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Environmental Surveillance at Los Alamos During 1976

Environmental Studies Group

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scientific laboratory
of the University of California
LOS ALAMOS, NEW MEXICO 87545

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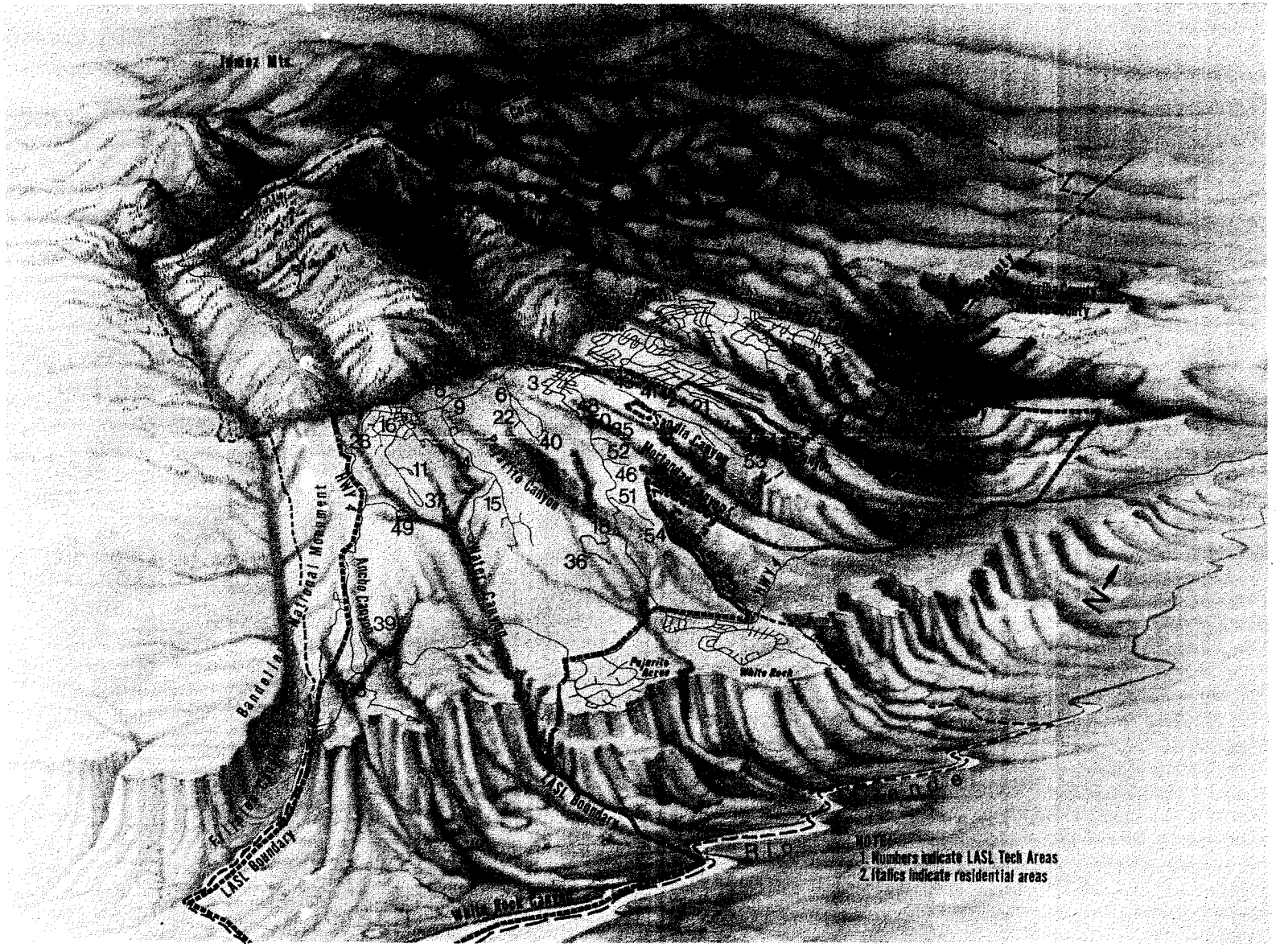


Fig. 1. Topography cf the Los Alamos, New Mexico, area.

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1976

by

Environmental Studies Group

ABSTRACT

This report documents the environmental monitoring program at the Los Alamos Scientific Laboratory (LASL) in 1976. Data are presented for concentrations of radioactivity measured in air, ground and surface waters, sediments, soils, and foodstuffs, and are compared with relevant U.S. Energy Research and Development Administration guides and/or data from other reporting periods. Levels of external penetrating radiation measured in the LASL environs are given. The average whole-body radiation dose to residents of Los Alamos County resulting from LASL operations is calculated. Chemical qualities of surface and ground waters in the LASL environs have been determined and compared to applicable standards. Results of related environmental studies are summarized.

I. INTRODUCTION

This report documents the results of the environmental monitoring program conducted at the Los Alamos Scientific Laboratory (LASL) during 1976. In keeping with Energy Research and Development Administration (ERDA) and Laboratory intent to keep information on environmental quality available to the public, it principally serves the purpose of providing public documentation of data on environmental quality and conditions in the vicinity of the Laboratory. In accordance with LASL contractual agreement, it additionally complies with the requirements specified in ERDA Manual Chapter (ERDAM) 0513.

The Laboratory is administered by the University of California for ERDA, under contract W-7405-ENG-36. The LASL environmental program is conducted by the Environmental Studies Group (Group H-8) as part of continuing environmental investigation and documentation.

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, and laser isotopes separation. LASL also conducts research programs in the physical sciences, energy research and development, and biomedical and environmental studies.

A. Physical Setting

The Los Alamos Scientific Laboratory and the residential communities of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico, about 100 km NNE of Albuquerque and 40 km

NW of Santa Fe, by air. The 111 km^2 Laboratory site and adjacent communities are situated on the Pajarito Plateau, which consists of a series of mesas separated by deep canyons that run eastward from the Jemez Mountains to the Rio Grande valley. Most Laboratory and community development is confined to the mesa tops; the surrounding land is essentially undeveloped. Large tracts of land north, west, and south of the Laboratory site are held by the U.S. Forest Service and the U.S. National Park Service. Indian pueblo lands border the Laboratory to the east (Figs. 1 and 2). The major plant associations of the area are coniferous forests and pinon-juniper woodlands, which support a typical variety of western mountain wildlife.

North-central New Mexico contains approximately one-half million people, of whom nearly 70% are concentrated in Albuquerque and another 10% are located in Santa Fe. The remainder of the population is distributed among small towns and Indian pueblos ranging in size from a few hundred to a few thousand inhabitants. About 12 000 people live in the residential area of Los Alamos proper and some 6000 more reside in the White Rock area.

The economy of the Santa Fe/Los Alamos area is based largely on Government operations (LASL and the New Mexico State Government offices in Santa Fe), large tourist trade, arts and crafts, and some light service industries. Subsistence agriculture is practiced to a limited extent within 20 to 40 km of Los Alamos. In the immediate area (less than 20 km from LASL) home gardening is practiced, but is not quantifiable from the amount of population subsistence provided.

B. Meteorology

Los Alamos has a semiarid, continental mountain climate. The average annual precipitation of 46 cm 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, when one day in four will have at least 2.5 mm of rain accumulations, and some rain falls on about half of the days. The annual average of 62 thunderstorm-days per year makes this area equivalent to the Gulf Coast states in thunderstorm occurrence. The showers tend to develop in early afternoon, with a secondary maximum about 1800 MST. They are accompanied by lightning, gusty surface winds (10-20 m/s), and occasional hail. Tornadoes have not been observed in this area.

Winter precipitation falls primarily as snow, with annual accumulations of about 1.3 m. The water equivalent of snowfall in Los Alamos varies between 1:10 and 1:20, the latter occurring in cold conditions and higher altitudes.

Summers are cool and pleasant. Maximum temperatures are generally below 32°C, and a large diurnal variation keeps nocturnal temperatures in the 12-15°C range. Winter temperatures are typically in the range from -10°C to 5°C. 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.

Annual insolation is approximately two-thirds of potential total insolation according to an analysis of one year's solar radiation described in Balcomb et al.,[1] which estimated an envelope to the observations of daily insolation. This implies that approximately one-third of the daylight hours in one year were affected by cloudiness. The most cloud-free month (January) had 85% of potential insolation while the minimum (July) had 55%.

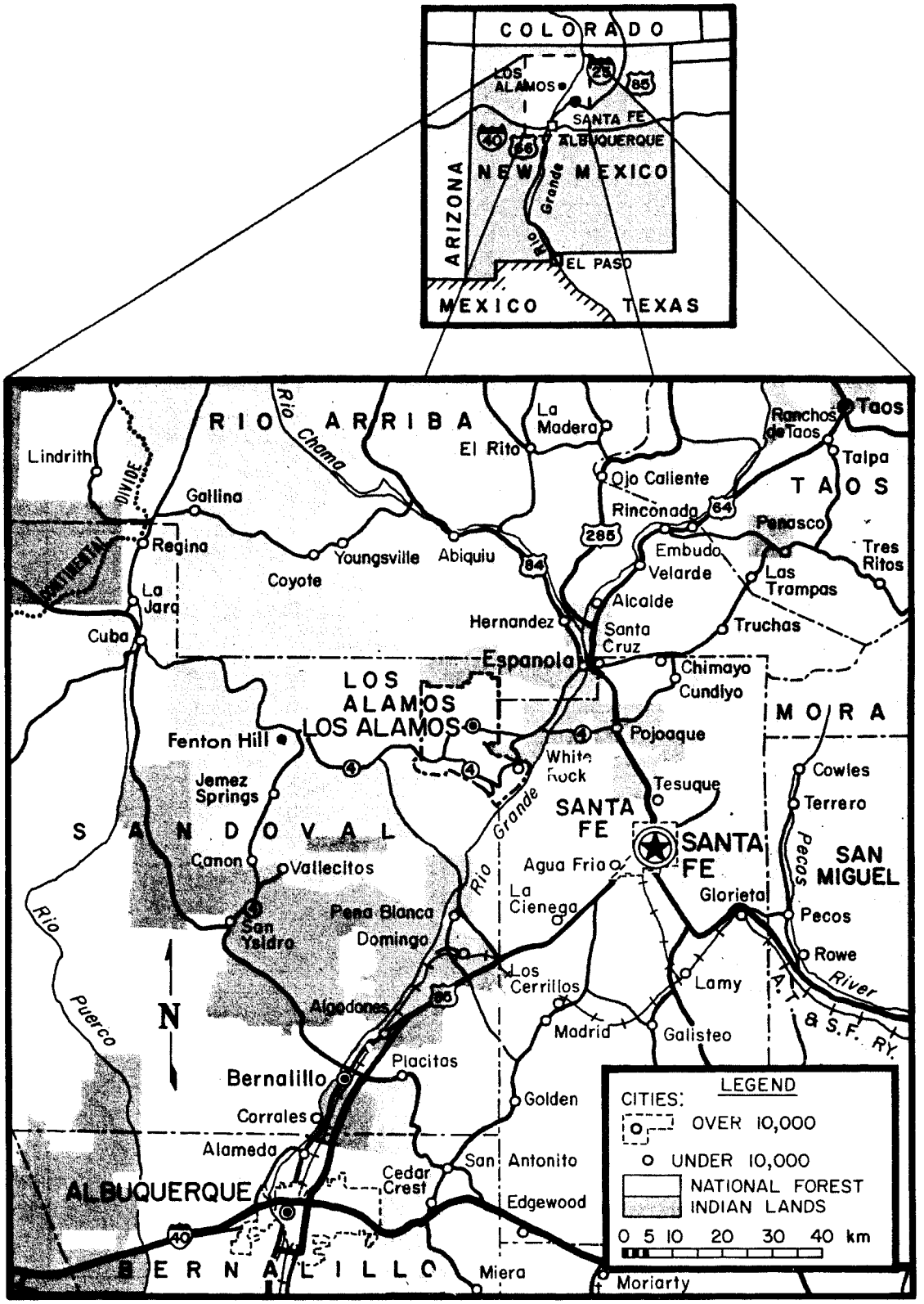


Fig. 2. North-central New Mexico.

Average relative humidity is 40%, ranging from 30% in May and June to above 50% in July, January, and February. The diurnal variation is very large and basically inverted to the diurnal temperature cycle. The summer months have nocturnal maxima of 80% and minima of 30%. Spring is the driest time, with a diurnal range from 15-50%.

Table I shows the means and extremes of temperature and precipitation for the period of record, 1910-1974, and separately for 1976. The beginning of the year was slightly warmer than average, but the second half year was distinctly cool. The year was drier than normal with total precipitation only 76% of average. February, July, and November had above average precipitation while January, October, and December had less than 10% of their normal accumulation.

II. SUMMARY OF RESULTS

This report summarizes the results of LASL's environmental monitoring program. Results of measurements of (1) radioactivity in air, ground and surface waters, sediments and soils, and foodstuffs, (2) external penetrating radiation, (3) chemical quality of surface and ground waters, (4) the chemical and radiochemical quality of potable supply waters, and (5) related ecological investigations are presented. The results of the environmental monitoring program for this reporting period confirm the generally low radiation and contaminant levels due to LASL operations previously observed[2,3,5] in the Los Alamos environs.

The average external penetrating radiation level for off-site locations was 118 mrem/yr. External penetrating radiation at on-site locations near facilities emitting radiation reached a maximum of about 480 mrem/yr. Annual mean concentrations of atmospheric tritium oxide for regional, perimeter, and on-site locations were 15, 23, and 60 x 10^{-12} μCi/mℓ, respectively. These concentrations are, respectively, 0.008, 0.012, and 0.0012% of the applicable uncontrolled-area and controlled-area Concentration Guides (CGs). (Concentration Guides represent levels of radioactivity considered acceptable in air breathed, or water drunk, by occupationally exposed persons in controlled areas or members of the general public in uncontrolled areas, see Table IV.) Atmospheric long-lived gross-alpha and gross-beta mean concentrations in the LASL environs were 1.3 and 64 x 10^{-15} μCi/mℓ, respectively, or 2.2 and 0.2% of their respective uncontrolled-area CGs. Atmospheric ^{238}Pu and ^{239}Pu concentrations in the LASL environs were 0.5 and 11.9 x 10^{-18} μCi/mℓ, respectively, which are 0.0007 and 0.02% of the uncontrolled-area CGs. The annual atmospheric uranium mean concentration was 59 pg/m^3 in the LASL environs, 0.0007% of the uncontrolled-area CG.

Radioactivity in surface and ground waters in the LASL environs was below applicable CGs. The chemical quality of most surface and ground water samples in the LASL environs met standards set for drinking water. The chemical quality of municipal and Laboratory sewage effluent samples was typical for such releases, and these releases do not become a source of potable water. The samples of potable supply water met applicable standards (see Table V) for all chemical and radiochemical constituents measured except arsenic. Water from one supply well had natural arsenic concentrations that exceeded the Environmental Protection Agency (EPA) drinking water standard. However, water from this well is mixed with water from other wells in the same field so the arsenic concentration in the distribution system is diluted to about 20% of the standard (see Section XI.B.).

No Laboratory-related concentrations of radionuclides were detected beyond a 20-km radius of the Laboratory. Consequently, individual and population dose assessments were made for Los Alamos County only. The only significant (~1 mrem/yr or greater) whole-body doses that could be attributed

to Laboratory effluents resulted from tritiated water vapor, ^{41}Ar, and mixed activation products (^{11}C, ^{13}N, and ^{15}O). The maximum above-background individual whole-body dose due to tritiated water vapor, at a site boundary, was calculated to be 0.76 mrem/yr, which is 0.15% of the ICRP-recommended[4] radiation protection standard of 500 mrem/yr for individuals in uncontrolled areas. The tritiated water vapor contributed a total population dose of approximately 0.25 man-rem to the 18 000 residents of Los Alamos County. Argon-41 was estimated by theoretical calculations to result in a maximum individual whole-body dose, in an uncontrolled area, of 3.1 mrem/yr, or 0.62% of the radiation protection standard. The estimated population dose from ^{41}Ar was 1.8 man-rem. Mixed activation products were estimated by theoretical calculations to result in a maximum individual whole-body dose, at a site boundary, of 22 mrem/yr, or 4.4% of the radiation protection standard. The estimated population dose attributable to mixed activation products was 1.9 man-rem. The maximum lung dose from airborne transuranic nuclides was calculated to be 0.2 mrem/yr, which is 0.013% of the radiation protection standard of 1500 mrem/yr for an individual in an uncontrolled area. For comparison, the residents of Los Alamos County receive an estimated 2750 man-rem from natural radiation sources.

Several related ecological investigations are also briefly summarized. These include studies of the distribution of ^{137}Cs in canyon soils, erosion rates, radiation received by rodents living near low-level contamination in a treated effluent receiving stream channel, and uranium deposited on ground surrounding dynamic test sites.

An inadvertent release of radioactive material occurred in July 1976. Approximately 22 000 Ci of tritium gas ($^{3}H_2$) was released from a vent on the Cryogenics Building at TA-3 due to an operational error. The gas was transported and dispersed by a northeast wind. Urine assay of potentially exposed Laboratory personnel and environmental measurements from air and vegetation samples showed no measurable exposure resulting from the release, either on- or off-site.

III. STATEMENT OF PARTICULARS

A. Geographic Coordinate System and Access Control

All Los Alamos County and vicinity locations referenced in this report are identified by the long-established LASL Cartesian coordinate system (see Fig. 3). This system is based on English units of measurement and is standard throughout the Laboratory, but completely independent of the U.S. Geological Survey and the New Mexico State Survey coordinate systems. The major coordinate markers shown on the maps are at 10 000-ft (3.048-km) intervals, but for the purposes of this report locations are identified to the nearest 1000 ft (0.30 km). The area within the LASL boundary (see Figs. 1 and 3) is considered a controlled area because the Laboratory has the capability of complete access restriction. Complete control would be instituted when deemed necessary. Under normal circumstances, however, public access roads that traverse the Laboratory site are open to commuters and other travelers; no continuous occupancy of these areas is permitted. Access to individual technical areas is restricted for safety and security reasons. Some of the more remote and little-used regions of the site are not actively controlled against public access, although most of the site is posted against trespassing and routine security patrols cover the entire site.

In November 1976, the Los Alamos Scientific Laboratory lands, encompassing 111 km^2, were designated as a National Environmental Research Park by the U.S. Energy Research and Development Administration. The ultimate goal is to encourage environmental research that will contribute understanding of how man can best live in balance with

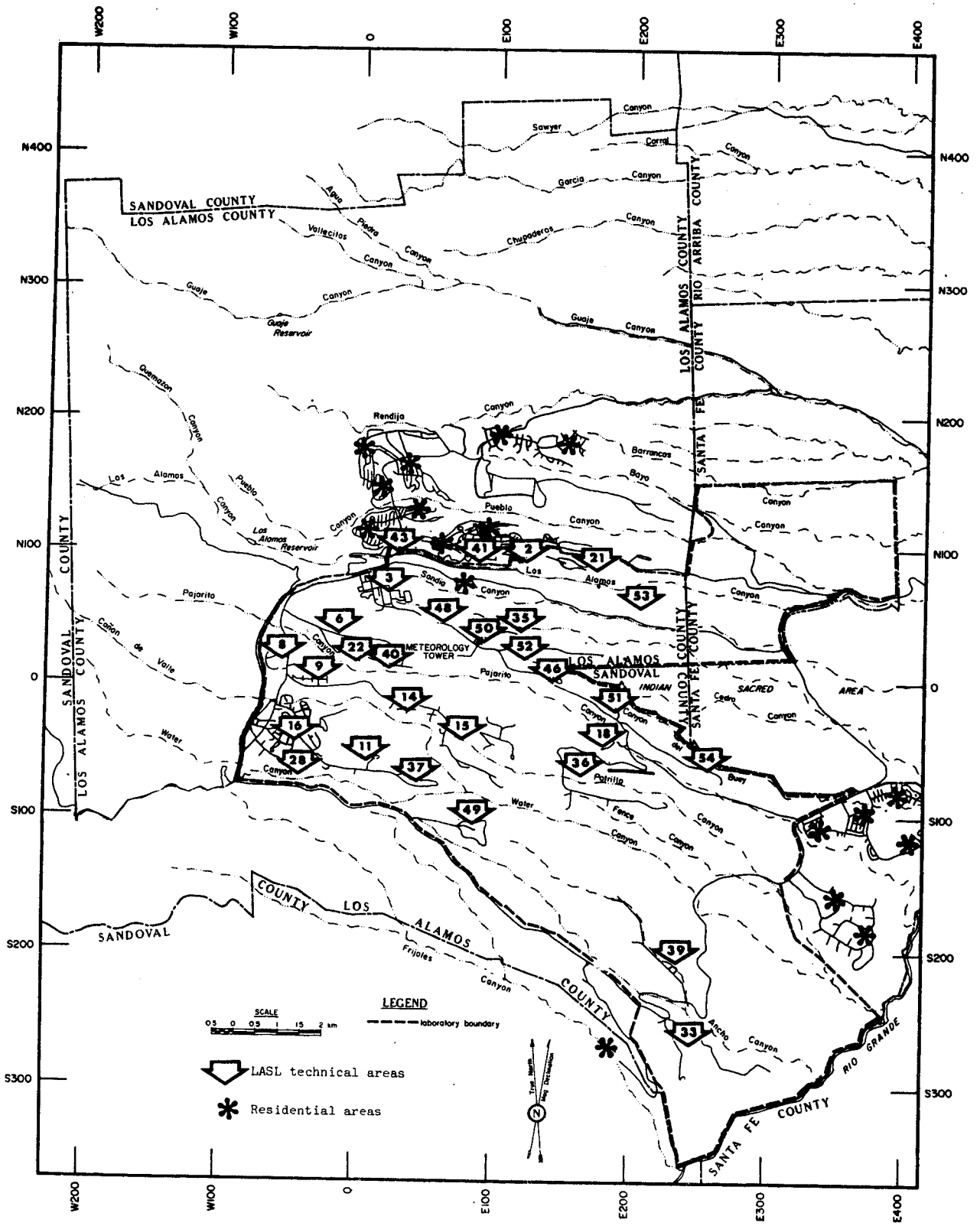


Fig. 3. Los Alamos County residential areas and LASL technical areas.

nature while enjoying the benefits of technology. Park resources are to be made available to individuals and organizations outside of LASL for the purposes of facilitating self-supported research on those subjects deemed appropriate and compatible with the LASL programmatic mission.

B. Units of Measurement and Statistical Treatment of Data

LASL scientific and technical documentation uses metric units. Table II provides conversion data for units of measure given in this text.

For many environmental measurements, particularly those from which a chemical or instrumental background must be subtracted, it is possible to obtain net values that are lower than the minimum detection limit (MDL) of the system (see Table III). It is not uncommon for individual measurements to result in values of zero or negative numbers due to statistical fluctuations in the measurements. Although a negative value for an environmental measurement 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 numerical tabulations in this report 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 is included in parentheses immediately following the primary numerical value. For contiguous measurements, such as air monitoring and environmental radiation, the parenthetical value indicates the 95% confidence range for the primary value, i.e., twice the square root of the variance, or 2 σ. For discrete data, e.g., water samples, soil samples, etc., the parenthetical value represents the average of the analytical errors associated with the measurements.

