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ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1977

Environmental Surveillance Group

LOS ALAMOS SCIENTIFIC LABORATORY

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Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, NM 87545

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ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1977

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ABSTRACT

This report documents the environmental monitoring program conducted at the Los Alamos Scientific Laboratory (LASL) in 1977. Data and interpretation show that radiation and radioactivity in the environment as a result of LASL operations were at levels well below applicable U.S. Department of Energy guidelines. The radiation doses attributable to LASL operations potentially received by members of the public were small fractions of naturally present background radiation. Data on non-radioactive releases from LASL operations were collected and compared, where appropriate, to federal and state standards. Effluents from several sanitary sewage treatment facilities exceeded discharge permit requirements. The chemical quality of some surface and shallow ground waters is influenced by LASL effluents. The quality of the municipal water supply from the deep ground water aquifer has not been affected by LASL operations and met all applicable standards. Results of several special studies provide understanding and documentation of certain unique environmental conditions in the LASL environs.

I. INTRODUCTION

This report documents the results of the environmental monitoring program conducted at the Los Alamos Scientific Laboratory (LASL) during 1977. In keeping with Department of Energy (DOE) and Laboratory intent to describe and document the possible influences of operations on the environment, this report provides data and interpretation of environmental conditions in the vicinity of LASL.

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 a continuing investigation and documentation program.

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, magnetic fusion, and radiobiology and medicine. In more recent years other programs have been added in astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, and biomedical and environmental research.

A unique combination of facilities which contribute to the various research programs exists at Los Alamos. These facilities include the 800 MeV proton accelerator, a tandem Van de Graaff accelerator, the Laser Laboratory, the Magnetic Fusion Laboratory, a flash radiographic facility, and a 10 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 km², was dedicated as a National Environmental Research Park. The ultimate goal of 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 those subjects deemed compatible with the LASL programmatic mission.

A. Physical Setting

The Los Alamos Scientific Laboratory and the adjacent residential areas of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico, about 100 km NNE of Albuqueque and 40 km NW of Santa Fe by air (Fig. 1). The 111 km² Laboratory site and adjacent communities are situated on the Pajarito Plateau. The Plateau consists of a series of mesas separated by deep canyons cut by intermittent streams that run eastward from an altitude of about 2400 m (7800 ft) at the flank of the Jemez Mountains to about 1800 m (6200 ft) at the eastern margin where it terminates above the Rio Grande valley. Most Laboratory and community developments are confined to the mesa tops (Fig. 2). The surrounding land is essentially 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. Indian pueblo lands border the Laboratory to the east.

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

B. Geology-Hydrology

The canyons in the Laboratory area are formed from the relatively soft Bandelier tuff composed of ashfall and ashflow pumice and rhyolite tuff that ranges from nonwelded to welded. The tuff is in excess of 300 m thick in places at the western part of the plateau and thins to about 80 m toward the east. It was deposited as a result of a major eruption of a volcano in the Jemez Mountains to the west about 1.1-1.4 million years ago.

Beneath the tuff are the older volcanic rocks of the Tschicoma Formation (western portion) and the Chino Mesa Basalts (eastern portion) or the fanglomerate Puye Formation (central portion). These formations all lie on top of the siltstone/sandstone Tesuque formation which extends on across the Rio Grande Valley and is in excess of 1000 m thick in places. The basement rocks are Precambrian granites.

Los Alamos area surface water is primarily intermittent stream flow. Springs on the flanks of the Jemez Mountains supply base flow to the upper reaches of some canyons, but the amount is insufficient to maintain surface flows across the Laboratory area before it is depleted by evaporation, transpiration and infiltration. Runoff from heavy thunderstorms or heavy snowmelt will reach 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 much as 1.5 km (0.9 mi).

Ground water occurs in three modes in the Los Alamos area: (1) water in alluvium in the canyons, (2) perched water in basalt, and (3) the main aquifer of the Los Alamos area.

Ephemeral stream flows in the canyons of the plateau have deposited alluvium that ranges from less than 1 m to as much as 30 m in thickness. The alluvium is quite permeable in contrast to the underlying volcanic tuff and sediments. The intermittent runoff in the canyons infiltrates into the 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 the water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into the underlying volcanics.

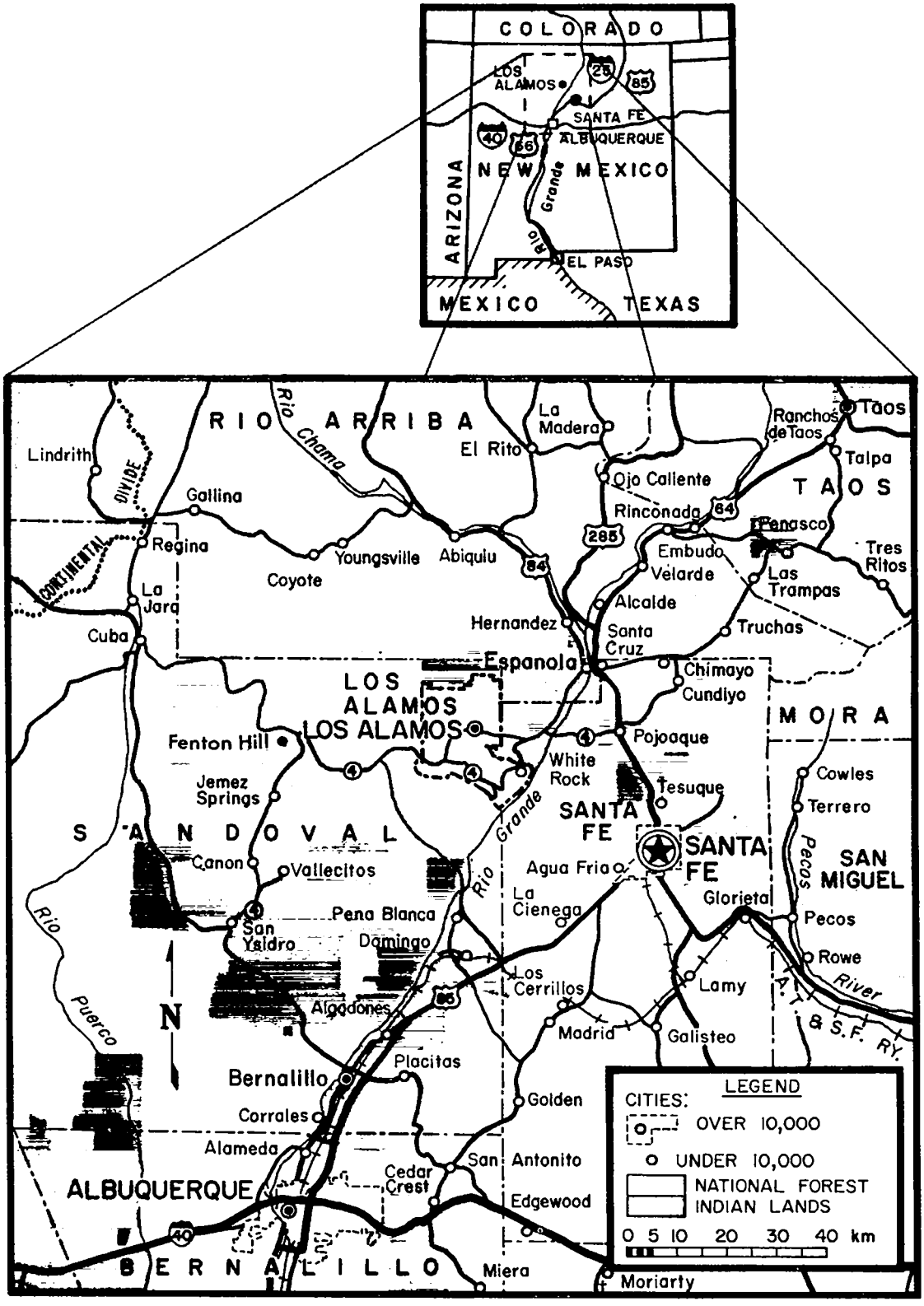


Fig. 1.
North-central New Mexico.

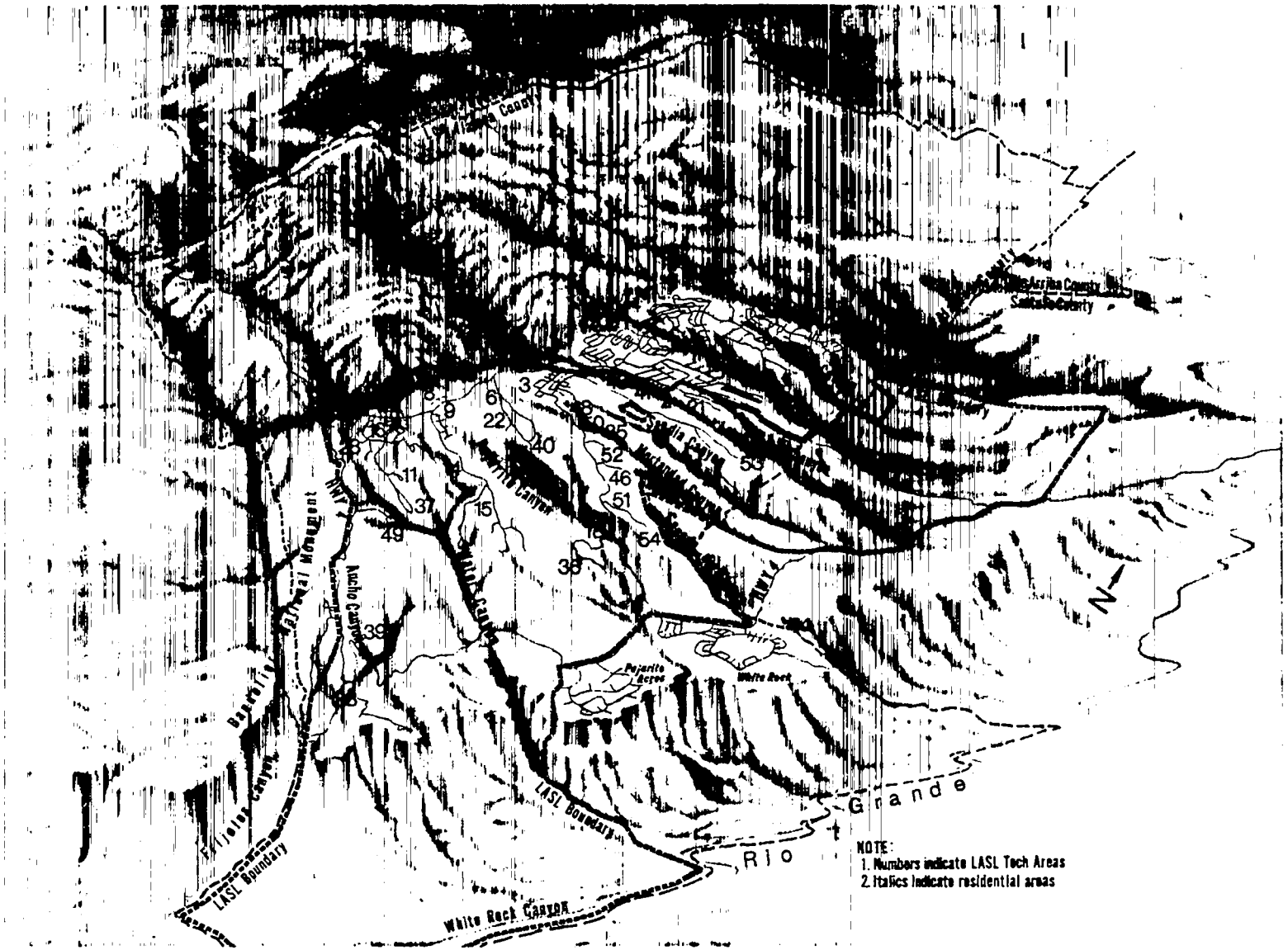


Fig. 2.
Topography of the Los Alamos, New Mexico area.

In lower Los Alamos and Pueblo Canyons a local body of perched water is formed in the basalts by water infiltrating from the alluvium into the underlying volcanics. This perched water discharges into Los Alamos Canyon west of the Rio Grande. This is the only perched water body beneath the plateau known to lie between the water in the alluvium and the main aquifer.

The deep aquifer below the layer of tuff in 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. The depth to the aquifer decreases from 360 m along the western margin of the plateau to about 180 m at the eastern margin. The water is under water table conditions in the western and central part of the Plateau and under artesian conditions in the eastern part and along the Rio Grande.

The major recharge area to the main aquifer is the intermountain basin of the Valles Caldera. 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 reach of the river between Otowi Bridge and the mouth of Rito de Frijoles receives an estimated 5.3 to 6.8 $\times$ 10^6 m^3 annually from the aquifer.

C. Meteorology

Los Alamos has a semiarid, continental mountain climate. The average annual precipitation of 46 cm (18 in.) is accounted for by warm-season orographic convective rain showers and winter migratory storms. Seventy-five percent of the annual total moisture falls between May and October, primarily as thunderstorms. Peak shower activity is in August. The annual average of 62 thunderstorm-days per year makes this area equivalent to the Gulf Coast states in thunderstorm occurrence. Winter precipitation falls primarily as snow, with annual accumulations of about 1.3 m.

Summers are cool and pleasant. Maximum temperatures are generally below 32°C (~90°F), and a large diurnal variation keeps nocturnal temperatures in the 12-15°C (54°F-59°F) range. Winter temperatures are typically in the range from −10°C to 5°C (14°F-41°F). Many winter days are clear with light winds, and strong solar radiation makes conditions quite comfortable even when air temperatures are cold. The annual total of heating degree days (degree days per day = 18.3°C — daily average temperature in degrees Celsius) is 3500, with January accounting for over 610 and July and August averaging 0. A summary of 1977 weather is given in Table 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. The 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 the 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.

D. Demographics

Los Alamos County is demographically different from the surrounding area. With a population estimated at 19 500, it is characteristically urban in nature, surrounded by more rural communities relying on farming and cattle and sheep herding, primarily in the valley areas. Two residential and related commerical areas exist in the county (see Fig. 3). Los Alamos, the original area of development, has an estimated population of 13 500, while White Rock has about 6000 residents. Commuting and general traffic is served by State Road 4, which runs through White Rock, and Loop 4, which runs through Los Alamos. Two federally owned roads, East Jemez and Pajarito Roads, cross this site and are normally open to public use. About one third of those employed in Los Alamos commute from other counties. Preliminary 1977 population estimates

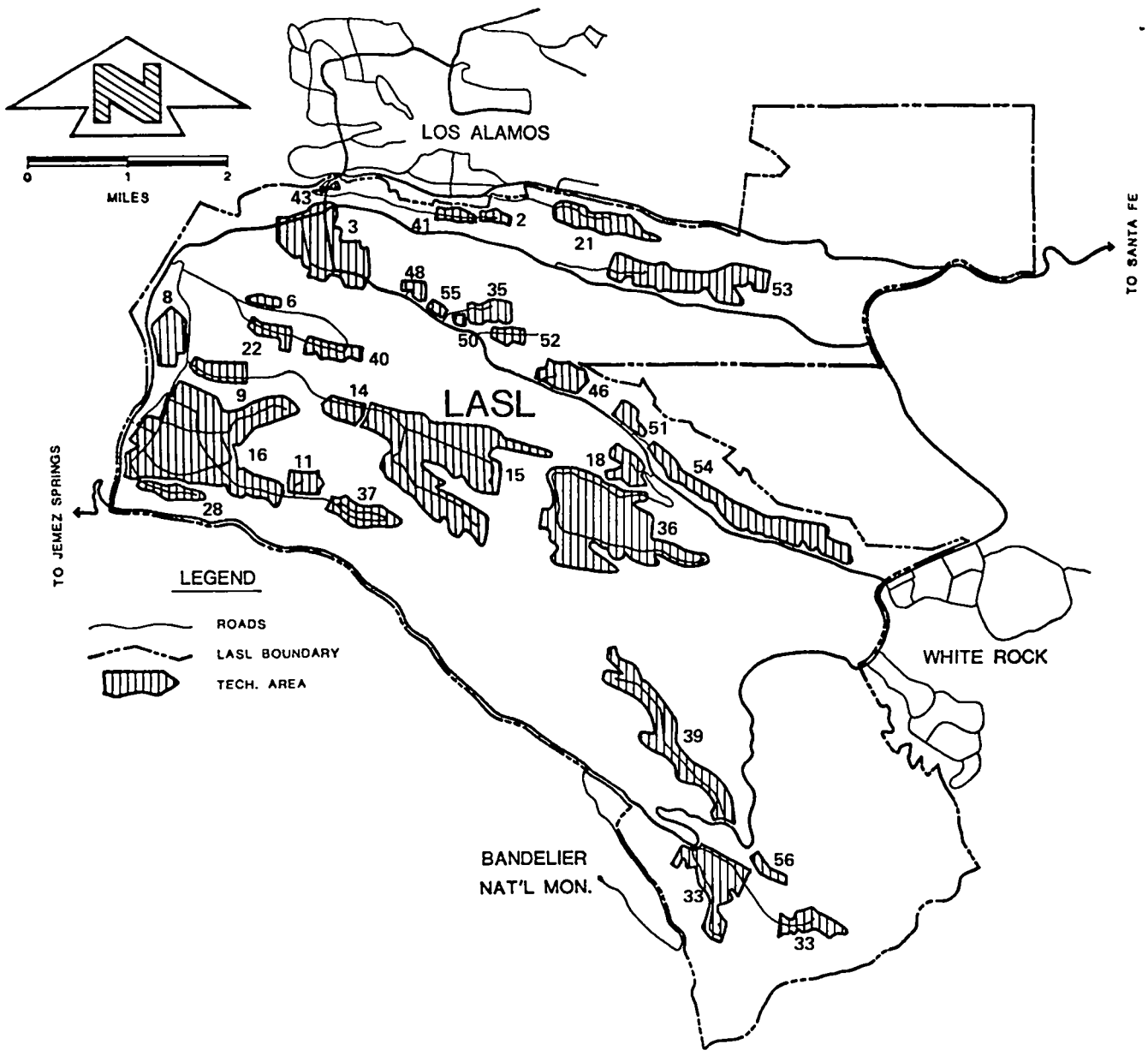


Fig. 3.
LASL technical areas and adjacent community areas.

place 98 000 people within an 80 km radius of Los Alamos.

E. Waste Disposal

LASL's activities are carried out in 30 active technical areas (TA) distributed over the LASL site (see Fig. 3). These facilities include hundreds of potential sources of waste effluent. However, processes with potential for significant releases are confined to only a few locations which are rigorously controlled and monitored.

The bulk of liquid radioactive waste from several major technical areas is routed to the central treatment facilities by a collection system that is completely separate from the sanitary sewage system. Radioactive wastes at remote locations are collected in holding tanks from which they are periodically collected and transported to the Central Waste Treatment Plant for processing. Radioactivity is removed at the treatment plants by physicochemical processes that results in a concentrated sludge subsequently handled as solid waste. The treated effluents are then released to canyons.

Between 90% and 95% of the total radioactively contaminated solid waste volume from the Laboratory is disposed of by burial at the waste disposal area, TA-54. The remaining 5-10% is classed as transuranic waste and stored retrievably. Environmental containment is provided by the dry geologic formations of the burial ground. Wastes containing significant amounts of tritium receive added containment engineered by special packaging in asphalt-coated, sealed metal drums.

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

F. Monitoring

Routine monitoring of radiation, radioactive materials, and chemical substances is conducted on the Laboratory site and in the surrounding region to assure compliance with appropriate standards and early identification of possible undesirable trends. This monitoring is in the environment and serves as a check on the specific effluent release points such as the radioactive waste treatment plants and the various stacks at nuclear research facilities.

Exposure from external penetrating radiation (primarily gamma radiation) in the LASL environs is monitored at stations equipped with thermoluminescent dosimeters (TLD). Atmospheric radioactivity samples were collected on a biweekly schedule at continuously operating air sample stations in Los Alamos County and vicinity. Monitoring for surface and ground water radioactivity provides routine surveillance of the possible dispersion of effluents from LASL operations. (Regional surface waters within 75 km of LASL are sampled to ascertain natural levels of radioactivity in water of the area.) Soil and sediment samples are also collected from the area for analysis. Sampling stations in Los Alamos County and the Rio Grande Valley are set up to monitor locally produced foodstuffs, principally fruits and vegetables.

II. SUMMARY

This report presents the results of the LASL environmental monitoring programs for 1977. Data and interpretive comparisons are included for:

- penetrating radiation
- radioactivity in air, water, soil, and foodstuffs
- radioactivity in airborne and liquid effluents
- chemical contaminants in airborne and liquid effluents
- chemical and radiochemical quality of the water supply

Several special studies on environmental conditions at Los Alamos are summarized.

Penetrating radiation in the Los Alamos area outside the LASL boundary averaged 127 mrem/yr. This level is because of multiple sources of natural radiation and LASL operations do not contribute to the total. Penetrating radiation at on-site locations near facilities emitting radiation reached a maximum of about 609 mrem/yr. The annual mean concentration of tritiated water vapor in air at perimeter locations was 23×10^{-12} μCi/mℓ, about 10×10^{-12} μCi/mℓ higher than background measured at regional stations, showing some effect of laboratory effluents. The mean concentration at perimeter locations is about 0.01% of the applicable uncontrolled area concentration guide (CG). (Uncontrolled area concentration guides represent levels of radioactivity considered acceptable in air

breathed or water ingested by members of the public and were derived to insure that continuous breathing of air or drinking of water containing radioactivity at the CG levels would not receive radiation doses exceeding the Radiation Protection Standards [RPS], see Appendix A.) Atmospheric long-lived gross-alpha and gross-beta mean concentrations in the LASL environs were 1.2×10^{-15} and 197×10^{-15} μCi/mℓ, respectively, both 2.0% of their respective uncontrolled area CGs. Gross-beta activity reached a maximum during September, shortly after the detonation of an atmospheric nuclear test by the People's Republic of China. The maximum beta activity concentration was about 8% of the appropriate CG. The atmospheric ^{239}Pu mean concentration off-site in the LASL environs was about 26×10^{-18} μCi/mℓ, which was 0.04% of the uncontrolled area CGs. The ^{239}Pu mean concentration was slightly higher than the value taken to represent regional background (though not statistically different) and may reflect the release of ^{239}Pu from LASL operations. The airborne radioactive effluents of possible maximum concern were the activation products ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O, released from the research reactor (TA-2) and the linear accelerator at the Los Alamos Meson Physics Facility (LAMPF, TA-53). Maximum concentrations for these isotopes at the Laboratory boundary and occupied locations were theoretically calculated using atmospheric dispersion models in order to estimate doses.

Radiation doses to members of the public (~0.1 mrem/yr or greater) attributable to radioactive airborne effluents from LASL operations were calculated from these measured or theoretically estimated concentrations. Such calculations indicate that maximum doses to people at occupied locations could be as high as 0.42 mrem/yr from tritiated water vapor (<0.1% of the RPS, see Appendix A), 0.06 mrem/yr from ^{239}Pu (<0.01% of the RPS), 0.9 mrem/yr from ^{41}Ar (<0.2% of the RPS), and 19 mrem/yr from combined ^{11}C, ^{13}N, and ^{15}O (3.8% of the RPS). The estimated total whole body population dose attributable to LASL operations for residents of Los Alamos County was 11.1 man-rem or about 0.4% of the total population dose due to normally present background radiation.

No pathways to humans were identified for radioactivity in treated liquid effluents. All water affected by such effluents contained radioactivity at levels well below appropriate CGs. No pathways for sediments in liquid waste discharge areas were identified. Commuters making two round trips a day on one federally owned road (Pajarito Road) crossing the site could have received as much as 0.6 mrem/y from one technical area where radiation emitting experiments are carried out. Two possible food pathways, involving honey and venison, could have resulted in doses of <4 mrem/y to a few people.

The water supply met all applicable DOE radioactivity standards and all U.S. Environmental Protection Agency (EPA) chemical quality standards. The integrity of the geological formations protecting the deep groundwater aquifer was confirmed by the lack of any measurements indicative of non-natural radioactivity or chemical contamination in the municipal water supply sources.

Non-radioactive airborne effluents from sources including a power plant, steam plants, an asphalt plant, a beryllium shop, and experiments utilizing high explosives were well within environmental quality standards. Effluents from 8 of 9 sanitary sewage plants operating under provisions of EPA permits exceeded one or more permit limits during at least one month of the year. Industrial effluents from 102 sources are expected to come under provisions of an EPA permit during 1978. Some 1977 data on the quality of these effluents is presented.

An inadvertent release of approximately 30 600 Ci of tritium gas ($^3H_2$) occurred in October 1977 from TA-33. Westerly winds carried the gas east over unoccupied land. Measurements from routine air sampling stations indicated no detectable exposure to the public. Laboratory personnel received no measurable exposures as determined by urine assay.

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 at 50 locations. Three of these locations are 28 to 44 km from the Laboratory boundaries in the neighboring communities of Española, Pojoaque, and Santa Fe. Sixteen are within 4 km of the boundary and serve to monitor the perimeter of the Laboratory. Thirty-one locations are within LASL boundaries. None of the measurements at regional or perimeter locations showed any statistically discernable readings that could be attributed to LASL operations. The table below summarizes the annual total doses for 1977 by group.

1977 EXTERNAL PENETRATING RADIATION

	Dose (mrem)		
Group	Minimum	Maximum	Average
Regional	90	104	95
Perimeter	100	145	127
On Site	120	609	172

The 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 used in the LASL monitoring program (TLD-100®) are insensitive to neutrons so the neutron contribution to the natural background radiation was not measured and, therefore, will be excluded from this discussion. The cosmic ionizing radiation level increases with altitude because of the reduction in the shielding effect of the atmosphere. At sea level it averages between 25 and 30 mrem/yr. Los Alamos, with a mean altitude of about 2.2 km, receives about 60 mrem/yr from the cosmic component. The regional monitoring locations, ranging from about 1.7 km altitude at Pojoaque to about 2.1 km at Santa Fe, receive from 50-60 mrem/yr.[1]

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 is about 15-25% because of variations in soil moisture content and snow cover.[1] There is also spatial variation because of different soil and rock types in the area. The 1964 (ARMS-II) aerial survey of terrestrial background radiation levels in the Albuquerque-Los Alamos area identified regions within Los Alamos County which differ by a factor of more than two (measurements ranged from 400-700 counts/s to 1200-1800 counts/s).[2] These findings correlate with data presented in Table II from the LASL TLD network. Assuming 60 mrem/yr for the cosmic component, the perimeter stations (see Fig. 4) recording the highest and lowest total doses indicated terrestrial components of 85 mrem/yr and 40 mrem/yr, respectively. These stations were located in areas identified in the ARMS-II survey as having 1200-1800 counts/s and 600-1200 counts/s, respectively. The data from the regional TLD stations (see Fig. 1) correspond with the ARMS-II data, also. Again assuming 60 mrem/yr for the cosmic components at these locations the terrestrial components of the total doses were 30 mrem/yr at Española, 44 mrem/yr at Pojoaque, and 31 mrem/yr at Santa Fe. The ARMS-II survey indicated these areas as having count rates of 400-800 counts/s, 1000-1400 counts/s, and 600-1000 counts/s, respectively.

Because of the widely varying values for the terrestrial background dose, choosing an "average" value for reference could be difficult. Oakley, in his interpretation of the ARMS-II data, gave a mean dose for the Albuquerque-Los Alamos survey equal to about 65 mrem/yr.[3] Adding to this the 60 mrem/yr cosmic component results in 125 mrem/yr. This is in substantial agreement with the 127 mrem/yr average for the perimeter stations in the LASL TLD network.

The doses recorded at on-site TLD stations (see Fig. 4) are expected to be higher than those at

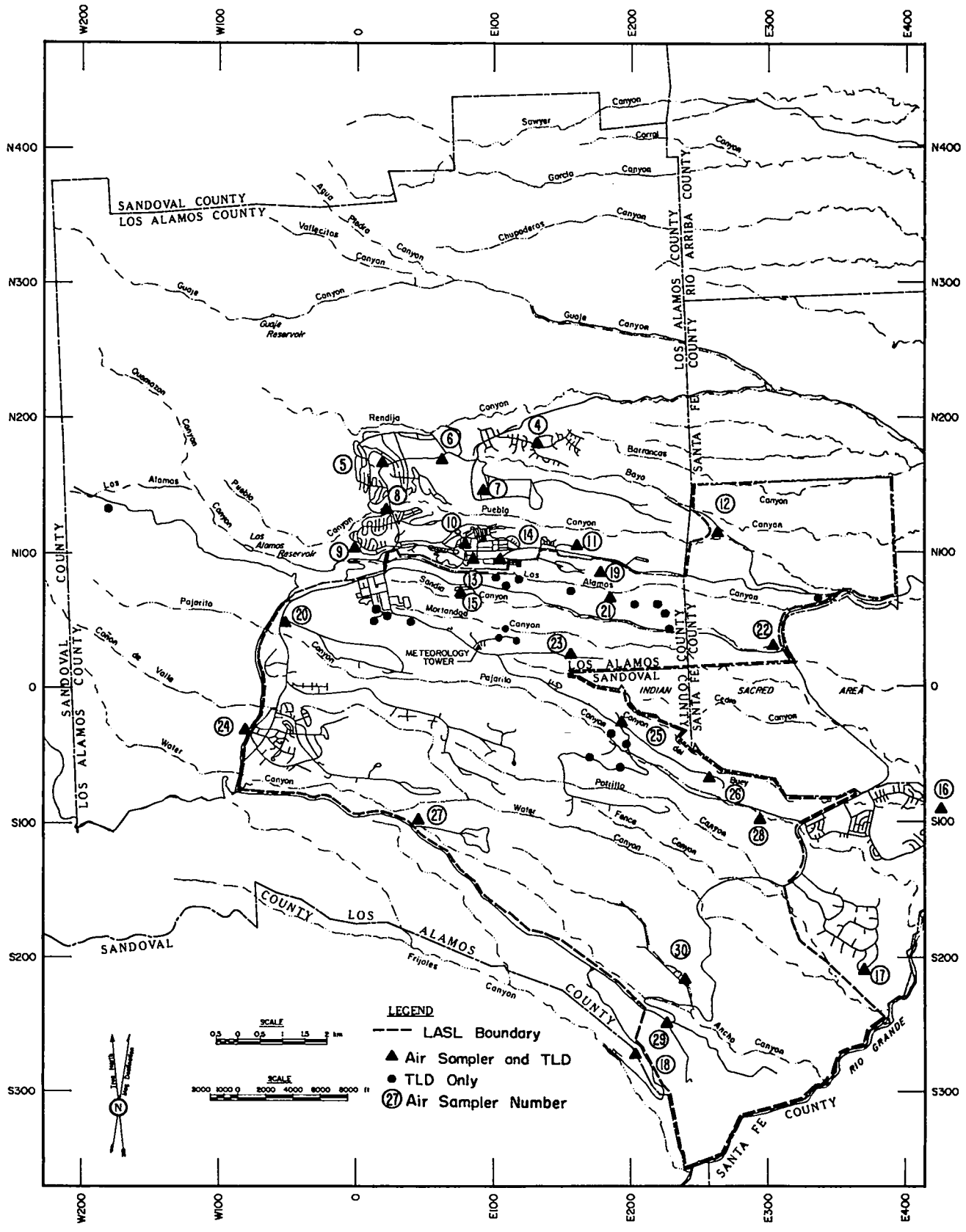


Fig. 4.
Thermoluminescent dosimeter and air sampler locations on or near the LASL site.

perimeter stations because the majority of on-site stations monitor known sources of radiation related to the operation of the laboratory. These sources include particle accelerators, criticality experiments, and radioactive waste burial sites. However, some on-site stations have been established to gather preoperational data at locations of facilities to be built in the future. Others serve as on-site background stations for use as a reference.

