LA-5184

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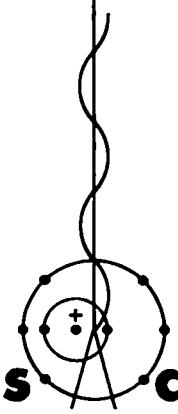
Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory

Calendar Year 1972



los alamos
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LOS ALAMOS, NEW MEXICO 87544

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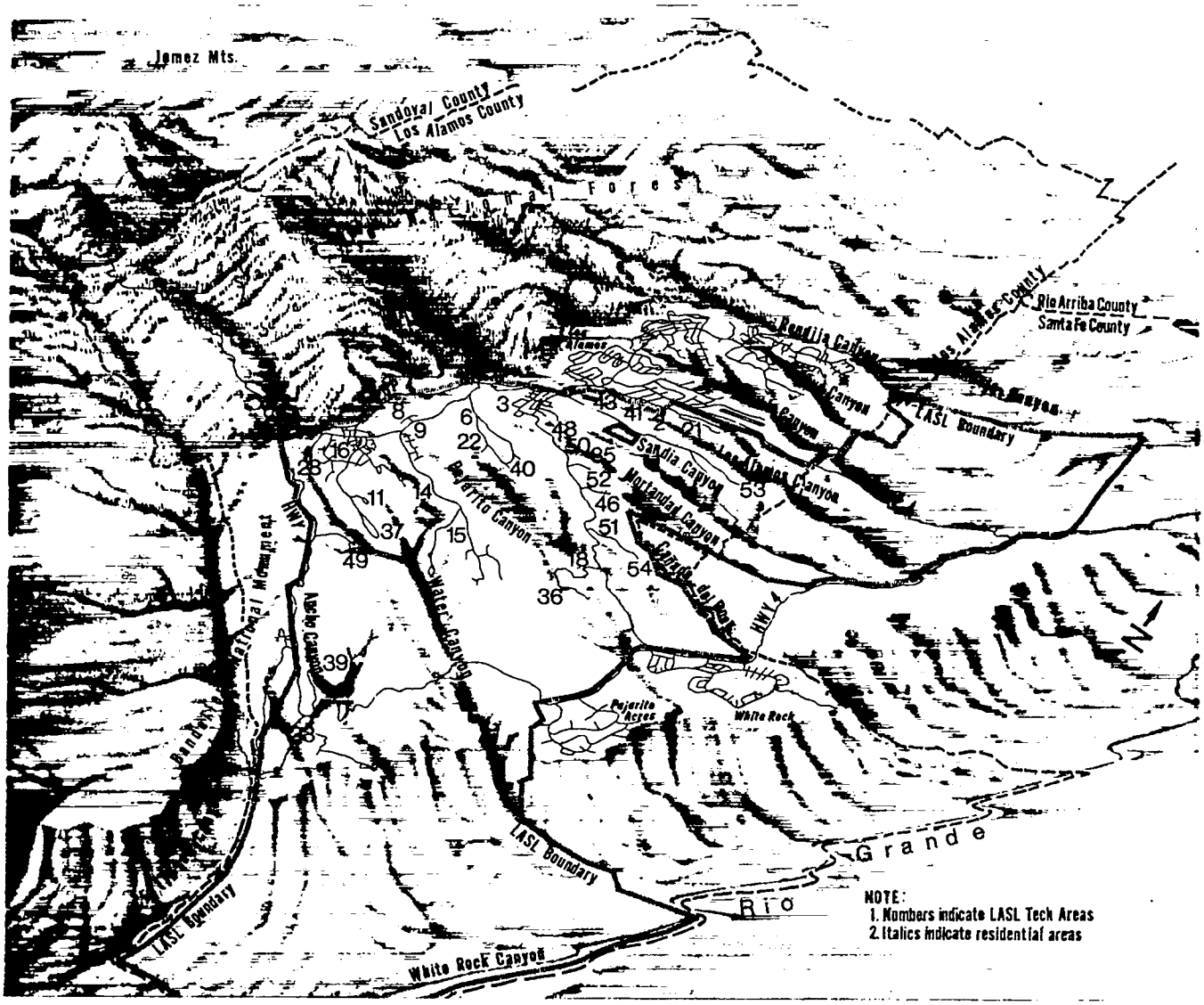

Topography of the Los Alamos, N. M., area.

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ENVIRONMENTAL MONITORING IN THE VICINITY OF THE LOS ALAMOS SCIENTIFIC LABORATORY

Calendar Year 1972

ABSTRACT

The environmental monitoring program in effect at the Los Alamos Scientific Laboratory of the University of California for calendar year 1972 is described. Results are given of routine monitoring of radiation levels and levels of radioactive and nonradioactive contaminants in the Laboratory environs, including the atmosphere, the Los Alamos water supply, local surface and ground water, sediments, and soils. Concentrations and levels are compared with applicable guide values and with results obtained at other geographical locations and locally during other reporting periods. Descriptions are given of special programs aimed at describing the physical and biological processes involved in the transport of Laboratory-generated radionuclides in liquid waste disposal areas. There is also a description of an environmental survey of certain AEC-controlled land parcels, as well as geologic, seismic, and meteorological studies of the Los Alamos area. Technical notes discuss the use of the honeybee as a biological indicator of radiocontamination, a new gamma-ray pulse height analyzer system intended for field use, an automated meteorological data acquisition system, and the determination of salt in pine trees near Los Alamos roadways.

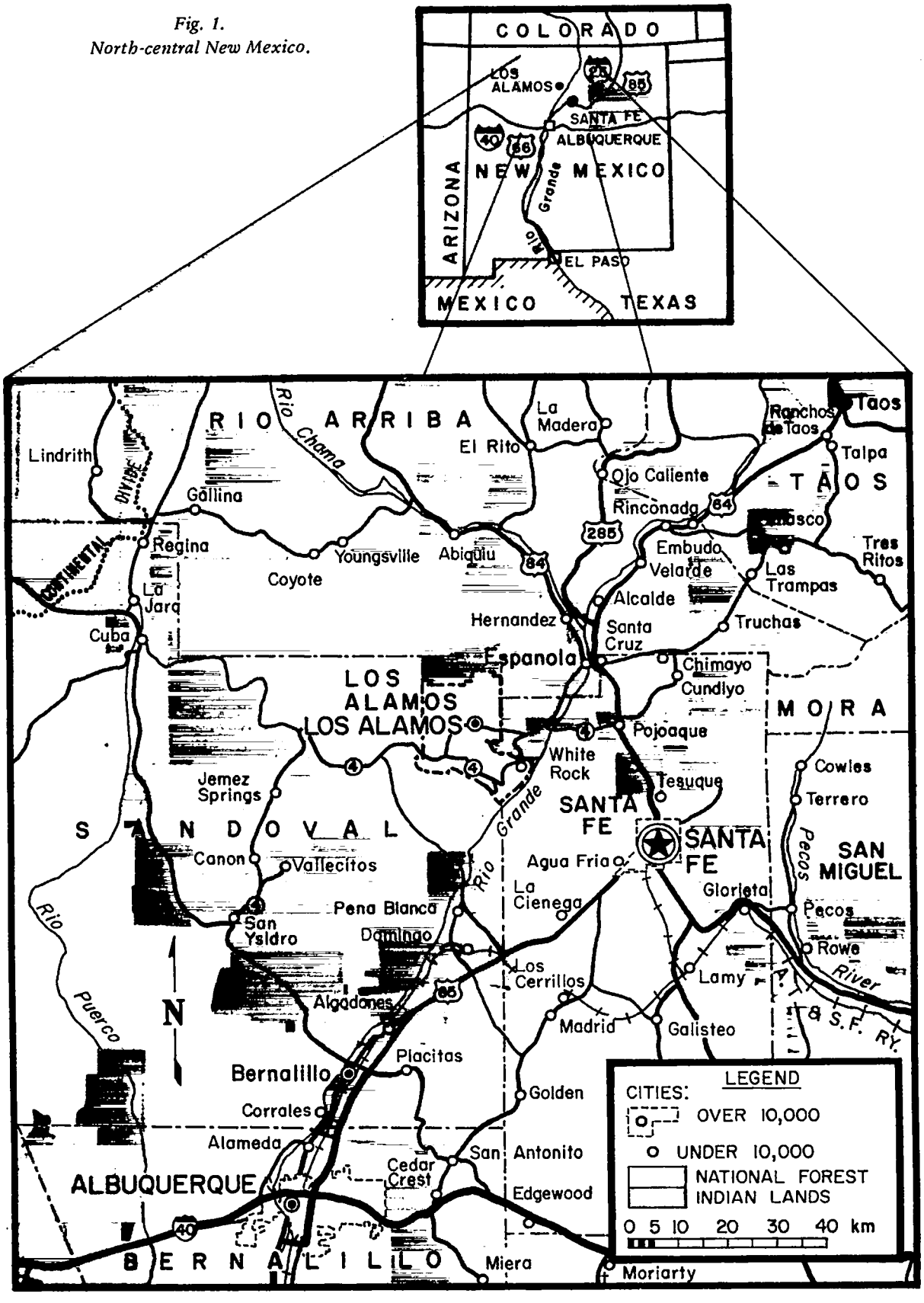
I. INTRODUCTION

This report describes the results of the environmental monitoring programs conducted by Group H-8 (Environmental and Field Programs) during the calendar year 1972 at the Los Alamos Scientific Laboratory (LASL). This facility is administered by the University of California for the U.S. Atomic Energy Commission (AEC) under Contract W-7405-ENG-36.

The Laboratory and the Los Alamos Community are located in north-central New Mexico (Fig. 1) on the Pajarito Plateau, situated west of the Rio Grande on the eastern slopes of the Jemez Mountains (Frontispiece). This location was originally chosen for the atomic weapons laboratory during World War II because of its relative isolation, and the area surrounding Los Alamos, including all of Los Alamos County and large portions of Sandoval, Rio Arriba, and Santa Fe Counties, remains largely undeveloped except for those areas occupied by the Laboratory facilities and associated communities. Large tracts of land in the Jemez Mountains to the north, west, and south of the Laboratory site are held by the U.S. Forest Service and U.S. National Park Service. This land is largely covered by fir and aspen forests that support the usual variety of western mountain wildlife. Agriculture is limited to home gardens and some grazing by beef cattle. In the river valleys to the east, agriculture is restricted to relatively small plots supported by irrigation. Primary crops are chili peppers, tree fruits, and alfalfa. Milk is not produced in commercial quantities in the immediate vicinity of Los Alamos. More detailed descriptions of the geology, climatology, and economy of the area are given in the appendixes of the January-June 1971 environmental monitoring report.[1]

The Laboratory site covers about 28,000 acres in and adjacent to Los Alamos County. The principal mission of the Laboratory is, as it has been since its inception in 1943, the design and development of weapons for the nation's nuclear arsenal. This program is supported by extensive research programs in nuclear physics,

Fig. 1.
North-central New Mexico.



hydrodynamics, conventional explosives, chemistry, metallurgy, radiochemistry, and biology. In addition to the weapons program, considerable effort is directed toward the peaceful uses of nuclear energy including medium-energy physics (Clinton P. Anderson Meson Physics Facility), space nuclear propulsion, controlled thermonuclear fusion (Sherwood Program), laser and geothermal research, nuclear safeguards, biomedical research, and space physics. These activities are located in 29 active Technical Areas (TA) widely spread over the LASL site. The locations of these areas are shown in Fig. 2, the basic map to which all others in this report are keyed. Appendix B in Ref. 1 contains descriptions of the programs being undertaken at each of the Technical Areas.

The routine monitoring programs (air, external radiation, water, sediments, soils) conducted by Group H-8 in 1972 remain substantially unchanged from those reported for July-December 1971.[2] New sampling equipment capable of somewhat higher air flow rates is gradually being phased into the atmospheric monitoring program, and several new analyses are being conducted on certain water samples. Major expansion lies in an area referred to as "Special Studies," which encompasses both one-time and continuing studies of particularly important or interesting aspects of the environmental results of LASL operations. A radioecology program funded by the AEC Division of Biomedical and Environmental Research (DBER) was initiated in FY73 and utilizes LASL liquid waste disposal areas as natural laboratories for the study of ecological mechanisms that determine the ultimate fate of radioactive contaminants released to the environment. Results of the 1971 study of fauna in liquid effluent discharge areas mentioned in the July-December 1971 report are included in this report. Also included are results of an environmental survey of approximately 5500 acres being released by the AEC as unneeded real estate. This survey was made in cooperation with other Health Division groups and the LASL Engineering Department. Investigations conducted by outside consultants on the Los Alamos geologic characteristics and on tornado frequency and intensity are also summarized in this section. The Technical Notes section, initiated in the July-December 1971 report, continues with four articles of general relevance to the field of environmental surveillance.

Chemical and radiochemical techniques remain essentially as summarized in Appendix F of Ref. 1. Two major refinements recently introduced in the plutonium analyses are the use of a complete dissolution technique to improve and stabilize recovery and the substitution of ^{242}Pu for ^{236}Pu as a tracer to improve the quality of the alpha spectral measurements. An additional staff member and a technician have been hired by the Group to handle the increased workload.

Because averaging is a convenient (albeit occasionally misleading) method of concisely representing large amounts of data, many of the results of the LASL environmental surveillance efforts are given as averages of two or more numbers. A fundamental problem arises, however, when one attempts to derive an average for a data set containing values lower than some minimum detection limit (MDL). We have arbitrarily chosen the convention of using the value of the MDL in forming an average when a given measurement falls below the MDL. This is done without regard to the merit of the choice, knowing at least that a conservative, or worst case, estimate is obtained. Furthermore, a set of data containing the value of the MDL for one or more entries yields, at best, a truncated distribution. Thus, no standard deviation or confidence limit is calculated for such a data set.

II. EFFLUENTS ASSOCIATED WITH LABORATORY ACTIVITIES

Because the Laboratory is a large, broadly diversified organization employing several thousand people engaged in fundamental and applied research in the natural sciences, with emphasis on nuclear materials, the facilities include hundreds of potential sources of effluents and wastes. Processes known to have the potential for significant releases are confined to only a few locations and are rigorously controlled and monitored. Numerous laboratory hoods, drains, and waste receptacles exist, however, where procedural controls are relied upon for proper utilization. Information concerning airborne and liquid effluents and solid waste disposal is summarized in this section.

A. Airborne Effluents

The major sources of airborne contaminants at LASL and the amounts of effluent from each source are summarized in Table I. The "Other" category in Table I accounts for certain conventional explosive tests conducted in accordance with strict safety precautions by M (Dynamic Testing) and WX (Weapons Engineering) Divisions at firing sites remote from other occupied Laboratory sites and from residential areas. In addition to the radioactive materials listed in the table, the following quantities of nonradioactive materials were also used.

High explosive	8500 kg
Beryllium	26 kg
Lead	130 kg
Mercury	100 kg

Most of the debris from these tests is deposited in the immediate vicinity of the prepared firing site, and little of the hazardous material is widely dispersed into the

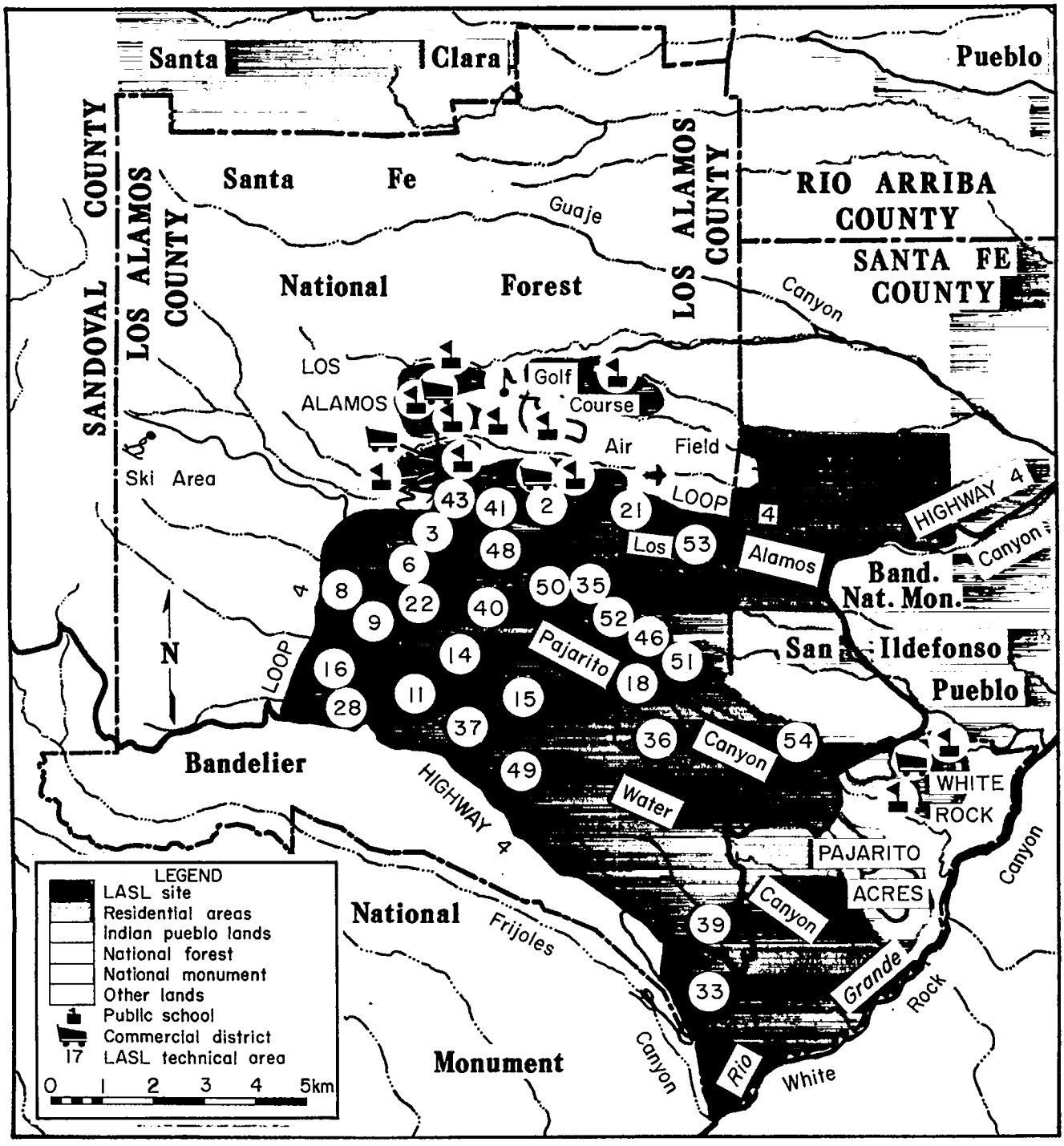


Fig. 2.
Los Alamos County and LASL Technical Areas.

TABLE I

SUMMARY OF MAJOR AIRBORNE EFFLUENTS

Technical Area	Unidentified Alpha[a] (μCi)	Unidentified Beta[b] (μCi)	^{238}Pu ^{239}Pu (μCi)	^{234}U ^{235}U (μCi)	^{238}D[c] (μCi)	^{131}I (μCi)	^{88}Rb ^{138}Cs (mCi)	^{133}Xe ^{135}Xe (Ci)	^{41}Ar (Ci)	^{3}H (Ci)
2	-	-	-	-	-	-	47	720	640	-
3	680	6700	7900	100	260	7400	-	-	-	48
9	-	-	-	-	-	-	-	-	-	70
21	<1	<1	2800	1200	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-	-	2900
35	-	-	18	-	-	-	-	-	-	2500
41	10	-	-	-	-	-	-	-	-	110
43	5	-	-	-	-	-	-	-	-	-
46	-	-	-	120	-	-	-	-	-	-
48	-	2700	110	8	-	-	-	-	-	-
50	-	140	27	-	-	-	-	-	-	-
Other	-	-	-	-	870[d]	-	-	-	-	1800

[a]Primarily ^{232}Th, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, and ^{241}Am.

[b]Primarily mixed fission products.

[c]Depleted uranium of varying compositions.

[d]Kilograms, correspond to approximately 0.32 Ci (Ref. 2). This amount not completely dispersed into the environment (see text).

environment. A program to measure these dispersal fractions is currently under review, but execution will depend on funding and availability of manpower.

B. Liquid Effluents

Most of the liquid effluent streams of the Laboratory are comprised of cooling water and sanitary sewage. The effluents are released into canyons that contain intermittent streams that recharge water in the alluvium. This water is depleted by evaporation and transpiration and does not reach the Rio Grande. None of the effluent streams recharges aquifers from which municipal, industrial, or irrigation waters are drawn.

The primary contaminated, or potentially contaminated, liquid effluents from LASL operations are collected by an elaborate system of acid sewers and are treated at the industrial liquid waste treatment plant at TA-21 or the central industrial liquid waste treatment plant at TA-50. Effluents from the TA-21 treatment plant are released into DP Canyon, a tributary to Los Alamos Canyon, and the effluents from TA-50 are released into Effluent Canyon, a tributary to Mortandad Canyon. Only waters with concentrations lower than those listed in Table II (i.e., in uncontrolled areas), AEC Manual Chapter 0524, are released, but evaporative and adsorptive processes tend to concentrate the contamination in the channel alluvium. The amounts of radionuclides released from these two sources are shown in Table II.

The discharge of treated water from cooling towers resulted in the release of some chemicals into Sandia Canyon from the Zia Company Power Plant in TA-3 and into Los Alamos Canyon from TA-2. Release of hexavalent chromate (Cr^{+6}) is of prime interest, and in April 1972 the chromate treatment at the power plant was changed to a polynodic phosphonate treatment (sanctioned by the U.S. Environmental Protection Agency (EPA) and New Mexico Environmental Improvement Agency (EIA)), and corrective action is under way by LASL for the TA-2 facility.

C. Solid Waste

Although the disposal of solid radioactive wastes is not directly pertinent to an environmental monitoring

TABLE II

SUMMARY OF MAJOR LIQUID EFFLUENTS

	TA-21	TA-50
Volume discharged, 10^6 liters	8.8	57
Radioactivity, mCi		
Gross alpha	0.93	14
Plutonium-238	0.16	7.7
Plutonium-239	0.10	1.0
Gross beta	16	380
Strontium-89	0.65	3.5
Strontium-90	1.0	5.5
Tritium	3600	6000

program, wastes improperly controlled in disposal could have a most significant environmental impact. A short summary of LASL disposal activities is included here for this reason, and to present a more complete picture of the Laboratory's waste treatment effort, as well as to convey an idea of the actual amounts of solid waste generated.

Solid wastes, consisting mostly of contaminated sludges from the industrial liquid waste treatment plants and potentially contaminated refuse from routine Laboratory operations, are buried in pits at TA-54 on the Mesita del Buey and in shafts at TA-21. These locations were chosen in consultation with the U.S. Geological Survey to assure long-time localization of radioactivity. Large pits are nominally 30 m wide by 180 m long by 9 m deep, and smaller ones are 15 by 90 by 9 m. The shafts at TA-21 are nominally 2.5 m in diameter and 5 to 20 m deep. They are asphalt-lined and do not penetrate to the water table, which is over 350 m below the surface at TA-21.

The quantities of materials placed in storage during 1972 are given in Table III. The total quantity of radioactive material in several of the categories is not estimated because individual consignments are below the limits of detection for any device to measure gross activity, and to multiply the large waste volumes by any assumed value for the possible concentration of radioactivity would be false and misleading. Laboratory accountability procedures, developed over many years, give assurance that only small quantities of radioactive materials are contained in Laboratory trash and scrap.

III. METEOROLOGICAL MONITORING PROGRAM

LASL's interest in meteorological variations stems from a wide variety of practical problems including design and maintenance of physical facilities and processing plants, transport and dispersal of trace atmospheric contaminants, planning for certain research projects, and evaluations required for safety analyses. The parameters chosen for presentation in this report reflect the more frequently requested variables and relate to these practical applications. To satisfy requests for more specialized climatological data, an expanding data base is maintained and some portions of it are being transferred to punched cards and magnetic tape to facilitate retrieval.

Tables IV and V present means and extremes of temperature and precipitation for the entire period of record and for 1972, respectively. A comparison of the two tables shows that the first half of the year was warm and extremely dry. However, above-average precipitation from late August through November made up much of the rainfall deficit, and below-average autumn temperatures brought the annual average temperature to 48.1°F, only 0.1°F above the long-term average. Early snow in northern New Mexico came as a result of above-average moisture and cold temperatures, and local winter resorts were open by mid-November.

The wind rose for 1972, Fig. 3, shows the predominant wind direction to be west-northwest for light, moderate, and strong winds. A breakdown of the winds by time of day shows the westerly flow to be most dominant at night, giving way to southeasterly mode after sunrise, and a weak maximum occurrence of south winds in the afternoon. In terms of diffusive mixing of airborne material, however, the west-northwest flow was dominant during the night when turbulence levels and mixing rates are lowest.

In addition to the mean transport property of the winds, the turbulent energy of the airflow is an important factor in the dispersal of contaminants. A useful measure of the turbulence is the variation, or total range, of the fluctuating wind direction, $\Delta\theta$, in a specified period of time, and another is the gust factor, the ratio of the maximum wind speed to the average wind speed over a given time interval. A 1-yr period ending May 7, 1972, was selected, and the average 10-min variations in wind direction and gust factor were estimated for each hour from the chart rolls produced by the wind sensors at the Administration Building (TA-3). These two sets of hourly estimates were analyzed according to direction variation and gust factor as functions of average wind direction and average wind speed. The totality of each set of measurements was grouped according to direction, speed, and direction variation or gust factor, and the occurrence frequency (percentage) was calculated for each category. The results for direction variation are shown in Fig. 4a, and for gust factor in Fig. 4b. Direction and speed are given by orientation of the radial bars, direction variation or gust factor is given by the widths, and occurrence frequency by the lengths, of the various segments of each bar.

The patterns demonstrate that most of the direction variation values are between 60 and 120°. The very low variation values are associated with weak northwest flow–a nocturnal drainage wind. The highest lateral turbulence values (variation $\geqslant$120°) are associated with two general wind conditions, moderate northwest winds and light easterly winds. Both are symptomatic of thermal convection associated with afternoon static instability.

There are some applications, such as drainage design and runoff estimates, that require the frequency distribution of precipitation rates. Figure 5 presents the average number of hours per year that the rainfall rate was exceeded as a function of the rate in inches per hour.