C. 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 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 ERDAM 0500, Health and Safety, Chapters 0510, 0511, 0513, 0524, and 0550.

In the case of radioactive materials in the environment, the standards contained in ERDAM 0524 (see Table IV) take precedence over other Federal or State regulations. However, the ERDA standard for uranium in water (1500 and 60 mg/ℓ for controlled and uncontrolled areas, respectively) does not consider chemical toxicity. Therefore, for the purposes of this report, the more restrictive standards[4] of the International Commission on Radiological Protection (ICRP) for uranium in water of 60 mg/ℓ for an occupational 40-h week, and 1.8 mg/ℓ for a nonoccupational 168-h week, are preferred. For atmospheric uranium, the ERDA and ICRP standards are in agreement. For chemical pollutants, the controlling standards are those promulgated by either the EPA or the appropriate New Mexico State agency (Table V).

D. Analytical Quality Control Program

A routine quality control program is maintained on the environmental analytical chemistry to provide regular evaluation of the results. In addition, the program provides data useful in assessing the capabilities of the various procedures. Data generated by this program are presented here, along with a discussion of the methods of data analysis.

For most procedures, quality control involves analyses of blanks and standards along with routine analyses of unknown samples. Blanks are matrix materials containing quantities of the constituent below the detection limit of the analytical procedure. Standards are materials containing known quantities of the constituent.

Quality control samples for gross-alpha, gross-beta, tritium, and ^{137}Cs are provided by the EPA as part of their ongoing laboratory intercomparison program. Standards for plutonium analyses are prepared by adding known quantities of ^{239}Pu to soils from deep wells, Teklad hamster food (to represent vegetation), ground beef, beef bones, or triple-distilled water. Standards for uranium analyses are well-characterized, reference samples of various grades of uranium ore from the International Atomic Energy Agency. Blanks for uranium were selected from a large number of analyses of air filters containing quantities of uranium at less than the detectable limit.

The characteristics of the various analytical procedures were evaluated from the quality control samples. The percent recovery (% Recovery = $\frac{\text{Reported Quantity}}{\text{Known Quantity}} \times 100$) was calculated for each analysis of a quality control standard. A mean value ($\bar{x}$) of the percent recovery for all analyses of a given type was calculated by weighting each value (x_i) by the uncertainty associated with it:

$$\bar{x} = \frac{\Sigma_i \; x_i/\sigma_i^2}{\Sigma_i \; 1/\sigma_i^2} \quad .$$

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

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

These calculated values are presented below. The weighted mean of the percent recovery is indicative of the accuracy of the analysis. The standard deviation is a measure of its precision.

PERCENT RECOVERY
IN QUALITY CONTROL STANDARDS

Analyses	No. of Samples	Percent Recovery (Weighted Mean) ($\bar{x} \pm \sigma$)
^{239}Pu(>0.13 pCi)	35	92 ± 11
^{239}Pu(<0.13 pCi)	10	94 ± 29
^{137}Cs	27	99 ± 9
Gross-alpha	36	94 ± 19
Gross-beta	39	96 ± 8
Tritium	28	101 ± 31
Uranium	48	101 ± 8

The weighted mean of the absolute quantity of the constituent measured in blank materials and the standard deviation of the mean are given as follows.

QUANTITY OF CONSTITUENT REPORTED IN BLANKS

Analyses	No. of Determinations	Units	Weighted Mean	Standard Deviation (1σ)
^{238}Pu	54	pCi	-9.7×10^{-4}	3.7×10^{-2}
^{239}Pu	38	pCi	3.2×10^{-4}	2.2×10^{-2}
Uranium	153	ng	25	12

Detection limits for analyses performed in conjunction with the environmental monitoring program are presented in Table III. Results greater than the defined value of the 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. Detection limits for ^{239}Pu, ^{238}Pu, and uranium are calculated from the mean blank value + 2 σ. Tritium and ^{137}Cs are instrumental analyses; the blank is evaluated and subtracted out of the calculated result. Therefore, the detection limit is merely 2 σ of repetitive determinations of the instrumental blank. Gross-alpha and gross-beta are analyzed simultaneously by counting on a gas proportional counter and electronically discriminating the output pulses. As there is crosstalk generated by the detection of the two types of emissions, the detection limit of one is a function of the other's count rate. Detection limits in Table III assume 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.

Quality control monitoring has successfully identified several analytical problems associated with the environmental monitoring program. For example, there was an unexplained increase in tritium concentration in routine water monitoring in the autumn of the year. Careful evaluation of the quality control samples showed a similar increase in the blank waters from the EPA. The increase is now attributed to contamination in the scintillation liquid used in the analyses, to an extent equivalent to about 2×10^{-6} μCi/mℓ. Correction to allow for this contamination provided satisfactory results for the EPA blanks and standards.

Quality control on $^{238,239}Pu$ analyses of the air filters showed an untraced loss of the plutonium isotopes from this matrix, i.e., the recovery was 50%-75% vs the >90% seen on analyses of most matrices. The problem was traced to an inadequate method of dissolution. Subsequent development work improved the technique, and the recovery of ^{239}Pu from filter standards is now comparable to results for the quality control standards.

Comparison between uranium analyses on air filter blanks and samples indicated that the quantity of uranium in the aliquots was below the detection limit of the procedure. Analyses were rerun using larger sample aliquots.

IV. ENVIRONMENTAL RELEASES FROM LASL OPERATIONS

LASL's activities are carried out in 30 active technical areas (TA) distributed over the LASL site (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 environmental monitoring program emphases are dictated by the types and quantities of potentially hazardous materials being used in LASL programs and by the demography, ecology, hydrology, and geology of this location. Emphasis is placed on the analyses for tritium, uranium, and plutonium in samples of the environmental media. Fission product radionuclides are generally of lesser concern, due to the minimal amounts handled, but selected samples are analyzed for radioactive species of cesium and strontium.

The documented release of radioactive materials to the atmosphere from LASL operations is shown in Table VI. These data were compiled from stack effluent monitoring determinations. Releases of plutonium in 1976 were about 25% of the total released in 1975 and less than 10% of the total released in 1974,[2,5] due largely to improved filtration systems at TA-3. Mixed fission product releases were higher in 1976 than in 1975 by about 75% due to programmatic differences. Argon releases were higher in 1976 than in 1975 by about 40% due to increased operation of the Omega West Reactor (TA-2). Tritium releases were lower in 1976 than in 1975 by about 45% due to programmatic differences.

In addition to the releases from stacks listed in Table VI, some depleted uranium (uranium with reduced amounts of isotopes other than ^{238}U) is dispersed by experiments employing conventional high explosives. Most of the debris from these experiments is deposited on the ground in the vicinity of the firing point, and relatively little is dispersed as air-suspended particulate. In 1976 approximately 1023 kg of depleted uranium were used in such experiments. Based on previous measurements of isotopic composition[6] this mass is estimated to contain approximately 0.38 Ci of activity

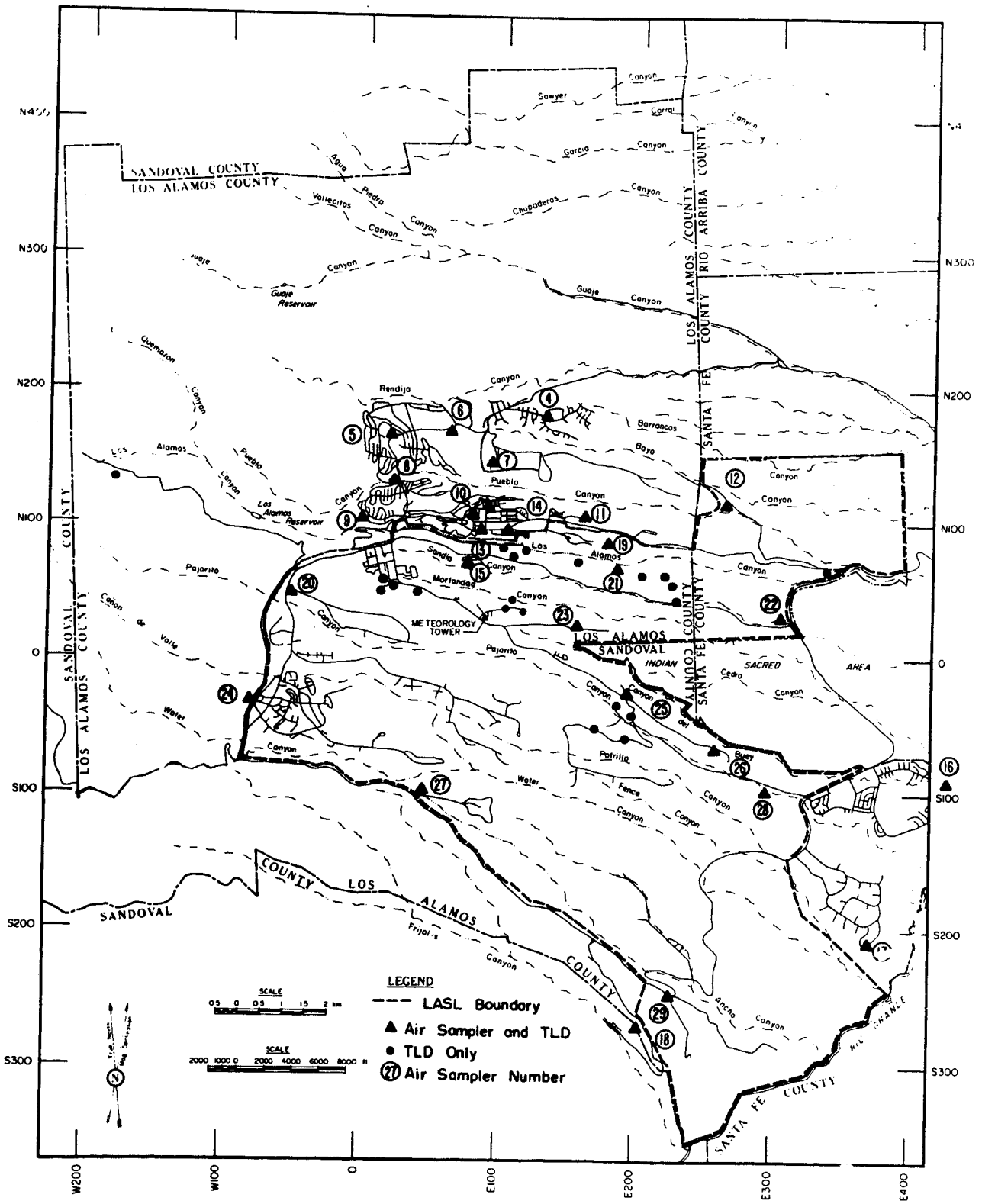


Fig. 4. TLD and air sampler locations.

(uranium only, excluding daughters). 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 Section VI.F.).

V. EXTERNAL PENETRATING RADIATION

A. Procedures

Exposure from external penetrating radiation (primarily gamma radiation) in the LASL environs is monitored by 48 thermoluminescent dosimeter (TLD) stations. Three regional stations are located 28 to 44 km from the Laboratory boundaries in the neighboring communities of Espanola, Pojoaque, and Santa Fe (see Fig. 2). Fifteen stations are within 4 km of the boundary and are classed as perimeter stations. Thirty stations are located within LASL boundaries and are classed as on-site stations. Twenty-one of the on-site stations are located near LASL nuclear facilities, in groups of three to six stations per facility, to monitor these sources of radiation. All TLD stations are on a 13-wk integration cycle. Locations for on-site and perimeter stations are given in Fig. 4, and map coordinates identify locations in the data tabulation (see Table VII).

Each of the TLD monitors consists of three Harshaw TLD-100® LiF (natural isotopic composition) chips, 6.4 mm square by 0.9 mm thick. The TLDs are annealed, calibrated, and read by standard techniques. The annealing cycle is 1 h at 400°C, followed by 1 h at 100°C. For each annealing batch, an independent calibration factor is determined by standard radiation (from 10 mR to 160 mR) with ^{60}Co. The chips are heat-sealed in an opaque polyethylene envelope which is sealed in an opaque 7-mℓ polyethylene vial for placement in the field. Latent thermoluminescence after annealing and transit dose are compensated for by control dosimeters. All TLDs are read with an Eberline model TLR-5 reader with 15-s, 140°C preheat and 15-s, 240°C integration cycles. During handling, exposure to light is minimized. As the TLDs are calibrated in a known radiation flux from a ^{60}Co source as measured by air-ionization instruments, a conversion factor of 1 rem (tissue) = 1.061 R is used.[7]

B. Results

The annual external penetrating radiation dose values determined from the TLD environmental radiation monitoring program are summarized in Table VII according to regional, perimeter, and on-site locations. The values are the total dose integrals for 1976 for each station. For regional and perimeter stations, and for those on-site stations not located close to known sources of radiation, the annual dose reported is four times the weighted mean of the four quarterly dose measurements. The reciprocal of the variance of each quarterly dose measurement is used for weighting both the mean and the uncertainty of the mean (2 σ, 95% confidence interval).[8] This method of calculating the annual dose assumes that there is no difference in the natural radiation dose rate during the four quarters at a particular dosimeter station. While this may not be strictly true, since soil moisture content and snow cover can cause temporal variations in dose rate, the assumption of constant dose rate is widely used in environmental dosimetry. The largest variation in quarterly doses at any of the 18 regional and perimeter stations was 57%. The smallest variation was 21%. The mean and standard deviation of the percent variation of quarterly doses of all 18 stations were 32% and 8%, respectively.

For those on-site stations that monitor nuclear facilities, temporal differences

are expected in the quarterly dose measurements. These differences may be as much as several hundred percent and application of the weighted mean is clearly not useful. Therefore, the cumulative sum of the four quarterly dose measurements was used for the annual dose for these stations. The uncertainty in the dose (2 σ, 95% confidence interval) is twice the square root of the sum of the variances of each 13-wk dose. This uncertainty is not related to the temporal differences between the quarterly doses for each station. The variance for each quarterly dose is derived from the distribution of the readings for the three individual chips in the dosimeter, from the calibration uncertainty, from the control dosimeter corrections, and from the instrumental background subtractions.

Significant spatial variations were also observed which result from differences in the terrestrial component of external environmental gamma radiation. These differences are a complex function of the topography, geology, hydrology, and meteorology of the monitoring sites. Due to atmospheric shielding of cosmic radiation, elevation is also a factor in natural radiation levels. As would be expected, the lower monitoring locations, e.g., Santa Fe, Pojoaque, Española, and Pajarito Acres, record the smallest dose rates. The weighted mean for all off-site (regional and perimeter) stations is 118.2 mrem/yr, with an uncertainty of ± 27.4 mrem/yr (2 σ, 95% confidence interval). Again, the assumption is that the dose being measured is the same at all stations. This assumption cannot be strictly defended. However, if the highest dose and the lowest dose are discarded, the ranges of all the other values are within 3% at the 3 σ level. The arithmetic mean for all off-site stations is 118.3 mrem/yr, which supports the assumption.

VI. RADIOACTIVITY IN AIR

A. General Sampling Procedures

Atmospheric radioactivity samples were collected at 29 continuously operating air sampling stations in Los Alamos County and vicinity. On-site 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 LASL boundary. The regional monitoring stations are located 28 to 44 km from LASL at Espanola, Pojoaque, and Santa Fe (see Fig. 2) and serve as reference points for determining background atmospheric radioactivity concentrations.

Samples were collected over 2-week periods and totaled 729 for 1976. High volume positive displacement air pumps with flow rates of approximately 3 ℓ/s were used in the network. 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 actual sampling times were recorded.

Table IV lists Concentration Guides (CGs) for several radioactive species in air and water for uncontrolled (unlimited public access) and controlled (limited public access) areas. (See also Section III.A. regarding site access control.) Concentrations from the perimeter and regional stations are compared to uncontrolled-area CGs. Concentrations from on-site stations are compared to controlled-area CGs.

B. Daily Gross-Beta Radioactivity

Atmospheric radioactivity samples were collected daily (Monday through Friday) at one location (N50 E40) with the same kind of sampler as used for biweekly sampling. 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.

Figure 5 shows daily atmospheric gross-beta concentrations for 1976. Higher than normal activity occurred during the last quarter of the year. This abnormal activity is attributed to two atmospheric nuclear tests by the People's Republic of China. The Chinese exploded nuclear devices of ~0.2 megatons (MT) and ~4.0 MT, on 26 September 1976 and 17 November 1976, respectively, which injected radioactive debris into the troposphere and stratosphere. Qualitative gamma spectral analyses of atmospheric particulate samples collected after each test showed the presence of fission products (e.g., ^{141}Ce, ^{131}I, and ^{99}Mo). The highest gross-beta concentration, observed on 19 October 1976, was 1300 (± 170) x 10^{-15} μCi/mℓ, which is 4.3% of the uncontrolled-area CG.

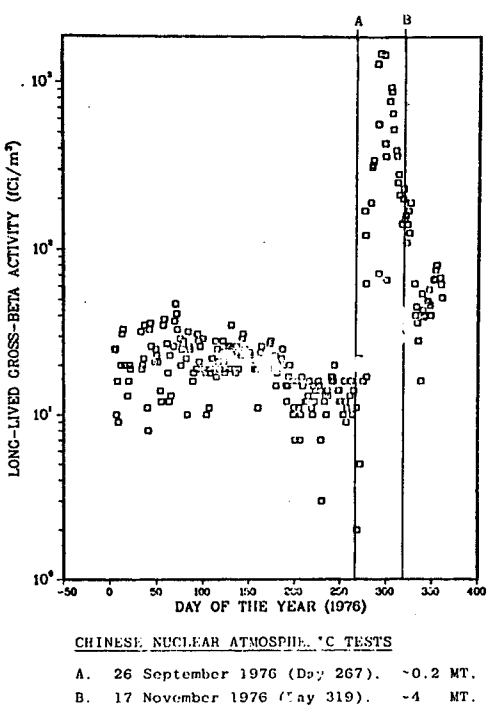


Fig. 5. Long-lived atmospheric gross-beta radioactivity for 1976.

C. Annual Gross-Alpha and Gross-Beta Radioactivity

Gross-alpha and gross-beta activities on the biweekly air filters were measured with a gas-flow proportional counter on collection day and 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 their long-lived parents) provided a record of long-lived atmospheric radioactivity.

The annual average biweekly gross-alpha and gross-beta concentrations are presented in Table VIII. Station and group means were weighted for the length of each sampling period and for the air volume sampled. The means were calculated using the following equation.[9]

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

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 1976 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.[9]

$$\sigma_{\bar{c}} = \left\{ \frac{\sum_{i=1}^{n} (v_i t_i \sigma_i)^2}{\left(\sum_{i=1}^{n} v_i t_i\right)^2} \right\}^{1/2} ,$$

where

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

σ_i = standard deviation (derived from nuclear counting statistics, air sample volume uncertainties, and analytical uncertainties of c_i).

Parenthetical values represent twice the propagated measurement uncertainties (2σ) associated with the annual means. The data are grouped according to off-site, perimeter, and on-site sampling locations. For gross-alpha activity, the group means were 1.4 (±0.1), 1.3 (±0.1), and 1.3 (±0.1) x 10^{-15} μCi/mℓ, respectively. The highest annual station mean gross-alpha concentration, 1.8 (±0.3) x 10^{-15} μCi/mℓ, is 0.09% of the controlled area CG.

For gross-beta activity, the regional, perimeter, and on-site annual means were 60 (±4), 65 (±2), and 65 (±2) x 10^{-15} μCi/mℓ, respectively. The highest observed station mean concentration of 143 (±20) x 10^{-15} μCi/mℓ (Royal Crest Trailer Court) is 0.5% of the uncontrolled-area CG. This mean is biased, since the station was only operated in August through December when atmospheric radioactivity levels were relatively higher due to fallout from the Chinese nuclear tests (see Section VI.B.). For comparison, the mean concentration for the three regional stations during the same period was 131 (±17) x 10^{-15} μCi/mℓ.

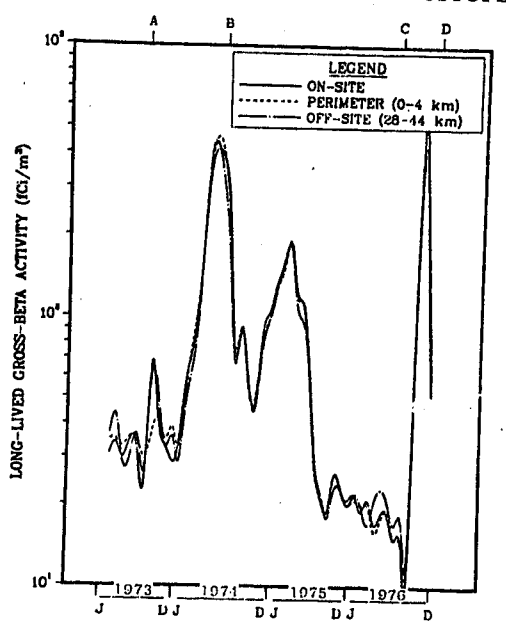
Significant temporal variations in long-lived gross-alpha and gross-beta concentrations (see Figs. 5 and 6) were observed this year. The major fluctuations, in November and December, were caused by the Chinese atmospheric nuclear explosive tests previously mentioned. All maximum values of long-lived gross-alpha and gross-beta activities occurred during these 2 months.

Data plotted in Fig. 6 also show there were no significant differences in atmospheric gross-beta concentrations among the regional, perimeter, and on-site sampling station groups this year. There have been no statistically significant differences over the past 3 yr. The similarities in concentrations imply that LASL operations have a negligible impact on the ambient atmospheric radioactivity in the Los Alamos vicinity.

D. Tritium

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 dessicant 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.

The concentrations for each station were averaged for 1976 and are presented in Table IX. Parenthetical values represent twice the propagated measurement errors



CHINESE NUCLEAR ATMOSPHERIC TESTS

A.	26 June 1973.	2 -3	MT.
B.	17 June 1974.	0.2-1	MT.
C.	26 September 1976.	~0.2	MT.
D.	17 November 1976.	~4	MT.

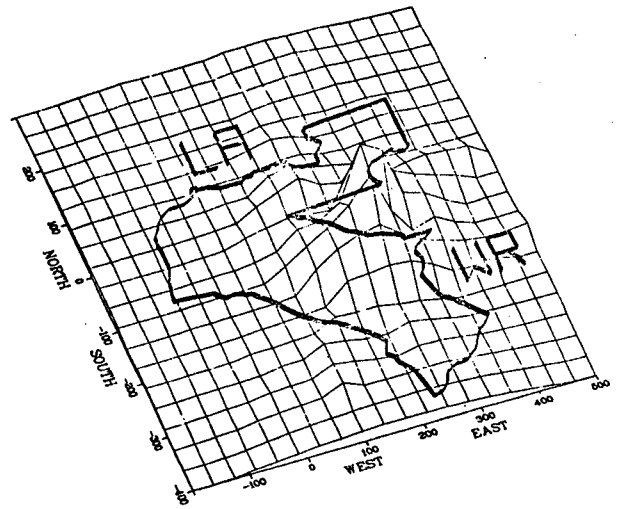
Fig. 6. Average monthly long-lived gross-beta radioactivity over the past 4 yr for on-site, perimeter, and off-site sampling locations.