2. Air

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 1977, no statistically significant difference was observed between the 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 of these contaminants were indistinguishable from background levels. Tritiated water vapor (HTO) concentrations at perimeter and onsite stations were about two and four times higher, respectively, than regional background HTO levels and are attributable to the Laboratory's HTO stack effluents. Elevated levels of airborne activity from short-lived fission products were detected for a short period of time following a nuclear atmospheric detonation by the People's Republic of China on September 17, 1977.

a. General. Atmospheric radioactivity samples were collected at 30 continuously operating air sampling stations in Los Alamos County and vicinity. Onsite and perimeter station locations are shown in Fig. 4; map coordinates identify locations in the data tables. Perimeter stations are 0 to 4 km from the Laboratory boundary. The regional monitoring stations, located 28 to 44 km from the Laboratory at Española, Pojoaque, and Santa Fe (Fig. 1), serve as reference points in determining the regional background for atmospheric radioactivity.

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 ^{40}K, 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. Also, periods of high humidity yield more tritiated water vapor per volume of air than do periods of low humidity. Spatial variations may be dependent on these same factors. Previous measurements of background atmospheric radioactivity concentrations are summarized in Table III and are useful in interpreting the air sampling data.

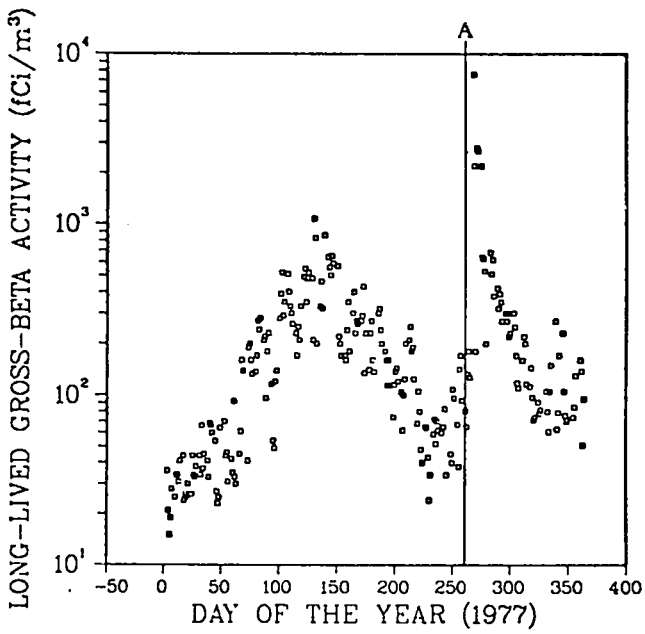
b. Daily Gross-Beta Radioactivity and Chinese Fallout Monitoring. Atmospheric radioactivity samples were collected daily (Monday through Friday) at the Occupational Health Laboratory (N050 E040). Atmospheric particulate matter on each filter was analyzed for gross-alpha and gross-beta activities on collection day and again 7 to 10 days after collection. The first measurement provided an early indication of any major change in atmospheric radioactivity, while the second measurements were used to observe temporal variations in long-lived atmospheric radioactivity. Results from this sampling program, showing daily atmospheric gross-beta concentrations for 1977, are graphed in Fig. 5. Abnormally high activity occurred during the last quarter of the year. This elevated activity is attributed to an atmospheric

nuclear test by the People's Republic of China over the Lop Nor testing area in southwest China. The test, on September 17, 1977, was reported to be a low yield nuclear device with an explosive power equivalent to approximately 20 000 tons of TNT.

Radioactive materials were injected into the troposphere and stratosphere over the mid-latitudes of the northern hemisphere by the above-ground detonation. Prevailing air currents carry airborne radioactive materials to the North American continent, usually within 4 to 7 days after a test. The radioactive debris slowly drops to the earth's surface as fallout over a period of several months or years. This process normally is intensified each spring when mixing of the stratosphere and troposphere increases fallout.

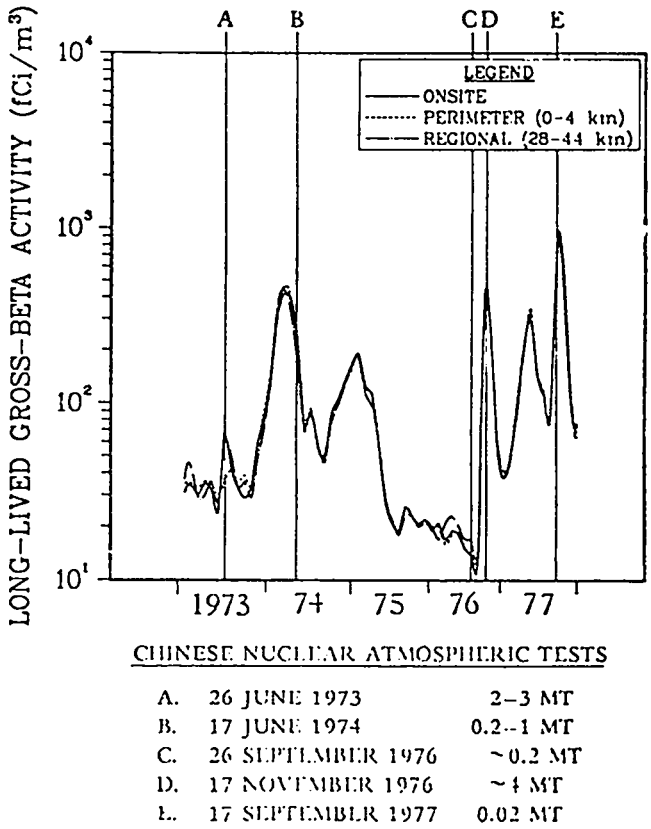
After the September 17 test, supplementary sampling was initiated to measure the fallout. Daily particulate samples were taken at the Occupational Health Laboratory (N050 E040) and at the offsite station at Española 28 km distant from the Laboratory, see Fig. 1). First evidence of the fallout arrival was observed in the particulate samples collected over the weekend September 23-26, ending at 8 a.m. on September 26 (6-8 days after detonation). The highest observed long-lived gross-beta concentration of 7600 (±1000) × 10^{-16} μCi/mℓ also occurred in the sample collected during September 23-26. This concentration is 8% of the uncontrolled area Concentration Guide (CG) for ^{131}I. Qualitative gamma spectral analyses of the atmospheric particulate samples showed the presence of fresh fission products (e.g., ^{141}Ce, ^{131}I, and ^{95}Zr) from the detonation. Table IV contains all data collected during the special Chinese fallout monitoring program.

c. Annual Gross-Alpha and Gross-Beta Radioactivity. The annual average biweekly gross-alpha and gross-beta concentrations are summarized below and shown in detail in Table V. Significant temporal variations in long-lived gross-alpha and gross-beta concentrations (Figs. 5 and 6) were observed during the year. The elevated activity during April and May was typical of that observed during most springs when mixing of the



A. CHINESE NUCLEAR ATMOSPHERIC TEST OF 0.02 MT ON 17 SEPTEMBER 1977.

Fig. 5.
Daily long-lived atmospheric gross-beta radioactivity for 1976.



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	~1 MT
E.	17 SEPTEMBER 1977	0.02 MT

Fig. 6.
Monthly average long-lived gross-beta radioactivity, 1973-1977, by sampling station groups.

SUMMARY OF ANNUAL ATMOSPHERIC RADIOACTIVITY MONITORING

Analysis	Composite Group	Units	Maximum Observed	Minimum Observed	Annual Mean	Mean As % CG
Gross-Alpha	Regional	10^{-15} μCi/mℓ	6.1 ±2.8	−0.5 ±0.6	1.4 ±2.4	2.3
	Perimeter	10^{-15} μCi/mℓ	5.5 ±2.4	−3.0 ±1.4	1.2 ±2.3	2.0
	Onsite	10^{-15} μCi/mℓ	5.2 ±2.4	−2.1 ±1.4	1.2 ±2.2	0.1
Gross-Beta	Regional	10^{-15} μCi/mℓ	1900 ±500	27 ±3	187 ±592	1.7
	Perimeter	10^{-15} μCi/mℓ	2200 ±600	30 ±10	197 ±605	2.0
	Onsite	10^{-15} μCi/mℓ	2300 ±600	13 ±3	213 ±707	0.005
Tritiated Water Vapor	Regional	10^{-12} μCi/mℓ	102 ±38	0.3 ±0.1	13 ±121	0.006
	Perimeter	10^{-12} μCi/mℓ	190 ±60	0.4 ±0.1	23 ±55	0.011
	Onsite	10^{-12} μCi/mℓ	790 ±260	0.5 ±3.6	52 ±184	0.001
^{238}Pu	Regional	10^{-18} μCi/mℓ	0.2 ±1.5	−4.7 ±4.5	−1.5 ±2.1	0.000
	Perimeter	10^{-18} μCi/mℓ	2.9 ±2.1	−12 ±9	−1.8 ±5.4	0.000
	Onsite	10^{-18} μCi/mℓ	33 ±13	−15 ±17	−0.5 ±6.8	0.000
^{239}Pu	Regional	10^{-18} μCi/mℓ	31 ±7.5	1.3 ±6.1	16 ±24	0.027
	Perimeter	10^{-18} μCi/mℓ	166 ±12	−1.4 ±8.0	26 ±94	0.044
	Onsite	10^{-18} μCi/mℓ	58 ±16	−1.9 ±11	21 ±33	0.001
^{241}Am	Regional	10^{-18} μCi/mℓ	1.3 ± 5.1	−0.4 ±3.2	0.2 ±1.1	0.00011
	Perimeter	10^{-18} μCimℓ	19 ± 5.3	−1.7 ±6.2	4.1 ±14	0.00210
	Onsite	10^{-18}μCi/mℓ	7.3 ± 4.5	−3.3 ±6.0	1.3 ±5.7	0.00002
Uranium(total)	Regional	pg/m^3	614 ±103	60 ±7	187 ±371	0.0021
	Perimeter	pg/m^3	292 ±58	34 ±75	99 ±112	0.0011
	Onsite	pg/m^3	736 ±103	29 ±6	133 ±290	0.0001

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

stratosphere with the troposphere causes increased fallout of particulates. The major fluctuation in September was caused by the Chinese atmospheric nuclear explosion previously mentioned. All maximum values of long-lived gross-alpha and gross-beta activities occurred after the nuclear test in late September. These higher concentrations increased the annual station means for long-lived gross-beta activity from 3 to 4 times the means observed during 1976.

Data plotted in Fig. 6 also show that there were no significant differences in atmospheric gross-beta concentrations among the regional, perimeter, and onsite sampling stations this year. There have been no statistically significant differences over the past 5 years. This lack of statistically significant differences in concentrations indicates that Laboratory operations have a 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.

d. Tritium. The atmospheric tritiated water concentrations for each station for 1977 are summarized above and shown in detail in Table VI. The relatively higher levels observed at the Los Alamos airport are similar to those observed in previous years and are attributed to stack effluents from nearby TA-21. The relatively higher concentrations at TA-54 resulted from evapotranspiration of buried tritium contaminated wastes at this site. The annual mean for the onsite stations is statistically higher (at a >99% confidence level) than the regional and perimeter means. The higher value reflects tritium releases from Laboratory operations (see Sec. III.A.6). The annual mean atmospheric tritium concentrations for the perimeter and onsite stations are shown in Fig. 7. The highest annual mean of 187 (±362) pCi/m³ was at TA-54 (Station 26).

e. Plutonium. The annual average ^{238}Pu and ^{239}Pu concentrations for each station are summarized in the table above and listed in Table VII. Practically all ^{238}Pu concentrations were less than the minimum detectable limit of 2×10^{-18} $\mu Ci/m\ell$; ^{239}Pu concentrations were highest during the second

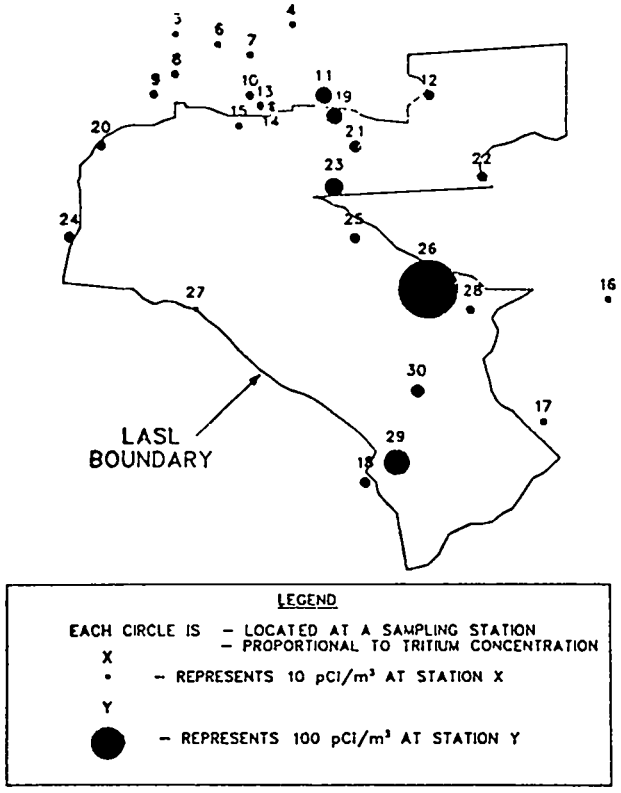


Fig. 7.
Annual mean atmospheric tritiated water vapor concentrations in the vicinity of LASL.

quarter (April-May-June), and the fourth (September-October-November-December). The relatively higher concentrations in the spring are attributable to mixing of the stratosphere with the troposphere. This mixing brings down radioactive particles from previous nuclear atmospheric explosions. The elevated concentrations in the fourth quarter were the result of the nuclear atmospheric detonation by the People's Republic of China on September 17, 1977. This year's atmospheric plutonium concentrations were 10-20% higher than the regional average background concentrations shown in Table III. They were also about 4 times higher than the plutonium concentrations last year. However, the 1976 plutonium averages were abnormally low since the usual spring maximum was absent. There was no significant difference (at a >99% confidence level) among the regional perimeter and onsite plutonium concentrations. This indicates the Laboratory contributions to atmospheric plutonium were indistinguishable from regional background levels.

f. Uranium and Americium. The 1977 atmospheric uranium concentrations are summarized above and listed in Table VIII. The uranium concentrations are dependent on the immediate environment of the sampling station. Those stations with higher annual averages and maximum values were all located in dusty areas where a higher filter dust loading accounts for more natural crustal-abundance uranium being collected. The annual averages of the stations are typical of regional average background atmospheric uranium concentrations (Table III). There were no statistically significant (at a >99% confidence level) temporal or geographical differences among the regional, perimeter, and onsite station groups.

The 1977 atmospheric americium concentrations are summarized above and listed in Table IX. Not only is there a wide variation in the data, but the 95% confidence level uncertainties associated with the concentrations are also high. Therefore, no attempt was made to interpret the data in detail. However, maximum observed values for all stations occurred during the sampling period from September through December. The higher concentrations during this period were the result of fallout from the Chinese nuclear test on September 17, 1977.

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. The results of the 1977 radiochemical quality analyses of water from regional, perimeter, water supply, and on-site non-effluent release areas indicate no effect from the effluent releases from LASL. Waters in the on-site liquid effluent release areas contain trace amounts of radioactivity. These on-site 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. The results of these analyses are compared to USDOE Radioactivity Concentration Guides (CGs) for uncontrolled areas (see Appendix A) as an indication of the very small doses that would be received.

Regional surface waters were collected within 75 km of LASL from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 8, Table X). Samples were also collected from seven perimeter stations located within about 4 km of the LASL boundaries (Fig. 9, Table X) and from 31 stations in White Rock Canyon of the Rio Grande (Fig. 10, Table X). Detailed analyses from the regional and perimeter stations are presented in Tables XI and 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 below.

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN REGIONAL AND PERIMETER WATERS

Analyses	Units (μCi/mℓ)	Regional	Perimeter		CG for Uncontrolled Areas
			Seven Stations	White Rock Canyon	
^{3}H	10^{-6}	6.5	22	---	3000
^{137}Cs	10^{-9}	150	160	190	30 000
^{238}Pu	10^{-9}	<0.4	<0.8	<0.8	5000
^{239}Pu	10^{-9}	<0.3	<0.1	<0.6	5000
Gross-alpha	10^{-9}	14	7	5	5000
Gross-beta	10^{-9}	25	18	19	300
Total U	μg/ℓ	7.2	13	20	1800

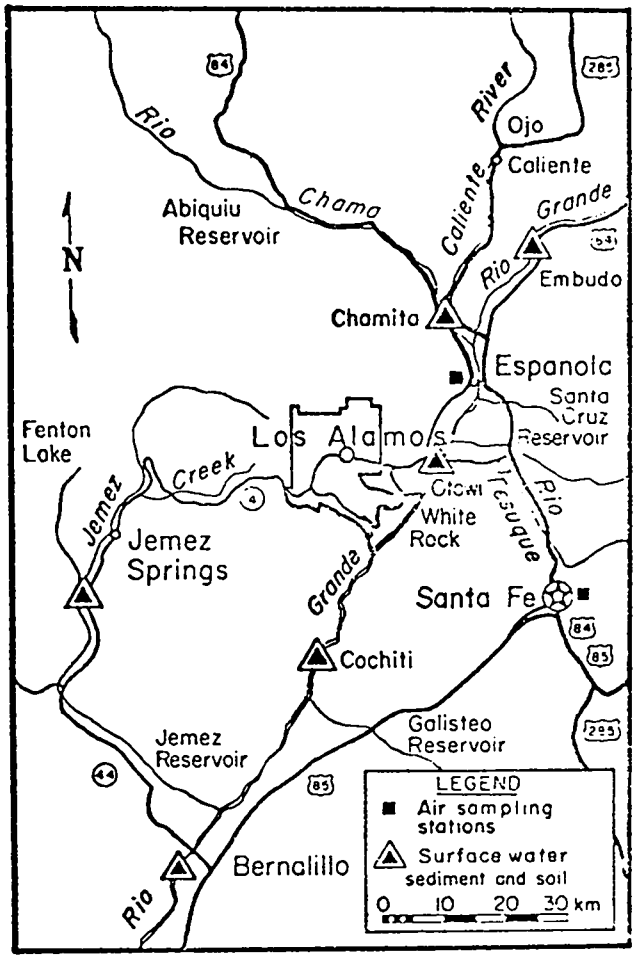


Fig. 8.
Regional surface water, sediment, soil, and air sampling locations.

The radionuclide concentrations in surface and ground waters from the regional and perimeter stations are low and have shown no effect from the release of liquid effluents at LASL. Plutonium concentrations are near the limits of detection. The concentrations 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. The wells are located on the plateau and in canyons east of the Laboratory (Fig. 9). 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 1977 the production from the wells and gallery was about 5.8 $\times 10^6$ m^3 (1528 $\times 10^6$ gal), with the wells furnishing about 96% of the total production and the gallery about 4%. 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. 9, Table X).

Detailed radiochemical analyses from the wells, gallery, and distribution system are presented in Table XIII. A comparison of maximum concentrations found in these waters with CGs for uncontrolled areas is given below.

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATER SUPPLY

Analysis	Units μCi/mℓ	Wells and Gallery	Distribution System	CGs for Uncontrolled Areas
^{3}H	10^{-6}	6.7	5.5	3000
^{137}Cs	10^{-9}	140	200	30 000
^{238}Pu	10^{-9}	<0.1	<0.06	5000
^{239}Pu	10^{-9}	<0.3	<0.03	5000
Gross-alpha	10^{-9}	9	4	5000
Gross-beta	10^{-9}	8	7	300
Total U	μg/ℓ	6.8	4.0	1800

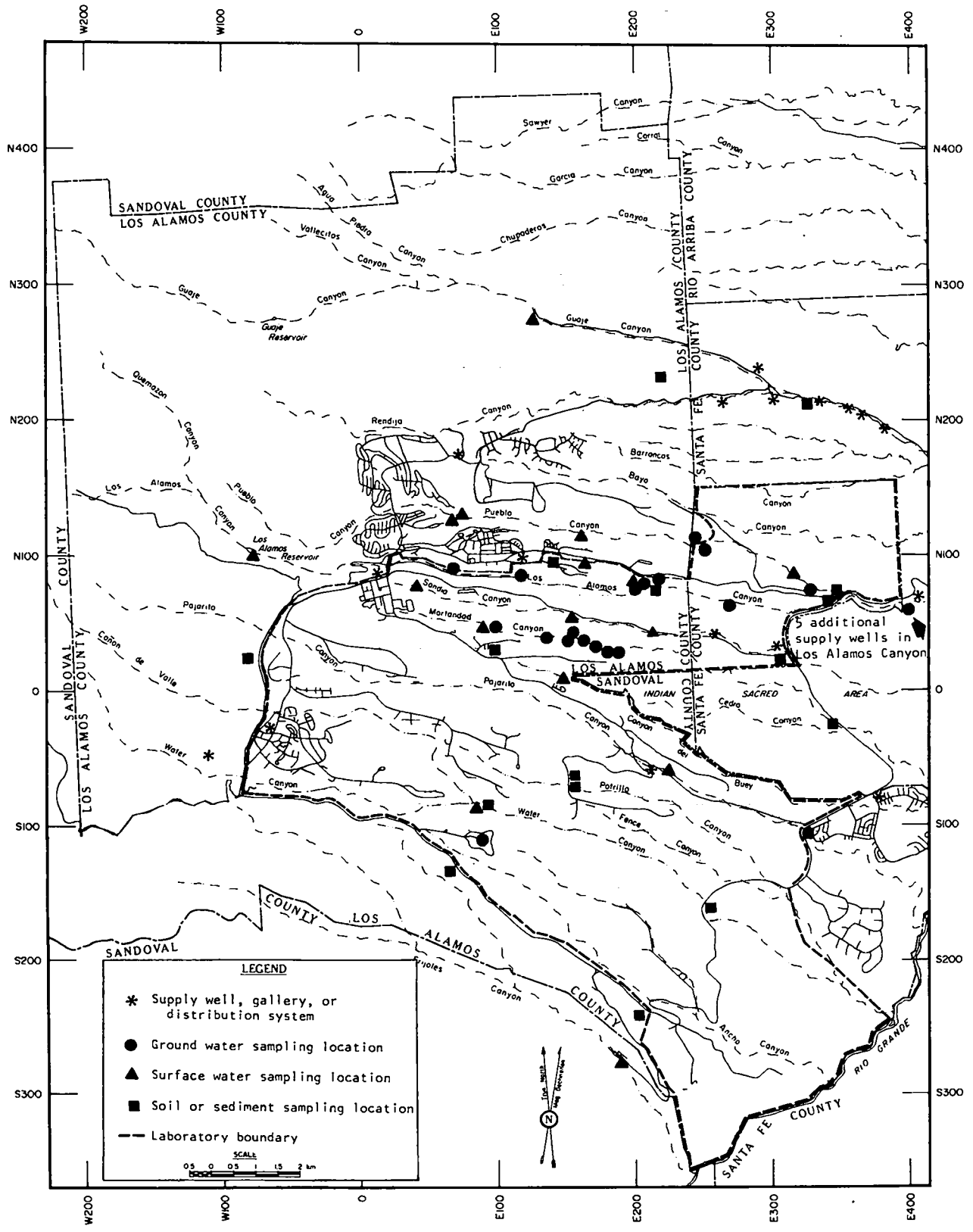


Fig. 9.
Water, soil, and sediment sampling locations on or near the LASL site.

The radioactivity occurring in the water supply is low and naturally occurring. Plutonium is below limits of detection. Samples from the water supply 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 twice the screening limit. Dilution by water from the remainder of the wells results in concentrations at points of use that meet the EPA criteria for municipal supply without requiring further detailed analyses.

c. On-Site Surface and Ground Waters. The on-site 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. The on-site non-effluent release areas consist of six test wells completed into the main aquifer, one test well completed in a perched aquifer, and three surface water sources (Fig. 9, Table X). Detailed radiochemical analyses are shown in Table XIV. The maximum concentration of radioactivity at the ten stations is as follows:

MAXIMUM RADIOACTIVITY IN ONSITE WATERS IN AREAS NOT RECEIVING EFFLUENTS

Analysis	Units (μCi/mℓ)	On-Site Non-Effluent Area	CGs for Controlled Areas
^{3}H	10^{-6}	7	100 000
^{137}Cs	10^{-9}	150	400 000
^{238}Pu	10^{-9}	<0.2	100 000
^{239}Pu	10^{-9}	<0.4	100 000
Gross-alpha	10^{-9}	3	100 000
Gross-beta	10^{-9}	40	10 000
Total U	μg/ℓ	3	60 000

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

The 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. Surface water in these canyons infiltrates into the alluvium before leaving the LASL boundaries (Fig. 9, Table X). The maximum concentration of radioactivity in each of the four canyons is given below:

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATERS IN AREAS RECEIVING EFFLUENTS

Analyses	Units (μCi/mℓ)	Acid-Pueblo	Sandia	DP-Los Alamos	Mortandad	CGs for Controlled Areas
^{3}H	10^{-6}	3	14	149	1620	100 000
^{137}Cs	10^{-9}	210	<120	230	450	400 000
^{238}Pu	10^{-9}	<0.04	<0.2	1.8	12	100 000
^{239}Pu	10^{-9}	4.7	<0.1	3.7	1.6	100 000
Gross-alpha	10^{-9}	5	8	300	76	100 000
Gross-beta	10^{-9}	200	66	10 700	1670	10 000
Total U	μg/ℓ	5	6	158	25	60 000

The radioactivity observed in Acid-Pueblo Canyon (6 stations) results from residuals of treated and untreated radioactive liquid waste effluents released into the canyon before 1964 (Table XIV). The 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 no release of radionuclides to the environment (Table 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 industrial effluent containing radionuclides (Table XIV).

The three areas, Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons, contain surface and ground water with measurable amounts of radioactivity. The concentrations are well below concentration guides for controlled areas. The 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 in 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 years prior to release of any industrial effluents.

4. Radionuclides in Soil and Sediments

Radioactivity in regional and perimeter soil and sediment samples represents naturally occurring nuclides or worldwide fallout. One on-site soil sample contained a trace amount of radioactivity attributed to LASL operations. On-site sediment samples from canyons that have or are now receiving industrial effluents contained measurable amounts of radioactivity. The concentration of plutonium in sediments transported beyond the LASL boundary is low, the maximum concentration being about a factor of 10 above worldwide fallout levels.

a. Regional and Perimeter Soils and Sediments. Soil and sediment samples were collected in the same general locations as the regional and perimeter water sampling stations (Figs. 8 and 9). The exact locations are shown in Table XV and analyses are presented in Table XVI (see Appendix B.3 for methods of collection, analysis, and reporting of soil and sediment data). These samples provide a normal baseline for comparison with samples collected in and adjacent to the Laboratory. The maximum concentrations of radionuclides in the regional and perimeter samples are as follows:

MAXIMUM RADIOACTIVITY IN REGIONAL SOILS AND SEDIMENTS

		Regional		Perimeter	
Analysis	**Units**	**Soils**	**Sediments**	**Soils**	**Sediments**
^{90}Sr	pCi/g	0.40	0.16	0.44	0.14
^{137}Cs	pCi/g	1.1	0.46	2.4	0.39
^{238}Pu	pCi/g	<0.30	<0.003	<0.01	<0.01
^{239}Pu	pCi/g	0.02	<0.01	<0.80	<0.04
Gross-alpha	pCi/g	15	14	9	9
Gross-beta	pCi/g	8.6	12	11	7
Total U	μg/g	3.9	3.4	5.1	3

Worldwide fallout of plutonium in the region in 1970 ranged from 0.001 to 0.004 pCi/g for ^{238}Pu and from 0.001 to 0.012 pCi/g for ^{239}Pu. The plutonium values reported generally fall within this range. A special set of sediments from the Rio Grande and major tributaries entering the Rio Grande between Otowi Bridge and Cochiti Reservoir were collected in September. These offsite samples (6 from the Rio Grande, 9 from major tributaries, Fig. 10, Table XV) indicated only background concentrations of radionuclides (Table XVI).

b. On-Site Soil and Sediments. On-site soils were collected from four stations within Laboratory boundaries. Sediment samples were collected from four on-site noneffluent release areas (Fig. 9, Table XV), and from 13 stations in canyons that have received or are now receiving industrial effluents. Three stations were sampled in Lower Los Alamos Canyon (off-site), an area that has received runoff from Acid-Pueblo and DP-Los Alamos Canyons (on-site). Detailed analyses are shown in Table XVII. The maximum radioactivity concentrations are as follows:

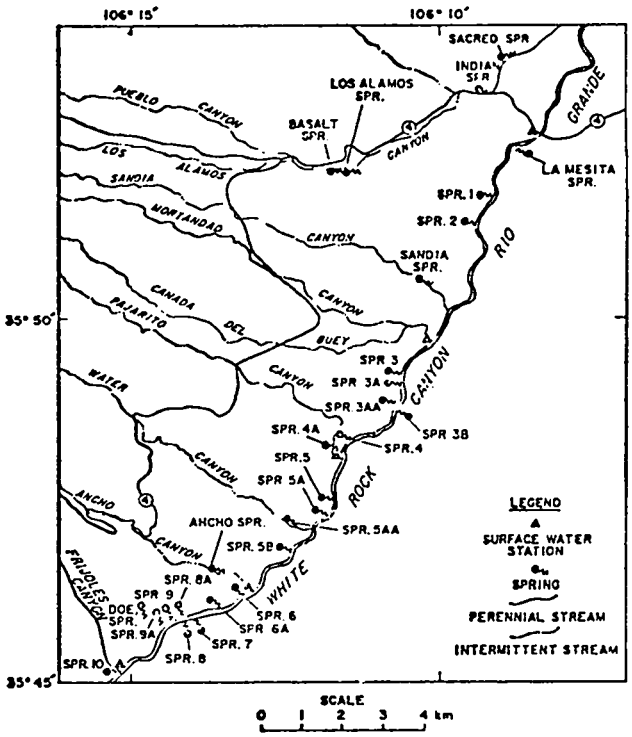


Fig. 10.
Water sampling locations in White Rock Canyon of the Rio Grande.

MAXIMUM RADIOACTIVITY IN ONSITE SOILS AND SEDIMENTS

			Sediments				
Analysis	Units	Soils	Non-Effluent Area	Pueblo	DP Los Alamos	Lower[1] Los Alamos	Mortandad
^{90}Sr	pCi/g	0.46	0.28	<0.16	10	0.17	7.7
^{137}Cs	pCi/g	1.2	2.3	0.18	26	0.45	<1700
^{238}Pu	pCi/g	<0.02	<0.01	<0.01	0.40	0.05	107
^{239}Pu	pCi/g	6.9	<0.04	1.2	1.1	0.11	11
Gross-alpha	pCi/g	17	12	3	4	22	120
Gross-beta	pCi/g	12	15	3	47	3	1360
Total U	μg/g	8.7	5.6	3.1	<6.2	7	<8

[1]Off-site concentrations transported from Pueblo and DP-Los Alamos Canyons.

