in New Mexico will contract a cancer from all causes.[25] For Americans the average lifetime risk is a 1 in 4 chance of contracting a cancer and a 1 in 5 chance of dying from the disease.[26] The Los Alamos and White Rock additional doses attributable to LASL operations are equivalent to the additional exposure a person would get from riding in a jet aircraft for 3.5 and 0.36 h, respectively.

The additional exposure (which is likely overestimated) 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[27] 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 LASL operations because of increased radon levels inside the homes. The EPA has estimated the annual whole body dose to individuals from global fallout to be 4.4 mrem of which 2.5 mrem is due to ingestion of ^{90}Sr.[28]

B. Environmental Protection Programs at LASL

1. LERC/EEC Program

In order to assist DOE to comply with requirements of the National Environmental Policy Act (NEPA), LASL has a Laboratory Environmental Review Committee (LERC). The membership consists of representatives from several Associate Directors offices, Financial Management, the Engineering Department, and the Health Division. The LERC has responsibility to review environmental assessments (EAs) and other environmental documents prepared for DOE by the Laboratory. Additionally, LERC identifies and reviews items of environmental interest that are generated by Laboratory activities or that affect the Laboratory programs and property. An Environmental Evaluations Coordinator (EEC), based in the Environmental Surveillance Group (H-8), assists LERC by coordinating with user groups, Health Division and the Engineering Department on development of environmental documents and providing input to project design at the earliest stage for appropriate environmental decision making.

Projects that may require an EA or EIS are screened by the EEC to determine what form of environmental documentation is necessary. When needed, various resource persons are identified by

the EEC to assist in preparation of the draft environmental document for the proposed construction or programmatic project.

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

2. Quality Assurance Program

LASL has a Quality Assurance (QA) program[29] for engineering, construction, modification, and maintenance of DOE-owned 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. QA is implemented from inception of design through completion of construction by a project team approach. The project team consists of individuals from the DOE program division, DOE Albuquerque Operations and Los Alamos Area Offices, LASL operating group(s), LASL Engineering Department, 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 QA 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, archeological resources, etc.), environmental consequences of the proposed project (airborne effluents, liquid effluents, industrial waste, solid waste, noise levels, traffic patterns, etc.), and environmental impact assessment (air, water, land, visual, noise, odor, biota, etc.).

3. Archeology

Protection of archeological sites at LASL (mandated by several Congressional acts and Executive Order 11593) is also part of the QA program. A proposed location for a new facility is checked to determine if there are any archeological sites in the area. An attempt is first made to adjust siting so as to preserve the site. If alternative siting is not feasible, then the site is excavated to gain knowledge about it and recover artifacts before it is destroyed. The decision as to which course to follow is based on the value of the archeological site, on the availability of alternative locations for the new facility, and on the programmatic impact if the new facility were not built at that location.

A survey of more than 450 archeological sites in LASL environs was made between March 1973 and July 1975. This survey of the pre-Columbian Indian ruins is summarized in a report,[30] which is used during construction planning to avoid damage to such sites if possible, or to provide the lead time necessary to conduct required salvage archeology. 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 and authority to protect the sites.

Twenty additional archeological sites were located at LASL in 1979 and have been added to the inventory of historic sites. During the year one pre-Columbian ruin (LA-4718) was excavated. It proved to be an exceptionally interesting site with a 2 m deep kiva and plans are being made to put a roof over the kiva to preserve it.[31]

Two local boys made an important and interesting find of two 15th century pottery vessels (Fig. 18) sealed with lime plaster.[32] The boys brought the pots to LASL where a series of nondestructive tests were made. X-rays showed how one pot rim fitted over the other pot rim. Neutron radiography revealed feathery-looking contents inside.

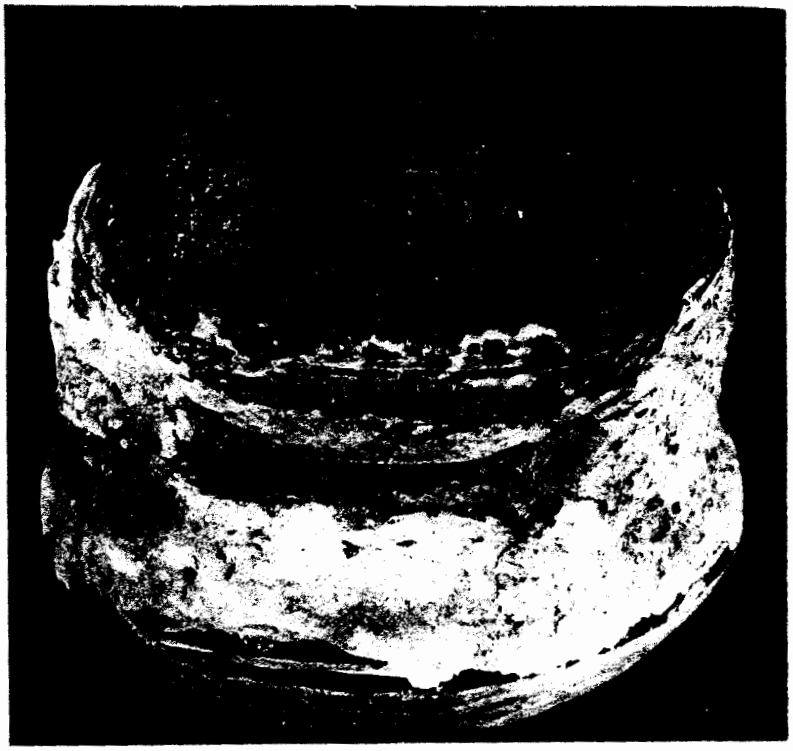


Fig. 18.
Two Indian pots sealed with the only known use of lime plaster found so far in the Southwest.

The pots were scrutinized by drilling a small hole, about 3 mm in diameter, through the top pot. An optical borescope, a slender metallic rod with a light at one end and an eyepiece at the other, was inserted. Inside, feathers of several different colors, ranging from reddish to white to soft orange, could be seen. Yucca plant fibers, twisted into cords, also came into view. The feathers and other samples, small bits of which were pulled from the pot with a fine wire, have been sent to the Smithsonian Institute for ornithological and other analyses. The feathers have been tentatively identified as belonging to the macaw, which would make them imported; they could also be from an indigenous species like the flicker. The pots have been placed in the Bradbury Science Hall by the finders.

Five log cabins, which date from the early years of this century, are located within LASL boundaries. All are deteriorating rapidly, and the Historic Preservation Branch of the National Park Service is preparing a preservation plan for the structures. Borings of the logs will be taken to estimate construction dates by dendrochronology. Serious damage to one of the log cabins, the Anchor Ranch Ice House, was done by vandals during the summer of 1979. The entire north wall was pulled over—presumably by someone who wanted some well-cured poles.

4. Decontamination and Decommissioning Work

During the spring of 1979, old tritium handling equipment was removed from building TA-35-2. To monitor for possible airborne release of tritium during decontamination operations, two special air sampling stations were established. The samplers were located within 3 m of the building in which the decontamination took place. Atmospheric tritiated water vapor (HTO) concentrations measured by

these two samplers ranged from 29 to 270 $\times 10^{-12}$ μCi/mℓ and averaged 114 $\pm$ 78 $\times 10^{-12}$ μCi/mℓ or about ten times normal onsite HTO levels. The controlled area CG for HTO is 5 $\times 10^{-6}$ μCi/mℓ and uncontrolled area CG is 2 $\times 10^{-7}$ μCi/mℓ (see Appendix A). HTO measured in ambient air outside the facility could have been from the decontamination operation and/or from off-gassing of the tritium handling equipment. Concentrations measured, however, were three to four orders of magnitude less than the appropriate CGs.

Work continued in 1979 at DP site (TA-21), in decontamination of buildings that were former plutonium handling facilities. Once decontaminated, the buildings will be used for other research activities. In conjunction with these activities, several underground structures (manholes, sewer lines, etc.) next to the buildings were removed along with associated contaminated soil. Soil was removed to the extent practicable, since it was not possible to remove all contaminated soil without threatening building foundations. The location and extent of soil decontamination was carefully documented for the time when the buildings are removed and the soil decontamination can be completed.

Radioactively contaminated air washers are being removed from TA-35-7 and disposed of at LASL's Radioactive Materials Disposal Site (TA-54). Possible contaminants in the washers were ^{90}Sr, ^{137}Cs, fission products, and low level transuranics. Four months into the project no indication of any airborne radioactivity from the operation has been seen on filters from two special air samplers located within 10 m of the facility.

C. Related Environmental Studies

The Environmental Science Group (LS-6) at LASL conducts research and experimental studies under auspices of the DOE. Some of the research programs conducted by LS-6 complement routine monitoring and research conducted by the Environmental Surveillance Group (H-8) in providing a better understanding of the ecosystem surrounding LASL in relation to the Laboratory's operations. Following are highlights of several of these research programs.

1. Fire Ecology at Bandelier National Monument [L. D. Potter (Plant Ecologist, Biology Department, University of New Mexico) and T. S. Foxx (LS-6)]

The role of fire in the ecosystem has been of increasing interest. For nearly 70 years a policy of total fire suppression was followed by Bandelier National Monument and the U.S. Forest Service. In 1976 a study was funded by the National Park Service to provide baseline data for a fire management plan. The study included a determination of fire frequency prior to start of the total fire suppression policy and plant succession after fire. Fire frequency was determined by fire scar dating and plant succession by examining areas known to have been burned. This baseline study was near completion in June 1977, when the La Mesa Fire burned 62 km^2 and swept over established plots. The area burned was under management of Bandelier National Monument, Santa Fe National Forest, and LASL.

To determine how this fire affected areas of known fire history, plots were examined to determine the amount of foliar singeing sustained during the La Mesa Fire. Resulting data showed that for the La Mesa Fire, the longer the interval since the last fire, the more foliar damage. Areas which had not burned within the last 27 years showed nearly complete tree kill. Analysis of fire scarred trees revealed a fire frequency averaging 17 years and ranging from 8 to 27 years. Alteration of the 8 to 27 year fire cycle was probably due to three factors: 1) settlement of the area began about 1894, one year after what appears to have been the last major fire; 2) extensive logging in the late 1800s and 1900s virtually cleared some areas of trees; 3) by 1920 the Bandelier National Monument and adjacent forested land were under a policy of total fire suppression which has existed to this day. Thus, the holocaustic nature of the La Mesa Fire can be attributed to over 80 years of fuel load accumulation. This study provides a case for more frequent fires.[33]

To protect valuable archeological resources from severe erosion and to maintain integrity of the watershed, the area was successfully seeded by air with six native grasses. A number of parameters related to germination of the grasses was examined under studies funded by the Eisenhower Consortium and LASL.[9,34] Success of germination varied from an average of 27% to a high of 97%. The density and

foliage cover of slender wheatgrass and sheep fescue is expected to help natural regeneration of ponderosa pine as well as to bring wildlife into the burned areas.

2. Status of Flora in the NERP [T. S. Foxx and G. D. Tierney (Consulting Botanists, LS-6)]

The Endangered Species Act of 1973 (Public Law 93-205) mandated location of habitats of plant species in danger of extinction on state and federal lands. In 1976 the Los Alamos National Environmental Research Park (NERP) was established with the ultimate goal of providing a study area "to contribute to the understanding of how man can best live in balance with nature while enjoying the benefits of technology."[35] Under this mandate a preliminary study[36] to provide information as to the location of possible endangered and threatened species within the NERP was initiated August 1977.

This initial study was confined to Water and Mortandad Canyons and adjacent mesas as representative of the larger (111 km^2) NERP. These areas were selected because they contained the greatest variety of habitats and provided a collecting transect dissecting the NERP. Each area was surveyed seasonally. Collections of all species were made initially and the occurrence of certain species was recorded. This provided not only information about species' diversity and distribution in each canyon, but also a more precise habitat description.

Among the flora in the area, one species, grama grass cactus *(Pediocactus paprycanthus)* that is on the Smithsonian Endangered and Threatened Species List, was found. It was located in an area adjacent to the NERP. The population was small and various human activities are contributing to deterioration of its habitat.

Fourteen plants on the New Mexico State Protected List were located. Only the Larkspur Violet *(Viola pedatifida)* appears to be of any significance. It is a rare peripheral, which has been collected infrequently in New Mexico. A small population was found and its habitat could be damaged by logging or herbicides. All other species on the protected list were ennumerated for informational purposes. None of those plants were considered rare or in need of protection from Laboratory activities, other than to preserve some natural flora of the area.

At the present time 280 species representing 62 taxonomic families were collected or noted in Mortandad, Effluent and Water Canyons. A number of these species had not previously been reported for the area. Much of the area surveyed was heavily disturbed due to activities prior to and since establishment of the Laboratory. There were various stages of plant succession. The upper portion of Water Canyon burned in the 1977 La Mesa Fire and now shows post-fire succession, increased size in many plant species, and heavy browsing of most shrubs.

This continuing study is designed to provide a data base so that LASL may comply with existing federal and state laws concerning protection of plant species. This data base will furnish necessary information for floristic dynamic studies.

3. Changes in Quality of Surface Water Related to La Mesa Fire, 1977 [W. D. Purtymun (H-8) and Howard Adams (H-7)]

Quality of water data was collected from a surface water station near the Bandelier National Monument Headquarters in Cañon de los Frijoles prior to and after the wildfire burned about 26 km^2 of the drainage area above the station.[37] The burn brought about a slight increase in calcium, bicarbonate, chloride, fluorides and total dissolved solids in base flow at the station (Fig. 19). Those constituents in base flow have shown a general decline in concentration with time as fire debris and ash is removed from the drainage area and channel with continued runoff.

Samples of base flow and storm runoff were collected in Cañon de los Frijoles and Capulin Canyon. About 3 km^2 of the drainage area at Capulin Canyon was burned by the La Mesa Fire in 1977. Samples of base flow and storm runoff in Cañon de los Frijoles indicated barium, calcium, iron, bicarbonate, manganese, lead, phenol, and zinc concentrations were elevated in storm runoff when compared to base flow (Fig. 20) concentrations. Analyses of base flow and storm runoff in Capulin Canyon indicated barium, calcium, iron, and manganese concentrations were elevated during runoff events when compared to base flow concentrations. Bicarbonates varied, but showed no statistically significant trends. Phenols and lead were below limits of detection. Presence of phenols in runoff is from decay of

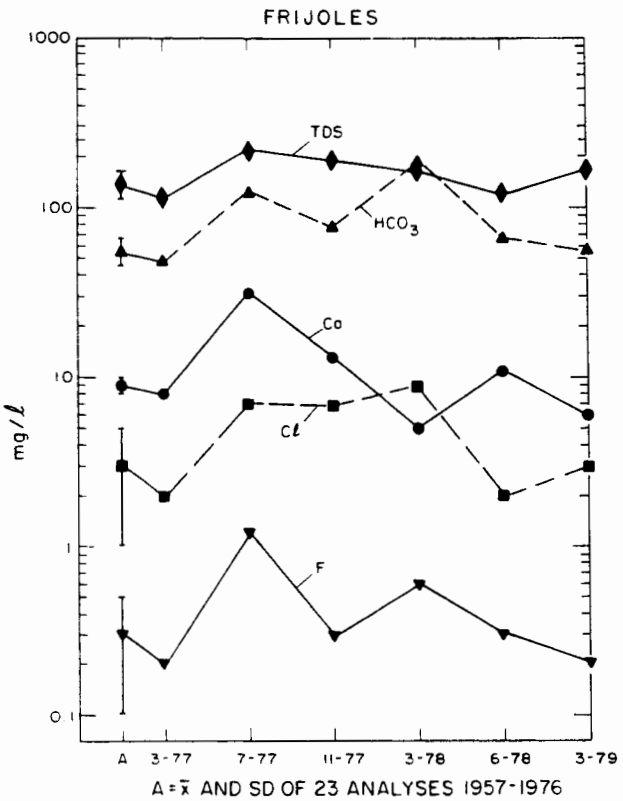


Fig. 19.
Variation in chemical constituents in base flow in Cañon de los Frijoles prior to and after the La Mesa Fire.

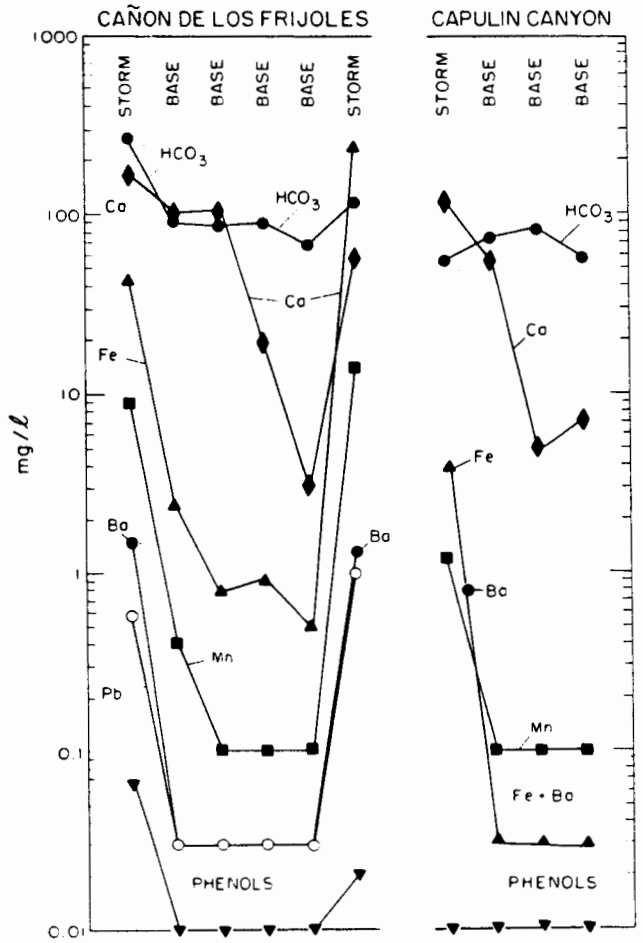


Fig. 20.
Variation in chemical constituents in base flow and storm runoff in Cañon de los Frijoles and Capulin Canyon after the La Mesa Fire.

vegetation in the drainage area. Lead concentrations found in runoff in Cañon de los Frijoles could possibly be from automobile emissions as it was not detected in the runoff events in Capulin Canyon. The Monument Headquarters in Cañon de los Frijoles is subject to heavy vehicle traffic, while Capulin Canyon is remote, with no vehicle access.

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

LASL is currently evaluating the feasibility of extracting thermal energy from hot dry rock (HDR) geothermal reservoirs at its Fenton Hill Site (TA-57). The concept involves drilling two deep holes into HDR, connecting these holes by hydraulic fracture, 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 (≈30 km W of Los Alamos, Fig. 21) has been determined for use in geohydrology and environmental studies. The results of past studies and detail data have been reported elsewhere.[38-43] Table E-XXVII summarizes the 1979 data on 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 one abandoned well. Water quality has varied slightly; however, the variations in quality are normal due to seasonal fluctuations.

Three ponds at the site contain water used in drilling operations and water used in the experimental

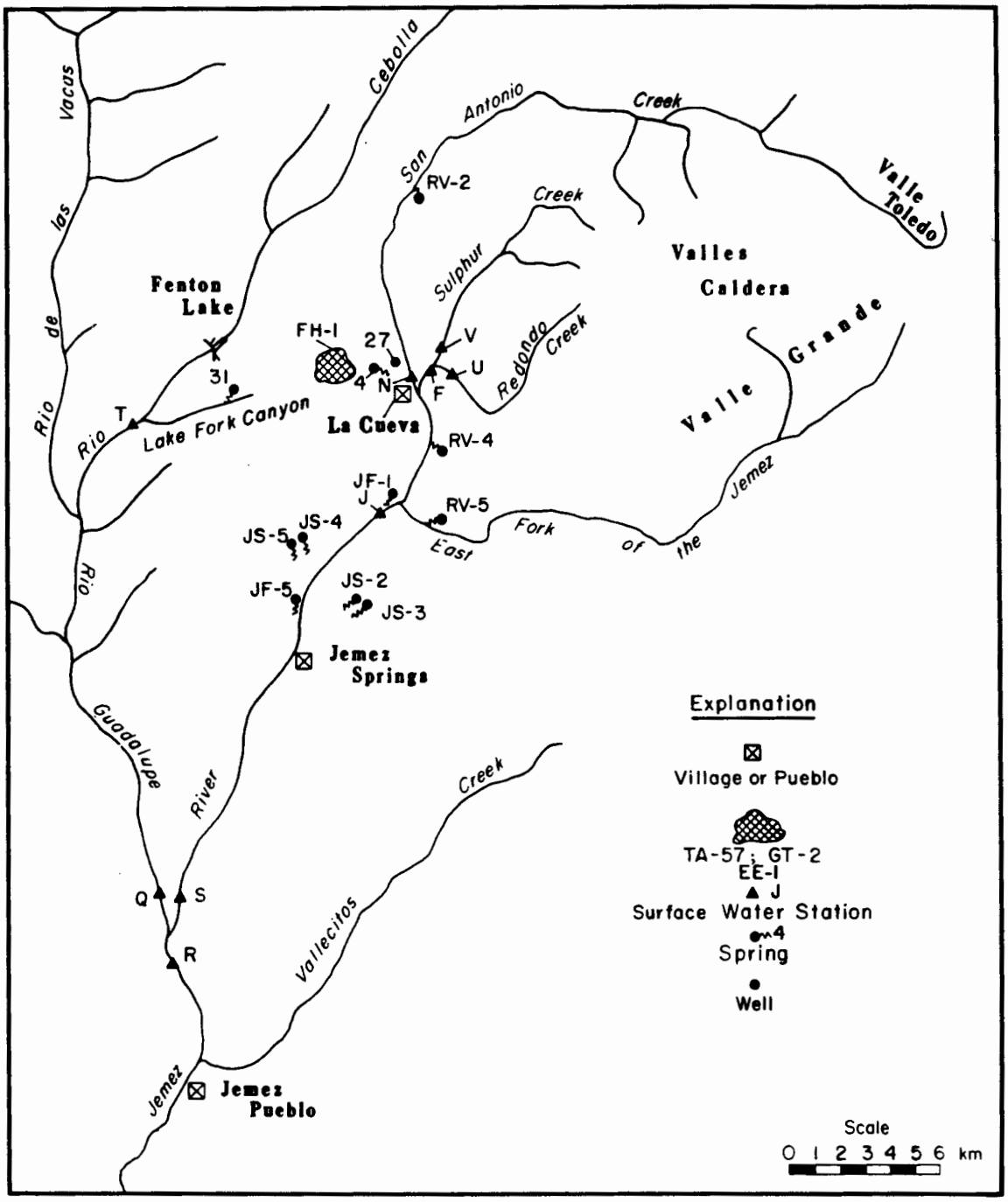


Fig. 21.
Water sampling locations in vicinity of Fenton Hill Geothermal Site (TA-57).

TABLE XXIX

AVERAGE CONCENTRATIONS OF SELECTED ELEMENTS IN PONDS AND IN SURFACE AND GROUND WATER AT TA-57
(concentrations in mg/ℓ)

Locations[a]	As	B	Cd	F	Li
Pond 1 (TA-57)	0.094	4.4	<0.001	3.1	2.63
Pond 2 (TA-57)	0.091	4.1	<0.001	2.2	2.93
Pond 3 (TA-57)	0.108	4.2	<0.001	3.6	2.79
Surface Water (9 Locations)	0.024	0.3	<0.002	0.8	<0.3
Water Supply (4 Locations)	0.003	<0.05	<0.001	0.5	0.03
Springs (2 Jemez Fault)	0.088	9.4	<0.001	3.1	8.20
Spring (1 Volcanics)	<0.001	<0.05	<0.001	1.1	0.02
Abandoned Well (1)	<0.001	<0.005	<0.001	1.0	<0.02

[a]See Table E-XXVII and Fig. 21 for location of sampling sites.

loop in the dry hot rocks at a depth of about 3000 m below land surface. The water in the ponds is highly mineralized (890 to 5100 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. Table XXIX presents the concentrations of these elements in the ponds and waters monitored in the area. Discharge from the ponds is into a dry canyon and its rate is regulated so that it infiltrates into alluvium of the dry canyon within 300 m of the ponds. The average concentrations of arsenic, boron, fluoride and lithium at surface water stations is elevated at stations R and S as the result of discharge from thermal and mineral springs at stations JS-1 and JS-5.[44]

Water from the supply well at the Fenton Hill Site (FH-1) was analyzed for chemical and radiochemical constituents to determine if the water is acceptable for municipal or domestic use according to EPA standards or criteria. A comparison of the analytical results to standards show that the water is well below limits set for municipal use (Table XXX).

5. Effect of Rototilling on the Distribution of ^{137}Cs in Trinity Site Soil [T. E. Hakonson and G. C. White (LS-6)]

Soils and sediments are the major repositories of radioactive and stable elements released to the environment. Thus, processes that redistribute soils and sediments also redistribute environmental contaminants, particularly those contaminants that are tightly bound to soil or sediment. For example, wind and water erosion of soil and sediment causes redistribution of environmental plutonium, americium, and ^{137}Cs.[46-51]

Contaminants that are suspended by wind and water deposit on land or on biological surfaces that include the lung. Thus, methods that reduce contaminant concentrations on land surfaces where erosion occurs may be beneficial in reducing risks incurred through inhalation and ingestion of particles.

This report presents results of an experiment to determine changes in spatial distribution of ^{137}Cs in nuclear fallout contaminated soil after vigorous, shallow, mechanical rototilling The scale of the experiment and tilling method were chosen to simulate

TABLE XXX

CHEMICAL AND RADIOCHEMICAL CONCENTRATIONS IN WATER FROM SUPPLY WELL AT TA-57

	Supply Well FH-1	Standard or Criteria[a]
Chemical (mg/ℓ)		
Ag	<0.001	0.05
As	<0.001	0.05
Ba	<0.5	1.0
Cd	<0.01	0.010
Cl	19	250
Cr	<0.002	0.05
F	0.3	2.0
Hg	<0.0005	0.002
NO_3	1.5	45
Pb	0.002	0.05
Se	<0.005	0.01
TDS	244	1000
Radiochemical (pCi/ℓ)		
^{3}H	<0.6	20
^{137}Cs	<80	200
^{238}Pu	<0.03	7.5
^{239}Pu	<0.04	7.5
Gross alpha	2.3	5
Total uranium[b]	1.9	1800

[a]Environmental Protection Agency's National Interim Primary Drinking Water Regulations (see Appendix A).
[b]μg/ℓ.

conditions normally used in establishing and preparing a small garden plot.

Concentrations of ^{137}Cs in soil as a function of depth and tilling summarized in Table XXXI. In the 0 to 7.5 cm depth profile, the arithmetic mean concentration of ^{137}Cs and coefficient of variation (in parentheses) based on a sample size of 130 was 1.94 pCi/g (0.87) before tilling and 1.76 pCi/g (0.53) after tilling. In the 7.5 to 15 cm profile, concentrations averaged 0.08 pCi/g (2.8) before tilling and 0.38 pCi/g (1.9) after tilling.

Differences in concentrations of ^{137}Cs between upper and lower profiles before tilling were significant ($p < 0.01$) and differed by a factor of about 25. The concentration decrease after rototilling of about 10% in the surface 7.5 cm of soil was not significant at the 95% confidence level (i.e., $p = 0.289$, t-test with correction for unequal variances). In contrast, the concentration of ^{137}Cs increased significantly ($p < 0.01$) in the lower profile reflecting transfer of ^{137}Cs from the surface to the lower profile.