(2σ) associated with the annual means (see Section VI.C. for explanation of uncertainty calculation methods). The highest observed annual mean concentration for an uncontrolled area (Los Alamos Airport) was 51 (±4) x 10^{-12} μCi/mℓ, and for a controlled area (TA-54) the highest value was 330 (±32) x 10^{-12} μCi/mℓ. These concentrations are 0.026% and 0.0066%, respectively, of the uncontrolled and controlled area CGs specified for tritium in air. The relatively high concentration at TA-54 was possibly due to evapotranspiration of buried tritium wastes at this materials disposal site. These tritium concentrations, as well as the CGs, are for atmospheric tritiated water (HTO).

The annual means for the distributions of regional, perimeter, and on-site tritium concentrations were 15 (±2), 23 (±1), and 60 (±2) x 10^{-12} μCi/mℓ, respectively. The on-site mean is statistically higher (at a >99% confidence level) than the regional and perimeter means. The higher value reflects tritium releases from LASL operations (see Table VI). The annual mean atmospheric tritium concentrations for the perimeter and on-site stations are depicted graphically in Fig. 7. The relatively higher concentrations for the on-site stations are clearly seen. The highest annual mean concentration of 330 (±32) pCi/m^3 was observed at TA-54 (S080 E260).

E. Plutonium

After being measured for gross-alpha and gross-beta activities, the biweekly filters for each station were combined and dissolved to produce composite 6- or 8-wk samples for each station. An aliquot of each sample was saved for uranium analysis, and plutonium was separated by anion exchange from the remaining solution. The aliquots for uranium analyses were combined to represent 12- or 14-wk samples. The purified plutonium samples were separately electro-deposited and measured by alpha-particle pulse height analysis. Alpha-particle energy groups associated with the



Graphic representation of annual mean atmospheric tritiated water concentrations. Relative concentrations are indicated by height above the grid plane. The bold outline at the level of the grid plane indicates the Laboratory boundary; the letter symbols indicate the community areas of Los Alamos (LA) and White Rock (WR).

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

decay of ^{238}Pu and ^{239}Pu were then 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. Thus, when the notation ^{239}Pu is used it actually means the combined amount of ^{239}Pu and ^{240}Pu.

The annual average ^{238}Pu and ^{239}Pu concentrations for each station are listed in Table X according to regional, perimeter, and on-site sampling locations. Parenthetical values represent twice the propagated measurement uncertainties (2σ) associated with the annual averages (see Section VI.C. for explanation of uncertainty calculation method). The highest observed annual mean ^{238}Pu concentration for an uncontrolled area (Royal Crest) was 2.0 (±1.2) x 10^{-18} μCi/mℓ, and for a controlled area (TA-54) was 4.3 (±1.2) x 10^{-18} μCi/mℓ. These concentrations are, respectively, 0.003% and 0.0002% of the CGs specified for ^{238}Pu in air. The means for the distributions of

regional, perimeter, and on-site annual average ^{238}Pu concentrations were 0.0 (±0.4), 0.4 (±0.2), and 0.9 (±0.2) x 10^{-18} μCi/mℓ, respectively.

The highest observed annual mean concentration of ^{239}Pu in an uncontrolled area (Los Alamos Airport) was 6.8 (±1.1) x 10^{-18} μCi/mℓ, and for a controlled area (Booster P-1) was 171 (±11) x 10^{-18} μCi/mℓ. These concentrations are, respectively, 0.01% and 0.007% of the CGs specified for ^{239}Pu in air. The ^{239}Pu annual concentration value for the Booster P-1 station deviates from the normal range of values. This average is largely dependent on the maximum measurement of 1510 (±96) x 10^{-18} μCi/mℓ observed in July and would be 6 x 10^{-18} μCi/mℓ by omitting this value. The July value is believed to be unrealistic since a release and dispersion of ^{239}Pu from the Laboratory would most likely be noted at several stations. However, the high value could be due to a single soil particle, resuspended by the wind, from the nearby Materials Disposal Site (TA-54), or to cross-contamination in the analytical laboratory. The means for the distribution of regional, perimeter, and on-site annual average ^{239}Pu concentrations were 4.1 (±0.5), 5.2 (±0.3), and 22.5 (±1.1) x 10^{-18} μCi/mℓ, respectively. The higher on-site group mean is largely due to the previously mentioned high July measurement, and would have been 4.3 (±0.5) x 10^{-18} μCi/mℓ if that value were omitted.

F. Uranium

A sample was composited for each of the 29 stations, with aliquots taken from the dissolution for the plutonium procedure, to represent a 12- or 14-wk sampling period. The uranium content of the composite was determined by fluorometry and quarterly atmospheric uranium concentrations were calculated. The 12- or 14-wk uranium concentrations for each station were averaged (see Section VI.C. for explanation of averaging method) for 1976 and are shown in Table XI. Parenthetical values represent twice the propagated uncertainties (2σ) associated with the annual means (see Section VI.C. for explanation of uncertainty calculation method). The fluorometric analysis measures total uranium, therefore, the concentrations are given in mass concentration units.

The highest observed annual mean uranium concentration for an uncontrolled area (Diamond Drive) was 111 (±13) pg/m^3, and for a controlled area (Booster P-2) the highest value was 125 (±20) pg/m^3. These concentrations are, respectively, 0.0012% and 0.00006% of the relevant CGs for natural uranium in air. A third slightly elevated concentration 112 (±37) pg/m^3 was observed at TA-54. These three stations are all located in dusty areas where a higher filter dust loading may account for more natural crustal-abundance uranium being collected. The annual means of the regional, perimeter, and on-site uranium concentrations were 61 (±4), 59 (±2), and 60 (±3) pg/m^3, respectively. These average values are statistically indistinguishable.

VII. RADIOACTIVITY IN SURFACE AND GROUND WATERS

Surface and ground water radioactivity monitoring provides a routine surveillance of the potential dispersion of effluents from LASL operations. Grab samples of water are collected in 4-ℓ polyethylene bottles, acidified in the field with 5 mℓ of concentrated nitric acid, and returned to the laboratory within a few hours for filtration through 0.45-μm-pore membrane filters. All samples are analyzed radiochemically for dissolved plutonium (^{238}Pu and ^{239}Pu) and for tritium as HTO, as well as for total dissolved gross-alpha, -beta, and -gamma activities. Selected samples were analyzed radiochemically for ^{241}Am, ^{137}Cs, and ^{90}Sr. Total uranium concentrations were measured by fluorometry.

Analyses of surface and ground water from regional and perimeter stations reflect

base line levels of radionuclides in the area. A summary of these analyses is presented first for comparison with analyses from water supply and on-site stations. The summary tables in the text for the regional, perimeter, and water supply show maximum values from each group of stations. The table for the on-site stations shows the highest station average. More detailed results are presented in Table XII and XIII. The stations are grouped according to location or hydrologic similarity. Comparisons with appropriate concentration guides (Table IV) are included.

A. Regional and Perimeter

Regional surface water within 75 km of LASL was collected at six stations in the Rio Grande, Chama, and Jemez Rivers (Fig. 8, Table XII). Radioactivity concentrations were also determined for samples from six perimeter locations, three surface and three ground water stations, located <4 km outside the LASL boundary (Fig. 9, Table XII). The maximum concentrations of radioactive materials in these waters were

Analyses	Units (μCi/mℓ)	Regional Surface Water	Perimeter Surface and Ground Water	CGs for Uncontrolled Areas
^{3}H	10^{-6}	2.8	2.6	3 000
^{90}Sr	10^{-9}	16	8.5	300
^{137}Cs	10^{-9}	<32	31	30 000
^{238}Pu	10^{-9}	<0.02	<0.02	5 000
^{239}Pu	10^{-9}	<0.04	<0.03	5 000
Gross-alpha	10^{-9}	9	7	5 000
Gross-beta	10^{-9}	28	12	300
Total U	μg/ℓ	6	17	1 800[a]

[a]See Section III.C for explanation.

The radionuclide concentrations in water from regional and perimeter stations are low and have shown no change from previous analyses.[5] The concentrations are well below concentration guides for uncontrolled areas.

B. Water Supply

Water supplied to the Laboratory and the community came from 15 deep wells and 1 gallery. These sources produced a total of 6.4 x 10^{6} m^{3} during 1976. The water is

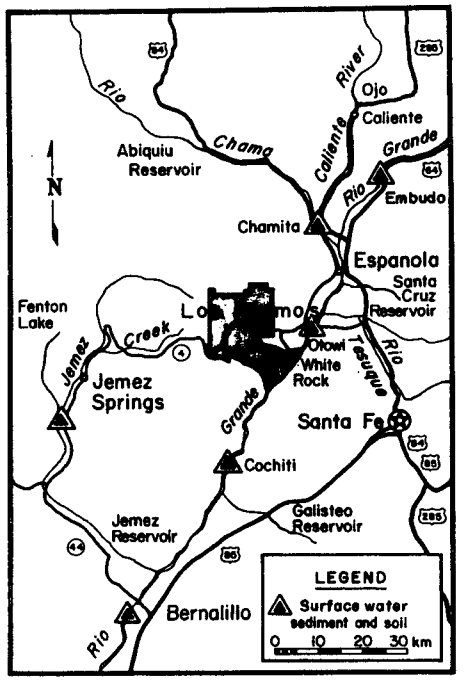


Fig. 8. Regional surface water, sediment, and soil sampling locations.

pumped from the main aquifer which lies at a depth of about 350 m below the surface of the mesas at Los Alamos. The gallery, located in the mountains to the west of Los Alamos, discharges from a perched water zone in the volcanics. Water samples were collected from the 15 wells and the gallery and at 5 stations on the distribution system within the Laboratory and community (Fig. 9, Table XII). The maximum concentrations of radioactive material in these waters were

Analyses	Units (μCi/mℓ)	Los Alamos Water Supply	CGs for Uncontrolled Areas
^{3}H	10^{-6}	2.4	3 000
^{90}Sr	10^{-9}	5.8	300
^{137}Cs	10^{-9}	<20	30 000
^{238}Pu	10^{-9}	<0.04	5 000
^{239}Pu	10^{-9}	<0.01	5 000
Gross-alpha	10^{-9}	9	5 000
Gross-beta	10^{-9}	16	300
Total U	μg/ℓ	5.6	1 800[a]

[a]See Section III.C for explanation.

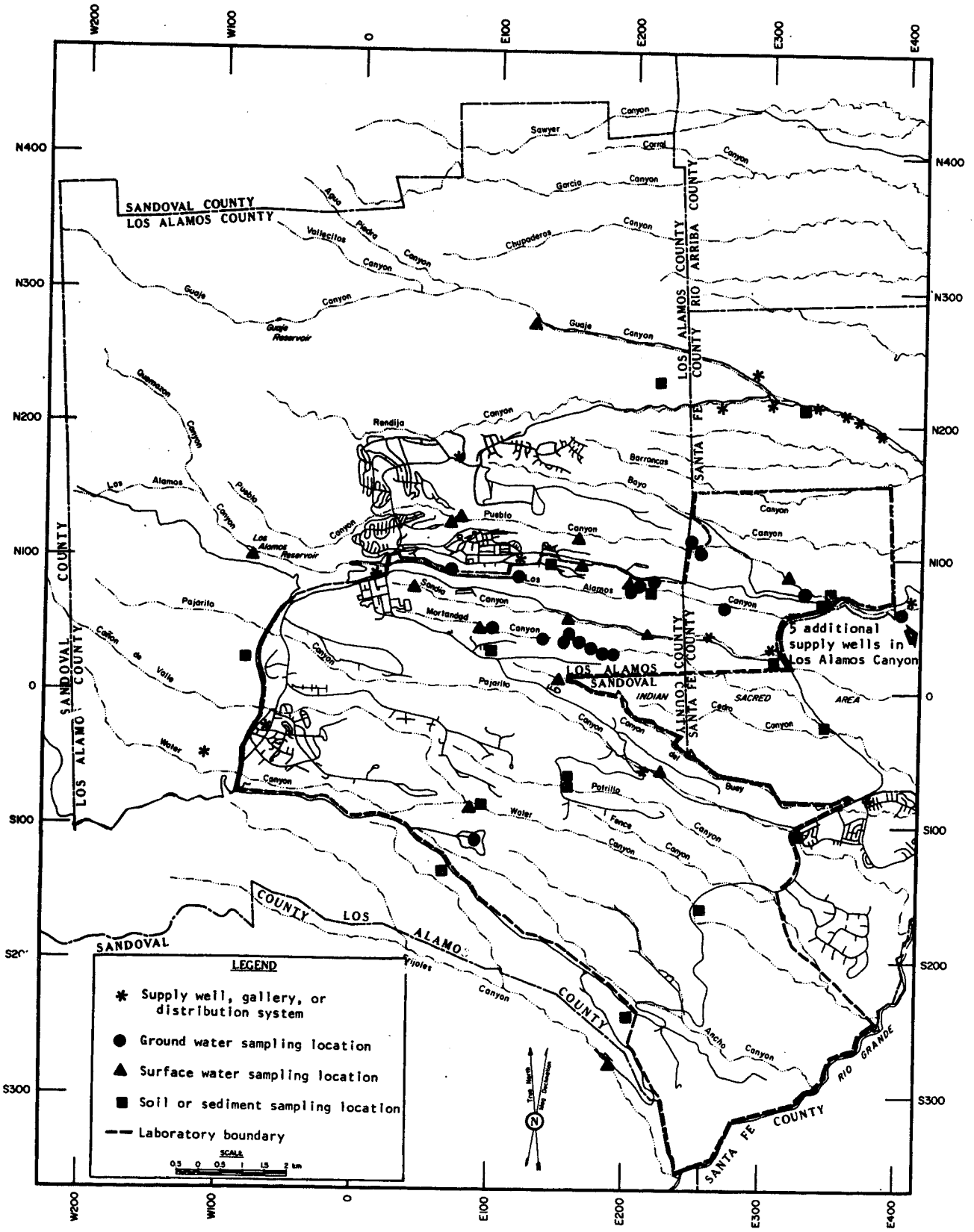


Fig. 9. Water, sediment, and soil sampling locations on or near the LASL site.

The radionuclide concentrations have shown no change from previous analyses.[5] The concentrations are well below concentration guides for uncontrolled areas.

C. On-Site Surface and Ground Waters

Radioactivity concentrations were determined for surface and ground water samples from six on-site locations that are not in Laboratory effluent release areas (Fig. 9, Table XIII). Three are surface water stations and three are from deep wells completed in the main aquifer as are the supply wells. The highest station-average concentrations for these six stations were

Analyses	Units (μCi/mℓ)	On-Site Non-effluent Areas	CGs for Controlled Areas
^{3}H	10^{-6}	3.3	100 000
^{90}Sr	10^{-9}	9.4	10 000
^{137}Cs	10^{-9}	<38	400 000
^{238}Pu	10^{-9}	0.01	100 000
^{239}Pu	10^{-9}	0.02	100 000
Gross-alpha	10^{-9}	2.9	100 000
Gross-beta	10^{-9}	14.5	10 000
Total U	μg/ℓ	1.2	60 000[a]

[a]See Section III.C for explanation.

The concentrations were near or below detection limits and were of the same magnitude as reported in 1975.[5]

The radioactivity concentrations for surface and ground water were determined from 22 locations in past and present Laboratory effluent release areas (Fig. 9, Table XIII). The surface and ground waters in these canyon areas are not a source of muncipal, industrial, or agricultural supply, and do not reach the Rio Grande except during storm runoff. The observation holes in these areas are completed into the stream channel alluvium and into the top of underlying volcanics and do not exceed 25 m in depth.

The highest station-average concentrations of radioactive materials in these waters were

Analyses	Units (μCi/mℓ)	Pueblo	Sandia	DP-Los Alamos	Mortandad	CGs for Controlled Areas
^{3}H	10^{-6}	2.6	5.1	445	2000	100 000
^{90}Sr	10^{-9}	60	-	384	84	10 000
^{137}Cs	10^{-9}	<14	<28	71	32	400 000
^{241}Am	10^{-9}	<1.2	<1.4	0.24	60	100 000
^{238}Pu	10^{-9}	0.6	<0.02	0.30	20	100 000
^{239}Pu	10^{-9}	0.74	<0.02	0.58	3.8	100 000
Gross-alpha	10^{-9}	7.8	1.6	810	76	100 000
Gross-beta	10^{-9}	115	20	1260	1120	10 000
Total U	μg/ℓ	0.7	<2.4	14	13	60 000[a]

[a]See Section III.C for explanation.

The radioactivity concentrations observed in Acid-Pueblo Canyon result from residuals of treated and untreated radioactive waste effluent released into the canyon before 1964. Radionuclides adsorbed by channel sediments are being resuspended by runoff and municipal sanitary waste treatment effluents. Sandia Canyon receives cooling tower blowdown from TA-3 power plant and some treated sanitary effluent. DP-Los Alamos Canyon reflects current release of treated radioactive waste effluents from the TA-21 industrial waste treatment plant. Mortandad Canyon received treated radioactive waste effluents from the TA-50 industrial waste treatment plant.

The areas receiving treated radioactive waste effluents have measurable amounts of radioactivity; however, the concentrations are well below the concentration guides for controlled areas.

VIII. RADIOACTIVITY IN SOILS AND SEDIMENTS

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 build-up 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 dry stream sediment samples was analyzed for ^{3}H. A few samples were also analyzed for ^{90}Sr.

Soil and sediment samples were collected in the same general locations as the regional and perimeter water samples to provide data on the normal concentrations of radioactive materials in the environment (Figs. 8 and 9, Table XIV). Soil and sediment samples were also collected at on-site locations (see Fig. 9, Table XIV). The maximum observed concentrations of radioactivity in regional, perimeter, and on-site soils and sediments were

		Regional and Perimeter		On-Site	
Analyses	Units	Soils	Sediments	Soils	Sediments
^{3}H	10^{-6} µCi/mℓ	6.4	4.1	11	17
^{90}Sr	pCi/g	13.9	5.9	10.5	8.5
^{137}Cs	pCi/g	1.7	0.23	-	1.5
^{238}Pu	pCi/g	0.004	0.003	0.005	0.115
^{239}Pu	pCi/g	0.033	2.06	0.193	0.720
Gross-alpha	pCi/g	18	10	10	10
Gross-beta	pCi/g	12	6.1	8.5	28
Total U	µg/g	3.9	2.7	5.3	30

Worldwide fallout plutonium in the region in 1970 ranged from 0.001 to 0.004 pCi/g for ^{238}Pu and from 0.001 to 0.023 pCi/g for ^{239}Pu.[10] Regional and perimeter soils fall within this range of values. A perimeter sediment sample from Pueblo Canyon, a former effluent release area now off-site, contained ^{239}Pu at a maximum concentration of 2.06 pCi/g which is a result of adsorption from low-level effluent released into the canyon prior to 1964. The on-site soil samples collected near TA-21 and TA-50, a plutonium processing plant and industrial waste treatment plant, respectively, contained 0.19 and 0.10 pCi/g of ^{239}Pu. Sediment samples collected from on-site treated effluent release areas are above regional levels due to adsorption of ^{238}Pu and ^{239}Pu from the effluents.

Tritium values for on-site soil and sediments were 2 to 4 times above those values typical for regional and perimeter soils and sediments. Gross-alpha, ^{137}Cs, and ^{90}Sr concentrations from the regional and perimeter stations were comparable to on-site stations.

Gross-beta and total U in the regional and perimeter soil and sediments and the on-site soils are comparable. Gross-beta and total U in sediments from on-site effluent release areas are the result of adsorption of radionuclides from effluents.

Three sediment sampling stations, located off-site in the lower reach of Los Alamos Canyon to the Rio Grande, were sampled in 1970 and again in 1976. This reach of the canyon receives intermittent storm runoff from the former release area in Acid-Pueblo Canyon and present release area in DP Canyon. The total Pu (^{238}Pu and ^{239}Pu) in 1970 for the three sample stations ranged from 0.37 to 0.60 pCi/g with an average of 0.45 pCi/g. In 1976, the total plutonium at the same stations ranged from 0.088 to 0.019 pCi/g with an average of 0.14 pCi/g. The concentrations in 1976 ranged from about 2 to 8 times regional levels attributable to worldwide fallout. Storm runoff has transported the radionuclides adsorbed or attached to the sediments out of the disposal areas.

IX. RADIOACTIVITY IN FOODSTUFFS

The limited foodstuff sampling program to evaluate possible dose commitment from consumption of locally produced foodstuffs initiated in 1975 was continued in 1976. Samples were collected during fall harvest in the Los Alamos area and in the Rio Grande valley at points both above and below the confluences with streams crossing the Laboratory. Twenty-four samples of fruit and vegetables were washed as they would be prior to consumption and then were analyzed for $^{238,239}Pu$, tritium oxide (HTO), and total uranium. In all cases the plutonium and uranium analyses gave values below the detection limits of ~0.001 pCi/g (dry weight)

for $^{238,239}Pu$ and ~0.01 μg/g (dry weight) for total U.

Tritium in foodstuffs was determined by distillation of water from the samples and subsequent liquid scintillation analysis of the distillate. The data presented below summarize the tritium content in water from various samples grouped according to different irrigation water supplies.

Location	Irrigation Water Source	No. of Samples	Tritium Concentration (10^{-6} μCi/mℓ) Average	Range
Espanola	Rio Chama[a]	4	2.6 (±0.4)	2.2-3.5
Ranchitos	Rio Chama[a]	4	3.5 (±0.4)	3.1-3.9
Cochiti	Rio Grande[b]	4	3.1 (±0.2)	2.9-3.4
Los Alamos	L.A. County	5	3.8 (±1.4)	2.3-5.9
White Rock	L.A. County	7	3.3 (±0.3)	2.7-3.7

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

There was no significant difference in tritiated water content between upstream, downstream, and local area samples. Additionally, these concentrations were between the ranges of values observed in local surface waters and meteoric water. Thus there is no indication of any measurable contribution from Laboratory operations.

X. RADIATION DOSE ASSESSMENT

A. Methods and Assumptions

The radiation dose assessments presented in this section are based on the effluent and environmental monitoring data of this report. Calculations are made for the radionuclides detected by the LASL monitoring network and for critical pathways associated with these effluents. The calculations represent estimates of doses incurred during the 1-yr period covered by the monitoring data. The mathematical models are those recommended by the ICRP,[4,11,12] and are summarized in the Appendix. No Laboratory-related concentrations of radionuclides were detected beyond a 20-km radius of the Laboratory; consequently, it was not considered necessary to do population dose assessments beyond Los Alamos County. The 1976 Los Alamos County population estimates (12 000 and 6000 people in Los Alamos and White Rock, respectively) were obtained from the Los Alamos County Planning Department. The estimated 97 000 population in the 80-km radius about the Laboratory was obtained from the LASL-developed Pathfinder Program[13] with updating from the "Statistical Abstract of the United States - 1976."

B. External Penetrating Radiation

Variations in terrestrial and cosmic radiation complicate any analysis of external radiation exposure as measured by the LASL environmental radiation TLD network. The variations in dose among the off-site stations (see Table VII) are believed to be due to the variation in natural radiation. All of these stations are within 11% of the annual dose recorded in 1975, indicating the year-to-year variation is less than the station-to-station variation.