TABLE III

SUMMARY OF SOLID WASTE DISPOSAL

Nature of Waste	Container or Stabilizer	Estimated Volume (liters)	Estimated Activity (Ci)
Contaminated sludge from TA-50 liquid waste treatment plant	Metal drums	260,000	9
Contaminated sludge from TA-21 liquid waste treatment plant[a]	Cement paste	530,000	300
Hot cell and glovebox wastes containing U, Pu, and fission products	Metal containers, wooden crates	16,000	79
Activated metal	Metal containers	340	15
Tritium and tritium contaminated wastes	Metal containers, concrete	8,700	2000
Uranium and uranium contaminated wastes	Metal containers, wooden crates	39,000	Not estimated
Plutonium and plutonium contaminated wastes	Metal containers, wooden crates	83,000	Not estimated
Contaminated animal tissue	Cardboard boxes	450	Not estimated
Low level sources	Metal containers	350	<1
Laboratory trash	Cardboard boxes, plastic bags	1,800,000	Not estimated
Metal scrap	Not packaged	1,600,000	Not estimated
Classified	Metal drums	16,000	Not estimated

[a]Placed in shafts at TA-21.

IV. ATMOSPHERIC MONITORING PROGRAM

The air monitoring program is designed to provide for general surveillance of the levels of gross alpha and beta radioactivity in air, the concentrations of those specific radionuclides directly associated with Laboratory operations, and the concentrations of certain nonradioactive materials.

To provide a system for locating and describing the stations, a polar grid has been centered on the site of the Laboratory meteorology tower. The station designation is related to this grid by two numbers: the first denotes the azimuth in degrees clockwise from north, and the second denotes the distance from the center in kilometers. Thus, a station numbered 90-22.7 would be 22.7 km directly east of the meteorology tower. The locations of all air sampling stations are shown in Fig. 6. For clarity, station locations are indicated on the map by serial numbers, and the correspondence between these numbers and the radial grid designations is given in Table VI. The common name associated with each station is also given.

A. Radioactive Materials

1. Daily Air Sampling. An air sampler drawing air through a 78-mm Microsorban filter having an efficiency

TABLE IV

CLIMATOLOGICAL SUMMARY

Latitude 35° 32′ North
Longitude 106° 19′ West
Elevation 7410 ft

Los Alamos, New Mexico

Means and Extremes for Period of Record: 1910 - 1972

	Temperature (°F)								Precipitation Totals (in.)										Mean Number of Days		
	Means				Extremes				Rain					Snow or Frozen Precipitation							
Month	Daily Maximum	Daily Minimum	Monthly	Highest	Year	Lowest	Year	Mean	Daily Maximum	Year	Monthly Maximum	Year	Mean	Daily Maximum	Year	Monthly Maximum	Year	Precipitation 0.10 in. or more	Maximum temperature 80° or above	Minimum temperature 15° or below
Jan	39.1	17.8	28.4	64	1963	-18	1963	0.83	2.45	1916	6.75	1916	9.6	15.0	1913	39.3	1949	2	0	8
Feb	42.9	21.5	32.2	66	1936	-14	1951	0.69	1.05	1915	2.44	1948	8.2	13.0	1915	23.8	1948	2	0	6
Mar	49.1	25.9	37.5	71	1971	-3	1948	0.95	2.25	1916	3.27	1919	9.9	18.0	1916	35.5	1958	3	0	3
Apr	58.5	33.9	46.2	80	1950	5	1925	0.99	1.45	1969	4.64	1916	4.1	12.0	1958	33.6	1958	3	0	0
May	67.8	42.8	55.3	89	1935	24	1938	1.28	1.80	1929	4.47	1929	0.8	9	1917	17.0	1917	3	1	0
Jun	77.6	51.6	64.6	93	1954	28	1919	1.37	2.51	1913	5.57	1913	0	0		0		3	14	0
Jul	80.4	55.2	67.8	95	1935	37	1924	3.39	2.78	1968	7.98	1919	0	0		0		8	19	0
Aug	77.8	54.1	66.0	92	1937	40	1947	3.76	2.26	1951	11.18	1952	0	0		0		8	12	0
Sep	72.3	48.0	60.2	94	1934	23	1936	1.97	2.21	1929	5.79	1941	0.2	6.0	1913	6.0	1914	5	5	0
Oct	62.0	37.8	49.9	82	1930	16	1970	1.61	3.48	1919	6.77	1957	1.5	9.0	1972	9.0	•••	3	0	0
Nov	48.9	26.5	37.8	69	1937	-4	1957	0.71	1.46	1931	3.30	1957	5.1	14.0	1931	34.5	1957	2	0	2
Dec	40.8	19.8	30.2	62	1933	-10	1924	0.92	1.35	1965	2.85	1965	10.8	18.0	1915	41.3	1967	3	0	6
Year	59.8	36.2	48.0	95	1935	-18	1963	18.36	3.48	1919	11.18	1952	50.2	18.0	••	41.3	1967	45	51	25

••1915 and 1916, •••1959, 1972

Precipitation records are from November 1910.

Temperature records are from October 1918.

TABLE V

CLIMATOLOGICAL SUMMARY FOR 1972

	Temperatures (°F)					Precipitation Totals (in.)						
	Means			Extremes		Rain		Snow or Frozen Precipitation		Number of Days		
Month	Daily Max	Daily Min	Monthly	High	Low	Total	Daily Max	Total	Daily Max	Precip ≥0.1 in.	Max Temp ≥80°F	Min Temp ≤15°F
Jan	41.7	17.7	29.7	55	-9	0.24	0.13	3.6	2.0	2	0	10
Feb	48.1	23.9	36.0	63	5	0.04	0.02	0.6	0.4	0	0	6
Mar	58.5	33.2	45.8	68	19	0.09	0.07	0.5	0.5	0	0	0
Apr	62.2	36.6	49.4	74	22	0.02	0.02	T	T	0	0	0
May	67.7	43.1	55.4	76	34	0.96	0.62	T	T	2	0	0
Jun	76.7	52.6	64.7	84	46	1.66	0.84	-	-	5	10	0
Jul	79.2	55.5	67.4	90	49	2.60	0.91	-	-	7	16	0
Aug	74.5	52.9	63.9	83	48	2.76	0.61	-	-	5	5	0
Sep	68.8	47.7	58.2	78	36	3.77	0.87	-	-	7	0	0
Oct	56.8	39.2	48.0	74	19	2.90	0.62	9.0	9.0	8	0	0
Nov	39.6	21.3	30.5	51	11	1.15	0.50	14.5	9.0	3	0	8
Dec	38.4	18.4	28.4	50	4	0.80	0.71	2.0	1.0	1	0	10
Year	59.4	36.8	48.1	90	-9	16.99	0.91	30.2	9.0	40	31	34

of about 99.8% for 0.3-μm dioctylphthalate (DOP) particles (a standard test aerosol for determining filter efficiency) and an 80-mm Welsh charcoal respirator cartridge at a rate of approximately 200 liters/min is maintained on the roof of Building LD-1, TA-50. The filter and the canister are changed daily. The particulate material on the filter is measured on the day of collection for gross alpha and beta emissions on an alpha-beta gas flow proportional counter and again 7 to 10 days after collection to measure long-lived activity. The initial measurements of the gross alpha and beta emissions provide an early detection of high activities relative to natural background levels. The 7-day measurements, after the decay of radon and thoron daughters, are used as the official records of activity. The alpha activity is consistently at or near the MDL of the system, approximately 10^{-15} μCi/ml, and is not reported here. The sensitivity of the system is adequate to give early warning of a significant accidental release, should one occur. The long-lived gross beta activity measurements for 1972 are shown in Fig. 7. They are comparable with national samples collected by the U.S. EPA,[3] and follow cyclic trends established by past years' data.[1,2] This trend is due to seasonal changes in atmospheric mixing that bring fission products from past atmospheric weapons testing to the ground. The pronounced peaks in mid-January and late March are the results of Chinese atmospheric nuclear tests of January 7 and March 18.

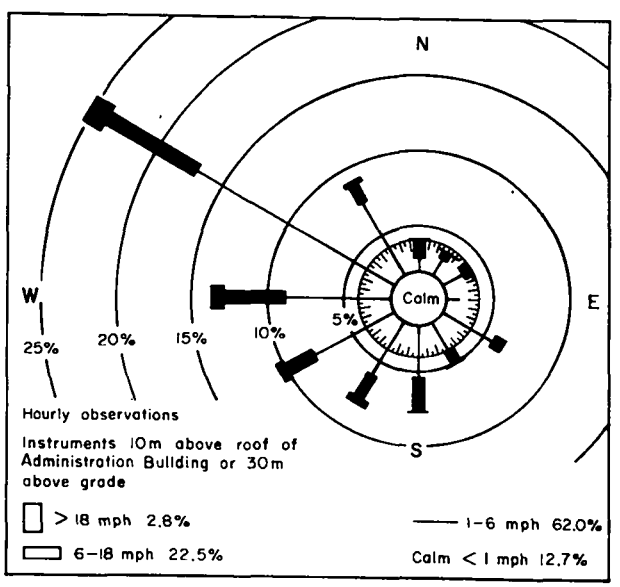


Fig. 3.
Wind rose for 1972.

The activity collected by the charcoal canister is measured by gamma-ray spectrometry for ^{131}I. None of the charcoal cartridges contained ^{131}I at a level of more than 10^{-14} μCi/ml, the estimated MDL of the system.

2. **Daily Deposition Sampling.** Deposition of gross beta activity on a 0.4-m^2 precipitation collector located at TA-50 is measured each workday. The collector is rinsed with water combined with whatever precipitation may have been collected. This water is filtered through a Whatman 41 filter and the gross beta activity of the filter and filtrate are measured separately to determine the

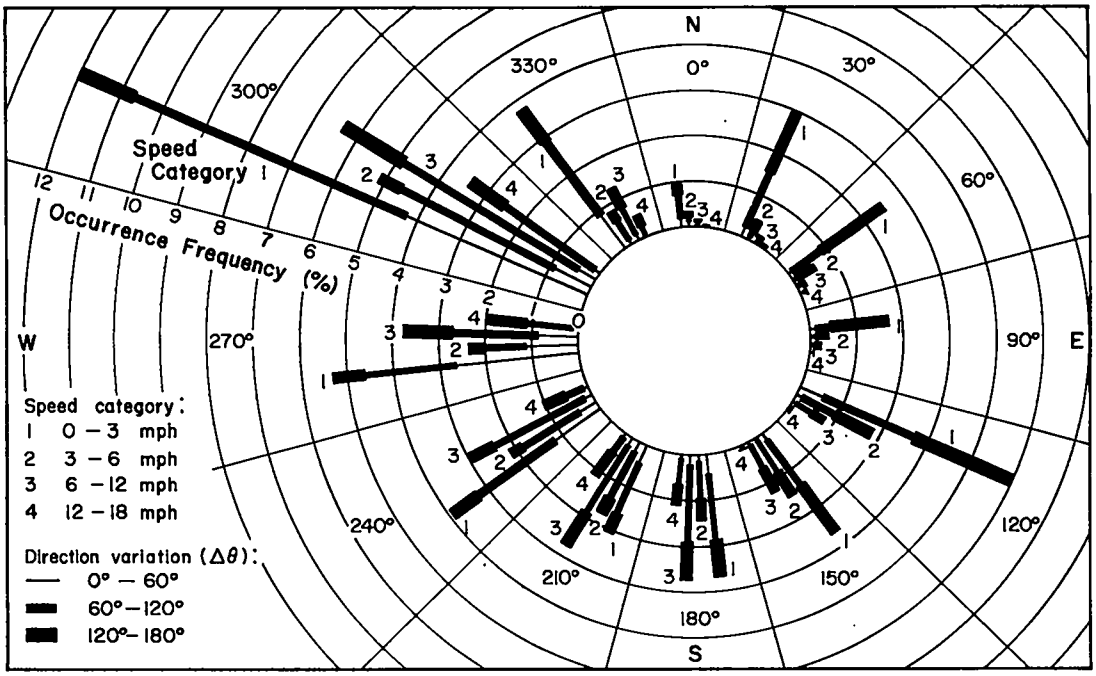


Fig. 4a.
Turbulence rose for direction variation.

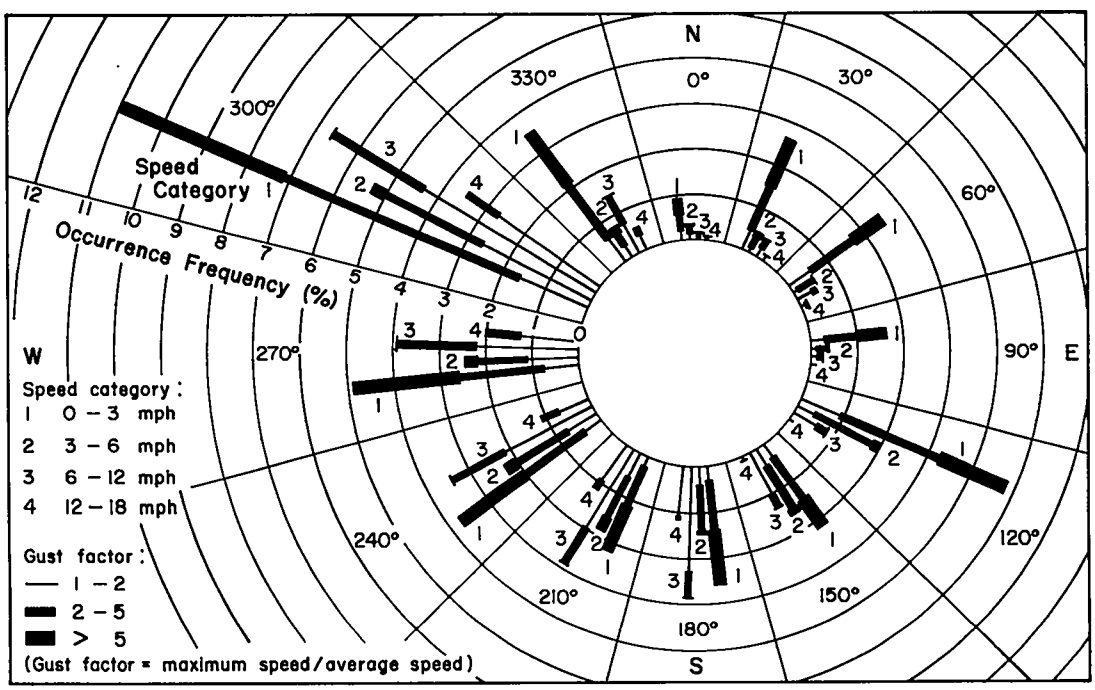


Fig. 4b.
Turbulence rose for gust factor.

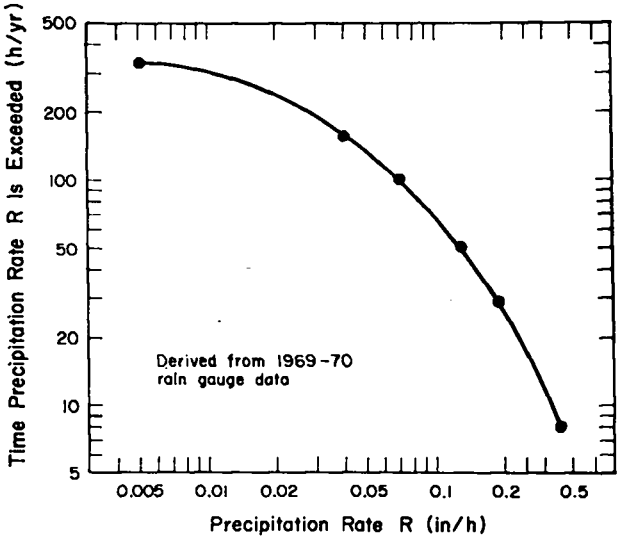


Fig. 5.
Frequency distribution of precipitation rates.

"soluble" component of the deposition activity. This separation is conducted to provide data for other studies, however, and for surveillance purposes, the two results are added and reported as total gross beta activity. A measurement is made immediately to augment the daily air sample data and again after 7 days to represent the long-lived gross beta activity free of radon and thoron products. The gross beta measurements and the natural precipitation recorded during the year are presented in Fig. 8; they also follow observed cyclic trends,[1,2] and the effects of precipitation scavenging are apparent.

3. Weekly Air Sampling. The main air monitoring program consists of a weekly sample collection from 35 continuous air sampling stations. An extensive revamping in 1971 resulted in a network that required no major changes during this reporting period, and virtually the entire array was operative during the entire period, giving 51 weekly samples for all but a few stations. Each station consists of a pump that pulls air through a Microsorban filter and a Welsh charcoal cartridge similar to those used to collect the daily sample. During the latter part of this reporting period, a program to replace some of the older and more troublesome pumps with new pumps of higher capacity and requiring less maintenance resulted in two different flow rates. The flow rate, as measured by rotameters, was 70 liters/min except for six new pumps whose rate was 200 liters/min.

On the first and tenth day after collection, each filter is measured simultaneously for gross alpha and beta activities by a gas flow proportional counter. The first-day count is for 30 min, and the tenth-day count is for 90 min.

Gross Activity. The gross alpha and gross beta activities are measured to maintain a historical record of these activities and for screening of the samples to detect unexpectedly high concentrations of radionuclides not covered by the more specific analyses. The results of the measurements of long-lived radionuclides are summarized in Table VI.

The gross alpha measurements have been corrected both for background of the counting chamber and for the approximately 0.1% of beta counts that feed into the alpha channel of the counter (cross-talk). Background, i.e., count of an unused filter (blank), normally runs 33 counts/90 min. A filter from the sampling array can thus be distinguished from the blank if it contains a total activity of more than 44 counts/90 min. Consideration of total flow through the filter yields an MDL of about 2×10^{-16} μCi/ml for the total collection (old pumps) and analysis procedure.

The average gross alpha measurements for the 35 stations were higher than those reported previously; however, the increase was not due to local sources, but to the 1972 Chinese tests. The maximum alpha activity observed at every station occurred during the detection of one or the other of the two Chinese tests. Because of the difficulty in determining when the effects of these tests had become negligible, all values were included in the averages given in the table. The magnitude of the influences of the two tests can be appreciated by observing the daily sample concentrations in Fig. 7. Figure 7 gives only the daily gross beta activity, but the weekly gross alpha activity followed the same pattern. No local releases of significant magnitude were observed. Spatial variations in gross alpha activity measured at all 35 stations can be described by a lognormal distribution (normal distribution of the logarithms of the numbers) and its associated random fluctuations (see Fig. 9). This lack of significant station effects, along with the small range in concentrations, leads one to conclude that the Laboratory has little influence on the level of this activity.

The gross beta averages, also given in Table VI, are higher than previously reported. Again, the maximums, and hence the inflated averages, were due to Chinese tests, and no local discharges were observed. The seasonal trend, reported previously[1,2] and shown in Fig. 7, was also observed with the weekly sample data. Results of measurements at all 35 stations are again lognormally distributed (see Fig. 9), reflecting the small influence of Laboratory activities on this level.

The gross beta measurements were corrected only for counter background because the cross-talk from the alpha channel is negligible. Background levels for the counter

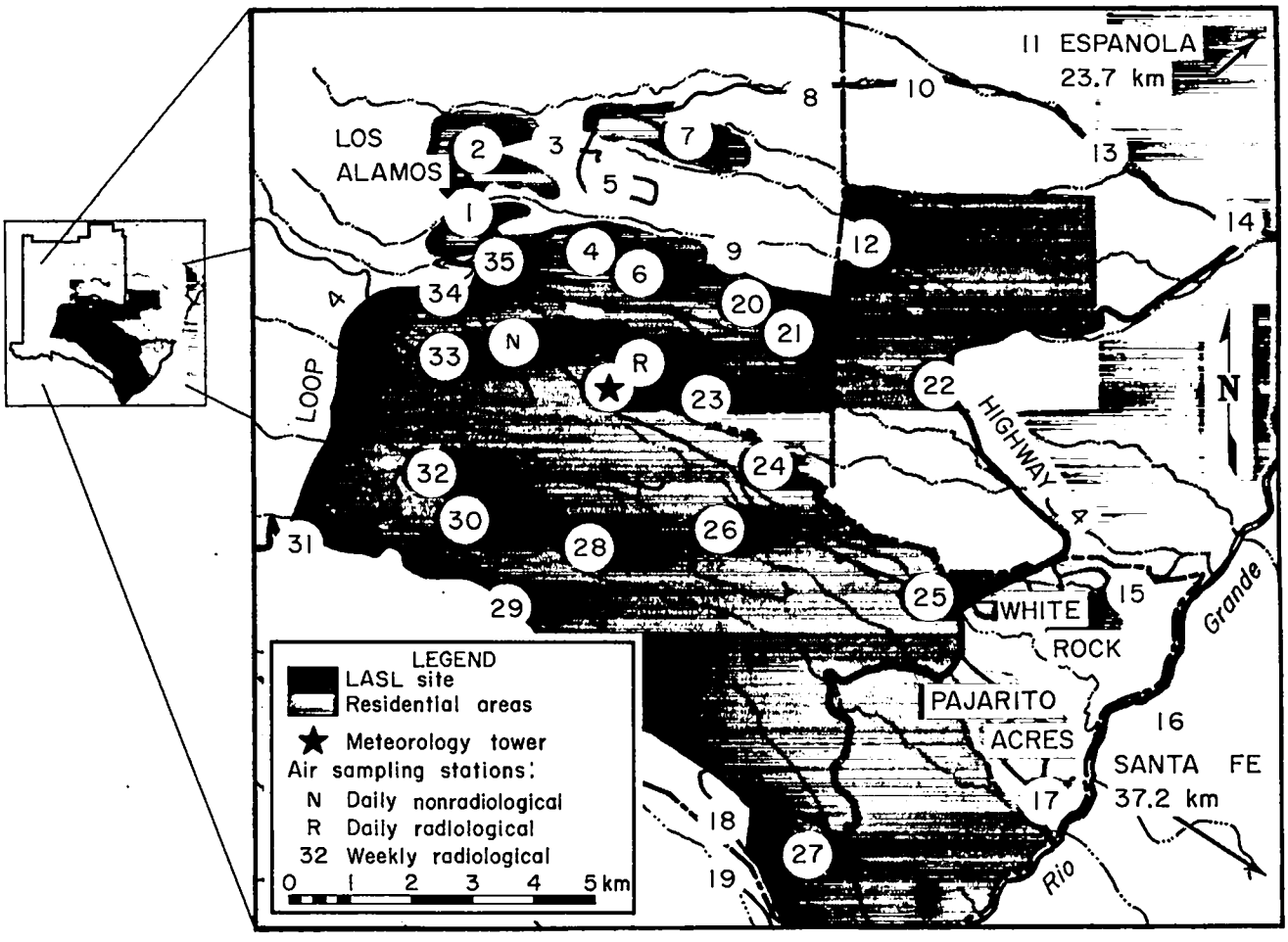


Fig. 6.
Locations of atmospheric monitoring stations.

(blank count of 680/90 min), together with sampling techniques, result in an estimate of 7 x 10^{-16} μCi/ml for the MDL of the gross beta activity.

The charcoal cartridges collected with the weekly particulate samples are analyzed for iodine on a gamma-ray spectrometer. Analysis of the cartridges indicated that ^{131}I could not have been present at concentrations above 10^{-14} μCi/ml, the estimated MDL of the system.

Plutonium and Americium. The weekly filters, after being measured for gross alpha and beta activities, are combined to represent 4-wk samples from each station and are analyzed radiochemically for ^{238,239}Pu. Composite 4-wk samples from six of the stations are also analyzed for ^{241}Am. The MDL is about 10^{-16} μCi/ml for each of the three isotopes. These concentrations are summarized in Table VII, and the ^{238}Pu concentrations are shown as isopleths in Fig. 10. At least one measurement at each station fell below the MDL.

The ^{238}Pu levels measured during this period followed established patterns. The highest concentrations occurred north and east of TA-21 and the CMR Building (TA-3) where releases of filtered process air containing traces of plutonium occurred (Table I). These results are generally consistent with the wind patterns shown in Fig. 3.

The maximum ^{238}Pu on-site average concentration, 8 x 10^{-17} μCi/ml at station 304-2.6 (Fig. 6 No. 34, TA-3) was 0.004% of the 2 x 10^{-12}-μCi/ml concentration guide value for the soluble form of the isotope, as listed in AEC Manual Chapter 0524, for a controlled area. The maximum off-site average concentration, 4.1 x 10^{-17} μCi/ml at station 350-4.3 (Fig. 6 No. 3, Los Alamos Golf Course), was 0.06% of the 7 x 10^{-14}-μCi/ml value for uncontrolled areas. The maximum 1-month concentration occurred at this same station and was 0.5% of the uncontrolled area guide value. The highest average for the 35 stations occurred during the period in which the debris of the March 18 Chinese atmospheric nuclear test was detected.