The data was also highly skewed, particularly for the 0 to 7.5 cm depth before tilling and the 7.5 to 15 cm profile after tilling. This skewness is reflected by the variability in the concentrations.

TABLE XXXI

CONCENTRATION OF ^{137}Cs IN SOIL AS A FUNCTION OF DEPTH AND TILLING AT TRINITY SITE

Depth (cm)	Treatment	Number of Samples	^{137}Cs Concentration (pCi/g) Mean	1 s	Median
0-7.5	Before tilling	130	1.94	1.69	1.30
0-7.5	After tilling	130	1.76	0.94	1.60
7.5-15	Before tilling	130	0.083	0.23	0.025
7.5-15	After tilling	130	0.38	0.73	0.13

A significant change in variability of the data was noted after tilling. Variability in concentrations decreased significantly ($p \leq 0.01$, Moses test of extreme reactions)[46] in the surface 7.5 cm of soil after tilling with a corresponding reduction in skewness. However, variability increased significantly in the 7.5 to 15 cm profile samples after tilling.

The relatively minor effect of tilling on the concentrations of ^{137}Cs in the surface 7.5 cm was surprising considering the vigorous tilling effort. This result implies that shallow rototilling of soil is only slightly effective in reducing surface concentrations of contaminants strongly fixed to soil. Although concentrations of ^{137}Cs in the 7.5 to 15 cm profile increased by a factor of four, the difference in concentration between upper and lower profiles was still a factor of about five.

Procedures such as soil removal and mechanical tilling to reduce concentrations of potentially hazardous contaminants from surface soil must be evaluated to justify costs and ensure compatability with intended objectives. Results of this study demonstrate that shallow rototilling was ineffective in reducing surface soil concentrations of ^{137}Cs. Thus, the effectiveness of shallow rototilling in reducing soil contaminant transport across land surfaces by wind and water would be minimal, assuming that ^{137}Cs and soil particle size relationships were not greatly altered. However rototilling did reduce variability in ^{137}Cs concentrations in surface soils. Thus, considerable benefit could be realized by designing sampling programs in similarly treated areas, since sample size requirements, and thus, costs are related as a square function to variability.[52]

6. LA/NERP Elk Studies [G. C. White and T. E. Hakonson (LS-6)]

Elk biotelemetry studies were continued during the past year in the Los Alamos/National Environmental Research Park (LA/NERP) area through cooperative research with Bandelier National Monument and New Mexico State University. Twelve elk were trapped and radio collared during January on Bandelier National Monument in the habitat created by the La Mesa Fire. Three additional animals were trapped and radio collared west of Bandelier National Monument on U.S. Forest Service lands during late March and April, also on habitat created by the La Mesa Fire.

Elk were lured into modified Clover traps using alfalfa as bait. The traps were set and checked morning and evening. In addition, radios which had been placed on elk and deer and later returned were used to monitor the traps. The radios were wired to the trap door so that when the trap was sprung, the radio was shut off. Thus as long as the radio signal could be picked up, the trap was open.

Captured elk were sedated with a horse sedative to ease handling of the animal. Radio collared animals are located on a weekly basis, or more frequently. Locations are plotted on a base map, and coded for machine processing. Weekly fixes for each animal

are plotted by computer on a map of the Jemez Mountains.

The severe winter of 1978-79 did not seem to cause much mortality of the elk wintering on the La Mesa Fire burn area. One animal was captured which appeared severely malnourished, and it later died. However, other animals captured during the winter all survived, and all of the animals which had been radio collared during the previous winter survived. A summary of mortalities (or presumed mortalities) is given in Table XXXII. Of the four elk known dead, two have died from natural causes, and two bulls (both legal size) were killed by hunters. One bull is believed to have been poached, and one radio failed. Otherwise the remaining 23 animals are still being tracked.

The importance of the La Mesa Fire burn area as a elk wintering habitat was demonstrated during the winter of 1978-79. The animals radio collared during the previous winter resided in the area rather than in areas where they had been captured. The shift in winter habitat was particularly swift, taking place during a period of a week immediately after a severe December snow storm which left up to 1 m of snow on the ground. An additional factor may also have been hunter pressure on U.S. Forest Service lands, forcing animals onto unhunted National Park Service lands.

The bull elk have traveled extensively about the Jemez Mountains, while the cows have tended to stay in southeastern portions of the area. Bulls 161, 202, 720, and 820 all summered more than 24 km from their capture locations, while all the cows summered within 24 km of their capture locations. Bull 202 was particularly interesting because he was killed more than 65 km from the area where he spent the winter. Areas where these bulls spent the summer are not any higher in elevation or more remote than the area used by the cows.

7. Computer Generated Movies to Display Biotelemetry Data [G. C. White (LS-6)]

The typical biotelemetry study generally results in a large amount of data that is difficult to interpret and display because of a lack of effective presentation methods. Biotelemetry data are actually three dimensional: x and y coordinates, and time. Thus, three dimensional methods of viewing the data would generally facilitate interpretation because any method of collapsing three dimensions into two results in some loss of information. Use of computer generated 16 mm movies to portray biotelemetry data has been explored to permit the time dimension of the data to be viewed in correct evolutionary sequence. A computer generated movie of the elk movements described in Section IV.C.6 has been made, and a movie of coyote movements on the Idaho National Environmental Research Park (INERP) has been made. For the elk, 3000 observations on 30 elk are summarized by the movie, while over 5000 observations for 5 coyote are summarized in the INERP movie.

The present version of these movies consists of a colored base map with a small square moving on the map to depict animal movements. Color intensity of the square is enhanced when the location of the animal is based upon an actual radio-location; whereas movement of the square at normal color intensity represents linear interpolation between actual radio fixes.

The time dimension is also displayed on the map. In the elk movie, the month and year are displayed simultaneously with animal movements data. Coyote data was taken intensively over 24 h periods, so a 24 h time line is used to show the time of day.

A permanent trace of all movements of one individual during an observation period can be obtained to facilitate identification of areas of frequent use and rough home range sizes. Data from multiple animals can also be displayed simultaneously to examine interactions between individuals, and sex and age classes as a function of season and habitat. Individuals or groups of animals (stratified by age or sex) can be distinguished by color of the squares. Movements of individual animals are not permanently traced due to the clutter that would result.

8. NERP Climatology Data [F. G. Fernald and D. A. Dahl (H-8)]

An automated meteorological tower network is being developed by the Environmental Surveillance Group (H-8) to provide meteorological data for environmental assessments, emergency response at atmospheric releases of pollutants, and climatological characterization. This includes future demands NERP will have for meteorological data in support of plant and animal life studies.

TABLE XXXII

STATUS OF RADIO COLLARED ELK AS OF NOVEMBER 9, 1979

Radio Frequency	Age at Capture	Sex	Date of Capture	Status
161	Calf	M	2/23/78	Alive
202	Calf	M	3/19/78	Killed by hunter 10/79
280	Adult	F	5/4/78	Alive
292	Adult	F	2/10/78	Alive
313	Calf	F	1/28/78	Alive
588	Yearling	M	2/16/78	Killed by hunter 9/78
615	Adult	F	2/10/78	Alive
639	Adult	F	1/25/78	Alive
734	Calf	M	2/21/78	Killed by lightning 7/78
760	Adult	F	2/18/78	Alive
771	Calf	F	1/26/78	Alive
790	Calf	F	2/13/78	Alive
820	Calf	M	2/14/78	Alive
843	Adult	F	1/21/78	Alive
880	Adult	F	2/8/78	Alive
173	Calf	M	1/3/79	Alive
214	Calf	F	1/5/79	Alive
262	Calf	F	1/7/79	Alive
323	Calf	F	1/9/79	Alive
330	Yearling	F	1/10/79	Radio failure
375	Adult	F	1/10/79	Alive
388	Adult	F	3/28/79	Died of malnutrition 4/79
405	Calf	M	1/14/79	Alive
447	Adult	F	1/11/79	Alive
490	Calf	M	1/18/79	Alive
565	Calf	F	1/19/79	Alive
602	Yearling	M	1/19/79	Presumed poached 7/79
703	Adult	F	4/15/79	Alive
720	Adult	M	4/16/79	Alive

Microprocessor controlled meteorological towers automatically preprocess and record measurements that include temperature, wind speed, wind direction, solar radiation, dewpoint temperature, humidity, and rainfall. The systems are capable of operating on solar power alone. Emphasis has been placed on accumulating an accurate data base from which accident assessments and climatological summaries can be readily drawn.

Meteorological data are currently collected and recorded at the Occupational Health Laboratory (OHL) and the active waste disposal site. A transportable tower as well as additional permanent installations are planned in order to provide data representative of the entire Laboratory area.

The microprocessor controlled data system is programmed to sample each sensor 256 times every 15 minutes. The data are then written to cassette tape as an eighty character record which includes a header identifying the station, the data and time, plus 23 data channels. These data channels are apportioned between means and standard deviations. If the mean values are sampled from 16 sensors, then the standard deviations of 7 sensors can be recorded

to fill the 23 data channels. If fewer sensors are monitored, more channels will be available to record standard deviations. Preprocessing greatly reduces the amount of data that must be recorded. A year's data from a single installation is reduced to a manageable 104 340 octal records of 80 characters each. Up to 15 days of data can be accumulated on the cassettes before they have to be retrieved. After checking for obvious recording or sensors errors, the data is written to the Computer Center's "Common File System" where it can be accessed by any potential LASL user.

The "state of the art" design utilizing low power CMOS technology, provides a microprocessor controlled data system that requires between 0.5 and 1.0 watt depending on the actual installation. The system operates on batteries that can be charged with either AC line or solar power. Since fully charged batteries will keep the systems alive for up to two weeks, they are essentially independent of power outages.

Emphasis has been placed on developing a data base that provides accurate, readily accessible meteorological data. Software to generate tabular and graphical daily summaries has been developed. Figure 22 presents a daily summary of the OHL tower and ground station data for December 2, 1979. The lower three panels show the horizontal windspeed and direction, and the vertical wind speed on the tower 21 m above the surface. The shaded area represents ±1 standard deviation about the 15 min means.

The center panel shows the tower temperature (20 m above the surface), ground station temperature (1 m above the surface), and ground station dewpoint temperature. The solid line is the ground station temperature, the shading shows the departure of the tower temperature from the ground station temperature, and the dashed line indicates dewpoint temperature. The remaining three panels present the net solar radiation on a horizontal surface, precipitation and relative humidity, and atmospheric pressure.

This day was selected as it very clearly shows the diurnal patterns affecting Los Alamos in absence of strong synoptic scale systems. Between midnight and 6 a.m., 2 m/s drainage flow prevailed from the northwest. The flow was quite smooth as evidenced by the narrow standard deviation ranges in the horizontal and vertical wind components. This was expected under the stable +0.2°C/m temperature lapse rate recorded at that time. As the day progressed, solar heating of the surface reversed the vertical temperature gradient, and the mixing and dispersal properties of the atmosphere increased as is apparent from the increased standard deviations of the wind components. The wind shifted from the northwest to northeast, and then continued to turn clockwise, first due to local southeast upslope flow along the Jemez Mountains, and then due to the regional southerly flow up the Rio Grande Valley. By late afternoon, the mixing layer deepened and momentum mixdown added a component of the upper level westerlies to the flow. By 1800 h the wind had completed its full 360° diurnal clockwise rotation and was again downslope out of the northwest. The boundary layer was again thermally stable, and the dispersion properties of the atmosphere were again suppressed.

Future plans call for expanding the automated tower network to three or four additional installations plus possible reinstrumentation of a 100 m tower. These data will provide excellent source for developing dispersion wind roses and other types of climatological summaries. As the data base expands, software will be developed to provide these climatological summaries on weekly, monthly, seasonal, and yearly bases. This meteorological data base can be easily interrogated to provide data for specially tailored analyses as required for NERP and other Laboratory investigations.

9. Special Study of Radionuclides from LAMPF Lagoons [R. W. Ferenbaugh and W. D. Purtymun (H-8)]

Cooling system leaks at the Los Alamos Meson Physics Facility (LAMPF) discharge water with activation product radionuclides, primarily ^{3}H, ^{7}Be, and ^{22}Na, into the lagoons below the facility. Samples of water, sediments, and transpirate from trees adjacent to the effluent stream from the lagoons have been collected every 1 to 1.5 months since the effluent began flowing in the Spring of 1979. The purpose of this sampling program is to ascertain the extent to which radionuclides are being dispersed from the lagoons. Figure 23 shows locations of the sampling sites relative to the lagoons and to Los Alamos Canyon. Between sites 2 and 3, the discharge stream drops from the plateau on which the

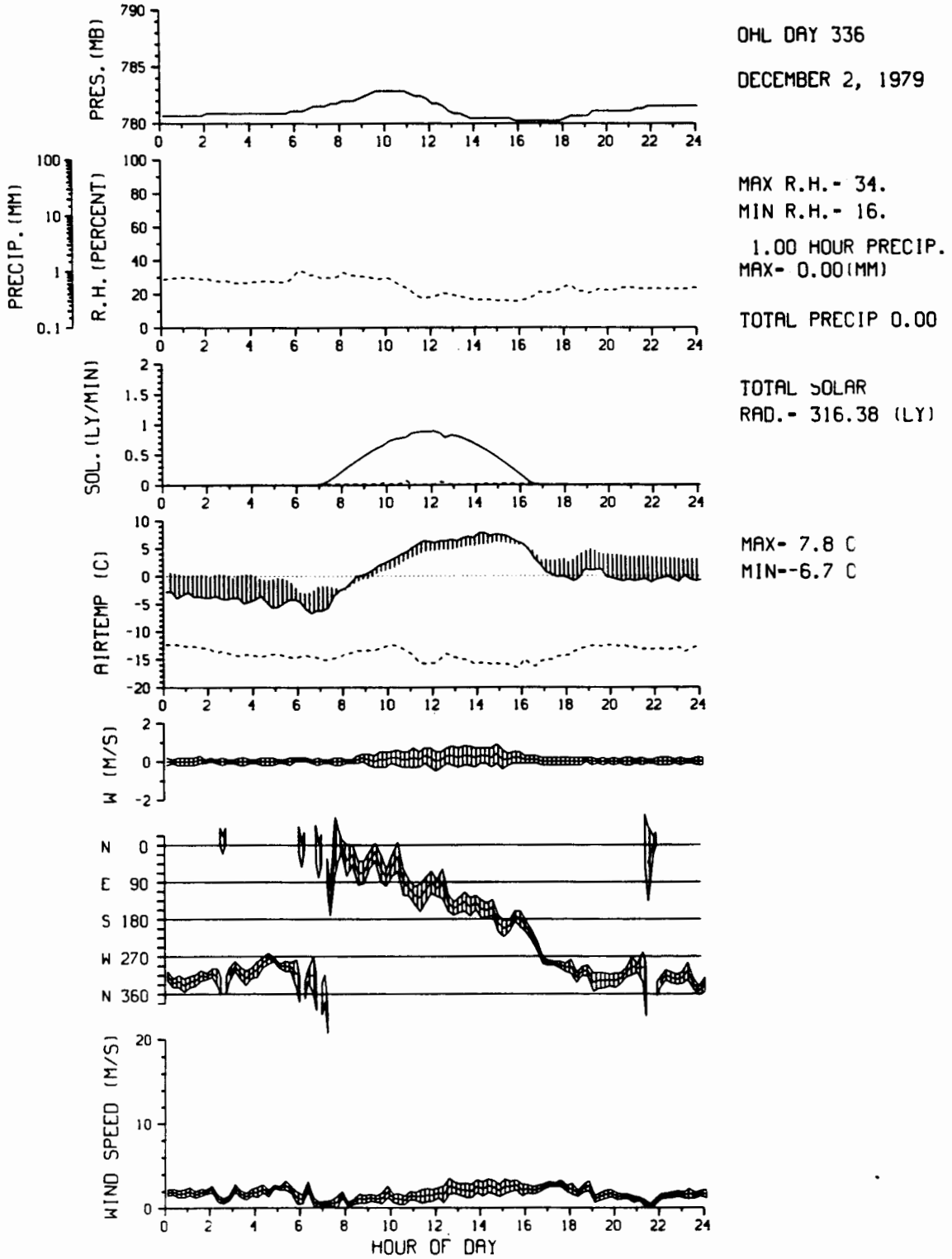


Fig. 22.
Summary of meteorological data from the OHL tower and ground level station for December 2, 1979.

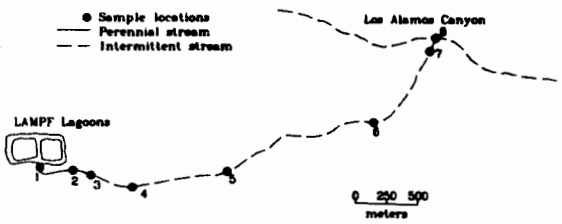


Fig. 23.
Sampling locations in vicinity of LAMPF lagoons.

lagoons are located into a side canyon that eventually connects with Los Alamos Canyon between sites 6 and 7. Surface water is found below site 4 only during heavy runoff events. A summary of analytical results obtained from the samples collected is presented in Table XXXIII. These data show that radionuclide concentrations decrease with progression down the canyon. Data from individual analyses seem to indicate that there is continuing accumulation of radionuclides at sites 1 through 4 with time, but this is uncertain due to the few number of samples so far analyzed. Transpirate from pinon and juniper trees located on stream banks at sites 2 through 4 show somewhat elevated tritium content as HTO. In general, the data show that while there has been some dispersal of radionuclides down the canyon into which the discharge occurs, there has been no detectable dispersion beyond the point at which the discharge stream sinks into alluvium.

TABLE XXXIII

ANALYTICAL RESULTS OF SAMPLES TAKEN BELOW LAMPF LAGOONS

	No. of Analyses	^{3}H	^{7}Be	^{22}Na
Water (pCi/ℓ)				
Station 1	5	$7.93 \pm 3.05 \times 10^{5}$	152 000 ± 137 000	2310 ± 947
Station 2	5	$7.73 \pm 2.92 \times 10^{5}$	357 000 ± 326 000	2290 ± 982
Station 3	4	$7.23 \pm 2.85 \times 10^{5}$	33 000 ± 46 700	2070 ± 1030
Station 4	3	$6.15 \pm 1.73 \times 10^{5}$	39 300 ± 32 100	1400 ± 757
Station 8	2	$0.02 \pm 0.02 \times 10^{5}$	75 ± 21	3 ± 6
Sediment (pCi/g)				
Station 1	3	$7.91 \pm 2.04 \times 10^{5}$	2580 ± 2980	2.2 ± 0.6
Station 2	5	$8.27 \pm 2.56 \times 10^{5}$	5010 ± 4530	5.9 ± 2.7
Station 3	5	$7.32 \pm 2.67 \times 10^{5}$	2770 ± 5280	1.9 ± 2.1
Station 4	5	$4.55 \pm 2.94 \times 10^{5}$	439 ± 455	1.5 ± 0.8
Station 5	5	$0.90 \pm 1.58 \times 10^{5}$	148 ± 331	0.5 ± 0.7
Station 6	5	$0.03 \pm 0.04 \times 10^{5}$	0.7 ± 0.9	0.01 ± 0.04
Station 7	4	$0.01 \pm 0.06 \times 10^{5}$	0.6 ± 0.6	0.01 ± 0.05
Station 8	4	$0.05 \pm 0.14 \times 10^{5}$	0.7 ± 0.9	0.03 ± 0.03
Transpirate (pCi/ℓ)				
Station 2	3	$3.47 \pm 0.61 \times 10^{5}$	483 ± 375	29 ± 21
Station 3	4	$2.70 \pm 1.00 \times 10^{5}$	708 ± 1550	129 ± 248
Station 4	7	$0.97 \pm 0.83 \times 10^{5}$	30 ± 526	5 ± 62
Station 5	5	$0.00 \pm 0.02 \times 10^{5}$	914 ± 2350	8 ± 63
Station 6	4	$0.01 \pm 0.04 \times 10^{5}$	250 ± 465	−20 ± 29
Station 8	3	$0.00 \pm 0.01 \times 10^{5}$	667 ± 1170	0 ± 20

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

Studies and evaluation of various alternatives for ultimate disposal of transuranic (TRU) wastes is part of the ongoing waste management programs at LASL. TRU wastes at LASL are buried at six previously used waste areas, and buried and retrievably stored at currently used areas. By October 1980, a document detailing various options for disposition of these wastes will be prepared. Total estimated volume of TRU wastes (>10 nCi/g) is about 21 200 m^3, with about 2300 m^3 estimated to be combustibles and about 7800 m^3 to be metals. Among alternatives being evaluated for future disposition of the wastes are: 1) continue present practices; 2) engineered-in-place improved barriers, such as additional earth and riprap cover; and, 3) exumation and retrieval, followed by some processing. Processing options include combustion, electropolishing, compaction, slurrying with cement paste, and simple repackaging without additional processing. Ultimate disposal considerations include deep pit burial at LASL or transfer to a federal repository when such a facility is available. Following review of this alternatives document, a decision will be made as to which of the many options will be evaluated in detail.

Several LASL groups are participating in the project. Included are WX-4 (a group in the Design Engineering Division) which is doing engineering and cost estimation work; the Health Physics Group (H-1) which is evaluating health risks associated with each alternative; the Waste Management Group (H-7), which is doing inventory and source term definition work, the Environmental Studies Group (LS-6) which is involved with environmental transport methodology and modeling; and the Environmental Surveillance Group (H-8) which is coordinating annd managing the project and developing a environmental surveillance plan.

The environmental surveillance plan details long-range sampling and evaluation of environmental media in and around active and previously used waste burial sites. The surveillance plan includes documentation of possible migration of wastes, comparisons of the data over prolonged time periods, and assurance that these areas are being managed and maintained in an environmentally acceptable manner. The plan will be applied to the retired waste sites and will provide for periodic sampling, analysis, and evaluation over the period of institutional control of these sites.

11. An Automated Transuranic Assay System for Soils [J. W. Nyhan, G. Trujillo, and B. J. Brennon (LS-6), and J. M. Crowell (H-1)]

Assaying soil and tuff samples containing low concentrations of transuranics currently requires time consuming, costly, and highly specialized analytical procedures. Currently, soil samples are dissolved in concentrated acid solutions and then passed through an ion exchange resin to achieve chemical separation. The sample is then electroplated onto a metal disk and assayed for transuranics using alpha spectrometry techniques. These procedures take several weeks and cost about $200 per sample. An automatic transuranic assay system for soils (ATASS) to reduce the time and expense of analyzing transuranics in soil and tuff samples from radioactive shallow land burial sites has been developed. The ATASS simultaneously measures the low- and high-energy gamma spectrum (0 to 2000 keV) of the components of soils and crushed geologic materials. An evaluation of the spectrum leads to quantitative identification of the transuranic sample constituents.

The counting system of ATASS includes two germanium detectors that simultaneously assay a sample. The intrinsic germanium (IG) detector consists of a hyperpure germanium crystal with a thin metal semiconductor surface barrier entry window. The IG crystal is mounted in a cryostat, which has a thin beryllium window and a cooled field effect transistor. This detector has excellent photon peak resolution in the 0 to 200 keV range with a total active detector area of 21 cm^2 and a crystal thickness of 7 mm. In order to also assay for high energy (200 to 2000 keV) gamma emitters with ATASS, a coaxial Ge(Li) detector was added to the system. The second detector has a right angle detector-dewar configuration and a total active volume of 125 cm^3. These two detectors are interfaced with analog to digital converter multiplexers, pulse amplifiers, high voltage power supplies, a multichannel analyzer, and a minicomputer.

The ATASS is mounted in a sample changer constructed to accept specially designed plastic sample containers. The sample changer consists of a lead lined wheel which is mounted vertically in the center of an aluminum framework (Fig. 24). The wheel has 20 evenly spaced sample holder positions. A small motor mounted in the center of the wheel allows it to turn and position a sample between the two detectors. The wheel holds the plastic sample containers which were designed to hold approximately 25 g of soil or tuff. The lid of the sample container is less than 1-mm thick and faces the IG detector (where low energy gamma emitters are assayed), whereas the bottom of the sample container is twice as thick as the lid and faces the Ge(Li) detector for high energy gamma emitter assays.

Although additional system characterizations work is still needed, preliminary indications are that ATASS is a very effective, inexpensive radionuclide assay system for waste management research. The sensitivity of the IG detector is demonstrated by uncontaminated tuff samples spiked with weapons grade plutonium and americium standard solutions to mimic field samples with activity levels of 50 pCi/g. There is good peak resolution in the low energy L x-ray region (0 to 20 keV) and the spiked sample spectra are distinct from the natural background of the sample, which defines peaks of naturally-occurring elements such as ^{210}Pb, ^{40}K, and thorium.

The ATASS system was calibrated for ^{241}Am detection and plutonium calibration work was initiated. Coefficients for converting counts per second to pCi ^{241}Am/g have been determined for the 59.537 keV gamma ray and for the Am x-rays (Table XXXIV). Furthermore, the ratios of x-ray intensities to gamma ray intensity were determined so that the

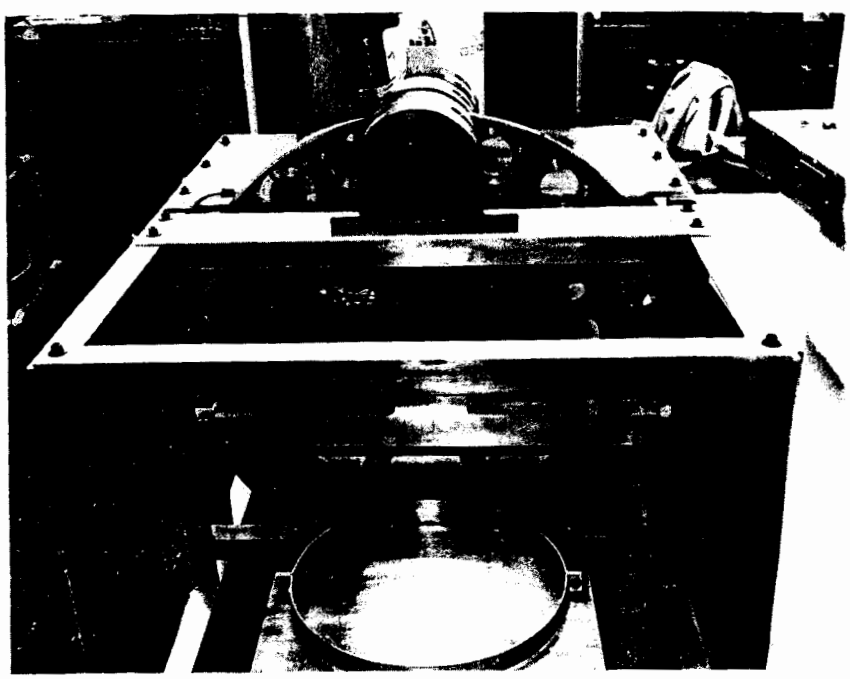


Fig. 24.
Sample changer for ATASS.

americium contribution of the x-rays can be stripped from the spectra for plutonium analysis. We have also examined linearity of response of the IG detector to varying low radionuclide concentrations and have found that the IG detector does respond linearly with increased concentrations of Am placed in sample containers (Table XXXV). Results of similar experiments with weapons grade plutonium are shown in Table XXXVI; however, the large variation between replicate plutonium assays in this experiment preclude any conclusions about linearity of response for plutonium at this time. We currently expect to measure activities as low as 5 pCi Pu/g and 0.05 pCi ^{241}Am/g with maximum sample counting times of 4.5 h.