Measurable ^{239}Pu was found in soil adjacent to the industrial waste treatment plant at TA-50 (Table XVII), which released an abnormally high amount of airborne ^{239}Pu this year because of special decontamination operations. The on-site soil and sediment analyses in non-effluent areas and in Sandia Canyon, which receives only effluent from the sanitary and power plants, were within normal ranges.

Radionuclides were present in concentrations above background in Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons. These canyons are presently receiving industrial effluents or have received industrial effluents (Table XVII). The

radionuclides in the treated effluents are adsorbed or attached to sediment particles in the alluvium. Concentrations are highest near the effluent outfall and decrease downgradient in the canyon as the sediments and radionuclides are transported and dispersed by other industrial effluents, sanitary effluents, and periodic storm runoff.

Storm runoff in Acid-Pueblo and DP-Los Alamos Canyons has transported some radionuclides off-site into lower Los Alamos Canyon (Table XVII). The maximum concentration of plutonium reported in 1977 in the lower canyon was about a factor of 10 greater than worldwide fallout levels in the area.

c. Preoperational Radioactivity in Soil Sediments at TA-55. Soil and sediment samples collected near the new plutonium facility to document preoperational conditions showed normal levels of radioactivity in all but one sample near an old contaminated facility.

As part of the preoperational environmental survey for the new Plutonium Facility at TA-55, soil and sediments from natural drainages were collected prior to any processing of plutonium at the plant (Fig. 11). Eight soil samples and nine sediment samples (4 interior drains, 5 exterior drains) were collected by taking 5 plugs using the standard environmental samples (7.6 cm dia, 4.5 cm length). The analyses are grouped according to soil or drain sediments and are shown in Table XVIII. Most values

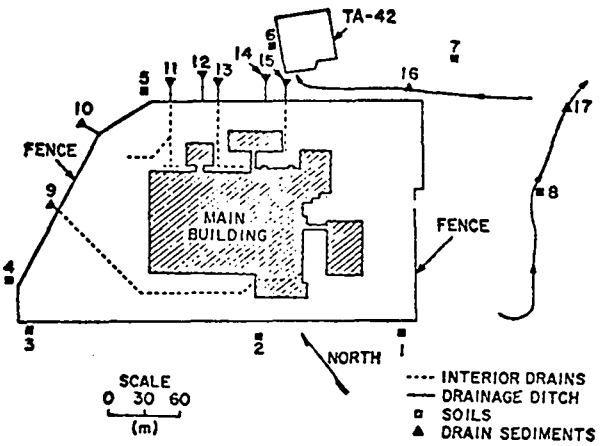


Fig. 11.
Soil and sediment sampling locations in the vicinity of TA-55.

fall in the range of naturally expected background or worldwide fallout. One soil sample (Location 6) contained a higher concentration of ^{238}Pu and ^{239}Pu when compared to other samples collected in the area. This plutonium is apparently related to wastes that were processed at TA-42. Location 6 is just west of the TA-42 fence. TA-42 was used in the early 1950s to study possible incineration of radioactive wastes and is currently undergoing decontamination and decommissioning.

5. Radioactivity in Foodstuffs

Fruit and vegetable samples collected in the vicinity of LASL showed no apparent influence from Laboratory operations except for peaches collected at an on-site location near a facility which emits tritium.

Fruit and vegetable samples were collected to monitor foodstuffs for possible radioactive contamination from Laboratory operations. Samples were collected during the fall harvest in the Los Alamos area and in the Rio Grande valley at points both above and below where stream channels crossing the Laboratory join the Rio Grande. The samples were washed as they normally would be prior to consumption, moisture was distilled from them and analyzed for tritiated water (HTO or T_2O), and edible portions were analyzed for $^{238,239}Pu$ and total uranium.

The data presented below summarize the tritiated water content in various samples according to different water supplies:

TRITIATED WATER CONTENT OF FOODSTUFFS

Location	Irrigation Water Source	No. of Samples	Tritium Concentration (pCi/mℓ) Average	Range
Hernandez	Rio Chama[a]	3	3.0 ±0.3	2.7-3.3
Ranchitos	Rio Grande[a]	4	3.4 ±0.5	2.7-4.0
Cochiti	Rio Grande[b]	4	3.4 ±0.4	2.9-3.8
White Rock	LA County	4	2.7 ±0.2	2.4-2.9
Los Alamos	LA County	3	3.4 ±0.7	2.7-4.1
TA-35	LA County	2	66 ±22	50-81

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

For samples on private land there is no significant difference in tritiated water content between upstream, downstream, and Los Alamos area samples. The concentrations are within the range of values observed in local surface water and atmospheric water vapor. Thus, there is no indication of any measurable offsite contribution from Laboratory operations. The two on-site samples from peach trees at TA-35 showed higher concentrations of tritiated water. These trees are within 20 m of a 23 m high stack that is a release point for tritium (see Table IX). The slightly elevated concentration of tritium in these peaches represents no significant health hazard 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 (3000 pCi/mℓ) for water.

Results of uranium in foodstuffs as characterized by water supply are listed below:

URANIUM IN FOODSTUFFS

Location	Irrigation Water Source	No. of Samples	Uranium Concentration (ng/g - dry weight) Average	Range
Hernandez	Rio Chama	3	1.7 ±2.1	0-4
Ranchitos	Rio Grande	4	6.3 ±6.7	0-13
Cochiti	Rio Grande	4	17 ±15	3-35
White Rock	LA County	4	3.3 ±4.5	1-10
Los Alamos	LA County	3	17 ±18	3-37
TA-35	LA County/DOE	1	1.1	

The results are similar to those measured previously and are consistent with what could be expected from slight surface contamination and for plants grown in different types of soil.

For all samples, the plutonium concentrations were less than the detection limits (~0.01 pCi/g) for $^{238,239}Pu$.

No meat, honey, or other foodstuffs were analyzed this year. Estimates for maximum possible doses from these pathways were made from data from previous years and are summarized below:

POSTULATED VENISON AND HONEY FOOD PATHWAY DOSES

Pathway	Consumption Rate (kg/yr)	Contamination	Calculated Dose (mrem/yr)
Venison consumption	110	1.8 pCi/g ^{137}Cs	3.9
Honey consumption	2.3	3 nCi/mℓ ^{3}H	0.12

The honey-producing bees apparently obtained nectar with an elevated tritium content from clover growing over a contaminated solid waste disposal site. The venison with slightly elevated ^{137}Cs content came from deer observed to frequent DP and Mortandad Canyons where effluents from the radioactive liquid waste treatment plants are discharged. Probable doses would be considerably less and would affect very few individuals as the quantity of food with trace contamination is very small.

6. Radioactive Effluents

Airborne radioactive effluents released from LASL operations in 1977 were typical of releases during the last several years. The greatest change was an increase in activation products from higher power operation of the linear accelerator at LAMPF. Liquid effluents from two waste treatment plants contained radioactivity at levels well below controlled area concentration guides.

Effluents containing radioactivity are discharged at LASL in the form of airborne materials in stack exhausts at twelve of the technical areas and as liquid discharges from two industrial waste treatment plants. The airborne effluents consist principally of filtered ventilation exhausts from gloveboxes, other experimental facilities, and some process facilities such as the liquid waste treatment plants; exhausts from the research reactor (TA-2); and exhausts from the linear accelerator at LAMPF (TA-53). The releases of various isotopes from the technical areas are detailed in Table XIX. The quantities of radioactivity released depend on the research programs conducted and result in significant year-to-year variations. For example, airborne uranium releases in 1977 were about 50% of those in 1976, and tritium releases in 1977 were about 65% of those in 1976. Airborne plutonium releases were about 90% higher in 1977 than in 1976 because of special work at the waste treatment plant (TA-50) for decontamination of some experimental equipment during the third quarter. Air activation products, especially ^{11}C, ^{13}N, and ^{15}0, were higher by a factor of about 8 in 1977 compared to 1976 because the linear accelerator was operating at much higher power levels in 1977. Other releases showed variation expectable from programmatic differences.

Treated liquid effluents are released from the Central Liquid Waste Treatment Plant (TA-50) and a smaller plant serving the old plutonium processing facility (TA-21). Details of the amount of activity released are presented in Table XX. None of the isotopes were at concentrations higher than about 7% of Concentration Guides for water in Controlled Areas. The releases from the large plant (TA-50) are discharged into a normally dry stream channel in which surface flow has not passed beyond the Laboratory boundary since before the plant began operation. The discharges from the smaller plant (TA-21) are made into a tributary of Los Alamos Canyon where runoff does at times flow past the boundary and transports some residual activity adsorbed on sediments.

In addition to the airborne releases from stacks, some depleted uranium (uranium consisting almost entirely of ^{238}U) is dispersed by experiments employing conventional high explosives. In 1977 about 1595 kg of depleted uranium were used in such experiments. Based on known isotopic composition, this mass is estimated to contain approximately 0.59 Ci of activity. Most of the 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 is aerosolized. Approximate dispersion calculations indicate that resulting airborne concentrations at site boundaries 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 continuous air sampling network (see Sec. III.A.2). Estimates of non-radioactive releases from these experiments are discussed in Sec. III.B.3.

7. Accidental Release

An accidental release of tritium gas resulted in no measurable exposure to the public or Laboratory personnel.

Approximately 3.17 g (30 600 Ci) of tritium gas were accidentally released to the atmosphere through a 23 m high stack at TA-33 at 2:23 p.m. on October 6, 1977. Gas escaped through a loose fitting during a transferring operation in a ventilated chamber. The escaping gas was diluted and moved to the east over unoccupied range land by a 9 m/s wind from the west. Tritiated water vapor samples from three nearby monitoring stations (TA-33, TA-39, and Bandelier Lookout) were collected between 3:30 and 4:00 the same day.

The results indicated a slightly higher tritium concentration at TA-33 than normally measured in 1976 and 1977. However, the background station concentration was also higher than in 1976 and 1977 for some unknown reason. All measurements were less than 0.15% of the Concentration Guide for an uncontrolled area.

Tritium monitoring surveys at TA-33 shortly after the release indicated no levels above instrument background. Urinalysis results from people at TA-33 during the release indicated no detectable exposure. Thus, there was no apparent exposure received by either Laboratory personnel or the general public.

B. Chemical Constituents

1. Chemical Quality of Surface and Ground Waters

Chemical analyses of surface and ground waters from regional, perimeter, and on-site non-effluent release areas varied slightly from previous years but showed no significant change. The chemical quality of water from the municipal supply for the Laboratory and community meets the standards set by the EPA and NMEIA. Analyses from on-site effluent release areas indicated that some constituents were higher than in naturally occurring waters; however, these waters are not a source of municipal, industrial, or agricultural supply.

a. Regional and Perimeter. Regional and perimeter surface and ground waters were sampled at the same locations as were used for radioactivity monitoring (Table X). The regional surface waters were sampled at six stations, with perimeter waters sampled at seven stations plus 31 locations in White Rock Canyon (Figs. 8, 9, and 10). Detailed analyses from the regional and perimeter stations are presented in Tables XI and XII, respectively. (See Appendix B.3 for methods of collection, analyses, and reporting of water data). The maximum concentrations for Cl^-, F^-, NO_3^-, and TDS were as follows:

MAXIMUM CONCENTRATIONS OF SELECTED CHEMICALS IN REGIONAL AND PERIMETER WATERS (concentrations in mg/ℓ)

		Perimeter	
Analysis	Regional	Routine Stations	White Rock Canyon
Cl	149	28	36
F	0.9	0.6	0.6
NO_3	1.8	12	42
TDS	580	238	430

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. On-Site Surface and Ground Waters. Water samples were collected from three surface water stations and seven wells, six completed in the main aquifer and one completed in a perched aquifer (Table X). They are located in on-site areas that do not receive industrial effluents (Fig. 9). Detailed results of analyses are given in Table XIV. The maximum concentrations for selected constituents were:

MAXIMUM CHEMICAL CONCENTRATIONS IN ONSITE NON-EFFLUENT WATER
(concentrations in mg/ℓ)

	Onsite Non-effluent Areas	
Analysis	**Surface Water**	**Ground Water**
Cl	109	9
F	0.9	0.6
NO_3	3.5	1.8
TDS	406	248

The quality of water from surface water stations varies slightly as base flow is diluted with varying amounts of storm runoff; however, both surface and ground water analyses have not changed significantly from previous years.

The chemical quality of surface and ground water was determined from 21 stations located in canyons that receive sanitary and/or industrial effluent (Fig. 9, Table X). Detailed analyses are presented in Table XIV. The maximum concentrations of selected constituents found in each canyon were as follows:

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

	Onsite Effluent Areas			
Analysis	**Acid-Pueblo**	**Sandia**	**DP-Los Alamos**	**Mortandad**
Cl	88	96	78	35
F	0.7	3.7	11	1.4
NO_3	81	38	1320	485
TDS	410	796	1946	850

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 Cl^- and NO_3^- concentrations in the four canyons reflects the release of effluents. The high concentrations of F^- and TDS in DP-Los Alamos and Mortandad clearly show the influence of the release of industrial effluents. 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. These waters are not a source of municipal, industrial, or agricultural supply.

2. Water Supply

The federally-owned well field produced water for the Laboratory and County that 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 X, Fig. 9). Detailed analyses are presented in Table XII. Appendix A gives the federal and state standards and criteria for municipal water supplies. The maximum concentration of chemical constituents from wells, gallery, and distribution system stations are compared to criteria in the following table:

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

Analyses	Supply Wells and Gallery	Distribution	Standard or Criteria
Cl	16	12	250
TDS	556	260	1000
As	0.54	0.020	0.05
Ba	<0.005	<0.005	1.0
Cd	<0.001	<0.001	0.010
Cr	0.017	<0.007	0.05
F	2.4	1.0	2.0
Pd	0.011	<0.005	0.05
Hg	<0.005	<0.005	0.002
NO_3	2.2	3.1	45
Se	<0.002	<0.002	0.01
Ag	<0.010	<0.010	0.05

The concentration of natural arsenic in one well in the Guaje Field (G-2) is near or slightly above the standard for drinking water; however, dilution in the system reduces the concentration to acceptable levels. All other constituents meet the criteria for water supply. There has been no significant change in chemical constituents from previous years.

3. Effluents

Nonradioactive effluents include airborne and liquid discharges. Airborne effluents from the power plant, steam plant, asphalt plant, beryllium shop, and experiments with explosives did not result in any measurable or theoretically calculable degradation of air quality. Eight of nine sanitary sewage treatment facilities exceeded EPA permit limits in one or more months. Industrial discharges from 102 points have been included in an application for an EPA discharge permit.

Nonradioactive chemical constituents of air quality in the Los Alamos area have not been monitored routinely as there are no significant air pollution sources in the vicinity. However, some measurements of sulfur dioxide (SO_2) and suspended particulates have been made by the New Mexico Environmental Improvement Agency (NMEIA). The most recent SO_2 measurements were made in October and November of 1976. None of the 515 hourly measurements were above the minimum detectable limit of 0.01 ppm. (The New Mexico Ambient SO_2 Air Quality Standard sets the maximum allowable SO_2 concentrations at 0.02 ppm annual arithmetic average and 0.10 ppm 24-hr average). Data on total suspended particulates for Los Alamos and nearby White Rock (Fig. 3) are comparable to typical rural communities. A summary of the 1977 data is presented in Table XXI. As shown in Table XXI, all values are within the limits of the New Mexico Total Suspended Particulates Standard.

One routine nonradioactive release is from the beryllium fabrication shop. However, exhausts from this location are filtered and continuously monitored to assure that the releases are within standards. Measurements for 1977 show that the beryllium in stack gases is less than 10% of the ambient air standards of 0.01 $\mu g/m^3$ (averaged over 30 days) established by the New Mexico Environmental Improvement Agency[4] and approved by the EPA.[5]

The power plant and steam plants all release combustion products as a result of burning natural gas for the boilers. Estimates of major emissions were made utilizing emission factors.[6,7] They indicated total releases of 12 100 kg of particulates, 700 kg of SO_2, and 218 000 kg of NO_2. Based on heat input rates, neither the power plant nor steam plants are required to meet emission standards for nitrogen dioxide (NO_2).[8] The power plant had heat input of about 0.2×10^{12} BTU during 1977, and the New Mexico standards apply to plants with heat input of 1×10^{12} BTU/year. However, all the plants do meet the standards according to stack gas measurements. The NO_2 stack emssion level established by the New Mexico Environmental Improvement Agency and approved by the Environmental Protection Agency is 248 parts per million (ppm), and measurements during 1977 show average levels of 41 ppm in effluent gases. Because of the negligible sulfur in natural gas, the SO_2 emissions are essentially zero, as confirmed by actual measurements. The fuel oil used in emergency situations is a low sulfur diesel grade, so it also presents no SO_2 emission problems.

An asphalt plant operated by the Laboratory support contractor, the Zia Co., was evaluated in September 1977 for particulate emissions. Measurements made by EPA-approved methods showed that average particulate emissions were 1.8 lb/hr, or about 5% of the standard specified by the New Mexico Environmental Improvement Agency for a plant with its production rate.[9]

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 XXII along with comparisons to applicable air quality regulations. The average concentrations are all less than 5×10^{-4} percent of applicable standards.

There are nine sanitary sewage treatment facilities serving the LASL complex which can release surface effluents. These are all covered by National Pollutant Discharge Elimination System (NPDES) permits. Interim limits on constituents in

the discharges were in effect through June 1977, and final limits took effect starting in July. Table XXIII summarizes the effluent monitoring data for these treatment facilities. The final permit conditions for all of the facilities based on 30-day averages are: 5-day biochemical oxygen demand (BOD_5), 30 mg/ℓ; total suspended solids (TSS), 30 mg/ℓ; pH, 6-9; and fecal coliform, 200/100 mℓ. Two plants met all final criteria during the second half of the year. All others exceeded at least one limit during one or more months.

Other types of industrial effluents are released at 102 points throughout the technical areas and are included in an application to the EPA for an NPDES permit. A permit is expected to be issued in mid-1978 with interim conditions to be met during an approximately 2-year period. This period will be covered by an abatement schedule detailing improvements required to achieve compliance with final permit conditions. The permit application identifies 12 categories of discharges. A total of 56 of the discharge points are for cooling water, 34 for treated cooling water, and 22 for noncontact cooling water. The other largest categories are for high explosive contaminated wastes (20 discharge points) and photographic process rinse wastes (13 discharge points). A summary of data on these industrial discharges is presented in Table XXIV, indicating the number of discharge points in each category, the range of average values for constituents expected to be regulated in the discharges, and the range of flow rates. The two treatment plants processing industrial liquid wastes constitute one of the categories. The non-radioactive constituents of these two discharges will be covered by the NPDES permit, but radioactivity will continue to be addressed by DOE regulations (see Sec. III.A.6).

IV. ENVIRONMENTAL EVALUATION

A. Radiation Doses

Some increments of radiation doses above natural and worldwide fallout background levels are received by Los Alamos County residents as a result of LASL operations. The largest estimated dose at an occupied location was 19 mrem or 3.8% of the radiation protection standard. This results from theoretically calculated atmospheric dispersion of airborne effluents from the proton accelerator at TA-53. Direct measurements will be made in 1978 to document actual conditions. Other minor exposure pathways such as direct radiation from an experimental facility and two unlikely food pathways may result in doses to several mrem/yr. No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. The radioactivity is absorbed in the alluvium before leaving the LASL boundaries and some is transported off-site with stream channel sediments during heavy runoff. The total population dose received by residents of Los Alamos County in 1977 was estimated to be 11.1 man-rem or about 0.4% of the 3100 man-rem to the same population from background radiation. As no significant pathways could be identified outside the County, the 11.1 man-rem dose also represents the population dose to the inhabitants living within an 80 km radius of LASL who receive an estimated 13 300 man-rem from background radiation.

One means of evaluating the significance of environmental releases of radioactivity is to interpret the exposures received by the public in terms of doses which 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 measurement 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 (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 were theoretically calculated from measured stack releases and atmospheric dispersion models. No exposure to ^{238}Pu, ^{239}Pu, or U was apparent as there was no statistical difference in measurements at off-site locations compared to the regional locations. However, for conservative illustration, the apparent difference in the regional and perimeter concentrations of ^{239}Pu was used to calculate a hypothetical maximum possible dose. The exposures utilized for dose calculations are summarized below:

EXPOSURES TO AIRBORNE RADIOACTIVITY

	Maximum Concentration (pCi/m^3)			
Isotope	**Boundary**	**Maximum Individual**	**Background (pCi/m^3)**	**Comment**
^{3}H (HTO)	1.7×10^{2}	5.1×10^{1}	1.4×10^{1}	Measured Data
^{11}C, ^{13}N, ^{15}O	4.5×10^{4}	4.5×10^{4}	0	Theoretical finite cloud dispersion, 4.4 m decay
^{41}Ar	5×10^{2}	4×10^{2}	0	Theoretical finite cloud dispersion, no decay
^{239}Pu	4.9×10^{-5}	4.9×10^{-5}	1.6×10^{-5}	Measured Data

The maximum boundary and individual doses attributable to these exposures are summarized below with a comparison to DOE Radiation Protection Standards (RPS) for the individual doses:

CALCULATED BOUNDARY AND MAXIMUM INDIVIDUAL DOSES FROM AIRBORNE RADIOACTIVITY

		Maximum Boundary Dose		Maximum Individual Dose		
Isotope	**Critical Organ**	**Location**	**Dose (mrem/yr)**	**Location**	**Dose (mrem/yr)**	**% RPS**
^{3}H (HTO)	Body Water	TA-54	0.42	Airport	0.09	0.02
^{11}C, ^{13}N, ^{15}O	Whole Body	N of TA-53	67	Restaurant N of TA-53	19	3.8
^{41}Ar	Whole Body	N of TA-53	2.1	Townsite N of TA-2	0.9	0.18
^{239}Pu	Lung	Air Sampler	0.06	Air Sampler	0.06	0.004

All other atmospheric releases of radioactivity (see Table XIX) 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 the 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.[10-14] Small quantities of radioactive contaminants transported during periods of heavy runoff have been measured in canyon sediments beyond the LASL boundary. However, no significant exposure pathways from the sediments to humans have been identified.

No radioactivity in excess of normal background concentrations was detected in drinking water, perennial surface water, or ground water at any off-site location.

There are no known significant aquatic pathways or food chains to humans in the local area. Two minor potential foodstuff pathways involving venison and honey have been identified and are discussed in Sec. III.A.5. They have been estimated to result in a maximum of <4 mrem/yr to an individual and are unlikely to actually occur.

Measurements of external penetrating radiation showed no statistically distinguishable doses at any off-site locations that could be attributed to LASL operations. Variations among stations or over time were all within expectable ranges. The location north of TA-53 indicated by theoretical calculations to have the maximum potential exposure rate because of release of gamma-emitting isotopes (69 mrem/yr at boundary and 20 mrem/yr for maximum individual) was not monitored by dosimeters during 1977 but will be added to the routine network in 1978. The nearest routine stations (at LA Airport and TA-21) did not show any distinguishable elevated doses. On-site measurements of above background doses were expected and do not represent potential exposure to the public except in the vicinity of TA-18. Members of the public regularly utilizing the DOE-controlled road which passes by TA-18 could receive as much as about 0.6 mrem/yr of direct gamma and neutron radiation. This value was derived from 1975 data[15] on total dose rates using 1977 gamma doses measured by TLDs and assumptions of exposure time related to typical driving patterns. All of the other facilities generating above-background radiation are located in controlled areas precluding entry by the general public. The on-site station near the laboratory boundary at State Highway 4 recorded a dose of 217 mrem/yr. This has been determined to be because of a localized accumulation of ^{137}Cs on stream channel sediments originating from release of treated effluents upstream. (See Table XVII, DP-Los Alamos and Lower Los Alamos Canyons.)

Cumulative population whole body doses attributable to LASL operations were estimated from measured (^{3}H as HTO) or theoretically calculated (^{11}C, ^{13}N, ^{15}O, and ^{41}Ar) exposures and data on the Los Alamos County population. The Los Alamos County Planning Department estimated 13 500 residents in the Los Alamos townsite and 6000 in the White Rock-Pajarito Acres area. The dose estimates were the following:

1977 WHOLE BODY POPULATION DOSES IN LOS ALAMOS COUNTY

Isotope	Whole Body Population Dose (man-rem)
^{3}H (as HTO)	0.38
^{11}C, ^{13}N, ^{15}O	7.1
^{41}Ar	3.6
Total	11.1
Natural Background	3100

No estimate of population lung dose from plutonium was made because (1) population dose calculations are of interest as a means of estimating genetically significant doses[16], (2) the whole body doses because of plutonium exposure would be much smaller than the lung dose estimated for the maximum individual (0.06 mrem/yr) because translocation from the lung is very small, and, (3) the appropriateness of making whole body population dose estimates from very low dose rates is in question.[17]

The total individual whole body dose because of natural background in Los Alamos County was estimated as 161 mrem/yr, consisting of 127 mrem/yr measured external radiation, an assumed 18 mrem/yr from internal natural radioactivity, and 17 mrem/yr from cosmic neutron radiation.[8] This gives a total population dose of about 3100 man-rem resulting from normally present sources.

The cumulative whole-body population dose to the estimated 98 000 inhabitants of the 80 km circle around Los Alamos because of LASL operations is considered to be the same, 11.1 man-rem, as for Los Alamos County. This is because the next nearest population centers are far enough away that no lab-related concentrations of radioactivity could be detected as a result of much greater dispersion of all isotopes and additional decay during transit time for short-lived isotopes (^{11}C, ^{13}N, ^{15}O, ^{41}Ar). By contrast, the 98 000 inhabitants of the area received an estimated 13 300 man-rem from natural background, assuming average individual doses of about 101 mrem/yr from external x and gamma radiation, 18 mrem/yr for internal natural radioactivity and 17 mrem/yr from cosmic neutron radiation.[8]

Thus, doses potentially attributable to releases of effluents contribute about 0.4% to the total dose received by Los Alamos County residents and about 0.07% to the population within an 80 km radius of the Laboratory.

B. Related Environmental Studies

1. La Mesa Fire

The La Mesa fire, June 16-23, 1977, burned about 15 270 acres of the Santa Fe National Forest, Bandelier National Monument, and LASL lands. The burn included Ponderosa pine, fir, and aspen at higher elevations and along north facing slopes of canyon walls, and piñon-juniper at lower elevations on mesa tops. The light, moderate, and severe burn areas within the Laboratory boundary were mapped using infrared aerial photographs taken after the fire and information from the National Park Service (Fig. 12). The total burn area within the Laboratory was about 2620 acres. The intensity of the burn on Laboratory lands is summarized below:

SEVERITY OF BURN ON LASL LANDS

Degree of Burn	Acres	% of Burn
Light	700	47
Moderate	1090	41
Severe	830	32
	2620	100

The burn within LASL boundaries consumed vegetation in about 20% of the drainage area of Water Canyon and about 23% of the drainage area of Ancho Canyon. Several large runoff events in July from heavy precipitation transported large amounts of ash and soil to the Rio Grande. A study was initiated in early August to determine the extent of soil erosion in 15 sites in the severe burn area and five sites in a control area. Subsequent precipitation and runoff stripped little soil from the study sites. The initial runoff event in July removed most, if not all, of the debris resulting from the fire.

In cooperation with the U.S.F.S., DOE lands were reseeded with a mixture of native grass species (slender wheatgrass, western wheatgrass, hard fescue, blue grama, spike muhley, and sand dropseed) on July 9 and 10. One hundred eighty acres were set aside during seeding operations as natural succession biological study areas. Seeding was done at a rate of approximately 10 lb of seed per acre or 100 seeds per square foot.

2. Waste Burial-Site Surveillance

Several programs for surveillance and evaluation of existing waste burial sites at LASL are presently in a developmental stage. During the past year, measurements of the radionuclide contents of surface soils and vegetation have been completed. Several monitoring methods for detection of water and waste movements from the burial sites are being evaluated for routine use. Evaluation of the existing sites includes use of the monitoring data

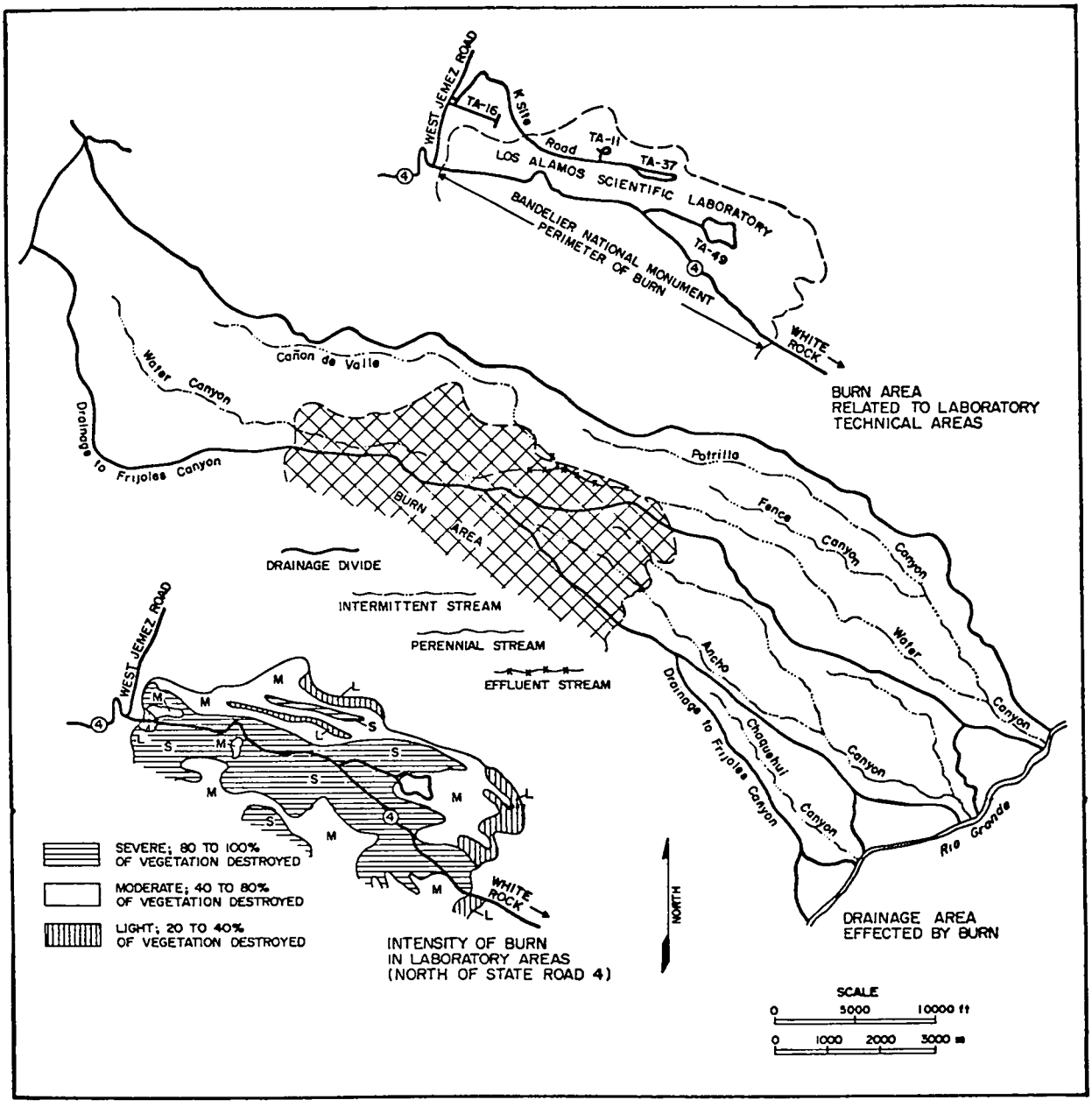


Fig. 12.
La Mesa fire burn areas showing intensity of burn.

coupled with hydrologic and vegetation transport models which are under development for prediction of migration of radionuclides in the surrounding burial media.