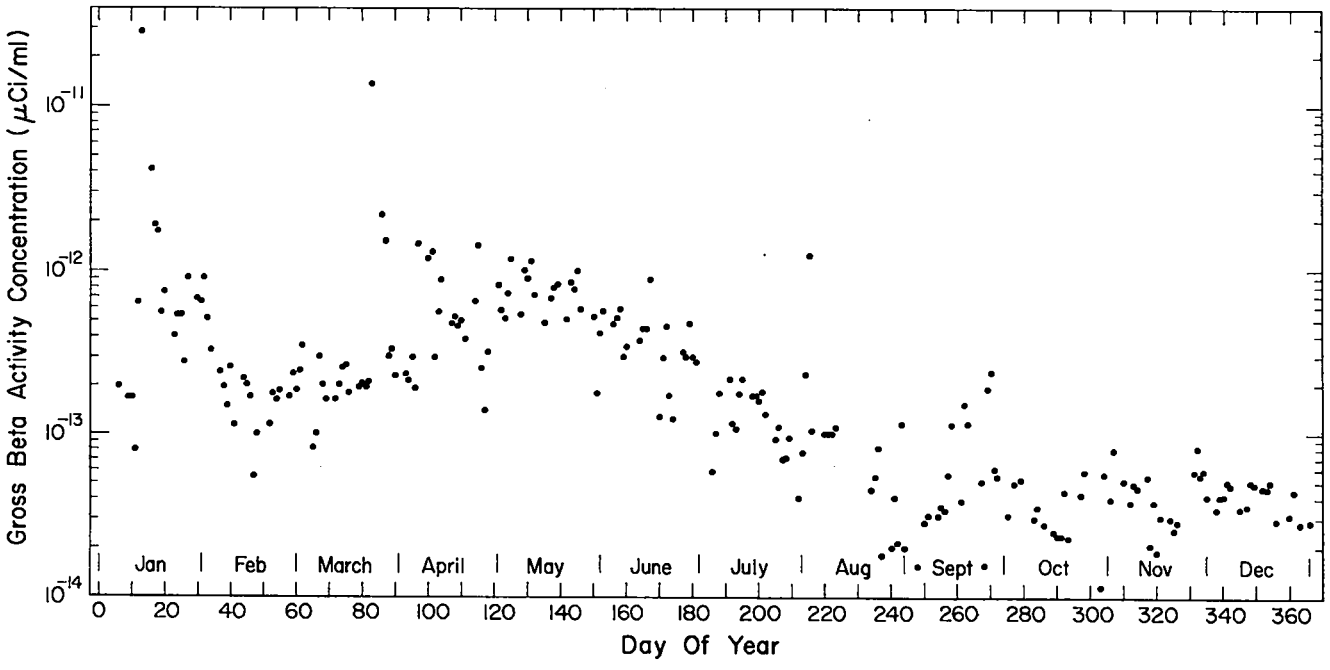


Fig. 7.
Daily air sample measurements of gross beta activity.

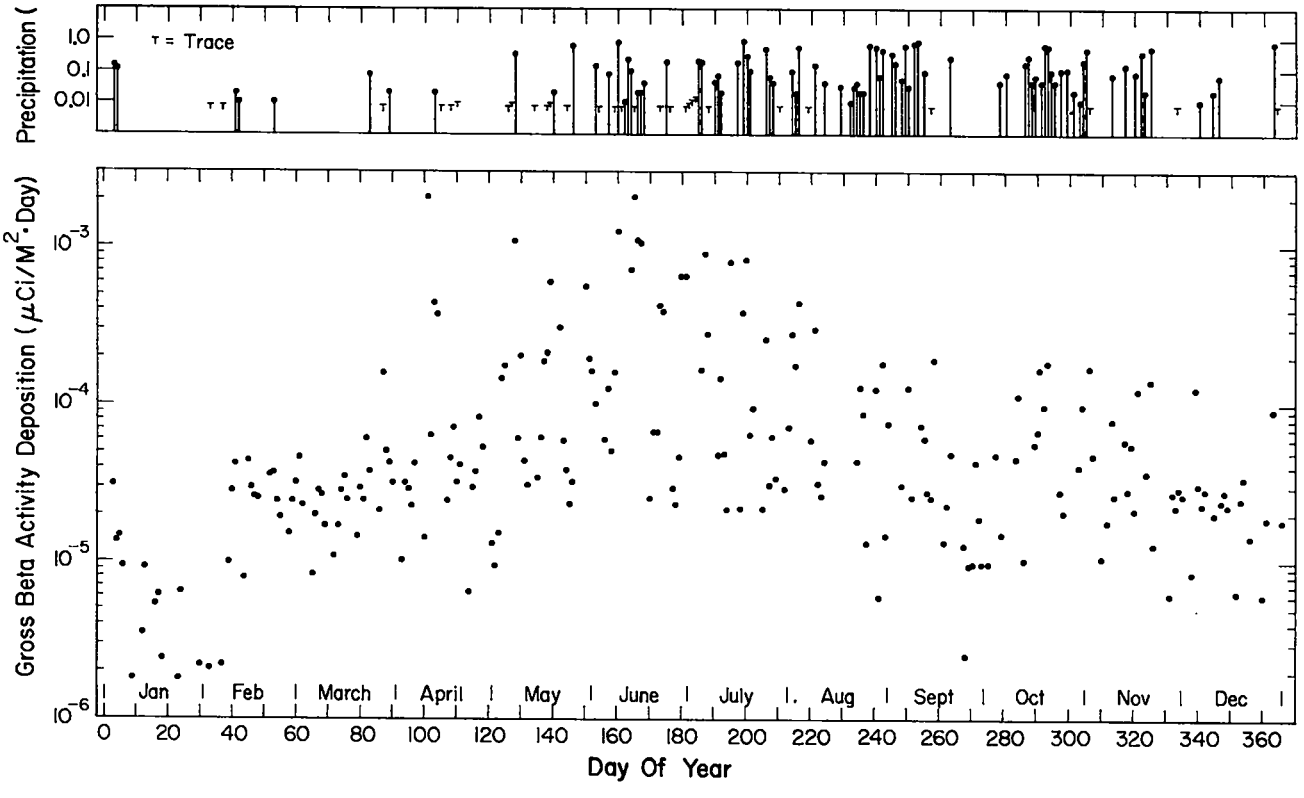


Fig. 8.
Daily deposition sample measurements of gross beta activity.

TABLE VI

GROSS ALPHA AND GROSS BETA ACTIVITY MEASUREMENTS OF WEEKLY AIR SAMPLES

Station		Gross Alpha Concentration		Gross Beta Concentration		
Map No.	Array Designation	Max	Av[a]	Max	Av[a]	Remarks
		(10^{-15} μCi/ml)		(10^{-13} μCi/ml)		
Off-Site Stations:						
1	330-3.8	4.2	1.6 ± 0.2	16.8	1.9 ± 0.8	Diamond Drive
2	335-4.9	3.6	1.6 ± 0.3	21.9	1.8 ± 0.9	Arkansas Avenue
3	350-4.3	4.6	1.5 ± 0.3	15.5	2.0 ± 1.0	Golf Course
4	351-2.4	4.7	1.6 ± 0.3	24.4	1.9 ± 1.0	Fuller Lodge
5	3-3.7	4.5	1.7 ± 0.3	18.3	1.9 ± 0.9	Cumbres Jr. High
6	15-2.0	6.0	1.4 ± 0.3	22.0	2.0 ± 1.0	Acorn Street
7	18-4.9	3.6	1.6 ± 0.2	19.9	1.9 ± 0.9	Barranca School
8	36-7.0	4.8	2.0 ± 0.3	26.0	1.8 ± 1.0	Guaje Booster 2
9	42-3.1	6.4	1.9 ± 0.4	19.5	2.0 ± 1.0	Airport
10	50-8.6	4.6	1.9 ± 0.3	31.9	2.0 ± 1.3	Guaje Booster 1
11	55-23.7	6.2	2.1 ± 0.5[b]	25.7	1.9 ± 1.1[b]	Española
12	64-5.8	7.6	1.6 ± 0.4	16.5	1.9 ± 0.8	Bayo STP
13	64-10.2	4.7	1.7 ± 0.3	29.4	1.9 ± 1.2	Well G-1
14	78-12.4	3.7	1.7 ± 0.2	15.9	2.2 ± 1.0	Well LA-3
15	111-10.6	4.3	1.6 ± 0.3	16.4	1.8 ± 0.7	White Rock STP
16	122-37.2	7.2	2.0 ± 0.4[c]	19.2	1.8 ± 0.8[c]	Santa Fe
17	132-11.1	4.2	1.3 ± 0.3	19.0	1.9 ± 0.8	Pajarito Acres
18	164-8.5	4.5	1.4 ± 0.2	21.9	1.8 ± 0.9	Bandelier Lookout
19	164-9.4	4.4	1.5 ± 0.2	32.7	1.8 ± 0.8	Bandelier HQ
On-Site Stations:						
20	58-3.1	2.8	1.3 ± 0.2	14.1	1.7 ± 0.6	TA-21
21	73-3.0	7.5	2.2 ± 0.4	18.6	1.9 ± 0.9	TA-53
22	92-6.7	5.3	1.5 ± 0.3	17.6	1.8 ± 0.8	Well PM-1
23	99-2.0	9.5	1.6 ± 0.4[b]	18.7	2.0 ± 0.9[b]	Beta Site
24	122-3.7	4.0	1.5 ± 0.2	20.3	2.0 ± 1.0	Pajarito Booster 2
25	123-7.0	4.5	1.6 ± 0.3	17.7	1.8 ± 0.7	Pajarito Booster 1
26	141-3.3	3.5	1.1 ± 0.2	20.3	1.7 ± 0.9	TA-36
27	156-9.4	9.8	1.9 ± 0.6	32.7	2.1 ± 1.3	TA-33
28	189-2.8	3.5	1.3 ± 0.2	21.4	2.0 ± 1.0	TA-15
29	204-4.2	4.4	1.5 ± 0.3	23.2	1.9 ± 1.0	TA-49
30	224-3.5	3.7	1.2 ± 0.2	20.8	1.8 ± 0.8	TA-11
31	242-6.3	4.7	1.5 ± 0.3	22.7	1.9 ± 1.0	W. Jemez Road
32	245-3.3	3.4	1.1 ± 0.2	17.6	1.8 ± 0.8	TA-16
33	277-3.3	5.2	1.5 ± 0.3	21.5	2.0 ± 1.0	TA-6
34	304-2.6	4.0	1.5 ± 0.3	19.4	1.7 ± 0.8	TA-3
35	319-3.1	5.3	1.5 ± 0.3	21.4	1.8 ± 0.9	TA-43

[a]Average and 95% confidence limits for the average.

[b]One sample lost.

[c]Two samples lost.

The overall average annual concentration for the 35 stations of the LASL air sampling network was 2.4×10^{-17} μCi/ml, as compared to an average annual value of 3.8×10^{-18} μCi/ml for 10 reporting stations of the EPA Radiation Alert Network[4-7] across the U.S. during 1971.

The ^{239}Pu measurements, not easily represented pictorially, also relate to the plutonium emissions from the CMR Building and TA-21. The maximum on-site average concentration, 1.2×10^{-16} μCi/ml at station 277-3.3 (Fig. 6 No. 33, TA-6), was 0.006% of the AEC Manual Chapter 0524 guide limit of 2×10^{-12} for the soluble form of the isotope for controlled areas, and the maximum off-site average concentration, 7.3×10^{-17} μCi/ml at station 42-3.1 (Fig. 6 No. 9, Los Alamos Airport), was 0.1% of the 6×10^{-14}-μCi/ml guide limit for uncontrolled areas. The maximum off-site average for a given month, 3.6×10^{-16} μCi/ml, occurred at station 330-3.8 (Fig. 6

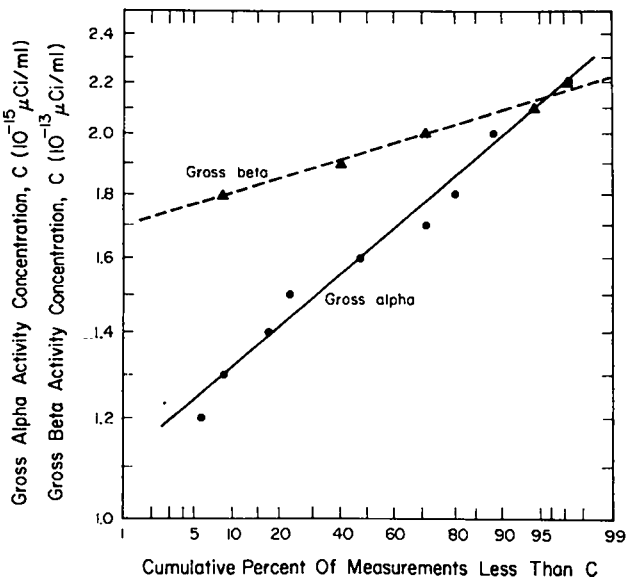


Fig. 9.
Logarithmic-probability plots of weekly gross activity measurements.

No. 1, Diamond Drive), and was only 0.6% of the uncontrolled area guide value. The overall average annual concentration for all 35 stations was 4.5 x 10^{-17} μCi/ml, compared to an average value of 5.0 x 10^{-17} μCi/ml for the 10 reporting stations of the EPA Radiation Alert Network.

The highest average ^{241}Am concentration of the six stations routinely measured, 4.4 x 10^{-17} μCi/ml, occurred at station 73-3.0 (Fig. 6 No. 21, TA-53), the station closest to TA-21, where ^{241}Am emissions may be expected in association with plutonium. This value was less than 0.001% of the AEC Manual Chapter 0524 concentration guide value of 6 x 10^{-12} μCi/ml for the soluble form of the isotope. The effort directed at measurement of this isotope will be studied in greater detail during 1973 in order to develop a more comprehensive program.

Uranium. An aliquot of each of the 4-wk composite samples was saved to form a 12-wk composite which was analyzed fluorometrically for uranium. The MDL of the system, which does not distinguish separate uranium isotopes, is about 0.5 x 10^{-10} μg/ml. Although depleted uranium is involved in LASL explosive tests, there does not appear to be a station effect with distance from the

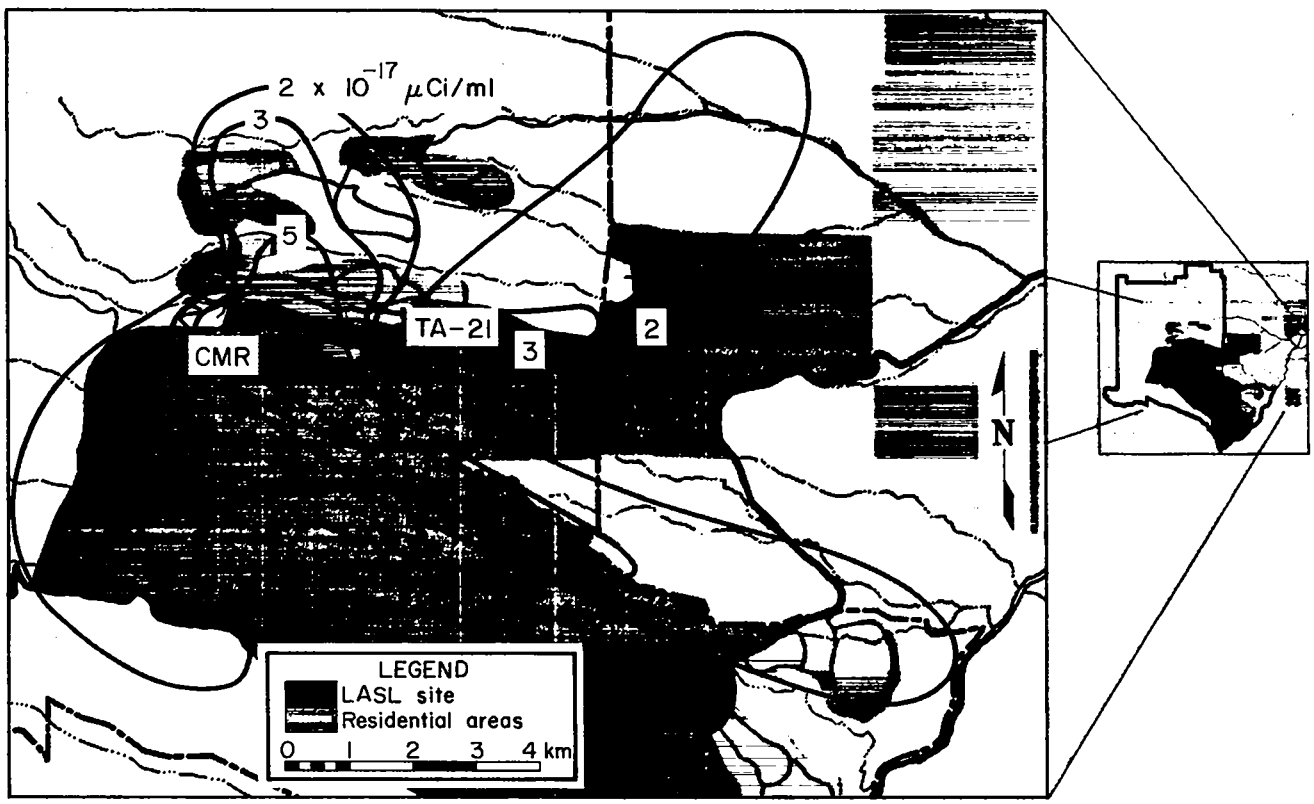


Fig. 10.
Plutonium-238 concentration isopleths.

TABLE VII

PLUTONIUM AND AMERICIUM CONCENTRATIONS IN AIR

Station		^{238}Pu Concentration		^{239}Pu Concentration		^{241}Am Concentration	
Map No.	Array Designation	Max (10^{-17} μCi/ml)	Av[a] (10^{-17} μCi/ml)	Max (10^{-17} μCi/ml)	Av[a] (10^{-17} μCi/ml)	Max (10^{-17} μCi/ml)	Av[a] (10^{-17} μCi/ml)
Off-Site Stations:							
1	330-3.8	3.4	1.7	36.3	6.9	-	-
2	335-4.9	19.4	3.2	16.0	4.7	-	-
3	350-4.3	35.0	4.1	11.7	4.0	-	-
4	351-2.4	11.7	3.1	10.4	4.3	-	-
5	3-3.7	7.0	2.4	19.1	5.0	-	-
6	15-2.0	3.3	1.4	10.8	3.5	-	-
7	18-4.9	3.7	1.5	14.8	4.6	-	-
8	36-7.0	7.3	1.9	8.7	3.6	-	-
9	42-3.1	20.9	2.8	26.5	7.3	-	-
10	50-8.6	6.8	2.5	19.7	4.7	-	-
11	55-23.7	1.9	1.4	10.8	3.8	-	-
12	64-5.8	13.6	2.9	12.2	3.7	-	-
13	64-10.2	3.1	1.6	12.6	4.7	-	-
14	78-12.4	4.6	1.9	8.9	4.1	-	-
15	111-10.6	9.9	2.2	18.6	6.1	-	-
16	122-37.2	2.6	1.4[b]	7.3	3.3[b]	8.0	2.7[c]
17	132-11.1	4.8	1.9	10.5	3.8	-	-
18	164-8.5	5.9	1.7[b]	14.4	3.1[b]	-	-
19	164-9.4	3.6	1.6[b]	10.1	2.8[b]	-	-
On-Site Stations:							
20	58-3.1	17.6	3.1	11.2	5.3	-	-
21	73-3.0	5.3	1.9	14.8	4.5	17.8	4.4
22	92-6.7	4.2	1.7	11.3	3.2	-	-
23	99-2.0	8.1	2.5	11.2	4.3	-	-
24	122-3.7	24.1	3.4	10.6	3.8	-	-
25	123-7.0	4.7	1.7	14.3	3.7	-	-
26	141-3.3	5.1	1.2	13.6	4.5	-	-
27	156-9.4	3.7	1.8	9.9	3.7	-	-
28	189-2.8	4.9	1.9	8.9	3.2	6.1	2.2
29	204-4.2	5.2	2.0	24.1	5.6	-	-
30	224-3.5	5.9	1.8	9.9	3.0	8.7	3.3
31	242-6.3	9.4	2.1	10.1	3.4	-	-
32	245-3.3	5.8	2.1	7.6	3.6	9.7	4.0
33	277-3.3	13.3	2.8	93.0	11.7	-	-
34	304-2.6	40.4	8.0	22.4	5.8	8.8	3.2[b]
35	319-3.1	25.7	5.0	12.2	5.0	-	-

[a]Includes one 3-wk sample and twelve 4-wk samples.

[b]One sample lost.

[c]Two samples lost.

areas of the explosive testing. The concentrations, given in Table VIII, are approximately 50% lower than those reported for the last 6 months of 1971.

Tritium. In addition to the particulate sample and the ^{131}I sample, a separate sample is collected at each station every week for tritium measurement. Air is drawn through a tube of silica gel dessicant at an average flow of approximately 50 ml/min. This procedure permits water vapor collection at about 95% efficiency. The water vapor is collected by heating the dessicant and condensing the resulting vapor. A standard aliquot of this water is

TABLE VIII

TRITIATED MOISTURE AND TOTAL URANIUM CONCENTRATIONS IN AIR

Station		Tritiated Moisture		Total Uranium	
Map No.	Array Designation	Max (10^{-11} μCi/ml)	Av	Max (10^{-10} μg/ml)	Av
Off-Site Stations:					
1	330-3.8	8.3	2.5	1.0	0.9
2	335-4.9	4.3	2.1	0.9	0.7
3	350-4.3	7.7	2.2	1.8	1.1
4	351-2.4	12	2.9	0.8	0.6
5	3-3.7	8.7	2.9	1.7	1.1
6	15-2.0	9.4	3.1	1.8	1.0
7	18-4.9	7.1	2.3	1.1	0.6
8	36-7.0	8.0	2.3	1.2	0.9
9	42-3.1	19	3.6	0.8	0.6
10	50-8.6	8.6	2.3	1.5	0.8
11	55-23.7	3.6	2.0	1.8	1.1
12	64-5.8	5.7	2.4	0.9	0.6
13	64-10.2	6.8	2.2	1.3	0.8
14	78-12.4	6.5	2.1	1.0	0.7
15	111-10.6	8.9	2.5	1.2	0.8
16	122-37.2	4.6	2.1	0.9	0.8
17	132-11.1	6.8	2.3	1.1	0.7
18	164-8.5	65	4.4	0.9	0.6
19	164-9.4	6.0	2.2	1.7	0.9
On-Site Stations:					
20	58-3.1	12	3.6	1.0	0.7
21	73-3.0	18	3.3	1.2	0.7
22	92-6.7	11	3.3	1.1	0.6
23	99-2.0	70	11	1.4	0.7
24	122-3.7	11	3.2	0.8	0.7
25	123-7.0	21	4.8	0.9	0.6
26	141-3.3	15	2.9	1.3	0.6
27	156-9.4	230	18	1.2	0.9
28	189-2.8	7.7	2.8	1.1	0.6
29	204-4.2	5.3	2.1	2.4	1.2
30	224-3.5	4.8	2.4	0.8	0.6
31	242-6.3	4.2	2.1	0.7	0.6
32	245-3.3	12	3.1	0.9	0.6
33	277-3.3	8.4	2.9	0.8	0.6
34	304-2.6	16	3.3	0.6	0.5
35	319-3.1	8.3	2.8	0.7	0.6

analyzed for tritium content by liquid scintillation counting and the resulting figure is combined with the average humidity for the week to obtain an estimate of the average tritiated vapor content per unit volume of air. The collection system and counting procedure result in a MDL of approximately 5 x 10^{-12} μCi/ml (50% relative humidity, 9°C temperature, 750 mbar pressure).

Measurements of tritiated water vapor in air are summarized in Table VIII and shown graphically as isopleths in Fig. 11. At least one measurement at each station fell below the MDL. As expected, the highest concentrations were near TA-33 and TA-35 due to tritium releases (Table I). The highest average for an on-site station, which occurred at 156-9.4 (Fig. 6 No. 27, TA-33), was 0.004% of the concentration guide value for controlled areas of 5 x 10^{-6} μCi/ml, as listed in AEC Manual Chapter 0524. The highest average for an off-site or uncontrolled area occurred at station 42-3.1 (Fig. 6 No. 9, Los Alamos Airport) and was 0.02% of the AEC recommended guide of 2 x 10^{-7} μCi/ml for uncontrolled areas.

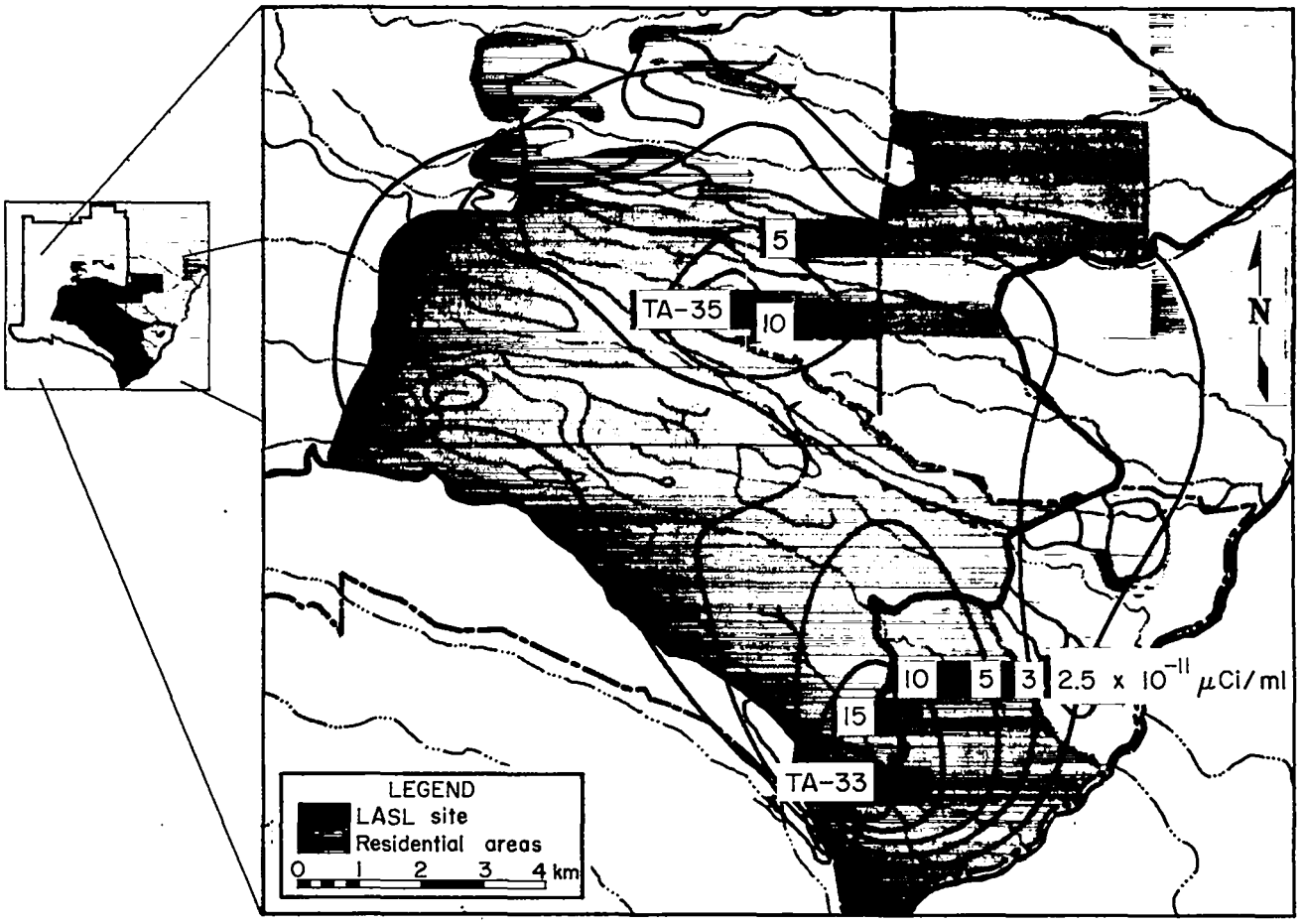


Fig. 11.
Tritium concentration isopleths.

