LEONE

DOE/EIS-0018

Final Environmental Impact Statement

Los Alamos Scientific Laboratory Site

Los Alamos, New Mexico

U.S. DEPARTMENT OF ENERGY

December 1979

Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price:

Printed Copy: $15.00
Microfiche: $15.00

COVER SHEET

FINAL ENVIRONMENTAL IMPACT STATEMENT
DOE/EIS-0018

(a) Lead Agency: The Department of Energy

(b) Proposed Action: Los Alamos Scientific Laboratory Site, Los Alamos, Los Alamos and Santa Fe Counties, New Mexico.

(c) For Further Information Contact: Mr. Gordon Facer, Deputy Director, Division of Safety, Environment, and Emergency Actions, Office of Military Applications, Office of the Assistant Secretary for Defense Programs, Mail Station A-362, Germantown Building, Washington, DC 20585, (301) 353-3011, (2) Dr. Robert J. Stern, Acting Director, NEPA Affairs Division, Office of the Assistant Secretary for Environment, Room 4G-064, Forrestal Building, Washington, DC 20585, (202) 252-4600, (3) Mr. Stephen H. Greenleigh, Esq., Acting Assistant General Counsel for Environment, Room 6G-064, Forrestal Building, Washington, DC 20585, (202) 252-6947.

For Copies of the EIS Contact: Mr. Gordon Facer at the address noted above.

(d) Designation: Final EIS.

(e) Abstract: The statement assesses the potential cumulative environmental impacts associated with current, known future, and continuing activities at the LASL site. This includes the adverse impacts from postulated accidents associated with the activities. Various effluents including radioactive ones are released to the environment. However, a continuing, comprehensive, monitoring program is carried out to assist in the control of hazardous effluents. Alternatives considered to current operation of LASL include: cessation or relocation of programs; continue activities as presently constituted; further limitation of adverse impacts by institutional or other improvements in various operations; and expansion of current activities.

DOE/EIS-0018

DOE/EIS-0018
UC-2, 11

Final Environmental Impact Statement

Los Alamos Scientific Laboratory Site

Los Alamos, New Mexico

U.S. DEPARTMENT OF ENERGY
Washington, D.C. 20585

Responsible Official

Ruth C. Clusen
Assistant Secretary for Environment

December 1979

PREFACE

This environmental impact statement (EIS) was prepared in compliance with the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4231) by the Department of Energy (DOE) to determine the environmental impacts of continuing its activities at the Los Alamos Scientific Laboratory (LASL).

A notice was published in the Federal Register on July 15, 1976, (41 FR 29208), annnouncing that a statement would be prepared to assess the cumulative impact on the environment of the continued operation of LASL. The notice solicited comments and suggestions for consideration in the preparation of the statement. Fifteen responses were received from federal and state agencies and private citizens; these comments were taken into account in the preparation of the draft environmental impact statement (DEIS) which was issued on June 27, 1978.

The DEIS described the ongoing activities at the LASL site, discussed the actual and potential impacts of these activities on the surrounding environment, and provided background and analyses to assess LASL's environmental impact of the current and continuing activities at the site. The existing environmental factors and the overall cumulative environmental impacts of the various missions and activities at the site and those anticipated impacts of continuing and planned activities were evaluated.

Comments on the DEIS were received from 15 individuals and organizations. The areas of substantive concerns raised in the comment letters and considered in the preparation of this final document include: (1) the mission and location of the Laboratory, (2) the biological behavior of radionuclides, (3) water supply for Los Alamos, (4) waste management, (5) accident analysis, (6) radiological dose and dose interpretation, (7) radioactive materials in the environment, (8) transportation of radioactive materials, and (9) additional details desired. Section 11 of this final EIS summarizes the areas of concern, provides a generic response to the comments, and indicates where major modifications have been made. Copies of the comment letters and DOE staff responses are included as appendix I of the statement.

This EIS addresses the LASL site as a whole. The level of detail is general, with special emphasis in those areas that have, or might be considered to have, potential for significant environmental impacts. The cumulative environmental results of Laboratory activities to date are covered insofar as information permits. Generally, data included are those accumulated through calendar year 1978. Many long-term environmental studies are under way as part of ongoing research and monitoring programs. These are designed to continuously document interactions of Laboratory activities with the environment and permit reevaluations of significance as knowledge increases.

The Laboratory's offsite involvement with nuclear weapons test activities conducted at the Nevada Test Site and geothermal activities at the Fenton Hill Geothermal Site are not covered in this statement because these activities have been assessed separately. Environmental impact statements have been prepared previously for specific new Laboratory projects, such as the New Plutonium Processing Facility and the Radioactive Solid Waste Volume Reduction Facility and are noted here at appropriate points and are also included in the list of references.

One addition to this final document is the incorporation of the annual monitoring report, "Environmental Surveillance at Los Alamos During 1978," as Appendix H. References to this appendix were noted in the text at numerous locations where it could be consulted for additional or updated details. This Appendix H documents the environmental surveillance program conducted by the Los Alamos Scientific Laboratory (LASL) in 1978.

Another addition is Section 3.3.5 Transportation of Radioactive Materials. This section describes a variety of radioactive material shipments to and from LASL and identifies the packages and vehicles used. An estimate of the overall risk from these transportation activities is presented in Section 4.2.14.

Brief summaries of the significant changes made in affected sections are noted at the beginning of these sections. Details have been incorporated by direct inclusion in the statement, reference to other sources, and the addition of the surveillance report as Appendix H.

To permit a better understanding of this statement, the use of scientific terms have been minimized, and a glossary has been attached which defines or explains those terms that, though essential to the text, are not in customary usage. Because many DOE orders, manuals, and directives are still being promulgated, and were not considered final as of the time this EIS was being written, numerous references have been made herein to ERDA Manual Chapters (ERDAM) which continue to serve as guidelines until superseded by the final DOE orders and manuals.

TABLE OF CONTENTS

FIGURES

TABLES

1. SUMMARY

This Environmental Impact Statement (EIS) assesses the environmental impacts of the Department of Energy's* activities at the Los Alamos Scientific Laboratory (LASL) site in Los Alamos and Santa Fe Counties at Los Alamos, New Mexico, and assesses actual and potential impacts on the surrounding environment. The EIS provides environmental input into decisions regarding the continuing activities at the Los Alamos Scientific Laboratory with coverage of some further growth and evolution of research programs in new areas.

In January 1943 a wartime laboratory was established at Los Alamos, New Mexico. Its sole mission was the development of a fission bomb. This project culminated in the detonation of the first atomic bombs in 1945. Since then, the primary mission of LASL has continued to be nuclear weapons research and development, including the first thermonuclear bomb. However, expansion of Laboratory efforts has incorporated numerous programs to develop peaceful uses of nuclear energy in such areas as fission reactors, space technology, controlled thermonuclear reactions, and medical and biological applications. In recent years there has been increasing diversification into nonnuclear research areas, notably geothermal and solar energy resources and use of superconductor technology for energy storage and transmisson. The four major research program areas are national security, energy, biomedical and environmental, and physical research.

To illustrate the magnitude of the efforts at LASL, during 1978, employment at the Laboratory and in conjunction with the Laboratory's operations totalled about 8,000. This included employees of DOE's Los Alamos Area Office, the University of California, and other DOE contractors located in Los Alamos. The combined Fiscal Year (FY) 1978 payroll was approximately $190 million, and project expenditures totalled about $325 million.

Los Alamos is a small incorporated county, located in north-central New Mexico about 100 km (60 mi) north-northeast of Albuquerque and 40 km (25 mi) northwest of Santa Fe by air (see Figures 1-1 and 1-2). Within the County there are 111-km^2 (27,500-acre) LASL site (a small portion is in Santa Fe County) and two adjacent communities, informally identified as Los Alamos townsite and White Rock. They are situated on the Pajarito Plateau between the Jemez Mountains to the west and the Rio Grande Valley to the east. The plateau consists of a series of relatively narrow mesas separated by deep, steepsided canyons that trend east-southeast from the Jemez Mountains down to the Rio Grande.

Most of the Laboratory and community development is confined to the mesa tops. The Laboratory site includes 30 active technical areas, where the 124 principal buildings are located. Tangible use of the Laboratory land area includes building sites, test areas, waste disposal locations,

---

*The "Department of Energy (DOE)" designation is used throughout this document. However, it should be noted that LASL was operated for the Corps of Engineers from 1943 until 1947; for the Atomic Energy Commission (AEC) from 1947 until January 19, 1975; for the Energy Research and Development Administration (ERDA) from January 20, 1975, until September 30, 1977; and for the Department of Energy since October 1978.

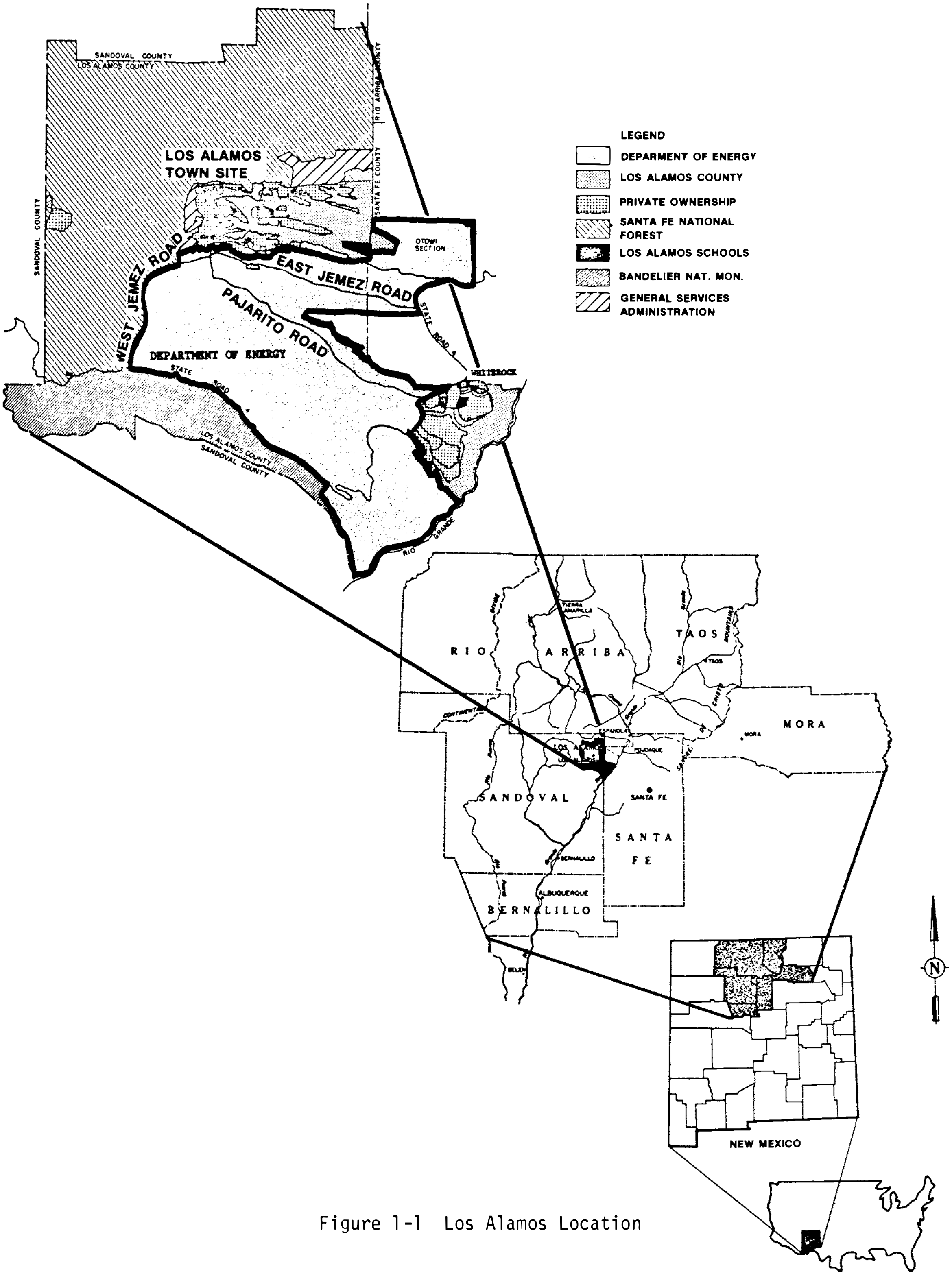


Figure 1-1 Los Alamos Location

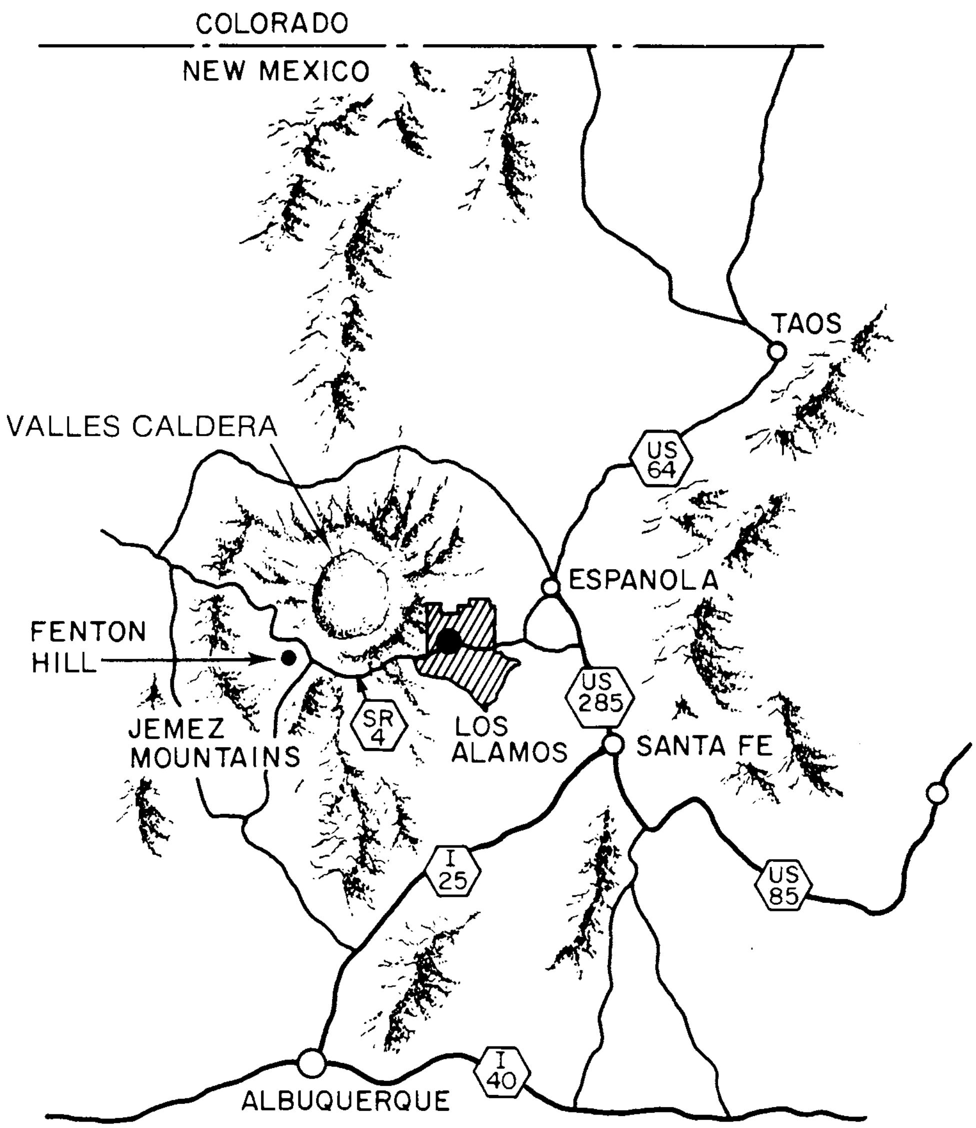


Figure 1-2 Regional Setting of LASL

roads, and utility rights-of-way. However, these uses account for only a small fraction of the total land area; most land is used in a less tangible way to provide a buffer zone for isolation for security and safety purposes and as reserves for future structure locations. This large, undeveloped portion also provides refuge for significant wildlife populations. The land around the Laboratory and immediately adjacent communities is undeveloped; nearly all of it is under control of the Forest Service, the National Park Service, or Indian Pueblos.

Water is supplied to the Laboratory and the adjacent community areas from federal-owned well fields. About 35% of the annual water usage is for the Laboratory; the rest is sold to Los Alamos County for distribution to commercial and residential users. Water withdrawals are in conformance with State water rights limitations. Some water requirements are satisfied by recycling of treated effluents. Conservation of water by the community and LASL reduced total water use by about 30% between 1976 and 1978.

Principal energy sources are natural gas and electricity. Private gas and electric utilities serve White Rock. Natural gas is purchased from private utilities and transported to the Los Alamos Townsite area through federally owned pipelines. In recent years, about 63% of the gas consumed by LASL and the Townsite has been used to operate a DOE-owned electric generating plant and several steam plants. About 19% of the gas is distributed in the community by Los Alamos County, and the rest is used directly by the Laboratory. Total gas usage by LASL and the community has declined in both 1977 and 1978. Electricity is supplied by onsite federal generation (about 30%) and purchases from offsite suppliers (about 70%). Total energy consumption is expected to increase about 15% by 1985, assuming planned programmatic changes and some conservation measures are implemented. Intensive energy conservation measures including some requiring substantial capital expenditures might be able to reduce consumption about 6% from present use by 1985. Conservation measures implemented by the Laboratory have resulted in an overall decrease in usage of about 2.5% between 1976 and 1978 in spite of program expansion. The primary resources used for the operation and maintenance of the Laboratory include land, water, and energy; other resources include the materials for structures and experimental facilities and the supplies for conducting research programs.

Liquid, gaseous, and solid wastes are generated as byproducts of the Laboratory operation. Liquid wastes include radioactively contaminated solutions, chemically contaminated wastes, sanitary sewage, cooling water discharges, and storm drainage. Nonradioactive liquid effluents from 104 industrial discharge points and 10 sanitary sewage treatment facilities came under the regulation of a single NPDES permit in 1978. Most of the discharges met the permit requirements, and improvements are under way or proposed for funding to achieve better compliance. The ordinary sanitary liquid wastes are processed by conventional sewage treatment plants, lagoons, and septic tanks. Industrial liquid wastes are processed by special treatment plants to remove radioactive components and to detoxify or neutralize other chemical agents. Table 1-1 summarizes the results of analyses of treated effluents released from the Central Waste Treatment Plant in 1978 which constitute about 90% of the radioactivity released in liquid. The treated effluents contain radioactive pollutants at levels of only a few percent of guidelines applicable to exposure to the public from ingestion of water and food. Behavior of those effluents in the natural environment is the subject of continuing studies. Three canyon areas of particular interest are Pueblo, Los Alamos, and Mortandad Canyons. The discharges into these canyons contained trace quantities of tritium (^{3}H), cesium-137 (^{137}Cs), plutonium-238 (^{238}Pu), americium-241 (^{241}Am), strontium-89 and -90 ($^{89-90}Sr$), uranium-235 (^{235}U), and

TABLE 1-1

EFFLUENT FROM CENTRAL WASTE TREATMENT PLANT IN 1978

Radioactive Isotopes	Activity Released (mCi)	Average Concentration (μCi/mℓ)
^{239}Pu	4.05	0.099×10^{-6}
^{238}Pu	1.83	0.045×10^{-6}
^{241}Am	1.73	0.043×10^{-6}
^{89}Sr	2.64	0.065×10^{-6}
^{90}Sr	10.4	2.57×10^{-7}
^{3}H	12,300	0.30×10^{-3}
^{137}Cs	317	0.78×10^{-5}
U-Total	176 grams	4.34×10^{-3} mg/ℓ

Nonradioactive Constituents	Average Concentration (mg/ℓ)
Cd[a]	0.003
Ca	26.0
Cl	48.4
Cr[a]	0.04
Cu[a]	0.27
F	3.8
Hg[a]	0.009
Mg	1.4
Na	354
Pb[a]	0.044
Zn[a]	0.46
CN	0.04
COD[a]	51
$NO_3(N)$	90
PO_4	0.44
TDS	1345
pH[a]	6.8-12.3
Total Effluent Volume	4.058×10^{7} ℓ

[a]Constituents regulated by NPDES permit.

some stable elements. Treated wastes have been discharged into Los Alamos canyon since 1952 and will continue at least until decontamination of the old plutonium processing facility is completed. Pueblo Canyon is a tributary of Los Alamos Canyon. Untreated wastes were discharged into it between 1944 and 1951, then treated wastes were discharged until 1964. Mortandad Canyon has received treated wastes since 1964, and this will probably continue for several years.

The effluents are released to normally dry stream beds within the Laboratory boundaries and infiltrate into the alluvium, recharging the perched water bodies as shown by studies mentioned later in this statement. The majority of the radionuclides are absorbed into the sediments in varying quantities. The absorption, coupled with dilution by natural runoff, results in very low concentrations of radioactivity in the water contained within the alluvium, only fractions of a percent of drinking water concentration guides. There is no indication that the liquid effluents enter waters used for human consumption. The liquid effluents are isolated from the deep ground water aquifer by thick layers of dry rock. There has been no change in the chemical or radiochemical quality of water in the main aquifer.

The transport of the sediment downstream by intermittent runoff is responsible for some offsite transport of radioactivity. Although heavy precipitation may result in flow all the way to the Rio Grande river about four times a year, the effluent generally infiltrates into the channel alluvium before reaching the river. The portion of Los Alamos Canyon between the Rio Grande and the confluence with Pueblo Canyon has received about 2.5 millicuries (mCi) of plutonium per year both from residuals of former discharges into Pueblo Canyon and from treated effluents released into upper Los Alamos Canyon. The plutonium concentrations on soils and sediments in Mortandad Canyon are at background levels at the LASL boundary. Concentrations of plutonium in sediment samples from the Rio Grande are not above the minimum detectable limits of 0.01 picocuries per gram (pCi/g). Thus, no adverse environmental effects are believed to result from these liquid disposal practices. Some of the treated effluents provide increased water supply resulting in additional vegetation and greater carrying for wildlife, and some are recycled to meet industrial water requirements.

Gaseous wastes include combustion products from power and steam plants and vehicles, as well as small amounts of radioactive and nonradioactive materials. The amounts of waste radioactive materials released to the atmosphere are low, and based on atmospheric sampling and other measurements during 1978, the largest calculated radiation dose to be received by any individual beyond the LASL boundary was less than 1 percent of the annual individual dose limit recommended by the National Committee on Radiation Protection (NCRP). Some atmospheric releases of natural and depleted uranium result from experiments in controlled test areas with high explosives. Table 1-2 summarizes the principal radioactive and nonradioactive atmospheric releases during 1978.

Solid wastes include domestic solid wastes, explosives and hazardous chemical wastes, and radioactively contaminated wastes. Ordinary solid wastes are disposed of in a County sanitary landfill operated in accordance with U.S. Environmental Protection Agency guidelines. Explosives wastes are burned in accordance with established safety practices. Radioactively or chemically contaminated solid materials are buried in specially designated pits in controlled areas. Materials contaminated with transuranic radioactivity above specified levels are placed in special storage to ensure retrievability. Table 1-3 summarizes the estimated total radionuclide content of materials placed in subsurface disposal and retrievable storage through December 1976 and the principal additions in 1977 and 1978.

TABLE 1-2

PRINCIPAL ROUTINE ATMOSPHERIC EMISSIONS IN 1978*

Radioactive

Radionuclides	Curies
^{3}H	18,631.
Plutonium and Americium	0.000112
Uranium (stacks)	0.000526
Uranium (dynamic tests)	0.51
Mixed Fission Products	0.0016
^{32}P	0.000085
^{234}Th	0.0019
^{131}I	0.000081
^{41}Ar	589.
^{11}C, ^{13}N, ^{15}O	116,449.
^{7}Be	0.0000002

Nonradioactive

Vehicle Operation and Maintenance

Pollutant	Estimated Amount (metric tons)
Gasoline Evaporative Losses	28.3
Carbon Monoxide	213.
Hydrocarbons	21.
Nitrogen Oxides	29.
Sulfur Oxides	1.1
Particulates, Exhaust	0.6
Particulates, Tires	1.2

Electric Power Plant

Pollutant	Estimated Amount (metric tons)
Sulfur Oxides	0.6
Hydrocarbons	1.1
Carbon Monoxide	17.9
Particulates	10.5
Nitrogen Oxides	739.

Chemical Vapors and Gases

Chemical	Estimated Amount (kg)
Acetone	2700
Carbon Monoxide	4100
Ethyl Acetate	1600
Freons	3300
Helium	6800 - 13,600
Methyl Ethyl Ketone	3500
Methylene Chloride	800
Sulfur Hexafluoride	8200
Trichloroethane	13,700
Trichloroethylene	2000

*There were no accidental releases in 1978.

TABLE 1-3

ESTIMATED CUMULATIVE RADIONUCLIDE CONTENT OF PRINCIPAL MATERIALS PLACED IN SUBSURFACE DISPOSAL AND RETRIEVABLE STORAGE

Radionuclides	Disposal and Storage Through Dec. 1976[a] (Curies)[b]	Disposal During 1977 and 1978 (Curies)[c]	Retrievably Stored During 1977 and 1978 (Curies)[c]
^{3}H	163,044	99,350	---
^{22}Na	29	1×10^{-6}	---
^{60}Co	146	0.01	---
^{90}Sr - ^{90}Y	2,987	0.001	---
^{137}Cs	5	0.005	---
Uranium[d]	140	3.4	0.03
Plutonium[d]	57,728	49.3	23,740
^{241}Am	6,733	23.6	9,669
Mixed Fission Products	990	2,615	0.34
Mixed Activation Products	443	84.1	---

a) Historic data are known to be incomplete due to lack of detailed records on quantities of activity placed in known disposal areas during earlier years of Laboratory operation.

b) Activity in curies, decay corrected through 1976.

c) Activity in curies at time of disposal.

d) Combined activity of all isotopes recorded.

A continuing, comprehensive monitoring program, including procedures ranging from continuous monitoring of some effluents to regular periodic sampling of air, water, soil, and biological materials at onsite and offsite locations, has shown that no significant environmental impacts have resulted from Laboratory effluent or waste disposal. Some radioactivity is measurable above normal background near the Laboratory; however, the levels are very low and do not present health or safety hazards. Table 1-4 summarizes the maximum individual and population offsite dose that may be attributed to routine releases of Laboratory effluents.

Some small risk of environmental impact results from the possible occurrence of a major accident. All Laboratory activities were analyzed to determine all accidents of operational and natural origin. The worst possible accidents of various types and the environmental consequences of the potentially most significant postulated accidents were evaluated. The types of accidents or natural disasters evaluated include explosion; criticality; fire in a plutonium processing facility; radioactive material spill; accidental releases of fission products, tritium, biological materials, or toxic chemicals; an aircraft crash into a facility; a transportation accident; and an accelerator accident. Each situation is statistically possible, but mitigating factors make the likelihood of any of the worst possible accidents extremely small.

Table 1-5 summarizes the major consequences to the general population that could result from the potential accidents in LASL facilities involving radioactive materials that were evaluated for this document. Of these accidents, the maximum dose to a member of the general public would result from a release of fission products from the research reactor. The accident is postulated to occur as the result of blockage of coolant flow leading to partial melting of some fuel elements and release of radioactive Iodine and noble gases. The maximum cumulative population dose would result from the release of tritiated water vapor caused by an aircraft crashing into a tritium research facility. The greatest consequence to members of the general public resulting from an accident involving nonradioactive materials would be exposure to relatively high levels of aerosolized beryllium for a short period of time. Potential accidents involving transportation of radioactive materials related to LASL operations were also evaluated and are discussed in Chapter 4, Section 4.2.14.

Secondary impacts of the operation of LASL largely relate to land use, economic, and population factors. The original Los Alamos townsite was federally constructed to house Laboratory employees and their families. Many community facilities were turned over to, or built for, Los Alamos County without cost to the community when Federal control over the community was relinquished in the 1960's. The majority of County residents are still Laboratory employees and their families. Any significant growth in Laboratory employment will have a proportional effect on population growth in the County and surrounding region with concomitant requirements for housing, utilities, and community services.

Unavoidable environmental effects resulting from the continued operation of LASL include land use, resource consumption, and effluent release. Continued operation of LASL requires dedication of the present laboratory lands for the foreseeable future, excluding the possibility of alternative land uses. Recently the LASL reservation has been declared a National Environmental Research Park to enhance potentials for multiple use.

Some release of radioactive materials and chemical substances will continue. Present releases are all at concentrations lower than limits set by applicable standards. Some releases are expected to be further reduced by new research facilities or pollution control equipment already under construction or planned. The continuing comprehensive environmental monitoring program ensures that any adverse trends, should they develop, will be quickly detected so that appropriate mitigating actions can be taken

TABLE 1-4

CALCULATED BOUNDARY AND MAXIMUM INDIVIDUAL DOSES FROM AIRBORNE RADIOACTIVITY

		Maximum Boundary Dose		Maximum Individual Dose		
Isotope	Critical Organ	Location	Dose (mrem/yr)	Location	Dose (mrem/yr)	%RPS[c]
^{3}H (HTO)	Whole Body	TA-54	0.071	Airport	0.029	0.0058
^{11}C, ^{13}N, ^{15}O	Whole Body	Restaurant N. of TA-53	14[a]	Restaurant N. of TA-53	3.8	0.76
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack	1.2	Apts. N. of TA-2 Stack	0.7	0.14
^{239}Pu	Lung	TA-54	0.024	Bandelier	0.0079[b]	0.00053

[a]Estimated from TLD measurements June-Dec. 1978.
[b]For a 50 yr dose commitment, bone becomes the critical organ. A maximum individual would receive a 50 yr dose commitment to bone of 0.53 mrem.
[c]RPS = Radiation Protection Standards (See Appendix H-59).

1978 WHOLE BODY POPULATION DOSES TO LOS ALAMOS COUNTY RESIDENTS

Exposure Mechanism	Whole-Body Population Dose (man-rem)
Atmospheric Tritium (as HTO)	0.23
Atmospheric ^{11}C, ^{13}N, ^{15}O	8.4
Atmospheric ^{41}Ar	1.9
Total Due to LASL Atmospheric Releases	10.5
Cosmic and Terrestrial Gamma Radiation[a]	1570
Cosmic Neutron Radiation (∿17 mrem/yr/person)	330
Self Irradiation from Natural Isotopes in the Body (∿24 mrem/yr/person)	470
Average Due to Airline Travel (0.22 mrem/hr at 9 km)	13
Total Due to Natural Sources of Radiation	2383
Medical Exposure (∿103 mrem/yr/person)	2020

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

TABLE 1-5

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS AT LOS ALAMOS

Accident Type	Maximum Dose Commitment[a] to Individual Members of the General Public (rem)		Worst Case Population Dose[b] Commitment in County (man-rem): Los Alamos Townsite	or	Worst Case Population Dose[b] Commitment in County (man-rem): White Rock	95 Percentile Population Dose[c] Commitment in Region Outside County to 80 km Radium Plus Metropolitan Albuquerque (man-rem)
Explosion	26	(bone)	2.6×10^3		1.4×10^3	3.6×10^1
Criticality #1	0.5	(thyroid)	3×10^2		1×10^2	2×10^1
Criticality #2	0.001	(thyroid)	3×10^{-2}		1×10^{-2}	2×10^{-3}
Fission Product Release	57	(thyroid)	6×10^3		2×10^3	3×10^2
	22	(whole body)	5×10^3		2×10^3	3×10^2
Air Crash	4.8	(whole body)	7×10^3		2×10^3	5×10^2
Natural Background	0.15		1.8×10^3		7.7×10^2	7.3×10^4

[a]Time integrated total dose commitments, except for bone-seeking nuclides (e.g., plutonium) where integration was for 50 years.

[b]Doses (rem) in Los Alamos Townsite and White Rock are not additive. Only one would actually occur depending on prevailing wind direction.

[c]Values (rem) are expected to be exceeded only 5% of the time; 50 percentile values are approximately 1/10 of those shown.

before significant adverse effects occur. An internal quality assurance program reviews all new proposals during the design process to permit consideration of possible safety and environmental consequences before construction or program initiation.

Another unavoidable adverse effect is the potential for accidents. Safety Analysis Reports are prepared, and Standard Operating Procedures are prescribed to minimize risk potential for accidents. These procedures are mandatory for any operation that has a significant potential for accidents or environmental impact.

The use of nonrenewable natural resources such as fuels, construction materials, and consumable supplies constitutes the principal irreversible and irretrievable commitment required by the operation of LASL. In a less tangible but equally real way, the human resources invested in establishing the Laboratory and its many research programs also represent an irreversible and irretrievable commitment. Most land used for structure sites and some solid waste disposal areas must be considered irreversibly committed unless, and until, better alternative uses are found. Land areas that have low levels of radioactive or chemical contamination would probably have to be decontaminated before unrestricted access could be permitted. Some minor irreversible commitments have occurred and will probably occur in the future. For example, some small archaeological sites have been destroyed by construction. However, salvage archaeological studies have been conducted at important sites in keeping with Federal regulations.

The relationship of LASL's previous and continued operation to land-use plans, policies, and controls is discussed in regard to both unavoidable adverse environmental effects and irreversible and irretrievable commitment of resources. The LASL reservation is a long-term commitment of land and must suffice for the forseeable future since the site is constrained by contiguous land uses and characteristics. The master planning efforts at LASL address the management of land, other physical resources, and utilities to assure their most prudent use in support of the Laboratory's missions. The State of New Mexico has no applicable land-use regulations. The Los Alamos County Planning Commission deals exclusively with County and private lands. The Laboratory adheres to Federal laws regarding archaeological and other historic sites. It has been determined that there are no prime or unique farmlands in the LASL site. Hence, sustained operation of LASL is not in direct conflict with any known Federal, State, or local land-use plans.

A secondary impact is the need for housing and residential lands in communities adjacent to the Laboratory to accommodate possible growth in LASL employment. A Comprehensive Plan for Los Alamos County, adopted in 1963 and updated in 1976, is the basic County planning document. It provides the fundamental direction to accommodate a population of up to 31,000, almost twice the present level. The high percentage of Federally owned lands in northern New Mexico and the policy of retaining land in Federal ownership, such as the LASL reservation, has an impact on regional land use. The effects of a population increase resulting from LASL's growth will be concentrated in residential development. LASL's operation will result in a small contribution to the present trends in northern New Mexico of subdivision development, increasing urbanization, changes in land-use patterns, and rising land prices.

Short-term use of the local environment and resources must be considered in view of long-term national goals. The short-term uses of the local environment do not generally preclude alternative future uses. Land areas that have low levels of radioactive or chemical contamination might have to be decontaminated to permit unrestricted use; in other cases, it might not be economically practicable to perform sufficient decontamination to permit their release to unrestricted use. Some short-term uses of non-renewable fuel and mineral resources are involved in the construction and operation of research facilities. Continued operation of the Laboratory, including proposed expansions, will not change the qualitative nature of short-term uses of the environment and natural resources. No contemplated or prospective activities are expected to result in any major adverse environmental impacts. Some future obligations for decommissioning are considered as part of the economic life-cycle costs.

Alternatives to the continued operation of the Los Alamos Scientific Laboratory that have been considered are no action, cessation or relocation of programs, modified future trends, limitation of adverse impacts, and institutional alternatives.

The "no-action" alternative for the existing Laboratory is no change from present facilities and operations with the consequence of no change in continuing environmental impacts.

Cessation or relocation of Laboratory programs would present a number of problems. Complete rebuilding at other locations would reduce locally some impacts, such as the release of radioactive materials and other pollutants, solid waste generation, water and energy consumption, land use, and accident potential, but it would only transfer such environmental costs to another location. The same expenditure on improving the existing facilities would be more productive. Complete cessation of all programs would result in a loss of benefits of research and development in areas significant to national needs such as national defense, energy, biomedical, and environmental programs. Either action would result in great cost by wasting productive facilities and human resources without any significant environmental benefits. Removal of the Laboratory would delete at least $285 million annually in personal incomes and other Laboratory-related expenditures from the New Mexico economy.

A major increase in the rate of future growth as an alternative would reflect substantial changes in national policy at the Congressional or Executive levels of Federal Government. Such growth would induce both primary and secondary impacts of new construction, incremental land use, increased consumption of water and energy resources, and additional waste disposal requirements. Secondary impacts would include added economic input to the region.

Modification of procedures or facilities are economic and productive alternatives. The adverse impacts of LASL's operation could be limited by replacement or improvement of existing facilities, alteration of procedures, conservation, and additional long-range site planning. Precedents for such alternatives exist throughout the history of LASL operations. The new Plutonium Processing Facility is a recent example of facility replacement with increased productivity as well as improved environmental protection and operational safety. Improved safety measures and waste treatment technologies have been instituted when available, and further improvements are expected. Conservation measures and a quality assurance program identify, and will continue to minimize, environmental consequences of new projects in early planning stages.

Some institutional alternatives considered to minimize certain adverse impacts are limiting public access to onsite roads, implementation of mass transit, encouraging water conservation in the community, and the release of additional lands for housing.

The essence of the environmental trade-off analysis lies in national policy decisions that the work done at LASL is essential. If the goals of research are realized, the benefits would encompass maintenance of the national defense, increased national self-sufficiency of energy resources, improved quality of life, and reductions of environmental impact throughout the nation.

On a local scale, benefits are economically, physically, and socially significant. Employment and educational opportunities have been provided by the Laboratory. Total federal expenditures related to LASL have significantly benefitted the depressed economy of northern New Mexico, and the LASL reservation has served as a preserve for both wildlife and archaeological sites.

Principal commitments of natural resources include land, water, natural gas, and electricity. Environmental costs are incurred as a result of waste disposal. The resident community results in secondary environmental costs in terms of land use, resource consumption, and waste generation. Continuing review, coupled with the demonstrated efforts to improve environmental awareness and minimize environmental impacts, will assure that Laboratory missions are conducted in the most efficient manner.

An environmental trade-off analysis of the alternatives suggests that retention of the existing research program with minimization of specific environmental costs through suitable improvements in procedures and facilities would be a productive course of action. The largely short-term commitments and uses of natural resources and the local environment are minor compared to the demonstrated and expected long-term benefits.

Me (Moderator)

2. BACKGROUND

This environmental impact statement has been prepared to provide the environmental imput into DOE decisions related to the continued activities of the Los Alamos Scientific Laboratory site with some further growth and evolution of research programs in new areas. The Laboratory's general mission and activities, as described in detail in Section 2.3., Programs, are anticipated to remain essentially the same. Future directions, as detailed in Section 2.4, are based on current projections showing roughly a 3% annual increase in personnel from about 7,685 employees in FY 77 to about 8,600 employees in FY 81. Because of the uncertainty of future funding, specific projections of funding, personnel levels, and programmatic emphasis would not be meaningful beyond FY 82.

2.1. HISTORY

The Los Alamos Scientific Laboratory was established in January 1943 as Project Y of the War Department's World War II Manhattan Engineer District--the code name for the effort to develop the atomic bomb. The mission of Project Y was the design and assembly of the first nuclear fission bomb.

The wartime programs under the Manhattan District were associated with centers of research in nuclear science that continue to be active at Los Alamos, New Mexico; the Radiation Laboratory in Berkeley, California; the Clinton Laboratory in Oak Ridge, Tennesee; the Hanford Works in Richland, Washington; and the Metallurgical Laboratory in Chicago, Illinois.

The Project Y location--a remote mountain plateau 40 km (25 mi) by air northwest of Santa Fe, New Mexico, was chosen primarily in the interests of secrecy and safety because of its isolation. The land for the Project Y Laboratory came under the jurisdiction of the War Department in 1943 with the acquisition of Ranch School property, homestead and grazing land, and Forest Service public domain. The Los Alamos Ranch School provided available facilities to begin the project. The town of Los Alamos was established as part of Project Y and operated by the federal government to provide housing and community necessities for project personnel. The Los Alamos wartime effort culminated in July, 1945 with the successful test of the first bomb near Alamogordo, New Mexico.

In January 1947, the Atomic Energy Commission (AEC) replaced the Manhattan District with the responsibility for nuclear research and development. The Laboratory of that time focused on developing new nuclear weapon models and pursuing possibilities for more effective and reliable weapons.

With the start of the Korean War in 1950, LASL, as the AEC's nuclear weapons laboratory, was directed to accelerate development of a thermonuclear (fusion) weapon. In the early 1950's, in addition to developing fission bombs, LASL tested the first thermonuclear bomb at Eniwetok in the South Pacific. Early in its history, LASL started in nuclear reactor development by building the first aqueous homgeneous reactor (water boiler) and the first mercury cooled, plutonium fueled fast reactor (Clementine). LASL had extended its wartime work in nuclear reactor development, and the Omega West Reactor was built in 1956 which is still actively used for research. LASL's reactor technology involvement resulted in the Los Alamos Power Reactor Experiments (LAPRE I and II) and the Los Alamos Molten Plutonium Reactor Experiment (LAMPRE) of the 1960's, which contributed to present breeder-reactor technology. Also, the helium cooled Ultra High Temperature Reactor Experiment, UHTREX, was built and delivered heat at 1300^{o}C. The effort to create a thermonuclear bomb stirred an interest in Controlled Thermonuclear Reactions (CTR) as a source of power, and in 1951 LASL began a series of experiments in plasma confinement technology, leading to the current CTR theta- and Z-pinch research program.

LASL continued expanding its efforts toward developing peaceful uses of nuclear energy; by the 1960's, it included space applications, power reactor programs, controlled thermonuclear research, and radiobiology and medicine. A major effort was in high temperature fuel and materials technology for the joint National Aeronautics and Space Administration-AEC nuclear rocket program. Significant contributions were also made in thermionic, fast-breeder, and ultra-high-temperature reactor technology, as well as in the areas of nuclear physics, solar astronomy, chemistry, metallurgy, materials science, mathematics and computers, and health research.

In 1971 the Laboratory underwent a reorganization and reorientation, resulting in expansion into astrophysics, earth sciences, energy resources, nuclear fuel safeguards, and laser research. In 1972 the Laboratory completed the 800-Mev proton accelerator of the Clinton P. Anderson Los Alamos Meson Physics Facility, the first national facility for research in medium-energy physics. Scyllac, an 8-m-(26-ft) diameter controlled thermonuclear reaction device, became operational in the spring of 1974.

In January 1975 the AEC was abolished under the Energy Reorganization Act of 1974 and the research and development responsibilities for all sources of energy, including the nuclear weapons program, were assumed by the Energy Research and Development Administration (ERDA).

Under ERDA, the Laboratory continued its nuclear research and development programs, including weapons work, and expanded laser fusion and laser isotope separation projects. It has, in addition, greatly expanded its nonnuclear energy programs--enlarging existing activities or initiating new ones in solar and geothermal energy, superconducting electrical energy storage and transmission, hydrogen fuel technology, advanced heat transfer technology, fossil-fuel use, energy systems analysis, and biomedical and environmental research. On October 1, 1977, the Department of Energy (DOE) was established and that organization assumed ERDA's responsibilities, at which time ERDA was abolished.

Most of the World War II facilities have now been demolished and the land returned to public use. Major facility expansion occurred in 1951-53 with the construction of 14 new technical areas, and this number has increased steadily to a current total of 30. The federal government presently controls 111 km^2 (27,500 acres) of land for use by DOE. Most of this land is located in Los Alamos County, but a small portion is located in Santa Fe County. Because of a severe shortage of office and laboratory space, LASL is presently leasing an unused school building and portions of several commercial office buildings in the City of Los Alamos. The technical areas have developed in widely scattered locations, reflecting specific siting needs or topographic restraints. All of the permanent Laboratory technical areas are located on DOE land.

As the Laboratory was rebuilt following World War II, the AEC upgraded and expanded the housing and commercial establishments. In 1949 the County of Los Alamos was created by the New Mexico State Legislature, carved out of Santa Fe and Sandoval counties. However, until 1957 the entire community remained closed to the public, with passes required for all residents, including children. Los Alamos County remained government property until 1965 when, as a result of Federal transfer legislation passed in 1962, the AEC began the process of transferring land. Residences and commercial property were sold first, and on July 1, 1967, the AEC transferred title to more than $20 million worth of public-use land, roads, buildings, and some of the utility systems to Los Alamos County. The final stages of this transfer are being completed. The disposal agreement also called for direct financial support to the Los Alamos County Government and to the Los Alamos School System, to be paid yearly. This support is renegotiated annually. In FY 78 this assistance, intended to compensate for Los Alamos's small industrial and commercial tax base, amounted to $1,268,000 for county operations and $2,850,000 for the schools.

2.2 CURRENT MISSIONS AND ACTIVITIES

Since it is impossible to set quantitative values on the benefits of basic research, qualitative and philosophical terms are necessary to define the purpose of LASL's activities. Weapons research is dedicated to meeting the needs of our national security programs that involve nuclear weapons. Current missions and activites at LASL include research and development programs related to the intermediate and long-term energy needs. Environmental research at LASL is providing information on the behavior of waste materials in natural systems. Such data are important in making future energy resource development decisions to minimize adverse effects.

The Laboratory has a wide range of research and development programs, funded principally by DOE. The Laboratory also does work for other Federal agencies; during FY 78 this constituted about 8.3% of its effort. All of these activites are conducted in DOE-owned facilities and do not contribute any unique environmental effects, although they do contribute to the cumulative impact such as resource consumption and waste generation. The following is a brief review of major Laboratory programs and reflects the Laboratory's interdisciplinary approach to research.

2.2.1. National Security Programs

A primary mission of the Laboratory is research and development work on fission and thermonuclear weapons, including the basic scientific and engineering support activities. LASL was originally founded for the purposes of national security and has continued as one of the three designated national nuclear weapons laboratories. Rather than quantifying the cumulative benefits of this effort, they are best assessed in terms of national defense policy. A strong nuclear capability is a matter of national policy, and LASL plays an essential role in carrying out that policy. The current LASL program for national security comprises three parts: weapons development activities, laser fusion studies, and fissile materials security and recovery work.

Weapons development activities include the research, development, and testing activities that lead to the production of nuclear weapons. Since the early 1950's, the Laboratory has concentrated on the design and development of nuclear assembly systems, and the production of weapons has been taken over by other DOE facilities. The major effort at LASL is devoted to the development of new weapon concepts, their evaluation through calculation, local experimentation with components and mockups, development of hardware, and underground testing of promising systems at the Nevada Test Site at Mercury, Nevada.

Underground testing is very expensive.[2-1] Hence, efforts are made to elucidate the complex processes involved in a nuclear explosion by use of theoretical calculations and experimentation. A primary function of the LASL Central Computing Facility is to calculate the effects of design changes on weapon performance and to analyze and reduce experimental data. Radiochemical analyses of the samples of fission products, averaging about 1.5 curies, from underground tests in Nevada are performed at LASL to provide additional details on the performance of test devices. They are shipped in accordance with current Department of Transportation regulations. The detonation motion of non-nuclear mockups can be studied by means of PHERMEX, a high-intensity flash x-ray machine, and other diagnostic devices. This local mockup testing is less expensive than full scale experiments at the Nevada test site.

Basic and applied research required to support the weapons effort includes programs in nuclear physics, theoretical and experimental work on the properties of materials under extremely high temperatures and pressures, the development of mathematical and computer techniques, the chemistry and metallurgy of the materials in a nuclear system, the chemistry and physics of explosives, and the development of specialized electronic and photographic instrumentation.

The laser fusion studies are concerned with the use of laser energy to initiate fusion reactions in deuterium and the application of the energy released by these reactions. Toward this end, effort is being devoted to the study of the interaction of high-intensity laser light with matter and to the physics of laser-produced plasmas. Development is under way of short-pulse, high-energy lasers and laser systems, such as carbon-dioxide gas lasers, to initiate thermonuclear burn of fusion-fuel pellets containing tritium and deuterium.

The principal experimental device associated with the program is an eight-beam CO_2 laser, with a 10^{13} watt peak pulse power, designed to produce basic physics and engineering data. Systems and engineering studies are being carried out on potential applications of laser-initiated fusion in such areas as electrical power production, nuclear-weapon diagnostics, and nuclear-weapons effects simulation.

Fissile materials security and recovery work is the third part of the current LASL Weapons Program. Tons of low-enrichment uranium are used throughout the world to fuel nuclear power reactors, which, in turn, produce large quantities of fissile materials. Materials such as ^{235}U and ^{239}Pu are carefully controlled and guarded against misuse because of their high production cost, their strategic importance as ingredients of nuclear weapons, and the potential health hazard from their radioactivity. LASL research is directed towards reducing the chances of loss or diversion of nuclear materials.

The development and application of chemical and spectrochemical assay techniques has been an important part of LASL's operation since the Laboratory was founded. An analytical chemistry group is participating in a nationwide cross-calibration of measurement techniques and in the preparation of standard specimens for distribution to nuclear processing plants.

The main objective of LASL's fissile materials assay project is to develop methods of assaying the fissile material content of process streams, reactor fuels, and scrap and waste from fabrication plants by means other than conventional chemical analysis. The methods are adaptable to both continuous or batch processes. This project has resulted in the development of instrumentation and calibration techniques applicable to a wide variety of materials and shapes, ranging from nuclear explosive systems and reactor fuel elements to residues and scrap materials in barrels from processing plants. A Mobile Nondestructive Assay Laboratory (MONAL), designed and operated by LASL, has been in use since 1971. The MONAL has visited a number of nuclear material fabrication plants, both to demonstrate the assaying technique and to perform assays as a service to the plant.

LASL also has a continuing program to convert fissile scrap material back to usable special nuclear materials. The bulk of the material processed to date is from the now terminated nuclear rocket (Rover) program.

2.2.2. Energy Programs

Along with weapons development, research and development work in energy resources and applied energy technology have become recognized as important to the national interest. LASL's energy technology research has been concentrated on four energy resources: fusion, geothermal, solar, and fission, with some work in coal and oil shale.[2-1] Alternative energy resources hold the potential of maintaining or improving quality of life and achieving national energy independence. LASL has been committed to research in fusion power for many years. In the early 1970's, several non-nuclear energy and energy-related programs were added to the LASL fission and fusion reactor programs. Consequently, the Laboratory now carries out a broad spectrum of energy programs ranging from computer studies to hardware development. Included are reactor programs, advanced isotope separation studies, space nuclear systems development, controlled thermonuclear research, and applied energy technology.

Reactor programs are important since assessments of the nation's potential future energy sources consider fission reactors to be an important factor in the nation's energy program through the end of this century. Continued work on fuels, reactor safety, and radioactive waste management are all directed toward improving the efficiency and safety of the fission power cycle as well as minimizing certain potentially adverse environmental impacts. If nuclear power will be part of this nation's energy resources, it is essential to follow through on fission research.

Much of LASL's recent work has been related to reactor safety, specifically regarding gas-cooled and water-cooled reactors. This reactor safety work includes development of calculational methods for design and analysis, study of the decay power produced by fission products, and assessment of the reliability of reactor components. The objective is to develop broad-based programs applicable to a wide range of reactors. The ability to define potential accident sequences leads to design criteria that can minimize or eliminate safety problems.

For a number of years, LASL has been involved in the national effort to develop a Liquid-Metal-Cooled Fast-Breeder Reactor (LMFBR), in which fissions of the fissile ^{235}U or ^{239}Pu fuel release high energy neutrons that breed new fissile material. Emphasis at LASL is on evaluation of irradiated fuels, improvement in the design of fuel elements, and performance of safety calculations. Current involvement includes studies of advanced fuels for the LMFBR, development of calculational methods of assessing reactor performance and safety, and performance of certain general analytical chemistry work supporting the overall reactor program.[2-3, 2-4]

LASL also has an advanced reactor program involving high-temperature, gas-cooled reactors. It includes development of improved coated-particle graphite-matrix fuels, systems studies aimed at the technical and economic evaluation of developed reactor designs for the application of nuclear heat in high-temperature industrial processes, and studies on material behavior under high-temperature reactor conditions.

Advanced isotope separation studies also may be important in development of the nation's future energy sources. The objective of this research activity is to develop methods other than the traditional gaseous diffusion, electromagnetic, or centrifuge methods now used to separate isotopes. Each chemical element, such as uranium, has several isotopes that, though identical chemically, differ from one another in mass and nuclear properties. There are currently two LASL isotope separation projects under way. The first is based on the fact that lasers can selectively initiate photochemical reactions in a chemical compound containing two or more isotopes--molecules containing one isotope would react and molecules containing other isotopes would not. The second is based on the fact that molecules containing lighter isotopes evaporate more quickly than those containing heavier isotopes.

The main effort of the laser isotope separation program has been directed at the separation of uranium isotopes, which if successful could have major impacts on the nuclear power industry. The laser method is also applicable to the separation of deuterium from ordinary hydrogen. Deuterium is a primary fuel for the controlled thermonuclear fusion program. Additionally, there are many other rare and useful isotopes that can potentially be isolated by this technique.

LASL has several plants for separation-by-evaporation of the stable (i.e., nonradioactive) isotopes of carbon, oxygen, and nitrogen (the ICON program). These isotopes are used as extremely sensitive tracers in chemical structure research and field studies of such processes as fertilizer uptake by crop plants. The Laboratory produces several tons of ^{13}C, ^{14}N, ^{15}N, ^{16}O, ^{17}O, and ^{18}O per year for application in agricultural, environmental, and biomedical research.

The Los Alamos Meson Physics Facility (LAMPF) also is involved in isotope separation. At the terminus of the main LAMPF proton beam, protons not diverted to nuclear-particle experiments are being used to produce large quantities of a new series of proton-rich radioisotopes that are frequently more useful for research and medical applications than the neutron-rich isotopes produced in nuclear reactors. A facility at LAMPF is being used specifically to separate these isotopes and study their properties.

LASL's space nuclear systems development included the large R&D effort terminated in FY 73 on the design and testing of nuclear rocket reactors. Also, basic chemical and metallurgical studies are continuing on radioisotopic power sources for satellites and other spacecraft. Present activities include studies and systems analyses of potential designs for nuclear reactor power plants to provide electric power for advanced space missions, and further development of ^{238}Pu for use as an advanced radioisotopic heat source. In the latter area, various ^{238}Pu compounds are prepared and evaluated, ceramic and cermet fuel forms are developed and characterized, and the safety aspects of the use of ^{238}Pu power sources are studied.

Fusion is being pursued from two major directions: by the use of magnetic fields such as with ZT-40 and by the use of high-powered lasers. The goal of the Controlled Thermonuclear Research (CTR), or Magnetic Fusion Program, is the development of a new energy source (see Figure 2.2) based on the fusion of light elements, as contrasted with the fission of very heavy elements as in present nuclear reactors. Both processes release enormous amounts of energy, but fusion has several advantages over the fission process. For example, fusion uses isotopes of hydrogen as its fuel and produces radioactive wastes that are relatively easy to manage. These isotopes, such as deuterium and tritium, can be mined or bred in essentially limitless quantities. Fusion reactions have been produced in the laboratory, but achievement of an economical net gain in energy is expected to require many more years of effort. LASL has built four previous high-density, pulsed machines for the CTR program; these were all linear devices. The fifth generation device, Scyllac, was the first to use a toroidal shape. A laser fusion experiment, Helios, is presently operating. The next generation laser fusion experimental facility, Antares, is under construction.

Other program directions include developing energy storage systems and insulators for CTR applications. The CTR program also includes studies and experiments needed to correlate the work with laser-fusion activities.

The applied energy technology program includes projects in geothermal and solar energy, superconducting power transmission, magnetic energy storage devices, and thermochemical production of hydrogen.

The Los Alamos Dry Geothermal Source Demonstration Project is developing methods of economically extracting energy from hot, dry rock in the earth's crust, as compared to systems that depend on natural underground resources of hot water or steam. The hot rock is fractured by hydraulic pressure and then water is circulated to extract the heat. Research and development for this project will include studies in geochemistry, geophysics, heat flow, fluid flow, rock mechanics, seismology, environmental effects, and related subjects to ensure an economical and environmentally acceptable system. Hot, dry rock geothermal energy appears to have minimal adverse environmental impacts and is essentially a limitless source. The environmental impact of this project is being monitored and will not be included in this Environmental Impact Statement. An environmental assessment for the Fenton Hill project has been completed and appended to the Memorandum of Agreement between DOE and the Forest Service.[2-5]

LASL has several programs involving research and development on the use of solar energy for heating and cooling buildings. These include systems and controls analysis of solar-heated and -cooled buildings, development of a prototype solar-heated-and-cooled-mobile home, and evaluations of sun-tempered and other solar-heated structures. The Laboratory has developed integrated solar collector roof structures. The solar energy program includes objectives for producing components easily incorporated into conventional building techniques. The National Security and Resources Study Center at Los Alamos, completed early in 1977, uses these advanced flat-plate solar collectors developed by LASL, and will provide a utilization demonstration of an energy-saving 100-ton solar Rankine-cycle cooling unit. The building will serve an important role in a national series of proof-of-concept solar energy experiments.

LASL has two applied energy technology projects involving cryogenics and superconductivity. Superconductivity is a phenomenon in which certain metals and alloys will, at very low temperatures, conduct electricity with no loss of power. LASL is applying this effect to the development of superconducting, direct-current, power transmission lines, to conduct large quantities of electrical power great distances in relatively small underground conduits without the large power losses incurred in conventional transmission lines.

A superconductive magnetic energy storage system now under study could provide a power generation load-leveling method that would result in significant savings in fuel and in capital and operating costs. Such a system would be capable of storing large amounts of energy in a relatively small volume. Some small loss is to be expected in the transfer of energy into and out of the system, but the overall efficiency of a superconducting magnetic energy storage device, including the energy required for refrigeration, is expected to be 95%, compared with the 70% experienced in pumped hydrostorage. The system could be advantageously coupled with a superconducting direct current transmission line described above.

2.2.3. Biomedical and Environmental Programs

The LASL biomedical and environmental programs were initiated in 1947 to develop methods to determine worker exposure to radioactive materials, particularly plutonium. They were later extended to studies on radioactive fallout from atmospheric weapons testing. Examples of applications of nuclear technology in health and medical research include use of radioisotopes and mesons, particularly in cancer treatment, and development of plutonium-fueled thermoelectric generators for powering heart pacemakers and an artificial heart. Other ongoing research relates to the detection and treatment of various human and animal diseases. For example, biomedical research contributes to the diagnosis, alleviation, and better treatment of diseases such as cancer. LASL developed liquid scintillation counting techniques and the use of ^{14}C as a tracer in biology and medical research.

Today the scope of LASL biomedical and environmental research programs has broadened. The three major program areas are biomedical and environmental research, waste management, and operational health and safety.

The biomedical and environmental research at the Laboratory include ongoing, long-term programs on the effects of radiation and pollution on man and his environment. Studies on the effects of non-uniform distribution of the dose from radioactive isotopes deposited in the body, the so-called hot-particle project, is particularly significant for understanding the toxicity of inhaled alpha emitters. The broad base of research technology in cellular and molecular biology is providing the tools for a better understanding of radiation damage and carcinogens of all types, radioactive and nonradioactive. Stable isotopes are synthesized into compounds of biological interest for studies of normal metabolism and disease states in plants and animals, including man.

The Biomedical and Radiation Therapy Research Facility associated with LAMPF was originally used for preclinical radiobiological studies needed to evaluate the advantages of negative pi mesons for radiation treatment of cancer. These studies have led to clinical trials with human cancers that began in 1976 in cooperation with the University of New Mexico Cancer Treatment Research Center. The LAMPF accelerator is also used to produce radioisotopes for use in nuclear medical diagnosis and treatment. The facility was also involved in solving the problems associated with producing a satisfactory ^{238}Pu power source for the artificial heart program.

Present environmental research emphasizes determining the behavior of selected radioactive and non-radioactive materials in the various ecosystem components. These studies, associated with nuclear, geothermal, and coal energy operations, are supported by continuing work on an environmental resources inventory that involves collecting quantitative information on plants, animals, and soils in the Los Alamos area. The LASL reservation has been designated a National Environmental Research Park.

The waste management program is devoting increasing efforts to the overall technology of the treatment, handling, and disposition of transuranic-contaminated solid radioactive wastes. This includes monitoring past and present waste burial sites and evaluating the risk potential for movement of these materials. Research areas include assessment of acceptable waste management practices for transuranic elements, methods to achieve such practices, criteria for safe packaging of solid radioactive wastes, risk analysis of past burial practices, and incineration studies.

Radioactive liquid waste management research is centered on the two industrial liquid waste treatment plants that serve the Laboratory complex. The variety of wastes that must be treated necessitates a continuing program of research and development, which additionally contributes to solving world-wide problems of safely handling radioactive wastes. Present work is directed toward the goal of developing systems that will reduce radioactive discharge. Ion exchange, reverse osmosis, evaporation, and recycling processes are under investigation.

Occupational health and safety projects at LASL constitute three major areas of research--industrial hygiene, industrial safety, and health physics. Generally, research in these areas is determined by specific needs generated by the Laboratory's programs; however, the results often have applications for the protection for industry and public protection. The complementary routine inspection and monitoring of Laboratory activities is described in more detail in Section 3.3.4.

Industrial hygiene activities include major research efforts in aerosols, filter and ventilation system evaluation, characterization of hazardous aerosols in the work place or under simulated conditions, and respirator evaluation and training programs. Other concerns include monitoring and analysis for radioactive and nonradioactive materials in biological fluids and tissues and a new program for developing analytical techniques for measuring organic carcinogens used throughout U.S. industries.

Industrial safety studies contribute to a broad range of research on problems of national interest such as laser safety standards, guides for electrical safety in research, low-temperature engineering, computer protection, hazardous-material handling, and analysis of large scale events. Health physics research involves a wide range of problems concerned with improved radiation safety.

2.2.4. Physical Research Programs

Most of the physical research program at LASL is related to the operation of the Clinton P. Anderson Los Alamos Meson Physics Facility (LAMPF) and the associated accelerator research studies. The balance is distributed among a large number of smaller, basic research type, support programs.

The LAMPF facility consists of a linear proton accelerator approximately 800 m (0.5 mi) long, designed to produce an 800-million-electron-volt proton beam with an average intensity of one milliampere. Energetic protons striking a target produce subnuclear particles, called pi mesons, which are of particular interest in nuclear physics since they are believed to be the "glue" that holds atomic nuclei together. The pi meson is not ordinarily found as a free particle since its lifetime is only a small fraction of a microsecond. However, this time is long enough for a beam of mesons to be focused and conducted along a channel to experimental apparatus. There, the interactions of mesons with other materials help reveal the fundamental structure of nuclei.

The LAMPF capability for meson production is unique in the world. LAMPF is used by over a thousand scientists from all over the world for experiments in medium-energy nuclear physics, biophysics, radiochemistry, cancer therapy, and other fields.

The support programs in nuclear science include a large number of research projects. There are several studies in nuclear theory and nuclear chemistry related to medium-energy physics as well as research relevant to the fission and fusion reactor programs. Other LASL research is focused on molecular and mathematical sciences, materials research, thermochemical hydrogen studies, and geoscience investigations.

In addition to the work at LAMPF, the Laboratory also conducts considerable nuclear research using other facilities. A vertical 8-million-electron-volt (MeV) Van de Graaff and a 15-MeV tandem Van de Graaff are arranged so they can be operated separately or in series to produce beams of 23-MeV protons or accelerated ions of ^{2}H, ^{3}H, ^{3}He, and ^{4}He and heavier isotopes. These particle beams are used in studies, sometimes involving polarized beams and targets, of light nuclei and their stability, neutron and charged particle scattering and reaction cross sections, nuclear models and reaction mechanisms, and nuclear fission and neutron source reactions. Another facility, the 8-megawatt Omega West Research Reactor, is used for external neutron beam experiments, radiation damage studies, in-core irradiation of instrumented samples, fissionable material assay, and neutron radiography. A major physical research program involves studies of the energy-level structure of nuclei using high-resolution measurements of gamma rays emitted following neutron capture or beta-ray emission. It is presently being used in programs for neutron activation analysis of water samples taken throughout the nation. Omega West is under the jurisdiction of DOE and meets DOE standards for research reactors that are equivalent to NRC standards for research reactors.

Molecular and mathematical sciences provide basic research support to DOE's programmatic work in energy conservation, magnetic fusion, fossil-fuel energy, and geothermal energy. LASL projects involve heat-pipe research, a study of the radiation produced in high-temperature plasmas when seeded with high-atomic-number impurities (expected to arise from wall materials in fusion reactors), basic investigations in plasma physics, a study to determine the potential of using active organometallic complexes to remove SO_2 from fossil power plant flue gases, and two projects designed to facilitate the use of improved mathematical techniques and computer technology in the solution of problems.

The materials research activity supports DOE's programmatic work in magnetic fusion energy, conservation, nuclear energy, and many energy- and defense-related R&D activities. The basic understanding of high-temperature material properties is being improved. Materials potentially useful as electrodes in thermodynamic high-temperature topping cycles are receiving special attention. A library of equation-of-state computer codes for a large number of materials of interest to energy researchers is being developed. These codes cover wide ranges of temperature and density for use in hydrodynamic computer calculations. High temperature irradiation damage effects (creep and physical property changes) on materials interest to the magnetic fusion program are being investigated, and techniques to separate tritium gas from the molten lithium blanket in fusion reactors are being considered.

The hydrogen thermochemical cycles are being studied to discover and engineer a method for producing hydrogen from water, using heat generated by nuclear, solar, or other sources of energy. The usual constraint of environmental acceptability applies, and the efficiency must be higher than that for the production of hydrogen by electrolysis. Thermodynamic and kinetic studies of potential cycles are being carried out to select the more promising cycles for further study. Engineering studies to provide plant design data, to investigate possible pilot plant designs, and to foster industry participation and eventual transfer of the technology to industry constitute the more applied aspects of this program.

The geosciences program involves basic research in support of LASL's weapon program, and the hot, dry rock geothermal energy program and other applied geosciences programs. The major effort is in basic geosciences research in the areas of geology, petrology, and experimental geophysics. Particular emphasis is being given to developing a more basic understanding of thermal activity in the earth's crust and of rock mechanics and rock fracturing phenomena. The several smaller components of this program include basic research on rock-water interactions at high temperatures and pressures, thermodynamic and chemical kinetic modeling of geochemical systems, and basic geochemical research on minerals of interest to the LASL geothermal energy program.

An increasing number of spinoffs are applicable to practical problems. For example, the developmental work on the Los Alamos Meson Physics Facility (LAMPF) led to the design of improved medical X-ray units, a significant advance of that technology. Another was the rock melting Subterrene drill that evolved from basic high-temperature material studies. It was applied to the preservation of American Indian ruins by melting drain holes without vibration or shock damage.

2.2.5. General Support Programs

Services provided in general support of the Laboratory include financial accounting; procurement and property accounting and control; personnel and wage/salary services; information services that include extensive technical libraries; public relations including information and visitior services; medical services; safety and plant engineering; plant security; fire protection; utilities; maintenance; legal; general administration; precision machine shops; facilities for electronics design, fabrication, and maintenance; developmental laboratories for the fabrication of new or unusual materials required to support the research and development program; cafeterias; laundry; computer services; garage and vehicle maintenance; steam generating plants; water wells and water treatment plants; and sewage treatment facilities.

2.3. FUTURE DIRECTIONS

The proposed action contemplates a continuing evolution of LASL programs. Since these change continually, as projects are completed and as national priorities are revised, the description of program goals is in essence a description of anticipated benefits from LASL's continued operation. The potential benefits of weapons research, applied research on energy technology, or basic health and environmental research are difficult to quantify. The development of commercial fusion power could radically increase the world's energy supply, and a better understanding of the effects of radiation on living matter is likely to increase our understanding of the causes and cures of cancer.

Over the years the trend at LASL has been increasingly toward diversification into related areas of nuclear, and more recently, non-nuclear, energy applications. Overall, current plans project maintenance of a vigorous program of basic research relevant to national security, various areas of energy production, and expansion of LASL as a center for selected major development programs.

Table 2-1 shows the projected expenses and manpower requirements to carryout planned programs for FY 77 through FY 81. Since programmatic funding decisions are made on a year-by-year basis, the actual budgets may change. These figures represent the best estimates available based on information current to March 1979.

TABLE 2-1

MANPOWER REQUIREMENTS AND EXPENSES

	ACTUAL			PROJECTED	
	FY 1977	1978	1979	1980	1981
Manpower (FTEs)*					
DOE/LAAO	359	339	343	463	463
UC	6035	6370	6825	6825	6825
Other DOE Contractors	1174	1293	1379	1301	1335
Total	7568	8002	8547	8589	8623
Expenses (in millions of dollars)					
Operating Cost					
DOE/LAAO**	6.9	7.4	8.3	10.1	10.7
UC	210.3	246.4	273.6	296.0***	322.2***
Other DOE Contractors	30.5	35.0	40.5	45.1	49.9
Total	247.7	288.8	322.4	351.2	382.8
Plant and Capital Equipment					
DOE/LAAO	---	---	---	---	---
UC	26.6	29.7	44.3	44.5	72.0
Other DOE Contractors	16.0	12.6	18.1	33.2	62.5
Total	42.6	42.3	62.4	77.7	134.5

*Full-time equivalents

**Includes the following DOE/LAAO costs not reflected in LASL operations.	1.0	1.1	1.2	1.1	1.2

***Preliminary estimate

The table gives the total for each year and a breakdown between University of California and other DOE contractors at LASL. Approximately half of the effort at LASL is devoted to the national security programs and half to other research projects. National security programs include weapons development, nuclear materials safeguards and security, and laser fusion (see Section 2.2.1). Other research projects fall into four basic categories: energy programs (see Section 2.2.2), biomedical, environmental and safety programs (see Section 2.2.3), physical research (see Section 2.2.4), and regulation and reimbursables. Regulation and reimbursables represent work performed for federal agencies other than DOE, such as the Nuclear Regulatory Commission, the National Aeronautics and Space Administration, the Environmental Protection Agency, the Department of Defense, and the Department of Health, Education and Welfare. The environmental effects of these activities have been included with the cumulative impact of the Laboratory; they do not represent any significant or unique environmental impacts.

Table 2-1 includes the estimated manpower requirements, operating expenses, capital equipment, and construction costs. Manpower requirements include indirect and support personnel such as those persons doing work classified as overhead within research program areas. Examples are routine environmental, health, and safety monitoring; general administrative and engineering functions; and secretarial and clerical assistance. Operating expenses and capital equipment investments are required to implement continuing and projected programs.

Construction projects presently underway include general plant projects representing improvement and modification of existing facilities, minor new construction to meet changing and expanding program needs, and road and utility system improvements. A number of projects were described in the DEIS but have been deleted herefrom because they are no longer being actively considered. Environmental review of all construction projects begins at the conceptual design phase by the Laboratory Environmental Review Committee (LERC). This includes the preparation of appropriate NEPA documents and recommending the incorporation of mitigating measures in the design and operation which will avoid adverse environmental effects. See Appendix H, pages H-43 and H-44 for additional detail. The following specific projects are also now under design or construction.

The High Energy Gas Laser facility (Antares program) is scheduled for completion in 1984 and will provide a system that is scaled up from the current high-energy gas lasers. This will permit an assessment of the technical feasibility of initiating themonuclear reaction by laser irradiation. Demonstration of thermonuclear yields from laser-target interaction is a major step in the development of the technology required for commercial applications of laser fusion power. The facility also has a military application in providing laboratory simulation of weapons effects as an alternative to full-scale thermonuclear weapons testing.

Upgrading of security and protection measures relating to special nuclear materials is an ongoing project. This project will reduce the chances of loss or diversion of nuclear material and will provide for compliance with DOE regulatons.

A new Detonator Facility is planned to replace obsolete quonset huts, constructed in 1944, in which explosive assembly and detonator experimentation work is performed. The project includes a 35,000 square foot building and upgrading of the water system at the technical area.

A new Tritium Facility is planned which will be an addition to an existing building in Los Alamos Canyon. The 3000 sq. ft. addition will permit relocation and upgrading of tritium handling operations now conducted in an obsolete facility in another, far off, technical area at the LASL.

Also a high priority project is the Target Fabrication Facility at the laser fusion complex. This facility will provide necessary target fabrication and office space in the energy program's Laser Fusion Facility now under construction.

Environmental assessments were developed for each of the above projects and were considered in the evaluation of the Laboratory's cumulative effect and the assessment of mitigating actions.

A new Plutonium Processing Facility was completed in 1979. The facility is constructed to meet recent requirements for fire protection, ventilation, filtration, radiation protection, and protection from natural disasters such as tornado or earthquake. It incorporates the most reliable designs for minimizing routine releases and the probability of accidents. The final Environmental Impact Statement, issued in January 1972, found the potential environmental impacts would be acceptable.[2-6]

Design and construction of the Intense Neutron Source Facility (INS) has been cancelled. The facility was one of several to study the effects of high-level neutron radiation on metals and insulators to be used for the magnetic fusion energy program. The final Environmental Impact Statement issued in July 1976 for the funding of the construction and operation of the INS found that the potential environmental impacts would have been acceptable.[2-7]

There are a number of construction projects in the planning process. Environmental impact assessments have been prepared to accompany budget requests for each of these. Of special importance is the Laboratory Support Complex to provide much needed office space. This facility will be a three-story office building with a cafeteria and a gross area of approximately 12,500 m^2 (135,000 ft^2) located in the main technical area. It will allow consolidation of many fragmented groups and phasing out temporary office space being leased offsite.

A proton storage ring and other additions to the Los Alamos Meson Physics Facility (LAMPF), including an experimental support facility, are also being planned. The proton storge ring facility will consist of an underground building and a prefabricated metal building with a total gross area for the two structures of 2000 m^2 (22,000 ft^2). These facilities will provide a means of calibrating detectors and testing data-acquisition systems at LASL before underground nuclear weapons tests at the DOE Nevada Test Site. The experimental support facility will be a staging area facility of approximately 650 m^2 (7000 ft^2).

Improvements to the industrial waste collection and treatment system are in design. The project would include installation of 6700 m (22,000 ft) of an electronically monitored double-encased industrial waste sewer system to replace the existing system. This would decrease the danger of sewer line leakage and contamination of the environment by toxic or radioactive materials. Improvements to the liquid waste treatment facilities include supplementary processes to reduce the radioactivity content of plant effluent.

A tritium system test assembly to demonstrate the tritium fuel cycle and environmental control system for a Tokamak experimental fusion-power reactor is under construction. An existing building is being modified to house the new facility.

Other construction projects being considered include further plant upgrading in keeping with occupational health and safety requirements and improvements to the electric and water systems and to other utilities. Two facilities for waste volume reduction and contaminated materials reclamation are being planned to reduce the volume of contaminated wastes being generated and to study the feasibility of recovery and reuse of materials and equipment. Appropriate NEPA documents are prepared as necessary before final approval for construction.

The discussion is intended to give only the broadest outlines of possibilities for new research areas and expansion of facilities by identifying the maximum range of factors receiving current consideration. Anticipated environmental effects of individual proposed projects have been included in the evaluation of the cumulative impact and the assessment of mitigating effects in this document. Unique or special aspects may have to be treated in documents specific to individual construction projects.

REFERENCES

2-1 U. S. Energy Research and Development Administration, "Final Environmental Statement: The Nevada Test Site, Nye County, Nevada," ERDA-1551 (September 1977).

2-2 U. S. Energy Research and Development Administration, "A National Plan for Energy Research, Development and Demonstration: Creating Energy Choices for the Future," ERDA 76-1 (June 1976).

2-3 U. S. Energy Research and Development Administration, "Final Environmental Statement: High Performance Fuel Laboratory, Hanford Reservation, Richland, Washington," ERDA 1550 (September 1977).

2-4 U. S. Energy Research and Development Administration, "Final Environmental Statement: Safety Research Experiment Facilities, Idaho National Engineering Laboratory, Idaho," ERDA 1552 (September 1977).

2-5 DOE Contract DE-AC 32-79AL10001, Januray 3, 1979: "Interagency agreement between U.S Department of Energy and U.S. Forest Service."

2-6 U. S. Atomic Energy Commission, "Environmental Statement: Plutonium Facility, Los Alamos Scientific Laboratory, New Mexico," USAEC Report WASH-1506 (January 1972).

2-7 U. S. Energy Research and Development Administration, "Final Environmental Statement: Intense Neutron Source Facility, Los Alamos, New Mexico," ERDA-1548 (July 1976).

3. CHARACTERIZATION OF THE EXISTING ENVIRONMENT LIKELY TO BE AFFECTED BY THE PROPOSED ACTION

In this chapter the environmental features of Los Alamos, New Mexico, are described, with emphasis on those features, beneficial as well as adverse, that are related specifically to the continuing operation of LASL. Environmental impacts will be discussed in the next chapter. The three catagories used to characterize the existing environment at Los Alamos, New Mexico, are the physical environment, the socio-economic environment, and the routine operations.

Summary of Changes

The following summarizes the changes and updating of material which have been made in this chapter as a result of the review and comment on the DEIS.

Physical Environment. No major changes are noted in the geology, hydrology, meteorology, or ecology sections. In the geological hazards section, a new paragraph addresses the requirements of DOE regulation 10 CFR 1022 for floodplain review in response to Executive Order 11988, Floodplain Management. The ecology section is updated to include the Jemez Mountain Salamander on the State endangered species list and notes required close coordination with the Fish and Widelife Service before determining the impact of any significant change of Laboratory activity.

Socio economic Environment. No significant changes have been made in this section. Trends are generally as previously predicted in growth, demographics, economics, and land use. Archaeological activities of the future are to be governed by new regulations in 36 CFR 800, requiring more active participation by the State Historic Preservation Officer. An explanation of the Los Alamos National Historic Landmark is included, noting that properties affected are on either county or private land, not on land under DOE jurisdiction.

Routine Operations. Water demand in Los Alamos County was noted as decreasing 30% from the projected use for the 1977-78 period. Conservation measures are showing an effect in electric demands as well. Impacts for the new 115 kv line proposed by Public Service Company of New Mexico (PSCNM) to cross LASL property and terminate at the Main Technical Area are addressed in a DOE Environmental Impact Statement, DOE/EIS-0049-D, concerning the entire proposed 50 MWe geothermal demonstration project on the Baca Ranch. The new NPDES permit covering 104 industrial discharge points and 10 sanitary sewage treatment facilities at LASL are noted, and reference made to more detailed information in Appendix H. The discussion of radioactive waste management at LASL was revised in response to requests for additional information and clarity on radioactive waste disposal techniques. Numerous publicly available reports are cited.

A new section on Transportation of Radioactive Materials describes procedures, regulations, current operations and summarizes data on shipments in 1978.

3.1 PHYSICAL ENVIRONMENT

The physical environment is described by defining the earth, water, air, plants, and animals in the context of the geologic, hydrologic, meteorologic, and biologic processes that link them together. Although approached as seperate entities herein, for the sake of organizational clarity, each is characteristically significant only in terms of the whole.

3.1.1 Geology

The technical areas of the Los Alamos Scientific Laboratory and communities of Los Alamos and White Rock are located on the Pajarito Plateau (see Figure 3.1.1-1). The plateau is 16 to 24 km (10 to 15 mi) wide and 40 to 48 km (25 to 30 mi) long, lying on the eastern flank of the Jemez Mountains. The plateau slopes eastward from an altitude of about 2400 m (7800 ft) along its western margin to about 1800 m (6200 ft) to the east where it terminates above the Rio Grande at the Puye Escarpment and the rim of White Rock Canyon. The surface of the plateau is cut into numerous narrow "finger mesas" by southeast trending intermittent streams. The dissected eastern margin of the plateau stands 90 to 300 m (300 to 1000 ft) above the Rio Grande.

Historical

The Pajarito Plateau forms a topographically high area along the western margin of the Rio Grande depression[3-1, 3-2] (see Figure 3.1.1-2). The depression began to form about 21 million years ago as the result of faulting. The structural depression extends from southern Colorado, through central New Mexico, into northern Mexico. Sediments were eroded from the highland mass to the east and west and formed the basin fill sedimentary rocks of the Tesuque Formation of the Santa Fe Group[3-3, 3-4, 3-5, 3-6] (see Figure 3.1.1-3). These sediments occur directly over the Precambrian basement rocks with no intervening layers representing mesozoic or paleozoic eras. The Santa Fe Group of Middle Miocene to Pliocene epoch (12 to 25 million years ago) was deposited by a southward flowing river in the depression (see Table 3.1.1-1).[3-7] Volcanic activity that occurred during the formation of the Santa Fe Group deposited numerous basalt flows and plugs through the sediments. These basalt eruptions in the area laid down a series of basalts which flowed northwest into the White Rock area from centers southwest of Los Alamos.

The volcanic rocks of the Jemez Mountains began with a series of eruptions during the Pliocene epoch (12 million years ago) along the western margin of the depression southwest of Los Alamos. The volcanic rocks (Polvadera Group) built a high mountain mass northward from the original vents. The volcanoes covered an area of over 2600 km^2 (1000 mi^2) and attained a thickness of at least 1500 m (4500 ft). The volcanic activity was climaxed during mid-Pleistocene Epoch (1.1 to 1.4 million years ago) by two gigantic pyroclastic explosions that deposited 400 km^3 (100 mi^3) of rhyolite tuff and pumice (Bandelier Tuff) around the flanks of the volcanic mass. This ejection of the tuff and pumice was followed by collapse of the center of the highlands forming a large caldera (a large basin-shaped depression). Subsequent volcanic activity was the intrusion of rhyolite domes in the caldera.[3-8, 3-9] The final volcanic activity took place in the southwest part of the caldera about 42,000 years ago with the eruption of a rhyolite pumice. Only hot springs and solfataric activity remain in the caldera as a reminder of the volcanic activity.

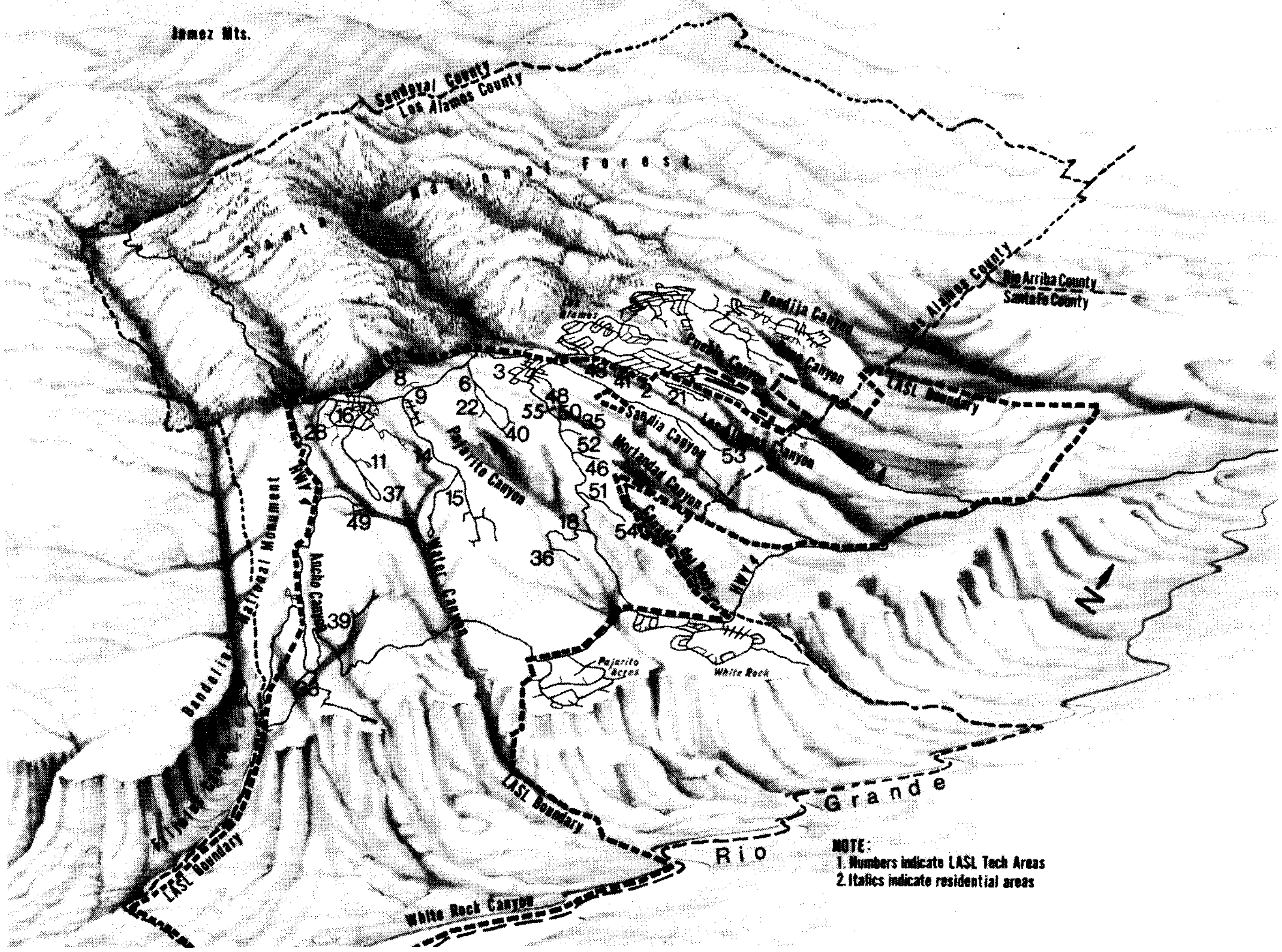


Figure 3.1.1-1 Artist's Rendition of LASL and Environs

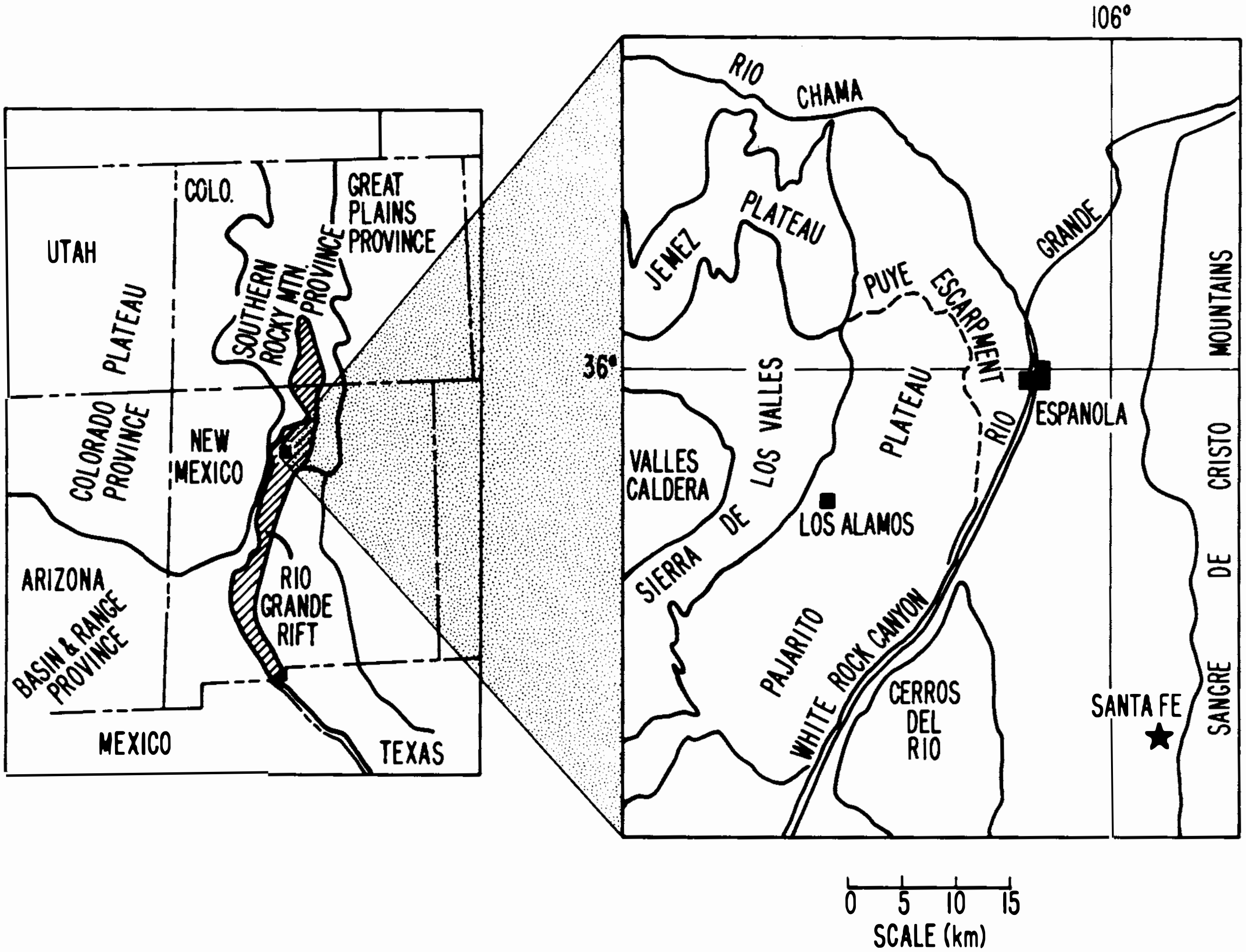


Figure 3.1.1-2 Physiographic Features of the Los Alamos Area

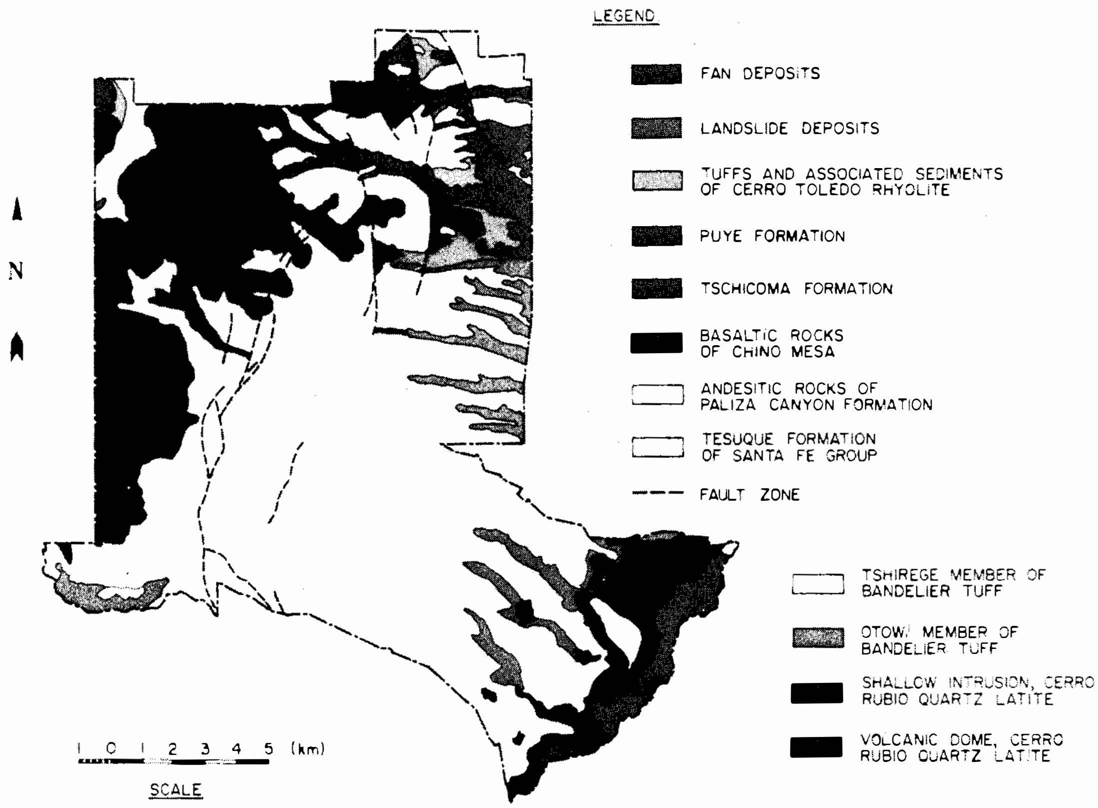


Figure 3.1.1-3 Geology of Los Alamos County

TABLE 3.1.1-1

GEOLOGIC TIME SCALE

Era	Period	Epoch	Approximate Age at Start of Time Division (Years Before Present)
Cenozoic	Quarternary	Holocene	10 Thousand
		Pleistocene	2 Million
	Tertiary	Pliocene	12 Million
		Miocene	25 Million
		Oligocene	40 Million
		Eocene	60 Million
		Paleocene	70 Million
Mesozoic			225 Million
Paleozoic			600 Million
Precambrian			>600 Million

The volcanic activity is a classic example of a resurgent caldera. The subcircular depression in the highland of the Jemez Mountains is from 20 to 30 km (12 to 20 mi) in diameter and from 150 to 600 m (500 to 2000 ft) deep. The caldera at one time contained a lake which was later drained by headward erosion of the Jemez River that breached the caldera walls. On the west side of the caldera a structural dome (Redondo Peak) rises to an elevation of 3,430 m (11,254 ft). A broad apron of dissected rhyolite tuff forms the Pajarito Plateau around the highlands of the Jemez Mountains. The easternmost part of the Jemez mountains, formed by the Tschicoma Formation adjacent to the plateau, is the Sierra de los Valles.

Geology

The volcanic and sedimentary rocks cropping out near Los Alamos range in age from Tertiary to Quaternary. The geologic formations in the Los Alamos area include the Santa Fe, Polvadera, and the Tewa Groups (see Figure 3.1.1-3).

The Santa Fe Group includes the sedimentary and volcanic rocks that are related to the Rio Grande structural trough. They range in age from middle Miocene to Pleistocene. The base of the Santa Fe is above the latitic and limburgitic flows and breccias exposed in the Cienega area. The youngest units of the Santa Fe are the terrace deposits and alluvia of present valleys. The Santa Fe Group formations exposed in the Los Alamos area, from the oldest to youngest, are the Tesuque Formation, the Puye Conglomerate, and the Basaltic Rocks of Chino Mesa (see Figure 3.1.1-4).

The Tesuque Formation is middle Miocene to early Pliocene in age. The Tesuque Formation is composed of siltstones and sandstones with lenses of clay deposited as basin fill sediments in the depression. It underlies the Pajarito Plateau and crops out along White Rock Canyon of the Rio Grande.[3-3]

The Puye Conglomerate, from the late Pliocene, consists of about 200 m (650 ft) of well-rounded pebbles, cobbles, and small boulders of quartzite, quartz, and granite with some volcanic debris in a matrix of arkosic sand.[3-10] It interfingers with the Tshicoma Formation and the Basaltic Rocks of Chino Mesa beneath the Pajarito Plateau and crops out along the Rio Grande. The Puye is divided into two members, the Totavi Lentil and the Fanglomerate Member. The Puye Conglomerate was eroded from the Tschicoma Formation forming a volcanic debris over the Tesuque Formation in the central and eastern parts of the plateau. The conglomerates interfinger with basalt flows that were emplaced from the southeast. The conglomerate interfingers with the younger flows of the Tschicoma Formation to the west. The Tschicoma Formation interfingers and overlies the Tesuque along the western part of the plateau and forms the mountain mass of the Sierra de los Valles.

Those flows that form the steep walls of White Rock Canyon and cap the high mesas to the east are the Basaltic Rocks of Chino Mesa. The sequence of flows that erupted from vents in the Cerros del Rio is greater than 390 m (1300 ft) thick at Chino Mesa. Their age is late Pliocene to middle or late Pleistocene.[3-10]

The Polvadera Group is the sequence of basaltic, andesitic, dacitic, and rhyolitic rocks, 1520 m (5000 ft) thick, that form part of the central and most of the northern Jemez Mountains. The group is late Pliocene to early Pleistocene in age. Of the Polvadera formations, the Tschicoma is the only one that crops out in the Los Alamos area.[3-11]

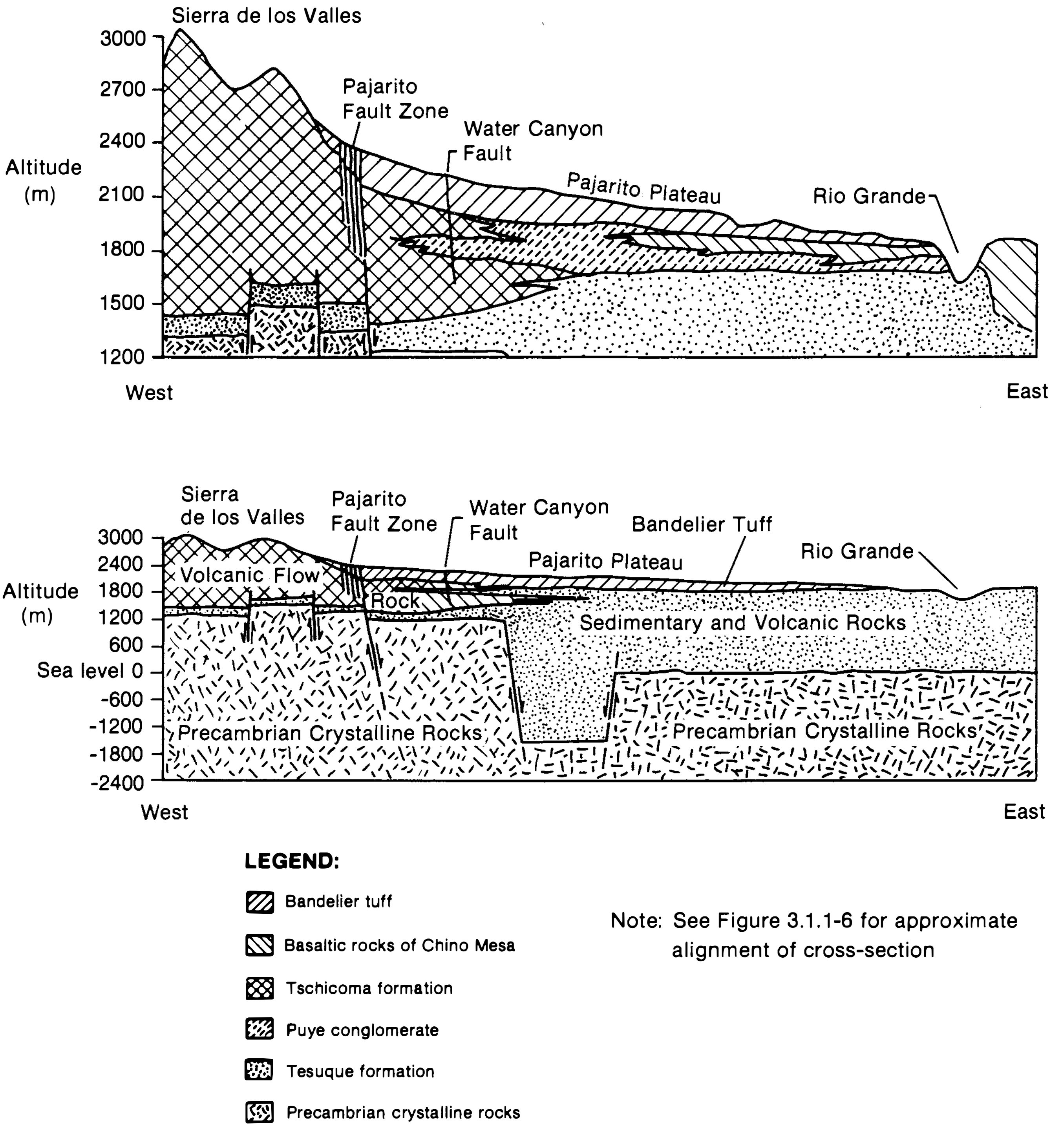


Figure 3.1.1-4. Geologic Stratigraphic Relationships

The Tschicoma Formation consists of andesites, dacites, rhyodacites, and quartz latites. Radiometric dates of 6.7 to 3.7 million years indicate an age of middle to late Pliocene. West of Los Alamos in the Sierra de los Valles, the Tschicoma is greater than 790 m (2600 ft) thick.

The rhyolitic tuff and thyolite and quartz latite domes which constitute the latest eruptive rocks of the Jemez Mountains are in the Pleistocene Tewa Group. In the Los Alamos area the Cerro Toledo Rhyolite and the Bandelier Tuff are the only formations of the Tewa group that crop out.[3-10]

The Cerro Toledo Rhyolite outcrops in a small area north of Los Alamos in Rendija and Guaje Canyons. Within the Valles Caldera the rhyolites are mainly volcanic domes with some associated sediments; however, north of Los Alamos they are reworked tuff and sediments that overly the Puye Conglomerate. They are less than 30 m (98 ft) thick.

The Bandelier Tuff caps the Pajarito Plateau. It is 80 to 320 m (260 to 1050 ft) thick and is composed of two members. The lower member, the Otowi, is a massive pumiceous tuff breccia of ash-flow origin as much as 80 m (260 ft) thick, that erupted from the Toledo Caldera. The upper member, the Tshirege, is a succession of cliff-forming welded ash flows as much as 100 m (330 ft) thick, that erupted from the Valles Caldera. The basal units of both members are ash falls. The basal unit of the Tshirege has a radiometric date of 1.1 million years.[3-11]

The tuff laps onto the flanks of the Sierra de los Valles and slopes gently to the east, where it terminates in cliffs or steep slopes along White Rock Canyon or as isolated outcrops above the Puye Escarpment. The surface of the plateau formed by the tuff has been dissected by southeastward trending intermittent streams into a number of long narrow mesas.