The variations in some of the on-site data (in addition to natural background variations) are caused by variation in the radiation emissions at the various Laboratory facilities. Thus station-to-station, and, for the most part, year-to-year comparisons are not meaningful. It is believed that the elevated dose at the State Highway 4 location resulted from radioactive waste discharges into canyons upstream of this station. The TLD-measured dose rates have been confirmed by high-pressure ion-chamber measurements. Preliminary in-situ spectral measurements indicate elevated ^{137}Cs levels in this area. The elevated dose rate at this station does not represent a significant exposure potential to the people in the area because there is no residential or other usage of this area by the populace.

The dose rates at the off-site stations are consistent with the expected values (126-175 mrem/yr) due to natural environment radiation estimated for New Mexico by the U.S. Environmental Protection Agency,[14,15] and are similar to a TLD-measured dose rate

of 143 mrem/yr at Colorado Springs, Colorado.[16] Because there was no indication of off-site incremental external penetrating radiation resulting from Laboratory operations, individual and population doses for these exposures were not calculated.

C. Radioactivity in Air

The whole-body dose resulting from the inhalation and skin absorption of tritiated water vapor was calculated using the formula $D = 2.4 \times 10^6$ C (where D is dose in rems and C is concentration in μCi/mℓ; see Appendix for details). The highest potential dose at a LASL boundary was estimated from the measurements at TA-54, which is within 0.4 km of a boundary with unoccupied land. The annual average concentration there (330×10^{-12} μCi/mℓ) would result in a whole-body dose of 0.76 mrem/yr (0.15% of the individual dose limit) above background. Background concentrations of tritiated water vapor were 15×10^{-12} μCi/mℓ as measured at the three regional stations. The highest calculated individual dose above background at an occupied location, based on measurements at the airport, would be 0.086 mrem/yr, which is 0.017% of the radiation protection standard for an individual (500 mrem/yr) or 0.05% of the radiation protection standard for an average dose to the population (170 mrem/yr). The White Rock dose above background would be 0.011 mrem/yr based on an average concentration of 18×10^{-12} μCi/mℓ. These doses combine to provide a total of 0.18 man-rem to the 12 000 residents of Los Alamos and 0.07 man-rem to the 6000 residents of White Rock.

The average uranium concentrations in air were a very small percentage (.0012% maximum) of the appropriate CGs for breathing air. Three stations, Booster P-2, TA-54, and Diamond Drive, had slightly elevated concentrations of uranium compared to the other stations. Booster P-2 and TA-54 are located in dusty areas where additional dust loading of the filters could account for a greater mass of natural crustal-abundance uranium being collected on the filters. The Diamond Drive station had concentrations comparable to Booster P-2 and TA-54, which are similar to values experienced at off-site as well as on-site stations in previous years.[2,5] Thus, no dose calculation for atmospheric uranium was made.

Only 2 stations, Booster P-1 and TA-54, indicated ^{239}Pu concentrations in air statistically higher than the average concentrations measured at the other 27 stations in the air sampling network. The highest station average, at Booster P-1, was strongly influenced by the single maximum sample of 1510×10^{-18} μCi/mℓ. (Without this sample, the average would be 6.0×10^{-18} μCi/mℓ.) The TA-54 station is a new station located at the solid radioactive waste disposal area.

The highest potential dose at a LASL boundary was estimated from the measurements at Booster P-1 station, which is approximately 0.8 km from a Laboratory boundary. Using the equation $D = 1.3 \times 10^{12}$ C (where D is dose in rems and C is concentration in μCi/mℓ; see Appendix for details) the dose to the lung from the average concentration of 171×10^{-18} μCi/mℓ at Booster P-1 would be 0.2 mrem/yr which is 0.013% of the radiation protection standard of 1500 mrem/yr for an individual in an uncontrolled area.

The perimeter stations indicate an average concentration of 5×10^{-18} μCi/mℓ and the off-site stations an average concentration of 4×10^{-18} μCi/mℓ. If this slight difference is assumed to be due to Laboratory effluents, and not variations in fallout patterns due to location and elevation differences, the associated dose to the lung at perimeter stations would be 0.001 mrem, which is 0.0002% of the appropriate radiation protection standard and equivalent to the lung dose due to external penetrating radiation received by riding in a jet at 9000 m for 5 s, or wearing a typical luminous-dial watch for about 3 h.[15]

Because measured concentrations of ^{238}Pu in air were predominately below the detection limit, it was not possible to distinguish between background and any contribution from effluents. Therefore, no estimate of an incremental ^{238}Pu dose due to Laboratory operations was made. For completeness, doses were estimated based on total concentrations with no allowance for subtracting background due to worldwide fallout. As would be expected from the ^{239}Pu data, the ^{238}Pu average concentrations were a maximum at Booster P-1 and TA-54. To estimate the dose to members of the public at an occupied location, the Booster P-1 station average was used. The average concentration of 3.2×10^{-18} μCi/mℓ (strongly influenced by the maximum of 25.2 $\times 10^{-18}$ μCi/mℓ) would result in a total lung dose of 0.004 mrem/yr, or 0.003% of the individual radiation protection standard. The calculation was made from the formula $D = 1.35 \times 10^{12}$ C (where D is dose in rems and C is concentration in μCi/mℓ; see Appendix for details). The maximum dose at a site boundary was estimated from data collected at the TA-54 station (which is ~0.4 km from a site boundary at an unoccupied location) as 0.006 mrem/yr total dose to the lung. The laboratory contribution to these doses, if any, would be a small fraction of the total.

The potential dose due to ^{41}Ar was calculated with the technique developed by the Nuclear Regulatory Commission[17] assuming immersion in a semi-infinite cloud. Theoretical calculations of the dispersion of the 339 Ci of ^{41}Ar (an activation product with a 1.83 h half-life) released from the Omega West Reactor stack (located on Mesita de Los Alamos just south of TA-2, see Fig. 3) in 1976 indicate a maximum uncontrolled area dose of 3.1 mrem/yr, which is 0.62% of the radiation protection standard for an individual. The estimated dose to the townsite population from this release is 1.8 man-rem. Radiation from ^{41}Ar would be included in the dose documented by the TLD external penetrating radiation measurements. The estimated maximum dose is less than the uncertainty in the TLD measurements.

The largest amount of radioactivity (5890 Ci, Table VI) released to the atmosphere was due to the short-lived isotopes ^{11}C, ^{13}N, and ^{15}O created as activation products from air during operation of the linear accelerator at LAMPF. Theoretical calculations (see Appendix for details) based on Gaussian diffusion models give an estimated maximum annual boundary dose of 22 mrem/yr. This calculation assumes a finite cloud size and that the receptor is at the cloud centerline. No decay was assumed during transit from the stack to the nearest site boundary (0.8 km north). This would tend to overestimate the dose because ^{15}O has a half-life slightly over 2 min (^{11}C and ^{13}N have 10- and 24.4-min half lives, respectively). The amount of overestimate is not known because the proportions of the three isotopes as they leave the stack are not known. Extending the theoretical dispersion calculations and taking some credit for decay (~30 min) at the townsite lead to an estimated average individual dose of 0.16 mrem/yr and a total population dose of about 1.9 man-rem. The average individual doses would be documented as part of the TLD measurements and are less than the uncertainty in the TLD measurements.

Theoretical calculations for all other isotopes for which there is a measured release (see Table VI) indicate doses much less than those calculated (theoretically or from actual measurements) and thus are not included in this report.

The population doses from tritium, ^{41}Ar, and mixed activation products (other isotopes gave insignificant doses by comparison) combine to give 4 man-rem above background to the estimated 18 000 residents of Los Alamos County. This is the estimated total population dose which could be attributed to Laboratory effluents. Note that the portion due to argon and mixed activation

products (3.7 man-rem) would be included in the overall external penetrating radiation dose measured by TLDs.

By comparison, the residents of Los Alamos County would receive 2750 man-rem from natural radiation sources. This assumes contributions from internal radioactivity of 18 mrem/yr, the neutron component of cosmic radiation as 17 mrem/yr (ref. 14), and average external gamma radiation from cosmic and terrestrial sources as 118 mrem/yr (see Table VII, perimeter stations). Using the same assumptions for internal radioactivity and neutron components, and an average of 92 mrem/yr for natural external radiation to residents outside Los Alamos County (see Table VII, regional stations), leads to an estimated 12 800 man-rem population dose from natural radiation sources within an 80-km radius.

D. Other Nuclides and Pathways

Theoretical calculations were made of doses expected to be received from all airborne radioactive effluents listed in Table VI. Results indicated these gave insignificant doses in comparison to those listed for tritium and activation products and thus are not included here.

Potential exposure pathways to man could result from eating deer and honey found to contain some contamination during ecological studies conducted within the Laboratory boundaries. Assuming the maximum measured concentrations of 1.8 pCi/g of ^{137}Cs in deer muscle or 3000 pCi/mℓ of tritium in honey, and large but credible consumption rates of 110 kg/yr of venison or 2.3 kg/yr of honey, resulting estimated individual maximum doses are 3.9 mrem/yr from eating venison and 0.12 mrem/yr from eating honey.

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 the points of discharge and in the alluvium of the canyons below the outfalls. Small quantities of radioactive contaminants have been measured in canyon sediments beyond the LASL boundary, probably transported there during periods of heavy runoff. However, no 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. Consequently, no potential dose contributions beyond those already discussed could be identified or evaluated.

XI. CHEMICAL QUALITY OF SURFACE AND GROUND WATERS

Monitoring of selected chemical quality parameters of surface and ground waters provides an additional means for detecting the potential dispersion of effluents from LASL operations. Water samples are collected in 1-ℓ polyethylene bottles and returned to the laboratory for filtration through Whatman #2 filters. Standard methods are used to analyze samples for gross chemical characteristics and a selected list of ions. Samples are collected twice a year for chemical quality analyses. The summary tables in the text for the regional and water supply show maximum values for each group of samples while the perimeter and on-site stations show the highest station-average values for each group. The stations are grouped according to location or hydrologic similarity. Detailed results are presented in Tables XV through XVIII. Comparison is made with drinking water standards found in Table V.

A. Regional and Perimeter

Regional surface waters within 75 km of LASL are sampled at six stations on the Rio Grande, Chama, and Jemez Rivers (Fig. 8, Table XV). In addition, the chemical quality of water is determined from six perimeter locations, and three surface and three

ground water stations located <4 km outside the LASL boundary (Fig. 9, Table XVI). These analyses are made to provide a continuing record of the chemical quality of water in the area. All of these waters met drinking water standards (see Table V) for the constituents measured, with the occasional exception of Total Dissolved Solids (TDS). No significant changes from previous reporting periods were noted.[2,5] The maximum or highest station-average observed concentrations of Cl^-, F^-, NO_3^-, and TDS for these perimeter and regional samples were

	Concentrations (mg/ℓ)		
Constituent	Regional (Max.)	Perimeter (Highest Station Average)	Standard or Criteria
Cl^-	58	33	250
F^-	1.4	0.6	2.0
NO_3^-	0.8	24	45
TDS	664	326	500

B. Water Supply

The Los Alamos water supply system, which serves the Laboratory and the community, is sampled at each of the 15 supply wells and a supply gallery, and at 5 points in the distribution system (see Fig. 9, Table XVII). The chemical quality from individual wells varies slightly from periods of light (winter) to periods of heavy (summer) pumpage. The chemical quality varies between wells in the three fields due to local conditions occurring within the aquifer around the wells. The maximum concentrations for all chemical constituents measured were below applicable EPA Interim Primary Drinking Water Standards (see Table V) with the exception of arsenic.

	Concentrations (mg/ℓ)	
Constituents	Water Supply (Maximums)	Standards or Criteria
As	0.051	0.050
Cl^-	15	250
F^-	2.0	2.0
Hg	0.0002	0.002
NO_3^-	1.7	45
Se	<0.001	0.01
TDS	434	500

The occurrence of natural arsenic in Well G-2, Guaje Well field, is near or slightly above the standard of 0.050 mg/ℓ. However, the low arsenic inputs from the remaining six wells in the field dilute the concentration to acceptable levels before it reaches the first distribution point. Samples from this point had arsenic concentrations ranging from 0.007 to 0.013 mg/ℓ in 1976.

One well in the Los Alamos field, Well LA-6, contained arsenic concentrations ranging from 0.150 to over 0.200 mg/ℓ, or 3 to 4 times the drinking water standard for arsenic. It was determined during special tests in 1976 that the water could not be diluted sufficiently with pumpage from other wells in the field to result in water of acceptable quality. Additional tests were made to isolate sections of the well at various depths. It was determined that the aquifer throughout the well contained high arsenic concentrations. The arsenic, derived from a deep source, is apparently dispersed through the well by a fault. The well was placed on standby to be used only in emergency conditions such as fire. It is tested periodically, with the water pumped to waste. Tests in October 1976 indicated arsenic concentration ranged from 0.142 to 0.172 mg/ℓ. It is calculated that the arsenic concentration from the well would have to be reduced to 0.100 mg/ℓ at a pumping rate of 1100 ℓ/m to allow dilution with other pumpage in the field to meet the drinking water standards.[19]

C. On-Site Surface and Ground Waters

Chemical analyses were made on samples from three on-site ground water and three on-site surface water locations that are not in Laboratory effluent receiving areas (see Fig. 9, Table XVIII). The quality of water from surface water locations varies slightly as base flow is diluted with varying amounts of storm runoff; however, both the surface water and ground water analyses indicated no significant changes from various reporting periods.[2,5] These waters met drinking water standards for the constituents measured. The waters from these sources are not used for domestic, municipal, or industrial supply. The average station high concentrations of Cl^-, F^-, NO_3^-, and total dissolved solids (TDS) that are indications of Laboratory release for the six stations were

Constituent	Concentration (mg/ℓ) On-Site, Non-Effluent Areas	Standard or Criteria
Cl^-	24	250
F^-	0.6	2
NO_3^-	1.3	45
TDS	350	500

Chemical quality was determined for samples of surface and ground waters in canyons which are current or former recipients of industrial effluents (see Fig. 9, Table XVIII). Acid-Pueblo Canyon received industrial wastes from 1943 to 1964 and currently receives treated municipal sewage effluent, which is a large portion of the total flow. Sandia Canyon receives cooling tower blowdown from the TA-3 power plant and some treated sewage effluent. Except for snowmelt or storm runoff, these effluents constitute the total flow in Sandia Canyon. DP-Los Alamos Canyon receives effluents from industrial waste and sanitary sewage treatment plants and cooling tower blowdown from TA-21 and TA-2. Mortandad Canyon receives the effluent from the industrial waste treatment plant at TA-50. This effluent is a major part of the flow except during storm runoff or spring snowmelt. The highest station-average concentrations of Cl^-, F^-, NO_3^-, and TDS for these canyons were

Constituent	Concentration (mg/ℓ) Acid-Pueblo	Sandia	DP-Los Alamos	Mortandad	Standard or Criteria
Cl^-	44	49	90	30	250
F^-	0.8	1.2	4.2	1.4	2
NO_3^-	44	33	58	189	45
TDS	370	620	1930	890	500

The chemical quality of waters in each of these areas is clearly influenced by the input of effluents. None of these waters is a source of either municipal or domestic water supply, but the surface waters in these canyon areas are used by wildlife. In some places these waters do not meet drinking water standards for chemical criteria, specifically for TDS, F^-, and NO_3^-. They do meet proposed EPA[18] criteria for TDS and NO_3^- in water used for livestock.

D. Fenton Hill Site Surface and Ground Waters

The chemical quality of surface and ground water in the vicinity of the Fenton Hill site, of the LASL Dry Hot Rock Geothermal Energy Experiment (~30 km W of Los Alamos, see Fig. 10), has been measured to determine the geohydrology, for environmental studies, and to fulfill monitoring requirements. The results of preliminary studies and detailed chemical data have been reported elsewhere.[20,21]

Table XIX summarizes the chemical quality data for nine surface water stations, four water supply locations, two springs along the Jemez Fault, three springs discharging from recent volcanics, and one additional well that is abandoned. It also summarizes the quality of water from three ponds that contain water from experiments related to development of the geothermal loop in the dry hot rock at a depth of 3000 m below land surface. The water in the

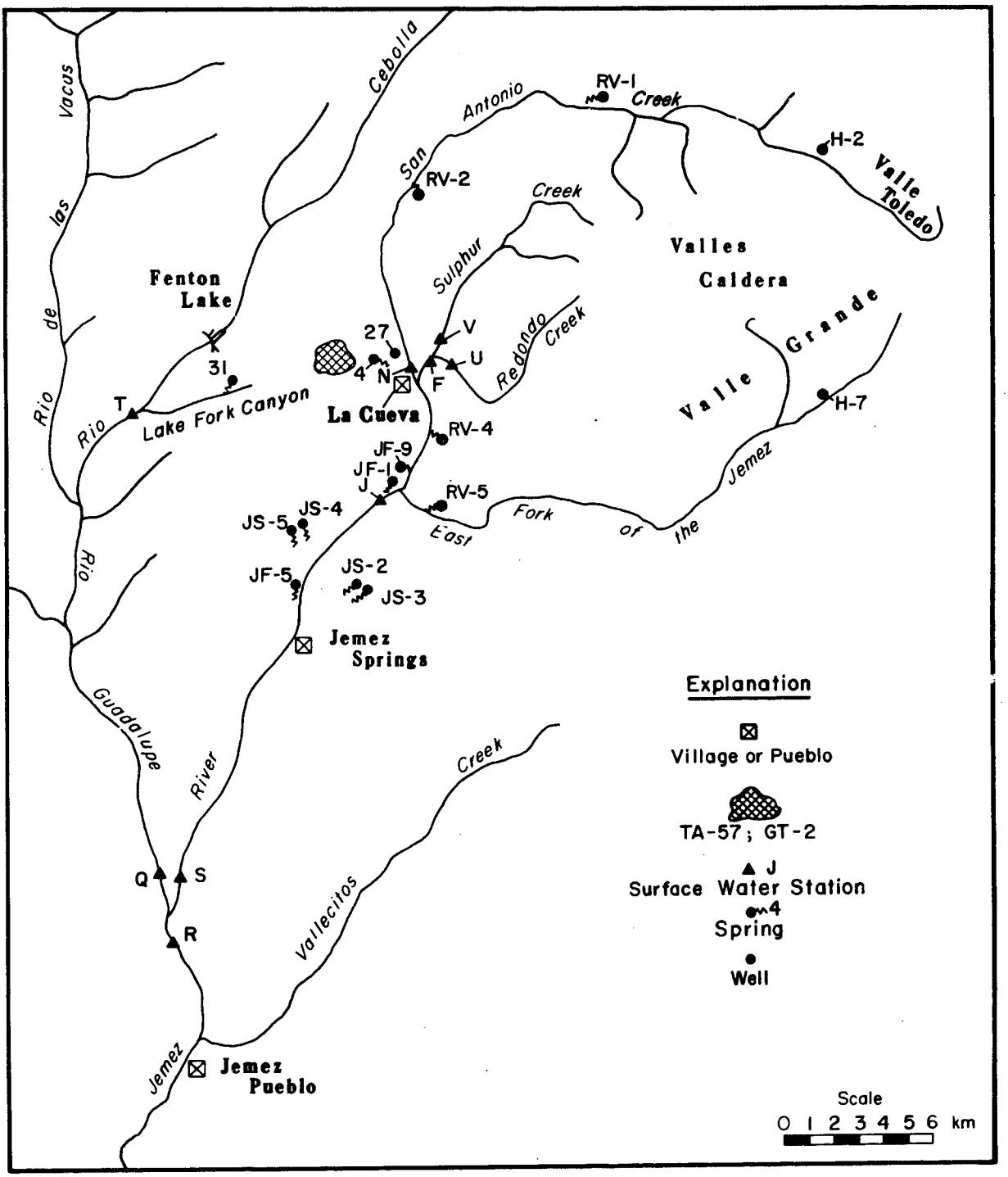


Fig. 10. Fenton Hill Sampling Station map.

ponds is highly mineralized; it is recirculated or released into a nearby dry channel after treatment to remove harmful constituents. Release is made when quality is acceptable to the U.S. Forest Service. No flow reaches perennial streams in the area.

A supply well was completed at the geothermal site at a depth of about 137 m. The quality of water from the wells is good with Cl^- at 7 mg/ℓ; F^-, 0.2 mg/ℓ; NO_3^-, <0.4 mg/ℓ; and TDS, 200 mg/ℓ. However, the water is moderately hard with a hardness of 90 mg/ℓ due to calcium and magnesium concentrations of 31 and 4 mg/ℓ, respectively. The well, located near the ponds, shows no indication of seepage from the ponds.

XII. ECOLOGICAL STUDIES

A. Radiation Exposures Measured in Rodents Inhabiting a Liquid Radioactive Effluent Receiving Area at Los Alamos

A preliminary study was completed to determine the external gamma radiation exposures to rodents inhabiting an area where low-level treated radioactive effluents are released within the LASL land areas.

A 50 x 50 m site near the effluent outfall in DP Canyon was chosen for this study. It has measurable, but variable, levels of ^{137}Cs in the soil, which have accumulated from the release of the treated effluent. Rodents in the study area were trapped, implanted with thermoluminescent dosimeters, and released for subsequent recapture and TLD retrieval. A detailed description of the experimental design and sampling methodology are reported elsewhere.[22]

The following table shows that the contaminated area produces a readily measurable radiation exposure to rodents living in the area. Exposures averaging 26 mrad/d were measured in harvest mice, with somewhat lower averages obtained for deer mice (8.3 mrad/d), pinon mice (1.9 mrad/d), and chipmunks (1.4 mrad/d). In all cases, individual exposures were higher than the 0.4 mrad/d attributable to natural external background sources in the Los Alamos area (see Section X.B).

Species exhibiting the higher radiation doses were caught most often (i.e., 50-70% of the time) along the effluent stream channel. Here, radiation intensities at the ground surface measured 20-87 mrad/d. Low doses were found in rodents captured in this zone less than 20% of the time.

Correlation of elevated exposure levels with species is attributed, at least in part, to differences in habitat requirements and mobility. The smaller, less mobile, harvest mice and deer mice are associated with the dense vegetation cover and greater radiation intensities along the stream channel. The larger, more mobile, pinon mice and chipmunks are associated with the open forest adjacent to the study plot.

RADIATION DOSES RECEIVED BY NATIVE RODENTS IN A DISPOSAL AREA FOR TREATED RADIOACTIVE EFFLUENT

Species	No.	Dose (mrad/day)[a] Mean	S.D.
Harvest Mouse (Reithrodontomys megalotis)	8	26	10
Deer Mouse (Peromyscus maniculatis)	4	8.3	9.6
Pinon Mouse (Peromyscus trueii)	5	1.9	0.9
Chipmunk (Eutamias minimus)	13	1.4	1.2

[a]Primarily due to ^{137}Cs gamma rays.

This study showed that the accumulation on soil of ^{137}Cs from liquid effluent release increased the average radiation exposure of small ground-dwelling rodents in the area by a factor of as much as 50. Average doses of 26 mrad/d were observed in harvest mice, although individual measurements for this species were as much as 50 mrad/d. The total estimated dose during the average 1-yr life span for this species would be about 9.5 rads average for the species or a maximum of 18 rads for an individual. The average exposures to the other three species were 3-18 times less than that for harvest mice.