B. Nonradioactive Materials.

A sample of 24-h duration is taken on the roof of the Occupational Health Laboratory (TA-3) and is analyzed by Group H-5 (Industrial Hygiene). The sample is taken on a different day approximately every second week by drawing air at about 1500 liters/min through an 8- by 10-in. glass fiber filter provided by the EPA. The filters are then analyzed for suspended particulate material, benzene-soluble organic material, cadmium, and lead. A similar sampling arrangement is used with a Whatman 41 filter for airborne beryllium measurements. The results of these analyses for 1972 are given in Table IX. Geometric means were not calculated when several samples of a group fell below the MDL.

The state of New Mexico has established ambient air quality standards,[8] and comparisons are made to these standards. The Los Alamos geometric mean was about 28% of the established standard of 60 $\mu g/m^3$ for the annual geometric mean for total suspended particulates. The maximum beryllium concentration was 4% of the permissible 30-day average of 0.01 $\mu g/m^3$. The total heavy metals (atomic number greater than 21) concentration standard is 10 $\mu g/m^3$, again based on a 30-day average. The Los Alamos total of maximum lead and cadmium concentrations was less than 6% of this value. These low levels of nonradioactive atmospheric contaminants tend to reflect the rural location of Los Alamos and the low level of industrial activity.

V. EXTERNAL RADIATION MONITORING PROGRAM

A thermoluminescent dosimeter (TLD) array is maintained to monitor gamma and x-radiation at natural background levels to provide information on any possible contribution from Laboratory activities. The stations that constitute this array have been assigned polar grid designations according to the same scheme used in the

TABLE IX

NONRADIOACTIVE PARTICULATE CONCENTRATIONS IN AIR

Contaminant	No. of Samples	Geometric Mean Concentration ($\mu g/m^3$)	Maximum Concentration ($\mu g/m^3$)	MDL ($\mu g/m^3$)
Suspended particulates	30	16.6	65.2	0.2
Benzene soluble organics	31	--	4.6	0.4
Cadmium	31	--	0.0095	0.000003
Lead	31	0.063	0.57	0.0009
Beryllium	29	--	0.0004	0.00002

atmospheric monitoring program discussed in Sec. IV. Their locations are shown in Fig. 12, again using serial numbering on the map for clarity.

Each of the 59 stations in the array is composed of three Harshaw TLD-100 chips. These are cut from single crystals of LiF (natural lithium) and are 3.18 mm square by 0.89 mm thick, with a mass of 23 to 24 mg. The three chips are wrapped together in aluminum foil and put in a 17-mm-diam by 50-mm-long cylindrical polyethylene container for placement in the field. The TLDs in the field

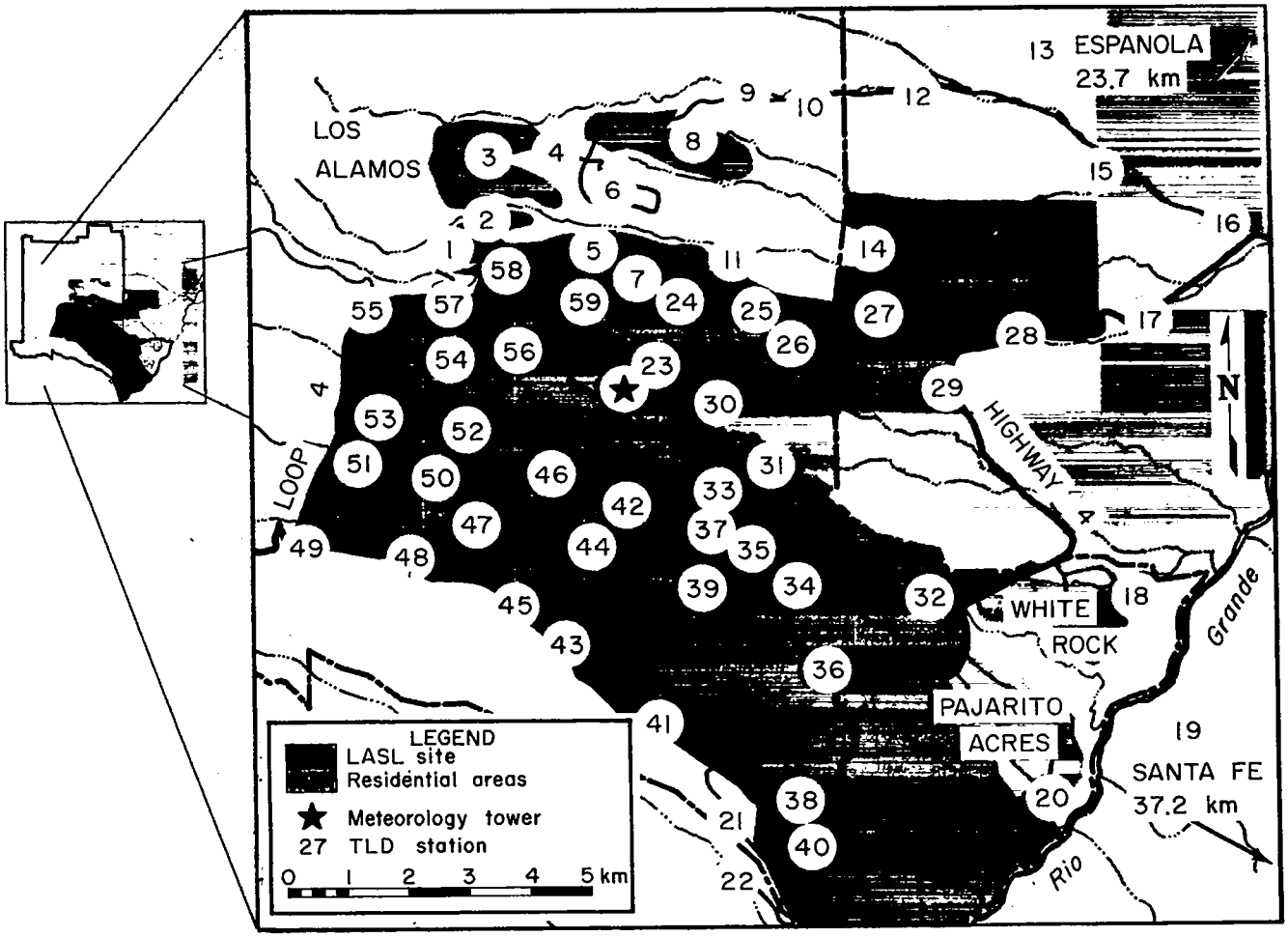


Fig. 12.
Locations of thermoluminescent dosimeter stations.

are exchanged with fresh ones at regular periods and the thermoluminescence is measured by means of an Eberline TLR-5 reader. The exposure of each chip is inferred, using identical calibration chips that have received known exposures from a ^{60}Co source under controlled conditions. The average of the three exposures is then taken to give the total exposure for the period of the exchange at the particular station.

The stations were operated on a 4-wk exchange schedule for the first 24 wk of 1972, starting January 12. Operating experience revealed that the exchange interval could be relaxed to 12 wk for 45 of the 59 stations. The last exchange for which data are available for this report took place December 12, giving 48 wk of data for the year.

In general, there was very little temporal variation in exposure rate, which remained fairly constant over the year at approximately 13 mR/month.

Total exposures for calendar year 1972 at the 59 TLD stations in the Los Alamos area were estimated from the 48 wk of data and are presented in Table X. The spatial variation can be accounted for by statistical fluctuations about a central mean value, except for five stations. These stations, one off-site and four on-site, are discussed later and are excluded from the following argument. It can be shown statistically that these exposures fit a lognormal distribution function reasonably well, a result consistent with the results of many other environmental measurements. A geometric mean of 147 mR and a geometric standard deviation of 1.17 (multiplicative) are obtained for the 21 off-site stations, with corresponding values of 160 mR and 1.14 for the 33 on-site stations under consideration. Furthermore, these means are statistically equal at the 95% level of confidence, so that the entire group of results may be adequately described by a single lognormal distribution with a geometric mean of 155 mR and a standard deviation of 1.16, as shown in Fig. 13. The lack of significant station effects indicates that this level of external radiation is caused by natural terrestrial and solar sources, the variation being due to the random nature of these sources. For comparison, TLD-measured exposure at Colorado Springs (elevation 1880 m) is reported[9] to be about 143 mR/yr, and the range at locations closer to sea level is likely to be 25 to 80 mR/yr, depending on geology.

The single off-site station not included in the above discussion is located at the headquarters complex of Bandelier National Monument (station 164-9.4, Fig. 12 No. 22). This station indicated slightly higher levels than the other stations during the July-December 1971 reporting period as well. None of the air samples collected at this same station indicated any unusually high levels of airborne radioactivity. It is very doubtful that the response of the TLDs at this station is due to Laboratory activities. It is probably due to a combination of two effects: first, a slightly higher than normal contribution from naturally occurring terrestrial gamma-emitting radionuclides; and second, the geometry of the station. The station is located next to an adobe-brick wall at the bottom of a 175-m-deep canyon which is about 350 m wide.

Of the four on-site stations mentioned above, two, stations 129-3.9 (Fig. 12 No. 33, TA-18) and 138-3.4 (Fig. 12 No. 35, TA-36) are positioned so as to monitor TA-18. Their response is due solely to operation at TA-18 of fast burst reactors (research reactors that are operated in such a manner as to produce very short and very intense bursts of neutrons). A third, station 152-9.2 (Fig. 12 No. 38, TA-39) is located near the base of a cliff approximately 75 m high. No air sampler is located at this station for comparison, but the somewhat elevated level reported during 1971 indicates that terrestrial sources, mentioned in the preceding paragraph, could quite possibly account for the high measurement. The cause of the high measurement at the remaining station, station 75-5.3 (Fig. 12 No. 28, Highway 4), is unexplained. No air sampler is located there, and a high TLD indication was not reported during 1971. It is doubtful that Laboratory activities influenced either of the latter two results. The three stations whose results are not clearly understood will be studied further by use of field instrumentation and by small displacements of the TLD packets from their usual positions.

VI. WATER MONITORING PROGRAM

The water monitoring program is designed for surveillance of the Los Alamos municipal water supply drawn from the deep aquifer underlying the Laboratory area, as well as for general surveillance of the ground and surface waters in the vicinity. Samples from supply wells are collected at the individual wellheads during pumping, and samples of surface water are bailed from a convenient pool or allowed to flow directly into the sample container. For samples from observation holes and test wells, sufficient water is drawn and discarded to make the sample representative of the ground water at the time of sampling. All samples are analyzed by radiochemical methods for gross alpha, beta, and gamma activities and for tritium, plutonium, and cesium (^{137}Cs). A fluorometric technique is used to measure uranium concentration. Standard chemical analyses are made for calcium, magnesium, sodium, fluorides, chlorides, nitrates, carbonates, bicarbonates, chromates, total dissolved solids, hardness, pH, and conductivity. Concentrations of mercury, cadmium, lead, and beryllium are measured to establish background levels for these metal ions and to assure that

TABLE X

SUMMARY OF THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station		Exchange Interval	Annual Exposure	
Map No.	Array Designation	(wk)	(mR)	Remarks
Off-Site Stations:				
1	315-3.6	12	130	47th Street
2	330-3.8	12	146	Diamond Drive
3	335-4.9	4	124	Arkansas Avenue
4	350-4.3	12	156	Golf Course
5	351-2.4	12	141	Fuller Lodge
6	3-3.7	12	196	Cumbres Jr. High
7	15-2.0	12	153	Acorn Street
8	18-4.9	4	133	Barranca School
9	20-5.8	12	194	Sportsman's Club
10	36-7.0	12	148	Guaje Booster 2
11	42-3.1	4	187	Airport
12	50-8.6	12	137	Guaje Booster 1
13	55-23.7	12	111	Española
14	64-5.8	12	179	Bayo Canyon STP
15	64-10.2	12	141	Well G-1
16	78-12.4	4	141	Well LA-3
17	83-10.7	12	138	Totavi
18	111-10.6	4	127	White Rock STP
19	122-37.2	12	145	Santa Fe
20	132-11.1	4	123	Pajarito Acres
21	164-8.5	12	174	Bandelier Lookout
22	164-9.4	4	229	Bandelier HQ
Average[a]	-	-	147	
Range			137-157	
On-Site Stations:				
23	18-0.2	12	117	TA-50
24	23-1.9	4	203	TA-2
25	58-3.1	12	124	TA-21
26	73-3.0	4	139	TA-53
27	75-5.3	12	135	East Road
28	83-8.1	12	244	Highway 4
29	92-6.7	12	173	Well PM-1
30	99-2.0	12	152	Beta Site
31	122-3.7	12	188	Pajarito Booster 2
32	123-7.0	12	189	Pajarito Booster 1
33	129-3.9	4	597	TA-18
34	134-5.5	12	188	TA-36
35	138-3.4	4	339	TA-36
36	140-7.3	12	174	Water Canyon
37	141-3.3	12	215	TA-36
38	152-9.2	12	236	TA-39
39	156-4.2	12	174	TA-36
40	156-9.4	12	155	TA-33
41	174-6.4	12	153	Highway 4
42	184-2.0	12	181	TA-15
43	184-5.1	12	161	Highway 4
44	189-2.8	4	193	TA-15
45	204-4.2	12	151	TA-49
46	225-1.9	12	153	E. TA-9
47	225-3.8	12	152	TA-11
48	228-4.7	12	166	Highway 4
49	242-6.3	4	162	W. Jemez Road
50	245-3.3	12	158	TA-16

Station		Exchange Interval (wk)	Annual Exposure (mR)	Remarks
Map No.	Array Designation			
51	251-5.0	12	147	TA-16
52	254-2.8	12	156	E. TA-9
53	261-4.3	12	167	TA-9
54	277-3.3	12	134	TA-6
55	286-4.5	12	163	W. Jemez Road
56	296-1.8	4	157	OHL
57	304-2.6	12	150	TA-3
58	319-3.1	12	162	TA-43
59	346-3.2	12	149	Trailer Court
Average[a]	-	-	160	
Range			152-168	
All Stations:				
Average[a]	-	-	155	
Range			149-161	

[a]Geometric mean. Range gives the 95% confidence limit for the average, and was calculated from the geometric standard deviation. Stations 22, 28, 33, 35, and 38 are not included in these calculations (see text).

no hazardous concentrations remain undetected. Analyses for other constituents may be run in addition to, or instead of, the above if there is evidence that such analyses are necessary.

The plutonium determinations performed on these water samples deserve special mention because tenuous identifications of trace amounts of this material were made on several occasions. These identifications are believed to be due to cross-contamination in the analytical laboratory or to fluctuations of the MDL, both very real problems at the low concentrations being investigated here. Thus, those samples in which traces of plutonium were found are reported, although they are probably not indicative of actual plutonium contamination of the water from which they were taken. Verification will depend upon patterns established by analyses of future sample collections.

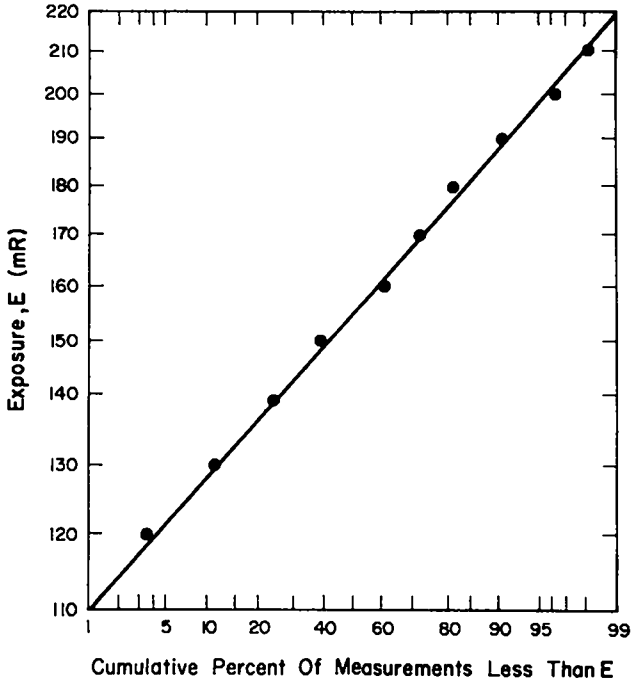


Fig. 13.
Logarithmic-probability plot of annual exposure measurements.

A. Los Alamos Water Supply

The municipal water supply system at Los Alamos is operated and maintained by the Utilities and Engineering (U/E) Division of the Zia Company under contract to the AEC. Operational records are provided to Group H-8, which acts in an advisory capacity concerning use of system equipment and long-range utilization and conservation of the deep aquifer from which the water supply is drawn. LASL reports are used for reporting annual evaluations of operations to the AEC and for publication of other specific information as it becomes available.[10,11]

During 1972, about 6.8 billion liters of water were supplied to Los Alamos from 16 supply wells ranging in depth from 265 to 795 m and from one gallery which has been developed on the eastern flanks of the Jemez Mountains (Fig. 14). These sources, as well as two test wells, were sampled to monitor the quality of water in the main aquifer. The range and average of constituents in this water are given in Table XI.

There is a slight variation in water quality from periods of light pumpage (winter) to periods of heavy pumpage (summer). The routine radiochemical, chemical, and

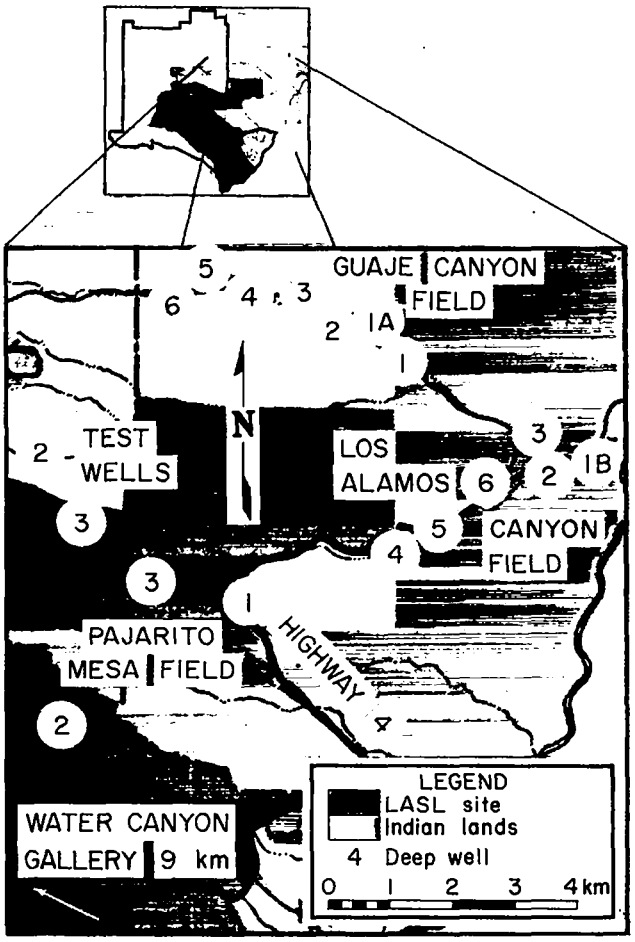


Fig. 14.
Locations of Los Alamos water supply system wells.

metal-ion analyses indicated no significant change in water quality during this reporting period as compared to previous analyses.[1,2] Except for two instances, the maximum concentrations were well below the limits defined by the appropriate U.S. Public Health Service standards[12] for drinking water or concentration guides for radioactive materials as given in AEC Manual Chapter 0524, Table II (uncontrolled areas). The two high concentrations were fluoride and dissolved solids, at one well each. The averages in both instances were within the standards.

To evaluate the quality of water with respect to certain chemicals specified in the drinking water standards, a set of 17 samples was sent to an outside contractor, Controls for Environmental Pollution, Santa Fe, N.M., for a special set of analyses for arsenic, barium, copper, cyanide, iron, manganese, selenium, silver, and zinc (Table XI). At two wells, traces of arsenic were found, one above the recommended limit of 0.01 μg/ml given in Table 5.21 of Ref. 12, and one at the rejection limit of 0.05 μg/ml given in Table 5.22. Consequently, another set of 16 samples was collected and sent to the N.M. EIA laboratories for a reanalysis for arsenic, copper, selenium, and zinc. The higher of the two arsenic concentrations was corroborated, whereas the lower was not–instead, a similar low level was found in another sample. The two lower values were very near the MDL for the analytical procedure and might be erroneous, whereas the higher verified value appears to be real. However, the arithmetic average arsenic concentration for the 16 producing wells falls well below the rejection limit, as does the average weighted by pumpage (the offending well, LA-6, produces only 5% of the Los Alamos water supply). The presence of arsenic in natural water is not uncommon, and is due to its presence in the aquifer rather than to contamination. The problem will be studied further in 1973. Concentrations of all other materials covered by these special analyses fell below the recommended limits.

B. Regional Surface Waters

Off-site rivers and reservoirs in and adjacent to the Los Alamos area are sampled and analyzed routinely to provide information on general water quality in the area and to serve as background for other measurements. During this period, 16 water samples were collected at four river stations: the Rio Chama at Chamita, and the Rio Grande at Embudo, Otowi, and Cochiti (Fig. 15). Sixteen water samples, two each, were taken from the other stations at Caliente River, Santa Cruz Reservoir, Tesuque Creek, Galisteo Reservoir, the Rio Grande at Bernalillo, Jemez Creek, Fenton Lake, and Abiquiu Reservoir (Fig. 15). Only one sample was collected from Jemez Reservoir. These nine stations are 35 to 50 km from the approximate center of the LASL site.

The range and average of constituents of water from these sampling stations are shown in Table XII. The quality of this water fluctuates drastically due to variations in discharge and in size and terrain of the drainage area. Jemez Reservoir was dry when visited in early summer. In late fall a sample of base flow was collected from the channel below the reservoir. The water was highly mineralized (dissolved solids 1430 μg/ml), as were both samples from Galisteo Reservoir (dissolved solids 1580 μg/ml and 3030 μg/ml). The high mineral concentrations in these waters are due to the small dilution by runoff of the base flow which leaches minerals from the "red bed" terrain that constitutes most of the drainage area of these two streams. Traces of ^{238}Pu were reported in water collected from the Caliente River in the spring and in both samples of water collected from Santa Cruz Reservoir collected in the spring and fall. Again, identification of ^{238}Pu is tenuous at these low levels.

TABLE XI

ANALYSES OF LOS ALAMOS WATER SUPPLY SYSTEM SAMPLES

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Routine Analyses:						
Gross alpha	10^{-9} μCi/ml	35	<2.0	20	<2.1	1.0
Gross beta	10^{-9} μCi/ml	35	<1.0	11	<3.0	1.0
Plutonium-238	10^{-11} μCi/ml	36	<5.0	<5.0	<5.0	5.0
Plutonium-239	10^{-11} μCi/ml	36	<5.0	<5.0	<5.0	5.0
Cesium-137	10^{-7} μCi/ml	35	<3.5	<3.5	<3.5	3.5
Tritium	10^{-6} μCi/ml	35	<1.0	<1.0	<1.0	1.0
Total uranium	10^{-4} μg/ml	35	<2.0	250	<29	2.0
Silica	μg/ml	45	28	84	54	1.0
Calcium	μg/ml	52	3.0	29	15	2.0
Magnesium	μg/ml	52	<2.0	11	<5.0	2.0
Sodium	μg/ml	52	6.0	180	33	1.0
Carbonate	μg/ml	52	0	0	0	-
Bicarbonate	μg/ml	52	40	360	110	3.0
Chloride	μg/ml	52	<1.0	16	<5.0	1.0
Fluoride	μg/ml	52	<0.1	3.1	<0.3	0.1
Nitrate	μg/ml	52	<0.1	1.2	<0.3	0.1
Chromate	10^{-2} μg/ml	24	<2.0	2.4	<2.1	2.0
Dissolved solids	μg/ml	52	38	550	180	-
Hardness	μg/ml	52	20	110	58	-
pH	--	52	7.3	8.7	7.9	-
Conductivity	μmho/cm	52	70	600	190	-
Cadmium	10^{-4} μg/ml	17	<2.5	3.0	<2.6	2.5
Lead	10^{-3} μg/ml	17	<1.0	<1.0	<1.0	1.0
Beryllium	10^{-4} μg/ml	17	<2.5	<2.5	<2.5	2.5
Mercury	10^{-5} μg/ml	17	<2.0	<2.0	<2.0	2.0
Cadmium[a]	10^{-4} μg/ml	17	<2.5	<2.5	<2.5	2.5
Lead[a]	10^{-3} μg/ml	17	<1.0	13	<1.7	1.0
Beryllium[a]	10^{-4} μg/ml	17	<2.5	<2.5	<2.5	2.5
Mercury[a]	10^{-5} μg/ml	17	<2.0	400	<26	2.0
Special Analyses:						
Arsenic	10^{-2} μg/ml	34	<2.0	16	<2.9	2.0
Barium	10^{-2} μg/ml	17	<1.0	6.0	<1.9	1.0
Copper	10^{-2} μg/ml	33	<2.0	10	<3.1	2.0
Cyanide	10^{-2} μg/ml	17	<1.0	<1.0	<1.0	1.0
Iron	10^{-2} μg/ml	17	<1.0	13	<4.6	1.0
Manganese	10^{-2} μg/ml	17	<1.0	<1.0	<1.0	1.0
Selenium	10^{-2} μg/ml	33	<2.0	3.0	<2.1	2.0
Silver	10^{-2} μg/ml	17	<1.0	2.0	<1.1	1.0
Zinc	10^{-2} μg/ml	33	<2.0	17	<2.9	2.0

[a]Particulates.

C. Surveillance Water Sampling

1. Surface and Ground Water. Samples of surface and ground water were collected and analyzed to help assess the overall impact of Laboratory operations on the environment. Sampling locations are shown in Fig. 16.