The Bandelier Tuff is the most important geologic unit of this environmental impact statement, since all facilities of LASL are sited on this geologic formation. It is exposed along canyon walls and is covered by a thin mantle of soil on the surface of the mesas. The ashfalls and ashflows are described as nonwelded, moderately welded, and welded tuff. Nonwelded tuff has a high porosity of 40% to 60% by volume, slight cohesion of glassy fragments, and crumbly fracture. Moderately welded tuff has a lesser degree of porosity, ranging from 30% to 55% by volume. It has moderate cohesion with slight deformation of glassy fragments, and somewhat brittle fracture. Welded tuff has a low porosity of 15% to 40% by volume, good cohesion, a high degree of deformation by flatting of glassy fragments, and a brittle fracture. The tuff has a large range in porosity in each of the classifications, indicating welding is only one of several factors determining porosity.[3-12]

The degree of welding influences the physical and hydrologic characteristics of the individual ash flow tuff units. The density ranges from less than 1 g/cm^3 for nonwelded tuff (pumice) to 2.2 g/cm^3 for welded tuff. The bearing capacities are proportional to the density of the tuff; the greater bearing capacities occur with greater density tuff. The pores in the tuff are not all interconnected; however, in general the nonwelded tuff has a greater permeability. Hydraulic conductivities range from 3×10^{-3} m/day for a welded tuff to as much as 2 m/day in a nonwelded tuff.[3-13] The natural moisture content of the tuff forming the mesas between the southeastward trending canyons is generally less than 5% by volume.

The tuff is rhyolitic in composition and contains small rock fragments of rhyolite, latite, pumice, and crystal fragments of sanidine and quartz, in a matrix of glass shards and welded ash. Dark minerals are scarce, although traces of crystal fragments of biotite, horneblende, and pyroxene have been identified.[3-10] The rhyolite and latite rock fragments are dark gray and hard, and may be as much as 5 to 8 cm (2 to 3 in) in length. Pumice is light gray and, in nonwelded units, may be as much as 15 cm (6 in) in length.

The surface of the exposed tuff becomes "case hardened" as it is exposed to the weather. This rind forms a protective surface that resists erosion by wind and water; however, exposed pumice fragments weather out rapidly, giving some of the units a pitted surface.

Joints are common in the tuff units, dividing the tuff into irregular blocks. The joints were formed as the ashflow cooled. Joint frequency decreases with a decrease in the degree of welding (fewer joints are found in nonwelded tuff than in welded tuff). The predominant joint sets are vertical or near vertical. Joints range from closed to open as much as 5 cm (2 in) and may contain a clay platting or fill.

The nonwelded tuff strata are found at the base of the Bandelier Tuff in the Otowi Member and lower part of the Tshirege Member. The upper part of the Tshirege Member is made up of moderately welded tuff and a lesser thickness of welded tuff. A test hole near the center of the plateau penetrated 283 m (930 ft) of Bandelier Tuff.[3-13] Nonwelded tuffs in the Otowi Member and lower part of Tshirege Member make up 70% of the thickness, while in the upper part of the Tshirege Member moderately welded tuffs make up 20% and welded tuffs the remaining 10%. Almost all of the Laboratory facilities are sited on the moderately welded or welded ashflow.

Topography and Soils

Topography influences soil development and affects drainage, runoff, and erosion. The direction a slope faces is an important ecological influence of topography. South-facing slopes normally are warmer and drier than north-facing slopes and thus can have an important effect on the kind and amount of vegetation growing in an area.

The Pajarito Plateau occupies about 47% of the Los Alamos County land area (see Table 3.1.1-2 and Figure 3.1.1-5), from an elevation of 2073 to 2377 m (6800 to 7800 ft) with the Jemez Mountains occupying about 32% of the land area above 2377 m (7800 ft). The topography of Los Alamos is most frequently expressed in terms of slope gradient or percent of slope. Four slope gradient classes, and the percent of the Los Alamos land area represented by each, are also presented in Table 3.1.1-2. The 20% or greater slope class, comprising about 54% of the County land area, occurs extensively in the mountainous regions of the County, in areas with steep canyon sideslopes, and along the Rio Grande. Many portions of the broad mesa tops and canyon floors have slope gradients of 0%-5%. More frequently, however, two or more slope gradient classes occur within an 14 km^2 (3400 acres) area. This is roughly the size of White Rock, which has mostly 0%-5% slopes, but also 5%-10% and 10%-20% slope classes, for example.

An intensive soil survey of about 79% of the 280 km^2 of Los Alamos County including all of the LASL site within the county was completed by a joint LASL-Soil Conservation Service project. General and detailed descriptions were developed for each of 61 soil mapping units including information on soil color, texture, structure, consistency, clay films, size distributions, permeability depth, hydrologic properties, pores, pH, and soil horizon boundaries. Detailed maps at a scale of 1 inch = 1320 feet were prepared and are included in the report.[3-13A]

TABLE 3.1.1-2

ESTIMATED PERCENTAGE OF LOS ALAMOS COUNTY LAND AREA IN GIVEN ELEVATION CLASSES

Elevation Class (m)	Percent of County land area
1615 - 1768	1.86
1768 - 1920	2.89
1920 - 2073	17.38
2073 - 2225	27.88
2225 - 2377	19.45
2377 - 2530	9.63
2530 - 2682	8.11
2682 - 2835	6.13
2835 - 2987	5.57
2987 - 3139	1.10

ESTIMATED PERCENTAGE OF LOS ALAMOS COUNTY LAND AREA IN GIVEN SLOPE CLASSES

Slope Class (%)	Percent of County land area
0 - 5	19.89
5 - 10	12.13
10 - 20	14.40
over 20	53.58

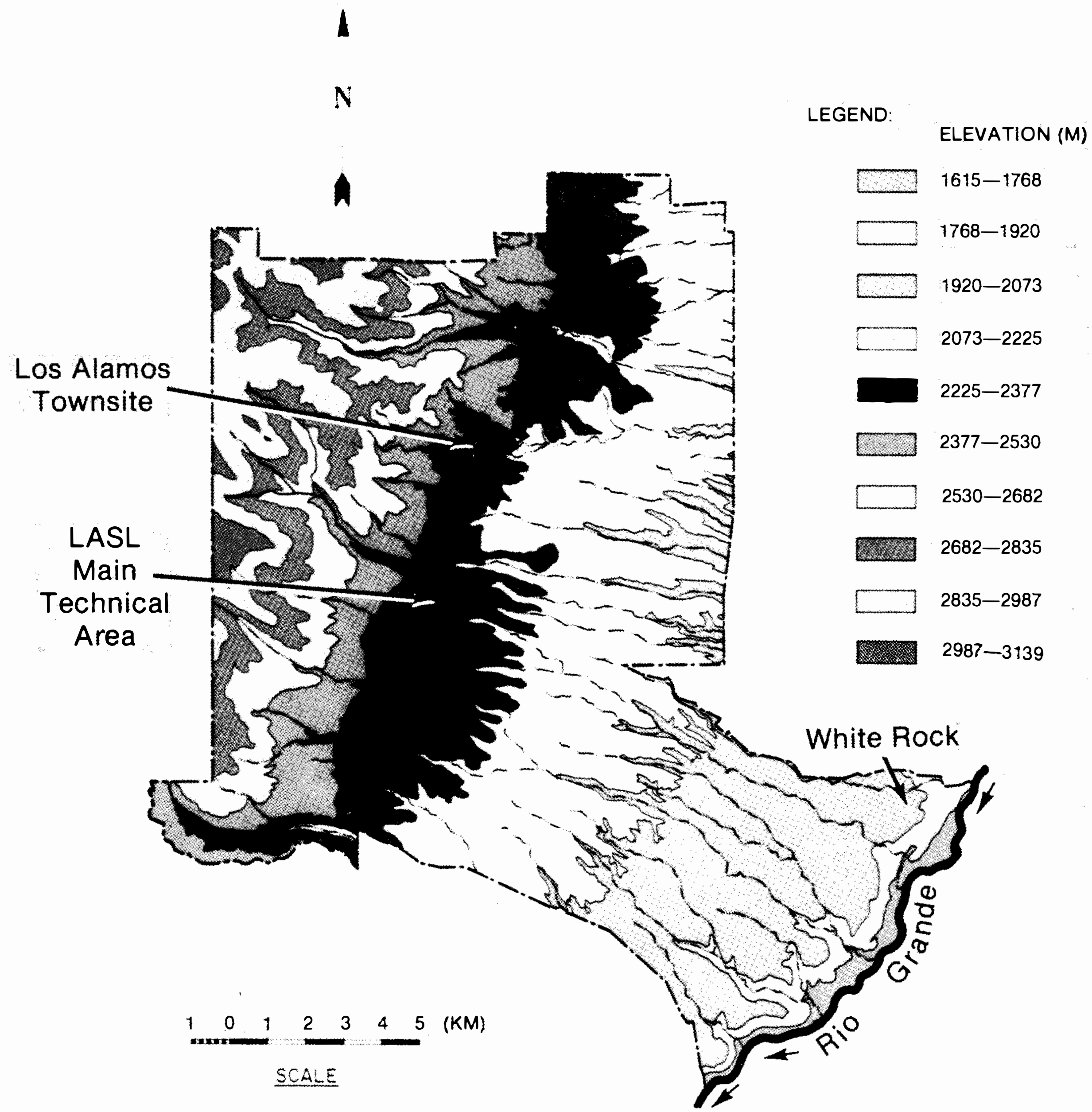


Figure 3.1.1-5. Topography of Los Alamos County

Natural Resources

The natural resources considered are sand and gravel, clay, pumice, and tuff.

Sand and gravel are used for construction purposes as aggregate for concrete, asphalt paving, and road base. The major deposit now used occurs along the Rio Grande, north of Otowi Bridge, and is recent alluvium formed along the river. There is a small sand and gravel operation at Totavi, in the lower member of the Puye Conglomerate (see Figure 3.1.1-6).[3-14] During the early years of Project Y, much of the sand and gravels used were taken from this deposit. The land is owned by the San Ildefonso Pueblo. The gravel deposit is about 50 ft. thick and is overlain by 20 to 50 ft. of overburden.[3-10]

Sands and gravel have also been taken from terrace deposits in Los Alamos Canyon, from the floors of Pajarito and Water Canyons, and from fluvial outwash near the flanks of the mountains. The terrace and outwash deposits have now been exhausted; however, small sand and gravel deposits may exist west of the previously worked areas in Pajarito and Water Canyons.

Two beds of clay of commercial quality occur on the land owned by San Ildefonso Pueblo just east of DOE-controlled property. These clays were formed in an ancient lake near the top of the Puye Conglomerate. The clays of commercial quality occur in two beds that are about 20 and 27 ft thick.

Pumice from the Lower Otowi Member of the Bandelier Tuff is used principally as a natural, light weight, concrete aggregate. Commercial deposits of pumice are being worked to the east and northeast of Los Alamos. Pumice deposits of possible commercial value lie adjacent or within Los Alamos County. Guaje Flats has been estimated to contain 5.4×10^6 m^3(7×10^6 yd^3)[3-15] of extractable pumice. Another deposit, to the southeast, is estimated to contain about 5.8×10^6 m^3 (7.5×10^6 yd^3).[3-15]

The moderately welded and welded units of the Bandelier Tuff are suitable as foundation rocks, structural building stone, ornamental stone, or insulating material.[3-12] These units are widespread on the plateau. Volcanic tuff has been used successfully by Zia Company as the aggregate in soil-cement sub-bases for roads.[3-16] The cost of cement-treated tuff as subgrades compares favorably with the cost of water-stabilized base course material.

Seismology

The Los Alamos area lies within the Rio Grande depression which was formed by a complex series of faults. Adjustments that result in seismic activity are still taking place along the faults within the depression.

The faults trend north-south in the Los Alamos area, displacing the Bandelier Tuff (see Figure 3.1.1-6).[3-14] The faults constitute zones of weakness in the earth's crust. Reactivation or movement along the faults could cause surface displacement. Laboratory facilities are not located across any known fault zones. In the vicinity of Los Alamos, the Pajarito Fault is downthrown to the east with a maximum displacement of 120 m (390 ft); the Guaje Mountain Fault is downthrown to the west with a maximum displacement of 16 m (52 ft); and the Water Canyon Fault is downthrown to the east with a maximum displacement of 9 m (30 ft).

A study of seismic risk in the Los Alamos area was made based on seismological and historical records.[3-17] The data for all shocks occurring within 111 km (70 mi) of Los Alamos included: (1) historical non-instrumented reports of earthquakes before 1962, and (2) records of instrumented studies of shocks from 1962 to 1972. Magnitudes were inferred from the historical reports that, of necessity, related to effects (intensity).

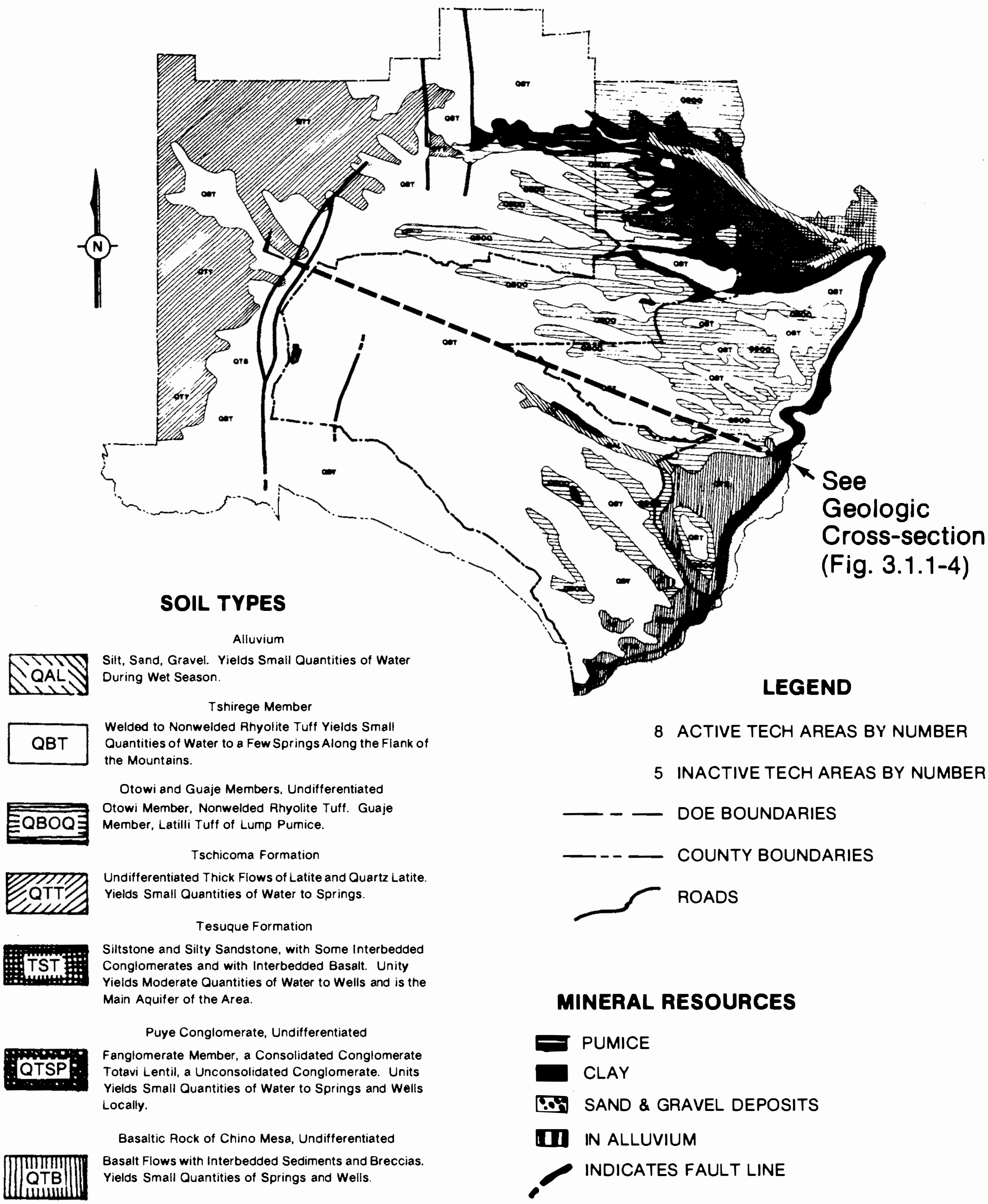


Figure 3.1.1-6. Natural Resources of Los Alamos County

The strongest earthquake to occur within the region of study during the 100-year period, 1872 to 1972, had a probable magnitude of 5.5 on the Richter scale. Estimates of the strongest shock to occur in a 100-year period, based on extrapolation of the earthquake frequency-magnitude relation, range from 3.9 to 5.4. The study concludes that the Los Alamos area is subject to an earthquake of magnitude 5.5 once every 100 years somewhere within the Rio Grande Depression from Albuquerque northward about 200 km (130 mi).

Another evaluation of seismic risk in the Los Alamos area was made based on geologic evidence.[3-18] The studies of fault characteristics yielded a theoretical interpretation of likely magnitude and frequency of shocks produced from rupture along faults or in fault zones based on 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 breaking the upper Tshirege Member of the Bandelier Tuff.

Calculations implied that these faults produced 133 seismic events with average local magnitude of 6.7 (range 5.9 to 6.8-Richter) in the past 1.1×10^6 years. In terms of seismicity of the area, this means that magnitude-6.7 earthquakes occurred at approximately 8270-year intervals, or that magnitude-4.8 earthquakes occurred at 100-year intervals.

The seismicity of the Los Alamos region is estimated by the second evaluation to be one magnitude-5 earthquake per 100-yr, in good agreement with the seismological study of historical records.[3-17] 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-year interval) and substantially less than that of an equivalent area in Southern Califonia.[3-19]

Another geologic and seismic study proposed two design basis earthquakes for the operation of the new Plutonium Processing Facilities. This study approached the problem in terms of effects in Los Alamos of earthquakes that might occur in the region. The effects are ranked on the modified-Mercalli scale of intensities. The effects of an earthquake are dependent on the energy released by the earthquake (related to Richter magnitude) as well as distance and rock material between the earthquake center and the location where effects are observed. Thus there is no single relation between Richter magnitude and Mercalli intensity. For the new Plutonium Processing Facility, the earthquakes considered were an "Operating Base Earthquake" of intensity VII, and horizontal ground motion acceleration of 1.7 m/s^2 (5.5 ft/s^2); and a "Safe Shutdown Earthquake" of intensity VIII and an horizontal ground motion acceleration of 3.2 m/s^2 (10.6 ft/s^2). The response spectra for these two hypothetical events were based on analyses of other earthquakes of similar intensity, modified to fit the Los Alamos area geology.[3-7]

Graphic evidence of the realtively low seismicity is provided by a number of pinnacles 3 to 18 m (10 to 60 ft) high, that stand in Rendija Canyon, just north of Los Alamos (see Figure 3.1.1-7). These were eroded from soft formations and capped with boulders two to five times the diameter of the supporting pinnacle. These formations are unstable, and it is reasonable to think that they would topple under the influence of any sizable ground tremors. It has been estimated that an 18 m (60 ft) pinnacle would require tens of thousands of years to develop with the erosion rate normal in the major canyons of the area.[3-20]

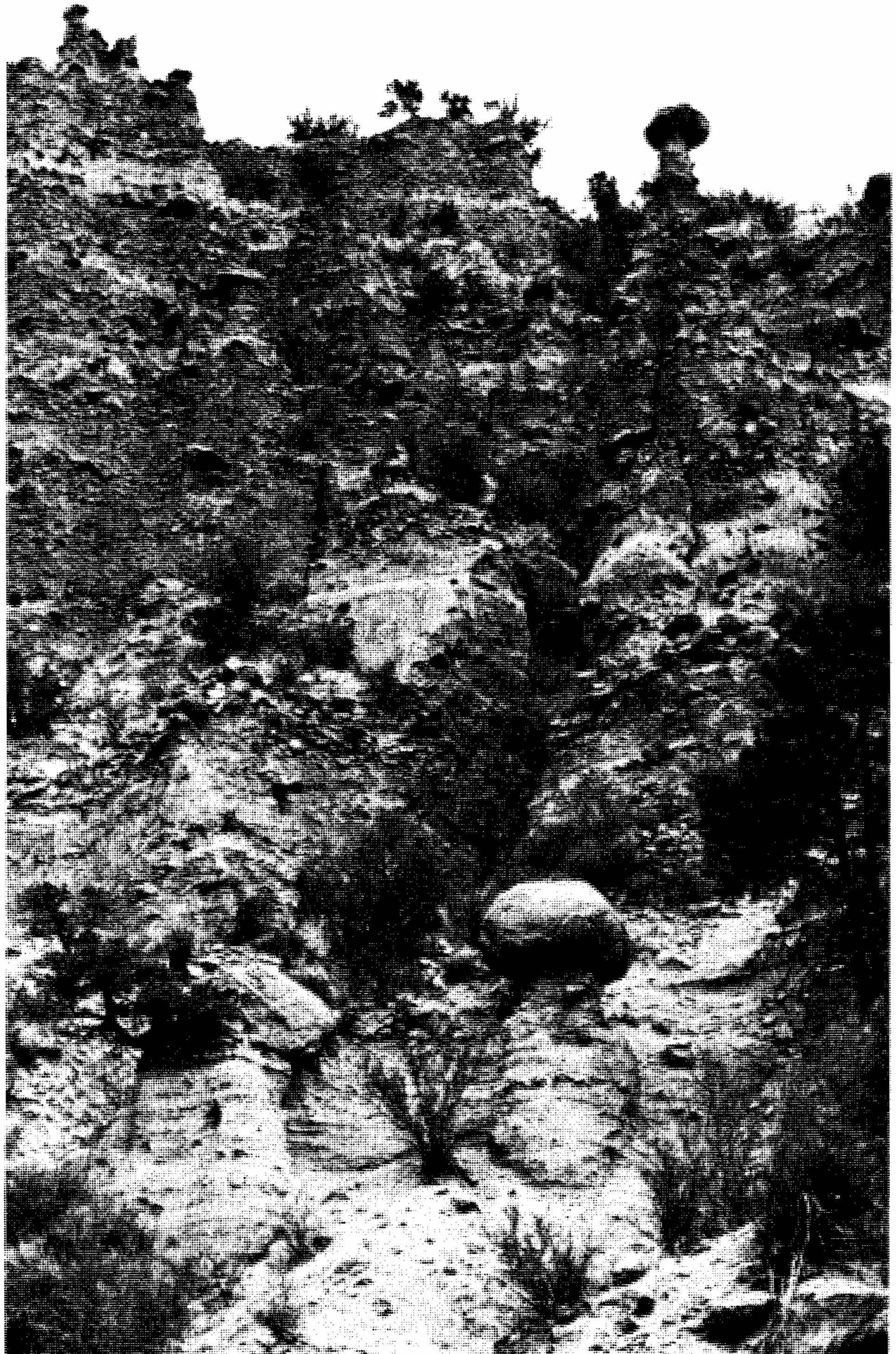


Figure 3.1.1-7 Pinnacle Formation in Rendija Canyon

Other Geological Hazards

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 ashflow 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 years.

Landslides, except for isolated rock falls from the mesa rims, are an unlikely hazard at Los Alamos because of the dry climate, deep water table, and the rock characteristics. Though isolated rock falls occur from the canyon rims, the estimated horizontal erosion rates at the rim are small and indicate that very little change is expected to occur in the topography of the area in the next few hundred years.[3-21] Omega West and W-Site in Los Alamos Canyon have experienced some isolated rock falls in the past with no damage. Recommendations made by the USGS to reduce the rockfall potential by implacement of rock catches and stabilization have been carried out.[3-22]

Ground compaction caused by withdrawal of water from the main aquifer is not considered to be a significant geologic hazard. There has not been a significant lowering of the water table except in the vicinity of the well field. The aquifer is of silty sandstone, sandstone and conglomerate and, as such, is not particularly susceptible to compaction when water is withdrawn.

3.1.2 Hydrology

Hydrologic studies in the Los Alamos area were conducted by the US Geological Survey (USGS) from 1946 to 1972 in conjunction with the development of ground water supplies for Los Alamos. The USGS also studied interaction of solid and liquid waste disposal operations with the local hydrology. LASL began hydrologic investigations in 1969 in connection with various environmental programs. The hydrology of the Jemez Mountains to the west of Los Alamos has been investigated by the Laboratory in relation to development of the Fenton Hill Geothermal site.

The Rio Grande, the master stream of the region, drains more than 37,000 km^2 (14,000 mi^2) in northern New Mexico and Colorado. The average discharge of the Rio Grande at the Otowi Bridge gaging station was about 1 km3/yr (0.82×10^6 acre-ft/yr) for the 1955 to 1974 period. Daily suspended sediments discharged at the station for the period 1947-1974 ranged from 2.7×10^3 kg (3 tons) to 3.4×10^8 kg (3.7×10^5 tons).

Surface stream tributaries to the Rio Grande within about 100 km (60 mi) of Los Alamos are the Chama, Caliente, Santa Cruz, Nambe, and Tesuque Rivers to the north and east; the Jemez and San Antonio Creeks to the west; and the Santa Fe and Galisteo Rivers to the south (see Figure 3.1.2-1).[3-23] Flood control, irrigation, and water supply reservoirs include Abiquiu on the Chama River, Santa Cruz on the Santa Cruz River, Two-mile, Nichols, and McClure on the Santa Fe River, Galisteo on the Galisteo River, Jemez on the Jemez River, and Cochiti on the Rio Grande.

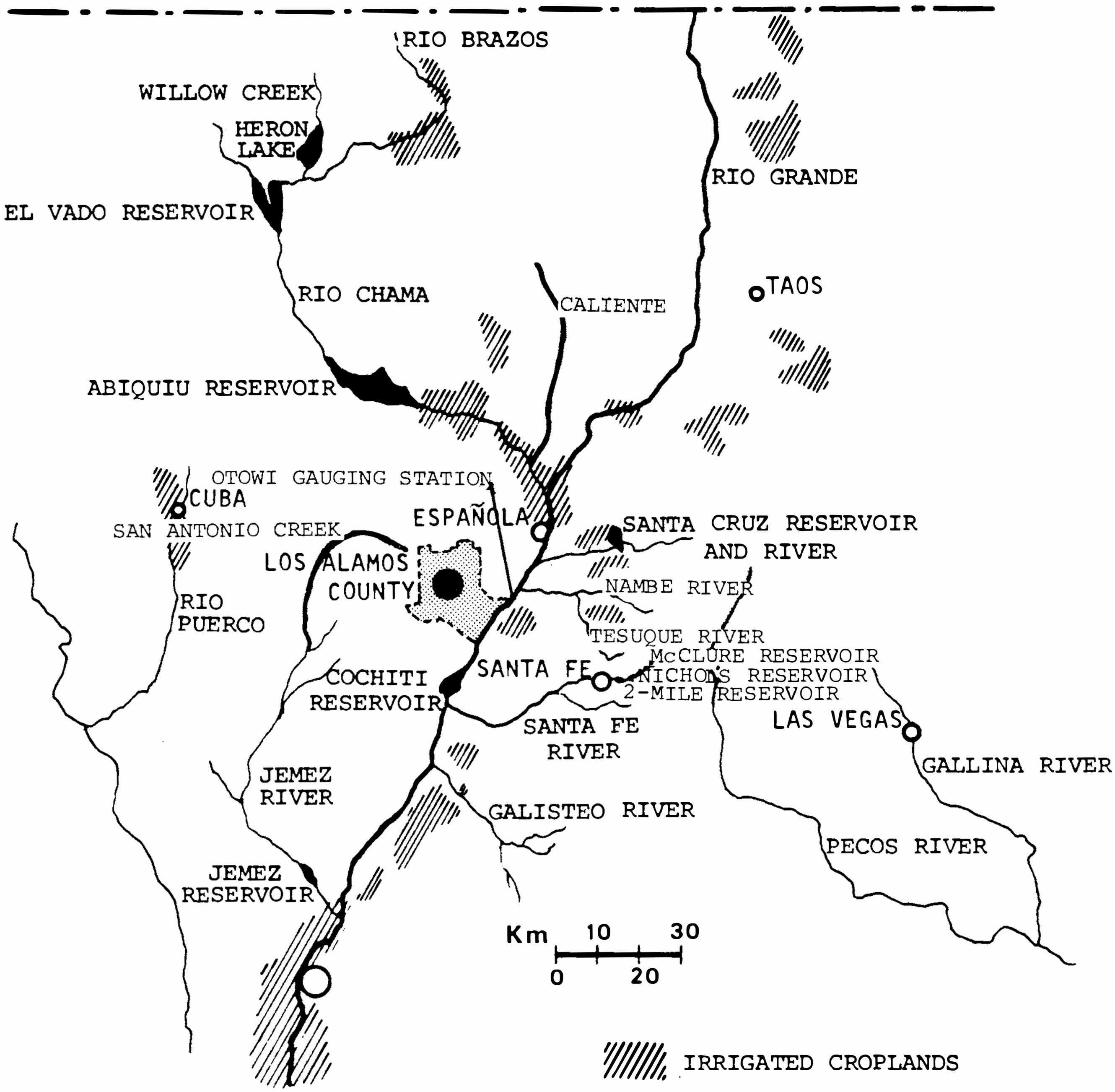


Figure 3.1.2-1. Regional Surface Waters

Cochiti is a new reservoir, which began filling in 1976. It is designed to provide flood control, sediment retention, recreation, and fishery development. The dam is a 9 km (5.5 mi) long, earthfill dam located on the Rio Grande about 30 km (19 mi) southwest of Otowi Bridge and about 15 km (9 mi) from the southernmost point of the LASL boundary. The 5×10^6 m^2 (1200-acre) surface area permanent pool will extend upstream some 12 km (7.5 mi) reaching a point about 5 km (3 mi) from the southernmost point of the LASL boundary, and will have a capacity of nearly 62×10^6 m^3 (50,000 acre-ft). The flood-control pool extends upstream to the Otowi Bridge with a total volume of 750×10^6 m^3(602,000 acre-ft).

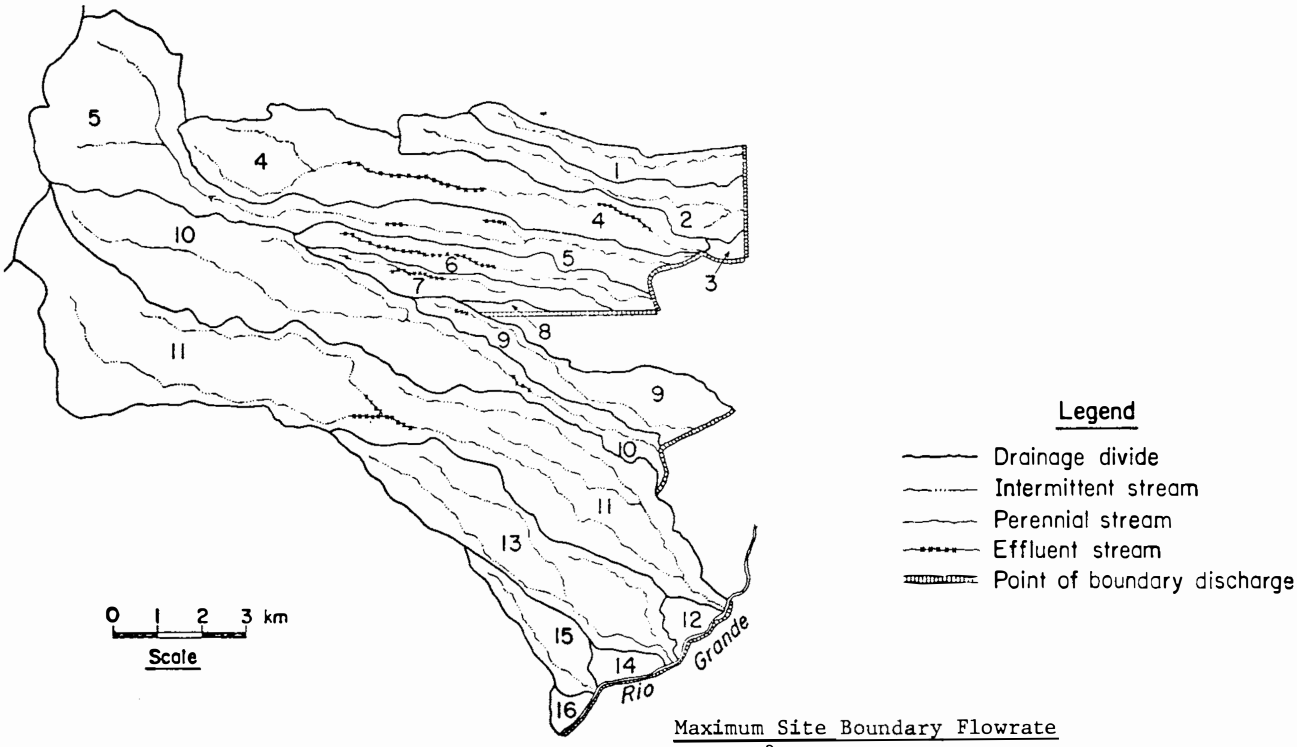
Essentially all downstream flow passes through the reservoir. Flood flows are temporarily stored and released at safe rates. The sediment trapping function of the dam is expected to trap at least 90% of the sediments carried by the Rio Grande. Approximately 6.2×10^6 m^3 (5000 acre-ft) per year will be lost to evaporation from the permanent pool. The reservoir will provide for boating and fishing. A recreation-oriented community development is taking place on Cochiti Pueblo land with landlease sales and housing developments underway. The ultimate population is projected as about 50,000.[3-24]

There are no municipal water supplies taken directly from the Rio Grande downstream from LASL in New Mexico. Irrigation water is taken from the Rio Grande downsteam from LASL at numerous diversions starting below Cochiti Dam.

The quality of surface waters in the Upper Rio Grande Basin is generally good. The bacterial and chemical quality of all streams, with the exception of a reach of the Rio Grande between Española and Otowi Bridge, is considerably better than that required by the New Mexico State Water Quality Control Commission stream standards. The poor quality below Española to Otowi Bridge is attributed to the population concentration in the Española Valley.[3-25] This reach is upstream of Los Alamos.

In the Los Alamos area, there is intermittent stream flow in canyons cut into the Pajarito Plateau. Perennial flow to the Rio Grande occurs in the Rio de los Frijoles to the south of the Laboratory and the Santa Clara to the north. Springs between 2400 and 2700 m (7900 and 8900 ft) elevation on the slopes of the Sierra de los Valles supply base flow throughout the year to the upper reaches of Guaje, Los Alamos, Pajarito, and Water Canyons, and Canyon del Valle. These springs discharge water perched in the Bandelier Tuff and Tschicoma Formation at rates from 7 to 530 ℓ/min (2 to 140 gal/min). The volume of flow from the springs is insufficient to maintain surface flow within more than the western third of the canyons before it is depleted by evaporation, transpiration, and infiltration into the underlying alluvium.

Sixteen drainage areas, with a total area of 212 km^2 (52,500 acres), pass through or originate within the Laboratory boundaries (see Figure 3.1.2-2).[3-26] Stream flow in these canyons is intermittent. Runoff from heavy thunderstorms or unusually heavy snowmelt will reach the Rio Grande. Four Canyons--Pueblo, Los Alamos, Pajarito, and Water--have areas greater than 20 km^2 (5,000 acres). Ancho Canyon has 17 km^2 (4,200 acres), and all the rest have less than 10 km^2 (2,500 acres). Theoretical flood frequency and maximum discharge in ten of the well-defined channels of the sixteen drainage areas range from 1.1 m^3/s for a two-year frequency to 21 m^3/s for a 50-year frequency. Flooding does not pose a problem in the Los Alamos area.[3-26] Highways are sometimes closed for an hour when flash floods in canyons cross the pavement. Nearly all community and Laboratory structures are located on the mesa tops which drain rapidly into the deep canyons.



Key	Drainage Areas Canyon	km^2	Maximum Site Boundary Flowrate (m^3sec) by Frequency[a] 2Yr	 10-Yr	 50-Yr
1	Barranca	4.9	1.5	6.7	14
2	Bayo	9.8	2.5	8.5	19
3	--	0.3	--	--	--
4	Pueblo	22.3	3.1	10	21
5	Los Alamos	27.5	3	11	20
6	Sandia	7.0	2	8.5	18
7	Mortandad[b]	4.7	--	--	--
8	--	0.5	--	--	--
9	Canada del Buey	8.8	2.6	9.4	21
10	Pajarito	27.5	3	10	20
11	Water	33.2	2.8	9.6	18
12	--	1.3	--	--	--
13	Ancho	17.4	2.3	8.2	17
14	--	1.6	--	--	--
15	Chaquehui	4.7	1.1	4.5	10
16	--	1.0	--	--	--

a) Theoretical estimates (made for areas with reasonably defined channels) using nomographic methods. A particular flow can be expected to be equalled or exceeded in the time period. Alternatively, the 2, 10, and 50 year events can be interpreted to have probabilities of occurrence in a given year of 0.5, 0.1, and 0.02, respectively.

b) Mortandad Canyon is the only major canyon for which no run-off is predicted, owing to lack of a main channel in the lower portions.

Figure 3.1.2-2. Surface Drainage Areas Crossing or Originating on LASL Site

Potential flood conditions at three technical areas located in canyons were evaluated to determine whether any special hazards could result from damage to facilities. These evaluations also address the requirements of DOE regulations 10 CFR 1022 for floodplain review in response to Executive Order 11988, Floodplain Management. The evaluation was carried out in accord with the Flood Hazard Evaluation Guidelines for Federal Executive Agenices prepared by the United States Water Resources Council in response to Executive Order 11296, Evaluation of Flood Hazard. The basic technique utilized to compute flood frequency and maximum discharges was developed by the U.S.G.S. for New Mexico.[3-26A]

Pajarito Site is located in Pajarito Canyon below a drainage area of 26 km^2 (10 mi^2). The 100-year storm (i.e., probability 0.01 in any year) will result in a discharge of 31 m^3/s (1080 ft^3/s). The channel at the site is restricted by a bridge which will carry 42 m^3/s (1500 ft^3/s).

Omega Site and W-Site are located in Los Alamos Canyon near the western edge of the Pajarito Plateau. The two sites are about 600 m (2000 ft) apart with a drainage area of about 20.5 km^2 (8mi^2) above the sites. The 100-year storm would produce a maximum flow of about 25 m^3/s (870 ft^3/s) at the sites. An extrapolation indicates a 500-year flood (i.e., probability 0.002 in any year) would have peak flow of about 37 m^3/s (1290 ft^3/s).

A box culvert at W-Site extends under the parking lot and has a carrying capacity of 156 m^3/s (5500 ft^3/s) while a restriction at the entrance of the channel at Omega Site will carry about 46 m^3/s (1600 ft^3/s). Thus, the channels at both sites should carry the maximum flow of 25 m^3/s (870 ft^3/s) produced by a 100-year storm. If the channel should become clogged with debris, the resulting overflow would be carried by roadways or parking lots adjacent to the channel and would not cause damage to the structures in the area.

Another flood hazard considered was failure of the Los Alamos Canyon Reservoir located about 3 km (1.9 mi) west of TA-41 and TA-2. The dam is a concrete-core, rock and earth-filled dam with a capacity of 49 x 10^3 m^3 (13 x 10^6 gal). The concrete spillway will carry a flow of 16 m^3/s (580 ft^3/s) which is ample for the estimated flow of 12 m^3/s (440 ft^3/s) produced by a 100-year storm. If the dam should fail, an evaluation was made with complete failure and drainage over a 45-minute period. Assuming for the water from the breached dam to crest within 15 minutes at TA-41 and TA-2 and recession of flow for 30 minutes, the restriction at TA-2 would carry 97% of the flow for the 45-minute period. The other 3% would flood the parking lot and roadway at the site, causing little, if any, damage to the structures.

Also in compliance with the requirement in the DOE regulations 10 CFR 1022 for wetlands review in response to Executive Order 11990, Protection of Wetlands, it is noted that no areas apparently qualifying as wetlands are documented on USGS maps of the area or in the recently completed soil survey of Los Alamos County performed in cooperation with the Soil Conservation Service.[3-13A]

Sanitary sewage effluents from both the townsite and the Laboratory are released into Pueblo and Sandia Canyons in sufficient volume to saturate the alluvium and maintain surface flows for a few tenths of a kilometer. Mortandad Canyon contains a small perennial stream maintained for about 1.5 km (0.9 mi) by effluents from a LASL cooling tower and an industrial-waste treatment plant.

Ground water (subsurface water) occurs as perched water in alluvium and basalts and, in the zone of saturation, in sediments of the main aquifer of the Los Alamos area.[3-27, 3-10] The relationship of the occurrence of ground water to lithologic units is shown on Figure 3.1.2-3.

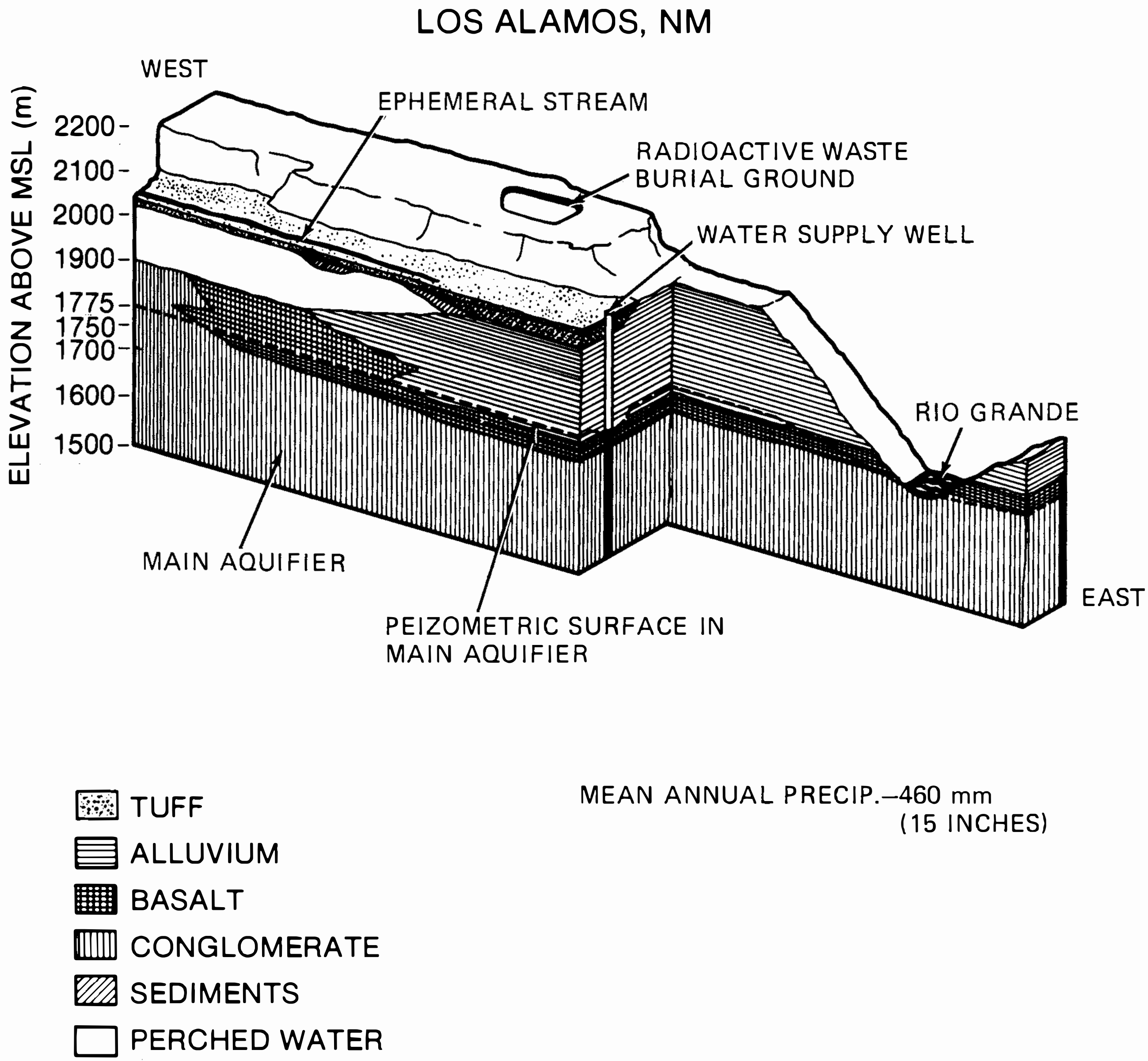


Figure 3.1.2-3. Hydrological Cross Section

Water from rainfall and snowmelt infiltrates the surface, providing moisture to the soil zone and supporting plant growth. This moisture does not move more than a few meters into the tuff on the tops of the mesas.[3-28] The tuff, as a result, has a low moisture content (generally <5% by weight)--too low even for most plants to extract water.[3-21]

Two types of alluvium have developed in the stream channel. Drainage areas heading on the mountain flanks are made up of sand, gravels, cobbles, and boulders derived from the Tschicoma Formation and Bandelier Tuff. Drainage heading on the plateau contains only sands, gravels, and cobbles derived from the Bandelier Tuff. The alluvium is quite permeable, allowing rapid infiltration of rainfall and streamflow. The alluvium generally overlies the less permeable tuff. Water infiltrates downward in the alluvium until its movement is held back by the tuff. This results in the build-up of a ground water perched within the alluvium.[3-29] The perched water moves down gradient in the alluvium at a rate from 1 to 20 m/day (3 to 60 ft/day). Hydraulic conductivity of the alluvium ranges from 141 m/day for a sand aquifer to 50 m/day for a silty-sand aquifer.[3-30]

As water perched in the alluvium moves down the gradient, it is lost by evaporation and transpiration through plants and infiltration into underlying tuff. Vegetation is lush where surface or perched water in the alluvium is present. Water moving from the alluvium into the volcanic debris in the lower reach of Pueblo Canyon and the mid-reach of Los Alamos Canyon recharges a local body of perched water within the basaltic rock of Chino Mesa. Water from this perched aquifer discharges at the base of the basalt in Los Alamos Canyon west of the Rio Grande. Transit time in the aquifer is about 3.8 m/day with a hydraulic conductivity of 114 m/day.[3-31]

Perched water is not found in the tuff, volcanic sediments, or basalts above the main aquifer in the central and western portions of the plateau. Test holes in these areas penetrated numerous rock units that had the potential of perching water above the main aquifer. The absence of water in these test holes indicates that the infiltration of surface water through the alluvium and the tuff is limited. Age dating of water from the main aquifer further supports the inference of insignificant infiltration of surface water through the alluvium and tuff to the main aquifer. Additional details on infiltration of alluvial water in waste discharge areas is provided in the discussion on the environmental fate of effluent release, 4.1.1.

The main aquifer in the Los Alamos area is located within the Tesuque Formation beneath the entire plateau and Rio Grande valley. The lower part of the Puye Conglomerate as well as the Tesuque Formation are within the main aquifer beneath the central and western portions of the plateau.[3-32] The depths to water below the mesa tops range from about 360 m (1200 ft) along the western margin of the plateau to about 180 m (600 ft) along the eastern part of the plateau. The thickness of potable water in the aquifer is estimated to be at least 1200 m (3900 ft).[3-32A] The hydraulic gradient of the aquifer averages about 11 m/km (60 ft/mi) within the Puye Conglomerate, but increases to about 20 m/km (100 ft/mi) along the eastern edge of the plateau as the water in the aquifer enters the less permeable sediments of the Tesuque Formation (see Figure 3.1.2-4). The average movement rate within the aquifer is about 0.3 m/day (1 ft/day) toward the Rio Grande.[3-33]

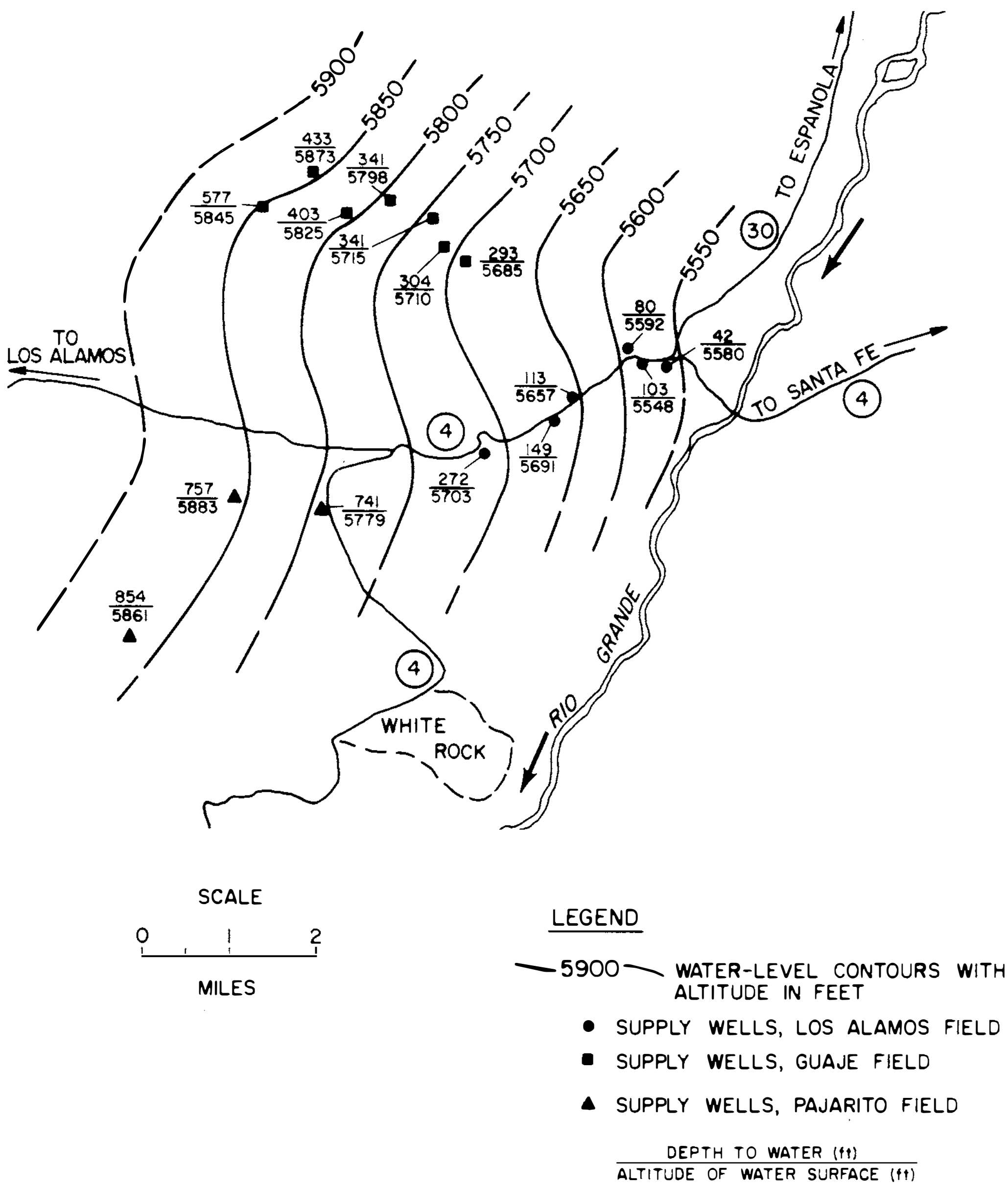


Figure 3.1.2-4. Generalized Contours on Top of Main Aquifer

The hydraulic conductivity and transmissivity is different for various rock units within the main aquifer. Aquifer tests in wells penetrating the Puye Conglomerate indicated hydraulic conductivities ranging from less than 1 m/day to 13 m/day. Tests in a well penetrating the Tschicoma Formation indicated a hydraulic conductivity less than 1 m/day.[3-31] Supply wells in the Los Alamos Field penetrating sediments of the Tesuque Formation have an average transmissivity of 198 m^2/day, with an average hydraulic conductivity of less than 1 m/day. The wells in the Guaje Field, which penetrate basalts interbedded with sediments in the Tesuque Formation, have an average transmissivity of about 186 m^2/day, with an average hydraulic conductivity of about 1 m/day.[3-27] Supply wells in the Pajarito Well Field penetrated basalts interbedded with sediments in the Puye Conglomerate and the Tesuque Formation. The transmissivities ranged from 500 to 4000 m^2/day, with hydraulic conductivities ranging from about 1 to 200 m/day,[3-34,3-35] The aquifer is under water table conditions in the western portion of the plateau. Along the eastern margins the aquifer is artesian; that is, the water level in a well penetrating the aquifer will rise above the top of the saturated water-bearing material.

The major recharge area for the deep aquifer is in the intermountain basins formed by the Valles Caldera. The saturated sediments and volcanics in the basin are highly permeable and recharge the main aquifer in sediments of the Tesuque Formation and Puye Conglomerate.[3-36] Minor amounts of recharge may occur in the deep canyons containing perennial streams on the flanks of the mountains.

The movement of water in the main aquifer is eastward toward the Rio Grande, where a part is discharged through springs and seeps into the river. It is estimated that the 18.4 km (11.5 mi) reach through White Rock Canyon below Otowi Bridge receives a discharge from the aquifer of 5.3 to 6.8 x 10^6 m^3 (4,3000 to 5,500 acre-ft) annually.[3-37]

3.1.3 Meteorology

Los Alamos has a semiarid continental mountain climate. The annual precipitation of 46 cm (18 in) is accounted for by warm-season orographic convective rain showers and winter migratory storms. Seventy-five percent of the annual total falls between May and October, primarily as thunderstorms (see Figure 3.1.3-1).[3-38] Peak shower activity is in August, when one day in four will have at least 2.5 mm (0.1 in) of rain accumulation and some rain is observed on half of the days. The annual average of 62 thunderstorm-days per year makes this area equivalent to the Gulf Coast states in thundershower occurrence. The showers tend to develop in early afternoon, with a secondary maximum about 1800 MST. They are accompanied by lightning, gusty surface winds (10-20 m/s), and occasional hail. Tornadoes have not been observed in this area.

Winter precipitation falls primarily as snow with annual accumulations of about 1.3 m (4.3 ft). The ratio of liquid water content to snow depth varies between 0.10 and 0.05, the latter occurring in cold conditions and higher altitudes.

Distributions of hourly and daily rainfall accumulations observed by a recording rain/snow gauge during a one-year period (1974) are shown in Figure 3.1.3-3.[3-26] The distributions are highly skewed toward low rates, with a median hourly accumulation of 0.75 mm (.03 in) and a range of 0.25 to 13.5 mm (0.1 to 0.5 in). Daily accumulations ranged from 0.25 to 50 mm (.01 to 2.0 in), with a median value of 1.75 mm (.01 in). There were 80 days with measurable precipitation in the analyzed record.

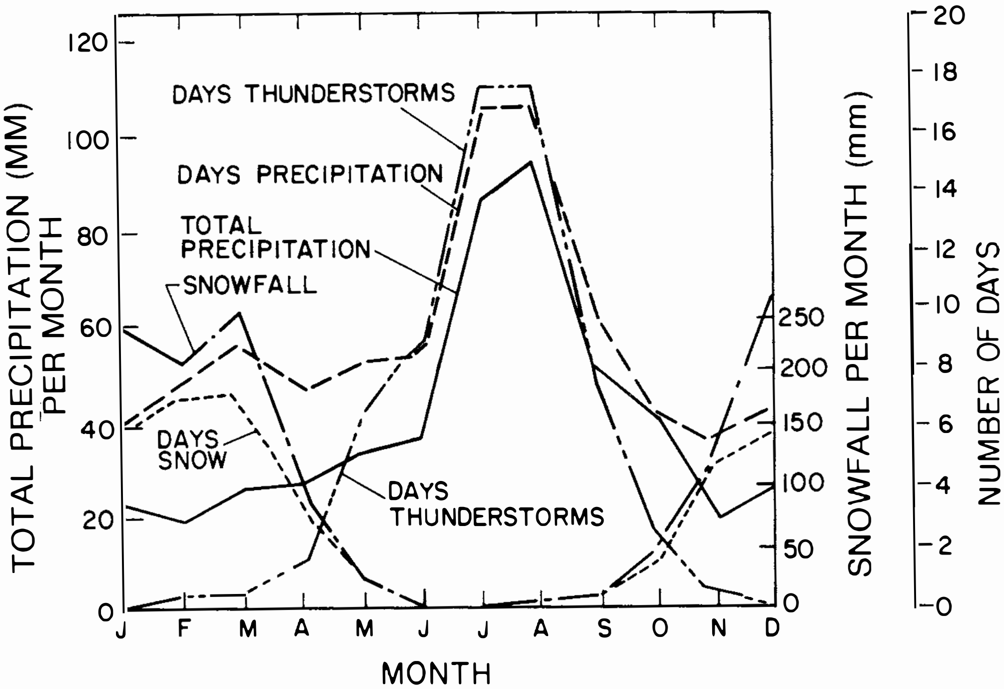


Figure 3.1.3-1. Average Annual Variation in Precipitation

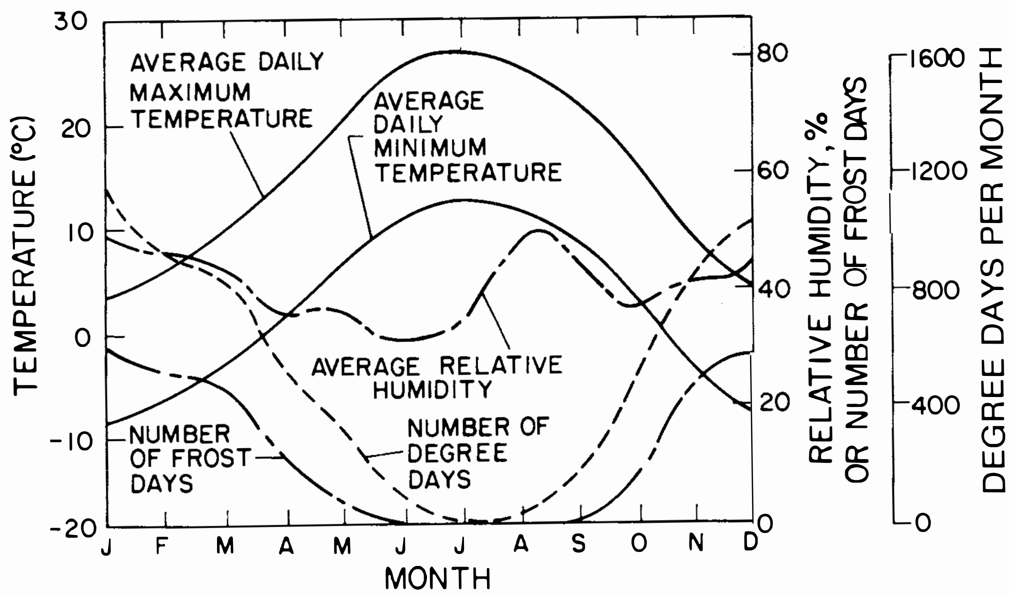
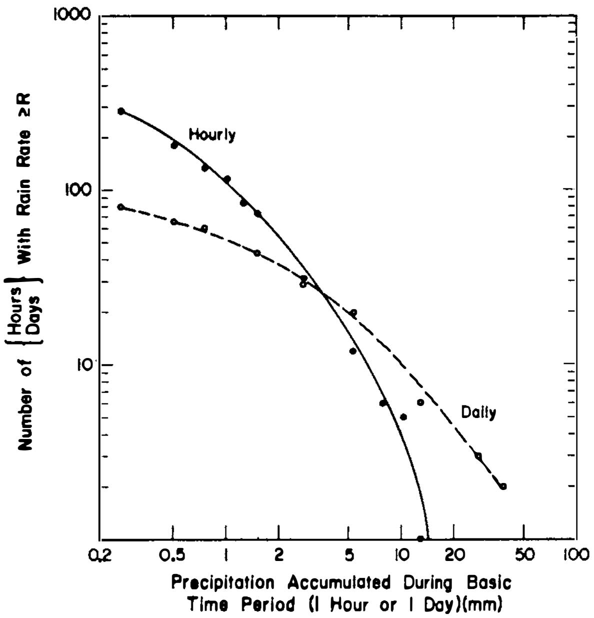


Figure 3.1.3-2. Average Variation in Temperature and Humidity



Month	LASL Total[a] (mm)	No. of Stations Reporting	Network Mean (mm)	Standard Deviation (mm)	Coefficient of Variation
June	11.9	57	13.7	5.9	0.42
July	83.3	63	68.7	20.5	0.30
Aug	30.5	59	41.8	8.3	0.20
Sept	56.1	64	55.9	9.9	0.18
Oct	11.4	54	12.2	4.4	0.36

[a]Data collected at the LASL meteorological tower.

Figure 3.1.3-3. Rain-Gauge Network Data for 1973

To determine patterns of rainfall, and to aid in estimation of surface run-off and soil moisture movement in the drainage basins around Los Alamos, 72 rain gauges were distributed as widely as possible throughout the county. A record of daily observations at each site was compiled from June through October, 1973. This period was chosen to illustrate the variability of summertime precipitation in the LASL area. Figure 3.1.3-1[3-26] lists some gross statistics for the monthly totals of the network, giving some indications of the spatial variability of monthly precipitation totals.

Precipitation totals from the LASL meteorological tower are fairly representative of the spatial means. However, the variation of rainfall across the network is quite large. The coefficient of variation (the ratio of the standard deviation to the mean) is between 0.18 and 0.42. The largest variations were in June and October when much of the rainfall came from a few major thunderstorms.

It is also pertinent to identify consistent aspects of the precipitation patterns. Figure 3.1.3-4[3-26] shows the isohyets of the June-through-October rain in 1973. The net gradient parallel to the terrain slope is 2-3 mm/km, and one or more lobes of precipitation maxima are oriented along the terrain gradient. Two primary thunderstorm tracks help to explain the patterns of Figure 3.1.3-4. The more common track was the west-to-east movement of convective cells originating in the Jemez Mountains. At an elevation of 3,430 m (11,254 ft), Redondo Peak is a most probable site of cell formation, and could explain a west-to-east oriented rainfall maximum. Such convective cells diminished as they traveled eastward. The second track led up the Rio Grande valley from the south, occurred far less frequently, but often accounted for very heavy rains. Precipitation diminished to the west away from the center of the tract. The rain-gauge network is evidently situated near the edge of these storms. It must be stressed that the conclusions drawn from one season's rainfall data are tentative and only suggestive of possible mechanisms.

Summers are cool and pleasant. Maximum temperatures are generally below 32^{o}C (90^{o}F), with the extreme recorded of 35^{o}C (95^{o}F). A large diurnal variation keeps nocturnal temperatures in the 12^{o}C to 15^{o}C (54^{o}F to 59^{o}F) range. Winter temperatures are typically in the range from -10^{o}C to 5^{o}C (14^{o}F to 41^{o}F), with the extreme recorded of -28^{o}C (-18^{o}F). Many winter days are clear with light winds, and strong solar radiation makes conditions quite comfortable even when air temperatures are cold. The annual total of heating degree days (Celsius) is 3500, with January accounting for over 610 while July and August average zero degree days. Figure 3.1.3-2[3-38] presents relevant temperature parameters on a monthly basis.

LASL performed an analysis of one year's solar radiation.[3-39] By estimating an envelope to the observations of daily insolation, an annual observed value of about two-thirds the potential insolation is obtained. The reduction is due to cloudiness, implying that approximately one-third of the daylight hours in one year were affected by cloudiness. The most cloud-free month (January) had 85% of potential insolation while the minimum (July) had 55%.

Average relative humidity is 40%, ranging from 30% in May and June to above 50% in July, January, and February. The diurnal variation is very large and basically inverted to the diurnal temperature cycle. The summer months have nocturnal maxima of 80% and minima of 30%, while the driest time, spring, has a diurnal range from 15%-50%. Figure 3.1.3-2 shows the average relative humidity on a monthly basis.

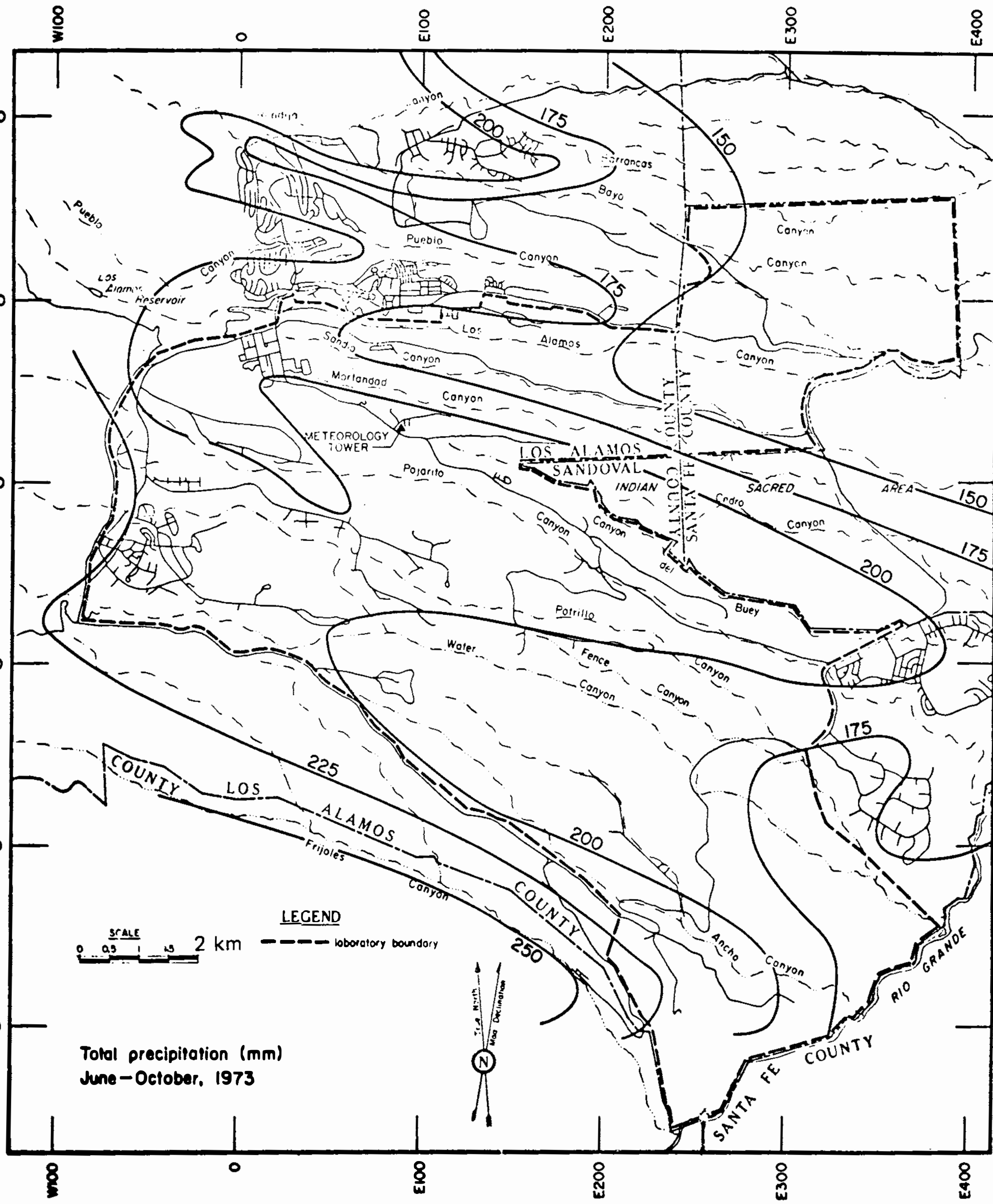


Figure 3.1.3-4. Total Precipitation Isohyets

Major spatial variation of surface winds in Los Alamos is caused by the unusual terrain. Under moderate and strong atmospheric pressure gradients, flow is channeled by the terrain features of the area, while under weak gradient flow, a distinct diurnal slope wind cycle exists. The interaction of these two domains gives rise to a westerly flow predominance on the western part of the Laboratory site and a southerly component at the east end of the mesas. At most sites near-calm conditions exist 10%-15% of the time; 80% of the wind speeds are less than 3 m/sec (10 ft/sec), and less than 1% of the time 10-minute-averaged winds are greater than 16 m/sec (52 ft/sec). The nocturnal period, from 2000 to 0800 MST, is representative of stable thermal stratification. The nighttime winds show the greatest incidence of calm conditions, 8.2% of the total hours of record. During the period of insolation, 0800 to 1600 MST, the air is generally unstable, and 1600 to 2000 MST is a transition period during which the statistics are strongly affected by transient processes associated with sunset (see Figure 3.1.3-5).[3-26]

The terrain configuration at Los Alamos makes it inadvisable to extrapolate the wind rose from a single site or to assume that transport follows straight paths. Several sources of data show that transport winds vary significantly over the area. One-year records of simultaneous hourly winds at three sites, the main technical area and two sites near the ends of mesas, covering the period May 1971 to April 1972 have been processed to determine spatial differences in the wind field (see Figure 3.1.3-6). For all speeds, the winds at the main technical area are dominated by northwest flow (flow from the northwest). This suggests a downslope drainage to account for the light winds. The wind roses calculated for the two sites at the ends of mesas show a distinct southerly maximum.

Day time winds in the main technical area are more uniformly distributed in direction than those at night and have a weak northwest-southeast axis and secondary maxima in the southerly and northeasterly directions. Again, winds greater than 9 m/sec (30ft/sec) are predominantly from the northwest. The transition period also reflected the westerly dominance with a northwesterly maximum occurrence. Previous studies have shown that the weak west-to-northwest drainage flow has the lowest levels of turbulence and therefore results in the poorest dispersion of stack emissions.

One statistic of interest is the fraction of the hours when the wind direction difference between the three sites exceeded 90 degrees. This occurred 20% of the time, primarily with wind speeds of less than 2 m/sec (7ft/sec). These data suggest that the drainage flow, which is quite well organized in the western portion of the Laboratory closer to the Jemez Mountains, weakens and gives way to a southerly flow created by air channeling through the Rio Grande depression at the eastern end of the Laboratory site.

Atmospheric diffusion depends on three primary considerations; source factors (size, duration, elevation above ground, temperature) terrain factors (roughness, slope, vegetative cover, solar heating), and meteorological factors (wind speed and direction, temperature stratification, turbulence energy). There is considerable interdependency among all of the factors listed and many of the available formulae for estimating atmospheric dispersion represent attempts at generalizing the inter-relationships.[3-40]

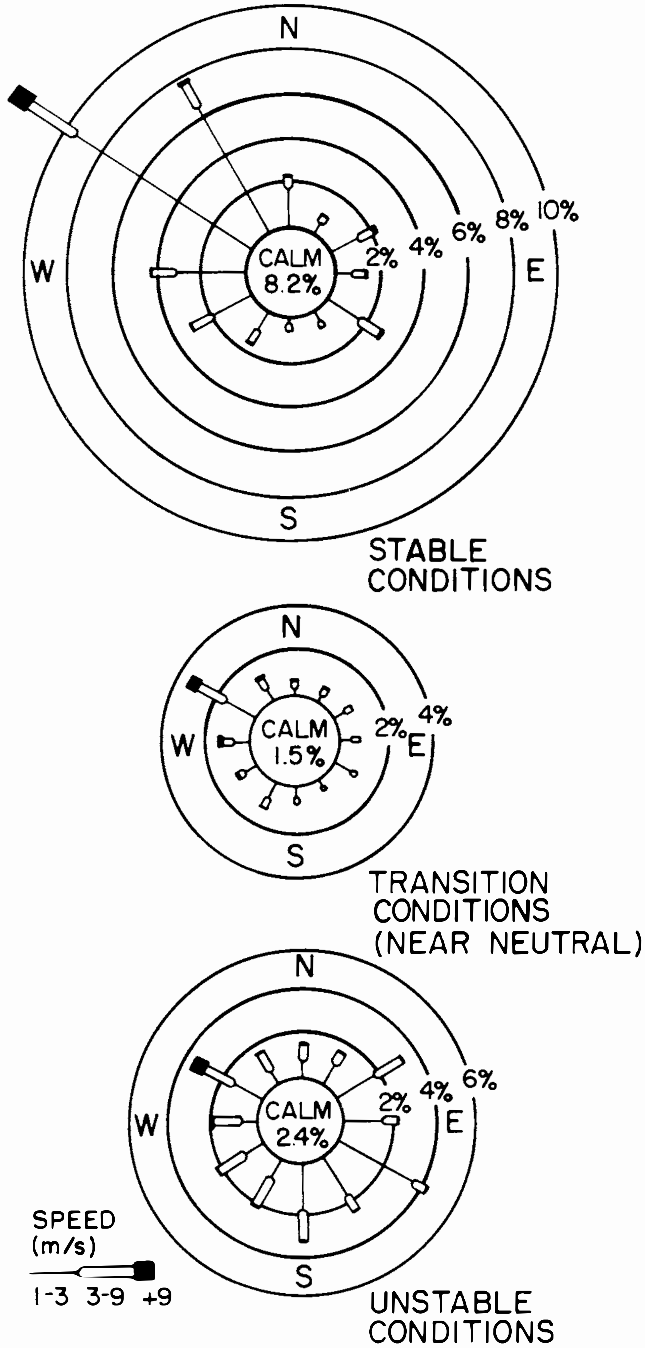


Figure 3.1.3-5 Wind Roses Showing Diurnal Cycle

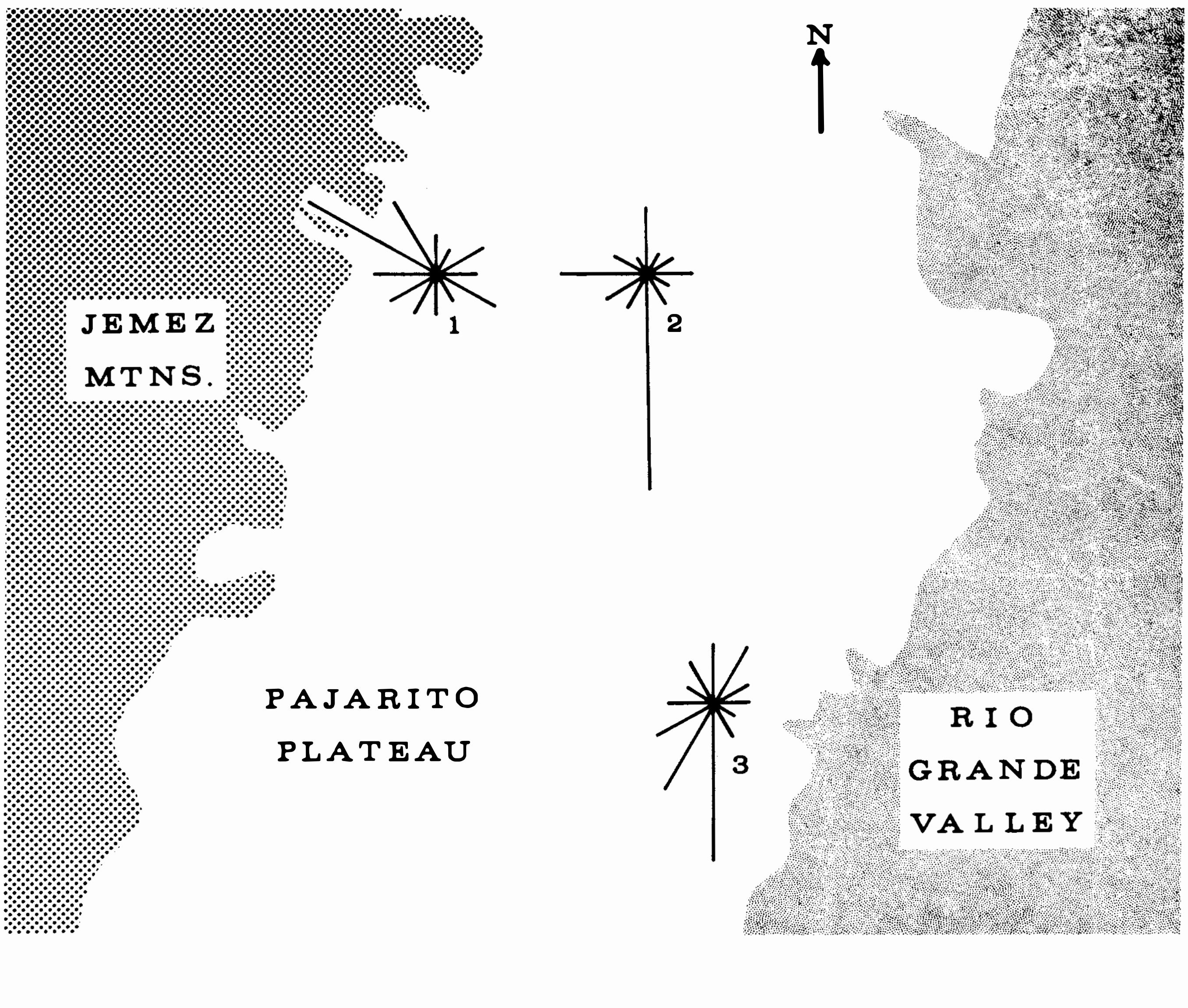


Figure 3.1.3-6. Wind Roses at Three Sites Showing Spatial Variation

The application of the meteorological parameters depends on modeling assumptions tying them to the diffusion coefficients. Several methods of selecting the diffusion coefficients are available depending on available input data. Important factors include expressions such as power laws in downwind distance, tables, and graphs of the parameters.[3-41, 3-42] Suitably selected relationships considering these various factors have been used in estimating consequences of possible accidents in Section 4.2.

As would be expected from the wind roses shown in Figure 3.1.3-5, there is a distinct orientation of the concentration pattern toward the southeast, or parallel to the canyons. This feature suggests an important role of drainage winds in transporting effluents released in the western portion of the laboratory site. Stable thermal stratification is an integral feature of the drainage winds, as is a reduced level of turbulence. Therefore, these flows, representing about 10% of nighttime hours, have the poorest capacity for dilution of released material. The stable temperature stratification inhibits vertical mixing, and horizontal mixing is constrained by the presence of the canyon walls. For purposes of estimation, the dilution beyond travel distances of a few kilometers may be neglected. Hence, for drainage within canyons that open into populated areas, the effective distance from release point to receptor is severely reduced. In particular, sites that have a drainage wind component into Pajarito Canyon can produce abnormally high concentrations of effluents in White Rock. Worst case concentrations in White Rock, 10 km (6 mi) distant, will be equivalent to worst case estimates in the western residential area or the main Townsite, located at distances of only 2-3 km (1-2 mi) from the central Laboratory areas. However, the White Rock exposures are not likely to grossly exceed those of other population centers, and conditions of deposition on vegetative surfaces will operate to reduce population hazard. In general, the upper portions of Pajarito Canyon are well forested, and a shallow plume, trapped in a canyon bottom, will tend to be scoured by the vegetation. This self-cleaning concept is not likely to be valid for sites located further down the canyon. Further study of drainage winds is needed for a quantitative inclusion of the depostion processes. However, preliminary estimates suggest that a two-orders-of-magnitude reduction in exposure in White Rock due to deposition in route may be reasonable.

Another complicated transport process relevant to potential dispersion of materials from sites located in the bottom of canyons has been identified. Two mechanisms have been documented that can lead to an exchange of air between canyon and mesa tops. The first is convective mixing in an unstably stratified atmosphere. This is basically a daytime phenomenon, probably most prevalent in the warm season. The second mechanism occurs under all stabilities when the cross-canyon wind exceeds 2 m/sec (6.6 ft/sec). There is a separated flow giving rise to a major roll eddy as shown in Figure 3.1.3-7. This means that there are many circumstances under which material could be readily transported from the canyon bottom to the mesa top.

There is significant variation in both frequency and maximum wind speed (intensity) of tornadoes in various parts of the world. There is a sharp decline in frequency and intensity between the Central Plains of the U.S., where tornadoes are frequent and severe, and the Rocky Mountains, where they seldom occur and are generally weak.

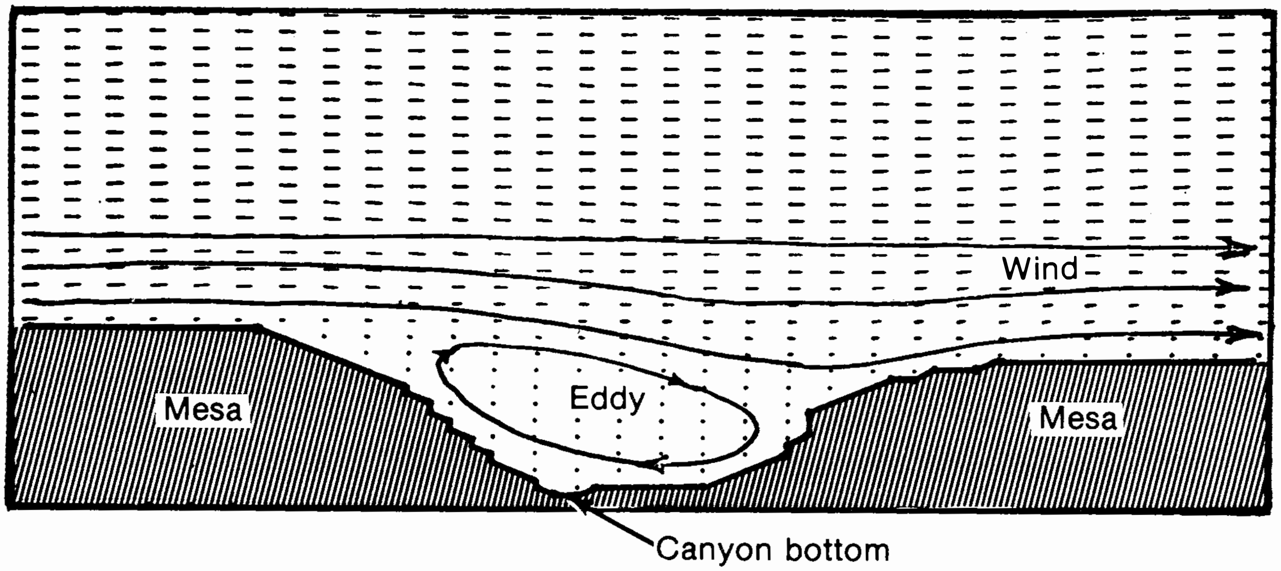


Figure 3.1.3-7. Major Roll Eddy Between Canyon Bottom and Mesa Top

An investigation into the likelihood and nature of a tornado in the Los Alamos area was conducted to determine the maximum intensity tornado for which structures at Los Alamos should be designed.[3-43] Intensities of the 235 tornadoes reported in New Mexico and southern Colorado (to 39^{o} north latitude) from 1950 through 1971 were studied. Both frequency and intensity were found to decrease very rapidly with increasing 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 midwestern evening storms.

No tornadoes have been observed in Los Alamos County. Only two were recorded in 60 years of record for the 1^{o} quadrangle centered on Los Alamos; these were to the east and at lower elevations. The study concluded that 113-157 mph tornadoes are very unlikely, and that there is no possibility of 158-206 mph tornadoes at Los Alamos; it defined the maximum intensity tornado for which structures at Los Alamos should be designed (see Table 3.1.3-1).[3-44] The Laboratory is presently using these criteria for its design basis tornado on buildings of a critical nature.

Lightning is common in the vicinity of the Pajarito Plateau. Local climatological records indicate an average of 62 thunderstorm days per year--defined as a day on which thunder is heard. Lightning protection is an important consideration applied to each facility at LASL. In most cases the protection is that prescribed in the National Fire Codes.[3-45, 3-46] In buildings of higher risk, the more stringent requirements of Army Regulations are followed.[3-47] There has been one death in Los Alamos directly caused by lightning.

3.1.4 Ecology

The diversity of ecosystems in the Los Alamos area is due partly to the dramatic 1500 m (5000 ft) elevational gradient from the Rio Grande on the east to the Jemez Mountains 20 km (12 mi) to the west, and to the many canyons with abrupt surface slope changes that dissect the area (see Figures 3.1.4-1 and 3.1.1-8). Six major vegetative complexes or community types are found in Los Alamos County. These are juniper-grassland, piñon-juniper, ponderosa pine, mixed conifer, spruce-fir, and subalpine grassland (see Figure 3.1.4-2). The juniper-grassland is found along the Rio Grande on the eastern border of the plateau and extends upward on the south-facing sides of canyons, at 1700-1900 m (5600-6200 ft). The piñon-juniper generally in the 1900-2100 m (6200-6900 ft) elevation range, includes large portions of the mesa tops and north-facing slopes at the lower elevations. Ponderosa pine is found in the western portion of the plateau in the 2100-2300 m (6900-7500 ft) elevation range. These three are the predominant community types, each occupying about one-third of the LASL reservation. The mixed conifer at the 2300-2900 m (7500-9500 ft) elevation, interfaces with the ponderosa pine in the deeper canyons and north slopes and extends to the west from the higher mesas on the slopes of the Jemez Mountains. The subalpine grasslands are mixed with the spruce fir communities at higher elevations of 2900-3200 m (9500-10,500 ft).

TABLE 3.1.3-1

TORNADO DESIGN CRITERIA FOR LOS ALAMOS

Maximum total windspeed	90 m/s	(200 mph)
Rotational windspeed	76 m/s	(170 mph)
Translational speed	13 m/s	(30 mph)
Radius of circle of maximum rotational wind	30 m	(100 ft)
Maximum pressure drop at center	5200 Pa	(.75 psi)
Maximum rate of pressure change	2275 Pa/s	(.33 psi/s)

Figure 3.1.4-1. Aerial View of Pajarito Plateau Looking East

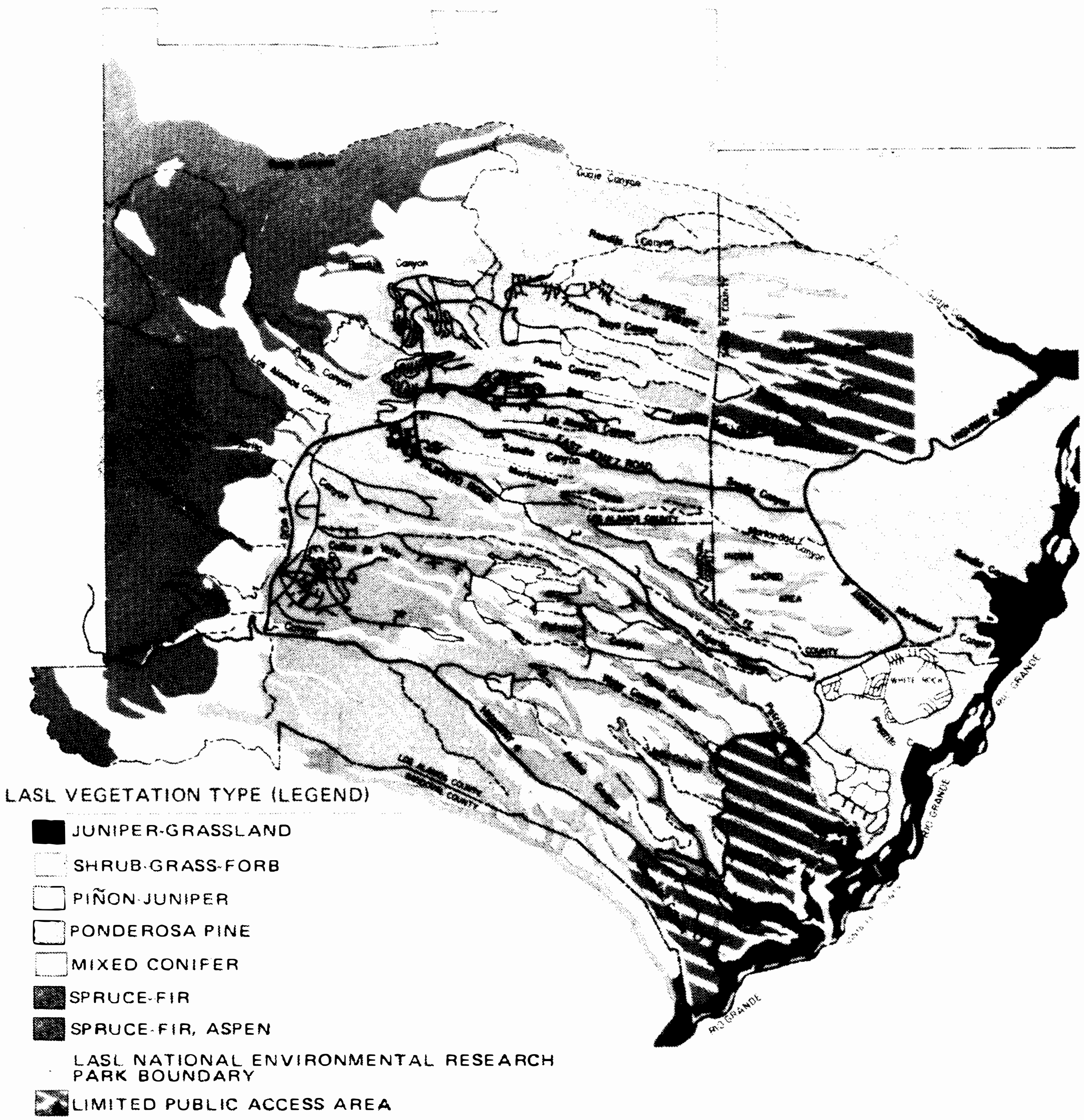


Figure 3.1.4-2. Overstory Vegetation at LASL

The prounounced east-west canyon and mesa orientation, with accompanying differences in soils, moisture, and solar radiation, produces an interlocking finger effect, resulting in many ecotones, or transitional overlaps of plant and animal communities within small areas (see Figure 3.1.4-2).

Detailed studies were started in mid-1972 to characterize the plant and animal resources of the LASL environs by inventories of the densities and distributions of fauna and flora, descriptions of the physical components such as soils and seasonal weather patterns, and determinations of the ecological relationships such as food chains and webs.[3-48]

The results of these studies serve as the basis for much of the material that follows. However, it must be recognized that the existing data base on plant and animal resources in the LASL environs is currently limited in detail and scope. Quantitative data are available for only a few selected biotic components, primarily in the radioecological study areas. Successively less detail is available from the general Laboratory area, and for several major plant and animal groups, data are completely lacking. Examples of species where informational deficiencies exist include bear, mountain lion, coyote, fox, bats, frogs, mosses, and mushrooms.

Flora and Fauna

Coniferous trees are the dominant vegetation in the county, with ponderosa pine and Douglas-fir predominating at elevations above 2100 m (6,900 ft), while piñon pine and one-seeded juniper are most abundant at the lower elevations [3-26] (see Figure 3.1.4-3).

The vegetative understory is that vegetation growing under the dominant trees. The understory of the area in general is sparse, although certain locations (e.g., canyon bottoms, some south slopes, and some mesa tops) harbor a wide variety of shrubs, grasses, and forbs. The combination of a dense overstory and understory in the canyon bottoms, along with available free water, provides excellent habitat for wildlife, particularly in the restricted areas of government property.

Almost 350 individual plant species have been tentatively identified in the general LASL area as listed in Appendix A. Greater species diversity in higher plants other than grasses occurs at higher elevations (see Table 3.1.4-1). A maximum of 18 taxonomic families and 28 non-grass species were recorded in the subalpine grassland. Members of the composite and grass families occur with the highest frequency and comprise the highest percentage of the ground cover at all the elevational sites. Total ground cover reaches a maximum of 100% at the higher elevations (i.e. the subalpine grassland) and decreases steadily to a minimum of less than 15% in the juniper-grassland community along the Rio Grande.[3-49]

Information concerning faunal resources in the Los Alamos environs is largely qualitative in nature. Species lists have been compiled from field observations and published data, although in some cases species occurrence has not been verified. A compilation of existing information on faunal species occurring in Los Alamos County is presented in Appendices B, C, and D.[3-49]

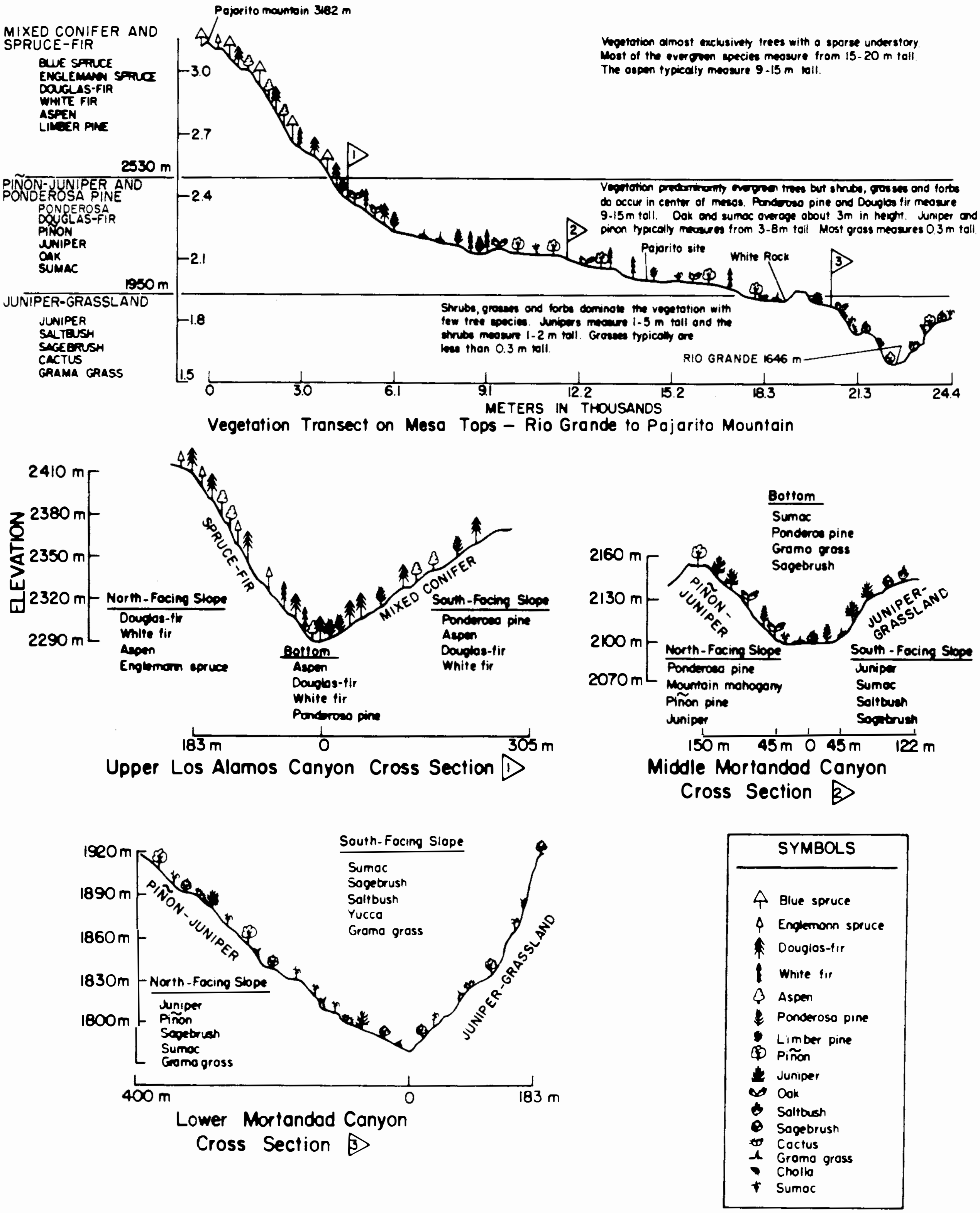


Figure 3.1.4-3. Vegetation Transect

TABLE 3.1.4-1

FLORA DISTRIBUTION BY COMMUNITY TYPE ALONG AN ELEVATIONAL GRADIENT

Overstory Vegetation Type	Approximate Elevation (m)	Number of Families	Number of Species[a]
Spruce-Fir	2900	18	28
Subalpine Grassland	2900	10	24
Mixed Conifer	2300	9	22
Ponderosa Pine	2100	12	25
Pinon-Juniper	1900	8	17
Juniper-Grassland	1700	8	11

a) Grass species not included in tabulation

Invertebrates play a potentially significant role in the cycling of materials and energy in natural systems. Studies were begun at LASL in 1975 to characterize ground dwelling and nomadic invertebrate species composition and trophic level relationships. A minimum of 350 species were identified from pitfall sampling in the canyon liquid waste receiving areas. Invertebrate trophic level relationships are being studied, but results are not complete. The major consumer groups, such as herbivores and carnivores, appear to be well represented. However, present data indicate that carnivores are present in greater numbers than expected, possibly because of sampling biases and the problem of assigning a trophic level to omnivores. The canyons that receive liquid effluents support a greater diversity of invertebrate species than occur on a nearby mesa top and in a dry canyon.[3-50, 3-51]

Small mammal studies have initially determined species composition, diversity, and indications of densities, movement patterns, and food habits. These studies resulted in the identification of 17 species representing six taxonomic families that occur in the LASL area. The deer mouse (*Peromyscus maniculatus*) is apparently the most widely distributed small mammal, since it was encountered in all overstory vegetation types throughout the LASL environs (see Figure 3.1.4-4). Additionally, the least chipmunk (*Eutamias minimus*) and woodrats (*Neotoma* spp.) occur in most of the vegetation types. Gapper's redbacked vole (*Clethrionomys gapperi*) was found within fir-aspen-spruce forests. The montane vole (*Microtus montanus*) predominately inhabits meadows in mountain forests. The meadow vole (*M. pennsylvanicus*) was limited to grass-sedge communities in the canyon study areas which have continuous water-flow. Shrews (*Sorex* spp.) were also associated with canyon areas where water was available, or mesic sites within the forest. The piñon mouse (*P. truei*) was associated with piñon-juniper vegetation. The western harvest mouse (*Reithrodontomys megalotis*) was found in the canyon sites having dense stands of grasses and forbs.[3-52, 3-53]

Rocky Mountain mule deer (*Odocoileus heminonus*) is the most important and prevalent big game species in the area, both in numbers and distribution. During fawning in the first week of July the adult females select relatively undistrubed areas of the Laboratory. Fall and winter deer densities are higher on the Laboratory reservation than on the bordering US Forest Service land at higher elevations to the west (see Figure 3.1.4-5). This situation is reversed during the summer, when deer densities on the Forest Service land are considerably above those on the Laboratory. These density fluctuations are related to the fall migration of deer from the higher elevations of the Forest Service land to the Laboratory. Deer movements into the Laboratory during the fall result from both the heavy hunting pressure and the deeper snows on Forest Service land.[3-54]

Rocky Mountain elk (*Cervus canadensis*), nearly exterminated throughout New Mexico during the turn of the century, were reintroduced about 1920. The last transplant of elk in the Los Alamos area occurred in January 1966, when 58 head were released on the US Forest Service land west of the Laboratory. Increasing use of the LASL area by elk has been noted over the last five years. Areas of elk use in the Los Alamos environs are shown in Figure 3.1.4-6.