Radioactive wastes at Los Alamos Scientific Laboratory are first screened for transuranium element content. Wastes containing greater than 10 nCi of transuranics per gram of waste are placed in retrievable storage. These wastes are placed on special pads in the LASL burial ground at Mesita del Buey (TA-54). Nonretrievable wastes are disposed of in pits dug into the Tshirege member of the Bandelier Tuff. High level beta-gamma wastes are disposed of in special shafts drilled into the Bandelier Tuff. Tritium waste receives special packaging, dependent on the level of activity. Routine tritium waste (5-30 m^3/yr) is packaged in asphalt-lined 115 or 210 ℓ drums. Where significantly large quantities of tritium are contained, the waste is packaged in a 115-ℓ drum which then is sealed inside of an asphalt coated 210-ℓ drum. For very high tritium content wastes, the waste-containing 115-ℓ drum is encased in asphalt in a 210-ℓ drum.

Two monitoring programs have recently been initiated at the LASL radioactive solids waste disposal site at TA-54 (Fig. 3). A soil moisture monitoring program is being used to obtain data describing the changes in water content, with depth and time, in fill material overlying buried waste and in the tuff surrounding waste disposal shafts to a radius of 6 m. The data are used to infer the quantities of moisture penetrating to the depth of the waste material and moving outward from the waste. Information on such moisture movement is required to determine if a hydrologic mechanism for transporting radionuclides out of the disposal emplacement exists.

The data for one hole are presented in Fig. 13. The major variations in water content occur within a meter of the surface, presumably because of spring snowmelt and summer storms. No significant changes occur below 3 m. The decrease in water content with depth may indicate a small downward moisture flux; work is in progress to resolve this question.

Moisture readings are made once a month for each of 10 augered holes; 4 into crushed tuff backfill, 6 into adjoining tuff. Additional boreholes will be drilled and monitored as more pits and shafts are completed. The measurements are made using a neutron soil moisture probe. Fast neutrons emitted by the probe are thermalized by hydrogen atoms in the water molecules, and the return incidence of slow neutrons is electronically converted to a measure of the volumetric water content of the soil surrounding the probe. A computer program compiles, coordinates, analyzes, and graphically displays this information.

A project for collection of meteorological data is in the completion phase. A 40-ft steel tower and an adjoining instrumentation shelter were erected at TA-54. Initial climatological measuring and recording equipment includes three anemometers and three temperature thermistors, a dew point cell, a weighing bucket snow and rain gauge, an IR thermometer, and several soil heat-flow disks. These instruments measure and record wind speed, air temperature, humidity, precipitation, surface tem-

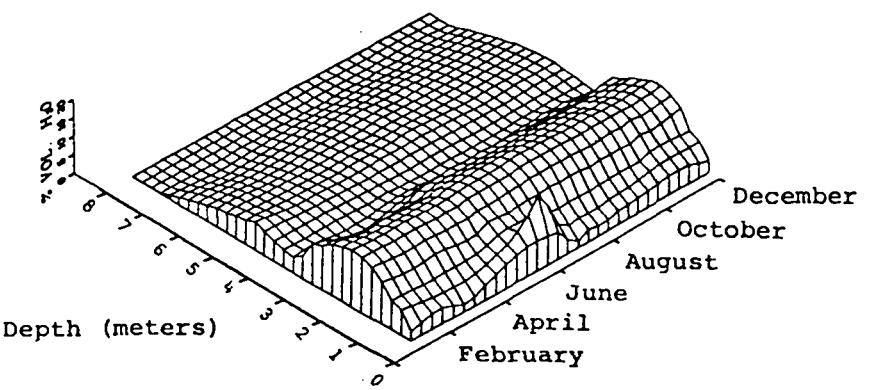


Fig. 13.
Soil moisture monitoring data for bore hole in radioactive solid waste disposal area.

perature, and heat transfer in the soil, respectively. The system will be operated in two modes. Continuous surveillance of wind direction and velocity will provide data for evaluating possible accidental atmospheric releases during site operations, as well as providing information on local climatological phenomena. Secondly, intensive studies are conducted on atmospheric dispersion processes, soil moisture flux, and evaporation and precipitation.

Complementing the development of a monitoring system for LASL solid radioactive waste disposal sites, various geologic investigations have been undertaken, including a horizontal core-drilling project under old disposal pits at TA-54, surface monitoring studies of disposal sites at TA-50 and TA-6 (Fig. 3), and a routine geologic inspection and approval program for new disposal pits or shafts.

3. Long-Term Ecological Effects of Exposure to Uranium at LASL Firing Sites

The long-term ecological consequences of releasing appreciable amounts of natural and depleted uranium to LASL terrestrial ecosystems have been studied during the past three years. Objectives of these studies were to (1) describe the uranium concentrations and distribution at LASL testing sites, as determined by analyzing soil and biota samples; (2) describe small mammal and vegetative communities at selected LASL testing sites and surrounding areas exposed to various amounts and physical forms of uranium; (3) analyze plant and soil invertebrate communities associated with various amounts of uranium at LASL testing sites to determine responses to the chemical toxicity of uranium; (4) evaluate inventory estimates obtained by annuli and isopleth methods, spatial distributions, and particle size correlations of uranium in soils; and (5) determine the relative importance of surface transport of uranium by surface creep, saltation, reflotation (suspension), and surface water runoff.

An estimated 75 000 to 100 000 kg of uranium were expended during conventional explosive tests at several LASL testing areas during 1949-1970. Of this, about 35 000 — 45 000 kg of natural uranium were used during 1949-1954, and 40 000 — 50 000 kg of depleted uranium ($^{235}U/^{238}U$ <0.0072) were used during 1955-1970.[18] Four LASL sites were initially selected for study: three firing sites and a control. E-F site (TA-15) at 2190 m elevation was the location of most (about 66%) uranium expenditure, had relatively high uranium concentrations in soils, and contained several large pieces of corroding uranium. Minie Site (TA-36) at 2100 m elevation was chosen as having potentially moderate uranium concentrations, and Lower Slobovia (LS) (TA-36) at 2000 m was chosen as a potentially low uranium concentration site. The nature of the explosives tests at Minie and LS Sites scattered smaller particles than those at E-F Site. Control sites were at approximately 2000 m and 2190 m elevations. Each study site measured 500 by 500 m.

Results of the first year of study[19] showed that E-F Site soil averaged 2400 ppm of uranium in the upper 5 cm and 1600 ppm at 5-10 cm. Lower Slobovia Site soil from two subplots averaged about 2.5 and 0.6% of the E-F Site concentrations. E-F Site vegetation samples contained about 320 ppm of uranium in November 1974 and about 125 ppm in June 1975. Small mammals trapped in the study areas in November contained a maximum of 210 ppm of uranium in the gastrointestinal tract contents, 24 ppm in the pelt, and 4 ppm in the remaining carcass. In June, maximum concentrations were 110, 50, and 2 ppm in similar samples and 6 ppm in lungs. These data emphasized the importance of reflotation of respirable particles in the upper few millimeters of soil as a contamination mechanism for several components of the LASL ecosystem. Vegetation community analyses and initial results of the soil invertebrate studies did not reveal conclusive differences in the effects of the various gradients of uranium in the study and control sites.

Emphasis during the second year of study[20] was shifted to E-F Site environs, where a polar coordinate sampling pattern was devised for determination of the soil uranium inventory. Samples were taken at the intersections of radii that extended from the detonation point every 45° and concentric circles 10, 20, 30, 40, 50, 75, 100, 150, and 200 m from the detonation point. Duplicate 30 cm deep soil cores were collected with a polyvinylchloride coring tube (2.5 cm i.d.) and later cut into segments corresponding to 0 to 2.5 , 2.5 to 5.0 , 5.0 to 10 , 10 to 15 , 15 to 20 , and 20 to 30 cm depths. Analyses of the 0 to 2.5 cm segments from each sampling point were used to determine the horizontal distribution of uranium from the detonation point (Fig. 14). The uranium distribution with

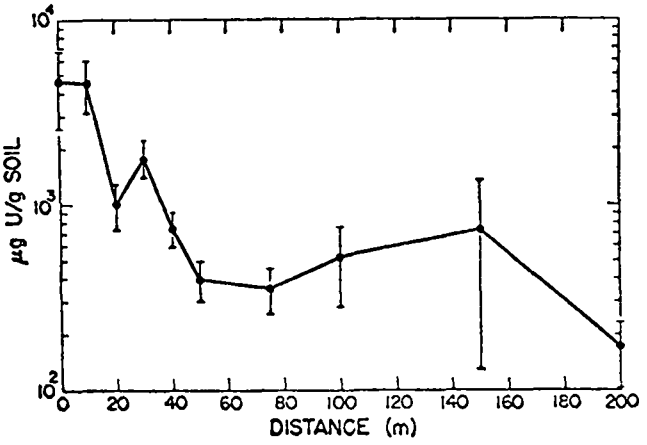


Fig. 14.
Mean surface (0 to 25 mm deep) uranium concentration in soil at E-F Site, 1976.

depth at locations 0, 10, 20, 30, 40, and 50 m from the detonation point (Fig. 15) indicated that uranium has migrated into or penetrated the soil significantly to the maximum sampling depth.

Uranium movement from E-F Site by surface water transport was indicated by the presence of above-background (>0.6-1.2 ppm) concentrations in Potrillo Canyon alluvium to distances of 5 km downstream. The amount of uranium estimated to lie in the E-F Site drainage to as far as 9 km down Potrillo Canyon is 58 kg. Although seemingly large, this amount is <0.1% of the uranium expended at E-F Site during 1943-1973, and it indicates that only minor amounts have moved appreciably. The importance of storm runoff as a transport medium for E-F Site soil uranium was indicated by samples of standing water and runoff obtained during two rainstorms (Table XXV). The solubility, and hence movement, of uranium was greater than generally expected.

The 1977 studies[21] of the uranium inventory within the 0- to 5-cm depth of soil at E-F Site produced two independent estimates, one of 4480 kg within a surface area of 125 660 m² determined by summing the amounts calculated in the annuli of the polar coordinate system, and another of 2970 kg within a surface area of 119 140 m² obtained by calculating areas within uranium concentration isopleths in a 126 000 m² circle centered on the detonation point (Fig. 16) generated by a computer program and their respective median uranium concentrations. The 6000 m² discrepancy in total surface areas resulted from the lack of data from the

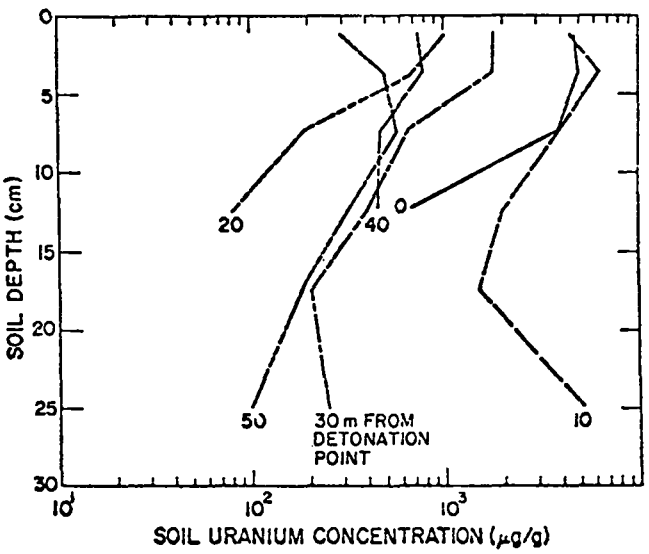


Fig. 15.
Uranium distribution vs soil depth and distance at E-F Site.

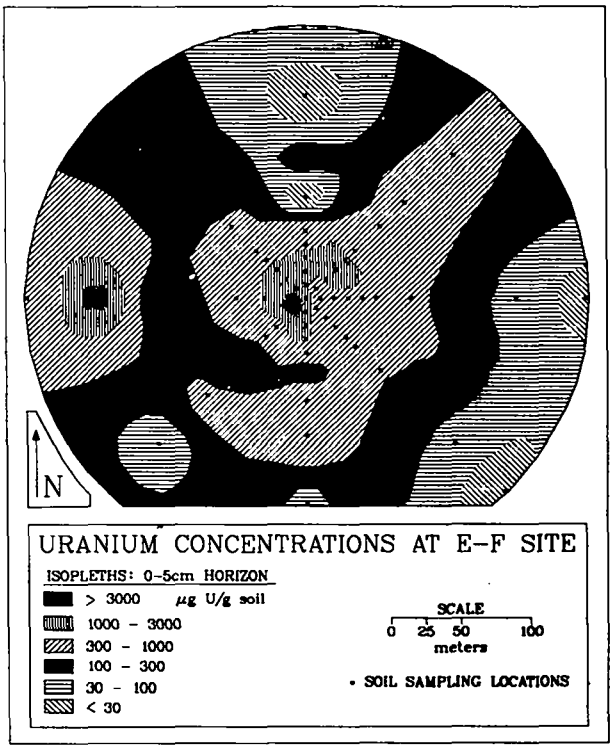


Fig. 16.
Calculated isopleths of uranium concentrations in the 0 to 5 cm soil horizon at E-F Site.

200 m sampling location south of the firing point because that location falls within Potrillo Canyon and prevented extrapolation of the isopleths to that region. If we assume that the 100 to 300 ppm uranium isopleth applied to that area, the two estimates are within 2% of agreement. From these data we have estimated that the uranium inventory in the 0 to 5 cm soil horizon at E-F Site is within the range of 3000 to 4500 kg, not including particles >6 mm in size, which were screened from the samples during processing and sampling.

Spatial variability in sampling for uranium distribution by a polar coordinate system was evaluated by analysis of uranium concentrations in randomly selected duplicate soil cores taken at locations 0.5 m from and parallel to those reported last year. Mean variations for surface (0 to 2.5 cm depth) soils were lowest (18%) in samples collected at 10 m from the detonation point and greatest (96%) at 50 m. Individual values ranged from 7 to 106% and showed no consistent pattern related to distance from the origin of the uranium. Uranium concentrations in deeper (30 cm) soil cores showed that soil sampling results were strongly influenced by the variable deposition of past uranium debris in the form of fragments that ranged from 2 mm to several cm in diameter and by the subsequent variable leaching and corrosion processes that transported uranium to deeper soil profiles and to distant locations by surface water runoff.

Uranium concentrations in six soil size fractions obtained from forty 0 to 5 cm and 5 to 10 cm depth cores showed considerable variation but suggested that small (<53 μm) uranium particles predominated at 10 m from the detonation point; larger (1-2 mm) particles were most important and intermediate-sized (105-500 μm) particles were of secondary importance at 20 to 50 m distances; and most of the uranium at the periphery of the 126 000 m^2 study area was associated with small particles.

Initial results from Bagnold dust collectors maintained for three months at two locations near the E-F Site detonation point indicated that uranium particles in the >100 μm diam range, those expected to move by forces of surface creep and saltation, were most active at the ground surface. Fine particulates with relatively high uranium concentrations predominated in collector heights above 0.5 cm, demonstrating the importance of suspension in the redistribution of uranium.

Uranium concentrations in tissues of deer mice (*Peromyscus maniculatus)* and pocket gophers *(Thomomys bottae)* collected at E-F Site indicated that there was a difference among amounts in several tissue types and that deer mice generally contained higher mean uranium concentrations in their tissues than did pocket gophers. The 1977 results were 2-100 times those measured in similar samples collected during November 1974 and June 1975; however, the range of values was highly variable and reinforced our previous observations that massive sample sizes would be necessary to provide conclusive results. Highest uranium concentrations were in gastrointestinal tract contents with slightly lower values in pelts. Kidneys and livers contained about 5-10% of pelt values, and lungs and carcass samples contained amounts that were slightly above background. These data support our previous conclusion that the greater bioavailability of uranium in the top few mm of soil at E-F Site resulted in greater contamination of the deer mouse population than of the sympatric pocket gopher population. The amounts of uranium in the deer mouse and pocket gopher lung samples were similar to one another and to carcass values, arguing against appreciable inhalation of uranium particles; positive values occurred in only one specimen of each species.

Invertebrate populations in areas of high (2400 - 16 000 ppm) and medium (20 - 80 ppm) uranium concentrations in soils were sampled by pitfall trapping and insect net sweeps to evaluate possible effects of exposure to such levels upon those animals. The overall comparisons of numbers of individuals and numbers of species in the study areas revealed no conclusive evidence of a gross differential response to the areas that contain relatively high uranium concentrations in soils compared to nearby control areas.

4. Plutonium Distribution and Concentration Variability in Canyon Waste Receiving Areas

Special ecology studies on transuranics in the environment began in FY74 to characterize and compare the distribution and transport of plutonium in ecosystem components in the canyon liquid waste receiving areas at Los Alamos. Results of this work as well as site descriptions have been reported in detail in several papers.[22-29]

A major accomplishment of these studies has been the characterization of plutonium concentration variability in several canyon ecosystem components. Design of studies of plutonium is particularly difficult because of the large variability of the data. Assurance of conclusive results from an expensive field effort requires careful design based on good estimates of the mean concentration and its variance.

Several investigators have noted that the coefficient of variation ($c = \sigma/\mu$) is relatively constant over a wide range of concentration. An efficient approach to the design of a plutonium study is to select a value of $\hat{c}$ (a caret denotes estimate of) from the literature, and combine this estimate with the expected concentration for the field study, as demonstrated by Eberhardt.[29] Before realistic values of $\hat{c}$ are taken from the literature, the researcher should have some feeling for the statistical properties of $\hat{c}$.

A Monte Carlo simulation study of the statistical properties of $\hat{c}$ leads us to conclude that a $\hat{c}$ based on less than 5 observations is nearly worthless because the lower confidence bound will always include zero, and that for $\hat{c}$ in the range 0.1 to 2.0, a minimum of 50 observations is necessary before much confidence can be associated with the concentration estimate.

Results of our field studies demonstrated the importance of stream banks in governing the spatial distribution of plutonium in the Los Alamos canyons. Comparison of distributions among canyons with different temporal use histories indicates that the stream banks, which are heavily vegetated in the canyons, not only accumulate effluent radionuclides but limit the rate of radionuclide transport to downstream areas by erosional processes.

There has been considerable movement of plutonium from the soil surface into the soil profile at all our study areas (Table XXVI). In all cases, less than 50 percent of the soil column inventory of plutonium was present in the surface 2.5 cm of soil, indicating that with time, surface inputs of plutonium become less available for horizontal transport by wind and water.

Plutonium-soil particle size relationships[27,28] have led us to the following conclusions:

1. Less than 15 percent of the plutonium and 10 percent of the soil mass is present in readily resuspendable silt-clay soil size fractions ($<53\ \mu m$) in the canyons, even though plutonium concentrations are generally highest in this fraction.

2. Differences in plutonium-soil particle size relationships have an important bearing on the potential for transport by wind and water.

The concentrations of plutonium in Los Alamos vegetation are dependent on the levels of plutonium in associated soils. The relationship between plutonium in soil and vegetation was predictable using the equation:

$$y = 0.25\ X^{1.1};\ n = 9,\ r^2 = 0.85,$$

where y is the concentration of plutonium in vegetation (pCi/g dry weight) and X equals the soils concentration (pCi/g). Mean plant/soil plutonium concentration ratio estimates for native grasses ranged from 0.13 - 0.93, while values for forbs ranged from 0.23 - 0.31. Although these values reflect the low transfer of plutonium to plants under field conditions, they are 10 to 10^6 times higher than ratios derived from greenhouse studies.[30,31] Contamination of plant surfaces with fine soil particles is considered the most likely cause of the high plant/soil ratios observed in the field.

Plutonium in internal organs (i.e., liver, bone, and muscle) from rodents sampled within our study areas generally could not be measured with certainty ($P \leq 0.05$). However, levels in pelt and gastro-intestinal (GI) tract samples were readily measured and can be correlated with plutonium in study areas soils using the equation:

$$y = 0.004X^{0.66},\ n = 8,\ r^2 = 0.90,$$

where y is the concentration in tissue and X is the soil concentration.

More than 95 percent of the plutonium body burden in rodents was associated with pelt and GI tract samples. These data suggest that a physical process such as soil resuspension and/or soil ingestion is the primary mechanism of plutonium transfer to study area rodents.

Concentrations of plutonium in plants and animals from the canyon study sites reflect soil plutonium contamination. We believe that the primary mechanism resulting in contamination of biota is governed by physical rather than

physiological processes. In no case was there clear evidence of trophic level increase as soil plutonium is transferred to biota.

5. Radionuclide Uptake by Vegetable Crops in the Mortandad Canyon Garden Plot During 1976

A garden study was initiated in 1976 to determine the availability of radionuclides to vegetables grown in contaminated soil in Mortandad Canyon. The garden was located on an alluvial fan in an area which has received runoff-transported industrial liquid effluents since 1963. An area of about 200 m^2 was fenced to prevent animal intrusion and diked to prevent further flooding with stream channel water. Garden soil was rototilled to a depth of about 30 cm and fertilized with manure and chemical fertilizers. Soil samples were taken prior to crop seeding to determine the uniformity of radionuclide distribution and the physical-chemical properties of the soil. In 1976, radish, onion, corn, squash, and tomato crops were planted. Samples of crops were harvested at various times during the growing season and were washed using standard food preparation procedures. Soil was also collected from the rooting zone of each sample. This report summarizes preliminary data on the plutonium and cesium concentrations in radishes and tomatoes and the relationship of radionuclide concentrations in plants to those in soils (i.e., concentration ratios).

A summary of the radionuclide concentrations in radish, tomato and soil samples is presented in Table XXVII along with estimates of the concentration ratios. Samples were harvested at various intervals during the growing season and included a 24 day and 37 day post-planting collection for radishes and a 95 day post-planting collection for tomatoes.

In general, soil plutonium and cesium were available to both of these vegetable crops, including edible parts preferred for human consumption. Although it is difficult to make direct comparisons between species because of morphological and physiological differences, the data demonstrate that plutonium levels in edible plant parts were at least 10 times higher in radishes than in tomatoes, while cesium-137 concentrations were about equivalent in edible parts of both species.

In general, highest concentrations of cesium and plutonium were observed in the leaves and stems (tops) of both species with the exception of tomato roots which very likely contained surficial soil despite the wash treatment.

Concentration ratios for garden samples reflect the low bio-availability of cesium and plutonium. However, although we consider these to be low, they are relatively high compared to results from greenhouse studies.[32,33] In the past, we have attributed relatively high concentration ratios to the presence of particulates on external plant surfaces.[34,35] Recent results in our laboratory, using titanium, aluminum, and tin as indicators of soil contamination on plants, indicate that less than 70 percent of the soil on plant surfaces can be removed by sonic cleaning methods.

In conclusion, these results demonstrate that the cesium and plutonium in garden soils can be transferred to edible portions of radish and tomato crops and that standard food washing procedures do not remove all the contamination. Available data demonstrate that radishes contain at least 10 times higher plutonium concentrations than tomato fruit when grown on the same soil with the same level of contamination. The vegetative plant parts generally contain higher plutonium and cesium concentrations than edible parts; however, time series data for radishes indicate that plutonium concentrations in vegetative parts decrease with increasing plant maturity and approach the levels in the radish.

Cesium and plutonium in garden soils are not readily available to radish and tomato crops and, in particular, to edible plant parts, as inferred from concentration ratios. However, the concentration ratios observed in the garden study are high relative to greenhouse data and may indicate a greater bioavailability of effluent radioactivity or the inability to remove surficial contamination with standard food washing procedures.

6. Fenton Hill Site (TA-57) Surface and Ground Waters

The chemical quality of surface and ground water in the vicinity of the Fenton Hill site, LASL's Hot Dry Rock Geothermal Energy Experiment (≃30 km W of Los Alamos, Fig. 17), has been determined for use in geohydrology and environmental studies. The results of past studies and detailed data have been reported elsewhere.[36,37,38]

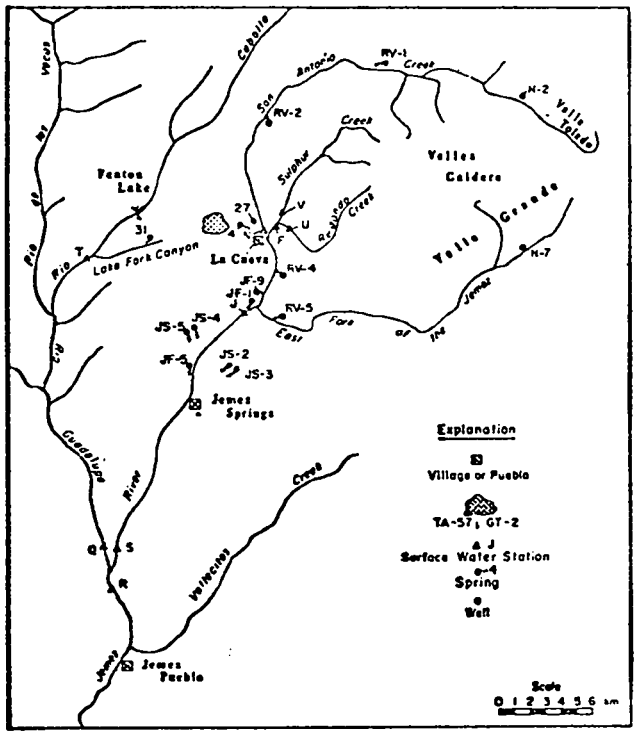


Fig. 17.
Water sampling locations in vicinity of Fenton Hill (TA-57) Geothermal Site.

Table XXVIII summarizes the 1977 data on 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 well that is abandoned. It also summarizes the quality of water from two ponds that contain water used in experiments related to the development of the circulation loop in the hot dry rock at a depth of 3000 m below the land surface. There has been no significant change in the quality of water from previous analyses.

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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. LASL operations pertaining to environmental quality control are conducted in accordance with the directives and procedures contained in DOE's Health and Safety Manual, Chapters 0510, 0511, 0513, 0524, and 0550.

In the case of radioactive materials in the environment, the standards contained in Manual Chapter 0524 are used as a basis for evaluation. However, the DOE standard for uranium in water (1500 and 60 mg/ℓ for controlled and uncontrolled areas, respectively) does not consider chemical toxicity. Therefore, for the purposes of this report, the more restrictive standards[40] of the International Commission on Radiological Protection (ICRP) for uranium in water (60 mg/ℓ for an occupational 40-h week, and 1.8 mg/ℓ for a non-occupational 168-h week) are preferred. For atmospheric uranium, the DOE 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 the environment that is determined to result in whole body or organ doses equal to the Radiation Protection Standards (listed in Table A-II) for internal and external exposures.

Obviously, there are uncertainties in relating the RCG to the Radiation Protection Standards. Thus, common practice and stated DOE 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." For chemical pollutants in water supply, the controlling standards are those promulgated by either the EPA or the New Mexico State Environmental Improvement Agency (Table A-III).

Radioactivity in public water supply is governed by EPA regulations contained in 40CFR141. These regulations provide that combined radium-226 and radium-228 shall not exceed 5 pCi/ℓ and gross-alpha activity (including radium-226 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. (Fed. Reg. Vol. 41, No. 133, July 9, 1976).

B. Sampling Procedures and Statistical Treatment of Data

1. Thermoluminescent Dosimeters

Harshaw TLD-100® LiF chips, 6.4 mm square by 0.9 mm thick, were used in the LASL TLD network dosimeters. The chips were annealed for 1 hr at 400°C followed by 1 hr at 100°C before use in the dosimeter. The TLD reader was an Eberline model TLR-45 adjusted for 15s, 140°C preheat and 15s, 240°C integration cycles. Incandescent lighting was used exclusively during all phases of annealing, dosimeter preparation, and read-out. Three chips were heat sealed in a black polyethylene envelope and then placed in an opaque, thick walled (3 mm) 7 mℓ polyethylene vial. This assembly constituted one dosimeter. For each annealed batch an independent calibration was determined. Six dosimeters were exposed to ^{60}Co radiation at the nominal levels of 0, 10, 20, 40, 80, and 160 mR. A factor of 1 rem (tissue) = 1.061 R was 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 was used as recommended by the International Commission on Radiation Protection.[41] A method of weighted least squares linear regression was used to determine the relationship between TLD reader units and dose (weighting factor was $1/s^2$).[41] Control dosimeters were used to compensate for latent thermoluminescence and doses in transit.

In order to limit the magnitude of the uncertainty of the doses calculated for each of the LASL TLD network sites, the LiF chips used in the program were selected in the following manner. All candidate chips were exposed to 500 mR. Chips which read outside the range $\bar{y} \pm 2s$ were culled ($\bar{y}$ = mean light count reading, s = standard deviation). As a result of this screening procedure, the variation of values of the quantity s/y was less than 6% for the remaining chips (y = individual readings).

Although the integration cycle for individual dosimeters was 13 wk, and quarterly doses were calculated for the purpose of observing possible trends in the exposure at each site, the total annual dose at each site is more useful for comparison among sites and for calculating population dose contributions. To calculate these annual doses the calibration data from each of the 13 wk TLD sets were combined. The result of this combination was a regression line obtained from 24 points, four at each of six nominal levels of irradiation.[42] The data from the four 13 wk dosimeters at each site were then pooled. Since each dosimeter contained three chips, three replicate sets were formed using the light counts from one chip in each 13 wk dosimeter per replicate. The light counts in each replicate were summed, appropriate background counts subtracted, and total annual dose calculated along with upper and lower limits (at the 95% confidence level).[43] This method includes the sources of variance in the calibration data as well as in the site dosimeter data in the calculation of the uncertainty of the annual dose. The average doses reported for the three categories of TLD stations are the arithmetic means (and the 2σ deviation of those means) of the total annual site doses in each category.

2. Air Sampling.

Samples were collected at 30 continuously operating stations over 2-week periods during 1977. High volume positive displacement air pumps with

TABLE A-I

DOE 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^{-3}	3000
^{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^{-5}	20
^{238}Pu	7×10^{-14}	5×10^{-6}	5
^{239}Pu[d]	6×10^{-14}	5×10^{-6}	5
^{241}Am	2×10^{-13}	4×10^{-6}	4
	(pg/m^3)[c]		(mg/ℓ)
U, natural[c]	6.1×10^{6}	2×10^{-5}	60
			1.8 (ICRP[e])

CONCENTRATION GUIDES 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}
^{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/m^3)[c]		(mg/ℓ)
U, natural[c]	1.8×10^{8}	5×10^{-4}	1500
			60 (ICRP[e])

[a]This table contains the most restrictive CGs for nuclides of major interest at LASL (DOE 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 DOE "uranium special curie" by using the factor 3.3×10^{-18} pCi/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

DOE RADIATION PROTECTION STANDARDS FOR EXTERNAL AND INTERNAL EXPOSURES

Individuals and Population Groups in Uncontrolled Areas

Type of Exposure	Annual Dose Equivalent or Dose Commitment (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 IN WATER SUPPLY (MCL) FOR INORGANIC CHEMICALS[a]

Contaminant	Maximum Level (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

[a]USEPA National Interim Primary Drinking Water Regulations (40CFR141-, 201-207, Fed. Reg. 40, -59566-59588, Dec. 24, 1975) and NMEIA 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 58.4 to 63.8°F.

flow rates of approximately 3 ℓ/s were used. Atmospheric aerosols were collected on 79 mm diam polystyrene filters. Part of the total air flow (~2 mℓ/s) was passed through a cartridge containing silica gel to adsorb atmospheric water vapor for tritium analyses. Air flow rates through both sampling cartridges were measured with variable-area flow meters, and sampling times were recorded.