The off-site monitoring consisted of collection of two water samples each from Los Alamos Spring and Basalt Spring, and one sample each from the stream in Frijoles Canyon and from Los Alamos Reservoir (Table XIII). The on-site monitoring consisted of collection of one sample of surface water each from Cañada del Buey, Pajarito

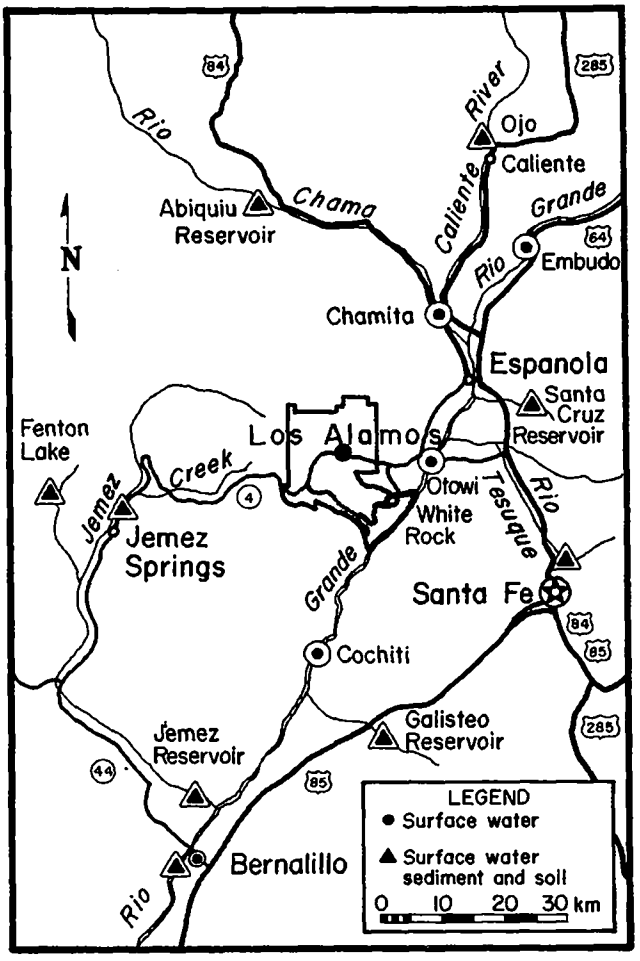


Fig. 15.
Locations of regional surface water, sediment, and soil sampling stations.

Canyon, and Water Canyon (Table XIV). No results were abnormal for these stations.[1,2]

2. **Sanitary Sewage Facility Effluents.** The monitoring of effluents from residential and technical area sewage treatment facilities fulfills two needs. It reflects the extent to which the facilities are achieving their intended purposes, and it provides a means for detection of accidental releases of pollutants to the environment through the sanitary sewer. The locations of the numerous facilities (numerous because of the rugged topography of the area) are shown in Fig. 17.

Municipal Facilities. Los Alamos County personnel operate and maintain the county's three sewage treatment plants and one lagoon system, and they perform the analyses necessary to monitor the plants' performances. The two facilities serving Los Alamos proper, the Pueblo Canyon Plant and the Bayo Canyon Plant, are standard-rate trickling filter plants, and the White Rock facility is a high-rate trickling filter plant. The lagoon system, which serves Pajarito Acres, consists of three lagoons in series. They are 1 m in depth and have a combined surface area of 13,000 m^2. A total of 19 million liters of Pueblo Plant effluent was used as irrigation water for the County golf course during the summer months of 1972.

The results of analyses of grab samples and the average effluent flows from each facility are shown in Table XV. Although the possibility of industrial pollutants reaching these facilities is remote, the four effluents are sampled quarterly for determinations of constituents associated with LASL activities. The results of these analyses are shown in Table XVI, and the concentrations are similar to those reported previously.[1,2]

Technical Area Facilities. The Zia Company, under contract with the AEC for the maintenance of LASL utilities, operates and maintains the technical area sewage treatment facilities. There are four treatment plants, one each at TA-3 and TA-16, consisting of an Imhoff tank, a standard-rate trickling filter and secondary clarifier, one extended aeration plant at TA-21, and one Imhoff tank-clarifier plant at TA-41, lagoon systems at TA-8, TA-18, and TA-53, and 65 septic tanks.

The average volume of effluents discharged to the environment and results of monthly analyses performed by Zia personnel to monitor plant effluent quality are shown in Table XV. The average for the TA-21 plant effluent includes samples collected during the early part of the year when the plant was experiencing operational difficulties. The average biochemical oxygen demand (BOD) and chemical oxygen demand (COD) of effluent from this plant since April 1972 were 31 and 88 mg/liter, respectively.

The conservation of water by reuse is practiced by the Zia Company in its management of a steam plant located near the TA-3 sanitary waste treatment plant. An average of 1 million liters of TA-3 plant effluent is used daily as makeup water for the steam plant's cooling tower.

A cooperative effort in which Zia personnel collect weekly composite samples for radiochemical analyses by LASL's Industrial Waste Treatment Group, H-7, permits detection of accidental releases of radioactivity. H-7 anlayses indicate that no detectable discharges occurred during this reporting period. This sampling program was useful in determining the magnitude of the ammonium-bifluoride release from TA-3 into Sandia Canyon (reported in Sec. IX.A).

Septic tank modifications to permit the collection of samples from tanks that have a potential for radioactive contamination were begun by the Zia Company during

TABLE XII

ANALYSES OF REGIONAL SURFACE WATER SAMPLES

Determination	Unit	No. of Samples	Range		Av	MDL
			Min	Max		
Gross alpha	10^{-9} μCi/ml	33	<1.0	11	<2.0	1.0
Gross beta	10^{-9} μCi/ml	33	<1.0	17	<5.0	1.0
Plutonium-238	10^{-11} μCi/ml	33	<5.0	12	<6.0	5.0
Plutonium-239	10^{-11} μCi/ml	33	<5.0	<5.0	<5.0	5.0
Cesium-137	10^{-7} μCi/ml	33	<3.5	<3.5	<3.5	3.5
Tritium	10^{-6} μCi/ml	33	<1.0	12	<2.0	1.0
Total uranium	10^{-4} μg/ml	33	<2.0	260	<38	2.0
Calcium	μg/ml	33	11	420	60	2.0
Magnesium	μg/ml	33	4.0	100	16	1.0
Sodium	μg/ml	33	3.0	330	49	1.0
Carbonate	μg/ml	33	0	0	0	-
Bicarbonate	μg/ml	33	4.0	380	130	3.0
Chloride	μg/ml	33	<1.0	240	<18	1.0
Fluoride	μg/ml	33	<0.1	1.7	<0.5	0.1
Nitrate	μg/ml	33	<0.1	3.2	<0.2	0.1
Dissolved solids	μg/ml	33	50	3000	420	-
Hardness	μg/ml	33	44	1500	210	-
pH	--	33	6.7	7.7	7.3	-
Conductivity	μmho/cm	33	75	2600	470	-
Cadmium	10^{-4} μg/ml	12	<2.5	5.0	<2.9	2.5
Lead	10^{-3} μg/ml	12	<1.0	4.5	<1.9	1.0
Beryllium	10^{-4} μg/ml	12	<2.5	<2.5	<2.5	2.5
Mercury	10^{-5} μg/ml	12	<2.0	<2.0	<2.0	2.0
Cadmium[a]	10^{-4} μg/ml	12	<2.5	<2.5	<2.5	2.5
Lead[a]	10^{-3} μg/ml	12	<1.0	4.3	<1.3	1.0
Beryllium[a]	10^{-4} μg/ml	12	<2.5	4.7	<2.7	2.5
Mercury[a]	10^{-5} μg/ml	12	<2.0	9.0	<5.0	2.0

[a]Particulates.

the latter part of 1972. A routine sampling schedule will be established upon completion of this project.

VII. SEDIMENT MONITORING PROGRAM

Sediments are those earthen materials that have been transported and reworked by surface water. Samples were collected at the nine 35- to 50-km-distant stations from which regional surface water samples were obtained (Fig. 15). In addition, samples were taken for surveillance from canyon stream beds in the vicinity of the Laboratory at the stations shown in Fig. 16. Some of these sources are natural streams flowing either perennially or intermittently during the rainy season, and some are streams produced by effluents from Laboratory or municipal facilities. Sediment samples from perennial streams were taken from dunes built up in eddies behind boulders in the main channel. From the intermittent streams, samples were collected across the main channel to a 2-cm depth with a 7.5-cm scoop. In still water the samples were dredged from the bottom with a bailer at some convenient point. The samples were placed in new polyethylene containers for storage and transported to the laboratory. Samples were leached with acids, and determinations of gross alpha and beta activities, plutonium, cesium, and uranium were made on the acid leach.

A. Regional Sediments

Sediments were collected and analyzed from the regional surface water sampling stations shown in Fig. 15 to provide general data on the quantities of radioactive material in the environment beyond the general Laboratory area. Results of the analyses are given in Table XVII.

B. Surveillance Sediment Sampling

Locations of sediment sampling stations are shown in Fig. 16. Results of the analyses for on-site and off-site

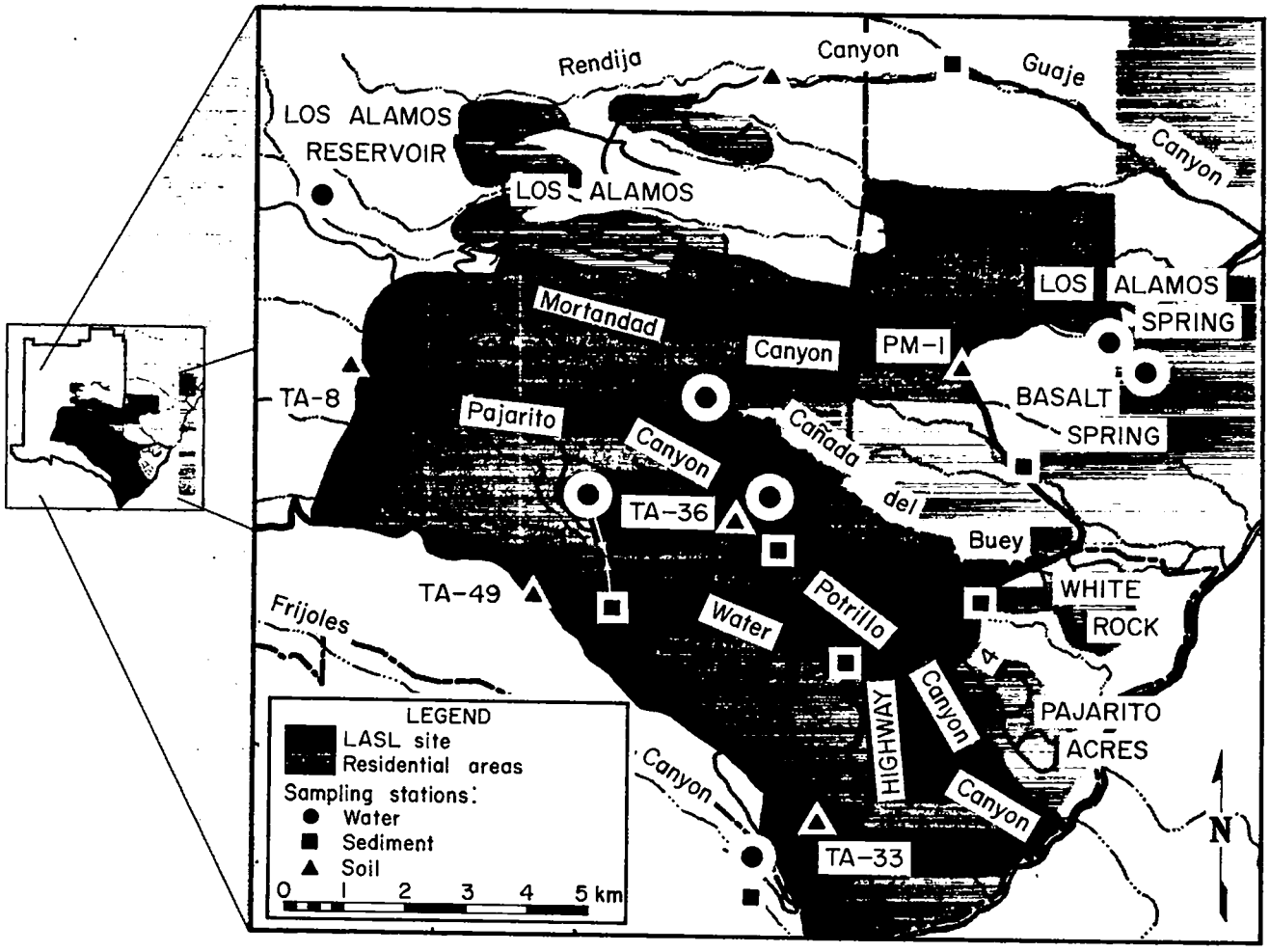


Fig. 16.
Locations of surveillance water, sediment, and soil sampling stations.

samples are given in Table XVIII. In general, the results from this sampling program were consistent with previously reported values.[1,2] Concentrations of plutonium lie in the range expected to result from worldwide fallout. One on-site sample exhibited a high uranium concentration, probably due to the fact that it was collected in an area where explosive tests could be expected to disperse uranium locally.

VIII. SOIL MONITORING PROGRAM

Soils are those earthen materials that are weathered in place. They are sampled primarily to indicate the possibility of deposition of contaminants from the atmosphere. Samples are collected by taking five plugs, 7.5 cm in diameter and 5 cm deep, at the corners and center of a square that is 10 m on a side. The five plugs are combined into a single composite sample and analyzed for gross alpha and beta activities, plutonium, cesium, tritium, and uranium, using basically the same techniques as for sediment samples. Samples were taken at the regional surface water stations (Fig. 15) and at stations established for general surveillance in the vicinity of Los Alamos (Fig. 16).

A. Regional Soils

A summary of the results from the samples taken at distances of 35 to 50 km from the center of the

TABLE XIII

ANALYSES OF OFF-SITE SURFACE AND GROUND WATER

Determination	Unit	Los Alamos Spring	Basalt Spring	Frijoles Canyon	Los Alamos Reservoir	MDL
No. of Samples		2	2	1	1	
Gross alpha	10^{-9} µCi/ml	2.0	<1.0	<1.0	<1.0	1.0
Gross beta	10^{-9} µCi/ml	4.0	4.0	1.0	<1.0	1.0
Plutonium-238	10^{-11} µCi/ml	<5.0	<5.0	<5.0	<5.0	5.0
Plutonium-239	10^{-11} µCi/ml	<5.0	<5.0	<5.0	<5.0	5.0
Cesium-137	10^{-7} µCi/ml	<3.5	<3.5	<3.5	<3.5	3.5
Tritium	10^{-6} µCi/ml	<1.0	<1.0	<1.0	<1.0	1.0
Total uranium	10^{-4} µg/ml	46	30	13	15	2.0
Calcium	µg/ml	38	30	10	8.0	2.0
Magnesium	µg/ml	9.0	9.0	7.0	6.0	1.0
Sodium	µg/ml	32	19	11	7.0	1.0
Carbonate	µg/ml	0	0	0	0	-
Bicarbonate	µg/ml	88	86	56	44	3.0
Chloride	µg/ml	22	14	4.0	2.0	1.0
Fluoride	µg/ml	0.8	0.4	0.1	<0.1	0.1
Nitrate	µg/ml	2.6	2.5	0.1	0.1	0.1
Dissolved solids	µg/ml	260	200	130	98	-
Hardness	µg/ml	130	110	52	44	-
pH	--	7.4	7.8	7.3	7.0	-
Conductivity	µmho/cm	280	230	100	80	-
Cadmium	10^{-4} µg/ml	4.7	6.3	<2.5	<2.5	2.5
Lead	10^{-3} µg/ml	<1.0	<1.0	6.0	3.0	1.0
Beryllium	10^{-4} µg/ml	<2.5	<2.5	<2.5	<2.5	2.5
Mercury	10^{-5} µg/ml	<2.0	<2.0	<2.0	<2.0	2.0
Cadmium[a]	10^{-4} µg/ml	<2.5	<2.5	<2.5	<2.5	2.5
Lead[a]	10^{-3} µg/ml	1.6	2.2	<1.0	<1.0	1.0
Beryllium[a]	10^{-4} µg/ml	<2.5	<2.5	<2.5	<2.5	2.5
Mercury[a]	10^{-5} µg/ml	4.5	4.5	<2.0	<2.0	2.0

[a]Particulates.

Laboratory area is given in Table XIX. The values are in line with those expected from natural radioactivity and from worldwide fallout from past weapons tests.[13]

B. Surveillance Soil Sampling

A summary of the results from the samples taken in the vicinity of Los Alamos County (Fig. 16) is given in Table XX. Again, the values found are in general agreement with those expected from natural activity and worldwide fallout.

IX. SPECIAL STUDIES

In addition to the routine monitoring programs designed to provide information on background radiation levels in northern New Mexico and to provide continuing surveillance of the Los Alamos vicinity, special programs are undertaken to provide more intensive coverage of areas of particular interest or to study in detail individual possible sources of contamination. These programs may be single investigations or continuing studies designed to provide increased information on the ultimate fate of materials discharged to the environs.

A. Monitoring in Effluent Discharge Areas

Monitoring of sediment, soil, surface water, and ground water in alluvium is conducted at three on-site and one off-site (previously on-site) locations in areas where effluent is or has been released to the environment. The on-site locations are TA-21 and DP-Los Alamos Canyons, TA-3 and Sandia Canyon, and TA-50 and Mortandad Canyon; the off-site location is the TA-45 (dismantled) and Acid-Pueblo Canyon area. The stations at which samples were collected are shown in Fig. 18.

TABLE XIV

ANALYSES OF ON-SITE SURFACE WATER

Determination	Unit	Cañada del Buey	Pajarito Canyon	Water Canyon	MDL
No. of Samples		1	1	1	
Gross alpha	10^{-9} μCi/ml	<1.0	<1.0	<1.0	1.0
Gross beta	10^{-9} μCi/ml	2.0	3.0	3.0	1.0
Plutonium-238	10^{-11} μCi/ml	<5.0	<5.0	<5.0	5.0
Plutonium-239	10^{-11} μCi/ml	<5.0	<5.0	<5.0	5.0
Cesium-137	10^{-7} μCi/ml	<3.5	<3.5	<3.5	3.5
Tritium	10^{-6} μCi/ml	1.0	3.0	<1.0	1.0
Total uranium	10^{-4} μg/ml	18	31	13	2.0
Calcium	μg/ml	11	11	30	2.0
Magnesium	μg/ml	4.0	8.0	9.0	1.0
Sodium	μg/ml	17	27	15	1.0
Carbonate	μg/ml	0	0	0	-
Bicarbonate	μg/ml	60	80	68	3.0
Chloride	μg/ml	6.0	14	30	1.0
Fluoride	μg/ml	1.0	<0.1	<0.1	0.1
Nitrate	μg/ml	0.1	0.1	4.0	0.1
Dissolved solids	μg/ml	160	160	190	-
Hardness	μg/ml	44	60	110	-
pH	--	7.3	7.0	7.1	-
Conductivity	μmho/cm	140	190	260	-
Cadmium	10^{-4} μg/ml	2.5	3.8	<2.5	2.5
Lead	10^{-3} μg/ml	5.5	4.5	5.5	1.0
Beryllium	10^{-4} μg/ml	<2.5	<2.5	<2.5	2.5
Mercury	10^{-5} μg/ml	<2.0	<2.0	<2.0	2.0
Cadmium[a]	10^{-4} μg/ml	<2.5	<2.5	<2.5	2.5
Lead[a]	10^{-3} μg/ml	<1.0	<1.0	<1.0	1.0
Beryllium[a]	10^{-4} μg/ml	<2.5	<2.5	<2.5	2.5
Mercury[a]	10^{-5} μg/ml	13	<2.0	<2.0	2.0

[a]Particulates.

The significant feature of any continuing program to study the movement of contaminants is the long-range trend rather than the concentration in any one sample or group of samples. The measurements obtained from a given sampling location will vary with the nature of the effluent and amount of rainfall in the period immediately preceding the sample collection and with the amount of water stored in the alluvium as affected by the rainfall in the drainage area over the preceding few months. It is necessary, therefore, to include all these variables in a detailed analysis of the transport processes involved. Such an analysis is beyond the scope of this report and will be reported elsewhere.[14] A summary of measurements made during 1972 is given here, using simple averages for the several samples taken at each station, and pointing out general trends only.

1. TA-45 (Dismantled) and Acid-Pueblo Canyons. Acid and Pueblo Canyons received untreated wastes from 1943 to 1951 and treated industrial effluents from the industrial liquid waste treatment plant at TA-45 from 1951 until 1964, when the operations were transferred to the new plant at TA-50. Shallow ground water in alluvium, surface water, and sediments were monitored to determine the environmental distributions of contaminants resulting from the past release of these effluents. The results of analyses on the water and sediment samples are given in Tables XXI and XXII, respectively. The traces of plutonium found in the water were probably released from the sediments that captured the plutonium when TA-45 was active. All concentrations are in agreement with those reported earlier.[1,2,15]

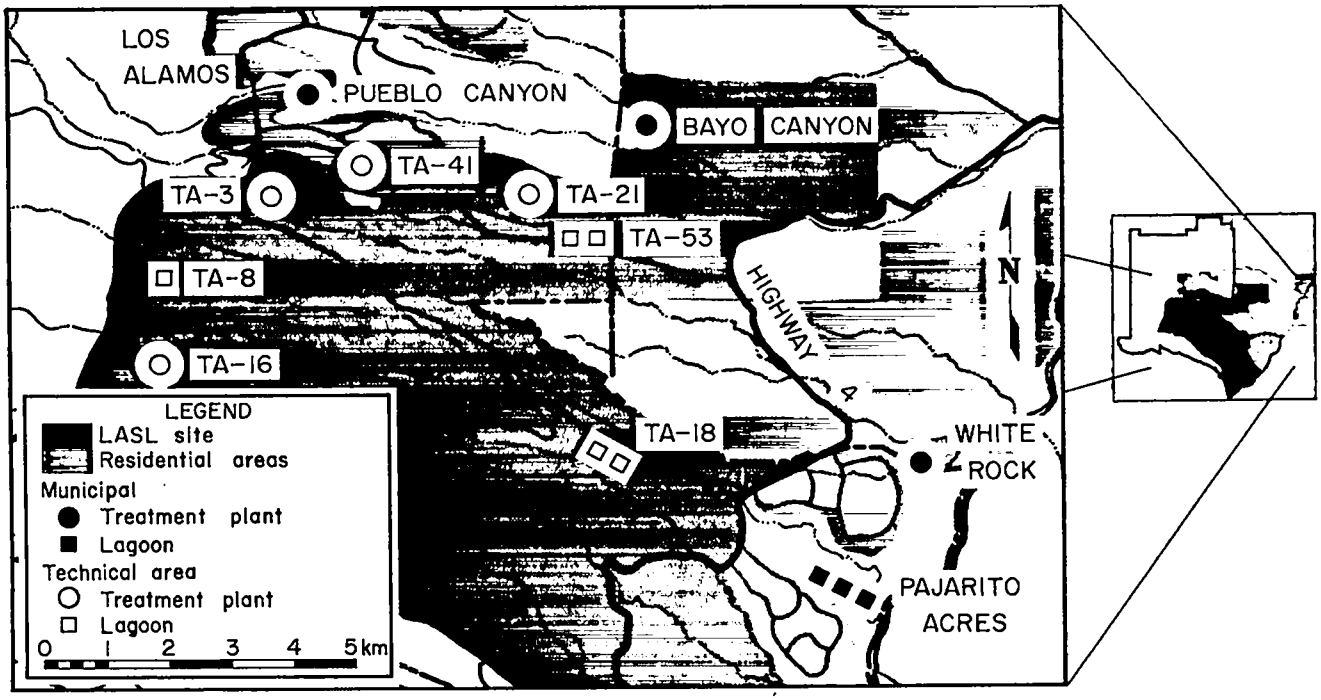


Fig. 17.
Locations of sanitary sewage treatment facilities.

TABLE XV

SANITARY WASTE TREATMENT FACILITY EFFLUENTS

Plant Location	Av Daily Flow (10^6 liters)	Effluent Av BOD (mg/liter)	Effluent Av COD (mg/liter)
Municipal:[a]			
Bayo	4.54	12.3	71
Pueblo	1.44	19.0	111
White Rock	1.17	21.6	86
Pajarito Lagoon	0.15	39.8	113
Technical Area:[b]			
TA-3	1.50	9.9	36
TA-8 Lagoon	0.01	28.1	160
TA-16	0.87	6.8	35
TA-18 Lagoon	0.02	16.7	168
TA-21	0.03	40.5	103
TA-41	0.09	17.4	56
TA-53 Lagoon	0.29	16.3	90

[a]Results of 6 to 12 grab samples.

[b]Results of monthly 24-h composite samples.

2. TA-21 and DP-Los Alamos Canyons. DP Canyon receives the effluent from an industrial liquid waste treatment plant, a sanitary sewage treatment plant, and several cooling towers, all located at TA-21, the main facility for processing plutonium metal and developing ^{238}Pu heat sources. These effluents provide a volume of water sufficient to maintain flow in the DP Canyon channel a relatively large percentage of the time. However, this liquid soaks into the alluvium upstream of the confluence with Los Alamos Canyon, about 1.5 km below the TA-21 outfall. The stream in Los Alamos Canyon flows only during periods of heavy runoff from precipitation. Samples were taken from the stream in DP Canyon and from shallow observation holes in the alluvium in Los Alamos Canyon at various distances below the treatment plant outfall. The analyses of these samples are summarized in Table XXIII. The table shows a decrease in concentration of both radioactive and nonradioactive contaminants with downstream distance. (Ground water stations 4 and 5 are located in Los Alamos Canyon above the confluence with DP Canyon.) A corrosion inhibitor used in a cooling process at TA-2 contributes the chromate in the ground water at station 5. Efforts are being made to replace the cooling tower and the treatment process to eliminate the chromates now being released into the Los Alamos Canyon stream.