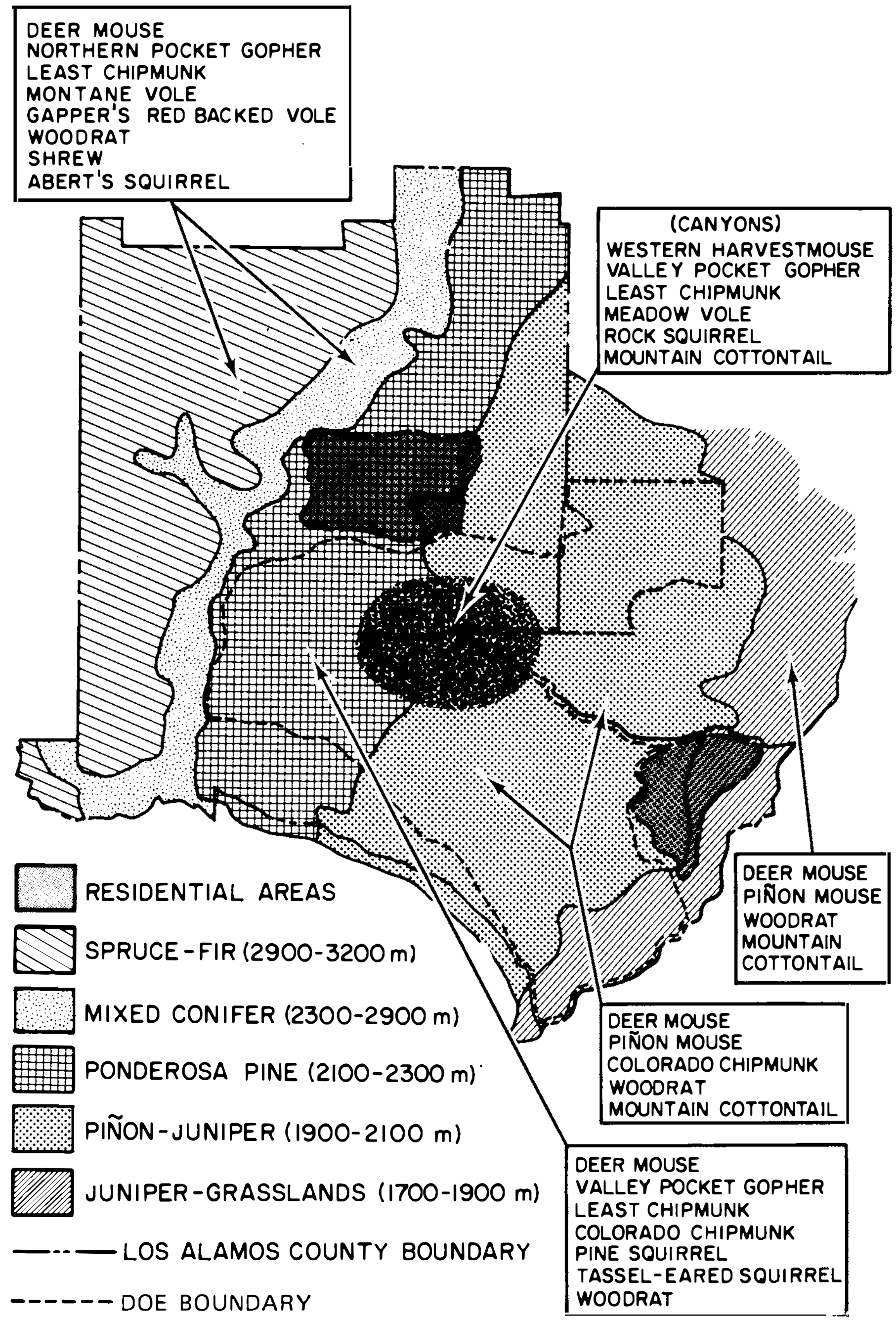


Figure 3.1.4-4. Small Mammal Distribution in Los Alamos County

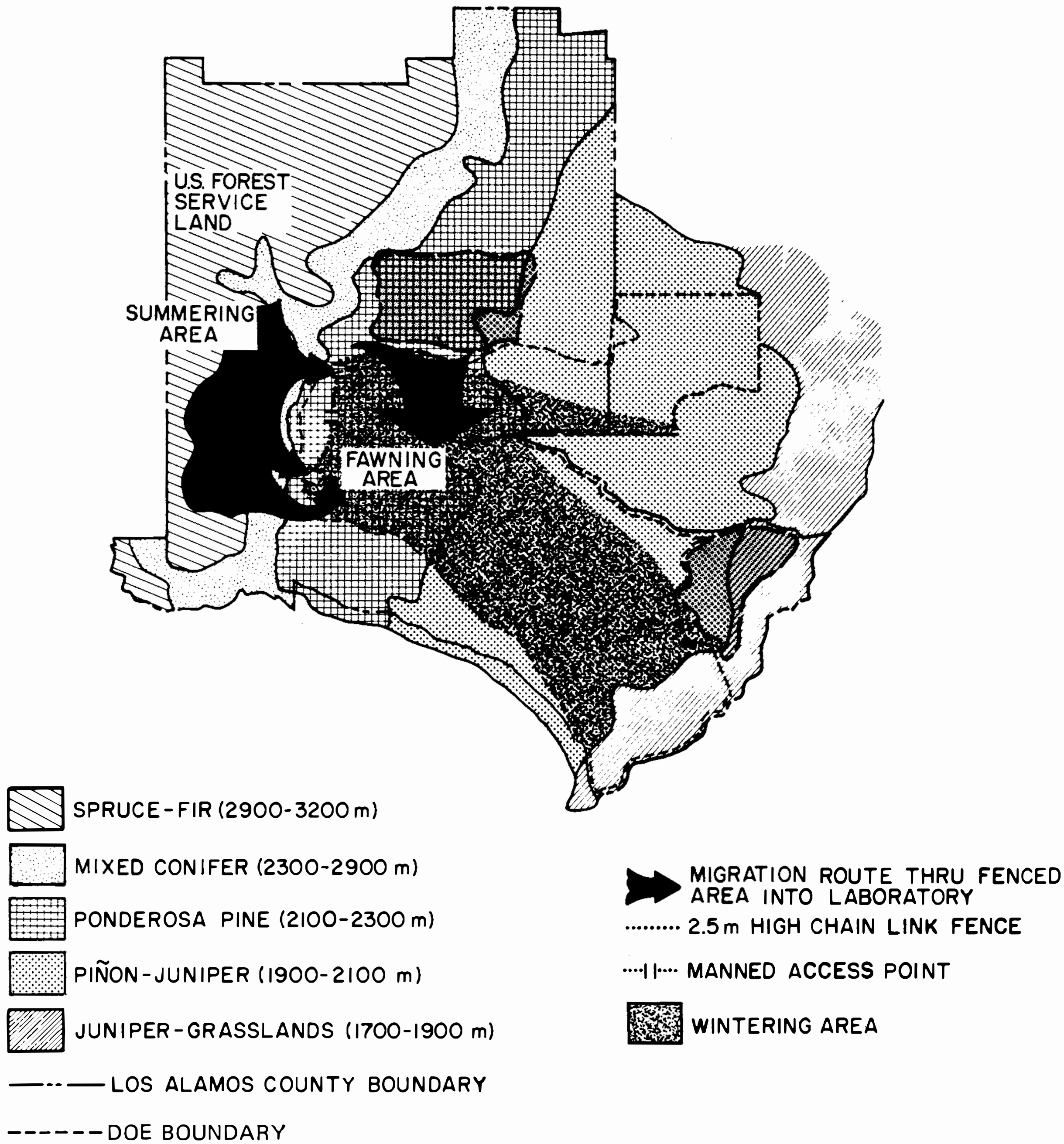


Figure 3.1.4-5. Areas of Deer Use in Los Alamos County

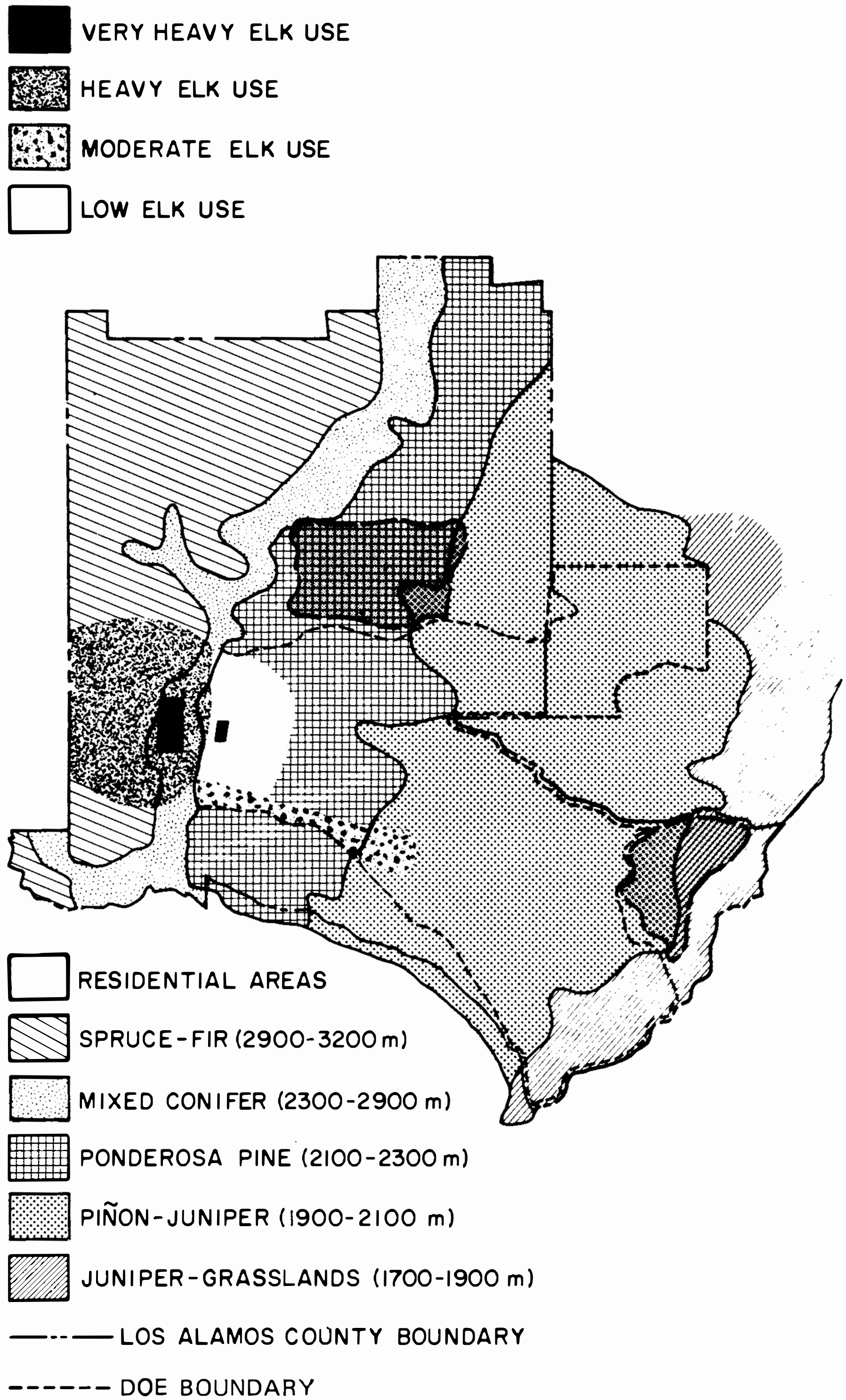


Figure 3.1.4-6. Areas of Elk Use in Los Alamos County

Cold-blooded animals in the area include several species of fish found in the Rio Grande. The carp, chub, white sucker, and carp-sucker are abundant in the waters of the Rio Grande on the eastern site boundary. A few brown trout inhabit the Rio Grande but never reach significant population densities because of the extreme turbidity of the river water. A large variety of game fish, principally large mouthed bass and walleye pike, were introduced in 1974 into the newly-completed Cochiti Reservoir, 10 km (6 mi) downstream from the Laboratory.[3-55]

There are at least nine reptiles in the LASL environs (see Appendix C) including small lizards and king, bull, garter, and rattlesnakes. The Jemez Mountain salamander is a potentially important amphibian because of its rarity.[3-56] The presence of other reptilian and amphibian species is suspected but has not been documented.

Birds represent by far the largest variety of vertebrate wildlife in the area. There are some 187 species from 44 families reported in the area. Permanent residents include 37 species, and 46 others probably summer or breed in Los Alamos County. The rest are transitory migrants. The bird communities of the Los Alamos Scientific Laboratory are much more diverse and dynamic than they appear to the average observer. A list of avian species known or expected to occur in the LASL environs is presented in Appendix D, which is divided into seven categories of occurrence.

About 90 bird species regularly occupy the LASL environs, of which about one-half are present throughout the year; this listing is expected to change as more data are obtained. Elevational replacements among bird species show considerable overlap in range, reflecting the considerable habitat changes that result from the east-west orientation of the alternating mesa-canyon topography of the area.

Often-observed permanent residents include the common raven, pygmy nuthatch, western bluebird, juncos, and rufous-sided towhee. Summer birds commonly observed include the turkey vulture, red-tailed hawk, American kestrel, chipping sparrow, and violet-green swallow. One nesting pair of peregrine falcons has been observed within the area for the last twelve years. At least one more species, the burrowing owl, may be expected to occur within the piñon-juniper community. The wide-ranging birds of the area often migrate into the large areas of undeveloped woods and canyons surrounding the site.

A special aspect of the faunal resources of LASL that deserves attention is that of endangered species, including those that are presently in jeopardy or those that are threatened by loss of habitat or other factors. The New Mexico Wildlife Conservation Act passed by the 1974 State Legislature required that the State Game Commission develop a list of endangered wildlife species and subspecies indigenous to New Mexico. According to the Act, the term "endangered" refers both to endangered and threatened species. The list as adopted January 24, 1975, further defines the term into two groups: Group 1, the species and subspecies whose prospects of survival or recruitment in New Mexico are in jeopardy (otherwise known as endangered), and Group 2, the species and subspecies whose prospects of survival or recruitment within the state are likely to be in jeopardy within the forseeable future (otherwise known as threatened). Table 3.1.4-2 lists the endangered species that may occur in north-central New Mexico and perhaps in the Los Alamos area. Some of the endangered species may also be on the Federal list; however, those listed meet the qualifications of "endangered" and their occurrence has been substantiated in New Mexico. The species lists are dynamic and therefore are subject to change. Close coordination with the Fist and Wildlife Service will continue to assure that the most recent information is available to determine the impact of any significant change of Laboratory activity.

TABLE 3.1.4-2

STATE LISTED ENDANGERED SPECIES FOR NORTH CENTRAL NEW MEXICO

	Group 1 Endangered	Group 2 Threatened
Mammals	Black-footed ferret[a]	Pine marten[a]
	River otter[a]	Mink[a]
Birds	Peregrine falcon	Osprey
	Whooping crane	Red-headed woodpecker
	White-tailed ptarmigan[a]	Zone-tailed hawk
	Sage grouse[a]	
	Mexican duck[a]	
	Bald eagle[a]	
Amphibians		Jemez Mountain Salamander
Fish	Shovelnose sturgeon[a] (exterminated)	Suckermouth minnow[a]
	Bluntnose shiner	

a) Not documented in Los Alamos County

Although they are included in the table, the river otter, mink, white-tailed ptarmigan, sage grouse, shovelnose sturgeon, proserpine shiner, and suckermouth minnow have not been reported in the area and are very unlikely to be present. The pine marten has been reported in the County, but its presence has not been confirmed.

The black-footed ferret is associated with prairie dogs in grassland plains and mountains up to the 3200 m (10,500 ft) elevation. Although it has not been reported in the LASL environs, there is a possibility of the black-footed ferret being present at the lower elevations in the area.

The Rio Grande cutthroat trout is found in headwater streams of clear, cold flowing water with flow rates greater than 0.06 m^3/sec (2.0 ft^3/sec). There are no surface waters of this type in the area. It has been confirmed to be in the Jemez Mountain streams, including Canones, Peralta, Polvadera, and Chihuahuenas Creeks.[3-56]

The Jemez Mountain salamander is a small, secretive species indigenous only to the Jemez Mountains. Its habitat is volcanic substratum. The decaying logs of spruce and fir provide the necessary shade and moisture, especially on north slopes. Loss of its habitat from lumbering, fire, and real estate development plus disturbance by excessive collecting could threaten its survival. It is found in many drainages in the area, with the population concentrated in the Jemez Mountains on the north side of Los Griegos, and in Cebolla Creek and its tributaries. It is also found closer to LASL environs in Los Alamos, Pajarito, and Frijoles Canyons.[3-57]

The Southern bald eagle might be found in the adjoining Jemez Mountain area during the fall and spring migration; there are no known eyries. Red-headed woodpeckers are a summer resident of the LASL environs and are presumed to breed in the area. Osprey are transients in the area during fall and spring migration.

Because of the variety of complex interlocking ecotones in the Los Alamos area there is no single ecological structure of food webs that can characterize the associations of flora and fauna in the area. Food-web relationships for the biota of the Laboratory environs have been studied only enough to provide general descriptions and expectations. However, a reasonably complete description can be given for the three canyon areas studied in connection with effluent disposal. Pueblo, Los Alamos, and Mortandad Canyons are the subject of continuing environmental studies attempting to determine the fate of trace materials contained in the effluent from present and former industrial waste treatment plants. Extensive sampling programs have provided a basic understanding of the ecosystems in the canyons of the Pajarito Plateau. Table 3.1.4-3 summarizes the understanding of food web relationships developed through these studies.[3-55]

Generally, the larger mammals and the birds are wide-ranging and occupy commensurately large habitats, from the dry mesa-canyon country at lower elevations to the high mountain tops west of the Laboratory. The smaller mammals, reptiles, invertebrates, and vegetation are more sensitive to the variations in elevation, and thus are confined to generally smaller habitats.[3-53]

At the lower elevations of 1800-1940 m (5900-6300 ft), the canyons are dry except during rainfall runoff events. The sheer canyon walls at the lower elevations serve as important nesting habitat for the birds of prey. Herbivorous rodents, insects, and small birds probably form the bases for the food webs in the lower canyons.

TABLE 3.1.4-3

FOOD WEB RELATIONSHIPS IN LASL ENVIRONS

	Juniper-grassland (1700-1900 m)	Piñon-juniper (1900-2100)	Canyons (Riparian)	Ponderosa Pine (2100-2300 m)	Mixed Conifer (2300-3200 m)
Producers	One-seeded juniper Four-winged saltbush Prickly pear Feathergrass Three-awn Dropseed	Piñon pine One-seeded juniper Rabbitbrush Apache plume Mountain mahagony Blue grama	Narrowleaf cottonwood White squaw currant Narrowleaf hoptree New Mexico forestiera Boxelder Sedge Kentucky bluegrass Little bluestem	Ponderosa pine Gambels oak Skunkbush Antelope bitterbrush Mountain muhly	Douglas-fir Ponderosa pine Quaking aspen Engelmann spruce White fir Shrubby cinquefoil Mountain muhly Mountain broome
Consumers; (Herbivores)	Deer mouse Piñon mouse Mountain cottontail Woodrat	Deer mouse Piñon mouse Colorado chipmunk Mountain cottontail Woodrat Rocky Mountain mule deer	Western harvestmouse Meadow vole Least chipmunk Mountain cottontail	Deer mouse Valley pocket gopher Colorado chipmunk Least chipmunk Pine squirrel Rock squirrel Tassel-eared squirrel Woodrat Rocky Mountain mule deer	Deer mouse Northern pocket gopher Montane vole Gapper's redbacked vole Least chipmunk Abert's squirrel Shrew Woodrat Rocky Mountain mule deer Rocky Mountain elk Western blue-bird Gray-headed junco
Consumers; (Carnivores, Insectivores, Omnivores)	Coyote Gray fox Bobcat Scrub jay Piñon jay Rattlesnake	Coyote Gray fox Bobcat Steller's jay Piñon jay Common raven Spiny lizard	Coyote Racoon Mountain lion American black bear Steller's jay Common raven American kestrel Golden eagle Gopher snake	Mountain lion American black bear Pygmy nuthatch Common flicker Common raven Pygmy nuthatch	Ermine Mountain lion American black bear Green-tailed towhee Clark's nutcracker Hairy woodpecker

At the higher elevations of 1940-2180 m (6360-7150 ft), the canyons are relatively narrow and densely forested. Surface water is perennial as a result of treated Laboratory and municipal effluents. The lower elevation vegetation types grades into less prominence with other plants assuming dominance. Mice generally decrease in population density at higher elevations in the canyons while rodent population densities increase with elevation on the mesa tops. This apparent anomaly is at least partly due to the relationship of canyon and mesa-top rodent study sites to ecotonal areas. Rodent species present include those already mentioned for the lower elevation as well as tree squirrels and the meadow vole, a species typical of moist habitats. Bird populations appear to markedly increase along the ecotone between the piñon-juniper and ponderosa pine communities.

The mountainous areas to the west of the Laboratory are heavily forested with open areas created by lightning-strike forest fires. This area has not been studied in sufficient detail to determine all major faunal associations.

Seasonal variation in some of the plant and animal communities in the canyons is presently under study. Preliminary estimates of understory vegetation and small mammal biomass, which appear in Figure 3.1.4-7, indicate some of the complex relationships between flora and fauna. Though there is a increase in total small mammal biomass with increasing elevation, the total biomass for plants (at the same elevations used for the mammals) goes from high to low to high reflecting a switch from forbs to grass.

Past and present human use of the LASL environs has resulted in areas of vegetation undergoing secondary succession. This has had, and will continue to have, important consequences to the natural systems. Farming by prehistoric Indians and by Spanish and Anglo settlers before the Laboratory's establishment in 1943, created open grassy areas on the mesas that have not completely returned to climax plant communities. These areas afford suitable feeding areas for herbivores, especially the deer and elk, with adjacent timbered canyon slopes providing cover for these species. The food-web relationships of the mesa areas are related to those of the canyons to some degree.[3-58]

Birds are strongly dependent upon the vegetation of an area to produce a spectrum of environments that may be classified as (1) a lower habitat threshold occupied during seasonal movements or during times of strong intra-specific competition; (2) an optimum habitat for vital functions of mating, nesting, and feeding; and (3) a zone of exclusion imposed by plant succession. The clearing of the ponderosa pine forest has created large openings with an appreciable "edge effect" that is exploited by bird communities. Margins of clearings often have 95% more birds, representing 40% more species, compared to undisturbed stands of trees; however, openings that are heavily developed offer no such increase in bird or other animal communities. The succession sequence of vegetation results in a richness of bird life that testifies to the general health of the ecosystem.

3.1.5 Ambient Environmental Quality

A general discussion of environmental quality parameters relating to the region surrounding Los Alamos is provided here as a basis for comparison. Within limits of available information, this may be considered indicative of present normal conditions for the region. The data reflect natural conditions as well as widespread influences due to human activities such as release of wastewaters from various municipalities and worldwide fallout from atmospheric testing of nuclear explosives.

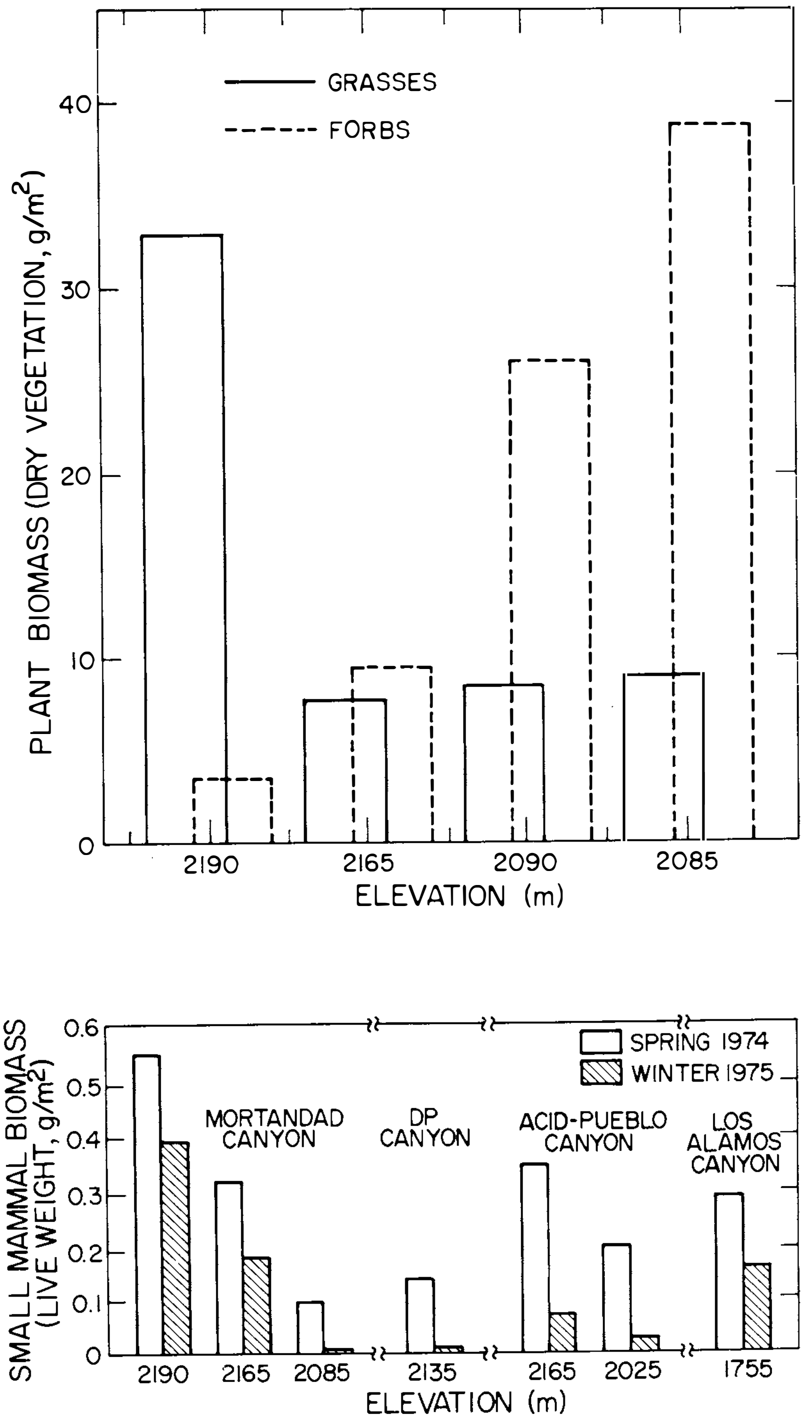


Figure 3.1.4-7. Vegetation and Small Mammal Biomass Variation with Elevation

Water Quality

Surface and ground waters in the region fall within the upper Rio Grande Basin as defined by the New Mexico State Engineer Office and the Interstate Stream Commission. The following descriptive information is excerpted from a draft planning document prepared by the New Mexico Water Quality Control Commission in August 1976.[3-25]

"Surface water quality in the Upper Rio Grande Basin is generally suitable for most uses.

"Minimum levels of dissolved oxygen (DO) are consistently sustained according to measurments at key stations located along the Rio Grande and its tributaries. Maintenance of a minimum concentration of DO is crucial for fish and other aquatic animal life to thrive, and is enhanced in the Rio Grande and its mountain tributaries by rapid streamflows that assure constant reaeration of water. Where measured in the basin, BOD and COD levels appear to be fairly low; although when compared to other stations, BOD samples taken at Otowi Bridge are somewhat elevated. This is probably attributable to discharge of organic material from the wastewater treatment plant in Española.

"Mean fecal coliform levels in the Rio Grande above Española are consistently low. At the Otowi monitoring station below Española, data from the U.S.G.S. and the EIA indicate log mean levels of 120 colonies per 100 mℓ for the period from 1969 to 1973, 540 colonies per 100 mℓ for 1974, and 170 colonies per 100 mℓ for 1975. These levels are well below the stream standard of 1,000 colonies per 100 mℓ, monthly log mean.

"Changes in bacteriological quality may simply be year-to-year variations, probably related to thunderstorm activity, or may be attributable to expanding populations along the Rio Grande in the Española area. The infrequent sampling for bacteriological quality in this stretch of the Rio Grande is not adequate to compare actual trends in the river against applicable standards.

"Compared to standards recommended by the National Academy of Sciences, levels of zinc, iron, copper and manganese in the Rio Grande are not elevated. There are no adopted New Mexico stream standards for heavy metals. Elevated boron and selenium levels have been observed at a number of locations along the Rio Grande; naturally elevated concentrations of these metals are not uncommon in arid regions.

"According to available data for the Upper Rio Grande Basin, there is some indication that phosphorus and nitrogen levels increases in lower reaches. Mean total phosphorus measured at Lobatos, Colorado, is .124 mg/ℓ and mean total nitrogen is .488 mg/ℓ; at Otowi Bridge, similar samples measured .19 mg/ℓ and .55 mg/ℓ.

"These characteristics may precipitate more acute problems in Cochiti Reservoir. Wastewater from Española, White Rock, and Los Alamos discharge to the Rio Grande within twenty-five miles of Cochiti, and thus may increase nutrient loading to the reservoir. In an effort to prevent potential algal blooms in Cochiti Reservior, the New Mexico EIA Water Quality Division has recommended a phosphorus removal program from those wastewater effluents which will directly impact Cochiti Reservior.

"Total dissolved solids concentrations at Otowi Bridge rarely exceed the applicable standard. Total dissolved solids loads at the New Mexico-Colorado State line and at Otowi Bridge average 65,000 tons and 247,000 tons respectively for the period of record.

"Projections of TDS loads in the Rio Grande assume that population increases in southern Rio Arriba County and Santa Fe County and mineral production in Taos and Rio Arriba Counties will result in increased water use and TDS load in the Rio Grande between the New Mexico-Colorado State line and Otowi Bridge. Development of tributary units of the San Juan-Chama project in Taos, Rio Arriba and Santa Fe Counties are expected to increase the TDS load in the Rio Grande by about 4,600 tons per year.

"General water uses in Santa Fe County are expected to have a minor effect upon TDS load at Otowi Bridge. The expanding water demands of urban populations in Santa Fe and Los Alamos, particularly Santa Fe's increasing reliance upon withdrawals from the Buckman Well Field to serve its municipal needs, is expected to affect TDS in the Rio Grande.

"Average chloride and sulfate concentrations are generally low throughout the Upper Rio Grande Basin. Levels in excess of stream standards for chloride have been observed at the Otowi Bridge Station, but these only comprise 0.6% of the measurements taken. Available data does not correlate these measurements to the minimum flow of 100 cfs for which the stream standard applies.

"An analysis of the effect of chlorinated municipal wastewater upon chloride concentrations in the Rio Grande indicates that only 2.8% of the increase in dissolved chlorides, and 0.08% of the increase in total dissolved solids in the reach from Otowi Bridge to Bernardo is due to municipal chlorination. This stream reach includes the city of Albuquerque and others in the Middle Rio Grande Basin. It is estimated that a doubling of municipal populations in this area would accordingly double the increase in salinity and chloride levels, but even so, would have a minor impact upon chloride and salinity levels in the Rio Grande.

"The turbidity of water is caused by the presence of suspended and colloidal matter, which has the effect of reducing light penetration and clarity....Measurements of stream turbidity in the Rio Grande at Otowi Bridge exceed the applicable standard in 36% of the samples taken.

"Sedimentation is a persistent and major water quality problem in the Upper Rio Grande Basin. It impairs range and farm lands, reduces the channel capacity of streams, depletes reservior capacity, generates flood problems, interrupts irrigation systems, and is detrimental to crop production. Factors that affect sediment yield include topography, geology, soils, climate, ground cover, run-off, land use, sheet erosion and channel erosion.

"The general classes of potential nonpoint water contamination in the Upper Rio Grande Basin include agriculture, forestry activities, mining, construction, waste disposal and those related to hydrological modification.

"Construction related problems usually involve sedimentation from altered runoff patterns and increased potential for erosion. Erosion could be caused by highway construction. Residential contruction on steep slopes which is increasing in the Santa Fe drainage area contributes to the sediment load in nearby streams. Increasing urban density and expanding urban areas, particularly Santa Fe and Española will create additional volumes of runoff as recharge areas are covered by impermiable streets and structures.

"Another source of concern is the subsurface disposal of domestic waste in septic tanks in areas with shallow water tables. Settlement patterns have generally followed the Rio Grande and Chama floodplains, where ground water level is high and the additional danger of flooding causes discharge of contaminants into surface water. Expansion of such suburban communities as is occurring in Pojoaque, Nambe, San Jose and Hernandez will require more effective wastewater disposal systems to avoid degradation of surface and ground water quality.

"Recreational activities in Northern New Mexico are posing significant water degradation problems. Recreation facilities such as those at El Vado, Santa Cruz, and Cochiti Reservoirs and those along streams near urban areas receive intense use and are the focus of much of this activity. Without proper land use controls, erosion from construction activities on hillsides and inadequate wastewater disposal systems are likely to increase sediment and nutrient loading in adjacent surface waters.

"Municipal wastewater treatment in the Upper Rio Grande Basin currently produces effluent which generally does not comply with applicable secondary treatment requirements. Factors hampering adequate secondary treatment include: outmoded design, underdesigned facilities, inadequate operation and maintenance programs, and time delays in replacement or modification of existing treatment facilities.

"There are currently three wastewater treatment facilities in Española; the Española Westside plant, the Española Eastside plant, and the Valley Estates plant. The latter plant is privately operated and maintained by the Valley Estates Homeowners Association, and a National Pollutant Discharge Elimination System (NPDES) permit is being issued to this facility. NPDES permits were issued to both of the Española treatment facilities in 1974. Neither plant can achieve secondary treatment levels....The eastside plant is heavily overloaded and is not capable of meeting secondary treatment levels. The westside plant is capable of high treatment levels, but is not operating efficiently as a result of lack of adequate controls and monitoring devices. (Planning efforts for improvement are underway.)"

"There are three wastewater treatment facilities serving Los Alamos County. These facilities meet the most recent EPA requirements for secondary treatment facilities and have recently been upgraded to be in full compliance with the National Pollutant Discharge Elimination Systems (NPDES).

Regional surface waters within 75 km (46 mi) of Los Alamos are sampled as part of the LASL routine surveillance program. Samples are taken from four locations on the Rio Grande and one each from the Rio Jemez and Rio Chama, tributaries to the Rio Grande. Results for chemical quality analyses on the samples collected in 1976 are presented in Table 3.1.5-1. This section and section 3.1.2, Hydrology, provide background for impact evaluation in section 4.1.1.

Air Quality

Ambient air quality in the Los Alamos area has not been documented in detail except for radioactivity which is discussed in the next section, Chapter 4, and Appendix H (page H-36). Some measurements of SO_2 and suspended particulates have been made by the New Mexico Environmental Improvement Agency (NMEIA).

The NMEIA took 857 hourly SO_2 measurements between October 12, 1976, and November 19, 1976. None of the measurements were above the minimum detectable limit of 0.01 ppm. Data on total suspended particulates over the past several years in Los Alamos and White Rock is comparable to typical rural communities. A summary of the data for 1976 is presented in Table 3.1.5-2.[3-59, 3-60] As shown in the table, all values are within the limits of the State of New Mexico Ambient Air Quality Standards.

As a further indication of the general regional air quality, data collected by the NMEIA in Santa Fe (40 km southeast of Los Alamos) is presented in Table 3.1.5-3.[3-59, 3-61] This table includes data on SO_2, NO_2, and CO as well as the relevant state standards for those substances. The Santa Fe data is probably quite similar to what would be observed in Los Alamos, as there are no major point effluent sources that would influence air quality of the two cities in substantially different ways.

TABLE 3.1.5-1

CHEMICAL QUALITY OF REGIONAL SURFACE WATER IN 1976[a]

Analyses	Concentrations (mg/1)		
	Min	Max	Ave
Bicarbonate	105	160	119(±19)
Calcium	34	51	39(±5.5)
Carbonate	0	0	0
Chloride	5	58	16(±18)
Fluoride	0.1	1.4	0.4(±0.4)
Magnesium	3	14	8.7(±3.2)
Nitrate	>0.4	0.8	0.4(±0.3)
Sodium	13	96	32(±25)
TDS	222	664	337(±130)
Hardness	113	153	135(±16)
pH	7.6	8.3	7.9(±0.4)
Conductance (mS/m)	2.5	86	40(±19)

a) See Appendix H (page H-88 for 1978 figures) and a comparison to 1977 figures (page H-32).

TABLE 3.1.5-2

SUMMARY OF TOTAL SUSPENDED ATMOSPHERIC PARTICULATES IN LOS ALAMOS AND WHITE ROCK FOR 1976 [a]

(All concentrations in $\mu g/m^3$)

	Los Alamos				White Rock			
Month	Samples	Max	Min	Mean	Samples	Max	Min	Mean
January	6	30	19	26	5	31	10	22
February	4	88	21	47	4	88	6	30
March	6	135	26	60	6	147	15	64
April	5	50	22	34	4	61	19	47
May	5	69	30	48	5	39	12	30
June	5	95	35	60	5	96	31	56
July	5	33	20	25	5	48	14	29
August	5	63	18	35	5	58	18	33
September	5	33	7	24	5	41	6	22
October	5	67	24	37	5	46	23	34
November	5	53	25	37	5	56	29	38
December	5	55	20	39	5	51	20	32

Total Suspended Particulates	Maximum Allowable Concentration
24 hour average	150 $\mu g/m^3$
7 day average	110 $\mu g/m^3$
30 day average	90 $\mu g/m^3$
Annual geometric mean	60 $\mu g/m^3$

a) See Appendix H (page H-105) for updated information.

TABLE 3.1.5-3

SUMMARY OF ATMOSPHERIC SULFUR DIOXIDE, NITROGEN DIOXIDE, AND CARBON MONOXIDE HOURLY CONCENTRATIONS IN SANTA FE FOR 1976

Month	No. Hourly Samples	SO_2 (ppm) Max	Min	Mean	No. Hourly Samples	NO_2 (ppm) Max	Min	Mean	No. Hourly Samples	CO (ppm) Max	Min	Mean
January	4	0.000	0.000	0.000	4	0.0150	0.0000	0.0096	602	17.50	0.00	3.79
February	4	0.078	0.020	0.025	4	0.0417	0.0062	0.0173	560	21.00	0.50	3.35
March	5	0.000	0.000	0.000	6	0.0102	0.0000	0.0045	-	-	-	-
April	3	0.005	0.004	0.005	3	0.0203	0.0032	0.0123	54	10.00	0.50	3.70
May	4	0.011	0.008	0.010	4	0.0125	0.0041	0.0094	564	14.00	0.50	2.53
June	4	0.012	0.008	0.010	4	0.0088	0.0072	0.0081	646	14.50	0.00	3.41
July	2	0.005	0.005	0.005	2	0.0097	0.0048	0.0073	-	-	-	-
August	2	0.010	0.009	0.010	3	0.0108	0.0036	0.0062	-	-	-	-
September	4	0.018	0.007	0.013	4	0.0100	0.0046	0.0061	-	-	-	-
October	5	0.012	0.004	0.008	5	0.0067	0.0011	0.0042	-	-	-	-
November	4	0.009	0.002	0.005	4	0.0024	0.0011	0.0018	152	15.00	0.00	2.03
December	4	0.007	0.004	0.006	5	0.0139	0.0022	0.0064	703	20.00	1.00	4.49

Constituent	Maximum Allowable Concentration
Sulfur Dioxide	
24 hour average	0.10 ppm
Annual Arithmetic average	0.02 ppm
Nitrogen Dioxide	
24 hour average	0.10 ppm
Annual arithmetic average	0.05 ppm
Carbon Monoxide	
8 hour average	8.7 ppm
1 hour average	13.1 ppm

Natural and Fallout Radioactivity

The natural penetrating radiation (x-and gamma-rays) background is composed of cosmic and terrestrial components. The magnitude of the cosmic component is largely a function of altitude. Sea level cosmic radiation levels are lowest, at about 29 mrem/year.[3-62] Los Alamos is about 2.17 km (1.35 mi) above sea level, with an expected cosmic radiation dose equivalent around 70 mrem/yr. The terrestrial component of background penetrating radiation comes mostly from the natural radioactive decay chains of ^{232}Th and ^{238}U and from the decay of ^{40}K. In addition, 5 to 15 percent of the total is due to fallout from atmospheric weapons testing. The magnitude of the terrestrial component is subject to temporal variation because of such factors as rainfall and snow cover. Rainfall decreases the dose from ^{40}K because of the increased shielding from the moisture in the soil. It increases the dose from the ^{238}U decay series by decreasing the migration rate of radon gas to the surface and thereby enhancing the accumulation of radon daughters in the soil. Snow cover acts as shielding to reduce the dose from all components. Temporal variations in the terrestrial background dose are probably in the range of 15%-25%. The magnitude of the terrestrial component is also subject to spatial variation. Topography and geology vary with location and so does the dependent radiation background. Based on 1966 aerial surveys, the terrestrial component in the Los Alamos area is about 65 mrem/yr.[3-63] Summing the cosmic and terrestrial components, the average expected total yearly dose is about 135 mrem/year, and the average total yearly doses as measured at perimeter stations and reported by LASL for the years 1974, 1975, and 1976 are as follows: 137 mrem/yr, 134 mrem/yr and 118 mrem/yr.[3-64, 3-65, 3-66]

World-wide background atmospheric radioactivity is composed of fallout from atmospheric weapons tests, natural radioactive constituents from the decay chains of ^{232}Th and ^{238}U, ^{40}K, and tritiated water vapor. Since the aerosol being sampled is mostly due to resuspension from the soil, there can be large temporal fluctuations in mass sampled. These fluctuations depend primarily on meteorological conditions. Periods of high winds contrast with periods of heavy rain or snowfall, since the precipitation naturally removes much of the suspended mass. Also, periods of high humidity yield more tritiated water vapor per volume of air than do periods of low humidity. Spatial considerations are also important in determining background atmospheric radioactivity. Samplers in abnormally dusty or humid locations show more radioactivity per volume of air because of the greater mass sampled.

LASL uses data from three air sampling stations that are remote from the Laboratory boundaries as an indication of the regional background for atmospheric radioactivity. These stations at Española, Pojoaque, and Santa Fe, New Mexico, are so distant (see Figure 3.1.5-1) from LASL that the effects of LASL operations are negligible. Table 3.1.5-4[3-26, 3-64, 3-65, 3-67] shows a comparison between data averaged from these three stations and data published for Santa Fe by the Environmental Protection Agency.

Besides the naturally occurring radionuclides from the uranium and thorium decay chains and ^{40}K, the only other major sources of radioactivity in soils are from tritiated water and fallout radionuclides from atmospheric nuclear tests. The nuclides from fallout of primary interest are ^{238}Pu, ^{239}Pu, and ^{90}Sr. The activity ratio between ^{239}Pu and ^{90}Sr can be used to distinguish whether the fallout is from atmospheric tests or from stack emissions. A study has been made of the activity ratio for soils in the Los Alamos, Española, and Santa Fe areas. This study shows that the plutonium and strontium are from fallout and that their levels in the soil are similar to, but no greater than, those reported for soil in Colorado, Ohio, and New York, where similar studies have been done.[3-68]

TABLE 3.1.5-4

REGIONAL AVERAGE BACKGROUND ATMOSPHERIC RADIOACTIVITY CONCENTRATION

Radioactivity Constituent	Activity (all units 10^{-15} μCi/mℓ)			
	EPA[a]		LASL[b]	CG[c]
Gross α	not reported		1.2 ± 0.1	
Gross β	83		93 ± 5	3×10^4
^{241}Am	not reported		0.004 ± 0.004	2×10^2
^{238}Pu	0.0018	0.0018	0.0024 ± 0.0013	70
^{239}Pu	0.0199	0.0100	0.016 ± 0.002	60
Tritium	not reported		9800 ± 2000	2×10^8
Uranium	0.0408	0.0300	0.065 ± 0.012	7×10^4

a) U.S. Environmental Protection Agency data.[3-67]

b) Averages for 1973-1975.[3-26, 3-64, 3-65] See Appendix H (page H-16) for 1978 summary.

c) Concentration Guide for uncontrolled areas, Gross-alpha compared to CG for ^{239}Pu, Gross-beta compared to CG for ^{90}Sr.

LASL maintains a surveillance program for radioactivity in soils and sediments for regional sites and sites around the LASL perimeter. Data for 1976 from this program are summarized in Table 3.1.5-5, and the locations of the regional sites are shown in Figure 3.1.5-1.[3-64] The values for tritium (^3H) in the table are from soil moisture distilled from the samples and analyzed for tritium content. The values for the isotopes and activity levels from the regional and perimeter samples are assumed to be background values because of their distance from LASL. There were no statistically significant differences in the measurements for different locations.

Regional surface water samples are also collected at the sampling locations shown in Fig 3.1.5-1, and analyzed for radioactivity in order to provide an indication of the normal contribution from natural sources and worldwide fallout. The data from 1976 samples are summarized in Table 3.1.5-6. There were no statistically significant differences in the measurements.

3.2 SOCIOECONOMIC ENVIRONMENT

The socioeconomic environment is described by defining the land use, economic, demographic, institutional, transportation, archaeological, historic, and cultural factors that make up the whole. Generally, these aspects are discussed in terms of the Laboratory, Los Alamos County, and the northern New Mexico region. For the purposes of this discussion, the northern New Mexico region includes the six counties surrounding Los Alamos County: Rio Arriba, Santa Fe, Taos, Bernalillo, Sandoval, and Mora (see Figure 3.2-1). This generally encompasses the area within a 80 km (50 mi) radius of Los Alamos.

3.2.1. Land Use

The Los Alamos Scientific Laboratory was established on the site of the Los Alamos Ranch School for Boys on the Pajarito Plateau, 56 km (35 mi) by road northwest of Santa Fe, New Mexico. On November 25, 1942, the Undersecretary of War directed acquisition of the site, including a group of some 50 log buildings on 3.2 km^2 (790 acres) of Ranch School property, 11.7 km^2 (2900 acres) of homestead and grazing lands, and 185 km^2 (45,666 acres) of Forest Service public domain lands. Additional lands were acquired in 1947 and 1948 by the Atomic Energy Commission, the successor to the Manhattan Engineer District, totaling 79.8 km^2 (19,725 acres). In 1963, 15.9 km^3 (3,925 acres) of land comprising a portion of the Otowi Section were placed under administrative control of the Atomic Energy Commission by Presidential Proclamation.

The original Laboratory activities were established in the Ranch School buildings on a site where the present Los Alamos Community Center is located. When it became necessary to expand, wooden laboratory buildings were quickly built on the north rim of Los Alamos Canyon (the site of present-day Los Alamos Inn) adjacent to the original Ranch School buildings. Army-style barracks and many types of tarpapered dormitories, prefabs, hutments, and trailers provided most of the housing.

Although administered by the University of California, Los Alamos functioned as an Army post under the control of the US War Department for the first four years. In 1947, the newly created US Atomic Energy Commission (AEC) assumed control of the Laboratory from the Army, and the operating contract with University of California was renewed. Major expansion occurred in 1951-1953 with the construction

TABLE 3.1.5-5

RADIOACTIVITY IN SOILS AND SEDIMENTS

Regional and Perimeter Locations in 1976[a]

Number of Samples Analyzed	Type of Activity	Units	Min.	Max.	Ave.
			Soils		
9	^{3}H	$10^{-6}\mu Ci/m\ell$	1.4(±0.6)	6.4(±0.8)	3.3(±0.6)
9	^{90}Sr	pCi/g	0.90(±2.00)	13.9(±6.40)	4.6(±2.70)
6	^{137}Cs	pCi/g	0.11(±2.03)	1.75(±0.12)	0.62(±0.06)
20	^{238}Pu	pCi/g	0.000(±0.001)	0.004(±0.003)	0.000(±0.002)
20	^{239}Pu	pCi/g	0.002(±0.002)	0.033(±0.008)	0.015(±0.004)
20	Gross-alpha	pCi/g	1.5(±1.6)	18(±8.0)	5,2(±2.6)
20	Gross-beta	pCi/g	3.3(±1.0)	11.6(±2.4)	5.7(±1.3)
9	Total-U	μg/g	1.1(±0.6)	3.9(±0.8)	1.9(±0.8)
			Sediments		
9	^{3}H	$10^{-6}\mu Ci/m\ell$	0.2(±0.6)	4.1(±0.8)	14(±0.7)
8	^{90}Sr	pCi/g	0.09(±0.18)	5.90(±0.60)	2.04(±2.30)
10	^{137}Cs	pCi/g	0.06(±0.02)	0.23(±0.04)	0.15(±0.04)
21	^{238}Pu	pCi/g	0.005(±0.007)	0.003(±0.002)	0.001(±0.001)
21	^{239}Pu	pCi/g	0.000(±0.000)	2,06(±1.00)	0.122(±0.008)
21	Gross-α	pCi/g	0.5(±0.8)	10(±4.0)	3.2(±1.6)
21	Gross-β	pCi/g	1.1(±0.6)	6.1(±1.4)	2.9(±0.8)
10	Total-U	μg/g	0.3(±0.6	2.7(±1.0)	1.3(±0.8)

[a] See Appendix H (pages H-20 and H-21) for 1978 summary data.

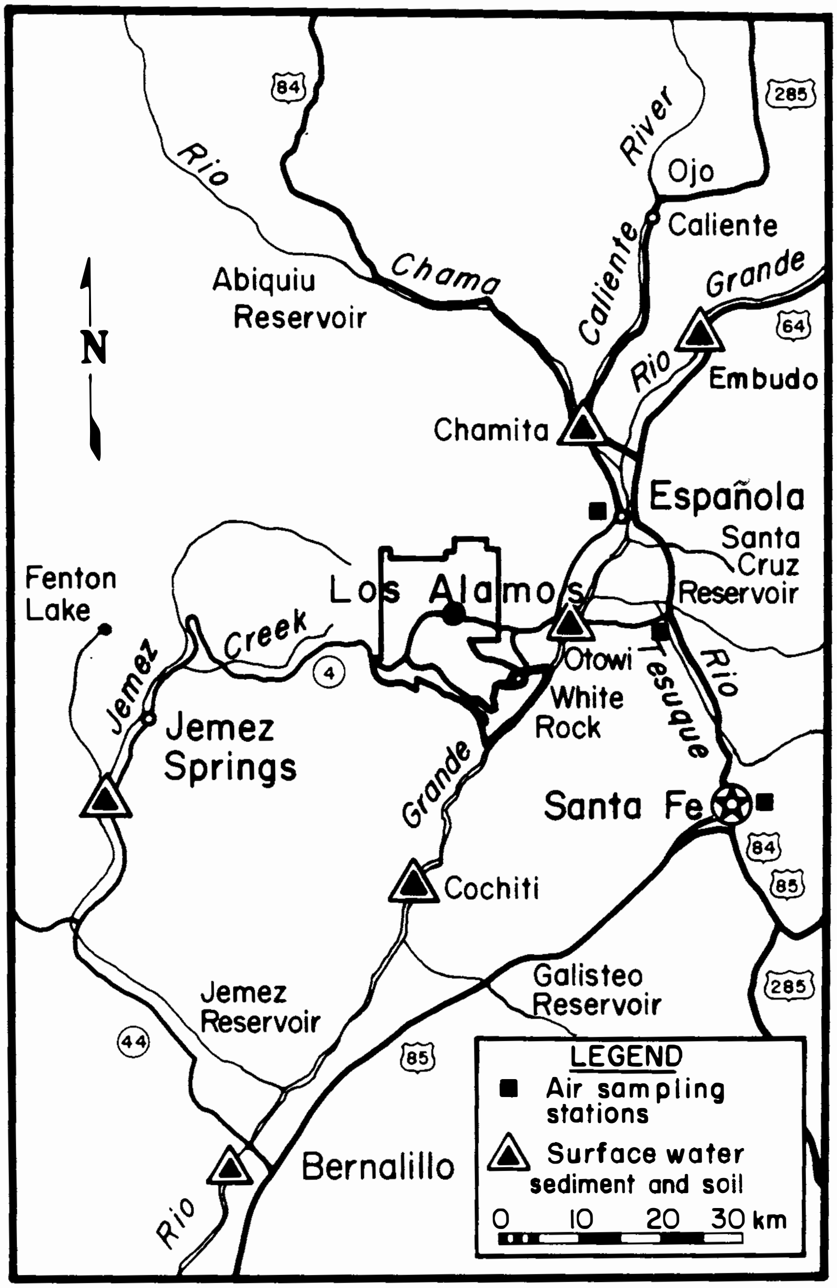


Figure 3.1.5-1. Regional Sampling Stations

TABLE 3.1.5-6

RADIOACTIVITY IN REGIONAL SURFACE WATERS IN 1976[c,d]

Number of Samples Analyzed	Type Activity	Units	Min.	Max.	Ave.[a]	Ave. as %CG[b]
12	^{3}H	$10^{-6}\mu Ci/m\ell$	0.7(±0.6)	2.8(±0.8)	1.6(±0.7)	<0.1
9	^{90}Sr	$10^{-9}\mu Ci/m\ell$	-1.8(±3.0)	16(±5.2)	3.9(±4.0)	1.3
6	^{137}Cs	$10^{-9}\mu Ci/m\ell$	-1(±28)	12(±32)	6(±10)	<0.1
18	^{238}Pu	$10^{-12}\mu Ci/m\ell$	-18(±24)	5(±20)	-8.2(±15.0)	<0.1
17	^{239}Pu	$10^{-12}\mu Ci/m\ell$	-13(±16)	30(±40)	-1.6(±11)	<0.1
18	Gross-α	$10^{-9}\mu Ci/m\ell$	-1(±6)	9(±6)	2.9(±3.6)	<0.1
18	Gross-β	$10^{-9}\mu Ci/m\ell$	3.0(±1.4)	28(±6)	9.2(±2.6)	3.1
18	Total U	$\mu g/\ell$	-0.1(±4.0)	6.1(±1.2)	1.9(±2.2)	<0.1

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

b) Concentration Guides for Uncontrolled Areas; gross-alpha compared to CG for ^{239}Pu, gross-beta compared to CG for ^{90}Sr.

c) Values in table indicate minimums, maximums, and averages for the samples from the locations on Figure 3.1.5-1.

d) See Appendix H (pages H-16 thru H-21) for 1978 summary data.

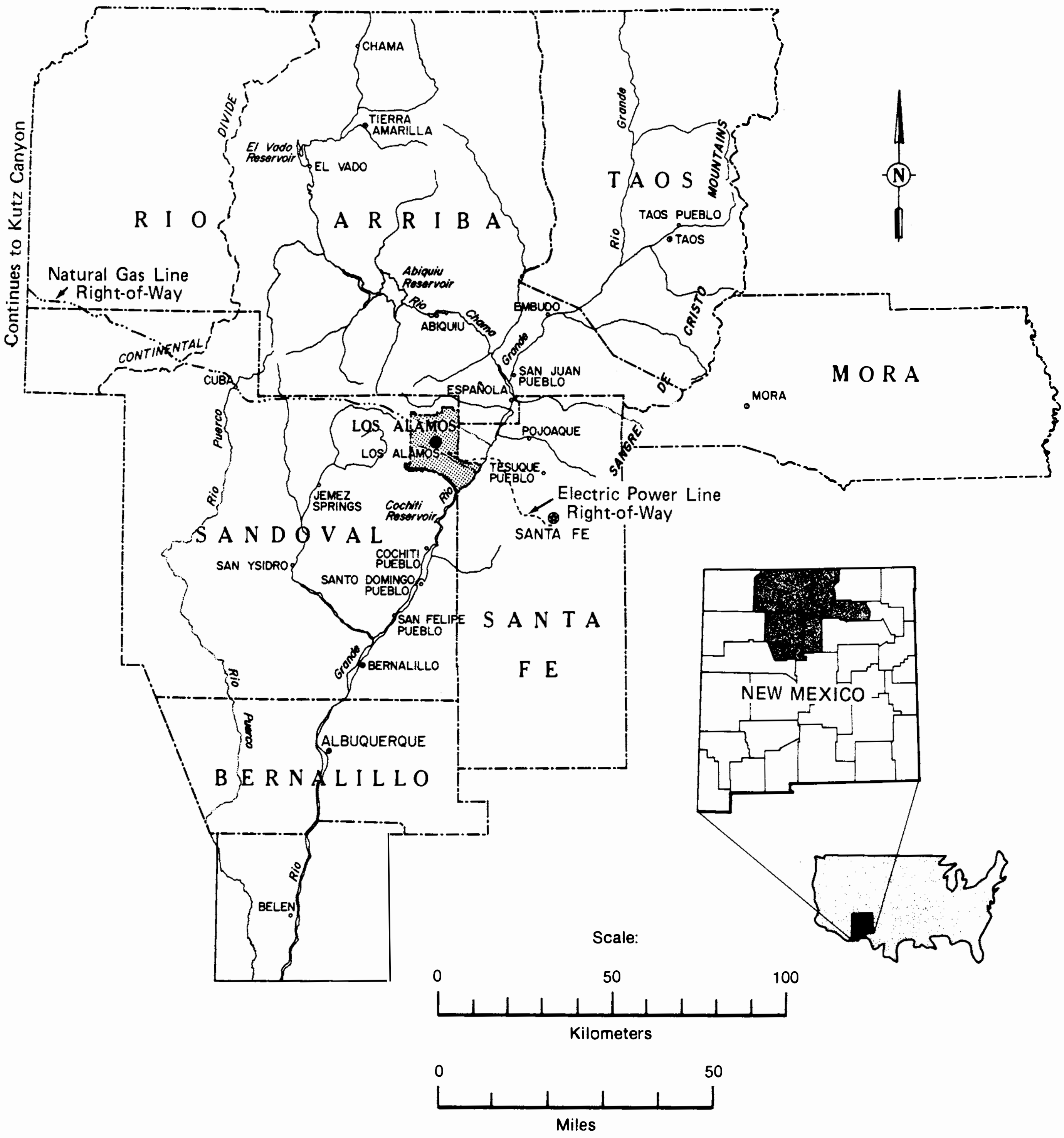


Figure 3.2-1. Northern New Mexico Region

of 14 technical areas. New sites were selected for the main Laboratory buildings on South Mesa across Los Alamos Canyon from the original Laboratory site. At this time, World War II Laboratory structures were demolished and the area where they were located became part of the townsite (see Figure 3.2.1-1).[3-14] Today there is a total of 30 active technical areas. In 1975 ERDA was established, and responsibility for LASL was transferred from the AEC to ERDA, and subsequently to DOE in 1977.

Disposition of AEC controlled lands began in 1958 when Federally owned land was sold to permit private residential development, and federally owned residences were first offered for sale to private individuals in 1965. Through the Community Disposal Act, land totaling approximately 30.4 Km^2 (7,500 acres) was transferred in the present Los Alamos and White Rock Communities from AEC ownership. At present, almost all community facilities have been turned over to County operation.[3-69] In 1959 approximately 14.6 km^2 (3,600 acres) were transferred to the Park Service by Presidential Proclamation extending the northern boundary of Bandelier National Monument (see Figure 3.2.1-2).[3-14] An additional 11.6 km^2 (2882 acres) extending the northwest boundary of Bandelier National Monument was transferred to the Park Service in 1963. In 1969, 110.8 km^2 (27,370 acres) of land forming the western and northern perimeters of Los Alamos County were transferred to the Forest Service in 1969. In 1973, the AEC excessed to GSA 14.0 km^2 (3,464 acres) of land in the Western and Northern Perimeter Tracts adjoining the Western and Northern Community and Barranca Mesa areas. In 1976 GSA transferred 9.1 km^2 (2,254 acres) to the Forest Service. Another tract in Los Alamos Townsite, comprising approximately 0.02 km^2 (4 acres) was transferred to the GSA in 1976 for eventual disposal to another government agency or the private sector.

Many easements are held by the Federal Government in Los Alamos County and Northern New Mexico for utility rights-of-way. They are basically no different from those associated with any community utility system, except they stem from the historic fact of the facilities having been originally constructed for the Federal Government in the early days of Los Alamos. Hundreds of easements exist in Los Alamos County for the water supply and distribution systems, natural gas distribution, electric power distribution, steam distribution, and other facilities. Outside Los Alamos County, easements are held by the Federal Government for rights-of-way for the water supply system, an electric power transmission line, and a natural gas transmission pipeline. The general nature of these facilities and their rights-of-way are described in the following paragraphs; their locations are indicated in Figures 3.2-1 and 3.3.1-1.

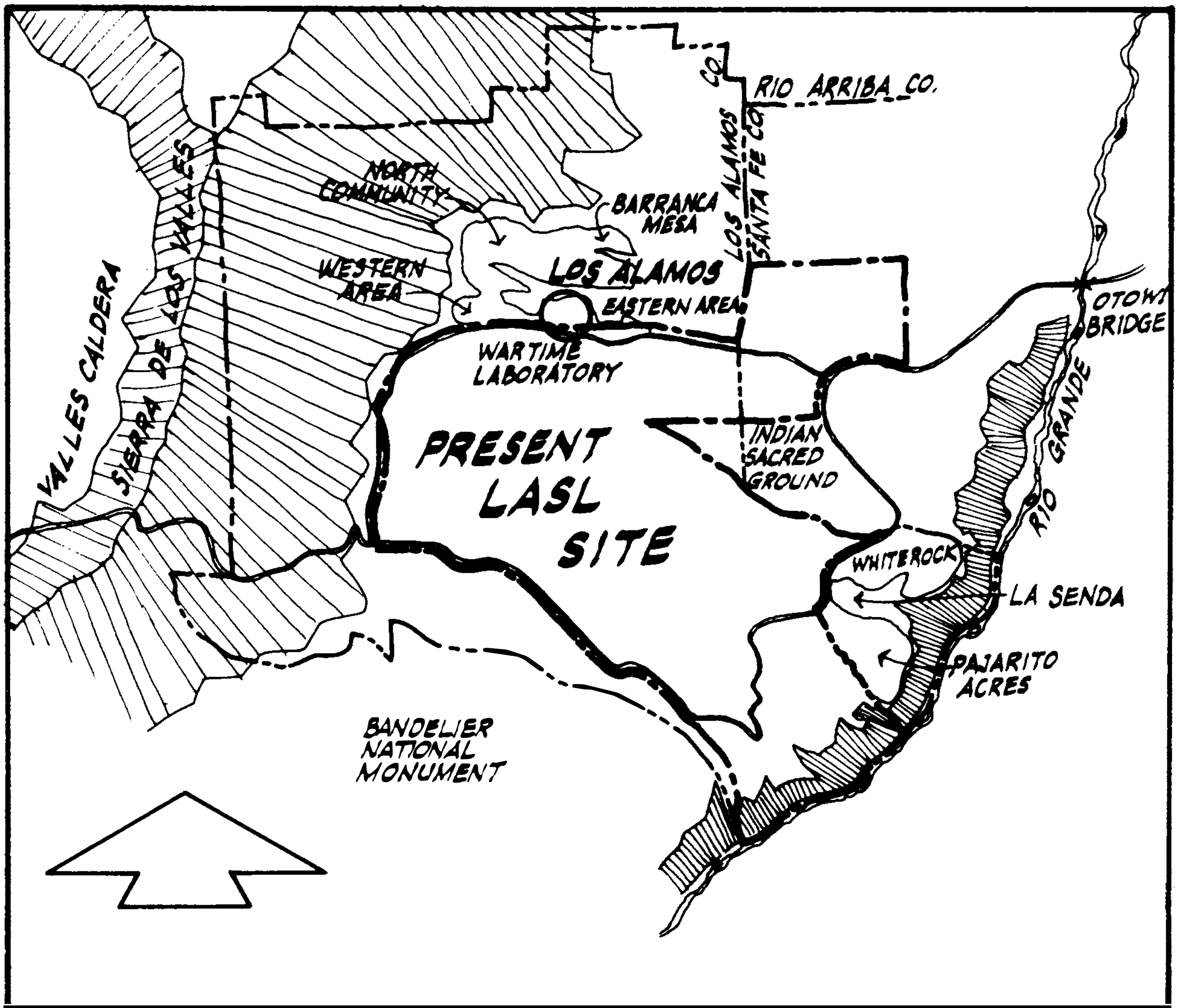


Figure 3.2.1-1. LASL Local Context Map

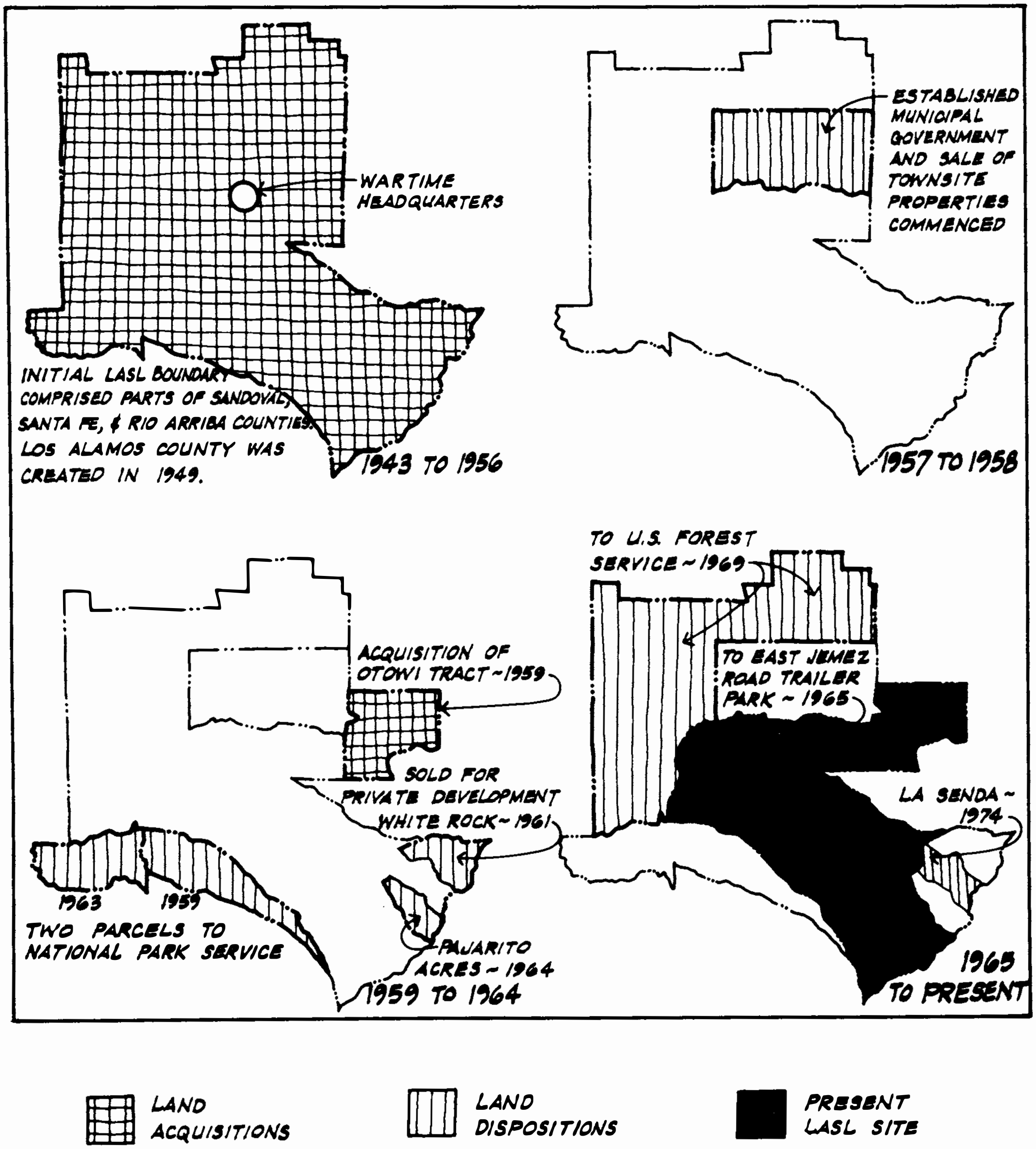


Figure 3.2.1-2. Sequence of LASL Development

Part of the water supply system is located on non-DOE lands in Santa Fe County (see Sec. 3.3.1 and Fig. 3.3.1-1). Most of the Los Alamos Well Field was completed in 1947-48 for the AEC consisting of wells, booster pump stations, underground water lines, overhead power lines, storage tanks, and other minor ancillary facilities. Access to the facilities is from State Road 4. Routine maintenance is performed on all facilities by the Zia Company under contract to DOE. Rights-of-way for the facilities are on easements from San Ildefonso Pueblo totalling about 0.7 km^2 (180 acres) and from the New Mexico State Highway Department along State Road 4. The easements are generally 100 m (300 feet) wide along the line with some wider sections at structure locations. The basic 50-year easement was established in 1952. The Guaje Well Field consists of the same types of facilities and was largely completed in 1951. It is located on easements from the Department of Agriculture, U.S. Forest Service, in Guaje and Rendija Canyons.

Two electric utility lines serve Los Alamos County including LASL and the community areas. One known as the Reeves Line extending toward Albuquerque is wholly owned and operated by Public Service Company of New Mexico (PNM). The other, known as the Zia Line, is owned by DOE but operated and maintained by PNM under contract. The Zia Line is a 115 kv overhead line on wood H-frame supports extending about 35 km (22 mi) from Los Alamos to a PNM substation south of Santa Fe, with a bladed access road between the supports. Most of the line is located on relatively sparsely vegetated pinon-juniper and grass rangeland. Normal maintenance is minimal, principally repair of damaged insulators and conductors. The line was built in approximately 1955-59 for the AEC and is located on a right-of-way that is mostly 30 m (100 ft) wide.

The right-of-way is located on easements from the U.S. Department of the Interior; Bureau of Land Management and United Pueblos Agency for San Ildefonso Pueblo; U.S. Department of Agriculture; U.S. Forest Service; the State of New Mexico; and a number of private owners.

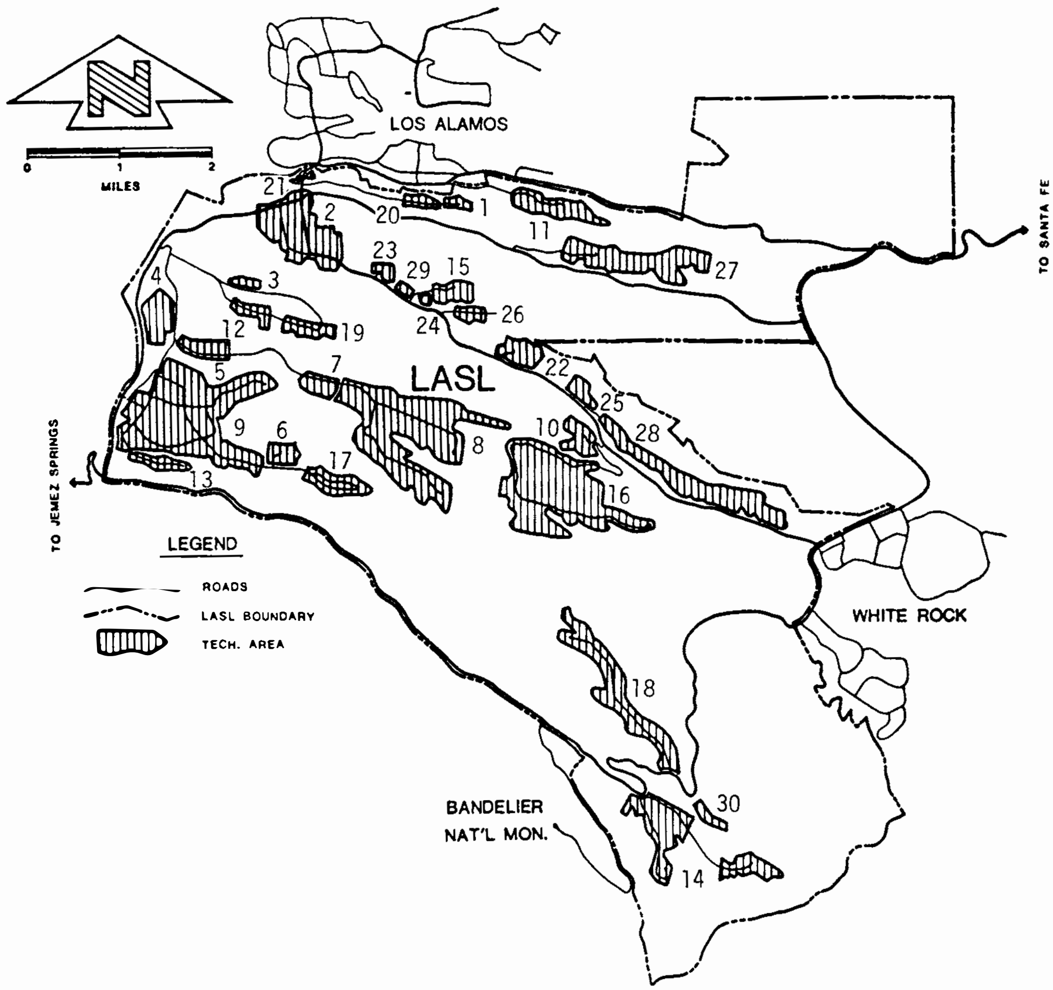
The natural gas line owned by DOE that serves LASL and Los Alamos County is now leased to and operated and maintained by the Gas Company of New Mexico. The 25-30 cm (10-12 in) high pressure underground gas line about 210 km (130 mi) west and north from Los Alamos County to the Kutz Canyon Compressor station near Bloomfield, NM. Most of the line was constructed in 1946-50 by the Corps of Engineers for the AEC. A segment of about 19 km (12 mi) was acquired by exchange from Southern Union Gas Company (now Gas Company of NM) in 1950. It has always been maintained and operated by the public utility company. The line crosses the Jemez Mountains from Los Alamos to Cuba, NM. Along this portion, access is assured by graded access roads along the route, some of which are maintained by Gas Company of NM and some of which have been taken over by the U.S. Forest Service as forest roads. These roads may be bladed once or twice a year to permit inspections and necessary maintenance. This access maintenance is the major environmental impact. Other maintenance includes occasional repair of leaks and replacement of small portions to assure safe operation. From Cuba the line extends on northwest, generally paralleling New Mexico State Road 44. From Nageezi on to Kutz Canyon (about 56 km or 35 mi) the line continues to parallel State Road 44 and is adjacent to two other Gas Company of NM lines that extend to Albuquerque. Along this 56 km stretch some realignment of the DOE and Gas Company of NM pipelines is underway because of reconstruction and improvement of State Road 44.

The rights-of-way for this 56 km portion are across lands owned or administered by the U.S. Department of the Interior, Bureau of Land Management; the Bureau of Indian Affairs for Navajo Tribal and Indian Allotment Lands; the New Mexico State Highway Department; and a number of private owners. Because of the realignments and problems with old records, easements along this stretch are currently being acquired or renegotiated. Rights-of-way easements for the 152 km (95 mi) of line from Nageezi to Los Alamos are held by DOE on Indian Allotment Lands, U.S. Forest Service lands, New Meixco State Highway Department lands, and a number of privately owned lands.

The easements are generally about 15 m (50 ft) wide. Much of the gas transmitted through this line is carried on to Santa Fe and other Northern New Mexico communities in a Gas Company of NM line.

The Federal Government presently controls 111 km^2 (27,500 acres) of land for use by LASL. The tangible dispostion of LASL land includes building sites, test areas, waste disposal locations, roads, and utility rights-of-way. However, these account for only a small fraction of the total land area; most land is used in a less tangible way to provide isolation for security and safety and as reserves for future structure locations. A comprehensive Master Plan program for the Laboratory lands has been initiated to assure adequate planning for the best possible use of available land in the future.[3-14]

The 124 major structures located in the 30 technical areas provide about 280,000 m^2 (3 X 10^6 ft^2) of usable space (see Figure 3.2.1-3). Nearly 80% of this building space is within five of the technical areas--South Mesa, DP-Site (plutonium and materials research), Los Alamos Meson Physics Facility, Ten-Site (laser and other research), and S-Site (weapons research). South Mesa is the main technical area of the Laboratory, with 36 buildings containing more than half of the usable space. Almost 60% of the Laboratory employees work in this area, representing most of the administrative and many of the research divisions. A recent addition in this area is the new National Security and Resources Study Center. The DP-Site activities have largely moved to the new plutonium facility site, but final disposition of the buildings at DP-Site has not been determined.



1	Omega Site	16	Kappa Site
2	Main Technical Area (South Mesa)	17	Magazine Area C
3	Two-Mile Mesa	18	Ancho Canyon
4	Ancho West	19	DF-Site
5	Ancho East	20	W-Site
6	K-Site	21	Health Research Laboratory
7	Q-Site	22	WA-Site
8	R-Site	23	Radiochemistry
9	S-Site	24	Liquid Waste Disposal Site
10	Pajarito Site	25	Radiation Exposure Facility
11	DP-Site, east & west	26	Reactor Development Site
12	TD-Site	27	Meson Physics Facility
13	Magazine Area A	28	Mesita del Buey Area
14	HP-Site	29	New Plutonium Processing Facility
15	Ten-Site Laboratory	30	Subterrene Basalt

Figure 3.2.1-3. LASL Technical Areas

All of the permanent Laboratory technical areas are located within the LASL boundaries (see Figure 3.2.1-3). Some temporary office space is provided off site by leasing commercial buildings in White Rock and an elementary school building in Los Alamos not needed by the school system because of declining enrollment. The Zia Company general administrative offices, warehousing and heavy equipment facilities are inside the Laboratory Reservation, in the Main Technical Area. The boundaries of the technical areas are defined by roads, by natural barriers such as canyon rims, and, in some cases, by security fencing which is at a considerable distance from the buildings. Thus, the indicated technical area outlines as shown on the map do not necessarily define developed areas--much undisturbed terrain is included.

Development occurs in numerous scattered areas, location and spacing generally reflecting a functional division of Laboratory activities and responses to specific siting needs such as security, safety, or topographic constraints. It is the policy, where possible, to locate new development adjacent to existing technical areas to minimize environmental impact and to take advantage of existing utilities and roads. Most development has taken place on mesa tops with slopes of less than 10%; intensive development has been restricted to 5% slopes where the need for excavation and fill operations can be minimized. Some structures require deep basements; for instance, the LAMPF required a significant excavation for the underground accelerator tunnel providing structural integrity as well as natural shielding for safety. However, for the most part natural topography has been respected.[3-14]

Limited access by the public is allowed in certain areas of the LASL reservation. The area north of Ancho Canyon between the Rio Grande and State Road 4 is open to hikers, rafters, and hunters, but woodcutting and vehicles are prohibited. The Otowi Tract northwest of State Road 4 is open to public access subject to the restrictions of the Antiquities Act. Two other roads across the Laboratory reservation are normally open to the public. These Federally-owned roads are Pajarito and East Jemez.

Within Los Alamos County itself, a total of 248 km^2 (61,320 acres) are under federal control, including the LASL reservation, Forest Service, National Park Service, and US Postal Service lands. The percentage of Federally owned land in Los Alamos County has decreased from 100% in 1946, to 93% in 1967, and 89% in 1975. Remaining lands are owned by Los Alamos County Government, Los Alamos County Schools, and private citizens (see Figure 3.2.1-4).[3-14, 3-70, 3-71]

Land use and ownership in Los Alamos County is summarized in Table 3.2.1-1.[3-70, 3-71, 3-72] The land use data cover land under the County Government's dominion and use and excludes most, but not all, Federally-owned land. Vacant and open-space land dominates all categories of land use within the county, accounting for 56% of the area under county government control. Of this vacant and open space land, the portion that can be developed for urban purposes amounts to 14% of the land within the County. The remaining area, 42% of the total, is useful only for recreational purposes, because of terrain limitations. The large proportion of open space results in a visual impact of uncrowdedness and low density that is highly valued by community residents.[3-73]

The remaining 44% of the land under county government control is the urbanized area. Residential areas are the predominant land use, accounting for 45% of the total urbanized area. This is somewhat higher than the national average of 39%. As shown in Table 3.2.1-2,[3-74] the majority, 58%, of the housing is provided by single-family detached homes. The single family detached home occupies an even higher percentage (87%) of the residential land area. The remaining 42% of the housing units are on 13% of the developed residential area. According to the 1970 national census, the rural population is

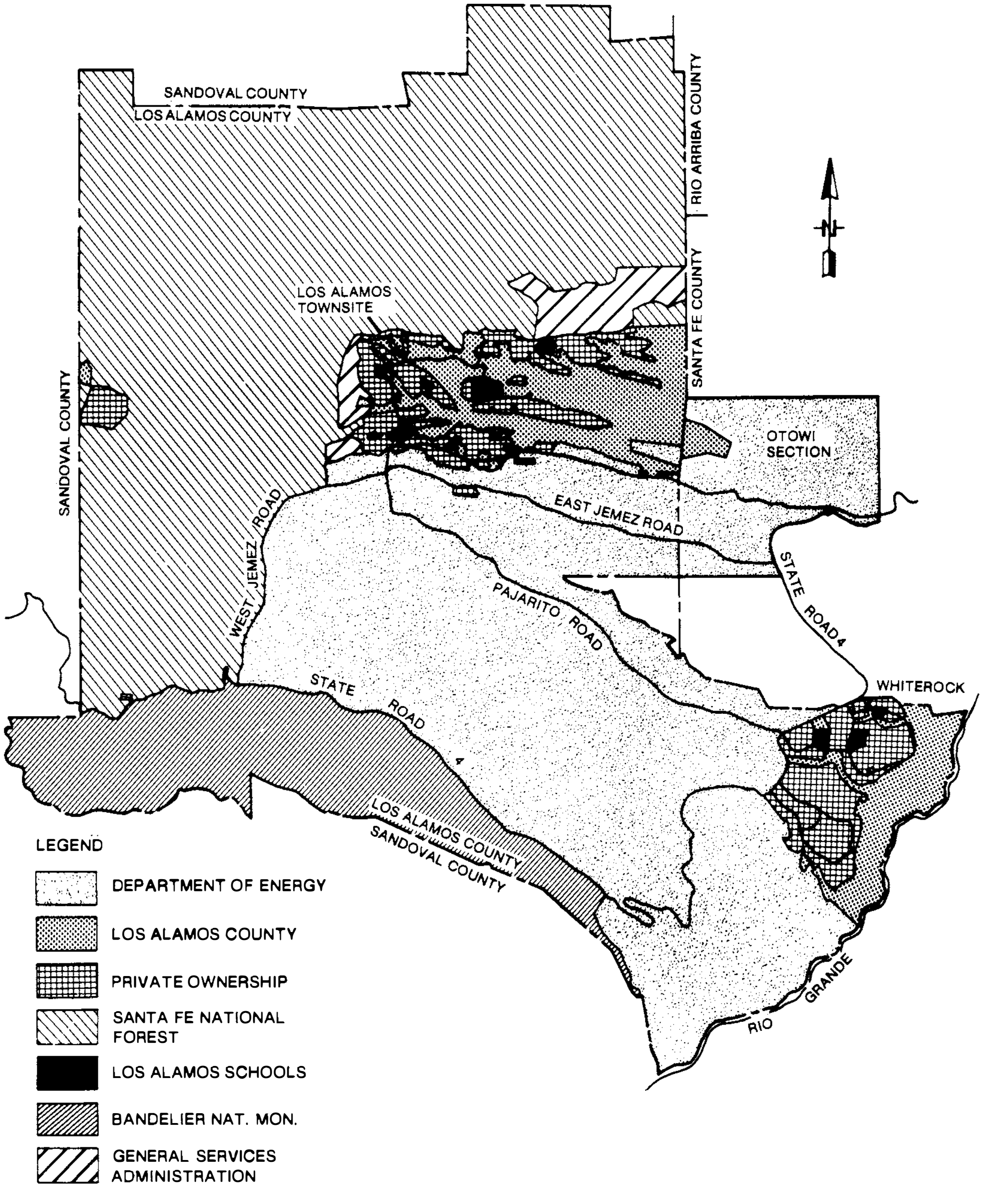


Figure 3.2.1-4. Land Ownership in Los Alamos Vicinity

TABLE 3.2.1-1

SUMMARY OF LAND OWNERSHIP AND USE IN LOS ALAMOS COUNTY[a]

Land Ownership

	Federal Lands				Private and Miscellaneous[c]	Total Area
	LASL	Forest Service	Misc.[b]	Total Federal		
Area km^2	111	111	26	248	32	280
Percent of Total	40	40	9	89	11	100

Land Use

Land Use Category	Area (km^2)	Percent of Total Urbanized Area	National Average Percent of Total
Residential	7.0	45	39
Commercial	0.3	2	5
Industrial[d]	0.5	3	11
Government, General Welfare, and Commumity Services	5.1	33	19
Streets and Rights of Way	2.7	17	26
Developable Vacant Open Space and Undevelopable Vacant Land	14.8	--	--
Total[e]	35.2		

a) Data as of July, 1975.
b) Includes National Park Service, U.S. Postal Service, etc.
c) Includes Los Alamos County Government, Los Alamos Schools, and private owners.
d) Industrial category includes transportation, communication, and utilities.
e) Data covers land under Los Alamos Government dominion and excludes most, but not all, Federally-owned land.

TABLE 3.2.1-2

RESIDENTIAL LAND USE IN 1974 IN LOS ALAMOS

	Number of Units	Percent of Total Units	km^2	Percent of Total Residential Land
Single-family detached housing	3240	58%	6.1	87%
Multiple family units	2150	39%	0.80	12%
Mobile home units	165	3%	0.1	1%
Total	5555	100%	7	100%

nominal with 27 people living on five farms with an average size of 0.02 km^2 (4.8 acres).[3-75] These are actually a few large lots in Pajarito Acres Subdivision. The proportion of commercial and industrial land use in the unchanged area is much lower than the national average (see Table 3.2.1-1) because the major employment sector, LASL, is not included in urbanized land area.

Industrial growth has not occurred for many reasons: the limited amount of suitable land available, the limited water supply, the small labor force, the remoteness from most markets, poor transportation connections, and the scarcity of raw materials. The exception is research and development firms that reinforce the Laboratory effort.

Commercial land use at present includes the Community Center Complex of retail, professional, and administrative services, with about 41,040 m^2 (441,600 ft^2) of floor space. Other commercial areas in the townsite and White Rock provide an additional 20,070 m^2 (215,900 ft^2) of floor space, for a total of 61,110 m^2 (657,500 sq ft) of commercial floor space in the county.[3-71]

The government, general welfare, and community services categories amount to 33% of the urbanized land, which is a considerably higher proportion than the national average of 20%. In contrast, the proportion of land used for streets and rights-of-way is much less than the national average.

Los Alamos County is bounded by private lands on the west, Indian lands on the north and part of the east, the Bandelier National Monument along the south, and Forest Service lands along the southwest, southeast, and part of the east. Along the eastern boundary is a small area that is discontiguous from, but a part of, the Bandelier National Monument. In the V-shaped area protruding into the eastern side of the LASL site is a tract of sacred ground belonging to an Indian pueblo (see Figure 3.2.1-4). Los Alamos County also owns a small piece of land in Santa Fe County; this is the site of the Bayo Canyon sewage treatment plant.

Control of land in the vicinity of Los Alamos is dominated by state and Federal government and Indian reservations. The region of interest is that within an approximate 80 km (50 mi) circle around Los Alamos largely contained within the portion of the Rio Grande drainage basin in the counties of Los Alamos, Rio Arriba, Taos, Sandoval, Santa Fe, and Bernalillo.[3-14] The area is truncated on the east by the drainage divide of the Sangre de Cristo Mountains and extended further south along the irrigable lands of the Rio Grande. Land ownership in the surrounding counties of Rio Arriba, Sandoval, Santa Fe, Bernalillo, Mora, and Taos is summarized in Table 3.2.1-3.[3-70, 3-76]

Surrounding Los Alamos County, three Federal agencies control a significant portion of land use: the Bureau of Indian Affairs, the Forest Service and the Bureau of Land Management.[3-72] The Bureau of Indian Affairs office in Santa Fe is responsible for the Jicarilla Apache Reservation and the Eight Northern Pueblos: Cochiti, San Juan, San Ildefonso, Picuris, Santa Clara, Santo Domingo, and Pojoaque. Although the Bureau of Indian Affairs provides technical assistance, final responsibility for land use policy and decision-making rests with each tribal council. Land use policies developed by the state or local units of government have no legal authority to regulate land use by Indians on reservation lands. The increasing pressure from population growth for development of tribal lands, particularly east of Los Alamos near Santa Fe and Espanola, will have a major effect on growth patterns in the region.

The Forest Service manages two National Forests in northern New Mexico. The Sante Fe National Forest includes the Pecos River Forest Reserve, the Pecos Wilderness, the Jemez Forest Reserve east of the Rio Grande, and the San Pedro Parks Wilderness. The Carson National Forest includes the Taos

TABLE 3.2.1-3

SUMMARY OF LAND OWNERSHIP AND USE IN THE LOS ALAMOS REGION IN 1975

Land Ownership

	FEDERAL										INDIAN LANDS		STATE		PRIVATE		Total Area
	Forest Service		Bur. of Land Management		Defense[a]		Misc. Fed.[b]		Total Fed.								
County	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2
Los Alamos	111	40	0	0	111	40	26	9	248	89	0	0	0	0	32	11	280
Rio Arriba	5,613	37	2,247	15	1	0	43	0	7,904	52	2,618	17	439	3	4,275	28	15,236
Santa Fe	1,014	21	338	7	3	0	5	0	1,360	28	322	6	348	7	2,914	59	4,944
Sandoval	1,502	16	2,381	25	0	0	112	1	3,995	42	2,632	3	325	3	2,675	28	9,627
Taos	2,130	36	838	14	0	0	0	0	2,968	51	252	4	393	7	2,233	38	5,846
Bernalillo	311	10	70	2	221	7	24	1	626	21	901	0	130	4	1,371	45	3,028
Mora	402	8	31	1	0	0	3	0	436	9	0	0	330	6	4,269	85	5,035
Total	11,083	25	5,905	13	336	1	213	1	17,537	40	6,725	15	1,965	4	17,769	40	43,996

Land Use (km^2)

	Grazing Lands	Commercial Timber	Built-up[c]	Agriculture	Recreation	Miscellaneous[d]	Total
Los Alamoa	111	-0	32	0	26	111	280
Rio Arriba	10,486	4,215	175	207	86	67	15,236
Santa Fe	4,230	406	149	150	5	4	4,944
Sandoval	8,025	1,285	143	76	93	5	9,627
Taos	3,503	1,998	67	194	82	2	5,846
Bernalillo	2,132	225	381	69	--	221	3,028
Mora	4,116	748	50	103	12	6	5,035
Total	32,603	8,877	997	799	304	416	43,996

a) Defense includes lands under DOE control, eg LASL.

b) Miscellaneous Federal ownership includes the National Park Service, the U.S. Postal Service, etc.

c) Built-up includes urban areas, lands subdivided for residential and industrial uses, and roads.

d) Miscellaneous includes defense lands, and lakes and reservoirs with surface area of 0.16 km^2 or more.

Forest Reserve and the portion of the Jemez Forest Reserve west of the Rio Grande. These National Forests are managed under multiple use planning for lumbering, grazing, recreation, and mineral and power production with resulting revenues being redistributed to the counties. Los Alamos County residents are heavy recreational users of these areas.

The Bureau of Land Management manages all federal lands not under the jurisdiction of another federal agency; basically the land left over after the distribution of territorial land in New Mexico. This land is leased to private individuals for specific uses such as grazing, lumbering, mining, and agriculture. Occasionally these lands are traded or sold.

Other Federal land owners include the National Park Service and the Bureau of Sport Fisheries and Wildlife. The National Park Service land is mainly Bandelier National Monument, part of which was declared a wilderness area in 1976. Bandelier has also been authorized to expand southward, so this land use category will increase.[3-77]

The State Land Office manages state trust lands. These lands are not public domain but are held in trust for the actual users, various institutions. They are managed to produce revenue by leasing for livestock, timber, agriculture, oil, gas, and other mineral production. The State Forest Service also manages lands in the region.

Most of the land is open range grassland, pinon-juniper, or forested. Most of the population outside the cities of Albuquerque, Los Alamos, and Santa Fe is distributed in the small towns and villages along the Rio Grande and its tributaries.

Land use in the Los Alamos region is shown in Table 3.2.1-3.[3-70, 3-76] Grazing is the largest single category, although the column covers all noncommercial forest and woodlands. Not all grazing land is included, since practically all of the commercial timber areas are also used for grazing and some agricultural cropland is also used for grazing. The miscellaneous column also includes some grazing lands. Therefore the total land acreage used for grazing may be larger.[3-25, 3-72]

Commercial timber is the second largest category. This covers all land capable of producing saw timber that is not withdrawn from timber use and is economically available. These lands are generally also used for grazing and recreation. Another land use in the region, mineral production, is not shown in the table. Like grazing and timber harvesting, a large portion is done on land leased from federal or state agencies. Mineral production includes oil, gas, copper, iron, manganese, uranium, feldspar, sand, gravel, coal, caliche, and salt. See Section 3.2.2 for further discussion of mining in the region. Geothermal energy is a new land use being developed in the region.

The built-up category of land use implies a much larger percentage of urban areas in the region than is actually the case. That is because this category includes roads and their rights-of-way. In addition, lands that have been subdivided for residential and industrial uses are included, even though these areas have not actually been developed in some cases. Unfortunately data is not available that accurately depicts the predominantly rural character of the region.

Agriculture is restricted largely to the irrigable land adjacent to the Rio Grande and its tributaries. Within the area of interest, the principal crops are grown on about 344 km^2 (85,000 acres), which is about half of the potentially irrigable land. Even so, some 95% of the cropped land is considered economically restricted because of low productivity, limited water availability, and small farm size. Agriculture accounts for roughly 3% of economic production yet is responsible for 65% of the water depletions in the area. See Section 3.2.2 for further discussion of agricultural activities in the region.

The acreage for recreation includes state and national parks and lands administered by the Bureau of Sport Fisheries and Wildlife and the State Game and Fish Department. As mentioned earlier, the recreation category does not include all the recreational land use areas in the region since practically all of the commercial timber lands and a portion of the grazing lands are also used for recreational purposes. These lands are also important wildlife habitats. As will be discussed in the next section, land use is very closely related to the economy of the region.

3.2.2. Economy

The economy of the region is based mainly on Federal and state government operations, a large tourist trade, and agriculture. In addition, there is some light industry, construction, mining, and arts and crafts (see Figure 3.2.2-1).[3-78]

Government is the most important economic force in the region, amounting to one-fifth to one-third of the total employment per county, except for Los Alamos where the government sector directly accounts for three-fourths of the employment. State government employment has been gradually increasing over the years. The City of Santa Fe is the state capitol and thus headquarters for almost all state government agencies. The City of Albuquerque in Bernalillo County is headquarters for most of the Federal agencies in New Mexico.

In addition to the direct contribution to the region's economy, the indirect impact of government activity is substantial. Construction activity is largely dependent on public projects. Major construction projects such as government buildings, highway programs, the Abiquiu and Cochiti dams, the San Juan-Chama Transmountain Diversion Project, and municipal water and sewer improvements are financed by public funds. The proportion of indirect government-induced employment cannot be accurately estimated.

Tourism is the second most important economic activity in the region. It has been characterized by steady growth and is especially crucial to the economies of Santa Fe, Taos, and Bernalillo Counties.[3-76] Correspondingly, the services and trade sectors rank closely after government in numbers of workers. Santa Fe, the oldest city in the United States, is a major national tourist attraction. It is surrounded by tourist attractions such as Indian pueblos, national monuments, historic Spanish villages, and skiing, hunting, fishing, and wilderness areas.

Agriculture was once the major economic activity in the region, but has been declining steadily since 1940. This decline is the result of many interrelated factors, such as inadequate processing facilities and marketing mechanisms, a reduction in commercial farms, and inefficient use of water. Small traditional farms are steadily being replaced with larger agricultural holdings, and the average value per acre has been increasing. Farming is practiced along the valley bottoms, principally the Rio Grande, but the scarcity of water limits its development in other areas. Almost two-thirds of the cropped acreage is for alfalfa, hay, and pasture; the rest is used for corn, small grain, chili, orchards, and truck and family gardening. Depending on market and weather conditions, wheat, potatoes, and grain corn vary as the leading crops after hay. Fruit growing has become a leading income producer in Rio Arriba County. Lettuce, onions, and potatoes are also important crops in Santa Fe County. A significant portion of the crops is marketed and consumed within the area through farmers' markets and roadside stands. On many small farms most of the agricultural produce is consumed by the family. Truck farms supply some produce to local markets. The bulk of the hay and grain crops is consumed by livestock within the area. A large portion of the farming is done by lower economic groups for subsistence or as a supplement to income.[3-72]

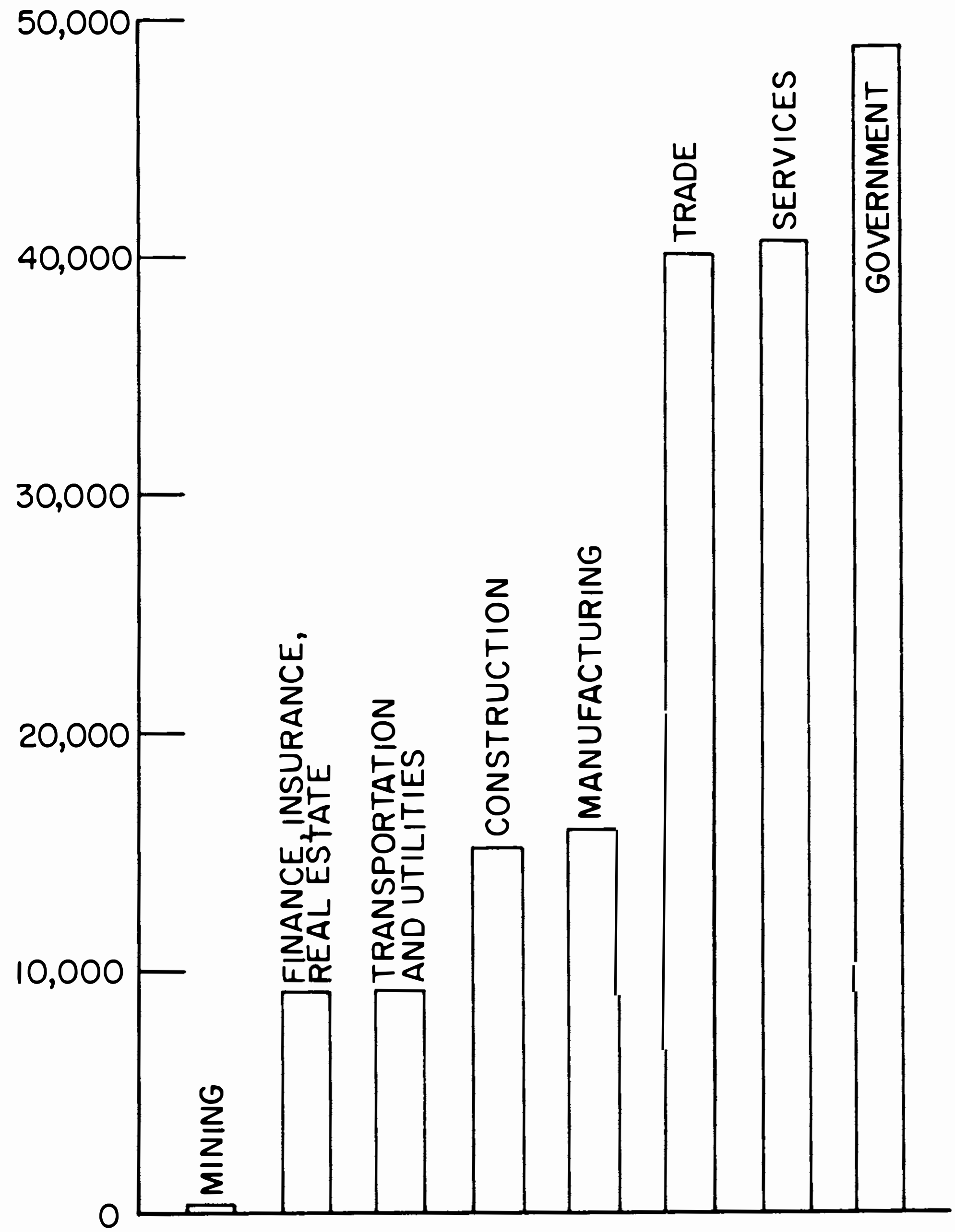


Figure 3.2.2-1. Distribution of Non-Agricultural Employment in Northern New Mexico Region in 1975.

Livestock operations in the area account for over 50% of the total value added by agricultural type activities to the economy of the area but contribute only 3-5% of the total economic production in the area. Livestock raising and production includes both small part-time and large-scale commercial enterprises. Cattle are the principal livestock with milk cows representing 3% of the total. Operations involve both the grazing and sale of steers and cow/calf operations. Agriculture activities for the operations are restricted to hay and grain crops, with little or no cash sales of produce. The bulk of cash sales involves the yearling steer operations, with a much smaller proportion derived from cow/calf operations. The primary difference between the large- and small-scale operations lies in the percentage of return on investments. The small-scale operations are generally of a subsistence or part-time nature and do not contribute substantially to the owner's cash income. The large-scale operations realize a minimal return on the owner's investment and some cash income.[3-23, 3-79] Cattle ranching is a major activity in the northern part of the state, but again the generally arid conditions limit ranges to a relatively low head-per-acre ratio. In addition, the decline in livestock grazing has been affected by the inadequate processing facilities locally, the decrease in available grazing land, and over-grazing. As with farming, the trend is to relatively large ranches. One agricultural activity, raising chickens, has been increasing in the region.[378]

Another traditional economic activity in the region, mining, has fluctuated depending on market demand. During the early seventies, mineral production and the products' prices have been increasing. The total value of mineral production for the region in 1972 was over $90 million. Sand, gravel, and stone are the most commonly exploited minerals in the region. Other industrial mineral resources include perlite, mica, pumice, gypsum, limestone, clay, beryllium, and feldspar. The prime metal ores are molybdenum in Taos County and copper and zinc in Santa Fe and Sandoval Counties. Rio Arriba and Sandoval Counties possess natural gas and petroleum resources. Other energy resources in the region are coal, peat, uranium, and geothermal. Since mining is a relatively labor-intensive industry, its multiplier effects have a broad economic impact for the region.[3-72, 3-76, 3-78]

Manufacturing has experienced slow growth in the region. The principal categories are lumber and wood products, food products, and printing and publishing. Outside of Albuquerque, scientific instruments and stone, clay, and glass products have importance. In Albuquerque, jewelry and machinery are important products. The City of Albuquerque is the industrial hub, with 90% of the 617 manufacturing firms in the region.[3-76] It is becoming a leading center for exchange of goods and services throughout the southwestern United States and clearly dominates the economy of the region and the state.