Gross-alpha and gross-beta activities on the biweekly air filters were measured with a gas-flow proportional counter on collection day and again 7 to 10 days after collection. The first count was used to screen samples for inordinate activity levels. The second count (made after adsorbed, naturally occurring, radon-thoron daughters had reached equilibrium with the long-lived parents) provided a record of long-lived atmospheric radioactivity.

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

After being measured for gross-alpha and gross-beta activities, the biweekly filters for each station were cut in half. The first group of filter halves were then combined and dissolved to produce composite 6- or 8-wk samples for each station. The second group of filter halves was saved for uranium analysis.

Plutonium was separated by anion exchange from the solution. For 11 selected stations, the eluent solutions from the plutonium separation were combined to represent 12- or 14-wk samples. For each of the 11 stations, americium was then separated from the composite samples by cation exchange. The purified plutonium and americium samples were separately electro-deposited 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 were integrated, and the concentration of each

radionuclide in its respective air sample was calculated. This technique does not differentiate between ^{239}Pu and ^{240}Pu.

Uranium analyses were made on the second group of filter halves, which represented 12- or 14-wk samples. The analyses were done by neutron activation analysis, which is described in Appendix C.

Silica gel cartridges from the 29 air sampling stations were analyzed biweekly for tritiated water. The cartridges contained a small amount of 'indicating' gel at each end to indicate desiccant oversaturation. During cold months of low absolute humidity, sampling flow rates were increased to ensure collection of enough water vapor for analysis. Water was distilled from each silica gel sample, yielding a 2-wk average atmospheric water vapor sample. An aliquot of the distillate was then analyzed for tritium by liquid scintillation counting.

On May 23, 1977, five air sampling stations (6. Golf Course, 8. Diamond Drive, 10. Fuller Lodge, 14. Acorn Street, and 28. Booster P-1) were eliminated from the air sampling network. These stations were extremely close to other sampling locations and so were superfluous. A new sampler at TA-15, near sites where experiments utilizing high explosives are performed, was added to the sampling network on August 1, 1977. This sampler will provide data not now gathered for the southern portion of the Laboratory's interior and will be useful for monitoring emissions from the explosive testing. Also, starting on March 28, 1977, the composite period for plutonium analyses was increased from 6 or 8 wk to quarterly. This was done to increase the amount of analyte, since >50% of the plutonium analyses done on the 6- or 8-wk composites were near or below the analytical detection limit.

Station and group means were weighted for the length of each sampling period and for the air volume samples. The means were calculated using the following equation.[44]

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

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 1977 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.

The standard deviations for station and group means were similarly weighted by using the following equation.

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

where

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

Parenthetical values for the maximums and minimums represent twice the propagated measurement uncertainties (2σ) associated with the reported maximum or minimum value.

Measurements of the air particulate samples required 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-III). Individual measurements not uncommonly resulted 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 or negative 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. To provide an indication of the precision of the numerical value, an additional value for maximum and minimum concentrations is included in parentheses immediately following the primary numerical value. The parenthetical value indicates the 95% confidence range for the primary value; i.e., twice the square root of the variance, or 2σ.

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 on-site stations. Surface and ground water grab samples are taken one to three 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 through a Whatman #2 filter. Samples for trace constituents in the water supply were 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 on-site stations.

Soil samples were 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 were combined to form a composite sample for radiochemical analyses. Sediment samples were collected from dune buildup behind boulders in the main channels of perennially flowing streams. Samples from the beds of intermittently flowing streams were collected across the main channel. The soil and sediment samples were analyzed for gross-alpha and gross-beta activities, total uranium and ^{238}Pu and ^{239}Pu. Moisture distilled from the soil and drain sediment samples at TA-55 was analyzed for ^{3}H.

The average concentrations of radionuclides and chemical constituents are reported for a number of individual analyses in Tables XI through XIV and Tables XVI and XVII. 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 parenthetical value following the primary value represents twice the standard deviation of the distribution of observed values, or the analytical variation for individual result.

C. Analytical Chemistry Methods

1. Procedures

a. Plutonium and Americium. Soil and sediment samples are dried, sieved through <1.7 mm screens, 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 1**N** $NaNO_2$ added to ensure that Pu is in the tetravalent state. The solution is passed through a pre-conditioned 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.

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 non-aqueous solvent-anion exchange step separates the rare earth elements, other actinides, and Ra from Am. Eluate from this column is 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 for counting.

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 the 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 Beckman LS-200 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 20% HDEHP in toluene. Yttrium is back extracted into 3N 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 (OWR). 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 $^{238}U\ (n,\gamma)\ ^{239}U \rightarrow {}^{239}Np + \beta$. 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. All U results in soils were obtained by this method.

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. 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.

A paper has been submitted for publication which compares these two techniques with the fluorimetric analysis of U.[45] The latter method has been used for U analysis of surveillance standards in the past.

g. Stable Elements. Mercury, As, Ba^{++}, Cd^{++}, Cr, Pb^{++}, and Se are analyzed by atomic absorption spectrophotometry. Mercury is done by the Perkin-Elmer cold vapor technique. Arsenic and Se are analyzed in a graphite furnace using Ni to stabilize the elements.[46] Standard chemical methods were used for analyses of SiO_2, Ca^{++}, Mg^{++}, Na^{+}, HCO_3^-, $SO_4^=$, Cl^-, TDS, and total hardness. Nitrates were determined using the colorimetric method and F^- by the specific ion electrode method.

2. 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 fills 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 Environmental Protection Agency 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 and the International Atomic Energy Agency are used to evaluate the uranium analysis procedures. Internal standards are prepared by adding known quantities of analyte to blank matrix materials.

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.

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 (x_i) by the uncertainty associated with it (σ_i).

$$\bar{x} = \frac{\Sigma_i\, x_i/\sigma_i^2}{\Sigma_i 1/\sigma_i^2}$$

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

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

These calculated values are presented in Table C-I. 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, whereas most of the environmental samples were approaching the limits of detection.

Analysis of blanks provides a criterion to judge the probability that samples were contaminated during the analysis. Table C-II presents weighted means and standard deviations of the absolute quantity of analyte reported in blank materials analyzed during 1977.

3. Limits of Detection

Data from the analysis of blanks also provide a means of calculating limits of detection for the various procedures. Table C-III 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-II). For tritium, the detection limit is merely 2σ 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

TABLE C-I

ANALYTICAL CAPABILITIES EVALUATED FROM QUALITY CONTROL STANDARDS

Analyses	No. of Samples	R* (Weighted Mean) $\bar{x} \pm \sigma$
Tritium	15	0.99 ± 0.12
^{137}Cs	22	0.96 ± 0.29
^{238}Pu	12	0.93 ± 0.17
^{239}Pu	42	0.91 ± 0.14
^{241}Am	17	1.01 ± 0.14
Gross-alpha	15	0.98 ± 0.27
Gross-beta	15	0.89 ± 0.21
Uranium (Epithermal activation)	16	0.97 ± 0.06
Uranium (Delayed neutron)	26	0.97 ± 0.03

*$R = \frac{\text{Reported Quantity}}{\text{Known Quantity}}$

TABLE C-II

QUANTITY OF CONSTITUENT REPORTED IN BLANKS

Analyses	No. of Samples	Quantity (Weighted Mean) $\bar{x} \pm \sigma$	Units
^{137}Cs	13	-0.15 ± 9	pCi
^{238}Pu	44	0.0018 ± 0.013	pCi
^{239}Pu	20	0.0012 ± 0.007	pCi
^{241}Am	21	0.04 ± 0.04	pCi
Uranium (Delayed neutron)	4	15 ± 6	ng
Uranium (Epithermal activation)	153	25 ± 12	ng

TABLE C-III

DETECTION LIMITS FOR ANALYSES OF TYPICAL ENVIRONMENTAL SAMPLES

Parameter	Approximate Sample Volume or Weight	Count Time	Concentration
Air Sample			
Tritium	3 m	100 min	10^{-12} μCi/mℓ
^{238}Pu	1.2×10^4 m³	8×10^4 sec	2×10^{-12} μCi/mℓ
^{239}Pu	1.2×10^4 m³	8×10^4 sec	10^{-12} μCi/mℓ
^{241}Am	2.5×10^4 m³	8×10^4 sec	2×10^{-12} μCi/mℓ
Gross-alpha	3.8×10^3 m³	100 min	3×10^{-16} μCi/mℓ
Gross-beta	3.8×10^3 m³	100 min	3×10^{-16} μCi/mℓ
Uranium (Delayed neutron)	2.5×10^4 m³		1 pg/m³
Water Sample			
Tritium	0.005 ℓ	100 min	7×10^{-7} μCi/mℓ
^{137}Cs	0.5 ℓ	5×10^4 sec	4×10^{-8} μCi/mℓ
^{238}Pu	0.5 ℓ	8×10^4 sec	9×10^{-12} μCi/mℓ
^{239}Pu	0.5 ℓ	8×10^4 sec	3×10^{-11} μCi/mℓ
^{241}Am	0.5 ℓ	8×10^4 sec	2×10^{-10} μCi/mℓ
Gross-alpha	0.9 ℓ	100 min	1×10^{-9} μCi/mℓ
Gross-beta	0.9 ℓ	100 min	5×10^{-9} μCi/mℓ
Uranium (Delayed neutron)	0.025 ℓ		1 μg/ℓ
Soil Sample			
Tritium	1 kg	100 min	0.003 pCi/g
^{137}Cs	100 g	5×10^4 sec	10^{-1} pCi/g
^{238}Pu	10	8×10^4 sec	0.003 pCi/g
^{239}Pu	10	8×10^4 sec	0.002 pCi/g
^{241}Am	10	8×10^4 sec	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

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-III 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 significantly 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-III, 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.

D. Methods for Dose Calculations

1. Airborne Tritium

The dose resulting from continuous inhalation of tritiated water vapor was calculated using the following equation.

$$D(t) = 51\ CI_a f_a Et/\gamma m,$$

where

D(t) = dose equivalent delivered during continuous exposure time t(days), in rem
51 = $(1.6 \times 10^{-6}$ erg/MeV)$(8.64 \times 10^4$ s/day)$(3.7 \times 10^4$ dis/s-μCi)/(100 erg/g-rad)
C = average airborne concentration, in μCi/mℓ
I_a = average air intake rate
$I_a = 2 \times 10^7$ mℓ/day (Ref. 47)
f_a = fraction of inhaled material reaching organ of interest
f_a = 1 for tritium (oxide) (Ref. 47)
E = effective energy deposition per disintegration, including the quality factor for dose equivalent conversion
E = 0.010 MeV-rem/dis-rad (Refs. 47,48)
t = duration of exposure, in days
λ = effective elimination rate, in day^{-1}
$\lambda = 0.069\ day^{-1}$ (Ref. 48)
m = mass of organ of interest, in g
$m = 4.3 \times 10^4$ g for body water (Ref. 47).

Therefore,

$$D(t) = 1.2 \times 10^6 \text{ for inhalation.}$$

Because skin absorption of tritiated water vapor is approximately equal to the amount of tritiated water inhaled,[48] the total dose because of ingestion of airborne tritiated water vapor becomes

$$D(t) = 2.4 \times 10^6\ C.$$

2. 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-sec half-lives, respectively. Neutron reactions with air at the Omega West reactor form ^{41}Ar (1.8 h half life). The concentrations of these isotopes at the appropriate site boundary were calculated using the annual average meteorological dispersion coefficient

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

and the source term Q. The dose was calculated using semi-infinite cloud assumptions and was then corrected for cloud size. The gamma dose rate in a semi-infinite cloud can be represented by the equation[49]

$$\gamma_\infty^D(x,y,o,t) = 0.25\ \bar{E}\gamma\ X(x,y,o,t),$$

where

$\gamma_\infty^D(x,y,o,t)$ = gamma dose rate (rad/sec) to a person located at point x,y at ground level and time t
$\bar{E}\gamma$ = average gamma energy per decay (MeV)
X(x,y,o) = plume concentration in curies/m^3 at time t.

Dose rate corrections for estimated plume size (if the cloud cannot be construed to be semi-infinite) were taken from standard graphical compilations.[49] $\bar{E}_\gamma$ was 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 was used.[50]

3. Airborne Actinides

Lung dose calculations were made for potential inhalation of the actinides and were based upon the following assumptions.

1. All of the airborne plutonium and americium was highly insoluble and therefore behaved according to the model for Class Y materials, as defined by the ICRP Task Group on Lung Dynamics.[51]
2. All of the airborne plutonium and americium particles were in the size range of 0.01- to 0.1-μm dia, for which deposition in the pulmonary region is maximum.[52]

The following equation was used to calculate lung doses resulting from inhalation of plutonium or americium.

$$D(t) = 51\, CI_a f_a f_r ET/\lambda m\left(1 - \frac{1-e^{-\lambda t}}{\lambda t}\right),$$

where

C and I_a are as defined before

f_a = 0.7 (max) for the pulmonary region (Ref. 51)
f_r = fraction of pulmonary deposition undergoing long-term retention
f_r = 0.6 for actinides (Class Y) (Ref. 51)
E = 53 MeV-rem/dis-rad for ^{239}Pu
E = 57 MeV-rem/dis-rad for ^{238}Pu
E = 57 MeV-rem/dis-rad for ^{241}Am (Ref. 47)
λ = mean clearance rate, in day^{-1}
λ = 0.0014 day^{-1} for actinides (Class Y) from the pulmonary region (Ref. 52)
m = 1000 g for the lungs (Ref. 47).

All other quantities are as defined previously for the airborne tritium calculation. Therefore,

D(365 days) = 2.4×10^{10} CE
= 1.3×10^{12} C for ^{239}Pu
= 1.35×10^{12} C for ^{238}Pu
= 1.4×10^{12} C for ^{241}Am.

Because many of the factors involved in the above equation as well as the measurements of airborne concentrations are valid to only one significant figure, the dose calculations were rounded off accordingly.

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TABLE I

MEANS AND EXTREMES OF TEMPERATURE AND PRECIPITATION

CLIMATOLOGICAL SUMMARY 1910-1974[a]

	Temperature (°C)							Precipitation Total (mm)										Mean No. of Days		
	Means			Extremes				Rain[c]					Snow/Frozen Precipitation							
Month	Max	Min	Mo Mean	High	Yr	Low	Yr	Mean	Daily Max	Yr	Mo Max	Yr	Mean	Daily Max	Yr	Mo Max	Yr	Precip ≥2.5 mm	Max[b] Temp ≥26.7°C	Min[b] Temp ≥−9.4°C
Jan	3.9	−7.9	−2.0	17.8	1963	−27.8	1963	21.21	62.23	1916	171.45	1916	246.1	381.0	1913	989.2	1949	2	0	8
Feb	6.1	−5.8	0.1	18.9	1936	−25.6	1951	17.38	26.67	1915	61.89	1948	204.8	330.2	1915	604.2	1948	2	0	6
Mar	9.4	−3.4	3.1	21.7	1971	−19.4	1948	25.38	57.15	1916	104.4	1973	261.3	457.2	1916	938.8	1973	3	0	3
Apr	14.6	1.0	7.8	26.7	1950	−15.0	1925	24.69	36.83	1969	117.86	1916	103.9	304.8	1958	853.4	1958	3	0	0
May	19.9	6.0	12.9	31.7	1935	−4.4	1938	32.16	45.72	1929	113.54	1929	19.7	228.6	1917	431.8	1917	3	1	0
Jun	25.3	10.9	18.1	33.9	1954	−2.2	1919	34.64	34.80	1931	141.49	1913	0.0	0.0	---	0.0	---	3	14	0
Jul	26.9	12.9	19.9	35.0	1935	2.8	1924	86.06	70.61	1968	202.69	1919	0.0	0.0	---	0.0	---	8	19	0
Aug	25.4	12.3	18.9	33.3	1937	4.4	1947	94.53	57.40	1951	283.97	1962	0.0	0.0	---	0.0	---	8	12	0
Sept	22.4	8.9	15.7	34.4	1934	−5.0	1936	50.02	56.13	1929	147.07	1941	4.9	152.4	1913	152.4	1913	5	5	0
Oct	16.7	3.2	9.9	27.8	1930	−8.9	1970	41.31	88.39	1919	171.96	1957	36.9	228.6	1972	228.6	1972	3	0	0
Nov	9.4	−3.1	3.2	20.6	1937	−20.0	1957	17.77	37.08	1931	83.82	1957	126.4	335.6	1931	876.3	1957	2	0	2
Dec	4.9	−6.8	−1.0	16.7	1933	−23.3	1924	23.01	34.29	1965	72.39	1965	266.8	457.2	1915	1049.0	1967	3	0	6
Year	15.4	2.3	8.9	35.0	1935	−27.8	1963	468.16	88.39	1919	283.97	1952	1270.8	457.2	1915	1049.0	1967	45	51	25

CLIMATOLOGICAL SUMMARY 1977[a]

	Temperature (°C)					Precipitation Total (mm)						
	Means			Extremes		Rain[c]		Snow/Frozen Precipitation		No. of Days[b]		
Month	Max	Min	Mo Mean	High	Low	Total	Daily Max	Total	Daily Max	≥2.5 mm	≥26.7°C	≥−9.4°C
Jan	2.4	−10.9	−4.3	8.9	−17.8	35.1	11.9	365.8	119.4	4	0	22
Feb	7.2	−6.6	0.3	14.4	−12.2	2.3	1.0	25.4	12.7	0	0	6
Mar	8.8	−5.3	1.8	16.1	−13.3	5.3	3.8	0	0	1	0	7
Apr	15.0	1.6	8.3	22.2	−10.6	60.2	14.5	101.6	63.5	7	0	1
May	19.9	6.0	13.0	30.0	1.7	25.9	16.8	0	0	2	2	0
Jun	27.3	12.1	19.7	32.2	7.2	27.7	11.9	0	0	4	22	0
Jul	26.2	12.4	19.3	31.7	9.4	85.1	13.2	0	0	11	16	0
Aug	25.7	13.2	19.4	32.8	9.4	130.0	28.4	0	0	10	13	0
Sept	23.0	9.7	16.3	30.	5.6	10.2	5.8	0	0	1	4	0
Oct	18.4	3.7	11.1	24.4	−2.8	3.8	3.0	0	0	1	0	0
Nov	11.0	−1.6	4.7	17.2	−10.6	35.6	22.9	50.8	50.8	2	0	1
Dec	7.5	−4.2	1.7	15.0	−12.8	3.6	2.0	20.3	12.7	0	0	3
Year	16.0	2.5	9.3	32.8	−17.8	424.8	28.4	563.9	119.4	43	57	40

[a]Los Alamos, New Mexico; Latitude 35°32' North, Longitude 106°19' West; Elevation 2260 m.
[b]26.7°C-80°F; −9.4°C-15°F.
[c]Includes liquid water equivalent of frozen precipitation.

TABLE II

ANNUAL THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station Location	Coordinates	Annual Dose: Dose mrem	95% Conf Interval mrem	95% Conf Interval percent
Regional Stations	(28-44 km)	Uncontrolled Areas		
Española		90.4	3.5	3.9
Pojoaque		103.9	3.6	3.5
Santa Fe		90.8	3.5	3.9
Regional Average		95.0 ± 15.4		
Perimeter Stations	(0-4 km)	Uncontrolled Areas		
Barranca School	N180 E130	131.3	3.8	2.9
Cumbres School	N150 E090	124.1	3.8	3.1
Golf Course	N160 E060	131.9	3.8	2.9
Arkansas Avenue	N170 E020	134.9	3.8	2.8
Diamond Drive	N130 E020	130.6	3.8	2.9
48th Street	N110 E000	144.8	4.0	2.8
Fuller Lodge	N110 E090	138.4	4.0	2.9
Acorn Street	N100 E110	123.0	3.8	3.1
LA Airport	N110 E160	140.7	4.0	2.8
Bayo Canyon S.T.P.	N110 E260	131.4	3.8	2.9
Bandelier Lookout	S270 E200	129.5	3.9	3.0
Pajarito Acres	S210 E370	99.8	3.6	3.6
White Rock S.T.P.	S090 E430	120.5	3.8	3.2
Pajarito Ski Area	N130 W180	130.5	3.8	2.9
Gulf Station	N100 E100	111.6	3.6	3.2
Royal Crest	N080 E080	111.6	3.6	3.2
Perimeter Average		127.2 ± 23.5		
On-Site Stations		Controlled Areas		
TA-21	N090 E170	129.0	3.8	3.0
State Hwy 4	N070 E350	217.0	4.9	2.3
Well PM-1	N030 E310	139.0	4.0	2.9
TA-53	N040 E230	123.2	3.8	3.1
TA-53	N070 E160	131.4	3.8	2.9
TA-53	N060 E190	157.3	4.1	2.6
TA-53	N060 E200	176.5	4.3	2.4
TA-53	N060 E220	470.1	10.0	2.1
TA-53	N050 E230	159.7	4.1	2.7
TA-2	N080 E100	130.0	3.8	2.9
TA-2	N080 E110	139.9	3.9	2.8
TA-2	N080 E120	166.3	4.2	2.5
TA-6	N060 W050	124.4	3.8	3.1
TA-16	S030 W080	128.2	3.8	3.0
TA-49	S100 E040	119.6	3.7	3.1
TA-33	S250 E230	137.8	3.9	2.8
Booster P-1	S100 E300	133.0	3.9	2.9
TA-18	S040 E190	136.0	3.9	2.9
TA-18	S030 E190	136.9	3.9	2.9
TA-18	S040 E200	243.5	5.5	2.3
TA-18	S060 E190	162.8	4.1	2.5
TA-18	S050 E170	142.0	4.0	2.8
TA-52	N020 E170	122.0	3.8	3.1
TA-35	N040 E110	137.1	4.0	2.9
TA-35	N030 E110	143.3	4.0	2.8
TA-35	N030 E100	139.0	4.0	2.9
TA-3	N040 E010	149.3	4.0	2.7
TA-3	N060 E010	609.2	13.4	2.2
TA-3	N050 E020	204.1	4.9	2.4
TA-3	N050 E040	131.4	3.8	2.9
On-Site Average		174.5 ± 209.8		

TABLE III

REGIONAL AVERAGE BACKGROUNDS ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS

Radioactive Constituent	Activity (10^{-15} μCi/mℓ)		
	EPA[a]	LASL[b]	CG[c]
Gross α[d]	Not reported	1.2 ± 0.1	60
Gross β[e]	83	85 ± 5	1×10^5
^{241}Am	Not reported	0.004 ± 0.004	2×10^2
^{238}Pu	0.0018 ± 0.0018	0.0018 ± 0.0015	70
^{239}Pu	0.0199 ± 0.0100	0.013 ± 0.002	60
Tritium	Not reported	11 000 ± 2200	2×10^8
Uranium	0.0408 ± 0.0300 (120 ± 88)[f]	0.065 ± 0.012 (200 ± 37)[f]	7×10^4

[a]U. S. Environmental Protection Agency data.
[b]Annual averages for 1973-1976.
[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/m^3.

TABLE IV

LONG-LIVED ATMOSPHERIC GROSS-BETA CONCENTRATIONS FOLLOWING CHINESE NUCLEAR TEST ON SEPTEMBER 17, 1977

Sampling Period	Gross-Beta (10^{-15} μCi/mℓ)	
	OHL	Española
9/17 - 9/19	81 ± 11	83 ± 11
9/19 - 9/20	65 ± 9	88 ± 12
9/20 -9/21	133 ± 17	99 ± 13
9/21 - 9/22	180 ± 20	260 ± 30
9/22 - 9/23	127 ± 16	43 ± 6
9/23 - 9/26	7600 ± 1000	4600 ± 600
9/26 -9/27	2200 ± 300	3100 ± 400
9/27 - 9/28	180 ± 20	400 ± 50
9/28 - 9/29	2800 ± 400	1090 ± 140
9/29 -9/30	2700 ± 300	1800 ± 200
9/30 - 10/3	2200 ± 300	1800 ± 200
10/3 - 10/4	640 ± 80	460 ± 60
10/4 - 10/5	630 ± 80	500 ± 60

TABLE V

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

Station Location	Coordinate	Total Air[b] Volume (m^3)	Gross-Alpha Concentrations-fCi/m^3 (10^{-15} μCi/mℓ)						Gross-Beta Concentrations-fCi/m^3(10^{-15} μCi/mℓ)					
			Number of Biweekly Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]	Number of Biweekly Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]
Regional Stations (28-44 km) - Uncontrolled Areas														
1. Española	---	94 086	26	3	2.8 ± 1.4	−0.5 ± 0.6	1.2 ± 1.5	2.0	26	0	1900 ± 500	36 ± 10	197 ± 72	2.0
2. Pojoaque	---	74 253	26	2	6.1 ± 2.8	0.1 ± 0.6	1.7 ± 2.3	2.9	26	0	1800 ± 400	28 ± 8	213 ± 621	2.3
3. Santa Fe	---	91 124	19	2	4.6 ± 2.0	0.1 ± 0.6	1.3 ± 2.9	2.2	19	0	700 ± 180	27 ± 6	156 ± 433	1.7
Regional Group Summary		259 463	71	7	6.1 ± 2.8	−0.5 ± 0.6	1.4 ± 2.4	2.3	71	0	1900 ± 500	27 ± 3	187 ± 592	1.7
Perimeter Stations (0-4 km) - Uncontrolled Areas														
4. Barranca School	N180 E130	97 126	26	4	4.8 ± 2.2	0.2 ± 0.4	1.4 ± 2.2	2.4	26	0	2100 ± 600	57 ± 14	221 ± 721	2.3
5. Arkansas Avenue	N170 E020	89 768	26	6	4.0 ± 1.8	−0.6 ± 0.6	1.2 ± 2.1	2.1	26	0	1130 ± 280	41 ± 10	180 ± 453	2.0
6. Golf Course	N160 E060	42 441	11	2	2.1 ± 1.0	−1.0 ± 0.6	0.9 ± 1.6	1.5	11	0	410 ± 100	54 ± 14	143 ± 280	1.3
7. Cumbres School	N150 E090	86 875	26	6	3.9 ± 1.8	−1.6 ± 0.8	1.2 ± 2.3	1.9	26	0	1420 ± 360	43 ± 12	202 ± 592	2.0
8. Diamond Drive	N130 E020	30 586	11	4	1.9 ± 1.0	−2.1 ± 1.2	0.7 ± 2.1	1.2	11	0	520 ± 140	57 ± 14	122 ± 264	1.3
9. 48th Street	N110 E000	87 755	26	7	3.9 ± 1.8	−1.8 ± 1.0	0.9 ± 2.4	1.5	26	0	1240 ± 320	30 ± 10	178 ± 508	1.7
10. Fuller Lodge	N110 E080	31 169	11	4	1.7 ± 0.8	−3.0 ± 1.4	0.4 ± 2.5	0.7	11	0	480 ± 120	49 ± 12	153 ± 300	2.0
11. LA Airport	N110 E160	100 722	26	7	3.4 ± 1.6	−2.1 ± 1.0	1.0 ± 2.5	1.7	26	0	1380 ± 360	51 ± 14	203 ± 593	1.7
12. Bayo Stp	N110 E260	89 959	19	3	2.1 ± 1.0	−2.7 ± 1.2	1.1 ± 2.1	1.8	19	0	800 ± 200	55 ± 14	178 ± 606	1.7
13. Gulf Station	N100 E100	97 049	26	5	3.5 ± 1.6	−1.7 ± 0.8	1.1 ± 2.0	1.8	26	0	1120 ± 280	33 ± 8	200 ± 524	2.0
14. Acorn Street	N100 E110	42 017	11	2	2.6 ± 1.2	−1.0 ± 0.6	1.1 ± 2.0	1.8	11	0	380 ± 100	57 ± 14	141 ± 273	1.3
15. Royal Crest	N080 E080	87 467	19	3	3.7 ± 1.6	0.1 ± 0.2	1.6 ± 2.3	2.6	19	0	920 ± 240	39 ± 10	196 ± 606	2.0
16. White Rock	S090 E430	85 906	26	4	5.5 ± 2.4	0.2 ± 0.4	1.5 ± 2.3	2.5	26	0	2000 ± 600	59 ± 16	225 ± 794	2.3
17. Pajarito Acres	S210 E370	81 282	26	5	4.2 ± 1.8	0.2 ± 0.8	1.5 ± 2.0	2.5	26	0	2200 ± 600	58 ± 14	237 ± 858	2.3
18. Bandelier	S270 E200	69 939	26	6	4.5 ± 2.0	0.1 ± 0.4	1.7 ± 2.3	2.8	26	0	2200 ± 600	46 ± 12	243 ± 788	2.7
Perimeter Group Summary		1 120 061	316	68	5.5 ± 2.4	−3.0 ± 1.4	1.2 ± 2.3	2.0	316	0	2200 ± 600	30 ± 10	197 ± 606	2.0
Onsite Stations - Controlled Areas														
19. TA-21	N090 E170	77 152	26	7	3.0 ± 1.4	−0.4 ± 0.6	1.1 ± 1.5	0.06	26	0	2000 ± 600	33 ± 8	195 ± 655	0.005
20. TA-6	N060 W050	96 135	26	5	5.0 ± 2.2	−0.7 ± 0.6	1.3 ± 2.2	0.07	26	0	1500 ± 400	23 ± 6	202 ± 605	0.005
21. TA-53 (LAMPF)	N060 E190	89 067	26	5	3.8 ± 1.8	−1.4 ± 0.8	1.1 ± 2.0	0.05	26	0	1600 ± 400	26 ± 6	207 ± 649	0.005
22. Well PM-1	N030 E310	98 133	26	9	3.8 ± 1.8	−1.9 ± 1.2	1.0 ± 2.3	0.05	26	0	2300 ± 600	29 ± 8	228 ± 896	0.005
23. TA-52	N020 E170	95 921	26	7	3.9 ± 1.8	−1.2 ± 0.6	1.1 ± 2.1	0.06	26	0	1600 ± 400	20 ± 6	204 ± 637	0.005
24. TA-16	S030 W080	91 797	26	6	4.0 ± 1.8	−1.3 ± 0.8	1.0 ± 2.2	0.05	26	0	1180 ± 300	25 ± 6	183 ± 502	0.005
25. Booster P-2	S030 E190	96 910	26	6	3.9 ± 1.8	−1.0 ± 0.8	1.3 ± 2.2	0.07	26	0	1490 ± 380	31 ± 8	207 ± 622	0.005
26. TA-54	S080 E260	100 137	26	6	3.4 ± 1.6	−2.1 ± 1.4	1.1 ± 2.0	0.06	26	0	2200 ± 600	33 ± 10	221 ± 868	0.005
27. TA-49	S100 E040	94 545	26	5	3.9 ± 1.8	−0.6 ± 0.6	1.1 ± 2.0	0.06	26	0	1700 ± 400	13 ± 3	210 ± 707	0.005
28. Booster P-1	S100 E300	42 592	11	1	4.8 ± 2.2	0.1 ± 0.3	1.7 ± 2.6	0.09	11	0	440 ± 120	38 ± 10	146 ± 297	0.003
29. TA-33	S250 E230	98 783	26	5	4.3 ± 2.0	−0.1 ± 0.6	1.5 ± 2.1	0.08	26	0	1700 ± 400	41 ± 10	222 ± 678	0.005
30. TA-39	S210 E210	41 739	11	3	5.2 ± 2.4	−0.2 ± 0.4	1.7 ± 3.0	0.08	11	0	2000 ± 600	40 ± 20	375 ± 019	0.010
Onsite Group Summary		1 022 911	282	66	5.2± 2.4	−2.1 ± 1.4	1.2 ± 2.2	0.06	282	0	2300 ± 600	13 ± 3	213 ± 707	0.005