TABLE XVI

ANALYSES OF MUNICIPAL SEWAGE TREATMENT PLANT EFFLUENT WATER

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Gross alpha	10^{-9} μCi/ml	16	<1.0	3.0	<1.1	1.0
Gross beta	10^{-9} μCi/ml	16	7.0	98	17	1.0
Plutonium-238	10^{-11} μCi/ml	16	<5.0	12	<5.5	5.0
Plutonium-239	10^{-11} μCi/ml	16	<5.0	<5.0	<5.0	5.0
Cesium-137	10^{-7} μCi/ml	16	<3.5	<3.5	<3.5	3.5
Tritium	10^{-8} μCi/ml	16	<1.0	1.6	<1.1	1.0
Total uranium	10^{-4} μg/ml	16	<2.0	33	<17	2.0
Calcium	μg/ml	16	13	29	18	2.0
Magnesium	μg/ml	16	2.0	17	9.0	1.0
Sodium	μg/ml	16	54	92	73	1.0
Carbonate	μg/ml	16	0	0	0	-
Bicarbonate	μg/ml	16	80	270	170	3.0
Chloride	μg/ml	16	22	38	31	1.0
Fluoride	μg/ml	16	0.3	1.7	0.8	0.1
Nitrate	μg/ml	16	0.4	15	5.8	0.1
Dissolved solids	μg/ml	16	380	590	440	-
Hardness	μg/ml	16	43	120	82	-
pH	--	16	6.8	7.9	7.3	-
Conductivity	μmho/cm	16	420	660	500	-
Cadmium	10^{-4} μg/ml	8	<2.5	3.8	<2.7	2.5
Lead	10^{-3} μg/ml	8	<1.0	4.7	<1.5	1.0
Beryllium	10^{-4} μg/ml	8	<2.5	<2.5	<2.5	2.5
Mercury	10^{-5} μg/ml	8	<2.0	<2.0	<2.0	2.0
Cadmium[a]	10^{-4} μg/ml	8	<2.5	6.1	<3.1	2.5
Lead[a]	10^{-3} μg/ml	8	<1.0	15	<4.6	1.0
Beryllium[a]	10^{-4} μg/ml	8	<2.5	<2.5	<2.5	2.5
Mercury[a]	10^{-5} μg/ml	8	<2.0	93	<16	2.0

[a]Particulates.

TABLE XVII

ANALYSES OF REGIONAL SEDIMENT SAMPLES

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Gross alpha	10^{-6} μCi/g	7	<1.0	3.1	<1.4	1.0
Gross beta	10^{-8} μCi/g	7	<3.0	14	<8.0	3.0
Plutonium-238	10^{-9} μCi/g	9	<3.0	9.0	<4.1	3.0
Plutonium-239	10^{-9} μCi/g	9	<3.0	25	<6.6	3.0
Cesium-137	10^{-8} μCi/g	9	2.0	7.8	4.0	2.0
Total uranium	10^{-2} μg/g	9	23	70	42	1.0

Analyses of one sample of soil taken at soil station 1 (near TA-21) and of two sediment samples taken from the stream channel below the plant are shown in Table XXIV. The concentration of ^{239}Pu in the soil was slightly above that expected from worldwide fallout and probably the result of airborne material from TA-21. The sample collected at sediment station 3 exhibited an above-normal concentration of ^{238}Pu and ^{239}Pu. However, the sample taken at station 4, about 2.5 km farther downstream, did not show high radionuclide levels, indicating that concentrations decrease with downstream distance. Only trace amounts of radionuclides are contained in the industrial

TABLE XVIII

ANALYSES OF SURVEILLANCE SEDIMENT SAMPLES

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Off-Site Stations:						
Gross alpha	10^{-6} μCi/g	4	<1.0	2.5	<1.4	1.0
Gross beta	10^{-6} μCi/g	4	3.8	12	6.8	3.0
Plutonium-238	10^{-9} μCi/g	4	<3.0	<3.0	<3.0	3.0
Plutonium-239	10^{-9} μCi/g	4	<3.0	26	<8.8	3.0
Cesium-137	10^{-6} μCi/g	4	2.8	9.1	5.2	2.0
Total uranium	10^{-3} μg/g	4	45	62	54	1.0
On-Site Stations:						
Gross alpha	10^{-6} μCi/g	3	<1.0	2.6	<1.5	1.0
Gross beta	10^{-6} μCi/g	3	4.5	14	8.5	3.0
Plutonium-238	10^{-9} μCi/g	3	<3.0	7.6	<4.5	3.0
Plutonium-239	10^{-9} μCi/g	3	<3.0	4.1	<3.6	3.0
Cesium-137	10^{-6} μCi/g	3	4.5	4.8	4.6	2.0
Total uranium	10^{-3} μg/g	3	9.0	520	190	1.0

TABLE XIX

ANALYSES OF REGIONAL SOIL SAMPLES

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Gross alpha	10^{-6} μCi/g	9	<1.0	5.8	<1.9	1.0
Gross beta	10^{-6} μCi/g	9	6.2	18	9.7	3.0
Plutonium-238	10^{-9} μCi/g	9	<3.0	10	<4.4	3.0
Plutonium-239	10^{-9} μCi/g	9	4.0	14	8.8	3.0
Cesium-137	10^{-6} μCi/g	9	3.2	11	4.8	2.0
Tritium[a]	10^{-6} μCi/ml	9	<3.0	6.2	<3.5	3.0
Total uranium	10^{-3} μg/g	9	9.0	78	42	1.0

[a]Soil moisture distilled from sample.

effluents released into DP canyon, but for years these trace amounts have been retained by the sediments, resulting in relatively high concentrations.

3. TA-3 and Sandia Canyon. The stream in Sandia Canyon is produced by the effluent from the cooling towers at the power plant and from a sewage treatment plant in TA-3, both operated by the Zia Company. Table XXV is a summary of the results of analyses performed on samples taken from this stream. Chromate was used as a corrosion inhibitor in the cooling tower water until April 1972, when a new process, using Betz Dispersant 419, was introduced. The new process meets U.S. EPA and N.M. EIA standards. Before April, chromate concentration in the stream at the two stations ranged from 0.59 to 5.13 μg/ml. After April, the residual chromate concentration in the stream ranged from 0.01 to 0.06 μg/ml. We anticipate that these residual chromates will decline with time and additional storm runoff.

An accidental release of 250 to 300 kg of fluorides in the form of a dilute ammonium bifluoride solution entered the stream in early fall of 1972. The highest concentration of fluoride recorded was 48 μg/ml at surface water station 7. There was no indication of damage to plants or animal life in the canyon, and the water in the stream is not a source of recharge to the Los Alamos water supply. Measures were initiated to prevent future releases.

TABLE XX

ANALYSES OF SURVEILLANCE SOIL SAMPLES

Determination	Unit	No. of Samples	Range Min	Range Max	Av	MDL
Off-Site Stations:						
Gross alpha	10^{-6} μCi/g	4	2.3	3.8	2.6	1.0
Gross beta	10^{-6} μCi/g	4	4.7	17	12	3.0
Plutonium-238	10^{-9} μCi/g	4	<3.0	<3.0	<3.0	3.0
Plutonium-239	10^{-9} μCi/g	4	9.0	19	15	3.0
Cesium-137	10^{-6} μCi/g	4	5.9	8.4	7.2	2.0
Tritium[a]	10^{-6} μCi/ml	4	<3.0	5.7	<4.0	3.0
Total uranium	10^{-2} μg/g	4	15	97	38	1.0
On-Site Stations:						
Gross alpha	10^{-6} μCi/g	2	1.0	2.3	1.7	1.0
Gross beta	10^{-6} μCi/g	2	<3.0	12	<7.5	3.0
Plutonium-238	10^{-9} μCi/g	2	<3.0	<3.0	<3.0	3.0
Plutonium-239	10^{-9} μCi/g	2	<3.0	15	<9.0	3.0
Cesium-137	10^{-6} μCi/g	2	4.3	7.1	5.7	2.0
Tritium[a]	10^{-6} μCi/ml	2	<3.0	<3.0	<3.0	3.0
Total uranium	10^{-2} μg/g	2	58	73	67	1.0

[a]Soil moisture distilled from sample.

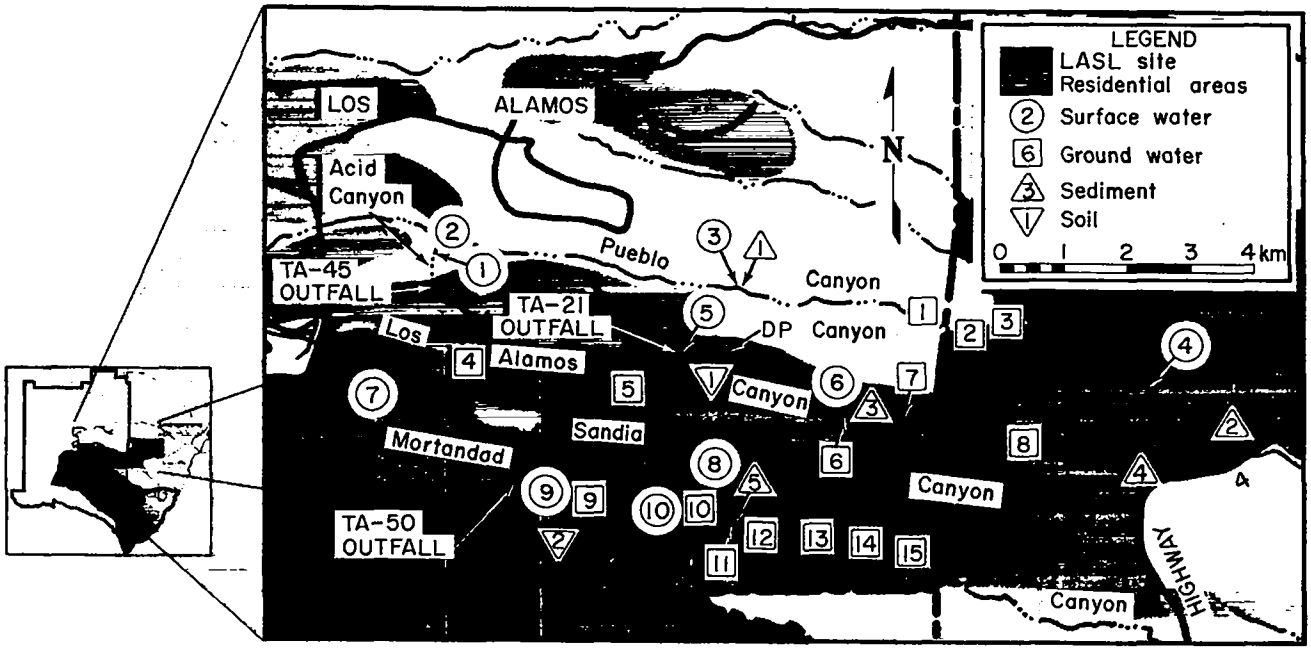


Fig. 18.

Locations of effluent discharge areas and water, sediment, and soil sampling stations.

TABLE XXI

ANALYSES OF WATER SAMPLES FROM ACID AND PUEBLO CANYONS

Determination	Unit	Surface Water Station 1	2	3	4	Ground Water Station 1	2	3
No. of Samples		2	2	2	2	2	2	2
Gross alpha	10^{-9} µCi/ml	2	1	1	2	2	2	2
Gross beta	10^{-9} µCi/ml	130	10	14	20	7	5	7
Plutonium-238	10^{-11} µCi/ml	<5	11	<5	5	<5	14	<5
Plutonium-239	10^{-11} µCi/ml	42	9	11	8	7	7	7
Cesium-137	10^{-7} µCi/ml	<4	<4	<4	<4	<4	<4	<4
Tritium	10^{-8} µCi/ml	1	<1	<1	<1	1	20	1
Total uranium	10^{-4} µg/ml	17	14	14	16	11	11	18
Calcium	µg/ml	24	15	16	17	22	31	18
Magnesium	µg/ml	5	6	5	4	2	9	6
Sodium	µg/ml	86	75	73	76	60	24	69
Carbonate	µg/ml	0	0	0	0	0	0	0
Bicarbonate	µg/ml	120	82	100	130	90	86	120
Chloride	µg/ml	73	41	39	39	40	31	40
Fluoride	µg/ml	1	3	3	3	2	1	2
Nitrate	µg/ml	1	12	8	10	6	2	4
Dissolved solids	µg/ml	310	420	360	390	350	270	370
Hardness	µg/ml	80	85	60	56	64	120	68
pH	--	7	7	8	7	7	7	8
Conductivity	µmho/cm	400	430	400	450	360	280	380
Cadmium	10^{-4} µg/ml	<3[a]	<3[a]	4[a]	4[a]	11[a]	130[a]	<3[a]
Lead	10^{-3} µg/ml	4[a]	3[a]	4[a]	8[a]	4[a]	5[a]	5[a]
Beryllium	10^{-4} µg/ml	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]
Mercury	10^{-5} µg/ml	<2[a]	<2[a]	<2[a]	<2[a]	13[a]	<2[a]	<2[a]
Cadmium[b]	10^{-4} µg/ml	5[a]	5[a]	<3[a]	5[a]	68[a]	14[a]	7[a]
Lead[b]	10^{-3} µg/ml	2[a]	12[a]	5[a]	6[a]	5[a]	13[a]	5[a]
Beryllium[b]	10^{-4} µg/ml	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]
Mercury[b]	10^{-5} µg/ml	<2[a]	67[a]	13[a]	27[a]	27[a]	170[a]	<2[a]

[a]One sample.

[b]Particulates.

TABLE XXII

ANALYSES OF SEDIMENTS FROM PUEBLO CANYON

Determination	Unit	Sediment Station 1	2
No. of Samples		1	1
Gross alpha	10^{-6} µCi/g	<1	<1
Gross beta	10^{-6} µCi/g	4	4
Plutonium-238	10^{-9} µCi/g	12	<3
Plutonium-239	10^{-9} µCi/g	2600	370
Cesium-137	10^{-6} µCi/g	3	4
Total uranium	10^{-2} µg/g	42	32

4. TA-50 and Mortandad Canyon. Mortandad Canyon receives the effluent from the central industrial waste treatment plant at TA-50, where the industrial liquid wastes from the majority of the Laboratory's technical areas are processed. The effluent produces a flowing stream for only a relatively short distance below the outfall. The surface water in this stream was sampled at two locations, and the ground water in alluvium at greater distances from the outfall was sampled by using established shallow observation holes. The results are given in Table XXVI.

There is an overall decrease in contaminant concentration as one progresses from the TA-50 outfall to the vicinity of ground water station 14, at which point a sudden increase is noted for most constituents. This area is at the eastern extremity of the ground water in alluvium, and the increase may be due to a reconcentration

TABLE XXIII

ANALYSES OF WATER SAMPLES FROM DP AND LOS ALAMOS CANYONS

Determination	Unit	Surface Water Station		Ground Water Station				
		5	6	4	5	6	7	8
No. of Samples		3	3	4	4	3	4	4
Gross alpha	10^{-9} μCi/ml	13	3	<1	2	2	3	2
Gross beta	10^{-9} μCi/ml	2500	610	5	130	190	92	7
Plutonium-238	10^{-11} μCi/ml	32	7	6	16	9	10	9
Plutonium-239	10^{-11} μCi/ml	570	27	8	18	18	15	6
Americium-241	10^{-11} μCi/ml	33[a]	15[a]	12[a]	<5[a]	12[a]	<5[a]	<5[a]
Cesium-137	10^{-7} μCi/ml	<4	<4	<4	<4	<4	<4	<4
Tritium	10^{-6} μCi/ml	400	170	1	20	150	190	28
Total uranium	10^{-4} μg/ml	67	33	11	7	26	30	13
Calcium	μg/ml	43	23	24	25	21	24	21
Magnesium	μg/ml	8	4	7	8	5	7	8
Sodium	μg/ml	210	120	53	75	97	110	55
Carbonate	μg/ml	0	0	0	0	0	0	0
Bicarbonate	μg/ml	360	210	79	100	200	170	110
Chloride	μg/ml	140	58	74	50	55	68	26
Fluoride	μg/ml	3	4	<1	1	4	5	1
Nitrate	μg/ml	20	7	<1	1	6	6	<1
Chromate	10^{-2} μg/ml	---	<1	<1	380	2	2	2
Dissolved solids	μg/ml	930	490	250	400	470	480	220
Hardness	μg/ml	140	75	88	97	69	86	85
pH	--	8	8	7	7	8	8	8
Conductivity	μmho/cm	1100	600	350	480	580	620	270
Cadmium	10^{-4} μg/ml	43[a]	53[a]	3[a]	7[a]	11[a]	10[a]	<3[a]
Lead	10^{-3} μg/ml	3[a]	3[a]	<1[a]	<1[a]	3[a]	3[a]	<1[a]
Beryllium	10^{-4} μg/ml	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]	<3[a]
Mercury	10^{-5} μg/ml	<2[a]	<2[a]	<2[a]	<2[a]	<2[a]	<2[a]	<2[a]
Cadmium[b]	10^{-4} μg/ml	<3[a]	<3[a]	<3[a]	3[a]	3[a]	6[a]	6[a]
Lead[b]	10^{-3} μg/ml	3[a]	<1[a]	14[a]	15[a]	12[a]	14[a]	19[a]
Beryllium[b]	10^{-4} μg/ml	<3[a]	<3[a]	<3[a]	<3[a]	4[a]	5[a]	6[a]
Mercury[b]	10^{-5} μg/ml	<2[a]	<2[a]	10[a]	4[a]	<2[a]	4[a]	<2[a]

[a]Two samples.

[b]Particulates.

caused by evapotranspiration. The increase in tritium is attributed to the down-canyon progress of a slug of tritiated water released by the TA-50 treatment plant several years ago.

Analyses of one soil sample from soil station 2 (near TA-50) and one sediment sample from the Mortandad Canyon channel downstream from TA-50 are summarized in Table XXVII. The constituents in the soil sample were about what may be expected from worldwide fallout except for ^{239}Pu. The gross beta activity, ^{238}Pu, ^{239}Pu, and ^{137}Cs found in the sediment sample resulted from adsorption or attachment of those radionuclides to material in the sediments.

B. Concentration of Environmental Materials in the Tissues of Small Mammals

In the summer of 1971, personnel of the N.M. EIA (under contract to the U.S. Army) conducted an ecological study of sylvatic plague and an evaluation of systemic insecticides and rodenticides for the control of wild rodents and their fleas in certain locations in New Mexico, including the Los Alamos area. Seventy-five animals from the Los Alamos trapping grids were made available to LASL's Health Division for study. The genus and species of the small mammals collected and the canyon collection locations are shown in Table XXVIII. The tissue

TABLE XXIV

ANALYSES OF SOIL AND SEDIMENT SAMPLES FROM NEAR TA-21 AND IN LOS ALAMOS CANYON

Determination	Unit	Soil Station 1	Sediment Station 3	Sediment Station 4
No. of Samples		1	1	1
Gross alpha	10^{-8} μCi/g	3	<1	<1
Gross beta	10^{-8} μCi/g	13	<3	6
Plutonium-238	10^{-9} μCi/g	6	37	4
Plutonium-239	10^{-9} μCi/g	520	370	4
Cesium-137	10^{-8} μCi/g	7	7	5
Tritium[a]	10^{-6} μCi/ml	6	-	-
Total uranium	10^{-2} μg/g	34	40	33

[a]Soil moisture distilled from sample.

TABLE XXV

ANALYSES OF WATER SAMPLES FROM SANDIA CANYON

Determination	Unit	Surface Water Station 7	Surface Water Station 8
No. of Samples		4	4
Gross alpha	10^{-9} μCi/ml	2	2
Gross beta	10^{-9} μCi/ml	15	16
Plutonium-238	10^{-11} μCi/ml	<5	<5
Plutonium-239	10^{-11} μCi/ml	<5	<5
Cesium-137	10^{-7} μCi/ml	<4	<4
Tritium	10^{-6} μCi/ml	4	4
Total uranium	10^{-4} μg/ml	1	1
Calcium	μg/ml	28	28
Magnesium	μg/ml	12	9
Sodium	μg/ml	120	110
Carbonate	μg/ml	0	0
Bicarbonate	μg/ml	130	110
Chloride	μg/ml	48	64
Fluoride	μg/ml	52	4
Nitrate	μg/ml	5	2
Chromate	10^{-3} μg/ml	18	130
Dissolved solids	μg/ml	910	590
Hardness	μg/ml	120	110
pH	--	7	8
Conductivity	μmho/cm	790	620
Cadmium	10^{-4} μg/ml	<3[a]	4[a]
Lead	10^{-3} μg/ml	<1[a]	<1[a]
Beryllium	10^{-4} μg/ml	<3[a]	<3[a]
Mercury	10^{-5} μg/ml	<2[a]	<2[a]
Cadmium[b]	10^{-4} μg/ml	<3[a]	3[a]
Lead[b]	10^{-3} μg/ml	<1[a]	2[a]
Beryllium[b]	10^{-4} μg/ml	<3[a]	<3[a]
Mercury[b]	10^{-5} μg/ml	<2[a]	9[a]

[a]One sample.
[b]Particulates.

concentrations of environmental tritium, plutonium, and mercury at these locations are reported below. This work was conducted by Groups H-4 (Biomedical Research), H-5, and H-8 of the Health Division.

Trapping networks were established in DP, Mortandad, and Guaje Canyons (Figs. 18 and 2). The trap lines were positioned near the treated industrial liquid waste outfalls in DP and Mortandad Canyons. Trap lines were also placed 300 and 600 m downstream (east) from the outfalls. The Guaje Canyon grid served as a control sample collection source.

Tissue retrieval was conducted at necropsy. The hide was removed first, followed by the kidneys, liver, and a section of skeletal muscle. The carcass was then autoclaved and the skeleton dissected out. The remaining soft tissues were combined with the hide and designated the "remainder." Plutonium determinations were made on the liver, muscle, bone, and remainder tissue fractions. Tritium concentrations were measured in the water from liver samples, and mercury concentrations were measured in the kidney samples.

A wet ashing-ion exchange-electrodeposition-alpha pulse height measurement procedure was used to isolate and measure plutonium. Water distilled from the liver tissues was measured for tritium activity by liquid scintillation counting. The kidneys were weighed and then oxidized, using an acid permanganate ashing solution. The sample solution was further prepared by a standard $SnCl_2$-mercury volatilization method. The treated sample aliquot was then transferred to a special atomic absorption cell for mercury measurement.

Organs and tissue types from identical animal species and from a common collection location were combined for the above analyses. The observed plutonium concentrations are shown in Table XXIX. The range and average values for the combined tissues are summarized in this table without regard to genus or species. About half of the liver composites were lost during analysis. The results obtained show the rodents inhabiting the effluent-receiving canyons to have tissue concentrations of plutonium significantly above the levels measured in the Guaje-Canyon control samples. A full-scale plutonium ecology study program in the Los Alamos areas involved with the disposal of treated liquid waste materials was initiated in July 1972 under the auspices of the DBER. Current results of this study are summarized in the following section.

The tritium assay results are summarized in Table XXX. Tritium levels higher than those for the control samples are corroborated by similar data derived from the above-mentioned ongoing study. The radioecological extent and aspects of this finding are being pursued.

Measurements of mercury concentrations in rodent kidney samples are summarized in Table XXXI. The

TABLE XXVI

ANALYSES OF WATER SAMPLES FROM MORTANDAD CANYON

Determination	Unit	Surface Water Station 9	Surface Water Station 10	Ground Water Station 9	Ground Water Station 10	Ground Water Station 11	Ground Water Station 12	Ground Water Station 13	Ground Water Station 14	Ground Water Station 15
No. of Samples		4	4	4	4	4	4	4	4	3
Gross alpha	10^{-9} µCi/ml	12	12	11	9	2	2	2	1	1
Gross beta	10^{-9} µCi/ml	520	520	610	340	110	130	70	70	50
Plutonium-238	10^{-11} µCi/ml	870	600	390	93	13	8	9	8	10
Plutonium-239	10^{-11} µCi/ml	72	90	35	16	8	<5	6	11	52
Americium-241	10^{-11} µCi/ml	76[a]	86[a]	50[a]	10[a]	19[a]	22[a]	8[a]	110[a]	31[a]
Cesium-137	10^{-7} µCi/ml	7	<4	4	<4	<4	<4	<4	<4	<4
Tritium	10^{-6} µCi/ml	24	36	47	64	78	60	44	79	130
Total uranium	10^{-4} µg/ml	32	84	76	79	27	34	18	18	9
Calcium	µg/ml	17	27	35	35	34	34	40	46	56
Magnesium	µg/ml	5	6	5	8	11	12	12	11	17
Sodium	µg/ml	61	260	240	260	200	23	170	170	110
Carbonate	µg/ml	0	8	3	0	0	0	0	0	0
Bicarbonate	µg/ml	210	340	290	260	220	250	190	170	140
Chloride	µg/ml	14	39	28	42	57	73	74	76	57
Fluoride	µg/ml	1	2	2	1	1	1	<1	<1	<1
Nitrate	µg/ml	10	68	65	67	49	56	51	50	49
Dissolved solids	µg/ml	480	1100	980	1000	810	920	770	790	720
Hardness	µg/ml	61	96	110	120	130	130	150	160	210
pH	--	8	8	8	8	7	8	8	7	7
Conductivity	µmho/cm	530	1200	1100	1200	960	1100	930	940	820
Cadmium	10^{-4} µg/ml	4[b]	12[b]	3[b]	18[b]	22[b]	5[b]	6[b]	<3[b]	-
Lead	10^{-3} µg/ml	<1[b]	18[b]	45[b]	29[b]	26[b]	<1[b]	<1[b]	<1[b]	-
Beryllium	10^{-4} µg/ml	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	-
Mercury	10^{-5} µg/ml	<2[b]	<2[b]	<2[b]	<2[b]	<2[b]	<2[b]	<2[b]	<2[b]	-
Cadmium[c]	10^{-4} µg/ml	<3[b]	6[b]	<3[b]	4[b]	<3[b]	<3[b]	<3[b]	<3[b]	-
Lead[c]	10^{-3} µg/ml	<1[b]	<1[b]	18[b]	30[b]	6[b]	<1[b]	<1[b]	<1[b]	-
Beryllium[c]	10^{-4} µg/ml	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	<3[b]	4[b]	<3[b]	-
Mercury[c]	10^{-5} µg/ml	30[b]	<2[b]	3[b]	<2[b]	19[b]	15[b]	15[b]	<2[b]	-

[a]Two samples.

[b]One sample.