TABLE XXXIV

RADIONUCLIDE SENSITIVITY CALIBRATION FOR ATASS SYSTEM

^{241}Am Content in ^{239}Pu Standards: $0.0161 \frac{\text{pCi Am}}{\text{pCi Pu}}$

			Sensitivity (c/s)/(pCi/g)
^{241}Am	59.537 keV	γ-ray	0.0283 ± 1.6%
	L_α X-ray		0.00137 ± 2.5%
	L_β X-ray		0.00542 ± 1.3%
	L_γ X-ray		0.00179 ± 1.2%
^{239}Pu[a]	L_α X-ray		0.000315 ± 4.6%
	L_β X-ray		0.000970 ± 3.7%
	L_γ X-ray		0.000273 ± 2.8%

[a]Corrected for ^{241}Am content.

TABLE XXXV

RESULTS OF EXPERIMENTS SHOWING LINEARITY OF IG DETECTOR RESPONSE TO VARYING AMOUNTS OF ^{241}Am

Amount-of ^{241}Am Added to Sample Container (pCi)	Average Net Counts for 16 000 s Count Time	Average Net c/s/pCi
1.02	37.0(33.5)[a]	36.3(32.8)
5.10	139.0(7.02)	27.3(1.38)
10.2	258.0(21.5)	25.3(2.11)
102	2513.0(220)	24.6(2.16)
1020	28 360.0(4606)	27.8(4.52)
15 300	427 237.0(5384)	27.9(0.35)

[a]Average of three replicate determinations with mean standard deviation in parenthesis.

TABLE XXXVI

IG DETECTOR RESPONSE TO VARYING AMOUNTS OF WEAPONS GRADE PLUTONIUM

Amount of Plutonium Added to Sample Container (pCi)	Average Net Counts for 16 000 s Count Time	Average Net c/s/pCi
4.5	102 (68.8)[a]	22.7(15.3)
9.0	168 (95)	18.7(10.6)
19.5	91 (66.6)	4.67(3.42)
22.5	112 (71)	4.98(3.16)
45	265 (69.9)	5.89(1.55)
90	392 (93)	4.36(1.03)
1500	4103 (239)	2.74(0.16)
13 320	45 621 (2972)	3.43(0.22)

[a]Average of three replicate determinations with mean standard deviation in parentheses.

ACKNOWLEDGMENTS

This report was compiled by the staff of the Environmental Surveillance Group (H-8) of LASL's Health Division. Principal contributors included A. J. Ahlquist, D. A. Dahl, R. W. Ferenbaugh, F. G. Fernald, E. S. Gladney, T. C. Gunderson, W. R. Hansen, W. D. Purtymun, K. H. Rea, A. K. Stoker, C. R. Steen, A. D. Talley, and L. J. Walker. Much of the sampling and data collection was done by G. H. Brooks, Jr., C. Conley, F. R. Craven, R. R. Critchfield, G. R. Fox, M. N. Maes, J. Rice, R. Romero, J. G. Salazar, H. K. Torres, D. M. Van Etten, and C. L. Wardlow. Analytical chemistry was performed by C. E. Burns, W. M. Eberhardt, W. E. Goode, P. L. Johnson, D. Knab, G. M. Martinez, L. Ortiz, J. W. Owens, R. J. Peters, D. R. Perrin, and W. H. Schweitzer. Typing was done by V. Halloran and M. L. Keigher. Word processing and assembly of this report was done by K. Derouin.

Special thanks to LASL's Environmental Studies Group (LS-6) for descriptions of their environmental research. Principal contributors included T. S. Foxx, T. E. Hakonson, C. L. Meci, J. Crowell, B. J. Drennon, J. W. Nyhan, L. D. Potter, J. G. Steger, G. D. Tierney, G. Trujillo, E. M. Wewerka, and G. C. White. Technical support was provided by K. V. Bostick, E. M. Karlen, and J. L. Martinez.

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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 the regulations of several federal and state agencies in order to verify the Laboratory's compliance with these standards. Because many DOE orders, manuals, and directives are still being promulgated and were not considered final at the time this report was being written, numerous references have been made to Energy Research and Development Administration (ERDA) Manual Chapters which continue to serve as guidelines until superseded by the final DOE orders and manuals. LASL operations pertaining to environmental quality control are conducted in accordance with the directives and procedures contained in ERDA's Health and Safety Manual, Chapters 0510, 0511, 0513, 0524, and 0550.

In the case of radioactive materials in the environment, the guides contained in Manual Chapter 0524 are used as a basis for evaluation. However, the ERDA 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 ERDA and ICRP standards are in agreement. The standards are listed in Table A-I in the form of a Radioactivity Concentration Guide (CG). 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 ERDA policy in Manual Chapter 0524 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 technically and economically practicable."

Because some radioisotopes remain in the body and cause exposure long after intake has occurred, the RPSs require consideration of the 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 Ref. 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 pCi/ℓ and gross alpha activity (including ^{226}Ra, but excluding radon and uranium) shall not exceed 15 pCi/ℓ. A screening level of 5 pCi/ℓ is established as part of the monitoring requirements to determine whether specific radium analyses must be performed.

For man-made radionuclides the EPA drinking water regulations specify that concentration be limited to levels that would result in doses 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^{-6} μCi/mℓ.[A2] The calculated concentration using bone as the critical organ and the EPA

prescribed methods[A2] for ^{238}Pu or ^{239}Pu is 7.5×10^{-9} $\mu Ci/m\ell$.

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TABLE A-1

ERDA RADIOACTIVITY CONCENTRATION GUIDES (CGs)

Concentration Guides for Uncontrolled Areas[a,b]

Nuclide	CG for Air (μCi/mℓ)	CG for Water (μCi/mℓ)	CG for Water (nCi/ℓ)
^{3}H	2×10^{-7}	3×10^{-8}	3000
^{7}Be	---	2×10^{-8}	2000
^{11}C, ^{13}N, ^{15}O	3×10^{-8}	---	---
^{41}Ar	4×10^{-8}	---	---
^{89}Sr	3×10^{-10}	3×10^{-6}	3
^{90}Sr[d]	3×10^{-11}	3×10^{-7}	0.3
^{131}I[d]	1×10^{-10}	3×10^{-7}	0.3
^{137}Cs	5×10^{-10}	2×10^{-6}	20
^{238}Pu	7×10^{-14}	5×10^{-8}	5
^{239}Pu[d]	6×10^{-14}	5×10^{-8}	5
^{241}Am	2×10^{-13}	4×10^{-8}	4
	(pg/m³)[c]		(mg/ℓ)
U, natural[c]	9×10^{6}	2×10^{-5}	60 1.8 (ICRP[e])

Concentration Guide for Controlled Areas[a,b]

Nuclide	CG for Air (μCi/mℓ)	CG for Water (μCi/mℓ)	CG for Water (nCi/ℓ)
^{3}H	5×10^{-6}	1×10^{-1}	1×10^{5}
^{7}Be	---	5×10^{-2}	5×10^{4}
^{11}C, ^{13}N, ^{15}O	1×10^{-6}	---	---
^{41}Ar	2×10^{-6}	---	---
^{89}Sr	3×10^{-8}	3×10^{-4}	300
^{90}Sr	1×10^{-9}	1×10^{-5}	10
^{131}I[d]	4×10^{-9}	3×10^{-5}	30
^{137}Cs	1×10^{-8}	4×10^{-4}	400
^{238}Pu	2×10^{-12}	1×10^{-4}	100
^{239}Pu[d]	2×10^{-12}	1×10^{-4}	100
^{241}Am	6×10^{-12}	1×10^{-4}	100
	(pg/m³)[c]		(mg/ℓ)
U, natural[c]	2.1×10^{6}	5×10^{-4}	1500 60 (ICRP[e])

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[a]This table contains the most restictive CGs for nuclides of major interest at LASL (ERDA Manual Chap. 0524, Annex A).

[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 ERDA "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

[d]Of the possible alpha and beta emitting radionuclides released at LASL, ^{239}Pu and ^{131}I, respectively, have the most restrictive CGs. The CGs for these species are used for the 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 which consider chemical toxicity.

TABLE A-II

ERDA RADIATION PROTECTION STANDARDS FOR EXTERNAL AND INTERNAL EXPOSURES

Individuals and Population Groups in Uncontrolled Areas

Type of Exposure	Annual Dose Equivalent or Dose Commitment (rem)[a]	
	Based on Dose to Individuals at Points of Maximum Probable Exposure	Based on an Average Dose to a Suitable Sample of the Exposed Population[b]
Whole body, gonads, or bone marrow	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 eye,[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(s) that would commit the individual to an organ dose which 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 Safety, Standards, and Compliance, a worker may exceed 5 rem/year provided his/her average exposure per year since age 18 will not exceed 5 rem per year.

[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
NO_3	45
Se	0.01
Ag	0.05
TDS	1000

Radiochemical Contaminant	MCL (μCi/mℓ)
^{137}Cs	200×10^{-9}
Gross alpha	5×10^{-9}
^{3}H	20×10^{-6}
^{238}Pu	7.5×10^{-9}
^{239}Pu	7.5×10^{-9}

[a]USEPA 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.

APPENDIX B

SAMPLING PROCEDURES AND STATISTICAL TREATMENT OF DATA

1. Thermoluminescent Dosimeters

Lithium fluoride chips, 6.4 mm square by 0.9 mm thick, are used in both 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. 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 an oven maintained at 400°C. After 1 h the vials are removed from the oven and placed between massive copper blocks at room temperature.

The TLD reader is set for 15 s, 140°C preheat and 15 s, 240°C integration cycles. Incandescent lighting is used exclusively during all phases of annealing, dosimeter preparation, and readout to prevent ultraviolet-induced spurious TL (thermoluminescence). Four chips are placed in a molded nylon acorn nut, size 3/8-16, then closed with a 3/8-16 × 1/4 in nylon set screw. This assembly constitutes one dosimeter.

For each annealed batch, two calibration sets are exposed. One set is read at the beginning of the dosimetry cycle along with field and calibration sets from the previous cycle. The second is read at the end of the previous cycle. The second is read at the end of the cycle to detect possible sensitivity drift. Each calibration set consists of 20 dosimeters irradiated at the following levels: 3 at 0 mR are stored as laboratory controls, 3 at 0 mR accompany the set to the irradiation facility and serve as calibration controls, 3 at 0 mR accompany the field set as transit controls, 4 at 10 mR, 4 at 20 mR, 1 each at 40, 80, and 160 mR. A factor of 1 rem (tissue) = 1.061 R is used in evaluating the dosimeter data. This factor is the reciprocal of the product of the roentgen to rad conversion factor of 0.957 for muscle for ^{60}Co (the isotope used for TLD calibrations) and the factor 0.985, 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 reciprocal of 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 10 R exposure. At the end of each field cycle, whether calendar quarter or 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 the square root of the sum of squares of the individual standard deviation by assuming that the 95% confidence interval closely approximates the same interval as ±2 standard deviations. The dose at the LASL boundary north of LAMPF is calculated differently. Here 12 locations are in close proximity and the dose at the end of each cycle is calculated as the mean of all 12 locations. Because there is a dosimeter containing four chips at each location, this is actually a grand mean (or mean of means) and the standard deviation is therefore smaller by a factor of almost a third ($1/\sqrt{12}$) than that of any of the individual dosimeters.

In order to calculate the magnitude of the component of the total dose caused by LAMPF operations, three locations along the south boundary of LASL are used for background values. These locations are distant from and unaffected by LAMPF or any other laboratory source of radiation. They are close

enough in elevation to the LAMPF site to experience similar climatic conditions such as rain and snowfall.

The rationale for this calculation is based on the ratio of the dose recorded by the unshielded dosimeter to that for the lead and Lucite-shielded dosimeter. This ratio should be the same for dosimeters at both the north and south boundaries because the cosmic gamma component is quite stable and because the terrestrial conditions are nearly the same. Any decrease in the ratio at the north boundary is assumed to be caused by LAMPF operations. The actual method of calculation follows. Let z be the dose component from LAMPF, u and v be the unshielded and shielded dose means, respectively, at the north boundary, u' and v' be their counterparts at the south boundary, and S_u, S_v, $S_{u'}$, $S_{v'}$ be the standard deviation of these means. Then

$$z = u - (v|u'/v'|) \quad .$$

The uncertainty associated with this value can be determined from the relationship[B4]

$$S_z^2 = (\partial_z/\partial_u)^2 S_u^2 + (\partial_z/\partial_v)^2 S_v^2 + (\partial_z/\partial_{u'})^2 + (\partial_z/\partial_{v'})^2 S_{v'}^2 \quad .$$

2. Air Sampling

Samples are collected monthly at 25 continuously operating stations during 1979. Positive displacement air pumps with flow rates of approximately 3 ℓ/s are used. Atmospheric aerosols are collected on 79 mm diam polystyrene filters. Part of the total air flow (2.4 – 3.1 mℓ/s) 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.

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 the long-lived parents) provides a record of long-lived atmospheric radioactivity.

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. Water is distilled from each silica gel sample, yielding a monthly average atmospheric water vapor sample. An aliquot of the distillate is then analyzed for tritium by liquid scintillation counting.

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) of

the system were sometimes obtained (see Table C-IV). Individual measurements often 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[B6] values are included in the population. For this reason, the primary value given in the tables of air sampling results is the actual value obtained from an individual measurement or group of measurements. These primary values are those used in making subsequent statistical analyses and in evaluating the real environmental impact of Laboratory operations.

Station and group means are weighted for the length of each sampling period and for the air volume sampled. The means were calculated using the following equation.[B6]

$$\bar{c} = \frac{\sum_{i=1}^{N} v_i t_i c_i}{\sum_{i=1}^{N} v_i t_i}$$

where

$\bar{c}$ = annual mean station or group atmospheric radioactive species concentration.

c_i = atmospheric radioactive species concentration for station or group i during t_i,

N = total number of samples during 1979 for a station or group,

t_i = length of routine sampling period for station or group i, and

v_i = air volume sampled for station or group i during t_i

Standard deviations for station and group means are similarly weighted by using the following equation.

$$\sigma_{\bar{c}} = \left\{ \frac{\left[\frac{N \sum_{i=1}^{N} (v_i t_i c_i)^2}{\left(\sum_{i=1}^{N} v_i t_i \right)^2} \right] \left[\frac{N \sum_{i=1}^{N} (v_i t_i c_i)^2}{\left(\sum_{i=1}^{N} v_i t_i c_i \right)^2} - 1 \right]}{N-1} \right\}^{1/2}$$

where

$\sigma_{\bar{c}}$ = standard deviation of $\bar{c}$.

To indicate the precision of the maximum and minimums, an uncertainty term representing twice the propagated measurement uncertainty (2σ) associated with the reported maximum or minimum value is included in the data tables.

3. Water, Soil, and Sediment Sampling

Surface and ground water sampling points are grouped according to location and hydrologic similarity; i.e., regional, perimeter, and onsite stations. 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.

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 and sediment stations are also grouped according to location and hydrologic similarity; i.e., regional, perimeter, and onsite stations.

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.

Cumulative samplers are set in a dry stream to collect samples of intermittent storm runoff. The sampler consists of a heavy angle iron driven into the channel with a heavy polyethylene bottle attached by a strap. The intake nozzle to the bottle, consisting of a 1 cm diam copper tube fitted through the plastic bottle cap, faces upstream and is placed about 4 cm above the channel. A vent hole (0.4 cm diam) is drilled into the bottle neck to vent air during initial filling of the sampler and to allow some continuous circulation of water and sediments into the bottle. The average time to fill the sampler is about 2 min; however, this can vary considerably, depending on the volume and velocity of flow.

The samples are filtered through a 0.45 μm filter. The radioactivity and chemical composition of the solution is defined as filtrate passing through the filter, while the radioactivity is suspended sediments is defined as the residue on the filter.

The average concentrations of radionuclides and chemical constituents are reported for a number of individual analyses in Tables E-XIII through E-XVI and Tables E-XVIII and E-XX. 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 METHODS

1. Procedures

a. Plutonium and Americium. Soil and sediment samples are dried, sieved through a No. 12 screen (<1.7 mm), and split into 10 g aliquots. Each aliquot is leached with HF - HNO_3.

Waters are acidified to ~1% HNO_3 in the field. Immediately upon arrival in the laboratory, they are filtered through 0.45 μm pore membrane filters, split into 500 mℓ aliquots, and evaporated to dryness with HNO_3. The residue is treated with HF to dissolve silica.

Air filters are ignited in platinum dishes, treated with HF-HNO_3 to dissolve silica, wet ashed with HNO_3-H_2O_2 to decompose the organic residue and treated with HNO_3-HCl to ensure isotopic equilibrium.

Vegetation samples are ashed in a high temperature oven and then treated like soil samples. All samples are spiked with standardized ^{242}Pu and ^{243}Am during dissolution to serve as a chemical recovery tracer.

Dissolved samples are thoroughly digested in 7.2 N HNO_3, and 1N $NaNO_2$ added to ensure that Pu is in the tetravalent state. The solution is passed through a preconditioned anion exchange column. The initial eluate and the first 20 mℓ of a 7.2 N HNO_3 wash is saved for ^{241}Am analysis. The column is then washed with 7.2 N HNO_3 and 8 N HCl. Plutonium is eluted with a freshly prepared solution of 1 g/ℓ NH_4I in 1 N HCl. The eluate is appropriately conditioned and Pu is electrodeposited from a 4% solution of $(NH_4)_2C_2O_4$. The plated Pu is counted on an alpha spectrometer. Values reported for ^{239}Pu are the sum of ^{239}Pu and ^{240}Pu, since both have identical alpha energies.

For water and air filter samples, the eluate from the Pu column is conditioned to ensure the removal of HNO_3 and adjusted to 0.5 N HCl. This solution is loaded on a cation exchange column, rinsed with 0.5 N HCl followed by 2.0 N HCl, and Am is eluted with 4 N HCl. The eluate is converted to the nitrate, made 6 N with HNO_3, then mixed with ethanol in the proportion 40% 6 N HNO_3-60% ethanol, and loaded on a preconditioned anion exchange column. The column is washed with 75% methanol-25% 6 N HNO_3, and 60% methanol-40% 6 N HNO_3. Americium is eluted with 60% methanol-40% 2.5 N HNO_3. This nonaqueous solvent-anion exchange step separates the rare earth elements, other actinides, and Ra from Am.

For soil and vegetation samples the eluate from the Pu column is converted to 6 N HCl. Americium is extracted into 0.015 N DEHPP and then back extracted with $(NH_4)_2CO_3$. The back extract is decomposed with HCl, HNO_3, and $HClO_4$, dissolved in 3 N HCl. The solution is brought to 3 N in HF and Am is coprecipitated with YF_3. The YF_3 is dissolved with H_3BO_3 in 6 N HNO_3, then mixed with ethanol in the proportion 40% 6 N HNO_3-60% ethanol, and loaded on a preconditioned anion exchange column. The column is washed with 75% methanol-25% 6 N HNO_3 and 60% methanol-40% 6 N HNO_3. Americium is eluted with 60% methanol-40% 2.5 N HNO_3. This nonaqueous solvent-anion exchange step separates the rare earth elements, other actinides, and Ra from Am. The Am effluent is evaporated and dissolved in 2 mℓ HCl and 2 mℓ 6 N NH_4SCN. the pH is adjusted to ~3 with NH_4OH. The adjusted sample is loaded on a preconditioned anion exchange column. The column is washed with 2 N NH_4SCN to separate rare earth elements. Americium is eluted with 2 N HCl.

Air and water sample eluates from the methanol-HNO_3 column and soil and vegetation sample eluates from the SCN^- column are conditioned and Am electrodeposited from 5 N NH_4Cl adjusted to the methyl red endpoint. Electrodeposited Am is counted on an alpha spectrometer.

b. Gross Alpha and Beta. Two g of soil or sediment are leached in hot HNO_3-HCl, and the supernate is transferred to a stainless steel planchet and dried for counting.

Nine hundred mℓ of water are acidified with 5 mℓ of HNO_3 and evaporated to dryness. The residue is treated with HF-HNO_3 to dissolve silica, and H_2O_2 and HNO_3 to destroy organics. Residue is dissolved in 7.2 N HNO_3, and then transferred to a counting planchet.

Air filters are mounted directly on counting planchets.

Samples appropriately loaded on the planchets are counted on a thin window, dual channel gas proportional counter. Activity is calculated with appropriate corrections for cross talk between the two channels and the effect of mass loading on the counting efficiency.

c. Tritium. Soils are heated to evaporate the soil moisture, the condensate is trapped, and 5 mℓ aliquots are transferred to scintillation vials.

Water samples are acidified to ~1% HNO_3 in the field and filtered through 0.45 μm pore membrane filters immediately upon arrival in the laboratory. Five mℓ of the water are transferred into a scintillation counting vial.

Atmospheric water is trapped in a desiccator in the field. Moisture is removed from desiccant in the laboratory, and appropriate aliquots taken for scintillation counting. Fifteen mℓ of scintillation liquid are added to each sample, which is then vigorously shaken.

Samples are counted in a liquid scintillation counter for 50 min or 10 000 counts, whichever comes first. Standards and blanks are counted in conjunction with each set of samples.

d. ^{137}Cs and Gross Gamma. Soils and sediments are sieved through a No. 12 (<1.7 mm) screen. One hundred grams of the sieved soils are weighed into polyethylene bottles.

Water samples are acidified in the field to ~1% HNO_3 and filtered through 0.45 μm pore membrane filters. Five hundred mℓ of each sample are transferred to a standard 500 mℓ polyethylene bottle for counting.

The radionuclide ^{137}Cs is determined by counting on a Ge(Li) detector coupled to a multichannel analyzer. The activity is calculated by direct comparison with standards prepared in the same geometrical configuration as the samples. Gross gamma is measured by counting in an NaI(Tl) well counter, which accommodates the 500 mℓ bottles. A single channel analyzer adjusted to register gamma radiation between 0 and 2 MeV is interfaced to the detector. Gross gamma determinations are reported as net counts per unit time and unit weight.

e. ^{90}Sr. Sample preparation and dissolutions are similar to those described in the section on Pu. After dissolution, the residue is dissolved in HCl, the pH is adjusted to 2, and Y is separated from Sr by extraction into 20% HDEHP in toluene. The isolated ^{90}Sr is left undisturbed for two weeks to allow the daughter ^{90}Y to attain radioactive equilibrium. After that period, inactive Y carrier is added and ^{90}Y is again extracted from ^{90}Sr by solvent extraction into 5% HDEHP in toluene. Yttrium is back extracted into 3 N HNO_3 and precipitated as the hydroxide. Yttrium hydroxide is redissolved and the oxalate is precipitated. This precipitate is oven fired to the oxide which is filtered and weighed to determine the chemical yield. Yttrium oxide precipitate is counted on a gas proportional counter to measure the activity. Samples are recounted after three days to verify the separation of ^{90}Y from other beta-emitting nuclides.

f. Uranium. Analyses for U were performed in one of two ways—instrumental epithermal neutron activation analysis or delayed neutron activation analysis. In the first method, two gram samples are irradiated in the epithermal neutron port at the Los Alamos Omega West Reactor. A period of two to four days is allowed to pass after the irradiation, and the samples are counted on a Ge(Li) gamma-ray spectrometer. The 228 and 278 keV transitions from ^{239}Np are used for the quantitative determination. The nuclear reaction is $^{238}U\ (n,\gamma) \rightarrow {}^{239}Np + \beta$. Obviously the ratio measures the major isotope of U and calculates total U assuming ^{238}U is >99% of the total U. This assumed value will probably not vary significantly in environmental samples.

For samples with U concentrations greater than 100 ppm, another epithermal irradiation may be used. Following a 5 min irradiation and 10 min

decay, the 75 keV gamma ray from ^{239}U may be observed directly rather than waiting for the total decay to ^{239}Np. Results from both epithermal methods have been reported in the literature.[C1,C2]

In the second method, samples are irradiated in a thermal neutron port and pneumatically transferred to a neutron counter where the delayed neutrons produced by the fission of ^{235}U are measured.[C8] The technique is very manpower efficient and has a lower limit of detection than does the epithermal irradiation method. However, total U is calculated assuming a $^{235}U/^{238}U$ ratio of 0.0072. Variations in this ratio will produce inaccuracies in the result, hence samples likely to contain depleted U were not analyzed by this method because of the lower limits of detection. Most of our U analyses are done by this method because it is the more sensitive.

An advantage to having both U techniques available is that samples containing enriched U may be measured. The ^{235}U content may be determined by delayed neutrons and the ^{238}U content by epithermal activation. Total U is the sum of these, and a rough indication of the isotope ratio may also be given.

A comparison of these methods with the more traditional fluorometric technique for U analysis in soils has been published.[C4]

2. Stable Elements

Four instrumental methods are used for a wide variety of stable element determinations. Neutron activation and atomic absorption are the principal techniques with ion chromatography, ion selective electrodes, and combustion analysis used in a supplementary role. Elements and anions determined by the various methods are summarized in Table C-I. In addition, standard chemical methods are used for HCO_3^-, total dissolved solids (TDS), and total hardness. It should be noted that our Hg method of choice is cold vapor atomic absorption using the standard Perkin-Elmer technique.

3. Analytical Chemistry Quality Evaluation Program

Control samples are analyzed in conjunction with the normal analytical chemistry workload. Such samples consist of two general types. Blanks are matrix materials containing quantities of analyte below the detection limit of the analytical procedure. Standards are materials containing known quantities of the analyte. Analyses 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 permits the evaluation of the capabilities of a particular analytical technique under a certain set of circumstances. The former function is one of analytical control, the latter is called quality assurance.

Quality control samples are obtained from outside agencies and prepared internally. The EPA provides water, foodstuff, and air filter standards for analysis of gross alpha, gross beta, ^{3}H, ^{137}Cs, and ^{239}Pu as part of the ongoing laboratory intercomparison program. The Environmental Measurements Laboratory (EML) provides soil, water, bone, tissue, vegetation, and air filter samples each containing a wide variety of radionuclides. These are part of a laboratory intercomparison of DOE-supported facilities. 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.

Quality assurance for the stable element analysis program is maintained by the analysis of certified or well-characterized environmental materials. The National Bureau of Standards (NBS) has a large set of silicate, water, and biological Standard Reference Materials (SRM). 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). Other trace elemental standards have been purchases from a private company.

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; i.e., they are not normally handled as a unique set of samples. We feel that it would be difficult for the analyst to give the samples special attention even if they were so inclined. We endeavor to run at least 10% of the

TABLE C-I

ANALYTICAL METHODS FOR VARIOUS ELEMENTS AND ANIONS

Technique	Elements/Anions Measured	References
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	C1,5,6,7,8
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	C1,9,10,11,12,13,14
Thermal Neutron Capture—Gamma Ray	Al,B,Ca,Cd,C,Gd,H,Fe,Mg N,P,K,Si,Na,S,Ti	C1,15,16,17,18, 19,20,21,22
Radiochemical	Sb,As,Cu,Au,Ir,Hg,Mo,Os,Pd Pt,Ru,Se,Ag,Te,Th,W,U	C1,23,24,25,26, 27,28,29,30
Atomic Absorption	Sb,As,Ba,Be,Bi,Cd,Ca,Cr,Co,Cu F,Ga,In,Fe,Pb,Li,Mg,Mn,Hg,Mo, Ni,K,Se,Si,Ag,Na,Sr,Te,Tl,Sn, Ti,V,Zn	C31,32,33,34,35, 36,37,38
Ion Chromatography	F^-,Cl^-,Br^-,NO_2^-,NO_3^-, SO_3^{-2},SO_4^{-2},PO_4^{-3}	C39
Ion Selective Electrodes	F^-,NH_4^+	C40
Combustion	C,N,H	C22

stable element analyses as quality assurance samples using the materials described above. A more detailed description of our Quality Assurance Program using SRM is in preparation.