[a]The filters are held 7-10 days before analysis to allow naturally occurring radon-thoron daughters to each equilibirum 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^{-14} μCi/mℓ (α)
= 1×10^{-10} μCi/mℓ (β)

TABLE VI

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR CONCENTRATIONS

Station Location	Coordinates	Total Air[a] Volume (m^3)	Number of Biweekly Samples	No. Samples <MDL[b]	Concentrations - pCi/m^3 (10^{-12} $\mu Ci/m\ell$) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas								
1. Española	---	121	26	1	33 ± 10	0.3 ± 11	12 ± 18	0.006
2. Pojoaque	---	114	26	1	102 ± 38	1.5 ±1.6	16 ± 43	0.008
3. Santa Fe	---	110	19	1	51 ± 16	0.7 ± 0.8	11 ± 36	0.005
Regional Group Summary		347	71	3	102 ± 38	0.31 ± 0.11	13 ± 33	0.006
Perimeter Stations (0-4 km) - Uncontrolled Areas								
4. Barranca School	N180 E130	121	26	0	69 ± 22	2.5 ± 1.4	16 ± 29	0.008
5. Arkansas Avenue	N170 E020	122	26	1	61 ± 20	0.8 ± 0.3	14 ± 24	0.007
6. Golf Course	N160 E060	50	11	0	29 ± 10	1.3 ± 0.6	15 ± 16	0.007
7. Cumbres School	N150 E090	122	26	0	78 ± 26	4.9 ± 2.0	18 ± 30	0.009
8. Diamond Drive	N130 E020	50	11	0	63 ± 20	7.5 ± 3.4	21 ± 33	0.010
9. 48th Street	N110 E000	122	26	0	80 ± 40	4.2 ± 1.8	21 ± 38	0.010
10. Fuller Lodge	N110 E090	50	11	0	65 ± 22	11 ± 3.8	25 ± 34	0.012
11. LA Airport	N110 E160	118	26	0	190 ± 60	6.8 ± 2.6	51 ± 87	0.025
12. Bayo Stp	N110 E260	104	18	1	190 ± 60	0.7 ± 0.6	29 ± 97	0.014
13. Gulf Station	N100 E100	115	25	0	150 ± 50	4.6 ± 2.4	23 ± 39	0.011
14. Acorn Street	N100 E110	49	11	0	53 ± 18	9.8 ± 3.6	26 ± 31	0.013
15. Royal Crest	N080 E080	112	19	1	83 ± 26	0.4 ± 0.1	20 ± 49	0.010
16. White Rock	S090 E430	122	26	0	62 ± 20	2.9 ± 1.6	17 ± 25	0.008
17. Pajarito Acres	S210 E370	122	26	0	71 ± 24	3.6 ± 1.6	16 ± 34	0.008
18. Bandelier	S270 E200	121	26	0	107 ± 34	2.1 ± 0.8	29 ± 60	0.014
Perimeter Group Summary		1508	314	3	190 ± 60	0.4 ± 0.1	23 ± 55	0.011
Onsite Stations - Controlled Areas								
19. TA-21	N090 E170	140	26	0	270 ± 80	7.5 ± 3.4	52 ± 116	0.0010
20. TA-6	N060 W050	122	26	1	150 ± 40	0.5 ± 3.6	25 ± 77	0.0005
21. TA-53 (LAMPF)	N060 E190	121	26	0	160 ± 60	3.3 ± 2.0	35 ± 72	0.0060
22. Well PM-1	N030 E310	122	26	0	140 ± 40	7.0 ± 2.6	30 ± 62	0.0060
23. TA-52	N020 E170	121	26	0	190 ± 60	5.4 ± 2.2	57 ± 98	0.0011
24. TA-16	S030 W080	122	26	1	330 ± 100	1.0 ± 4.0	30 ± 131	0.0060
25. Booster P-2	S030 E190	122	26	0	76 ± 24	1.6 ± 0.6	27 ± 37	0.0005
26. TA-54	S080 E260	120	26	0	620 ± 200	4.2 ± 3.6	187 ± 362	0.0037
27. TA-49	S100 E040	122	26	0	37 ± 12	2.9 ± 2.0	12 ± 16	0.0002
28. Booster P-1	S100 E300	50	11	0	66 ± 22	1.8 ± 0.6	23 ± 36	0.0004
29. TA-33	S250 E230	116	26	0	790 ± 260	5.5 ± 2.2	8 ± 329	0.0016
30. TA-39	S210 E210	48	11	0	94 ± 30	4.2 ± 2.0	39 ± 669	0.0007
Onsite Group Summary		1332	282	2	790 ± 260	0.5 ± 3.6	52 ± 184	0.0010

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

[b]Minimum detectable limit = 1×10^{-12} $\mu Ci/m\ell$.

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

[d]Controlled area radioactivity concentration guide = 5×10^{-8} $\mu Ci/m\ell$.
Uncontrolled area radioactivity concentration guide = 2×10^{-7} $\mu Ci/m\ell$.

TABLE VII

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

Station Location	Coordinates	Total Air[a] Volume (m^3)	^{238}Pu (10^{-15} $\mu Ci/ml^a$) Number of 6-8 Wk Samples	No. Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]	^{239}Pu (10^{-15} $\mu Ci/ml^a$) Number of 6-8 Wk Samples	No. Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas														
1. Española	---	94 815	5	5	−1.5 ± 1.5	−3.8 ± 5.9	−1.9 ± 1..1	0.00000	5	1	27 ± 5.6	5.9 ± 6.6	16 ± 25	0.028
2. Pojoaque	---	64 605	4	4	−0.8 ± 3.7	−2.8 ± 2.3	−1.7 ± 2.6	0.00000	4	1	22 ± 4.4	1.3 ± 6.1	15 ± 29	0.026
3. Santa Fe	---	111 024	5	5	0.2 ± 1.5	−4.7 ± 4.5	−1.1 ± 2.6	0.00000	5	1	31 ± 7.5	5.4 ± 6.0	16 ± 23	0.027
Regional Group Summary		270 444	14	14	0.2 ± 1.5	−4.7 ± 4.5	−1.5 ± 2.1	0.00000	14	3	31 ± 7.5	1.3 ± 6.1	16 ± 24	0.027
Perimeter Stations (0-4 km) - Uncontrolled Areas														
4. Barranca School	N180 E130	96 171	5	5	1.5 ± 1.9	−9.1 ± 7.4	−2.9 ± 10	0.00000	5	2	67 ± 9.2	5.2 ± 6.5	30 ± 66	0.060
5. Arkansas Avenue	N 170 E020	90 218	5	5	1.1 ± 2.1	−9.4 ± 6.6	−2.3 ± 5.0	0.00000	5	1	27 ± 6.4	5.3 ± 6.2	17 ± 27	0.029
6. Golf Course	N160 E060	27 390	2	2	−2.7 ± 4.4	−8.0 ± 5.8	−5.9 ± 11	0.00000	2	0	9 ± 6.4	6.9 ± 5.3	8 ± 1	0.013
7. Cumbres School	N160 E090	66 933	4	4	−0.5 ± 2.0	−7.9 ± 18.1	−4.0 ± 8.6	0.00000	4	1	24 ± 5.2	2.3 ± 20	13 ± 39	0.022
8. Diamond Drive	N130 E020	23 445	2	2	−1.8 ± 8.3	−2.9 ± 6.4	−2.6 ± 3.3	0.00000	2	1	15 ± 13	−1.4 ± 8.0	7 ± 25	0.013
9. 48th Street	N110 E000	89 266	5	5	0.9 ± 2.0	−5.2 ± 7.7	−0.7 ± 2.5	0.00000	5	1	104 ± 10	6.0 ± 11	42 ± 100	0.070
10. Fuller Lodge	N110 E090	18 840	2	2	−6.9 ± 5.7	−12 ± 8.8	−10 ± 12	0.00000	1	1	1.1 ± 6.3	1.1 ± 6.3	1.1 ± 6.3	0.001
11. LA Airport	N110 E160	77 665	4	4	0.2 ± 9.9	−2.5 ± 5.5	−1.3 ± 2.2	0.00000	4	1	22 ± 3.7	12 ± 7.8	18 ± 28	0.030
12. Bayo Stp	N110 E260	101 218	5	4	2.1 ± 2.0	−6.5 ± 6.1	−0.5 ± 4.4	0.00000	5	0	166 ± 12	7.5 ± 7.2	65 ± 235	0.109
13. Gulf Station	N100 E100	96 809	5	4	2.9 ± 2.1	−5.2 ± 4.5	−0.6 ± 6.3	0.00000	5	1	31 ± 8.1	0.8 ± 5.8	25 ± 38	0.042
14. Acorn Street	N100 E110	24 824	2	2	−5.1 ± 4.0	−5.1 ± 5.6	−5.1 ± 2.7	0.00000	2	0	9 ± 5.3	7.3 ± 6.9	8 ± 9	0.014
15. Royal Crest	N080 E080	101 092	5	5	−0.3 ± 1.4	−5.0 ± 5.3	−1.4 ± 1.2	0.00000	5	1	21 ± 2.9	3.0 ± 5.2	16 ± 27	0.028
16. White Rock	S090 E480	87 945	5	5	1.2 ± 2.8	−5.3 ± 4.5	−1.7 ± 4.5	0.00000	5	1	25 ± 4.3	0.6 ± 5.0	17 ± 26	0.028
17. Pajarito Acres	S210 E370	82 495	5	5	1.3 ± 2.0	−5.4 ± 5.9	−1.1 ± 4.6	0.00000	5	1	27 ± 6.9	4.1 ± 5.8	21 ± 32	0.036
18. Bandelier	S270 E200	73 164	5	5	0.1 ± 3.2	−5.6 ± 10	−1.2 ± 2.7	0.00000	5	1	64 ± 8.4	9.6 ± 9.8	28 ± 58	0.047
Perimeter Group Summary		1 056 494	61	59	2.9 ± 2.1	−12 ± 8.8	−1.8 ± 5.4	0.00000	60	13	166 ± 12	−1.4 ± 8.0	26 ± 94	0.044
Onsite Stations - Controlled Areas														
19. TA-21	N080 E170	66 932	4	4	−0.1 ± 3.7	−8.0 ± 5.3	−2.1 ± 2.7	0.00000	5	0	28 ± 8.0	9.4 ± 7.3	21 ± 32	0.0010
20. TA-6	N060 W050	95 181	5	5	1.6 ± 1.8	−11 ± 9.9	−1.9 ± 6.1	0.00000	5	0	21 ± 3.1	8.9 ± 6.0	17 ± 27	0.0008
21. TA-53 (LAMPF)	N060 E190	90 784	5	5	0.3 ± 2.3	−4.8 ± 3.6	−1.0 ± 2.7	0.00000	5	2	24 ± 4.2	0.4 ± 5.0	18 ± 33	0.0009
22. Well PM-1	N030 E310	98 455	5	5	2.8 ± 4.9	−3.5 ± 4.1	0.1 ± 5.2	0.00001	5	1	30 ± 7.5	3.0 ± 5.5	21 ± 40	0.0010
23. TA-52	N020 E170	96 032	5	4	16 ± 8.1	−2.9 ± 4.2	0.9 ± 9.5	0.0005	5	1	25 ± 4.8	3.7 ± 6.5	21 ± 33	0.0010
24. TA-16	S030 W080	70 061	4	4	0.6 ± 1.8	−15 ± 17	−2.1 ± 5.5	0.00000	4	1	23 ± 4.8	2.2 ± 21	19 ± 34	0.0009
25. Booster P-2	S030 E190	96 305	5	3	4.6 ± 2.8	−3.4 ± 5.6	1.4 ± 7.9	0.00007	5	2	29 ± 4.6	4.5 ± 5.5	21 ± 39	0.0010
26. TA-54	S080 E280	99 933	5	3	33 ± 13	−3.9 ± 2.6	2.3 ± 1.8	0.00011	5	0	58 ± 16	26 ± 7.2	34 ± 30	0.0017
27. TA-49	S100 E040	98 736	5	5	0.2 ± 2.0	−8.0 ± 5.6	−2.3 ± 3.2	0.00000	5	2	25 ± 4.6	0.8 ± 5.1	16 ± 15	0.0008
28. Booster P-1	S100 E300	26 729	2	2	−2.8 ± 4.7	−6.6 ± 10	−4.2 ± 2.0	0.00000	2	1	18 ± 7.8	−2.9 ± 10	10 ± 36	0.0005
29. TA-33	S250 E280	99 487	5	5	1.0 ± 2.1	−6.8 ± 4.1	−1.2 ± 3.8	0.00000	5	1	23 ± 4.5	6.8 ± 9.8	18 ± 30	0.0009
30. TA-39	S210 E210	38 609	2	2	1.3 ± 2.6	−3.1 ± 3.7	0.1 ± 5.1	0.00001	2	0	22 ± 7.0	22 ± 4.5	22 ± 27	0.0011
Onsite Group Summary		972 243	52	47	33 ± 13	−15. ± 17	−0.5 ± 6.8	0.00000	53	11	58 ± 16	−1.9 ± 11	21.1± 33	0.0010

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

[b]Minimum Detectable Limit = 2×10^{-15} $\mu Ci/ml$ (^{238}Pu)
= 3×10^{-15} $\mu Ci/ml$ (^{239}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^{-13} $\mu Ci/ml$ (^{238}Pu)
= 2×10^{-13} $\mu Ci/ml$ (^{239}Pu)

Uncontrolled Area Radioactivity Concentration Guide = 7×10^{-14} $\mu Ci/ml$ (^{238}Pu)
= 6×10^{-14} $\mu Ci/ml$ (^{239}Pu)

TABLE VIII

ANNUAL ATMOSPHERIC URANIUM CONCENTRATIONS

Station Location	Coordinates	Total Air[a] Volume (m^3)	Number of 12-14 Wk Samples	No. Samples <MDL[b]	Uranium - pg/m^3 Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas								
1. Española		94 074	4	0	245 ± 63	72 ± 18	176 ± 171	0.0020
2. Pojoaque	---	74 064	4	0	257 ± 52	94 ± 32	154 ± 134	0.0017
3. Santa Fe	---	111 010	4	0	614 ± 103	60 ± 12	218 ± 541	0.0024
Regional Group Summary		279 148	12	0	614 ± 103	60 ± 7	187 ± 371	0.0021
Perimeter Stations (0-4 km) - Uncontrolled Areas								
4. Barranca School	N180 E130	97 176	4	0	225 ± 58	50 ± 10	122 ± 194	0.0014
5. Arkansas Avenue	N170 E020	88 488	4	1	82 ± 21	34 ± 75	56 ± 32	0.0006
6. Golf Course	N160 E060	28 025	1	0	127 ± 85	127 ± 85	127 ± 85	0.0014
7. Cumbres School	N150 E090	87 080	4	0	155 ± 66	46 ± 9	97 ± 115	0.0011
8. Diamond Drive	N130 E020	19822	1	0	149 ± 121	149 ± 121	149 ± 121	0.0017
9. 48th Street	N110 E000	83 710	4	0	139 ± 33	60 ± 12	112 ± 96	0.0012
10. Fuller Lodge	N110 E090	20 207	1	0	225 ± 99	225 ± 99	225 ± 99	0.0025
11. LA Airport	N110 E160	100 722	4	0	162 ± 42	50 ± 10	110 ± 123	0.0012
12. Bayo Stp	N110 E260	101 268	4	0	160 ± 48	41 ± 8	86 ± 103	0.0010
13. Gulf Station	N100 E100	97 549	4	0	99 ± 21	48 ± 10	83 ± 63	0.0009
14. Acorn Street	N100 E110	27 288	1	0	167 ± 44	167 ± 44	167 ± 44	0.0019
15. Royal Crest	N080 E080	101 092	4	0	112 ± 91	57 ± 11	87 ± 51	0.0010
16. White Rock	S090 E430	85 403	4	0	101 ± 85	57 ± 12	83 ± 49	0.0009
17. Pajarito Acres	S210 E370	81 337	4	0	104 ± 53	42 ± 9	72 ± 72	0.0008
18. Bandelier	S270 E200	71 158	4	0	292 ± 58	47 ± 10	118 ± 179	0.0013
Perimeter Group Summary		1 090 325	48	1	292 ± 58	34 ± 75	99 ± 112	0.0011
Onsite Stations - Controlled Areas								
19. TA-21	N090 E170	80 150	4	0	121 ± 49	50 ± 10	97 ± 83	0.00005
20. TA-6	N060 W050	97 149	4	0	350 ± 74	61 ± 12	166 ± 319	0.00008
21. TA-53 (LAMPF)	N060 E190	88 362	4	0	189 ± 66	56 ± 11	108 ± 145	0.00005
22. Well PM-1	N030 E310	98 531	4	0	128 ± 72	53 ± 11	91 ± 92	0.00004
23. TA-52	N020 E170	91 963	4	0	105 ± 22	53 ± 11	82 ± 67	0.00004
24: TA-16	S030 W080	93 794	4	0	736 ± 103	53 ± 11	275 ± 813	0.00013
25. Booster P-2	S030 E190	97 525	4	0	195 ± 39	87 ± 18	135 ± 115	0.00007
26. TA-54	S080 E260	99 781	4	0	310 ± 103	63 ± 13	169 ± 249	0.00008
27. TA-49	S100 E040	92 102	4	0	167 ± 33	31 ± 7	111 ± 161	0.00005
28. Booster P-1	S100 E300	27 394	1	0	246 ± 146	246 ± 146	246 ± 146	0.00012
29. TA-33	S250 E230	99 735	4	0	144 ± 73	29 ± 6	80 ± 118	0.00004
30. TA-39	S210 E210	38 608	2	0	96 ± 19	39 ± 9	77 ± 143	0.00004
Onsite Group Summary		1 005 094	43	0	736 ± 103	29 ± 6	133 ± 290	0.00006

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 2 pg/m^3.
[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 = 2.1×10^8 pg/m^3.
[d]Uncontrolled area radioactivity concentration guide = 9×10^6 pg/m^3.
NOTE: One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses can be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

TABLE IX

ANNUAL ATMOSPHERIC ^{241}Am CONCENTRATIONS

Station Location	Coordinates	Total Air Volume (m^3)[a]	Number of 12-14 Wk 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	---	111 010	4	4	1.3 ± 5.1	−0.4 ± 3.2	0.2 ±1.1	0.00011
Regional Group Summary	---	111 010	4	4	1.3 ± 5.1	−0.4 ± 3.2	0.2 ± 1.1	0.00011
Perimeter Stations (0-4 km) - Uncontrolled Areas								
7. Cumbres School	N150 E090	87 080	4	3	19 ± 6.2	0.1 ± 5.9	6.8 ± 18	0.0034
11. LA Airport	N110 E160	100 722	4	3	7.1 ± 5.2	−1.0 ± 2.9	2.3 ± 9.2	0.0011
12. Bayo Stp	N110 E260	101 268	4	3	19 ± 5.3	0.5 ± 3.7	6.1 ± 18	0.0030
16. White Rock	S090 E430	85 403	4	3	8.2 ± 5.8	−1.7 ± 6.2	1.2 ± 8.3	0.0006
Perimeter Group Summary		374 473	16	12	19 ± 5.3	−1.7 ± 6.2	4.1 ± 14	0.0021
Onsite Stations - Controlled Areas								
20. TA-6	N050 W050	97 149	4	4	1.0 ± 5.1	0.1 ± 5.4	0.3 ± 0.8	0.000005
21. TA-53 (LAMPF)	N050 E190	88 362	4	3	7.3 ± 4.6	−3.3 ± 6.0	1.2 ± 9.8	0.000020
24. TA-16	S030 W080	93 794	3	3	0.1 ± 5.1	−0.6 ± 4.2	−0.1 ± 0.7	0.000000
25. Booster P-2	S030 E190	97 525	4	3	5.5 ± 5.2	−1.5 ± 5.2	1.6 ± 5.3	0.000027
26. TA-54	S080 E260	99 781	3	2	5.9 ± 4.1	4.5 ± 5.1	5.2 ± 2.6	0.000087
27. TA-49	S100 E040	92 102	4	4	2.7 ± 5.1	−1.6 ± 5.6	0.0 ± 3.7	0.000000
Onsite Group Summary		568 713	22	19	7.3 ± 4.6	−3.3 ± 6.0	1.3 ± 5.7	0.000022

[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 standard deviations). Uncertainties for station and group means are ±2 standard deviations.
[d]Controlled area radioactivity concentration guide = 6×10^{-12} μCi/mℓ.
Uncontrolled area radioactivity concentration guide = 2×10^{-13} μCi/mℓ.

TABLE X

LOCATION OF SURFACE AND GROUND WATER STATIONS

Stations	Location: Latitude Coord N-S	or	Location: Longitude Coord E-W	Type[a]
Regional				
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	36°37'		106°19'	SW
Bernalillo-Rio Grande	35°17'		106°36'	SW
Jemez River	35°40'		106°44'	SW
Perimeter				
Los Alamos Reservoir	N105		W075	SW
Guaje Canyon	N215		E315	SW
Basalt Springs	N065		E395	GW
La Mesita Spring	N076		E550	GW
Test Well 2	N115		E145	GW
Test Well 2A	N115		E145	GW
Frijoles Canyon	S280		E190	SW
White Rock Canyon	b		b	b
Water Supply				
Distribution				
Fire Station 1	N083		E011	D
Fire Station 2	N096		E018	D
Fire Station 3	N082		E376	D
Fire Station 4	N174		E070	D
Fire Station 5	S028		W076	D
Los Alamos Field				
LA-1B	N123		E510	GW
LA-2	N125		E500	GW
LA-3	N126		E485	GW
LA-4	N065		E405	GW
LA-5	N076		E425	GW
Guaje Field				
G-1	N190		E385	GW
G-1A	N197		E380	GW
G-2	N205		E365	GW
G-3	N215		E340	GW
G-4	N213		E315	GW
G-5	N228		E295	GW
G-6	N215		E265	GW
Pajarito Field				
PM-1	N030		E310	GW
PM-2	S054		E202	GW
PM-3	N042		E260	GW
Water Canyon Gallery	S040		W125	GW
Noneffluent Areas				
Test Well 1	N070		E300	GW
Test Well 1A	N070		E300	GW
Test Well 3	N080		E120	GW
Canada del Buey	N010		E150	SW
Pajarito Canyon	S060		E225	SW
Water Canyon	S090		E085	SW
Test Well DT-5A	S110		E090	GW
Test Well 8	N040		E150	GW
Test Well DT-9	S155		E140	GW
Test Well DT-10	S110		E125	GW
Effluent Release Areas				
Acid-Pueblo Canyon				
Acid Weir	N130		E060	SW
Pueblo 1	N130		E075	SW
Pueblo 2	N115		E160	SW
Pueblo 3	N085		E315	SW
Hamilton Bend Spr	N110		E260	GW
Sandia Canyon				
SCS-1	N080		E040	SW
SCS-2	N055		E155	SW
SCS-3	N035		E220	SW
DP-Los Alamos Canyon				
DPS-1	N095		E160	SW
DPS-4	N080		E205	SW
Obs Hole LAO-C	N085		E070	GW
Obs Hole LAO-1	N085		E115	GW
Obs Hole LAO-2	N080		E205	GW
Obs Hole LAO-3	N080		E215	GW
Obs Hole LAO-4	N075		E240	GW
Obs Hole LAO-4.5	N065		E270	GW
Mortandad Canyon				
Gaging Station 1	N050		E090	SW
Obs Hole MCO-3	N045		E095	GW
Obs Hole MCO-4	N035		E135	GW
Obs Hole MCO-5	N040		E160	GW
Obs Hole MCO-6	N036		E160	GW
Obs Hole MCO-7	N030		E170	GW
Obs Hole MCO-7.5	N030		E180	GW
Obs Hole MCO-8	N030		E185	GW

[a]SW = Surface Water; GW = Ground Water; D = Water Supply, Wells,and Gallery.
[b]31 stations, 5 surface water,and 26 ground water (spring) located in White Rock Canyon on the Rio Grande from Otowi to the mouth of Frijoles.

TABLE XI

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE WATER FROM REGIONAL STATIONS

Radiochemical (average of a number of analyses)

Stations	No. 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	Gross-α 10^{-9} μCi/mℓ	Gross-β 10^{-9} μCi/mℓ	Total U μg/ℓ
Chamita	3	3.4 ± 2.8	103 ± 114	0.03 ± 0.12	0.05 ± 0.16	−0.8 ± 2.8	11 ± 6.8	4.5 ± 4.8
Embudo	3	3.0 ± 2.3	39 ± 64	0.01 ± 0.06	−0.04 ± 0.16	0.5 ± 2.7	7.9 ± 2.2	2.7 ± 2.0
Otowi	3	2.0 ± 1.8	103 ± 180	0.02 ± 0.10	−0.04 ± 0.10	0.3 ± 1.6	8.3 ± 8.2	3.9 ± 0.8
Cochiti	3	3.6 ± 5.4	10 ± 92	−0.01 ± 0.02	−0.02 ± 0.02	−0.4 ± 1.2	7.7 ± 4.0	3.7 ± 2.0
Bernalillo	3	3.2 ± 2.8	33 ± 122	−0.02 ± 0.08	0.1 ± 0.04	0.1 ± 2.4	9.0 ± 2.4	4.0 ± 0.4
Jemez River	3	3.1 ± 2.6	24 ± 141	−0.07 ± 0.28	−0.07 ± 0.22	6.6 ± 13	23 ± 5.3	1.1 ± 0.8
Minimum		1.1 ± 0.6	−50 ± 140	−0.23 ± 0.24	−0.2 ± 0.60	−2.1 ± 2.8	5.3 ± 2.2	0.8 ± 0.6
Maximum		6.5 ± 0.8	150 ± 140	0.10 ± 0.40	0.14 ± 0.78	14 ± 8.0	25 ± 6.0	7.2 ± 1.0
Average		3.0 ± 2.8	52 ± 135	−0.01 ± 0.14	−0.02 ± 0.14	1.1 ± 7.2	11 ± 12	3.3 ± 3.0

Chemical (average of a number of analyses)

Concentrations in mg/ℓ

Stations	No. of Analyses	Ca^{2+}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3	Cl^{-}	F^{-}	NO_3^{-}	TDS	Hard	pH	Cond mS/m
Chamita	2	69	11	40	0	167	11	0.3	0.4	475	218	8.0	60.0
Embudo	1	33	5	24	0	108	11	0.4	0.9	308	105	8.3	35.0
Otowi	2	46	6	25	3	131	11	0.4	0.4	344	142	8.2	39.0
Cochiti	2	50	7	24	6	130	6	0.3	0.4	361	155	8.3	39.5
Bernalillo	2	54	10	32	0	145	4	0.3	1.3	338	174	8.2	50.5
Jemez River	3	50	5	89	5	189	119	0.8	0.4	495	144	8.2	78.5
Minimum		33	5	22	0	108	1	0.3	<0.4	300	105	7.9	35.0
Maximum		69	16	111	16	200	149	0.9	1.8	580	238	8.5	90.0
Average		52 ± 20	8 ± 6	44 ± 58	3 ± 12	152 ± 60	36 ± 102	0.5 ± 0.4	0.4 ± 0.9	403 ± 182	160 ± 70	8.2 ± 0.4	54.0 ± 35.0

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 error term for that analysis.

TABLE XII

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

Station	No. of Analyses	Radiochemical (average number of analyses) ³H 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	3	2.4 ± 3.6	87 ± 150	−0.02 ± 0.4	0.02 ± 0.06	−0.2 ± 1.0	4.6 ± 2.0	0.3 ± 1.1
Guaje Canyon	3	1.7 ± 2.1	7 ± 200	−0.01 ± 0.04	−0.03 ± 0.08	0.5 ± 2.4	4.6 ± 4.2	0.4 ± 0.7
Basalt Spring	3	3.3 ± 3.3	−10 ± 227	0.06 ± 0.24	−0.13 ± 0.46	0.8 ± 0.8	7.3 ± 7.1	1.1 ± 1.2
La Mesita Spring	3	2.1 ± 2.5	17 ± 61	−0.01 ± 0.03	−0.02 ± 0.04	6.4 ± 1.6	11 ± 1.3	12 ± 2.1
Test Well 2	2	1.4 ± 0.3	−45 ± 127	−0.10 ± 0.28	−0.09 ± 0.26	−0.2 ± 0.7	4.7 ± 1.3	1.3 ± 2.8
Test Well 2A	2	21.6 ± 2.4	100 ± 113	−0.02 ± 0.00	−0.02 ± 0.00	−0.4 ± 1.4	4.6 ± 2.6	0.9 ± 2.3
Frijoles Canyon	3	2.9 ± 2.7	13 ± 81	−0.00 ± 0.00	−0.00 ± 0.06	0.1 ± 1.2	9.1 ± 16	1.5 ± 2.9
Minimum		0.5 ± 0.6	−140 ± 140	−0.20 ± 0.60	−0.04 ± 1.00	−0.9 ± 1.6	1.7 ± 1.4	−0.2 ± 0.4
Maximum		22 ± 1.4	160 ± 120	0.20 ± 0.80	0.05 ± 0.10	7.2 ± 3.8	18 ± 4.0	13 ± 2.6
Average		4.4 ± 12	22 ± 156	−0.01 ± 0.14	−0.04 ± 0.20	1.2 ± 5.0	6.6 ± 8.0	2.3 ± 8.0
White Rock Canyon[a]								
Puye Formation	8	---	29 ± 143	−0.01 ± 0.02	−0.01 ± 0.02	−0.3 ± 1.1	3.4 ± 2.2	0.8 ± 0.8
Tesuque Fm (F.G. Sed)	5	---	32 ± 149	−0.01 ± 0.02	−0.01 ± 0.02	0.6 ± 0.8	4.7 ± 8.3	1.9 ± 1.9
Tesuque Fm (C.G. Sed)	10	---	−71 ± 199	−0.01 ± 0.02	−0.01 ± 0.02	−0.6 ± 0.7	2.0 ± 3.1	0.6 ± 1.2
Tesuque Fm (Basalts)	3	---	−43 ± 163	−0.05 ± 0.18	−0.04 ± 0.11	2.3 ±7.5	13 ± 8.0	8.8 ± 19.9
Surface Water (3 stations)	4	---	−12 ± 110	0.02 ± 0.12	0.02 ± 0.11	−0.8 ± 2.5	6.1 ± 6.8	0.1 ± 1.9
Surface Water (Sanitary eff)	1	---	−40 ± 140	−0.01 ± 0.02	0.00 ± 0.02	−0.8 ± 3.4	19 ± 4.0	1.1 ± 0.2
Minimum		---	−240 ± 140	−0.15 ± 0.14	−0.10 ± 0.20	−2.6 ± 2.6	0.5 ± 1.6	0.0 ± 2.2
Maximum		---	190 ± 140	0.10 ± 0.80	0.10 ± 0.60	4.9 ± 3.4	19 ± 4.0	20 ± 4.0
Average		---	−17 ± 176	−0.01 ± 0.06	−0.01 ± 0.06	−0.1 ± 2.8	4.9 ± 9.4	1.7 ± 7.2

Station	No. of Analyses	Chemical (average of a number of analyses) Concentrations in mg/ℓ Ca^{2+}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	F^{-}	NO_3^{-}	TDS	Hard	pH	Cond mS/m
Los Alamos Reservoir	2	7	2	6	0	44	4	0.2	0.9	123	25	7.9	---
Guaje Canyon	2	7	3	8	0	42	1	0.2	0.9	122	30	7.9	11.0
Basalt Spring	2	28	8	13	0	85	14	0.5	10	219	97	8.0	28.5
La Mesita Spring	2	34	1	27	0	124	6	0.3	11	204	90	8.1	31.0
Test Well 2	1	14	4	171	0	66	9	0.6	1.8	94	53	7.7	17.0
Test Well 2A	1	18	4	40	0	42	28	0.4	1.8	128	64	7.6	28.0
Frijoles Canyon	2	13	3	11	2	67	4	0.2	<0.4	129	44	8.2	15.0
Minimum		6	<1.0	5	0	32	1	0.1	<0.4	80	24	7.6	10.0
Maximum		34	9	171	4	124	28	0.6	12	238	100	8.4	33.0
Average		17 ± 22	3 ± 4	28 ± 92	0 ± 2	69 ± 64	8 ± 16	0.3 ± 0.4	4.0 ± 5.3	135 ± 94	57 ± 60	7.9 ± 0.4	19.8 ± 17.8
White Rock Canyon													
Puye Formation	8	20	2	14	0	83	6	0.3	2.2	175	59	7.8	210
Tesuque Fm (F.G. Sed)	5	27	1	26	3	127	8	0.4	1.3	226	72	8.1	290
Tesuque Fm (C.G. Sed)	10	14	2	13	0	73	4	0.3	1.8	160	44	7.9	170
Tesuque Fm (Basalts)	3	36	4	50	5	200	12	0.4	2.6	354	109	7.9	430
Surface Water (3 stations)	4	29	7	16	3	95	6	0.3	1.3	211	99	8.2	252
Surface Water (sanitary eff)	1	16	12	71	0	126	36	0.4	42	426	89	7.2	510
Minimum		10	0	11	0	66	0	0.2	0	138	34	7.2	140
Maximum		56	12	119	14	330	36	0.6	42	430	178	8.5	630
Average		22 ± 20	3 ± 6	21 ± 44	1 ± 8	10 ± 100	7 ± 14	0.3 ± 0.2	3.2 ± 7.5	208 ± 166	67 ± 64	7.9 ± 0.6	244 ± 232

[a]Springs grouped according to hydrologic unit.