[c]Particulates.

average values measured in Mortandad and Guaje Canyons are comparable to those measured in kidney samples from the general human population. Mercury concentration levels in rodent kidney samples from DP Canyon are significantly higher than those from the other canyons. Additional studies into the origins and environmental extent of the mercury are planned.

C. Ecological Investigation of Radioactive Materials in Waste Discharge Areas

Three canyon areas at Los Alamos have received LASL-generated effluents containing several radionuclides in varying amounts. Because use histories of these areas vary (one dates back to 1943), there was an opportunity to study the effects of environmental "aging" on the bioavailability of these radionuclides. The studies in these outdoor laboratories began in July 1972 and are being conducted under the auspices of the DBER. The project is summarized here, and the lengthy data tables will be saved for a later publication.[16] The investigation consists of two stages: first, a detailed biotic inventory of the area, and second, the collection and study of various types of samples from the subject area. Corollary to the second stage is a resurvey of Trinity Site (where the world's first nuclear device was detonated) to obtain additional information on the effects of environmental aging.

Stage 1. The faunal and floral composition of the environs of the Laboratory is diverse, primarily because of

TABLE XXVII

ANALYSES OF SOIL AND SEDIMENT SAMPLES FROM NEAR TA-50 AND IN MORTANDAD CANYON

Determination	Unit	Soil Station 2	Sediment Station 5
No. of Samples		1	1
Gross alpha	10^{-8} μCi/g	3	2
Gross beta	10^{-8} μCi/g	13	24
Plutonium-238	10^{-9} μCi/g	4	2000
Plutonium-239	10^{-9} μCi/g	100	780
Cesium-137	10^{-8} μCi/g	6	63
Tritium[a]	10^{-8} μCi/ml	9	-
Total uranium	10^{-2} μg/g	37	67

[a]Soil moisture distilled from sample.

a 1200-m elevational gradient extending in the east-west direction in the county. The landscape is dominated by an overstory of ponderosa pine *(Pinus ponderosa)*, pinon pine *(Pinus edulis)*, and one-seeded juniper *(Juniperus monosperma)*. The ponderosa pine and pinon-juniper ecotone (intermingling zone) ranges from 2100 to 2200 m on the mesa tops and from 1950 to 2050 m in the canyon bottoms where soil and moisture conditions are more favorable. The herbaceous and shrubby understory is characteristically sparse for the area as a whole. However, the canyon bottoms support a lush growth of vegetation dominated by grasses, especially the genera *Poa* and *Bouteloua*. Shrub species occur primarily at the lower elevations of the canyon bottoms. Salt bush *(Atriplex canescens)* and big sage *(Artemisia tridenta)* are the most common species. A reference library of plant specimens found on Laboratory property currently contains 110 specimens that have been identified by personnel of the Biology Department of the University of New Mexico.

The canyon areas also harbor the majority of the animal and bird species. Restricted human access to Laboratory property and an abundance of vegetation, along with surface water from Laboratory effluents, have created an ideal living and hunting area for a wide variety of mammals, including rarely-seen species such as the black bear *(Ursus americana)*, the bobcat *(Lynx rufus)*, the mountain lion *(Felis concolor)*, the golden eagle *(Aquila chrysaetos)*, and the turkey *(Meleagris gallopaud)*. The mule deer *(Odocoileus hemionus)* is the most abundant large herbivore, and the coyote *(Canis latrans)* is the most abundant carnivore. Nearly 200 species of birds can be found in Los Alamos County,[17] including a sizable overwintering population of ravens *(Corvus corax)*. About 225 species of fauna occur in the county. Several state and federal agencies, including the N.M. Department of Game and Fish, the N.M. EIA, the U.S. Forest Service, and the U.S. Fish and Wildlife Service contributed information on the vegetation and animals of this area.

Stage 2. A series of sampling stations has been permanently marked in Acid, Pueblo, DP, Los Alamos, and Mortandad Canyons (Fig. 18). Acid and Pueblo Canyons received untreated and, later, treated industrial liquid waste for a 21-yr period from 1943 to 1964; DP and Los Alamos Canyons have received treated industrial liquid waste for a 20-yr period beginning in 1952; and Mortandad Canyon has received treated industrial liquid waste for an 8-yr period beginning in 1964. Two stations--at 100 and 200 m above the liquid effluent outfalls--serve as "background radionuclide" areas, whereas stations at 0, 20, 40, 80, 160, 320, 640, 1280, 2560, 5120, and 10,240 m below the outfalls provide sample materials that have been exposed to the radionuclide-contaminated effluents. A combination of radiochemical techniques is used to analyze the samples for ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am.

A piece of 2-cm-diam polyvinyl chloride pipe was used to collect sediment cores at the middle and at two lateral

TABLE XXVIII

SMALL-MAMMAL COLLECTIONS (1971) IN WASTE DISCHARGE AREAS

Common Name	Genus and Species	Total Number Collected At: DP	Mortandad	Guaje
Colorado chipmunk	Eutamias quadrivittatus	10	8	3
Least chipmunk	Eutamias minimus	--	--	4
Deer mouse	Peromyscus maniculatus	7	5	16
Pinon mouse	Peromyscus truei	7	10	--
House mouse	Mus musculus	1	--	--
Brush mouse	Peromyscus boylii	--	1	--
Rock squirrel	Spermophilus variegatus	--	1	1
Long tailed vole	Microtus longicaudus	--	--	2
Wood rat	Neotoma mexicana	--	--	1

TABLE XXIX

PLUTONIUM CONCENTRATIONS OBSERVED IN TISSUES OF 1971 VECTOR RODENTS

(Disintegrations Per Minute Per Gram of Wet Tissue)

Composited Tissue	Outfall Range Min	Outfall Range Max	Outfall Av	300-m Line Range Min	300-m Line Range Max	300-m Line Av	600-m Line Range Min	600-m Line Range Max	600-m Line Av
				DP Canyon					
Liver	< 0.01		<0.01	<0.01	0.029	<0.024	<0.01		<0.01
Muscle	< 0.01		<0.01	<0.01		<0.01	<0.01	0.014	<0.013
Bone	0.12	0.30	0.22	<0.01	0.048	<0.039	<0.01	0.013	<0.011
Remainder	0.003	0.007	0.005	<0.001	0.003	<0.002	<0.001	0.003	<0.001
				Mortandad Canyon					
Liver	Lost			0.017		0.017	9.81		9.81
Muscle	<0.01	0.027	<0.024	0.011	0.068	0.026	<0.001	0.007	<0.001
Bone	0.110	0.174	0.164	0.084	0.269	0.223	<0.01		<0.01
Remainder	0.198	0.208	0.206	0.012	1.296	0.333	0.038	0.071	0.062
				Guaje Canyon[b]					
Liver				<0.01		<0.01			
Muscle				<0.01	0.048	<0.020			
Bone				<0.01	0.020	<0.016			
Remainder				<0.001	0.013	<0.009			

[a]Tissue types were combined within each genus and collection location for plutonium analysis. Results of these analyses were then summarized for presentation here without regard to genus or species at each collection point.

[b]Guaje Canyon served as a control area.

TABLE XXX

TRITIUM CONCENTRATIONS OBSERVED IN WATER FROM LIVER OF 1971 VECTOR RODENTS

(pCi ^{3}H per ml Water)

Location	Range Min	Range Max	Av
DP Canyon	5	55	24
Mortandad Canyon	12	119	55
Guaje Canyon	<5	15	<7

TABLE XXXI

MERCURY CONCENTRATIONS OBSERVED IN KIDNEY TISSUES OF 1971 VECTOR RODENTS

(μg Hg per g Wet Tissue)

Location	Range Min	Range Max	Av
DP Canyon	0.10	0.70	0.26
Mortandad Canyon	0.01	0.13	0.07
Guaje Canyon	0.02	0.10	0.05

positions of the stream channels for a total of three cores at each sampling station. The pipe was driven into the sediment to a maximum depth of 33 cm, and each pipe, along with the contained core, was sealed in a polyethylene bag and frozen to facilitate sectioning (for the vertical distribution data).

The above-ground portions of the grasses and forbs and the terminal leaves and stems from the shrub and tree species were also sampled at each station, where possible. Vegetation samples were also frozen in sealed polyethylene bags.

Rodents were collected by means of snaptrap grids at five locations in each of the three canyon systems. Two of the locations were 100 and 200 m above the outfall areas, and the remaining three were at the 0-, 2560-, and 10,240-m post-outfall stations. This arrangement allowed

estimation of bioavailability of radionuclides as a function of distance along, and lateral distance from, the stream channels. A few samples of other animals, such as mule deer *(O. hemionus)*, Steller's jays *(Cyanositta stelleri)*, and ravens *(C. corax)*, were taken from each canyon and from other parts of the county, the latter constituting a background sample.

A complete set of sample materials consisting of about 500 individual specimens was obtained from the three canyon areas in October and November 1972 and is in various stages of radionuclide analysis.

A complete set of analyses for any one of the five radioisotopes of interest is not yet available. However, sufficient data on tritium are available to provide a preliminary picture of the radioecological behavior of this nuclide in the components of the three canyon ecosystems.

Acid Canyon, an area that has not been used for liquid waste disposal for 10 years, has relatively small quantities of tritium in stream-channel water, vegetation, and small mammals. A maximum of 8 pCi/ml ^{3}H was measured in moisture from oak (*Quercus gambelli*), but the overwhelming majority of samples averaged from 2 to 4 pCi/ml. These values closely approximate the tritium levels in vegetation samples from the Laboratory environs as a whole.[18]

In Mortandad and DP Canyons, tritium levels in samples from areas near the outfalls average higher by about a factor of 10 than the Acid Canyon samples. The maximum concentration of tritium in moisture from DP Canyon vegetation and rodents was 176 and 21 pCi/ml, respectively, whereas the corresponding values for Mortandad Canyon were 60 and 49 pCi/ml. There is an obvious sphere of influence of the tritium-contaminated effluents in Mortandad and DP Canyons. The effluent water that disappears into the alluvium about 1 km below the outfalls apparently continues to supply tritium to the vegetation for an additional distance downstream. However, at distances over 3 km below the outfall, the levels of tritium in vegetation drop to ambient levels for the Los Alamos area (2 to 4 pCi/ml).

The fact that the ratio of tritium in the biotic samples to tritium in the effluent water was less than one (e.g., ratio of picocuries per milliliter in free water of biotic samples to picocuries per milliliter in effluent water is less than one) indicates that tritium is not concentrated in the environment.[19] However, studies on honeybees [see Technical Notes (Hakonson)] from these canyons show an anomaly with respect to these findings.

Cesium-137, present in the liquid waste effluents, is being incorporated into biological tissue. This finding has been reported by others.[20] The highest concentrations of ^{137}Cs–about 1000 pCi/liter–are found in Mortandad Canyon effluent water at the place where it leaves the treatment facility.

Plutonium and americium data are still fragmentary, but apparently the hide and lungs of rodents contain the highest ^{238}Pu and ^{239}Pu concentrations. This suggests that resuspension and inhalation of plutonium may be the most important entry into rodents.

A resurvey was made of Trinity Site, on White Sands Missile Range in New Mexico, to determine the concentrations of radionuclides in soils, vegetation, and assorted animal life as a follow-up to surveys conducted from 1947-1950.[21] Analysis of the resurvey data should provide additional information on the biological availability of radionuclides (particularly plutonium) that were dispersed by a nuclear detonation and that have aged in a natural environment for over 27 yr. Sampling transection was initiated at ground zero, and was continued in a northeasterly direction (along the principal fallout pathway) at 8-km increments to a distance of 60 km. Results from the collection effort are not yet available.

D. Los Alamos Land Areas Environmental Radiation Survey, 1972

Details of an environmental radiological evaluation of about 5500 acres in eight parcels of Los Alamos County land owned by the AEC are presented in Los Alamos Scientific Laboratory report LA-5097-MS. This real property was surveyed before its transfer from the AEC to the U.S. Bureau of Land Management. The environmental assessment of the property included a careful search of LASL's administrative records to determine the extent to which the land might have been involved in the Laboratory's activities. This search, together with personnel interviews, did not reveal any indication of disposal, burial, or storage of radioactive materials on the surveyed property.

Radiation levels were measured in the field to assess *in situ* evidence of radiocontaminants. Total exposure rates in microroentgens per hour were obtained with a gamma radiation sensitive instrument. The average gross gamma radiation measurements from these land parcels were not significantly different from background radiation levels measured in north-central New Mexico. The measured rates generally fell within the range of 13 to 21 $\mu R/h$, which has been reported as normal for the Los Alamos elevation, depending on local anomalies in the composition of the earth's crust.

A gamma radiation sensitive instrument could not be used to measure environmental plutonium, americium, and other heavy metals of interest because their low-energy photon emissions are not efficiently detected. The problem was solved by development at LASL of a

portable, spectral-selective, low-energy photon detection system, the Los Alamos Field Pulse Height Analyzer (LAFPHA), which was used to obtain gross indications of plutonium and americium contamination in the field. LAFPHA is described in the Technical Notes (Johnson) section of this report. In the field, this detection device showed no radioactive contamination above natural radiation levels.

Soil and vegetation samples were collected for radiochemical analysis at each designated sampling point. The soil samples consisted of a 7.5-cm-diam by 5-cm-deep core sample taken from the center and corners of a 10-m square. These soil cores were combined into a single soil sample representing a point within a given parcel. Ponderosa, pinon, and juniper needles were analyzed. These predominant species were selected because they are perennial and may have retained airborne contaminants. Determinations were made on these soil and plant samples for: tritium (in the free moisture of plant tissues), gross beta activity, ^{137}Cs, $^{238,239}Pu$, ^{241}Am, and uranium (total).

Tritium measurements from plant moisture were measurably higher than those from other north-central New Mexico samples. This is consistent with previous environmental reports[1,2] which show tritium activity in the atmospheric water to be about twice as high. Standards for tritium concentration in the moisture of vegetation have not been established, but observed concentrations were about 0.1% of those listed for tritium in the concentration guides in AEC Manual Chapter 0524 for tritium in water for uncontrolled areas.

Gross beta and ^{137}Cs concentrations in soil averaged about 20 and 3 pCi/g, respectively, and in vegetation averaged about 5 and 2 pCi/g. Concentrations measured on the surveyed land parcels were not significantly different from background values measured in soil and vegetation samples from north-central New Mexico.

Most measurements for both plutonium isotopes ranged from 0.01 to 0.10 pCi/g of soil for the survey samples and also for the north-central New Mexico controls. A soil sample from one survey location near a Laboratory research facility had a plutonium concentration higher than worldwide fallout levels by a factor of two to three. The average plutonium concentrations for the other land areas do not differ significantly from observed background concentrations of plutonium in soil due principally to worldwide fallout. The average range for plutonium concentration in vegetation was <0.001 to 0.02 pCi/g (wet weight) of plant tissue. No comparable data have been reported previously, but survey samples and control area samples showed comparable levels in vegetation.

Average ^{241}Am concentration in the land survey samples ranged from <0.03 to 0.10 pCi/g in soil and from 0.006 to 0.03 pCi/g (wet weight) in vegetation. These concentrations are identical with values from background area samples. No background values for americium in soil or vegetation are available for comparison.

The average uranium concentration in soil and vegetation ranged from 0.42 to 0.92 μg/g in soil and <0.03 to 0.21 μg/g in wet tissue. These values fall within previously reported ranges.

Results of this radiation survey indicate that the land parcels included in this study have radiation levels at or near background. No abnormal *in situ* field radiation levels were observed either in total gamma radiation measurements or from readings for low-energy photons obtained with LAFPHA. Measurements of gross beta, ^{137}Cs, $^{238,239}Pu$, ^{241}Am, and total uranium in these soil and vegetation samples show concentrations similar to those at locations far removed from nuclear energy installations. Tritium concentrations in general, and plutonium and americium concentrations at a few points, were higher than past weapons-testing fallout would indicate.

E. Tornado Frequency and Intensity in the Southernmost Portion of the Rocky Mountains

LASL has been authorized to conduct preliminary planning and Titles I and II design work for a new plutonium processing plant that must meet recently established AEC minimum criteria for plutonium-handling facilities. The structure must be designed to withstand a tornado or an earthquake of a certain minimum intensity; consequently, the design of the plant requires studies of interest to the environmental field. A summary of the tornado study is presented in this section, and the seismicity studies are summarized in Sec. IX.F.

The investigation into the likelihood and nature of a tornado in the Los Alamos area was conducted by T. Theodore Fujita of the University of Chicago's Satellite and Mesometeorology Research Project.[22]

In various parts of the world there is significant variation in both frequency and maximum wind speed (intensity) of tornadoes. Current statistics indicate that the U.S. ranks first in both intensity and frequency of tornadoes, followed by India, Canada, Europe, Australia, Japan, New Zealand, and by other areas where tornadoes are less frequent. In the U.S. there is a strong negative gradient in frequency and intensity between the central plains, where tornadoes are frequent and severe, and the Rocky Mountains, where they seldom occur and are generally weak.

Intensities of all (235) tornadoes reported in New Mexico and southern Colorado (to 39° north latitude) from 1950 through 1971 were studied. The area was divided into 15′ quadrangles of latitude and longitude, and the mean elevation and elevation range were recorded for each quadrangle. The intensities were then correlated with these two parameters. Both frequency and intensity

were found to decrease very rapidly with increasing mean elevation and elevation range. Furthermore, a study made of annual and diurnal variations in tornado occurrences in connection with meteorological characteristics of the atmosphere indicated that tornadoes in mountainous regions are spawned from premature thunderstorms and develop earlier in the day than in plains regions. These midday tornadoes are considerably weaker than the mid-western evening storms.

Finally, the maximum intensity tornado for which structures at Los Alamos should be designed was defined by Fujita as

Maximum windspeed	200 mph
Rotational windspeed	170 mph
Translational speed	30 mph
Radius of circle of maximum rotational wind	100 ft
Maximum pressure drop at center	0.75 psi
Maximum rate of pressure change	0.33 psi/sec

F. Geologic and Seismic Studies of the Los Alamos Area

In compliance with the minimum criteria for plutonium-handling facilities, the architect-engineer for the proposed new LASL plant, the Fluor Corporation of Los Angeles, executed a consulting contract with the geoscience engineering firm of Dames and Moore to provide a study of the geologic, foundation, hydrologic, and seismic characteristics of the site. It was recognized by the Laboratory, at about the same time, that other programs, for instance the geothermal energy project, would require a better understanding of the geology and seismicity of the area. For this reason LASL arranged contracts with Drs. A. R. Sanford and A. J. Budding of the New Mexico Institute of Mining and Technology to study the seismicity of the Los Alamos area. This coincidence in timing made it logical for Fluor to retain both Sanford and Budding as contributors to the evaluation of seismic risk at Los Alamos. These studies enhance our total knowledge and understanding of the environment, and summaries are included here.

The Dames and Moore study[23] included detailed evaluations of the geologic features within a 330-km radius of the site and thorough explorations of the area immediate to the site. The proposed site is on the Pajarito Plateau, a part of the Rio Grande depression that is a major structural feature extending north to south through central New Mexico. The plateau was formed by ashflows and ashfalls of rhyolite tuff that were extruded from the Jemez Volcanic Locus to the west. Geologic history indicates that the Rio Grande depression began forming in early Tertiary time, but Quarternary faulting and volcanic activity were also associated with the formation of the depression.

The north-south trending trace of the Pajarito Fault, which is considered "active" according to AEC criteria, lies about 4.5 km west of the proposed plant site. However, a trench excavated across the site showed no evidence of faulting or tectonic fractures associated with the Pajarito Fault system, and the probability of surface faulting occurring in the immediate vicinity of the site during the lifetime of the facility is minimal.

According to historical records the largest earthquake in the area had an intensity of about VIII on the Modified Mercalli Scale (a measure of observed effects). This earthquake occurred in 1918 at Cerrillos, about 60 km southeast of Los Alamos. In accordance with the criteria, two design basis earthquakes were defined: An "Operating Base Earthquake" of intensity VII, but less than VIII, and horizontal ground motion acceleration (hgma) of 0.17 g; and a "Safe Shutdown Earthquake" of intensity VIII and hgma of 0.33 g. The response spectra for the two hypothetical events were based on analyses of other earthquakes of similar intensity and hgma modified to fit the geology of the Los Alamos area.

The Sanford study[24] of seismic risk in the Los Alamos Area was based on seismological records. The data for all shocks occurring within 111 km of Los Alamos included (1) historical noninstrumented reports of earthquakes before 1962, and (2) records of instrumented studies of shocks from 1962 to 1972. Magnitudes were inferred from the historical reports which, of necessity, related to effects (intensity).

The strongest earthquake to occur within the region of study during the 100-yr period, 1872-1972, had a probable magnitude of 5.5 on the Richter scale. Estimates of the strongest shock to occur in a 100-yr period, based on extrapolation of the earthquake frequency-magnitude relation, range from 3.9 to 5.4, depending on the data set used. The study concludes that the Los Alamos area is subject to an earthquake of magnitude 5.5 once every 100 yr somewhere within the Rio Grande depression from Albuquerque to Questa.

The Budding evaluation[25] of seismic risk in the Los Alamos Area was based on geologic evidence. Geologic studies related to fault characteristics yield theoretical data on the magnitude and frequency of shocks produced from rupture along faults or in fault zones, that is, data on the past seismic history of the area. Data required are the length of the fault, offset or throw of the fault, and age of stratigraphic units broken by the faults. The major faults studied were the Pajarito, Los Alamos, Guaje Mountain, and Water Canyon faults. All are north-south trending faults downthrown to the east or west and breaking the upper Tshirege Member of the Bandelier Tuff. The age

of the Tshirege Member has been estimated by the potassium-argon method at 1.1 million years.

Calculations revealed that these faults produced 133 seismic events with average local magnitude of 6.7 (range 5.9 to 6.8) in the past 1.1 million years. In terms of seismicity of the area this means that magnitude-6.7 earthquakes occurred at approximately 8270-yr intervals or that magnitude-4.8 earthquakes occurred at 100-yr intervals. The seismicity of the Los Alamos region is thus estimated to be one magnitude-5 earthquake per 100 yr, in good agreement with the seismological study of Sanford. The seismicity of this section of the Rio Grande depression is less than that of the Albuquerque-Socorro section (with an estimated maximum magnitude shock of 6 in a 100-yr interval) and substantially less than that of an equivalent area in Southern California.

The Rio Grande depression has the potential for future volcanic eruptions, as does the dormant Jemez Volcanic Locus. Although the possibility of a major rhyolite ash-flow and ashfall type of eruption is remote, a smaller rhyolite eruption could occur. The structural development and periodicity of past eruptions indicate a very low probability of even the smaller event occurring within the next 1000 yr.

Other geological hazards of lesser significance, such as rock falls, landslides, and ground compaction due to withdrawal of ground water do not pose any significant problem at the site.

Subsurface conditions at the proposed site were explored by test drilling. The excavation of the building will be to 8 m into the tuff with foundations bearing on a moderately welded unit. This unit will provide good vertical and lateral support, with a design for a spread foundation.

There is no danger of flooding at the site due to its topographic location on the top of a mesa. Surface water runoff from precipitation goes into a small canyon that is tributary to the Rio Grande. Infrequent storm runoff percolates into the alluvium on the canyon floor because of the small drainage area and large volume of unsaturated alluvium within the project boundaries.

Ground water occurs in two separate systems: an upper perched ground water body in the alluvium of the canyon; and a deeper aquifer. The water in the alluvium is recharged from storm runoff and the effluents released from two Technical Areas. As the water in the alluvium moves eastward it is depleted by evapotranspiration and exists as a ground water body of limited extent, terminating about 5 km east of the proposed site.

The deep ground water body is recharged from precipitation on the high mountains to the west, with the water in the aquifer moving eastward toward the Rio Grande, where a part is discharged into the river. The top of the deep aquifer lies 400 m below the surface of the mesa at the proposed site. Movement of water in the aquifer is estimated at 22 m per year.

The Dames and Moore report[23] concludes that "the site proposed for the plutonium facility . . . is suitable for this proposed use, from the standpoint of its geologic, foundation, hydrologic and seismological setting."

X. DISCUSSION

The results of the monitoring program for this report period confirm the generally low radiation levels in the Los Alamos environs noted in previous periods. Measurements of the gross activities in air and precipitation indicate concentrations similar to those measured at other locations in the northern hemisphere where activity is entirely attributable to the presence of worldwide fallout. Airborne plutonium and tritium measurements reveal that Laboratory activities have elevated slightly the levels of both materials above the concentrations expected from fallout due to past weapons testing and reentry and burnup of isotope power sources contained in space vehicles.

In the text, comparisons were made between observed concentrations and applicable guides for off-site and on-site areas, respectively. Since site boundaries are near some of the on-site stations used for these comparisons and since public use of adjacent roads is normally permitted (although use can indeed be restricted), comparisons are made in this section between on-site concentrations and off-site guides.

The highest average of total plutonium ($^{238}Pu + ^{239}Pu$) concentration at a station accessible to the public was 1.4×10^{-16} μCi/ml and occurred at station 304-2.6 (Fig. 6 No. 34, TA-3). (Station 277-3.3 recorded a slightly higher average total concentration, but is located in a remote area inaccessible to the public.) This combined on-site concentration is approximately 0.23% of the most restrictive guide value of 6×10^{-14} for the soluble form of ^{239}Pu in uncontrolled areas.

During this reporting period the highest average on-site tritiated moisture concentration in the Los Alamos area was 1.8×10^{-10} μCi/ml, less than 0.1% of the guide value of 2×10^{-7} μCi/ml for uncontrolled areas. This concentration was sufficient to produce a whole-body dose of about 0.3 mrem, using the Quality Factor of 1.7 used in the derivation of the 1960 ICRP-NCRP maximum permissible concentrations that apparently served as the bases for the AEC Manual Chapter 0524 concentration guides. If the Quality Factor of 1.0 now accepted by the ICRP and NCRP is used for these low-energy beta radiations, this dose is about 0.2 mrem. This may be compared with the radiation protection guide for annual dose to the whole body (AEC Manual Chapter 0524) of 500 mrem for an individual or 170 mrem for the most restrictive segment of the population.

External gamma- and x-radiation levels, as measured by the TLD array were comparable to those measured elsewhere at approximately the same elevation. This suggests that the predominant contribution to external dose is from cosmic and naturally occurring terrestrial sources.