The capabilities of the analytical procedures are evaluated from the quality control samples. 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 of ($\bar{x}$) of R for all analyses of a given type is calculated by weighting each value ($\bar{x}_i$) by the uncertainty associated with it (s_i).

$$\bar{x} = \frac{\Sigma_i \, \bar{x}_i/s_i^2}{\Sigma_i \, 1/s_i^2}$$

The standard deviation (s) of the weighted mean is calculated assuming a normal distribution.

$$s = \sqrt{\frac{\Sigma_i \, (\bar{x} - x_i)^2}{N - 1}}$$

These calculated values are presented in Tables C-II and C-III. The weighted mean of the R is a measure of the accuracy of the 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 the precision. The precision is a function of the quantity of analyte; i.e., as the absolute quantity approaches the limit of detection, the precision increases. For instance, the precision for ^{137}Cs determinations is quite large because many of the standards approached the limits of detection of the measurement. Conversely, the precision for the uranium analyses is unrealistically small because the standards contained quantities of uranium significantly above the detection limits.

Analysis of blanks provides a criterion to judge the probability that samples were contaminated during the analysis. Table C-IV presented weighted means and standard deviations of the absolute quantity of analyte reported in blank materials analyzed during 1979.

4. Limits of Detection

Data from the analysis of blanks also provide a means of calculating limits of detection for the various procedures. Table C-V 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 analysis of blanks (Table C-IV). For tritium, the detection limit is merely 2s of repetitive determinations of the instrumental blank. 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 the detection of the two types of emissions, the detection limit of one is a function of the counting rate of the other. Detection limits in Table C-V are calculated assuming that counting rates for both alpha and beta are at background levels. 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.

For most routine water samples, concentrations of ^{137}Cs were determined with a NaI(Tl) well counter. An automatic sample changer used in conjunction with the system signficantly reduced the cost of the analyses. However, the smaller volume and higher background associated with the NaI(Tl) detector significantly degraded the limit of sensitivity for this analysis. No blanks were measured to assess these limits, but they are estimated to be an order of magnitude greater than that given in Table C-IV, which was determined by counting 500 mℓ samples on a Ge(Li) detector.

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

TABLE C-II

ANALYTICAL QUALITY ASSURANCE STANDARDS FOR STABLE ELEMENT ANALYSES

Element	Soil		Water		Vegetation		Air Particulates	
	R[a] ($\bar{x} \pm s$[b])	No. Determinations	R[a] ($\bar{x} \pm s$[b])	No. Determinations	R[a] ($\bar{x} \pm s$[b])	No. Determinations	R[a] ($\bar{x} \pm s$[b])	No. Determinations
Ag	1.04 ± 0.05	12		0		0		0
Al	1.00 ± 0.03	18		0		0	0.95 ± 0.05	5
As	1.01 ± 0.11	35	0.95 ± 0.11	31		0	1.04	2
Ba	1.19 ± 0.26	21		0		0		0
Be		0	1.11 ± 0.16	16		0		0
Br		0		0	1.06 ± 0.07	14	1.05 ± 0.05	6
Ca	1.03 ± 0.03	3	1.18 ± 0.17	21		0		0
Cd		0	1.00 ± 0.21	42		0		0
Ce	1.08	1		0		0		0
Cl		0	1.07 ± 0.11	65	0.96	2	1.10 ± 0.15	3
Co	0.96 ± 0.11	16	0.96 ± 0.13	6		0	2.33 ± 0.39[c]	5
Cr	1.08 ± 0.09	14	1.04 ± 0.13	32	0.86 ± 0.06	4	1.01 ± 0.14	6
Cs	0.95 ± 0.14	15		0		0		0
Cu	0.99 ± 0.25	44	0.94 ± 0.04	12		0		0
Eu	0.98	2		0		0		0
F		0	1.07 ± 0.20	47		0		0
Fe	0.98 ± 0.06	30	0.99 ± 0.05	12	0.99 ± 0.16	12	0.96 ± 0.13	6
Ga	0.88 ± 0.02	3		0		0		0
Hg	0.88	2	0.97 ± 0.04	7		0		0
K	1.10 ± 0.10	6	1.02 ± 0.05	18		0	1.11 ± 0.08	4
La	0.96 ± 0.09	8		0		0	0.91 ± 0.08	6
Lu	1.10	1		0		0		0
Mg		0	1.01 ± 0.07	14		0		0
Mn	0.99 ± 0.04	10	0.97 ± 0.08	6		0		0
Mo	0.94 ± 0.46	36		0		0		0
Na	0.90	2	1.02 ± 0.05	6		0		0
Pb	0.96 ± 0.18	24	1.03 ± 0.11	24		0		0
Rb	1.03 ± 0.10	17		0	1.08 ± 0.21	12		0
Sb	1.06 ± 0.19	17		0		0		0
Sc	0.97	1		0		0		0
Se	0.96 ± 0.11	48	0.99 ± 0.11	18		0		0
Si	0.97 ± 0.07	9		0		0		0
$SO_4^=$		0	0.95 ± 0.05	47		0		0
Ta	1.09 ± 0.18	14		0		0		0
TDS		0	1.0 ± 0.03	5		0		0
Th	1.06 ± 0.03	16		0		0		0
Ti	0.97 ± 0.05	7		0		0		0
U	0.99 ± 0.06	111	1.01 ± 0.03	32		0		0
V	1.04 ± 0.09	17	1.10	2		0	0.90 ± 0.15	5
W	1.14 ± 0.32	21		0		0		0
Yb	1.00	1		0		0		0
Zn	0.86 ± 0.07	24	1.21 ± 0.45	12		0	1.02 ± 0.05	4

[a]R is the weighted mean.
[b]Three or more samples required to calculate s.
[c]Suspect NBS informational value may be in error.

TABLE C-III

RADIOCHEMICAL QUALITY ASSURANCE ON EPA AND EML PROGRAMS

Analysis	No. of Samples	R[a] ($\bar{x} \pm s^2$)
Alpha	30	1.04 ± 0.22
Beta	30	1.07 ± 0.15
^{3}H	7	1.06 ± 0.19
^{51}Cr	8	1.11 ± 0.10
^{60}Co	14	1.08 ± 1.13
^{65}Zn	6	3.25 ± 1.04
^{90}Sr	35	0.99 ± 0.26
^{134}Cs	8	0.99 ± 0.54
^{137}Cs	29	1.02 ± 0.42
^{239}Pu	8	0.87 ± 0.57
U, natural	7	0.82 ± 0.13

[a]R is the weighted mean.

TABLE C-IV

QUANTITY OF CONSTITUENT REPORTED IN BLANKS

Analysis	No. of Samples	Quantity (Weighted Mean) ($\bar{x} \pm s$)	Units
^{90}Sr	15	0.0055 ± 0.06	pCi
^{137}Cs	26	1.2 ± 11	pCi
^{238}Pu	23	−0.0064 ± 0.069	pCi
^{239}Pu	23	0.0010 ± 0.029	pCi
^{241}Am	6	0.019 ± 0.013	pCi
Uranium (Delayed neutron)	4	15 ± 6	ng
Uranium (Epithermal activation)	153	25 ± 12	ng
Gross alpha	9	0.032 ± 0.35	pCi
Gross beta	9	0.57 ± 0.93	pCi

TABLE C-V

DETECTION LIMITS FOR ANALYSES OF TYPICAL ENVIRONMENTAL SAMPLES

Parameter	Approximate Sample Volume or Weight	Count Time	Concentration
Air Sample			
Tritium	3 m^3	100 min	10^{-12} μCi/mℓ
^{238}Pu	1.2×10^4 m^3	8×10^4 s	2×10^{-18} μCi/mℓ
^{239}Pu	1.2×10^4 m^3	8×10^4 s	3×10^{-18} μCi/mℓ
^{241}Am	2.5×10^4 m^3	8×10^4 s	2×10^{-18} μCi/mℓ
Gross alpha	3.8×10^3 m^3	100 min	3×10^{-16} μ/Ci/mℓ
Gross beta	3.8×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Uranium (Delayed neutron)	2.5×10^4 m^3	60 s	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 s	4×10^{-8} μCi/mℓ
^{238}Pu	0.5 ℓ	8×10^4 s	9×10^{-12} μCi/mℓ
^{239}Pu	0.5 ℓ	8×10^4 s	3×10^{-11} μCi/mℓ
^{241}Am	0.5 ℓ	8×10^4 s	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		1 μg/ℓ
Soil Sample			
Tritium	1 kg	100 min	0.003 pCi/g
^{137}Cs	100 g	5×10^4 s	10^{-1} pCi/g
^{238}Pu	10	8×10^4 s	0.003 pCi/g
^{239}Pu	10	8×10^4 s	0.002 pCi/g
^{241}Am	10	8×10^4 s	0.01 pCi/g
Gross alpha	2	100 min	0.8 pCi/g
Gross beta	2	100 min	0.003 pCi/g
Uranium (Epithermal activation)	2		0.03 μg/g

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APPENDIX D

METHODS FOR DOSE CALCULATIONS

A. Airborne Tritium and Actinides

Measured annual average concentrations in air, after subtracting background, are multiplied by standard breathing rates[D1] to determine annual intake via inhalation. This intake is then multiplied by appropriate dose conversion factors[D2,D3] to convert intake into annual dose and 50 year dose commitments for various organs. Dose commitment factors for tritium include an increase by a factor of 1.5 over inhalation intake to account for skin absorption of tritium. Where appropriate, assumptions in references D2 and D3 have been changed to reflect the latest recommendations of the International Commission on Radiation Protection.[D4]

B. Airborne Air Activation Products

Nuclear reactions with air in the target areas at LAMPF 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-s half-lives, respectively. Neutron reactions with air at the Omega West Reactor and LAMPF form ^{41}Ar (1.8 h half-life). The concentrations of these isotopes $[X(r,\theta)]$ at the appropriate site boundary are calculated using the annual average meteorological dispersion coefficient (based Gaussian plume dispersion models)

$$X(r,\theta)/Q$$

and the source term Q. The gamma dose rate in a semi-infinite cloud at time k can be represented by the equation[D5]

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

where

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

$\overline{E\gamma}$ = average gamma energy per decay (MeV), and

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

Dose rate corrections for estimated plume size (if the cloud cannot be construed to be semi-infinite) is taken from standard graphical compilations.[D5] $E\gamma$ is 1.02 MeV for the positron emitters (two 0.511 MeV gammas are produced in the positron annihilation process) and 1.29 MeV for ^{41}Ar. For maximum individual doses, a shielding factor (because of structure shielding) of 0.7 is used.[D6]

C. Man-rem Estimates

Calculation of population dose estimates (in man-rem) are based on measured data to the extent possible. For background radiation, average measured values for Los Alamos, White Rock, and regional stations were multiplied by the appropriate population number. Tritium average doses were calculated from average measured concentrations in Los Alamos and White Rock above background (as measured by regional stations). These doses were multiplied by appropriate population data. For ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O, atmospheric dispersion models (see previous Section B) were used to calculate an average dose to the area in question which was then multiplied by appropriate population figures. Dispersion factors for TA-2 and TA-3 are given in Table D-I. Background radiation doses due to airline

travel is 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]

TABLE D-I

DISPERSION FACTORS (x/Q) USED FOR POPULATION DOSE ESTIMATES

Source	Location	x/Q (s/m³)
TA-2	Los Alamos	2×10^{-6}
TA-2	White Rock	7×10^{-8}
TA-53	Los Alamos	5×10^{-7}
TA-53	White Rock	1×10^{-7}

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APPENDIX E

ENVIRONMENTAL DATA TABLES

TABLE E-1

MEANS AND EXTREMES OF TEMPERATURE AND PRECIPITATION CLIMATOLOGICAL SUMMARY 1951-1979[a]

	Temperature (°C)							Precipitation (mm)										Mean No. of Days		
	Means			Extremes				Rain[b]					Snow/Frozen Precipitation							
Month	Max	Min	Mo. Mean	High	Year	Low	Year	Mean	Daily Max	Year	Mo. Max	Year	Mean	Daily Max	Year	Mo. Max	Year	Precip >2.5 mm	Max Temp >32°C	Min Temp <0°C
Jan	4.2	−7.5	−1.7	17.8	1953	−27.8	1963	20.9	24.9	1952	47.8	1952	240	250	1958	770	1979	2	0	30
Feb	6.0	−5.9	0.1	17.8	1957	−27.2	1951	17.0	24.4	1975	47.5	1964	190	270	1975	490	1964	2	0.26	
March	9.3	−3.0	3.2	21.7	1971	−16.7	1965	25.7	41.7	1973	104.4	1973	250	360	1973	910	1973	3	0	23
April	14.2	1.0	7.6	25.0	1965	−11.7	1973	21.2	50.8	1975	82.0	1975	120	510	1975	850	1958	2	0	13
May	19.4	6.1	12.8	31.1	1951	−4.4	1976	28.4	34.3	1952	88.9	1952	20	300	1978	410	1978	3	0	2
June	25.3	11.3	18.3	33.9	1954	0.0	1975	29.5	29.7	1969	86.4	1960	0	0	---	0	---	3	0	0
July	26.8	13.4	20.1	33.9	1957	7.2	1961	83.2	62.7	1968	167.6	1968	0	0	---	0	---	8	1	0
Aug	25.2	12.4	18.8	32.8	1977	6.1	1957	101.5	57.4	1951	284.0	1952	0	0	---	0	---	9	0	0
Sept	22.2	9.1	15.6	30.6	1956	−3.3	1971	41.8	47.2	1973	115.6	1975	2	40	1971	40	1971	4	0	0
Oct	16.7	3.8	10.3	26.1	1957	−9.4	1976	39.1	52.3	1957	172.0	1957	40	230	1972	230	1959	3	0	7
Nov	9.3	−2.7	3.3	18.9	1975	−25.6	1976	24.6	45.0	1978	167.6	1978	130	300	1976	880	1957	2	0	22
Dec	5.0	−6.6	−0.8	15.0	1965	−25.0	1978	24.9	40.6	1978	72.4	1965	300	560	1978	1050	1967	2	0	30

CLIMATOLOGICAL SUMMARY 1979[a]

	Temperature (°C)					Precipitation (mm)				No. of Days		
	Means			Extremes		Rain[b]		Snow/Frozen Precipitation				
Month	Max	Min	Mo. Mean	High	Low	Total	Daily Max	Total	Daily Max	Precip ≥2.5 mm	Max Temp >32°C	Min Temp <0°C
Jan	0.5	−11.0	−5.3	5.6	−22.8	71.4	23.1	770	250	2	0	31
Feb	5.5	−6.8	−0.7	15.6	−15.6	3.6	2.5	30	30	1	0	28
March	9.3	−2.8	3.3	15.6	−8.9	32.3	11.2	190	110	6	0	30
April	14.7	1.2	8.0	21.7	−6.7	10.9	4.8	0	0	1	0	12
May	17.7	4.3	11.0	23.9	−2.2	78.7	18.0	0	0	3	0	6
June	24.1	9.4	16.8	31.1	0.0	53.6	17.3	0	0	4	0	1
July	27.8	12.7	20.3	32.2	7.2	19.8	8.4	0	0	5	2	0
Aug	25.5	10.9	18.2	31.1	7.8	59.2	32.5	0	0	6	0	0
Sept	24.3	9.3	16.8	30.0	3.3	20.8	10.4	0	0	3	0	0
Oct	19.3	5.1	12.2	25.6	−3.9	15.0	6.1	100	100	4	0	5
Nov	6.4	−5.4	0.5	13.3	−13.3	12.2	4.3	20	10	7	0	26
Dec	8.3	−5.5	1.4	15.0	−11.1	9.1	5.8	230	180	4	0	31

[a]Los Alamos, New Mexico; latitude 35°32' north, longitude 106°19' west; elevation 2260 m.

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**		
Española	---	97.3	3.3	3.4
Pojoaque	---	94.2	3.4	3.6
Santa Fe	---	84.1	3.3	4.0
	Regional Average	91.9		
Perimeter Stations	**(0-4 km)**	**Uncontrolled Areas**		
Barranca School	N180 E130	124.5	5.9	4.7
Cumbres School	N150 E090	120.2	3.8	3.2
Arkansas Avenue	N170 E020	144.8	3.4	2.3
48th Street	N110 E000	144.0	3.4	2.4
LA Airport	N110 E160	129.6	3.3	2.6
Bayo Canyon S.T.P.	N110 E260	147.3	3.9	2.6
Bandelier Lookout	S270 E200	123.0	3.3	2.7
Pajarito Acres	S210 E370	111.6	3.3	3.0
White Rock S.T.P.	S090 E430	118.6	3.3	2.8
Pajarito Ski Area	N130 W180	114.2	3.3	2.9
Gulf Station	N100 E100	130.8	3.4	2.6
Royal Crest	N080 E080	129.2	3.8	3.0
	Perimeter Average	128.2		

Station Location	Coordinates	Annual Dose: Dose (mrem)	Annual Dose: 95% Conf Interval (mrem)	Annual Dose: 95% Conf Interval (per cent)
Onsite Stations		**Controlled Areas**		
TA-21	N090 E170	112.4	3.3	3.0
State Hwy 4	N070 E350	186.5	3.5	1.9
Well PM-1	N030 E310	133.2	3.4	2.5
TA-53	N060 E190	150.1	3.4	2.3
TA-2	N080 E110	123.7	3.8	3.1
TA-2	N080 E120	167.5	3.4	2.0
TA-6	N060 W050	129.1	3.6	2.8
TA-16	S030 W080	125.1	3.4	2.7
TA-49	S100 E040	108.7	3.4	3.1
Booster P-1	S100 E300	122.3	3.3	2.7
TA-18	S030 E190	252.0	3.7	1.5
TA-35	N040 E110	132.9	3.4	2.5
TA-35	N030 E110	123.8	3.4	2.7
TA-3	N060 E010	153.1	3.4	2.2
TA-3	N050 E040	128.8	3.3	2.6
TA-54	S080 E260	153.8	3.4	2.2
	Onsite Average	143.9		

TABLE E-III

LOCATION 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	E020
6. Cumbres School	N150	E090
7. 48th Street	N110	E000
8. LA Airport	N110	E160
9. Bayo STP	N110	E260
10. Gulf Station	N100	E100
11. Royal Crest	N080	E080
12. White Rock	S090	E430
13. Pajarito Acres	S210	E370
14. Bandelier	S270	E200
Onsite		
15. TA-21	N090	E170
16. TA-6	N060	W050
17. TA-53 (LAMPF)	N060	E190
18. Well PM-1	N030	E310
19. TA-52	N020	E170
20. TA-16	S030	W080
21. Booster P-2	S030	E190
22. TA-54	S080	E260
23. TA-49	S100	E040
24. TA-33	S250	E230
25. TA-39	S210	E210

TABLE E-IV

REGIONAL AVERAGE BACKGROUND ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS

Radioactive Constituent	Activity—pCi/m³ (10^{-15} μCi/mℓ)		
	EPA[a]	LASL[b]	CG[c]
Gross alpha[d]	Not reported	1.4 ± 0.5	60
Gross beta[e]	83	89 ± 126	1×10^5
^{241}Am	Not reported	0.0024 ± 0.0038	2×10^2
^{238}Pu	0.0018 ± 0.0018	0.013 ± 0.014	70
^{239}Pu	0.0199 ± 0.0100	0.0020 ± 0.0035	60
Tritium	Not reported	9200 ± 9800	2×10^8
Total uranium	0.0408 ± 0.0300	0.032 ± 0.030	7×10^4
	(120 ± 88)[f]	(98 ± 94)[f]	

[a]"Radiological Quality of the Environment," (EPA-520/1-76-010), USEPA, Office of Radiation Programs, Washington, DC (1976).
[b]Annual averages for 1973-1979.
[c]Concentration Guide for uncontrolled areas.
[d]Gross alpha activity compared to CG for ^{239}Pu.
[e]Gross beta activity compared to CG for ^{131}I.
[f]pg/m³.

TABLE E-V

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

Station Location	Total Air[b] Volume (m^3)	Gross Alpha Concentrations—fCi/m^3 (10^{-15} µCi/mℓ) No. Monthly Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]	Gross Beta Concentrations—fCi/m^3 (10^{-15} µCi/mℓ) No. Monthly Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]
Regional Stations (28-44 km)—Uncontrolled Areas													
1. Española	83666	12	0	2.6 ± 1.2	0.4 ± 0.2	1.2 ± 1.2	1.9	12	0	37 ± 10	13 ± 3	25 ± 15	0.02
2. Pojoaque	78384	12	0	5.9 ± 2.6	0.6 ± 0.3	1.5 ± 1.7	2.5	12	0	132 ± 34	18 ± 4	27 ± 15	0.02
3. Santa Fe	85300	12	0	2.7 ± 1.2	0.3 ± 0.2	1.5 ± 1.5	2.5	12	0	44 ± 12	9 ± 2	23 ± 22	0.02
Regional Group Summary	24735	36	0	5.9 ± 2.6	0.3 ± 0.2	1.4 ± 1.5	2.3	36	0	132 ± 34	9 ± 2	25 ± 17	0.02
Perimeter Stations (0-4 km)—Uncontrolled Areas													
4. Barranca School	88754	12	1	5.0 ± 2.2	0.2 ± 0.1	2.5 ± 3.2	4.1	12	0	62 ± 16	2.0 ± 0.3	31 ± 31	0.03
5. Arkansas Avenue	79354	12	0	6.9 ± 3.0	1.0 ± 0.4	3.1 ± 3.4	5.2	12	0	52 ± 14	19 ± 4	34 ± 18	0.03
6. Cumbres School	83701	12	0	7.4 ± 3.2	0.7 ± 0.3	3.2 ± 3.5	5.3	12	0	55 ± 14	11 ± 3	31 ± 23	0.03
7. 48th Street	84024	12	0	4.3 ± 1.8	0.5 ± 0.2	1.7 ± 2.1	2.8	12	0	42 ± 10	13 ± 3	28 ± 17	0.02
8. LA Airport	94138	12	0	4.1 ± 1.8	0.4 ± 0.2	1.9 ± 2.4	3.2	12	0	35 ± 8	17 ± 4	25 ± 13	0.02
9. Bayo STP	93938	12	0	5.3 ± 2.4	0.3 ± 2.4	2.0 ± 2.8	3.3	12	0	45 ± 12	11 ± 3	26 ± 23	0.02
10. Gulf Station	82467	12	0	4.9 ± 2.2	0.7 ± 0.3	2.1 ± 2.6	3.4	12	0	55 ± 14	4.2 ± 1.0	28 ± 28	0.02
11. Royal Crest	81215	12	3	3.7 ± 1.6	0.0 ± 0.1	1.6 ± 2.4	2.6	12	1	48 ± 12	5.0 ± 1.2	17 ± 26	0.01
12. White Rock	83957	12	0	2.8 ± 1.2	0.4 ± 0.2	1.4 ± 1.3	2.3	12	0	35 ± 10	18 ± 4	23 ± 10	0.02
13. Pajarito Acres	84672	12	0	5.5 ± 2.4	0.6 ± 0.3	2.6 ± 2.7	4.3	12	0	59 ± 16	24 ± 6	33 ± 19	0.03
14. Bandelier	79773	12	0	6.0 ± 2.8	0.6 ± 0.3	2.7 ± 3.3	4.4	12	0	60 ± 16	18 ± 4	28 ± 26	0.02
Perimeter Group Summary	935993	132	4	7.4 ± 3.2	0.0 ± 0.1	2.2 ± 2.8	3.7	132	1	62 ± 16	4.2 ± 1.0	28 ± 23	0.02
Onsite Stations—Controlled Areas													
15. TA-21	78801	12	0	5.1 ± 2.2	0.7 ± 0.3	2.3 ± 2.5	0.11	12	0	58 ± 14	24 ± 6	32 ± 20	0.0008
16. TA-6	86746	12	1	5.6 ± 2.4	0.0 ± 0.1	2.1 ± 3.0	0.10	12	0	52 ± 14	12 ± 3	23 ± 21	0.0005
17. TA-53 (LAMPF)	76055	12	0	4.9 ± 2.2	0.7 ± 0.3	2.2 ± 2.0	0.10	12	0	49 ± 12	10 ± 3	33 ± 23	0.0008
18. Well PM-1	84222	12	0	5.3 ± 2.2	0.7 ± 0.3	2.3 ± 2.9	0.11	12	0	47 ± 12	22 ± 6	31 ± 16	0.0007
19. TA-52	89606	12	0	3.5 ± 1.6	0.4 ± 0.2	2.1 ± 2.1	0.10	12	0	53 ± 14	18 ± 4	27 ± 27	0.0006
20. TA-16	75609	12	0	6.2 ± 2.8	0.5 ± 0.2	2.7 ± 2.9	0.13	12	0	55 ± 14	16 ± 4	27 ± 22	0.0006
21. Booster P-2	92441	12	1	4.5 ± 2.0	0.0 ± 0.0	2.4 ± 2.6	0.12	12	1	44 ± 12	7 ± 2	20 ± 30	0.0005
22. TA-54	95250	12	0	4.9 ± 2.2	0.8 ± 0.4	2.6 ± 3.1	0.12	12	0	57 ± 14	20 ± 6	34 ± 22	0.0008
23. TA-49	90147	12	0	4.3 ± 1.8	0.5 ± 0.2	2.3 ± 2.4	0.11	12	0	55 ± 14	19 ± 4	30 ± 28	0.0007
24. TA-33	92876	12	0	5.7 ± 2.4	0.4 ± 0.2	2.5 ± 2.9	0.12	12	0	58 ± 14	6.1 ± 1.6	31 ± 28	0.0007
25. TA-39	80338	12	0	4.5 ± 2.0	0.4 ± 0.2	1.7 ± 2.8	0.08	12	0	38 ± 10	11 ± 3	21 ± 24	0.0005
Onsite Group Summary	942091	132	2	6.2 ± 2.8	0.0 ± 0.0	2.3 ± 2.7	0.11	132	1	58 ± 14	6.1 ± 1.6	28 ± 26	0.0007

[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 for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample standard deviations). Uncertainties for station and groups means are ±2 standard deviations.