B. Long-Term Effect of Exposure to Uranium

Nearly 75 000 kg of natural and depleted uranium used in LASL's dynamic testing program have been dispersed at E-F Site, near TA-15, which has a 33-yr use history. This location has a wide range of uranium concentrations in soils, plants, and animals. It has been studied to gain information on possible uranium chemical toxicity responses and potential food chain transmission. During the past year, studies were made at E-F Site to describe (1) uranium concentrations and distribution in soil relative to depth in the soil profile and distance from the points of dispersion, (2) redistribution of uranium by storm runoff, and (3) possible responses of soil invertebrate communities to uranium chemical toxicity.[23]

Soil samples obtained on a polar coordinate sampling scheme at the site showed highest surface (0-2.5 cm) uranium concentrations, averaging 4500 μg/g, occurred within 10 m of the dispersion point. Uranium concentrations at sampling locations at 50-200 m beyond the dispersion point were generally <15% of this value. The estimated isoconcentration lines for uranium in surface soils at E-F Site are depicted in Fig. 11.

Analyses of a limited number of soil samples collected to depths of 30 cm within a radius of 50 m of the dispersion point showed that significant penetration and/or migration of uranium into the soil profile has occurred. The mean value of 100 μg/g of uranium measured in the samples from the 20-30 cm depth, at a radius of 50 m, is about 50 times greater than the background values for this area.

Most of the uranium at E-F Site is apparently available for surface transport, mainly by storm runoff, and can move into the Potrillo Canyon drainage. Characteristics of storm runoff transport of uranium were investigated during two heavy rainfall events. A permanent sampling network was established for further sampling of alluvium in Potrillo Canyon.

The highest total uranium concentrations were observed in the standing water samples taken within the detonation crater with values ranging from 87 to 282 mg/ℓ. Most of the uranium was dissolved, with values ranging from 83 to 99%. This indicates a much greater solubility than expected from review of the literature.[24] The uranium concentration associated with the suspended sediments for the 1975 rainfall event was 3900 μg/g, a value comparable to average surface soil uranium concentrations in that area.

Surface (0-2.5 cm) alluvial soil samples from the Potrillo Canyon intermittent stream bed, collected at a point 250 m from the dispersion point, contained 300 ppm, or about 10% of the values measured at the dispersion point; at 2800 m from the dispersion point the values were about twice background. Within 200 m of E-F Site, the concentrations were highly variable to depths of 15 cm; but at distances between 350-5000 m from the site the uranium was homogeneously distributed to depths of at least 20 cm. An estimated 58 kg of uranium were located in the upper 15 cm of alluvium in the canyon below E-F Site, with 76% of it within 30 m of the source and the remainder distributed down the canyon to 9000 m. The 58-kg inventory represents <0.1% of the estimated total uranium expended at E-F Site since 1943, indicating that only minor amounts of the material have moved any appreciable distance from the point of origin.

The litter- and soil-inhabiting invertebrates in the area were studied by extracting the contents of 1-dm^2 soil cores by the Tullgren funnel method.[25] Over 9800 specimens, representing 100-110 species, were isolated from 217 samples. Species of the Order Acarina (ticks and mites) were most abundant, representing 78% of total

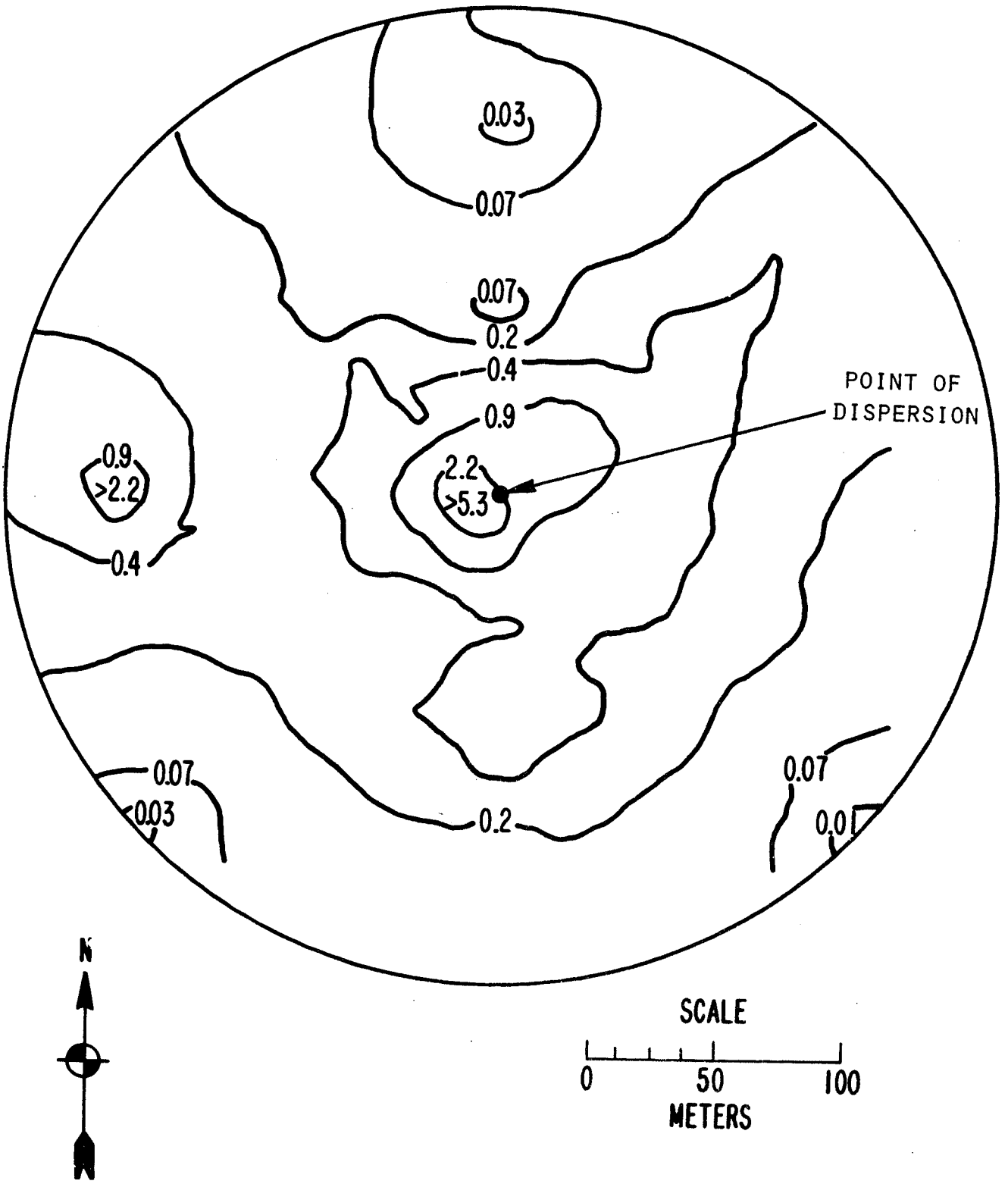


Fig. 11. Estimated contour lines of uranium concentrations (mg U/g) in surface soil (0-2.5 cm depth) samples obtained at E-F Site on a polar coordinate sampling scheme.

animals and occurring in 93% of the samples. All but one of the 15 families of Acarina identified are predators. In general, the soil and litter macrofauna populations and species diversities were apparently reduced at the high uranium study areas compared to their control area counterparts.

C. Distribution and Transport of ^{137}Cs in Los Alamos Soils

As part of the continuing ecological studies in liquid waste disposal areas, the distribution of ^{137}Cs in and near the stream channel in Mortandad Canyon was studied. Measurements of erosion were also made to help describe actual and potential transport of nuclides attached to sediments.

A set of soil samples was collected at three locations to determine concentration gradients of ^{137}Cs across the canyon sites (i.e., from mesa top to mesa top). One set of 60-cm soil cores was obtained at locations of 0.02, 0.1, 0.2, 0.38, 0.5, and 10 m from the stream channel, as well as on the adjacent mesa tops. These 12 cores were frozen and cut up into 0-10, 10-20, 20-40, and 40-60 cm segments for each sampling location.

A set of soil ^{137}Cs data is shown in Fig. 12 for Sites I, II, and III, located 320, 1300, and 2600 m, respectively, from the effluent outfall in Mortandad Canyon. The stream channel sediments at Site I contained higher levels of ^{137}Cs than the stream bank soils, which generally contained elevated levels of ^{137}Cs horizontally as far as 0.38 m away from the stream channel and down to the 40-cm soil depth. The mesa top soil samples at Site I also contained slightly elevated levels of soil ^{137}Cs. The spatial distribtuion of ^{137}Cs in the Site II bank soils was similar to that at Site I, except for the greater horizontal distribution of ^{137}Cs found at 10 m from the stream channel center in the south bank topsoil. This was probably a result of ^{137}Cs-contaminated runoff overflowing the regular stream channel during rainstorms. Site III channel sediments contained higher ^{137}Cs levels than the stream bank soils, which showed elevated ^{137}Cs soil concentrations to a depth of only 10 cm.

In order to further evaluate downstream transport of soil radionuclides, a soil erosion experiment was initiated in June 1975 to measure soil losses or gains for segments of the stream channel in Mortandad Canyon. Meter sticks were driven into the sediments in the center of the stream channel at 100-m intervals from 1.2 to 2.7 km from the effluent outfall, a normally dry segment of this intermittent stream. The soil level at each of these stakes was recorded at many different times from June 12, 1975, through November 4, 1976, a total of 512 days.

The data presented in Table XX show that the alluvium in the upper portions of the canyon (1.2-1.9 km from the outfall) was eroded and generally redeposited a short distance away (1.9-2.2 km from the effluent outfall). For example, an estimated 90 000 kg of sediments were lost from the 1.2-1.9-km segment during 512 days, whereas about 120 000 kg of soil were deposited downstream in the 1.0-2.2-km segment. The 2.2-2.7-km segment exhibited a very small gain in soil mass during this same time frame.

The largest changes in soil movement occurred during July in both 1975 and 1976 in the upper portions of the canyon, i.e., 1.4 and 2.7 km from the effluent outfall (see Fig. 13). This seasonal effect is related to the first of the large summer rains which occur in the area, resulting in large amounts of soil being moved downstream in runoff. Although larger total amounts of rain normally occur in August, the erosion data indicate the first few summer runoff events exert more influence on the inventory of soil in the canyon than does subsequent erosion throughout the summer. Very little change in soil depths occurred at the 2.7-km station at any time, suggesting that stream channel erosion-deposition patterns did not extend this far downstream.

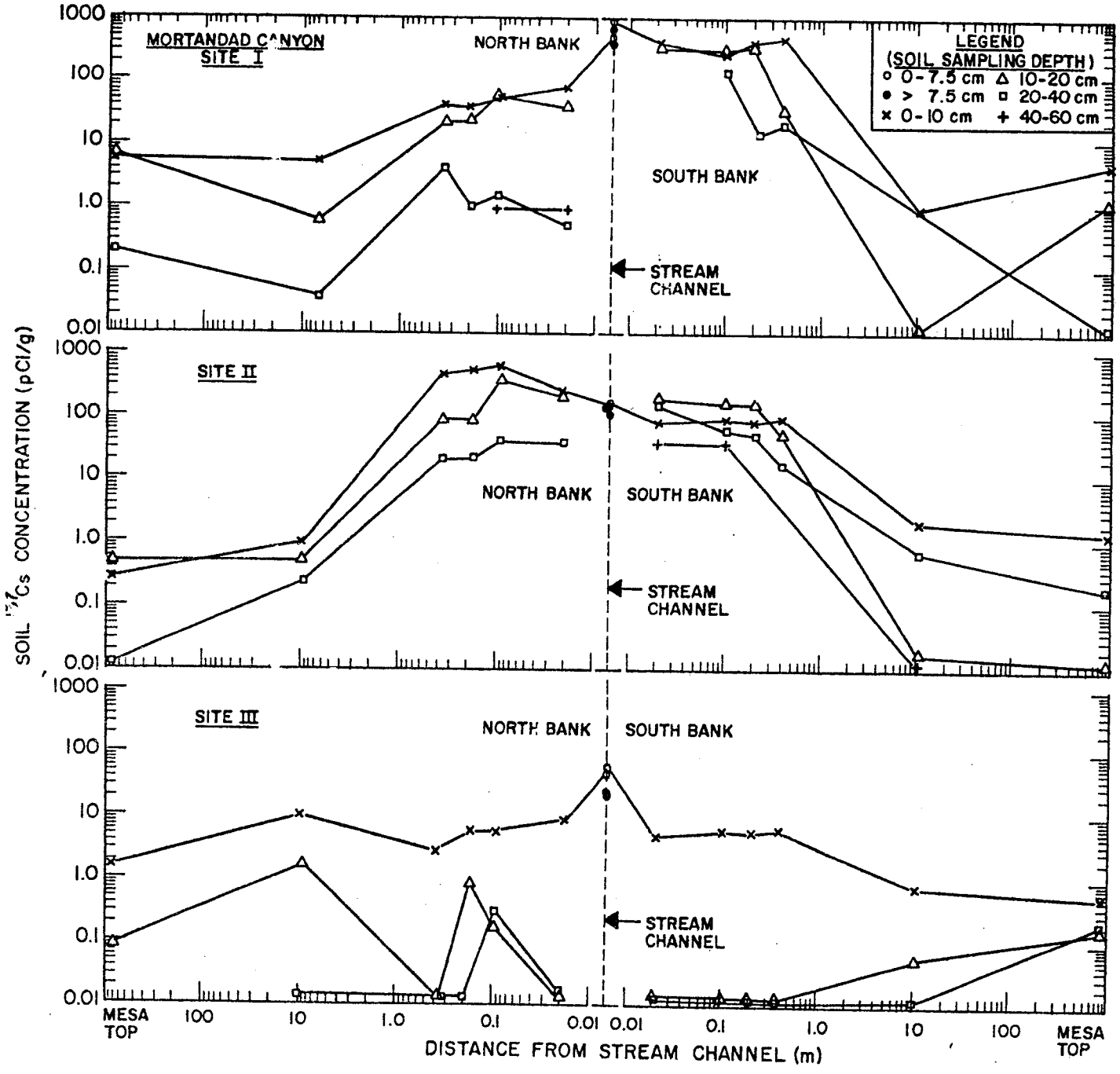


Fig. 12. Cesium-137 in soils from stream channels and banks.

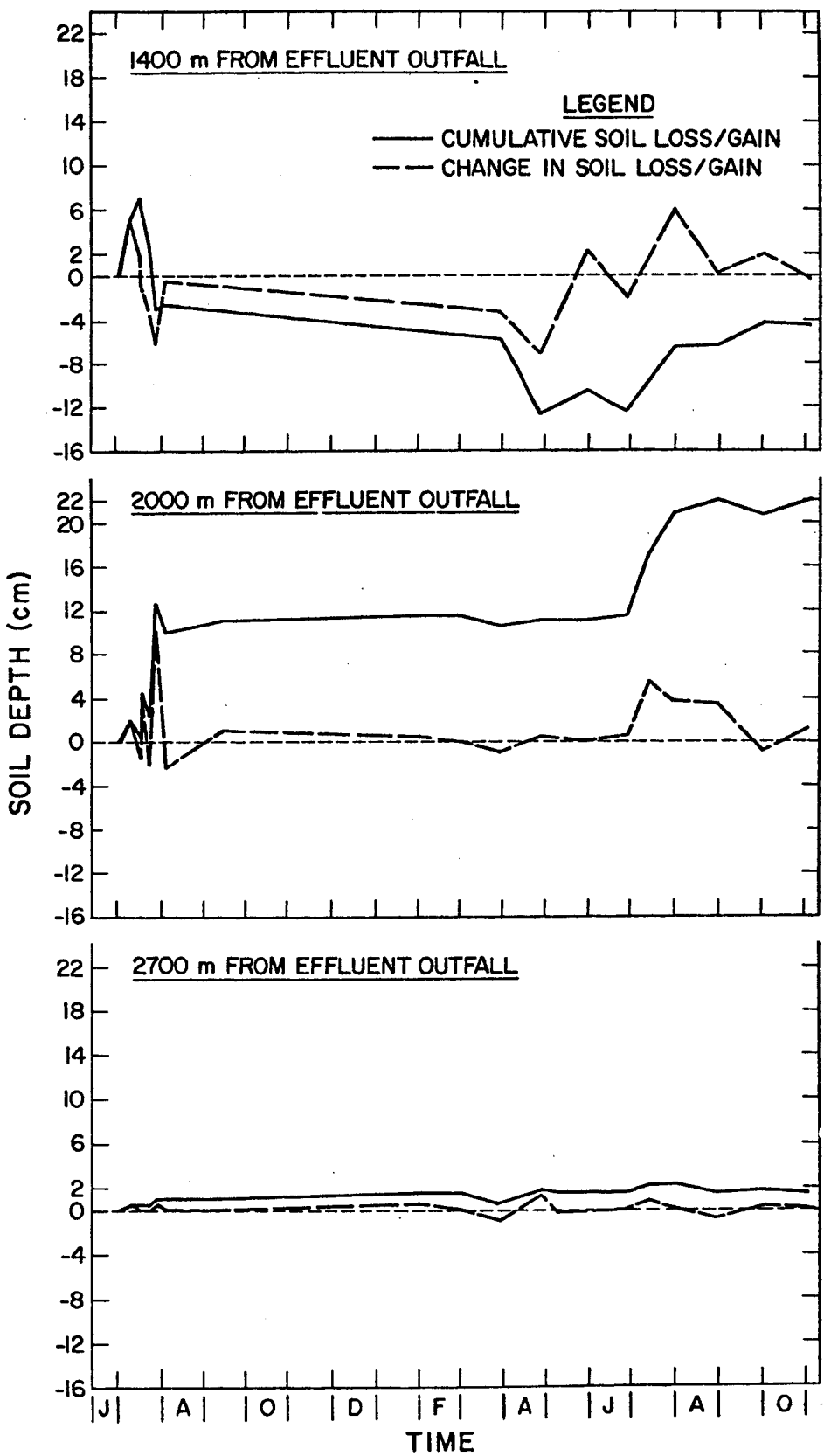


Fig. 13. Stream channel erosion.

XIII. UNPLANNED RELEASE

On the morning of July 15, 1976, approximately 2.27 g, or about 22 000 Ci, of tritium gas ($^3H_2$) were inadvertently released to the environment from the roof vents of the Cryogenics Building (SM-34) at TA-3. The release was caused by operational error resulting in exhausting a supply tank of tritium gas while air was being evacuated from the tritium-handling system. The escaping gas was diluted and moved to the southwest by a moderately unstable 4-m/s (8 mph) northeast wind. Part of the gas was drawn into the building air intake, which increased tritium concentrations in the building to the extent that the building was evacuated. Ninety-two potentially exposed people submitted urine samples for tritium assay. Analyses showed no personnel received any detectable exposure from the release. These findings supported the expectation that the release was in the form of elemental gas ($^3H_2$) and no significant oxidation to tritiated water (HTO) had occurred. Tritiated water vapor has a higher potential for exposure than tritium gas. Tritium gas in the atmosphere undergoes oxidation at a rate of <1% a day.

The nearest point at which a member of the public could have been exposed was 100 m downwind on Diamond Drive, an on-site, ERDA-controlled road normally open for public use. Tritium oxide (HTO) measurements were made on moisture distilled from silica gel cartridges collected from routine air net sampling stations on the afternoon of July 15. They showed no significant difference between upwind and downwind stations and indicated no overall deviation from expected values for the 2-wk integration period. Vegetation samples (grass, pine needles, weeds) collected on July 16 at seven of nine downwind vegetation sample locations indicated no significant difference in tritiated water concentrations compared to four upwind vegetation sampling locations. One of the slightly elevated locations was near the Van de Graaff accelerator where small quantities of tritium and tritiated water vapor have been released for a number of years. Thus, activity in these samples was attributed to Van de Graaff operations. Elevated activity (36 pCi/mℓ vs an average of 8.4 pCi/mℓ at the upwind stations) at the other station (near the entrance to TA-16) is not believed to be caused by this release because the nearby air sampling station did not indicate elevated concentrations of tritium oxide. (The CG for tritium in drinking water in uncontrolled areas is 3000 pCi/mℓ.) Thus, there was no apparent exposure to either Laboratory personnel or the general public as a result of the release. No decontamination operations were necessary because of the gaseous nature of the release.

XIV. RADIOLOGICAL SURVEY AND DECONTAMINATION OF A FORMER TECHNICAL AREA

A major portion of the resources of the environmental surveillance program during 1976 was devoted to support of field operations at the site of the former Main Technical Area (TA-1) at Los Alamos (approximate location N95 E57, Fig. 3). Technical Area One was located on land around Ashley Pond, which is now owned partly by the County and partly by private interests. The original Laboratory facilities were constructed and used from 1943 through 1965. Work carried on in the facilities resulted in varying degrees of radioactive contamination of some buildings, the waste handling system, and land. Beginning in the 1950s, research work was gradually moved from TA-1, which was immediately adjacent to the townsite, to new areas south of Los Alamos Canyon. When vacated, the obsolete TA-1 facilities were decontaminated and demolished. Major operations to remove structures began in 1954 and continued intermittently through 1965. In 1966 the land occupied by TA-1 was turned over to Los Alamos County or sold to private interests because it was sited in a central area useful to the future

development of the townsite and because it was considered that residual radioactive contamination did not present any health or safety hazards. Development of both public facilities and commercial establishments began shortly after disposal and continues to the present.

Increased concern over radioactive contamination at extremely low levels, i.e., essentially detectable levels, led the AEC (now ERDA) to request radiological surveys of various former AEC lands released to the public, including the remaining undeveloped portion of TA-1, using modern, more sensitive techniques.

Field work for the TA-1 survey was initiated in 1974 and led to extensive exploratory excavation and decontamination efforts starting late in 1975 and continuing through August 1976. Decontamination was undertaken to reduce as much as practicable any remaining question about potential safety or health implications of the residual contamination found during the survey.

Surveillance program personnel were involved in many phases of the program including daily management, collection and analysis of some 8000 soil samples, and documentation of the project. Full details of the findings are presented elsewhere.[26] It is believed that the TA-1 area in its present condition poses no risk to human health.

XV. ACKNOWLEDGMENTS

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APPENDIX

DEVELOPMENT OF FORMULAS USED FOR DOSE CALCULATIONS

Airborne Tritium

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

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

where

$D(t)$ = dose equivalent delivered during continuous exposure time t(days), in rem

$$51 = \frac{(1.6 \times 10^{-6} \text{erg/MeV})(8.64 \times 10^4 \text{ s/day})(3.7 \times 10^4 \text{ dis/s-}\mu\text{Ci})}{100 \text{ erg/g-rad}}$$

C = average airborne concentration, in μCi/mℓ

I_a = average air intake rate
= 2×10^7 mℓ/day (Ref. 11)

f_a = fraction of inhaled material reaching organ of interest
= 1 for tritium (oxide)(Ref. 11)

E = effective energy deposition per disintegration, including the quality factor for dose equivalent conversion
= 0.010 MeV-rem/dis-rad (Refs. 4, 11, and 12)

t = duration of exposure, in days

λ = effective elimination rate, in day^{-1}
= 0.069 day^{-1} (Ref. 12)

m = mass of organ of interest, in g
= 4.3×10^4 g for body water (Ref. 11).