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 error term for that analysis.

TABLE XIII

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM MUNICIPAL WATER SUPPLY AND DISTRIBUTION

Station	No. of Analyses	Radiochemical (average 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	Gross-α 10^{-9} μCi/mℓ	Gross-β 10^{-9} μCi/mℓ	Total U μg/ℓ
Los Alamos Field (5 wells)	10	2.2 ± 4.2	14 ± 139	−0.05 ± 0.14	−0.03 ± 0.12	2.4 ± 6.1	4.3 ± 3.7	3.6 ± 5.0
Guaje Field (7 wells)	14	2.1 ± 2.9	42 ± 93	−0.02 ± 0.04	−0.01 ± 0.06	−0.1 ± 1.4	3.9 ± 2.2	1.0 ± 0.8
Pajarito Field (3 wells)	6	1.7 ± 2.7	30 ± 114	−0.02 ± 0.06	−0.01 ± 0.04	0.4 ± 1.8	4.6 ± 3.1	1.0 ± 1.8
Water Canyon (gallery)	2	2.7 ± 1.7	−2 ± 79	−0.03 ± 0.04	−0.01 ± 0.04	0.2 ± 0.8	2.4 ± 0.4	0.2 ± 0.0
Distribution (5 stations)	15	2.4 ± 3.3	14 ± 185	−0.04 ± 0.12	−0.04 ± 0.22	0.3 ± 2.8	3.9 ± 2.7	1.6 ± 2.0
Minimum		0.4 ± 0.6	−140 ± 140	−0.20 ± 1.40	−0.40 ± 0.30	−2.4 ± 2.0	1.8 ± 1.6	−0.1 ± 0.2
Maximum		6.7 ± 0.8	200 ± 120	0.01 ± 0.10	0.04 ± 0.30	9.0 ± 6.0	8.4 ± 3.0	6.8 ± 1.4
Average		2.3 ± 6.6	20 ± 130	−0.03 ± 0.10	−0.02 ± 0.07	0.7 ± 1.8	4.0 ± 2.8	1.7 ± 3.2

Station	No. of Analyses	Chemical (average of a number of analyses) Concentrations in mg/ℓ SiO_2	Ca^{+2}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3	SO_4	Cl^{-}	TDS	Hard	pH	Conductance mS/m
Los Alamos Field (5 wells)	10	34	10	<1	56	0	137	---	6	256	29	8.3	36.0
Guaje Field (7 wells)	13	67	15	2	19	0	84	---	5	174	45	7.9	19.0
Pajarito Field (3 wells)	6	87	21	6	15	0	103	---	8	218	77	8.2	23.0
Water Canyon (gallery)	2	---	8	3	6	0	46	---	2	108	32	7.6	11.0
Distribution (5 stations)	10	60	14	4	26	0	90	3.5	6	177	46	8.4	22.0
Minimum		30	6	<1	5	0	44	<1	<1	107	16	7.4	10.0
Maximum		96	26	9	141	0	300	9.9	14	556	100	9.0	88.0
Average		60 ± 42	14 ± 12	3 ± 6	29 ± 54	0 ± 0	69 ± 138	3.5 ± 8	6 ± 8	198 ± 192	45 ± 46	8.2 ± 0.6	33.0 ± 86.0

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 error term for that analysis.

TABLE XIII (continued)

	EPA Standard Constituents (average of a number of analyses) Concentrations in mg/ℓ									
Number of Analyses	As 42	Ba 21	Cd 40	Cr 61	F 62	Pb 40	Hg 44	NO_3 41	Se 42	Ag 42
Los Alamos Field (5 wells)	0.011	<0.0005	<0.001	0.006	1.0	<0.005	<0.0005	0.3	<0.002	<0.010
Guaje Field (7 wells)	0.008	<0.0005	<0.001	0.002	0.4	<0.005	<0.0005	0.3	<0.002	<0.010
Pajarito Field (3 wells)	0.002	<0.0005	<0.001	0.002	0.3	<0.005	<0.0005	0.3	<0.002	<0.010
Water Canyon (gallery)	<0.001	<0.0005	<0.001	0.001	0.1	<0.005	<0.0005	0.2	<0.002	<0.010
Distribution (5 statons)	0.008	<0.0005	<0.001	0.003	0.5	<0.005	<0.0005	0.5	<0.002	<0.010
Minimum	<0.001	<0.0005	<0.001	<0.001	<0.1	<0.005	<0.0005	<0.1	<0.002	<0.010
Maximum	0.054	---	---	0.017	2.4	0.011	---	0.7	---	---
Average	0.008	<0.0005	<0.001	0.003	0.5	<0.005	<0.0005	0.3	<0.002	<0.010
USEPA and NMEIA MPL	0.05	1.0	0.010	0.05	2.0	0.05	0.002	45	0.01	0.05
% MPL (av con)	1.6	<1	<10	6	25	<6	<3	3	<20	<2

TABLE XIV

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM ON-SITE 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	^{239}Pu 10^{-9} μCi/ml	Gross-α 10^{-9} μCi/ml	Gross-β 10^{-9} μCi/ml	Total U μg/l
Noneffluent Areas								
Test Well 1	1	---	−18 ± 0	−0.05 ± 0.00	−0.07 ± 0.00	0.9 ± 2.2	6.8 ± 2.2	0.3 ± 0.2
Test Well 1A	3	2.2 ± 2.7	27 ± 120	−0.04 ± 0.04	−0.00 ± 0.01	−0.2 ± 0.7	9.8 ± 6.6	0.3 ± 1.2
Test Well 3	3	2.7 ± 3.6	93 ± 110	−0.02 ± 0.06	−0.01 ± 0.04	0.2 ± 0.2	2.9 ± 1.3	1.2 ± 0.7
Canada del Buey	3	3.7 ± 2.4	11 ± 52	−0.02 ± 0.06	−0.01 ± 0.02	1.1 ± 1.4	8.1 ± 3.9	1.9 ± 2.1
Pajarito Canyon	3	6.2 ± 1.0	30 ± 85	−0.02 ± 0.04	−0.01 ± 0.02	1.3 ± 0.7	28 ± 36	0.2 ± 1.0
Water Canyon	2	1.5 ± 0.3	86 ± 14	−0.00 ± 0.03	−0.00 ± 0.02	1.4 ± 5.0	16 ± 14	1.7 ± 3.3
Test Well DT-5A	3	1.4 ± 1.6	−28 ± 90	−0.01 ± 0.02	0.00 ± 0.08	0.6 ± 1.9	5.3 ± 5.3	0.7 ± 0.1
Test Well-8	3	2.0 ± 3.1	−23 ± 220	0.04 ± 0.16	0.02 ± 0.04	0.4 ± 0.3	3.1 ± 1.9	0.3 ± 0.2
Test Well DT-9	1	---	60 ± 40	−0.06 ± 0.06	0.02 ± 0.08	0.8 ± 1.2	3.6 ± 1.6	0.8 ± 0.2
Test Well DT-10	1	0.2 ± 0.6	90 ± 120	−0.40 ± 0.06	0.10 ± 0.40	1.2 ± 1.4	4.9 ± 1.8	0.7 ± 0.2
Minimum		0.2 ± 0.6	−130 ± 140	−0.06 ± 0.06	−0.07 ± 0.10	−1.0 ± 2.6	2.3 ± 1.6	−0.3 ± 0.4
Maximum		6.8 ± 0.8	150 ± 120	0.14 ± 0.22	0.10 ± 0.40	3.1 ± 2.2	40 ± 8.0	2.8 ± 0.6
Average		2.9 ± 4.0	29 ± 138	−0.03 ± 0.18	−0.00 ± 0.06	0.6 ± 1.8	9.5 ± 20	0.8 ± 1.6
Effluent Release Areas								
Acid-Pueblo Canyon (former release area)								
Acid Weir	3	1.1 ± 0.3	57 ± 81	0.00 ± 0.01	0.88 ± 1.60	1.6 ± 1.3	119 ± 140	2.5 ± 4.2
Pueblo 1	3	1.2 ± 1.8	−11 ± 69	−0.00 ± 0.03	0.01 ± 0.04	0.0 ± 0.5	16 ± 5.3	0.4 ± 0.2
Pueblo 2	3	2.3 ± 1.7	40 ± 299	−0.01 ± 0.04	0.00 ± 0.00	1.9 ± 5.4	21 ± 22	0.6 ± 0.2
Pueblo 3	3	2.1 ± 1.6	13 ± 101	−0.02 ± 0.04	1.6 ± 5.4	−0.6 ± 4.4	25 ± 5.8	1.1 ± 2.2
Hamilton Bend Spr	1	0.7 ± 0.6	40 ± 100	0.03 ± 0.04	−0.01 ± 0.01	2.2 ± 3.0	18 ± 4.0	0.4 ± 0.6
Minimum		0.2 ± 0.6	−20 ± 60	−0.01 ± 0.01	−0.01 ± 0.01	−0.9 ± 2.8	11 ± 2.8	0.2 ± 0.6
Maximum		3.3 ± 0.6	210 ± 160	0.03 ± 0.04	4.7 ± 0.28	5.0 ± 4.0	200 ± 40	4.8 ± 1.0
Average		1.6 ± 1.7	26 ± 145	−0.00 ± 0.04	0.61 ± 2.8	0.9 ± 3.7	43 ± 104	1.1 ± 2.6
Sandia Canyon								
SCS-1	3	10 ± 6.7	73 ± 83	0.02 ± 0.08	−0.04 ± 0.14	0.1 ± 1.3	40 ± 45	3.2 ± 2.5
SCS-2	3	11 ± 7.2	−10 ± 100	−0.02 ± 0.06	−0.01 ± 0.02	2.7 ± 9.2	35 ± 27	3.6 ± 4.0
SCS near SR4	3	11 ± 5.7	47 ± 168	0.02 ± 0.06	−0.03 ± 0.06	−0.3 ± 3.0	32 ± 14	3.3 ± 3.5
Minimum		7.2 ± 0.8	−60 ± 40	−0.06 ± 0.06	−0.12 ± 0.2	−2.0 ± 8.0	24 ± 6.0	1.5 ± 0.6
Maximum		14.3 ± 1.0	120 ± 120	0.04 ± 0.18	0.02 ± 0.10	8.0 ± 12	66 ± 14	5.5 ± 1.0
Average		10.9 ± 5.8	37 ± 130	0.01 ± 0.08	−0.02 ± 0.08	0.8 ± 5.8	36 ± 12	3.4 ± 3.0
DP-Los Alamos Canyon								
DPS-1	3	130 ± 6.5	−5.8 ± 117	0.69 ± 1.96	1.67 ± 3.50	106 ± 336	3870 ± 1180	108.0 ± 92.6
DPS-4	3	43 ± 4.4	93 ± 110	0.03 ± 0.04	0.15 ± 0.16	−1.0 ± 26	763 ± 110	6.8 ± 7.4
Obs Hole LAO-C	3	3.0 ± 3.0	3 ± 50	−0.00 ± 0.04	−0.01 ± 0.00	2.7 ± 2.6	14 ± 5.3	2.0 ± 3.6
Obs Hole LAO-1	3	33 ± 8.5	36 ± 62	0.02 ± 0.04	−0.00 ± 0.03	−1.0 ± 6.9	209 ± 39	1.2 ± 1.3
Obs Hole LAO-2	2	29 ± 5.7	85 ± 410	−0.14 ± 0.46	0.10 ± 0.00	−1.5 ± 18	370 ± 113	2.8 ± 0.6
Obs Hole LAO-3	2	25 ± 5.4	−11 ± 110	−0.01 ± 0.04	−0.00 ± 0.02	4.0 ± 2.8	141 ± 5.7	4.5 ± 3.2
Obs Hole LAO-4.5	3	11 ± 2.4	23 ± 130	0.02 ± 0.04	0.02 ± 0.04	2.3 ± 2.5	12 ± 3.2	1.6 ± 1.5
Obs Hole LAO-4	2	12 ± 0.9	110 ± 113	0.16 ± 0.38	−0.10 ± 0.28	1.1 ± 5.9	17 ± 1.6	0.8 ± 0.0
Minimum		1.5 ± 0.6	−70 ± 140	0.30 ± 0.40	−0.20 ± 0.40	−12 ± 14	11 ± 2.8	0.5 ± 0.3
Maximum		149 ± 4.0	230 ± 180	1.82 ± 0.18	3.67 ± 0.26	300 ± 400	10 700 ± 2200	158.0 ± 2.0
Average		38 ± 85	39 ± 150	0.11 ± 0.81	0.26 ± 1.63	16 ± 130	746 ± 4600	17.9 ± 40.6
Mortandad Canyon								
Gaging Station 1	3	565 ± 1830	230 ± 294	6.96 ± 18.93	0.96 ± 0.06	4.7 ± 52	1040 ± 1116	2.6 ± 1.9
Obs Hole MCO-3	3	316 ± 190	30 ± 151	6.5 ± 14	0.59 ± 0.88	25 ± 16	490 ± 140	8.8 ± 4.3
Obs Hole MCO-4	3	371 ± 787	30 ± 144	5.4 ± 4.9	0.96 ± 1.3	46 ± 54	413 ± 273	18 ± 23
Obs Hole MCO-5	3	506 ± 998	87 ± 81	1.2 ± 1.6	0.09 ± 0.50	11 ± 8.9	47 ± 33	5.2 ± 3.1
Obs Hole MCO-6	3	514 ± 1167	43 ± 81	0.28 ± 0.10	0.04 ± 0.06	30 ± 38	54 ± 57	9.2 ± 12
Obs Hole MCO-7	3	240 ± 250	120 ± 72	0.12 ± 0.18	−0.04 ± 0.10	6.4 ± 3.0	15 ± 1.9	1.9 ± 2.1
Obs Hole MCO-7.5	3	963 ± 376	93 ± 250	0.30 ± 0.54	0.00 ± 0.24	42 ± 22	84 ± 54	8.8 ± 6.7
Obs Hole MCO-8	1	630 ± 20	130 ± 140	0.28 ± 0.08	0.01 ± 0.03	7.0 ± 6.0	25 ± 6.0	4.7 ± 1.0
Minimum		21 ± 1.0	−40 ± 120	0.06 ± 0.14	−0.2 ± 0.60	−25 ± 14	14 ± 3.2	0.7 ± 0.6
Maximum		1620 ± 80	450 ± 140	11.9 ± 0.60	1.55 ± 0.16	76 ± 36	1670 ± 340	25.1 ± 5
Average		490 ± 880	92 ± 210	2.77 ± 8.17	0.34 ± 1.00	23 ± 42	290 ± 800	7.7 ± 13

TABLE XIV (continued)

Station	No. of Samples	Chemical (average of a number of analyses)										pH	Cond mS/m
		Ca^{2+}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	F^{-}	NO_3^{-}	TDS	Hard		
Noneffluent Areas													
Test Well 1	1	34	8	20	0	118	<1	0.3	0.4	248	90	8.2	29.0
Test Well 1A	1	18	11	66	0	106	3	0.5	40	330	90	7.7	48.0
Test Well 3	2	19	5	12	0	88	16	0.4	1.3	171	68	7.9	20.0
Canada del Buey	2	12	4	18	0	44	109	0.7	2.2	322	44	7.1	20.0
Pajarito Canyon	1	44	14	31	0	82	<1	0.1	1.8	406	168	7.1	57.0
Water Canyon	1	10	3	23	0	64	3	0.3	<0.4	246	36	8.1	16.0
Test Well DT-5A	2	9	3	14	0	57	2	0.2	1.3	128	32	7.6	13.0
Test Well-8	1	10	4	11	0	56	0	0.3	0.4	110	44	8.1	15.0
Test Well DT-9	1	10	2	11	0	56	0	0.2	0.9	190	34	8.3	13.0
Test Well DT-10	1	11	3	10	0	64			1.8	162	41	8.3	14.0
Minimum		8	1	10	0	36	0	0.1	<0.4	106	28	7.0	13.0
Maximum		44	14	66	0	118	109	0.9	40	406	168	8.3	57.0
Average		16 ± 22	5 ± 8	19 ± 26	0 ± 0	71 ± 48	12 ± 60	0.3 ± 0.4	3.9 ± 20	225 ± 202	66 ± 80	7.8 ± 1.0	23.0 ± 28.0
Effluent Release Areas													
Acid-Pueblo Canyon (former release area)													
Acid Weir	2	17	6	44	5	68	53	0.6	24	308	69	8.2	44.6
Pueblo 1	2	12	5	64	0	51	38	0.6	73	394	50	7.0	49.6
Pueblo 2	2	14	5	59	0	67	40	0.6	50	357	54	7.1	48.0
Obs Hole PO-3B	1	34	7	34	0	88	1	0.4	19	268	112	7.6	44.0
Hamilton Bend Spr	1	10	7	61	0	96	39	0.6	39	354	54	7.7	53.0
Pueblo 3	2	14	3	68	10	107	35	0.6	31	343	43	8.3	25.5
Minimum		8	2	10	0	34	1	0.3	17	226	30	6.9	31.0
Maximum		34	7	77	20	122	88	0.7	81	410	112	9.4	58.0
Average		16 ± 16	5 ± 4	56 ± 40	3 ± 14	77 ± 50	37 ± 44	0.5 ± 0.2	42 ± 40	343 ± 108	58 ± 48	7.7 ± 1.6	48.0 ± 16.0
Sandia Canyon													
SCS-1	2	28	7	96	0	130	8	2.6	34	677	98	8.1	82.0
SCS-2	2	36	8	137	32	195	86	1.7	12	731	126	8.9	113.0
SCS-3 near SR4	2	38	8	71	4	190	36	1.6	16	734	128	8.1	110.0
Minimum		22	6	12	0	112	1	1.0	9.7	624	80	7.8	76.0
Maximum		42	9	141	64	234	96	3.7	38	796	141	10.0	116.0
Average		34 ± 14	8 ± 2	102 ± 96	12 ± 62	172 ± 96	50 ± 78	2.0 ± 2.0	21 ± 24	714 ± 138	8.4 ± 1.6	8.4 ± 1.6	102.0 ± 33.0
DP-Los Alamos Canyon													
DPS-1	2	26	4	250	14	405	20	7.9	814	1503	82	8.2	180.0
DPS-4	1	25	2	21	0	224	47	2.4	122	626	72	8.3	92.0
Obs Hole LAO-C	2	22	5	46	0	87	69	0.2	0.4	278	77	7.6	43.0
Obs Hole LAO-1	2	21	2	70	5	133	64	0.8	8.4	327	61	8.1	43.0
Obs Hole LAO-3	1	20	3	86	0	198	3	1.8	66	470	65	7.5	72.0
Obs Hole LAO-4	1	18	5	43	0	116	21	1.1	13	260	66	7.5	39.0
Obs Hole LAO-4.5	1	15	2	35	0	66	30	0.6	0.4	194	48	7.5	23.0
Minimum		15	<1	21	0	66	3	0.2	0.4	194	48	7.4	23.0
Maximum		28	5	366	28	500	78	10.9	1320	1946	87	8.6	207.0
Average		22 ± 8	4 ± 2	92 ± 204	4 ± 18	185 ± 266	37 ± 48	2.4 ± 6.6	185 ± 820	551 ± 1060	69 ± 24	7.9 ± 0.8	75.9 ± 109.0
Mortandad Canyon													
Gaging Station 1	1	9	<1	95	0	192	3	0.6	132	388	22	8.2	55.0
Obs Hole MCO-3	1	8	5	175	0	280	27	1.4	295	740	40	8.2	110.0
Obs Hole MCO-4	1	35	2	189	0	310	35	0.8	418	850	96	8.0	120.0
Obs Hole MCO-5	1	22	4	169	14	272	26	0.8	405	718	72	8.4	92.0
Obs Hole MCO-6	1	22	4	175	16	298	25	1.2	378	728	72	8.6	94.0
Obs Hole MCO-7	1	8	2	80	6	164	19	0.6	485	302	30	8.6	43.0
Obs Hole MCO-7.5	1	22	4	143	0	254	26	0.4	286	628	72	8.0	89.0
Minimum		8	<1	80	0	164	3	0.4	132	302	22	8.0	43.0
Maximum		35	5	189	16	310	35	1.4	485	850	96	8.6	120.0
Average		18 ± 20	3 ± 2	147 ± 86	5 ± 14	253 ± 110	23 ± 20	0.8 ± 0.8	343 ± 228	622 ± 402	58 ± 54	8.3 ± 0.4	86.0 ± 28.0

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 error term for that analysis.

TABLE XV

LOCATIONS OF SOIL AND SEDIMENT STATIONS

Stations	Latitude Coordinates N-S	or	Longitude Coordinates E-W
Regional Soil and Sediments[1]	a		a
Perimeter Soils			
Sportsman's Club	N040		E210
Near TA-8	N025		W075
Near TA-49	S155		E090
Near TA-33	S240		E220
Near Frijoles Park Hdq	S280		E190
Perimeter Sediments			
Guaje near G-4	N213		E315
Mortandad at SR-4	S030		E350
Pajarito at SR-4	S105		E320
Frijoles at Park Hdq	S280		E190
White Rock Canyon Sediments			
Rio Grande at Sandia Canyon	35°50'		106°10'
Rio Grande at Pajarito Canyon	35°48'		106°12'
Rio Grande at Ancho Canyon	35°46'		106°12'
Rio Grande at Frijoles Canyon	35°45'		106°15'
Rio Grande at Alamo Canyon	35°43'		106°17'
Rio Grande at Cochiti Res	35°41'		106°18'
Sandia Canyon at Rio Grande	35°50'		106°10'
Canada del Ancha at Rio Grande	35°50'		106°10'
Mortandad at Rio Grande	35°50'		106°10'
Pajarito at Rio Grande	35°48'		106°12'
Water Canyon at Rio Grande	35°47'		106°12'
Ancho Canyon at Rio Grande	35°46'		106°12'
Chiquihui at Rio Grande	35°46'		106°14'
Frijoles at Rio Grande	35°46'		106°15'
Alamo at Rio Grande	35°43'		106°17'
On-Site Soils			
TA-21	N095		E140
TA-50	N035		E095
TA-36	S068		E152
PM-1	N020		E310
On-Site Sediments Noneffluent Areas			
Potrillo Canyon	S072		E152
Water Canyon at Beta	S090		E095
Water Canyon at SR-4	S172		E258
Ancho Canyon at SR-4	S260		E265
On-Site Sediment Effluent Areas			
Pueblo Canyon (Former Release Area)			
TW-2	N115		E145
At SR-4	N070		E347
DP-Los Alamos Canyon			
DPS-1	N095		E160
DPS-4	N080		E205
GS-1	N080		E118
TW-3	N080		E120
At SR4	N065		E342
Mortandad Canyon			
GS-1	N050		E090
MCO-5	N040		E150
MCO-7	N030		E170
Lower Los Alamos Canyon[b]			
LA-4	N065		E405
LA-2	N125		E500
Otowi	N090		E550

[a]Locations are the same as for surface water station (Table X).
[b]Off-site, drainage from Acid-Pueblo and DP-Los Alamos Canyons.

TABLE XVI

RADIOCHEMICAL ANALYSES OF
REGIONAL AND PERIMETER SOILS AND SEDIMENTS
(average of a number of analyses)

Regional Soils	No. of Samples	^{90}Sr pCi/g[a]	^{137}Cs pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Gross-α pCi/g	Gross-β pCi/g	Total U μg/g
Chamita	2	0.09 ± 0:14	0.66 ± 0.26	0.014 ± 0.001	0.014 ± 0.010	7.0 ± 8.6	8.0 ± 0.7	3.0 ± 0.1
Embudo	2	0.40 ± 0.22	0.55 ± 050	−0.000 ± 0.004	0.012 ± 0.007	4.1 ± 0.6	7.0 ± 3.0	2.0 ± 0.6
Otowi	2	0.04 ± 0.04	1.01 ± 0.14	0.150 ± 420	0.013 ± 0.023	4.3 ± 4.4	6.4 ± 2.2	3.8 ± 0.3
Cochiti	2	0.03 ± 0.06	0.30 ± 0.50	−0.001 ± 0.004	0.002 ± 0.003	7.0 ± 8.6	6.6 ± 1.7	2.1 ± 0.6
Bernalillo	2	0.05 ± 0.03	0.19 ± 0.36	−0.001 ± 0.003	0.001 ± 0.006	4.9 ± 0.8	5.2 ± 1.7	2.4 ± 0.8
Jemez River	2	0.14 ± 0.08	0.14 ± 0.20	0.010 ± 0.020	−0.010 ± 0.40	8.4 ± 18.8	7.0 ± 4.5	1.5 ± 0.7
Minimum		0.03 ± 0.06	0.06 ± 0.04	−0.001 ± 0.001	−0.001 ± 0.010	1.7 ± 12	4.6 ± 1.2	1.2 ± 1.2
Maximum		0.40 ± 0.22	1.06 ± 0.28	0.300 ± 0.300	0.021 ± 0.006	16.0 ± 8.0	8.6 ± 2.0	3.9 ± 1.8
Average		0.13 ± 0.28	0.47 ± 0.68	0.027 ± 0.170	0.005 ± 0.044	5.9 ± 7.6	6.7 ± 2.6	2.5 ± 1.6
Regional Sediments								
Chamita	2	−0.01 ± 0.10	0.07 ± 0.02	0:000 ± 0.001	0.001 ± 0.000	1.3 ± 1.0	1.7 ± 0.1	1.2 ± 0.8
Embudo	2	−0.04 ± 0.12	0.12 ± 0.08	0.000 ± 0.001	0.001 ± 0.002	1.6 ± 0.3	1.3 ± 0.3	2.2 ± 1.4
Otowi	2	0.08 ± 0.08	−0.01 ± 0.2	0.002 ± 0.004	0.004 ± 0.002	2,0 ± 0.8	2.9 ± 1.6	0:9 ± 1.1
Cochiti	2	0.03 ± 0,02	0.04 ± 0.02	−0.010 ± 0.028	0.015 ± 0.043	2.7 ± 2.0	1.7 ± 1.0	1.9 ± 2.3
Bernalillo	2	−0.05 ± 0.03	0.09 ± 0.26	−0.002 ± 0.006	0.006 ± 0.018	7.8 ± 18	3.4 ± 5.4	2.9 ± 1.6
Jemez River	2	0.16 ± 0.16	0.39 ± 0.20	0.001 ± 0.001	0:006.± 0.001	13.0 ± 2.8	8.2 ± 9.9	2.2 ± 1.4
Minimum		−0.02 ± 0.10	−0.08 ± 0.16	−0.020 ± 0.030	−0.30 ± 0.040	0.9 ± 0.8	1.2 ± 0.6	0.5 ± 1.4
Maximum		0.16 ± 0.16	0.46 ± 0.12	0.003 ± 0.003	0.013 ± 0.014	14 ± 8.0	12 ± 2.6	3.4 ± 1.6
Average		0.04 ± 0.14	0.12 ± 0.30	−0.001 ± 0.006	0.001 ± 0.020	4.7 ± 10	3.2 ± 6.0	1.9 ± 1.8
Perimeter Soils								
Sportsmen's Club	2	−0.01 ± 0.08	0.93 ± 0.32	−0.003 ± 0.001	0.018 ± 0.010	7.4 ± 4.6	8.6 ± 0.4	2.9 ± 0.4
Near TA-8	2	0.35 ± 0.06	1.94 ± 1.30	−0.010 ± 0.040	0.122 ± 0.219	6.6 ± 1.2	11.7 ± 1.7	3.6 ± 4.4
Near TA-49	2	0.14 ± 0,14	0.92 ± 1.15	0.004 ± 0.000	0.020 ± 0.040	4.6 ± 5.7	7.2 ± 12	4.5 ± 0.6
Near TA-33	2	0.15 ± 0,08	0.43 ± 0.12	0.002 ± 0.003	0.010 ± 0.004	7.8 ± 1.6	7.9 ± 1.8	3.4 ± 3.1
Near Frijoles	2	0.44 ± 0,28	0.87 ± 0.22	0.002 ± 0.007	0.020 ± 0.008	5:6.± 3.2	6.4 ± 0.3	2.0 ± 1.7
Minimum		−0.01 ± 0,08	0.39 ± 0.08	−0.030 ± 0.060	0.005 ± 0.018	2.6 ± 1.2	2.9 ± 0.8	1.4 ± 2.4
Maximum		0.44 ± 0,28	2.40 ± 0.38	−0.004 ± 0.012	0.200 ± 0.800	9.0 ± 4.0	11.4 ± 2.6	5.1 ± 1.6
Average		0.21 ± 0,36	1.02 ± 1.20	−0.002 ± 0.020	0.036 ± 0,059	6.4 ± 3.6	8.3 ± 5.6	3.5 ± 2.6
Perimeter Sediments								
Guaje near G-4	2	0.02 ± 0.20	−0.04 ± 0.26	−0.001 ± 0.003	0.001 ± 0,001	1.8 ± 0.3	1.6 ± 0.3	0.4 ± 3.7
Mortandad at SR-4	2	0.14 ± 0.04	0.09 ± 0.22	0.001 ± 0.002	0.006 ± 0,012	5.0 ± 0.3	5.8 ± 2.0	2.3 ± 0,8
Pajarito at SR-4	2	−0.06 ± 0.12	0.27 ± 0.34	−0.005 ± 0.013	0.002 ± 0.021	7.3 ± 4.8	6.5 ± 0.4	2.8 ± 0.6
Frijoles at Bandelier	2	0.04 ± 0.02	−0,02 ± 0.34	0.003 ± 0.006	0.003 ± 0.002	1.6 ± 0.7	1.8 ± 1.8	0.9 ± 1.6
Minimum		−0.06 ± 0.12	−0.14 ± 0.14	−0:009 ± 0.014	−0.006 ± 0,012	1.3 ± 0.8	1.1 ± 0.8	−0.9 ± 1.8
Maximum		0.14 ± 0,04	0.39 ± 0.12	0.005 ± 0.012	0.010.± 0,040	9.0 ± 4.0	6.6 ± 1.6	3.0 ± 1.4
Average		0,04 ± 0.16	0.08 ± 0.34	−0.001 ± 0.008	0.002 ± 0.010	3.9 ± 5.4	3.9 ± 5.0	1.6 ± 2.6
White Rock Canyon Sediments[b]								
Rio Grande	6	0,06 ± 0.22	0.31 ±0.57	0.001 ± 0.011	0.010 ± 0,020	4.5 ± 6.5	6,1 ± 8.1	2.3 ± 1.9
Major Tributaries to Rio Grande	9	0.67 ± 0.94	0.32 ± 0.68	0.001 ± 0.002	0.010 ± 0.020	2,8 ± 2.1	3.1 ± 4.8	2.2 ± 1.9
Minimum		−0.08 ± 0.15	0.01 ± 0.06	−0.002 ± 0.003	0.000 ± 0.002	1.2 ± 0.8	1.1 ± 0.8	0.4 ± 1.0
Maximum		1.23 ± 0.34	0.95 ± 0.26	0.013 ± 0.004	0.027 ± 0.008	9.0 ± 4.0	11.2 ± 2.6	3.7 ± 1.2
Average		0.43 ± 0.96	0.31 ± 0.62	0.001 ± 0.004	0.010 ± 0.018	3.5 ± 4.6	4.3 ± 6.8	2.2 ± 1,8

[a] ^{90}Sr, one analysis.