[e]Of the possible radionuclides released at LASL, ^{239}Pu and ^{131}I are the most restrictive. The CGs for these species are used for the gross alpha and gross beta CGs, respectively.
Controlled Area Radioactivity Concentration Guide = 2×10^{-12} µCi/mℓ (α)
= 4×10^{-9} µCi/mℓ (β)
Uncontrolled Area Radioactivity Concentration Guide = 6×10^{-13} µCi/mℓ (α)

TABLE E-VI

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR CONCENTRATIONS

Station Location	Total Air Volume (m^3)[a]	No. Monthly Samples	No. Samples <MDL[b]	Concentrations—pCi/m^3 (10^{-12} μCi/mℓ) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
1. Española	123	12	3	20 ± 10	−1.4 ± 1.0	3.7 ± 13	0.001
2. Pojoaque	114	12	5	9 ± 3	−0.4 ± 0.8	1.9 ± 5.3	0.001
3. Santa Fe	122	12	2	9 ± 3	−0.3 ± 0.8	2.4 ± 5.1	0.001
Regional Group Summary	359	36	10	20 ± 10	−1.4 ± 1	2.7 ± 8.7	0.001
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	118	12	3	13 ± 4	0.8 ± 1.0	2.7 ± 4.2	0.001
5. Arkansas Ave	113	12	5	40 ± 18	0.2 ± 0.6	2.7 ± 7.1	0.001
6. Cumbres School	123	12	1	24 ± 8	0.2 ± 0.8	4.3 ± 13	0.002
7. 48th Street	123	12	2	17 ± 6	0.7 ± 1.0	4.4 ± 10	0.002
8. LA Airport	120	12	2	65 ± 22	0.8 ±0.8	9 ± 34	0.004
9. Bayo STP	123	12	4	13 ± 4	0.1 ± 0.6	3.5 ± 8.0	0.001
10. Gulf Station	123	12	1	15 ± 6	1.0 ± 0.8	4.1 ± 7.5	0.002
11. Royal Crest	117	12	0	16 ± 6	1.3 ± 0.6	6.7 ± 9.9	0.003
12. White Rock	122	12	2	10 ± 3	0.4 ± 0.6	4.1 ± 5.4	0.002
13. Pajarito Acres	122	12	2	48 ± 16	0.6 ± 0.6	6.6 ± 25	0.003
14. Bandelier	122	12	1	19 ± 6	0.4 ± 0.2	6.2 ± 12	0.003
Perimeter Group Summary	1326	132	23	65 ± 22	0.1 ± 0.6	4.9 ± 15	0.002
Onsite Stations—Controlled Areas							
15. TA-21	120	12	1	11 ± 3	1.0 ± 1.0	3.8 ± 6.1	0.0001
16. TA-6	122	12	4	7 ± 2	−0.3 ± 0.8	2.8 ± 4.5	0.0001
17. TA-53 (LAMPF)	122	12	1	16 ± 6	0.6 ± 0.8	4.3 ± 8.6	0.0001
18. Well PM-1	122	12	3	9 ± 3	−3.0 ± 1.2	3.6 ± 7.7	0.0001
19. TA-52	122	12	0	130 ± 40	1.8 ± 1.0	15 ± 64	0.0003
20. TA-16	117	12	5	5 ± 2	−0.1 ± 0.6	2.2 ± 3.9	0.0000
21. Booster P-2	119	12	1	63 ± 20	0.9 ± 0.8	8.1 ± 31	0.0002
22. TA-54	123	12	0	130 ± 40	5.9 ± 2.2	35 ± 74	0.0007
23. TA-49	119	12	4	40 ± 12	−0.4 ± 0.6	5.4 ± 21	0.0001
24. TA-33	110	11	0	73 ± 24	3.2 ± 1.4	40 ± 42	0.0008
25. TA-39	119	12	0	36 ± 12	3.8 ± 1.6	16 ± 21	0.0003
On-Site Group Summary	1315	131	19	130 ± 40	−3.0 ± 1.2	12 ± 42	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^{-10} μCi/mℓ.

[c]Uncertainties for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample standard deviations). Uncertainties for station and group means are ±2 standard deviations.

[d]Controlled area radioactivity concentration guide = 5×10^{-6} μCi/mℓ. Uncontrolled area radioactivity concentration guide = 2×10^{-7} μCi/mℓ.

TABLE E-VII

ANNUAL ATMOSPHERIC ^{239}Pu and ^{240}Pu CONCENTRATIONS

Station Location	Total Air Volume (m³)[a]	^{239}Pu—aCi/m³ (10^{-18} μCi/mℓ[a]) Number of Samples	No <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]	^{240}Pu—aCi/m³ (10^{-18} μCi/mℓ[a]) Number of Samples	No <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas													
1. Española	85152	5	5	1.5 ± 2.2	−5.2 ± 4.7	−1.8 ± 3.4	0.0	5	3	25 ± 4.8	−0.5 ± 1.5	8.4 ± 26	0.014
2. Pojoaque	87954	5	5	−2.7 ± 2.2	−5.7 ± 4.5	−3.8 ± 3.7	0.0	5	3	12 ± 49	−0.9 ± 1.8	3.3 ± 5.3	0.006
3. Santa Fe	93752	5	5	−1.5 ± 1.7	−6.2 ± 4.5	−2.1 ± 1	0.0	5	2	9.1 ± 53	1.3 ± 1.8	3.6 ± 2.2	0.006
Regional Group Summary	266858	15	15	1.5 ± 22	−6.2 ± 4.5	−2.6 ± 3.2	0.0	15	8	25 ± 4.8	−0.9 ± 1.8	5 ± 15	0.008
Perimeter Stations (0-4 km)—Uncontrolled Areas													
4. Barranca School	83759	5	5	−1.4 ± 1.8	−12 ± 7.8	−3.4 ± 3.1	0.0	5	3	17 ± 3.9	−7 ± 25	6.6 ± 22	0.011
5. Arkansas Avenue	77628	5	5	−1.8 ± 2.1	−6.1 ± 6.2	−2.7 ± 1.5	0.0	5	2	20 ± 69	−1.2 ± 1.3	5.4 ± 9.2	0.009
6. Cumbres School	87027	5	5	1.6 ± 2.9	−6.2 ± 4.5	−0.9 ± 3.5	0.0	5	1	83 ± 11	−1.7 ± 1.5	25 ± 91	0.041
7. 48th Street	92241	5	5	0.3 ± 2.1	−14 ± 15	−2.4 ± 6.7	0.0	5	1	33 ± 6.7	3.3 ± 2.2	13 ± 28	0.022
8. LA Airport	101124	5	5	−1.3 ± 4.7	−3.9 ± 3.1	−2 ± 1.7	0.0	5	1	14 ± 4.5	1.4 ± 4.5	4.8 ± 5	0.008
9. Bayo STP	98239	5	5	−2 ± 1.3	−4.4 ± 3.9	−2.5 ± 1.3	0.0	5	1	17 ± 5.1	−0.2 ± 1.3	4.8 ± 6.3	0.008
10. Gulf Station	78747	5	5	−1.1 ± 1.9	−7.1 ± 4.5	−2.8 ± 2	0.0	5	1	12 ± 3.3	−2.6 ± 2.9	8.4 ± 13	0.014
11. Royal Crest	75755	5	5	−0.3 ± 3.2	−5.3 ± 5.1	−2.1 ± 2.4	0.0	5	2	21 ± 6.6	−0.3 ± 1.8	4.4 ± 6.6	0.007
12. White Rock	88259	5	5	−1.5 ± 1.8	−4.4 ± 2.9	−2.5 ± 1.2	0.0	5	2	23 ± 6.6	0.1 ± 1.5	4.2 ± 6.5	0.007
13. Pajarito Acres	83397	5	5	−0.2 ± 2.3	−6.7 ± 4.5	−1.8 ± 2	0.0	5	1	16 ± 5.8	0.5 ± 2.1	6.2 ± 9.2	0.010
14. Bandelier	77173	5	5	−1.9 ± 1.9	−4.6 ± 5	−2.6 ± 1.2	0.0		1	14 ± 5.1	−0.6 ± 1.7	6 ± 10	0.010
Perimeter Group Summary	943349	55		1.6 ± 2.9	−14 ± 15	−2.3 ± 2.9	0.0	55	16	83 ± 11	−7 ± 25	8.1 ± 30	0.013
Onsite Stations—Controlled Areas													
15. TA-21	85195	5	5	−1.5 ± 2.4	−6.5 ± 4.7	−2.5 ± 0.8	0.0	5	2	17 ± 5.6	0.0 ± 1.7	6.1 ± 10	0.0003
16. TA-6	93917	5	5	−1.3 ± 1.6	−5.8 ± 4.2	−2.4 ± 1.1	0.0	5	3	8.3 ± 3.9	−1.8 ± 2.5	3.3 ± 7.8	0.0002
17. TA-53 (LAMPF)	89237	5	5	−1.4 ± 1.7	−8 ± 5	−2.3 ± 2	0.0	5	1	12 ± 5	−0.2 ± 1.8	4.9 ± 6.4	0.0002
18. Well PM-1	91165	5	5	−2 ± 1.8	−5.9 ± 4.9	−2.8 ± 1.6	0.0	5	1	11 ± 4.1	0.2 ± 2.1	5.3 ± 6.3	0.0003
19. TA-52	85005	5	5	2.1 ± 2.8	−7.1 ± 4.3	−1.1 ± 4.8	0.0	5	0	14 ± 5.3	4.5 ± 2.4	8.4 ± 7.5	0.0004
20. TA-16	99348	5	4	20 ± 6.9	−3.3 ± 2.4	−0.3 ± 8.5	0.0	5	2	242 ± 20	0.8 ± 1.6	20 ± 75	0.0010
21. Booster P-2	91977	5	5	−2 ± 1.9	−5.1 ± 4.6	−2.7 ± 1.4	0.0	5	3	11 ± 4.1	0.7 ± 1.7	3.2 ± 5.5	0.0002
22. TA-54	91963	5	5	2 ± 3.2	−2.9 ± 2.2	−1 ± 4.2	0.0	5	1	132 ± 14	−0.1 ± 2.1	23 ± 70	0.0012
23. TA-49	91727	5	5	−1.7 ± 1.5	−4.2 ± 4.5	−2.8 ± 3.6	0.0	5	2	13 ± 3.8	1.3 ± 2.9	4.6 ± 5.1	0.0002
24. TA-23	91842	5	5	−2.1 ± 2.1	−6.5 ± 4.3	−2.9 ± 2.2	0.0	5	1	12 ± 4	1 ± 2.6	6.9 ± 8.6	0.0003
25. TA-39	86689	5	5	−1.7 ± 1.9	−4.2 ± 4.3	−2.6 ± 2.5	0.0	5	2	9 ± 4.5	−0.3 ± 2.6	3.7 ± 8	0.0002
Onsite Group Summary	998065	55	54	2.5 ± 6.9	−8 ± 5	−2.1 ± 3.8	0.0	55	18	242 ± 20	−1.8 ± 2.5	8.3 ± 33	0.0004

[a]Air volumes (m³) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum Detectable Limits = 2×10^{-18} μCi/mℓ (^{239}Pu).
= 3×10^{-18} μCi/mℓ (^{240}Pu).
[c]Uncertainties for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample standard deviations). Uncertainties for station and group means are ±2 standard deviations.
[d]Controlled Area Radioactivity Concentration Guide = 2×10^{-12} μCi/mℓ (^{239}Pu).
= 2×10^{-12} μCi/mℓ (^{240}Pu).
Uncontrolled Area Radioactivity Concentration Guide = 7×10^{-14} μCi/mℓ (^{239}Pu).
= 6×10^{-14} μCi/mℓ (^{240}Pu).

TABLE E-VIII

ANNUAL ATMOSPHERIC URANIUM CONCENTRATIONS
(concentrations in pg/m³)

Station Location	Total Air[a] Volume (m³)	Number of Quarterly Samples	No. Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
1. Española	78 607	4	0	112 ± 19	64 ± 19	85 ± 64	0.0007
2. Pojoaque	81 428	4	0	116 ± 18	34 ± 18	75 ± 87	0.0006
3. Santa Fe	86 956	4	2	87 ± 24	15 ± 17	28 ± 28	0.0003
Regional Group Summary	246 991	12	2	116 ± 18	15 ± 17	62 ± 75	0.0007
Perimeter Stations (0-4 km)—Uncontrolled Areas							
4. Barranca School	79 344	4	0	85 ± 19	36 ± 19	51 ± 61	0.0005
5. Arkansas Ave	72 708	4	1	58 ± 24	18 ± 20	34 ± 32	0.0003
6. Cumbres School	80 559	4	1	69 ± 27	17 ± 19	37 ± 36	0.0004
7. 48th Street	85 773	4	0	62 ± 25	24 ± 17	37 ± 17	0.0004
8. LA Airport	95 359	4	0	179 ± 22	45 ± 16	88 ± 94	0.0010
9. Bayo STP	90 449	4	0	120 ± 16	23 ± 16	60 ± 108	0.0007
10. Gulf Station	71 951	4	1	190 ± 32	28 ± 32	78 ± 63	0.0009
11. Royal Crest	69 755	4	0	109 ± 26	18 ± 20	71 ± 70	0.0008
12. White Rock	81 752	4	2	98 ± 18	35 ± 18	60 ± 71	0.0007
13. Pajarito Acres	76 581	4	1	65 ± 28	17 ± 19	35 ± 42	0.0004
14. Bandelier	76 581	4	1	87 ± 31	8 ± 20	43 ± 46	0.0005
Perimeter Group Summary	874 936	44	6	190 ± 32	8 ± 20	54 ± 73	0.0006
Onsite Stations—Controlled Areas							
15. TA-21	78 717	4	0	251 ± 55	45 ± 19	83 ± 70	0.00004
16. TA-6	86 709	4	1	59 ± 25	7 ± 17	33 ± 49	0.00002
17. TA-53 (LAMPF)	82 759	4	0	97 ± 18	43 ± 18	79 ± 76	0.00004
18. Well PM-1	84 081	4	1	58 ± 24	7 ± 18	30 ± 34	0.00002
19. TA-52	77 955	4	0	130 ± 29	64 ± 17	78 ± 18	0.00004
20. TA-16	92 287	4	2	63 ± 23	6 ± 16	26 ± 33	0.00001
21. Booster P-2	84 905	4	1	107 ± 23	7 ± 18	39 ± 46	0.00002
22. TA-54	84 879	4	0	114 ± 18	52 ± 18	78 ± 74	0.00004
23. TA-49	84 632	4	1	101 ± 23	16 ± 18	41 ± 35	0.00002
24. TA-39	84 770	4	2	83 ± 23	7 ± 18	39 ± 79	0.00002
25. TA-39	79 583	4	2	62 ± 25	8 ± 19	26 ± 30	0.00001
Onsite Group Summary	921 277	44	10	251 ± 55	6 ± 18	50 ± 64	0.00002

[a]Air volumes (m³) at average ambient conditions of 77 kPa barometric pressure and 15°C.

[b]Minimum detectable limit = 1 pg/m³.

[c]Uncertainties for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample standard deviations). Uncertainties for station and group means are ±2 standard deviations.

[d]Controlled area radioactivity concentration guide = 2.1×10^6 pg/m³.
Uncontrolled area radioactivity concentration guide = 9×10^8 pg/m³.

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

[concentrations in aCi/m^3 (10^{-18} μCi/mℓ)]

Station Location	Total Air Volume (m^3)[a]	Number of Quarterly Samples	No Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km)—Uncontrolled Areas							
3. Santa Fe	86956	4	4	−1.1 ± 4.6	−6 ± 10	−3.1 ± 4.7	0.0
Regional Group Summary	86956	4	4	−1.1 ± 4.6	−6 ± 10	−3.1 ± 4.7	0.0
Perimeter Stations (0-4 km)—Uncontrolled Areas							
6. Cumbres	80559	4	4	−0.5 ± 7.1	−1.3 ± 5.1	−0.9 ± 1	0.0
8. LA Airport	91337	4	4	0.1 ± 4.2	−4.6 ± 5.2	−1.5 ± 4.3	0.0
9. Bayo STP	90449	4	4	1.2 ± 6.8	−1.1 ± 4.4	−0.7 ± 1.8	0.0
12. White Rock	81752	4	4	0.9 ± 5.1	−1.8 ± 6.5	−0.7 ± 2.6	0.0
Perimeter Group Summary	344097	16	16	1.2 ± 6.8	−4.6 ± 5.2	−1 ± 2.6	0.0
Onsite Stations—Controlled Areas							
16. TA-6	86709	4	4	3.8 ± 9.1	−5.1 ± 7.6	−1.6 ± 6.2	0.0
17. TA-53 (LAMPF)	82759	4	4	2.5 ± 7.2	−1.8 ± 5.1	−0.3 ± 3.5	0.0
20. TA-16	92287	4	4	−0.8 ± 4.6	−3.9 ± 5.6	−2.4 ± 3.8	0.0
21. Booster P-2	84905	4	4	0.0 ± 5	−1.6 ± 6.2	−0.8 ± 1.1	0.0
22. TA-54	87122	4	3	37 ± 10	−0.7 ± 4.8	5 ± 20	0.00008
23. TA-49	84773	4	4	1.8 ± 11	−1.8 ± 6.4	−0.4 ± 3.5	0.0
Onsite Group Summary	518555	24	23	37 ± 10	−5.1 ± 7.6	−0.1 ± 9.4	0.0

[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 for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample deviations). Uncertainties for station and group means are ±2 standard deviations.
[d]Controlled area radioactivity concentration guide = 5×10^{-8} μCi/mℓ.
Uncontrolled area radioactivity concentration guide = 2×10^{-7} μCi/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	---	---	6	GWD
Tesuque Fm (F.G. Sed)	---	---	7	GWD
Tesuque Fm (F.G. Sed)	---	---	8	GWD
Tesuque Fm (Basalts)		---	9	GWD
Surface Water	---	---	10	SW
Surface Water (Sanitary Effluents)	---	---	11	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 (Cont)

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
Hamilton Bend Spring	N110	E255	48	GW
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 (Cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Mortandad Canyon				
GS-1	N040	E100	62	SW
MCS-3.9	N040	E140	63	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
10-Site Canyon	N025	E130	70	SW

[a]See Fig. 11 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 7 stations; Tesuque Fm (F. G. Sed) 0 stations this period; Tesuque Fm (C. G. Sed) 9 stations; Tesuque (basalts) 3 stations; surface water 3 stations; surface water (sanitary effluents) 1 station.

TABLE E-XI

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE WATER FROM REGIONAL STATIONS

Radiochemical (average of a number of analyses)

Station	No. of Analyses	^{3}H (10^{-6} µCi/mℓ)	^{137}Cs (10^{-6} µCi/mℓ)	^{239}Pu (10^{-6} µCi/mℓ)	^{240}Pu (10^{-6} µCi/mℓ)	Gross α (10^{-6} µCi/mℓ)	Gross β (10^{-6} µCi/mℓ)	Total U (µg/ℓ)
Chamita	2	0.7 ± 0.0	22 ± 24	−0.02 ± 0.02	−0.01 ± 0.00	4.8 ± 0.6	13 ± 7.9	4.2 ± 2.6
Embudo	2	0.8 ± 1.0	−1 ± 27	0.00 ± 0.03	−0.02 ± 0.02	0.3 ± 3.1	5.5 ± 8.5	1.8 ± 1.7
Otowi	1	0.3 ± 0.6	0 ± 80	−0.05 ± 0.04	−0.03 ± 0.04	1.4 ± 2.4	7.6 ± 2.4	3.6 ± 0.8
Cochiti	2	0.5 ± 0.3	−24 ± 45	0.00 ± 0.00	−0.01 ± 0.04	1.1 ± 3.1	7.0 ± 3.0	3.1 ± 1.8
Bernalillo	2	0.7 ± 0.6	−8 ± 63	−0.02 ± 0.03	0.00 ± 0.02	3.1 ± 5.4	7.9 ± 3.8	3.5 ± 2.8
Jemez	2	0.8 ± 0.1	20 ± 56	0.02 ± 0.01	0.00 ± 0.04	3.1 ± 3.7	14 ± 0.6	1.7 ± 0.3
No. of Analyses		11	11	11	11	11	11	11
Minimum		0.3 ± 0.6	−40 ± 40	−0.05 ± 0.04	−0.03 ± 0.03	−0.8 ± 2.0	2.5 ± 1.2	1.2 ± 0.8
Maximum		1.2 ± 0.8	40 ± 80	0.00 ± 0.02	0.00 ± 0.02	5.0 ± 4.0	16 ± 3.4	5.1 ± 0.8
Average		0.7 ± 0.5	2 ± 47	−0.01 ± 0.03	−0.01 ± 0.03	2.4 ± 4.1	9.2 ± 8.8	3.0 ± 2.4

Chemical (concentrations in mg/ℓ, one analysis)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cℓ	F	NO_3	TDS	Hard	pH	Cond (mS/m)
Chamita	11	49	12	3.0	36	0	164	0.6	114	13	0.3	1.3	444	180	8.6	50
Embudo	16	25	5	2.9	12	0	134	<0.1	39	4	0.4	1.4	216	106	8.6	26
Otowi	16	38	8	2.9	21	0	154	1.2	64	7	0.5	1.0	300	135	8.7	36
Cochiti	16	35	8	2.9	21	0	154	0.7	54	7	0.4	0.2	274	130	8.8	34
Bernalillo	16	39	8	3.8	34	0	151	1.0	63	19	0.5	0.3	330	140	8.9	42
Jemez	26	29	5	7.2	45	0	176	0.1	20	52	0.8	0.3	376	100	8.7	45
No. of Analyses	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	11	25	5	2.9	12	0	134	<0.1	20	4	0.3	0.2	216	100	8.6	26
Maximum	26	49	12	7.2	45	...	176	1.2	114	52	0.8	1.4	444	180	8.9	50
Average	17 ± 10	36 ± 17	8 ± 5	3.8 ± 3.4	28 ± 24	0	156 ± 28	0.6 ± 0.9	59 ± 63	17 ± 36	0.5 ± 0.3	0.8 ± 1.0	323 ± 160	132 ± 57	8.7 ± 0.2	39 ± 17

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

TABLE E-XII

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE AND GROUND WATER FROM PERIMETER STATIONS

Station	No of Analyses	Radiochemical (average of a number of analyses)						
		^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (10^{-9} μCi/mℓ)	^{239}Pu (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	Gross α (10^{-9} μCi/mℓ)	Gross β (10^{-9} μCi/mℓ)	Total U (μg/ℓ)
Los Alamos Reservoir	2	0.6 ± 0.7	13 ± 16	0.00 ± 0.00	−0.02 ± 0.03	0.2 ± 0.1	4.8 ± 5.1	0.2 ± 0.4
Guaje Canyon	1	0.7 ± 0.6	−40 ± 60	0.01 ± 0.06	0.01 ± 0.06	1.7 ± 1.4	3.7 ± 0.4	0.4 ± 0.8
Basalt Spring	1	0.8 ± 0.6	10 ± 80	−0.03 ± 0.03	0.04 ± 0.04	0.7 ± 2	8.9 ± 2.6	1.9 ± 0.8
Frijoles Canyon	2	0.8 ± 0.1	−15 ± 70	−0.03 ± 0.01	−0.02 ± 0.05	−0.2 ± 0.4	3.4 ± 1.7	0.1 ± 0.3
La Mesita Spring	1	0.5 ± 0.6	−10 ± 40	−0.01 ± 0.02	−0.01 ± 0.02	5.8 ± 3.4	8.8 ± 2.6	14 ± 2.8
No. of Analyses		7	7	7	7	7	7	7
Minimum		0.3 ± 0.6	−40 ± 60	−0.03 ± 0.03	−0.03 ± 0.04	−0.3 ± 1.2	2.8 ± 1.2	0.0 ± 0.8
Maximum		0.8 ± 0.6	18 ± 42	0.01 ± 0.06	0.04 ± 0.04	5.8 ± 3.4	8.9 ± 2.6	14 ± 2.8
Average		0.7 ± 0.8	−6 ± 49	−0.01 ± 0.03	0.00 ± 0.05	1.2 ± 4.2	5.4 ± 5.3	2.4 ± 10
White Rock Canyon[a]								
Puye Formation	7	−0.4 ± 0	−4 ± 58	−0.02 ± 0.04	0.00 ± 0.04	1.1 ± 1.2	3.2 ± 1.8	1.1 ± 1.2
Tesuque Fm (C. G. Sed)	9	−0.1 ± 0.3	12 ± 35	−0.01 ± 0.04	0.01 ± 0.01	0.6 ± 1.1	2.3 ± 1.1	0.5 ± 1.9
Tesuque Fm (basalt)	3	−0.2 ± 0.1	−23 ± 83	−0.01 ± 0.04	0.00 ± 0.02	1.9 ± 5.1	3.9 ± 3.9	8.2 ± 25
Surface Water (3 stations)	3	0.2 ± 1.1	0 ± 20	0.01 ± 0.05	−0.03 ± 0.07	0.6 ± 1.9	2.8 ± 1.9	0.4 ± 1.5
Surface Water (sanitary effluents)	1	0.0 ± 0.6	30 ± 80	−0.02 ± 0.14	−0.02 ± 0.06	−1.1 ± 2.4	16 ± 3.8	0.5 ± 0.8
No. of Analyses		23	23	23	23	23	3	23
Minimum		−0.7 ± 0.6	−70 ± 80	−0.04 ± 0.04	−0.08 ± 0.06	−1.1 ± 2.4	1.4 ± 1	0.0 ± 0.8
Maximum		0.7 ± 0.6	50 ± 60	0.04 ± 0.22	0.03 ± 0.03	4.9 ± 2.6	16 ± 3.8	23 ± 4.6
Average		−0.2 ± 0.6	2 ± 52	−0.00 ± 0.02	0.00 ± 0.03	0.8 ± 2.3	3.4 ± 5.7	1.8 ± 9.3

TABLE E-XII (Cont)

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	18	4	2	2	6	3	42	0.1	8	5	0.1	<0.1	126	30	7.8	9
Basalt Spring	22	22	8	3.8	19	0	139	<0.1	36	29	0.6	16	266	110	8.5	30
Frijoles Canyon	26	6	3	2.5	10	3	56	0.1	11	3	0.2	1	162	25	8.3	13
La Mesita Spring	44	31	2	2.7	32	0	166	0.1	19	9	0.3	8	244	100	8.9	31
No. of Analyses	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Minimum	18	4	2	2	6	0	42	<0.1	8	3	0.1	<0.1	126	25	7.8	9
Maximum	44	31	8	3.8	32	3	166	0.1	36	29	0.6	16	266	110	8.9	31
Average	28 ± 23	16 ± 26	4 ± 6	3 ± 2	17 ± 23	2 ± 4	101 ± 122	0.1 ± 0.0	19 ± 25	12 ± 24	0.3 ± 0.4	6 ± 15	200 ± 133	66 ± 90	8.4 ± 0.9	21 ± 23
White Rock Canyon[a]																
Puye Formation	51	21	2	2.9	12	0	103	<0.1	5	4	0.6	2.8	139	55	8.3	15
Tesuque Fm (C. G. Sed.)	63	15	3	2.3	12	0	93	<0.1	4	3	0.5	1.4	116	48	8.4	14
Tesuque Fm (Basalts)	45	22	3	4.1	49	0	209	<0.1	11	4	0.5	4.7	286	53	8.6	28
Surface Water (3 stations)	58	16	4	2.5	11	0	90	0.7	5	4	0.4	1.6	161	48	8.4	13
Surface Water (Sanitary effuents)	78	29	9	16	61	0	134	45	31	44	1.0	32	468	96	8.3	49
No. of Analyses	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	21
Minimum	36	10	<1	1.6	9	---	71	<0.1	2	2	0.3	<0.1	40	32	7.9	9
Maximum	78	29	9	16	116	0	383	45	31	44	1	32	528	68	8.7	49
Average	57 ± 21	19 ± 11	3 ± 4	34 ± 6	19 ± 48	0	113 ± 125	2.1 ± 19	7 ± 13	5 ± 17	0.5 ± 0.3	4 ± 13	168 ± 226	53 ± 28	8.4 ± 0.4	18 ± 21

[a]Average of a number of analyses.

Note: ± value represents twice the standard deviation of the distribution of observed values unless only analysis is reported. Then the value represents twice the uncertainty term for that analysis.