The decline in both farming and livestock grazing is largely responsible for the depressed economic condition of the region. Unlike other areas in the nation, decreasing agricultural employment has not been offset by increased activity in other sectors. The generally modest economic development is further hampered by the large numbers of unskilled workers and by language and educational difficulties. There has been a trend, however, towards an increased percentage of jobs in the services, trade, and finance, insurance and real estate sectors, with a corresponding lower proportion of direct government employment. There has been a concentration of jobs in Albuquerque, Santa Fe, and Los Alamos. With the exceptions of Albuquerque, Santa Fe, and Los Alamos, unemployment in the area has consistently exceeded state and national averages (see Table 3.2.2-1).[3-78, 3-80] Although the total jobs in the region have increased by 20% between 1970 and 1975, this growth in employment has not kept up with the

TABLE 3.2.2-1

EMPLOYMENT, INCOME, AND POVERTY STATUS IN LOS ALAMOS REGION

Employment Status 1976[3-80]	Mora	Taos	Rio Arriba	Los Alamos	Santa Fe	Albuquerque Metropolitan Area	Northern New Mexico Region
Labor force	1,163	7,217	9,356	7,303	27,580	161,991	214,610
Unemployed	388	1,085	2,000	353	2,474	13,146	19,446
Unemployment rate	33.4%	15.9%	21.4%	4.8%	9.0%	8.1%	9.1%
Income & Poverty Status 1975[3-78]							
Total number of families	1,055	4,099	5,620	3,877	12,228	81,312	108,191
Median family income	\$3,100	\$5,308	\$5,544	\$15,273	\$8,018	\$8,868	\$8,638
Number receiving welfare	188	687	798	52	793	4,514	7,031
or public assistance	(18%)	(17%)	(14%)	(1%)	(6%)	(6%)	(6%)
Number of families	605	1,468	1,930	83	2,221	11,521	17,828
below poverty level	(51%)	(36%)	(34%)	(2%)	(18%)	(14%)	(16%)

growth in the labor force. Consequently the unemployment rate has risen in every county including Los Alamos in the region over this period (see Figure 3.2.2-2).[3-78, 3-80] The region has two seasonal employment patterns as well. In Santa Fe and Los Alamos Counties there are pronounced unemployment surges in June that decline in September, because of a student influx into the labor market. In the rest of the region unemployment peaks in the winter months, January through April, and gradually diminishes through the summer and fall. This pattern reflects the dependency on tourism, agriculture, forestry, and construction.[3-72]

As a result of the economically depressed status of the region the median income in the region is low, less than the national average, and the percentage of families with income below the national poverty level is high. Welfare or public financial assistance is a major source of income in Mora, Taos, Sandoval, and Rio Arriba Counties, with 14 to 18% of the families receiving economic aid (see Table 3.2.2-1).[3-78]

In this setting, LASL finds itself the only major industrial employer in North Central New Mexico, with the regional economy highly dependent on it. Because of the lack of comparable high-technology employers in the region, there is a very limited technical labor pool from which to draw, and the preponderance of more highly skilled workers must be imported from outside the region.

In Los Alamos County the economy is based largely on the Federally funded operations of LASL and the associated activities of Zia, Los Alamos Contractors Inc. (LACI), EG&G, and the Los Alamos Area Office of DOE (LAAO). This has a large economic impact on the surrounding counties since 35% of these workers live outside Los Alamos County. Table 3.2.2-2 summarizes the distribution of workers employed in Los Alamos. Employees of the trade, construction, and service sectors are not included in the table, but presumably a similar percentage of these are from the surrounding region.

The dependency of the economy of Los Alamos on DOE's operations is easily illustrated by the employment structure of the county. The direct federally funded employment of LASL, Zia, LACI, EG&G, and LAAO has varied between 72% and 67% of total employment since 1967. The percentage of employment that is due to the supporting services sector has been increasing. Retail trade and services dominate this sector, accounting for one-fourth of all employment. Although contract construction only accounts for 4% of total employment, it also plays an important role in the local economy (see Table 3.2.2-3).[3-80]

As mentioned earlier, unemployment is extremely low in Los Alamos compared to the surrounding communities and the rest of the nation. There are two underemployed groups, however: women and adolescents. Many women hold non-technical degrees, and others with technical degrees often have obsolete skills. The adolescents are generally students between 16 and 21 years of age. Again there are few non-technical jobs, and summer employment opportunities are limited.[3-71]

Los Alamos has not generated the large downtown area that is characteristic of other communities of comparable size. There are two main commercial areas, the community center in Los Alamos townsite and the shopping centers in White Rock, plus two other neighborhood shopping areas in Los Alamos townsite.

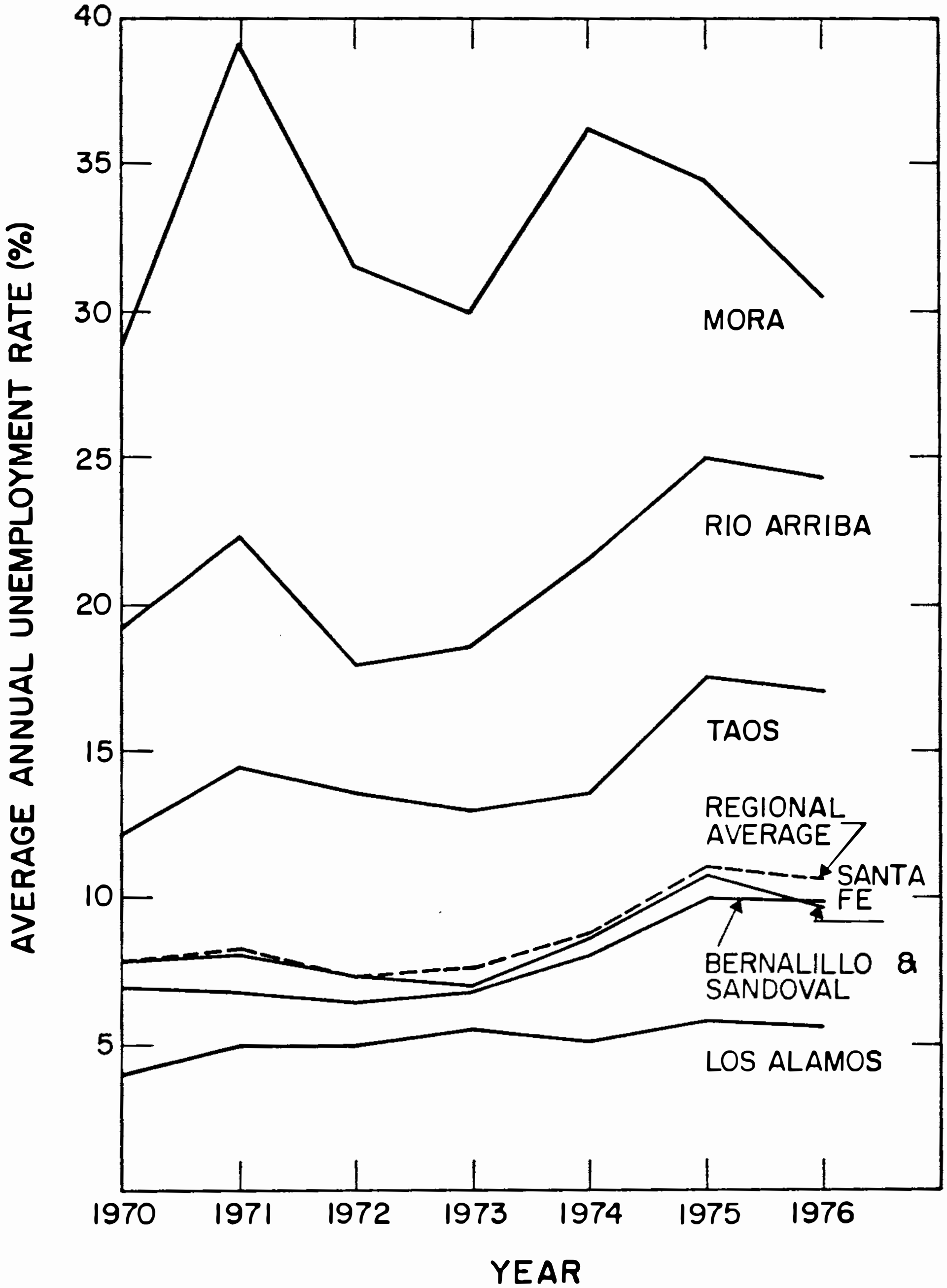


Figure 3.2.2-2. Unemployment Rates for Northern New Mexico

TABLE 3.2.2-2

COUNTY OF RESIDENCE IN NORTHERN NEW MEXICO FOR WORKERS AT LOS ALAMOS
(LASL, Zia, EG&G, LAAO, and Los Alamos County Employees in 1976)

	Community	County Total	
Los Alamos County		5703	66%
Los Alamos Townsite	3773		
White Rock	1930		
Rio Arriba County		1527	18%
Española and Fairview	1027		
Santa Cruz, Truchas, etc.	204		
San Juan Pueblo, Dixon, Alcalde, etc.	228		
Abiquiu, El Rito, etc.	68		
Santa Fe County		1256	14%
Santa Fe and Pojoaque	1009		
Cerrillos, Chimayo, and Tesuque	247		
Taos County		71	1%
Taos, Ranchos de Taos	28		
Penasco, Ojo Caliente, Rodante, etc.	43		
Bernalillo County		54	1%
Albuquerque, Belen, Bernalillo	54		
Sandoval County		35	-
Jemez Springs, Jemez Pueblo, Pena Blanca	35		
Mora County		4	-
La Cueva	4		
Total		8650	

SALARY IMPACT OF LOS ALAMOS SCIENTIFIC LABORATORY
OUTSIDE OF LOS ALAMOS COUNTY

	Number of LASL Employees January 1979	Yearly Salaries
Santa Fe, Las Vegas, Cochiti,	557	$10,973,645
Pojoaque, Tesuque, El Rancho, Cuyamungue, San Ildefonso, Nambe	401	6,617,983
Española, Fairview, Santa Cruz, San Juan Pueblo, La Mesilla	813	11,507,247
Hernandez, El Rito, Chamita, Ojo Caliente, Canjilon, Mendanales, Abiquiu, Coyote	72	787,362
Dixon, Alcalde, Embudo, Taos, Velarde, Arroyo Seco	121	1,552,697
Penasco, Truchas, Cundiyo, Chimayo, Cordova, Trampas	199	2,340,698
Jemez Springs, Jemez Pueblo	56	994,173
Albuquerque, Corrales, Bernalillo, Belen, San Pendro	64	1,039,345
Miscellaneous	70	1,661,424
Total	2,353	$37,474,844

TABLE 3.2.2-3

EMPLOYMENT STRUCTURE OF THE LOS ALAMOS COUNTY

	GOVERNMENT EMPLOYMENT		COMMERCIAL SECTOR EMPLOYMENT							
Year	LASL, ZIA LACI, LAAO	% of Total	Trade	Service	Finance, Insurance, & Real Estate	Contract Construction	Other	Total Commercial Employment	% of Total	Total Employment
1967	5,372	70	525	1,351	103	240	93	2,312	30	7,684
1968	5,527	72	522	1,254	70	202	83	2,131	28	7,658
1969	5,728	71	570	1,169	94	385	99	2,317	29	8,045
1970	5,827	72	543	1,125	90	373	98	2,229	28	8,056
1971	5,624	70	561	1,414	101	293	85	2,454	30	8,078
1972	5,728	69	598	1,532	134	316	50	2,630	31	8,358
1973	6,081	68	700	1,576	126	382	96	2,880	32	8,961
1974	6,219	67	755	1,755	165	261	77	3,013	33	9,232

In 1976 White Rock, with about one-third of the population, had 25% of the commercial floor space in the county. Retail trade occupies 50% of the total commercial floor space in Los Alamos County and returned $59.97 gross income per square foot of enclosed space in 1974. Services occupy 43% of the total commercial floor space, but only returned $18.09 per square foot. Finance, insurance, and real estate accounted for 6% of the commercial floor space, returning $42.73 per square foot.[3-71]

The total amount of commercial development in Los Alamos is low in proportion to the population. The special circumstances of Los Alamos as a closed town earlier limited retail activities. Competition from Santa Fe, Española, and Albuquerque has continued to limit commercial development.[3-81] The proportion of total payroll spent locally has been increasing and reached 36% in 1974, which is still low considering the size of the community. In addition, workers who live outside the county spend their income in the communities of their residence. Los Alamos does not serve as a market area for any surrounding communities, but rather the other communities in the region benefit greatly from the payrolls of Los Alamos. The economic impact of DOE's activities in Los Alamos on the region will be discussed in greater detail in Section 4.3.5.

3.2.3 Demography

For the counties of Mora, Rio Arriba, Santa Fe, Sandoval, and Taos a demographic pattern is evident in Table 3.2.3-1.[3-75] The majority, 73%, of the population is people of Spanish language or Spanish surnames. Nevertheless the term minority will be used in this discussion in view of the proportions nationally. Indians represent 10% of the population, and Negro and other minorities, 1%. Bernalillo County differs from the other six counties of the region with a smaller proportion of Indian or Spanish and a larger proportion of non-minority and Negro. Los Alamos has the smallest proportion of minorities in the region.

In the urban counties of Santa Fe, Bernalillo, and Los Alamos the number of persons per household is 3.3 to 3.4, compared to the state average of 3.4 (see Table 3.2.3-2).[3-78] The size of the average household increases considerably in the more rural counties of Mora, Rio Arriba, Sandoval, and Taos, ranging between 3.6 to 4.2 persons per household. The same type of pattern is evident in the percentage of women in the working force, varying between 14 and 30% in the rural counties and rising to between 41 and 43% in the urban counties. The average for the state is 37%.

As discussed in Section 3.2.2, the economy of the region is generally depressed, with low incomes and high unemployment rates. Predictably the median family incomes of the minority groups are less than the averages for all families, and the percentage of families below poverty level is greater. However, there is a considerable difference in income for minority groups in Los Alamos County compared to the rest of the region or the state. The family income of residents of Los Alamos classified as Spanish is almost twice that of the statistical average, and over four times the family income of Mora County's Spanish population.

The population in the six surrounding counties that encompass most of the present area of interest includes a large rural population and two main urban centers. The two main urban centers are the city of Albuquerque in Bernalillo County and the city of Santa Fe in Santa Fe County. Santa Fe County had

TABLE 3.2.3-1

MINORITY DISTRIBUTION IN NORTHERN NEW MEXICO

(1970 Census)

	Spanish[a]	%	Indian	%	Negro	%	Other Minority Groups	%	Total
Bernalillo	123,814	39.2	5,834	1.8	6,689	2.1	2,463	.8	315,774
Los Alamos	2,699	17.8	71	0.5	61	0.4	63	0.4	15,198
Mora	4,419	94.6	2	-	1	-	10	.2	4,673
Rio Arriba	20,691	82.2	2,755	10.9	49	.2	200	.8	25,170
Sandoval	11,159	63.8	6,796	38.9	19	.1	106	.6	17,492
Santa Fe	34,883	64.9	1,096	2.0	268	.5	230	0.4	53,756
Taos	15,109	86.3	1,193	6.8	28	.2	277	1.6	17,516
State	407,286	40.1	72,788	7.2	19,555	1.9	7,842	0.8	1.016,000

[a]This column includes some Indians with Spanish surnames; therefore, county rows may add to more than 100%.

TABLE 3.2.3-2

SELECTED STATISTICS FOR LOS ALAMOS AND SURROUNDING COUNTIES

Population (1970)	Los Alamos	Rio Arriba	Sandoval	Santa Fe	Taos	Bernalillo	Mora	State
Total	15,198	25,170	17,492	53,756	17,516	315,774	4,673	1,016,000
Median age	26.7	21.0	21.3	24.8	23.3	24.4	22.6	23.9
Age Distribution								
Under 17	42%	45%	45%	39%	42%	38%	43%	40%
18 - 44	35%	32%	32%	35%	31%	38%	26%	36%
45 - 64	20%	16%	17%	18%	17%	18%	19%	18%
65 & over	2%	7%	7%	8%	9%	6%	12%	7%
Persons per household	3.4	3.9	4.2	3.4	3.6	3.3	3.6	3.4
Percentage of working women	43	29	28	43	30	41	14	37
Percentage of 25 and older with 4 or more years of college	39	6	10	17	9	17	4	13
Percent of public school expenditure from Federal sources (1973/1974)	50.4	10.1	23.2	4.5	5.1	4.7	3.6	9.5
Persons per square mile	121	4	4	24	7	226	3	8
Persons per doctor (1974)	589	1,820	1,629	539	1,890	528	4,300	910

a 1975 population of about 62,000 with 45,000 living in the city of Santa Fe, accounting for its 74% urban character. Further south, Bernalillo County had 365,200 people in 1975.[3-82] The urban growth of Santa Fe and Albuquerque has accounted for most of the growth in their two counties, and includes substantial net immigration (see Table 3.2.3-3).[3-75, 3-78, 3-82] Those two urban centers, along with Los Alamos County, account for 80% of the region's population.

The majority of the region's rural population is in towns, villages, and Indian pueblos ranging in size from a few hundred to a few thousand. The nearest such community is Española, about 20 km (12 mi) to the northeast of Los Alamos, with a 1975 population of over 5600. Local rural communities have experienced little net population growth. Four counties, Sandoval, Rio Arriba, Mora, and Taos, accounted for about 74,800 people in 1975, all classed as rural. Taos, Mora, and Rio Arriba have almost the same populations as they did 20 years ago. Sandoval has grown from 12,500 in 1950 to 22,600 in 1975. Large out-migration, especially of youth seeking employment, has nearly cancelled out natural rates of increase (see Table 3.2.3-3).[3-75, 3-78, 3-82] The rate of population loss in the rural areas has slowed considerably since the 50's and 60's, although the economic factors accounting for this movement are still present. However, there has been a decided trend towards in-migration in the people over 55.[3-78, 3-82] This is in direct contrast with the trend for Los Alamos, where the percentage of residents over 65 is 2%, about one-fourth that of the region and the state. However, the proportion is increasing and should reach the state and regional averages during the next decade.

Population projections are speculative at best but offer at least some basis on which to plan for future requirements. Official projections for New Mexico counties are compiled by the Office of Business Economics and Economic Research Service (OBERS) and the Bureau of Business Research (BBR) at the University of New Mexico.[3-83] The lower projection in each case is the more recent projection made by local demographers. A compilation of recent estimates shows Los Alamos with an expected 1980 population of 16,800 to 27,300, Santa Fe 59,200 to 65,100, and Bernalillo 353,500 to 424,300. Projections for the rural counties--Rio Arriba, Sandoval, and Taos--bracket the 1970 population with growth to 66,500 (BBR) or decrease to 54,100 (OBERS). Expectations then are that the rural counties will remain stable, with considerable urban growth occurring in Santa Fe and Albuquerque.

By the end of 1975, the officially estimated population of Los Alamos County was 15,900. This indicates the growth rates since 1970 are lower than the preceding two decades, when the population grew from about 10,500 in 1950 to 13,000 in 1960 and 15,200 in 1970.[3-78] Historically, Los Alamos County has grown in proportion to the level of LASL's research and development efforts. The shape of Los Alamos County's population will continue to be intimately dependent on its federal agency affiliations.

Los Alamos County is demographically unusual in several respects. By comparison with all other New Mexico counties it has the highest family income, highest proportion of college graduates, and the highest population density.

The median age in Los Alamos County is 26.7, which is higher than the state average and much higher than any other county in the region. The age distribution of Los Alamos has its roots in the origin of the community wherein large numbers of young professionals were imported, many of whom started their families in Los Alamos. Over the years the population has matured with the Laboratory; the largest five-year age groups of adults being 25-29 in 1950, 35-39 in 1960, and 45-49 in 1970.

TABLE 3.2.3-3

COMPONENTS OF POPULATION CHANGE IN NORTHERN NEW MEXICO

	1960	1970	1975	1960-1970 Inferred Net Migration[a]	1970-1975 Inferred Net Migration[a]
Bernalillo	262,199	315,774	365,200	1,449	29,000
Los Alamos	13,037	15,198	15,900	-48	100
Mora	6,028	4,673	4,900	-2,210	0
Rio Arriba	24,193	25,170	28,000	-4,774	400
Sandoval	14,201	17,492	22,600	-224	3,400
Santa Fe	44,970	53,756	62,000	0278	3,800
Taos	15,934	17,516	19,300	-1,478	600
State	951,023	1,016,000	1,147,000	-119,893	59,000

a) Inferred net migration is the change in population minus the natural increase. The natural increase is births minus deaths.

There has consistently been a notch in the population distribution at the younger ages 15 to 24. In the early days this may have been due to so many newly formed families; it is now largely related to the high proportion of high school graduates that go away to college. The acceptance of newer birth control techniques has resulted in a slight notch in the 5-10 year age category and a pronounced drop in the five years and younger group.

One implication of these unusual population characteristics is that increasing numbers of retirees can be expected, especially in the next five to ten years. The retirement sector has grown substantially since 1950. Earlier, housing assignments were strictly controlled and only those working in Los Alamos could reside in the community. A survey in 1974 concluded that 95% of all county residents 60 years of age and over intend to continue residing in their present homes after retirement.[3-84] Recently, about half of the roughly 200 annual retirees have been remaining in the community; if trends are projected using national rates, Los Alamos can expect three to four times as many people in the 65-74 age bracket in the next ten to fifteen years. While a population growth of about 1400 can be anticipated just from retirees, the exodus of youth seems likely to continue as they go to college; about 75% of high school juniors and seniors recently interviewed do not intend to return.[3-71] Los Alamos has been following the national trends towards smaller families and a decreasing percentage of married couples.

About 3000 LASL/Zia/Federal employees live "off the hill," mainly in the surrounding counties of Santa Fe, Rio Arriba, Sandoval, Taos, and Bernalillo. Another 1500 to 2200 persons employed in other community enterprises also commute from surrounding areas. This reflects the chronic housing shortage, which is the result of the limited amount of land available for residential development and the corresponding high cost of land and houses. Many employees can not afford to buy homes in Los Alamos, despite the high median family income.

The crime index in Los Alamos is below the national average. The rate for violent crimes is very low. The rate for property crimes is lower than that of the surrounding regions. Juvenile crime accounts for 70% of the arrests, but the juvenile crime rate is still low compared to the regional and national averages. Social problems focus on alcohol and drug use among teenagers.

3.2.4 Institutional

The large percentage of Federally owned lands in the region (mentioned earlier in Section 3.2.1) affects the institutional structure. Only Congress is authorized to pass laws affecting the administration of Federal property. The Multiple Use and Sustained Yield Act of 1960 and the Classification and Multiple Use Act of 1964 have changed the administration of lands in the region and affected the regional economy.

Federal agencies having resource management responsibilities in the region include the Forest Service and Farmer's Home Administration of the U.S. Department of Agriculture, the U.S. Geological Survey of the U.S. Department of the Interior, the U.S. Army Corps of Engineers, the Bureau of Reclamation, the Bureau of Indian Affairs, the Fish and Wildlife Service, the Soil Conservation Service, and the Agricultural Stabilization and Conservation Service.[3-25]

There are many state agencies that have jurisdiction over particular aspects of the county. The State Engineer Office and the New Mexico Water Quality Control Commission are responsible for water rights and water quality management. The two interstate compacts affecting water use in the region are the Rio Grande Compact of 1938, amended in 1948, and the Costella Creek Compact. There is also one international treaty, the Rio Grande Convention of 1906. Los Alamos County is declared part of the Rio Grande Underground Basin. Other important state agencies include the National Resource Conservation Commission, the Department of Game and Fish, the Parks and Recreation Commission, and the Environmental Improvement Division.[3-25]

As the only H class county in the state, the powers of the Los Alamos County government are granted by the State Legislature. The county coordinates planning activities with the North Central New Mexico Economic Development District and the State Planning Office. In 1973 the New Mexico State Legislature passed a law giving the counties responsibility for managing subdivision of land, and Los Alamos County has since enacted subdivision regulations. The County Comprehensive Plan was adopted in 1964, and revised in 1976. In 1977 the County Zoning Ordinance was revised and adopted.

DOE has administrative control of all of the LASL reservation. The security force's responsibilities include policing activities, generally to prevent the entry of unauthorized persons into restricted areas. There is an agreement with the Los Alamos County Police Department authorizing them to ticket traffic violators on the public access roads across DOE lands. The State Police have authority over state highways, such as State Road 4. The Indian tribal police have authority over roads that cross tribal lands. In certain situations this results in overlapping authorities.

The Los Alamos County Charter was adopted in 1967. The County is governed by a seven-member County Council elected at large. Other elected officials include the County Judge, the County Clerk, the County Assessor, and the County Sheriff. The County Council appoints the chief administrative officers such as the County Manager, Attorney, and Utilities Manager. The County Council also appoints a five-member Utilities Board, a three-member Board of Equalization and a Planning Commission.

The schools are administered separately by a five-member elected School Board, with the professional management of a superintendent. The school system is funded jointly by the State of New Mexico, county school taxes, and the Federal government. The public school system consists of one high school, two junior high schools, and six elementary schools. All but two elementary schools are located in Los Alamos townsite. There are three preschool and two daycare facilities. Kindergarten is offered in the public schools, and the high school offers a night school. There are also a remedial speech and reading therapy clinic, a vocational project for the handicapped, and a branch of the Northern New Mexico Community College.

The public schools in the remaining counties in northern New Mexico reflect the overall poor economic conditions of the region. This is clearly reflected in the net operating cost per pupil, which ranged in the other counties between 60% and 75% of the cost in Los Alamos (see Table 3.2.4-1).[3-78]

There are presently four vocational training schools in the region. Colleges and universities include the University of New Mexico and two private four-year colleges in Santa Fe.

TABLE 3.2.4-1

SCHOOL EXPENDITURES IN NORTHERN NEW MEXICO

County	Net Operational Cost per Pupil 1973/1974
Bernalillo	$ 723
Los Alamos	1,169
Mora	848
Rio Arriba	773
Sandoval	883
Santa Fe	699
Taos	715

3.2.5 Community Services

Telephone communication facilities are installed and operated by Mountain States Telephone and Telegraph Company, with line and microwave links to Santa Fe.

The Los Alamos Medical Center houses hospital, clinical laboratory, and private medical services, as well as psychological counseling services, a coronary unit, and a complete pharmacy. It was originally built under the AEC administration and operated by Zia Company. In 1964 ownership and operation were transferred to the Lutheran Hospital and Homes Society, a non-profit corporation that manages hospitals and nursing homes throughout the country. The 88-bed hospital admits an average of 2200 patients per year, with an average daily occupancy of 35. The hospital cost per patient per day was about $140 in 1976, which is comparable to the region, although the doctors' and lab costs are often high proportionally.

The doctor/patient ratio for the county is 1/589,[3-78] with 30 doctors in the county. In addition, a half dozen specialists commute regularly from Santa Fe. LASL also has its own occupational medical staff and facilities for employee use only. There are seven dentists in the county.

The County Health Department, the Council on Alcoholism, and the Visiting Nurse Service provide additional health care services. The DOE fire department operates an ambulance service. The high-quality medical resources of Los Alamos County are atypical of the northern New Mexico region.

The Los Alamos Family Council, the community's mental health agency, helps individuals and families in the Los Alamos area overcome personal crises and live in a generally better emotional climate. Many of these services are free, others are offered for fees based on "ability to pay." Persons living in, or employed in Los Alamos County and their families, are served. Programs offered include: personal counseling services, Big Brothers - Big Sisters, YES (Youth Employment Service), Friends - Tutors, Crisis Intervention, The Day Out, and Los Alamos County Senior Citizens Program.

Additional community services are provided by groups such as the YMCA and Scouting organizations, Casa Mesita, a County Extension Agent, and the Public Library.

3.2.6 Transportation

Northern New Mexico is traversed by Interstate Highway 25 in a generally northeast-southwest direction. It connects Santa Fe to Albuquerque. This route is designated US 85 in some portions where the construction to meet interstate standards is not completed. From Santa Fe, US 285 proceeds northward connecting with State Road 4 shortly before Española (see Figure 3.2.6-2). State road 4 is the only highway in the county, providing the main access to Los Alamos. It runs through White Rock with a loop that runs through the Los Alamos townsite. State Road 4 intersects with a main highway, US 285, about 32 km (20 mi) east of Los Alamos, which provides access to Santa Fe and Albuquerque. Some Federally owned and Zia-maintained roads, notably East Jemez and Pajarito Roads, are open to public use and carry a large portion of the commuting traffic. Total county-owned road mileage is 164 miles (265 km).[3-71] The transportation network for Los Alamos County is shown in Figure 3.2.6-1.

There is no public bus service in Los Alamos County, and the nearest commercial bus terminal is in Santa Fe. There are a number of trucking firms furnishing freight service for most commodity classes. The nearest rail connection is the Atchison, Topeka and Santa Fe line at Lamy, 83 km (52 mi) east. The long distances to rail and bus connections make this type of travel virtually unusable for Los Alamos residents.[3-84]

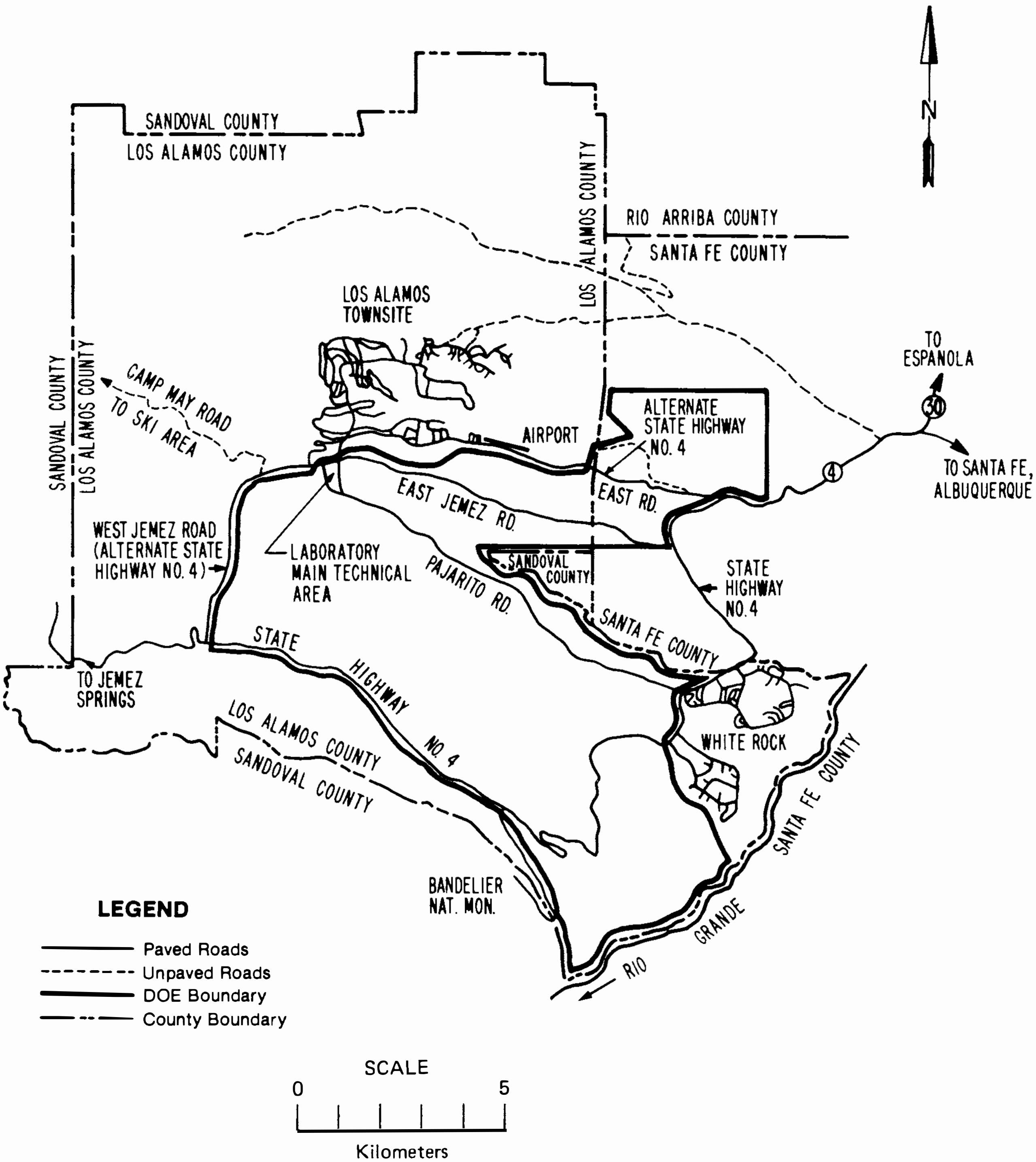


Figure 3.2.6-1. Transportation Network in Los Alamos County

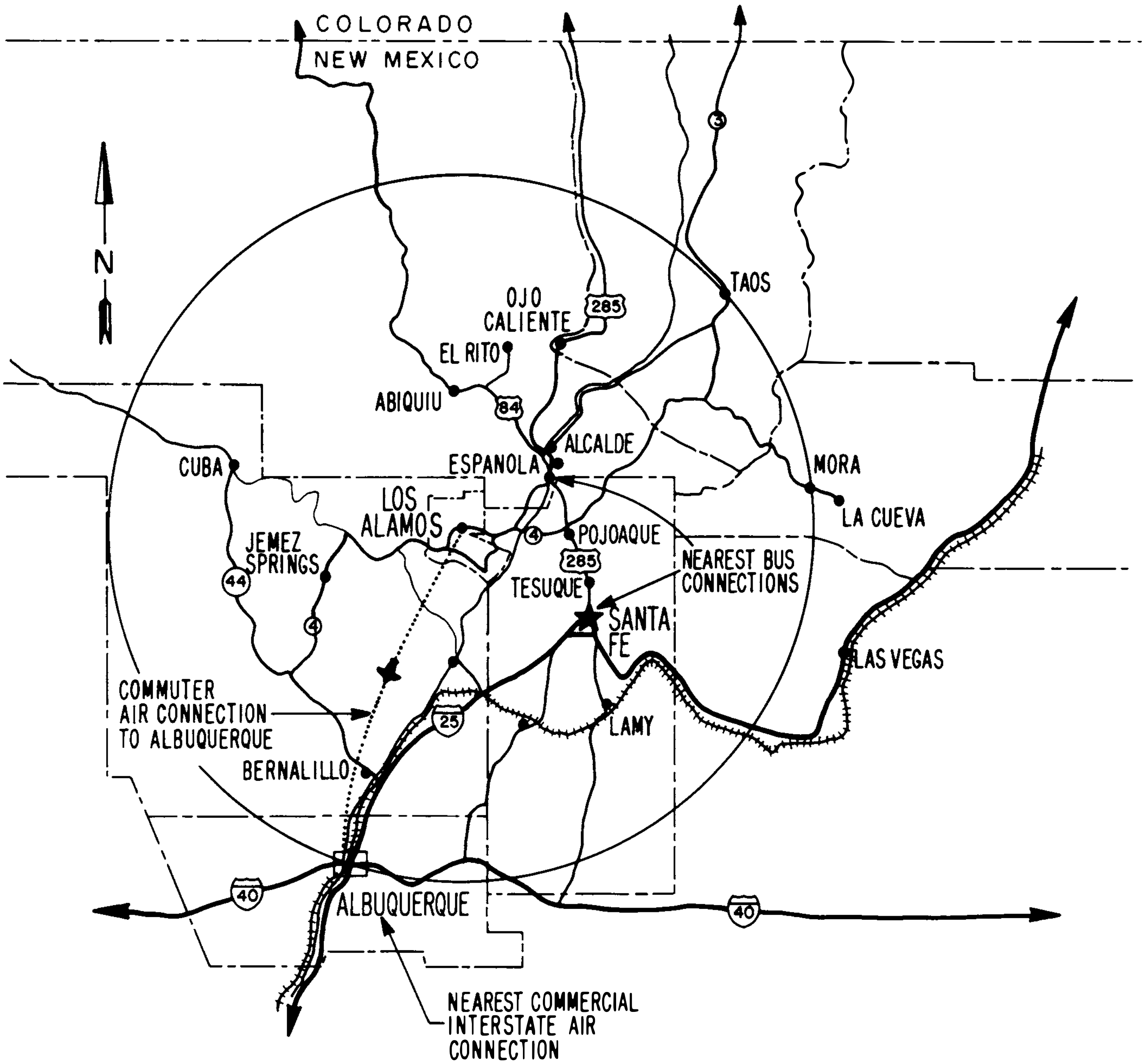


Figure 3.2.6-2

Regional Transportation Network Within
Approximate 80 Km (50 mi) Circle of Los Alamos

The major commercial airport for northern New Mexico is in Albuquerque. The Los Alamos Airport is a private airport owned by the Federal government under the administrative jurisdiction of DOE, and managed for DOE by the Zia Company. Constructed around 1943, it was opened to private pilot use around 1961. The Federal Aviation Agency licensed pilots in the Los Alamos area may be issued permits to use the airport facilities on a permanent basis; pilots of transient aircraft may acquire permission to use the facilities.

The airport has one runway running east-west at an elevation of 2180 m (7150 ft). All take-offs are from west to east, and all landings are from east to west. An FAA Restricted Area Special Use Airspace (R-5101) is located immediately south and west of the airport. Thirty-one tie down spaces at Los Alamos Airport are leased by DOE to private aircraft owners, as well as thirteen hanger spaces and five transient tie down spaces. In addition, AVGAS, a non-profit corporation, leases an area for dispensing aviation gasoline and oil and for operating a mechanic service. DOE plans to upgrade the airport runway for additional safety and more convenient handling of larger and heavier aircraft.

Ross Aviation, Inc., has a contract with DOE to provide passenger and freight services between Los Alamos and Albuquerque. The scheduled flights are available to the public. Ross carried 23,603 passengers either to or from Los Alamos during FY 76. Freight averaged about 8,000 lbs a week. During the period September 1, 1975 through August 31, 1976, local FAA-licensed pilots made 7951 landings/take-offs, and transient pilots made 1142 landings/take-offs for a total of 9093 flights.

Transportation facilities in the county are based on the road network and the Los Alamos airport. The private automobile dominates all forms of transportation in Los Alamos County. Los Alamos has traditionally given minimal consideration to convenient access to or by public transportation. Individual transportation in Los Alamos is essentially all by private automobile. Work-related driving, mostly getting to and from work, constitutes a substantial portion of vehicle travel. A county study made estimates based on LASL, Zia, and LACI employees' residences and work places, and traffic surveys. For the county as a whole, total annual vehicle travel was estimated at 64×10^6 km (40×10^6 mi). The Laboratory employees' work-related travel amounts to about one-third of this. All other work-related driving accounts for somewhat less than a third of the travel, and shopping-social-recreational driving accounts for somewhat more than a third.[3-84]

A large number of workers commute to Los Alamos, some from a long distance (see Figure 3.2.6-1). In response to the 1973 gasoline shortage, LASL operated a commuter bus service for several months between Los Alamos and the Pojoaque, Española, and Santa Fe areas. However, people seem committed to their private cars, and after the shortage abated it was impossible to maintain patronage at economically feasible levels.

The Federal government provides a motor pool for official business, maintained and operated by the Zia Company, consisting of passenger vehicles, trucks, and maintenance vehicles. Within the LASL site, transportation is a major planning concern, as it relates to the large area encompassed by the site, the physical dispersion of activities, and investments in parking lots and roads.

A recent transportation study recommended improvements to the intersection of Pajarito Road with East and West Jemez Roads near the main technical area. The consultants also suggested widening of some roads, other minor improvements and development of a bus system.[3-85]

Municipally, the Los Alamos County Comprehensive Plan recommends a public transportation system in the County and for routes between Los Alamos and Santa Fe, Española and Albuquerque.

3.2.7 Archaeology

The north-central New Mexico area has an abundance of prehistoric Indian ruins. The pre-Columbian Indian legacy is a significant one since the modern Pueblo Indian culture is so influential in this area. The Rio Grande Valley Pueblo Indians traditionally claim direct descendancy from the inhabitants of Bandelier and Puye Cliffs Ruins, and numerous other, lesser known sites are scattered across the plateau and in the valley. A Laboratory report, LASL 77-4, "Pajarito Plateau Archaeological Survey and Excavations," documents the sites within LASL boundaries.[3-86]

The oldest evidence of human presence on the Pajarito Plateau is a Folsom point, indicating the hunting culture of the late Pleistocene (8000 B.C.). At least two other types of projectile points have been found from the "archaic" period of North American archaeology, dating from 2000 B.C. to A.D. 500. After this, the Puebloan culture developed in the valleys of the Rio Grande and its tributaries. Village living evolved around A.D. 700, and agriculture and ceramic craft were introduced to the area.

These archeological sites are located throughout the LASL site (see Figure 3.2.7-1).[3-86] The period of Puebloan occupation started in the mid-13th century and lasted until the mid-16th century.

Several hundred 13th-14th century settlements are found on mesa tops, within the ecotone between the pinon-juniper woodland and the ponderosa pine forest. This is the area from the rim of White Rock Canyon up to an elevation of about 2250 m (7400 feet), which was apparently as high as the Indians could produce crops. Associated with these pueblos were many one-to-four room structures that appear to have been storage houses near fields, or seasonal homes. Most structures are found on the crests of the mesas, where dryland farming was practiced. During this period, the entire Pajaritan community probably consisted of several hundred people.

About the end of the 14th century, the population apparently abandoned the higher elevation and concentrated below the 2150 m (7000 ft) level. About this time, the large villages at Otowi, Tsankawi, Tshirege, and Navawi came into being. Sites occupied during the 15th and 16th centuries are located at the lower elevations of the Plateau. These sites are the larger 15th and 16th century settlements containing several hundred ground-floor rooms and attaining two- and three-story heights.[3-87, 3-88]

By the beginning of the 16th century, all the villages had been abandoned except for the big ones, each of which held a population of as many as two- to five-hundred people. Then in the second half of the 16th century, the Pajarito Plateau was abandoned by the Indians. Legends say the Pajaritans moved to the Tewa village of San Ildefonso. Some could also have moved to other villages in the Rio Grande Valley.[3-86]

Three sites located within the Laboratory reservation have been proposed by LASL as historic sites to be protected by law: the Otowi and Little Otowi Ruins east of Los Alamos, cavate ruins including a cave kiva and game trap near Mortandad Canyon, and the Tshirege Ruin near White Rock.

Archaeological sites on the Los Alamos Scientific Laboratory site are considered an historic and cultural resource. In the past, archaeological sites threatened by construction have been excavated by a consulting archaeologist. If possible, locations of buildings, utilities, and roads have been shifted to avoid disturbance of archaeological sites. Routine maintenance and construction activities that involve surface disturbance must receive review for impact on archaeological sites before proceeding. For a more detailed discussion, see Appendix H (page H-43-44). Future actions regarding archaeological resources will be governed by new regulations in 36 CFR 800. These regulations will require a much more active participation of the State Historic Preservation Officer in decisions regarding historic and cultural resources.

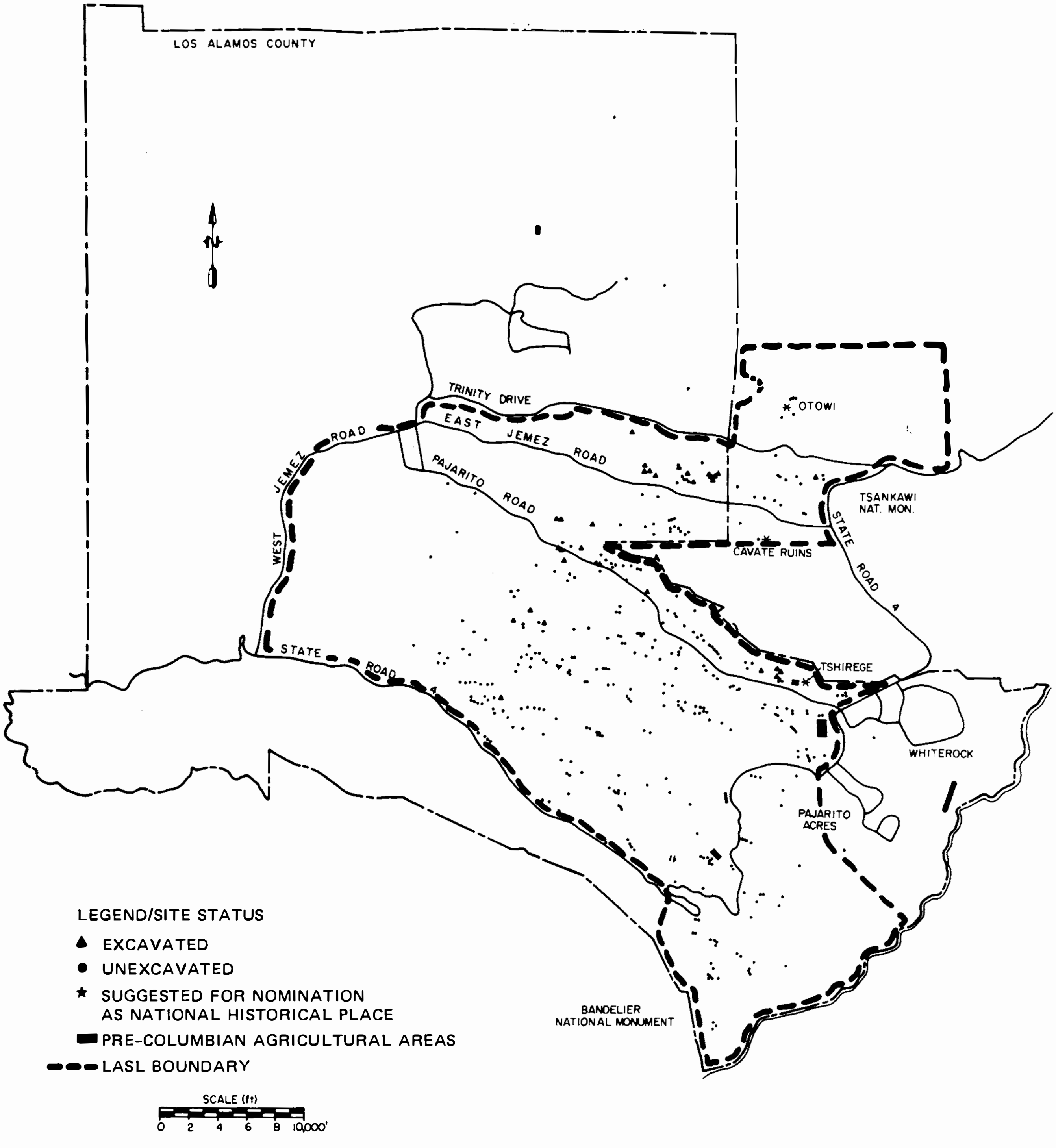


Figure 3.2.7-1. Archaeological Sites in LASL Vicinity

Four pre-Columbian sites in the Pajarito Plateau/Rio Grande Valley area have been established as National Historic Sites and are open to the public:[3-89]

Bandelier National Monument--16 km (10 mi) south of Los Alamos off State Highway 4; represents Pueblo civilization between 1300 and 1500; abandoned around 1580; encompasses several settlement areas, the best known of which are the Tyuonyi and Tsankawi Ruins; sites include ruins of a 400-room, 3-story communal dwelling, excavated kivas, and volcanic cliff cave diggings; several are as yet unexcavated.

Pecos National Monument--40 km (25 mi) southeast of Santa Fe off U.S. Highway 84-85; inhabited between 1400 and 1850; consists of a multistoried dwelling of 660 rooms and some 22 kivas; population was probably around 2500.

Puye Cliffs Historical Ruins--6 km (3.5 mi) south and 9 miles west of Santa Clara Pueblo; inhabited between the late 1200's and the mid-1500's; consists of many caves honeycombed in volcanic cliffs and multistoried mesa-top structures; some restoration has been completed.

Chaco Canyon National Monument--Located in northwestern New Mexico off State Highway 56, Chaco Canyon was one of the most important prehistoric cultural and commercial centers, although it was not part of the Rio Grande Valley complex. This highly developed agricultural civilization reached its peak in the eleventh and twelfth centuries. The largest ruins are Pueblo Bonito, Chettro Kettle, Casa Rinconada, and Pueblo del Arroyo--Pueblo Bonito alone may have housed 1200 inhabitants.

3.2.8 Historic

The first exploration by Europeans in New Mexico was led by Francisco Vasquez de Coronado in 1540. The expedition was sponsored by Viceroy Antonio de Mendoza of Mexico in hopes of finding gold and silver. Part of this expedition probably passed near Los Alamos. Another expedition that passed through the Los Alamos area was led by Antonio de Espejo in 1582. Espejo's report on mines in New Mexico resulted in an abortive attempt to settle New Mexico in 1590 by Gaspar Castaño de Sosa with a group of around 165 colonists (see Figure 3.2.8-1).[3-90, 3-91]

In 1598 a group of 140 settlers led by Don Juan de Onate established the Spanish capitol at the confluence of the Rio Chama and the Rio Grande across from the San Juan Pueblo. Apparently a peaceful co-respect was established, although the capitol was moved to Santa Fe in 1610, 18 years before Oñate's death.

Unlike the European colonists east of the Mississippi who included large numbers of women, the Spaniards who settled in New Mexico were mostly mensoldiers and priests who came to establish Spanish rule and the Catholic Church. Intermarriage with the Indians produced an indigenous Spanish/Pueblo culture rather than an established European lifestyle.[3-92]

Individuals or groups were often rewarded for meritorious service by granting them large acreas of land. This Spanish land-grant system respected Indian land holdings and set aside prescribed Pueblo holdings. Thus the best land along rivers had long since been settled before the Anglo Americans arrived 250 years later. The effect of the land grant system can still be seen in the present land ownership patterns. Los Alamos includes the Ramon Vigil Grant and part of a previous land grant dating back to the will of Captain Andres Montoya in 1740.[3-93, 3-94]

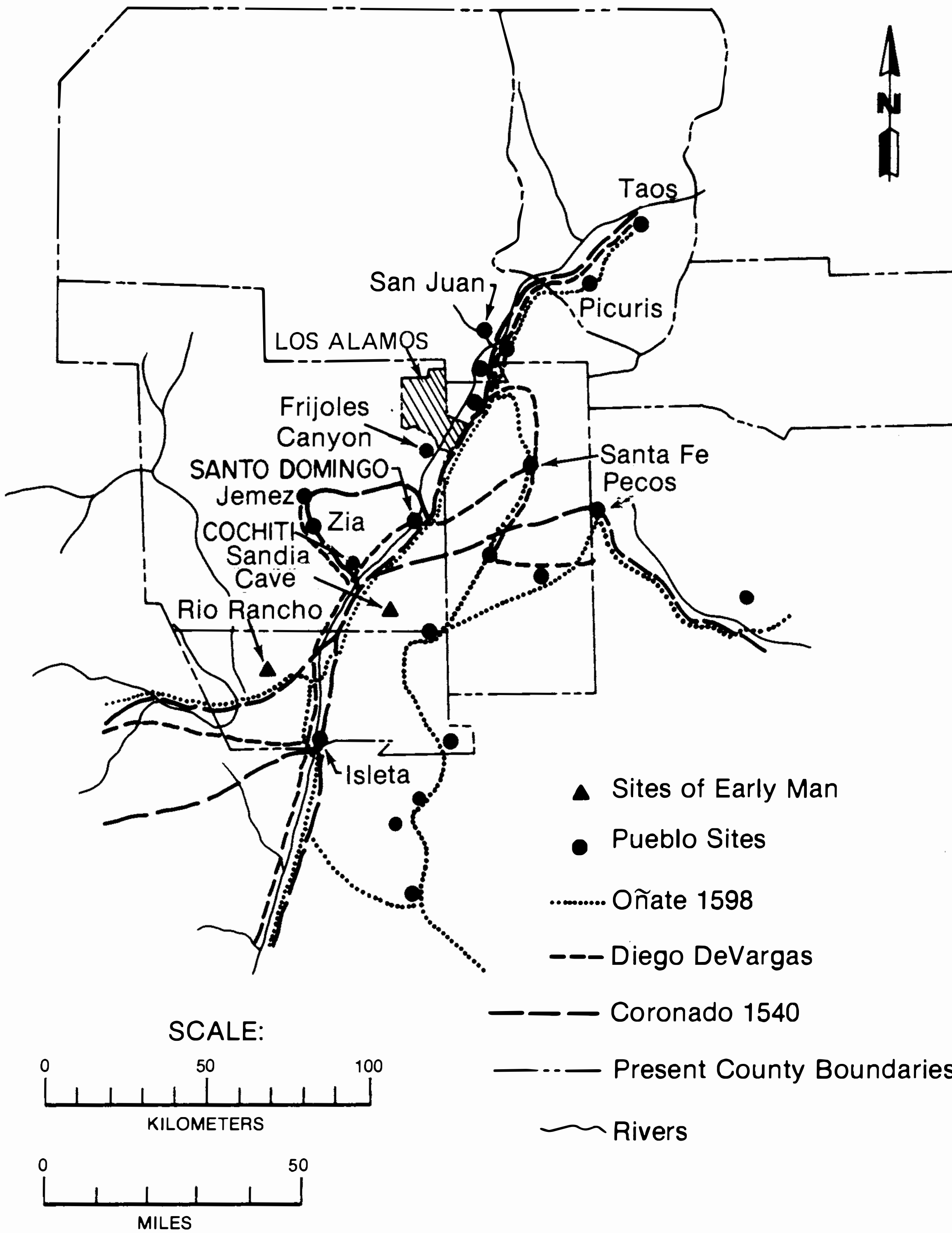


Figure 3.2.8-1. Historic Sites in Northern New Mexico

Under Spanish rule, the economy was one of Indian farming and Spanish cattle and sheep herding. Indian/Spanish conflicts arose in large part due to Spanish Church/State internal frictions and resulted in the Pueblo Revolt of 1680. A Pueblo coalition led by the San Juan Indians established Indian independence which lasted 12 years until resubjugation by Don Diego de Vargas in 1692.

The Mexico War of Independence from Spain brought the territory under the dominion of the new Republic of Mexico in 1821, but Mexico City was so far away that the effect in Santa Fe was merely a symbolic change of flags over the Palace of the Governors. The amount of Mexican support that Santa Fe received was insignificant in comparison with the economic impact of the Santa Fe Trail.

When the Mexican-American War culminated with the Treaty of Guadelupe-Hidalgo in 1848, the Territory of New Mexico came under U.S. jurisdiction. With the influx of settlers, great parcels of land were usurped, irrespective of the established holdings under the Spanish land grant system. This activity was supported by the corrupt Anglo government referred to as the "Santa Fe Ring". The counter resistance from the Spanish and Indians helped perpetuate and preserve a separate Spanish/Pueblo culture and minimized the eastern cultural influence from political domination. By 1912, when New Mexico became a state, the situation was a tolerant stand-off, with different cultures maintaining a separate coexistence of small farms, large ranches, and mixed-bag mining to support the new state.[3-92]

Homesteading on the Pajarito Plateau began in the 1880's, but remained transitory for another forty years. The area was used for cattle ranching and some farming. Henry Buckman developed an extensive lumbering operation. During this period, Adolph Bandelier's excavations of the prehistoric ruins on the Pajarito Plateau generated national interest. The introduction of the railroad into the region increased tourism. The Jemez National Forest was created in 1904, and Bandelier National Monument was established in 1916. Ashley Pond, a Detroit businessman, started the Los Alamos Ranch School, which enrolled its first students in 1918.[3-93, 3-94] The school flourished for nearly a quarter of a century. Its facilities were appropriated and expanded to accommodate the staff of the Federal Project Y atomic bomb laboratory.

During World War II, Los Alamos was a military establishment. In 1947 President Truman signed an Executive Order transferring all Manhattan Engineering District property to the civilian AEC and decreeing all Los Alamos residents to be federal wards--a "political limbo." The populace was, for example, without the right to adopt, divorce, probate, or vote (all state jurisdictions).

Largely in response to frequently occurring political quandries, legal jurisdiction over the community of Los Alamos (the Laboratory remained exempt) was transferred to the State of New Mexico by the March 1949 Act of Retrocession in which the President established Los Alamos as Precinct 17 of Sandoval County. Further, in June 1949, the separate County of Los Alamos was formed by The New Mexico State Legislature.[3-93]

The establishment of Los Alamos County brought some of the state's political environment into interplay with the community's heretofore separate identity. Under the new county status community services, property, etc. remained under AEC ownership, control, and funding and were locally governed by a three member County Commission (appointed by the Governor) and the area AEC Manager. Before creation of the county, local affairs had generally been under the advisement of a Town Council and the jurisdictional approval of either the Commanding Officer (military) or the AEC Manager (Federal). The community remained 100% Federally controlled and owned until the late fifties, when the fences and guard gates were removed. In the mid-sixties services and property were transferred to community control and ownership.

County and community controls remained under the general jurisdiction and ordinances prescribed by the state, pursuant to county classification. These were administered by the County Commission and modified by various local plans and programs. In 1967 the Los Alamos County Charter was adopted as the prima facie source for civic controls and advisement, and it continues to be the administrative institution for local government. This established the present institutional structure as described earlier in Section 3.2.4. Los Alamos thus evolved largely independent of state and neighboring community political influences.

Contrary to popular belief, LASL is not the National Historic Landmark listed on the National Register. Los Alamos County has one designated National Historic Landmark. The area of a sheltered plaque south of Ashley Pond commemorating the site of the Ranch School ice house, where the first atomic weapons were assembled, constitutes the original landmark. The area was expanded in the mid 1970's to include a landmark district of three Historic Tracts totalling about 13.25 acres. These tracts include the ice house site, the nine extant structures of the Ranch School and Ashley Pond. These properties are all privately or County owned; none are part of DOE property.

3.2.9 Cultural and Aesthetic Factors[3-89]

The descendents of the prehistoric Southwest Indian culture, the modern Pueblo Indians, live in 19 pueblo villages ranging across New Mexico in an arc from Zuni to Taos, with a total population of about 19,000 (see Figure 3.2.9-1). The Rio Grande Valley contains 15 of the New Mexican pueblos, representing the Towa, Tiwa, Tewa, and Eastern Keres language groups. The Western Keres language is represented by the Acoma and Laguna Pueblos, located further west along with Zuni Pueblo, which speaks Zunian. Spanish is the adopted language most common to all the villages, and English is also spoken by most of the younger villagers.

The majority of modern pueblo settlements date from the 13th to 16th centuries. Each village is a self-contained political unit, and, although not organized as a single tribal unit, all participate in the All-Pueblo Council which deals with matters common to all. Civic affairs are directed by a council of leaders through an elected governor and his assisting officers. The priesthood controls religious and ceremonial matters. Of great significance in the Pueblo Indian culture is the blend of Christian (Church) and Indian (Kiva) religious aspects; the former is of Spanish origin, the latter, indigenous.

Economy is largely agriculture and farming with some livestock, crafts, and wage working. The median income is low. Pottery is by far the most popular craft. Other outstanding Rio Grande Valley craft work includes beading, turquoise, shell, and silver jewelry (predominantly by the Santa Domingo Indians), leather work, plaited basketry (by the Jemez Indians), and drum making.

Of the 15 pueblos scattered across the Rio Grande Valley, several are worth special mention. The Santa Domingo Pueblo, population 2200, is the most conservative of the pueblos, following a pre-Spanish life style with heavy native Indian religious influence. The Taos Pueblo, probably the most widely publicized of the pueblos, exhibits traditional architecture and living conditions.

Several pueblos perpetuate traditional Indian culture through ceremonial observances; the Jemez Pueblo is distinctive for its skilled performance of several classic dances; the San Felipe Pueblo for its annual Green Corn Dance; and the San Juan Pueblo for its Los Matachines performances, which dramatize the 1680 Pueblo Revolt against the Spanish dominion.

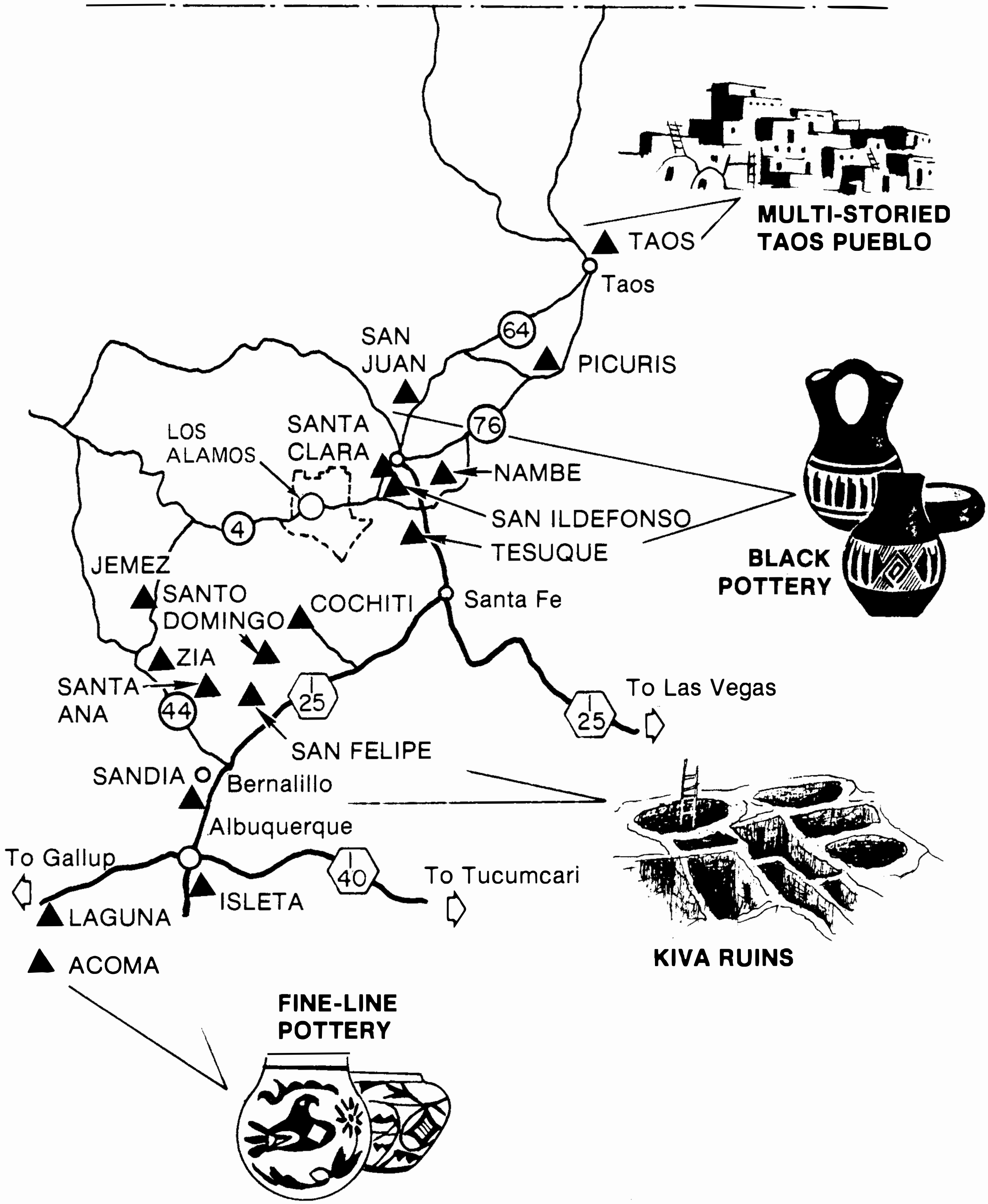


Figure 3.2.9-1. Present-Day Rio Grande Valley Indian Pueblos

Although at least half the pueblos produce some pottery, the Zia, San Ildefonso, and Santa Clara traditional-style products are renowned and much in demand by collectors throughout the United States. The Zia pottery has become popular lately among the local Anglo population as cookware.

One of the great contributions of any native people is the influence of their local folklore and traditions. For example, Black Mesa is a large, solitary mesa on the San Ildefonso Pueblo, reputed to be the home of resident Indian spirit forces, and few Anglo or Spanish-Americans in the region would knowingly profane its sacredness. Also, few gardens are planted before the snow is off the natural "thunderbird" formation visible on the side of a local mountain.[3-89]

Pueblo cultural traditions are best known today through Indian ceremonials, festivals, dances, and crafts. Santa Fe, New Mexico's capital, is situated in the heart of Pueblo country and provides ample evidence of historical and modern Indian culture, such as the Institute of American Indian Arts, the Wheelwright Museum, and some of the best Indian crafts shops in the Southwest, plus an Indian Arts and Crafts Market and Festival each August.

The city of Santa Fe is a cultural center for the region. The annual Santa Fe Fiesta is part of the region's Spanish cultural tradition. The nationally acclaimed Santa Fe Opera presents summer outdoor performances featuring many apprentices from the Metropolitan Opera. The Orchestra of Santa Fe presents five programs a year. Santa Fe often attracts well known performers, including popular, jazz, and classical. The Greer Garson Theater is the major dramatic organization. The area is dotted with unique craft enterprises, and both Santa Fe and Taos are renowned for their arts and crafts traditions.[3-72]

In Los Alamos County, Fuller Lodge serves as the center for cultural activities and provides space for meetings, concerts, lessons, and other varied programs. The high school auditorium is also used for performances. There are over 15 groups founded in music and the dramatic arts in Los Alamos, such as the Sinfonietta (a small orchestra), the Choral Society, and the Los Alamos Light Opera. The Little Theatre Group uses the Performing Arts Center in the Community Center. Other annual events in the county include an art show, rodeo, horse show, and fair. The two museums in Los Alamos are the County-owned Historical Museum, adjacent to Fuller Lodge, and the Bradbury Science Hall and Museum managed by LASL. The county also has a public library. The University of New Mexico has a branch resident center in Los Alamos County. Cultural interests are well supported by Los Alamos residents.[3-71, 3-84]

Recreational facilities in both the County and the region are exceptional and well used by the residents of Los Alamos. The county manages 33 parks. These, combined with facilities owned by the schools and private organizations, provide a wide range of recreational opportunities (see Table 3.2.9-1).[3-95] Tennis, swimming, skiing, ice skating and hockey, golf, and baseball are especially popular sports. In the surrounding region, hunting, fishing, hiking, and camping are major recreational activities. Bandelier National Monument is heavily used by Los Alamos residents. In addition to the Los Alamos ski area, there are six other ski areas in northern New Mexico.[3-72, 3-96]

The striking natural setting of the Laboratory contributes to the visual quality of LASL. The Laboratory has taken advantage of this and limited its maintained landscape efforts to small areas in the developed sites, in 26 of which some type of maintained landscaping has been installed around buildings. Many of the outlying maintained areas, generally landscaped with grass, are being converted

TABLE 3.2.9-1

RECREATIONAL FACILITIES IN LOS ALAMOS COUNTY AS OF 1976[a]

Tennis Courts	25	Totlots	19
Baseball fields	21	Picnic areas	15
Basketball courts	24	Horeshoe pits	4
Soccer and football fields	11	Swimming pools	8
Handball courts	3	Gymnasiums	9
Rifle and archery ranges	3	Horse stables	2

Other available facilities in Los Alamos County include:

Rodeo grounds	Golf course
Bowling	Arts and crafts
Minature golf	Ice skating
Roller skating	Sledding
Skiing	Camping
Fishing	

a) Includes those owned by the County Government, the schools, and private organizations.

to Southwestern landscaping concepts, which require less maintenance and less water. This approach uses boulders, gravel, and native drought-resistant trees and bushes. Almost all the public roads outside the technical areas are bordered by sizable natural vegetation. In the higher elevations toward the west end of the site, dense stands of ponderosa pine virtually enclose the roads and effectively screen the view from the road. This is a lesser factor in the lower elevations where pinon and juniper predominate. The four major northwest-southeast trending roads on or adjacent to the LASL site run for long distances along mesa tops before dropping into broad canyons at the eastern side of the site. The mesa top roads provide intermittent long view glimpses of the Rio Grande Valley, Sangre de Cristo Range, Sandia Range, and the closer Jemez Range. The alternate route of State Road 4, which loops through Los Alamos townsite, provides dramatic views of Pueblo Canyon and a portion of Bayo Canyon, and a designated scenic overlook takes virtually the entire Otowi tract into view.[3-14]

This natural landscaping contrasts sharply with the physical appearance of the Laboratory facilities. These facilities are the result of the Laboratory's history and the safeguards required for the nature of the work performed. The crash-program LASL mission and wartime shortages took priority, and most structures were, in spite of the obvious accomplishments which took place in them, temporary, and often prefabricated. Later, during the 50's and 60's, most of these were replaced with more durable, strictly utilitarian facilities, designed in response to stringent AEC construction budgets. At the same time, utilities, roads, parking lots, and security fencing proliferated as a byproduct of Laboratory growth.

In recent years the growing nationwide concern over "quality of environment and quality of life," reflecting changing values and priorities, has become a prominent issue for the Los Alamos community and LASL management. Some recently built structures have been designed with attention to pleasing appearance but with an overall emphasis on utility. Often security requirements have resulted in a lack of landscaping and a large number of unscreened structures and open spaces. On a smaller scale are pump houses, utility service buildings, plain metal buildings, guard stations and the required flood lights and wires. There are some 112 km (70 mi) of chain link fencing, 2.5 m (8 ft) high, topped with three strands of barbed wire. Most of the fencing is not publicly visible because of screening by vegetation and topography. The only places that fencing has a notable public visual impact is at or near entrances to controlled technical areas.

Many buildings in the community itself retain the institutional appearance of the Laboratory facilities, but more consideration has been given to distinctive architecture for newer community structures. Examples are the new Los Alamos school additions, the County Building, and the new facade on the Credit Union Building.

3.3. ROUTINE OPERATIONS

Routine operations at LASL include the supply and consumption of resources, such as water and energy, routine maintenance, the disposal of liquid, gaseous, and solid wastes, and various precautionary procedures.

3.3.1. Supply and Consumption of Resources

Resources routinely consumed by LASL and basic to the operation of the physical plant include water, electricity, natural gas, steam, gasoline, and, to a lesser extent, propane, diesel oil and fuel oil. Other resources used and consumed include construction material, supplies, chemicals, and equipment which are necessary to LASL's research efforts.

Water

An initial water resource investigation of the Los Alamos region of the Rio Grande depression and subsequent investigations of the geology and groundwater resources have been made.[3-3, 3-10, 3-97] Monitoring of well and well field characteristics began when wells were placed in operation. These data were necessary to insure a reliable and continuing historical record to provide guidance for management of water resources and the distribution system. Since 1971 the Laboratory has continued formal documentation of well characteristics and presented recommendations for operation and rehabilitation of the older wells. A summary of well characteristics from 1947-1971 has been compiled.[3-98]

One gallery and three Federally owned well fields--Los Alamos, Guaje, and Pajarito--provide the water supply. The Los Alamos field consists of five wells (one on stand-by), four booster stations, and 19 km (12 mi) of 36 cm (14 in) steel water line (see Figure 3.3.1-1). The wells in the field are from 265 m (870 ft) to 599 m (1965 ft) deep and are completed into the sediments of the Tesuque Formation[3-27] (see Figure 3.1.2-3). The pumping rate of the five wells ranges from 19 ℓ/s (300 gpm) to 37 ℓ/s (590 gpm). The total capacity is about 140 ℓ/s (2200 gpm) or 12 x 10^3 m^3/day (3.1 mgd). However, the maximum capacity at Booster Station 4 is about 115 ℓ/s (1825 gpm) or 10 x $10^3 m^3$/day (2.6 mgd). Thus, the five wells in the field are now capable of producing more water than can be handled through the booster-transmission system.[3-99] The wells in the Guaje field are from 463 m (1520 ft) to 610 m (2000 ft) deep and are completed in the sediments and associated basalts in the Tesuque Formation. The pumping rates of the seven wells range from 17 ℓ/s (270 gpm) to 35 ℓ/s (550 gpm). The total capacity is about 180 ℓ/s (2855 gpm) or 16 x $10^3 m^3$/day (4.1 mgd) through the 14.4 km (9 mi) of line. The maximum capacity of the three booster stations in this system is 171 ℓ/s (2710 gpm) or 15 x 10^3 m^3/day (3.9 mgd). The Pajarito field consists of three wells, three booster stations, and 23 km (14 mi) of 30 cm (12 in) and 41 cm (16 in) concrete cylinder water line. The three wells are from 701 m (2300 ft) to 777 m (2550 ft) deep and are completed in the lower part of volcanic debris of the Puye Conglomerate and sediments and interbedded basalts of the Tesuque Formation. The pumping rates of the wells range from 39 ℓ/s (620 gpm) to 87 ℓ/s (1380 gpm). The total production capacity is 210 ℓ/s (3300 gpm) or 18 x $10^3 m^3$/day (4.8 mgd). The maximum booster capacity on the transmission system is 227 ℓ/s (3600 gpm) or 20 x $10^3 m^3$/day (5.2 mgd). Total production from the three well fields during 1976 was 6.4 x $10^6 m^3$ (1.7 x 10^9 gal). Cumulative production (1947-1976) from these fields is 120 x $10^6 m^3$ (32 x 10^9 gal).

One of the original sources developed in the early years of the project is still in use and makes a valuable contribution to the water supply.[3-100] Water Canyon Gallery is located west of the Pajarito Plateau on the flanks of the Jemez mountains (see Figure 3.3.1-1). Water discharges from fractures in a welded tuff of the Bandelier Tuff, is collected in a gallery, flows by transmission lines to a microfilter station, and is pumped into one of the system reservoirs. The average annual discharge from 1970 through 1976 varied from 4.2 ℓ/s (67 gpm) to 5.9 ℓ/s (94 gpm). The production in 1976 was 1.6 x $10^5 m^3$ (41 x 10^6 gal), and cumulative production (1947-1976) is 6.1 x $10^6 m^3$ (1.6 x 10^9 gal).

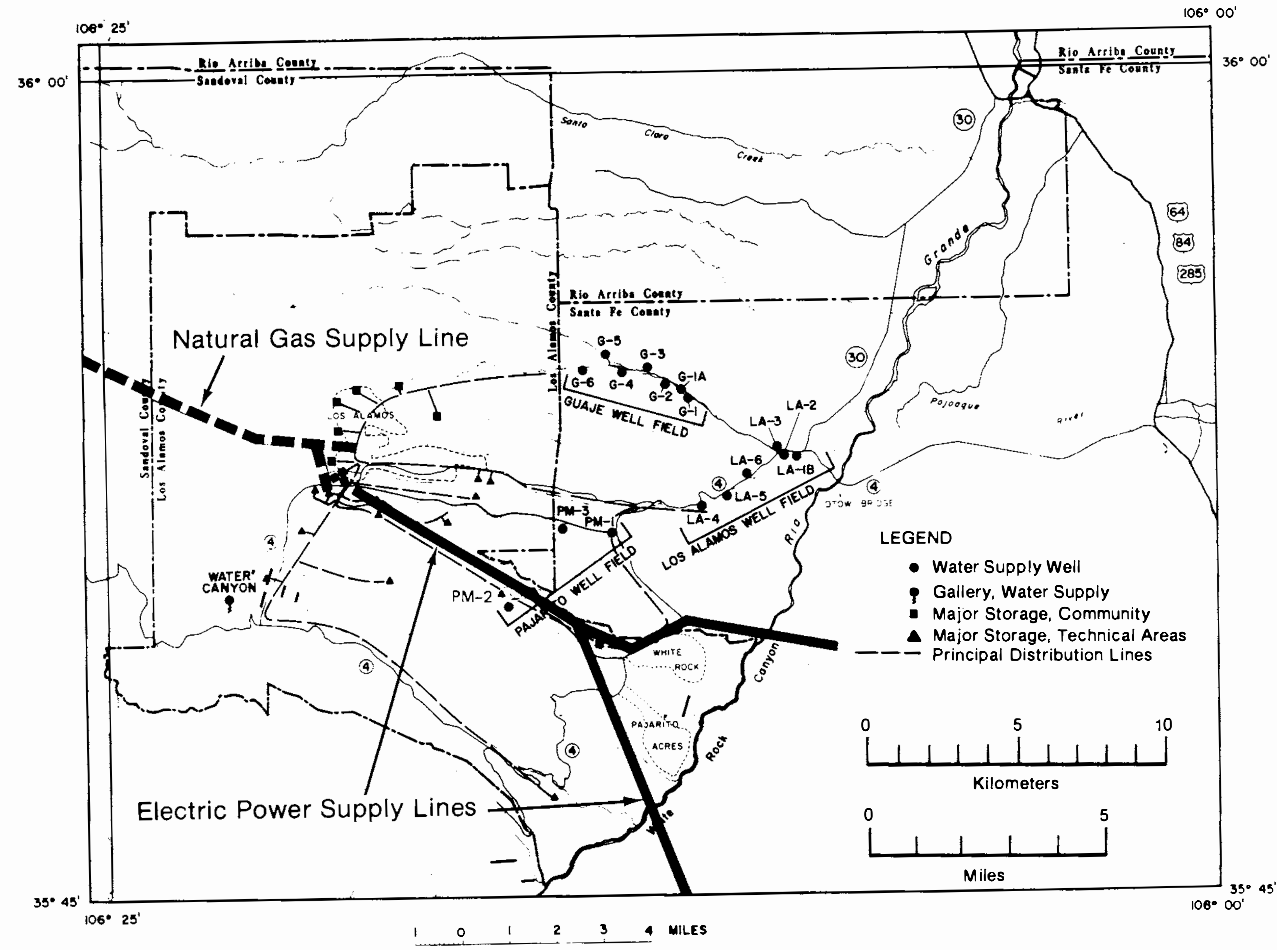


Figure 3.3.1-1. Los Alamos Utilities Supply Systems

The water from the transmission lines and gallery is collected in a number of reservoirs (covered tanks) for distribution to the technical areas and the community. The four reservoirs that serve the technical areas have a capacity of $1.6 \times 10^4 m^3$ (4.2×10^6 gal). The eight reservoirs in the community have a capacity of $9.7 \times 10^4 m^3$ (26×10^6 gal).

The chemical quality of water varies within the well fields because of local conditions in the aquifer. See Table 4.1.1-2 for chemical quality parameters routinely monitored. (See also Appendix H, page H-18 and H-35.)

The public water supply system in Los Alamos County serves LASL research and support facilities and the communities of Los Alamos, White Rock, and Pajarito Acres. On July 1, 1967, the AEC transferred the community water distribution system to Los Alamos County.[3-101]

The total demand for water in Los Alamos County during FY 76 was $6.5 \times 10^6 m^3$ (1.7×10^9 gal). It can be seen from Figure 3.3.1-2 that LASL facility and support functions account for roughly one-third of the total usage. Included in that third, however, is water used by the Zia power plant to generate electricity, part of which goes to the community. The residential and commercial sectors used a total of $4.3 \times 10^6 m^3$ (1.1×10^9 gal) during FY 76. Using an estimated population of 15,900, [3-82] this amounted to $0.74\ m^3$ (196 gal) of water per person per day.

The total demand for water in Los Alamos County through 1978 is shown in Figure 3.3.1-2. The demand in 1976 was $6.5 \times 10^6 m^3$ (1.7×10^9 gal); however, the demand declined to 5.8×10^{63} (1.53×10^9 gal) in 1977 and to $5.6 \times 10^6 m^3$ (1.48×10^9 gal) in 1978. The decline in demand was due to conservation by both LASL and the residents of the county encouraged by higher water rates. It is anticipated that the demand will again increase with growth of LASL and the county, but probably at lower rates than previously projected. In 1978, the LASL related uses amounted to about $2 \times 10^6 m^3$ (0.52×10^9 gal) or about 11% less than in 1976. In 1978, the community use was $3.7 \times 10^6 m^3$ (0.98×10^9 gal). Using an estimated population of 19,600 this amounted to $0.52\ m^3$ (137 gal) of water per person per day, or a decrease of 30% over a two-year period.

Energy

Major energy inputs to Los Alamos are principally in the form of electricity and natural gas (see Figure 3.3.1-1) with lesser inputs being provided by gasoline, propane, and fuel oil. In recent years Laboratory-related use has accounted for more than 80% of the electric power purchased or generated by DOE with the other 20% being resold to the County for distribution in the Los Alamos townsite and to commercial users. White Rock is served directly by the Public Service Company of New Mexico (PSCNM). Roughly half of the total power is purchased from PSCNM and the Bureau of Reclamation; the other half is generated by the Federally owned gas-fired power plant operated by Zia. The purchased power comes from various generating stations on the northern New Mexico power grid (PSCNM) and from the Bureau of Reclamation's Colorado River Storage Project.

Electric use by LASL grew from about 190 to 235×10^6 kwh between FY 72 and FY 75 (see Figure 3.3.1-3). During FY 76 LASL electrical energy consumption increased by 83×10^6 kwh over the FY 75 figure. This increase is due primarily to high energy consumption experimental facilities such as LAMPF. Additional increases are expected as the LAMPF experimental program expands and the operating time is increased. Intensified research on controlled thermonuclear reactions will also require substantial increments of electric power. The additional power requirements will be met predominately by additional purchased power. In 1977, LASL electrical demand grew only by about 11×10^6 kwh and in 1978 dropped 19×10^6 kwh to a level of 310×10^6 kwh, indicating that conservation measures

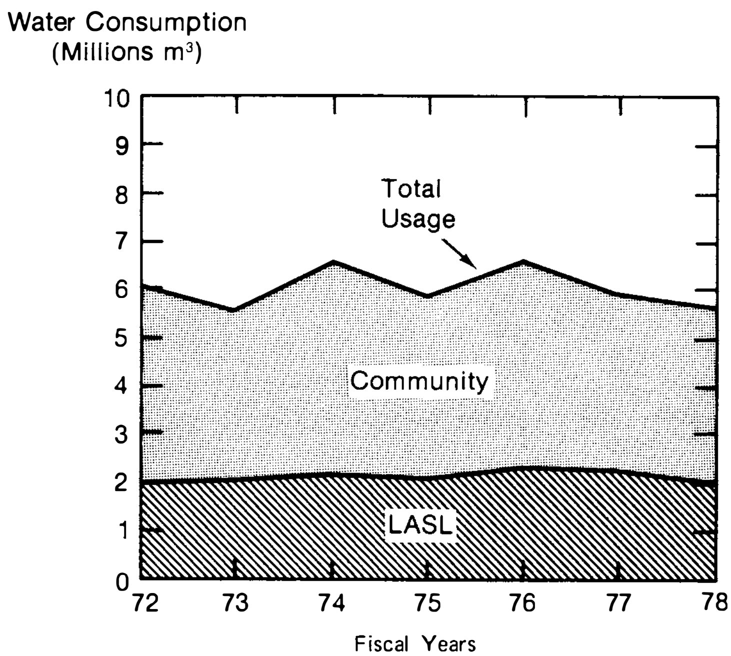


Figure 3.3.1-2. Los Alamos County Water Consumption

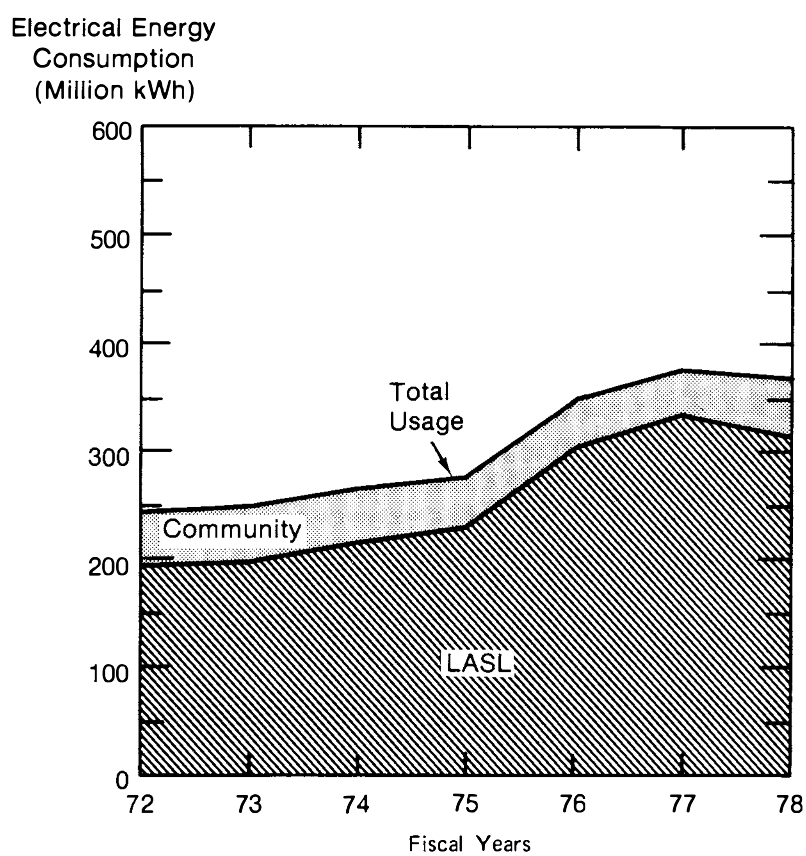


Figure 3.3.1-3. Los Alamos County Electrical Energy Consumption

are beginning to be effective (see Figure 3.3.1-3). It is likely that future growth will be at rates lower than previously projected. The PSCNM is expected to complete improvements to the northern New Mexico power grid that will be adequate to supply anticipated demand through 1983. The two existing transmission lines leading to Los Alamos, modified for compatibility with PSCNM improvements, are adequate to handle this demand. A new 115 kv line is being planned by the PSCNW that will carry electricity generated by a 50 MWe geothermal demonstration project located on the Baca property. The Environmental Impact Statement, DOE/EIS-0049-D, for this project incorporates a discussion of environmental impacts of the transmission corridor that will cross the LASL site and terminate at main technical area. Specific impacts to laboratory land addressed in that DEIS are visual impacts along the scenic highway and laboratory work sites, land use conflicts with proposed laboratory development, construction impacts and subsequent restoration and stablization procedures, access through hazardous areas, potential change in animal migratory patterns, and potential impacts on rare or endangered species.

Natural gas is purchased from the Gas Company of New Mexico. In recent years (FY 72-76) an average of 19% has been resold to the county for residential and commercial use, 63% has been used to fire boilers for the electric generating plant and the steam plants, and 18% has been used directly by the Laboratory (see Figure 3.3.1-4). The steam plants and the power plant serve both LASL and the community. Natural gas consumption has not changed appreciably during the last five fiscal years because of the mild weather, limited new construction, and conservation. Consumption is expected to increase somewhat in the future, mainly because of new Laboratory facilities and homes. The use of gas for electric power generation will remain relatively constant since no expansion of the power plant capacity is planned. The present transmission pipelines are adequate to handle all anticipated demands. Actual consumption in the future is more likely to be limited by gas allocations than by facilities. Actual use continued to decline in 1977 and 1978 as shown in Figure 3.3.1-4 despite continued growth of the Laboratory and the townsite, indicating the effectiveness of conservation measures. As of August 1978, gas for the townsite was no longer bought and resold by DOE, but billed directly by the Gas Company of New Mexico.

Some heat energy is distributed by centralized steam systems that use natural gas as fuel. There are four regularly used steam systems (one supplied by the power plant, three by steam plants) and one standby plant that supply four technical areas and some community facilities.

Government motor pool vehicles consumed about 2.6×10^6 ℓ (680,000 gal) of gasoline in FY 76. This use includes gasoline for heavy equipment, trucks, passenger vehicles, and some stationary equipment. Between 1970 and 1972, usage ranged from about 2.05 to 2.24×10^6 ℓ (542,000 to 592,000 gal). Propane usage for heating at remote locations and operation of some equipment was 60,000 ℓ (16,000 gal) in 1975 and 80,000 ℓ (21,000 gal) in 1976. Diesel oil is used only for a few motor pool trucks, fire trucks, and emergency electric generators. Fuel oil is stored to provide a standby emergency supply for the power and steam plants in case of a natural gas shortage. About 1.93×10^6 ℓ (510,000 gal) are kept on hand, with only small amounts used on a regular basis for practicing emergency procedures and testing equipment.

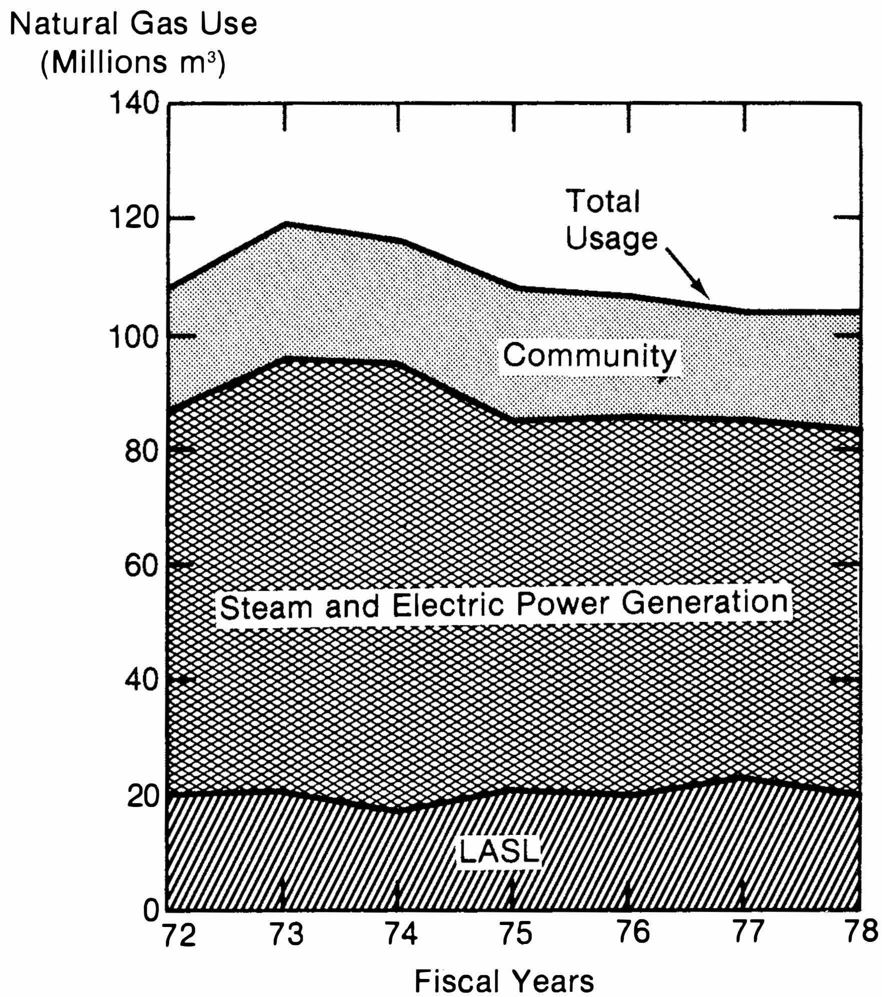


Figure 3.3.1-4. Los Alamos County Natural Gas Use

Other Resources

Other resources used or consumed at LASL cover a wide variety of materials. One of the largest categories is the construction material required for modification of old facilities and the completion of new buildings. In general, these materials are neither unusual nor consumed in quantities greater than similar construction elsewhere. Many of the research facilities in the buildings are complex--including specially designed equipment with large quantities of valuable materials required for their fabrication.

Many supplies, chemicals, and equipment used in the conduct of research represent an investment of consumable natural resources as well as human resources. Table 3.3.1-1 shows some of the major categories and economic values for FY 76. In terms of the load on regional transportation, all supplies must be delivered to Los Alamos by truck. The total annual tonnage for LASL is about 61,000 metric tons (134 x 10^6 lbs). This is handled by an estimated 80 to 100 truck trips per week, many of which are also making deliveries to other businesses. About 80% of the LASL supplies are brought by some 20 commercial carriers, with the balance carried on government vehicles mainly from Albuquerque. The traffic load is a small fraction of the 17,000 to 30,000 vehicle trips per week on the three main arteries leading into Los Alamos.

Certain materials used in LASL operations are of special interest because of their rarity or great value. Examples are helium and precious metals. Helium is used both as a liquid and as compressed gas. The average annual usage 1974-1976 was 76,300 ℓ (20,000 gal) as liquid and 76,300 m^3 (2,695,200 ft^3) as gas. In 1977 the Laboratory initiated a helium collection and recycling effort. A large helium plant acquired for the CTR program has sufficient capacity to handle the Laboratory recycling.

Precious metals are accounted for in terms of economic value (see Table 3.3.1-2). Most precious metals are not consumed but are reclaimed by decontamination or reworking and put to other use once a given purpose has been served.

3.3.2 Routine Maintenance

Routine insect and rodent control at LASL both inside buildings and on Laboratory grounds is contracted to a licensed commercial pest exterminator. Zia Co. applies all herbicides. The pest control plan for the Laboratory is submitted yearly to DOE for review by the Federal Working Group on Pest Management. This is done to assure that all pesticides proposed for use have either an EPA or USDA registration number and that all proposed applications conform with EPA and USDA registered uses and label specifications. The pesticide application frequency schedule for treatment of LASL grounds is specified (seven categories) and varies from one application every two years to a "once only" application. Insect and rodent control inside buildings is accomplished primarily on an "on call" basis except for some areas that require routine application varying in frequency from once per month to once per year. The common names for pesticides used at LASL are listed in Table 3.3.2-1 with the target pest(s) indicated. Much of the herbicide application is necessary to comply with DOE criteria regarding fire and security protection.

TABLE 3.3.1-1

MATERIALS FOR OPERATION AND MAINTENANCE OF LASL DURING FY 76[a]

Category	$ Thousands[b]
Hardware and small tools	1,391
Chemical and small tools	1,790
Metals and metal alloys	802
Electronic supplies	3,127
Mechanical materials and supplies	594
Medical materials and supplies	20
Office materials and supplies	1,399
Clothing	315
Laboratory supplies	1,560
Miscellaneous materials and supplies	382
Special process spares	623

a) Pro-rated from figures for FY 76 and FY 76T.

b) Includes materials in use, but not unused materials in stock.

TABLE 3.3.1-2

PRECIOUS METALS AT LASL AS OF JUNE 30, 1976[a]

Metal	$ Thousands[b]
Gold	160
Silver	2
Platinum	1,320
Palladium	5
Rhodium	40
Iridium	53
Osmium	0.4

a) Includes metals in stock, in use, and returned to stock for cleaning and reworking.

b) Due to the many forms in which theme materials are supplied, the best summary is in the costs to LASL.

TABLE 3.3.2-1

PESTICIDES USED AT LASL

Target Pest(s)	Common Name of Pesticide[a]
Rats, mice, gophers	Diphacinone
Gophers	Strychnine[b]
Cockroaches, silverfish, spiders	Propoxur
Cockroaches	Pyrethrum
Clover mites	Dicofol
Mosquitoes	Temophos
Fungus and mildew (lawns)	Chlorox
Cattails	Dalapon
Broad leaf weeds	2,3,6-TBA
	2,4-D (amine)
	DCPA
Weeds	Bromacil
Vegetation	Benefin
	Ammonium sulfamate

a) Due to various formulations, the total amount of active ingredients used is not available.

b) Below-ground application only.

Custodial maintenance of the LASL physical plant is carried out by the Zia Co. The nature of programs at a research facility such as LASL necessitates high quality maintenance to preserve the safety of personnel, maintain security, and protect the environment. All custodial personnel are security-cleared or in the process of being cleared. No one is permitted in a secured area until cleared. The custodial force as of January 1977 numbered 262 persons. This force is responsible for the maintenance of 423,084 m^2 (4,554,185 ft^2). Routine cleaning frequency in most areas is once/day but varies considerably with the type and use of the facility to cleaning on an "on call" basis. Custodial personnel are not permitted in some special research areas except under very rigid supervision on a special request basis. The great variety of housekeeping tasks requires a similar variety of cleaning and maintenance products including household ammonia, bleach, 13 types of special purpose cleaners, deordorants, two types of detergents, 5 types of polishes, waxes, and finishes, rock salt, two types of sealants, 9 types of soaps, floor stripper, two types of soda, and two types of sweeping compounds.

3.3.3. Waste Disposal

In the early days of the Laboratory, the singular, pressing mission was to make a nuclear bomb. Wastes were handled by the best available methods, but relatively little was known about some of the materials and time and manpower were limited. Solid wastes were buried in pits dug into the tuff on mesa tops--a practice that, with refinements, is still considered the most effective method for this area. Gaseous wastes were filtered using the technology of the time. Liquids with low levels of contamination were discharged into a canyon area unused for other purposes; liquids with higher levels of contamination were discharged into rock-filled pits dug into the tuff. Many of these practices would not be considered adequate by today's standards; fortunately they did not continue for long and led to research into more suitable procedures. Furthermore, continued monitoring over the years has shown that no safety or environmental hazards have resulted from these practices, as discussed in more detail in sections 3.3.4, Environmental Monitoring Programs, and 4.1, Primary Impacts.

Liquid Wastes

Liquid wastes include radioactively contaminated solutions, chemically contaminated wastes, sanitary sewage, cooling water discharges, and storm drainage. Each is handled differently. Radioactively and chemically contaminated wastes are collected and treated separately from sanitary wastes. All liquid sanitary wastes entering the LASL collection systems are eventually routed to LASL treatment plants for routine processing. A special case is the waste collection system at the Health Research Laboratory, where an administrative procedure dictates that liquid wastes containing radioactive or hazardous chemicals be collected in separate portable containers and hauled to one of the contaminated waste treatment plants described below for appropriate processing.

In 1948 a joint effort was started with the US Public Health Service to develop a method for removing plutonium and other radionuclides from radioactive liquid waste. Bench-scale experiments showed that conventional water treatment plant methods could be modified for treatment of radioactive wastes. In 1951 a plant employing flocculation-sedimentation-filtration, with chemicals and flow rates based on the bench-scale studies, began processing radioactive and general industrial wastes for the principal technical areas.[3-101A, 3-101B] In 1963 this original plant was replaced with a facility known as the Central Waste Treatment Plant (see Figure 3.3.3-1). The main technical areas had moved away from the original plant during the intervening years. The new plant was more centrally located with respect to the waste sources and further south from the townsite. An ion-exchange facility for the removal of strontium was incorporated into this plant.

The bulk of the radioactive liquid waste is routed to the central treatment facilities by pipe collection systems that are completely separate from the sanitary sewage systems (see Figure 3.3.3-2). These collection systems differ from the usual sanitary sewer networks because waste character, topography, and, in some cases, a need to monitor individual sources, require the use of a considerable number of storage tanks, neutralization stations, and pumps. Limited quantities of liquid radioactive wastes are generated at remote locations. These wastes are collected in holding tanks on location. Periodically, small portions of these wastes are sampled for assay and batches of waste are collected from the tanks and transported to the Central Waste Treatment Plant for processing. U.S. Department of Transportation regulations are used as a guide to transportation of these batch wastes.[3-101C]

The main radioactive elements removed from wastes before discharge to the environment are plutonium (^{238}Pu and ^{239}Pu), americium (^{241}Am), uranium (^{235}U), strontium (^{89}Sr and ^{90}Sr), and cesium (^{137}Cs). The plutonium, americium, and uranium are removed at the treatment plants by a chemical process that results in the concentration of the radionuclides in a sludge. At the Central Waste Treatment Plant this sludge is dewatered by vacuum filtration until it is a solid with the consistency of wet clay (30-40% solids). Further drying would result in little additional volume reduction and would increase the possibility of airborne dust during packaging. It is then placed in polyethylene-lined steel or unlined fiber drums, depending upon retrievability requirements, and handled as contaminated solid waste (see Figure 3.3.3-3). In 1976, eighty-three 215-ℓ (57 gal) steel drums and six hundred and thirty 200-ℓ (53 gal) fiber drums were used to package 138,300 ℓ (36,500 gal) of dewatered sludge for delivery to burial at the waste burial/storage area. None of the packages contained sufficient transuranic activity to require storage as explained later in this section under <u>Solid Wastes</u>. The total sludge volume contained 2.75 Ci of ^{238}Pu, 0.36 Ci of ^{239}Pu, and 0.15 Ci of ^{241}Am. Strontium and cesium in wastes at the Central Waste Treatment Plant are removed by ion exchange and separate batch chemical treatment of the spent regenerant. The spent regenerant is treated by addition of a chemical precipitant to remove most of the radioactivity into a sludge which is dewatered by vacuum filtration and handled as the other sludges. The liquid is reprocessed through the treatment plant. After many years of use, the ion exchange resin is removed from the columns, solidified by dewatering, and handled as solid waste.