Therefore,

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

Because skin absorption of tritiated water vapor is approximately equal to the amount of tritiated water inhaled,[12] the total dose due to ingestion of airborne tritiated water vapor becomes

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

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.[27]

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.[28]

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,

f_a = 0.7 (max) for the pulmonary region (Ref. 27)

f_r = fraction of pulmonary deposition undergoing long-term retention
= 0.6 for actinides (Class Y)(Ref. 27)

E = 53 MeV-rem/dis-rad for ^{239}Pu
= 53 MeV-rem/dis-rad for ^{238}Pu
= 57 MeV-rem/dis-rad for ^{241}Am (Ref. 11)

λ = mean clearance rate, in day^{-1}

= 0.0014 day^{-1} for actinides (Class Y) from the pulmonary region (Ref. 28)

m = 1000 g for the lungs (Ref. 11).

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

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

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

Airborne Argon-41

The dose due to the noble gas, ^{41}Ar, was calculated using a model developed by the U.S. Nuclear Regulatory Commission[17] which assumes immersion in a semi-infinite cloud and is represented by the following equation.

$$D_{\infty}^{T} = 1.11\ S_f \Sigma_i \chi_i(r,\theta) DFB_i\ ,$$

where

$D_{\infty}^{T}(r,\theta)$ = the annual total body dose due to immersion in a semi-infinite cloud at the distance r in the sector at angle θ from the discharge point in mrem/yr

1.11 = average ratio of tissue to air energy absorption coeffients

S_f = the attenuation factor accounting for dose reduction due to the shielding provided by residential structures (0.7) dimensionless

$\chi_i(r,\theta)$ = annual ground-level concentration of nuclide i at the distance r in the sector at angle θ from the release point in pCi/m^3

DFB_i = total body dose factor for radionuclide i which includes the attenuation of 5 g/cm^2 of tissue in $mrem\text{-}m^3/pCi\text{-}yr$.

In calculations for maximum dose, no allowance was made for the reduction due to shielding provided by structures, (i.e., S_f = 1.0). The factor $\chi_i(r,\theta)$ is calculated from the meteorological dispersion coefficient $\frac{\chi}{Q}i(r,\theta)(\frac{sec}{m^3})$ and the source term Q (pCi/sec). $\frac{\chi}{Q}i(r,\theta)$ is calculated from local meteorological information using the Gaussian dispersion model. Q is provided from annual effluent release monitoring. For ^{41}Ar, $DFB_i = 8.84 \times 10^{-3}$ $mrem\text{-}m^3/pCi\text{-}yr$. Thus, for the single isotope ^{41}Ar at a single location we have

$$D_{\infty}^{T}(mrem/yr) = 1.11 \times 8.84 \times 10^{-3}(\frac{mrem\text{-}m^3}{pCi\text{-}yr}) \times \frac{\chi}{Q}\ (\frac{sec}{m^3}) \times Q(\frac{pCi}{sec}) \times S_f$$

or

$$D_{\infty}^{T}(mrem/yr) = 9.8 \times 10^{-3} \times \frac{\chi}{Q} \times Q \times S_f\ .$$

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. The concentrations of these isotopes at the site boundary were calculated using the meteorological dispersion coefficient $\frac{\chi}{Q}(r,\theta)$ and the source term Q. The dose was calculated using semi-infinite cloud assumptions and was then corrected for cloud size. It has been shown[29] that the gamma dose rate in a semi-infinite cloud is represented by the equation

$$\gamma D_{\infty}^{1}(x,y,o,t) = 0.25\ \overline{E}\gamma\ \chi(x,y,o,t)\ ,$$

where

$\gamma D_{\infty}^{1}(x,y,o,t)$ = gamma dose rate (rad/sec) to a person located at (x,y,o) at time t

$\overline{E}\gamma$ = average gamma energy per decay (MeV) (positron annihilation produces two 0.511 MeV gammas, thus $\overline{E}\gamma$ = 1.02 MeV)

$\chi(x,y,o,t)$ = plume concentration in curies/m^3 at time t .

To correct dose rate for estimated plume size (if the cloud cannot be construed to be semi-infinite), values were taken from standard graphical compilations.[29]

Because the mixture of isotopes in the cloud is not known, it was assumed there was no radioactive decay in the cloud during the transit time to the nearest border.

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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							
Mo	Max	Min	Mo Mean	High	Yr	Low	Yr	Mean	Daily Max	Yr	Mo Max	Yr	Mean	Daily Max	Yr	Mo Max	Yr	Precip. ≥2.5mm	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	1952	0.0	0.0	--	0.0	--	8	12	0
Sep	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	1959 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 1976[a]

	TEMPERATURE (°C)					PRECIPITATION TOTAL (mm)				NO. OF DAYS[b]		
	MEANS (Daily Values)			EXTREMES		RAIN[c]		SNOW/FROZEN PRECIPITATION				
Mo	Max	Min	Mo Mean	High	Low	Total	Daily Max	Total	Daily Max	≥2.5mm	≥26.7°C	≤-9.4°C
Jan	5.6	-9.4	1.8	13.3	-17.8	2.0	1.0	25.4	12.7	0	0	13.
Feb	10.0	-4.3	2.9	17.8	-12.8	26.9	11.7	0.0	0.0	3	0	2
Mar	10.4	-4.4	3.1	18.3	-12.2	17.5	7.4	185.0	76.0	2	0	5
Apr	15.0	-0.1	7.4	21.1	- 8.9	18.3	4.8	0.0	0.0	4	0	0
May	19.7	4.7	12.2	27.8	- 4.4	27.4	14.5	51.0	51.0	4	2	0
Jun	26.1	9.3	17.7	31.7	0.6	5.3	2.3	0.0	0.0	0	16	0
Jul	26.8	10.5	18.7	32.2	7.2	120.6	31.5	0.0	0.0	10	16	0
Aug	24.6	9.6	17.1	28.3	6.7	77.0	20.6	0.0	0.0	7	8	0
Sep	20.6	6.5	13.6	28.3	1.1	31.0	11.7	0.0	0.0	5	2	0
Oct	14.8	-1.0	6.9	22.8	-9.4	0.5	0.3	0.0	0.0	5	2	0
Nov	9.8	-6.2	1.8	18.9	-25.6	25.4	25.4	305.0	305.0	1	0	6
Dec	5.2	-9.7	-2.2	10.6	-13.3	2.3	1.3	30.0	20.0	0	0	17
Year	15.7	0.5	8.4	32.2	-25.6	354.2	31.5	596.4	305.0	36	44	43

[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

UNITS OF MEASUREMENT CONVERSIONS

Quantity	This Report	ERDAM 0524	International (SI)	Common Usage
Radioactivity Concentrations				
Airborne	= 10^{-12} μCi/mℓ	= 10^{-12} μCi/mℓ	= 0.037 $s^{-1}m^{-3}$	= 1 pCi/m^3
	= 10^{-15} μCi/mℓ	= 10^{-15} μCi/mℓ	= 3.7 x 10^{-5} $s^{-1}m^{-3}$	= 1 fCi/m^3
	= 10^{-18} μCi/mℓ	= 10^{-18} μCi/mℓ	= 3.7 x 10^{-8} $s^{-1}m^{-3}$	= 1 aCi/m^3
In Liquids	= 10^{-9} μCi/mℓ	= 10^{-9} μCi/mℓ	= 37 $s^{-1}m^{-3}$	= 1 pCi/ℓ
	= 10^{-12} Ci/m	= 10^{-12} μCi/m	= 0.037 $s^{-1}m^{-3}$	= 10^{-3} pCi/ℓ
In Solids	1 pCi/g	-	= 37 $s^{-1}kg^{-1}$	= 1 pCi/g
	1 fCi/g	-	= 0.037 $s^{-1}kg^{-1}$	= 10^{-3} pCi/g
Chemical Properties				
Concentrations in Liquids	1 mg/ℓ	-	= 1 g/m^3	= 1 ppm
	1 μg/ℓ	-	= 1 mg/m^3	= 1 ppb
	1 ng/ℓ	-	= 1 μg/m^3	= 10^{-3} ppb
Exchange Capacity	1 eq/kg	-	= 1 (equivalent)/kg	= 10^2 meq/100 g
Electrical Conductance	1 mS/m	-	= 1 mS/m	= 10 μmho/cm
Fluid Flow Rates	1 m^3/s	-	= 1 m^3/s	= 6 x 10^4 ℓpm
				= 2120 cfm
	1 ℓ/s		= 1 dm^3/s	= 60 ℓpm
				= 2.12 cfm
Meteorological Data				
Temperature	°C	-	K = °C + 273.15	°F = 1.8(°C) + 32
Precipitation	1 mm	-	= 1 mm	= 0.039 inch
Wind Speed	1 m/s	-	= 1 m/s	= 2.237 mph
Air Pressure	1 kPa	-	= 1 kPa	= 9.87 x 10^{-3} atmos.
				= 10 mbar
				= 0.145 psi
				= 0.295 in. Hg
Geological Data				
Water Volume	1 m^3	-	= 1 m^3	= 8.11 x 10^{-4} ac. ft
Discharge	1 ℓ/s	-	= 1 dm^3/s	= 0.0353 cfs
				= 15.9 gpm
				= 2.28 x 10^4 gpd
	1 m^3/s	-	= 1 m^3/s	= 35.3 cfs
				= 1.59 x 10^4 gpm
				= 2.28 x 10^7 gpd
Absorbed Radiation	rad, rem	rem	Gy (gray)	= 100 rad
Radioactivity	Ci	-	Bq (bequerel)	= 2.70 x 10^{-11} Ci

TABLE III

DETECTION LIMITS FOR RADIOCHEMICAL ANALYSES OF TYPICAL ENVIRONMENTAL SAMPLES

Parameter	Approximate Sample Volume or Weight	Count Time	Detectable Concentration
Air Sample			
^{238}Pu	1.2×10^4 m^3	8×10^4 sec	2×10^{-18} μCi/mℓ
^{239}Pu	1.2×10^4 m^3	8×10^4 sec	3×10^{-18} μCi/mℓ
Gross-alpha	3.8×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Gross-beta	3.8×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Tritium	3 m^3	100 min	1×10^{-12} μCi/mℓ
Uranium	2.5×10^4 m^3		2 pg/m^3
Water Sample			
^{238}Pu	0.5 ℓ	8×10^4 sec	4×10^{-11} μCi/mℓ
^{239}Pu	0.5 ℓ	8×10^4 sec	1×10^{-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
Tritium	0.005 ℓ	100 min	7×10^{-7} μCi/mℓ
^{137}Cs	0.500 ℓ	5×10^4 sec	1×10^{-8} μCi/mℓ
Uranium	0.01 ℓ		6 μg/ℓ
Soil Sample			
^{239}Pu	10 g	8×10^4 sec	0.002 pCi/g
^{238}Pu	10 g	8×10^4 sec	0.003 pCi/g
Gross-alpha	2 g	100 min	0.8 pCi/g
Gross-beta	2 g	100 min	4 pCi/g
Tritium	1 kg	100 min	0.003 pCi/g
^{137}Cs	500 g	5×10^4 sec	10^{-2} pCi/g
Uranium	2 g		0.030 μg/g

TABLE IV

ERDA RADIOACTIVITY CONCENTRATION GUIDES (CGs)

CONCENTRATION GUIDES FOR UNCONTROLLED AREAS[a,b]

Nuclide	CG for Air (μCi/mℓ)	CG for Water (μCi/mℓ)	CG for Water (nCi/ℓ)
^{3}H	2×10^{-7}	3×10^{-3}	3 000
^{89}Sr	3×10^{-10}	3×10^{-6}	3
^{90}Sr[d]	3×10^{-11}	3×10^{-7}	0.3
^{131}I	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
U, natural[c]	(pg/m^3)[c]	2×10^{-5}	(mg/ℓ)
	9×10^{6}		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}
^{89}Sr	3×10^{-8}	3×10^{-4}	300
^{90}Sr[c]	1×10^{-9}	1×10^{-5}	10
^{131}I	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
U, natural[c]	(pg/m^3)[c]	5×10^{-4}	(mg/ℓ)
	2.1×10^{8}		1 500
			60 (ICRP[e])

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

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

[c]One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses may be converted to the ERDA "uranium special curie" by using the factor 3.3×10^{-11} μCi/pg.

[d]Of the possible alpha and beta emitting radionuclides released at LASL, ^{239}Pu and ^{90}Sr, 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, see Sec. III.C (Ref.4).

TABLE V

WATER STANDARDS

DRINKING WATER STANDARDS FOR CHEMICALS

Constituent	Symbol	Concentration Limit (mg/ℓ) PHS and EPA[a] Mandatory	Recommended	EPA[b] Primary Regulations	NMWQCC[c]
Alkyl benzene sulfonate	ABS	-	0.5	-	-
Arsenic	As	0.05	0.01	0.05	0.05
Barium	Ba	1.0	-	1.0	1.0
Boron	B	-	-	-	0.75
Cadmium	Cd	0.01	-	0.01	0.01
Carbon chloroform extract	CCE	-	0.2	-	-
Chloride	Cl^-	-	250.	-	-
Chromium hexavalent	Cr^{+6}	0.05	-	-	-
Total	Cr	-	-	0.05	0.01
Copper	Cu	-	1.0	-	0.05 (0.1)[d]
Cyanide	CN	0.2	0.01	-	-
Fluoride	F^-	≈1[e]	-	2.0[e]	-
Iron	Fe	-	0.3	-	-
Lead	Pb	0.05	-	0.05	0.05
Manganese	Mn	-	0.05	-	0.1
Mercury	Hg	-	-	0.002	0.001
Molybdenum	Mo	-	-	-	0.01
Nickel	Ni	-	-	-	0.1
Nitrate	NO_3^-	-	45.	45.	-
Phenols		-	0.001	-	-
Selenium	Se	0.01	-	0.01	0.01
Silver	Ag	0.05	-	0.05	0.05
Total dissolved solids	TDS	-	500.	-	-
Zinc	Zn	-	5.0	-	0.1(0.5)[d]

[a]PHS Regulations on Drinking Water Standards, 42 CFR 72, 201-207, Fed. Reg. 27:2152, Mar. 6, 1962. Also in PHS Publ. 956 and EPA Bulletin 956.

[b]EPA National Interim Primary Drinking Water Regulations, 40 CFR 141, Fed. Reg. 40: 59566-59588, Dec. 24, 1975.

[c]New Mexico Water Quality Control Commission Regulations.

[d]Concentrations shown in parentheses are permitted in community sewer systems.

[e]The concentration standard for fluoride varies depending upon temperature. The values given are appropriate for Los Alamos conditions.

TABLE VI

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTALS FOR 1976

Location	^{238}Pu ^{239}Pu (μCi)	^{235}U ^{238}U (μCi)	^{234}Th (mCi)	MFP[a] (μCi)	^{131}I (mCi)	^{41}Ar (Ci)	^{32}P (μCi)	^{3}H (Ci)	$^{11}C, ^{13}N, ^{15}O$ (Ci)
TA-2	--	--	--	--	--	339	--	--	--
TA-3	39.5	363	2.5	415	0.3	--	--	--	--
TA-9	--	--	--	--	--	--	--	129	--
TA-15	--	--	--	--	--	--	--	--	--
TA-21	12.2	870	--	0.6	--	--	--	95	--
TA-33	--	--	--	--	--	--	--	1349	--
TA-35	2.4	--	--	--	--	--	--	1657	--
TA-41	--	--	--	--	--	--	--	--	--
TA-43	7.7	--	--	--	--	--	74	--	--
TA-46	--	0.3	--	--	--	--	--	--	--
TA-48	5.0	112	--	1231	--	--	--	--	--
TA-50	1.1	--	--	27	--	--	--	--	--
TA-53	--	--	--	--	--	--	--	171	5890

[a]Mixed Fission Products.

TABLE VII

ANNUAL THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station Location	Coordinates	Annual Dose: Dose mRem	2σ error mRem	2σ error %
Regional Stations	(28-44 km)		Uncontrolled Areas	
Espanola, NM		90.8	±14.6	(16.1%)
Pojoaque, NM		92.7	±13.1	(14.1%)
Santa Fe, NM		92.6	±11.6	(12.5%)
Perimeter Stations	(0-4 km)		Uncontrolled Areas	
Barranca School	N180 E130	118.5	± 7.2	(6.1%)
Cumbres School	N150 E090	137.4	±19.5	(14.2%)
Golf Course	N160 E060	123.3	±11.9	(9.6%)
Arkansas Avenue	N170 E020	129.6	±14.9	(11.5%)
Diamond Drive	N130 E020	124.2	±14.3	(11.5%)
48th Street	N110 E000	142.9	±12.3	(8.6%)
Fuller Lodge	N110 E090	129.2	± 9.6	(7.4%)
Acorn Street	N100 E110	119.9	±16.2	(13.5%)
L.A. Airport	N110 E160	129.5	±13.3	(10.3%)
Bayo Canyon S.T.P.	N110 E260	126.2	±12.0	(9.5%)
Bandelier Lookout	S270 E200	120.5	± 5.4	(4.5%)
Pajarito Acres	S210 E370	93.8	±10.3	(11.0%)
White Rock S.T.P.	S090 E430	125.0	±10.3	(8.2%)
Pajarito Ski Area	N130 W180	121.4	±15.5	(12.7%)
Gulf Station	N100 E100	111.6	±13.4	(12.0%)
	Off-Site Weighted Annual Average	118.2	±27.4	(23.2%)
On-Site Stations			Controlled Areas	
TA-21	N090 E170	149.5	±12.2	(8.1%)
State Hwy 4	N070 E350	228.7	±35.9	(15.7%)
Well PM-1	N030 E310	158.4	±19.5	(12.3%)
TA-53	N040 E230	130.8	± 8.0	(6.1%)
TA-53	N070 E160	132.3	± 6.6	(5.0%)
TA-53	N060 E190	156.9	± 3.6	(2.3%)
TA-53	N060 E200	152.0	± 1.7	(1.1%)
TA-53	N060 E220	307.2	±16.6	(5.4%)
TA-53	N050 E230	150.4	± 7.9	(5.3%)
TA-2	N080 E100	134.9	± 8.0	(5.9%)
TA-2	N080 E110	152.2	± 8.4	(5.5%)
TA-2	N080 E120	165.3	±11.5	(7.0%)
TA-6	N060 W050	134.4	±18.2	(13.6%)
TA-16	S030 W080	116.7	± 9.9	(8.5%)
TA-49	S100 E040	127.2	± 5.4	(4.3%)
TA-33	S250 E230	118.5	± 8.6	(7.3%)
Booster P-1	S100 E300	135.0	±16.7	(12.4%)
TA-18	S040 E190	162.8	±10.7	(6.4%)
TA-18	S030 E190	191.1	±17.0	(8.9%)
TA-18	S040 E200	362.5	±22.8	(6.3%)
TA-18	S060 E190	431.9	±34.8	(8.1%)
TA-18	S050 E170	156.0	± 9.5	(6.1%)
TA-52	N020 E170	120.3	±14.4	(12.0%)
TA-35	N040 E110	136.6	± 6.6	(4.7%)
TA-35	N030 E110	144.2	± 6.9	(4.8%)
TA-35	N030 E100	139.1	± 7.8	(5.6%)
TA-3	N040 E010	146.7	± 9.7	(6.6%)
TA-3	N060 E010	484.4	±20.2	(4.2%)
TA-3	N050 E020	182.4	± 7.1	(3.9%)
TA-3	N050 E040	141.9	± 5.8	(4.1%)

TABLE VIII

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

Station Location	Coordinate	Total Air Volume (m^3)	Gross-Alpha Concentrations-fCi/m^3 (10^{-15} μCi/mℓ[b]) Number of Biweekly Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]	Gross-Beta Concentrations-fCi/m^3 (10^{-15} μCi/mℓ[b]) 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														
Espanola	--	95059	26	0	3.4(±1.6)	0.7(±0.3)	1.2(±0.1)	2.0	26	0	530(±140)	14(±4)	60(±7)	0.2
Pojoaque	--	83352	26	0	4.8(±2.2)	1.0(±0.4)	1.6(±0.2)	2.7	26	0	540(±140)	14(±4)	62(±6)	0.2
Santa Fe	--	99038	26	0	4.3(±2.0)	0.6(±0.8)	1.4(±0.1)	2.3	26	0	560(±140)	11(±3)	60(±7)	0.2
Off-Site Group Summary:		277449	78	0	4.8(±2.2)	0.6(±0.8)	1.4(±0.1)	2.3	78	0	560(±140)	14(±4)	60(±4)	0.2
Perimeter Stations (0-4 km) Uncontrolled Areas														
Barranca School	N180 E130	104408	26	0	6.8(±3.2)	0.7(±0.3)	1.5(±0.2)	2.5	26	0	750(±200)	12(±3)	68(±8)	0.2
Arkansas Avenue	N170 E020	92829	26	0	2.7(±1.8)	0.7(±0.3)	1.2(±0.1)	2.0	26	0	790(±200)	10(±3)	64(±8)	0.2
Golf Course	N160 E060	106065	26	1	3.0(±1.6)	0.1(±0.4)	1.3(±0.2)	2.2	26	0	710(±180)	12(±3)	64(±7)	0.2
Cumbres School	N150 E090	92525	26	0	3.5(±2.0)	0.5(±0.3)	1.3(±0.2)	2.2	26	0	730(±180)	8(±2)	63(±8)	0.2
Diamond Drive	N130 E020	93201	26	0	3.7(±1.2)	0.6(±0.3)	1.2(±0.1)	2.0	26	0	770(±200)	8(±2)	58(±7)	0.2
48th Street	N110 E000	917[illegible]	26	0	2.5(±1.2)	0.6(±0.3)	1.1(±0.1)	1.8	26	0	690(±180)	9(±2)	59(±7)	0.2
Fuller Lodge	N110 E090	8[illegible]78	26	0	4.2(±2.4)	0.6(±1.2)	1.2(±0.1)	2.0	26	0	760(±200)	13(±3)	59(±7)	0.2
L.A. Airport	N110 E160	104319	26	1	3.4(±2.0)	0.0(±0.8)	1.3(±0.1)	2.2	26	1	660(±160)	2(±6)	65(±7)	0.2
Bayo S.T.P.	N110 E260	99172	26	1	3.5(±1.6)	0.1(±0.4)	1.1(±0.2)	1.8	26	0	630(±160)	12(±3)	60(±7)	0.2
Gulf Station	N100 E100	103696	26	0	2.8(±1.2)	0.8(±0.4)	1.2(±0.1)	2.0	26	0	770(±200)	12(±3)	68(±8)	0.2
Acorn Street	N100 E110	105904	26	0	2.6(±1.2)	0.5(±0.2)	1.1(±0.1)	1.8	26	0	440(±120)	8(±2)	45(±4)	0.2
Royal Crest	N080 E080	36476	10	1	4.2(±2.[illegible])	0.0(±1.0)	1.6(±0.3)	2.7	10	0	720(±180)	12(±3)	143(±20)	0.5
White Rock S.T.P.	S090 E430	90889	26	0	3.4(±1.6)	0.6(±0.8)	1.3(±0.2)	2.2	26	0	590(±160)	13(±3)	61(±7)	0.2
Pajarito Acres	S210 E370	87112	26	0	4.4(±2.0)	0.6(±1.2)	1.5(±0.2)	2.5	26	0	810(±200)	14(±4)	71(±8)	0.2
Bandelier Lookout	S270 E200	100207	26	0	4.2(±2.0)	0.7(±1.0)	1.4(±0.2)	2.3	26	0	670(±180)	12(±3)	71(±8)	0.2
Perimeter Group Summary:		1398526	374	4	6.8(±3.2)	0.0(±0.8)	1.3(±0.1)	2.2	374	1	810(±200)	2(±6)	65(±2)	0.2
On-Site Stations - Controlled Areas														
TA-21	N090 E170	94051	26	0	5.4(±2.8)	0.7(±0.3)	1.3(±0.2)	0.07	26	0	650(±160)	10(±3)	63(±7)	0.006
TA-6	N060 W050	100634	26	0	3.0(±1.4)	0.7(±0.3)	1.2(±0.2)	0.06	26	0	650(±160)	11(±3)	61(±7)	0.006
TA-53 (LAMPF)	N060 E190	100187	26	0	2.8(±1.2)	0.6(±0.8)	1.2(±0.1)	0.06	26	0	640(±160)	12(±3)	58(±7)	0.006
Well PM-1	N030 E310	105690	26	0	3.1(±1.6)	0.7(±0.4)	1.2(±0.1)	0.06	26	0	740(±180)	11(±3)	66(±8)	0.007
TA-52	N020 E170	102490	26	0	4.7(±2.2)	0.7(±0.3)	1.4(±0.2)	0.07	26	0	690(±180)	11(±3)	64(±8)	0.006
TA-16	S030 W080	95823	26	1	3.0(±1.6)	0.2(±0.1)	1.0(±0.1)	0.05	26	0	670(±180)	10(±3)	61(±8)	0.006
Booster P-2	S030 E190	96510	26	1	4.5(±2.2)	0.0(±0.8)	1.4(±0.2)	0.07	26	0	560(±140)	13(±3)	63(±7)	0.006
TA-54	S080 E260	67128	17	0	3.7(±2.0)	0.9(±0.4)	1.8(±0.3)	0.09	17	0	690(±180)	13(±3)	91(±12)	0.009
TA-49	S100 E040	103126	26	1	3.6(±1.8)	0.1(±0.1)	1.2(±0.1)	0.06	26	0	610(±160)	1(±1)	57(±7)	0.006
Booster P-1	S100 E300	103833	26	1	5.3(±2.4)	0.0(±1.0)	1.5(±0.2)	0.08	26	0	1410(±360)	12(±3)	70(±9)	0.007
TA-33	S250 E230	105928	26	1	3.8(±1.8)	0.1(±1.0)	1.3(±0.2)	0.07	26	0	770(±200)	11(±3)	72(±9)	0.007
On-Site Group Summary:		1075400	277	5	5.4(±2.8)	0.0(±0.8)	1.3(±0.1)	0.07	277	0	1410(±360)	10(±3)	65(±2)	0.007