TABLE E-XIII

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

Location	No. of Analyses	Radiochemical						
		^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (10^{-6} μCi/mℓ)	^{239}Pu (10^{-6} μCi/mℓ)	^{239}Pu (10^{-6} μCi/mℓ)	Gross α (10^{-6} μCi/mℓ)	Gross β (10^{-6} μCi/mℓ)	Total U (μg/ℓ)
Los Alamos Well Field								
Well LA-1B	1	0.1 ± 0.6	0 ± 40	−0.04 ± 0.03	−0.03 ± 0.03	9.0 ± 6.0	5.8 ± 2.2	6.2 ± 1.2
Well LA-2	1	−0.4 ± 0.6	27 ± 30	−0.01 ± 0.02	0.00 ± 0.01	2.1 ± 2.2	5.5 ± 2.0	3.7 ± 0.8
Well LA-3	1	0.4 ± 0.6	35 ± 36	−0.02 ± 0.02	0.00 ± 0.02	0.9 ± 1.8	4.4 ± 1.8	2.1 ± 0.8
Well LA-4	1	0.0 ± 0.6	0 ± 12	−0.01 ± 0.03	0.00 ± 0.02	−0.8 ± 1.4	2.5 ± 1.6	0.9 ± 0.8
Well LA-5	1	0.2 ± 0.6	20 ± 80	−0.01 ± 0.02	0.00 ± 0.02	−0.01 ± 1.6	6.5 ± 2.0	1.8 ± 0.8
Guaje Well Field								
Well G-1	1	−0.01 ± 0.6	40 ± 60	−0.04 ± 0.04	-0.01 ± 0.02	−0.8 ± 1.4	3.7 ± 1.6	0.7 ± 0.8
Well G-1A	1	0.1 ± 0.6	−4 ± 26	0.01 ± 0.03	−0.02 ± 0.03	−0.4 ± 1.4	4.0 ± 1.8	0.7 ± 0.8
Well G-2	1	−0.2 ± 0.6	0 ± 40	−0.03 ± 0.03	0.00 ± 0.02	−0.5 ± 1.6	4.4 ± 1.8	1.4 ± 0.8
Well G-3	1	0.0 ± 0.6	0 ± 40	0.00 ± 0.01	0.00 ± 0.01	−1.4 ± 1.4	3.1 ± 1.6	1.5 ± 0.8
Well G-4	1	−0.3 ± 0.6	20 ± 28	0.00 ± 0.03	−0.02 ± 0.03	−0.3 ± 1.2	3.3 ± 1.6	1.0 ± 0.8
Well G-5	1	0.3 ± 0.6	15 ± 14	−0.02 ± 0.03	0.00 ± 0.01	0.3 ± 1.4	2.5 ± 1.6	1.8 ± 0.8
Pajarito Well Field								
Well PM-1	1	0.5 ± 0.6	20 ± 80	−0.01 ± 0.03	−0.01 ± 0.03	1.1 ± 1.8	4.7 ± 2.0	2.2 ± 0.8
Well PM-2	1	0.8 ± 0.6	9 ± 38	−0.01 ± 0.03	−0.01 ± 0.02	0.0 ± 1.2	2.8 ± 1.6	0.4 ± 0.8
Well PM-3	1	0.5 ± 0.6	10 ± 40	−0.01 ± 0.02	−0.01 ± 0.01	−0.2 ± 1.8	4.2 ± 1.8	1.0 ± 0.8
Water Canyon Gallery	1	0.3 ± 0.6	−4 ± 26	0.00 ± 0.03	0.00 ± 0.03	−0.7 ± 1.0	5.0 ± 1.8	0.4 ± 0.8
No. of Analyses		15	15	15	15	15	15	15
Minimum		−0.4 ± 0.6	−4 ± 26	−0.04 ± 0.04	−0.03 ± 0.03	−1.4 ± 1.4	2.5 ± 1.6	0.4 ± 0.8
Maximum		0.8 ± 0.6	40 ± 60	0.01 ± 0.03	0.00 ± 0.02	9.0 ± 6.0	5.8 ± 2.2	6.2 ± 1.2
Average		0.2 ± 0.7	13 ± 28	−0.01 ± 0.03	−0.01 ± 0.02	0.6 ± 5.0	4.2 ± 2.4	1.7 ± 3.0
Distribution								
Fire Station 1	2	0.6 ± 1.3	0 ± 28	0.00 ± 0.05	−0.01 ± 0.04	0.1 ± 0.6	2.8 ± 0.1	0.8 ± 1.0
Fire Station 2	2	0.7 ± 0.3	4 ± 40	0.00 ± 0.01	−0.01 ± 0.03	1.0 ± 0.6	3.4 ± 3.0	3.1 ± 0.6
Fire Station 3	2	0.5 ± 0.3	0 ± 0	0.00 ± 0.00	0.00 ± 0.01	0.9 ± 0.6	4.4 ± 3.1	1.3 ± 1.4
Fire Station 4	2	0.4 ± 0.1	30 ± 0	−0.01 ± 0.01	0.00 ± 0.01	−0.2 ± 2.2	2.7 ± 1.7	0.6 ± 1.6
Fire Station 5	2	0.5 ± 0.6	2 ± 35	−0.01 ± 0.03	−0.01 ± 0.03	0.4 ± 1.0	3.3 ± 2.7	1.1 ± 3.1
No. of Analyses		10	10	10	10	10	10	10
Minimum		0.1 ± 0.6	−10 ± 80	−0.02 ± 0.03	−0.02 ± 0.04	−0.9 ± 0.7	2.1 ± 1.2	0.0 ± 0.8
Maximum		1.0 ± 0.6	30 ± 60	0.01 ± 0.02	0.01 ± 0.03	1.2 ± 0.6	5.5 ± 2.0	3.3 ± 0.8
Average		0.5 ± 0.5	7 ± 31	0.00 ± 0.02	0.00 ± 0.02	0.5 ± 1.3	3.4 ± 2.2	1.4 ± 2.3
Los Alamos Well LA-6*	1	0.2 ± 0.6	50 ± 60	0.00 ± 0.03	−0.01 ± 0.01	−1.1 ± 2.0	3.1 ± 1.8	2.0 ± 0.8

TABLE E-XIII (Cont)

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

Location	Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pb	Se
Los Alamos Well Field										
Well LA-1B	<0.001	0.05	<0.5	<0.01	0.02	2.8	<0.0005	<2	<0.01	<0.005
Well LA-2	<0.001	<0.01	<0.5	<0.01	0.02	1.2	<0.0005	<2	<0.01	<0.005
Well LA-3	<0.001	<0.01	<0.5	<0.01	0.01	0.6	<0.0005	<2	<0.01	<0.005
Well LA-4	<0.001	<0.01	<0.5	<0.01	<0.01	0.3	<0.0005	<2	<0.01	<0.005
Well LA-5	<0.001	0.04	<0.5	<0.01	<0.01	0.8	<0.0005	<2	<0.01	<0.005
Guaje Well Field										
Well G-1	<0.001	<0.01	<0.5	<0.01	<0.01	0.4	<0.0005	<2	<0.01	<0.005
Well G-1A	<0.001	<0.01	<0.5	<0.01	<0.01	0.5	<0.0005	<2	<0.01	<0.005
Well G-2	<0.001	0.04	<0.5	<0.01	<0.01	1.2	<0.0005	<2	<0.01	<0.005
Well G-3	<0.001	<0.01	<0.5	<0.01	<0.01	0.4	<0.0005	<2	0.01	<0.005
Well G-4	<0.001	<0.01	<0.5	<0.01	<0.01	0.3	<0.0005	<2	0.01	<0.005
Well G-5	<0.001	<0.01	<0.5	<0.01	<0.01	0.3	<0.0005	<2	<0.01	<0.005
Well G-6	0.001	<0.01	<0.5	<0.01	<0.01	---	<0.0005	---	0.19	<0.005
Pajarito Well Field										
Well PM-1	<0.001	<0.01	<0.5	<0.01	<0.01	0.3	<0.0005	<2	<0.01	<0.005
Well PM-2	<0.001	<0.01	<0.5	<0.01	<0.01	0.3	<0.0005	<2	<0.01	<0.005
Well PM-3	<0.001	<0.01	<0.5	<0.01	<0.01	0.4	<0.0005	<2	<0.01	<0.005
Water Canyon										
Gallery	<0.001	<0.01	<0.5	<0.01	<0.01	0.2	<0.0005	<2	<0.01	<0.005
No. of Analyses	16	16	16	16	16	15	16	15	16	16
Minimum	<0.001	<0.01	<0.5	<0.01	<0.01	0.2	<0.0005	<2	<0.01	<0.005
Maximum	---	0.05	---	---	0.02	2.8	---	---	0.19	---
Average	<0.001	<0.01 ± 0.02	<0.5	<0.01	<0.01 ± 0.01	0.7 ± 1.3	<0.0005	<2	0.02 ± 0.09	<0.005
Distribution										
Fire Station 1	<0.001	<0.01	<0.5	<0.01	0.006	0.3	<0.0005	<2	<0.01	<0.005
Fire Station 2	<0.001	0.01	<0.5	<0.01	0.008	0.7	<0.0005	<2	<0.01	<0.005
Fire Station 3	<0.001	<0.01	<0.5	<0.01	0.003	1.0	<0.0005	<2	<0.01	<0.005
Fire Station 4	<0.001	<0.01	<0.5	<0.01	0.004	0.4	<0.0005	<2	<0.01	<0.005
Fire Station 5	<0.001	<0.01	<0.5	<0.01	<0.002	0.6	<0.0005	<2	<0.01	<0.005
No. of Analyses	5	5	5	5	5	5	5	5	5	5
Minimum	<0.001	<0.01	<0.5	<0.01	<0.002	0.3	<0.0005	<2	<0.01	<0.005
Maximum	---	0.01	---	---	0.008	1.0	---	---	---	---
Average	<0.001	<0.01 ± 0.00	<0.5	<0.01	<0.005 ± 0.005	0.6 ± 0.6	<0.0005	<2	<0.01	<0.005
USEPA and NMEIA MPL	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]	<0.001	0.23	<0.5	<0.01	0.016	2.2	<0.0005	2.2	0.006	<0.005

TABLE E-XIII (Cont)

Location	Other Chemical Constituents (concentration in mg/ℓ, one analysis)													
	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	26	5	<1	2.9	154	0	354	<0.1	36	15	588	30	8.5	64
Well LA-2	23	5	<1	1.3	58	0	127	<0.1	13	12	280	25	9.0	28
Well LA-3	26	9	<1	1.8	31	0	132	0.1	7	3	206	40	8.8	16
Well LA-4	29	8	<1	2.2	18	0	88	0.1	3	2	138	25	8.8	15
Well LA-5	29	5	<1	1.5	32	0	98	<0.1	4	2	184	25	9.1	15
Guaje Well Field														
Well G-1	62	7	<1	3.1	21	0	100	2.0	4	2	230	30	8.7	15
Well G-1A	56	6	<1	3.0	25	0	90	2.0	4	2	218	15	8.8	15
Well G-2	50	6	<1	2.8	39	0	151	2.0	4	3	262	25	8.9	19
Well G-3	40	7	1	1.9	22	0	95	2.0	3	2	212	30	8.7	15
Well G-4	34	10	3	2.0	14	0	80	2.0	3	2	156	50	8.7	15
Well G-5	31	10	4	2.1	11	0	88	2.0	4	3	158	60	8.6	15
Well G-6														
Pajarito Well Field														
PM-1	32	14	6	3.6	20	0	136	3.0	5	6	234	85	8.5	24
PM-2	54	5	3	2.2	11	0	71	2.0	2	2	160	30	8.4	12
PM-3	70	13	8	3.6	17	0	149	<0.1	6	7	224	30	8.4	25
Water Canyon														
Gallery	74	4	3	2	4	0	34	2.0	10	1	96	40	7.8	8
No. of Analyses	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Minimum	23	4	<1	1.3	4	0	34	<0.1	2	1	96	15	7.8	8
Maximum	74	14	8	3.6	154	---	354	3.0	36	15	588	85	9.0	64
Average	42 ± 34	8 ± 6	2 ± 4	2.4 ± 1.4	32 ± 73	0	120 ± 144	1.3 ± 2.1	7 ± 17	4 ± 8	223 ± 224	36 ± 35	8.7 ± 0.6	20 ± 26
Distribution														
Fire Station 1	64	5	3	2.1	10	0	76	2.0	2	2	190	45	8.4	12
Fire Station 2	37	7	<1	2.1	34	0	129	2.0	6	4	228	35	8.8	20
Fire Station 3	38	14	7	3.7	19	0	137	0.1	6	8	262	90	8.4	26
Fire Station 4	50	8	2	2.2	18	0	90	<0.1	4	3	210	45	8.7	20
Fire Station 5	32	6	2	2.2	28	0	95	0.1	6	4	200	25	8.5	17
No. of Analyses	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Minimum	32	5	<1	2.1	10	0	76	<0.1	2	2	190	25	8.4	12
Maximum	64	14	7	3.7	34	---	137	2.0	6	8	262	90	8.7	26
Average	44 ± 26	8 ± 7	3 ± 5	2.5 ± 1.4	22 ± 19	0	105 ± 53	0.9 ± 2.1	5 ± 4	4 ± 5	218 ± 57	48 ± 50	8.6 ± 0.4	19 ± 10
Los Alamos Well LA-6*	25	2	<1	1.2	71	0	190	<0.1	6	3	298	5	9.2	31

*Los Alamos Well LA-6 on stand by; not used (see LA-7012-MS).

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

TABLE E-XIV

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM ONSITE STATIONS

Station	No. of Analyses	Radiochemical (average of a number of analyses) ^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (10^{-6} μCi/mℓ)	^{238}Pu (10^{-6} μCi/mℓ)	^{239}Pu (10^{-6} μCi/mℓ)	^{241}Am (10^{-6} μCi/mℓ)	Gross α (10^{-6} μCi/mℓ)	Gross β (10^{-6} μCi/mℓ)	Total U (μg/ℓ)
Noneffluent Areas									
Test Well 1	1	1.0 ± 0.6	30 ± 40	−0.04 ± 0.06	0.02 ± 0.06	---	−0.1 ± 1.6	4.2 ± 1.8	0.0 ± 0.8
Test Well 3	1	−0.1 ± 0.8	−20 ± 40	0.00 ± 0.03	0.01 ± 0.02	---	1.4 ± 1.0	3.2 ± 1.2	1.1 ± 0.8
Deep Test 5A	3	0.4 ± 1.0	5 ± 45	−0.03 ± 0.03	−0.02 ± 0.04	---	0.8 ± 2.2	5.3 ± 3.6	1.6 ± 1.4
Test Well 8	2	0.4 ± 1.1	0 ± 28	−0.02 ± 0.03	−0.02 ± 0.01	---	−0.2 ± 2.5	2.7 ± 0.8	0.2 ± 0.8
Deep Test 9	1	0.2 ± 0.6	−40 ± 46	−0.01 ± 0.06	−0.02 ± 0.04	---	2.3 ± 2.0	3.8 ± 1.8	0.9 ± 0.8
Deep Test 10	1	−0.1 ± 0.3	−10 ± 40	0.01 ± 0.06	−0.02 ± 0.06	---	0.7 ± 1.4	1.3 ± 1.6	0.7 ± 0.8
Canada del Buey	2	2.1 ± 3.4	−15 ± 71	−0.01 ± 0.04	0.01 ± 0.01	---	1.0 ± 3.7	6.4 ± 5.2	1.3 ± 2.8
Pajarito Canyon	2	2.0 ± 0.4	15 ± 71	0.00 ± 0.04	−0.02 ± 0.03	---	0.6 ± 0.7	5.0 ± 1.2	0.3 ± 0.8
Water Canyon	1	−0.1 ± 0.8	10 ± 80	0.01 ± 0.03	0.01 ± 0.04	---	0.5 ± 1.6	10 ± 2.8	0.0 ± 0.8
Test Well 2	2	0.4 ± 1.3	11 ± 54	−0.01 ± 0.05	0.00 ± 0.02	---	0.2 ± 0.7	8.2 ± 21	0.3 ± 0.8
No. of Analyses		16	16	15	15	---	16	16	15
Minimum		−0.1 ± 0.8	−40 ± 40	−0.04 ± 0.06	−0.03 ± 0.03	---	−0.1 ± 1.6	1.3 ± 1.6	0.0 ± 0.8
Maximum		3.3 ± 0.8	40 ± 60	0.01 ± 0.06	0.02 ± 0.06	---	2.3 ± 2.0	16 ± 3.6	2.3 ± 0.8
Average		0.7 ± 2.0	0 ± 48	−0.01 ± 0.04	−0.01 ± 0.03	---	0.6 ± 1.9	5.0 ± 7.5	0.8 ± 1.6
Effluent Release Areas									
Acid-Pueblo Canyon (former release area)									
Acid Weir	2	1.0 ± 1.8	−10 ± 28	0.00 ± 0.05	0.28 ± 0.62	---	1.9 ± 1.8	56 ± 115	0.4 ± 1.3
Pueblo 1	2	0.9 ± 0.1	31 ± 25	−0.01 ± 0.002	0.00 ± 0.03	---	0.7 ± 1.1	14 ± 20	0.4 ± 1.1
Pueblo 2	2	1.0 ± 0.0	0 ± 27	0.00 ± 0.00	0.04 ± 0.01	---	0.2 ± 1.0	13 ± 11	0.2 ± 0.4
Pueblo 3	2	0.7 ± 0.3	10 ± 28	0.00 ± 0.04	0.01 ± 0.05	---	0.5 ± 3.4	30 ± 52	0.3 ± 0.7
Hamilton Bend Spr	2	0.4 ± 0.7	−4 ± 13	−0.02 ± 0.01	0.05 ± 0.08	---	2.1 ± 2.4	14 ± 7.9	1.5 ± 4.2
Test Well 1A	2	0.6 ± 1.3	5 ± 14	−0.01 ± 0.01	0.01 ± 0.01	---	0.4 ± 0.3	7.2 ± 1.1	0.6 ± 1.8
Test Well 2A	2	19 ± 1.4	0 ± 28	0.01 ± 0.01	0.00 ± 0.03	---	0.4 ± 0.3	1.7 ± 0.3	0.0 ± 0.0
No. of Analyses		14	14	14	14	---	14	14	14
Minimum		0.2 ± 0.6	−20 ± 100	−0.03 ± 0.02	−0.01 ± 0.04	---	−0.7 ± 1.4	1.6 ± 1.6	0.0 ± 0.8
Maximum		20 ± 1.0	40 ± 60	0.02 ± 0.03	0.50 ± 0.14	---	2.6 ± 2.2	97 ± 10	3.0 ± 0.8
Average		3.4 ± 14	4 ± 31	0.00 ± 0.03	0.06 ± 0.26	---	0.9 ± 2.0	19 ± 50	0.5 ± 1.7

TABLE E-XIV (Cont)

Station	No. of Analyses	Radiochemical (average of a number of analyses) ^{3}H (10^{-9} µCi/mℓ)	^{137}Cs (10^{-9} µCi/mℓ)	^{238}Pu (10^{-9} µCi/mℓ)	^{239}Pu (10^{-9} µCi/mℓ)	^{241}Am (10^{-9} µCi/mℓ)	Gross α (10^{-9} µCi/mℓ)	Gross β (10^{-9} µCi/mℓ)	Total U (µg/ℓ)
DP—Los Alamos Canyon									
DPS-1	2	3.2 ± 0.3	24 ± 16	0.08 ± 0.10	0.39 ± 0.71	7.6 ± 0.80	27 ± 9.9	208 ± 119	71 ± 19
DPS-4	2	9.3 ± 4.5	10 ± 28	0.04 ± 0.03	0.22 ± 0.24	1.6 ± 0.24	5.5 ± 1.4	360 ± 57	6.4 ± 7.9
LAO-C	2	1.5 ± 2.3	11 ± 25	−0.01 ± 0.05	0.01 ± 0.04	0.09 ± 0.12	1.1 ± 2.1	4.2 ± 8.5	1.0 ± 2.4
LAO-1	2	3.8 ± 7.8	4 ± 17	0.00 ± 0.01	0.03 ± 0.02	−0.02 ± 0.08	0.2 ± 0.4	55 ± 140	0.3 ± 0.7
LAO-2	2	8.2 ± 6.9	14 ± 11	0.03 ± 0.03	0.12 ± 0.07	0.97 ± 0.16	3.4 ± 1.7	245 ± 127	1.8 ± 2.4
LAO-3	2	7.6 ± 10	−7 ± 28	0.01 ± 0.01	0.03 ± 0.03	0.25 ± 0.12	3.8 ± 3.5	112 ± 117	1.2 ± 3.4
LAO-4	2	3.2 ± 0.6	−15 ± 42	0.00 ± 0.06	0.06 ± 0.01	0.23 ± 0.14	1.3 ± 2.3	22 ± 7.1	0.6 ± 0.1
LAO-4.5	2	4.3 ± 0.0	15 ± 42	−0.01 ± 0.03	0.01 ± 0.01	0.16 ± 0.10	2.5 ± 3.0	13 ± 12	1.2 ± 1.6
No. of Analyses		16	16	16	16	8	16	16	16
Minimum		0.7 ± 0.6	−30 ± 80	−0.02 ± 0.04	−0.01 ± 0.06	−0.02 ± 0.08	0.0 ± 1.8	1.2 ± 1.6	0.0 ± 0.8
Maximum		11.2 ± 1.4	30 ± 80	0.11 ± 0.08	0.64 ± 0.18	7.6 ± 0.80	30 ± 14	380 ± 80	77 ± 15
Average		5.2 ± 6.8	7 ± 32	0.02 ± 0.07	0.11 ± 0.32	1.4 ± 5.2	5.5 ± 17	127 ± 261	10 ± 48
Sandia Canyon									
SCS-1	2	5.8 ± 0.7	15 ± 14	0.03 ± 0.11	0.01 ± 0.01	−0.01 ± 0.10	0.4 ± 0.7	25 ± 2.8	1.9 ± 0.1
SCS-2	2	7.2 ± 0.7	7 ± 37	−0.01 ± 0.02	0.00 ± 0.02	0.01 ± 0.12	0.4 ± 1.3	16 ± 8.1	1.8 ± 0.3
SCS-3	2	6.5 ± 0.7	4 ± 66	0.00 ± 0.03	0.00 ± 0.02	0.03 ± 0.08	1.1 ± 0.4	16 ± 12	1.4 ± 1.3
No. of Analyses		6	6	6	6	3	6	6	6
Minimum		5.5 ± 0.8	−20 ± 80	−0.02 ± 0.03	−0.01 ± 0.04	−0.01 ± 0.10	0.2 ± 3.8	12 ± 2.8	1.0 ± 0.8
Maximum		7.5 ± 1.2	27 ± 24	0.07 ± 0.06	0.01 ± 0.02	0.03 ± 0.08	1.3 ± 2.0	26 ± 6	2.0 ± 0.4
Average		6.5 ± 1.4	8 ± 36	0.01 ± 0.06	0.00 ± 0.02	0.01 ± 0.04	0.7 ± 1.0	19 ± 11	1.7 ± 0.7
Mortandad Canyon									
GS-1	2	307 ± 913	120 ± 256	2.70 ± 1.70	1.64 ± 2.45	1.27 ± 0.32	8.9 ± 17	203 ± 388	0.8 ± 0.7
MCO-3	2	49 ± 73	15 ± 14	2.42 ± 6.22	0.26 ± 0.69	0.70 ± 0.40	12 ± 8.5	42 ± 38	1.9 ± 3.3
MCO-4	2	95 ± 72	−15 ± 71	0.26 ± 0.18	0.10 ± 0.26	5.6 ± 0.60	24 ± 2.8	104 ± 205	2.0 ± 1.3
MCO-5	2	68 ± 8.5	0 ± 57	1.32 ± 3.24	0.25 ± 0.65	1.6 ± 0.24	16 ± 4.2	60 ± 75	3.0 ± 3.8
MCO-6	2	51 ± 60	10 ± 58	0.19 ± 0.09	0.04 ± 0.01	0.48 ± 0.20	11 ± 17	27 ± 32	3.0 ± 2.7
MCO-7	2	75 ± 6.5	−11 ± 27	0.19 ± 0.01	0.06 ± 0.03	0.01 ± 0.22	16 ± 18	30 ± 8.5	3.8 ± 1.3
MCO-7.5	2	113 ± 104	7 ± 103	0.23 ± 0.06	0.07 ± 0.14	−0.40 ± 1.0	27 ± 54	35 ± 32	7.1 ± 8.1
10-Site Canyon	1	3.7 ± 0.8	2 ± 18	0.04 ± 0.06	0.01 ± 0.03	---	1.8 ± 1.4	15 ± 3.4	1.1 ± 0.8
No. of Analyses		15	15	15	15	7	15	15	15
Minimum		3.7 ± 0.8	−40 ± 60	0.04 ± 0.06	0.01 ± 0.06	−0.40 ± 1.0	1.8 ± 1.4	15 ± 3.4	0.5 ± 0.8
Maximum		650 ± 20	210 ± 40	4.62 ± 0.34	2.51 ± 0.24	5.6 ± 0.60	46 ± 20	340 ± 60	4.3 ± 0.8
Average		104 ± 312	17 ± 117	0.98 ± 2.88	0.19 ± 0.50	1.3 ± 4.0	15 ± 22	68 ± 171	2.9 ± 4.7

TABLE E-XIV (Cont)

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	
Noneffluent Areas																
Test Well 1	26	32	2	4.0	21	0	151	0.1	2	13	0.5	1	186	85	8.4	24
Deep Test 5A	50	3	2	2.7	21	0	76	1.0	2	2	0.3	3	180	33	8.4	13
Test Well 8	76	4	1	1.8	11	0	44	1.0	1	2	0.2	1	54	70	9.7	7
Deep Test 9	40	5	3	1.0	11	0	27	1.0	2	2	0.4	2	138	35	8.3	10
Deep Test 10	58	6	3	1.4	11	0	80	2.0	1	2	0.4	1	130	50	8.5	12
Canada del Buey	58	3	2	1.9	6	3	22	1.0	6	3	0.7	1	78	10	7.6	3
Pajarito Canyon	15	7	4	3.3	15	3	56	<0.1	14	17	0.2	3	192	55	8.2	16
Test Well 2	26	7	3	1.1	9	0	83	<0.1	2	2	0.4	2	172	55	8.4	12
No. of Analyses	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Minimum	15	3	1	1.0	6	0	22	<0.1	1	2	0.2	1	54	10	7.6	3
Maximum	76	32	4	4.0	21	3	151	2.0	14	17	0.7	3	192	85	9.7	24
Average	44 ± 41	8 ± 19	3 ± 2	2.2 ± 2.2	13 ± 11	<1 ± 3	67 ± 82	0.8 ± 1.3	4 ± 9	5 ± 12	0.4 ± 0.3	2 ± 2	141 ± 104	49 ± 47	8.4 ± 1.2	12 ± 12
Effluent Release Areas																
Acid-Pueblo Canyon (former release area)																
Acid Weir	66	11	2	4.8	58	0	71	<0.1	14	61	0.5	8	276	45	8.3	37
Pueblo 1	20	9	3	5.4	34	0	90	10	20	20	0.3	22	258	45	8.3	25
Pueblo 2	34	8	2	4.7	31	0	71	5	18	22	0.3	10	222	45	8.3	22
Pueblo 3	34	9	3	7.1	49	0	88	14	21	30	0.5	22	292	90	8.2	16
Hamilton Bend Spr	34	8	4	7.3	69	0	110	21	29	40	0.9	31	370	50	8.0	42
Test Well 1A	10	9	3	6.2	64	0	132	<0.1	22	38	0.8	1	290	40	8.7	38
Test Well 2A	4	16	4	2.5	18	0	49	<0.1	14	28	0.2	<1	92	45	9.0	17
No. of Analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum	4	8	2	2.5	18	0	49	<0.1	14	20	0.2	<1	92	40	8.0	16
Maximum	66	16	4	7.3	69	---	132	21	29	61	0.9	31	370	90	9.0	42
Average	29 ± 41	10 ± 6	3 ± 2	5.4 ± 3.3	46 ± 38	---	87 ± 55	7.2 ± 16	20 ± 10	34 ± 28	0.5 ± 0.5	14 ± 23	257 ± 171	51 ± 35	8.4 ± 0.7	28 ± 21
DP—Los Alamos Canyon																
DPS-1	16	43	5	8.9	123	0	173	<0.1	46	127	4.0	21	580	145	8.7	80
DPS-4	20	10	2	24	130	0	178	<0.1	18	72	10.0	80	558	30	8.6	70
LAO-C	34	6	3	2.9	20	0	49	<0.1	9	30	0.1	1	154	25	8.0	18
LAO-1	34	8	3	3.4	31	0	58	<0.1	11	36	0.2	1	200	45	8.4	24
LAO-2	17	13	3	25	129	0	151	<0.1	29	76	6.4	89	560	55	8.7	72
LAO-3	23	22	5	33	117	0	156	<0.1	33	90	2.3	98	536	95	8.4	72
LAO-4	21	12	5	6.9	47	0	71	<0.1	17	51	1.0	9	238	60	8.4	34
LAO-4.5	26	13	6	5.0	46	0	112	5.0	19	39	0.5	7	182	65	8.5	38
No. of Analyses	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Minimum	16	6	2	2.9	20	0	49	<0.1	9	30	0.1	1	154	25	8.0	18
Maximum	34	43	6	33	130	---	178	5.0	46	127	10.0	98	580	145	8.7	80
Average	24 ± 14	16 ± 24	4 ± 3	14 ± 24	80 ±97	---	119 ± 106	0.7 ± 3.5	23 ± 25	65 ± 66	3.1 ± 7.1	38 ± 86	376 ± 394	65 ± 78	8.5 ± 0.5	51 ± 50

TABLE E-XV

LOCATION OF SOIL AND SEDIMENT STATIONS

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 13)[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
Cochiti	35°37'	106°19'	---
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
North Mesa	N135	E165	S5
East of Airport	N095	E220	S6
West of Airport	N115	E135	S7
South SR-4 near S-Site	S085	W035	S8
Perimeter Sediments			
Guaje near G-4	N215	E325	1
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 Reservoir	N100	W065	8
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-XV (Cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 13)[a]
Onsite Soils			
TA-21	N095	E140	S9
TA-50	N035	E095	S10
TA-36	S090	E150	S11
PM-1	N020	E310	S12
West of TA-53	N070	E105	S13
East of TA-53	N050	E220	S14
East of New Sigma	N060	E065	S15
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
R-Site Road East	S040	E100	S22
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 SCS-2	N050	E175	31
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
Pajarito at TA-18	S055	E195	41

TABLE E-XV (Cont)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation (Figure 13)[a]
Pajarito at SR-4	S105	E320	42
Potrillo at TA-36	S075	E150	43
Potrillo East of TA-36	S085	E225	44
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. 13 for numbered locations.