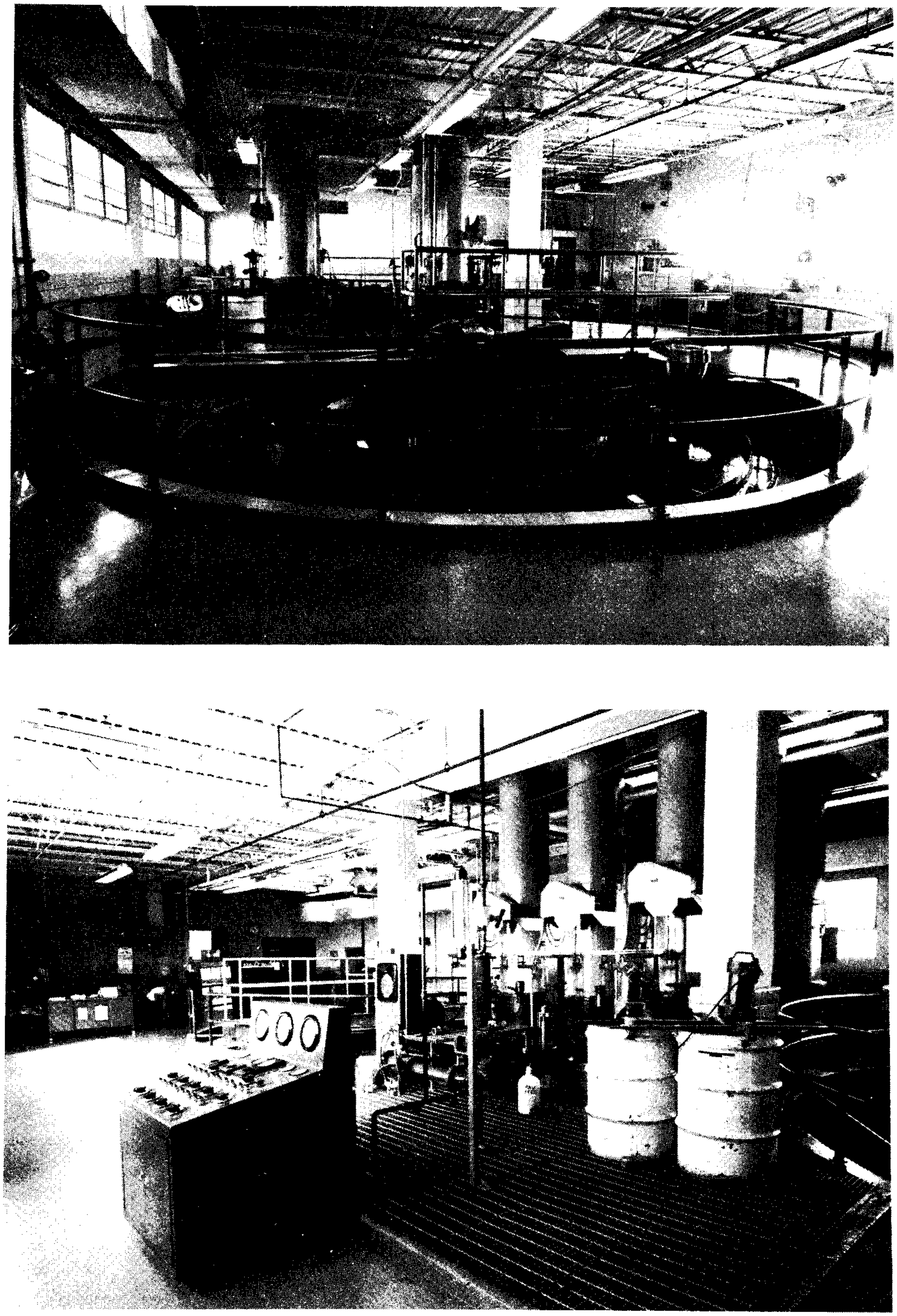


Figure 3.3.3-1 Central Waste Treatment Plant at LASL

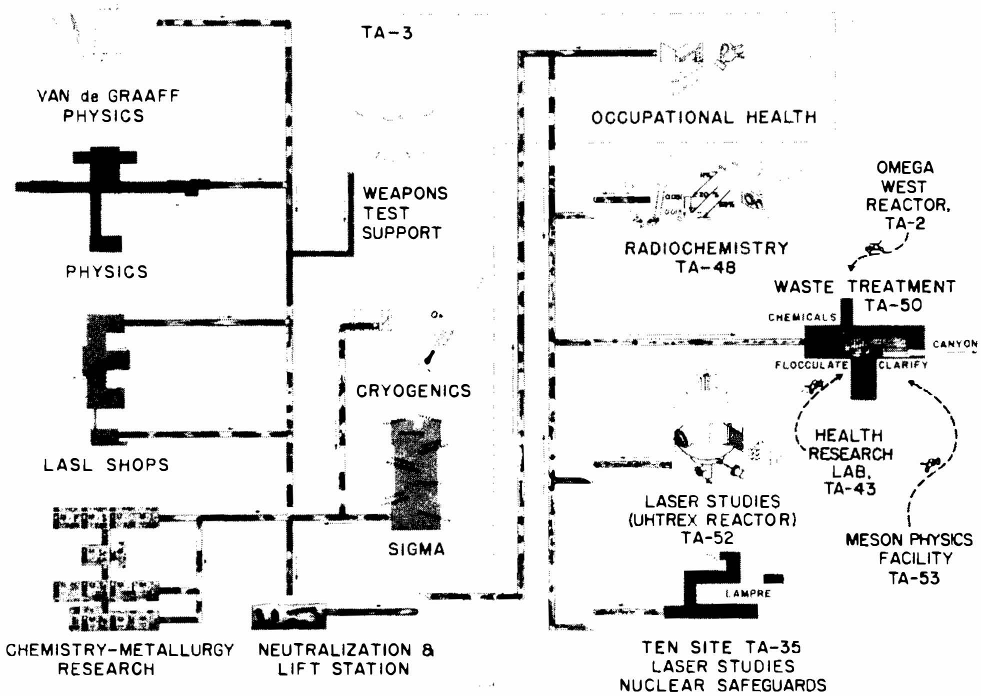


Figure 3.3.3-2 Schematic Diagram of the Waste Collection System Serving the Central Waste Treatment Plant

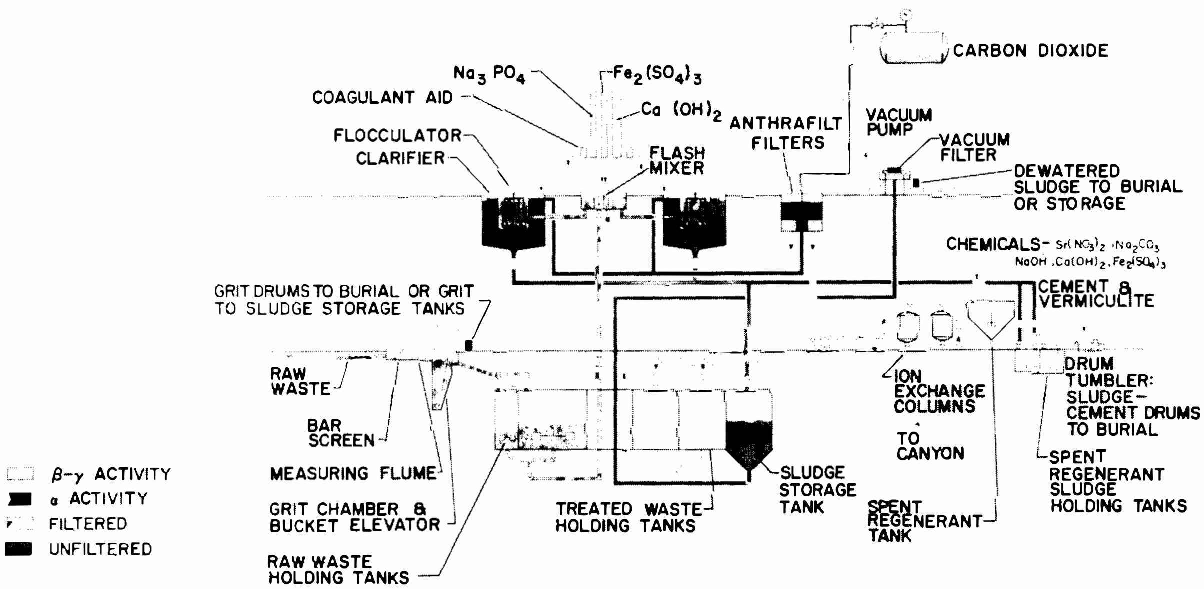


Figure 3.3.3-3 Schematic Flow Diagram of the Normal Method of Operation at the Central Waste Treatment Plant

In 1952 treatment of wastes from the Plutonium Processing Facility at a technical area east of the Townsite was initiated in a plant using an identical treatment process.[3-101D] In 1967 this plant was replaced with a plant located approximately 100 m east. The plutonium facility was remote enough from the Central Waste Treatment Plant and produced enough waste to warrant a separate plant. The new Plutonium Processing Facility is in an area adjacent to the Central Waste Treatment Plant. Its wastes are treated at the Central Waste Treatment Plant along with most of the other radioactive liquid wastes generated at LASL. The east plant built in 1967 will be required for intermittant treatment of radioactive wastes, other than those containing plutonium, which will be generated by operations remaining in the old technical area.

At the Plutonium Processing Facility Waste Treatment Plant, the sludge is mixed with cement to form a paste and pumped to asphalt-lined burial shafts where it hardens. Americium-containing waste is also mixed with cement and pumped into retrievable metal containers. In 1976, 137,400 ℓ (36,300 gal) of paste were pumped to the retrievable containers and 148,200 ℓ (39,200 gal) were pumped to the non-retrievable burial shafts. Radioactivities involved are shown in Table 3.3.3-1. In 1978, larger amounts of ^{241}Am were placed in retrievable storage because of decontamination at the old plutonium processing facility.

The wastes containing most of the strontium and cesium received at the east plant are collected in separate process waste storage tanks, neutralized, mixed with cement, and pumped to the burial shafts. During each treatment, samples of the cement paste are collected for curing and compressive strength testing to ensure and document appropriate mixtures for solidification. The normal industrial waste flow to this plant contains very little of the strontium-cesium waste and thus is given only the physical-chemical precipitation treatment.[3-101D]

Tritium is present in the normal industrial waste stream, but at concentrations averaging much less than DOE Concentration Guides.[3-102] The processes described above for removal of other radioactive elements are not effective in removing tritium, so administrative requirements and standard operating procedures are used to ensure that tritium-bearing wastes are kept separate. These wastes are then solidified and handled as solid wastes for burial.

Since their inception, all of the treatment plants have been operated to "concentrate and contain" radioactivity in wastes to the extent that radioactivity released in the treated liquid was at the lowest practicable level, that is, as low as technically and economically achievable. For example, the plutonium concentrations in effluents have averaged less than 10% of the concentration guides during the past few years (see Figure 3.3.3-4.). A continuous effort is made to minimize the quantity of plutonium released. Administrative requirements implemented by standard operating procedures provide for retreatment of any batch of effluent if the plutonium concentration exceeds 40% of the DOE Concentration Guide.

TABLE 3.3.3-1

RADIOACTIVE SLUDGE AND CEMENT PASTE WASTES PLACED AT THE PLUTONIUM PROCESSING FACILITY TREATMENT PLANT IN 1978

	Non-Retrievable Shafts	Retrievable Containers
^{238}Pu	0.46 Ci	5.11 Ci
^{239}Pu	0.60 Ci	14.91 Ci
^{241}Am	16.35 Ci	3321. Ci
Mixed Fission Products	0.007 Ci	0.20 Ci

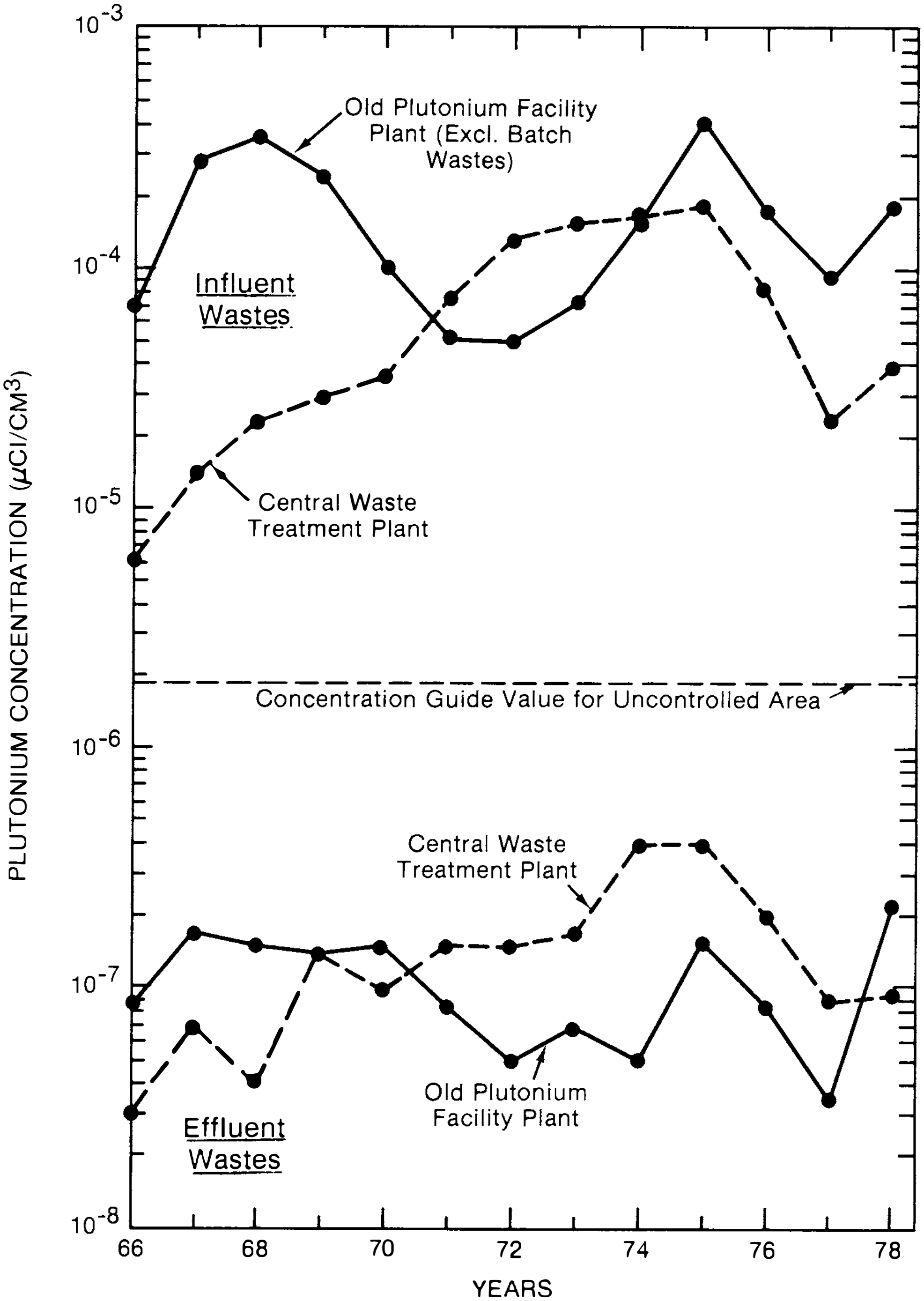


Figure 3.3.3-4. Annual Average Plutonium Concentrations, 1966-1978

The volume of waste has not increased as rapidly as the development of the Laboratory and the addition of new facilities largely because of a continuing effort to keep wastes that do not require treatment from entering the system. The Wāste Management Group's policy is to accept for treatment all liquids that are potentially contaminated with radioactivity. However, experience has shown that in most cases the large flow increases have no potential for contamination, and they are terminated or redirected to storm or sanitary waste collection systems. All pump motors at pumping stations are equipped with timers to indicate total hours of operation; this allows computation of the quantity of waste received at the station. In cases where wastes drain directly to the industrial sewers, other metering devices are used to indicate the rate at which wastes are being generated. Administrative controls and standard operating procedures limit the concentrations of radionuclides. Unusual increases in waste volumes are investigated immediately. As shown in Figure 3.3.3-5, the volume of liquid waste treated annually has been controlled.

Effluents from these two LASL waste treatment plants are presently discharged in compliance with the National Pollution Discharge Elimination System (NPDES) permit issued by the Environmental Protection Agency. The quality of these effluents is discussed in more detail in Section 4.1.1.

Waste treatment personnel are also concerned with nonradioactive chemical wastes, most commonly heavy metal solutions, cyanide solutions and metal-containing acid pickling baths, fluoride cleaning solutions, and chromic acid solutions. The majority of these wastes are routine and are disposed of by following detailed standardized operational procedures at the Central Waste Treatment Plant. Occasionally, specific wastes require some bench-scale experimentation before they can be treated.

The concentrates resulting from these treatment practices are disposed of as solid wastes at an established chemical waste burial area. Small quantities, less that 200 ℓ (55 gal), of liquid wastes, that cannot be reduced by any practical treatment, are also disposed at the chemical waste burial areas.[3-103] In 1976, 14,000 ℓ (3,700 gal) of flouride cleaning solution, 1,000 ℓ (260 gal) of chromium wastes, 1,000 ℓ (260 gal) of copper wastes, 600 ℓ (160 gal) of nickel wastes, and 3,300 ℓ (870 gal) of miscellaneous wastes were disposed of in this manner.

Certain dilute wastes containing explosive residues and organic compounds are generated at sites handling high explosive materials.[3-104] These wastes flow through detention or settling basins to permit removal of particulate matter, then to the environment. The solids are collected periodically from the basins and burned in an operation described in the section on Solid Wastes (3.3.3.3). Monitoring studies indicate that the average daily discharge of about 50,000 ℓ (13,000 gal) from the six major generating sites are not producing health or safety hazards from residual high explosive materials in soils over which the effluents flow.[3-104]

Approximately 45,000 ℓ (12,000 gal) of uncontaminated waste oil and grease are disposed of each year through the Zia vehicle motor pool, the heavy equipment shop, and two major machine shops. The oil is collected in a storage tank located at each site. Much of the motor vehicle oil is taken from Zia by a commercial firm for recycling. The balance of the waste oil and grease is disposed of in the County-operated landfill. An additional 57,000 ℓ (15,000 gal) of grease and water is collected annually from the Laboratory cafeterias. At the County sanitary landfill the oil, grease and water are dumped into a trench and immediately covered with dirt.

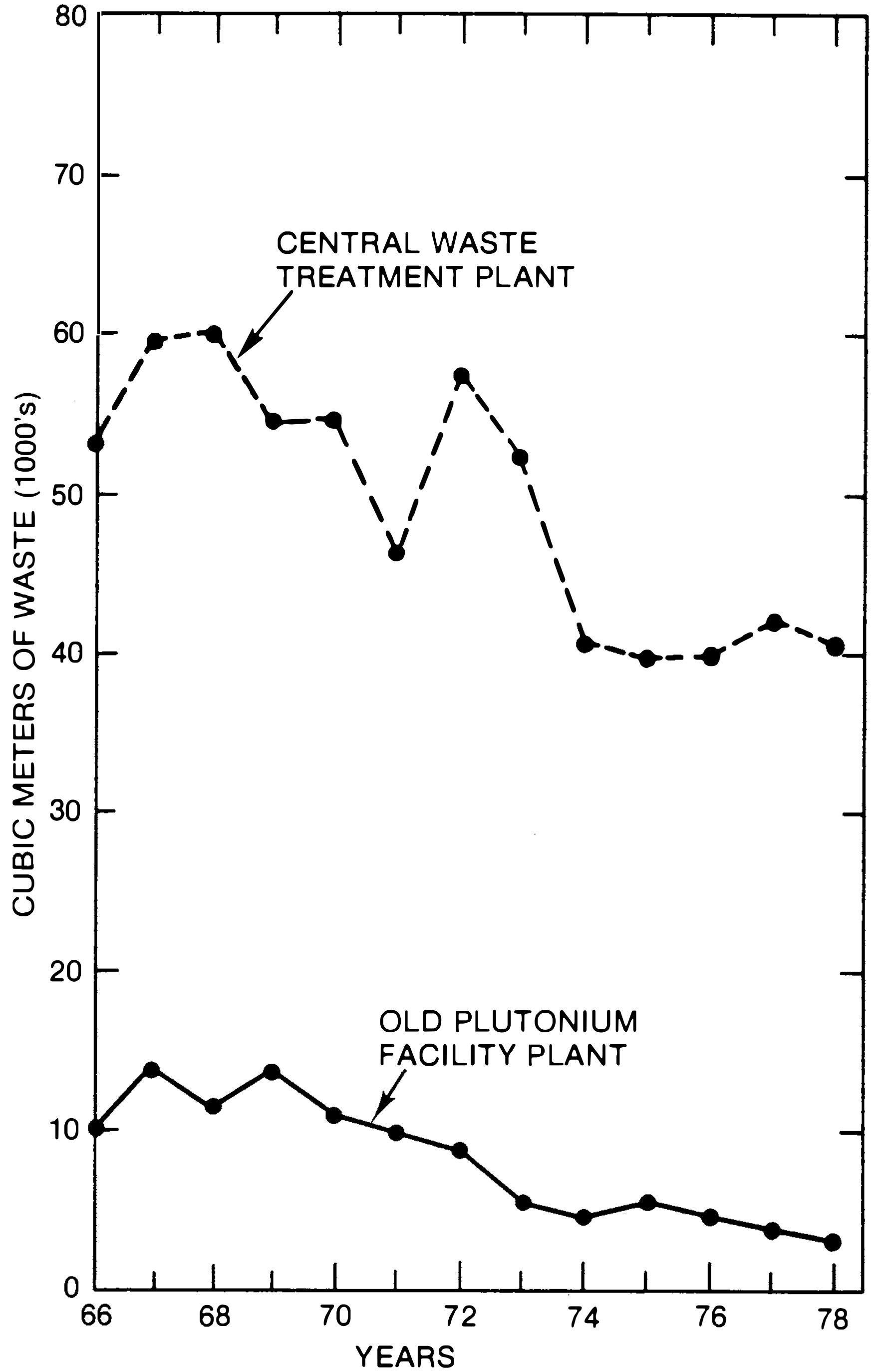


Figure 3.3.3-5. Volumes of Waste Treated per Year, 1966-1978

Approximately 30 cooling water discharges are scattered throughout the technical areas, 15 of which discharge more than 3,800 /day (1000 gal/day) on any operating day. Some of these discharges contain small concentrations (less than 50 ppm) of water conditioners and algicides. Phosphonic acids and polyacrylate dispersants are added in small quantities; these materials are biodegradable. Lithium hypochlorite is used in small quantities as an algicide, but average chlorine residuals are low and readily dissipate after contacting the ground surface. Within a year, quarternary ammonium compounds are expected to replace the hypochlorites now used. The cooling towers at the electric generating plant use chlorinated effluent from the Main Technical Area sewage treatment plant and chlorinated water from the water distribution system.

Sanitary sewage treatment at LASL technical areas requires four treatment plants, six lagoons, and over 30 septic tanks (see Figure 3.3.3-6). These facilities range from plants serving approximately 2800 people at the main administration and lab area of South Mesa to septic tanks serving only one person at places like protective force security stations. Remoteness of locations, local topography, and economics preclude a collection system with one central treatment facility.

The effluents from the treatment plants and lagoons are discharged into normally dry canyons or streambeds where they soak into the on-site alluvium, are depleted by evaporation, or are further diluted by mixing with natural runoff. The major influence on the environment is to provide additional water supply for vegetation and wildlife. The quality of these effluents are discussed in detail in Section 4.1.1.

The septic tanks at remote technical areas are similar to common household units. They are designed as recommended by the USPHS Manual of Septic Tank Practice to provide the most effective and economical treatment of sanitary wastes at isolated locations. Seepage pits or sand filters are used following the septic tanks, depending upon spatial restrictions and local soil percolation rates. The tanks are widely spaced and present no potential contamination of surface or ground waters.[3-105, 3-106]

In October 1978, the EPA issued a single NPDES permit to DOE covering effluents from the 104 industrial discharge points and 10 sanitary seweage treatment facilities at LASL. The permit, number NM 0028355, was published by EPA in advance for public comment and review by the New Mexico Environmental Improvement Division. A summary of the outfall categories, constituent limits, and compliance status is in Section III.B.3.b. of Appendix H.

Rainfall runoff and snowmelt results in storm drainage from streets, roads, parking lots, and other impervious areas. It is controlled and routed to minimize erosion, with most drains discharging into natural water courses in the canyons. Because of the small amount of impervious area in relation to the natural drainage, the additions of water to natural flow are generally insignificant.

The County treats all sanitary wastes generated outside the Laboratory boundaries. The County owns and operates three sanitary waste treatment facilities. There are two trickling filter plants serving the Los Alamos townsite, one in Pueblo Canyon and the other in Bayo Canyon. They are presently operating at about 85% and 45% of design capacity, respectively. About one-third of the Pueblo plant effluent is used to irrigate the golf course during the normal irrigation season. There is also a trickling filter plant in White Rock, presently operating at about 60% of design capacity. See Section 4.3.1 for additional information on effluents.

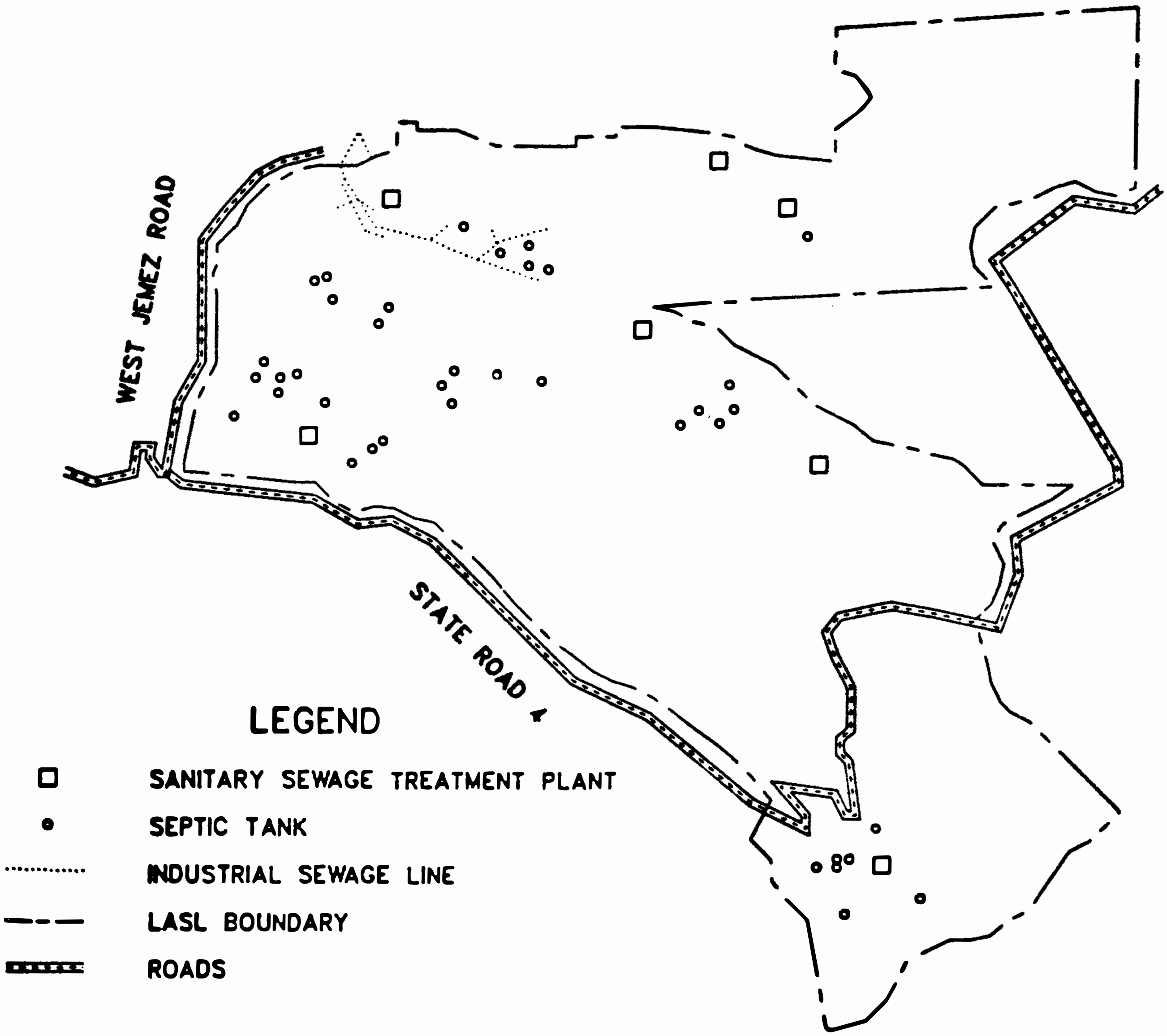


Figure 3.3.3-6. LASL Sanitary and Industrial Waste Disposal Systems

Solid Wastes

LASL defines radioactively contaminated solid waste as any material that contains known or suspected radioactive contamination and that is judged to have no recoverable value or additional useful life. Generation of radioactive solid waste has averaged about 6000 m^3 (7800 yd^3) per year over the past 20 years and has ranged between approximately 4000 m^3 (5230 yd^3) and 8000 m^3 (10,460 yd^3) annually through 1978. Much larger volumes, ranging up to 14,000 m^3 (18,300 yd^3), were generated in 1975 and 1976 because of major decontamination projects associated with former facilities.

Radioactive contamination contained in waste buried since 1972 has ranged between approximately 3,500 and 39,000 Ci per year, of which about 90% (65,000 Ci) has been tritium. Based upon present and projected Laboratory programs, an estimated 30,000 Ci annually is expected to be buried through the forseeable future; most (80%-90%) of this is expected to be tritium.

Before mid 1971, all radioactive wastes at LASL were disposed of by burial. Since then, procedures and techniques have been developed to store transuranic wastes for at least a 20-year period, pending possible removal to a more permanent facility. Between 280 m^3 and 425 m^3 (10,000 to 15,000 ft^3) of retrievable transuranic waste are generated per year. Most of this comes from the plutonium operations at the Plutonium Processing Facility.

All solid waste materials generated in LASL operations are classified into one of three categories according to the type and amount of known or suspected contamination. These are:

Type 1 - Waste materials generated in Laboratory areas where no radioactive materials are handled. These are disposed of at the Los Alamos County Landfill.

Type 2 - Waste materials, generated in areas where radioactive materials are used, but known to contain materials contaminated with transuranic radionuclides below 10 nCi per gram of waste (less than 100 nCi/g of ^{238}Pu contaminated waste).* Such wastes are buried at the LASL radioactive waste disposal site.

Type 3 - Waste materials contaminated with transuranic radionuclides in excess of 10 nCi/g (greater than 100 nCi/g of ^{238}Pu)* require special packaging and handling. These waste materials are stored retrievably at the radioactive waste disposal site for a 20-year period in accordance with DOE policy.[3-107]

*The 10 nCi/g criteria for wastes containing mixed transuranic contamination is required by DOE procedures[3-107]; the 100 nCi/g criteria for wastes containing only ^{238}Pu contamination is a LASL administrative procedure.

Radioactive solid waste generated at LASL includes combustible and noncombustible trash, chemicals, equipment, building debris, sludge and cement paste from the radioactive liquid waste treatment plant, absorbed oils, animal tissue, and hot-cell waste. Radioactive contaminants known to be or potentially in these wastes, and the precentage of total waste volume containing the contaminents are: transuranics (mostly $^{238,239}Pu$ and ^{241}Am), 65%; uranium (enriched, normal, depleted), 27%; mixed fission product and activation product radionuclides, 7%; tritium, 1%.

All waste materials generated at the LASL Plutonium Processing Facility are instrumentally assayed to determine whether they will be buried or require retrievable storage. The Multi-Energy Gamma Assay System (MEGAS) was developed at LASL specifically to survey low-density wastes. This instrumentation has a sensitivity well below the 10 nCi/g level to ensure that radioactive wastes are properly segregated and handled. In other Laboratory areas, administrative segregation procedures are used to identify wastes requiring retrievable storage.

Approximately 75% of the waste volume buried or stored originates at three Laboratory areas. About 20% of the total is generated at the Plutonium Processing Facility, about 40% at the laboratories in the Main Technical Area on the South Mesa, and about 15% at the Central Waste Treatment Plant. The radioactive waste disposal area in use is Area G, located on Mesita del Buey (see Figure 3.3.3-7). The dedicated waste disposal area contains a total of about 320,000 m^2 (80 acres) of which approximately 150,000 m^2 (37 acres) has been in active use since 1958. Based upon current waste generation rates, this area should provide an additional 15 or more years use. However, since the entire Mesita del Buey has been designated for the handling of operational solid waste, there will still be another 90,000 m^2 (23 acres) available for use beyond that time. If prospective waste volume reduction plans are successful, the useful period will be extended.

Area G on Mesita del Buey is centrally located with regard to most present and future Laboratory operations. Most of the waste handled comes from the Main Technical Area and the Plutonium Processing Facility and must be transported about 10 and 16 km (6 and 10 mi), respectively. In addition, waste from the Plutonium Processing Facility has been transported through the townsite. DOE procedures provide that shipments of hazardous materials by an agency of the Federal Government in its own vehicles operated by its own employees are not considered to be in interstate commerce,[3-108] and the Department of Transportation's Regulations are not applicable to such shipments. The DOT packaging regulations are followed where possible, as a matter of DOE/LASL policy. Where not physically or economically feasible, radioactive waste shipments at LASL are made in a manner which afford equivalent protection of the public's health and safety as would compliance with the DOT's regulations. Once the old Plutonium Processing Facility is decontaminated transport will then be entirely on Laboratory property along Pajarito Road for a distance of only about 7.2 km (4.5 mi) from the new Plutonium Facility.

For wastes to be buried, packaging is provided to meet the requirements of safe on-site handling and transport. Following burial of the waste, the containment is provided by the geologic media of the burial ground. Trash-type wastes that are generated in laboratory room areas where radioactive materials are handled, most of which have no detectable contamination, are in all cases assumed to be at least potentially contaminated. These wastes are packaged in cardboard boxes and/or plastic bags

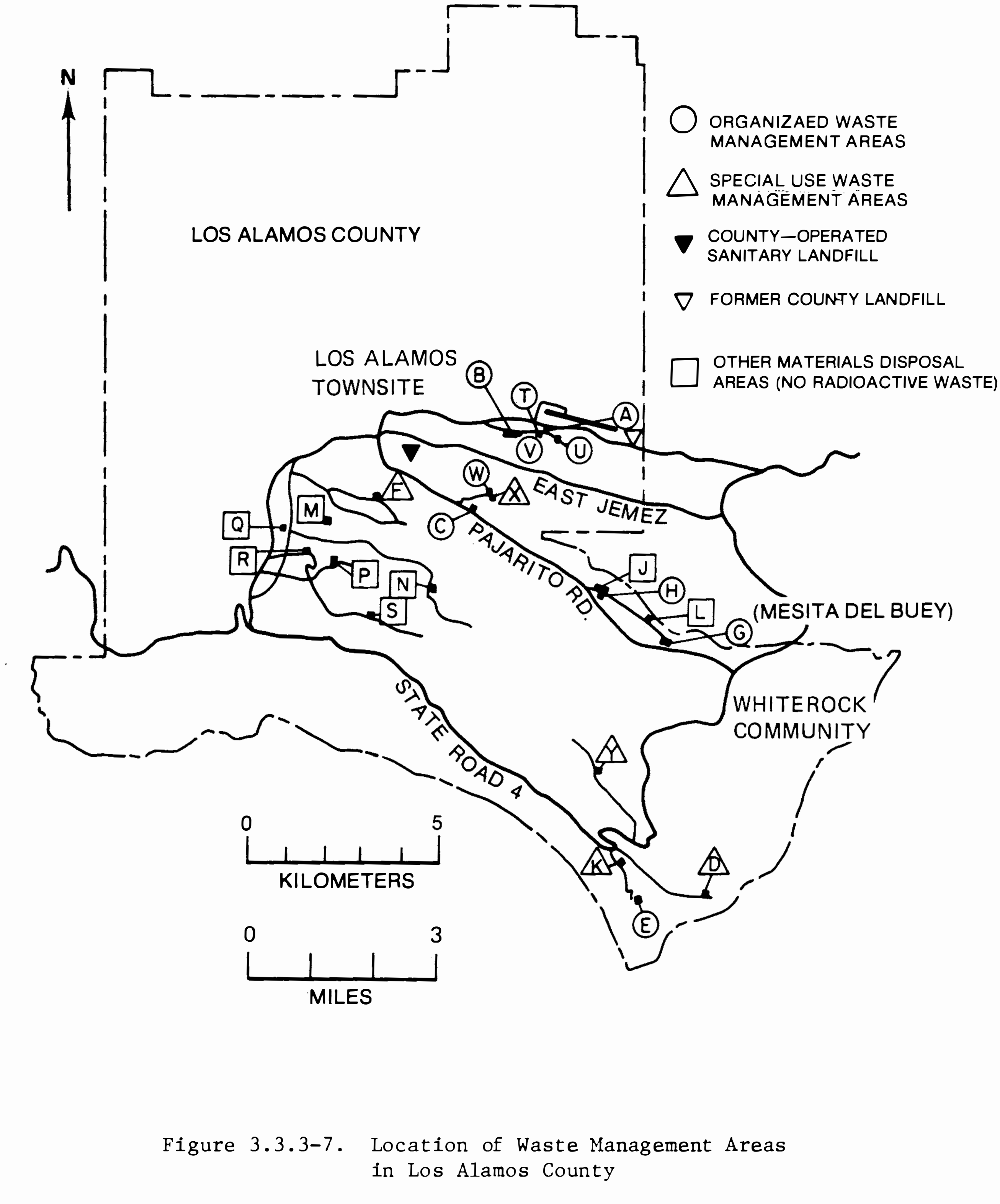


Figure 3.3.3-7. Location of Waste Management Areas in Los Alamos County

and are transported to the radioactive waste disposal area in truck-handled, locked, waste containers. However, it should be noted that two types of truck-handled trash waste disposal bins ("Dempster Dumpsters") are located throughout the LASL complex. Where radioactive materials are used, Dumpsters for radioactive waste are employed. These Dumpsters are clearly identified and locked with keys distributed only to a selected few individuals responsible for loading the bins. Locks are also provided on the dumping mechanism for these contaminated waste Dumpsters with keys located only at the radioactive waste disposal area. In areas where radioactive materials are handled, Dumpsters for nonradioactive waste are also locked with keys distributed to a selected few individuals. These individuals are given the responsibility to inspect material each time it is loaded. A portal monitor (gamma-ray detector) is in operation at the County-operated landfill to help preclude the inadvertent dumping of radioactive waste.

Other waste materials, chemically contaminated and/or containing larger amounts of radioactivity, are packaged in sealed metal or fiber drums and transported by truck. Radioactive waste oils are absorbed on solids prior to packaging in metal containers. Equipment and building debris may be packaged in wooden crates and transported by truck. Because of the high mobility of tritium even in extremely dry environments, wastes containing greater than 20 mCi/m^3 of tritium are packaged in special asphalt-coated, sealed metal drums. Complete encasement of tritium wastes with asphalt is accomplished when more than 100 Ci/m^3 are present. Most of the very high activity tritium wastes consist of tritiated water absorbed on molecular sieve or other sorbant.

All waste packages and/or transport vehicles are monitored prior to leaving the generator site to assure that there is no external contamination. Following delivery of waste to the disposal site, all transport vehicles again are monitored for contamination prior to leaving the site. A health physics technician is present at the radioactive waste disposal site during all working hours to handle routine monitoring and any unusual circumstances.

All nontransuranic (nontrievable) trash type wastes are compacted and baled to reduce volume before burial. A volume reduction factor between 5:1 and 6:1 is being attained, with approximately 85 m^3 (3000 ft^3) of waste being treated monthly. The compacted bale, measuring about 0.4 m^3 (14 ft^3) and weighing approximately 200-300 kg (440-660 lbs), is placed directly into a disposal pit for burial.

The compactor-baler is located in a small building at the Mesita del Buey disposal site. The unit, model DHBS-2MR, manufactured by the Consolidated Baling Machine Company, Brooklyn, New York, is specially designed to compact radioactive wastes and contain radioactivity.[3-108A]

Operated in accordance with established procedures,[3-108B] any possible contamination is contained by filtering air flowing through the unit through roughing and High Efficiency Particulate Air Filters at the rate of approximately 90 m^3 (3200 ft^3) per minute. Air is exhausted from the compactor room to the outside through a single HEPA filter at the rate of seven room air changes per hour. Continuous alpha, beta-gamma, and tritium air monitors with alarms operate in the compactor room when the unit is in use.

Most of the nonretrievable radioactive solid waste generated at LASL is disposed at the Mesita del Buey site by burial into pits and shafts. In 1974, LASL waste management and environmental scientists significantly expanded criteria, developed in 1965 by the U.S. Geologic Survey,[3-21] to ensure adequate containment of radioactive wastes. The criteria describe disposal facility sites, orientation, construction, approval, use, documentation, and site conditioning requirements following use.[3-108C] Burial pits typically measure 120 to 180 m (400 to 600 ft) long by 8 to 30 m (25 to 100 ft) wide by 8 to 11 m (25 to 40 ft) deep. Burial pits typically are filled in layers, with vehicles that deliver waste to the site entering the pit over noncontaminated backfill whenever possible. Combustible waste that is not compacted, wind-disbursable wastes, and waste having any possible external contamination are covered with excavated tuff backfill on the day it is delivered. When the capacity of a disposal pit is reached, a final covering to ground level of a minimum of 1 m (3 ft) of excavated tuff is applied. An additional mounding over the pit of up to 1 m (3 ft) also may be applied depending upon pit orientation, drainage patterns, and other factors. Shafts generally measure 0.6 to 2.4 m (2 to 8 ft) in diameter by 8 to 20 m (25 to 60 ft) deep.

Waste materials routinely placed into disposal shafts include tritium waste, high beta-gamma radioactive wastes, animal tissue, classified waste, many contaminated chemical wastes, and other wastes whose properties might indicate that shaft disposal would be safer than pit disposal. Non-transuranic cement paste waste generated at the liquid waste treatment facility at the LASL Plutonium Processing Facility is disposed without additional packaging into shafts at that site (LASL disposal Area T).

Disposal shafts at the Mesita del Buey site are filled no closer than three feet of the ground surface. Excavated tuff backfill may then be added before capping the shaft with a minimum 1 m (3 ft) plug of concrete. Concrete then is used to mound up to an additional 0.3 m (1 ft) above the ground surface.

Retrievable transuranic wastes (Type 3) require special packaging such that the waste package can be retrieved in twenty years. The ultimate disposition of such retrievable wastes is to be determined by DOE on a nationwide basis, with several options now being considered. Thus, only quality-controlled packaging, meeting stringent specifications, are used for the bulk of the LASL transuranic wastes, contaminated with ^{239}Pu. These are 210-ℓ (55 gal) DOT 17C drums and and wooden crates of varying size coated with 3.2 mm (1/8") of fire retardant fiberglass reinforced polyester. These wastes are stored in a modified disposal pit. Pit modifications, intended to assure protection of the waste packages in the storage array, include an asphalt paved floor, and sumps for collection and containment of water from rain and snow. Wastes packaged in drums and crates are stacked to within 1 to 1.5 m (3 to 5 ft) of the ground surface. The stack is covered on top with 3/4 inch plywood and the entire stack is encased in heavy vinyl. Excavated tuff is used to backfill to the ground surface. Before the backfilling, access pipes are installed that allow for monitoring conditions such as temperature, humidity, radioactive contamination, and combustible gases.

Recoverable high activity ^{238}Pu and ^{233}U wastes are retrievably stored in concrete casks, each holding two 115-ℓ (30 gal) drums of waste, and placed in shallow trenches. After filling and sealing, the casks are covered with heavy-gauge galvanized corrugated sheet metal, and excavated tuff is backfilled to ground level with a minimum cover of 1 m (3 ft). Additional backfill is used to mound approximately 0.6 m (2 ft) over the trench to provide for proper drainage.

Retrievable cement paste waste that is generated at the Plutonium Processing Facility's liquid waste treatment plant is pumped into welded, galvanized, corrugated metal pipe sections that are standing vertically in a 7 m (23 ft) deep pit at the site. These pipe sections, which have a 0.3 m (1 ft) cement plug at the bottom, are filled to within 0.3 m (1 ft) of the top and a cement plug is poured to seal the unit. Finally they are covered with excavated tuff backfill.

Planning and design work have been completed and fabrication initiated for the installation of a LASL waste size-reduction facility, initially planned for installation at the Central West Treatment Plant. This facility is different from the volume-reduction facility discussed above in that cutting and disassembly techniques will be used to reduce the size of bulky wastes such as transuranic contaminated equipment generated by the decontamination of the Plutonium Facility at DP-site. Substantial volume reduction and decontamination of the wastes are anticipated, thus markedly reducing the volume of transuranic waste requiring retrievable storage.

Waste Management Studies

A variety of special studies have been under way at LASL for several years addressing environmental conditions, geologic and hydrologic properties and processes, equipment, packaging, methodology, and theoretical modeling relating to burial of radioactive waste. (Refs. 3-108D, 3-108E, 3-108F, 3-108G, 3-108H, 3-108I, 3-108J, 3-108K, 3-108L.) These continuing studies are producing a growing body of knowledge about the subsurface disposal areas at Los Alamos. The programs are expected to contribute information and understanding of general value as well as being especially important to planning future waste management options. Many of the studies are focused on the hydrology of the present and former disposal areas. They range from general studies of the geology of the plateau to very localized investigations of moisture movement in and near disposal sites. Some have been undertaken specifically in response to suggestions from independent reviews.[3-108M]

Another major study effort recently initiated by the LASL Health Division is the examination of long-term waste management alternatives for the buried and retrievably stored wastes in the various locations at LASL. The environmental consequences, economic costs, and radiological risks to the public and workers are being estimated for three major alternatives. The alternatives are to continue present practices, to provide added engineered containment for the inactive sites, and to selectively retrieve transuranic wastes burial prior to the time when wastes with activity greater than 10 nCi/g began to be stored. For each major alternative, several options will be evaluated for resistance to natural phenomena, accidental release of the buried waste, and long-term monitoring requirements. The analysis will address the inactive sites as well as the currently used disposal sites.

Present environmental monitoring programs ongoing within the disposal area include the collection of meteorological data and measurement of moisture content and movement within the tuff below filled disposal pits. During certain disposal and storage operations, air filter samples are routinely taken and assayed. One air sampling station of the routine LASL environmental monitoring network operates within the area. Within the retrievable transuranic waste storage facilities in the area, monitoring for temperature, relative humidity and radiolytic gas formation are routinely carried out to provide information these storage environments and to assure that the requirements of retrievable storage are being met.

The burial of wastes followed by covering the material with uncontaminated earthen backfill provides for physical isolation of the waste from the environment. For the wastes to enter the environment, some transport process must occur. The transport mechanism of greatest potential concern is the movement of precipitation (rain or snow) into the waste, and subsequent leaching of the radionuclides into ground or surface waters. This has led to considerable study of hydrologic transport processes within and adjacent to waste disposal sites at Los Alamos.

These investigations have shown that very little, if any, of the approximately 40 cm/year (16 in/year) precipitation at the waste disposal area enters the waste material. The bulk of the precipitation either runs off immediately, or is held in the upper few meters of the surface material. The eastern part of Mesita del Buey (the location of the current main disposal area) is underlain by about 75 m (250 ft) of unsaturated tuff and the western part by about 180 m (600 ft).[3-21] The surface of the mesa is about 30 m (100 ft) above the adjacent canyons. These canyons are floored with alluvial material deposited, in part, by ephemeral streams that flow only after major precipitation or snowmelt events. Saturated zones are present to a limited extent in the alluvium, as indicated in Figure 3.1.2-3, recharged by precipitation and stream flow.

The regional ground water aquifer is in sediments located beneath the tuff, at depths of about 300 m (990 ft).[3-21] There is no evidence of recharge to this aquifer, or to perched water in streambed alluvium, from precipitation which might enter the waste material.

Measurements at monthly intervals utilizing neutron moisture probes in 10 access holes in the fill overlying disposal areas and in the adjacent tuff show that precipitation moisture penetrates no more than about 5 m below the surface, with no significant changes in moisture content at depths greater than about 8 m.[3-108L, 3-109] Below that depth, moisture contents of the tuff are in the range of 1%-5% by volume. At this water content, moisture movement occurs principally as vapor diffusion. Only contaminants which are present as gases or volatile liquids may be transported by diffusion of water vapor. Although tritium falls in this category, present practices assure proper containment.

Previously, waste materials containing tritium were placed in both pits and shafts at Los Alamos. Now tritium disposal is restricted to shafts and requires that special containment be used to restrict movement of tritium gas or tritiated water vapor away from the shafts. Investigations at the disposal area have described the distribution of tritium within an area occupied by several disposal shafts.[3-110, 3-111] It was shown that tritium was moving away from some older shafts through the tuff, primarily through zones of higher porosity, through open fractures, and along interfaces between ashflows. The tritium concentrations in the soil moisture immediately adjacent to the shafts were higher than that allowed for public ground or surface water supplies. However, the slow rate of movement away from the shafts (allowing for decay of the tritium) and dispersion within the tuff, reduced those concentrations to below maximum permissible concentrations within the upper few meters of the surface. Some tritium diffuses into the atmosphere. A tritium air sampler is operated continuously within the disposal area. Data from this sampler indicates air concentrations higher than normal background, but at less that 1% of the concentration guide for uncontrolled areas.[3-66] These concentrations are below those considered to be harmful. The studies also indicated that there was virtually no downward movement of tritium below about 20 m (65 ft).

Measurements adjacent to and below the waste disposal pits show water contents generally lower than those in the fill overlying the waste (about 15% by volume). Theoretical calculations, using these observed moisture values, demonstrate that very little, if any, water moves through the waste material. This small quantity of water, on the order of 0.1 cm/year (0.04 in/year) or less, would not produce any significant leaching of the wastes.[3-109] Further, as the bulk of water movement occurs as vapor diffusion, little if any radionuclide transport can occur.

In an effort to determine if any leaching has occurred, core samples were removed from beneath one of the older disposal pits at Area G by drilling five horizontal holes into the canyon wall adjacent to the mesa top.[3-111A] Preliminary analyses of samples from these cores showed gross alpha and gross beta values within the range expected of normal uncontaminated soil materials. Further analyses ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am produced results that were below detection limits for all samples. Analyses of the cores indicated natural uranium concentrations that were indistinguishable from the natural uranium content of the Bandelier Tuff elsewhere. Thus, there was no indication of any radionuclide migration within a few meters of the bottom of the pit.

Estimates of the rate of erosion of Mesita del Buey over the last million years indicate that exposure of the waste by vertical erosion may occur within 50,000 years.[3-109] Lateral erosion of the sides of the mesa may expose waste in the pits closest to the mesa edge in approximately 100,000 years. Within that time-frame, all major radionuclides other than ^{239}Pu will have decayed away before waste exposure. The average plutonium concentration in all the pits is presently at or below the 10 nCi/g maximum permitted for burial and will be reduced by a factor of two to four before exposure.

Similar geologic conditions prevail at the other fourteen locations on the plateau where radioactive wastes have been disposed of by burial (see Figure 3.3.3-7). Most of these are former sites with only three having been used in recent years. One is for classified material (to be discussed later), one was used for burial of debris from demolition, and one was used for the deep disposal of cement paste containing waste. This latter area, near the old Plutonium Processing Facility, is now being used for placement of the cement-paste-corrugated-metal-pipe storage of retrievable level waste and disposal of cement paste.

All of the currently active disposal sites and all but two (Areas B and V) of the inactive sites are inside security areas that prevent entry by the public. In addition, most of these areas are marked or fenced (or both) to prevent unnecessary entry by employees. Area V is adjacent to a security area and inside a posted no trespassing area. Area B is partly paved with asphalt and fenced for use by Los Alamos County as a trailer/camper storage area for county residents. Recent surveys in Area B indicate that no one should receive any radiation above background from this present use. The non-paved portion of Area B is separately fenced and marked to prevent unauthorized entry. All disposal areas remain DOE property.

General History of Sub-Surface Waste Disposal

In general, three types of solid waste management operations have been conducted at Los Alamos. In the first several years of Laboratory operations during World War II, expediency dictated rapid disposal of contaminated wastes with less stringent controls than presently required. The technical areas generating radioactive wastes operated their own burial areas, and no Laboratory-wide supervision or uniform record keeping existed. There is confidence that all areas used for disposal of radioactive wastes are known in terms of location and the general facilities or operations from which wastes originated. Various internal memorandums, official technical notebooks, and engineering drawings have all contributed to this knowledge even though formal waste disposal records were not generally kept until the mid-1950's.

The reduction in research pressure following the war permitted an increased awareness and concern for the adequacy of disposal techniques. A waste disposal section was organized and formalized the use of designated burial areas to receive Laboratory-wide waste as well as some for special or single-use disposal operations. By 1959, detailed records of content and composition of wastes were kept routinely, and the quality of the records has improved since then. Beginning in 1974, a computer-based waste records system was initiated to maintain data on the exact nature of the wastes including the location of disposal within a particular burial or storage facility, such as a pit. An effort was started and is continuing to incorporate as much information as possible from old records and documents into the computer data base. Considerable work has been done and continues on locating and consolidating all relevant information on the old disposals.[3-111B]

The third type of solid waste operation practiced at LASL is that of retrievable storage of wastes. Starting in 1971, retrievable wastes have been placed in engineered storage designed to permit recovery after at least a twenty-year period. These practices have been described earlier. Complete data on the nature, amount, and exact locations of such wastes are carefully maintained.

Brief descriptions of the formerly and presently used radioactive waste disposal areas are provided in the following paragraphs. The designated subsurface waste areas known to contain radioactive material are shown on Figure 3.3.3-7. The letter designation is one used by waste management personnel for reference convenience and does not necessarily indicate chronology of use. Note that some areas were not used for solid waste disposal as such (e.g., Areas T, U, and V), but are now considered along with solid waste areas because they all share common features in terms of management considerations and future alternatives. A summary of available quantitative data on the radioactivity content is provided in Tables 3.3.3-2 and 3.3.3-3. Note that these tables do not contain information on the old areas for which good quantitative data is not available. For certain areas and isotopes (principally U and Pu) Book Physical Inventory Difference, BPID, data (see Section 3.3.4, Materials Accountability) can be utilized to place upper bounds on the amounts of disposed radioactivity. This has not been done for this report because of the degree of speculation required and the belief that it would not alter the basic conclusions regarding the adequacy of containment of waste. Such information will be considered, as appropriate, in relation to the study of future management alternatives. Table 3.3.3-3A presents more detailed data on disposal and retrievable storage for calendar years 1977 and 1978 based on more complete record keeping.

TABLE 3.3.3-2

ESTIMATED RADIONUCLIDE CONTENT OF MATERIAL PLACED IN DISPOSAL PITS AND SORPTION BEDS, AS OF DECEMBER 31, 1976[a]

	Pits		Sorption Beds		
Isotope	C 1958-1959	G 1959-1976	T 1945-1951	U 1945-1968	V 1945-1961
^{3}H			4		
^{90}Sr-^{90}Y		2683			<0.1
^{227}Ac				1	
U [b]	25	56			
^{238}Pu		39			
^{239}Pu [c]	26	336	10		<0.1
^{241}Am	149	2061			
Fission Products		600			
Induced Activity		51			
Total	200	5826	14	1	<0.1

a) All values in curies, decay corrected.

b) Includes isotopes ^{234}U, ^{235}U, ^{236}U, ^{238}U.

c) Material generally consisting of approximately 94% (by weight) ^{239}Pu and 6% ^{240}Pu.

TABLE 3.3.3-3

ESTIMATED TOTAL RADIONUCLIDE CONTENT OF MATERIALS PLACED IN SUBSURFACE DISPOSAL AND STORAGE AS OF DECEMBER 31, 1976[a,b]

Isotope	Area C (1960-1969)	Area G (1965-1976)	Area T (1968-1976)	Total in Disposal Pits and Absorption Beds	TRU-Retrievable Solid Waste Storage G	T	Total
^{3}H	39,186	123,853		4			163,043
^{22}Na	14	15					29
^{60}Co	11	135					146
^{90}Sr-^{90}Y	27	277		2,683			2,987
^{137}Cs		5					5
^{233}U	5	5	7		41		58
U [c]	.1	.1	.1	81		.1	81
^{238}Pu		4	47	39	55,958	14	56,062
^{239}Pu [d]		53	193	372	1,018	30	1,666
^{241}Am			3,761	2,210	25	737	6,733
Fission Products	30	357	3	600			990
Induced Activity	20	372		51			443
							232,243

a) All values in curies, decay corrected.

b) Data are known to be incomplete due to the lack of early Laboratory disposal records. Tritium, which accounts for over 70% of both cumulative disposed and decayed curies, is included only since 1960; no pre-1960 disposal records are known. Also, some past-1960 tritium disposals were not recorded. No quantitative data is included for Areas A, B, D, E, F, H, K, W, X, and Y, because no data is available; see text.

c) Includes isotopes 234, 235, 236, 238.

d) Weapons Pu mostly (94 wt% ^{239}Pu; 6 wt% ^{240}Pu); Ci value based upon $\sim$0.072 Ci alpha activity per gram.

TABLE 3.3.3-3A

RADIONUCLIDE CONTENT OF MATERIALS PLACED IN

SUBSURFACE DISPOSAL AND STORAGE IN 1977 AND 1978[a]

	Disposed		Retrievably Stored	
	1977	1978	1977	1978
^{3}H	40,910	58,440		
^{14}C		$1x10^{-6}$		
^{22}Na		$1x10^{-6}$		
^{35}S		0.001		
$^{57,60}Co$	$1x10^{-12}$	0.01		
^{84}Rb	0.01			
^{85}Kr	0.001			
^{88}Y	0.005	0.035		
^{90}Sr		0.001		
^{137}Cs		0.005		
^{147}Pm		$1x10^{-6}$		
^{210}Po	0.005	0.002		
^{226}Ra		0.002		
^{232}Th	$1.1x10^{-10}$	0.004		
^{237}Np		$7.5x10^{-6}$		
^{238}Pu	1.6	1.78	12.6	8.6
Pu[b]	15.89	30.01	10,556	13,163
^{241}Am	7.02	16.54	6,348	3,321
U[c]	2.4	1.01	0.02	0.01
MFP[d]	1,389	1,226	0.14	0.196
MAP[e]	7.7	76.39		

a) All values in curies at time of disposal or storage, majority of material emplaced at Area G, so me emplaced at Area T according to procedures described in text.
b) Alpha activity of mixtures of Pu isotopes.
c) Includes isotopes 234, 235, 236, 238.
d) Mixed Fission Products.
e) Mixed Activation Products.

Area A was operated from 1945 to 1946 and covers 5000 m^2 (1.25 acres) and originally contained pits for burial of solid waste and two buried tanks for storage of solutions containing ^{239}Pu. The waste burial pits were excavated in the volcanic tuff, and the waste was covered with the crushed tuff and soil removed from the pit. No records were kept of the types and volumes of waste placed in these pits. However, it is known that little, if any, transuranic material was involved. Plutonium was an extremely scarce material during the years this area was used, and every effort was made to recover it from waste material. The pits undoubtedly contain trace quantitites of many of the longer-lived radionuclides present in fission products and irradiated material that are known to exist in other disposal areas, but it is not presently possible to identify them specifically due to lack of records. The pits in Area A were also used for the disposal of chemical wastes.

Area A was reactivated in April 1969 with the excavation of another pit to be used for burial of debris from demolition work. This debris was contaminated with transuranic elements at <10nCi/g and with small amounts of uranium. This pit was used until 1978 and received a final cover in mid 1978.

Recent investigations have shown that the ^{239}Pu contaminated liquid wastes stored in the two 1.89×10^5 ℓ (5×10^4 gal) tanks have not leaked. Presently this waste, estimated to contain alpha activity equivalent to about 94 g of ^{239}Pu (about one-half of which is ^{241}Am) is being removed in small batches through an underground pipe to the present Plutonium Processing Facility waste treatment plant for processing. By mid-1979, approximately 80% of the contents were removed and treated. Once emptied, it is planned to refill the tanks with nonretrievable cement paste for disposal.

Area B was used through 1948. It was operated in the same manner as Area A, using pits for burial of all waste, including some chemical materials such as gas cylinders containing uncertain amounts of HCl, H_2S, and HF. Only limited records exist on the types of volume of material placed in this area. The general inferences concerning radionuclides in Area A apply also to Area B. Concern over the proximity of waste disposal operations to other areas prompted the opening of a new disposal area and the closing of Area B. Area B covers 24,000 m^2 (6.0 acres).

Area C was first opened in 1948 and covers 48,000 m^2 (11.8 acres). Pit disposal techniques were used for Laboratory waste, with separate pits for radioactive and chemical wastes. Wastes containing larger quantities of radioactivity were placed in vertical shafts, as much as 7.6 m (25 ft) deep. Six pits were used in this area for radioactive waste disposal, all of which were filled by late 1964. Use of the disposal shafts in this area continued through 1969.

Records of the types and volumes of waste placed in Area C before 1954 are incomplete. Beginning in 1951 data were recorded on the curie content of sludge generated by the Central Waste Treatment Facility and buried in this area. The curie content of some isotopes placed in this area can be inferred from material accountability records, which indicate the amount of varous materials removed from the inventory and considered to have been disposed of as waste. Some of this material was released in liquid effluents, and some escaped to the atmosphere. Thus, these records provide only an upper limit on the material actually placed in the disposal area.

The first complete records of curie content and composition of wastes placed in Area C begin in 1960 and apply only to the material placed in disposal shafts and Pit 5. Beginning in 1967, shafts were in use in both Area C and Area G, and this dual usage continued through 1969.

Area D is located within HP-Site. It contains two underground chambers at a depth of approximately 14 m (45 ft) that were used for subsurface detonation of explosives containing short-lived ^{210}Po. The shafts were last used in 1948. No records have been found on the amounts of radioactivity present. One shaft was opened for inspection in 1952, and a 600-lb. charge of TNT was set and detonated. The A small crater over the chamber resulted and was backfilled to ground level with clean earth.

Area E was used between 1949 and the mid-1960's for burial of contaminated solid wastes. Unknown amounts of material contaminated with ^{238}U, ^{210}Po, and Be were disposed. Essentially all of the ^{210}Po has decayed.

Area F is located on Two-Mile Mesa and was used, from 1946 through perhaps the early fifties, for local disposal of wastes before the organization of a Laboratory-wide disposal section. Wastes were placed in shallow pits or trenches, but information on the types and quantities of radionuclides disposed of (if any were) is not available. Some ^{90}Sr and about 30 mCi of ^{137}Cs as well as high explosives wastes are present.

Area G is the primary solid waste disposal and retrievable storage area used by LASL since 1957. The area contains six large pits, 30 x 180 x 8 m (100 x 600 x 25 ft), and eleven smaller pits of varying dimensions, which have been used for routine burial of Laboratory-generated radioactive wastes. In addition, three pits are presently in use in the active area and two more remain to be dug. While early disposals did not have details on curie contents recorded, isotopic composition was noted. Current practice, as described earlier, maintains detailed information on all aspects of the waste. Waste disposal and storage procedures used at Area G are those described in detail earlier in this section.

Americium-241 is present in some of these pits, occurring in association with plutonium in drums of cement paste generated by liquid treatment facilities and disposed in Area G pits through 1967. Tritium wastes were routinely disposed of in pits through about 1963 when shaft disposal for these wastes was initiated. Between 1963 and 1967, a few special disposals involving tritium were made into pits at Area G. Estimates have been made of the curie content of some of the various isotopes (including tritium) disposed in Area G before 1974 using material accountability data. Since 1974, detailed disposal records have been maintained in the waste management computer records system. This information is included in Table 3.3.3-3.

In addition to the disposal pits, Area G contains over 90 disposal shafts used for burial of intermediate and low-level contaminated wastes. Records on the types and activities of these wastes are generally good. Undocumented but small quantities of the nuclides listed in Table 3.3.3-4 have been disposed of in the shafts.

Since 1971, solid waste contaminated with transuranic radionuclides at activity levels greater than 10 nCi/g of waste (greater than 100 nCi/g in the case of ^{238}Pu) have been specifically packaged and placed in 20 year retrievable storage in accord with DOE regulations.

TABLE 3.3.3-4

NUCLIDES DISPOSED OF IN AREA G SHAFTS

^{24}Na*	^{91}Y *	^{144}Ce	^{227}Ac
^{32}P *	^{105}Ag*	^{147}Pm	^{232}Th
^{51}Cr*	^{114}In*	^{152}Eu	^{240}Pu
^{57}Co	^{131}I *	^{182}Ta*	^{242}Pu
^{59}Fe*	^{133}Xe*	^{191}Au*	^{244}Cm
^{65}Zn	^{140}Ba*	^{210}Po*	^{252}Cf
^{85}Kr			

*Those with short half-lives (less than 140 days have essentially decayed away. Many of the others have decayed significantly.

Area H contains shafts used for the disposal of uncontaminated classified material. However, it is known that some radioactive material was inadvertently placed in this area because of some trace level tritium contamination detected in subsurface samples taken near one of the shafts. No records are available to determine the nature or amount of what was buried.

Area K is located about two miles from Area D and was operated for the local disposal of wastes generated at HP-Site. A shallow pit in the area was used for disposal of tritium-contaminated solutions between 1950 and 1959. Septic tanks in the area have received liquid wastes contaminated with ^{235}U and ^{238}U. One additional septic tank received two emergency releases of plutonium-contaminated liquid in 1961. No records are available to document the curie content. The contaminated septic tanks and any contaminated soil will be removed as a decommissioning project when funds become available.

Area T has been used for waste disposal in two different ways. From 1945 to 1967 absorption beds were used for subsurface disposal of liquid wastes resulting from recovery of plutonium. Beginning in 1968, treated liquid wastes were mixed with cement and placed in vertical shafts. The two disposal ions are discussed separately in this section:

Absorption beds--Four trenches approximately 35 m (115 ft) long by 6 m (20 ft) wide and 1.2 m (4 ft) deep were excavated in the tuff. These trenches were backfilled with coarse material, grading from 0.2 m (8 in) boulders in the bottom, through gravel, to fine sand at the surface. Liquid wastes containing plutonium and americium were discharged to these beds from 1945 to 1952. From 1945 to 1967, the beds received effluent from a liquid waste treatment facility. The use of these beds was discontinued in 1967. Hydrofluoric acid used in plutonium recovery operations is known to have been present in the waste discharge, as is some tritium.

Disposal shafts--The operation of the liquid waste treatment facility at DP-Site, near Area T, resulted in the production of a sludge residue contaminated with plutonium and americium. For many years this material was placed in steel drums for disposal at Area C and Area G. In 1968, the operation of a pug mill was instituted, which mixed the waste material with cement. This cement paste was pumped directly into asphalt-coated vertical shafts approximately 20 m (65 ft) deep and 2-2.4 m (6-8 ft) diameter.

This practice continued through 1975, when techniques were developed for retrievable storage of that portion of the paste contaminated with more than 10 nCi of alpha activity per gram of paste. The nonretrievable paste is now placed in 2 m (6 ft) diameter shafts 20 m (65 ft) deep. Solidification of the paste occurs within a day of its placement in a shaft. The contaminated paste contains ^{90}Sr, ^{238}Pu, ^{241}Am, ^{132}Cs, and uranium.

Area U contains two absorption beds similar to those in Area T. The beds were used for subsurface disposal of contaminated liquid wastes between 1945 and 1968. The primary radionuclide present in these wastes was ^{210}Po. No records were kept of the amount discharged; however, the short half-life of the material would have produced a decay of the material to innocuous levels by 1972. During 1953, approximately 2.5 Ci of ^{227}Ac were discharged to the pits, a portion of which remained undecayed as of the end of 1974.

Area V was used for the disposal of contaminated liquid waste from laundry operations during the years of 1945 to 1961, using three absorption beds similar to those in Area T. An estimated total of 3 Ci of ^{89}Sr, ^{140}Ba, and ^{140}La were present in the liquid discharged to the beds. Based on their short half-lives, these nuclides have decayed to an undectable level. In addition, small quantities of ^{90}Sr and ^{239}Pu were contained in the waste.

Area W is used for the subsurface storage of two coolant tanks associated with the LAMPRE reactor dismantled in 1963. Two stainless steel tanks, each containing 110-115 ℓ (30 gal) of irradiated metallic sodium, are encased in carbonsteel sleeves and located in separate vertical shafts about 35 m (115 ft) deep. This doubly contained disposal was designed to permanently contain the sodium and is not expected to suffer any corrosion problems. Current plans call for entombment by constructing a new concrete structure over the tanks. The sodium is known to be contaminated with ^{137}Cs, ^{22}Na, and possibly ^{239}Pu. The total activity present in the tanks is not known.

Area X in close proximity to Area W, is being used for the subsurface storage of the LAPRE reactor vessel. The vessel was buried in 1964, containing only a residual amount of ^{235}U. Other activation products are also expected to be present. The thick stainless steel reactor walls provide containment adequate for storage in the dry tuff. The vessel may be removed for burial at Area G.

Area Y has been used since 1966 for disposal of waste from dynamic testing operations. The material consists principally of high explosive-contaminated wastes, although slight amounts of depleted uranium may be present.

Hazardous Chemical Wastes

Hazardous chemical wastes include inorganic and organic solids and liquids, and other solid and liquid residues contaminated with these chemicals. Approximately 9,500 ℓ (2,500 gal) of miscellaneous acids, bases, and organic chemicals, 9,500 ℓ (2,500 gal) of oils, and inorganic solutions resulting from chemical precipitation of fluoride and other wastes were disposed of in 1976. In addition, batch wastes are often produced in small amounts, less than 200 ℓ (50 gal), which can not be reduced or otherwise practically treated. Also requiring disposal are reactive metals, unusable or leaky gas cylinders (empy or partially filled), capacitors, and other chemically contaminated equipment items.

These hazardous wastes are transported for disposal to a separately fenced area, Area L, located about 1.5 km (1 mile) from the radioactive waste burial Area G, on Mesita del Buey. Presently within this area, deep shafts and shallow trenches are used for disposal of the various categories of chemicals. Shafts typically measure 0.6 to 1.8 m (2 to 6 ft) in diameter by 15 m (50 ft) deep, and all are equipped with personnel safety covers. Separate shafts are used for the disposal of different categories of waste chemical. These categories are: acids, bases, organics, inorganics, and reactive metals. Separate shafts also are used for gas cylinders and drums containing bulk waste oils and solvents. Containers of these latter wastes are lowered into the appropriate shafts. Bulk inorganic salt solutions are disposed of into a shallow trench to allow evaporation of the water content. Fill dirt is periodically applied to each of the shafts and trenches receiving wastes as a basic precautionary measure against fire or dispersal. Where wastes are too large or bulky for disposal in the chemical disposal area, disposal is accomplished at the radioactive waste site nearby, with adequate provision for isolation from radioactive wastes.

The hazardous chemical waste disposal area, as presently fenced, has a projected lifetime of at least ten or more years.

Decontamination and Decommissioning

Decontamination and decommissioning operations are carried out as the need arises to permit use of contaminated facilities for different programmatic objectives, to permit relinquishment of DOE control over property, or to permit complete demolition of obsolete facilities. These operations result in the generation of solid waste. A variety of facilities or land areas have been decontaminated in the past and additional such operations are expected in the future. Preliminary planning identified 12 specific facilities and 4 onsite land areas as likely candidates for decontamination or decommissioning during the next decade.[3-111C] Four of the facilities have been or are being decontaminated or decommissioned. Six of the remaining facilities are no longer in active use and have generally low-level contamination. The projects have been roughly estimated to cost between $15,000 and $7,500,000 with a total of about $17,000,000. The volume of solid waste, actually or potentially radioactively contaminated, has been estimated to range from about 250 m^3 (325 yd^3) to 25,000 m^3 (33,000 yd^3) for individual projects and total as much as 40,000 m^3 (52,000 yd^3). This waste will be similar to wastes already disposed at the currently used Area G (see preceeding section) and would be equivalent in volume to about seven years' worth of routinely generated solid waste. Thus, it is expected that the wastes from anticipated decontamination and decommissioning operations can be handled by established procedures and contained within areas already designated for solid radioactive waste disposal.

Individual decontamination and decommissioning projects are planned in detail as the programmatic needs require or as funding becomes available. Standard operating procedures are prepared and reviewed for all health and safety aspects. Environmental effects are considered in assessments as appropriate (e.g., Ref. 3-112). In general, one of the goals of decontamination and decommissioning projects at LASL is to reduce actual or potential adverse environmental effects by consigning contaminated materials to a controlled disposal area known to have minimal probability of permitting dispersal of wastes.

In the last two years, two major decontamination and decommissioning projects, identified in the site plan, have been completed and two others are under way. An old experimental incinerator facility[3-112A] and a filter building were decommissioned and the sites completely decontaminated. These sites were decontaminated to conditions considered as low as practicable to achieve, which resulted in this case in no penetrating radiation detectable above natural background and detectable alpha radioactivity at less than 20 pCi/g above natural background. The sites remain within the LASL boundary.

Decontamination operations have started on the old Plutonium Processing Facility and on a tritium handling facility. These operations are intended to result in sufficient cleanup to permit alternative uses of the buildings for other programs with no significant exposures to workers. Neither of these facilities is in an area open to the public.

Six of the remaining facilities are no longer in active use and they are: (1) Water Boiler Reactor, (2) LAMPRE Reactor, (3) UHTREX Reactor, (4) Air Washers, (5) Sodium Storage Tanks, and (6) LAPRE-II Vessel.

Contaminated Equipment

Equipment or items removed from a potentially contaminated facility may either go to a repair shop specifically set up for handling only this type of equipment, or it may be used in another installation handling radioactive materials, or it may be disposed of in the contaminated waste dump. If removable contamination is detected, it must either be cleaned or the equipment packaged prior to being removed from a controlled area. The only materials or equipment permitted to be salvaged are those with no detectable contamination as measurable by the most appropriate portable instrumentation. Initial checks are made at the point of salvage, and routine rechecks are made at the salvage yeard.

Gaseous Wastes

Gaseous waste includes those materials released to the atmosphere either as gases or mixed with gases, usually air. At LASL, this includes both radioactive and non-radioactive materials.

Radioactive materials are released to the atmosphere as the result of routine operations from twelve of the technical areas. These releases are continuously monitored by particulate and/or gas stack samplers. The amounts of waste radioactive materials released to the atmosphere are small enough that environmental concentrations resulting from these releases are well below the DOE concentration guides for uncontrolled areas for airborne radioactive material as measured by the routine environmental monitoring program (see Section 4.1.2.1 and Appendix H). The waste materials released include radioactive isotopes of americium, plutonium, uranium, tritium, iodine and argon. Small quantities of mixed fission products are released at facilities handling irradiated reactor fuel (see Table 3.3.3-5). Data on releases of specific isotopes from different technical areas in 1978 are presented in Appendix H.

Careful consideration has been given to the sampling programs and the use of particulate and/or gas treatment systems. There are about 90 stacks at LASL from which gaseous or airborne radioactivity are released. These stacks are located in 14 of the principal technical areas (see Table E-XXI in Appendix H). The emission controls range from simple holdup prior to release for short-lived gases to complex filtration for particulates. Most treatment systems at facilities handling americium and plutonium are equipped with High Efficiency Particulate Air (HEPA) filters that remove at least 99.7% of the particulates from the stream. Several such systems were installed in the early 1970's, and a significant reduction in plutonium releases was achieved. The New Plutonium Facility has the most elaborate filtration system at LASL with two completely independent ventilation exhaust systems, each having a completely redundant backup system on standby. Each of the systems provides at least three complete stages of HEPA filters in series for ^{239}Pu glovebox systems and at least four stages of

HEPA filters in series for ^{238}Pu glovebox systems. Each ventilation system has a complete fire detection, temperature control, and fire supression system designed to permit continued operation in the case of a glovebox fire. Gaseous radioactive argon released from the Omega West Reactor has a short (1.8 hour) half-life, which reduces its environmental impact. Short-lived radioactive gases and particulates generated at LAMPF are filtered and released via a tall stack. No significant quantities of gases result from critical assemblies because of the short-pulsed nature of their operation. Gaseous tritium and tritiated water vapor releases are reduced, where possible, by exhaust air treatment systems such as catalytic converters, microsieve, and adsorbers that collect and contain the tritium. A small amount of atmospheric radioactivity is released by explosive tests. These releases are covered under Section 4.1.2.3. Used filter materials and other solid wastes generated by air cleaning operations are disposed of as solid radioactive wastes as covered earlier in this section.

Continuous stack sampling is conducted at each stack where airborne radioactive emissions routinely occur. The samples provide documentation of cumulative releases. Some stacks have continuous monitors to supplement workplace air monitors in the immediate detection of abnormal releases. In most cases, stack samples are collected on filter media for 168 hours. In cases where gaseous emissions occur (e.g., tritium and activation gases), the monitoring is by other techniques such as flow-through Kanne chamber detectors. Isokinetic sampling tubes are generally placed 5-10 duct diameters downstream in a straight run or immediately after a blower to assure a good mixing and a uniform velocity profile. In almost all cases, the ANSI Standard N13.1-1969, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities," is fulfilled. The New Plutonium Facility utilizes specially designed flow conditioning units in each of its two stacks to provide a flat velocity profile to assure representative sampling by a 16-probe isokinetic sampler. Both continuous monitoring for Pu and cumulative filter samples collection are performed. The continuous monitor transmits data to a control computer which sums emission activity daily and is programmed to alarm at a present level to notify control room operators and the health physics office of higher than normal stack releases.

Several future reductions are expected with facility modifications and the construction of new facilities with improved treatment capabilities. Examples of planned improvements include additional HEPA filter systems for certain research facilities, new tritium handling systems with exhaust-air treatment and holdup systems, and design modifications that reduce the air volumes available for activation and improve containment of short-lived radioactive gases at accelerator facilities.

In the last ten years (1968-1978) there were two reportable (by criteria of chapter 0502) non-routine or accidental releases of airborne radioactive material. Both involved tritium and are noted as part of Table 3.3.3-5. The one occurring in 1976 is discussed in Section 4.2; the one occurring in 1977 was described in a LASL Environmental Surveillance Report.[3-112B]

TABLE 3.3.3-5

ATMOSPHERIC RELEASES OF RADIOACTIVITY FROM STACKS
FROM 1974 THROUGH 1977

Radionuclides	Activity Released (Curies)[a] 1974	1975	1976	1977
^{32}P	---	---	0.000074	0.000304
^{234}Th	---	6.6	0.0025	0.0052
^{241}Am, ^{238}Pu, ^{239}Pu	0.0008	0.00025	0.000068	0.000127
^{233}U, ^{235}U, ^{238}U	0.0008	0.00092	0.0013	0.0007
Missed Fission Products	0.0014	0.0010	0.0017	0.0028
^{131}I[b]	0.0047	0.0014	0.0003	0.00009
^{41}Ar[b]	312	327	339	792
^{3}H	7488	6200	3401[c]	2227[d]
^{11}C, ^{13}N, ^{15}O[b]	---	---	5890	48173[e]

---

a)Values are derived from continuous monitoring data collected from exhaust air stacks at the LASL which are release points from nuclear research facilities. See Appendix H (page H-102) for 1978 data and further discussion.

b)Note that the half-lives of ^{131}I, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O range from about 2 min to 8 days; thus, these nuclides decay rapidly.

c)Activity released during calendar year 1976 does not include accidental 22,000 Curie tritium (^{3}H) release that occurred on July 15, 1976, at TA-3, SM-34 Cryogenics Laboratory.

d)Activity released during calendar year 1977 does not include 30800 Ci tritium (^{3}H) release from HP site on October 6, 1977.

e)Releases of air activation products from LAMPF have increased with higher operating power; see additional information in Appendix H (page H-29 and H-41).

3.3.4 Precautionary Procedures

Health and safety, monitoring, security, safeguards, fire protection, and emergency procedures are essential ingredients in the operation of LASL. They are intended to preserve the wellbeing of Laboratory and related employees as well as the general public, to protect the environment and the large investment in facilities, and to maintain the secrecy of information essential to national defense. In many ways all of these functions are interrelated even though there are numerous areas of unique responsibility.

Health and Safety

Health and safety involves two major areas of concern: public health and safety, and occupational health and safety. The public safety is ensured primarily by controlling access and releasing only effluents which meet appropriate standards. The effluent control measures have already been discussed. The controlled exclusion of the public from all potentially dangerous technical areas prevents inadvertent exposure to radiation or radioactive materials, explosives, toxic materials, and physically dangerous situations involving such things as heavy equipment and construction. This exclusion is provided by the same measures as used for security (guards and fences) as well as extensive use of signs that prohibit entry and show the reason, such as "Danger, Explosives" or "Danger, Radiation."

Occupational Health and Safety addresses aspects of physical protection for all LASL employees, including implementing the provisions of the Federal Occupational Safety and Health Act. Five primary concerns are control of radiation hazards, protection from nonradioactive toxic exposures, industrial accident prevention, protection from adverse effects of catastrophic accidents in neighboring facilities, and occupational medical services providing periodic health checks, consultation, and on-the-job first-aid services.

Major components of the Health and Safety programs include:

Health Physics--measurement and control of exposure to ionizing radiation; personnel monitoring by film and thermoluminescent dosimetry badges, whole body counting, lung counting, and urinalysis; facility monitoring; exhaust stack monitoring; collaboration in preparation of Standard Operating Procedures and Emergency Plans, new facility design, and supervision of all equipment decontamination.

Industrial Medicine--pre-employment and periodic physical examinations, care for minor illnesses and occupational injuries, personnel counseling and guidance, and maintenance of first-aid stations at outlying sites.

Safety--personnel and property protection including unique problems of high explosives, transportation, lasers, fire protection, high temperatures and pressures, large impulse electric currents, hydrogen handling, and cryogenics. (The Laboratory has earned several national citations for outstanding safety experience including an AEC Award of Merit in 1973.)

Industrial Hygiene--recognition, evaluation, and control of health hazards throughout the Laboratory and community, including toxic chemicals, aerosols, particulates, and noise, and provision of respiratory protective equipment and ventilation and air cleaning equipment.

Industrial Waste Treatment--treatment of radioactive and chemically toxic liquid, solid, and gaseous wastes generated by the Laboratory to eliminate any health or safety hazards and to avoid contaminating the environment.

Environmental Studies--documentation and evaluation of environmental effects; management of routine solid waste operations; special research applicable to the Los Alamos area in geology, hydrology, meteorology, biology, and ecology; review of planned projects to anticipate and avoid or mitigate environmental impacts.

See Section 4.1.3 for a more detailed discussion regarding radiation measurements and assessments.

Monitoring

Routine monitoring of radiation, radioactive materials, and chemical substances is conducted on the Laboratory site and in the surrounding region to assure compliance with appropriate standards and to provide identification of any undesirable trends should they occur. The results of these continuing studies are reported annually in documents distributed to state and federal agencies and to interested persons. Recent results are summarized in Section 4.1.3. Each of the components of this program is described briefly. More detailed descriptions of sampling methodologies and analytical techniques are presented in the Environmental Surveillance Reports.[3-65, 3-66, 3-66A] The 1978 report is included as Appendix H. This monitoring is in addition to the routine and continuous monitoring conducted at specific effluent release points such as the radioactive waste treatment plants and the various stacks at nuclear research facilities. The following description reflects the practice in 1976-77. Some modifications were implemented in 1978 and are described in Appendix H.

Exposure from external penetrating radiation (primarily gamma radiation) in the LASL environs is monitored by 50 thermoluminescent dosimeter (TLD) stations. TLD station locations are graphically represented in Figure 3.3.4-1. Three of these stations are located more than 28 km (17 mi) from the Laboratory boundaries in neighboring communities of Española, Pojoaque, and Santa Fe (see Figure 3.1.5-1). Sixteen stations are located within 4 km (2 mi) of the boundary. Twenty-one of the 31 on-site dosimeter stations are located near LASL nuclear facilities in groups of three to six stations to monitor these known sources of radiation. All TLD stations are on a 13-week integration cycle. Many TLD monitoring locations were selected to reduce systematic radiation differences caused by variations in natural background.

Atmospheric radioactivity samples are collected at 29 continuously operating air sampling stations in Los Alamos County and vicinity. Present on-site and perimeter station locations are shown in Figure 3.3.4-1. Samples are collected biweekly. "Hi-Vol" air samples are used in the network. Air flow into the samplers is split to collect atmospheric aerosols on a filter and water vapor for tritium analysis on an adsorbent. The filters are analyzed for gross-alpha and gross-beta activities and for plutonium, americium, and uranium concentrations. Air-flow rates through both sampling cartridges are monitored with variable-area flow meters, and sampling times are recorded with an electric clock.

Tritium analyses are performed on biweekly samples from each of the 29 air sampling stations. A liquid scintillation counting technique is used in conjunction with measured absolute humidity to give the two week average tritiated water vapor concentration in air.

Gross-alpha and gross-beta activities on the biweekly air filters from each station are measured with a gas-flow proportional counter on the first and tenth day after collection. The first count is used to screen the samples for excessive or lab-related levels of activity. The second count provides a record of long-lived atmospheric radioactivity.

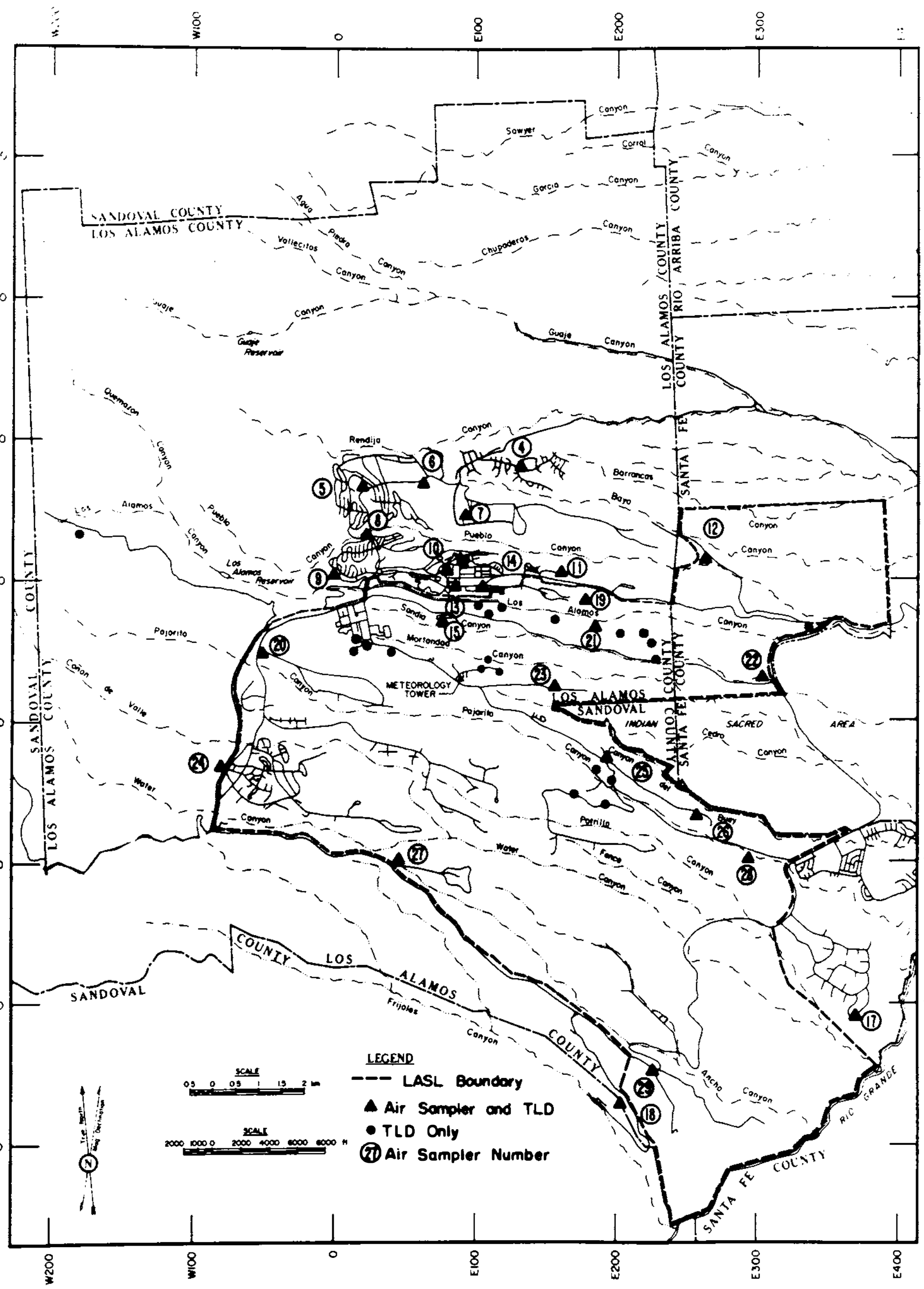


Figure 3.3.4-1. Air Sampler and Thermoluminescent Dosimeter (TLD) Stations for 1977

After being measured for gross-alpha and gross-beta activities, the biweekly filters from each station are combined and dissolved to produce composite 6- or 8-week samples for each station. An aliquot of each sample is saved for uranium analysis, and plutonium is separated from the remaining solution. For 11 selected stations, the plutonium solutions are combined to represent 12 or 14 week samples. For each of these 11 stations, americium samples are measured for alpha-particle emission with a solid-state alpha detection system. Appropriate alpha-particle energy groups are then integrated, and the concentrations of ^{238}Pu, ^{239}Pu, and ^{241}Am are calculated. This technique does not permit differentiation between ^{239}Pu and ^{240}Pu. Uranium content of filters is determined from 12 or 14 week composites for each of the 29 air sampling stations. The uranium content of the samples is determined by fluorometric techniques.

Surface and ground water radioactivity monitoring provides a routine surveillance of the potential dispersion of effluents from LASL operations. The surface and groundwater stations were located to provide background levels beyond LASL boundaries and to intercept any transport of chemical or radioactive contaminants within or beyond the LASL boundaries. Water samples are collected, acidified, and filtered through 0.45-μm-pore membrane filters. The samples are analyzed radiochemically for dissolved plutonium (^{238}Pu and ^{239}Pu) and tritium as HTO, as well as for dissolved gross-alpha, -beta, and -gamma activities. Selected samples are analyzed for americium (^{241}Am). A fluorometric technique is used to measure total uranium concentrations.

Radioactivity concentrations are determined for water samples from six on-site locations that are not Laboratory effluent release areas and from 23 locations in past and present Laboratory release areas (see Figure 3.3.4-2. The surface and ground waters in these areas are not a source of municipal, industrial, or agricultural supply and do not reach the Rio Grande except during storm runoff.

Regional surface waters within 75 km (46 mi) of LASL are sampled at six locations to ascertain normal levels of radioactivity in waters of the area (see Figure 3.1.5-1). Radioactivity concentrations are also determined for samples from six perimeter surface and ground water stations located <5 km (3 mi) outside the LASL boundary, from 16 wells and 1 gallery that furnish the water supply for Los Alamos, and from 5 stations on the distribution system (see Figure 3.3.4-2).

Monitoring of selected chemical quality parameters of surface and ground waters provides an additional means for detecting the potential dispersion of effluents from LASL operations. Standard methods are used to analyze samples for gross chemical characteristics and a selected list of ions. Samples are collected twice a year from the same locations used in monitoring for radioactivity. Routine analyses are performed for Ca, Cl, F, Mg, Na, CO^3, HCO^3, NO^3, SO^4, total dissolved solids, hardness, conductance, and pH. Water supply samples are also analyzed for As, Se, and silica.

Soil samples are collected by taking five plugs, 75 mm (3 in) in diameter and 50 mm (2 in) deep, at the center and corners of a square 10 m (33 ft) on a side. The five plugs are combined to form a composite sample for radiochemical analyses. Sediment samples are collected from dune build-up behind boulders in the main channels of perenially flowing streams. Samples from the beds of intermittently flowing streams are collected across the main channel. The soil and sediment samples are analyzed for gross-alpha and gross-beta activities, total uranium, and ^{238}Pu and ^{239}Pu. Moisture distilled from the soil samples is analyzed for tritium.

Soil and sediment samples are collected in the same general locations as the regional water samples to provide data on the normal concentrations of radioactive materials in the environment beyond the range of possible influence by LASL operations (Figure 3.1.5-1). Samples are also collected at offsite, perimeter, and on-site stations (see Figure 3.3.4.-2).

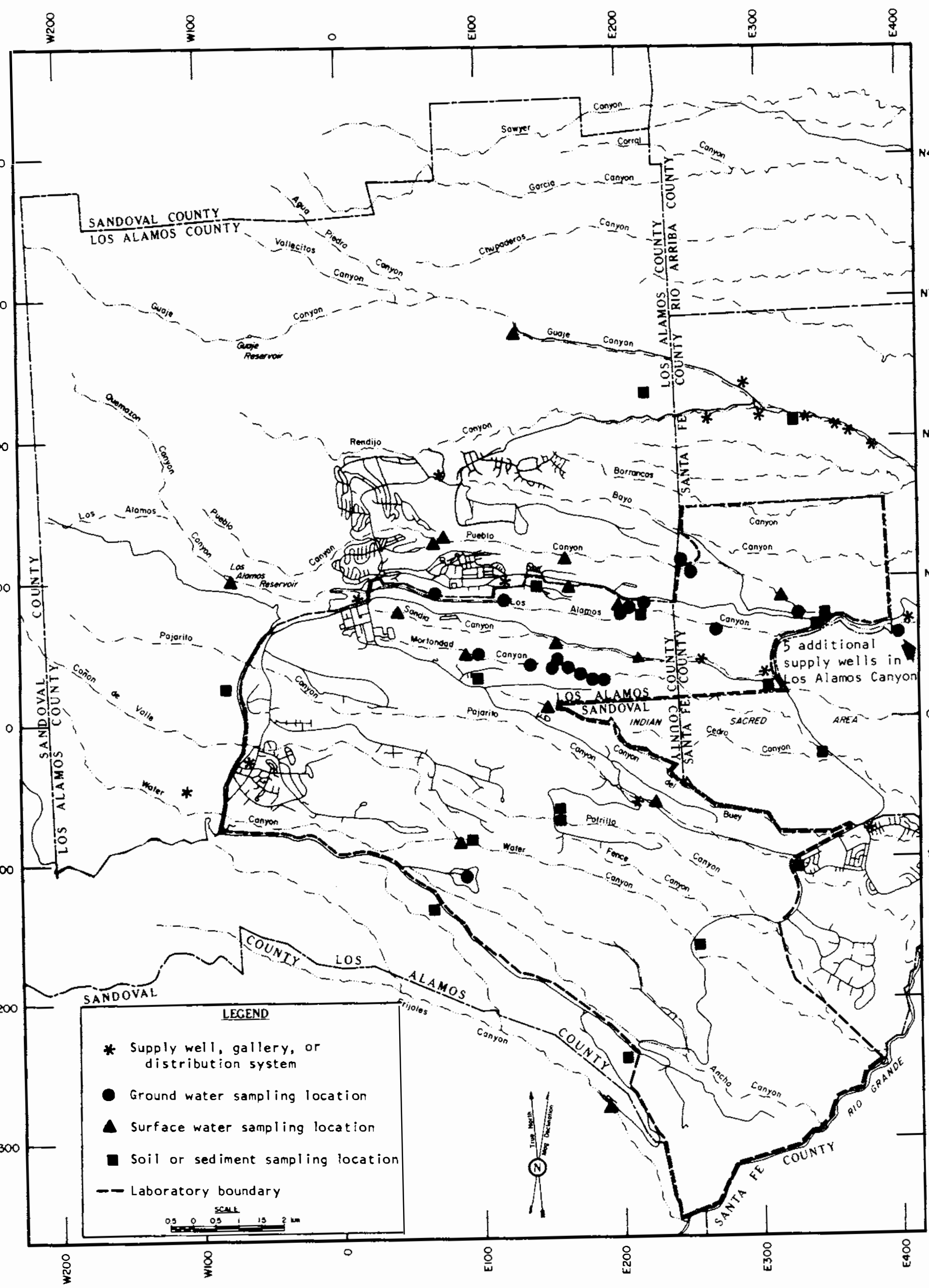


Figure 3.3.4-2. Water and Soil Sampling Stations for 1977

A sampling program was initiated during 1975 to evaluate possible dose commitment resulting from the consumption of locally produced foodstuffs. As an initial objective, radionuclide detectability was established for certain foodstuff samples collected during the fall harvest. Levels of tritium oxide (HTO), ^{238}Pu, ^{239}Pu, and uranium were determined for selected samples of fruits, vegetables, and cows' milk. Sampling locations included Los Alamos County and the Rio Grande Valley.

LASL maintains a capability to conduct special monitoring studies in all the above areas. These studies are conducted in conjunction with single experiments performed by groups in the technical operating divisions of the Laboratory when deemed necessary or prudent. Special studies are conducted to determine the fate of specific containments in our environment.

Security

Security involves three major areas of interest as defined by DOE--the protection of classified documents and materials, the protection of unclassified special nuclear materials, and the physical protection of government property. Each of these categories has detailed requirements for physical barriers, personnel identification and access control by armed guards, and inspection schedules during operating and non-operating hours.

The physical barriers include the buildings themselves and the security fencing that surrounds many of the technical areas. The fencing is one of the most visible aspects of many Laboratory areas and serves to protect the public from entering potentially dangerous areas, in addition to its security function.

The Federally employed protective force of armed guards provides the operational side of security. The uniformed guards have the basic mission of controlling access to secured areas by permitting only authorized persons to enter and of assuring that all classified material is adequately safeguarded. Because of their rounds during non-working hours, they also occasionally detect and report equipment malfunctions such as leaking pipes, overheated motors, or ventilation problems.

Safeguards and Security*

Certain materials that are utilized at the Los Alamos Scientific Laboratory, particularly plutonium and enriched uranium, must be considered as targets for illegal diversion and malevolent use. DOE has the authority and responsibility to insure that its contractors protect these materials against possible diversion into unauthorized hands and also protect the public against possible illegal use of such materials.

Objectives of the DOE safeguards program include continuous study to fully understand possible threats; development of safeguards to counter the range of credible threats; assessment of safeguards effectiveness; enforcement of safeguards requirements through administrative, civil, and criminal procedures; planning against all reasonably conceivable contingencies; and, finally, vigilant continuous program review to assure that every requirement or change is recognized and implemented. All of these considerations go into the program for safeguarding strategic nuclear materials (SNM) at LASL.

DOE Safeguards and Security Program

To prevent successful malevolent acts, DOE uses an in-depth approach that considers:

(1) Deterring attempts.
(2) Minimizing possibilities of success.
(3) Minimizing consequences.

---

*Directives for safeguards and security matters had been ERDA Manual Chapters of the 6100 Series (presently these are being revised to conform with the DOE directives system).

To achieve this, DOE uses a system composed of three basic subsystems: physical protection, material control, and accountability.

(1) Physical protection comprises personnel reliability determinations and all measures related to access control, physical barriers, penetration alarms, and armed protective response and recovery forces.

(2) To physically and administratively restrict access to SNM to only those persons who have been determined to be trustworthy and who have an operational need for such access.

(3) To detect and thwart any attempt at unauthorized access.

(4) To maintain an adequate, well-trained, and equipped Protective Force with immediate response capability.

(5) To coordinate with Federal, state, and local law enforcement agencies.

Such systems utilize physical barriers, electronic alarm and detection systems, personnel access control procedures, an armed security force, and trained operating personnel.

Physical Barriers--Much of the Laboratory is surrounded by barbed wire fence and "No Trespassing" signs are posted as required by DOE regulations. All special nuclear material protected areas are surrounded by chain link security fence topped with barbed wire and are lighted during hours of darkness. Roads inside each security area fence are routinely patrolled by the DOE Protective Force. Access to security areas is controlled by armed guards on a 24-hour basis.

All persons entering secure areas in the Laboratory must have an appropriate security badge. Visitors, vendors, and other nonresident personnel must be properly identified, escorted, and logged in before being issued a temporary badge.

Two-way radio and telephone communication are maintained between the main gate guard posts and the DOE Protective Force headquarters. There are additional features in the Plant's protection system which would alert the protective force in the event of an attempted forced entry.

Internal Security Areas--SNM material access areas are buildings wherein the quantities or the forms of SNM warrant additional protection. SNM Access Areas are in buildings located within SNM Protected Areas. Doors to such buildings are locked and alarmed, except for routine entrances during operating hours. The buildings are patrolled during nonoperational hours by armed Plant Protection guards.

SNM Protected Areas are surrounded by chain link security fences, topped with barbed wire. These fences are lighted during hours of darkness. Access to these areas is through guard posts manned by armed guards. It is possible for an area to contain both SNM and classified matter. At LASL, all SNM storage vaults meet DOE requirements.

On-site Transfers--Physical transfers of special nuclear material outside secure facilities, or between separate buildings, are made in locked vehicles escorted by armed guards when the quantities are equal to or greater than "Significant Quantities" as defined by DOE regulations.

Personnel Access Controls--Only authorized persons who are properly badged may enter security areas. Uncleared visitors are issued badges at the main gates after appropriate identification, but cannot go into security areas or SNM areas unless escorted by cleared and authorized personnel. Records are maintained of all badges issued.

Within the Laboratory, access to particularly sensitive areas is more stringently controlled. Special area designator on the badge is required in some cases while in other areas an exchange badge system is required. In some areas, access is limited to those personnel identified on an access list.

Unescorted access to SNM Access Areas (buildings) requires a proper DOE access authorization and approval for the area. However, additional access controls are in effect for SNM storage areas. For example, vaults have specific custodians for lock combinations which are required for vault access, and all persons are logged in and out of the vaults. When not attended by authorized personnel, SNM vaults are secured. Virtually all are also under alarm protection and the one exception soon will be.

Access to Limited Areas requires a proper access authorization or continuous escort. Area clearance is not required; however, uncleared personnel must be under continuous escort due to classified interests.

Radiometric Searches--Radiometric searches are planned for all persons, packages, briefcases, and all vehicles, etc., entering or leaving an SNM-Protected Area. The instruments required, both hand-held and in-place monitors, are on order and should be delivered soon. At two key facilities, searches are already being accomplished using hand-held SNM monitors.

In the event a radiometric alarm is activated, the Protected Area portals are secured and the person or vehicle detained by the guard until cause of the alarm condition can be determined. If the condition cannot be resolved by the guard, knowledgeable operating personnel are brought in to resolve the problem. If a person or vehicle should penetrate the Protected Area barriers in an unauthorized manner, the perimeter barrier gates would be secured and the Protective Force emergency plan would be implemented.

Materials Control

Materials Control System--Special nuclear materials (SNM) are located in specific areas throughout the Laboratory site. Each area is assigned one or more account numbers under which all transactions are observed and recorded. The areas are under the management of operating supervisors, custodians, or other individuals responsible for the safety, the use, and the internal control of SNM. These individuals verify and report physical inventories of each transfer to or from their areas. Multiple copy material transfer forms are filled out and signed by the responsible individuals before each transfer. Two copies are sent to materials control records personnel who check the correctness of the data and record the transaction. The receiver verifies the identification of the material and in some cases, the quantity of SNM. Transfers are checked independently and redundantly as the material moves through the facility.