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

b. mℓ at ambient conditions of ~580 mm Hg barometric pressure and ~15°C.

c. Minimum Detectable Limit = 0.3×10^{-15} μCi/mℓ(α)
= 0.3×10^{-15} μCi/mℓ(β)

d. Reported uncertainties are counting uncertainties at the 95% confidence level (±2 sample standard deviations).

e. Of the possible radionuclides released at LASL, ^{239}Pu and ^{90}Sr 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)
= 1×10^{-9} μCi/mℓ(β)

Uncontrolled Area Radioactivity Concentration Guide = 6×10^{-14} μCi/mℓ(α)
= 3×10^{-11} μCi/mℓ(β)

TABLE IX

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR CONCENTRATIONS

Station Location	Coordinates	Total Air Volume (m^3)	Number of Biweekly Samples	No. Samples <MDL[b]	Concentrations - pCi/m^3 (10^{-12} $\mu Ci/m\ell$[a]) Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas								
Espanola	--	91	26	2	61(±24)	0(±4)	16(±1)	0.008
Pojoaque	--	84	26	1	73(±4)	0(±3)	16(±1)	0.008
Santa Fe	--	84	26	3	69(±4)	0(±4)	14(±4)	0.007
Off-Site Group Summary:		259	78	6	69(±4)	0(±4)	15(±2)	0.008
Perimeter Stations (0-4 km) - Uncontrolled Areas								
Barranca School	N180 E130	87	26	0	32(±12)	5(±2)	11(±1)	0.006
Arkansas Avenue	N170 E020	86	26	0	36(±12)	4(±2)	13(±1)	0.007
Golf Course	N160 E060	83	26	1	68(±22)	1(±3)	18(±2)	0.009
Cumbres School	N150 E090	83	26	0	77(±26)	3(±6)	20(±2)	0.010
Diamond Drive	N130 E020	87	26	1	38(±12)	0(±3)	21(±2)	0.011
48th Street	N110 E000	85	26	1	50(±16)	0(±3)	18(±1)	0.009
Fuller Lodge	N110 E090	84	26	1	62(±22)	0(±3)	24(±2)	0.012
L.A. Airport	N110 E160	84	26	0	104(±40)	13(±6)	51(±4)	0.026
Bayo S.T.P.	N110 E260	81	26	0	43(±16)	5(±4)	16(±1)	0.008
Gulf Station	N100 E100	73	23	0	42(±16)	5(±4)	22(±2)	0.011
Acorn Street	N100 E110	81	26	0	80(±26)	7(±3)	36(±3)	0.018
Royal Crest	N080 E080	27	9	0	106(±38	3(±2)	31(±5)	0.016
White Rock S.T.P.	S090 E430	83	26	0	60(±20)	2(±1)	23(±2)	0.012
Pajarito Acres	S210 E370	80	26	0	47(±16)	5(±4)	16(±1)	0.008
Bandelier Lookout	S270 E200	78	26	0	94(±30)	8(±10)	27(±2)	0.014
Perimeter Group Summary:		1182	370	4	106(±38)	0(±3)	23(±1)	0.012
On-Site Stations - Controlled Areas								
TA-21	N090 E170	83	26	0	210(±60)	10(±4)	40(±3)	0.0008
TA-6	N060 W050	85	26	1	150(±40)	0(±3)	25(±2)	0.0005
TA-53 (LAMPF)	N060 E190	82	26	0	102(±18)	18(±8)	49(±3)	0.0010
Well PM-1	N030 E310	86	26	0	140(±40)	4(±3)	35(±3)	0.0007
TA-52	N020 E170	85	26	0	340(±120)	24(±8)	118(±8)	0.0024
TA-16	S030 W080	84	26	1	91(±30)	0(±3)	20(±2)	0.0004
Booster P-2	S030 E190	76	25	0	80(±14)	5(±2)	34(±2)	0.0007
TA-54	S080 E260	50	17	0	960(±300)	34(±12)	330(±32)	0.0066
TA-49	S100 E040	86	26	1	74(±24)	0(±2)	22(±2)	0.0004
Booster P-1	S100 E300	83	26	0	114(±20)	4(±1)	37(±3)	0.0007
TA-33	S250 E230	81	26	0	214(±82)	10(±3)	59(±5)	0.0012
On-Site Group Summary:		881	276	3	960(±300)	0(±3)	60(±2)	0.0012

a. mℓ at ambient conditions of ∿580 mm Hg barometric pressure and ∿15°C.

b. Minimum Detectable Limit = 1×10^{-12} $\mu Ci/m\ell$.

c. Reported uncertainties are counting uncertainties at the 95% confidence level (±2 sample standard deviations).

d. Controlled Area Radioactivity Concentration Guide = 5×10^{-6} $\mu Ci/m\ell$.

Uncontrolled Area Radioactivity Concentration Guide = 2×10^{-7} $\mu Ci/m\ell$.

TABLE X

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

Station Location	Coordinates	Total Air Volume (m^3)	^{238}Pu (10^{-18} µCi/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^{-18} µCi/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														
Espanola	--	95059	8	8	1.4(±1.4)	-1.7(±1.3)	-0.2(±0.6)	0.0000	8	3	9.4(±3.2)	0.4(±2.3)	4.1(±0.9)	0.007
Pojoaque	--	75744	8	7	3.8(±3.2)	-1.6(±3.6)	-0.2(±0.8)	0.0000	8	3	7.8(±3.2)	1.7(±2.0)	4.4(±1.0)	0.007
Santa Fe	--	99037	8	6	2.2(±1.4)	-1.6(±1.3)	0.4(±0.6)	0.0006	8	3	7.4(±3.0)	1.0(±2.8)	3.8(±0.8)	0.006
Off-Site Group Summary:		269840	24	21	3.8(±3.2)	-1.7(±1.3)	0.0(±0.4)	0.0000	24	9	9.4(±3.2)	0.4(±2.3)	4.1(±0.5)	0.007
Perimeter Stations (0.4 km) - Uncontrolled Areas														
Barranca School	N180 E130	104468	8	8	1.7(±1.8)	-0.2(±1.2)	0.4(±0.7)	0.0006	8	1	9.6(±2.8)	0.9(±1.6)	6.0(±1.0)	0.01
Arkansas Avenue	N170 E020	92829	8	6	2.8(±2.4)	-1.7(±1.4)	0.4(±0.7)	0.0006	8	3	6.6(±2.6)	1.4(±2.6)	4.4(±1.0)	0.007
Golf Course	N160 E060	106065	8	7	3.1(±2.4)	-0.7(±1.8)	0.7(±0.6)	0.001	8	1	8.3(±3.2)	1.5(±1.6)	5.1(±1.0)	0.009
Cumbres School	N150 E090	92525	8	8	1.9(±2.8)	-1.4(±3.2)	0.0(±0.7)	0.0000	8	3	6.4(±3.2)	0.2(±1.4)	4.0(±0.9)	0.007
Diamond Drive	N130 E020	83201	8	6	3.6(±5.9)	-2.7(±2.6)	0.8(±1.2)	0.001	8	4	7.2(±3.2)	1.0(±1.4)	4.3(±1.3)	0.007
48th Street	N110 E000	91745	8	7	2.7(±2.2)	-1.3(±1.6)	0.4(±0.7)	0.0006	8	4	4.8(±2.6)	1.0(±1.8)	3.6(±0.9)	0.006
Fuller Lodge	N110 E090	89978	8	7	2.9(±2.6)	-0.7(±2.6)	0.2(±0.7)	0.0003	8	1	10.5(±3.8)	2.0(±2.0)	6.1(±1.2)	0.01
L.A. Airport	N110 E160	104319	8	8	1.9(±1.8)	-0.4(±1.4)	0.6(±0.7)	0.0009	8	2	12.0(±4.4)	1.0(±2.0)	6.8(±1.1)	0.01
Bayo S.T.P.	N110 E260	99172	8	7	2.1(±1.8)	-2.2(±1.1)	-0.4(±0.5)	0.0000	8	3	8.0(±2.8)	1.5(±2.0)	5.1(±1.0)	0.009
Gulf Station	N100 E100	51375	4	3	2.4(±2.0)	-1.5(±1.8)	0.9(±1.0)	0.001	4	1	13.0(±5.0)	1.2(±3.4)	5.5(±1.7)	0.009
Acorn Street	N100 E110	105904	8	7	2.3(±2.4)	-1.9(±1.4)	0.1(±0.6)	0.0001	8	3	18.7(±5.2)	2.0(±1.8)	5.4(±1.0)	0.009
Royal Crest	N080 E080	36476	3	1	2.9(±1.6)	0.2(±1.8)	2.0(±1.2)	0.003	3	2	5.4(±2.2)	1.5(±2.0)	3.6(±1.4)	0.006
White Rock S.T.P.	S090 E430	90889	8	8	1.8(±2.2)	-1.3(±0.9)	0.2(±0.7)	0.0003	8	2	11.9(±4.0)	1.3(±2.8)	5.2(±1.1)	0.009
Pajarito Acres	S210 E370	87112	8	8	1.8(±2.4)	-1.7(±3.6)	-0.2(±0.7)	0.0000	8	2	7.8(±2.8)	2.0(±2.6)	5.4(±1.1)	0.009
Bandelier Lookout	S270 E200	100135	8	6	5.3(±3.4)	-1.3(±1.8)	0.5(±0.7)	0.0007	8	1	9.2(±3.4)	0.7(±1.6)	6.2(±1.2)	0.01
Perimeter Group Summary		1336393	111	97	5.3(±3.4)	-2.7(±2.6)	0.4(±0.2)	0.0006	111	33	18.7(±5.2)	0.2(±1.4)	5.2(±0.3)	0.009
On-Site Stations - Controlled Areas														
TA-21	N090 E170	94049	8	5	3.9(±2.8)	-0.5(±1.1)	1.4(±0.7)	0.00005	8	1	9.5(±2.4)	1.2(±2.0)	6.2(±1.0)	0.0003
TA-6	N060 W050	100634	8	8	2.0(±2.2)	-0.9(±1.8)	0.1(±0.6)	0.000005	8	3	7.8(±3.4)	0.1(±1.6)	3.8(±1.0)	0.0002
TA-53 (LAMPF)	N060 E190	100189	8	8	0.7(±2.0)	-1.8(±1.5)	-0.1(±0.6)	0.00000	8	3	8.5(±3.0)	-0.1(±1.8)	5.0(±1.1)	0.0003
Well PM-1	N030 E310	105700	8	6	3.3(±2.2)	-0.9(±1.3)	0.9(±0.8)	0.00005	8	2	8.5(±3.0)	0.2(±1.8)	4.6(±1.1)	0.0002
TA-52	N020 E170	87919	7	6	2.1(±2.0)	-1.4(±1.4)	-0.1(±0.6)	0.00000	7	1	6.2(±3.2)	1.8(±1.8)	4.9(±1.2)	0.0002
TA-16	S030 W080	95786	8	6	3.0(±2.4)	-1.2(±1.8)	0.6(±0.7)	0.00003	8	2	6.5(±2.8)	1.8(±2.0)	4.1(±0.9)	0.0002
Booster P-2	S030 E190	96923	8	6	2.8(±2.2)	-1.4(±1.2)	0.6(±0.7)	0.00003	8	2	11.5(±4.6)	1.8(±1.8)	5.8(±1.0)	0.0003
TA-54	S080 E260	50963	4	0	6.6(±2.8)	2.3(±2.0)	4.3(±1.2)	0.0002	4	0	69.9(±9.0)	4.9(±1.9)	26.8(±2.9)	0.001
TA-49	S100 E040	102763	8	8	1.8(±2.8)	-1.0(±0.9)	0.4(±0.7)	0.00005	8	3	7.7(±3.2)	0.2(±1.8)	3.9(±0.9)	0.0002
Booster P-1	S100 E300	103833	8	6	25.2(±4.8)	-0.9(±0.7)	3.2(±1.0)	0.0002	8	1	1510(±95)	2.3(±3.0)	171(±11)	0.009
TA-33	S250 E230	105928	8	7	2.3(±2.2)	-1.5(±1.6)	0.0(±0.6)	0.00000	8	1	11.5(±3.8)	2.5(±2.0)	5.3(±1.0)	0.0003
On-Site Group Summary		1044687	83	66	2.52(±4.8)	-1.8(±1.5)	0.9(±0.2)	0.00005	83	19	1510(±96)	-0.1(±1.8)	22.5(±1.1)	0.001

a. mℓ at ambient conditions of ∿580 mm Hg barometric pressure and ∿15°C.

b. Minimum Detectable Limit = 2×10^{-18} µCi/mℓ(^{238}Pu)
= 3×10^{-18} µCi/mℓ(^{239}Pu)

c. Reported uncertainties are counting uncertainties at 95% confidence level (±2 sample standard deviations).

d. Controlled Area Radioactivity Concentration Guide = 2×10^{-12} µCi/mℓ(^{238}Pu)
= 2×10^{-12} µCi/mℓ(^{239}Pu)

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

TABLE XI

ANNUAL ATMOSPHERIC URANIUM

Station Location	Coordinates	Total Air Volume (m^3)	Number of 12-14 Wk Samples	No. Samples <MDL[b]	Uranium - pg/m^3[a] Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas								
1. Espanola	--	95059	4	0	146(±18)	13(±7)	72(±7)	0.0008
2. Pojoaque	--	59368	3	0	117(±20)	22(±9)	68(±9)	0.0008
3. Santa Fe	--	99037	4	1	83(±13)	2(±16)	45(±6)	0.0005
Off-Site Group Summary:		253464	11	1	146(±18)	2(±16)	61(±4)	0.0007
Perimeter Stations (0-4 km) - Uncontrolled Areas								
4. Barranca School	N180 E130	76704	3	1	134(±27)	2(±16)	67(±12)	0.0007
5. Arkansas Avenue	N170 E020	92829	4	0	105(±14)	27(±7)	66(±8)	0.0007
6. Golf Course	N160 E060	106065	4	0	64(±19)	40(±6)	54(±6)	0.0006
7. Cumbres School	N150 E090	67327	3	0	77(±22)	4(±13)	43(±9)	0.0005
8. Diamond Drive	N130 E020	70453	3	0	179(±39)	50(±9)	111(±13)	0.0012
9. 48th Street	N110 E000	91745	4	0	63(±14)	39(±17)	53(±7)	0.0006
10. Fuller Lodge	N110 E090	89978	4	0	109(±26)	64(±14)	80(±12)	0.0009
11. L. A. Airport	N110 E160	104319	4	0	68(±27)	40(±8)	49(±8)	0.0005
12. Bayo S.T.P.	N110 E260	99172	4	0	61(±15)	37(±37)	45(±10)	0.0005
13. Gulf Station	N110 E100	76204	3	0	102(±14)	51(±12)	72(±7)	0.0008
14. Acorn Street	N100 E110	105904	4	0	134(±18)	9(±15)	75(±8)	0.0008
15. Royal Crest	N080 E080	36476	2	1	35(±10)	-7(±9)	23(±8)	0.0003
16. White Rock S.T.P.	S090 E430	90889	4	0	77(±13)	47(±8)	56(±5)	0.0006
17. Pajarito Acres	S210 E370	87112	4	0	56(±9)	32(±22)	45(±6)	0.0005
18. Bandelier Lookout	S270 E200	100135	4	0	55(±11)	24(±12)	34(±7)	0.0004
Perimeter Group Summary:		1295312	54	2	179(±39)	-7(±9)	59(±2)	0.0007
On-Site Stations - Controlled Areas								
19. TA-21	N090 E170	94049	4	0	52(±14)	30(±14)	42(±6)	0.00002
20. TA-6	N060 W050	100634	4	0	75(±11)	33(±9)	59(±9)	0.00003
21. TA-53 (LAMPF)	N060 E190	100189	4	0	107(±23)	34(±16)	62(±8)	0.00003
22. Well PM-1	N030 E310	105700	4	0	59(±16)	23(±8)	43(±8)	0.00002
23. TA-52	N020 E170	102490	4	0	80(±13)	38(±10)	61(±5)	0.00003
24. TA-16	S030 W080	95777	4	0	51(±9)	28(±13)	35(±6)	0.00002
25. Booster P-2	S030 E190	96510	4	0	271(±73)	47(±7)	125(±20)	0.00006
26. TA-54	S080 E260	50963	2	0	189(±80)	48(±10)	112(±37)	0.00005
27. TA-49	S100 E040	102763	4	0	71(±11)	24(±10)	54(±9)	0.00003
28. Booster P-1	S100 E300	103833	4	0	72(±9)	26(±15)	50(±5)	0.00002
29. TA-33	S250 E230	105928	4	0	52(±8)	7(±8)	41(±4)	0.00002
On-Site Group Summary:		1058836	42	0	271(±73)	7(±8)	60(±3)	0.00003

a. m^3 and mℓ at ambient conditions of ~580 mm Hg and ~15°C.

b. Minimum Detectable Limit = 2 pg/m^3

c. Reported uncertainties are counting uncertainties at 95% confidence level (±2 sample standard deviations)

d. Controlled Area Radioactivity Concentration Guide = 2.1×10^8 pg/m^3

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 ERDA "uranium special curie" by using the factor 3.3×10^{-11} μCi/pg.