[b]Locations are the same as for surface water stations (Table E-X).

TABLE E-XVI

RADIOCHEMICAL ANALYSES OF REGIONAL SOILS AND SEDIMENTS

	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	^{90}Sr (pCi/g)	^{241}Am (pCi/g)	Gross α (pCi/g)	Gross β (pCi/g)	Total U (μg/g)
Regional Soils									
Chamita	1.3 ± 0.6	0.82 ± 0.14	0.000 ± 0.003	0.142 ± 0.016	0.44 ± 0.16	0.022 ± 0.006	5.4 ± 2.4	8.1 ± 1.8	2.3 ± 0.4
Embudo	0.6 ± 0.6	0.88 ± 0.18	0.000 ± 0.004	0.020 ± 0.006	0.26 ± 0.14	0.003 ± 0.008	11 ± 4.0	12 ± 2.6	3.3 ± 0.6
Otowi	1.5 ± 0.6	0.96 ± 0.18	−0.002 ± 0.004	0.023 ± 0.010	0.40 ± 0.16	0.011 ± 0.006	8.1 ± 3.8	13 ± 2.8	4.1 ± 0.8
Cochiti	0.8 ± 0.6	0.25 ± 0.12	−0.001 ± 0.003	0.003 ± 0.004	0.10 ± 0.10	0.004 ± 0.003	7.8 ± 3.6	9.8 ± 2.2	2.8 ± 0.6
Bernalillo	1.9 ± 0.6	0.56 ± 0.12	0.000 ± 0.002	0.010 ± 0.008	0.18 ± 0.10	0.002 ± 0.004	4.8 ± 2.6	6.0 ± 1.6	2.1 ± 0.4
Jemez	0.0 ± 0.6	0.33 ± 0.14	−0.001 ± 0.002	0.005 ± 0.004	0.17 ± 0.14	0.001 ± 0.004	3.3 ± 1.0	4.1 ± 1.2	2.0 ± 0.4
No. of Analyses	6	6	6	6	6	6	6	6	6
Minimum	0.0 ± 0.6	0.25 ± 0.12	−0.002 ± 0.004	0.003 ± 0.004	0.10 ± 0.10	0.001 ± 0.004	3.3 ± 1.0	4.1 ± 1.2	2.0 ± 0.4
Maximum	1.9 ± 0.6	0.96 ± 0.18	0.000 ± 0.004	0.142 ± 0.016	0.44 ± 0.16	0.011 ± 0.006	11 ± 4.0	13 ± 2.8	4.1 ± 0.8
Average	1.0 ± 1.4	0.63 ± 0.60	−0.001 ± 0.002	0.034 ± 0.107	0.26 ± 0.27	0.004 ± 0.007	6.7 ± 5.6	8.8 ± 6.9	2.8 ± 1.6
74-77 May	—	1.06 ± .28	.016 ± .060	0.045 ± 0.010	1.00 ± 2.40	–	18 ± 4.0	12 ± 2.6	5.1 ± 1.6
Regional River Sediments									
Rio Chama									
Chamita[a]	---	0.05 ± 0.11	−0.001 ± 0.004	0.000 ± 0.001	−0.15 ± 0.18	---	1.0 ± 1.4	1.5 ± 2.8	1.1 ± 0.2
Rio Grande									
Embudo[a]	---	0.24 ± 0.20	−0.002 ± 0.014	0.004 ± 0014	−0.07 ± 0.14	---	4.7 ± 2.8	3.6 ± 1.1	3.0 ± 0.6
Otowi[a]	---	0.11 ± 0.04	0.000 ± 0.002	0.023 ± 0.085	0.12 ± 0.18	---	3.0 ± 1.3	5.0 ± 1.7	2.7 ± 0.6
Sandia	---	0.17 ± 0.06	0.000 ± 0.000	0.004 ± 0.000	−0.01 ± 0.13	---	3.3 ± 1.6	3.6 ± 0.5	2.2 ± 0.4
Pajarito	---	0.08 ± 0.10	0.000 ± 0.000	0.001 ± 0.000	0.01 ± 0.22	---	5.2 ± 1.4	2.5 ± 0.8	1.9 ± 0.4
Ancho	---	0.32 ± 0.10	0.000 ± 0.000	0.008 ± 0.000	2.5 ± 0.40	---	5.3 ± 1.3	6.6 ± 1.6	2.9 ± 0.4
Frijoles	---	0.12 ± 0.06	0.000 ± 0.000	0.002 ± 0.000	−0.16 ± 0.20	---	3.9 ± 0.9	2.6 ± 1.0	2.2 ± 0.4
Cochiti	---	0.29 ± 0.10	0.001 ± 0.004	0.032 ± 0.010	---	---	13 ± 6.0	15 ± 3.2	2.9 ± 0.6
Bernalillo	---	0.16 ± 0.10	−0.001 ± 0.003	0.004 ± 0.010	---	---	7.3 ± 3.4	7.3 ± 3.4	5.8 ± 1.6
Jemez River		0.16 ± 0.10	0.000 ± 0.000	0.002 ± 0.000	---	---	---	---	---
Jemez Pueblo	---	0.14 ± 0.06	−0.001 ± 0.004	−0.001 ± 0.003	---	---	8.0 ± 4.0	6.3 ± 1.6	2.8 ± 0.6
No. of Analyses		13	13	13	7	---	13	13	13
Minimum		0.01 ± 0.10	−0.005 ± 0.006	−0.001 ± 0.003	−0.15 ± 0.18	---	0.5 ± 0.6	0.5 ± 0.6	0.9 ± 0.2
Maximum		0.32 ± 0.10	0.001 ± 0.004	0.039 ± 0.008	2.5 ± 0.40	---	13 ± 6.0	15 ± 3.2	3.2 ± 0.6
Average		0.16 ± 0.38	0.000 ± 0.006	0.008 ± 0.050	0.32 ± 1.9	---	4.7 ± 6.6	4.8 ± 6.9	2.4 ± 3
74-77 May		.80 ± 0.14	.005 ± .012	.036 ± .006	0.94 ± 0.60		14 ± 8	13 ± 2.8	4.1 ± 2.6

[a]Two analyses.

Note: Value represents twice the standard deviations of the distribution of observed values unless only one analysis is reported, then the value represents twice the uncertainty term for that analysis.

TABLE E-XVII

RADIOCHEMICAL ANALYSES OF PERIMETER SOILS AND SEDIMENTS

Station	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{239}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross α (pCi/g)	Gross β (pCi/g)	Total U (μg/g)
Soils								
Sportsman Club	0.5 ± 0.6	1.01 ± 0.22	---	−0.004 ± 0.004	0.024 ± 0.010	7.2 ± 3.2	8.3 ± 2.0	4.2 ± 0.8
TA-8	0.4 +0 0.6	0.57 ± 0.10	0.79 ± 0.20	−0.001 ± 0.006	0.026 ± 0.012	9.0 ± 4.0	14 ± 3.0	4.0 ± 0.8
TA-49[a]	0.4 ± 0.6	1.04 ± 0.20	---	−0.001 ± 0.003	0.018 ± 0.008	9.0 ± 4.0	9.5 ± 2.2	4.8 ± 1.0
Frijoles[a]	96 ± 3.2	1.29 ± 0.24	---	−0.002 ± 0.003	0.024 ± 0.010	10 ± 4.0	13 ± 2.8	4.7 ± 1.0
North Mesa[a]	0.5 ± 0.6	0.90 ± 0.16	---	−0.001 ± 0.003	0.057 ± 0.012	9.0 ± 4.0	9.4 ± 2.2	4.4 ± 0.8
East of Airport[a]	0.3 ± 0.6	0.43 ± 0.08	1.1 ± 0.20	0.001 ± 0.004	0.013 ± 0.008	8.4 ± 3.6	7.9 ± 1.8	4.0 ± 0.8
West of Airport[a]	0.9 ± 0.6	1.18 ± 0.20	0.03 ± 0.14	0.004 ± 0.004	0.066 ± 0.012	7.7 ± 3.4	9.0 ± 2.0	5.3 ± 1.0
South SR-4 Near S-Site[a]	3.0 ± 0.8	0.96 ± 0.18	---	0.001 ± 0.003	0.019 ± 0.006	7.2 ± 3.2	8.7 ± 2.0	5.1 ± 1.0
No. of Analyses	8	8	3	8	8	8	8	8
Minimum	0.3 ± 0.6	0.43 ± 0.08	0.03 ± 0.14	−0.004 ± 0.004	0.013 ± 0.008	7.2 ± 3.2	7.9 ± 1.8	4.0 ± 0.8
Maximum	96 ± 3.2	1.29 ± 0.24	1.1 ± 0.20	0.004 ± 0.004	0.066 ± 0.012	10 ± 4.0	14 ± 3.0	5.3 ± 1.0
Average	13 ± 67	0.92 ± 0.58	0.64 ± 1.1	0.000 ± 0.005	0.031 ± 0.039	8.4 ± 2.0	9.9 ± 4.5	4.6 ± 1.0
Sediments								
Guaje Near G-4[a]	---	0.09 ± 0.10	−0.05 ± 0.16	−0.002 ± 0.002	−0.002 ± 0.003	1.5 ± 0.8	1.1 ± 0.6	2.2 ± 0.4
Guaje at SR-4[b]	---	0.09 ± 0.06	0.29 ± 0.18	0.000 ± 0.002	0.001 ± 0.002	2.0 ± 1.8	2.1 ± 3.1	3.1 ± 0.6
Bayo at SR-4	---	0.06 ± 0.06	---	−0.001 ± 0.002	−0.001 ± 0.002	2.3 ± 1.2	1.6 ± 0.8	1.9 ± 0.4
Pueblo at Acid Weir[a]	---	1.03 ± 0.18	0.68 ± 0:20	0.068 ± 0:012	10.6 ± 0.60	12 ± 4.0	6.0 ± 1.4	2.7 ± 0.6
Pueblo at PC-1[a]	---	0.12 ± 0.08	1.48 ± 0.26	0.003 ± 0.004	0.023 ± 0.008	3.3 ± 1.6	5.6 ± 1.4	2.6 ± 0.6
Pueblo at Pueblo 1[a]	---	0.29 ± 0.08	2.25 ± 0.30	−0.004 ± 0.010	0.270 ± 0.060	6.4 ± 3.0	12 ± 2.6	3.8 ± 0.8
Pueblo at Pueblo 2[a]	---	0.13 ± 0.06	0.30 ± 0.16	0.001 ± 0.006	0.630 ± 0.080	2.7 ± 1.4	3.3 ± 1.6	3.9 ± 0.8
Los Alamos at Reservoir	---	0.11 ± 0.06	0.08 ± 0.16	−0.001 ± 0.004	0.002 ± 0.004	4.1 ± 2.0	2.7 ± 1.0	2.6 ± 0.6
Los Alamos at Totavi[a,b]	---	1.39 ± 0.42	0.28 ± 0.14	0.006 ± 0.005	0.270 ± 0.026	3.0 ± 5.3	3.1 ± 4.9	3.0 ± 3.1
Los Alamos at LA-2[a,b]	---	0.52 ± 0.18	0.10 ± 0.18	0.010 ± 0.024	0.638 ± 1.42	1.3 ± 1.4	1.6 ± 1.7	2.2 ± 0.7
Los Alamos at Rio Grande[a,b]	---	0.07 ± 0.14	0.07 ± 0.11	0.000 ± 0.001	0.162 ± 0.444	2.4 ± 1.9	1.9 ± 2.8	1.8 ± 1.6
Sandia at Rio Grande	---	0.06 ± 0.04	−0.11 ± 0.22	−0.001 ± 0.002	0.000 ± 0.002	3.1 ± 0.8	2.5 ± 0.8	
Canada del Ancha	---	0.06 ± 0.06	0.12 ± 0.22	−0.001 ± 0.002	0.003 ± 0.004	2.4 ± 1.2	2.3 ± 0.6	1.1 ± 0.8
Mortantad at SR-4	---	0.16 ± 0.12	---	−0.001 ± 0.008	0.003 ± 0.006	6.8 ± 3.0	5.2 ± 1.4	3.6 ± 0.8
Mortantad at Rio Grande	---	−0.09 ± 0.10	0.05 ± 0.18	0.000 ± 0.000	0.000 ± 0.000	2.1 ± 1.0	1.6 ± 0.6	4.8 ± 0.8
Canada de Buey at SR-4	---	0.16 ± 0.10	---	0.001 ± 0.004	0.003 ± 0.004	3.1 ± 1.6	4.5 ± 1.2	2.5 ± 0.6
Pajarito at Rio Grande	---	0.08 ± 0.06	−0.70 ± 1.00	0.001 ± 0.004	0.003 ± 0.004	1.7 ± 1.6	2.3 ± 0.6	1.7 ± 0.8
Frijoles at Park Hdq.	---	0.03 ± 0.16	---	−0.001 ± 0.004	0.004 ± 0.003	2.0 ± 1.0	2.9 ± 1.0	3.0 ± 0.6
Frijoles at Rio Grande	---	0.12 ± 0.10	2.0 ± 0.40	−0.001 ± 0.002	−0.002 ± 0.004	1.2 ± 1.2	1.0 ± 0.4	4.6 ± 0.8
No. of Analyses	---	31	17	23	23	23	23	23
Minimum	---	−0.09 ± 0.10	−0.70 ± 1.00	−0.004 ± 0.010	−0.002 ± 0.004	0.8 ± 0.4	0.9 ± 0.4	1.1 ± 0.8
Maximum	---	1.53 ± 0.26	2.25 ± 0.30	0.068 ± 0.012	10.6 ± 0.60	12 ± 4.0	12 ± 2.6	4.8 ± 0.8
Average	---	0.45 ± 0.96	0.46 ± 1.46	0.004 ± 0.029	0.595 ± 4.40	3.1 ± 5.0	3.1 ± 4.9	2.7 ± 2.0

[a]Radioactivity above natural or world-wide fallout concentrations.
[b]Two analyses.

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

TABLE E-XVIII

RADIOCHEMICAL ANALYSES OF ONSITE SOILS AND SEDIMENTS

Stations	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross α (pCi/g)	Gross β (pCi/g)	Total U (μg/g)
Soils								
TA-21	1.9 ± 0.6	0.03 ± 0.12	0.13 ± 0.16	0.001 ± 0.003	0.017 ± 0.006	7.3 ± 3.2	6.1 ± 1.6	3.5 ± 0.8
TA-50[a]	1.9 ± 0.6	0.16 ± 0.08	0.25 ± 0.20	−0.002 ± 0.004	0.023 ± 0.008	12. ± 3.0	7.5 ± 1.8	4.4 ± 0.8
TA-36	1.2 ± 0.6	0.18 ± 0.08	---	0.001 ± 0.004	0.002 ± 0.004	8.9 ± 3.8	7.6 ± 1.8	4.2 ± 0.8
PM-1[a]	1.3 ± 0.6	0.94 ± 0.16	---	0.002 ± 0.006	0.022 ± 0.004	11. ± 4.0	15 ± 3.2	6.5 ± 1.4
West of TA-53[a]	1.3 ± 0.6	1.15 ± 0.24	0.56 ± 0.18	0.000 ± 0.002	0.076 ± 0.010	16. ± 4.0	19. ± 4.0	7.1 ± 1.4
East of TA-53[a]	2.0 ± 0.6	1.22 ± 0.20	0.35 ± 0.16	0.001 ± 0.004	0.031 ± 0.010	10. ± 4.0	12 ± 2.6	4.2 ± 0.8
East of New Sigma I[a]	17. ± 1.0	0.63 ± 0.12	---	0.078 ± 0.012	0.054 ± 0.010	10. ± 4.0	11 ± 2.6	3.4 ± 0.6
East of New Sigma II[a]	3.6 ± 0.8	0.94 ± 0.20	---	0.002 ± 0.002	0.061 ± 0.012	10. ± 4.0	15 ± 3.2	6.1 ± 1.2
East of TA-52[a]	2.5 ± 0.6	0.15 ± 0.08	---	0.234 ± 0.022	0.127 ± 0.016	13. ± 6.0	9.7 ± 2.2	3.7 ± 0.8
2-Mile Mesa	0.9 ± 0.6	0.60 ± 0.12	---	0.002 ± 0.002	0.009 ± 0.004	6.4 ± 2.8	6.5 ± 1.6	3.9 ± 0.8
Near TA-51[a]	1.1 ± 0.6	0.11 ± 0.10	0.90 ± 0.20	0.000 ± 0.004	0.013 ± 0.006	6.4 ± 2.8	5.9 ± 1.4	3.8 ± 0.8
East of TA-54[a]	13. ± 1.0	0.18 ± 0.08	0.23 ± 0.26	−0.001 ± 0.004	0.001 ± 0.004	18. ± 8.0	17 ± 3.6	4.8 ± 1.0
R-Site Road[a]	0.4 ± 0.6	3.1 ± 0.40	---	0.003 ± 0.003	0.061 ± 0.012	8.6 ± 3.8	13 ± 2.8	4.0 ± 0.8
R-Site Road East[a]	5.8 ± 0.8	1.04 ± 0.18	0.41 ± 0.18	−0.002 ± 0.006	0.031 ± 0.012	14. ± 6.0	17 ± 3.8	7.8 ± 1.6
Potrillo Drive	1.4 ± 0.6	0.77 ± 0.14	---	−0.005 ± 0.010	0.015 ± 0.012	10. ± 4.0	9.0 ± 2.0	4.1 ± 0.8
S-Site[a]	0.2 ± 0.6	0.74 ± 0.14	---	0.001 ± 0.002	0.012 ± 0.004	12. ± 6.0	14 ± 3.2	4.1 ± 0.8
Near TA-11	1.7 ± 0.6	0.59 ± 0.12	---	0.001 ± 0.004	0.010 ± 0.006	6.2 ± 2.8	7.0 ± 1.6	4.1 ± 0.8
Near DT-9	2.5 ± 0.6	0.72 ± 0.14	---	−0.002 ± 0.004	0.013 ± 0.008	9.0 ± 4.0	9.3 ± 2.2	4.3 ± 0.8
Near TA-33	26 ± 1.2	0.94 ± 0.16	---	−0.001 ± 0.004	0.017 ± 0.006	7.8 ± 3.4	8.9 ± 2.0	3.6 ± 0.8
No. of Analyses	19	19	7	19	19	19	19	
Minimum	0.2 ± 0.6	0.03 ± 0.12	0.13 ± 0.16	−0.002 ± 0.004	0.002 ± 0.004	6.2 ± 2.8	6.1 ± 1.6	3.4 ± 0.6
Maximum	26 ± 1.2	3.1 ± 0.40	0.90 ± 0.20	0.234 ± 0.022	0.127 ± 0.016	18. ± 8.0	19 ± 4.0	7.8 ± 1.6
Average	4.5 ± 14	0.75 ± 1.37	0.40 ± 0.52	0.016 ± 0.111	0.031 ± 0.063	10 ± 6.5	11 ± 8.2	4.6 ± 2.6
Sediments								
Pueblo at Hamilton Bend Spr[a]	---	0.05 ± 0.06	1.10 ± 0.26	0.002 ± 0.006	0.470 ± 0.040	4.2 ± 2.0	2.6 ± 0.8	4.3 ± 0.8
Pueblo at Pueblo 3[a]	---	0.02 ± 0.08	0.03 ± 0.16	0.001 ± 0.002	0.215 ± 0.022	1.5 ± 0.8	1.8 ± 0.4	1.8 ± 0.4
Pueblo at SR-4[a,b]	---	0.14 ± 0.28	0.04 ± 0.11	0.001 ± 0.001	0.493 ± 0.095	1.4 ± 1.2	1.1 ± 1.3	2.1 ± 0.4
DP Canyon at DPS-1[a]	---	8.7 ± 1.2	---	0.536 ± 0.028	1.070 ± 0.040	---	---	---
DP Canyon at DPS-4[a,b]	---	17 ± 8.8	3.47 ± 0.17	0.195 ± 0.178	0.683 ± 0.177	---	---	---
Los Alamos at Bridge	---	0.14 ± 0.12	0.10 ± 0.16	0.000 ± 0.002	0.001 ± 0.003	2.0 ± 1.0	1.7 ± 0.8	2.1 ± 0.4
Los Alamos at LAO-1[a]	---	0.79 ± 0.18	0.18 ± 0.20	−0.002 ± 0.006	0.361 ± 0.040	4.0 ± 1.8	2.9 ± 1.0	3.1 ± 0.6
Los Alamos at GS-1[a,b]	---	0.09 ± 0.10	0.52 ± 0.74	0.000 ± 0.001	0.217 ± 0.331	1.4 ± 0.1	0.8 ± 0.3	1.7 ± 0.4
Los Alamos at TW-3[a,b]	---	19 ± 7.3	3.40 ± 1.61	0.214 ± 0.219	0.775 ± 0.552	6.9 ± 12	22 ± 23	5.8 ± 1.2
Los Alamos at LAO-4[a,b]	---	12 ± 0.0	1.05 ± 1.32	0.137 ± 0.062	0.616 ± 0.209	4.8 ± 4.2	16 ± 9.2	3.2 ± 0.6
Los Alamos at SR-4[a,b]	---	7.25 ± 6.36	0.49 ± 0.41	0.061 ± 0.001	0.363 ± 0.076	2.8 ± 4.1	11 ± 21	3.7 ± 0.8
Sandia at SCS-2	---	0.05 ± 0.12	0.19 ± 0.28	0.000 ± 0.003	0.002 ± 0.003	2.2 ± 1.2	1.4 ± 0.8	2.2 ± 0.4
Sandia at SR-4[a]	---	0.20 ± 0.08	1.08 ± 0.20	−0.001 ± 0.006	−0.002 ± 0.004	2.5 ± 1.2	1.7 ± 0.8	3.0 ± 0.6
Mortandad near CMR[a]	---	0.28 ± 0.08	0.24 ± 0.17	0.183 ± 0.028	0.041 ± 0.012	3.8 ± 1.8	4.2 ± 1.2	2.2 ± 0.4

TABLE E-XVIII (Cont)

RADIOCHEMICAL ANALYSES OF ONSITE SOILS AND SEDIMENTS

Stations	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (pCi/g)	^{90}Sr (pCi/g)	^{238}Pu (pCi/g)	^{239}Pu (pCi/g)	Gross α (pCi/g)	Gross β (pCi/g)	Total U (μg/g)
Mortandad near MCO-2	---	0.23 ± 0.06	---	0.004 ± 0.004	0.010 ± 0.004	---	---	---
Mortandad at GS-1[a]	---	360 ± 60	---	5.75 ± 0.120	2.380 ± 0.60	---	---	---
Mortandad at MCO-5[a]	---	56 ± 8	---	3.390 ± 0.080	0.715 ± 0.032	---	---	---
Mortandad at MCO-7[a]	---	38 ± 6	---	1.220 ± 0.040	0.350 ± 0.011	---	---	---
Mortandad at MCO-9[a]	---	0.66 ± 0.12	1.73 ± 0.36	0.000 ± 0.002	0.012 ± 0.004	3.8 ± 1.8	4.9 ± 1.2	2.3 ± 0.4
Mortandad at MCO-13	---	0.89 ± 0.14	0.38 ± 0.20	−0.001 ± 0.003	0.035 ± 0.008	8.3 ± 3.6	10.7 ± 2.4	3.2 ± 0.3
Pajarito at TA-18[a]	---	0.58 ± 0.14	---	0.003 ± 0.006	0.012 ± 0.008	7.4 ± 3.4	9.5 ± 2.2	5.7 ± 1.2
Pajarito at SR-4	---	0.29 ± 0.10	---	−0.001 ± 0.003	0.010 ± 0.006	6.6 ± 3.0	6.6 ± 1.6	3.1 ± 0.6
Potrillo at TA-36[a]	---	0.23 ± 0.14	---	−0.001 ± 0.003	0.001 ± 0.003	14. ± 6.0	32 ± 6.0	15 ± 3.0
Potrillo East of TA-36[a]	---	0.12 ± 0.14	1.90 ± 0.40	−0.001 ± 0.002	0.000 ± 0.002	3.4 ± 1.6	3.6 ± 1.0	4.5 ± 1.0
Potrillo at SR-4	---	0.22 ± 0.12	---	−0.002 ± 0.004	0.009 ± 0.010	1.9 ± 1.0	1.4 ± 0.8	2.5 ± 0.6
Water at Beta Hole	---	0.10 ± 0.08	---	−0.001 ± 0.004	0.002 ± 0.004	1.8 ± 1.0	2.0 ± 0.8	1.7 ± 0.4
Water at SR-4	---	0.56 ± 0.12	---	−0.005 ± 0.004	0.008 ± 0.006	6.5 ± 1.4	9.0 ± 2.0	3.6 ± 0.8
Water at Rio Grande	---	0.15 ± 0.12	---	−0.001 ± 0.002	−0.001 ± 0.002	1.9 ± 0.8	1.5 ± 0.6	1.9 ± 0.8
Ancho at SR-4[a]	---	0.10 ± 0.16	---	0.019 ± 0.018	0.002 ± 0.012	1.2 ± 0.8	1.8 ± 0.8	1.7 ± 0.4
Ancho at Rio Grande	---	0.13 ± 0.08	---	−0.001 ± 0.002	0.002 ± 0.004	2.5 ± 1.2	2.9 ± 0.4	1.8 ± 0.8
Chaquihui at Rio Grande	---	0.18 ± 0.10	---	−0.001 ± 0.002	0.004 ± 0.004	1.9 ± 1.0	1.7 ± 0.6	2.3 ± 0.8
No. of Analyses		37	16	37	37	31	31	25
Minimum		0.02 ± 0.08	0.00 ± 0.20	−0.005 ± 0.004	−0.002 ± 0.004	0.9 ± 0.4	0.6 ± 0.4	1.7 ± 0.4
Maximum		360 ± 60	3.97 ± 0.38	5.75 ± 0.120	2.38 ± 0.060	14 ± 6.0	32 ± 6.0	15 ± 3.0
Average		16 ± 119	0.98 ± 2.30	0.333 ± 217	0.324 ± 0.932	3.8 ± 6.1	7 ± 16	3.4 ± 5.3

[a]One or more radionuclides above natural or worldwide fallout concentrations.
[b]Two or more analyses for selected radionuclides.