System Monitoring--Special Nuclear Materials are under continual accountability review. Transactions are reviewed to ensure the validity and propriety of material movement and disposition. The accounting system and its methods of operation are outlined in appropriate DOE directives. Holders of special nuclear materials operate according to the established written procedures. Periodic reviews of the areas are made to ensure that operations are consistent with established directives and procedures. Formal manuals compiling all relevant nuclear material accountability procedures are now in preparation.

In addition, the Laboratory maintains a staff whose responsibilities include the review of all systems, including the special nuclear material control, to ensure that operations are conducted efficiently and according to prescribed methods and procedures.

Materials Accountability

Information on all DOE-controlled special nuclear materials is maintained in the Nuclear Materials Management and Safeguards System (NMMSS) which is a DOE centralized automatic data processing system which receives and stores pertinent information regarding nuclear materials, and which is capable of providing information to all DOE organizations when properly pulsed concerning nuclear materials inventory and financial management programs, nuclear material contract administration activities, and safeguards activities.

The LASL nuclear materials accountability organization maintains a computerized nuclear materials accountability system. Information from the LASL system is used as input to the NMMSS. The NMMSS also provides reports to the LASL system. All source and special materials received at LASL are subject to control by the accountability organization.

Accountability System--The nuclear materials accountability system consists of a double entry accounting procedure utilizing computer capabilities for maintaining permanent records of all internal and external material activities and account balances. The accountability system is a double entry procedure implemented by the accountability organization with input data from operating personnel. The computerized input is verified by editing routines to identify format errors (such as invalid material descriptions); any errors are referred back to the operating group for correction.

The Nuclear Materials Accountability Computer System is now updated (by batch processing) formally twice a month and informally more often. A less detailed, manual accounting system is also maintained for independent backup and verification.

Plans are to upgrade the entire system by using a dedicated computer which will maintain accountability records in near-real time.

Material Balance Accounts--Material Balance Accounts are a required part of the accountability system. Each individual material balance area or account, while independent in itself, is part of the overall control system. The aggregate of all material in the separate accounts are compared monthly to the amount reflected by the overall LASL total constructed from off-site receipts and shipments and other adjustments to total inventory (for example radioactive decay and disposal of contaminated liquid and solid wastes).

Twice a year, special nuclear materials are inventoried to check the material on hand against that which is shown by accounting procedures to be on hand. The difference between these two quantities is known as "Book-Physical Inventory Difference" (BPID).[3-113] The conditions of material resulting from processing, errors in measurement, and many other circumstances can cause problems that are manifested in apparent material shortages or gains. Representative samples and reliable assays are difficult to obtain for heterogeneous materials. The multitude of measurements, each with a degree of error, can cause differences that contribute to the overall BPID shortage or gain. The processing of materials often causes line, tank, and glovebox holdups that are difficult to measure. For example, the recent decommissioning of the plutonium facility at DP-site has yielded about 12 kg of plutonium as holdup in lines and tanks. Estimates of the quantity of plutonium that might have been removed to waste burial in years past as surface contamination on gloveboxes, piping, ducting, etc., is consistent with the possibility that nearly all of the cumulative inventory difference tabulated to date (as of October 1978, approximately 50 kg) may in fact be attributed to waste burial. Similar considerations apply to enriched uranium as well (total BPID as of October 1978, approximately 83 kg).

Measurement Data Quality Control--At present the quality of the data is the responsibility of individual groups using methods appropriate to their operations. An overall quality control program for nuclear material measurement data is now being developed.

Inventories--Special nuclear materials are physically inventoried as directed by DOE. During an inventory, all operations are stopped and the transfer of material is ceased. The areas are cleaned, the material placed in good order and measured. Separately identifiable items are accounted for using their unique identification numbers and a physical count.

A number of items (as directed by DOE) that can be weighed or otherwise remeasured are chosen for verification. The results must compare favorably with the results of previous values within the error limits of the instruments used; discrepancies are investigated immediately.

In addition to the formal procedures outlined above, visual checks, review, or actual physical inventories in certain areas are conducted periodically.

Reporting--Summary reports of special nuclear material activity and inventories are routinely forwarded to DOE. These reports reflect the composition of ending inventories, account adjustments, and material activity between LASL and other DOE facilities and licensees.

Appraisals--At least once a year, LASL's special nuclear materials control and management systems are subject to appraisal by a survey team from the Albuquerque Operations Office of DOE. These appraisals consist of audits of the material accounting system, a 100% physical inventory of all SNM on hand, and a review of the materials management program including the forecasting and control procedures. The effectiveness of these ALO appraisals is assessed by DOE Headquarters. This assessment consists of routine reviews of reports of the ALO surveys and may include direct participating with the ALO survey team at Los Alamos Scientific Laboratory.

Plant Protection Security Force

LASL is provided guard protection by DOE's Los Alamos Area Office Protective Force. The Protective Force is properly trained and is equipped with reliable communications systems, suitable weapons, and vehicles. Backup manpower is available from local law enforcement agencies with whom two-way radio communication is maintained on a full-time basis. Contingency Plans call for additional support from other law enforcement agencies including the FBI and military units.

Additional weaponry is stored at alternate locations. Emergency power is available to the Central Dispatch Stations to maintain normal operations and communications in the event of normal power failure or loss, regardless of reason.

Weapons training and qualification are conducted initially and in accordance with all DOE regulations. Weapon qualification is part of the initial training program, and no guard is granted the authority by DOE to carry a specific weapon until all qualification requirements are completed. The Los Alamos Area Office maintains its own pistol and rifle range for training. Certain guards receive additional training on other types of combat weapons available at Los Alamos. Also, all guards are trained in riot and mob control.

Emergency Plans--Emergency plans have been devised for possible riots, demonstrations, sabotage, terrorist attacks, strikes, Civil Defense, and natural disasters. These plans specify notifications of Plant and off-site personnel, including management and other agencies, and provide guidance for necessary actions as the emergency situation may dictate.

Tests of security communications systems, both on-site and off-site, are conducted to ensure a proper response capability in the event of an emergency situation. Periodic exercises of the Protective Force are conducted for the purpose of safely and effectively evaluating Proective Force performance capabilities.

Continuous liaison is maintained by the Los Alamos Area Office Safeguards and Security Department with Federal, state, and local law enforcement agencies. Such liaison includes on- and off-site meetings for capability and mutual support comparisons, and tours of the facility to acquaint the various agencies with the security and safeguards programs.

Fire Protection

Five Federally operated fire stations presently serve the LASL complex. These facilities also serve the community of Los Alamos as needed. The manpower commitment to LASL fire protection was 96 in FY 76 and increased to 110 in FY 77.

Fire protection philosophy is based on highly protective risk criteria stressing the importance of automatic supression systems--sprinklers, inerting, area separation, or containment with automatic closing devices--with manual firefighting response serving as a backup to ensure protection objectives. The objective of fire loss prevention and control is achieved by assuring that fires will not result in injury to personnel, exposure of the public to hazardous chemicals, unacceptable impairment of programs, or excessive damage to or loss of government property. There is a continuing re-evaluation of the adequacy of fire protection by cooperative effort between operating divisions, the safety office, and DOE. This effort has been increased by the addition of a three-man Fire Prevention Inspection Unit in the DOE Fire Department.

Partly because of the age of some LASL facilities and the continually increasing replacement value, a number of inadequacies in automatic detection and supression equipment and water distribution have been identified. Progress has been made in correcting these problems, and budget requests have been made to cover the remaining items. Despite the dispersed locations of LASL technical areas, most are within five-minute response time zones.

As a result of the La Mesa fire in June 1977, attention has focused on fire safety and protection. The main purpose of these measures is to minimize the chance spread of fires. In addition to specifically maintained firebreaks, graded dirt roads throughout the Laboratory site serve as firebreaks. Currently, 16 km (10 mi) of 61 m (200 ft) wide firebreak exist. A second level of fire protection, fuelbreaks, includes security fences, utility rights of way, road sides, and other areas where thinning, cutting, and pruning reduce the fuel load and prevent fires from using understory and crowded tree conditions as ladders for fire creep and crown fire. These fuelbreaks are also areas used as firebreaks in emergencies. Cleared areas along the 46 km (29 mi) of security fencing provide a 6 m (20 ft) wide fuelbreak in addition to the roadside mileage.

A preemergency plan is now in the development stage. This plan identifies areas of potential or existing fuel loads and natural features which will enhance fuelbreak properties; defines resources for fire fighting such as water sources, helicopter landing areas, and access routes; and recognizes archaeology and aesthetics, where burning is preferable to razing, and thinning retains specimen vegetation and pleasing views while maintaining a functional fire protection role.

A three-acre demonstration project has been completed on Camp May Road, and the West Jemez and State Road 4 area has recently been upgraded by an extensive fuel break project. Adjacent Forest Service properties are closely coordinated, and halftime professional consultation services of a forest ranger are provided by DOE funding.

Emergency Procedures

Emergency plans have been formulated to protect LASL employees from the effects of operational accidents and natural disasters. Each site has a detailed procedure to follow in case of fire, explosion, release of toxic material, civil disturbance, or natural disaster. Furthermore, a county-wide Los Alamos Civil Defense Organization is prepared to provide coordination, communication, and assistance to all citizens in case of an emergency. The Civil Defense Organization maintains emergency shelters.

3.3.5 Transportation of Radioactive Materials

A variety of radioactive materials are shipped to and from LASL and transferred between technical areas at LASL during routine operations. Offsite shipments, both to and from LASL, are carried out by commercial common carriers including truck, air freight, government trucks, and DOE-operated Safe-Secure Trailers (SSTs). Onsite transfers are made in trucks by LASL personnel or, in the case of most wastes, by the Zia Company.

Numerous LASL groups are involved in various aspects of radioactive materials transportation to assure compliance with applicable DOE and Department of Transportation (DOT) regulations and guides. Areas which are particularly emphasized include radiation protection, appropriate packaging, safeguards and security, and documentation.

The Health Physics Group maintains current cognizance of regulations and works with LASL shippers to determine the required packaging for all outgoing shipments. They review and document all aspects of each outgoing shipment for conformance with DOT regulations, including measurements for radiation and absence of significant removable external contamination. All incoming shipments not regulated by DOT under 49 CFR Section 173.391, "Limited Quantities of Radioactive Materials and Radioactive Devices," comply with 49 CFR (Parts 171-179) that specify packaging, markings, labeling, and tamper sealing. These shipments are monitored at the receiving point for removable contamination before being transferred to the LASL addressee. All vehicles making deliveries of radioactive shipments are monitored for contamination prior to departing LASL. Transfers of radioactive materials between LASL technical areas are in conformance with the requirements of LASL Standard Operating Procedures (SOP's) or administrative controls that are in accord with DOE regulations. Even though they do not apply to such shipments, the transfer of radioactive materials between LASL technical areas are, wherever possible, either in conformance with the DOT regulations as required for off-site shipments or are under procedures such as those described above which provide for at least the maximum equivalent protection for workers and the public as the DOT regulations.

The Nuclear Materials Department is involved in all shipments of special Nuclear Materials in Strategic Quantities, classified forms, or otherwise having safeguards or security requirements both on- and off-site. Transfers of strategic quantities of materials between LASL technical areas are made in a special Safe Secure Vehicle (SSV) following security procedures. Any transfers that cannot be made in the SSV for particular reasons (e.g., size) are carried out with the cognizance of the Nuclear Materials Department and following all required security procedures.

Procedures for packaging and transporting solid radioactive wastes for burial or retrievable storage have been established jointly by the Health Physics and Waste Management Groups at LASL. Highlights of these procedures were discussed in Section 3.3.3.

Major reliance for safety in the transportation of radioactive materials is placed on the packaging. This is from the perspective of both normal (non-accident) transport to limit exposure to radiation and hypothetical accident conditions to limit the probability of release of radioactive materials. DOT regulations (49 CFR 171-178) include packaging requirements that specify the amounts of different forms of particular radioisotopes that may be put into given specification containers. These regulations are discussed in detail in the U.S. Nuclear Regulatory Commission (NRC) final EIS on the Transportation of Radioactive Material by Air and Other Modes.[3-114]

Air shipments of plutonium to and from LASL were terminated in April 1977. In the future, air shipments of plutonium to or from LASL would be expected to resume only if made in containers certified as meeting aircraft crash, accident safety criteria, or as otherwise permitted for National Security purposes in accordance with 10 CFR Part 871, "Air Transportation of Plutonium."

Because transportation of radioactive materials related to LASL operations include a diversity of isotopes, package types, quantities and mixtures of materials, and modes of transport, it is impractical to consider each shipment separately to evaluate the risks of normal transportation and potential accidents. To estimate the overall risk from transportation of radioactive materials, the same statistical approach utilized by NRC[3-114] was used. Data for nonexempt outgoing, incoming, and on-site shipments in 1978 were summarized into typical shipment categories that specify average parameters for each type of shipment in a format suitable for use in the computerized evaluation procedure[3-115] developed for and used in the NRC EIS.[3-114] The summarized data is presented in Table 3.3.5-1. Each entry gives the isotope, package type, average curie content of the package, average external radiation level, average number of packages per shipment, average number of shipments per year, and kilometers travelled by each shipment broken down by two modes of transportation. The dominant transportation modes were truck and air freight. The air freight mode typically involves truck transport for delivery to and from an airport. The distances include an allowance for on-site transfers at LASL associated with incoming and outgoing off-site shipments. Because of the different forms in which records are kept for incoming and outgoing shipments, certain differences in data presentation were required. For outgoing transportation, no distinction was made between shipments made in regular trucks and those made in DOE-operated SSTs even though a large portion of the plutonium and uranium shipments were made in SSTs. This has the result of increasing estimated risks because no credit is incorporated in the analysis for the extra safety afforded by SSTs. For certain categories of incoming shipments, the package type is indicated as ICV. These categories of shipments were made predominantly on SSTs. The ICV designation refers to package integrity parameters used in the NRC analysis technique for integrated container vehicles.[3-114] The analysis for LASL shipments assumed these parameters as an estimation of the extra protection beyond DOT regulation type packaging afforded by the SST. No cargo aircraft shipments are indicated in the incoming category because documentation of shipment mode by commercial carriers is not maintained at LASL (such documentation is the responsibility of the shipper). Therefore, all incoming shipments were assumed to be made by truck, as a conservative approach, because that would maximize both the normal and accident case transportation risk (see Chapter 6 of ref. 3-114).

The data for onsite shipments reflect transfer of radioactive materials between technical areas and of waste materials to the solid waste disposal area. As noted earlier, an allowance for onsite transfers of offsite incoming and outgoing shipments was included in the total distances for such shipments. The data in Table 3.3.5-1 were used to preform the analysis of transportation accident risks discussed later in Section 4.2.14.

TABLE 3.3.5-1

SHIPMENT PARAMETERS FOR STANDARD SHIPMENTS[a]

Material	Package[c] Type	Curies/ Package	External Radiation[d]	AIR FREIGHT[b] Packages/ Shipment	AIR FREIGHT[b] Shipments/ Year	AIR FREIGHT[b] km/ Shipment	TRUCK Packages/ Shipment	TRUCK Shipments/ Year	TRUCK km/ Shipment
			OUTGOING						
Am-241	BPU	3.97	0.40	1	13	1900			
Be-7, Fe-55	A	0.009	0.00	1	5	1900			
Pu analog[e]	BPU	0.049	0.13	1	10	5100			
Co-60	A	0.25	0.67	1	7	2700			
H-3	B	11570	0.00	1	17	1000			
Mixed fission products	BPU	2409	0.01	1	6	1600			
PuO_2 (86.5% Pu-239, 12% Pu-240, 1.5% Pu-241	BPU	3086	0.08				6	18	2200
Pu-239 (weapons grade)	BPU	1111	0.24				2	5	900
U-235 (93% enriched)	B	0.217	0.02				1	6	800
U-235 (special form)	B	0.26	0.00				1	14	700
U-235	BPU	11470	0.00				1	1	1300
U (depleted)	B	0.162	0.047	1	149	1100			
			INCOMING						
Am-241	ICV	1.158	0.0				1	80	1300
C-14	A	0.13	0.02				1	7	1300
Co-60	B	9.0	0.67				1	2	1300
H-3	B	4175	0.20				1	80	1300
Ir-192	B	88	1.3				1	1	1300
P-32	A	0.12	0.2				1	12	1300
Pu-238 (80% enriched)	ICV	677	0.0				1	80	1300
Pu-239 (10% enriched)	ICV	6288	0.0				1	80	1300
Pu-242 (90% enriched)	ICV	0.0028	0.0				1	80	1300
U-235 (93% enriched)	ICV	0.481	0.0				1	80	1300
U-237	A	3.75	1.0				1	1	1300
U (depleted)	A	0.014	1.5				1	80	1300
U (normal)	A	0.00102	1.5				1	80	1300
U-233 (95% enriched)	B	0.0362	0.2				1	80	1300
			ONSITE-WASTES						
Am-241	A	0.002	0.0				1	81	9.5
Co-57, Co-60, Cs-137	A	0.009	0.0				1	6	9.5
H-3	A	2015	5.0				1	29	9.5
Mixed activation products	A	1.736	2.0				1	44	9.5
Mixed fission products	A	23.4	2.0				1	53	9.5
Pu-238	DRUM	0.05	2.0				1	97	9.5
Pu-239	DRUM	0.153	2.0				1	146	9.5
Pu-239 (93%), Pu-240 (7%)	DRUM	0.402	2.0				1	439	9.5
Pu-239 (87%), Pu-240 (13%)	DRUM	1.063	2.0				1	120	9.5
Pu-239 (50%), Pu-240 (50%)	DRUM	2.735	2.0				1	18	9.5
Pu-238 (heat source)	DRUM	58.	2.0				3	30	9.5
U (depleted)	A	0.038	0.0				1	18	9.5
U-233, + U-235	A	0.003	0.0				1	34	9.5
U-238	A	0.001	0.0				1	315	9.5
		ONSITE-TECHNICAL AREA TRANSFERS							
U (93% enriched)	B	0.098	0.02				1	3600	9.5
Pu-238	B	1225	2.0				1	1800	9.5
Pu-239 (86.5%), Pu-240 (12%), Pu-241 (1.5%)	B	1487	2.0				1	1800	9.5

a) Averages and typical values developed from 1978 data for shipments related to LASL operations.

b) Air freight shipments are assumed to include truck transfers totaling 160 km to and from airport.

c) Package type refers specifically to the package integrity parameters based on actual tests (Table 5-8 in ref. 3-113) utilized in performing the risk analysis. Types A and B refer to general specification containers; BPU refers to a 2R container inside a 6M; ICV refers to integrated container vehicle which was assumed for this analysis to approximate shipment in approved packages carried by SST; DRUM refers to waste disposal drums which were modeled as Type A containers.

d) External radiation is the measured maximum external dose rate in mrem/hour at 3 feet from any external surface.

e) Plutonium analog represents a grouping of alpha emitting radionuclides such as californium, einsteinium, polonium, and thorium, which for purposes of this analysis were modeled as plutonium.

References

3-1 V. C. Kelley, "Tectonics of the Rio Grande Depression of Central New Mexico," New Mexico Geol. Soc. Guidebook, 3rd Field Conf. (1952).

3-2 V. C. Kelle, "Tectonic Map of a Part of the Upper Rio Grande Area, New Mexico," U. S. Geol. Survey Oil and Gas Inv. Map OM 157 (1954).

3-3 Z. Spiegel and B. Baldwin, "Geology and Water Resources of the Santa Fe Area, New Mexico, "U.S. Geol. Survey Water-Supply Paper 1525 (1963).

3-4 E. C. Cabot, "Fault Border of the Sangre de Cristo Mountains North of Santa Fe, New Mexico," Jour. of Geol., Vol. 46, No. 1 (1938).

3-5 C. S. Denny, "Santa Fe Formation in the Espanola Valley, New Mexico," Geol. Soc. Am. Bull., Vol. 51, No. 5 (1940).

3-6 T. Galuska and J. C. Blick, "Stratigraphy of the Santa Fe Group, New Mexico," Bulletin of Am. Museum of Nat. Hist., Vol 144 Art. 1, New York (1971).

3-7 Dames and Moore Earth Science, "Report of Geologic, Hydrologic, and Seismic Investigations, Plutonium Processing Facilities, Los Alamos Scientific Laboratory, Los Alamos, New Mexico," Dames and Moore, Los Angeles, Ca. (1972).

3-8 R. L. Smith, R. A. Bailey, and C. S. Ross, "Geologic Map of the Jemez Mountains, New Mexico," U. S. Geol. Survey Misc. Geol. Inv. Map I 571 (1970).

3-9 R. A. Bailey, R. L. Smith, and C. S. Ross, "Stratigraphic Nomenclature of Volcanic Rocks in the Jemez Mountains, New Mexico", U. S. Geol. Survey Bull. 1274-P (1969).

3-10 R. L. Griggs and J. D. Hem, "Geology and Ground-Water Resources of the Los Alamos Area, New Mexico," U. S. Geol. Survey Water-Supply Paper 1753 (1954).

3-11 R. A. Bailey, R. L. Smith, and C. S. Ross, "Stratigraphic Nomenclature of Volcanic Rocks in the Jemez Mountians, New Mexico," in U. S. Geol. Survey Bull. 1274-P, (1969).

3-12 W. D. Purtymun and F. C. Koopman, "Physical Characteristics of the Tshirege Member of the Bandelier Tuff with Reference to Use as Building and Ornamental Stone," U. S. Geol. Survey open-file report (1965).

3-13 J. E. Weir, Jr. and W. D. Purtymun, "Geology and Hydrology of Technical Area 49, Frijoles Mesa, Los Alamos County, New Mexico," U. S. Geol. Survey Admin. Report (1962).

3-13A J. W. Nyhan, L. W. Hacker, T. E. Calhoun, and D. L. Young, "Soil Survey of Los Alamos County, New Mexico, "Los Alamos Scientific Laboratory Report LA-6779-MS (June 1978).

3-14 Los Alamos Scientific Laboratory Engineering Department in collaboration with LASL Health Research Division and Kamnitzer, Marks, Lappin & Vreeland, Inc., Planning Consultants, "Los Alamos Scientific Laboratory Sketch Master Plan," (in preparation May 1977).

3-15 V. C. Kelley, "Los Alamos Project, Pumice Investigation," Los Alamos Scientific Laboratory, report (1948).

3-16 R. A. Pettitt, "Soil-Cement from Volcanic Material, Rural and Urban Roads," Chicago, Ill. (1969).

3-17 A. R. Sanford, "Seismicity of the Los Alamos Region Based on Seismological Data", Los Alamos Scientific Laboratory report LA-6416-MS (1976).

3-18 A. J. Budding and W. D. Purtymun, "Seismicity of the Los Alamos Area Based on Geologic Data," Los Alamos Scientific Laboratory report LA-6278-MS (1976).

3-19 A. R. Sanford, A. J. Budding, J. P. Hoffman, O. S. Alptekin, C. A. Rush, and T. R. Toppozada, "Seismicity of the Rio Grande Rift in New Mexico," New Mexico State Bur. of Mines and Min. Resour. Cir. 120, Socorro, N. M. (1972).

3-20 R. Willden and E. E. Criley, "Geology of Los Alamos," in Geologic Studies and Material Properties Investigations of Mesita de Los Alamos, Los Alamos Scientific Laboratory report LA-3728 (1968).

3-21 W. D. Purtymun and W. R. Kennedy, "Geology and Hydrology of Mesita del Buey," Los Alamos Scientific Laboratory report LA-4660 (1971).

3-22 T. E. Kelley, "Earthquake and Rockfall Potential Near Omega Site, Los Alamos, New Mexico," U.S. Geol. Survey (1970).

3-23 R. R. Lansford, principal co-investigator, "An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Upper Rio Grande Region," New Mexico Water Resources Research Institute Reports No. 021 (1973).

3-24 U. S. Army Engineer District, Albuquerque, " Final Environmental Statement: Cochiti Lake, New Mexico," Albuquerque, N. M. (1974).

3-25 Stephen R. Flance & Associates, "Upper Rio Grande Basin Plan," New Mexico Water Quality Control Commission (1976), pp V-1 to V-22.

3-26 K. J. Schiager and K. E. Apt, compilers, Environmental Surveillance at Los Alamos During 1973," Los Alamos Scientific Laboratory report LA-5586 (1974).

3-26A A. G. Scott and J. L. Kunkler, "Floor Discharges of Streams in New Mexico as Related to Channel Geometry," U.S. Geological Survey open-file report 76-414 (1976).

3-27 R. L. Cushman, "An Evaluation of the Aquifer and Well Characteristics of the Municipal Well Fields in the Los Alamos and Guaje Canyons Near Los Alamos, New Mexico," U. S. Geol. Survey Water-Supply Paper 1809-D (1965).

3-28 J. H. Abrahams, Jr., E. H. Baltz, and W. D. Purtymun, "Movement of Perched Ground Water in Alluvium Near Los Alamos, New Mexico," U. S. Geol. Survey Prof. Paper 450-B (1962).

3-29 J. H. Abrahams, Jr., J. E. Weir, Jr., and W. D. Purtymun, "Distribution of Moisture in Soil and Near-Surface Tuff on the Pajarito Plateau, Los Alamos County, New Mexico," U. S. Geol. Survey Prof. Paper 424-D (1961).

3-30 W. D. Purtymun, Dispersion and movement of Tritium in a Shallow Aquifer in Mortandad Canyon at the Los Alamos Scientific Laboratory," Los Alamos Scientific Laboratory report LA-5716-MS (1974).

3-31 J. E. Weir, Jr., J. H. Abrahams, Jr., J. R. Waldron, and W. D. Purtymun, "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, 1949-1955," U. S. Geol. Survey Admin. Report (1963).

3-32 W. D. Purtymun and J. B. Cooper, "Development of Ground-Water Supplies on the Pajarito Plateau, Los Alamos County, New Mexico," U. S. Geol. Survey Prof. Paper 650-B (1969).

3-32A T. E. Kelly, "Reconnaissance Investigations of Ground Water in the Rio Grande Drainage Basin, with Special Emphasis on Saline Ground Water Resources," U.S. Geological Survey Atlas HA-510 (1974).

3-33 C. V. Theis and C. S. Conover, "Pumping Test in the Los Alamos Canyon Well Field Near Los Alamos, New Mexico," U.S. Geol. Survey Water-Supply Paper 1619-I (1962).

3-34 J. B. Cooper, W. D. Purtymum, and E. C. John, "Records of Water-Supply Wells, Guaje 6, Pajarito Mesa 1, and Pajarito Mesa 2, Los Alamos, New Mexico," U.S. Geol. Survey Admin. Paper (1966).

3-35 W. D. Purtymun, "Record of Water-Supply Well PM-3, Los Alamos, New Mexico," U.S. Geol. Survey open-file report (1967).

3-36 W. D. Purtymun and S. Johansen, "General Geohydrology of the Pajarito Plateau, New Mexico," New Mexico Geol. Soc. Guidebook, 25th Field Conf. (1974).

3-37 W. D. Purtymun, "Geology and Hydrology of White Rock Canyon from Otowi to the Confluence of Frijoles Canyon, Los Alamos and Santa Fe Counties, New Mexico," U.S. Geol. Survey Admin. Report (1966).

3-38 K. I. Thomassen, "Conceptual Design Study of a Scyllac Fusion Test Reactor," Los Alamos Scientific Laboratory report LA-6024 (1976).

3-39 D. Balcomb, J. C. Hedstrom, S. W. Moore, and B. T. Rogers, "Solar Heating Handbook for Los Alamos," Los Alamos Scientific Laboratory report LA-5967-MS (1975).

3-40 D. H. Slade, "Meteorology and Atomic Energy," U. S. Atomic Energy Commission report TID-24190 (1968).

3-41 F. Pasquill, "Atmospheric Diffusion," D. Van Nostrand and Co., Ltd., London (1962).

3-42 H. E. Cramer, G. M. DeSanto, R. K. Dumbauld, P. Morgenstern, and R. N. Swanson, "Meteorological Prediction Techniques and Data System, Final Report," Contract No. DA-42-007-CML-552, U. S. Army Dugway Proving Ground, Utah (1964).

3-43 T. T. Fujita, "Estimate of Maximum Windspeeds of Tornadoes in Southernmost Rockies," Satellite and Mesometeorology Research Project Research Paper No. 105, University of Chicago (1972).

3-44 J. E. Herceg, compiler, "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory July through December 1971," Los Alamos Scientific Laboratory report LA-4871 (1972).

3-45 National Fire Protection Association, "Lightning Protection Codes" (1968).

3-46 National Fire Protection Association, "National Fire Codes, Volume 4, Building Construction and Facilities" (1973).

3-47 U. S. Army, "Army Material Command Regulations," AMCR 385-100 (1970).

3-48 W. C. Hanson, "Proposal to Designate Land Areas of the Los Alamos Scientific Laboratory as a National Environmental Research Park," in National Environmental Research Park Symposium, The Snake River Regional Studies Center, College of Idaho, Caldwell, Idaho (1975).

3-49 F. R. Miera, Jr., M. J. Romine, and L. E. Eberhardt, "Small Mammal and Vegetation Composition and Diversity Along a 1500 Meter Elevational Gradient in Los Alamos," Draft to be submitted to Southwest Natrualist (1977).

3-50 D. C. Lowry, "Ground Dwelling Invertebrates of Mortandad Canyon," Los Alamos Scientific Laboratory report (in draft).

3-51 W. C. Hanson and F. R. Miera, Jr., "Long-Term Ecological Effects of Exposure to Uranium," Los Alamos Scientific Laboratory report LA-6269 (1976).

3-52 F. R. Miera, Jr., and T. E. Hakonson, "Radiation Exposure to Rodents Inhabiting a Low-Level Liquid Radioactive Waste Receiving Area," submitted for publication in Health Physics (1977).

3-53 F. R. Miera, Jr., K. V. Bostick, T. E. Hakonson, and J. W. Nyhan, "Biotic Survey of Los Alamos Radioactive Liquid Effluent-Receiving Areas," Los Alamos Scientific Laboratory report LA-6503-MS (1976).

3-54 D. F. Petersen, E. C. Anderson, and E. M. Sullivan, compilers, "Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division, January through December 1976," Los Alamos Scientific Laboratory report LA-6313-PR (1977).

3-54A L. E. Eberhardt and G. C. White, "Movements of Mule Deer on the Los Alamos National Environmental Research Park," Los Alamos Scientific Laboratory Report LA-7742 (April 1979).

3-55 T. E. Hakonson, J. W. Nyhan, L. J. Johnson, and K. V. Bostick, "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos," Los Alamos Scientific Laboratory report LA-5282-MS (1973).

3-56 U. S. Department of Agriculture, Forest Service, "Draft Environmental Statement: Geothermal Leasing," Santa Fe National Forest, USDA, Forest Service, Southwestern Region, Albuquerque, N. M. (1976).

3-57 W. G. Degenhardt and S. R. Williams, "Distribution, Reproduction and Ecology of the Two New Mexican Plethodonts: The Jemez Mountain Salamander, Plethodon neomexicanus, and the Sacramento Mountain Salamander, Aneides hardyi," report for the U. S. Forest Service and the Western Interstate Commission for Higher Education (1974).

3-58 Los Alamos Scientific Laboratory, "The Los Alamos National Environmental Research Park," Los Alamos Scientific Laboratory report (1977).

3-59 Data from New Mexico Environmental Improvement Agency, Santa Fe, N. M.

3-60 New Mexico Environmental Improvement Agency, "Ambient Air Quality Standards," New Mexico Air Quality Standards and Regulations, Section 301.

3-61 Op Cit, Section 201.

3-62 National Council on Radiation Protection and Measurements, "Natural Background Radiation in the United States," NCRP Report No. 45, NCRP Publication, Washington, D. C. (1975).

3-63 D. T. Oakley, "National Radiation Exposure in the U. S.," U. S. EPA report ORP/SID 72-1 (1972).

3-64 K. E. Apt and V. J. Lee, "Environmental Surveillance at Los Alamos during 1974," Los Alamos Scientific Laboratory report LA-5977-PR (1975).

3-65 K. E. Apt and V. J. Lee, "Environmental Surveillance at Los Alamos During 1975," Los Alamos Scientific Laboratory report LA-6321-MS (1976).

3-66 Environmental Studies Group, "Environmental Surveillance at Los Alamos During 1976," Los Alamos Scientific Laboratory report LA-6801-MS (1977).

3-66A "Environmental Surveillance at Los Alamos During 1977," Los Alamos Scientific Laboratory Report LA-7263-MS (1978).

3-67 "Radiological Quality of the Environment (EPA-520/1-76-010), U.S. EPA, Office of Radiation Programs, Washington, D.C. (1976).

3-68 W. R. Kennedy and W. D. Purtyman, "Plutonium and Strontium in Soil in the Los Alamos, Espanola and Santa Fe, New Mexico, Areas", Los Alamos Scientific Laboratory report LA-4562 (1971).

3-69 U. S. Energy Research and Development Administration, "Los Alamos Community Operations: Background and Summary of Statistical Information," Los Alamos Area Office, U. S. Energy Research and Development Administration, Los Alamos, N. M. (1975).

3-70 New Mexico Interstate Stream Commission and New Mexico State Engineer Office, "County Profile, Los Alamos County: Water Resources Assessment for Planning Purposes," Santa Fe, N. M. (1975).

3-71 Los Alamos County, "The Revised Comprehensive Plan of Los Alamos County," Los Alamos, N. M. (1976).

3-72 North Central New Mexico Econmic Development District, "Overall Economic Development Program, Section I," Santa Fe, N. M. (1975).

3-73 P. A. Lupsha and R. U. Anderson, "The Los Alamos Report: Citizen Attitudes Towards Their City, Its Services and Its Future," Institute for Social Research and Development, University of New Mexico, Albuquerque, N. M. (1974).

3-74 Los Alamos County Planning Office, "County Lands," Los Alamos, N. M. (1975).

3-75 U. S. Bureau of Census, "Census of Population, 1970: General Social and Economic Characteristics, New Mexico," PC (1)-A33 (1971).

3-76 New Mexico Interstate Stream Commission and New Mexico State Engineer Office, "County Profile(s) - Bernalillo, Mora, Rio Arriba, Sandoval, Santa Fe, and Taos Counties: Water Resources Assessment for Planning Purposes," Santa Fe, N. M. (1975).

3-77 U. S. Department of the Interior, National Park Service, "Bandelier National Monument Master Plan," Bandelier National Monument, N. M (1974).

3-78 Bureau of Business and Economic Research, "New Mexico Statistical Abstract, 1975 Edition," University of New Mexico, Albuquerque, N. M. (1975).

3-79 R. R. Lansford, principal co-investigator, "An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico: Middle Rio Grande Region," New Mexico Water Resources Research Institute Report No. 022 (1973).

3-80 New Mexico Employment Security Commission, "Covered Employment and Wages: Quarterly Reports 1967-1976," New Mexico Employment Security Commission, Albuquerque, N. M.

3-81 Real Estate Research Corporation, "Economic Studies, Los Alamos County, New Mexico," San Francisco, Ca. (1964).

3-82 U. S. Bureau of Census, "1975 Population Estimates," U. S. Government Printing Office, Series P-26, No. 75-31 (1976).

3-83 Bureau of Business and Economic Research, "New Mexico Business," University of New Mexico, Albuquerque, N. M. (1972).

3-84 Steering Committee, "Community '75 Goals Program," report of the Steering Committee, Los Alamos County, N. M. (1974).

3-85 Paul C. Box and Associates, "Traffic Study: Los Alamos Scientific Laboratory, Los Alamos New Mexico," Paul C. Box and Associates, Traffic Engineering Consultants, Skokie, Ill. (1976).

3-86 C. R. Steen, "Pajarito Plateau Archaeological Survey and Excavations," Los Alamos Scientific Laboratory report LASL 77-4 (1977).

3-87 C. R. Steen," The Los Alamos Archeological Survey, Pajarito Plateau, New Mexico," New Mexico Geol. Soc. Guidebook 25th Field Conf. (1974).

3-88 F. C. Worman, "Archeological Salvage Excavations on the Mesita del Buey, Los Alamos County, New Mexico," Los Alamos Scientific Laboratory report LA-3636 (1967).

3-89 Federal Register, 43 FR 5162-5345, February 7, 1978.

3-90 W. A. Beck and Y. D. Haase "Historical Atlas of New Mexico," University of Oklahoma Press, Norman, Ok. (1969).

3-91 New Mexico State Planning Office, "The Historic Preservation Program for New Mexico," New Mexico State Planning Office, Santa Fe, N. M. (1973).

3-92 D. Muench and T. Hillerman, "New Mexico," Charles H. Belding, Portland, Ore. (1974).

3-93 M. B. Chambers, "Technically Sweet Los Alamos: The Development of a Federally Sponsored Scientific Community," Ph.D. Dissertation, University of New Mexico, Albuquerque, N. M. (1974).

3-94 R. A. Pettitt, "Los Alamos Before the Dawn," Pajarito Publications, Los Alamos, N. M. (1972).

3-95 Phoenix Forth, Inc., "Recreation Element for Los Alamos County," Phoenix Forth, Inc., Planning Consultants, Albuquerque, N. M. (1976).

3-96 New Mexico State Planning Office, "Outdoor Recreation: A Comprehensive Plan for New Mexico," New Mexico State Planning Office, Santa Fe, N. M. (1971).

3-97 K. Bryan, "Geology and Ground-water Conditions of the Rio Grande Depression in Colorado and New Mexico," in National Resources Committee, Regional Planning PT.6, the Rio Grande Joint Investigation in the Upper Rio Grande Basin in Colorado, New Mexico, and Texas, 1936-37, V. 1, (1938).

3-98 W. D. Purtymun and J. E. Herceg, "Summary of Los Alamos Well-Field Characteristics," Los Alamos Scientific Laboratory report LA-5040-MS (1972).

3-99 Herkenhoff and Associates, Inc., "Water System Improvements, Los Alamos, New Mexico," Cont. No. AT929-10-2201, prepared for U. S. Atomic Energy Commission, Gordon Herkenhoff and Associates, Inc., Engineers, Albuquerque, N. M. (1974).

3-100 W. D. Purtymun, "Water Supply at Los Alamos During 1975," Los Alamos Scientific Laboratory report LA-6461-PR (1976).

3-101 Water Supply Contract between U. S. Atomic Energy Commission (USERDA) and the County of Los Alamos, Contract No. AT (29-1)-1888 (June 24, 1967).

3-101A C. W. Christenson, M. B. Ettinger, G. G. Robeck, E. R. Herman, K. C. Kohr, and J. F. Newell, "Removal of Plutonium from Laboratory Wastes," Industrial and Engineering Chemistry, Vol. 43, p. 1509 (1951).

3-101B C. C. Ruchhoft, A. E. Gorman, and C. W. Christenson, "Wastes Containing Radioactive Isotopes," Industrial and Engineering Chemistry, Vol. 44, p. 545 (1952).

3-101C U.S. Department of Transportation Regulations for the Transport of Low Specific Activity Radioactive Material, 49 CFR 173.392.

3-101D L. A. Emelity and C. W. Christenson, "Replacement of an Old Treatment Plant, A Design Based on Experience," in Proceedings of a Symposium on Management of Low and Intermediate Level Radioactive Wastes, Aix-en-Provence, IAEA (1970).

3-102 U. S. Energy Research and Development Administration, "ERDA Manual, Part 0500 Health and Safety, Chapter 0524 Standards for Radiation Protection," U. S. Energy Research and Development Administration (April 8, 1975).

3-103 J. R. Buchholz and C. W. Christenson, "The Treatment of Toxic Chemical Wastes at the Los Alamos Scientific Laboratory," paper presented at the Second AEC Environmental Protection Conference, Albuquerque, New Mexico, April 16-19, 1974.

3-104 J. F. Baytos, "Analyses for Residual Explosives in Drainage Ditch Soil at Sump Effluent Outlets," Los Alamos Scientific Laboratory report LA-4925 (1972).

3-105 L. A. Emelity, R. Garde, and C. W. Christenson, "Waste Management in a Small, Widely Dispersed Mountain Community," technical presentation to XIII Inter-American Congress of Sanitary Engineering, Asuncion, Paraguay, available as Los Alamos Scientific Laboratory report LA-DC-13156 (1972).

3-106 A. D. Miller, "Sewage Treatment Facilities and Practices at Los Alamos, New Mexico," paper presented at Rocky Mountain Section of the American Water Works Association and the Water Pollution Control Association meeting, Albuquerque, N. M. (October, 1969).

3-107 U. S. Energy Research and Development Administration, "ERDA Manual, Part 0500 Health and Safety, Chapter 0511 Radioactive Waste Management," U. S. Energy Research and Development Administration (Sept. 19, 1973).

3-108 U. S. Energy Research and Development Administration, "ERDA Manual, Appendix 5201 Part IV Transportation of Property," U. S. Energy Research and Development Administration (July 14, 1975).

3-108A A. A. Suzalski, "Design and Performance of a Radioactive Waste Compactor," REO-M-398 (September 1971).

3-108B Consolidated Baling Machine Company, "Installation, Operation and Maintenance Manual, Model DHBS-2MR Baling Press," 156-166 Sixth Street, Brooklyn, NY.

3-108C L. J. Johnson, "Guidelines for Construction and Use of Solid Waste Disposal Facilities," LASL internal memorandum H8-WM-461 (April 1974).

3-108D Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Research Programs, July-Sept. 1973," Los Alamos Scientific Laboratory Report LA-5512-PR (Feb. 1974).

3-108E Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Research Programs, October-December 1973," Los Alamos Scientific Laboratory Report LA-5614-PR (May 1974).

3-108F Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Programs, January-March 1974," Los Alamos Scientific Laboratory Report LA-5666-PR (July 1974).

3-108G Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Programs, April-June 1974," Los Alamos Scientific Laboratory Report LA-5762-PR (October 1974).

3-108H Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Programs, July-December 1974," Los Alamos Scientific Laboratory Report LA-6100-PR (October 1975).

3-108I Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Research Programs, January-June 1975," Los Alamos Scientific Laboratory Report LA-6264-PR (March 1976).

3-108J Environmental Studies Group, "Quarterly Report, Transuranic Solid Waste Management Programs, July-December 1975," Los Alamos Scientific Laboratory Report LA-6481-PR (September 1976).

3-108K Environmental Group H-8, "Development Activities on Shallow Land Disposal of Solid Radioactive Waste, January-December 1976," Los Alamos Scientific Laboratory Report LA-6856-PR (June 1977).

3-108L L. J. Johnson and H. M. Lewis, compliers, "Nuclear Waste Management Technology Development Program, January-December 1977," Los Alamos Scientific Laboratory Report LA-7501-PR (October 1978).

3-108M T. E. Kelly, "Evaluation of Monitoring of Radioactive Solid-Waste Burial Sites at Los Alamos, New Mexico," U.S. Geological Survey Open-File Report 75-406 (1975).

3-109 M. L. Wheeler, W. J. Smith, and A. F. Gallegos, "Preliminary Evaluation of the Potential for Plutonium Release from Burial Grounds at Los Alamos Scientific Laboratory," Los Alamos Scientific Laboratory report LA-6694 (1977).

3-110 W. D. Purtymun, "Underground Movement of Tritium from Solid-Waste Storage Shafts," Los Alamos Scientific Laboratory report LA-5286-MS (1973).

3-111 M. L. Wheeler, J. L. Warren, "Tritium Containment After Burial of Contaminated Solid Waste," Proceedings of 23rd Conference on Remote Systems Technology (1975).

3-111A W. D. Purtymun, M. L. Wheeler, and M. A. Rogers, "Geologic Description of Cores from Holes P-3 MH-1 through P3-MH-S, Area G, Technical Area 54," Los Alamos Scientific Laboratory Report LA-7308-MS (May 1978).

3-111B M. A. Rogers, "History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas A, B, C, D, E, F, G, and T), A Source Document," Los Alamos Scientific Laboratory Report LA-6848-MS, Volumes I and II (June 1977).

3-111C "LASL 10-Year Decontamination/Decommissioning Site Plan, FY 1980-FY 1989," submitted to Albuquerque Operations Office, U.S. ERDA July 1977.

3-112 U.S. Energy Research and Development Administration, "Environmental Assessment for Decommissioning of the TA-42 Incinerator Facility and the TA-21-153 Filter Building at LASL," EIA/ECT/77-3, September 1977.

3-112A J. Harper and R. Garde, "The Decontamination of a 239-Plutonium Contaminated Incinerator Facility," presented at the International Symposium on Decontamination of Nuclear Facilities, Vienna, November 1978, proceedings to be published by the IAEA.

3-112B Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1977," Los Alamos Scientific Laboratory Report LA-7263-MS (April 1978).

3-113 U.S. Energy Research and Development Administration Report on Strategic Special Nuclear Materials Inventory Difference, ERDA 77-68, August 1977.

3-114 U.S. Nuclear Regulatory Commission, "Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes," Document NUREG-0170, Volumes I and II (December 1977).

3-115 J. M. Taylor and S. L. Daniel, "RADTRAN: A Computer Code to Analyze Transportation of Radioactive Material," Sandia Laboratories Report SAND76-0243 (April 1977).

4. POTENTIAL IMPACTS OF THE PROPOSED ACTION

Environmental impacts, both beneficial and adverse, have a vast scope. This chapter assesses the actual and probable environmental impacts of DOE's previous and continuing activities at Los Alamos, New Mexico, on those environmental features characterized in Chapter 3.

First consideration is given to primary impacts; the direct results of the existence and operation of LASL. Next, the potential consequences of accidents are analyzed. Finally, the secondary, or indirect, impacts on the adjacent community and the northern New Mexico region are evaluated.

Summary of Changes

The following summarizes the changes and updating of material which have been made in this chapter as a result of the review and comment on the DEIS.

Primary Impacts. Updated information on water use shows a decrease in per capita consumption. Water quality has not changed significantly. The reader is referred to Appendix H for additonal detail. Additional reference and discussion of general biological behavior of radionuclides is included. The reader is referred to Appendix H for recent data on monitoring results for dose assessments. Data on 1976-1978 radiation exposure of LASL workers was added. The Laboratory participation in the Formerly Utilized Sites Remedial Action Program (FUSRAP) is discussed. Because programs and facilities change, new facilities approved or proposed for FY 79-82 are summarized.

Potential Impact of Accidents. Standard Operating Procedures (SOPs) for facilities and operations posing significant hazards are noted as are emergency response plans for the Laboratory. Some additional information on historic accidents, more detailed bases for evaluations, decontamination procedures, and costs are incorporated by brief summary. Publicly available documents and new references are cited.

Secondary Impacts. Updates on population growth, land development, and area economics reflect no significant changes from the projected. Laboratory EEO statistics for 1979 detail the range of employment for minorities by category and salary level.

Routine monitoring for radiation and radioactive or chemical substances is conducted on the Laboratory site and in the surrounding region to determine compliance with appropriate standard and permit early identification of possible undesirable trends. Results and interpretation of the data for 1978 on penetrating radiation, chemical, and radiochemical quality of ambient air, surface, and ground water, municipal water supply, soils, and sediments, food, and airborne and liquid effluents are included in Appendix H. Comparisons with appropriate standards and regulations or with background levels from natural or other non-LASL sources provide a basis for concluding that environmental effects attributable to LASL operations are minor and cannot be considered likely to result in any hazard to the population of the area. Results of several special studies provide documentation of some unique environmental conditions in the LASL environs.

The monitoring results for radiation and radioactivity are as follows:

1. Penetrating Radiation. No measurements at regional or perimeter locations in the environmental network for any calendar quarter showed any statistically discernible increase in radiation levels that could be attributed to LASL operations. The LAMPF network showed an increase of 13.7 ± 1.4 mrem/yr at the LASL boundary north of the LAMPF facility.
2. Air. During 1978, no statistically significant difference was observed between the atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranuim measured at sampling locations along the Labortory perimeter and those measured in distant areas. This indicates Laboratory contributions to concentrations of these contaminants were less than the local variability in background levels. Tritiated water vapor (HTO) concentrations at perimeter and onsite stations were about three and four times higher, respectively, than regional background HTO levels and are attributable to the Laboratory's HTO stack effluents. Elevated levels of airborne activity from the short-lived fission products were detected for short periods of time following nuclear atmospheric detonations by the People's Republic of China on March 14 and December 14.
3. Surface and Ground Waters. The results of the 1978 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite non-effluent release areas indicate no effect from effluent releases from LASL. Waters in the onsite liquid effluent release areas contain trace amounts of radioactivity. These onsite waters are not a source of industrial, agricultural, or municipal water supplies.
4. Soils and Sediments. The number of soil and sediment stations was increased this year over the number in 1977. A sample from one soil station in the regional net contained ^{137}Cs and ^{239}Pu in excess of natural fallout. Three soil samples from perimeter stations contained ^{137}Cs and one station contained ^{239}Pu in excess of natural fallout. The concentrations were less than 10 times worldwide fallout levels. Eight other perimeter sediment samples, all from a former release area, contained concentrations of ^{241}Am, ^{238}Pu, and ^{239}Pu above fallout levels. Five onsite soil stations contained activity above normal fallout and are near Laboratory activities. Sediment samples that contained activity greater than fallout were from effluent release areas.
5. Foodstuffs. Fruit and vegetable samples collected in the vicinity of LASL showed no apparent influences from Laboratory operations except for peach tree leaves collected at an onsite location near a facility that emits tritium.
6. Radioactive Effluents. Airborne radioactive effluents released from the LASL operations in 1978 were typical of releases during the last several years. The greatest change was an increase in activation products from higher power operation of the linear accelerator at LAMPF. Liquid effluents from three waste treatement plants contained radioactivity at levels well below controlled area concentration guides.

Chemical anlaysis are also a part of the studies to determine the chemical quality of water. Chemical analyses of surface and ground waters from regional, perimeter, and onsite noneffluent release areas varied slightly from previous years, but showed no significant change. The chemical quality of water from the municipal supply for the Laboratory and community meets the standards set by the EPA and New Mexico Environmental Improvement Division (NMEID). Analyses from onsite effluent release areas indicated that some constituents were higher than in naturally-occurrng waters; however, these waters are not a source of municipal, industrial, or agricultural supply. Analyses were performed for 33 parameters related to water quality. The federally-owned well field produced water for the Laboratory and County, which met all applicable EPA standards.

Nonradioactive effluents include airborne and liquid discharges. Airborne effluents from the asphalt plant; beryllium shop; gasoline storage and combustion; power plant; gases and volatile chemicals; waste explosive burning; lead pouring; and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. A single NPDES permit for 104 industrial discharge points and 10 sanitary sewage treatment facilities took effect in mid-October. After the new permit took effect, 6 of the 10 santitary sewage treatment facilities exceeded one or more of the EPA permit limits in one or more months and 18 of the 104 industrial outfalls exceeded one or more limit. Eight of those responsible for the largest number of deviations are scheduled for already funded corrective measures to be carried out in 1979-80.

An environmental evaluation of radiation dose includes some increments of radiation doses above natural and worldwide fallout background levels are received by Los Alamos County residents as a result of LASL operations. The largest estimated dose at an occupied location was 3.8 mrem or 0.76% of the radiation protection standard. This estimate is based on boundary dose measurements of airborne effluents from the proton accelerator at TA-53. Other minor exposure pathways such as direct radiation from an experimental facility and two unlikely food pathways may result in doses to several mrem/yr. No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. The radioactivity is absorbed in the alluvium before leaving the LASL boundaries and some is transported offsite with stream channel sediments during heavy runoff. The total population dose received by residents of Los Alamos County in 1978 was estimated to be 10.5 man-rem or about 0.4% of the 2400 man-rem to the same population from background radiation and 0.5% of the population dose due to medical exposure. As no significant pathways could be identified outside the County, the 10.5 man-rem dose also represents the population dose to the inhabitants living within an 80 km radius of LASL who receive an estimated 11,900 man-rem dose from background radiation.

4.1 PRIMARY IMPACTS

The direct impact of the Laboratory's operation includes the effects on water quality and quantity and air quality. A discussion of chemical measurements and assessment has been included to provide a broader perspective on liquid and gaseous effluents released. The direct impact of the land used for the LASL reservation and some of the known influences studied by laboratory ecologists are described. The use of other resources, such as energy, materials for the construction of facilities, and supplies for conducting research, is summarized. A discussion of the aesthetic impact is included. Finally the impacts of future construction are anticipated.

4.1.1 Water Quantity and Quality

Total water consumption in Los Alamos County was about 6.6 million cubic meters (1.7 billion gallons) during 1976. Virtually all this water is from the deep groundwater reservoir underlying the Pajarito Plateau and is pumped by the three federally-owned well fields (see Figure 4.1.1-1) which are operated by Zia Co. (see Section 3.3.1). The aquifer has not been designated a sole source water supply by the EPA under the Clean Water Act. In addition to supplying the water needs of LASL, the Federal Government is under contract to furnish water to meet the demands of the county of Los Alamos. About 160,000 cubic meters (51 million gallons) were obtained during 1976 from a groundwater collection gallery in Water Canyon. About one-third of the total production, 2.30 million cubic meters (608 million gallons) was used in the technical areas of the Laboratory, DOE offices, and Zia operations in 1976. The other two-thirds, 4.30 million cubic meters (1.14 million gallons) was sold to the county and commercial users. The rate of water use in residential areas is somewhat higher than national averages, but typical of regions where extensive lawn irrigation is practiced. Water is recycled where possible. Most of the cooling water for the DOE electric generating plant is supplied by effluent from the nearby sanitary treatment plant. The effluent from a county operated sewage treatment plant is used during the summer for irrigation of the golf course and lawns at several of the schools.

The three well fields contain a total of 15 wells, five in the Los Alamos Field, seven in the Guaje Field and three in the Pajarito Field (see Figure 4.1.1-1). The wells and supply system are managed to efficiently supply the water, considering economic and hydrologic conditions. The operation of wells and boosters on the distribution system is restricted to off-peak electrical loads, generally from 4 p.m. to 8 a.m. The wells are pumped at rates to allow maximum yield and still ensure the longevity of the well fields.

The Los Alamos well field and the Guaje well field are the oldest well fields (completed in the late 40s and early 50s) and have experienced cumulative water level declines of 12 to 17 m (40 to 88 ft), at average annual rates of 0.3 to 1.2 m/year (1 to 4 ft/year). In 1967 annual pumpage limits of 1.5 to 1.9 x $10^6 m^3$/year (400 to 500 x 10^6 gal/year) were adopted for the two fields. Since then there has been either a reversal or deceleration of water-level declines in most of the wells, indicating that these withdrawals can be maintained. Declines in the next 10 years are projected at 3 to 6 m (10 to 20 ft) for most of the wells under current production

The Pajarito Well field, completed in the mid to late 60s has experienced declines of 3 to 7.3 m (10 to 24 ft) at average annual rates of 0.4 to 1 m/year (1.3 to 3.3 ft/year) with expected additional declines of 4.6 to 7.6 m (15 to 25 ft) in the next 10 years.[4-1]

Regional water level trends in the main aquifer have been monitored since 1960 in a test well located about 3.5 km (2.2 mi) southwest of one of the Pajarito Field supply wells. (The Pajarito Field has the largest pumping rates and provides about 40% of the total water supply.) The water in this test well has declined about 0.9 m (2.9 ft) from 1960 through 1978, with most of the deline, 0.7 m (2.2 ft), occurring before 1966 when the highest producing well in the Pajarito Field was completed. Thus, there appear to be only very minor effects on the main aquifer on a regional basis. Even in the immediate vicinity of the well fields other test wells have shown no significant water level changes. The maximum drawdowns at the pumping supply wells are about 2 - 3% of the estimated total aquifer thickness of 1200 m (3900 ft).

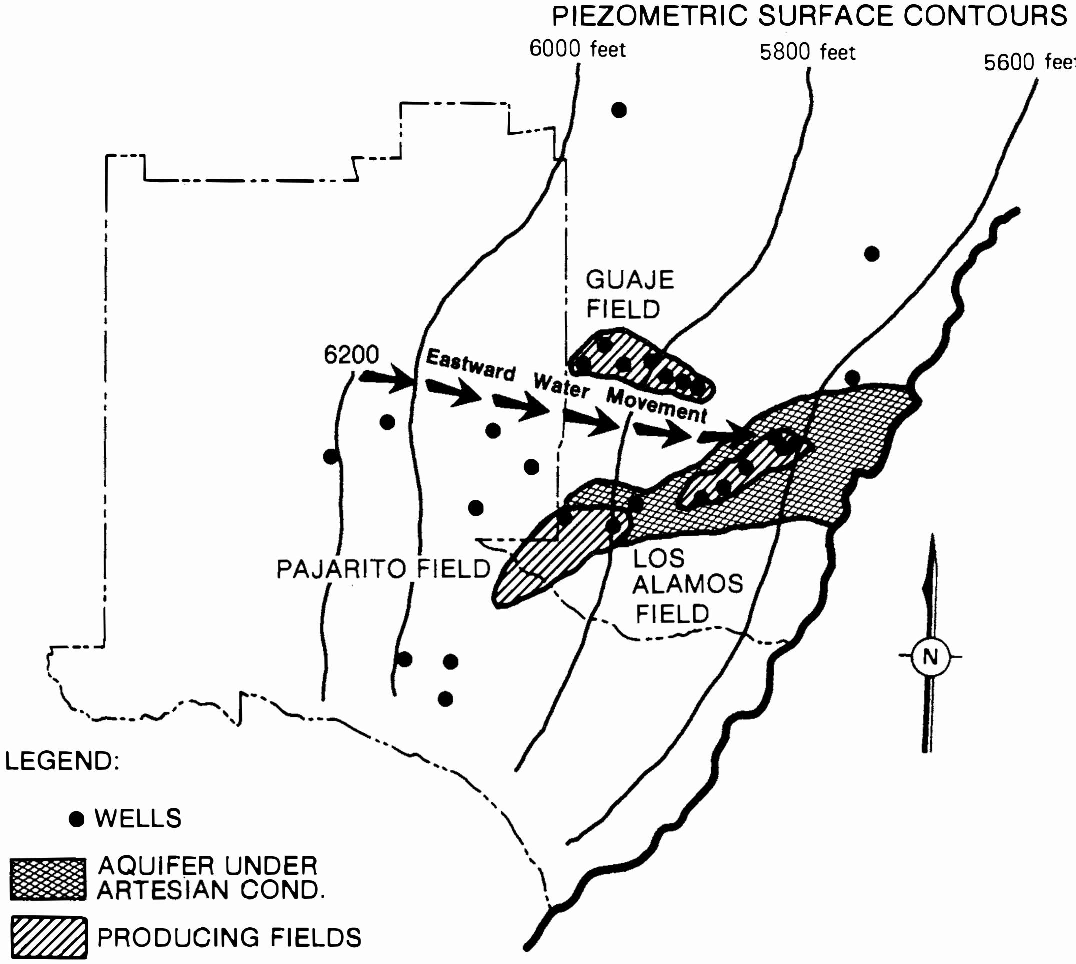


Figure 4.1.1-1

Los Alamos Well Fields

The three fields of water supply wells for Los Alamos are depicted (diagonal shading) in relation to Los Alamos County. Two of the fields--Los Alamos and Guaje--are located entirely in Santa Fe County in Los Alamos and Guaje Canyons. The Pajarito Field is located in both Santa Fe and Los Alamos Counties. New wells will probably be drilled in the vicinity of the Pajarito Field. The main aquifer is under artesian conditions (cross-hatched) where basalts form an overlying confining layer. The piezometric contour lines show the general decline of the water table down toward the Rio Grande indicating the general eastward movement of water in the main aquifer. The locations of other test and observation wells used to determine water levels and for monitoring are shown (dots).

The Water Canyon Gallery is located west of S-Site. The gallery furnishes part of the supply to the technical area and is a valuable part of the system, contributing as much annual production as some of the low yield wells in the Los Alamos and Guaje Field.

The existing well fields and supply system were barely adequate to meet the 1976 demand. However, the demand decreased in 1977 and 1978 apparently related to increased water costs. It is expected that consumption will still increase in the future with growth of the community and the Laboratory, though probably not at the rates projected in 1976. Two new high-yield wells are planned to be added in the Pajarito Field by 1982. These additional wells will supply both community and technical areas for peak demand and provide for future growth.[4-2] Additional storage capacity is being planned for the technical areas to meet anticipated growth, since the present storage capacity will be deficient by $2.5 \times 10^4 m^3$ (6.5×10^6 gal) by 1982.[4-2]

The existing storage for the county of Los Alamos is barely adequate for present demands. To meet the community demand and fire protection requirements an additional $7.6 \times 10^2 m^3$ (0.2×10^6 gal) storage reservoir is now on North Mesa for operational purposes. The ultimate storage requirement there is estimated at $2.9 \times 10^4 m^3$ (7.75×10^6 gal) to meet the projected increase in housing by 1982.[4-4]

The water rights established with the New Mexico State Engineer for production from the three well fields and gallery total $6.8 \times 10^6 m^3$ (5540 acre-feet) annually for pumpage of ground water from the aquifer in the Rio Grande Basin. The water rights provide a means of controlling water withdrawals in the interconnected natural water systems (surface and ground water) for protection of all users. The projected demand for pumpage would have exceeded the long-established water rights for the well fields and gallery by 1977. However additional water rights to surface water in the Rio Grande were acquired in 1976 to offset the effects of pumpage over and above the $6.8 \times 10^6 m^3$/year level.

These additional surface water rights amount to $1.48 \times 10^6 m^3$ (1200 acre-feet) annually. They were acquired from the San Juan-Chama Diversion Project and are to be used indirectly to offset the effect of pumpage of ground water in excess of water rights of $6.8 \times 10^6 m^3$ (5540 acre-feet) on the Rio Grande. The determination of effect is based on the eastward movement of ground water in the main aquifer with some discharge into the Rio Grande from seeps and springs in White Rock Canyon (see Section 3.1.2). The assumptions are that pumpage of ground water up to the rate of $6.8 \times 10^6 m^3$ (5540 acre-feet) have no effects on the amount of water in the Rio Grande not already accounted for in the allocations of water rights by the New Mexico State Engineer. Pumpage in excess of that amount is inferred to have the effect of reducing the natural discharge from the aquifer into the Rio Grande. The recently acquired surface water rights can then be released to offset any such reduction and maintain flow in the Rio Grande downstream with no net change. Because movement of water in the aquifer is slow the total effect of pumpage on the river will increase gradually and be delayed from the time pumpage begins to exceed the $6.8 \times 10^6 m^3$/yr (5540 acre-feet) level. The net effect on the river due to the increased production will be offset by release of the recently acquired surface water rights of $1.48 \times 10^6 m^3$ (1200 acre-feet).

The State Engineer's office has computed the amount of water that will be required to offset the decrease in groundwater discharge to the Rio Grande as the result of the estimated increases in pumpage. The net effect was determined using aquifer characteristics of 2040 m^2/day (50,000 $g/d/ft^2$) for transmissivity and 0.10 as a storage coefficient, a credit of 44% for return flow from release of effluents, and the projected increases in production above the long-standing water rights of $6.8 \times 10^6 m^3$ (5540 acre-feet). Thus, the projected additional pumpage in 1980 is $1.08 \times 10^6 m^3$ (875 acre-feet), however the net effect on the river in that year will be only $0.063 \times 10^6 m^3$ (51-acre feet) which must be released from storage at Abiquiu Reservoir (see Table 4.1.1-1). By the year 2025 the annual projected additional pumpage is estimated to be $3.58 \times 10^6 m^3$/year (2900 acre-feet). The projection beyond the year 1995 assumes no increases in demand based on stabilization of usage. Thus, the recently acquired water rights should be adequate until sometime after the year 2000. Because of the decline in water use experienced in 1977 and 1978, the projections made in 1976 now appear to be too high. It is likely that the projected effects will occur at later times, subject to actual growth of the community.

The effects on water quality in the Rio Grande resulting from substituting San Juan-Chama surface water for ground water inflow will be insignificant. Even if the full 1200 acre-feet/yr of ground water discharge reduction is reached it would amount to about 0.15% of the average annual flow in the Rio Grande at Otowi.

The general quality of water from the well fields, gallery and distribution system show low concentrations of constituents (see Table 4.1.1-2).[4-5] In general, the quality of the ground water has not changed during the period of production. The only significant changes have been a gradual increase in aresenic from well LA-6, and an increase of about 10% in TDS from the Pajarito Wells. (See Appendix H, pages H-35 and H-36, for detailed analyses.) All constituents from the 15 wells now in use are below the maximum permissible contaminant level.[4-6] Well LA-6 has been placed on standby to be used only in emergency (water supply for fire or disaster) because of high arsenic concentrations. The volume of water from the other five wells in the Los Alamos field was not sufficient to dilute the arsenic concentrations from well LA-6 to meet acceptable levels in the distribution system. The levels at point of distribution were at or above the limits of 0.050 mg/ℓ for arsenic. A series of tests were made to establish the zone yielding the high arsenic concentration to the well. It was determined that the entire part of the aquifer yielding water to the well contained high arsenic concentrations (range 0.140 to 0.200 mg/ℓ).[4-6A] The well has been off the line since early August 1975.

The natural radioactivity content of the water supply is measured to assure compliance with standards and verify absence of contamination. For the most recent reporting period (1976), the maximum value in relation to standards was for gross-beta radioactivity at <2% of the concentration guides. The next highest was ^{137}Cs at about 0.1%; all others (tritium, uranium, plutonium, and gross-alpha radioactivity) were a few hundredths to a few ten thousandths of a percent of the concentration guides (see Section 4.1.3). No significant changes from previous periods were noted.

Effluent Releases

The only two industrial waste discharges considered to have any potential for adverse environmental effects are the effluents from the two plants treating radioactive liquid wastes. The operation of these plants was described in Section 3.3.3. The characteristics of the treated effluents released in 1976 from the two plants are presented in Table 4.1.1-3. The cumulative releases through 1975 from the plants are covered in subsequent material in this section in connection with discussion of the effects on water and sediment quality in the canyons receiving the effluents. The quantities of radioactivity and chemical contaminants released are expected to decline in the future because of programmatic changes and waste treatment improvements now in preliminary planning.

TABLE 4.1.1-1

PROJECTED PUMPAGE IN EXCESS OF 6.9 x 10^6 m^3/YEAR AND COMPUTED NET EFFECT ON RIO GRANDE

	Projected[a] Pumpage Increment		Net Effect[b] on Rio Grande	
Year	$m^3 x 10^6$	(acre-feet)	$m^3 x 10^6$	(acre-feet)
1980	1.08	(875)	0.06291	(51)
1985	2.44	(1975)	0.28247	(229)
1990	3.24	(2625)	0.56123	(455)
1995	3.58	(2900)	0.83877	(680)
2000	3.58	(2900)	1.08423	(879)
2025	3.58	(2900)	1.86996	(1516)

a)Assumes no increase in demand beyond year 1995.

b)Volume of surface water necessary to offset decrease in river flow caused by pumpage which exceeds 6.8 x 10^6 m^3 (5541.3 acre-feet).

TABLE 4.1.1-2

CHEMICAL QUALITY OF THE LOS ALAMOS WATER SUPPLY WELLS AND GALLERY[a,f]

Constituent	Year Sampled	Min.	Max.	Ave.[b]	± s.d.	EPA Drinking Water Standards[c]
Arsenic	1977	<0.001	0.054	0.013	± 0.015	0.05
Bicarbonate	1977	48	284	102	± 55	
Barium	1977	--	<0.5	0.5	±	1.0
Boron	1974	<0.025	0.63	0.12[e]	± 0.18	
Cadmium	1977	--	<0.001	<0.001		0.010
Calcium	1977	7	26	15	± 6	
Chloride	1977	2	16	7	± 5	
Chromium	1977	<0.0001	0.0175	0.0064	± 0.0048	0.05
Copper	1972	<0.01	0.04	<0.02	± 0.01	
Cyanide	1972	<0.01	<0.01	<0.01		
Fluoride[d]	1977	0.04	2.44	0.532	± 0.611	2.0
Iron	1972	0.01	0.13	0.05	± 0.03	
Lead	1977	<0.001	0.011	0.002	± 0.003	0.05
Magnesium	1977	<1	9	4	± 3	
Manganese	1972	<0.01	<0.01	<0.01		
Mercury	1977	<0.00002	0.00037	0.00017	± 0.00011	0.002
Nickel	1974	<0.1	<0.1	<0.1[e]		
Nitrate (as N)	1977	0.1	0.4	0.3	± 0.1	10
Potassium	1972	30	96	62[e]	± 24	
Selenium	1977	--	<0.002	<0.002		0.01
Silver	1977	--	<0.00025	<0.00025		0.05
Sodium	1977	6	126	29	± 30	
Sulfate	1976	<0.1	29.7	5.5[e]	± 7.2	
Zinc	1972	<0.01	0.02	<0.01		
Total Dissolved Solids	1977	108	438	200	± 92	
Hardness	1977	22	100	52	23	
Surfactants	1972	<0.05	<0.05	<0.05[e]		
pH Units	1977	7.7	8.4	8.0	± 0.2	
Conductance, μmho/cm		120	880	266	185	

[a]All results in mg/ℓ, except where noted.

[b]Average of 1-2 samples from each of 15 wells and one gallery.

[c]EPA Interim Primary Drinking Water Standards.[4-5]

[d]Fluoride concentrations based on average daily maximum temperature. Public Health Service publication 956 gives 1.0 mg/ℓ optimum, range from 0.8 to 1.3 mg/ℓ recommended and twice the optimum (i.e., 2.0 mg/ℓ as grounds for rejection).

[e]Does not include gallery. Analysis not performed.

[f]Refer to Appendix H, page H-91, for most recent data.

TABLE 4.1.1-3

CHEMICAL AND RADIOCHEMICAL QUALITY OF TREATED EFFLUENTS IN 1976[b]

Type of Activity	Central Waste Treatment Plant 39.90 Million Liters Discharged Onsite Average 1976 Concentration	Plutonium Processing Facility Plant 4.70 Million Liters Discharged Average 1967 Concentration	Uncontrolled Area Concentration Guide[a]
^{3}H	4687×10^{-6} μCi/mℓ	185×10^{-6} μCi/mℓ	$3{,}000 \times 10^{-7}$ μCi/mℓ
^{89}Sr	23×10^{-9} μCi/mℓ	11×10^{-9} μCi/mℓ	$3{,}000 \times 10^{-9}$ μCi/mℓ
^{90}Sr	105×10^{-9} μCi/mℓ	96×10^{-9} μCi/mℓ	300×10^{-9} μCi/mℓ
^{137}Cs	4837×10^{-9} μCi/mℓ	221×10^{-9} μCi/mℓ	$20{,}000 \times 10^{-9}$ μCi/mℓ
^{238}Pu	187×10^{-9} μCi/mℓ	37×10^{-9} μCi/mℓ	$5{,}000 \times 10^{-9}$ μCi/mℓ
^{239}Pu	26×10^{-9} μCi/mℓ	47×10^{-9} μCi/mℓ	$5{,}000 \times 10^{-9}$ μCi/mℓ
^{241}Am	29×10^{-9} μCi/mℓ	27×10^{-9} μCi/mℓ	$4{,}000 \times 10^{-9}$ μCi/mℓ
U, Total	2.3 μg/ℓ	2.7 μg/ℓ	60,000 μg/ℓ

Constituent	Units	Central Waste Treatment Plant Min	Max	Avg	Plutonium Processing-Facility Plant Min	Max	Avg
Alkalinity (Phenol.)	mg/ℓ	<3	595	83	<3	2210	470
Alkalinity (Total	mg/ℓ	220	1260	570	1190	3550	1300
Ammonia	mg/ℓ	<0.1	11.0	2.6	8.0	191.0	40
Cadmium	μg/ℓ	<0.001	0.008	<0.001	0.001	0.041	<0.003
Calcium	mg/ℓ	<2	131	21	<2	81	13
Chemical Oxygen Demand	mg/ℓ	<8	79	44	27	214	109
Chloride	mg/ℓ	26	190	64	4	233	96
Chromium (hexavalent)	μg/ℓ	0.007	0.218	0.04	0.004	0.034	0.018
Chromium (Total)	μg/ℓ	<0.004	0.480	0.12	<0.004	0.55	0.038
Conductivity	μmho/cm	427	4389	2000	2541	13,860	5860
Copper	μg/ℓ	0.018	0.595	0.16	0.017	0.276	0.09
Cyanide	mg/ℓ	<0.004	0.13	<0.01	—	—	—
Fluoride	mg/ℓ	0.68	44	4.5	4.4	125	32
Hardness (Total	mg/ℓ	6	330	54	4	204	34
Lead	μg/ℓ	<0.001	0.232	<0.04	<0.001	0.252	0.02
Magnesium	mg/ℓ	<1	8	1	<1	5	1
Mercury	μg/ℓ	<0.001	0.140	<0.005	<0.001	0.004	<0.001
Nitrate	mg/ℓ	3.5	356.5	90	38	972	420
pH	—	6.7	11.6	—	7.2	12.0	—
Phosphate	mg/ℓ	<0.02	22.6	1.2	<0.02	16.16	0.8
Sodium	mg/ℓ	165	2000	450	420	2040	1010
Solids (Total)	mg/ℓ	732	3430	1520	1998	9916	4570
Zinc	μg/ℓ	<0.001	0.130	<0.02	<0.001	0.175	<0.04

a) See Section 4.1.3 for explanation.

b) See Appendix H, pages H-28, 29, and 103, for 1978 data.

The Plutonium Processing Facility Plant will be receiving smaller quantities of waste as research operations are moved to the new Plutonium Processing Facility during the next two years. After that it is anticipated that other research programs will continue to generate wastes for treatment but the plant will only need to be operated intermittently.

The Central Waste Treatment Plant will initially receive slightly larger quantities of waste as operations at the New Plutonium Processing facility get underway. However, major improvements to the Central Plant are now being planned. The first phase improvements, funded in FY 1978, include replacing the present old industrial waste collection line with 6,000 m (20,000 ft) of new doubly encased line including automatic leak monitoring. The second phase, planned for FY 1981 funding, will include upgrading of the treatment plant to include new filtration, ion exchange, and other processes to improve the quality of the effluent as regards both radiochemical and chemical quality. A proposal for FY 1982 funding would construct solar ponds for total evaporation of the final treated effluent so that no liquid will be released to Mortandad Canyon. About 50 Ci/year of ^{3}H would be evaporated with the water and all other radioactivity would end up on residue which will be handled as solid waste. Similar improvements are being planned for both plants.

Thus it is expected that release of effluents will continue at about present levels for another 4 to 6 years, after which time there will be no further discharge. All wastes will then be reduced to solid form for handling according to solid waste procedures.

With these improvements taken as assumptions it can be projected that additional radioactivity released to Mortandad Canyon (from the Central Waste Treatment Plant) may include another 75 mCi of plutonium, 1200 mCi of cesium, and 30 mCi of strontium based on the 1976 releases.

Of the ten major sanitary sewage treatment facilities, one practices total water reuse (the Main Technical Area plant), several have not discharged continuously during the period July 1975 to December 1976 (Ancho West, Pajarito Site, and the Reactor Development Site plants), and one began operation during that period (WA-Site plant). All of these facilities are operated under the provisions of the NPDES system. Analytical determinations on effluent samples are shown in Table 4.1.1-4 for the most recent complete reporting period. At the present time the EPA intends to consolidate the existing sanitary sewage treatment plant NPDES permits with a permit issued for the operation of industrial waste discharges. These treated sanitary waste discharges can be expected to continue at about current levels for the forseeable future.

Effluent Impact on Canyons

The three canyon areas into which wastes have been discharged are the subjects of continuing studies on the chemical and radiochemical quality of water and sediments. The studies include those conducted for monitoring purposes as well as special investigations regarding the behavior of low-level contaminants in the environment. Related ecological studies in the canyons are described in Section 4.1.5. The canyons will continue to receive low levels of contamination. These levels of contamination are not deleterious to health. No further operations are expected to add significantly to such low level but still measurable amounts of radioactivity. The canyons, within the controlled areas of LASL, will continue to be used as study areas to provide knowledge about low levels of radionuclides and their interrelationships to vegetation and animals in the local ecosystems.

TABLE 4.1.1-4

LASL TECHNICAL AREA SEWAGE TREATMENT PLANT EFFLUENT LIMITATIONS (NPDES) AND 1976[a] DATA[d]

	30-day Flow Avg (mgd)	30-day Flow Max (mgd)	30-Day Biochemical Oxygen Demand Avg (mg/ℓ)	30-Day Total Suspended Solids Avg (mg/ℓ)
Technical Area 03				
NPDES Permit Limit[b]	0.90	2.25	30	30
1976 Data[c]	0.284	0.774	34	19
Technical Area 09				
NPDES Permit Limit	0.001	0.0025	30	30
1976 Data[c]	0.0025	0.0035	2	1
Technical Area 16				
NPDES Permit Limit	0.10	0.25	30	30
1976 Data[c]	0.0056	0.0092	9	5
Technical Area 18				
NPDES Permit Limit	0.002	0.005	30	30
1976 Data[c]	0.0040	0.0071	59	36
Technical Area 21				
NPDES Permit Limit	0.017	0.0425	30	30
1976 Data[c]	0.0056	0.0073	64	27
Technical Area 41				
NPDES Permit Limit	0.009	0.225	30	30
1976 Data[c]	0.0014	0.0063	14	2
Technical Area 46				
NPDES Permit Limit	0.005	0.0125	30	30
1976 Data[c]	0.0037	0.0077	5	2
Technical Area 48				
NPDES Permit Limit	0.0033	0.00825	30	30
1976 Data[c]	0.0008	0.00100	3	1
Technical Area 53				
NPDES Permit Limit	0.009	0.0225	30	30
1976 Data[c]	0.026	0.0298	65	90

[a] National Pollutant Discharge Elimination System

[b] The above 9 plants are all operating under Interim NPDES Permit Limits.

[c] Avg data are averages over 12 months (12/1/75 - 11/30/76) of 30-day averages reported to EPA monthly. Max data are individual maxima for the total 12 month period.

[d] For 1976 data, refer to Appendix H, pages H-39, 106, and 107.

The canyons include Pueblo, Los Alamos, and Mortandad, and are shown in Figure 4.1.1-2. Pueblo Canyon received untreated radioactive wastes between 1944 and 1951, and treated radioactive effluents between 1951 and 1964. Los Alamos Canyon has received treated effluents since 1952 and discharges will probably continue until about 1980. Mortandad Canyon has received treated radioactive effluents since 1963 and discharges will continue until about 1980 when it is anticipated that some type of evaporation technology will eliminate liquid effluents from the Central Waste Treatment Plant. Figure 4.1.1-2 indicates the location of former and current major discharge points as well as the various sampling locations and test holes utilized to develop information on the environmental conditions.

In the two canyon areas presently receiving treated effluents (Upper Los Alamos and Mortandad) the basic conditions are similar. Under typical dry conditions, the effluent stream flows on the surface for distances of about 0.3 to 0.5 km (0.2 to 0.3 mi) before infiltrating into the channel alluvium. During periods of precipitation runoff or snow melt this distance may be extended. In Los Alamos Canyon and its tributary Pueblo Canyon, heavy precipitation may result in flow all the way to the Rio Grande about four times a year. All flow in Mortandad Canyon since at least 1960 has infiltrated into the alluvium before reaching the DOE boundary some 5 km (3 mi) downstream from the discharge point.

The effluents and natural runoff infiltrate into the alluvium, recharging the shallow perched water bodies. The majority of the radioactivity is adsorbed onto the sediments. The adsorption, coupled with dilution by natural runoff, results in very low concentrations of radioactivity in the water contained within the alluvium, only fractions of a percent of concentration guides applicable to drinking water. Water in these canyons is not used for industrial or domestic supply. As the water moves downstream, in the form of surface flow and as groundwater in the alluvium, concentrations decrease.

The adsorption of the radionuclides results in a buildup on the sediments near the discharge point. However, transport of the sediments by snowmelt and summer storm runoff events tends to redistribute the sediments and adsorbed radionuclides over a wider area. The highest concentration of radionuclides is associated with silt- and clay-sized particles in the sediments. However, these small particles make up less than 10% of the mass of the alluvium. Therefore, most of the radioactivity is associated with the larger-sized sediment particles. The larger particles are transported as bed load that moves more slowly than the suspended material and travels shorter distances downstream with each runoff event. The amount of material moved with each runoff event varies greatly, depending on the flow rate, the volume of runoff, the location within the canyon, and other factors. This transport process produces an irregular variation in radionuclide concentrations in the sediments within the various canyons and is responsible for some offsite transport of radioactivity in the case of Pueblo and Los Alamos Canyons. This phenomenon is illustrated in Tables 4.1.1-7, 4.1.1-12, and 4.1.1-21.

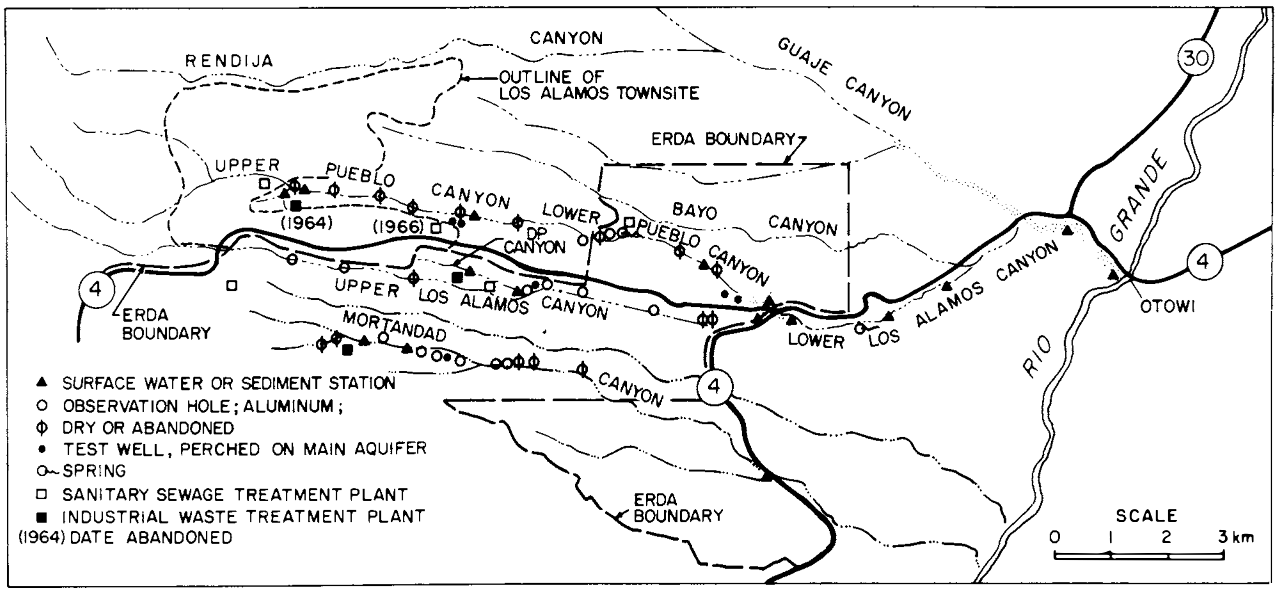


Figure 4.1.1-2

Canyon Water and Sediment Sampling Locations with Current and Former Major Effluent Discharge Points

Information on these processes and environmental quality measurements has been gathered over many years. Informal studies of radionuclides in Pueblo and Los Alamos Canyons were conducted in the 1940s.[4-8,4-9] Studies were made on the hydrology and chemical and radiochemical quality of water in the canyons by the U.S. Geological Survey between 1963 and 1969.[4-10 through 4-19] LASL-conducted environmental surveillance programs and special studies have contributed other data.[4-23 through 4-35] Various studies have demonstrated that storm runoff is an operative mechanism in transport of radionuclides in the canyons.[4-20 through 4-29]

Information on the types and quantities of radioactivity released to the three canyon areas has been compiled from estimates and official records. During the early years either no records or very limited information was kept on quantities of releases. Thus, many of the values used for early periods are only estimates.[4-23] In more recent years increasingly detailed information has been recorded. However, all totals must be considered estimates when they include earlier periods.

The following sections provide brief summaries of the patterns of water movement, historical and present chemical and radiochemical quality conditions, estimated inventories of radioactivity, and information on transport processes for each of the three canyon systems. These summaries are based on relevant information from the previously cited references as well as some unpublished data. For more recent data see the Environmental Surveillance Report for 1978, Appendix H, pages H-18 through H-24, H-32 through H-34, H-93 through H-95, and H-99 through H-101.

During 1978, extensive additional field sampling and measurements were completed in Acid-Pueblo and Lower Los Alamos Canyon under auspices of the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP). The radiological resurvey results and interpretation will be published by DOE in a detailed report.

Pueblo Canyon

Stream flow in the upper and lower reaches of Pueblo Canyon (see Figure 4.1.1-2) is now perennial because of treated sewage effluent released from two community sanitary treatment plants. This flow does not reach the confluence with Los Alamos Canyon except during runoff from summer showers or substantial snow melt. The effluent infiltrates into the stream channel and recharges water perched in the alluvium above the tuff and a small body of water perched in the Puye formation near the mid-reach of the canyon. The effluent in the lower reach of the canyon recharges an aquifer in the basalt that discharges in Los Alamos Canyon below the confluence with Pueblo Canyon.

The laboratory industrial effluents were released into a small tributary of Pueblo Canyon known as Acid Canyon starting in 1944. The discharge point was about 650 m (2100 ft) from the confluence with Pueblo. The concentrations of chemicals and radiochemicals were higher in the water in Acid Canyon during the period of discharge of untreated (1944-1951) and treated (1951-1964) effluents. The concentrations generally decreased in Pueblo Canyon because of dilution by the sanitary sewage plant effluents.

The chemical quality of water in Pueblo Canyon has been influenced largely by effluents from the three sanitary treatment plants (the two currently operated County plants: Pueblo, started in the mid-40s, and Bayo, started in 1963; and the Central Plant operated from the late 40's until 1966). The volume of industrial effluents released into the canyon was small compared to the sanitary effluents.

The surface and shallow ground water in the alluvium contained some high concentrations of fluoride and nitrates during the operation of the industrial treatment plant from 1954 to 1964 (see Table 4.1.1-5). Since 1964 the fluoride and nitrate levels have generally declined. Chlorides have increased, possibly because of leaching and runoff from salt used for deicing of the streets in the community. The radioactive substances released into Acid Canyon with the untreated effluents (1945 to 1951) included an estimated 3.8 Ci of tritium, 0.15 Ci of ^{239}Pu, <0.001 Ci of ^{89}Sr, and 0.048 Ci of ^{90}Sr. Radioactive materials released from the industrial waste treatment plants (1951-1964) include an estimated 14.8 Ci of tritium, 0.027 Ci of ^{239}Pu, <0.01 Ci of ^{90}Sr, <0.001 Ci of ^{235}U, and 0.067 Ci of unidentified alpha activity. Other minor amounts of radionuclides may have been released with the effluents. The estimated total amount of plutonium released into Acid and Pueblo Canyons is about 0.17 Ci.

Early studies detected plutonium in the surface flow of Pueblo Canyon.[4-9] Monitoring data from Pueblo Canyon is summarized for periods 1958-1964, 1970, and 1976 in Table 4.1.1-6. There was little if any detectable plutonium in surface or shallow groundwater in Pueblo Canyon after 1964. However, surface water in Acid Canyon still contains measurable plutonium (1976 data ranged from <0.05 to 1.9 pCi/ℓ) indicating some redissolution of plutonium previously adsorbed on sediments in the canyon.

Analysis for plutonium on sediments were not routinely made before 1970. Gross-alpha activity on sediments in Acid Canyon ranged from 34 to 2900 pCi/g between 1954 and 1961. Detailed studies of plutonium and cesium on sediments have been conducted in connection with transport and ecological research.[4-25, 4-26] Table 4.1.1-7 shows some of the data from these studies for plutonium and cesium concentrations at various distances down the canyon, and depth distributions for plutonium. The distances to the 640 m (2100 ft) station are in Acid Canyon, the balance extends down to the junction with Los Alamos Canyon.

Some detailed studies have attempted to define transport by runoff. During the snowmelt runoff in the spring of 1975, the volume of water, suspended sediments, and plutonium concentrations were measured at the mouth of Pueblo Canyon. The volume of water passing the station was about 3,400 m^3 (9.0×10^5 gal) from April 19 through 25. The water carried about 1,700 kg (3,748 lb) of suspended sediments. The amount of plutonium carried in solution was 1.4 μCi. This runoff combined with that from Los Alamos Canyon.

An inventory and relative distribution of plutonium in four segments of Acid-Pueblo Canyon was estimated from sediment plutonium data and is presented in Table 4.1.1-8. Calculations based on 1970 samples indicated that about 18.1 mCi remained in the 10.3 km (6.4 mi) section of stream

TABLE 4.1.1-5

RANGE OF SELECTED CHEMICAL CONSTITUENTS IN SURFACE AND SHALLOW GROUND WATER IN ALLUVIUM IN PUEBLO CANYON
(all units mg/ℓ)

	1954-1964[a]	1970	1976	1978[b]
Chlorides	13 - 47	22 - 44	5 - 65	19 - 40
Flourides	0.8 - 3.3	1.0 - 1.4	0.4 - 1.0	0.3 - 0.9
Nitrates	2 - 153	40 - 61	5.7 - 69	<2 - 26
Total Dissolved Solids	190 - 542	341 - 402	273 - 442	184 - 482

[a]Period of release of industrial effluents.
[b]See Appendix H, pages H-93 through 95 for detailed 1978 data.

TABLE 4.1.1-6

RANGE OF RADIOACTIVITY CONCENTRATIONS IN SURFACE AND SHALLOW GROUND WATER IN ALLUVIUM OF PUEBLO CANYON

	Units	1958-1964	1970	1976	1978[a]
Gross α	pCi/ℓ	-	<1-4	0.1-12	0.1-15
Gross β	pCi/ℓ	-	4-25	8.1-35	3.3-25
^{137}Cs	pCi/ℓ	-	-	<8.0	<40
^{239}Pu	pCi/ℓ	<0.5-11	<0.05	<0.05	<0.04
^{90}Sr	pCi/ℓ	-	-	<3.3-7.4	<2
^{3}H	pCi/ℓ	-	<1000-15,000	1000-8000	900-19,000
Total U	μg/ ℓ	-	<0.4-1.5	<0.4-4.0	0.1-50

[a]See Appendix H, pages H-93 through H-95, for detailed 1978 data.

TABLE 4.1.1-7

RADIONUCLIDE CONCENTRATIONS ON SEDIMENTS IN ACID-PUEBLO CANYON IN 1973[a]

Distance from Waste Outfall	Total Plutonium Concentration (pCi/g) Depth (cm) 0-2.5	2.5-7.5	7.5-12.5	Remainder[b]	^{137}Cs Concentration (pCi/g)
-100 m[c]	0.122	0.137			0.36
0	16.6	8.52			0.02
20 m	16.8				1.5
40 m	5.78	8.72	11.4	28.7	0.74
80 m	6.21	6.60	21.1	505	14
160 m	8.61	10.1	--	20.4	1.1
320 m	8.28	7.92	10.8	12.3	1.5
640 m	7.86	12.4	10.4	19.1	1.1
2.56 km[d]	36.3	369	2250		0.31
5.12 km	1.39	--	0.617	1.65	0.20
10.2 km	0.401	0.518	0.435		0.33

[a]See Appendix H, pages H-100 and 101, for 1978 data.

[b]The depth of the remainder section varied from 12.5 to 30 cm maximum.

[c]Negative distances represent background locations upstream from the waste outfalls.

[d]Extensive additional resampling in this part of the channel completed in 1978 as part of the FUSRAP program showed no sediment concentrations greater than 3.3 pCi/g.

TABLE 4.1.1-8

ACID-PUEBLO CANYON PLUTONIUM INVENTORY AND DISTRIBUTION

Meters Downstream from Waste-Outfall	Total Pu(mCi) Feb. 1970	% Total	Total Pu(mCi) Oct. 1972	% Total
0-480	4.6	25	2.4	21
480-2,600	8.7	48	4.3	37
2,600-6,800	2.3	13	2.3	20
6,800-10,280	2.5	14	2.6	22
Total	18.1	100	11.6	100

channel downstream from the former waste-outfall to the confluence with Los Alamos Canyon. This value represented about 11% of the estimated input of 170 mCi from 1943 to 1964. In 1972, the calculated inventory was 11.6 mCi for the same sections of stream channel. The difference between the 1970 and 1972 inventories indicates an annual loss from this stream section of about 2.2 mCi/year, or roughly 13% of the inventory per year. The loss appears to have been largely from the upper reaches of the canyon, where the stream channel is narrow, precipitous, and easily scoured. The inventory of plutonium attached to sediment particles in the lower sections, 2.6 to 10.3 km (1.6 to 6.4 mi), is apparently at steady-state, with annual gains equaling losses.

The ^{137}Cs sediment inventory for Acid-Pueblo Canyon was approximately 4.1 mCi in 1972 of which about 3.1 mCi is attributable to world-wide fallout background based on average preoutfall concentrations of 0.38 pCi/g. Few sediment samples from this canyon contained above-background levels of ^{137}Cs. Thus, the amount of ^{137}Cs released to the canyon was either small or it has since been transported downstream by storm runoff.

<u>Upper Los Alamos Canyon</u>

The Los Alamos Canyon drainage area extends to the flanks and crest of Sierra de los Valles and enters the Rio Grande to the east. Major tributaries are Guaje, Pueblo, and DP Canyons (see Figure 4.1.1-2). In the upper reach of the canyon, west of the DOE boundary on the flanks of the mountains, perennial surface flow occurs. Surface flow across the plateau within the DOE reservation is intermittent. There is some minor release of sanitary and cooling tower effluents from two technical areas in the canyon. Larger quantities of treated sanitary and industrial waste are released into a tributary, known as DP Canyon, north of Los Alamos Canyon. Only with major snowmelt or summer showers does surface runoff reach the Rio Grande. The effluents and runoff from precipitation recharge a small body of shallow groundwater in the alluvium. As the water in the alluvium moves downgradient part is lost to evaporation and infiltration into the underlying volcanic rocks or sediments.

Three nuclear reactors have been operated at Omega Site in Los Alamos Canyon: the Water Boiler, Clementine, and the Omega West Reactor (OWR). No contamination is known to have been released from Clementine (1948-1952). The main contamination release from the Water Boiler (1945-1974) was the dumping of once-through cooling water (3 gpm) into the canyon stream bed. This irradiated water contained a barely detectable amount of activity, predominantly 15-h ^{24}Na. Between 1956 and 1963, radioactive effluents from the OWR process water system were dumped into the stream bed at a maxmium rate of about 15 curies/yr. The principal activity was 15-h ^{24}Na, but small amounts of ^{51}Cr (28d), ^{65}Zn (244d), and ^{124}Sb (60d) were also released. From 1963 to 1968, the radioactive liquid effluents were allowed to decay in hold-up tanks and were diluted to environmentally acceptable levels before being dumped in the stream bed. Since 1968, the OWR liquid effluents have been transported to TA-50 for disposal. There is no record of any release of ^{239}Pu or tritium from operations at Omega Site.

The tributary DP Canyon drains only a small area and surface flow in it is intermittent, consisting mainly of the treated industrial and sanitary effluents, with occasional runoff from precipitation. In 1952 a treatment plant was constructed to handle liquid wastes from the technical area on the mesa between DP and Los Alamos Canyons. Treated effluents from this plant and a sanitary sewage treatment plant are released into DP Canyon. The effluents infiltrate into the alluvium of DP Canyon, which in turn adds recharge to water in the alluvium of Los Alamos Canyon.

The chemical quality of water in the shallow alluvial aquifer in upper Los Alamos Canyon has shown a slight decrease in fluorides and an increase in nitrates from 1966 to 1976 (see Table 4.1.1-9). Chloride and TDS have remained nearly constant. The quality of the effluents released from the waste treatment plant dominate the quality in the shallow aquifer in Los Alamos Canyon.

The estimated inventory of radioactive materials released to DP Canyon from 1952 through 1975 are shown in Table 4.1.1-10. (See Table 4.1.1-3 for 1976 releases.) Environmental samples of water from surface flow and the shallow alluvial aquifer show that concentrations vary from year-to-year because of differing amounts of storm runoff which dilute the industrial effluents in the aquifer. Radionuclides in water from Los Alamos Canyon above the junction with DP Canyon were near background levels; below the junction the concentrations show the effect of effluents from DP Canyon. The radionuclide concentrations in the shallow aquifer decrease downgradient in the canyon as the radionuclides are adsorbed on sediments of the alluvium. Table 4.1.1-11 shows ranges of values observed during the last decade. Detailed studies of plutonium and cesium on sediments have been conducted in connection with transport and ecological research.[4-25, 4-26] Table 4.1.1-12 shows some of the data from these studies for plutonium and cesium concentrations at various distances down the canyon, and depth distribution for plutonium. The distances to the 1.28 km (0.8 mi) station are in DP Canyon, the balance extends down Los Alamos Canyon to near the junction with Pueblo Canyon.

In 1967 a study was made to determine runoff volume, suspended sediment load, and amount of radioactivity carried out of DP Canyon by storm runoff.[4-27] Precipitation in the drainage area during the summer resulted in 23 runoff events that carried out about 88 x 10^3 kg (194 x 10^3 lb) of suspended sediments in 36.8 x 10^3 m^3 (9.7 x 10^6 gal) of water. About 74 μCi of gross-alpha emitters and about 40 x 10^3 μCi of gross-beta emitters were carried out of the canyon in solution. About 31 x 10^3 μCi of ^{90}Sr as well as traces of ^{239}Pu and ^{241}Am were carried in solution. The suspended sediments carried about 70 μCi of gross-alpha and 11.3 x 10^3 μCi of gross-beta emitters into Los Alamos Canyon.

The volume of water, suspended sediment, and bedload transport out of Los Alamos Canyon from the confluence with DP Canyon to the confluence with Pueblo were measured during the spring runoff of 1973. During 62 days about 425 x 10^3 m^3 (112 x 10^6 gal) of runoff flowed in Los Alamos Canyon at the confluence with Pueblo Canyon. It carried about 210 x 10^3 kg (463 x 10^3 lb) of suspended sediments and 2,880 x 10^3 kg (6349 x 10^3 lb) of bedload sediments out of the reach of Los Alamos canyon below DP. About 10 μCi of plutonium was carried in solution, 270 μCi with the suspended sediments, and 550 μCi with the bedload sediments. Some of this probably reached the Rio Grande and the remainder was deposited in bed sediments in lower Los Alamos Canyon below the junction with Pueblo Canyon.

Estimated inventories of plutonium on sediments in two sections of DP-Los Alamos Canyon are presented in Table 4.1.1-13. The plutonium inventories in May and August 1968 reflect the storm runoff transport phenomenon. The inventory in May shows the buildup of plutonium during the fall-

TABLE 4.1.1-9

RANGE OF SELECTED CHEMICAL CONSTITUENTS IN SHALLOW GROUND WATER IN THE ALLUVIUM OF UPPER LOS ALAMOS CANYON

(all units in mg/ℓ)

	1966	1970	1976	1978[a]
Chlorides	39 - 86	14 - 52	7 - 68	24 - 51
Fluorides	<0.1 - 16	<0.1 - 8.0	0.3 - 2.4	0.2 - 3.2
Nitrates	1.8 - 40	1.8 - 40	0.4 - 108	<2 - 39
Total Dissolved Solids	257 - 660	208 - 512	224 - 582	280 - 507

[a]See Appendix H, pages H-93 through 95 for detailed 1978 data.

TABLE 4.1.1-10

INVENTORY OF RADIONUCLIDES RELEASED INTO DP-LOS ALAMOS CANYON 1951-1977[a]

Radionuclide	Amount[b] (Curies)
^{241}Am	0.001
^{137}Cs	0.018
^{3}H	36.03
^{238}Pu	0.001
^{239}Pu	0.032
^{89}Sr	<0.001
$^{89-90}Sr$	0.041
^{90}Sr	0.006
^{235}U	<0.001
Unidentified Alpha	0.015
Unidentified Beta-Gamma	0.551

[a]See Appendix H, page H-103 for 1978 data.

[b]Corrected for decay through December 1977.

TABLE 4.1.1-11

RANGE OF RADIOACTIVITY CONCENTRATIONS IN SHALLOW GROUND WATER IN ALLUVIUM OF DP-LOS ALAMOS CANYON

(all units in pCi/ℓ except as noted)

	1968	1972	1976	1978[a]
Gross α	<1 - 11	<1 - 9	0.2 - 8.0	2.2 - 6.6
Gross β	10 - 103	2 - 239	8.9 - 440	9 - 222
^{137}Cs	<240	<350	<16	4 - 40
^{238}Pu	<0.05 - 0.11	<0.05 - 0.46	<0.05 - 0.38	<0.14
^{239}Pu	<0.05 - 0.15	<0.05 - 0.55	<0.05 - 0.16	<0.04 - 0.26
^{90}Sr	-	-	<1 - 56	1 - 111
^{3}H	<50,000 - 180,000	<1000 - 259,000	2000 - 43,200	1000 - 21,000
Total U	<0.4 - 2.4 μg/ℓ	<0.4 - 5.5 μg/ℓ	<0.4 - 4.9 μg/ℓ	0.4 - 4.2 μg/ℓ

[a]See Appendix H, pages H-93 through 95, for detailed 1978 data.