The Los Alamos water supply remained uninfluenced by Laboratory operations. Traces of naturally occurring arsenic were found in samples from one supply well, but dilution of the water in the remainder of the distribution system reduces the concentration to acceptable levels. Traces of plutonium were tenuously identified in water samples from two off-site bodies of surface water.

Small quantities of plutonium and some beta emitters, both a result of past disposal operations, were found in sediment collected in an off-site canyon. This area, although accessible to the public, is reasonably isolated, so that occupancy is limited to an occasional hiker or hunter. This low occupancy factor and/or the association of the material with large quantities of sediment would preclude the uptake of any significant quantities by people, animals, or plants.

Knowledge of this type of contamination is being augmented by two studies of the Los Alamos area, one conducted during the summer of 1971 and the other a continuing program conducted under the sponsorship of the DBER. The former program showed that there was uptake into small mammals of radionuclides from effluents released in two liquid waste disposal areas. The DBER investigation was initiated in July 1972 and is intended to take advantage of the varying and documented use histories of these two disposal areas, and a third area which has been abandoned, to study in detail the processes involved in the ecological assimilation of radionuclides into the environment. Only preliminary results are available, but they corroborate the findings of the 1971 study.

Because of the low emissions of radioactive materials that could enter the food chains and the insignificant use of the surrounding area for food production, the food supply at Los Alamos has not been sampled extensively. This is not believed to be a serious gap in documenting the exposures in the environs, and it will be filled partly by the information gained from the DBER program mentioned above and partly by a program of milk surveillance which is in the initial stages.

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THE HONEYBEE AS AN INDICATOR OF ENVIRONMENTAL RADIOCONTAMINATION

by

Thomas E. Hakonson

One aspect of the radioecological studies at Los Alamos deals with the identification of plant and animal species that can be used as biological indicators of radionuclide contamination in the natural environment. Honeybees *(Apis mellifera)*, used in the current study, are potentially useful as indicator organisms because they are known to incorporate and concentrate certain radionuclides within their bodies; they require a source of surface water for drinking and other purposes; they forage over a large area and come into contact with plants which are eaten by other organisms; they are colonizing insects and therefore are easily sampled; and they produce a food (honey) that is consumed by humans.

Hives of bees were placed near the outfalls of three Laboratory liquid waste disposal facilities, where the bees had access to water and vegetation possibly contaminated by various radionuclides. These outfalls are located in Acid Canyon, DP Canyon, and Effluent Canyon, which is a small tributary to Mortandad Canyon (Fig. 18). Use of the outfall in Acid Canyon was discontinued in 1964.

Bees, honey, and effluent water were collected routinely and analyzed for tritium, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am by a combination of radiochemical techniques. Analyses for plutonium and americium in bee, honey, and water samples are incomplete, but ^{137}Cs and tritium determinations are complete for the 4-month period subsequent to experiment initiation on June 29, 1972.

Cesium-137 was unmeasurable in any of the 150 bee and honey samples that were analyzed, even though levels of this radionuclide in DP and Mortandad Canyon effluent water averaged about 50 and 1000 pCi/liter, respectively.

Tritium, on the other hand, was readily measurable in the free water of bee and honey samples. Levels of tritium in bees rose from about 1 pCi/ml of sample water in background, or pre-experiment, samples to a maximum of 560 pCi/ml in Acid Canyon samples, 250 pCi/ml in DP Canyon samples, and 9600 pCi/ml in Mortandad Canyon samples (Figs. T-1, T-2, and T-3). Tritium levels decreased in all bee samples taken during September and October

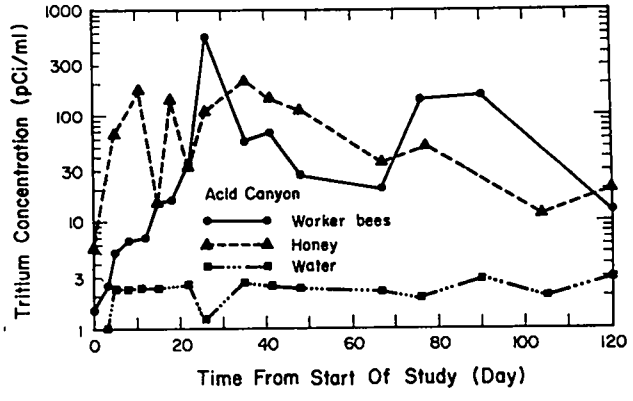

Fig. T-1.
Acid Canyon bee study.

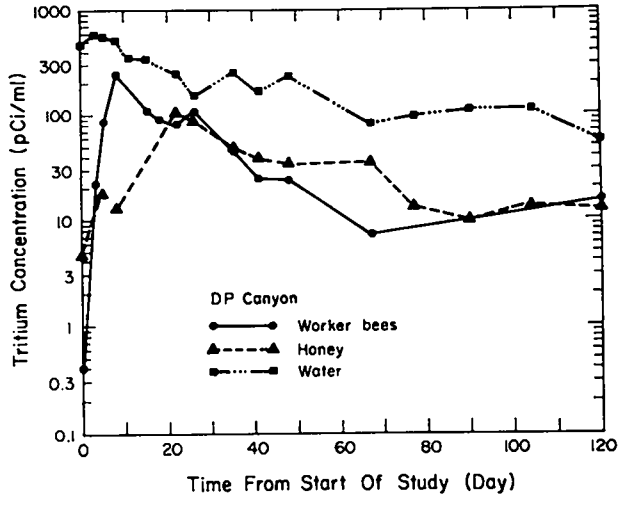

Fig. T-2.
DP Canyon bee study.

(the 60- to 120-day period shown in the figures). This decrease may possibly be correlated with seasonal changes such as colder ambient air temperatures and vegetation

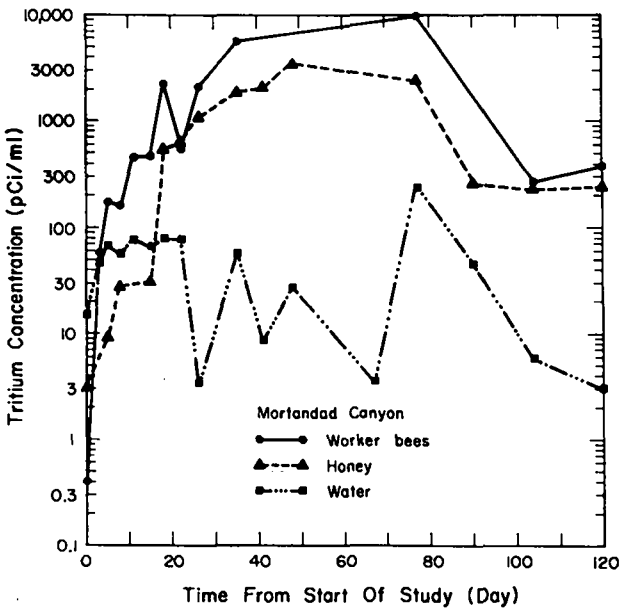

Fig. T-3.
Mortandad Canyon bee study.

dieback. It is interesting that tritium levels in honey during the 4-month period paralleled the corresponding data for the bees. It is not known whether the honey became contaminated with tritium from tritium-bearing effluent water or from food. The Acid and Mortandad Canyon preliminary data in Figs. T-1 and T-3 lead one to speculate that the bees either were obtaining tritium from a source other than the effluent water or were concentrating tritium, because the levels of this nuclide in bees from Acid and Mortandad Canyons were as much as 450 and 230 times the levels in the effluent water from the respective canyons. This is worrisome because there is very little evidence for the biological concentration of tritium. The alternative, that the bees were obtaining tritium from a source other than the effluent water, is also troublesome because such a source has not been located. Moreover, preliminary data indicate that the vegetation surrounding the beehives in the two canyons does not contain sufficient tritium to account for the tritium levels in the bees. In contrast to the above observations, the tritium activity in bee and honey samples from DP Canyon (Fig. T-2) was below that in the effluent water–the presumed source of the bees' drinking water. This amounts to a deconcentration of tritium activity by the bees. Further development of these incomplete studies is being planned.

LOS ALAMOS FIELD PULSE HEIGHT ANALYZER (LAFPHA) INSTRUMENT DEVELOPMENT AND USE

by

LaMar J. Johnson

An environmental radioactivity survey on more than 5500 acres of land near LASL was conducted during 1972. Because the determination of such materials as the actinides in a soil matrix by radiochemical techniques requires considerably more time and effort than *in situ* measurements (provided the soil does not shield the photon emissions from the detector), it immediately became apparent that the number of data points required by the survey could only be collected using a field measuring device sensitive enough to detect the presence of trace radiocontamination. A further requirement was that the device allow spectral measurements so that radioactivity from particular isotopes, rather than merely gross radioactivity, could be measured. *In situ* spectrometry has the important disadvantage that the accuracy of the anlysis depends on a separate knowledge of the radioactivity distribution with soil depth. Thus, for determining environmental levels of radioactivity in soil, both sample analysis in the laboratory and field spectral measurements are necessary. The transuranic elements, ^{238}Pu, ^{239}Pu, and ^{241}Am, were of primary interest in the above survey, and a detection system was needed that would measure the low-energy photons associated with their decay. A NaI(Tl) scintillation detector with a crystal diameter of 12.7 cm and 0.16-cm thickness was selected. This commercially available detector has become commonly known as the Field Instrument for the Detection of Low-Energy Radiation (FIDLER). The signal from this detector has been processed by a 2- or 3-channel count ratemeter in past applications. Such a count ratemeter readout entails a high degree of uncertainty in the visual interpretation of the rate-indicating dial and does not provide the spectral information needed to infer radionuclide identity.

To facilitate the above-mentioned environmental radioactivity survey and to overcome the ratemeter weaknesses, a portable (battery-powered) pulse height analyzer was developed. This analyzer, which processes the scintillation detector signal, was designated the Los Alamos Field Pulse Height Analyzer (LAFPHA). LAFPHA has six channels that simultaneously record input pulses. Each channel has independent lower and upper energy bound adjustments, allowing overlaps or gaps in the analyzed spectrum. Each channel has "blind" scalers, with the stored contents made available for display at the push of a button. The pulse counters have five decades of memory, but channels 2 and 5 have optional sixth decades that can be switched in as needed. A channel may be read out by pushing a button to activate a decoder/driver. Readout is light-emitting diode dot matrix assemblies. The press-to-read arrangement and the display of only the four top decades were chosen for power conservation. A preset timer controls the counting time of all channels. A count ratemeter can be used simultaneously in selected channels for instantaneous indication of activity level. In addition, an audible beeper can be switched into a channel of interest to alert to rate changes during a scanning survey.

The LAFPHA is shown in Fig. T-4. The electronics is enclosed in an aluminum aircraft luggage case with a total weight of 10 kg including the 12-V rechargeable battery

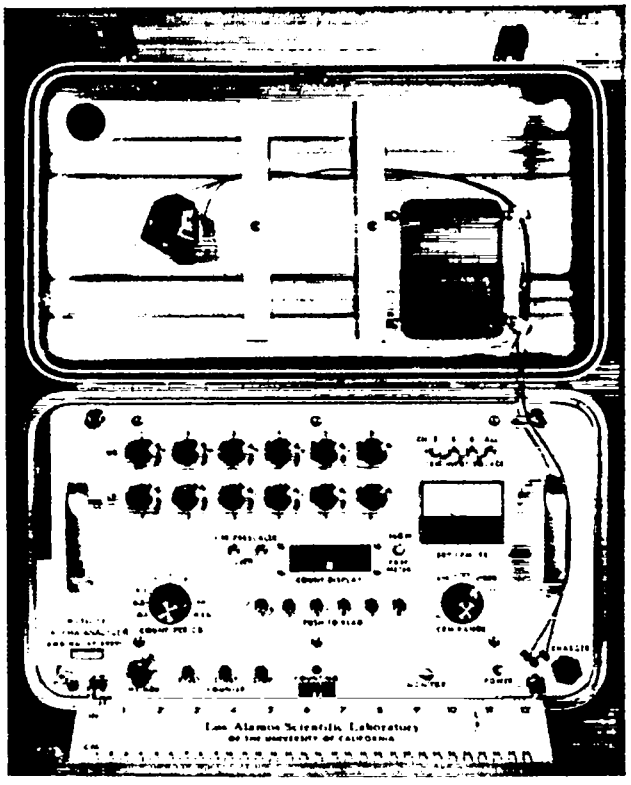

Fig. T-4.
The Los Alamos Field Pulse Height Analyzer (LAFPHA).

pack but not the detector assembly. Extensive use of integrated circuits provide good stability and enhanced reliability. Detailed electronic engineering features of the analyzer will be described elsewhere.*

The LAFPHA-FIDLER system was calibrated to estimate the plutonium and americium surface contamination levels. Uranium and neptunium L series x rays (approximate unresolved energy of 17 keV) are produced in the daughters of plutonium and americium, respectively. The daughter of ^{241}Pu by beta decay, ^{241}Am, also emits a 59.5-keV gamma ray. LAFPHA channels 2 and 5 were set to measure the 17-keV energy band and the 59.5-keV gamma ray, respectively. The energy bounds were set, somewhat arbitrarily, at 12.8 and 21.6 keV for channel 2, and at 52.0 and 65.6 keV for channel 5. The other channels were set at surrounding energy intervals to allow spectral interpretation, including indication of Compton continuum pulse collection due to the presence of higher energy photons at the measurement location. A signal monitoring tap for all pulses greater than the lower bound of channel 1 was also provided. The observed system resolution, as monitored by a standard laboratory multichannel analyzer from the LAFPHA processed signal, was 47% FWHM for the unresolved 17-keV x-ray band and 17% FWHM for the 59.5-keV line.

The surface plutonium and americium contamination response of the system was calibrated using a point source incrementally displaced radially to simulate concentric annular rings of uniform area contamination. Numerical integration of the observed response in terms of counts per minute per microcurie per square meter (cpm per μCi/m^2) provided the needed calibration factor. This calibration method is outlined in another report.* The factors obtained on the present system were 350 and 3200 cpm per μCi/m^2 above background for ^{239}Pu at 17 keV and ^{241}Am at 59.5 keV, respectively. For both calibration and field use of the system, the unshielded detector is placed in a tripod at 30 cm above the horizontal surface, thereby allowing it to sense photons from an area within a 2-m radius.

This system proved to be extremely valuable in documenting the low levels of environmental contamination for the above-mentioned survey reviewed in Sec. IX of this report. In addition to this survey application, the LAFPHA-FIDLER system has potential monitoring use in accidental plutonium release situations. The LAFPHA may also be usefully employed with other detectors, such as thicker NaI(Tl) crystals, for high-energy gamma-ray measurements. Xenon proportional counters, lithium-drifted silicon-diode detectors, etc., all could be coupled to the LAFPHA in field measurement circumstances where the use of laboratory-type analyzers is inappropriate or impossible.

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CENTRAL AUTOMATED METEOROLOGICAL DATA ACQUISITION SYSTEM

by

Joseph E. Herceg

A central automated meteorological data acquisition system has been acquired and installed at LASL's TA-50 (Liquid Disposal Site). This system, conceived largely by R. V. Fultyn, consists of two main parts, a steel instrument tower and a small computer which functions as an instrument controller and data receiver, recorder, and processor. The system is in the late preoperational phase of development, and this Technical Note is intended to summarize the composition and aims of the system rather than to present any data accumulated from it.

The instrument tower is a guyed, triangular, diagonally reinforced structure 90 m in height with instrument platforms nominally at the 90-, 45-, 22-, and 11-m levels. At each platform are located an orthogonal (u-v-w) anemometer set and a quartz thermometer sensor element. Additionally, a heated, tipping-bucket precipitation gauge, atmospheric pressure and relative humidity sensors, an evaporimeter, and a fifth thermometer sensor element will be installed at or near the base of the tower as well as a net radiometer at the 11- or 22-m level.

Each anemometer set consists of three propellers oriented in orthogonal directions capable of spinning either clockwise or counterclockwise. Each propeller is connected to a chopper disk which interrupts the light from a small electric bulb. Depending on the direction of rotation of the propeller, a mask covers one or the other of two phototransistors that detect the modulated light signal and transmit the resultant pulsed electrical signal to a terminal box at the base of the tower.

The quartz thermometer sensor at each level consists of a small quartz oscillator crystal whose frequency of oscillation is temperature-dependent. To provide a true indication of air temperature, the sensing element is positioned inside a cylindrical, open-ended vacuum bottle in the stream of air from a small fan. The signals from these sensors are transmitted to the ground by standard 50-Ω coaxial cables.

From the terminal box at the base of the instrument tower, all signals are carried through buried conduit to another terminal box in a basement room of building LD-1 (TA-50). At this point appropriate signals are routed to an interface package in a minicomputer (PDP-11) or to an analog-to-digital converter (ADC) or to the thermometer electronics package, both of which are controlled by the computer.

The computer performs four basic functions: first, it controls the instruments; second, it receives the data from the instruments; third, it records the incoming information on magnetic tape for future processing on a larger machine; and fourth, it performs a first, crude reduction of the data for a more-or-less real-time display of salient information. These functions are described individually for the particular program package that is currently under development.

Instrument Control. At the beginning of each minute, as determined by a line frequency clock inside the computer, the thermometer package is directed, under program control, to take temperature readings from each of the five sensing elements by stepping through the five channels in its multiplexer unit. Since this type of thermometer is an integrating device, accuracy is dependent upon integration time. Maximum accuracy (°C, six digits, four decimal places), the normal mode of operation, requires about 10 sec integration time per reading, so that the thermometer package is operating 50 sec out of every minute. At the 30-sec point of each minute the ADC is commanded to start its sequence of functions. This consists of reading each of the four input analog signals (pressure, humidity, evaporation, net radiation) by stepping through the four channels of its multiplexer. This sequence requires perhaps 200 μsec, hence its placement halfway through the minute.

Data Reception. When the instruments mentioned in the preceding paragraph have taken a reading and made it available to the computer, the computer stores the number in a buffer for future use. In addition, it remains ready to take readings from the precipitation gauge and anemometers at any time. This is accomplished as follows: The signal from each of the 24 phototransistors in the anemometers and the microswitch in the precipitation gauge is fed to an "interrupt card" in the computer interface unit. When a pulse, indicating rotation of an anemometer propeller or change of position of the gauge bucket, is sensed by the interrupt card, the function being performed by the computer is momentarily interrupted. During the interim, a counter is altered. The counter and type of alteration, incrementation or decrementation by unity, is determined by the origin of the signal that has

caused the interrupt to occur, that is, by the location and direction of rotation of the propeller. The anemometer counters are stored in a buffer for future use, and the counters are cleared every 1 sec. This integration time was chosen to measure the high-frequency components of the wind structure, and after the micrometeorology of the area has been adequately defined, it may be relaxed to 10 sec. The current value of the precipitation gauge counter is stored in the buffer each minute, and the counter is allowed to accumulate for 24 h to give a measure of daily precipitation.

Data Recording. At the end of each minute the data buffer is transferred to magnetic tape. Each transfer consists of an identification number, 720 anemometer counter values (i.e., 12 each second), five temperature readings, and the current values of the precipitation gauge counter and the four analog signals. The magnetic tape is a 7-track unit and recording is at the rate of 800 bits per inch.

Data Processing. While the data is coming in from the various instruments and being stored for eventual recording on magnetic tape at 1-min intervals, it is also being manipulated and stored for anlysis and display at 15-min intervals and at 24-h intervals. The 15-min analysis consists of computing, for each of the four instrument levels, the vector and scalar averages for the horizontal wind component, along with its average direction and its standard deviation; the average vertical wind speed and its standard deviation; and the speed of the maximum 1-sec horizontal gust. This information is displayed by a teletype unit along with the current value of the five temperatures, precipitation, pressure, humidity, evaporation, and net radiation. The daily display consists of the maximum 1-sec horizontal gust at each level, and the minimum and maximum temperatures at the ground. The last 15-min summary contains the total precipitation for the day.

DETERMINATION OF NaCl CONTAMINATION IN PINE TREES BY NEUTRON ACTIVATION TECHNIQUES*

by

H. O. Menlove
Group A-1 (Nuclear Analysis Research)

Many communities throughout the U.S. routinely use rock salt in the winter to melt snow and ice on roadways. After the ice is melted, the salt solution is spread beyond the roadway by splashing and drainage and causes ecological damage to the surrounding areas.

In recent years, pine trees in the vicinity of roadways and drainage ditches in the Los Alamos, New Mexico, area have been turning brown and dying. To help determine if salt is responsible for this problem, needles from the diseased trees were sampled during the summer and early fall of 1972 at 53 different areas throughout the city. The sample areas were selected by visually observing locations with a significant number of brown or dead pine trees. At least one tree was sampled in each area, and the sample consisted of about 15 needles selected from several branches. Similar control samples were obtained from healthy pine trees in nearby areas.

The NaCl content in the samples was measured using neutron activation techniques in which the neutron irradiations were obtained with a portable ^{252}Cf neutron source. Before irradiation and weighing, all samples were dried in an oven to reduce the moisture content. The needles were placed in 3-dram polyethylene vials, resulting in a net weight of ~4 g per sample. For the thermal neutron irradiations, a 3.3-mg ^{252}Cf source was placed in a large polyethylene moderator, and 13 sample vials were uniformly positioned at a distance 5 cm from the source. The thermal neutron flux was calculated to be 7.2×10^7 n/cm^2-sec at this distance, which corresponds to the radius with the maximum number of thermal neutrons. Normally, up to 12 samples were irradiated overnight for a period of ~15 h to produce ^{24}Na by means of the $^{23}Na(n,\gamma)\,^{24}Na$ reaction.

After irradiation, the induced gamma-ray activity in the samples was measured with a 12.7-cm-diam by 12.7-cm-long NaI crystal with a 5-cm-diam through-hole for positioning the sample in the center of the crystal. Because ^{24}Na has a 15-h half-life, the samples were not counted for 3 to 8 h so that the short-lived activities in the sample would be reduced. Figure T-5 shows the pulse-height spectra for an activated sample, control sample, and NaCl standard taken ~4 h after irradiation. The standard consisted of 0.100 g of NaCl in a typical polyethylene vial. The activated NaCl spectrum (top curve) shows the prominent ^{24}Na peaks at 1.39 and 2.75 MeV. These same peaks dominate the diseased sample spectrum but not the control sample. Both pine needle samples show the ^{56}Mn peak at 0.84 MeV. The ^{56}Mn was identified by its half-life, energy, and less intense peaks at 1.81 and 2.11 MeV. The manganese content varied considerably from sample to sample and cannot be correlated to the diseased trees.

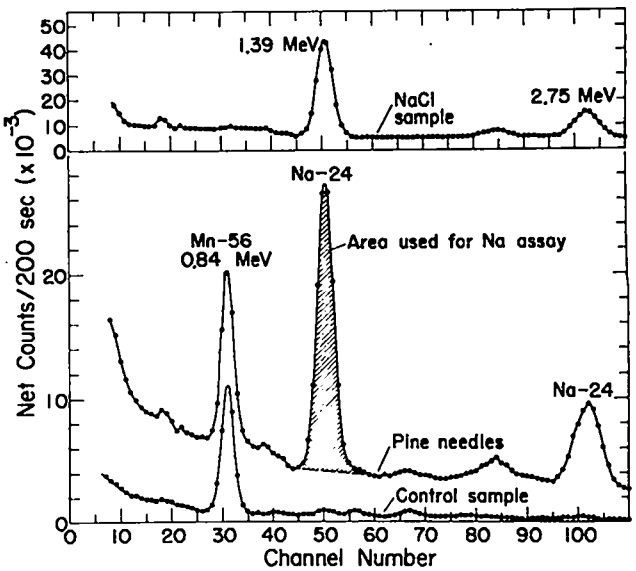

Fig. T-5.
Pulse height spectra for pine needle samples and NaCl standard.

To verify that the sodium in samples was from salt (NaCl), the chlorine content in several of the diseased samples was measured, using the $^{37}Cl(n,\gamma)^{38}Cl$ reaction to produce ^{38}Cl (37.3-min half-life). A 40-min neutron irradiation, followed by a 5- to 15-min wait and 100-sec count, gave the 2.2- and 1.6-MeV peaks from ^{38}Cl as well as the previously mentioned ^{24}Na and ^{56}Mn peaks in the

*Invited contribution. This Technical Note was previously discussed in "Rock Salt and Pine Trees," *Atom* (Los Alamos) 6, 1-3 (1972).

pulse-height spectrum. Comparison of diseased samples with a NaCl standard in the same irradiation showed that the nominal number of chlorine atoms equalled the number of sodium atoms.

The amount of ^{24}Na in the control samples was so small (Fig. T-5) that an 86-cm^3 Ge(Li) detector was used to measure the gamma-ray activity in the 1.39-MeV peak. The high resolution (1.83 keV at 1.33 MeV) of this detector made it easy to isolate the peak and subtract off the background.

All samples from the diseased trees contained at least 10 times as much NaCl as the control samples, and the average affected sample had 9120 ppm NaCl, which is 50 times greater than the 185-ppm average concentration in the control samples. The average diameter of the sampled trees was ~30 cm, and no correlation was found between the NaCl concentration and the tree's diameter.

To establish further that the NaCl contamination originated with road salt, two samples were taken from opposite sides of the same large tree located near a road. The sample from branches on the road side of the tree showed 11,900 ppm NaCl, whereas the sample from the opposite side of the tree had only 2400 ppm NaCl.

The pine needles affected by NaCl show brown tips, green midsections, and normal bases. To determine the location of the salt within the needles, one of the samples was separated into bases, green midsections, and brown tips; and the relative salt concentration was found to be 1, 3, and 6, respectively. Only entire needles were used for the sample results. Also, the brown (dead) control needles contained no more sodium than did healthy, green control needles.

In conclusion, over 2000 pine trees were observed to be diseased by rock salt in the survey area, which included 9 km^2 (2224 acres) in the center of Los Alamos. Because of their dominance in the area and their susceptibility to the salt, ponderosa pines were the only trees investigated. Many additional pine trees were affected by the salt in surrounding regions outside the surveyed area.

Neutron activation analysis can be done more readily *in situ*, with a portable system using small ^{252}Cf sources, than by the normal procedure of sending the samples to an accelerator or reactor for activation. With the high resolution Ge(Li) detector, the minimum sensitivity for sodium detection in the present work was ~5 ppm without any chemical separation or concentration. This high sensitivity makes the technique applicable to the analysis of salt in other vegetation and soil that are not as severely affected as the pine trees studied here.

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