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

TABLE E-XIX

RADIOCHEMICAL AND CHEMICAL ANALYSES OF SNOWMELT RUNOFF*

Solution	Radiochemical (average of a number of analyses)					
	^{3}H (10^{-6} μCi/mℓ)	^{137}Cs (10^{-9} μCi/mℓ)	^{238}Pu (10^{-9} μCi/mℓ)	^{239}Pu (10^{-9} μCi/mℓ)	^{90}Sr (10^{-9} μCi/mℓ)	Total U (μg/ℓ)
Guaje Canyon	0.0 ± 0.9(10)*	−5 ± 73(10)	−0.02 ± 0.06(10)	−0.05 ± 0.26(10)	0.6 ± 0.6(10)	0.0 ± 0.3(10)
Rendija Canyon	0.4 ± 0.2(4)	12 ± 25(4)	−0.02 ± 0.05(4)	−0.03 ± 0.06(4)	---	0.2 ± 0.4(4)
Pueblo at SR-4	0/4 ± 0.7(5)	−7 ± 41(5)	−0.01 ± 0.04(5)	0.13 ± 0.52(5)	---	0.4 ± 0.5(5)
Los Alamos at SR-4	1.3 ± 14(14)	6 ± 44(14)	−0.03 ± 0.14(13)	−0.01 ± 0.28(13)	3.3 ± 5.3(10)	0.6 ± 1.9(14)
Los Alamos at Totovi	1.2 ± 1.1(11)	11 ± 92(10)	−0.02 ± 0.06(10)	0.01 ± 0.05(10)	3.4 ± 3.6(10)	0.3 ± 0.7(11)
Los Alamos at Otowi	0.9 ± 1.1(8)	8 ± 40(8)	−0.02 ± 0.05(8)	0.00 ± 0.11(8)	3.0 ± 2.3(8)	0.8 ± 1.4(8)
Mortandad at MCO-5	67 ± 32(4)	13 ± 32(4)	1.34 ± 0.50(4)	0.52 ± 0.17(4)	40.5 ± 2.5(2)	2.2 ± 1.1(4)
Pajarito at SR-4	1.7 ± 0.8(14)	8 ± 52(14)	−0.03 ± 0.16(14)	0.00 ± 0.07(14)	0.5 ± 0.9(10)	0.3 ± 0.6(14)
Water at SR-4	0.4 ± 0.8(8)	20 ± 61(8)	−0.02 ± 0.09(8)	−0.01 ± 0.12(8)	0.7 ± 0.6(5)	0.4 ± 0.8(8)
Ancho at SR-4	1.5 ± 1.1(8)	−9 ± 17(7)	0.00 ± 0.04(7)	0.01 ± 0.05(7)	0.8 ± 0.8(7)	0.2 ± 0.4(7)
Suspended Sediments			(pCi/g)	(pCi/g)		
Guaje Canyon	---	---	−0.17 ± 0.64(10)	0.06 ± 0.46(10)	---	---
Rendija Canyon	---	---	0.41 ± 1.8(4)	0.17 ± 0.59(4)	---	---
Pueblo at SR-4	---	---	0.04 ± 0.05(5)	7.5 ± 2(5)	---	---
Los Alamos at SR-4	---	---	0.56 ± 1.8(14)	4.0 ± 6.4(14)	---	---
Los Alamos at Totovi	---	---	0.52 ± 0.89(11)	7.4 ± 9.8(11)	---	---
Los Alamos at Otowi	---	---	0.16 ± 0.17(6)	3.8 ± 4.2(6)	---	---
Mortandad at MCO-5	---	---	54 ± 39(3)	23 ± 21(3)	---	---
Pajarito at SR-4	---	---	0.03 ± 1.2(13)	0.80 ± 5.4(13)	---	---
Water at SR-4	---	---	0.00 ± 0.05(8)	0.06 ± 0.26(8)	---	---
Ancho at SR-4	---	---	0.001 ± 0.03(6)	0.10 ± 0.17(6)	---	---

	Chemical (average of a number of analyses, in mg/ℓ)					
	No. of Analyses	SO_4	Cℓ	F	NO_3	TDS
Guaje Canyon	10	14 ± 0	3 ± 2	0.3 ± 0.7	<1 ± 2	145 ± 58
Rendija Canyon	4	---	6 ± 3	0.2 ± 0.1	3 ± 2	162 ± 58
Pueblo at SR-4	5	---	32 ± 5	0.5 ± 0.2	20 ± 7	285 ± 78
Los Alamos at SR-4	14	12 ± 2	20 ± 20	0.5 ± 0.6	3 ± 6	149 ± 91
Los Alamos at Totavi	11	13 ± 2	15 ± 14	0.5 ± 0.6	3 ± 8	156 ± 52
Los Alamos at Otowi	8	---	16 ± 7	0.4 ± 0.2	2 ± 2	193 ± 72
Mortandad at MCO-5	4	---	18 ± 5	1.4 ± 1.6	116 ± 103	500 ± 169
Pajarito at SR-4	14	14 ± 0	19 ± 7	0.2 ± 0.0	2 ± 3	179 ± 70
Water at SR-4	8	---	11 ± 6	0.2 ± 0.1	2 ± 2	151 ± 38
Ancho at SR-4	7	---	6 ± 4	0.2 ± 0.1	2 ± 2	148 ± 42

*Parentheses indicate number of samples analyzed.

Note: ± value is twice the standard deviation of the distribution of a number of analyses.

TABLE E-XX

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTALS FOR 1979

Location	^{238}Pu ^{239}Pu (μCi)	^{241}Am (μCi)	^{235}U ^{238}U (μCi)	^{232}Th ^{234}Th (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 (μCi)
TA-2	---	---	---	---	---	---	351	---	---	---	---
TA-3	1067	---	261	1605	472	158	---	---	3013[c]	---	---
TA-9	---	---	---	---	---	---	---	---	5.0	---	---
TA-15	---	---	---	---	---	---	---	---	---	---	---
TA-18	---	---	4.0	---	---	---	---	---	---	---	---
TA-21	5.7	0.019	655	---	0.47	---	---	---	95	---	---
TA-33	---	--	---	---	---	---	---	---	10 470	---	---
TA-35	7.4	---	---	---	---	---	---	---	1300	---	---
TA-41	---	---	---	---	---	---	---	---	143	---	---
TA-43	0.75	---	---	---	---	---	---	18	---	---	---
TA-46	---	---	2.3	---	---	---	---	---	---	---	---
TA-48	0.33	---	6.8	---	1072	---	---	---	---	---	---
TA-50	2.9	---	---	---	11	---	---	---	---	---	---
TA-53	---	---	---	---	---	---	357	---	---	118 800	2.6
TA-54	0.013	---	---	---	---	---	---	---	---	---	---
TA-55	0.11	---	---	---	---	---	--	---	---	---	---

[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.

[c]Includes 3000 Ci unplanned release from TA-3-34 on May 4, 1979 (see Section III.A.7).

TABLE E-XXI

TOTAL SUSPENDED PARTICULATES AT LOS ALAMOS AND WHITE ROCK DURING 1979
(Data from New Mexico Environmental Improvement Division. All concentrations in $\mu g/m^3$.)

Los Alamos (Annual Geometric Mean = 35)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
No. of Samples	3	2	---	5	5	5	5	6	5	5	5	5
Maximum	63	29	---	77	71	72	51	45	46	40	45	62
Minimum	35	28	---	24	20	21	24	16	22	25	21	27
Mean	44	28	---	47	34	44	36	37	34	31	29	47
±1 Std Deviation	16	1	---	22	21	21	11	12	11	6	9	13

White Rock (Annual Geometric Mean = 35)

No. of Samples	4	5	5	5	5	5	5	6	5	5	5	5
Maximum	33	27	51	113	42	89	66	70	59	80	51	62
Minimum	19	15	21	24	13	13	29	28	31	17	14	27
Mean	27	23	30	55	22	51	47	47	45	49	33	40
±1 Std Deviation	6	5	12	36	12	33	13	17	11	29	15	14

TABLE E-XXII

QUANTITIES OF VOLATILE CHEMICALS AND COMPRESSED GASES USED AT LASL
(All amounts in kg)

	1972	1973	1974	1975	1976	1977	1978	1979
Acids								
Acetic							410	220
Hydrochloric							3700	4200
Hydrofluoric							8100	4700
Nitric							80000	58100
Perchloric							390	140
Phosphoric							710	450
Sulfuric							1700	2300
Gases								
Ammonia	4200	2700	3200	2600	2600	2900	3000	2500
Carbon Monoxide					4900	6200	9300	5500
Chlorine					500	680	500	640
Freon 12					2500	3400	2800	2000
Hydrogen Fluoride					1300	950	360	500
Nitrogen Oxides					7800	6700	640	1200
Sulfur Dioxide					120	290	160	110
Sulfur Hexafluoride	17400	6700	10300	11400	12200	13700	9200	11400
Inorganic Chemicals								
Ammonium Hydroxide								2200
Mercury					500	290	180	140
Organic Chemicals								
Acetone	18800	9200	12400	16100	15500	12700	10600	8300
Carbon Tetrachloride	300	290	250	100	250	230	200	280
Chloroform	360	250	500	380	370	190	160	200
Ethanol						9200	10900	9900
Freons	10900	13300	15000	10200	12400	13800	8200	9200
Kerosene	8100	5000	5900	4800	4600	4400	3800	4100
Methanol	590	540	1500	1700	6600	4300	2600	3300
Methylene Chloride	820	820	310	1000	820	2200	250	170
Methyl Ethyl Ketone				2300	9400	10600	14300	22000
Perchloroethylene	3400	680	1000	820	680	1000	1400	340
Toluene	2300	2100	1200	2700	3300	1600	2100	2100
Trichloroethane	25600	18300	25800	22900	34000	28300	24100	23800
Trichloroethylene	20400	15500	16200	9400	13200	10200	7400	6900

TABLE E-XXIII

ESTIMATED CONCENTRATIONS OF TOXIC ELEMENTS AEROSOLIZED BY DYNAMIC EXPERIMENTS

Element	1979 Total Usage (kg)	Percent Aerosolized (%)	Annual Avg. Concentration (ng/m^3)		Applicable Standard (ng/m^3)
			4 km	8 km	
Uranium	568	10	0.06	0.02	9000[a]
Be	10	2	0.0003	0.0001	10[b] (30 day avg)
Pb	0.1	100[c]	0.0001	0.00005	10 000[b] (for total heavy metals, N>21)

[a]ERDA Manual Chapter 0524.
[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.

TABLE E-XXIV

SANITARY SEWAGE TREATMENT FACILITIES EFFLUENT QUALITY SUMMARY[a]

Discharge Location	Permit Constituents	No. of Deviations	Range of Deviation/ Limit Ratios or pH	Discharge Location	Permit Constituents	No. of Deviations	Range of Deviation/ Limit Ratios or pH
TA-3	BOD_5[b]	0	---	TA-41	BOD_5	2	1.5 - 1.8
10401	TSS[c]	1	1.6		TSS	1	1.7
	Fecal Coliform[d]	0	---		Fecal Coliform[d]	2	10 - 19.1
	Flow (MGD)	0	---		Flow (MGD)	2	1.0 - 1.2
	pH[e]	0	---		pH	1	4.15
TA-9	BOD_5	0	---	TA-46	BOD_5	0	---
	TSS	0	---		TSS	0	---
	Flow (MGD)	72	1.0 - 17.6		Flow (MGD)	155	1.0 - 3.0
	pH	0	---		pH	0	---
TA-16	BOD_5	0	---	TA-48	BOD_5	0	---
	TSS	0	---		TSS	0	---
	Flow (MGD)	0	---		Flow	0	---
	pH	0	---		pH	0	---
TA-18	BOD_5	0	---	TA-53	BOD_5	0	---
	TSS	1	1.3		TSS	2	1.6 - 1.7
	Flow (MGD)	113	1.0 - 18.8		Flow	38	1.0 - 1.6
	pH	1	9.5		pH	11	9.2 - 11.0
TA-21	BOD_5	0	---	TA-35	BOD_5	1	1.2
	TSS	0	---		TSS	2	1.3 - 1.8
	Fecal Coliform[d]	6	1.45 - 300		Flow (MGD)	3	1.1 - 1.2
	Flow (MGD)	0	---		pH	2	9.3 - 9.6
	pH	0	---				

[a]Single NPDES permit NM 0028355.
[b]BOD_5 limits are 30 mg/ℓ (20-day avg), 45 mg/ℓ (7-day avg).
[c]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]pH limits not less than 6.0 or greater than 9.0 standard units.

TABLE E-XXV

INDUSTRIAL LIQUID EFFLUENT QUALITY SUMMARY[a]

Discharge Category	No. of Outfalls	Permit Constituents	No. of Deviations	Range of Deviation/Limit Ratios or pH[b]	No. of Outfalls Causing Deviations
Power Plant	6[c]	TSS	12	4.7 - 399.8	1
		Free Cl	1	1.2	1
		pH	14	1.3 - 11.6	4
Boiler Blowdown	3[c]	TSS	0	---	0
		Fe	1	1.2	1
		Cu	14	1.0 - 21.5	3
		P	3	1.0 - 1.1	2
		pH	38	9.5 - 12.1	3
Treated Cooling Water	35	TSS	1	1.16	1
		Free Cl	0	---	0
		P	0	---	0
		pH	0	---	0
Noncontact Cooling Water	29	pH	0	---	0
Radioactive Waste Treatment Plant Discharges	2	NH_3	0	---	0
		COD	0	---	0
		TSS	0	---	0
		Cd	0	---	0
		Cr	0	---	0
		Cu	2	1.1 - 2.6	2
		Fe	4	1.2 - 2.8	1
		Pb	2	1.1 - 2.2	1
		Hg	0	---	0
		Zr	2	1.9 - 2.2	1
		pH	2	3.4 - 5.6	2
High Explosives Waste Discharges	20[d]	COD	3	1.1 - 50.4	3
		TSS	2	1.4 - 1.7	2
		pH	1	5.5	1
Photo Waste Discharges	15	Cn	0	---	0
		TSS	0	---	0
		pH	0	---	0
		Ag	4	2.0 - 33.6	3
Printed Circuit Board Development Wastes	1	COD	0	---	0
		Cu	1	2.8	
		Fe	3	1.31 - 13.0	1
		Ni	0	---	0
		P	0	---	0
		pH	2	5.7 - 5.8	1

TABLE E-XXV (Cont)

Discharge Category	No. of Outfalls	Permit Constituents	No. of Deviations	Range of Deviation/Limit Ratios or pH[b]	No. of Outfalls Causing Deviations
Acid Dip Tank	1[e]	Cu	2	2.2 - 11.0	1
Rinse		pH	1	2.5	1
Gas Cylinder	1	TSS	0	---	0
Cleaning Waste		P	0	---	0
		pH	0	---	0

[a]Summary of reports to EPA or NPDES Permit NM 0028355.
[b]pH range limit on all outfalls is not less than 6.0 or greater than 9.0 standard units.
[c]Outfalls responsible for deviations scheduled for correction.
[d]Six of 20 outfalls responsible for deviations scheduled for correction.
[e]Source of excess Cu violations removed in 1979.

TABLE E-XXVI

QUALITY OF EFFLUENTS FROM LIQUID RADIOACTIVE WASTE TREATMENT PLANTS

	Waste Treatment Plant Location			
	TA-50		TA-21	
Radioactive Isotopes	Activity Released (mCi)	Average Concentration (μCi/mℓ)	Activity Released (mci)	Average Concentration (μCi/mℓ)
^{239}Pu	1.705	0.035×10^{-6}	0.057	0.04×10^{-6}
^{238}Pu	0.55	0.011×10^{-6}	0.087	0.054×10^{-6}
^{241}Am	4.68	0.096×10^{-6}	0.587	0.366×10^{-6}
^{89}Sr	6.07	0.125×10^{-6}	0.031	0.019×10^{-6}
^{90}Sr	14.16	2.91×10^{-7}	0.065	0.405×10^{-7}
^{3}H	32 700	0.67×10^{-3}	440	0.27×10^{-3}
^{137}Cs	170	0.35×10^{-3}	0.966	0.060×10^{-6}
^{234}U	0.21	0.043×10^{-7}	2.2	0.137×10^{-7}
^{238}U	0.20	0.041×10^{-7}	---	---

	Waste Treatment Plant Location	
	TA-50	TA-21
Nonradioactive Constituents	Average Concentration (mg/ℓ)	Average Concentration (mg/ℓ)
Cd[a]	0.001	0.25
Ca	74.4	23.2
Cl	50	69
Cr[a]	0.022	0.25
Cu[a]	0.41	0.16
F	2.9	392
Hg[a]	0.003	0.0009
Mg	6.3	6.5
Na	489	2947
Pb[a]	0.046	0.089
Zn[a]	0.22	0.79
CN	0.04	---
COD[a]	60	87
$NO_3(N)$	156	605
PO_4	1.07	4.54
TDS	2302	6694
pH[a]	9.1 - 12.8	5.4 - 12.5
Total Effluent Volume	4.858×10^7 ℓ	1.604×10^6 ℓ

[a]Constituents regulated by NPDES permit.

TABLE E-XXVII

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

	Surface Water	Water Supply	Spring (Jemez Fault)	Spring (Volcanics)	Abandon Well	Fenton Hill (Pond Fluid)
No. of Stations[a]	9	4	2	1	1	3
No. of Analyses	18	8	4	2	2	6
Chemical (mg/ℓ)						
SiO_2	40 ± 10	74 ± 14	48 ± 7	47 ± 4	72 ± 11	102 ± 29
Ca	27 ± 14	18 ± 12	89 ± 40	12 ± 1	25 ± 1	35 ± 27
Mg	5 ± 3	4 ± 2	24 ± 8	3 ± 0	8 ± 1	3 ± 2
Na	28 ± 26	16 ± 2	500 ± 269	15 ± 1	111 ± 9	640 ± 395
CO_3	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1 ± 2
HCO_3	80 ± 62	79 ± 21	602 ± 305	69 ± 7	337 ± 1	372 ± 375
SO_4	34 ± 64	4 ± 3	32 ± 3	3 ± 3	2 ± 0	726 ± 629
Cl	15 ± 21	7 ± 7	977 ± 593	3 ± 0	4 ± 1	156 ± 71
F	0.8 ± 0.3	0.5 ± 0.2	3.1 ± 0.9	1.1 ± 0.0	1.0 ± 0.1	3.0 ± 2.0
NO_3	1.3 ± 0.6	2 ± 1	2 ± 1	2 ± 1	1 ± 0	2 ± 3
TDS	242 ± 129	189 ± 36	2719 ± 1418	114 ± 23	446 ± 14	2338 ± 1499
Hard	87 ± 48	63 ± 34	322 ± 117	43 ± 3	94 ± 1	98 ± 72
pH	7.3 ± 1.5	7.5 ± 0.3	6.8 ± 0.4	7.3 ± 0.5	7.2 ± 0	8.4 ± 1.7
Conductance (mS/m)	37 ± 24	20 ± 7	388 ± 189	15 ± 1	73 ± 2	312 ± 208

[a]Sampling locations key on Fig. 21 as follows:
Surface Water—Locations F, J, N, Q, R, S, T, U, V.
Water Supply—Locations JS 2-3, JS 4-5, FH-1, 4.
Springs (Jemez Fault)—Locations JF-1, JF-5.
Spring (Volcanics)—Location 31.
Abandon Well—Location 27.
Fenton Hill (pond fluids—three ponds containing drilling fluids and circulation fluids from tests.

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.
CG (Concentration Guide)	The concentration of radioactivity in air or water that is determined to result in whole body or organ doses equal to ERDA'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.
Curie	A special unit of radioactivity. One curie equals 3.70×10^{10} nuclear transformations per second (abbreviated Ci).
gamma radiation	Short-wavelength electromagnetic radiation of nuclear origin which 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.
gross beta	The total amount of measured beta activity.
man-rem	The sum of radiation exposures received by a population. For example, two persons each with a 0.5 rem exposure have received man-rem. Also, 500 people each with an exposure of 0.002 rem have received one man-rem.
MCL (Maximum Contaminant Level)	Maximum permissible level of a contaminant in water specified by the EPA that is delivered to the free flowing outlet of the ultimate user of a public water system (see Appendix A and Table A-III).

rem	The unit of radiation dose equivalence which takes into account difference effects on humans of various kinds of ionizing radiation and permits them to be expressed on a common basis.
RPS (Radiation Protection Standard)	Standards for external and internal exposure to radioactivity as defined in ERDA Manual Chapter 0524 (see Appendix A and Table A-II in this report).
total uranium	Uranium having the isotopic content of uranium in nature (99.27% ^{238}U, 0.72% ^{235}U, 0.0057% ^{234}U).
tuff	Rock of compacted volcanic ash and dust.

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- W. E. Hale, US Geological Survey, Albuquerque, NM
- W. Schwarts, LFE, Richmond, CA
- J. Mueller, CEP, Santa Fe, NM
- New Mexico State Engineer, Santa Fe, NM
- Supervisor, Santa Fe National Forest, Santa Fe, NM
- Superintendent, Bandelier National Monument, Los Alamos, NM

Media
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- Los Alamos Chronicle, Los Alamos, NM
- Santa Fe New Mexican, Santa Fe, NM
- Albuquerque Journal, Albuquerque, NM
- Albuquerque Tribune, Albuquerque, NM
- New Mexico Independent, Albuquerque, NM
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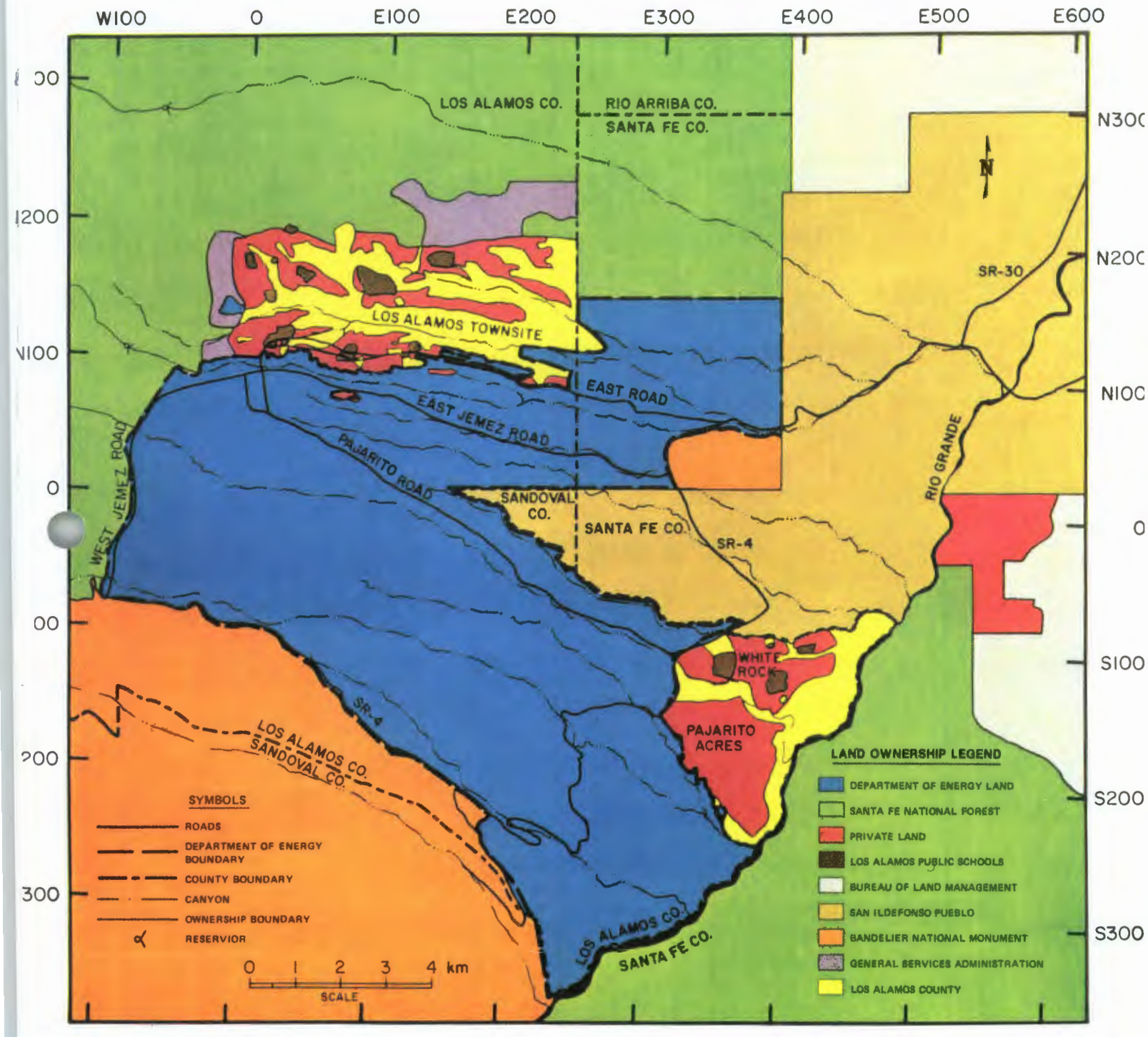

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