TABLE 4.1.1-12

RADIONUCLIDE CONCENTRATIONS ON SEDIMENTS IN DP-LOS ALAMOS CANYON IN 1973[c]

Distance from Waste Outfall	Total Plutonium Concentration (pCi/g) Depth (cm)				^{137}Cs Concentration (pCi/g)
	0-2.5	2.5-7.5	7.5-12.5	Remainder[a]	
-100 m[b]	0.036	0.036	0.044	0.051	0.31
0	957	1640			1700
20 m	24.8	16.4	2.63		190
40 m	18.2	_	11.4	0.488	5.9
80 m	-	10.4	1.87	0.831	49
160 m	0.332	2.25	0.369	0.328	24
320 m	0.196	0.252	0.225	2.34	15
640 m	0.344	0.481	0.445		51
1.28 km	0.864	0.878	0.644	1.78	13
2.56 km	0.183	0.0904	0.114		3.6
5.12 km	0.599	0.186			1.6

[a]The depth of the remainder section varied from 12.5 to 30 cm maximum.

[b]Negative distances represent background locations upstream from the water outfalls.

[c]See Appendix H, pages H-100 and 101, for 1978 data.

TABLE 4.1.1-13

LOS ALAMOS CANYON PLUTONIUM INVENTORY AND DISTRIBUTION

Meters Downstream from Waste-Outfall	Pu(mCi) May 1968	% Total	Pu(mCi) Aug 1968	% Total	Pu(mCi) Feb 1970	% Total	Pu(mCi) Oct 1972	% Total
0-1,800	3.9	78	0.4	27	4.6	81	3.2	86
1,800-6,600	1.1	22	1.1	73	1.1	19	0.5	14
Total	5.0	100	1.5	100	5.7	100	3.7	100

winter-spring months, and the August inventory represents the residual after the summer rainfall season. The plutonium losses from the section of Los Alamos Canyon from the confluence with DP Canyon to the DOE boundary apparently equaled gains, since the inventory remained relatively constant. The inventory estimate in February 1970 was 5.8 mCi, which represented about 20% of the cumulative 28.4 mCi released to the canyon at that time. About 12% (3.7 mCi) of the cumulative 31.7 mCi input remained in October 1972. The inventory estimates for all three years indicated that year-to-year losses approximately equal gains, even though one year's losses may occur within a short time period. The net loss of plutonium from May 1968 to February 1970 was about 1.25 mCi/year, based on inventory and current release from the plant. The net loss from February 1970 to October 1972 was 1.8 mCi/year which was based on inventory and current releases. The average of the two relative loss rates was about 1.5 mCi/m or about 23% of the inventory in the sediments and releases during the year. A simple mathematical model predicts that background levels (<0.01 pCi/g) would be achieved about 10 years after termination of effluent releases at current rates. The estimated inventory of ^{137}Cs on sediments in DP and Upper Los Alamos Canyons was about 154 mCi in 1972. About 84% was within 1.8 km (1.1 mi) of the outfall in DP Canyon.

Lower Los Alamos Canyon

The stream flow in lower Los Alamos Canyon below the confluence with Pueblo is intermittent. This reach of the canyon has received effluent residuals transported out of both upper Los Alamos and Pueblo Canyons (see Figure 4.1.1-2). Three sediment sampling stations, located off-site in the lower reach of Los Alamos Canyon between the junction with Pueblo Canyon and the Rio Grande, were sampled in 1970 and again in 1976. The total Pu (^{238}Pu and ^{239}Pu) in 1970 for the three sample stations ranged from 0.37 to 0.60 pCi/g with an average of 0.45 pCi/g. In 1976, the total plutonium at the same stations ranged from 0.088 to 0.019 pCi/g with an average of 0.14 pCi/g. The concentrations in 1976 ranged from about 2 to 8 times regional levels attributable to worldwide fallout.[4-46] About 160 mCi plutonium from Acid-Pueblo and 30 mCi plutonium from DP-Los Alamos have likely been transported into or through this lower reach over the past 30 years. The inventory estimates and relative distribution of plutonium in lower Los Alamos Canyon in 1968 and 1970 are presented in Table 4.1.1-14. It is apparent that little of the 190 mCi plutonium from the upper portions of Acid-Pueblo and DP-Los Alamos remains in the lower segment. The 1968 data reflect summer storm transport with 2.3 mCi present in May decreased to about 1 mCi in August. The inventory in February 1970 was 3.1 mCi. The estimated average annual plutonium loss due to sediment transport in this lower reach is about 53% per year based on the inventory data and input of about 2 mCi/yr from Pueblo and about 0.5 mCi/yr from upper Los Alamos Canyon. A simple mathematical model using these assumptions predicts background levels of <0.01 pCi/g would be reached about 10 years after effluent release is terminated. The estimate of ^{137}Cs on sediments in lower Los Alamos Canyon from the confluence of Pueblo and Los Alamos Canyons to the Rio Grande in 1972 was 10.2 mCi. The total ^{137}Cs inventory for the Acid-Pueblo-DP-Los Alamos Canyon system, including lower Los Alamos Canyon, was about 168 mCi. About 92% was in the upper Los Alamos Canyon, with less than 3% in Acid-Pueblo Canyon, and about 6% in lower Los Alamos Canyon.

Sediment samples from the Rio Grande have not contained concentrations of plutonium above detectable limits (0.01 pCi/g). This is not surprising considering that sediment loads passing Otowi bridge on the Rio Grande averaged 2.2×10^9 kg/yr (4.8×10^9 lb/year) during a recent 21 year period of record. The capacity for dilution of radioactivity with sediments as it enters the Rio Grande is large.

TABLE 4.1.1-14

LOWER LOS ALAMOS CANYON PLUTONIUM INVENTORY AND DISTRIBUTION

Segment (m)	Pu(mCi) May 1968	% Total	Pu(mCi) Aug 1968	% Total	Pu(mCi) Feb 1970	% Total
0-4,800	1.6	62	1.0	.98	2.0	65
4,800-7,200	0.7	38	<0.02	.2	1.1	35
Total	2.3	100	1.0	100	3.1	100

Mortandad Canyon

Mortandad Canyon heads on the Pajarito Plateau within the DOE reservation and is tributary to the Rio Grande (see Figure 4.1.1-2). The Central Waste Treatment Plant releases effluent into this canyon. The plant began operation in 1963. The stream in the upper reach of the canyon is perennial because of the release of these industrial effluents and cooling water. Storm runoff periodically adds to the flow.

The flow from the effluents and intermittent storm runoff recharges a small body of water in the alluvium that is perched on the underlying tuff. As the water in the alluvium moves eastward, steady losses to evapotranspiration and minor losses into the tuff occur so that the water in the alluvium is limited and does not extend to the DOE boundary. Studies of the geology and hydrology of the canyon were made before its use as an effluent receiving area.[4-37, 4-38]

A water balance for the canyon has been kept since 1961 using data from gaging stations and observation holes in the alluvium. In general, the losses due to evapotranspiration and seepage into the underlying tuff are about equal to inflow from effluents and storm runoff. Thus the aquifer remains about the same size, with about $20 \times 10^3\ m^3$ (14 acre-feet) of water in storage. The rate of movement of water in the alluvium and the hydrologic conductivity have been measured using tritium and chloride ion as tracers (see Table 4.1.1-15). The total travel time from the effluent outfall to the eastern edge of the aquifer was about 390 days.[4-49]

The DOE boundary lies about 5.1 km (3.1 mi) east of the effluent outfall. Since studies in the canyon began in 1960, there has been no surface flow in the canyon that has reached the boundary. Thus there has been no transport of radionuclides in storm runoff to the boundary. The volume of runoff is low due to the small drainage area of the canyon. In addition, the unsaturated alluvium in the lower part of the canyon is highly permeable and able to retain all runoff that has occurred for the past 17 years.

The industrial effluents released into the canyon have altered the quality of water in the shallow aquifer. The water has changed from slightly acid (pH ~6.8) to alkaline (pH ~8) because of the alkalinity of the effluents. Concentrations of many chemicals have increased since 1962, although not consistently with time (see Table 4.1.1-16). The largest increase has been in nitrates.

Table 4.1.1-17 compares the mass of chemicals released into the canyon from 1963 through 1974 with the ions in solution in the aquifer in 1962 and 1974. The estimate of residuals in solution in the aquifer is about 1 to 6% of the total in the effluents released after 1962.[4-40] The loss of chemicals is the result of uptake by vegetation, adsorption or precipitation of chemicals with alluvium materials, or losses with water into the underlying tuff.

In addition to these studies, monitoring of mercury concentrations in the Mortandad Canyon stream channel and bank soils associated with the effluent has been initiated. Samples were collected from a 100 m (330 ft) segment of the stream bed located 150 to 250 m (500 to 800 ft) below the outfall and were analyzed for mercury using a flameless atomic absorption procedure.[4-41] Initial results indicate that concentrations of mercury are present at levels well above the 12 ± 9 ppb that were measured in background samples (see Table 4.1.1-18). Although there is a high variability in soil mercury concentrations, it appears that this element may be concentrated preferentially in stream bank soils.

TABLE 4.1.1-15

MORTANDAD CANYON RATES OF ALLUVIAL WATER MOVEMENT AND HYDRAULIC CONDUCTIVITY

Canyon Location	Type of Unit	Velocity of Tracers (m/day)	Hydraulic Conductivity (m/day)
Upper	Coarse Sand	18	141
Middle	Silty-Sand-Clay	5	50
Lower	Silty-Sand-Clay	2	7.6

TABLE 4.1.1-16

RANGE OF SELECTED CHEMICAL CONCENTRATIONS IN SURFACE AND SHALLOW GROUND WATER IN ALLUVIUM OF MORTANDAD CANYON
(all units in mg/ℓ)

	1962[a]	1965	1970	1976	1978[b]
Chlorides	6 - 9	2 - 53	5 - 25	5 - 31	12 - 39
Fluorides	<0.1 - 0.4	<0.1 - 2.7	<0.1 - 1.4	<0.3 - 1.8	0.3 - 2.6
Nitrates	0.9 - 9.2	2.6 - 127	13 - 576	48 - 202	2 - 112
Total Dissolved Solids	143 - 610	232 - 645	234 - 1735	222 - 892	462 - 1340

[a] Prior to release of industrial effluents.

[b] See Appendix H, pages H-93 through 95, for detailed 1978 data.

TABLE 4.1.1-17

MASS INVENTORY OF CHEMICALS RELEASED AND IN STORAGE

Constituents	Kilograms x 10^3		
	Effluents, TA-50 1963-1974	In Storage 1962	In Storage 1974
Calcium	35	0.2	0.5
Magnesium	1.8	.08	.1
Sodium	174	.6	3.6
Carbonate	84	0	0
Bicarbonate	153	1.8	4.8
Chloride	31	.1	.6
Fluoride	1.3	.01	.02
Nitrate	145	.06	3.9
Total Dissolved Solids	642	6.4	14.9

TABLE 4.1.1-18

MERCURY CONCENTRATIONS IN MORTANDAD CANYON SOILS[a]

Deptn (cm)	Stream Channel (n = 10)		Stream Bank (n = 40)	
	Hg (ppb)	CV[b]	Hg (ppb)	CV[b]
0 - 2.5	99	1.4	150	0.92
2.5 - 7.5	74	0.62	170	1.3
7.5 - 30	75	0.60	120	1.9

[a]Background mercury levels in canyon soils average 12 ± 9 ppb (n = 10).

[b]Coefficient of variation, $\frac{\text{standard deviation}}{\text{average}}$.

The estimated amounts of radioactive materials released into Mortandad Canyon are shown in Table 4.1.1-19. The concentrations of radionuclides in surface flow and shallow water in the alluvium have generally increased as effluent release has continued (see Table 4.1.1-20). The table shows the shift in dominance from ^{239}Pu to ^{238}Pu after 1968 as more wastes containing ^{238}Pu were being treated. An estimate in 1972 of plutonium in solution in the aquifer was 19.2 μCi, or less than 1% of the cumulative 21.9 mCi released between 1963 and 1972. The majority of the plutonium is adsorbed on sediments in the channel or aquifer.

Special core samples from holes drilled through the alluvial aquifer in the mid-reach of Mortandad Canyon were collected in 1978 in an attempt to learn more about possible downward movement of contaminants. Radiochemical analyses for plutonium and cesium showed no detectable activity in the tuff beneath the aquifer. Some tritium was measurable in moisture distilled from samples taken at depths down to 8 m (26 ft) beneath the aquifer.

Measurements for tritium in samples from the stream connected aquifer in the alluvium of Mortandad Canyon were first made in 1966. Tritium was present from liquid waste released in early operations of the Central Waste Treatment Plant (1963 through 1966) or from a nearby technical area which discharged untreated waste in the late 1950s and early 1960s. In February 1967 the water in storage in the lower canyon contained about 9.3 Ci of tritium. In May 1969 about 1.2 Ci of tritium remained in storage.

Twenty curies of tritium discharged into Mortandad Canyon in November 1969 were used to determine the dispersion and movement of water in the shallow alluvial aquifer. It took 388 days for the peak concentration to move 3,000 m (10,000 ft) from the effluent outfall to the eastern end of the aquifer. The peak concentration decreased from 77,700 pCi/mℓ to 310 pCi/mℓ. Ground water in storage contained about 0.9 Ci of tritium before the release of the 20 Ci. About 3.9 Ci of tritium remained in storage at the end of 1970. The remaining 17.0 Ci were lost by evapotranspiration, infiltration into the underlying tuff, or remained suspended with soil moisture above the aquifer.[4-40]

Detailed studies of plutonium and cesium on sediments have been conducted in connection with transport and ecological research. Table 4.1.1-21 shows some of the data from these studies for plutonium and cesium concentrations at various distances down the canyon, and depth distributions for plutonium. All of the stations are within DOE property. At the DOE boundary the concentrations are background.

An estimated inventory of plutonium in sediments was made in 1970 and 1972 (see Table 4.1.1-22). The February 1970 inventory estimate was 18.5 mCi which compares with cumulative input of 22.3 mCi through 1969. The October 1972 estimate was 40 mCi, which compares closely with the cumulative input of 41.5 mCi through 1972. Changes in the relative distribution of the plutonium between the two sections are indicative of redistribution by storm runoff. Data show that plutonium on sediments is contained within the DOE boundary, less than 5.1 km (3.2 mi) below waste outfall.[4-23, 4-24, 4-40] The estimated inventory of ^{137}Cs on sediments within 30 cm (1 ft) of the surface for October 1972 was 319 mCi. This accounts for about one-tenth of the total which was released in the canyon.[4-23] The cesium has apparently moved to a depth greater than 30 cm (1 ft) within the alluvium because there is no evidence of surface transport past the DOE boundary.

TABLE 4.1.1-19

INVENTORY OF RADIONUCLIDES RELEASED INTO MORTANDAD CANYON
1963-1977

Radionuclide	Amount[a] (curies)
^{241}Am	0.007
^{137}Cs	0.848
^{3}H	251.15
^{238}Pu	0.051
^{239}Pu	0.039
^{89}Sr	<0.001
^{90}Sr	0.295
^{235}U	0.002
^{238}U	<0.001
Unidentified Alpha	0.039
Unidentified Beta-Gamma	8.36

[a]Corrected for decay through December 1977, see Appendix H, page H-103 for 1978 data.

TABLE 4.1.1-20

RANGE OF RADIOACTIVITY CONCENTRATIONS IN SURFACE AND SHALLOW GROUND WATER IN ALLUVIUM OF MORTANDAD CANYON
(units in pCi/ℓ except as noted)

	1968	1972	1976	1978[a]
Gross α	<1 - 10	<1 - 26	1 - 70	12 - 325
Gross	5 - 364	32 - 714	18 - 2800	18 - 790
^{137}Cs	<240 - 270	<350 - 1330	<8 - 32	<30 - 75
^{238}Pu	<0.05 - 0.59	<0.05 - 16.0	<0.05 - 43.3	<0.14 - 19
^{239}Pu	<0.05 - 1.26	<0.05 - 2.67	<0.05 - 8.3	<0.08 - 3.8
^{90}Sr	-	-	<2.0 - 99	<3 - 80
^{3}H	<50,000 - 360,000	900 - 183,000	25,000 - 3,300,000	95,000 - 382,000
Total U	0.4 - 3.1 μg/ℓ	0.2 - 12.4 μg/ℓ	0.4 - 7.8 μg/ℓ	4.3 - 32 μg/ℓ

[a]See Appendix H, pages 93 through 95 for detailed 1978 data.

TABLE 4.1.1-21

RADIONUCLIDE CONCENTRATIONS IN SEDIMENTS IN MORTANDAD CANYON IN 1973[c]

Distance from Waste Outfall	Total Plutonium Concentration (pCi/g) Depth (cm) 0-2.5	2.5-7.5	7.5-12.5	Remainder[a]	^{137}Cs Concentration (pCi/g)
-100 m[b]	2.69	0.771	0.117		2.0
0	129	274	390		2200
20 m	158	189	70.9		510
40 m	259	234	116		530
80 m	61.6	33.3	16.9		630
160 m	104	84.6	12.5		1200
320 m	70.8	59.0	27.4	6.68	290
640 m	32.7	31.4	31.3		320
1.28 km	13.8	18.2	13.0	9.64	90
2.56 km	--	9.04	6.97	2.26	91
5.12 km	0.114	0.079	0.065	0.105	0.57

[a]The depth of the remainder section varied from 12.5 to 30 cm maximum.

[b]Negative distances represent background locations upstream from the waste outfalls.

[c]See Appendix H, pages H-101 for 1978 data.

TABLE 4.1.1-22

MORTANDAD CANYON Pu INVENTORY AND DISTRIBUTION

Meters Downstream from Waste-Outfall	Total Pu (mCi) Feb 1970	% Total	Oct 1972	% Total
0 - 1,460	15.8	85	28.2	71
1,460 - 5,100	2.7	15	11.8	29
Total	18.5	100	40	100

The major transport of radionuclides in the canyon is by storm runoff. The increased development of Laboratory facilities, buildings, and parking areas in the drainage area will continue to increase the volume of storm runoff, hence transporting contaminants further down the canyon. Studies are being made of methods to increase infiltration into the unsaturated alluvium within the DOE reservation to prevent runoff from reaching the boundary.

Perched and Main Aquifer in Release Areas

The perched aquifers in the Puye Conglomerate and basaltic rocks below Pueblo and Los Alamos Canyons lie at depths ranging from 30 to 55 m (100 to 180 ft) below the canyon bottoms. These aquifers exhibit chemical quality similar to the surface and alluvial waters in Pueblo and Los Alamos Canyons. There is some tritium detectable in samples from one test well in the mid-reach of Pueblo Canyon that is completed in the perched aquifer. No detectable radioactivity has been noted in samples from other test wells or from Basalt Spring. (See Appendix H, pages H-89, H-90, and H-93, for data from 1978 samples.)

The main aquifer is at depths of 228 to 293 m (750 to 960 ft) below the three canyons that have or are now receiving industrial effluents. The chemical quality of water in the main aquifer is quite different than that found in surface water or the perched aquifer, and indicates no recharge from the surface water or perched aquifer. (See Appendix H, pages H-91 through H-95 for 1978 data.) Chemical and radiochemical quality of water in the main aquifer has remained constant for 30 years. There is no indication of any contamination from the release of industrial effluents (see Section 3.1.2, Hydrology).

4.1.2 Air Quality

Air quality is considered good in Los Alamos. Radioactivity due to Laboratory effluents is a small increment over natural background and worldwide fallout (see Section 4.1.3 for dose evaluation). All measurements of radioactivity in ambient air are small fractions of DOE Concentration Guides. Measurements of nonradioactive pollutants are not routinely made. Some measurements by the NMEIA of suspended particulates and sulfur dioxide indicate the air is well within state air quality standards. Routine emissions from the DOE power plant; DOE vehicles, and the beryllium shop are all within applicable standards. Periodic atmospheric dispersal of nonradioactive materials by experiments with chemical explosives have been evaluated and are not believed to result in any adverse effects. It is expected that future improvements to effluent controls will result in further reductions of radioactive materials. No future programs are expected to substantially alter air quality.

Some small amounts of radioactive materials are released from stacks of nuclear research facilities even after extremely careful air cleaning. These releases are all at levels well below the DOE concentration guides for breathing air, ERDA Manual Chapter 0524, as documented by continuous particulate or gas samplers in each stack. The radioactive materials include tritium, mixed fission products, and isotopes of nitrogen, argon, thorium, phosphorus, plutonium, uranium, carbon, oxygen, iodine, and rubidium.

Radioactive materials are released to the atmosphere from 12 of the technical areas as the result of routine operations. In each location where these releases are made, the exhaust systems are equipped with suitable air filtration systems to remove particles. Many of the systems have High Efficiency Particulate Air (HEPA) filters, which remove at least 99.97% of the particulates from the air stream. Gaseous radioactive materials from operation of the Omega West Reactor are contained for delayed release. Before 1974, gaseous fission products from the Water Boiler were vented. No significant quantities of gases result from critical assemblies today because of the short-pulsed nature of their operation. Gaseous tritium or tritiated water vapor released from trituim handling facilities are controlled by containment and operating procedures to the extent that concentrations are below DOE concentration guides for breathing air, ERDA Manual Chapter 0524. Recovery systems are employed to recycle tritium where possible. Some particulates containing natural or depleted uranium and thorium are released from high explosives tests. Because of the long half lives, there is only a small amount of radioactivity involved, and these materials are covered later in this section.

Proposals for future improvement of filtration and control systems include additional double HEPA filters for some of the presently used research laboratories. When the new Plutonium Processing Facility is completed, plutonium releases will be further reduced by filtration systems designed to meet more stringent criteria. Some tritium research is now located in a new facility equipped with an oxidizing microsieve tritium recovery exhaust air treatment system to reduce airborne tritium releases. Plans for the Tritium System Test Assembly also include similar tritium recovery systems designed in accordance with information gained from within LASL and other DOE research facilities.

Concentrations of atmospheric radioactivity are measured at 29 continuously operating air sampling stations in Los Alamos County and vicinity (see Figure 3.3.4-1). These stations are located on Laboratory land, along the Laboratory perimeter, and in residential areas. These locations also serve as TLD monitoring locations. Atmospheric aerosols are collected by filtration, and atmospheric water vapor is simultaneously collected with desiccant samplers. All air samples are collected over two-week periods. Tritium oxide (HTO) concentrations in the atmospheric water vapor samples allow HTO concentrations in ambient air to be calculated. A summary of atmospheric radioactivity monitoring data for 1976 is presented in Table 4.1.2-1. Data for 1973 through 1975 is given in Appendix E.

Annual average HTO concentrations for certain onsite locations range up to ten times average above background atmospheric levels, but still less than 0.01% of the DOE concentration guide for breathing air (see Table 4.1.2-2 and Section 4.1.3). Gross-alpha and gross-beta activities of the atmospheric aerosol samples are routinely determined. Systematic spatial variations (resulting from Laboratory operations) in these gross radioactivity concentrations have not been observed. Activities of ^{238}Pu, ^{239}Pu, ^{241}Am, and uranium are also determined on composited aerosol filters. In general, plutonium, americium, and uranium atmospheric concentration measurements are close to their respective minimum detection limits, which are well below DOE Concentration Guides. Spatial variations for these nuclear species have not been observed. The concentrations compare closely with regional average background atmospheric radioactivity concentrations (see Table 3.1.5-1).

TABLE 4.1.2-1

ANNUAL SUMMARY OF 1976 ATMOSPHERIC RADIOACTIVITY MONITORING[e]

Number and Type of Sampling Locations	Type of Analysis Performed	Mean Radioactivity Concentration	% CG[d]
3 regional[a]	gross α	1.4×10^{-15} μCi/mℓ	2.3
15 perimeter[b]	gross α	1.3×10^{-15} μCi/mℓ	2.2
11 on-site[c]	gross α	1.3×10^{-15} μCi/mℓ	0.1
3 regional	gross β	61×10^{-15} μCi/mℓ	0.2
15 perimeter	gross β	65×10^{-15} μCi/mℓ	0.2
11 on-site	gross β	65×10^{-15} μCi/mℓ	0.007
3 regional	tritiated H_2O	15×10^{-12} μCi/mℓ	0.01
15 perimeter	tritiated H_2O	23×10^{-12} μCi/mℓ	0.01
11 on-site	tritiated H_2O	60×10^{-12} μCi/mℓ	0.001
3 regional	^{238}Pu	$<0.1 \times 10^{-18}$ μCi/mℓ	<0.0001
15 perimeter	^{238}Pu	0.4×10^{-18} μCi/mℓ	0.0005
11 on-site	^{238}Pu	0.9×10^{-18} μCi/mℓ	0.00007
3 regional	^{239}Pu	4.1×10^{-18} μCi/mℓ	0.008
15 perimeter	^{239}Pu	5.2×10^{-18} μCi/mℓ	0.009
11 on-site	^{239}Pu	22.5×10^{-18} μCi/mℓ	0.0009
3 regional	Uranium	61 pg/m^3	0.0008
15 perimeter	Uranium	59 pg/m^3	0.0007
11 on-site	Uranium	60 pg/m^3	0.00003

a) 28-44 km from the LASL boundary.

b) 0-4 km from the LASL boundary.

c) Within the LASL boundary.

d) Percent of concentration guides.

e) See Appendix H, page H-16 for summary and pages H-80 through 84, for detailed data for 1978.

TABLE 4.1.2-2

DOE RADIOACTIVITY CONCENTRATION GUIDES (CGs)

CONCENTRATION GUIDES FOR UNCONTROLLED AREAS[a,b]

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

CONCENTRATION GUIDE FOR CONTROLLED AREAS[a,b]

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

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

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

[c]One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses may be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

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

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

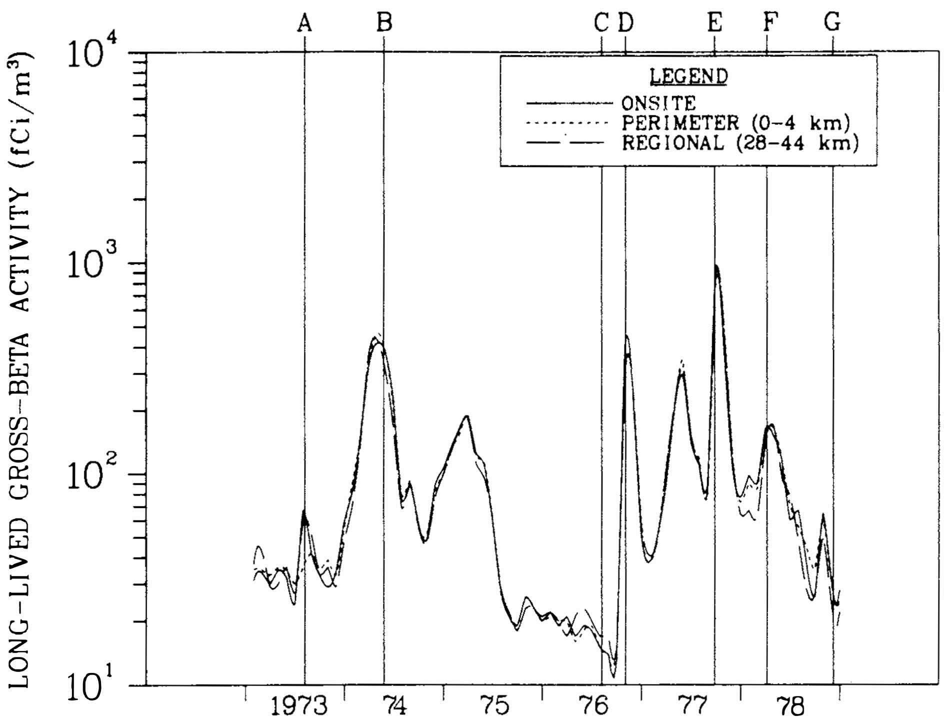
Temporal variations in onsite beta activity are shown in Figure 4.1.2-1.[4-36] The year-to-year atmospheric gross-beta activities for the past three years is depicted. The slightly higher beta activities in 1974 and 1976 were attributed to fallout from atmospheric testing by non-participants in the nuclear atmospheric testing moratorium. Some increase usually occurs early each calendar year as a result of the mixing of the stratosphere with the troposphere. This increase is evident for the 1974 and 1975 data. The beta activities for 1973 and 1976, however, were relatively low, and the characteristic spring maximum was absent.

The inventory of radioactive atmospheric releases before 1973 (see Table 4.1.2-3) was made on the basis of stack sampling through December 1972.[4-42] The absence of stack sampling programs during the early years of the Laboratory and continuing uncontained tests with high explosives involving natural or depleted uranium prevented preparation of a complete inventory. In general, the inventory covers releases during the period from 1948 through 1972 for plutonium, 1961 through 1972 for mixed fission products, and 1967 through 1972 for other radionuclides such as tritium, ^{235}U, and ^{238}U. Inventories of short-lived nuclides such as ^{131}I, ^{88}Rb, ^{133}Xe, ^{135}Xe, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O (whose half-lives range from about 2 minutes to 8 days) were not included, since they decay rapidly and have little biological significance. The activity values for ^{239}Pu include contributions from ^{241}Am and other alpha emitters associated with the ^{239}Pu. Data since 1973 is based on actual stack sampling.

Probable releases of radioactivity to the atmosphere during the next 25 years are likely to be less than releases to date. For example, if releases of plutonium were to continue at the 1976 rate for 25 years, the cumulative amount would be less than 1.5% of the total plutonium released before 1976. Construction and use of a new plutonium facility with extensive filtration equipment is expected to significantly reduce plutonium emissions. At the 1976 rate, tritium releases over 25 years would be about the same as the total before 1976. New treatment equipment and construction of new facilities for tritium research are expected to significantly reduce tritium releases from the 1976 level.

Some non-radioactive materials used or estimated to be produced in routine Laboratory operations have the potential for at least partial release to the atmosphere. The values in Table 4.1.2-4 represent either total quantities checked out of chemical warehouse stock, or estimated total possible production of byproducts during use of chemicals. Since most of the materials such as solvents are used in relatively small quantities in a wide variety of Laboratory operations located throughout the site, it is not known how much of the materials may actually be released to the atmosphere. Within the work areas concentrations are controlled and checked by industrial hygiene personnel to be within occupational health standards. Most atmospheric releases are from fume-hood or building exhaust systems which provide dilution. No ambient air monitoring is performed for these substances because in the concentrations released they are not considered to present any hazard. An attempt was made to measure some of the main organic materials in evironmental air samples but none could be detected. The analyses did identify some hydrocarbons associated with gasoline combustion by automobiles but at very low concentrations.

The potentially most significant nonradioactive release is from the beryllium fabrication shop. However, exhausts from this location are filtered and continuously monitored to assure that the releases are within standards. Measurements have shown that the beryllium in stack gases is less than 10% of the ambient air standards of 0.01 $\mu g/m^3$ (averaged over 30 days) established by the New Mexico Environmental Improvement Agency and approved by the EPA.[4-43]



CHINESE NUCLEAR ATMOSPHERIC TESTS

A.	26	JUNE 1973	2-3 MT
B.	17	JUNE 1974	0.2-1 MT
C.	26	SEPTEMBER 1976	~ 0.2 MT
D.	17	NOVEMBER 1976	~ 4 MT
E.	17	SEPTEMBER 1977	~ 0.02 MT
F.	14	MARCH 1978	~ 0.02 MT
G.	14	DECEMBER 1978	~ 0.02 MT

Figure 4.1.2-1

Average monthly long-lived gross-beta radioactivity over the past 6 years for onsite, perimeter, and offsite sampling locations. See Appendix H, pages H-12 through 14 and 78 for more current data.

TABLE 4.1.2-3

ATMOSPHERIC RELEASES OF RADIOACTIVITY

Cumulative Radionuclides Released to the Atmosphere
Prior to 1973[a]

^{3}H	120,000
Mixed Fission Products	0.006
^{235}U	0.086
^{238}U	0.005
^{238}Pu	0.056
^{239}Pu	1.2

Atmospheric Releases of Radioactivity from Stacks
During 1973 through 1976[b, f]

Radionuclides[c]	1973 (Curies)	1974[d] (Curies)	1975 (Curies)	1976 (Curies)
^{32}P	--	--	--	0.000074
^{232}Th	0.14 kg	--	--	--
^{234}Th	--	--	6.6	0.0025
^{241}Am, ^{238}Pu, ^{239}Pu	0.0087	0.0008	0.00025	0.000068
^{233}U, ^{234}U, ^{235}U	0.0012	--	--	--
^{233}U, ^{235}U, ^{238}U	--	0.0008	0.0009	0.0013
Mixed Fission Products	0.0140	0.0014	0.0010	0.0017
^{131}I	0.0042	0.0047	0.0014	0.0003
^{88}Rb	0.0013	--	--	--
^{133}Xe, ^{135}Xe	210	--	--	--
^{41}Ar	270	312	237	339
^{3}H	6129	7488	6200	3401[e]
^{238}U	0.21	--	--	--
^{11}C, ^{13}N, ^{15}O	--	--	--	5890

a) All values in curies, decay corrected.

b) Values are derived from continuous monitoring data of all stacks at LASL which are release points from nuclear research facilities.

c) From 1973, 1974, 1975, and 1976 Radioactive Effluent and Discharge Monitoring Reports. Note that the half-lives of ^{131}I, ^{88}Rb, ^{133}Xe, ^{135}Xe, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O range from about 2 min to 8 days; thus, these nuclides decay quickly.

d) ^{88}Rb, ^{133}Xe, and ^{135}Xe releases were eliminated because of the shutdown of the Water Boiler Reactor.

e) Activity released during calendar year 1976, does not include accidental 22,000 Curie tritium (^{3}H) release that occurred on July 15, 1976, at TA-3 (SM-34 Cryogenics Laboratory).

f) Data for 1977 in Table 3.3.3-5, data for 1978 included in Appendix H, pages H-28 through H-32 and H-102.

TABLE 4.1.2-4

MAXIMUM POTENTIAL RELEASES OF NONRADIOACTIVE SUBSTANCES TO THE ATMOSPHERE AT LASL[a,c]

Material	Total Amounts Used or Produced During 1975	
	kg	lb
Solvents		
Trichloroethylene	16,200	35,850
Methyl chloroform	25,800	56,900
Freons	15,000	33,050
Acetone	12,400	27,300
Perchloroethylene	1,020	2,250
Kerosene	5,940	13,100
Chloroform	480	1,050
Methanol	1,460	3,200
Methylene dichloride	300	670
Toluene	1,180	2,600
Carbon tetrachloride	240	540
Benzene	110	240
Gases		
Sulfur hexafluoride	10,300	22,800
Ammonia	3,180	7,000
Nitrogen oxides	7,200	15,900
Metals		
Cadmium	0.008	0.02
Beryllium[b]	0.00001	0.00002

a) These quantities are based on usage. Not all of the materials are released as discussed in the text because they may be chemically consumed or transformed to solid or liquid wastes.

b) Computed release from beryllium shop stacks; additional amounts are released by uncontained explosive test shots.

c) See Appendix H, pages H-36 through H-38, for 1978 data that includes estimates of actual rather than potential releases.

A batch plant for paving material releases some combustion products from natural gas burned for drying crushed rock aggregate. The exhaust from the drying process is directed through a water scrubber to control most of the particulates from the crushed rock. In colder weather this may result in a steam plume. Depending on the type of asphalt used, there can also be some release of petroleum-based volatile solvents used in the process. Exhaust emissions were sampled in September 1977. The average particulate emission from the stack was 0.011 gr/SCF, or 1.8 lbs/hr. Although a plant this size is not required to meet the given standards, the measurement was less than the new source performance standard of 0.04 gr/SCF specified in the Federal Register of March 8, 1974, page 9309, and New Mexico's standard of 35 lbs/hr. in EIA Standard No. 501 of June 26, 1971.

The power plant and steam plants all release combustion products from burning natural gas for the boilers (see Table 4.1.2-5).[4-44, 4-45] Based on heat input rates neither the power plant nor steam plants are required to meet emission standards for nitrogen dioxide (NO_2).[4-46] However, all the plants do meet the standards according to stack gas measurements. The NO_2 stack emission level established by the New Mexico Environmental Improvement Agency and approved by the Environmental Protection Agency is 248 parts per million (ppm), and measurements show average levels of 30 ppm in released gases. Because of the negligible sulfur in natural gas, the sulfur dioxide (SO_2) emissions are essentially zero, as confirmed by actual measurements. The fuel oil used in emergency situations is a low sulfur diesel grade, so it presents no SO_2 emission problems. Future potential changes in fuel use are discussed in Section 4.1.6.

LASL purchases roughly half the electricity it uses from the Public Service Company of New Mexico (PSCNM) and the Bureau of Reclamation. The purchased PSCNM power comes from various generating stations on their northern New Mexico power grid, but mainly from their San Juan Power Plant in the Four Corners Area. The Bureau of Reclamation power is hydroelectrically generated by the Colorado River Storage Project. Since no atmospheric emissions emanate from the hydroelectric power station, the only emissions to be considered are those from the PSCNM's San Juan Power Plant. Presently the San Juan Power Plant has one unit in operation. This unit has a 100% capacity of 326 megawatts, but is operated at an annual average 80% capacity factor. Estimates of emissions due to LASL consumption are presented in Section 4.3.2.

Cooling towers for the power and steam plants, and some experimental facilities such as LAMPF and the Omega West Reactor, release heat and water vapor to the atmosphere. Because of spacing and the relatively small size of these units, they do not produce any observable effects aside from condensation plumes during cold weather.

The Zia Company maintains a fleet of vehicles for LASL, DOE, and itself. Data on emissions from these vehicles for the last five years are in Table 4.1.2-6.[4-47] Exhaust emissions testing for carbon monoxide (CO) and hydrocarbons (HG) is part of Zia's routine vehicle maintenance program. Each time a vehicle is serviced, its exhaust emissions are measured to determine if they meet the Federal standards. If they do not, then maintenance on the vehicle is done to bring emissions into compliance with the federal standards for that model year.

TABLE 4.1.2-5

ESTIMATED ANNUAL EMISSIONS OF LASL POWER AND STEAM PLANTS[c]

	Fiscal Year (July 1 to June 30)				
	1972	1973	1974	1975	1976
Volume Natural Gas[4-44] Consumed ($m^3 \times 10^3$)	73,132	81,749	83,542	71,899	75,703
Particulates (160)[a]	11,700[b]	13,100	13,400	11,500	12,100
SO_2 (9.6)	700	800	800	700	700
NO_2 (2880)	210,600	235,400	240,600	207,100	218,000
HC (1120)	81,900	91,600	93,600	80,500	84,800
Organic Acids (960)	70,200	78,500	80,200	69,000	72,700
Aldehydes (160)	11,700	13,100	13,400	11,500	12,100
Ammonia (8)	600	700	700	600	600

a) Emission factors for natural gas combustion ($kg/10^6\ m^3$).

b) All annual emissions in kg, to nearest 100 kg.

c) See Appendix H, pages H-36 through H-38, for the most recent information.

TABLE 4.1.2-6

ESTIMATED ANNUAL EXAUST EMISSIONS OF LASL VEHICLES[a]

	Units	1972	1973	1974	1975	1976
Gasoline Used	ℓ	2,311,214	2,515,898	2,301,997	2,414,599	2,944,865
Distance Traveled	km	7,656,000	7,847,000	8,061,000	8,256,000	9,053,000
Kilometers per Liter	km/ℓ	3.31	3.12	3.50	3.42	3.07
CO (27.27 g/km)	Metric Ton (MT)	208.8	214.1	219.9	225.2	247.0
HC - Exhaust (2.66 g/km)	MT	20.4	20.9	21.5	22.0	24.1
- Evaporation (0.81 g/km)		6.2	6.3	6.5	6.7	7.3
NO_x (2.98 g/km)	MT	22.8	23.4	24.0	24.6	26.9
SO_x (0.12 g/km)		0.9	1.0	1.0	1.0	1.1
Particulates						
- Exhaust (0.24 g/km)	kg	1.8	1.8	1.9	1.9	2.1
- Tire Wear (0.43 g/km)	kg	3.3	3.4	3.5	3.6	3.9

a) See Appendix H, page H-38, for update on data.

Combustion products from government vehicles can be estimated as about 10% of the total for Los Alamos County, based on fuel consumption of about 2.5×10^6 ℓ (647,935 gal) annually, as compared to a county-wide total estimated consumption of about 1.8×10^7 ℓ (4,884,300 gal) annually. This estimate is based on an average daily vehicle travel in 1973 in Los Alamos County of 293,534 km ℓ (181,991 miles)[4-48] and an average of 5.0 km/ (13.6 mi/gal).[4-49]

Besides gasoline evaporative losses from vehicles, there are also losses in storage and distribution of fuel. Table 4.1.2-7[4-47] shows estimates of annual gasoline evaporative losses.

All large compressors have mufflers or noise suppression and emissions are minimal. Where the air or gas being compressed may be contamined, it is cleaned by appropriate filtration or absorption before entering the pump.

Vacuum system pumps handling relatively non-toxic materials are vented to the local house ventilation or to outside air. The amount of oil mist is minimized by proper maintenance of the pump and temperature control. If the vacuum pumps handle toxic chemicals, the effluent from the pump is cleaned by filtration or absorption prior to being vented into the ventilation system which has additional air cleaning.

Periodic dynamic experiments conducted with conventional explosives at firing sites remote from occupied Laboratory sites and residential areas release the combustion products of the explosives and certain other materials. In 1976 about 1020 kg (2250 lb) of depleted uranium was dispersed in these tests. Nonradioactive materials included about 26 kg (35 lb) of beryllium, 19 kg (42 lb) of lead, and 36 kg (79 lb) of mercury. Combustion product gases and some particulates are widely dispersed by atmospheric circulation, but are not measured by the air monitoring network. Most of the debris and particulates from these experiments are deposited on the ground close to the firing site. An estimated 100,000 kg (220,000 lb) of natural and depleted uranium have been used in dynamic experiments during the history of LASL. Most of this is distributed over the soil around the experimental areas on Laboratory property.[4-50]

An experimental and theoretical study was done to describe the atmospheric dispersion of debris from the above dynamic experiments with high explosives. Experimental measurements of airborne debris were then used to estimate the theoretical contribution of dynamic experimentation to atmospheric concentrations of dispersed material for a typical year in the Los Alamos environs. Annual atmospheric concentration estimates were obtained using the measured aerosolized values and through the use of a time-integrated version of the Gaussian puff model. Table 4.1.2-8 gives results at two distances on an annual basis.

A national emission standard for Hg is 1 $\mu g/m^3$ averaged over one day. The time integral for a hypothetical single experiment consuming a total of 16.4 kg of Hg (1976 monthly maximum) is 0.8 $\mu g\text{-}d/m^3$ (80% of standard). Atmospheric uranium concentrations have been routinely measured at LASL by a 26 station air sampling network. The spatial average concentration for uranium in 1976 was 0.06 ng/m^3. The expected levels of uranium due to the resuspension of continental dust is 0.08 ng/m^3 ($\pm$ a factor of 2). Actual sampling results for airborne uranium (0.06 ng/m^3 annual average) for 1976 are consistent with the theoretical analysis because the aerosolization percentages and crude dispersion model used do not underestimate dynamic experimentation contributions (calculational estimates ranged from 0.04-0.10 ng/m^3).

TABLE 4.1.2-7

ESTIMATES OF ANNUAL GASOLINE EVAPORATIVE LOSSES AT LASL[b]

	Units	Fiscal Year (July 1 to June 30) 1972	1973	1974	1975	1976
Gasoline Used	ℓ	2,311,214	2,515,898	2,301,997	2,414,599	2,944,865
Evaporation from 195,000 ℓ[a] combined total capacity storage tanks (0.025 kg/day - 10^3 ℓ)[4-47]	kg	1,800	1,800	1,800	1,800	1,800
Evaporation from vehicle filling service (1.10 kg/10^3 ℓ pumped)	kg	2,500	2,800	2,500	2,650	3,200
Evaporation from splash unloading to storage tanks (1.15 kg/ℓ)	kg	2,650	2,900	2,650	2,800	3,400
Gasoline spillage loss from vehicle filling service (0.067 kg/ℓ)	kg	150	200	150	200	200
TOTAL	kg	7,100	7,700	7,100	7,450	8,600

a) *Op cit.*, Compilation of Air Pollutant Emission Factors, Sections 4.3 and 4.4 (Density of gasoline is 0.7 kg/ℓ.

b) See Appendix H, page H-38, for update of information.

TABLE 4.1.2-8

CALCULATED ATMOSPHERIC CONCENTRATIONS OF ELEMENTS USED IN DYNAMIC EXPERIMENTS[c]

Element	1976 Annual Usage (kg)	Percent Aerosolized	Annual Avg. Conc. (ng/m^3) @ 4 km	@ 8 km	Applicable Standard (ng/m^3)
Uranium (D-38)	1023	10[a]	0.1	0.04	9000
Be	25.5	2[a]	0.0007	0.0002	10 (30 day avg.)
Hg	36.1	100[b]	0.05	0.02	None
Pb	18.6	100[b]	0.02	0.08	None
TOTAL			0.17	0.068	10,000 (For total heavy metals N > 21)

a)Based on experimental measurement.

b)Assumed percentage aerosolized.

c)See Appendix H, pages H-37, H-38, and H-104, for update.

4.1.3 Chemical Measurements and Assessment

General Biological Behavior of Radionuclides

Although many different radioactive materials have been used or produced at LASL, primary interest in the potential environmental impact focuses on tritium; the fission products 90Sr and 137Cs; the activation products 41Ar, 11C, 13N, 150; plutonium and uranium. This is because of the quantities in which these isotopes are used on a routine basis or the conditions of use which may result in limited release to the environs. The following is a general condensation and discussion of a voluminous literature regarding these isotopes. The primary concern with these materials as potential health hazards arises from their radioactivity and the accompanying emission of ionizing radiation. It is the radiation that produces the potential for health effects and not the chemical toxicity of the element.

Tritium is an isotope of hydrogen and chemically behaves similar to hydrogen with, however, some slight differences due to mass effects. It is radioactive with a half-life of 12.26 years and, upon decay, emits a very low-energy beta particle with an average energy of 0.0057 MeV. Because of the short range of the beta particle, tritium outside of the body presents no problem, and a radiation dose can only be incurred if it is taken into the body. Even here, the low energy requires that a large quantity, in terms of radioactivity, be in the tissue relative to other radioactive materials. For example, the radiation dose delivered by a given activity of tritium in a tissue is about 1% of that delivered by the same activity of ^{137}Cs in the same tissue. Tritium can be incorporated into any of the organic molecules found in the body of man or in nature. However, the most common forms of release are as hydrogen gas or as water. The tritiated water can be absorbed by the body by inhalation or ingestion, and a significant fraction can be absorbed through the skin from an atmosphere containing tritium moisture. In the hydrogen form the tritium enters the body only by inhalation with a low retention caused by exchange of the tritium with the hydrogen in the water molecules in the body and some direct solubility of the hydrogen. For this reason, tritium retention and hazard are much lower if the material is hydrogen gas rather than water. However, the tritium will slowly convert to water by exchange or oxidation so that releases to the atmosphere will be in the form of water at long times and distances after release (tens to hundreds of miles). Tritium is not concentrated by biological mechanisms, and the behavior of the water form in the environment is simply that of dilution by the various sources of water, either free or in the tissues of plants or animals. The radiation doses calculated from this material are those in a mass of free water, since most tissues are primarily water. The maximum permissible body burden, for occupational exposure, given by the ICRP and NCRP, is 1 mCi (1000 μCi) and is based on a whole body radiation dose of 5 rems/year.[4-51, 4-52, 4-53] The effects of chronic tritium exposure are assumed to be the same as those for whole body radiation; i.e., various types of cancers and possible genetic effects in later generations may occur.[4-54, 4-77] It has been postulated that increased genetic damage could result from the disruption of a gene by the decay of a tritium atom incorporated in a molecule, but experiments have shown such efforts to be unimportant in relation to the damage from direct radiation.[4-53A]

The primary fission products encountered at Los Alamos are ^{90}Sr and ^{137}Cs in the liquid waste streams and the treated effluents discharged to the onsite canyons.

Strontium-90 is a beta emitter with a half-life of 27.7 years and an average beta energy of 0.20 MeV. It also has a radioactive daughter, ^{90}Y, which has a half-life of 64 hours and emits a beta ray of 0.93 MeV average energy. Since the half-life of the daughter is relatively short compared to many metabolic and environmental processes, the daughter is usually considered to be in equilibrium with the parent so that both beta rays are considered to be emitted for each of the ^{90}Sr disintegrations. In many of its chemical properties, strontium is similar to calcium so that its behavior in the environs and in the body follows that of calcium; that is, those items in the food chain which are normally high in calcium would be expected to also accumulate ^{90}Sr. Since milk is an important source of calcium in the human diet, it has also been a major contribution to the ^{90}Sr burden of humans from fallout. Estimates of the potential damage must rely on animal studies and comparison with materials such as radium that deposit in the body in a similar manner. The primary site of deposition in the body is in bone, which is the major reservoir of calcium. The primary effect of strontium at the high levels used in animal studies has been bone cancer, although leukemias have also been produced. It is indicated by the United Nations Scientific Committee on the Effects of Atomic Radiations that single large doses of such materials in animals produce mainly bone cancers, whereas continuous doses or single low-level doses produce mainly leukemia, presumably because of a difference in the radiation dose rate to the sensitive tissues.[4-54] The maximum permissible body burden for occupational workers of 2 μCi was derived originally by comparative animal studies (using ^{89}Sr, a shorter-lived isotope) with radium.[4-51] Later recommendations by the Federal Radiation Council have incorporated considerations of the dose to the bone marrow and bone in comparison to the effects of external radiation.[4-55, 4-56]

Cesium-137 has a half-life of 30 years and emits beta rays with mean energies of 0.17 MeV (93.5%) and 0.43 MeV (6.5%). In addition, it emits a 0.66 MeV gamma photon in 84% of the disintegrations. As a result of the gamma, it can produce significant external radiation exposure if present at high levels on or in the ground. This is normally not a problem, however, because of the low levels encountered in all but accident conditions. Measurements of ^{137}Cs from fallout indicate that levels on the ground of about 0.1 $\mu Ci/m^2$ will produce a gamma dose rate of approximately 4 mR/year. (A mR is 1/1000 of a Roentgen (R), which is a measure of photon radiation exposure in air. Cesium is a member of the alkaline earth family and tends to behave like sodium and potassium, both elements necessary for plants and animals. It is found in the human diet in milk and meat and in somewhat lesser quantities in fruits, vegetables, and grains. Although it is normally tied to the soil so that its availability for uptake through roots is low, there are special circumstances in sandy soils with low exchange capacity where such uptake can be significant. Cesium-137 distributes widely throughout the body and results in essentially uniform whole body radiation.[4-51] From experience with external penetrating radiation one would expect the primary effect to be leukemia followed by miscellaneous other cancers associated with radiation exposure with the frequency of occurrence expected to increase with increasing quantities of ^{137}Cs in the body.

Another fission product, gaseous ^{131}I, is released in small quantities from the Main Technical Area. It has several pathways to man, including direct inhalation, deposition on leafy vegetables consumed by man, and ingestion of milk from cows or goats eating vegetation on which ^{131}I has been deposited. Since the primary food source of infants is milk, this can be the critical pathway when dairy animals are nearby. Iodine concentrates in the thyroid. Thus, if the primary food source is contaminated with ^{131}I (a beta-gamma emitter with an eight-day half life), that concentrates in the relatively small thyroid of an infant, the dose to the infant thyroid can be substantial compared to the dose to an adult thyroid from the same iodine release.

Argon is a noble gas that is present as a trace element in air. When exposed to neutrons, some of the primary natural isotope (99.6% ^{40}Ar) captures a neutron and becomes radioactive ^{41}Ar. This activation product, ^{41}Ar, is a beta-gamma emitter with a 1.8 hour half-life. Since ^{41}Ar is a noble gas, it does not react readily with other materials to form chemical compounds. Thus it remains in gaseous form and is a source of external radiation only to those exposed to or immersed in a cloud of the gas. Because of its short half-life the potential hazard passes quickly. Thus, only those living or working near such a source are potential receptors of a radiation dose from ^{41}Ar. For a LASL source, the only population at risk is the population of Los Alamos County. With the energetic gamma from ^{41}Ar decay (1.293 MeV in 99% of the disintegrations), the exposure is a whole body exposure and would affect the body in the manner as just described for ^{137}Cs.

Similarly, carbon, nitrogen, and oxygen in air become activated through various medium energy reactions caused by the 800 MeV proton beam and associated particles at LAMPF. The activation products ^{11}C, ^{13}N, and ^{15}O are all positron emitters with half lives of 20 minutes, 10 minutes, and 122 seconds, respectively. As a positron slows down, it interacts with a free electron. As a result of the interaction the positron and electron are annihilated and two 0.511 MeV photons are created.

As the activated air is exhausted out the stack at LAMPF, it diffuses with ambient air and primarily becomes a source of external whole-body radiation to those exposed to or immersed in the cloud. As with ^{41}Ar, the potential hazard passes quickly due to the short half lives with the Los Alamos County population being the only population at risk.

Uranium is a naturally occurring material which in nature consists of about 99.3% ^{238}U (half-life about 4.5 x 10^9 years), about 0.7% ^{235}U (half-life 7.1 x 10^8 years), and a negligible mass of the daughter of ^{238}U, ^{234}U, which is equal to the ^{238}U in units of activity. All of these isotopes are alpha emitters and form the beginning of a series of radioactive decay products that end in a stable lead isotope. In spite of wide use of uranium in various commercial products, by far the greatest damage to human health has occurred from these decay products that have been separated from the uranium ore, particularly ^{226}Ra and ^{222}Rn. In general, biological concentration of uranium along food chains does not seem to occur, and the chief effects noted with plants or animals are attributed to the chemical toxicity of uranium rather than the radiations.[4-51] Near relatively large pieces of debris, (up to several kilograms), plant toxicity may occur at soil concentrations near 50 ppm (50 μg U/g soil) near the roots, and acute toxicity may occur at levels ten times this.[4-50] At the occupational level in humans, the chemical toxicity and effect on kidney function is a consideration. At the lower levels, these changes seem to be reversible in that they disappear when exposure stops.[4-51] However, at the environmental levels, the radiation will be the important factor.

As indicated in later sections, plutonium contributes the least amount of individual and population dose at LASL. However, since there is some controversy with regard to the toxicity and safety aspects of plutonium, a more detailed discussion is presented.

Plutonium does not exist to any significant degree as a natural element. It is made in nuclear reactors and consists of several isotopes with the composition of any mixture dependent upon the exact method of production. The characteristics of the major isotopes are given in Table 4.1.3-1. The majority of the plutonium handled in past years at LASL has been either weapons-grade or heat-source plutonium. In the weapons-grade material, the predominant isotope is ^{239}Pu, with small fractions of ^{238}Pu, ^{240}Pu, and ^{241}Pu. The heat-source plutonium activity consists of about 85% ^{238}Pu. In future years it may be expected that mixtures containing higher fractions of the 240, 241, and 242 isotopes used in programs studying the use of plutonium as a reactor fuel with high irradiation levels. However on an activity basis, the biological effects of the various isotopes are generally similar. Since the emissions from plutonium are mainly alpha particles, which penetrate tissue only 50 μm (2×10^{-3} in), there is no concern with external radiation under environmental conditions. Thus, the effects of plutonium can occur only if the plutonium enters the body. Primary routes of entry are by ingestion and inhalation since absorption through intact skin is low. The quantities that could conceivably be absorbed from open wounds at the concentrations found in the environment is small. Ingestion is usually considered to be of relatively minor importance because plutonium is poorly absorbed from the gut of man and animals[4-51, 4-67] and the transfer from soil to plant is low.[4-57] Thus, discrimination factors occur at each step of the terrestrial food chains. This conclusion is generally accurate although there are some data that indicate that ingestion may contribute a somewhat higher fraction than was previously thought.[4-66] In field experiments, contamination of plants occurs primarily from the external deposition resulting from resuspension rather than root uptake.[4-58] Complexing agents, for example those used in fertilizers, may increase the uptake in plants resulting in possibly higher ingestion through these food chains. There is some speculation that the small fraction of plutonium incorporated into meat or plant foods may be more readily absorbed from the gut.[4-58A, 4-58B, 4-58C] Experiments on this are in progress at Battelle Northwest but results are not yet available. The uptake of plutonium from the gut of very young animals (newborn to several days) is considerably higher than for adults. However, this increased uptake lasts only a short time and occurs during a period of life where exposure to the environment is small.

Concentration of plutonium occurs in the food chains in the marine environment.[4-61] This is primarily because of the strong adsorption of the plutonium on diatoms and algae which serve as a food source for higher forms such as fish. Even here, however, there is about a factor of ten decrease in concentration for each trophic level starting with the primary concentrator, diatoms or algae.[4-62] Investigations continue on all of these factors but results to date still indicate that inhalation is the more important pathway.[4-63]

Inhalation occurs when the plutonium on ground or other surfaces becomes resuspended in the air by winds or mechanical means. This is a complex process with many variables such as soil characteristics, soil moisture, and terrain. Studies of resuspension are being made with a number of different systems including tracers, soils, and areas contaminated with plutonium.[4-64] Present indications are that the plutonium stabilizes in the soil with time so that the resuspension decreases, rapidly at first and then at a decreasing rate with the passage of time. Evaluation of this exposure route has been evaluated by several studies[4-61, 4-63] and was included in the proposed guidance by the EPA on plutonium in soils.[4-121]

TABLE 4.1.3-1

PLUTONIUM ISOTOPES

Isotopes	Major Radiation Emitted	Half-Life (Years)	Specific Activity (Ci/g)
^{238}Pu	α	86.4	17.4
^{239}Pu	α	24,390	0.0614
^{240}Pu	α	6,580	0.226
^{241}Pu	β	13.2	112
^{242}Pu	α	379,000	0.0039

The direct assessment of the effects of plutonium on humans cannot be done since there has never been a case of cancer in man known to be caused by plutonium.[4-64] Localized lesions resulting from plutonium imbedded in the skin by wounds have occurred but none have progressed to cancers.[4-65, 4-66] These are the most severe reactions that have been found in humans to date. The types of cancer that are of potential concern, as indicated by human experience with ^{226}Ra and animal experiments with plutonium, are bone cancers and liver cancers from plutonium absorbed into the body and lung cancers from plutonium deposited in the lung and retained there for long periods of time.

The lymph nodes in the lymphatic system draining the lung accumulate plutonium concentrations many times that of other tissue. However, the ICRP has examined this question and does not consider these nodes to be sufficiently radiosensitive to require consideration as a sensitive organ.[4-67]

The possibility of genetic effects as a result of plutonium in the gonads has been a recent concern. The following excerpt from the Rocky Flats Draft Environmental Impact Statement[4-79] summarizes this possibility.

"Effects in testes or ovaries at the cellular or tissue level have been observed only following plutonium doses much higher than the doses which would have resulted in other evidences of toxicity.[4-68,* 4-69] While studies of multi-generation genetic effects have not been performed, an investigation of cytogenetic effects in the testes of hamsters showed no significant increase in the frequency of chromosome aberations after calculated radiation doses of 1 and 4 rads.[4-70] The exposures employed in this study would result in significant life shortening and cancer induction, suggesting that genetic risks are small compared to somatic risks. Studies of chromosome aberrations in the germ cells of male mice after protracted exposure to ^{239}Pu, with doses ranging from 14 to 44 rads showed significant effects, in agreement with predictions based on previous studies with gamma ray and neutron exposures and assumed RBE and distribution factors.[4-71] Recent studies in mice have indicated that the critical spermatogonial stem cells of the testis may receive a 2 to 2.5 times higher dose from deposited plutonium than the average for the testis, due to inhomogeneities of distribution.[4-72] However, the total deposition of plutonium in the gonads is low, in all animal species studied, so that even allowing for preferential exposure of stem cells, the dose to these cells would not be expected to exceed the total body average."[4-73]

In a recent paper Grahn et al.[4-73A] studied dominant lethal mutation rate and reciprocal chromosome translocations in mice injected with ^{239}Pu and exposed to gamma rays and fast neutrons. They showed that the dominant lethal mutation rate is independent of total or accumulating doses with this effect dependent primarily on the dose rate or quantity of plutonium in the testis. They concluded that plutonium does not provide an unsual or unexpected genetic threat. The mutagenic efficiency ratios for plutonium compared to continuous ^{60}Co gamma irradiation ranges from 13 for dominant lethals to about 40 for reciprocal chromosome translations if the dose-rate from plutonium is expressed as the average to the entire mass of the gonad. Because of uneven distribution in the testis, the actual RBE for the effectiveness of the alpha particles would be even lower.

*Reference numbers have been changed to conform with numbering in this document.

Barnhart and Cox[4-73B] measured the RBE of ^{238}Pu alpha particles in vitro using one locus of a Chinese hamster cell line CHO. Linear slopes for dose versus mutations gave slopes of $4.79 \pm 0.50 \times 10^{-7}$ for alpha particles and $1.30 \pm 0.23 \times 10^{-7}$ for x-rays in the initial portions of both curves. These values were based upon viable cells remaining at the end of the experiment so that an RBE based upon total initial cells could be lower than the indicated 3.7.

Brandon[4-73C] has been examining the blood of both uranium miners and plutonium workers for chromosomal aberrations. His initial data have shown apparent changes in both groups, but the significance of this change in terms of health are unknown. It is also noted that the plutonium workers received unknown quantities of neutron radiation that could have affected the results.

Estimates of effects in bone have been derived from studies of humans who had significant burdens of ^{226}Ra and ^{224}Ra (radioactive materials that deposit in the bone as does plutonium) and comparative studies with animals, using both radium and plutonium, at high levels of exposure.[4-74] The current maximum permissible body burden for occupational exposure to plutonium of 0.04 μCi was derived in the late 1940s by comparison of the effects of plutonium with those of radium in rodents. The radium value used for this purpose of 0.1 is that quantity fixed in the body that had produced bone cancer in humans. Later experiments with beagles at the University of Utah have essentially confirmed this conclusion for plutonium, although there are some questions remaining on the exact behavior of plutonium in the bone over a long period.[4-75] These experiments also indicated that, in addition to the bone cancers produced with body burdens well above the maximum permissible body burden, an occasional liver cancer is also produced. There is speculation that these liver cancers may become of greater importance at lower exposure levels and longer lifetimes, such as those of the human. The irradiation of lung tissue by insoluble materials depositing in the lung and remaining there for long periods of time is under study with dogs at Battelle Northwest. In the initial group, the quantities of plutonium inhaled were so great that the majority of dogs died of relatively acute changes leading to fibrosis and pulmonary insufficiency. However, those dogs that survived this period did show a very high incidence of lung cancer. Additional dogs at lower exposure levels are now being observed. The current status of the inhalation studies using beagle dogs is given in the annual report of the Pacific Northwest Laboratory.[4-75A] For beagles exposed to ^{239}Pu oxide about 90 months prior to reporting, no deaths from lung tumors have been noted with lung burdens less than 5.3 nCi/g, some 300 times greater than the occupational limit for radiation workers. For exposures to ^{238}Pu oxide and times of about 60 months, deaths due to lung tumors have not occurred at lung burdens less than about 53 nCi/g or 3000 times the occupational limit. These studies are continuing. Other experiments with relatively high doses by various investigators with mice, rabbits, and rats have indicated that lung cancer can be produced by inhalation of levels of plutonium high compared to those in established limits.[4-76] Current limits on plutonium exposure in the lung are based upon calculated radiation doses limited by the observed effects from external radiation.

Estimates of the maximum risk for production of cancer and genetic effects by radiation have been derived by several groups.[4-77, 4-78] These have been applied to plutonium and compared to the risks derived from animal experiments in several environmental impact statements.[4-63, 4-79]

There have been questions raised as to the adequacy of the present standards for plutonium. The Natural Resources Defense Council has petitioned the government for a reduction in levels permitted based upon a hot particle hypothesis.[4-80] This hypothesis has been reviewed by a number of individuals and scientific organizations[4-81 through 4-85] and has been rejected by all. Gofman has postulated that cigarette smoking destroys the cilia in the bronchi leading to retention of plutonium particles in these areas for long times with resulting increase in dose and probability of cancer.[4-86] This theory has been rebutted by several individuals who point out a number of untenable assumptions in the hypothesis.[4-87, 4-88] Martell postulates that very small particles of natural radioactive materials in tobacco smoke are responsible for the carcinogenicity of tobacco smoke and, by analogy, concludes that plutonium particles should do the same thing.[4-89] This theory is unsupported by evidence and ignores the known chemical carcinogens in tobacco. Morgan has proposed a reduction in the maximum permissible body burden based on the multiplication of four factors.[4-90] However, there is no evidence to show that his proposed factors are independent of each other as would be required for his application. The first factor of these is based on data from beagle dogs that show the toxicity ratio to be 16 rather than the current value of 5.[4-91] However, Morgan does not consider the difference caused by the present ICRP estimate of 45% deposition in the bone[4-67] as compared to the 90% assumed at the time of the original standard development.[4-51] His second factor of 2 is based on the comparative surface-to-volume ratio in the beagle and man. His assumption that the man has a smaller surface-to-volume ratio would lead to a higher dose and therefore a higher risk of cancer. However, later data have shown that this difference does not exist.[4-92] His third factor of 10 is based on a more rapid deposition rate of plutonium in man than that in the dog leading to a higher dose to the critical surface cells of the bone in man. However, the greater life span of man than the dog will lead to decreased influence of this factor. Others have calculated this effect using only human data and have concluded that the present standards are reasonable.[4-93, 4-94] The fourth factor of 4 arises from a comparison of early effects in the lungs of baboons and dogs.[4-95] The extrapolation of these effects, which did not involve cancer, from lung tissue to bone is completely unfounded.

In conclusion, the present plutonium standards are well supported and the calculations and dose risk assessments presented for plutonium in the EIS were based upon methodology and current standards. However, in keeping with good scientific and public health principles, studies of the bases for the standard will continue at LASL.

An individual isotope of interest is ^{241}Am. This isotope results from the decay of ^{241}Pu, which is a low-energy beta emitter. When plutonium is chemically purified, the ^{241}Am is separated and can appear in effluents. In plutonium containing significant quantities of ^{241}Pu, the amount of ^{241}Am will increase (through radioactive decay) in the mixture with the passage of time. Since ^{241}Am is an alpha emitter, this results in a net increase in the rate of alpha emission, with a maximum reached in about 70 years after separation. The behavior of ^{241}Am in the environment is not well known, but the few experiments conducted indicate that it may be more soluble than plutonium and, therefore, more available to plants and animals.[4-96] The effect of this material in animals has not had extensive study, but it is generally assumed that the effects are similar to those of plutonium. Most of the plutonium used at LASL has been relatively low in ^{241}Pu.

As was noted in the individual discussions, all of the experience with the effects of these radioisotopes has occurred at experimentally administered levels, and resulting radiation doses were well above even the occupational levels. To discuss the possible effects at lower levels, it is necessary to extrapolate the data, often by several factors of ten. Some years ago it was assumed, for the purpose of setting standards of exposure, that the response, or effect on humans, followed a linear relationship with no threshold. That is, for a given effect, the incidence of the effect was proportional to the dose and there was an effect, no matter how low the dose. It was also assumed that for a given dose, effects were independent of the dose rate. It is impossible to either verify or discard this hypothesis for the low levels of dose involved in environmental exposures. For low LET radiation, there is some mounting evidence of a smaller effect for some types of cancers when the radiation is received at low dose rates although some theories and data suggest the opposite. The so-called linear hypothesis is used as the most pessimistic basis for estimating effects. In practice, the emissions are controlled to the minimum levels that can be practically achieved. Occupational standards, which are believed to represent a minimal risk to the worker, are below the levels at which effects have been noted. The population standards are 1/10th to 1/30th of these levels. For DOE operations, the exposure guidelines are implemented in terms of Radiation Protection Standards and Concentration Guides which set limits for the content of radioactivity in water or air such that occupational or continuous exposure would not result in excessive doses. The Concentration Guides are documented in ERDA Manual Chapter 0524. Estimation of possible effects in the population would require extrapolations over a range of doses of a thousand to a million times the levels noted in the environs. Current information does not justify such an extrapolation; but, even if done on the linear no-threshold assumption, it is clear that the risk of additional cancer from this source is very low.

As with radioactive materials, many stable elements are used at LASL. Following is a brief discussion of general toxicological considerations for those elements that are used in such quantities or ways as to permit limited release to the environment. In all cases, LASL complies with OSHA and EPA standards.

Acute respiratory disease resulting from exposure to beryllium has been recognized since the 1930s. Dermatitis and skin ulcers were also observed in acute beryllium poisoning. In most cases of acute exposure complete recovery takes place, with rest and removal from exposure, within one to three weeks. With others, the recovery period is as long as four months. With some, the effect is fatal.[4-96A] The amount of beryllium required to produce acute poisoning is estimated at 25 to 45 micrograms per cubic meter of air for some period of time. In one reported accident resulting in symptoms, the exposure lasted 20 minutes at 45 micrograms per cubic meter. Three types of skin lesions that may follow exposure to beryllium compounds are acute dermatitis, ulceration, and granulomas. Their occurrence depends on the nature of skin contact. The chronic effects of exposure to beryllium have been described as a variable latent period between last exposure and the onset of beryllium disease. The latent periods may be a few weeks to more than ten years. There is great individual variation in human reaction to beryllium exposure. Very slight exposures may produce the symptoms of the disease.

In some cases the beryllium content of the air may have been as low as 0.1 μg per cubic meter of air. The New Mexico 30-day average atmospheric concentration standard as adopted for EPA guidance is 0.01 μg per cubic meter.[4-43]

Cadmium enters the body mainly through ingestion or inhalation. Skin penetration by soluble cadmium compounds can take place, but this exposure is negligible. Daily intake by food in the US is estimated at 4 to 60 micrograms per day; fruit has the lowest cadmium level. Shellfish and kidney and liver of animals have the highest concentration. Air concentrations range from less than 0.001 to 0.05 $\mu g/m^3$. The amount inhaled depends on the volume of air (average is 20 m^3/day) and the ambient concentration of cadmium. The normal air concentrations from studies conducted in Phoenix, Arizona and Dallas, Texas indicated 0.006 $\mu g/m^3$ and 0.005 $\mu g/m^3$, respectively. Cadmium is found in cigarettes, 1 to 2 μg per cigarette. Tests indicate 0.1 to 0.2 μg cadmium per cigarette in the mainstream of the smoke. Cadmium concentration in water has been reported at 1 μg/ℓ (1 ppb or less). A cadmium oxide dose that resulted in two human deaths was calculated to be approximately 2,500 mg/m^3-minute. This represents an exposure to 100 mg/m^3 for 25 minutes or 50 mg/m^3 for 50 minutes. As little as 14.5 mg of cadmium taken orally by man has caused nausea and vomiting, but as much as 326 mg was not fatal. Thirteen to 15 ppm of cadmium in popsicles has sickened children as has 67 ppm in punch and 530 ppm in gelatin. Emphysema has been found among male workers chronically exposed to cadmium oxide dust in an alkaline battery factory in Sweden. Exposure concentrations ranged from 3 to 15 mg/m^3. In fatal cases of acute cadmium poisoning, pathological changes have been found in the kidneys. Prolonged exposure to cadmium oxide dust has given rise to renal damage in factory workers, with proteinuria as the most common clinical sympton. In workers suffering acute cadmium poisoning as a result of toxic exposure to cadmium oxide fumes, microscopic changes were evident in the liver. Increases in serum gamma globulin have also been reported in several exposed individuals. Anemia has been observed in cadmium workers exposed to cadmium oxide dust or fume. Anemia has also been found in experimental animals exposed to cadmium. Systematic administration of cadmium has caused acute testicular necrosis in a number of animal species. Although high concentrations have been found in testicular tissue in occupationally exposed humans, the same necrosis has not been reported in humans. Cadmium has been shown to cause hypertension in animals; however, evidence is still lacking for associating hypertension with cadmium exposure in humans.

Mercury is widely distributed in soil, dust, and water. Food contains trace amounts, between 0.005 and 0.25 ppm. The average "normal" value for mercury in urine is between 0.4 mg and 10 mg/liter. Mercury is also excreted in saliva, sweat, and milk. Mercury compounds are readily absorbed orally, by inhalation, or by any parenteral route and by mucous membranes. Metallic mercury is not readily absorbed in the gastrointestinal system. Vapors of metallic mercury are toxic. A stream of air passing over a 10 cm^2 surface becomes 15% saturated at room temperature and contains 3 mg of mercury per cubic meter of air. Acute exposure to mercury compounds at high levels causes a variety of gastrointestinal symptoms and a drop in urine output. In fatal cases syncope, convulsions, or unconsciousness precede death. On the basis of several investigations and an adequate safety margin, the current industrial threshold limit value of 0.05 mg mercury per cubic meter was established. The U.S. Food and Drug Administration's interim guideline for mercury in fish is no more than 0.5 ppm.

Lead dust and the dust and fumes of all but the most insoluble lead compounds (sulfides, chromates) are readily absorbed on inhalation and, to a lesser degree, ingestion. Lead and its inorganic compounds are not ordinarily absorbed through the skin. The first detectable clinical symptom of excessive lead absorption is an increase in the lead content of the urine, followed by an increase of lead in the blood. The early symptoms of lead intoxication are most commonly gastrointestinal disorders, constipation, abdominal pain, anorexia, and perhaps intermittent vomiting. Central nervous system manifestations and changes in blood cell morphology may also occur. Three hundred micrograms (300 μg) of elemental lead is considered to be the maximum daily permissible intake from all sources for children to prevent accumulation. Lead accumulates in bone and teeth.

Finely divided antimony is strongly irritating to tissues and mucous membranes. The lethal dose is between 100 and 200 mg. Chronic antimony poisoning is similar to chronic arsenic poisoning. Acute antimony poisoning from ingestion produces gastrointestinal symptoms that may occur concurrent with or be followed by hemorrhagic nephritis and hepatitis.

Calculated and Measured Doses

As discussed elsewhere in this report (see Section 3.3.3), Los Alamos Scientific Laboratory operations result in the release of small quantities of radioactive materials to the environment. Radiological dose estimates are provided for the significant exposure pathways among those diagrammed in Figure 4.1.3-1. Dose calculations are based on conservative models (models that are more likely to overestimate than underestimate the actual dose) and are intended to apply to the average adult unless otherwise stated. Specific persons will receive higher or lower doses depending upon their age, living habits, food preferences, or recreational activities. Source terms (amount of material released) are based on actual release measurements, and dose estimates are based on monitoring data from LASL radiological surveillance programs (see Section 3.3.4) and theoretical calculations. In this section, annual doses to individuals are expressed in millirem (mrem). The mrem is equal to 1/1000 of a rem and is a unit that permits comparison of radiation doses from different types of radiation (such as gamma rays, alpha particles, and neutrons) that produce different degrees of damage in human tissue for a given amount of absorbed energy. For X-rays the tissue dose in rem is slightly smaller than the Roentgen (the radiation exposure unit in air). Population doses are given in man-rem, which is an expression for the summation of whole body doses to individuals in a group, e.g., if 1,000 people were each exposed to 0.001 rem or two people each received 0.5 rem, the population dose in each case is one man-rem.

The radioisotopes released to the atmosphere from Laboratory operations having a potential for a significant radiological impact are: (1) ^{3}H (a radioactive isotope of hydrogen), (2) ^{41}Ar (a noble gas), (3) ^{131}I, (4) ^{238}Pu or ^{239}Pu, and (5) air activation products ^{11}C, ^{13}N, and ^{15}O.

Dose calculational models are included in Appendix H (pages H-40 through H-42 and H-73). Atmospheric effluent doses were calculated from environmental measurements except for ^{41}Ar, which was calculated from theoretical dispersion. Table 4.1.3-2 gives maximum individual and boundary dose calculations which are based on 1978 data. As can be seen from the data, the activated air products ^{11}C, ^{13}N, and ^{15}O, amd ^{41}Ar, contribute the bulk of the radiation exposure at the boundary and to the maximum individual. Tritium and ^{239}Pu cause insignificant exposure to the public. Calculations for other isotopes released in effluents resulted in doses <0.01% of the RPS and are not included in individual and population dose estimates.

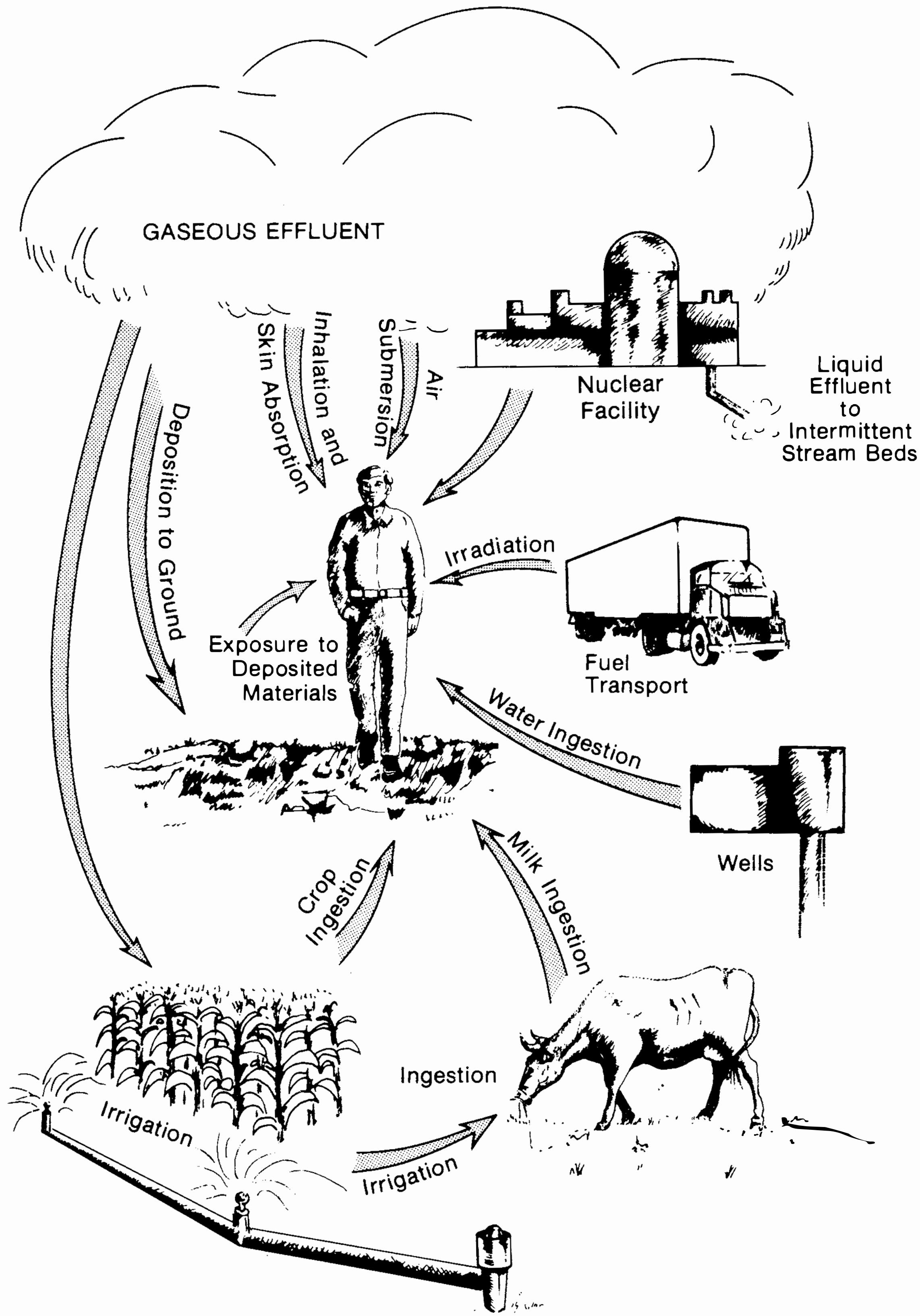


Figure 4.1.3-1

Potential Exposure Pathways for Contaminants

TABLE 4.1.3-2

CALCULATED BOUNDARY AND MAXIMUM INDIVIDUAL DOSES FROM AIRBORNE RADIOACTIVITY

		Maximum Boundary Dose		Maximum Individual Dose		
Isotope	Critical Organ	Location	Dose (mrem/yr)	Location	Dose (mrem/yr)	%RPS
^{3}H (HTO)	Whole Body	TA-54	0.071	Airport	0.029	0.0058
^{11}C, ^{13}N, ^{15}O	Whole Body	Restaurant N. of TA-53	14[a]	Restaurant N. of TA-53	3.8	0.76
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack	1.2	Apts. N. of TA-2 Stack	0.7	0.14
^{239}Pu	Lung	TA-54	0.024	Bandelier	0.0079[b]	0.00053

[a]Estimated from TLD measurements June-Dec. 1978.

[b]For a 50 yr. dose commitment, bone becomes the critical organ. A maximum individual would receive a 50 yr. dose commitment to bone of 0.53 mrem.

Population dose estimates from the 1978 atmospheric effluents are given in Table 4.1.3-3 where they are compared to natural and medical sources of radiation.

The calculated 8.4 man-rem from atmospheric ^{11}C, ^{13}N, and ^{15}O is probably high because it is subject to many of the same uncertainties that caused boundary dose calculations to overestimate actual doses from these isotopes by a factor of 9. The whole-body population dose to the estimated 105,000 inhabitants of the 80 km circle around Los Alamos because of LASL operations is estimated to be 10.5 man-rem, which is the population dose to Los Alamos County inhabitants.

Dispersion, dilution, and decay in transit reduce isotope concentration to very small fractions of the concentrations in Los Alamos so as to make exposure undetectable and theoretically a very small fraction of the estimated 10.5 man-rem. For example, ^{11}C, ^{13}N, and ^{15}O have concentrations more than 100,000 and 2,000,000 times lower in Española and Santa Fe than in Los Alamos, respectively. Similarly, ^{41}Ar concentrations are 600 and 2300 times lower in Española and Santa Fe than in Los Alamos, respectively. Thus, the total estimated population dose attributable to Laboratory effluents sums to 10.5 man-rem or 0.088% of the background dose (11,900 man-rem) to the population within an 80 km radius, or 0.44% of the population dose to Los Alamos County residents from natural radiation or 0.52% of the dose of county residents from medical radiation. In fact, county residents would receive more dose from airline travel than from Laboratory operations. Note that the portion of the population dose due to ^{41}Ar and ^{11}C, ^{13}N, and ^{15}O would be included in the overall external penetrating radiation dose measured by the thermoluminescent dosimeters.

All Laboratory liquid effluents are released to the environment on Laboratory property. The only pathway for exposure to the public from these radioactive liquid effluents is by water runoff transporting them in water and sediment beyond Laboratory boundaries and eventually to the Rio Grande. This can occur by surface runoff, caused by heavy thunderstorms or spring snow melt (see Section 4.1.1). It is known that small amounts of $^{238,239}Pu$ and ^{137}Cs have been transported off-site in sediments.[4-24, 4-98] Also, there are locations that have accumulated $^{238,239}Pu$ and ^{137}Cs in sediments in significant concentrations above background. These locations are stream channels that formerly received liquid waste effluent from Laboratory operations. Some of this land in Pueblo Canyon was released by the AEC and is now accessible to the public. Because of the natural characteristics of these locations (isolated and rugged) any person exposed to these contaminants would likely be exposed for only short periods and thus would receive <1 mrem from such an exposure. Also, because of location, it is unlikely that someone would gather sand from these streambeds to use in gardens, sandboxes, concrete, etc. These canyons of interest have been the subject of ecological studies since 1972 and thus are being closely monitored (see Section 4.1.1).

In lower Los Alamos County, which crosses the San Ildefonso Pueblo Reservation, some radioactivity has accumulated in the stream channel sediments and bank soils from transport out of Acid-Pueblo and upper Los Alamos Canyon (see Section 4.1.1 and Appendix H, pages H-20 -H-25 and H-100-H-101). Because cattle are at times grazed in this part of Los Alamos Canyon, a food chain analysis was made to estimate potential exposures. The largest potential uptake would occur during the years when spring snowmelt results in continuous flow in the stream channel for an extended period. Some of the data utilized in the analysis were collected for the radiological

TABLE 4.1.3-3
1978 WHOLE BODY POPULATION DOSES
TO LOS ALAMOS COUNTY RESIDENTS

Exposure Mechanism	Whole-Body Population Dose (man-rem)
Atmospheric Tritium (as HTO)	0.23
Atmospheric ^{11}C, ^{13}N, ^{15}O	8.4
Atmospheric ^{41}Ar	1.9
Total Due to LASL Atmospheric Releases	10.5
Cosmic and Terrestrial Gamma Radiation[a]	1570
Cosmic Neutron Radiation (∿17 mrem/yr/person)	330
Self Irradiation from Natural Isotopes in the Body (∿24 mrem/yr/person)	470
Average Due to Airline Travel (0.22 mrem/hr at 9 km)	13
Total Due to Natural Sources of Radiation	2383
Medical Exposure (∿103 mrem/yr/person)	2020

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

survey conducted under the FUSRAP program (see Sec. 4.1.1) and will be published in a detailed report of that work. The basic assumptions in the analysis include a beef steer obtaining all ingested water and vegetation for 3 months during each of two years from the lower Los Alamos Canyon. The water is considered to have 5 pCi/l of ^{239}Pu including that on suspended sediments (based on measurements from the 1975 spring snowmelt), and the bank soils 2 pCi/g of ^{239}Pu (based on measurements for the FUSRAP study). Uptake modeling parameters were based on experimental studies.[4-98A] Fifty year dose committments to a human adult eating the entire liver of the 2-year-old steer were calculated to be 3 x 10^{-5} mrem whole body dose and 1.3 x 10^{-3} mrem bone dose. These doses are larger than would be calculated for consumption of all other meat from the steer.

Transport of radioactivity on sediments from Los Alamos Canyon into the Rio Grande is not resulting in any doses statistically higher than those due to worldwide fallout. This is confirmed by the measurements of water, sediment, and fish from the Rio Grande downstream from the confluence with Los Alamos Canyon indicating no activity at levels statistically higher than present from worldwide fallout.[4-23, 4-34, 4-35, 4-36, 4-99] Thus food crop irrigation, drinking water, fish consumption, etc., are not considered to be significant exposure pathways to the public. Appendix H (pages H-25 through 28) provides the most recent data on monitoring results in these pathways.

The two main sources of public exposure to direct radiation are the Critical Assemblies Test Site and LAMPF. Critical assembly testing occurs on a regular, but intermittent basis. Short exposures are made with a Cockroft-Walton accelerator and various critical assemblies. Other assemblies, such as Godiva, are operated in short bursts (lasting fractions of a second). Direct radiation measurements by thermoluminescent dosimeters (see Section 3.3.4) have indicated the highest integrated exposures occur near the Critical Experiment Facility at Pajarito Site.[4-23, 4--35] Extensive neutron and gamma measurements during numerous tests led to the estimate of 1120 mrem/year at the most exposed location on Pajarito Road, a main thoroughfare between Los Alamos and White Rock.[4-100] Assuming a person made 15 round trips per week during the times tests were being conducted at Pajarito Site, at an average speed of 40 mph past the site, the calculated dose is about 1 mrem/year. The test schedule for critical assemblies is arranged to avoid bursts during the time school buses pass the site.

Direct radiation from LAMPF to the populace is very small as measured at the closest site boundary. Gamma radiation measurements while LAMPF is operating are indistinguishable from background. Neutron measurements indicate the site boundary dose from LAMPF will be on the order of 0.2 mrem/yr when LAMPF reaches full power.

TLD measurements indicate the Critical Assemblies Test Site (TA-18) provides the largest dose at a location potentially occupied by a member of the public. Thus, it is expected that doses to members of the public from the Van de Graaff and Omega Reactor will be less than that from TA-18.

Another potential pathway of exposure to man is through ingestion of foods contaminated by Laboratory effluents or operations. Vegetation sampling in offsite areas indicates only background levels of plutonium, tritium, uranium, and cesium. Thus, consumption of such vegetation or animals feeding on such vegetation does not cause a significant impact on humans. There are areas onsite that are not available to the public for use but are used by animals for forage; e.g., honeybees have been known to forage at old waste disposal areas and deposit tritium in their honey.[4-99, 4-101] If one were to consume 2.25 kg (5 lb) of honey per year, the dose from the tritium in honey from a hive on Laboratory property at the maximum concentration of 3,000 pCi/m of water is 0.12 mrem/year. Animals known to frequent such onsite areas, such as deer, have been sampled. The only radioactivity observed in Los Alamos deer has been ^{137}Cs in muscle. If one were to consume deer meat only (110 kg/year or 243 lb/year) contaminated to the maximum concentrations measured (1.8 pCi/g) from deer grazing in these Laboratory areas, the individual whole body dose would be 3.9 mrem/year. A theoretical calculation indicates the maximum dose from ^{131}I effluents would be 0.02 mrem to the thyroid of an infant who drank goats milk from a goat pastured in Pajarito Acres.

The viewpoint on estimated health effects as expressed by the National Council on Radiation Protection and Measurements is, "The NCRP continues to hold the view that risk estimates for radiogenic cancers at low doses and low dose rates derived on the basis of linear (proportional) extrapolation from the rising portions of the dose incidence curve at high doses and high dose rates, as described and discussed in subsequent sections of this report, cannot be expected to provide realistic estimates of the actual risks from low level, low-LET (linear energy transfer) radiations, and have such a high probability of overestimating the actual risk as to be of only marginal value, if any, for purposes of realistic risk-benefit evaluation."[4-101]

Despite this warning, the following estimates of risks are made based on the risk factors provided by the International Commission on Radiological Protection (ICRP) in ICRP Publication 26.[4-101A] The average total dose from natural radiation sources in Los Alamos County is about 120 mrem/yr. The total stochastic risk of cancer from uniform whole body irradiation for individuals is 1×10^{-4} per rem. The cancer risk due to natural background in Los Alamos for an individual is 0.12×10^{-4} per year, or the probability of injury by cancer is between zero and 1 in 83,000 per year. The average whole body dose attributable to LASL operations for an individual living in the Los Alamos townsite is about 0.8 mrem/yr, and in White Rock about 0.1 mrem/yr. The added risk of injury by cancer is estimated as between zero and 1 in 12,000,000 per year for the townsite and between zero and 1 in 100,000,000 per year for White Rock due to LASL activities. The normal incidence of cancer occurring in an individual is 1 in 405 per year for the New Mexico population.[4-101B] Other estimates of risk could be made for other types of injury, but the risks are even smaller.

In summary, the largest dose that could have been received by an individual beyond the LASL boundary as a result of LASL operations in 1978 was less than 0.8% of the annual dose limit; this due to ^{11}C, ^{13}N, and ^{15}O. The average whole body dose to Los Alamos residents resulting from LASL operations was less than 0.16% of the individual dose limit, or 0.45% of the population dose limit. Thus, neither the direct atmospheric releases nor any possible pathways resulting from release of liquid effluents have any signficant impact.

Some workers at LASL do receive radiation doses at levels higher than the general public. This is to be expected from the nature of some of the work involving radioactive materials and radiation producing equipment. All LASL programs are conducted with the safety and health of the workers being of paramount importance regardless of whether the potential hazards involve radiation, toxic chemicals, or physical hazards. In particular, all operations are conducted with the intent of minimizing exposures to radiation and keeping all exposures as low as practicable as required by DOE policy. Actual exposures are measured by badge or other dosimeters for all workers in locations where there are potentials for above background exposure. The dosimetry meets all requirements of DOE regulations which were established to meet the Federal radiation protection standards imposed on all Federal agencies. Further checks for possible inhalation or ingestion of radioactive materials are carried out on employees working in circumstances where such exposure might occur. These checks include bioassays by means of urine sampling and in-vivo whole body counting. The bioassay program exceeds the requirements of a forthcoming Health Physics Society - ANSI standard entitled, "Internal Dosimetry Standards for Plutonium."

In 1978, worker exposures were typical of the two previous years though slightly lower as indicated in Table 4.1.3-4. All laboratory sites maintained exposures within the whole body limits of 5000 mrem/yr and 3000 mrem/quarter.

An accidental exposure occurred on May 4, 1979, when tritium was released during an experiment in the Cryogenics Facility. The release caused a LASL employee to receive a radiation exposure of about 13 rems which exceeds the Department of Energy annual exposure standard of 5 rems. Ten other Laboratory employees at the facility received measurable exposures that were less than 0.6 rem.

4.1.4. Land Use

The environmental impact of land use at Los Alamos must be evaluated in terms of previous, as well as present and future land use. Farming by prehistoric Indians and by Spanish and Anglo settlers before the Laboratory's establishment in 1943 created open grassy areas on the mesas, which have not completely returned to natural vegetation patterns. Figure 4.1.4-1 shows the clear evidence of previous agricultural activities even after 30 years of different use. Approximately 15 km^2 (3,600 acres) of present Laboratory lands were used for agriculture, while most of the remaining areas were heavily used for grazing and logging. This previous grazing also affected the natural vegetation associations, but the prohibition of grazing since the early 1940's has allowed many of these areas to regain their carrying capacity for wildlife. Hunting and trapping were also done on the Pajarito Plateau during the early 1900's. There was also a convalescent camp, which was later purchased by Ashley Pond. This became the Los Alamos Boys Ranch, and a few ranch buildings are still standing.

Since the Laboratory's development, somewhat more land is now used and the character of present use is now urban rather than agricultural. Presently some 6 km^2 (1,600 acres) have been developed with buildings, parking lots, and roadways in the technical areas. As can be seen in Figure 4.1.4-1, much of this development has occurred in old farming fields. The Laboratory has minimized vegetation clearing, and areas around buildings have been left to natural vegetation wherever possible. Vegetation clearing, necessary to satisfy fire and security protection regulations, does increase erosion in some areas. Some cleared areas exist for parking and storage or are the result of construction requirements. In some of the dynamic testing areas, zones have been cleared near explosive detonation points to reduce fire hazards. Omega West and W-Site in Los Alamos Canyon have experienced some isolated rock falls in the past with no damage. However, the possibility of rock falls near the firing point may necessitate its relocation. Some solid radioactive waste disposal areas have been, or will be, allowed to return to natural vegetative cover. However, as a result of both pre-Laboratory and current uses of the land, less than 20% is no longer in a natural state. Table 4.1.4-1 summarizes the present level of development of the Laboratory's technical areas, totaling 16 km^2 (4,000 acres).

TABLE 4.1.3-4

RADIATION EXPOSURES FOR LOS ALAMOS WORKERS[a]

	Site-Wide Annual Exposures			
Calendar Year	No. of persons using Dosimeters	Total Dose (Man-Rem)	Average Dose (mrem/person)	Maximum Individual Dose (mrem)
1976	5386	400	74	<4000
1977	5621	445	79	<5000
1978	7402	372	50	<4000

1978 Dose Distribution

Proportion of Workers using Dosimeters (%)	Whole Body Dose (mrem)
74.9	none detectable above background
15.7	<100
6.7	100 - 499
2.7	500 - 3999
0	>4000

[a]Doses above background to all personnel utilizing dosimeters during year including LASL, ZIA, DOE employees, and visitors.

1974

Figure 4.1.4-1

Comparative aerial photographs of the Los Alamos area.

1935

These two aerial photos of the Los Los Alamos area were taken about 40 years apart. They cover almost identical areas and show the transitions in land use. (Orientation is with north at the top.) The darker horizontal line running across the middle of each is Los Alamos Canyon. Near the right edge, north of the canyon, Ashley Pond shows as a dark oval shape. In the upper middle is an area now forming a residential area that used to be cleared for farming. In the middle, just south of the canyon, is the South Mesa technical area. At the lower left is an irregular area that was cleared for farming and is now partly occupied as a technical site. Somewhat more land is now used for laboratory activities than previously used for farming and the character of present use is urban rather than agricultural. It is interesting to note the clear evidence of agriculture use even after 30 years of different use.

TABLE 4.1.4-1

LASL TECHNICAL AREAS

Site Designation	Land Area (km^2) Developed	Buildable	Total Area	Employee Population	Number of Buildings	Principal Facility or Use
Omega Site	0.02	0.04	0.09	26	1	Omega West Reactor
Main Technical Area (South Mesa)	0.56	0.33	1.08	2634	36	Administration Bldg., Van de Graff, shops, warehouses, CTR facilities
Two-Mile Mesa	0.02	0.09	0.11	7		
Ancho West	0.09	0.16	0.37	26	3	Non-destructible testing
Ancho East	0.16	0.14	0.30	24	1	Explosives development
K-Site	0.04	0.12	0.17		1	Explosives testing
Q-Site	0.10	0.12	0.24			Firing site
R-Site	0.81+	1.46	2.91	85	6	PHERMEX
S-Site	1.21+	1.43	2.85	263	12	High explosives
Pajarito Site	0.04	0.04	0.16	36	8	Pajarito Laboratory
DP-Site, East & West	0.19	0.09	0.38	210	12	Old Plutonium Processing Facility
TD-Site	0.08	0.06	0.19	63	5	Shops
Magazine Area A	0.08	0.06	0.18			Firing Site
HP-Site	0.09	0.65	0.92	16	3	Energy studies
Ten-Site Laboratory	0.05	0.04	0.11	153	7	Laser and nuclear safeguards
Kappa Site	0.61	1.11	2.23	25	1	High explosive
Magazine Area C	0.22	0	0.22	8		Explosives storage
Ancho Canyon	0.40	0.20	1.21	36	1	
DF-Site	0.05	0.11	0.18	30	1	
W-Site	0.03	0.03	0.08	101	3	
Health Research Laboratory	0.02		0.02	113	1	
WA-Site	0.11	0.08	0.23	134	8	UHTREX
Radiochemistry	0.02	0.03	0.07	70	1	
Liquid Waste Disposal	0.01	0.03	0.04	49	1	
Radiation Exposure Facility	0.02	0.02	0.06		1	Animal holding facility
Reactor Development Site	0.02	0.04	0.09	8		
Meson Physics Facility	0.26	0.45	0.93	339	9	Clinton P. Anderson Meson Physics Facility (LAMPF). Materials disposal areas.
Mesita del Buey Area	0.18	0.38	0.77			
New Plutonium Processing Facility	0.05	0	0.05			Under construction
Subterrene Basalt		0.02	0.07			Abandoned Hot, dry rock geothermal research
35 Total	5.54	7.33	16.32	4456	122	

As discussed earlier in Section 3.2.1, the natural topography has affected development patterns (see Figure 4.1.4-2). Generally, development has taken place on the mesa tops, resulting in the majority of the facilities being centralized in a few major technical areas. Although technical areas are scattered about the LASL reservation, location is generally in response to specific siting needs such as security, safety, or topographic requirements.

Present DOE land holdings constituting the LASL reservation are 95 km^2 (23,500 acres) in Los Alamos County and 16 km^2 (4,000 acres) in Santa Fe County (the Otowi Section). All the present LASL operating technical areas are in Los Alamos County.

Two former technical areas were located on land released from federal control in the 1960's. The original main technical area of the Laboratory, known as Technical Area One (TA-1), was located on land around Ashley Pond, which is now owned partly by the county and partly by private interests. The original Laboratory facilities were constructed and used from 1943 through 1965. Work carried on in the facilities resulted in varying degrees of radioactive contamination of some buildings, waste handling system, and land. Research work was gradually moved from TA-1, which was immediately adjacent to the townsite, to new Laboratory facilities on the other side of a major canyon from the townsite. The new facilities were relocated to provide for consolidation of central Laboratory buildings and greater physical separation of the Laboratory from residential and commercial areas. When vacated, the obsolete TA-1 facilities were decontaminated and demolished. Major operations to remove structures began in 1954 and continued intermittently through 1965. In 1966 the land occupied by TA-1 was released to Los Alamos County or private interests because it was sited in a central area useful to the future development of the townsite and because it was considered that residual radioactive contamination did not present any health or safety hazards. Development of both public facilities and commercial establishments began shortly after disposal and continues to the present.