TABLE XII

RADIOACTIVITY IN OFF-SITE AND SUPPLY WATERS

	Number of Samples	Type of Activity	Units	Min.	Max.	Ave.	Ave as % CG
Regional Surface Water							
	12	^{3}H	$10^{-6}\mu Ci/m\ell$	0.7(±0.6)	2.8(±0.8)	1.6(±0.7)	<0.1
	9	^{90}Sr	$10^{-9}\mu Ci/m\ell$	-1.8(±3.0)	16(±5.2)	3.9(±4.0)	1.3
	6	^{137}Cs	$10^{-9}\mu Ci/m\ell$	-1(±28)	12(±32)	6(±10)	<0.1
	18	^{238}Pu	$10^{-12}\mu Ci/m\ell$	-18(±24)	5(±20)	-8.2(±15.0)	<0.1
	17	^{239}Pu	$10^{-12}\mu Ci/m\ell$	-13(±-16)	30(±40)	-1.6(±11)	<0.1
	18	Gross-α	$10^{-9}\mu Ci/m\ell$	-1(±6)	9(±6)	2.9(±3.6)	<0.1
	18	Gross-β	$10^{-9}\mu Ci/m\ell$	3.0(±1.4)	28(±6)	9.2(±2.6)	3.1
	18	Total U	$\mu g/\ell$	-0.1(±4.0)	6.1(±1.2)	1.9(±2.2)	0.1
Perimeter Surface and Ground Water							
	12	^{3}H	$10^{-6}\mu Ci/m\ell$	0.8(±0.6)	2.6(±0.8)	1.6(±0.8)	<0.1
	8	^{90}Sr	$10^{-9}\mu Ci/m\ell$	-1.8(±3.5)	8.5(±4.9)	0.8(±4.2)	0.3
	6	^{137}Cs	$10^{-9}\mu Ci/m\ell$	-50(±60)	31(±22)	-1.3(±25)	<0.1
	18	^{238}Pu	$10^{-12}\mu Ci/m\ell$	-12(±-12)	10(±24)	-8.2(±9.8)	<0.1
	17	^{239}Pu	$10^{-12}\mu Ci/m\ell$	-7(±-13)	22(±28)	-12(±12)	<0.1
	18	Gross-α	$10^{-9}\mu Ci/m\ell$	-1.2(±1.4)	7(±4)	0.8(±1.8)	1.1
	18	Gross-β	$10^{-9}\mu Ci/m\ell$	-2.7(±1.0)	12(±2.8)	3.4(±1.5)	<0.1
	8	Total U	$\mu g/\ell$	-0.1(±4.0)	17(±2)	2.2(±2.0)	0.1
Los Alamos Water Supply							
	42	^{3}H	$10^{-6}\mu Ci/m\ell$	0.3(±0.6)	2.4(±0.8)	0.9(±0.7)	<0.1
	23	^{90}Sr	$10^{-9}\mu Ci/m\ell$	-1.7(±1.6)	5.8(±3.9)	-0.8(±2.4)	<0.1
	21	^{137}Cs	$10^{-9}\mu Ci/m\ell$	-6(±18)	20(±26)	5(±18)	<0.1
	1	^{241}Am	$10^{-12}\mu Ci/m\ell$	--	--	20(±200)	<0.1
	48	^{238}Pu	$10^{-12}\mu Ci/m\ell$	-23(±32)	20(±38)	-5.3(±9.2)	<0.1
	48	^{239}Pu	$10^{-12}\mu Ci/m\ell$	-13(±-14)	12(±14)	-2.9(±8.8)	<0.1
	62	Gross-α	$10^{-9}\mu Ci/m\ell$	-3(±6)	9(±4)	0.8(±2.0)	<0.1
	62	Gross-β	$10^{-9}\mu Ci/m\ell$	0.4(±1.8)	16(±4)	4.3(±1.6)	1.4
	48	Total U	$\mu g/\ell$	-0.1(<0.1)	5.6(±1.2)	1.0(±2.1)	<0.1

TABLE XIII

RADIOACTIVITY IN ON-SITE SURFACE AND GROUND WATER

(Average of a Number of Analyses)

Name and Coordinate		No. and Type	^{3}H $10^{-6}\mu Ci/m\ell$	^{90}Sr $10^{-9}\mu Ci/m\ell$	^{137}Cs $10^{-9}\mu Ci/m\ell$	^{241}Am $10^{-9}\mu Ci/m\ell$	^{238}Pu $10^{-9}\mu Ci/m\ell$	^{239}Pu $10^{-9}\mu Ci/m\ell$	Gross-α $10^{-9}\mu Ci/m\ell$	Gross-β $10^{-9}\mu Ci/m\ell$	Total U $\mu g/\ell$
Noneffluent Areas											
Test Well 3	N 80 E120	3-G	1.1(±0.7)	-0.3(±3.1)	21(±38)	--	0.01(±0.02)	-0.00(±0.02)	0.6(±1.2)	0.8(±1.4)	0.8(±2.0)
Canada del Buey	N 10 E150	2-S	2.1(±0.6)	--	--	--	-0.01(±0.02)	-0.01(±0.01)	2.0(±2.2)	4.9(±1.6)	0.7(±2.4)
Pajarito Canyon	S 60 E225	2-S	3.3(±0.8)	1.2(±2.4)	7(±14)	--	-0.01(±0.02)	-0.01(±0.03)	2.9(±3.6)	14.5(±1.9)	1.2(±1.2)
Water Canyon	S 90 E 85	2-S	1.6(±0.7)	1.4(±2.4)	8(±16)	--	-0.00(±0.00)	0.02(±0.03)	1.4(±1.7)	5.1(±1.8)	0.3(±2.6)
Test Well DT-5A	S110 E 90	3-G	1.3(±0.6)	1.0(±3.6)	11(±18)	--	-0.00(±0.02)	-0.00(±0.01)	0.4(±1.4)	2.4(±1.4)	0.7(±2.0)
Test Well 8	N 40 E150	3-G	2.1(±0.7)	9.4(±3.3)	2(±24)	--	0.00(±0.02)	-0.01(±0.01)	0.8(±1.4)	2.3(±1.4)	0.9(±1.0)
Acid-Pueblo Canyon (Former Release Area)											
Acid Weir	N130 E 60	3-S	2.6(±0.7)	60(±6.6)	8(±14)	0.12(±0.12)	-0.00(±0.02)	0.74(±0.07)	1.2(±3.6)	115(±24)	0.1(±0.1)
Pueblo 1	N130 E 75	3-S	1.8(±0.7	0.5(±3.0)	5(±14)	0.02(±0.14)	0.01(±0.02)	0.01(±0.02)	1.2(±2.4)	13(±3.2)	-0.1(±0.1)
Pueblo 2	N115 E160	3-S	1.4(±0.7)	2.5(±4.4)	0(±16)	0.30(±1.2)	-0.01(±0.01)	0.03(±0.03)	1.4(±3.2)	21(±4.6)	0.3(±1.2)
Obs. Hole PO-3B	N110 E245	3-G	7.6(±0.9)	3.9(±4.1)	9(±14)	0.70(±0.34)	0.06(±0.03)	0.35(±0.07)	7.8(±6.0)	21(±4.8)	0.7(±0.3)
Hamilton Bend Spr.	N110 E250	3-G	2.1(±0.7)	-0.4(±3.1)	-6(±14)	0.30(±0.40)	0.01(±0.02)	0.01(±0.02)	1.1(±3.2)	12(±3.0)	0.3(±0.4)
Pueblo 3	N 85 E315	3-S	1.4(±0.7)	-1.9(±3.1)	13(±12)	0.12(±0.14)	-0.01(±0.01)	0.01(±0.02)	0.7(±3.2)	17(±3.6)	0.1(±0.1)
Sandia Canyon											
SCS-1	N 80 E 40	3-S	3.7(±0.7)	--	12(±24)	-0.28(±0.32)	0.01(±0.02)	-0.00(±0.02)	0.9(±2.0)	17(±3.8)	0.9(±1.8)
SCS-2	N 55 E155	3-S	5.1(±0.8)	--	20(±28)	-2.3(±1.4)	-0.00(±0.02)	-0.01(±0.01)	1.1(±2.2)	16(±3.6)	1.0(±2.0)
SCS near SR 4	N 35 E220	2-G	2.9(±0.6)	--	--	--	0.00(±0.01)	0.01(±0.02)	1.6(±3.2)	20(±4.0)	1.4(±2.4)
DP-Los Alamos Canyon											
DPS-1	N 95 E160	3-S	445(±16)	384(±28)	71(±26)	--	0.30(±0.08)	0.58(±0.14)	810(±160)	1260(±254)	14(±1.8)
DPS-4	N 80 E205	1-G	48(±1.8)	--	--	0.00(±0.12)	0.01(±0.02)	0.12(±0.04)	6.0(±4.0)	530(±100)	-0.1(±4.0)
Obs. Hole LAO-C	N 85 E 70	2-G	2(±0.6)	--	--	--	0.00(±0.00)	0.00(±0.01)	3.8(±3.4)	9.8(±2.6)	1.3(±2.6)
Obs. Hole LAO-1	N 85 E115	3-G	20(±1.2)	56(±7)	16(±16)	--	0.01(±0.02)	0.01(±0.02)	1.2(±4.0)	167(±34)	1.3(±1.8)
Obs. Hole LAO-2	N 80 E205	3-G	27(±1.4)	32(±7)	10(±16)	--	0.15(±0.04)	0.09(±0.03)	5.5(±3.0)	223(±40)	1.5(±1.8)
Obs. Hole LAO-3	N 80 E215	3-G	12(±1.1)	22(±4)	--	--	0.01(±0.04)	-0.00(±0.03)	4.6(±7.0)	80(±16)	1.8(±1.8)
Obs. Hole LAO-4.5	N 65 E270	3-G	11(±1.0)	-1.2(±3.4)	--	0.24(±0.16)	0.01(±0.02)	0.02(±0.02)	1.5(±2.2)	13(±3.0)	1.2(±1.8)
Mortandad Canyon											
Gaging Station 1	N 50 E 90	3-S	190(±11)	5.2(±3.1)	32(±16)	--	12(±0.72)	1.92(±0.20)	26(±12)	186(±37)	1.6(±1.8)
Obs. Hole MCO-3	N 45 E 95	3-G	211(±8.2)	62(±8.2)	9(±46)	7.4(±1.4)	5.8(±0.39)	0.57(±0.06)	76(±32)	320(±66)	3.2(±1.8)
Obs. Hole MCO-4	N 35 E135	3-G	2000(±112)	84(±7.8)	23(±18)	1.3(±0.4)	20(±2.0)	3.8(±0.50)	17(±7.6)	1120(±240)	13(±1.9)
Obs. Hole MCO-5	N 40 E150	3-G	1034(±40)	2.5(±2.9)	9(±20)	-1.2(±1.2)	0.55(±0.06)	0.09(±0.04)	11(±9.4)	41(±8.0)	4.6(±2.0)
Obs. Hole MCO-6	N 35 E160	2-G	1760(±60)	--	--	10(±60)	0.34(±0.07)	0.04(±0.02)	20(±10)	40(±8.0)	5.1(±1.3)
Obs. Hole MCO-7	N 30 E170	3-G	266(±12)	5.1(±9.0)	12(±16)	0.04(±0.16)	0.41(±0.09)	0.03(±0.03)	14(±8.0)	28(±6.0)	3.6(±2.2)
Obs. Hole MCO-7.5	N 30 E180	3-G	205(±7.0)	-0.3(±2.3)	3(±16)	0.08(±0.08)	0.23(±0.06)	0.05(±0.02)	46(±30)	32(±6.6)	6.6(±2.2)
Obs. Hole MCO-8	N 30 E185	1-G	25(±2.0)	19(±4.6)	8(±16)	--	0.15(±0.06)	0.04(±0.03)	8(±4.0)	18(±2.0)	3.2(±1.0)

NOTE:

S = Surface water; G = Ground Water - ^{137}Cs and ^{3}H one or two analyses; ^{241}Am and ^{90}Sr one analysis.

TABLE XIV

RADIOACTIVITY IN SOIL AND SEDIMENTS

		Number of Sample	Type of Activity	Units	Min.	Max.	Ave.
Regional and Perimeter							
	Soils	9	^{3}H	$10^{-6}\mu Ci/m\ell$	1.4(±0.6)	6.4(±0.8)	3.3(±0.6)
		9	^{90}Sr	pCi/g	0.90(±2.00)	13.9(±6.40)	4.62(±2.70)
		6	^{137}Cs	pCi/g	0.11(±0.03)	1.75(±0.12)	0.62(±0.06)
		20	^{238}Pu	pCi/g	0.000(±0.001)	0.004(±0.003)	0.000(±0.002)
		20	^{239}Pu	pCi/g	0.002(±0.002)	0.033(±0.008)	0.015(±0.004)
		20	Gross-α	pCi/g	1.5(±1.6	18(±8.0)	5.2(±2.6)
		20	Gross-β	pCi/g	3.3(±1.0)	11.6(±2.4)	5.7(±1.3)
		9	Total U	μg/g	1.1(±0.6)	3.9(±0.8)	1.9(±0.8)
	Sediments						
		9	^{3}H	$10^{-6}\mu Ci/m\ell$	0.2(±0.6)	4.1(±0.8)	14(±0.7)
		8	^{90}Sr	pCi/g	-0.09(±0.18)	5.90(±2.60)	2.04(±2.30)
		10	^{137}Cs	pCi/g	0.06(±0.02)	0.23(±0.04)	0.15(±0.04)
		21	^{238}Pu	pCi/g	-0.005(< 0.007)	0.003(±0.002)	0.001(±0.001)
		21	^{239}Pu	pCi/g	0.000(±0.000)	2.06(±1.00)	0.122(±0.008)
		21	Gross-α	pCi/g	0.5(±0.8)	10(±4.0)	3.2(±1.6)
		21	Gross-β	pCi/g	1.1(±0.6)	6.1(±1.4)	2.9(±0.8)
		10	Total U	μg/g	0.3(±0.6)	2.7(±1.0)	1.3(±0.8)
On-Site							
	Soils						
		3	^{3}H	$10^{-6}\mu Ci/m\ell$	3.5(±0.6)	11(±1.0)	7.9(±0.8)
		3	^{90}Sr	pCi/g	0.74(±1.40)	10.5(±5.0)	4.80(±7.50)
		7	^{238}Pu	pCi/g	0.001(±0.002)	0.005(±0.005)	0.003(±0.004)
		7	^{239}Pu	pCi/g	0.007(±0.003)	0.193(±0.022)	0.144(±0.018)
		8	Gross-α	pCi/g	2.0(±1.0)	10(±4.0)	4.7(±2.0)
		8	Gross-β	pCi/g	1.5(±0.6)	8.5(±1.8)	4.8(±1.2)
		3	Total U	μg/g	2.7(±1.0)	5.3(±0.8)	3.6(±0.9)
	Sediments						
		7	^{3}H	$10^{-6}\mu Ci/m\ell$	2.3(±0.6)	17(±3.4)	7.1(±1.5)
		7	^{90}Sr	pCi/g	0.36(±2.10)	8.50(±2.80)	7.90(±4.00)
		9	^{137}Cs	pCi/g	0.17(±0.01)	1.53(±0.10)	0.55(±0.50)
		13	^{238}Pu	pCi/g	0.000(±0.001)	0.115(±0.016)	0.014(±0.003)
		13	^{239}Pu	pCi/g	0.001(±0.003)	0.720(±0.060)	1.06(±0.01)
		13	Gross-α	pCi/g	0.9(±0.6)	10(±4.0)	4.4(±2.2)
		13	Gross-β	pCi/g	0.5(±0.6)	28(±6.0)	8.9(±2.1)
		7	Total U	μg/g	0.3(±0.6)	30(±4.0)	6.4 (±1.2)

TABLE XV

CHEMICAL QUALITY OF REGIONAL SURFACE WATER

Analyses	Number of Analyses	Concentrations (mg/ℓ)		
		Min	Max	Ave
Bicarbonate	9	105	160	119(±19)
Calcium	9	34	51	39(±5.5)
Carbonate	9	0	0	0
Chloride	9	5	58	16(±18)
Fluoride	9	0.1	1.4	0.4(±0.4)
Magnesium	9	3	14	8.7(±3.2)
Nitrate	9	<0.4	0.8	0.4(±0.3)
Sodium	9	13	96	32(±25)
TDS	9	222	664	337(±130)
Hardness	9	113	153	136(±16)
pH	9	7.6	8.3	7.9(±0.4)
Conductance (mS/m)	9	2.5	85.5	39.5(±18.8)

NOTE: Value in parentheses is standard deviation of the distribution of a number of analyses.

TABLE XVI

CHEMICAL QUALITY OF PERIMETER SURFACE AND GROUND WATERS

Sampling Locations		No. & Type of Sample	Average Chemical Concentrations (mg/ℓ)										pH	Conductance mS/m
			Ca^{2+}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	F^{-}	NO_3^{-}	TDS	Hard		
Los Alamos Reservoir	N105 W 75	2-S	16	3	5	0	50	3	0.2	<0.4	98	52	7.7	11.0
Guaje Canyon	N215 E315	2-S	8	3	7	0	46	2	0.2	0.4	127	34	7.5	9.8
Basalt Spring	N 65 E395	2-G	30	4	12	0	82	17	0.4	10	191	94	7.8	26.1
La Mesita Spring	18 km E of L.A.	2-G	32	2	26	0	114	10	0.2	1.6	186	90	7.9	29.6
Test Well 1A	N 70 E300	2-G	20	8	57	0	114	33	0.6	24	326	81	7.8	49.8
Frijoles Canyon	S280 E190	2-S	10	4	9	0	48	2	0.2	<0.4	141	40	7.7	11.9

TABLE XVII

CHEMICAL QUALITY OF THE LOS ALAMOS WATER SUPPLY

Analyses	No. of Analyses	Concentrations (mg/ℓ) Min.	Max.	Ave.
Arsenic	40	0.002	0.051[a]	0.010(±12)
Bicarbonate	41	50	255	98(±47)
Calcium	41	5	27	14(±5.7)
Carbonate	41	0	0	0(±0)
Chloride	41	<1	15	5.0(±4.2)
Fluoride	41	0.2	2.0	0.5(±0.6)
Magnesium	41	1	12	3.0(±2.7)
Mercury	21	0.00005	0.0002	0.00009(±0.00003)
Nitrate	41	0.4	1.7	1.2(±0.6)
Selenium	40	<0.001	<0.001	<0.001(±0.001)
Silica	39	30	81	55(±18)
Sodium	41	11	104	26(±21)
TDS	41	46	434	190(±77)
Hardness	41	26	110	48(±24)
pH	41	7.4	8.4	8.0(±0.2)
Conductance (mS/m)	41	9.0	60	20.4(±10.1)

[a]Well G-2, Arsenic 0.050 to 0.051 mg/ℓ; at distribution after dilution 0.007 to 0.013 mg/ℓ.

NOTE: Value in parentheses is deviation of the distribution of a number of analyses.

TABLE XVIII

CHEMICAL QUALITY OF ON-SITE SURFACE AND GROUND WATERS

Source Sampled Name & Location		No. & Type of Sample[a]	Average Chemical Concentrations (mg/ℓ) Ca^{2+}	Mg^{2+}	Na^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	F^{-}	NO_3^{-}	TDS	Hard	pH	Conductance mS/m
Noneffluent Areas														
Test Well 3	N 80 E120	2-G	24	6	14	0	104	5	0.3	1.3	240	86	7.8	21.0
Canada del Buey	N 10 E150	1-S	14	8	16	0	36	12	0.6	<0.4	350	44	7.1	18.5
Pajarito Canyon	S 60 E225	2-S	25	8	15	0	66	24	0.2	<0.4	240	95	7.6	59.5
Water Canyon	S 90 E 85	1-S	10	5	21	0	70	10	0.2	1.3	192	38	7.9	14.0
Test Well DT-5A	S110 E 90	2-G	14	2	12	0	67	12	0.2	0.8	154	45	7.6	13.0
Test Well 8	N 40 E150	2-G	14	3	12	0	71	8	0.1	0.8	186	46	7.9	13.5
Acid-Pueblo Canyon (Former Release Area)														
Acid Weir	N130 E 60	2-S	17	2	54	0	96	42	0.6	4.8	214	54	7.6	43.0
Pueblo 1	N130 E 75	2-S	18	4	67	0	132	44	0.6	32.0	369	58	7.4	51.0
Pueblo 2	N115 E160	2-S	12	5	64	0	85	30	0.6	59.0	300	50	8.0	51.5
Obs. Hole PO-3B	N110 E245	2-G	31	12	26	0	86	35	0.5	22.0	293	123	7.7	41.0
Hamilton Bend Spr.	N110 E250	2-G	24	8	60	0	108	15	0.8	27.0	304	66	7.4	43.2
Pueblo 3	N 85 E315	2-S	14	4	72	0	94	36	0.6	44.0	319	50	7.5	52.0
Sandia Canyon														
SCS-1	N 80 E 40	2-S	26	10	78	0	104	47	1.0	33.0	535	107	7.5	69.5
SCS-2	N 55 E155	2-S	36	11	131	0	163	49	1.2	12.0	621	136	8.1	94.8
DP-Los Alamos Canyon														
DPS-1	N 95 E160	2-S	29	7	432	12	554	90	4.2	840.0	1927	102	8.7	272.7
Obs. Hole LAO-C	N 85 E 70	1-S	20	7	45	0	78	68	0.3	0.4	248	80	8.0	39.3
Obs. Hole LAO-1	N 85 E115	2-G	16	7	535	0	102	46	0.7	7.9	314	68	7.6	39.5
Obs. Hole LAO-2	N 80 E205	2-G	38	4	88	0	190	16	4.0	58.0	458	64	7.5	62.5
Obs. Hole LAO-3	N 80 E215	2-G	20	6	70	0	172	18	3.1	9.2	377	76	7.7	53.3
Obs. Hole LAO-4.5	N 65 E270	2-G	18	6	36	0	88	30	0.4	1.8	263	70	7.9	30.5
Mortandad Canyon														
Gaging Station 1	N 50 E 90	2-S	10	3	56	0	112	9	1.3	29.0	277	38	7.6	34.4
Obs. Hole MCO-3	N 45 E 95	2-G	17	6	159	0	248	21	1.2	125.0	660	65	8.0	88.8
Obs. Hole MCO-4	N 35 E135	2-G	32	2	196	0	330	30	1.3	189.0	884	90	7.8	121.2
Obs. Hole MCO-5	N 40 E150	2-G	24	6	185	0	239	26	0.8	187.0	721	88	7.7	106.5
Obs. Hole MCO-6	N 35 E160	1-G	24	6	173	0	310	24	1.4	175.0	712	85	8.1	106.3
Obs. Hole MCO-7	N 30 E170	2-G	16	4	121	0	186	16	0.7	98.0	548	57	8.1	72.8
Obs. Hole MCO-7.5	N 30 E180	2-G	20	8	158	0	237	20	0.4	167.0	698	87	8.2	99.2
Obs. Hole MCO-8	N 30 E185	1-G	28	7	102	0	184	19	0.4	140.0	590	104	8.0	80.0

[a]Number of samples analyzed and source, G = Ground Water, S = Surface water

TABLE XIX

CHEMICAL QUALITY OF WATER IN THE VICINITY OF FENTON HILL

	Surface Water	Water Supply	Springs (Jemez Fault)	Springs (Recent Volcanics)	Misc. Wells	Fenton Hill (Pond Fluids)
Number of Stations[a]	9	4	2	4	1	3
Number of Samples	28	16	6	6	3	6
Analyses (mg/ℓ)						
Bicarbonate	79(±59)	92(±32)	667(±267)	72(±26)	367(±15)	386(±488)
Calcium	35(±20)	21(±9.6)	128(±102)	11(±4)	28(±2)	24(±18)
Carbonate	0(±0)	0(±0)	0(±0)	0(±0)	0(±0)	56(±136)
Chloride	26(±30)	6(±3)	883(±570)	4(±1)	7(±3)	272(±168)
Fluoride	0.7(±0.4)	0.4(±0.2)	2.4(±0.6)	0.8(±0.2)	1.0(±0.2)	11(±19)
Magnesium	6(±3)	5(±3)	20(±8)	4(±2)	8(±1)	6(±4)
Nitrates (N)	0.4(±.2)	0.1(±0.5)	0.1(±0.17)	0.2(±0.1)	0.6(±0.5)	1.6(±3.6)
Silica	40(±11)	61(±17)	44(±3)	58(±12)	63(±6)	120(±52)
Sodium	27(±22)	19(±13)	593(±370)	20(±13)	114(±15)	358(±307)
Sulfate	53(±98)	11(±18)	30(±6)	4(±6)	2(±1)	160(±88)
TDS	255(±154)	167(±58)	2276(±1215)	164(±64)	444(±71)	1346(±973)
Hardness	114(±59)	75(±28)	401(±278)	44(±15)	104(±2)	85(±63)
pH	7.2(±1.4)	7.8(±0.3)	7.6(±0.4)	7.5(±0.5)	7.9(±0.0)	8.3(±0.7)
Conductance (mS/m)	38.7(±25.3)	20.7(±6.6)	390(±198)	16.8(±5.8)	70.7(±4.7)	215.7(±102.4)

[a]Sampling Locations keyed on Fig. 10 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, TA-57.

Springs (Jemez Fault) - TF-1, -5.

Springs (Recent Volcanics) - RV-2, -4, and -5, 31.

Miscellaneous Well - 27

Fenton Hill (Pond Fluids) Three ponds, TA-57.

NOTE: Value in parentheses is standard deviation of the distribution of a number of analyses.

TABLE XX

SOIL EROSION STAKE DATA FOR MORTANDAD CANYON
BETWEEN JUNE 12, 1975, AND NOVEMBER 4, 1976
(512 days)

Distance from effluent outfall (km)	Average stream channel width (cm)	Cumulative depth change (cm)	Cumulative change in soil weight (kg)[a]
1.2-1.3	160	+6.6	+15,000
1.3-1.4	89	-4.4	- 5,800
1.4-1.5	105	+10	+15,000
1.5-1.6	86	-5.1	-6,400
1.6-1.7	155	-13	-30,000
1.7-1.8	355	-13	-65,000
1.8-1.9	197	-4.8	-14,000
1.9-2.0	198	+22	+64,000
2.0-2.1	311	+7.1	+32,000
2.1-2.2	100	+18	+26,000
2.2-2.3	83	+0.20	+240
2.3-2.4	62	-3.8	-3,500
2.4-2.5	132	-2	-3,900
2.5-2.7	180	+1.6	+8,500

[a]Estimated using volume of stream channel and a bulk density value of 1.47 g/cm^3.

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