[b] Special study White Rock Canyon, 15 stations along Rio Grande from Otowi to Cochiti Reservoir.

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 error term for that analysis.

TABLE XVII

RADIOCHEMICAL ANALYSES OF ON-SITE SOILS AND SEDIMENTS
(average of a number of analyses)

On-Site Soils	No. of Samples	^{90}Sr[a] pCi/g	^{137}Cs pCi/g	^{239}Pu pCi/g	^{238}Pu pCi/g	Gross-α pCi/g	Gross-β pCi/g	Total U μg/g
TA-21	2	---	0.10 ± 0.08	0.004 ± 0.011	0.006 ± 0.003	7.4 ± 2.2	6.7 ± 2.6	3.2 ± 1.8
TA-50	2	0.08 ± 0.06	1.04 ± 0.42	0.011 ± 0.018	3.8 ± 8.9	12 ± 14	12 ± 0.4	8.4 ± 1.0
TA-36	2	0.10 ± 0.04	0.40 ± 0.18	0.002 ± 0.004	0.012 ± 0.004	12 ± 10	10 ± 0.0	3.4 ± 2.7
PM-1	2	0.46 ± 0.28	0.62 ± 0.02	0.001 ± 0.003	0.014 ± 0.008	6.1 ± 2.1	8.2 ± 2.1	4.6 ± 0.6
Minimum		0.08 ± 0.06	0.07 ± 0.08	−0.001 ± 0.003	0.007 ± 0.006	5.3 ± 2.4	5.7 ± 1.4	2.5 ± 1.4
Maximum		0.46 ± 0.28	1.19 ± 0.22	0.017 ± 0:004	6.98 ± 0.320	17 ± 8.0	12 ± 2.6	8.7 ± 2.0
Average		0.21 ± 0.42	0.54 ± 0.76	0.004 ± 0.012	0.967 ± 4.88	9.3 ± 8.6	9.2 ± 4.4	4.9 ± 4.6
On-Site Sediments Noneffluent Areas								
Potrillo	2	0.04 ± 0.02	0.20 ± 0.28	0.001 ± 0.000	0.004 ± 0.007	9.4 ± 7.4	9.9 ± 13.4	5.4 ± 0.7
Water Canyon at Beta	2	−0.11 ± 0.12	0.50 ± 0.86	−0.001 ± 0.003	0.006 ± 0.015	6.7 ± 9.3	4.8 ± 0.8	2.9 ± 0.7
Water Canyon at SR-4	2	0.29 ± 0.16	1.21 ± 3.03	−0.000 ± 0.003	0.023 ± 0.037	4.1 ± 5.5	7.8 ± 14.0	2.6 ± 2.1
Ancho Canyon at SR-4	2	0.04 ± 0.04	0.41 ± 0.76	0.000 ± 0.001	0.001 ± 0.018	3.9 ± 1.8	5.8 ± 1.4	2.5 ± 1.1
Minimum		−0.11 ± 0.12	0.10 ± 0.06	−0.002 ± 0.002	−0.005 ± 0.006	2.1 ± 1.0	2.8 ± 0.8	1.8 ± 1.6
Maximum		0.28 ± 0.16	2.28 ± 0.34	0.001 ± 0.012	0.036 ± 0.006	12.0 ± 4.0	14.6 ± 3.2	5.6 ± 1.8
Average		0.06 ± 0.32	0.58 ± 1.48	−0.000 ± 0.002	0.009 ± 0.024	6.3 ± 14.5	7.2 ± 9.0	3.6 ± 2.6
On-Site Sediments Effluent Areas								
Pueblo Canyon (former release area)					1.24 ± 0.658	2.8 ± 0.8	2.9 ± 1.6	1.6 ± 0.1
TW-2	2	−0.01 ± 0.15	0.18 ± 0.16	0.005 ± 0.008	0.304 ± 0.215	2.3 ± 0.0	2.0 ± 1.7	3.1 ± 1.8
At SR-4	2	0.09 ± 0.16	0.11 ± 0.12	0.002 ± 0.003				
DP-Los Alamos								
DPS-1	1[b]	10.20 ± 1.00	19 ± 16	0.401 ± 0.022	1.5 ± 0.038	3.0 ± 1.4	47 ± 10	4.8 ± 6.2
DPS-4	1[b]	4.60 ± 0.60	21 ± 0.84	0.116 ± 0.014	0.368 ± 0.024	1.5 ± 0.8	25 ± 6.0	0.9 ± 5.2
GS-1	2	−0.04 ± 0.14	2.3 ± 6.1	0.009 ± 0.016	0.466 ± 0.833	4.2 ± 1.4	6.5 ± 11	2.9 ± 0.1
TW-3	2	2.43 ± 0.28	26 ± 0.42	0.105 ± 0.017	0.264 ± 0.634	3.3 ± 1.7	41 ± 33	2.1 ± 2.6
At SR-4	2	0.05 ± 0.03	0.7 ± 0.08	−0.000 ± 0.008	0.022 ± 0.005	2.2 ± 1.1	3.9 ± 0.0	3.6 ± 0.1
Mortandad Canyon								
GS-1	1[b]	7.70 ± 0.80	920 ± 1700	107 ± 0.18	11.5 ± 0.220	120 ± 60	1360 ± 280	3.4 ± 1.6
MCO-5	1[b]	2.70 ± 0.40	71 ± 10	4.42 ± 0.100	0.94 ± 0.036	7.1 ± 3.0	67 ± 14	2.2 ± 3.4
MCO-7	1[b]	1.89 ± 0.28	52 ± 1.4	2.88 ± 0.080	0.587 ± 0.028	6.4 ± 2.8	54 ± 10	5.1 ± 8.2
Minimum		−0.04 ± 0.14	0.07 ± 0.04	−0.003 ± 0.010	0.02 ± 0.012	1.5 ± 0.8	1.4 ± 0.6	0.9 ± 5.2
Maximum		10.20 ± 1.00	920 ± 1700	107.100 ± 0.180	11.490 ± 0.220	120.0 ± 60.0	1360 ± 280	8.0 ± 8.0
Average		2.96 ± 7.11	111.17 ± 681.84	7.677 ± 55.070	1.276 ± 5.729	11.2 ± 60.3	111.0 ± 692.6	2.9 ± 4.0
Lower Los Alamos[c]								
LA-4	2	−0.03 ± 0.19	0.35 ± 0.28	0.000 ± 0.004	0.062 ± 0.126	2.4 ± 0.0	2.7 ± 0.4	3.5 ± 9.0
LA-2	2	−0.17 ± 0.22	0.17 ± 0.04	0.025 ± 0.069	0.066 ± 0.030	12 ± 28	2.6 ± 0.6	2.3 ± 0.0
Otowi	2	0.17 ± 0.12	0.21 ±0.02	0.001 ± 0.001	0.039 ± 0.103	3.2 ± 2.6	3.1 ± 0.0	3.5 ± 0.0
Minimum		−0.17 ± 0.22	0.15 ± 0.10	−0.002 ± 0.008	0.003 ± 0.006	2.1 ± 1.2	2.4 ± 1.0	0.3 ± 2.0
Maximum		0.17 ± 0.12	0.45 ± 0.08	0.04 ± 0.008	0.106 ± 0.012	22 ± 10	3.1 ± 1.0	6.7 ± 3.6
Average		−0.01 ± 0.34	0.24 ± 0.22	−0.01 ± 0.040	0.06 ± 0.080	5.9 ± 16	2.8 ± 0.6	3.2 ± 5.4

[a] ^{90}Sr, one analysis.
[b] ^{137}Cs and total U, two analyses.
[c] Off-site drainage from Acid-Pueblo and DP-Los Alamos Canyons.

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 error term for that analysis.

TABLE XVIII

RADIOCHEMICAL ANALYSES OF
SOIL AND DRAIN SEDIMENTS AT TA-55

Station	Type	Gross α pCi/g	Gross β pCi/g	Gross γ ncpm/g	^{137}Cs pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	^{90}Sr pCi/g	^{210}Po pCi/g	^{3}H 10^{-6} μCi/mℓ	Total U μg/g
1	Soil	16.0 ± 8.0	19.0 ± 4.0	6.28 ± 0.22	0.25 ± 0.08	−0.0014 ± 0.0014	0.0070 ± 0.0040	0.18 ± 0.16	1.64 ± 0.38	9.9 ± 0.8	4.2
2	Soil	10.0 ± 4.0	10.7 ± 2.4	6.71 ± 0.22	0.26 ± 0.06	−0.0024 ± 0.0028	0.0110 ± 0.0060	−0.01 ± 0.22	1.63 ± 0.34	9.9 ± 0.8	3.7
3	Soil	9.0 ± 4.0	11.5 ± 2.6	6.47 ± 0.22	−0.03 ± 0.16	0.0001 ± 0.0016	0.0540 ± 0.0100	---	1.64 ± 0.28	6.9 ± 0.8	8.0
4	Soil	12.0 ± 6.0	21.0 ± 4.0	7.05 ± 0.22	0.72 ± 0.14	−0.0001 ± 0.0060	0.0200 ± 0.0080	0.48 ± 0.20	2.40 ± 0.40	7.4 ± 0.8	6.3
5	Soil	9.0 ± 4.0	11.2 ± 2.6	6.11 ± 0.24	0.15 ± 0.06	0.0005 ± 0.0026	0.0070 ± 0.006	0.07 ± 0.16	1.49 ± 0.26	7.2 ± 0.8	3.5
6	Soil	9.0 ± 4.0	14.2 ± 3.0	8.28 ± 0.24	0.83 ± 0.16	0.0710 ± 0.0140	11.4 ± 0.80	0.41 ± 0.24	2.20 ± 0.40	6.5 ± 0.8	6.9
7	Soil	11.0 ± 6.0	12.2 ± 2.8	7.03 ± 0.22	0.56 ± 0.10	0.0036 ± 0.0030	0.0860 ±0.0120	0.29 ± 0.20	2.49 ± 0.28	5.9 ± 0.6	5.9
8	Soil	10.0 ± 4.0	13.6 ± 3.0	6.22 ± 0.24	0.27 ± 0.10	0.0020 ± 0.0040	0.0190 ± 0.0080	0.08 ± 0.34	1.75 ± 0.28	11.2 ± 0.8	4.2
Minimum[a]		9.0 ± 4.0	10.7 ± 2.1	6.11 ± 0.22	−0.03 ± 0.16	−0.0024 ± 0.0028	0.0070 ± 0.0030	−0.01 ± 0.22	1.49 ± 0.26	5.9 ± 0.6	3.5
Maximum[a]		16.0 ± 8.0	21.0 ± 4.0	7.05 ± 0.22	0.72 ± 0.14	0.0036 ± 0.0030	0.0860 ± 0.0060	0.49 ± 0.20	2.49 ± 0.28	11.2 ± 0.8	8.0
Average[a]		11.0 ± 4.9	14.17 ± 4.3	6.55 ± 0.76	0.31 ± 0.50	0.0003 ± 0.0040	0.03 ± 0.06	0.33 ± 0.70	1.86 ± 0.81	8.3 ± 4.0	5.1 ± 3.4
9	Drain Sediment	3.5 ± 1.6	2.3 ± 1.0	3.24 ± 0.18	0.00 ± 0.04	0.0007 ± 0.0020	0.0006 ± 0.0016	−0.03 ± 0.14	0.30 ± 0.34	5.1 ± 0.6	1.9
10	Drain Sediment	2.5 ± 1.2	2.3 ± 0.8	3.26 ± 0.18	−0.10 ± 0.16	0.0001 ± 0.0016	0.0024 ± 0.0022	0.13 ± 0.14	0.40 ± 0.10	3.4 ± 0.6	1.6
11	Drain Sediment	4.3 ± 2.2	6.8 ± 1.6	5.06 ± 0.20	0.24 ± 0.10	0.0001 ± 0.0026	0.0075 ± 0.0038	−0.17 ± 0.36	−4.00 ± 14	3.0 ± 0.6	3.7
12	Drain Sediment	11.0 ± 6.0	18.0 ± 4.0	6.05 ± 0.22	0.04 ± 0.04	0.0006 ± 0.0030	0.0003 ± 0.0028	0.19 ± 0.18	1.30 ± 0.26	3.6 ± 0.6	3.6
13	Drain Sediment	11.0 ± 4.0	11.9 ± 2.6	6.50 ± 0.22	0.11 ± 0.04	0.0001 ± 0.0020	0.0057 ± 0.0016	0.02 ± 0.28	1.83 ± 0.36	3.7 ± 0.6	5.0
14	Drain Sediment	7.8 ± 3.6	10.8 ± 2.4	6.41 ± 0.22	0.15 ± 0.04	0.0000 ± 0.0040	0.0030 ± 0.0040	0.06 ± 0.14	0.98 ± 0.14	4.5 ± 0.6	3.9
15	Drain Sediment	3.7 ± 2.0	7.9 ± 1.8	4.42 ± 0.20	0.05 ± 0.04	0.0004 ± 0.0022	0.0016 ± 0.0028	0.81 ± 0.38	0.55 ± 0.34	4.1 ± 0.6	2.6
16	Drain Sediment	3.8 ± 1.8	3.6 ± 1.0	4.53 ± 0.20	−0.04 ± 0.22	−0.0010 ± 0.0060	0.0022 ± 0.0038	0.20 ± 0.20	1.04 ± 0.22	3.2 ± 0.6	2.5
17	Drain Sediment	3.1 ± 1.6	4.1 ± 1.2	2.75 ± 0.18	−0.01 ± 0.02	0.0001 ± 0.0026	0.0035 ± 0.0030	0.10 ± 0.24	0.19 ± 0.24	4.9 ± 0.6	1.9
Minimum		2.5 ± 1.2	2.3 ± 1.0	2.75 ± 0.18	−0.10 ± 0.16	−0.0010 ± 0.0060	0.0003 ± 0.0028	−0.03 ± 0.14	−4.00 ± 14	3.0 ± 0.6	1.6
Maximum		11.0 ± 6.0	18.0 ± 4.0	6.50 ± 0.22	0.24 ± 0.10	0.0007 ± 0.0020	0.0075 ± 0.0038	0.81 ± 0.38	1.83 ± 0.36	5.1 ± 0.6	5.0
Average		5.6 ± 6.8	7.5 ± 10.5	4.7 ± 2.8	0.05 ± 0.20	0.0001 ± 0.0010	0.030 ± 0.0046	0.24 ± 0.56	0.31 ± 3.38	3.9 ± 1.5	3.0 ± 2.3

[a]Minimum, maximum, and average do not include soil analyses from Location 6.

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

TABLE XIX

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTAL FOR 1977

Location	^{238}Pu ^{239}Pu (μCi)	^{235}U ^{238}U (μCi)	^{234}Th (mCi)	MFP[a] (μCi)	^{131}I (μCi)	^{41}Ar (Ci)	^{32}P (μCi)	^{3}H (Ci)	$^{11}C, ^{13}N, ^{15}O$[c] (Ci)	^{7}Be (μCi)
TA-2	---	---	---	---	---	315	---	---	---	---
TA-3	33.5	337	5.2	481	88	---	---	400	---	---
TA-9	---	---	---	---	---	---	---	2.6	---	---
TA-15	---	---	---	---	---	---	---	---	---	---
TA-21	10.0	317	---	3.3	---	---	---	133	---	---
TA-33	---	---	---	---	---	---	---	615 [b]	--	---
TA-35	0.8	---	---	---	---	---	---	786	---	---
TA-41	---	---	---	---	---	---	---	---	---	---
TA-43	4.7	---	---	---	---	---	304	---	---	---
TA-46	---	0.004	---	---	---	---	---	---	---	---
TA-48	8.4	55	---	2192	---	---	---	---	---	---
TA-50	70	---	---	86	---	---	---	---	---	---
TA-53	---	---	---	---	---	477	---	290	47 173	0.3
TA-54	0.003	---	---	---	---	---	---	---	---	---

[a]Mixed fission products.

[b]Does not include 30 800 Ci release from TA-33-86 on October 6, 1977.

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

TABLE XX

LIQUID RADIOACTIVE EFFLUENT RELEASES IN 1977

	Waste Treatment Plant Location			
	TA-50		TA-21	
Isotope	Activity Released (mCi)	Average Concentration (μCi/mℓ)	Activity Released (mCi)	Average Concentration (μCi/mℓ)
^{238}Pu	2.57	0.061×10^{-6}	0.058	0.015×10^{-6}
^{239}Pu	1.47	0.035×10^{-6}	0.082	0.021×10^{-6}
^{241}Am	1.93	0.046×10^{-6}	0.21	0.054×10^{-6}
^{89}Sr	2.26	0.054×10^{-6}	0.03	0.007×10^{-6}
^{90}Sr	30.4	7.2×10^{-7}	0.55	1.41×10^{-7}
^{3}H	36 500	0.8×10^{-3}	3200	0.82×10^{-3}
^{137}Cs	142	0.034×10^{-5}	0.94	0.024×10^{-5}
U-total	108 grams	2.5×10^{-3} mg/ℓ	8 grams	2×10^{-3} mg/ℓ

TABLE XXI

TOTAL SUSPENDED PARTICULATES AT LOS ALAMOS AND WHITE ROCK DURING 1977

(Data from New Mexico Environmental Improvement Agency)

All Concentrations in $\mu g/m^3$

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
			Los Alamos (Annual Geometric Mean = 32)									
Number of Samples	6	4	5	5	6	7	5	4	5	5	5	5
Maximum	57	42	155	39	50	89	53	39	34	33	46	65
Minimum	16	24	20	15	27	25	17	11	16	23	23	15
Mean ± 1 Standard Deviation	40 ± 17	34 ± 9	63 ± 55	31 ± 10	36 ± 10	51 ± 25	29 ±14	26 ± 14	23 ± 7	29 ± 4	32 ± 9	34 ± 19
			White Rock (Annual Geometric Mean = 33)									
Number of Samples	6	4	4	5	6	7	5	4	5	5	5	5
Maximum	31	30	104	99	64	103	59	41	41	55	37	134
Minimum	18	8	26	14	27	17	24	9	14	25	16	29
Mean ± 1 Standard Deviation	23 ± 5	20 ± 10	51 ± 36	44 ± 34	48 ± 13	59 ± 31	36 ± 14	20 ± 15	28 ± 12	38 ± 12	26 ± 8	58 ± 44

TABLE XXII

ESTIMATED CONCENTRATIONS OF TOXIC ELEMENTS AEROSOLIZED BY DYNAMIC EXPERIMENTS

Element	1977 Total Usage (kg)	Percent Aerosolized (%)	Annual Avg. Concentration (ng/m^3)		Applicable Standard (ng/m^3)
			4 km	8 km	
Uranium	1595	10	0.2	0.006	9000[a]
Be	35.8	2	0.0009	0.0003	10[b] (30 day avg)
Pb	9.0	100 [c]	0.01	0.004	10 000 [b] (for total heavy metals, N>21)

[a]DOE 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 XXIII

SANITARY SEWAGE TREATMENT FACILITIES
EFFLUENT QUALITY SUMMARY

Facility Location	NPDES Permit Number	Biochemical Oxygen Demand			Total Suspended Solids			Fecal Coliform		
		Observed Range (mg/ℓ)	No. of Months Interim Std. Exceeded[a]	No. of Months Final Std. Exceeded[b]	Observed Range (mg/ℓ)	No. of Months Interim Std. Exceeded[a]	No. of Months Final Std. Exceeded[b]	Observed Range (mg/ℓ)	No. of Months Interim Std. Exceeded[a]	No. of Months Final Std. Exceeded[b]
TA-3	MN0024210	5.5 - 62	0	4	1.6 - 154	0	1	1000 - 198 000	3	6
TA-9	NM0024295	1 - 23	0	0	1 - 22	0	0	0 - 35	0	0
TA-16	NM0024236	1.5 - 25	0	0	0 - 16	0	0	50 - 21 000	1	5
TA-18	MN0024244	0 - 50	0	1	0 - 50	0	1	0 - 50	0	0
TA-21	NM0024252	11 - 122	1	4	8 - 93	0	5	600 - 121 000	2	6
TA-41	NM0024261	2.4 - 35	0	1	0 - 21	0	0	0	0	0
TA-46	NM0024341	1 - 38	2	1	0.6 - 49	1	0	0 - 3400	2	0
TA-48	NM0024741	1 - 26	0	0	0 - 15	0	0	0 - 1020	0	3
TA-53[c]	NM0024279	25 - 71	0	0	6 - 178	1	0	0 - 200	0	0

[a]Interim standards in effect through June 1977.
[b]Final standards in effect starting July 1977.
[c]TA-53 facility exceeded pH standard during one month, all other facilities met pH standards.

TABLE XXIV

INDUSTRIAL LIQUID EFFLUENT QUALITY SUMMARY[a]

Discharge Category	No. of Discharges	Principal Contaminants[b]	Range of Average Concentrations[c] (mg/ℓ) or pH	Range of Average Flows (gpd)
Spent Demineralizer and Softener	1	TSS	1 - 40	1500 - 4500
		res. Cl	---	
		pH	0.9 -13.2	
Boiler Blowdown	5	TSS	70 - 280	200 - 7000
		Fe	2 -11	
		Cu	0.1 - 0.2	
		P	10 - 30	
		pH	10.7 - 11.9	
Treated Cooling Water	34	TSS	<1 - 65	20 - 125 000
		res. Cl	0.2 - 30	
		P	0.1 - 1	
		pH	7.4 - 9.3	
Diatomaceous Earth Filter	1	TSS	1000	2000
		Fe	---	
		Oil	---	
		pH	7.0 - 8.5	
Non-Contact Cooling Water	22	pH	7.0 - 8.4	50 - 48 500
Photographic Wastewater	13	CN	0.001 -0.3	240 - 1800
		Ag	0.01 - 4.5	
		pH	7.0 - 10.3	
High-explosive Contaminated Wastewater	20	COD	7 - 3400	50 - 22 000
		TSS	2 - 200	
		pH	6.2.- 9.2	
Acid Dip Tank	1	Cu	4	750
		pH	6 - 9	
Cylinder Cleaning Waste	1	TSS	110	50 (batches)
		P	8	
Printed Circuit Process Waste	1	COD	56	4800
		Cu	0.15	
		Fe	0.68	
		Ni	0.03	
		P	7	
		pH	7.2 - 8	
Ultrasonic Cleaning	1	pH	7 - 9	100 (batches)
Industrial Waste Treatment Plants (TA-21 and TA-50)	2	pH	6.9 - 12.3	5000 - 95 000
		COD	3 -200	
		NH_4-N	1 - 210	
		TSS	<1 - 30	
		Cd	0.001 - 0.01	
		Cr total	0.02 - 0.6	
		Cu	0.001 - 0.4	
		Pb	0.001 - 0.1	
		Hg	0.001 - 0.04	
		Zn	0.001 - 1	
		Fe	0.001 - 3	

[a]Based on data collected for NPDES Permit application.
[b]Contaminants expected to be regulated by EPA permit.
[c]Ranges of averages found in samples collected from the various discharges during 1977.

TABLE XXV

URANIUM CONCENTRATIONS IN STANDING WATER AND RUNOFF FROM E-F SITE SEPTEMBER 5, 1975 AND SEPTEMBER 17, 1976

Sample	Date	Uranium in Water (μg U/ℓ)	Uranium in Suspended Sediments (μg U/ℓ)	Total Uranium (μg U/ℓ)	Uranium in Solution (%)
Standing water Detonation Point	1975	$86 \times 10^3 \pm 2 \times 10^3$	590 ± 30	86.6×10^3	99
	1976	$235 \times 10^3 \pm 5 \times 10^3$	$47 \times 10^3 \pm 4 \times 10^3$	282×10^3	83
Standing Water 20 m SW Detonation Area	1975	63 ± 6	$1.25 \times 10^3 \pm 0.2 \times 10^3$	1.3×10^3	5
	1976	240 ± 20	890 ± 30	1.1×10^3	21
Runoff 100 m SW of Detonation Point (mesa top drainage)	1975	52 ± 5	100 ± 8	152	34
	1976	---	---	---	---
Runoff 250 m SW of Detonation Point (canyon stream channel)	1975	37 ± 2	54 ± 5	91	41
	1976	125 ± 9	410 ± 20	535	23

TABLE XXVI

MEAN PERCENT PLUTONIUM INVENTORY IN 10 SOIL PROFILES FROM LOS ALAMOS CANYONS

Depth (cm)	Mortandad	Acid-Pueblo
0 - 2.5	20 (0.44)*	4.0 (0.76)
2.5 - 7.5	36 (0.23)	10 (0.48)
7.5 - 12.5	21 (0.55)	20 (1.3)
12.5 - 30	24 (0.79)	67 (0.18)

*$CV = SD/\bar{x}$

TABLE XXVII

RADIONUCLIDE CONCENTRATIONS IN RADISH AND TOMATO CROPS IN THE MORTANDAD GARDEN PLOT
1976

		^{137}Cs		^{239}Pu		^{238}Pu	
		pCi/g	CR*	pCi/g	CR	pCi/g	CR
24 day old radishes (n=8)	Radish	6.7(0.22)**	0.10(0.28)	0.03(0.42)	0.03(0.51)	0.28(0.47)	0.04(0.53)
	Tops	21 (0.30)	0.30(0.30)	0.24(0.34)	0.18(0.42)	1.6(0.35)	0.21(0.29)
	Soil	7.0(0.13)		1.4(0.22)		8.0(0.27)	
37 day old radishes (n=6)	Radish	5.1(0.39)	0.05(0.37)	0.04(0.26)	0.02(0.26)	0.27(0.22)	0.03(0.32)
	Tops	10 (0.60)	0.10(0.60)	0.05(0.39)	0.03(0.40)	0.29(0.58)	0.03(0.59)
	Soil	97 (0.53)		1.9(0.26)		11.(0.31)	
95 day old tomatoes (n=6))	Ripe-fruit	7.9(0.46)	0.10(0.54)	0.003(0.81)	0.003(0.80)	0.009(1.0)	0.002(1.3)
	Green-fruit	15 (0.50)	0.19(0.53)	0.001(0.82)	0.0006(0.77)	0.004(0.61)	0.0006(0.63)
	Tops	37 (0.33)	0.46(0.40)	0.07(0.46)	0.06(0.53)	0.38(0.48)	0.06(0.62)
	Root	22 (0.26)	0.27(0.27)	0.19(0.29)	0.17(0.44)	1.1(0.25)	0.17(0.41)
	Soil	82 (0.09)		1.3(0.50)		7.3(0.57)	

*Concentration ratio (CR) = pCi/g dry plant/pCi/g dry soil.

**Dry weight concentrations; parenthetic value is coefficient of variation (S.D./$\bar{x}$).

TABLE XXVIII

CHEMICAL QUALITY OF WATER IN THE VICINITY OF FENTON HILL
(average of a number of analyses, concentrations in mg/ℓ)

	No. of Stations*	No. of Samples	SiO_2	Ca^{2+}	Mg^{2+}	Na^+	CO_3^{2-}	HCO_3^-	SO_4	Cl^-	F^-	NO_3^-	TDS	Hard	pH	Cond mS/m
Surface Water	9	9	43 ± 13	40 ± 20	4 ± 3	38 ± 41	0 ± 0	92 ± 70	54 ± 104	46 ± 68	0.5 ± 0.3	0.3 ± 0.1	313 ± 203	118 ± 62	7.3 ± 1.5	459 ± 316
Water Supply	4	4	76 ± 7	18 ± 10	2 ± 1	13 ± 2	0 ± 0	91 ± 22	<1	4 ± 3	0.3 ± 0.1	0.9 ± 0.3	154 ± 43	55 ± 25	7.8 ± 0.2	203 ± 36
Springs (Jemez Fault)	2	2	44 ± 1	224 ± 124	16 ± 7	491 ± 369	0 ± 0	866 ± 467	15 ± 21	943 ± 732	2.1 ± 0.5	0.3 ± 0.1	2530 ± 1861	627 ± 337	7.7 ± 0.3	3740 ± 2348
Springs (Recent Volcanics)	1	1	53	13	2	18	0	64	1	4	0.9	1.2	122	39	7.9	150
Abandoned Well	1	1	68 ± 0	29	8	108	0	420	2	6	0.7	0.9	496	106	7.9	700
Fenton Hill (Pond Fluids)	2	2	142 ± 16	30 ± 5	1 ± 0	324 ± 165	18 ± 25	374 ± 150	260 ± 190	8 ± 3	6.2 ± 2.6	3.6 ± 2.0	1332 ± 897	79 ± 10	8.4 ± 0.4	1988 ± 1043

*Sampling locations keyed on Fig. 17 as follows.

Surface Water - F, J, N, Q, R, S, T, U, V.
Water Supply (Jemez Springs - La Cueva - Fenton Hill) - JS-2, -3, -4, and -5, 4, FH-1. Springs (Jemez Fault) - TF-1, -5.
Springs (recent volcanics) - 31
Abandoned well - 27
Fenton Hill (pond fluids) - Two ponds, TA-57.

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

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