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

Field measurements and sampling in the former TA-1 area were initiated in 1974. Radiation measurements showed no exposures above the range of natural background. However, soil samples showed some uranium and plutonium contamination in localized small spots indicating the possibility of additional subsurface contamination. Extensive exploratory excavation did find some subsurface contaminated liquid waste lines. Full details of findings and the decontamination results are presented in an extensive report.[4-102] Decontamination was undertaken to reduce as much as practicable any remaining question about potential safety or health implications of the residual contamination found during the survey. A total of approximately 14,600 m^3 (19,130 yd^3) of contaminated or potentially contaminated material (soil and structural debris) was removed from the TA-1 excavations and buried at the LASL solid radioactive waste disposal site. However, it is impossible to give absolute assurance that all contamination was found. All likely sources

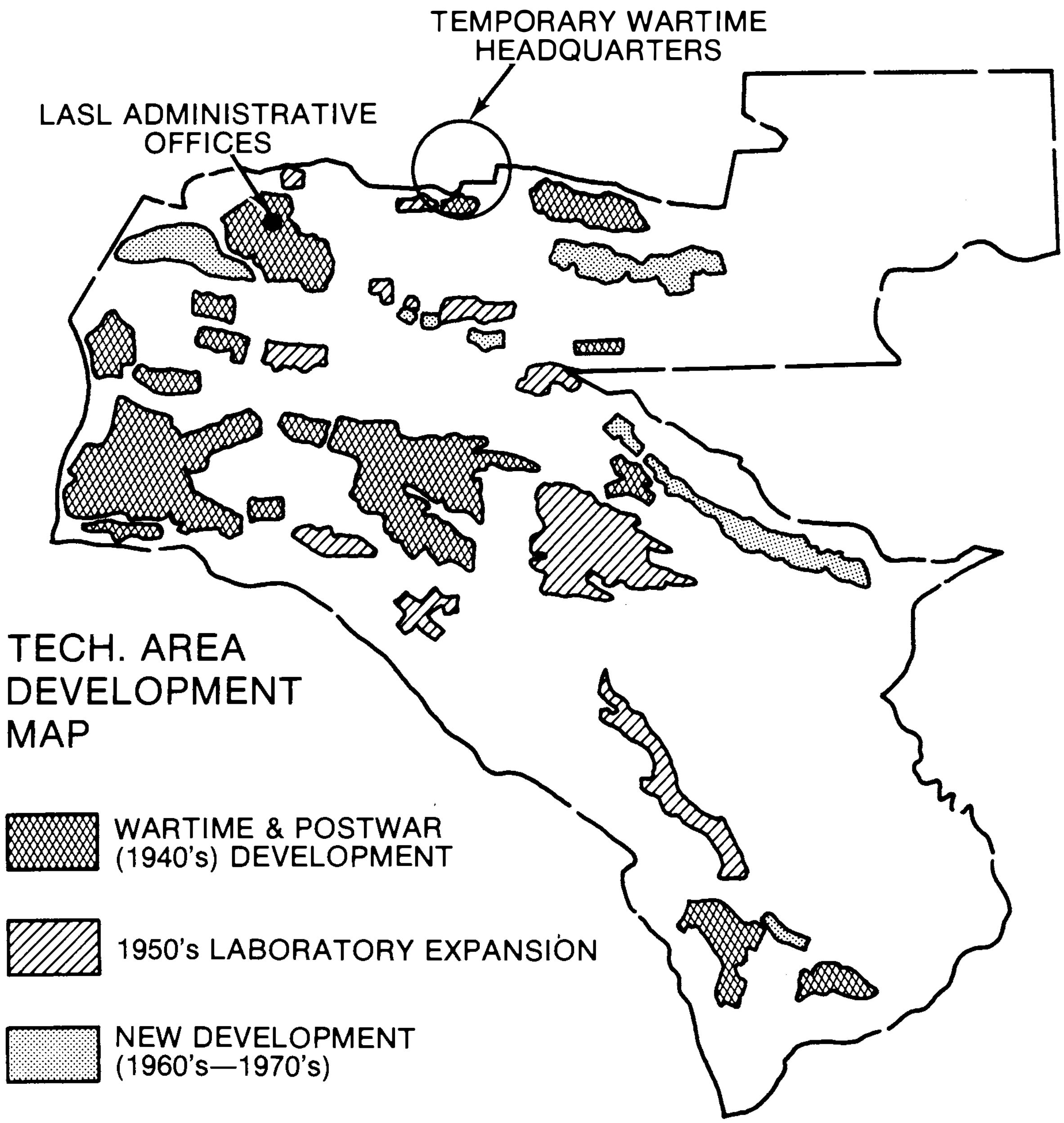


Figure 4.1.4-2

Sequence of Development of LASL Technical Areas of contamination in the remaining undeveloped portion of the former TA-1 area were investigated. All contamination found was removed to the lowest levels found practicable to attain, given due consideration to any potential health or safety hazards as well as the costs of further action. It is conceivable that other people or agencies might, in the future, find detectable contamination, although it is highly unlikely that any health hazard would be encountered. Based on experience gained during this operation, it is considered likely that pockets of contaminated soil would have been greatly diluted by normal construction activities, thereby minimizing any potential for exposure. Some evidence gained during this operation indicates that there are some potentially contaminated spots in the previously developed portions of the TA-1 area, but it is unlikely that they could in any way cause concern because of probable dilution by earthwork associated with the construction of new buildings and new landscaping and the fact that no instrumental indications of contamination were found on portions of the relandscaped but unbuilt areas. It is believed that the TA-1 area in its present condition poses no risk to human health.[4-102]

A second former LASL technical area was located in a portion of Bayo Canyon now owned by Los Alamos County. Testing operations with high explosives involving radioactive tracer materials resulted in the contamination of some of the land with ^{90}Sr. A major cleanup was undertaken in 1963 to remove residual high explosive and radioactive contamination, and the area was subsequently turned over to the county. Some residual strontium contamination is known to remain at depth in the vicinity of waste disposal pits used during the operational period but not completely excavated during cleanup. Present knowledge indicates that there are no health or safety problems associated with the current recreational use of the land. The area was subjected to a special intensive resurvey as part of the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP). The results of that work showed that no one is receiving radiation exposures detectable above natural background under present conditions of use due to the remaining residual contamination. Hypothetical evaluations of potential future use scenarios including residential development show that some individuals practicing extensive gardening could receive doses as much as 25% above natural background after a period of many years. The full details of the radiological survey and evaluation will be published by DOE in a report in the FUSRAP series. A follow up study will evaluate possible management options for the Bayo Canyon area.

Portions of Pueblo Canyon and a small tributary known as Acid-Pueblo Canyon contain some residual radioactive contamination remaining from the release of Laboratory effluents before 1964 (see Section 4.1.1). The land, previously entirely DOE controlled, is now partly county-owned land and partly DOE-controlled. Acid-Pueblo Canyon and the upper portion of Pueblo Canyon are on county land. Pueblo Canyon then crosses the DOE-controlled Pueblo Canyon Tract and Otowi Section. Present information derived from routine surveillance and special ecology studies indicate that there are no health or safety problems arising from the residual contamination. The area was reevaluated by extensive additional field measurements and sampling as part of the DOE FUSRAP program. The results indicate no significant exposures are likely to be received under present conditions of use. Hypothetical evaluations of potential future uses including residential development show that some exposures above background could occur. The full details of the radiological survey and interpretation will be published by DOE in a report in the FUSRAP series. A follow up study will evaluate possible management options for the Pueblo Canyon area.

The Pueblo Canyon tract comprises 0.38 km^2 (95 acres) of land.[4-103] It abuts the Otowi Section at its east boundary and is surrounded by Los Alamos County controlled lands on its other boundaries. The Pueblo Canyon tract was not included in the 1967 land transfer to Los Alamos County because it included an emergency landing strip for the Los Alamos Airport. By 1972 the emergency landing strip was no longer used, and the AEC declared the Pueblo Canyon tracts in excess to their needs. However, with trace quantities of radioactivity remaining in Acid-Pueblo and Pueblo Canyons, it is desirable to retain the Pueblo Canyon tract in the study area since the stream channel flows through the tract. A radioecology study program was initiated by LASL in 1972.

The portion of the Otowi Section that is presently under DOE administrative control is located in Santa Fe County and encompasses 16 km^2 (4,000 acres). The section is crossed by New Mexico State Road 4, the main access road to Los Alamos, and by the DOE-owned East Jemez Road, which also accesses Los Alamos and LASL. The stream channel from Pueblo Canyon also traverses the Otowi Section and empties into Los Alamos Canyon at the southeastern corner of the section.[4-103]

A 13.2 kv power distribution line also traverses the Otowi Section. In addition, the DOE water supply line and two booster stations from the Los Alamos Well Field supplying water to LASL and the Los Alamos community are located adjacent to State Road 4 on the section. If a replacement well for the Los Alamos well field will be needed in the future, it is desirable that it be located within the Otowi Section.

Of the Western and Northern Perimeter tracts transferred to the GSA for disposal, 4.9 km^2 (1,210 acres) still remain under GSA custody. This area contains Rendija Canyon and other portions of the Western Perimeter, which may be suitable for future residential development. The "Woodlot" located in the Western Perimeter area, comprising approximately 0.06 km^2 (14 acres), has been declared excess and is presently being transferred from DOE control to GSA for disposition.[4-103]

As summarized in Section 3.2.1 and shown on Figure 3.2.1-3, any further expansion is constrained because of adjacent land ownership and existing development and the physical characteristics of contiguous land areas. Therefore, essentially all future growth of the Laboratory is expected to be confined to the existing reservation.

Because of the extremely rough topography of the Laboratory lands, the amount of buildable land is a principal development constraint. Of the total DOE land available, 49 km^2 (12,000 acres) or 44% is considered buildable. This includes land with grades up to 20%, which is an absolute maximum buildable slope. For most purposes grades of 15% are a more realistic maximum.[4-104]

Using the growth projections presented in Section 2.2.3, the estimated developed area should be approximately 20 km^2 (4,900 acres), or 18% of the total Laboratory land area. However, the type, timing, and quantities of required new facilites are essentially unpredictable, and LASL must provide for an unknown amount of future development. In the past, however, the process of making actual land use decisions at LASL has largely been ad-hoc, in response to facilities requirements as they were generated by the budgeting process. Each new project has been treated as an independent entity.

To use the land and facilities efficiently, LASL is developing a Master Plan.[4-104] It includes a comprehensive inventory of natural resources, existing site development, and supporting facilities and services. Major land use constraints and opportunities as well as present and potential land use problems or conflicts are identified. The Master Plan's guidelines are oriented towards protecting the environment, reducing the impact of natural disasters, and minimizing development costs. An ongoing planning procedure is established to provide an annual update of objectives and make yearly recommendations to LASL management for short-term actions.

In view of the previous agricultural uses of the area, the US Soil Conservation Service was contacted. Based on the Soil Survey for Los Alamos County, it was determined that there are no prime or unique farmlands located within the LASL reservation.

Sand and gravels have been taken from deposits in the Los Alamos area, resulting in the removal of a few juniper, piñon, and ponderosa pine trees and a slight change in the topography. Because the sites are in isolated canyons in the areas of restricted access, the aesthetic effect is minimal.

Continued operation of the Laboratory, including proposed expansions, will not change the qualitative nature of short-term uses of the environment and natural resources. There will be some additional land committed to structures. Some land, due to presence of potentially hazardous materials, will be maintained under appropriate controls for the foreseeable future.

Many easements are held by the Federal Government in Los Alamos County and Northern New Mexico for utility rights-of-way. They are basically no different from those associated with any community utility system, except they stem from the historic fact of the facilities having been originally constructed for the Federal Government in the early days of Los Alamos. Hundreds of easements exist in Los Alamos County for the water supply and distribution systems, natural gas distribution, electric power distribution, steam distribution, and other facilities. Outside Los Alamos County easements are held by the Federal Government for rights-of-way for the water supply system, an electric power transmission line, and a natural gas transmission pipeline. The general nature of these facilities and their rights-of-way were discussed in Section 3.2.

4.1.5. Ecology

A general assessment of the effects of LASL operations on the natural environment must first consider those impacts that are readily observed and generally can be easily quantified and secondly, those impacts that are not easily observed and are generally very difficult to quantify. Unfortunately, many man-related impacts on natural systems fall into the latter category. Further complications arise in assessing LASL impacts on the surrounding natural environment in that the Laboratory has generally developed areas that were formerly used for agriculture; thus, most developed areas were not climax plant communities before Laboratory development in 1942 (see Figure 4.1.4-1). The latter fact coupled with the lack of ecological data especially from those years before the Laboratory's existence and up to 1972 (when comprehensive ecological studies were begun) demonstrate the generally limited basis available for assessing the environmental impact of Laboratory operations.

Assessing the impact of the Laboratory's physical development involves the ecological concept of niche, or the manner in which the natural resources of an ecosystem are functionally used by its components. Generally, all available niches are normally occupied by the various plant and animal species adapted to fill them. When the habitat is destroyed for project development, the immobile species occupying the habitat also will be destroyed. If any animals move into undeveloped areas, competition for the limited food and cover will eventually lead to the death of individuals until the population is stabilized at the carrying capacity of the remaining habitat. In addition, some species may be temporarily or permanently dispersed because of noise and human activity associated with construction.

Conversely, habitat favorable to certain wildlife can increase as a result of clearing, depending upon the nature and location of the development activity. The area where grass and browse species can grow may be increased, producing more food for wildlife. This increased edge effect especially benefits bird and small mammal species. This would, in turn, probably benefit raptorial hawks or other animal species dependent upon the birds and small mammals for food. Likewise, opening of dense forests produces habitat that should benefit big game if not accomplished on large continuous areas. However, these beneficial effects may be negated if activities in the area conflict with the normal behavior of wildlife species or if barriers are created that inhibit wildlife movement.

Approximately 15 km^2 (3600 acres) of land was dedicated to agricultural uses in those areas confiscated for Laboratory use in 1942 and most of the remaining areas were heavily used for grazing and logging. Buildings, parking lots, and roadways in the Laboratory's technical areas currently occupy a total area of 6 km^2 (1600 acres), much of which is located in old agricultural areas. The remainder was previously timber and grazing lands. Less than 20% of Laboratory land has been disturbed because of past and present land use (see Figure 4.1.4-1).

Restricted access and the prohibition of hunting in Laboratory areas also appears to have had some beneficial aspects for some wildlife. Large areas that remain relatively undisturbed serve as nesting and breeding areas for species that are intolerant of human encroachment. The predatory cats, hawks, and falcons occurring on the LASL site are examples. The apparently large numbers of predatory species attest to the diversity and abundance of food. Since grazing has been prohibited on Laboratory grounds since the early 1940s, many areas are returning to their natural vegetative associations and are thereby regaining carrying capacity for wildlife. In addition, a fire on the western margin of the plateau created open areas with shrubs and grasses that now support increasing numbers of elk.

Laboratory fencing has eliminated only a small portion of the total reservation from use by large, free-roaming animals, since few fenced areas are completely enclosed. It is known that security fences do block the direct movement of deer in some locations; however, there are very few areas on the Laboratory from which deer have been excluded because access to most areas is gained through guard gates or by movement around the fence. The enclosed areas are freely used by large mammals such as deer and coyotes, especially on the western margin of the plateau (see Figures 3.1.4-5 and 3.1.4-6).

Information from approximately 200 resightings of 28 marked Laboratory deer (20 adult females, 4 adult males, 1 juvenile female, 3 juvenile males) demonstrates the seasonal movement of this species to lower elevations during the fall and winter. In addition, the resightings indicate that individual deer restrict their movements to one or two mesa tops and that male deer move over considerably larger areas than do females. It also appears that juvenile males roam over a larger area than do adult males, which may be a reflection of dispersal in juveniles. The testing of explosives undoubtedly frightens some deer from the immediate area, however, many deer become acclimated to the testing and have been observed essentially ignoring the explosions. Besides the immediate effect of destruction of habitat, construction activities probably decrease deer use in the nearby vicinity for a while. It should be noted that because of the lack of hunting, Laboratory deer become accustomed to regular human activities and are quite tame and generally undisturbed by most Laboratory activities.

Many of the wildlife species in the area have only a limited fear of humans; bear, coyotes, mule deer, raccoons, and skunks are commonly observed onsite and in adjacent residential areas. Auto collisions with deer occur frequently, resulting in 50 to 75 deer mortalities per year in past years.

Deer densities have dropped considerably from population highs in the early 1960s. Densities in the ponderosa pine community type on the Laboratory have decreased from approximately 22 deer/km^2 (58 deer/mi^2) in the fall of 1965 to roughly 9 deer/km^2 (23 deer/mi^2) in the fall of 1976. Reproductive success appears to have decreased over the last 15 years based on herd classification counts. During the fall of 1965 approximately 60 fawns were observed for every 100 does sighted, whereas, in the fall of 1976 only 38 fawns were observed for every 100 does. Present data are not sufficient to determine whether these differences are real. Estimates based on pellet group counts from 114 sampling plots indicate that there are presently 1084 ± 416 deer ($p \leq 0.05$) residing on 103 km^2 of Laboratory and nearby U.S. Forest Service land. A general decrease in mule deer reproduction success has been observed statewide.

Deer populations in New Mexico have fluctuated from a low in the mid-1920's to population highs in the early 1960's. It now appears that deer populations in the northern part of the state, including Los Alamos, may be decreasing.[4-105] The reasons for these fluctuations are unknown. However, several factors may be involved statewide including disease, poaching, over-hunting, predation, poor range quality, and a loss of habitat.

Studies currently underway at Los Alamos are aimed at obtaining baseline data on deer numbers and habitat requirements in order to assess the magnitude and possible causes of any future changes in population density. Deer tagging and radio-telemetry studies are providing information on local movements, migratory movements, feeding areas, fawning areas, and the reactions of deer to various Laboratory activities and structures.[4-106] The data gained from these studies will be incorporated into planning for future LASL development.

Elk populations in the Los Alamos area appear to be increasing. Habitat improvements through fire and logging have resulted in the destruction of old-forest communities and the creation of disclimax (second growth) areas which are favored by elk. A few areas of the Laboratory, which were once cleared for agricultural purposes and are now abandoned, are showing signs of increasing elk use.

The relative abundance and distribution of small mammal species are presented in Table 4.1.5-1 as a function of elevation and habitat.[4-107] This abundance index (number of animals captured per 100 live trap nights) indicates the relative trapability of species in areas where they occur and for a particular species provides a general indication of abundance. The highest value of relative abundance (i.e., 34) was observed for the montane vole at the 2900 m (9500 ft) elevational sites. This species disappears from study site ecosystems at lower elevations and other species assume prominence. The relative abundance of all the remaining species, with few exceptions, averaged less than three individuals per 100 trap nights.

TABLE 4.1.5-1

RELATIVE ABUNDANCE AND DISTRIBUTION OF SMALL MAMMALS IN THE LASL ENVIRONS

Dominant Overstory Vegetation	Elevation m	*Peromyscus maniculatus*		*Peromyscus truei*		*Eutamias minimus*		*Reithrodontomys megalotis*		*Microtus montanus*		*Microtus pennsylvanicus*		*Clethrionomys gapperi*		*Neotoma spp.*		*Sorex spp.*		Totals	
		a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Subalpine grassland	2865	2.5	1.1							34	15									37	14
Spruce-fir	2865	6.4	4.7			2.6	0.8			13	8.6			0.9	1.3	0.7	0.3	0.3	0.6	22	2.1
Mixed Conifer	2560	10	2.0			1.0	1.2			0.4	0.5			0.2	0.3	1.8	0.9			13	3.4
Ponderosa pine	2255	0.9	1.3			1.0	1.6									0.2	0.3			2.0	3.2
Piñon-juniper	1950	0.9	0.7	2.2	2.1															3.8	2.8
Juniper-grassland	1645	6.1	4.7	6.6	2.3											0.3	0.4			13	1.9
CANYON STUDY AREAS																					
Mixed Conifer	2135–2190	1.1	1.6	3.1	2.7	2.4	2.2	0.3	0.6			0.5	0.6			0.04	0.01	0.2	0.1	7.4	4.9
Ponderosa pine/ piñon-juniper	2010–2090	1.3	1.8	2.2	2.5	2.2	3.0	0.6	0.5			0.1	0.2			0.1	0.2			5.8	4.6
Juniper-grassland	1755	0.2	0.3	6.0	5.5	2.2	3.0									0.2	0.3			8.6	2.8
DISTURBED HABITATS																					
Ponderosa pine/ piñon-juniper	2000–2190	11	6.6					3.0	3.2											14	7.7

a)Number of animals captured per 100 trap nights.
b)Standard deviation.

Because of their widespread occurrence and somewhat uniform abundance throughout the Los Alamos areas, the deer mouse and least chipmunk may be useful as indicators of habitat perturbances resulting from natural and man-caused events. Indications of this potential are evident for the deer mouse since their relative abundance in disturbed habitats averaged about a factor of 10 higher than in undisturbed areas at similar elevations.[4-107]

LASL operations represent a minimal impact upon bird communities when one considers the relationship of endangered species to testing locations and the observed responses of the majority of bird species to Laboratory activities. With increased ecological input to engineering programs to promote better land use practices and management procedures, LASL must be considered to have a positive direct effect upon the majority of bird communties. The indirect effect, mostly the attraction of a substantial human population, has been largely negative. Until recently, this latter aspect of LASL had not reached a serious point. One pair of peregrine falcons has occupied an eyrie in the LASL environs that may be seriously impacted by activities that are outside direct Laboratory participation. The increasing human housing problems have caused encroachment upon habitats immediately adjacent to the peregrine falcon eyrie and thereby increased possibilities for human discovery and resultant destruction of the birds. LASL has a special endangered species permit to study the falcon. A twelve-year history of reproductive performance of the falcons has been obtained by cooperation of a long-time Los Alamos resident and related to other falcon eyries in the Rocky Mountain environments. This eyrie had an outstanding record of producing 30 fledgling falcons during the period 1964-1971 but then began a period of reduced production during 1972-1973 and no production during 1974-1976. Limited data from one unhatched egg from the 1973 eyrie showed that it contained high levels of DDT (960 ppm) in the lipid fraction and that the egg shell was about 20% thinner than the average for other North American peregrine falcon eggs at the same time. These symptoms of pesticide poisoning presumably resulted from the ingestion of granivorous birds at the Mexican-Central American wintering grounds of the falcons, where there continues to be widespread DDT use. Inquiries about pesticide use in the Los Alamos environs by several responsible agencies have resulted in negative responses although the Forest Service is presently consulting its records of possible pesticide use in controlling pinebark beetles and tussock moths.

It is difficult to generalize on the specific effect of an activity without specific knowledge of the site and of the wildlife populations at the sites. The impact can be evaluated when the species population and their habitat requirements are known. Plans then can be directed to mitigating adverse impacts on the wildlife present at each site. Ongoing ecological studies in the Los Alamos area are designed with this application in mind.

An impact that is readily observed, but difficult to quantify, is the result of liquid effluents released to the environment from Laboratory sewage and industrial sources. It is obvious that these effluents have effected dramatic changes in the recipient ecosystems. However, quantification of these changes is difficult and has not been done for most areas because of the lack of baseline data. In addition, assessing the relative benefit or detriment of these liquids on plants and animals communities is generally subjective. The added water has obviously been detrimental to those species that have decreased in importance or been eliminated. Conversely, additional water has been beneficial to those species that have survived or become established in the affected areas.

Plant species such as cattails and several mesic site shrubs and grasses have replaced the xeric species found in the semi-arid climate. The lush vegetation would appear to be attractive to herbivorous wildlife and secondarily to carnivorous species, although results of ecological studies in these areas are not sufficiently conclusive to validate this observation.

The task of evaluating the impact of chemical contaminants on the LASL ecosystems is difficult with present data. Complicating factors include minimal quantitative data, the number of radioactive and stable species released to the environment, the concurrent release of various organic and inorganic chemicals, and the numerous differences in physical forms and chemical and biological behavior of the radionuclides and stable elements. In addition, the low concentrations of chemicals in the recipient ecosystems produce effects that cannot be measured. The persistence of some of the chemicals in the environment requires longterm study of buildup and availability to biota before quantitative evaluation is possible.

In the early 1970's, the Laboratory recognized the need to greatly expand the environmental monitoring program and to initiate comprehensive ecological studies to determine the fate of chemicals released to the environment. The ecological studies have generally dealt with radioactive constituents of liquid effluents released to three canyons.

As discussed earlier in Section 4.1.1, a radionuclide inventory in the soils and biota of liquid waste disposal areas was made to document amounts of ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am. Studies are underway to determine the pathways, mechanisms, and rates of transport of these materials between components of the canyon ecosystems represented by Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons. These studies were coupled with quantitative surveys of the soils and biota to provide a basis for compartmental analysis of plutonium and other radioactive and stable elements in the study ecosystems.

The preliminary results of these studies have revealed that tritium, in the form of tritiated water, is present at levels above background in the soils and biota of Los Alamos and Mortandad Canyons. Maximum levels are in the effluent water, about 600 pCi/ml. This is about 20% of the drinking water concentration guide for uncontrolled areas.[4-99] There is no indication that the tritium concentrates as it passes from source to recipient biota.

Tritium was observed in free roaming honey bee colonies placed in the canyon for research purposes.[4-25] Maximum levels in bee body moisture were about 10 nCi/ml, compared to 100 nCi/ml in surrounding mesa-top vegetation and 1000 nCi/ml in plants growing above one old solid waste burial ground. Sources of these higher concentrations, which are attributed to gaseous effluents or solid wastes, are in areas of restricted access to the general public. While no biological concentration occurs, the tritium picked up by the honey bees is also transferred to the honey, providing a potential pathway for transfer to humans. Calculations under worst-case assumptions demonstrate that radiation doses to a human ingesting tritium contaminated honey would be less than 0.1 percent of permissible exposures to the general population. Furthermore, private production of honey is a very minor enterprise in Los Alamos County.

The liquid effluent has resulted in minor contamination in canyon stream channel soils and, to a much lesser degree, biota, primarily in onsite areas.[4-26, 4-28, 4-108 through 4-110] Maximum levels of 3 nCi ^{137}Cs/g, 0.35 nCi ^{238}Pu/g, and 0.15 nCi ^{239}Pu/g have been measured in individual soil samples from the narrow (<1 m) stream channels near the waste effluent outfalls. However, concentrations in soils decrease rapidly with distance below the effluent outfalls to levels comparable with worldwide fallout. Concentrations at any one location are at least a factor of 10 lower in vegetation and at least 100 times lower in rodents than in corresponding soil samples. Controlled radionuclide uptake studies with plants and animals have further emphasized the lack of biomagnification of ^{137}Cs, ^{238}Pu, and ^{239}Pu by canyon wildlife.

Mule deer frequenting the canyon areas and presumably drinking the effluent water exhibited ^{137}Cs concentrations of up to 1.8 nCi/kg muscle, which is slightly elevated over levels in control deer samples. This does represent a potential transfer pathway for ^{137}Cs to humans, although calculations readily show that its importance from a radiation dose aspect is extremely minor. Levels of plutonium in deer and other large mobile species are generally not detectable.

The alluvial soils contain virtually all of the ^{137}Cs and plutonium inventoried in the canyon ecosystems. An example of the relative amounts of plutonium in soils, vegetation, and rodents from Mortandad and DP-Los Alamos Canyon is given in Table 4.1.5-2. Vegetation contains less than 0.1% of the total plutonium inventory, and rodents account for less than 0.0000003% of the total.

An experimental vegetable garden was recently established in a contaminated portion of Mortandad Canyon to evaluate the potential for food chain transfer of radionuclides and toxic stable elements to humans. The results of these experiments will be useful in evaluating the importance of low level soil radionuclide concentrations should Los Alamos land-use practices change and, in addition, will provide criteria for establishing radionuclide concentration standards for soils.

The hazards resulting from inhalation of wind-blown contaminated sediments appears to be a low order possibility in the canyons because of the generally moist condition of the alluvium and the dense vegetation cover overhanging and growing adjacent to the stream channel. However, highest concentrations of plutonium in ground dwelling rodents from the canyons are measured in lung and pelt tissues, indicating that resuspension processes may be important on a micro-scale.[4-109]

Elevated radiation doses, primarily from ^{137}Cs, can be measured in the immediate waste outfall areas in the canyons. A study was conducted near the waste outfall in DP-Los Alamos Canyon to measure radiation doses in small ground-dwelling rodents inhabiting the area.[4-111] The results of the study, which was accomplished through the implantation of thermoluminescent dosimeters in the rodents, demonstrated that relatively high doses were associated with rodent species most intimately associated with the contaminated area because of habitat preferences and mobility. Whole body radiation doses averaging about 9 rads/year were measured in certain species. This exceeds the radiation dose due to natural background by a factor of about 50. Results of a great many studies on radiation effects in Laboratory animals demonstrate that exposures of 9 rads/year are far below the doses that cause observable effects. Furthermore, those areas exhibiting elevated radiation backgrounds are in restricted-access locations on the LASL reservation where it is highly unlikely that an individual person would remain for any significant time. Thus, it is improbable that anyone, including employees authorized to be in such areas, is receiving doses approaching any applicable guidelines.

Studies are underway to determine radiation doses to free-ranging mule deer through the use of thermoluminescent dosimeter packages inserted into tracking collars placed on the deer. Such studies are the only realistic way of evaluating radiation doses to large animals that periodically wander into contaminated areas.

TABLE 4.1.5-2

RELATIVE DISTRIBUTION OF PLUTONIUM IN MORTANDAD AND DP-LOS ALAMOS CANYON ECOSYSTEM COMPONENTS NEAR THE EFFLUENT OUTFALLS

	Mortandad		DP-Los Alamos	
Ecosystem Component	nCi/m^2	% of Total	nCi/m^2	% of Total
Soil (depth)				
0 - 2.5 cm	2100	~27	12	~6
2.5 - 18 cm	5700	~73	200	~94
Live Vegetation				
Grass	0.67	9×10^{-3}	0.16	8×10^{-2}
Forb	0.009	1×10^{-4}	--	--
Rodent	2×10^{-5}	3×10^{-7}	3×10^{-5}	2×10^{-7}

Information on the ^{241}Am content of canyon ecosystem components is limited because of the problems encountered in developing a reliable analytical procedure for this element in environmental matrices. The limited amount of data available indicates that levels of ^{241}Am in soils and biota are lower than corresponding plutonium concentrations because of the lesser amounts of ^{241}Am in liquid effluents and its very low bioavailability.

Other studies were initiated on mercury in the canyons and depleted uranium on mesa top sites used for explosive experiments. The results of the studies indicate mercury is elevated in canyon soils as a result of liquid effluent release, and stream bank soils appear to be a major deposition loci for mercury relative to stream-channel soils. Mercury appears to be more mobile than ^{137}Cs in the canyons because of basic differences in transport behavior.

Studies on depleted uranium in firing site areas indicate that the most readily observed effect of test explosions on adjacent native plant communities is the result from the blast and resultant fires rather than from the chemical toxicity of uranium.[4-112] The affected areas are small, less than 0.02 km^2 (5 acres) and are covered with early successional stages of plant growth. A major objective of this program is to attempt to define anomalies in plant and animal community structure that can be attributed to chemical toxicity of uranium.

One of the major processes governing radionuclide distribution in the canyons results from storm runoff. Surface flow in these intermittent streams occasionally reaches the Rio Grande and, in the process, transports sediment-bound radioactivity to downstream areas.[4-28] Very slightly elevated levels of plutonium can be measured near the confluence of Los Alamos Canyon and the Rio Grande. In 1973 a sediment, water, and fish sampling program was established on the Rio Grande downstream from the Laboratory to document levels of radioactivity in sample materials. Results through the years clearly demonstrate that levels of radioactivity in Rio Grande sediments, water, and fish are well within levels that can be attributed to worldwide radioactive fallout sources.[4-34]

It is difficult to make definitive predictions of Laboratory impacts on the natural environment over the next 25 years. Certain aspects of present operational procedures will dramatically improve (i.e., the goal of zero release of liquid pollutants) in a few years resulting in improvements in the chemical quality of the environment. In addition, the continued acquisition of ecological research data will help improve land use practices to minimize the environmental impacts of activities such as facility development. In some cases, beneficial impact may result such as preservation or development of areas beneficial to wildlife. Ecological studies of chemical materials in the environment are required over long periods in order to detect subtle, long term effects. In cases where contaminants are thought to exist, studies are initiated. The results of these studies are reported in the yearly Environmental Surveillance Reports.

Many of these basic ecological studies are now being conducted in connection with the Laboratory's National Environmental Research Park (NERP) as discussed earlier in Section 2.2.3.[4-113]

4.1.6 Other Resource Utilization

Energy

Use of energy for the operation of DOE facilities at Los Alamos constitutes a major consumption of natural resources from external sources. The sources of supply and the transmission facilities were described in Section 3.3.1.6. In the past, DOE functioned as a supplier of electricity and natural gas for Los Alamos County as well as for the DOE facilities. Beginning in mid 1977, the county began making all purchases of natural gas and electricity directly from commercial suppliers. Existing transmission lines and pipelines will continue to transport the county purchases, but DOE will no longer be involved in the resale of energy or fuel.

The balance of this section will deal with the actual and projected uses of electricity and natural gas and related environmental impacts only for Laboratory-related operations and excludes energy usage attributable to the community. Thus there are differences between this section and Section 3.3.1 because of what is included.

Total energy consumption in FY 76 was approximately 5.6×10^{15} joules (3.3×10^{12} BTU) in terms of the energy value of the natural resources consumed on-site or used to generate purchased electricity. Note that these energy values reflect efficiency factors attributable to the genetration process and these numbers are much larger than the useful energy consumed as was discussed in Section 3.3.1. The distribution between purchased electricity and natural gas is indicated in Figure 4.1.6-1.[4-114] About half of the natural gas was used to generate electricity in the DOE power plant and the other half for space heating or processes. The natural resources providing the energy include natural gas, approximately 3.1×10^{6} MCF in FY 76, and coal and hydropower to produce the purchased electricity. About 62% of the purchased power was generated at coal burning power plants in the northwestern corner of New Mexico, the other 38% was generated by hydroelectric plants on the Colorado River Storage Project.

The emission of airborne pollutants resulting from the burning of natural gas for power production in Los Alamos is treated in Section 4.1.2, and the burning of coal in the Four Corners area is treated in Section 4.3.2.

The impact of energy consumption at Los Alamos in the future will depend first on the total energy needs and second on the mix of resources used to provide that energy. The total energy needs depend on assumptions about the expected programmatic development at LASL. A detailed consultant study was completed in 1976 to make projections of energy usage at LASL. The projections made by that study are depicted graphically in Figures 4.1.6-2, -3, and -4 (Reference 4-114). Each includes an envelope of use ranging from maximum expected use to the minimum that could be anticipated with an intensive energy conservation program. Because the study considered only LASL energy consumption, it is not possible to make direct comparison with the data in Figures 3.3.1-3 and -4. However, as noted in Section 3.3.1, progress has been made in the conservation of both electricity and natural gas usage. Total consumption in both categories declined between 1977 and 1978 in spite of growth in facilities and personnel.

Projected electrical energy consumption is shown in Figure 4.1.6-2.[4-114] An increased use of approximately 77×10^{6} kwh is expected between 1976 and 1985. Almost 48% of the increase is expected to be due to greater consumption at LAMPF, which will use an estimated 185×10^{6} kwh by 1985, compared to 148×10^{6} kwh in 1976. LAMPF presently uses and is expected to continue to account for about half

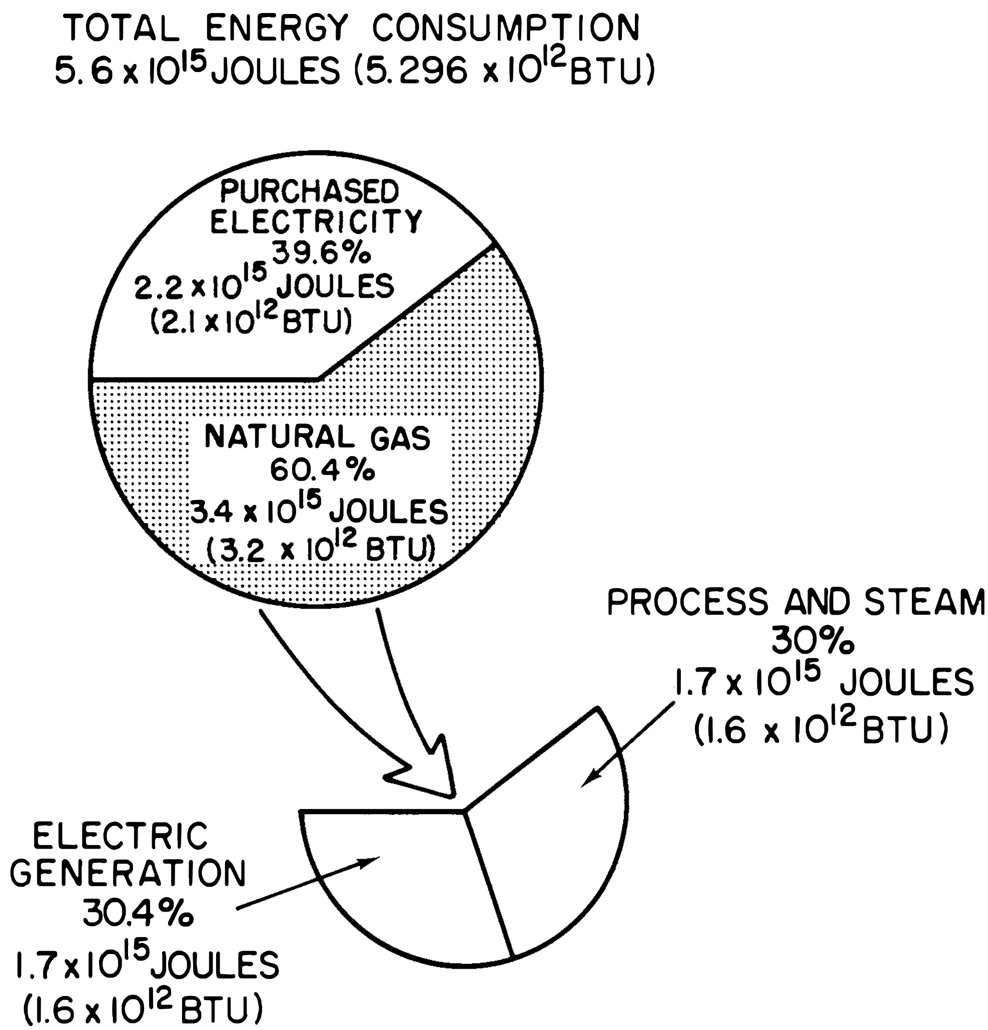


Figure 4.1.6-1

Total Laboratory Energy Consumption as Source Energy for FY 1976

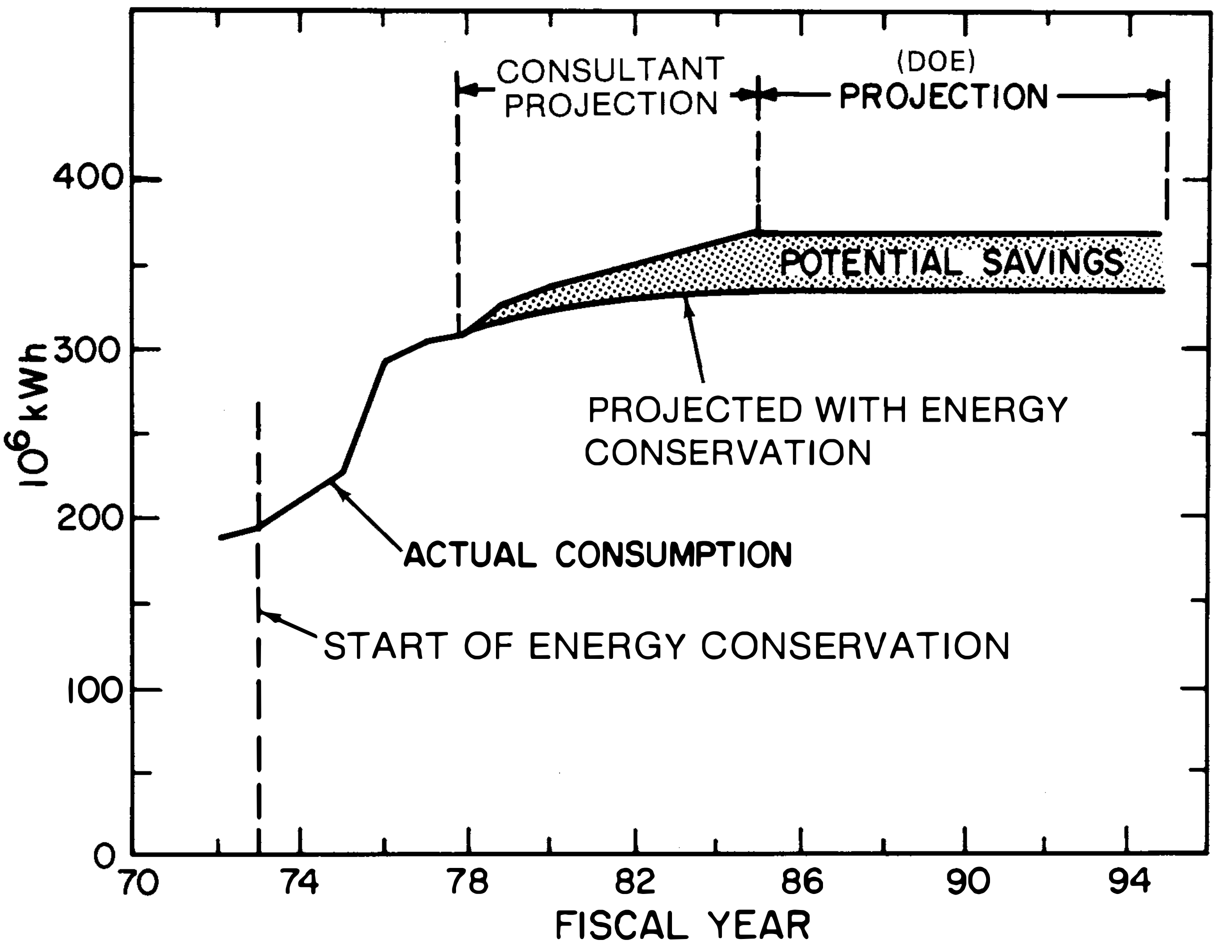


Figure 4.1.6-2

Annual Consumption of Electricity at LASL

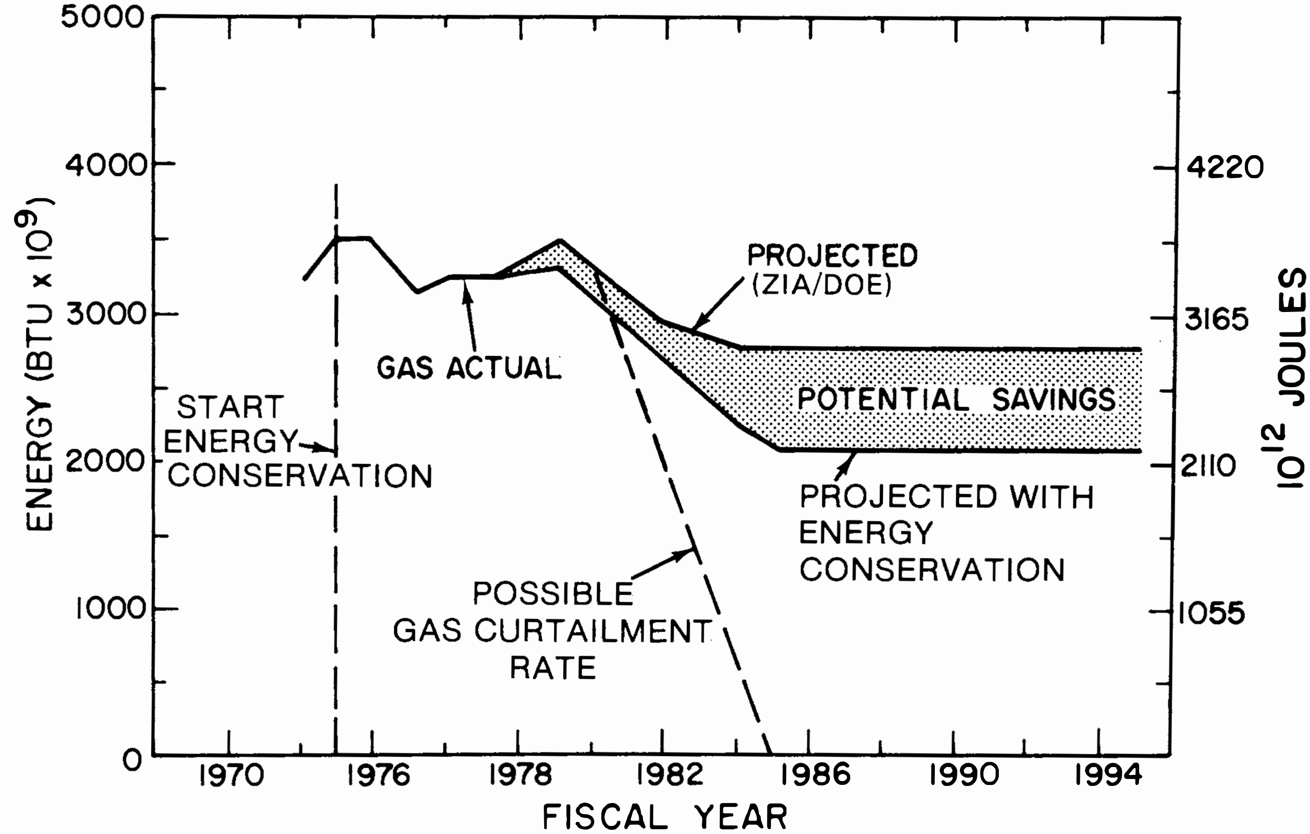
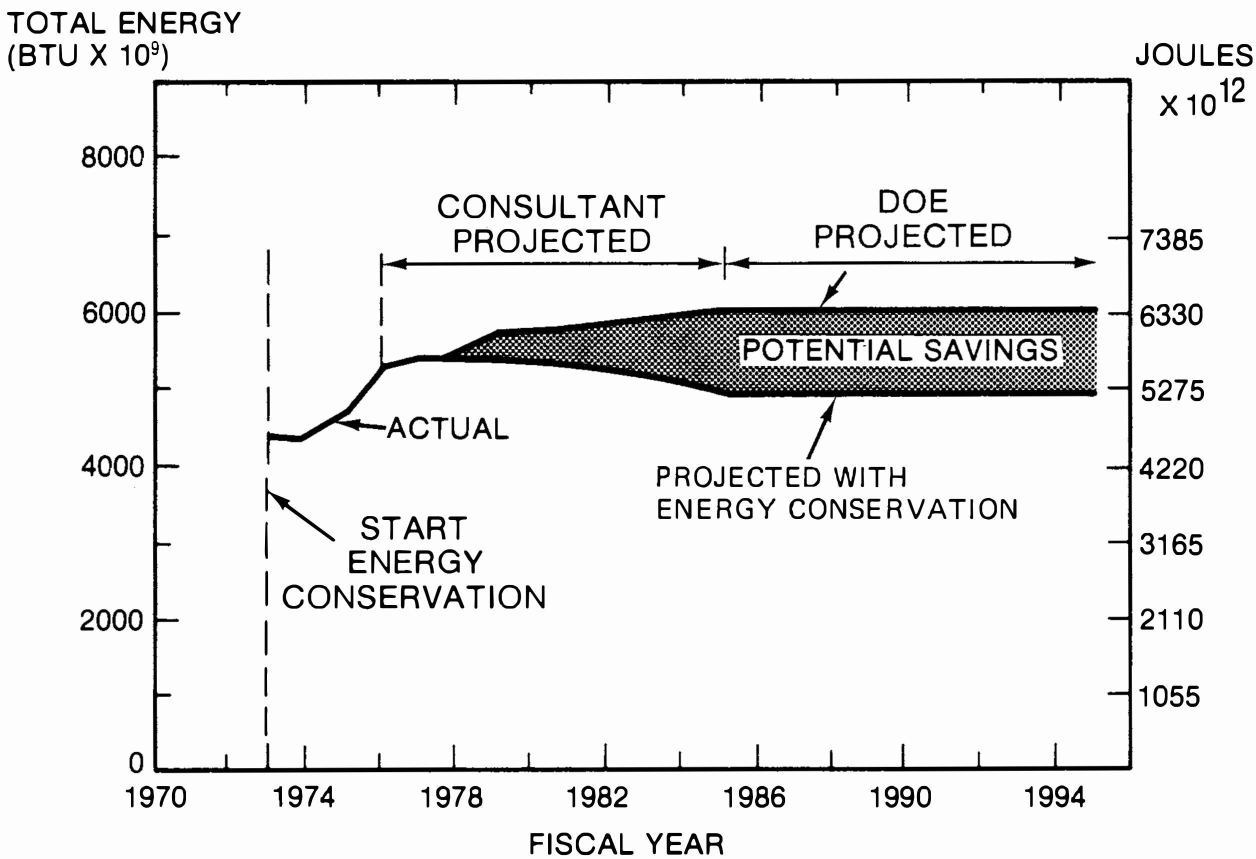


Figure 4.1.6-3

Annual Consumption of Fossil Fuels at LASL



NOTE: • ELECTRICAL CONSUMPTION REFERRED TO BTU'S @ GENERATING STATION (kWh X 11.6 X 10^3)
• ENERGY CONSUMPTION FOR LASL ONLY

Figure 4.1.6-4

Annual Total Energy Consumption at LASL in Source Energy Terms of the electrical consumption at LASL. Maximum possible electrical consumption savings of about 12% under the projection have been estimated. The increased needs will be met by additional purchases, with the largest fraction probably coming from Public Service Company generating plants. Most of the increases through 1982 will come from additional coal fired generating capacity; after 1982 some of the PSCNM power will be generated by the Palo Verde nuclear plant near Phoenix. Environmental effects of this additional power generation will depend on the PSCNM decisions about exact generating sources.

Projected local fossil fuel consumption is shown in Figure 4.1.6-3. The units are in energy only because of a possibility of conversion from natural gas to fuel oil by 1985. This assumption by DOE of the need to convert to fuel oil at LASL is based on expectations of limitations in the availability of natural gas and the infeasibility of using coal at Los Alamos.[4-114] There was an approximate 9% reduction in the use of gas between 1973 and 1975 resulting from the implementation of conservation projects. An increase is expected to occur, peaking in about 1979, because of planned facility and programmatic expansion. The longer range projections reflect savings expected from present and proposed conservation programs. An intensive additional energy conservation effort has been estimated to have the potential for an additional 36% savings by 1985. The figure also indicates the possible phaseout of natural gas, which would have to be replaced with fuel oil. If the change to fuel oil does take place, there will be some change in the nature of airborne effluents from the DOE power plant. However, it can be expected that appropriate environmental control technology will be added, if necessary.

The total energy consumption projection for the DOE Los Alamos operations in terms of source energy is shown in Figure 4.1.6-4.[4-114] This combines the information in the two preceding projections. The expectations are for a maximum increase of about 15% over current use by 1985, assuming present plans and some energy conservation are implemented. If an extremely intensive energy conservation program is carried out, there is some possibility of a 6% decrease by 1985 from present use. It must be noted that implementation of energy conservation involves consideration of the cost-effectiveness of capital and operational changes balanced against expected fuel costs as well as environmental considerations <u>per se</u>. The amount of energy conservation actually realized will be determined by a more detailed study of such trade offs. Some of the conservation measures being studied include reduction of lighting; additional insulation of buildings and water, steam, and condensate lines; modification of control systems for heating, ventilating, and air conditioning systems to maximize efficiency and reduce demand during non-use hours; modification of plans for new structures to incorporate all possible conservation measures; and addition of solar energy collection to some existing buildings.[4-114]

Additional minor inputs of energy in the form of gasoline, diesel fuel, and propane gas (see Section 3.3.1.2) result in some environmental impacts. The principal one is airborne emissions from government vehicles, which consume most such fuels. These emissions are treated in Section 4.1.2. Conservation practices, including car pooling, limiting speeds to 50 mph, and the use of bicycles, are encouraged at the Laboratory. Gradual replacement of existing motor pool vehicles with newer, more efficent, and less polluting vehicles will help achieve fuel savings.

Other Materials

Although many materials are used at LASL (Section 3.3.1.3), an effort is made to recycle when possible. After precious metals have served their research function, they are returned for cleaning, decontamination, and re-fabrication. Thus, only a very small quantity is actually consumed.

The purpose of the Zia-LASL Surplus Materials Recycle Program is to use excess material in subsequent projects. The policy of selling excess material to high bidders has been modified to accommodate the recycling program. Surplus materials used in the recycling program include maintenance or construction materials that are excess or have been removed from or left over from a job, and similar materials stockpiled in excess by using groups. Recycling efforts are exerted only on materials that are in economically repairable condition or that can be reused without excessive preparation. Inventory print-outs of available materials are furnished monthly to each LASL section or group that might recycle items. Material in excess at the completion of a job is returned to the recycle program for credit. When supplies, materials, and equipment are no longer useful they are delivered to Salvage and Surplus for disposal or recycling. Designated engineers, superintendents, or division chiefs make the decision that such items are no longer useful to LASL operations. Only Salvage and Surplus is authorized to dispose of government property, including scrap and waste. All appropriate materials considered for salvage and surplus are monitored, tagged, and cleared by a health physics surveyor before being removed from the job site.

LASL has a large central computer facility and many terminals thoughout the complex. Special waste receptacles have been marked for computer print-out paper and computer cards and placed in all areas where there are computer terminals. This paper is rough-sorted by Zia Co. custodians and fine-sorted by the local Explorer Scout Troop, which also has the responsibility for its transport to a trailer that is periodically picked up by a commercial paper recycling firm. Of the 480 tons of print-out paper and 105 tons of cards used by LASL during 1976, 120 tons of paper and 45 tons of cards were recycled.

The use of pesticides (Section 3.3.2) conforms to EPA and USDA registered uses and label specifications and no known resulting environmental problems were observed until a 1978 tree kill report. Results of that investigation have led to a reevaluation of some procedures. Results of the investigation are summarized in the 1978 Environmental Surveillance Report, Appendix H, page H-39. The use of cleaning and maintenance products (Section 3.3.2) results in some contributions to solid wastes and sanitary liquid wastes. No known environmental problems have been observed to have resulted. There are some known effects on pine trees from salt used during the winter for deicing by State Highway Department, Los Alamos County, and Zia.[4-114A, B, C] Every effort is made to use a minimum of salt within LASL.[4-114D]

4.1.7. Aesthetics

As discussed in Section 3.2.9, the utilitarian architectural style of the Laboratory was determined by the exigencies of Project Y during the war and by later austere construction budgets. The present facilities are useable and needed, and therefore will remain. Generally there are no codified visual quality standards applicable to the Laboratory.

The natural and maintained landscaping are the major aesthetic assets of Los Alamos. For an installation with the size and complexity of LASL, there are comparatively few buildings visible from publicly accessible roads. Most of the Laboratory structures are screened from public view by natural vegetation and by their location in controlled access areas. Altogether, some 68 structures in the technical areas can be seen by the public. The larger facilities, such as the Plutonium Processing Facility and the Main Technical Area, are the most noticeable of the 15 technical areas visible from public access roads. A negative visual impression is presented to visitors and employees by large industrial buildings, small support structures such as pump houses and guard stations, towers, masts, chimneys, overhead utilities, chain link fencing, and roadways. Although there have been efforts to site utility lines in less prominent areas, such as canyon bottoms, some overhead lines are silhouetted against the sky, giving them added visual prominence. Roadways at LASL generally have a negligible visual impact, since most are two lanes with a minimal amount of cut and fill.[4-104]

A series of plans for future improvements to visual quality are being developed as part of the LASL Master Plan.[4-104] Preliminary suggestions involve elaboration of the southwestern landscaping concept, maximum retention of natural vegetation, strategic planting of large trees, some use of screening fences, and use of a unified style for signs. Additional proposals include treatment of buildings by selective surface color application and large scale graphics and locating unsightly new buildings out of view from public roads. Finally, overhead utility lines would be screened or located out of view from public roads.

There is little expectation that funding specifically earmarked for visual improvements can be obtained. Past practice has been to give top priority to exterior maintenance work to maintain the integrity of a building, with no allowance even for exterior paint on buildings until recently. New facilities are now receiving more attention on an aesthetic and architectural design basis than has been typical of past structures. The National Security and Resources Study Center, the Occupation Health Laboratory, and the Clinton P. Anderson Meson Physics Facility are examples. However, structures will remain basically utilitarian to keep costs as low as possible. Improvements to the visual quality of existing facilities will have to be funded from LASL's operating budget, and will face stiff competition from other pressing LASL operating needs.

Another aesthetic asset of the Laboratory is that it also functions as a wildlife refuge. The policy, where possible, is to locate new development adjacent to existing technical areas to minimize environmental impact. This has permitted many areas of the Laboratory to remain undeveloped. Because grazing has been prohibited on Laboratory grounds since the early 1940's, many areas are returning to their natural vegetation associations and are regaining carrying capacity for wildlife. In addition, the various liquid effluents from LASL facilities have markedly increased water supply for vegetation and wildlife in some areas, and is at least partly responsible for the high density of wildlife in the area. Restricted access and limited hunting in Laboratory areas also appear to have had some beneficial aspects for wildlife. Large areas which remain relatively undisturbed serve as nesting and breeding areas for species that are intolerant of human encroachment. The large number of predatory species attest to the diversity and abundance of food. Many of the wildlife species in the area have only a limited fear of humans. The presence of endangered or threatened species further emphasizes that the LASL reservation also functions as a wildlife refuge.

However, some people, such as hikers, campers, and hunters, may consider the near-wilderness area placement of a major facility such as LASL to be an adverse aesthetic impact. This exclusion prevents their access to areas acknowledged to be scenically beautiful and rich in wildlife. The isolation itself was a major requirement for the original operation of Los Alamos. The exclusion is still unavoidable for reasons of security, safety, and contiguous land use. The exclusion is a mitigating measure protecting the public from potential hazards of exposure to contamination, dangerous test activities such as high explosive detonations, and potential risks from accidental releases. Also, the exclusion is not from a completely unique resource area in that similar landscape and opportunities for recreation are available in the Bandelier National Monument and nearby Forest Service lands.

An important indigenous aspect of local cultural interest and aesthetics is the profusion of pre-Columbian ruins peppering the area. In addition to being of environmental interest, these ruins are of extreme cultural importance to the local Indian people, who trace their descendancy from the peoples that inhabited them.

Potential effects of LASL's blast activities on nearby Bandelier Monument areas were assessed by measuring ground motions in the monument during times of relatively large test blasts. Results showed that other cultural noises (e.g., tour buses and foot traffic) exceeded the amplitudes from the blast. One exception was a north wall cave where the blast measure was only twice the foot traffic motions. Larger blasts are not expected to occur in the future; they, in fact, are showing a trend in decreasing the size.

It is a national policy to provide for the maintenance of archaeological sites through preservation, rehabilitation, or restoration as enunciated by Executive Order 11593, the National Historical Preservation Act of 1966 (16 U.S.C. 470 et seq.), the National Environmental Policy Act of 1969 (42 U.S.C. 4231 et seq.), the Federal Antiquities Act of 1906 (16 U.S.C. 431 et seq.), and the Historic Sites Act of 1935 (16 U.S.C. 461 et seq.). In essence these acts require total preservation and restoration of unique sites, and mapping and archaeological documentation of all other sites before effecting any civic or technological disturbance.

To implement this policy, and as a matter of general interest, an inventory of pre-Columbian Indian sites on LASL lands was made by LASL's consulting archaeologist.[4-115] Several hundred sites (shown on a LASL Archaeological Map, see Figure 3.2.7-2) were located over a two-year period. In addition to the map, a file of "site" cards was compiled. Each site located during the survey is described on a card and assigned a permanent number by the Laboratory of Anthropology of the Museum of New Mexico.

Strict procedures are followed at LASL to protect and preserve pre-Columbian Indian sites. Construction or maintenance activities that will involve archaeological sites are brought to the attention of the Environmental Studies Group. This includes smaller construction and maintenance activities that will require any earth surface disturbances. Major construction projects are reviewed for archaeological impact. The engineering divisions of both LASL and the Zia Company have copies of the LASL Archaeological Map and of the site cards to aid them in identifying Indian sites. Unique or especially valuable sites are posted with warning signs. If an identified site is in conflict with a construction or maintenance project, LASL's archaeologist examines the site to determine if minor changes in the construction plans will allow the site to remain. If the site must be salvaged, estimates are made as to the time needed for excavation and the amount of labor required.

Only salvage archaeology, rather than classical archaeology, is performed at LASL, and sites are protected whenever possible. When salvage archaeology is required, the LASL Engineering Division initiates the work orders, and LASL's archaeologist obtains permission to excavate from the Department of the Interior and the Department of Energy. Future determinations of importance and salvage archeology will be conducted in accordance with new regulations entitled, "Protection of Historic and Cultural Properties," 36 CFR 800, effective March 1, 1979.

Before excavation, a photograph is taken of the ruin. External aspects, including pottery sherds and any other artifacts found on the surface and the identity of the local flora, are recorded. The salvage crew is briefed on the proper procedure for the excavation, since procedures differ widely depending upon the ruin. An exploratory trench is dug into the side of the mound to establish the outer limitations of the architecture. Once these are established, excavation to floor level is performed, room by room, and photographed. Sub-floor pits are dug to check for burials, earlier floor levels, or evidence of possible earlier occupations. Features such as burials, firepits, grinding bins, storage pits, perishable materials, and datable wood are carefully exposed, photographed, and recorded.

Completed rooms with an identification sign are photographed, and a photograph of the entire excavated site is taken for the records. The completed site is mapped, and wall heights and thicknesses are noted.

The ruin is then reported as completely excavated and may be removed by the construction contractor. All sacked materials are marked, and large artifacts are removed to the Laboratory for study. Materials are cleaned, and laid out by rooms and levels for study. Analysis of materials includes identification of all pottery sherds and complete vessels. Pottery is restored if possible. Animal or human bones are identified; non-ceramic artifacts are measured and described. Perishable and fragile articles are given a special treatment with preservatives.

A final report is published that includes a description of the site, culture period, dates of occupation and abandonment, provenience and description of all artifacts, architectural features, and interrelationship with other sites.

4.1.8 Environmental Impacts of New Facilities to be Constructed

This section briefly summarizes anticipated environmental impacts of the several proposed new facilities described in Section 2 which are presently believed to have a good probability of being constructed in the near future. A number of projects were described in the DEIS but have been deleted herefrom because they are no longer being actively considered. The following summaries are based on information developed to prepare environmental assessments which accompanied official budget requests. Accordingly, they are not detailed studies but do identify the most significant or unique impacts associated with each proposed facility.

Intense Neutron Source

A Final Environmental Statement (ERDA-1548) has been prepared for the Intence Neutron Source (INS) Facility.[4-116] However, the project has been deferred. Should it be activated, the principal environmental impacts of the proposed facility from routine construction activities include clearing approximately six acres of land for the building, parking areas, and an access road. Liquid wastes discharge would consist primarily of cooling tower blowdown during operations. Significantly contaminated liquid and solid waste would be disposed at the existing LASL waste disposal area. Very small quantities (less than 100 curies per year) of tritium and traces of other radioactivity would result in site boundary doses not exceeding 5 mrem per year, or less than 5 percent of applicable radiation protection guidelines and less than 5 percent of the natural radiation background from naturally occurring radioactivity.

Proton Storage Ring

The planned proton storage ring and other additions including an experimental support facility at the Los Alamos Meson Physics Facility site are expected to produce minimal, generally short-term environmental impacts during the construction phase. The proton storage ring project has been designed in such a way that negligible radiation effects on the public health and safety are projected during normal operation. The facility will be fenced and therefore not accessible to the public. Airborne effluents will be discharged through the LAMPF existing high efficiency exhaust filter system. Contaminated waterborne wastes will be disposed at the central contaminated waste treatment facility. The maximum credible "worst case" accident would be the accidental dumping of an entire meson facility macropulse in the proton storage ring room. At the site boundary this would lead to a transient, maximum, radioactivity concentration which is less than the appropriate concentration guide. The only possible release of radioactive material which is possible involves the rupture of samples in one of the irradiation areas, accompanied by a failure in the ventilation cutoff system. Exposure to the meson facility-associated personnel from such an event would be comparable to the maximum permissible concentration guidelines for the public and thus within tolerable limits.

Occupational Health Laboratory Expansion

Operations to be conducted in the planned expansion of the existing Occupational Health Laboratory should have little or no effect on the environment. Waterborne effluents will consist of sanitary wastes which will be discharged to an existing site sewage treatment facility which is adequately sized to accommodate the load. Airborne effluents will be limited to air exhausted as relief for code-required fresh air makeup and highly diluted fumes from chemistry operations.

Industrial Waste Collection System

Planned improvements of the industrial waste collection system will result in a much reduced possibility of contamination of the environment by radioactive wastes. Because of the need to keep the existing system in operation during the construction of the proposed system, the problem of contaminating the environment with flowing wastes will be concentrated in those periods when the old system is disconnected and the new is connected. The procedures used to prevent waste loss will include controlling waste discharge, flushing with clean water, and absorbing any liquid that may appear.

Tritium System Test Assembly

Modification of an existing building to house a new tritium system test assembly has been carefully designed to minimize release to the environment.[4-117] Included in the facility will be a tritium waste treatment system for the routine cleanup of tritium contaminated effluents prior to exhaust to the atmosphere and an emergency tritium cleanup system should there be a large accidental release. The emergency system will be interfaced with the ventilation system. In the event of a tritium release, the emergency system will be activated. Contaminated liquid waste will be collected in a tank for controlled disposal. Contaminated solid wastes will be packaged under controlled conditions and according to federal regulations prior to transport to an existing radioactive solid waste disposal area. Under normal operating conditions, small amounts of tritium gas and water vapor are expected to be released through the stack. The annual average individual radiation dose in Los Alamos County resulting from routine operation of this facility was calculated to be much less than the contribution from natural background radiation, and no member of the public would receive more than 1 mrem/y. A postulated worst-case accident requires a twin-engine aircraft, of the commercial type used between Albuquerque and Los Alamos to crash onto the roof. A detailed analysis of this accident is presented in Section 4.2.

New Detonator Facility

The facility is designated to prevent accidental or discharge disturbances to the environment. An accident involving high explosives (HE) would be completely contained except in three areas, in which blowout panels will be installed. These relief panels would be directed toward high earthen berms. Accidental leakage of acid-holding container would be retained in sunken concrete pits, large enough to contain a complete spill. Laundry water exposed to HE effluents will drain to a sump and seepage pit with accessible drain line. No other hazards are foreseen that will impact the environment or general public.

New Tritium Facility

Construction activities for the building addition will take place in the immediate vicinity of existing structures requiring very little clearing or site preparation. Construction of the fence-like rock fall barrier will require removal of some trees and some earth work for access. Land disturbed during construction will be suitably contoured and reseeded with native grasses to minimize erosion problems.

Approximately 100 Ci/year of tritium gas is expected to be released as a result of routine operations. While this release is at a new location, it will represent a substantial decrease in overall atmospheric tritium release from LASL. Tritium operations during the last two years at the present obsolete site have emitted 600 to 1600 Ci annually, representing 28 to 40% of the total from all LASL operations. The reduction in effluent from this operation will be achieved through multiple containment and an efficient tritium recovery system. The 100 Ci expected release is estimated to result in maximum doses to members of the general public of about 0.4 mrem/yr, or less than 0.5% of the normal background in the Los Alamos area. This estimate is based on the worst case assumption that the tritium is all released in the oxide form (i.e., tritiated water). The expectation is that most of the release will be as gas resulting in smaller doses by a factor of as much as 10^4.

Solid radioactive wastes from the new facility will be nearly the same as those generated by current operations. They are estimated to average about 2 m^3/yr of contaminated laboratory trash and equipment, and 2 to 4 double-contained cylinders with about 5000 Ci of tritium as HTO absorbed on each molecular sieve from the tritium recovery system. This represents a somewhat larger amount of tritium consigned to disposal as solid waste, a direct consequence of the reduced atmospheric emissions. These types and amounts of solid radioactive wastes are routinely handled and disposed of at the approved solid radioactive waste disposal area within the LASL boundary. Industrial liquid wastes such as potentially tritium contaminated mop water, will go to a holding tank for periodic pickup and transport to the central liquid waste treatment plant.

The new facility will be designed to minimize the potential of any environmental release of tritium under credible accident conditions. There will be three levels of containment: the tritium handling and processing system itself, glove boxes containing the system, and the process room.

Target Fabrication

Three types of operations at this facility require disposal or dispersal of potentially hazardous materials. These hazards have all been considered from the viewpoint of protecting both the building occupants and the surrounding environment including other people and nearby flora and fauna. These operations are: routine disposal of acid, caustic, and solvent liquids; routine removal and disposal of toxic or acid chemical vapors; and dispersal of accidental release of tritium (^3H) gas. Disposal of the liquid waste will be accommodated by a special drain line from the involved labs to the chemical waste treatment plant at TA-50. Chemical vapors will be removed from the labs by a fume hood system and vented to the atmosphere via a stack at a height to be determined by the LASL. The quantity of these vapors will be small and will be well dispersed at the site boundary. The tritium gas facility is a state-of-the-art zero release system with complete secondary containment and inter-container air scrubbing. This environmentally approved, dry-box tritium handling system has been developed and is now in use in an existing fabrication laboratory. A separate exhaust system will maintain a negative air pressure in the tritium-filling laboratories. A tall stack will be provided to assure adequate dispersal in the unlikely event of an accidental release. Only in the event of a catastrophic fire or explosion could an entire inventory of tritium gas be released and be converted to tritium oxide. The converted tritium oxide could result in a maximum 1.9 rem dose at the nearest population center, given atmospheric conditions which would disperse the entire cloud in that direction.

High Energy Gas Laser Facility

Construction is expected to be completed in 1984 for a 91,000 square foot facility which will house laser-induced thermonuclear experiments for the Antares Program. Multiple CO_2 gas laser beams will be focused on deuterium-tritium targets to initiate fusion reactions. Direct radiation (mostly neutrons) from the reactions will be shielded to limit maximum theoretical exposures to 20 mrem/year; however, since there is no continuous occupancy, expected exposures would be much less. Maximum possible releases of radioactivity from normal operations are expected to be less than 6 Ci or ^{41}Ar and 12 Ci of ^3H per year. Increments to population exposure in Los Alamos from these releases will be no more than a few hundredths of a percent above natural background. Potential accidents were analyzed in detail in a preliminary safety analysis report and found to present no significant hazards to the public or the environment. The overall effects were considered in a 1973 environmental assessment accompanying the proposal for funding facility construction.

Laboratory Support Complex

This facility is an office-cafeteria complex, which includes a large parking lot. No industrial wastes are involved, so environmental effects will be limited to the construction phase, except for minor additional storm water runoff due to the parking lot addition.

General Plant Projects

Other construction projects, which include further plant upgrading and improvements to the electric and water systems, will generally take place either within or in the vicinity of existing facilities. The environment affected thus will be limited to small land areas normally within developed sites and, when practical, undeveloped land disturbed by construction will be returned to its natural condition through seeding with native grasses. Operations to be conducted in the improved or new facilities should have little or no effect on the environment.

4.2 POTENTIAL IMPACT OF ACCIDENTS

LASL operates many facilities which use or generate materials that could produce environmental damage if released in an uncontrolled fashion. This list of facilities includes the new Plutonium Processing Facility, DP-Site, LAMPF, the Omega West Reactor (OWR), Critical Assembly Facility, Tritium Systems Test Assembly, and storage areas for high explosives, special nuclear materials, other radioactive materials, and other potentially hazardous chemicals. LASL has recognized from the beginning the potential problems of these facilities, and, in many cases, safety analysis reports were developed to assure a thorough review of all aspects of design and operations affecting safety.

A detailed review process in now underway of nonreactor nuclear facilities at LASL which will be documented by the preparation of formal Safety Assessment Documents for many of the facilities in technical areas in accordance with DOE regulations (Manual Chapter 0531). Standard Operating Procedures (SOPs) are prepared, updated as necessary, and reviewed annually for any facilities or operations which involve potentially significant hazards for workers, the public, or the environment. Approximately 1500 such SOPs are in effect.

There are four general levels of emergency response plans for the Laboratory. Each facility has an emergency plan for the facility that is available at the operations office responsible for the facility. A Laboratory site plan, General Radiologic Emergency Plan for LASL (March 30, 1973, revised April 13, 1979) is available through H-Division. The Emergency Plan for Major Events defines responsibilities for activating the Emergency Relocation Center and designates community involvement. For example, such events as the La Mesa fire would be coordinated through this plan, and it is a joint management responsibility through H-Division and DOE. The Area Wide Emergency Plan provide guidance for the determination of international situations and "Act of God" catastrophies and is under the guidance of the DOE Area Office. The latter two have community involvement through the Los Alamos Civil Defense.

During routine operations at Los Alamos there have been inadvertant releases of hazardous material. Safety procedures and methods of operation assure rapid response to these incidents. Constant monitoring by automatic equipment (e.g., continuous room air stack monitors, radiation level alarms, portal monitors) and a large staff of health physics technicians assure rapid detection of radiation or radioactivity in abnormal amounts or unexpected locations. Over the years, there have been some minor incidents where radioactivity was inadvertently removed by personnel to uncontrolled areas. These were promptly resolved and no noteworthy incidents requiring significant decontamination efforts have occurred in recent years. Some incidents involving inadvertent release of radioactive material to the environment have occurred. In cases where decontamination was undertaken, the resulting wastes were buried in areas already designated for radioactive wastes. There have been no known serious short- or long-term effects on the environment or the area's population from such releases. The events which occurred in the last three years are described briefly for perspective.

In July of 1974 an industrial sewer line leak was detected. An estimated 10^6 ℓ (.26 x 10^6 gal) of liquid waste contaminated with about 200 mCi of principally ^{238}Pu was leaked. Approximately 280 m^3 (366 yd^3) of soil was removed so that gross-alpha concentration of not more than 10 pCi/g remained. During the testing of the line replacement, an additional 2000-4000 ℓ (500-1000 gal) of liquid waste, (about 0.4 mCi of ^{238}Pu), overflowed into a storm drain discharging to Mortandad Canyon. The area was cleaned and contaminant removed until no measurable contaminant remained.[4-34, 4-126]

On August 27, 1975, an operational error at the waste treatment plant resulted in about 300 ℓ (793 gal) of liquid sludge foaming over and contaminating an area of approximately 500 m^2 (5380 ft^2). About 80 m^3 (104 yd^3) of contaminated material was removed for burial. Soil samples taken at 2-m (6.5 ft) intervals over the excavated area showed all remaining gross-alpha levels below 20 pCi/g.[4-35]

Tritium gas was inadvertently released to the environment from roof vents of the Cryogenic Building in July of 1976. About 2.27 g (.08 oz) of tritium gas, or 22,000 Ci of $^3H_2$ was released. Measurements made both upwind and downwind showed no significant exposures to the general public could have occurred. Likewise, collected vegetation samples and measurements on 92 potentially exposed laboratory personnel showed no measurable exposures. No decontamination operations were necessary because of the gaseous nature of the release.[4-36]

Another release of tritium gas, about 3.17 g (0.09 oz) or 30,600 Ci, occurred in October 1977 from the HP site. This release resulted in some observed atmospheric concentrations near the site of tritiated water vapor greater than normally measured, but not significantly different then background stations. All measurements were less than 0.15% of the uncontrolled area Concentration Guide. Because of the location of the release, meteorological conditions at the time, and bioassay samples from workers at the site, there was no apparent exposure received by either Laboratory personnel or the general public.[4-36A]

Accidental releases of chemicals over the past several years were Hg, HF, and PCB. Ten pounds of Hg spilled on asphalt at the Chemical Warehouse. Most of the mercury was picked up with a special vacuum cleaner and the residue stabilized with flowers of sulfur. During an accidental release of UF_6 at the Critical Experiment Facility, about 20 kg of HF was produced by hydrolysis. All of the uranium was recovered, but some of the HF escaped into the air. A truck backed into a transformer that used a PCB as a dielectric. The PCB dripped to a concrete pad. The transformer and the pad were removed and held in a containment area to prevent escape into the environment.

In all these inadvertent releases during routine operations, the response and decontamination procedures provided a thorough amelioration of the incident and left no lasting environmental or human hazard potential. Similar minor operational incidents will probably occur in the future, but are not expected to result in significant environmental consequences.

Such incidents are not considered major accidents in the context of this section.

The accidents discussed in this section have been selected on the basis of potential environmental impact or effect on members of the general public rather than effects on occupational workers or Laboratory facilities. A much larger number of accident scenarios was considered, but only those accidents with the greatest potential consequence to the environment or general public have been presented. For the purpose of this statement, those operations unique to Los Alamos received the greatest emphasis. As a result, the environmental consequences considered most significant were land contamination with radioactive or toxic materials and radiological dose commitments to members of the general public. Potential hazards common to any light-industrial complex such as those from fuel oil, natural gas, high-voltage electricity, acids, solvents, steam, projectiles, sanitary wastes, vehicular traffic, and many others with probable consequences limited to occupational employees have not been presented. A history of significant operational accidents, including several fatalities from high explosives accidents (last one in 1959) and criticality accidents (last one in 1958) has been summarized in a public document.[4-117A]

A list of general types of accidents which could occur at Los Alamos, such as fire and explosion, was the first step taken in development of the analyses in this section.

An evaluation was made of each accident type for each facility in which such an accident could occur, and from these considerations the most serious accident of a given type was selected. A detailed analysis was then developed for the consequences that would result to the general public or the environment. The accidents were postulated in terms of the materials that could be released were the accident to occur. No emphasis was placed on the specific mechanism which might initiate the accident. For example, the explosion or fire accidents conceivably could be initiated by human operator error, equipment failure, or a natural disaster such as earthquake. Accordingly, the reader must keep in mind previous discussions on seismic and geologic hazards (Section 3.1.1), hydrology (Section 3.1.2), meteorology (Section 3.1.3), and precautionary measures. It is also important to note that most of the accidents could be initiated by more than one cause.

Because a given type accident might be caused by various chains of events, it is not possible to assign a single quantitative probability to its occurrence. Thus, the basic assumption in assessing the potential consequences is that the accident has occurred whatever its low but nonzero probability. The analyses use quantitative estimates of environmental transport and dispersion to estimate the probable consequences of the accident once it has happened. The probabilities discussed in the accident analyses refer only to those associated with meteorological transport and not to overall likelihood of the accident and its consequences occurring.

Much of the information developed in existing safety reports has been used in assessing the possible consequences of accidents at LASL facilities. Extensive additional detail is contained in such reports, which have been referenced where appropriate, and is only summarized here. These reports tend to be highly conservative in the sense that they predict much more severe accidents than would actually be expected. In this way, an "upper bound" is established for purposes of designing and evaluating safety features and controls to mitigate the potential consequences. However, more realistic assumptions which do take some reasonable credit for such designed safety features necessarily result in lesser predicted consequences and are the ones presented here.

The approximate locations of the potential accidents discussed can be found on Figure 3.2.1-3.

4.2.1 Accident Meteorology

Atmospheric dispersion of contaminants has been discussed in some detail in Section 3.1.3. It was shown that average dispersion characteristics (direction, wind speed, stability) vary greatly from technical area to technical area within the LASL site boundary. Because of this variability it would be necessary to have specific meteorological data for each technical area in order to give a reasonable estimate of the most likely pattern of atmospheric dispersion. Such data are not available and for this report it has been necessary simply to presume "worst case" conditions based on the Gaussian plume model. This in effect selects from the set of possible conditions that condition which produces the highest concentration at the location being evaluated. It ignores the fact that this condition, although possible, may rarely or never occur. Figure 4.2.1-1 demonstrates this effect for one technical area for which data is available. The Gaussian plume worst case predicts concentrations 1.5 to 2 times greater than that expected to occur more than 5% of the time and 15 to 20 times greater than that expected to occur more than half the time. Even this presumes that the wind is blowing directly between the source point and the receptor point. Thus, it is seen that "worst case" model assumptions produce an extremely pessimistic estimate of radioactive or toxic material concentrations. Figure 4.2.1-1 shows the worst case model estimates for ground level releases and from elevated releases at 20 and 50 meters. For comparison, the 5% and 50% probable values for a ground level release based on actual meteorological data are also shown.

Each of the technical areas at Los Alamos can be broadly characterized as being located either on a mesa top or in a canyon. Atmospheric dispersion for canyon locations was discussed in Section 3.1.3. Worst case Gaussian model conditions as described above have been presumed for mesa top locations. One or the other of these two models, as appropriate, was used to analyze all but one of the accidents described in the following sections. The case involving an accidental explosion was based on actual experimental data from the Nevada Test Site.[4-118, 4-119, and 4-120] Because this data was available there was no need to hypothesize dispersal and aeolian transport mechanisms.

Maximum individual doses and cumulative population doses in the Los Alamos and White Rock areas were derived from the dispersion estimates described above coupled with population distribution information in relation to the site of each accident considered. Cumulative population doses for the region outside Los Alamos County extending to a circle of 80 km (50 mi) radius plus the Albuquerque Metropolitan area (which lies just beyond the circle) were derived by folding together population distribution information and normalized concentrations (χ/Q) based on the Gaussian plume model and yearly meteorological data to yield values at the 50 and 95 percentile levels. The 50 percentile value can be considered an annual mean, the 95 percentile value would be expected to be exceeded only 5 percent of the time. The computed products for the regional population doses used for all radioactive release accidents are:

Percentile	(χ/Q) (population) (man-sec/m^3)
50	2×10^{-3}
95	2×10^{-2}

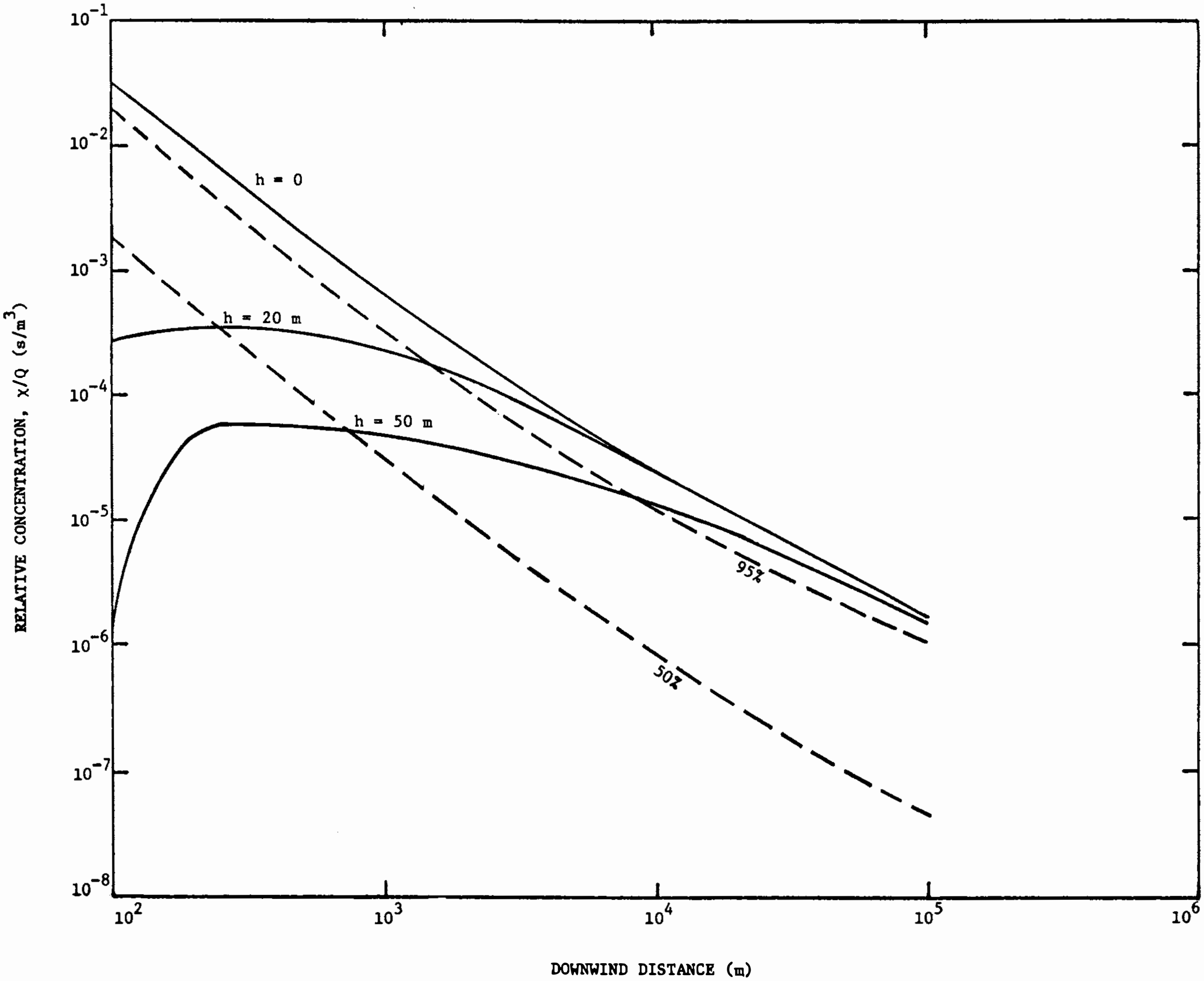


Figure 4.2.1-1

Atmospheric Dispersion from Generalized Mesa Top Release

Solid lines show worst case relative concentrations (χ/Q) for a wind speed of 1 m/s for 3 release heights (0, 20, and 50 m) above mesa top. For comparison, the dashed lines show values which will not be exceeded 95% and 50% of the time for ground level releases (h = 0).

No corrections have been made in these calculations for soil deposition or radioactive decay, both of which will lower the χ/Q values at large distances.

Maximum individual doses are discussed under each accident. They are summarized together with cumulative population doses in the final section (see Section 4.2.13).

4.2.2 Explosion

Natural gas is used extensively for heating and for experimental purposes. Although the potential for an explosion exists, the probability of an explosion occurring is no greater at LASL than at other comparable facilities. Loss of life and property damage from fire and explosion might occur in the immediate vicinity but the environmental impact of such an event at LASL would be no different than a gas explosion elsewhere.

LASL is unusual, however, in that high explosive (HE) and plutonium are handled in considerable quantities for prototype weapons development. The explosive potential of the HE and the contamination potential of the plutonium single out an explosion in the assembly building at the weapons development site as the worst possible explosion.

The operations in this building preclude a nuclear detonation. However, if a one-point detonation (detonation with no nuclear yield) of high explosives and subsequent spreading of plutonium were caused by an operational accident, the blast would probably result in major structural damage to the building but should not cause total destruction or collapse. Anyone inside the building would most likely be killed.

In the event of such a detonation, as much as about 300 Ci (alpha activity) of plutonium (mostly ^{239}Pu) could be released to the environment beyond the area of direct blast damage. To arrive at a reasonable estimate of the potential dose and contamination consequences from such a hypothetical accident, data from intentional tests of similar explosions conducted at the Nevada Test Site were utilized (Refs. 4-118, 4-119, 4-120). Modifications were made to account for quantities of high explosive and plutonium typical of LASL developmental assemblies and degree of containment. Wind velocities at the time of the Nevada tests were comparable to those frequently encountered at Los Alamos, but no allowances were claimed for additional turbulence which might result from topographic differences at Los Alamos. The maximum inhalation dose (50 year dose commitment based on the ICRP Task Group Lung Model[4-67]) of 32 rem to the lung or 39 rem to the bone would occur at about 400 m (1300 ft) downwind, and would be within the LASL boundary regardless of direction. Maximum doses at the nearest boundary, about 600 m (2000 ft) south at State Road 4, would be about 21 rem to the lung or 26 rem to the bone. Maximum doses at the nearest residence, about 6 km (4 mi) north, would be about 0.28 rem to the lung or about 0.34 rem to the bone.

The deposition of plutonium following the accidental dispersal would result in contamination of soil downwind of the location. The U.S. EPA has proposed a guidance regarding exposure to transuranium elements (including plutonium) in the environment, which is expressed as a dose rate to lung or bone tissue. As a means of implementing the proposed guidance, EPA has suggested a soil contamination screening level of 0.2 Ci/m^2 (in the top 1 cm and for soil particles less than 2 mm) so that areas not exceeding the level would generally be considered in compliance with the guidance recommendations. Areas exceeding the screening level would require more intensive evaluation to determine actual dose rates to exposed persons.[4-121] Data from the intentional Nevada tests were utilized to estimate the land area potentially involved. The estimated total land area contaminated to levels greater than 0.2 Ci/m^2 would be about 7.2 km^2 (2.8 mi^2 or about 1800 acres). Maximum contamination levels of about 50 Ci/m^2 would occur at a distance of about 1500 m (0.9 mi) downwind. Should contamination occur, various control measures, including necessary cleanup, would be taken to minimize potential continuing radiation exposures and residual contamination in accord with the DOE principal of as low as practicable and, assuming it is formally issued, the EPA guidance. Costs for cleanup could vary greatly, depending on the type of land contaminated and the methods chosen. An estimate of the range of such costs made by EPA extends from about $500/acre to $500,000/acre.[4-121A]

The seriousness of such a potential accident to individuals in the immediate area of this assembly building requires a continuing, rigorous, safety program to assure that the possibility of such an event is as low as possible. Army regulations[4-122] are strictly followed in all operations involving high explosives.

Accidents involving only high explosives (no associated radioactive materials) have occurred. As a result of a 1962 accidental death and the injury of several other young children, old explosive areas were thoroughly searched by volunteers and Army demolition experts to assure no loose, unexploded shells that could be scavenged remained from the Manhattan Project and military use era. Care for such hazards continues. Areas of known former potential within Lab boundaries are fenced. Under the direction and control of the local DOE, an explosive ordnance disposal team from Ft. Bliss searches the areas annually. Three additional areas, Bayo Canyon, East Jemez Road, and Lower Pajarito Road, are surveyed by the Lab every two years for possible weathering and thus exposure of potentially explosive material.

4.2.3 Criticality

A variety of operations involving plutonium are carried out in the new Plutonium Processing Facility. These operations include recycle, metal production, metal fabrication, and research and development. A detailed review of potential accidents was started during facility design in the early 1970's and was formally documented in a Final Safety Analysis Report prior to startup of operations.[4-123] Nuclear criticality is one of the risks that is recognized in any facility processing significant quantities of fissionable material. Each process planned for the new Plutonium Processing Facility has been studied, and credible mechanisms for the development of a critical configuration have been eliminated. It is, however, recognized that if a process gets out of control and if no appropriate response is made by the people involved, there would exist a finite probability of a criticality accident. Since no credible accident initiation mechanism is recognized, it is unrealistic to attempt a detailed evaluation of the accident consequences. Experience has shown, however, that accidents can occur much more readily in solution processing areas and that peak powers associated with solution accidents would not be expected to rupture tanks or otherwise damage process equipment. Such an accident may be expected to be of significant consequence only inside the building, with an energy release corresponding to 10^{17} or 10^{18} fissions and a lethal radius of ten to thirty feet. Some gaseous fission products would find their way through the ventilation system and out the stack. The quantities of several fission gases formed during an excursion involving 5×10^{17} fissions are given in Table

4.2.3-1. Much of the iodine would be expected to remain in the accident area, but, in the absence of any data and in the interest of examining the magnitude of possible exposure, it will be assumed that one-half of the iodine and all of the noble gases are released. Particulate material, including plutonium, would be trapped by the ventilation system. The nearest point of public access is Pajarito road, 150 m (500 ft) away. Using a release point 15 m (50 ft) above grade, the relative concentration (/Q) at a distance of 150 m (500 ft) is 5×10^{-4} s/m^3 as interpolated from Figure 4.2.1-1. Assuming that 50% of the iodine formed is released, the calculated thyroid dose commitment is 0.5 rem. The exposure from the noble gases would be small in comparison. Direct radiation doses would be high in the immediate area of the criticality accident inside the building; however, since the process is surrounded by concrete walls and ceiling at least 36 cm (14 in) thick and is located away from points of public access, exposures to the general public would be very small.

Another facility which could conceivably experience a criticality accident is the Critical Experiments Facility. The safety analysis of the Critical Experiments Facility areas was recently updated.[4-124] Unlike a reactor, these critical assemblies do not have large inventories of fission products because the total number of fissions in each experiment is limited to a comparatively small number (10^{19} fissions total or a pulse operation of 10^{18} fissions).

One credible accident at the Critical Experiments Facility would be an unintentional burst on the order of 5×10^{17} fissions from a bare enriched-uranium assembly such as Godiva IV. Assuming some melting of the metal, the release of mixed fission products after ten minutes might be as high as 0.5 Ci. Under these conditions, a person driving by on Pajarito Road would receive less than 1 mrem thyroid dose commitment. (Because the radionuclides involved have a short half-life, the total dose commitment is received in a short time; e.g., a few weeks for iodine. All doses have been integrated to give total dose commitment.) The corresponding whole body dose to a person located 180 m (600 ft) from the kiva would be less than 0.1 mrem. The estimated direct radiation dose at this distance would be less than 100 mrem to a person present at the instant of the burst.

4.2.4 Transportation at LASL

In general the probability of a serious transportation accident and the consequences of such accidents are no different at LASL than elsewhere. There are no biological materials of greater risk than Class II at LASL, the most significant nonradioactive toxic chemical is beryllium, and the shipment of all radioactive materials follows DOE requirements. The potentially serious transportation accident at LASL considered in the draft Environmental Impact Statement could no longer happen in the way or at the location described because of changes in procedures and the vehicles (SSTs) now used to transport shipments including both high explosives and radioactive materials outside LASL boundaries. Any transport of radioactive materials in combination with high explosives within the LASL boundaries occurs in the same general area described in Section 4.2.2 and the potential worst case accidents would have estimated maximum consequences of about the same magnitude.

The more general issue of transport of radioactive materials, both on and off site, associated with LASL operations is considered in a new section, 4.2.14. Effects and risks of both accidents and normal (non-accident) transportation are included.

4.2.5 Accidental Spill

The industrial waste treatment facility described in Section 3.3.3.1 has associated with its process two influent waste storage tanks, two effluent waste storage tanks, a sludge storage tank, and a pump house. The tanks are constructed of reinforced concrete with a wall thickness of 30 cm (1 ft).

TABLE 4.2.3-1

RADIOACTIVE FISSION GASES FORMED IN A CRITICALITY EVENT

(5×10^{17} Fissions)

Isotope	Quantity (curies)
^{131}I	0.505
^{133}I	6.70
^{135}I	22.5
^{133}Xe	1.41
^{135}Xe	20.90

The structure looks like a concrete box with interior partitions of 30 cm (1 ft) dividing it into the six compartments that form the tanks themselves. The rupture of these storage tanks and release of their contents to the environment is considered to be the worst possible spill at the LASL. This spill has been postulated not because of its likelihood, but because it involves the largest single volume of waste. All other isolated sources of radioactive or otherwise toxic materials at the LASL are much smaller in volume, thus containment of these wastes in the event of an accident would be much easier. The two influent waste storage tanks have a combined capacity of 3.8×10^5 ℓ (100,000 gal). Under normal conditions, they could contain 3×10^5 ℓ (80,000 gal) of waste. The expected concentration of radioactive materials in the waste would be 0.45 μCi/ℓ ^{238}Pu and 0.05 μCi/ℓ ^{239}Pu. Much smaller concentrations of other contaminants would be present.

The sludge holding tank would typically contain 9.5×10^4 ℓ (12,000 gal) of $Fe(OH)_3$ sludge with an 8% solids concentration and radioactive material concentrations of 5 to 10 μCi/ℓ ^{238}Pu, 0.5 to 1 μCi/ℓ ^{239}Pu and, as in the influent holding tanks, smaller concentrations of other contaminants.

The 30 cm (1 ft) reinforced concrete walls of the storage tanks virtually eliminate all accidents except an earthquake with a Richter magnitude greater than 7. The likelihood of an earthquake is discussed in Section 3.1.1. More assurance is added in that three sides of each of the tanks are underground and the fourth side adjoins an underground pump house at a lower elevation with a capacity of 1.2×10^5 ℓ (31,500 gal).

Because of the underground capacity of the tanks, it is reasonable to assume that in the event of wall failure, the pump house would retain 1.2×10^5 ℓ (31,500 gal) of waste, the influent waste holding tanks would retain 1.9×10^5 ℓ (50,000 gal) of waste, and the sludge holding tank would retain 1.5×10^4 ℓ (4,000 gal) of waste. These volumes would be totally underground and would be retained for several days allowing for containment measures such as the construction of an earthen dam. For the purpose of this statement, the two 9.5×10^5 ℓ (25,000 gal) treated waste storage tanks have been assumed to be empty. This would be a typical situation at a time when the influent tanks contained 3.0×10^5 ℓ (80,000 gal) of waste. If there were any water in the treated waste holding tanks, it would mean that an equal volume from the influent waste holding tanks had been transferred and treated. The combined underground storage of the two treated effluent tanks, used to store treated waste until proper treatment can be verified, is 9.5×10^4 ℓ (25,000 gal). This volume would also be retained underground in the event of tank wall failure.

In summary, the total underground capacity of the influent storage tanks, the sludge holding tanks, the pump house, and the effluent holding tanks is 4.2×10^5 ℓ (110,000 gal) and the total waste would be expected to be 3.0×10^5 ℓ (80,000 gal) of liquid waste and 4.5×10^4 ℓ (12,000 gal) of sludge, or 3.5×10^5 ℓ(92,000 gal) total. Therefore, there is reasonable assurance that no waste would be released to the environment, except for some seeping underground from the storage tanks.

Following such a hypothesized accident, emergency measures would have to be undertaken almost immediately to effect treatment of routine wastes until the incapacitated tanks were once again in use.

Two conditions can be assumed. Either the treatment plant survived the incident or it did not. If the treatment plant which is located 30 m (100 ft) from the storage tanks survived the accident, the plumbing could be modified immediately to operate the plant without the usual flexibility afforded by the storage tanks and the pump house. The treatment would nonetheless still be effective.

If the treatment plant were inoperable, immediate steps would be required to reduce the waste volume. Operations throughout the LASL would be curtailed by notifying operating groups to eliminate or reduce effluents to a minimum. By curtailing waste-producing operations and using emergency storage capacities at the various LASL sites, little, if any, untreated waste would be released to the environment.

The distance the waste would flow down Mortandad Canyon would be much less than the 0.2 km (0.3 mi) traveled by routine treated effluents from the plant. These effluents are released at a rate of 160 ℓ (600 gal) per minute. Since natural runoff in this canyon has not reached the LASL boundary since 1960, it is extremely unlikely that any of the waste would cross the LASL boundary before cleanup operations could begin.[4-125]

The problems involved with cleanup operations following such an incident can be anticipated. Cleanup operations following two accidental spills of similar wastes from line leaks that occurred in 1974[4-126] provide assurance that the area can be restored for uncontrolled public release without significant radiation exposure to the public or the workers. The cleanup operation would, however, create large quantities of low-level contaminated wastes that would require controlled disposal. Documentation of previous cleanup operations gave no indication that the public or the working personnel received any exposure due to the leaks. Air samples were taken continuously at both sites until the cleanup operations were completed and no positive alpha radioactivity was detected. A total of 155 nose swipes were taken in conjunction with these operations; all were negative for alpha contamination. A total of 650 m^3 of soil was removed in 155 truckloads in this operation. Surface contamination in the areas cleaned is now at or below ambient alpha levels. The total cost of cleanup was about $50,000 for each operation.

4.2.6 Fire

In postulating the worst fire that might occur at the LASL, no emphasis was placed on the dollar value of the building, although replacement would certainly have an effect on the environment. Instead, the postulated fire was selected on the basis of causing the most direct environmental impact, such as the release of contaminants (either radioactive or nonradioactive).

Because many of LASL's activities involve radiochemicals, and particularly plutonium, the release of plutonium by a fire was evaluated first. The new plutonium facility was designed and built for the highest degree of containment even in the case of a maximum credible plutonium fire. The redundant and fire protected HEPA filtration system would not release any plutonium significantly above average normal operating levels, even in the event of such a fire.[4-123, 4-131]

The greatest environmental consequences from an accidental release of radioactive materials involving a fire are described later in connection with a postulated aircraft accident (Section 4.2.11). The release of toxic materials in a fire is considered in Section 4.2.10. From an overall perspective, the maximum environmental effects from an accident involving fire would result from the loss of life and property in a forest fire (see Section 4.1.4).

4.2.7 Mixed Fission Product Release

The most likely area for a significant accidental release of mixed fission products is Omega Site, which is the location of an 8 MW experimental research reactor. Accidents that may have some potential for the release of fission products are: (1) reactivity accidents; (2) equipment failures; (3) natural disasters; (4) loss of coolant flow; and (5) loss of coolant.[4-132]

Several experimental programs conducted in the early sixties supplied considerable data on the nature and characteristics of reactivity-caused excursions in aluminum-core reactors.[4-133, 4-134, and 4-135] Some of these were destructive tests which provided direct data on the fractional release of fission products to the atmosphere. For the Omega West Reactor (OWR) there are no known or believable mechanisms which cause reactivity insertion rates greater than one tenth of that needed to produce a significant fission product release. Possible reactivity accidents would involve control rod breakage, control rod withdrawal, startup, servo control failure, or core loadings. Of these, melting would occur only in the case of the core loading accident. If a fuel element were deliberately dropped in the just-critical core, this event might be expected to result in melting approximately 2% of the fuel surfaces.[4-135]

Since the OWR is a low pressure, low temperature research reactor, it is not subject to damage from many abnormal conditions problematic in power reactors. These causes, usually related to equipment or component failures, include accidents such as the introduction of cold coolant slugs, system depressurization, loss of load, and step increases in load. As a specific example, since natural convective circulation of the pool water is sufficient to cool the reactor, complete loss of electrical power at the OWR will result only in a reactor shutdown with no other complications.

It is possible that the reactor cooling system and other components outside the reactor tank might be ruptured or otherwise damaged by tornadoes, earthquakes, floods, or other natural disasters. The massive concrete and steel shield and foundation structure around the reactor tank, damage to the tank from such events is most unlikely. Breaks or ruptures in the external coolant pipes will not drain the reactor tank to a level that would expose the core.[4-132]

Loss of coolant flow does not present any problems, because of the relatively low power level of the OWR and the automatic convective loop provided.[4-132] Even if the convective loop were not provided, the numerous other openings between the upper tank and the plenum underneath the core (such as holes underneath the lead shield and beryllium reflector, the control rod slots, and the instrument port clearance holes) would provide an adequate convective return path. This is confirmed by the fact that 4,920 ℓ/min (1300 gal/min) of the total 13,250 ℓ/min (3500 gal/min) normal coolant flow go through these openings.

The argument can be made, with respect to a loss-of-coolant accident, that because of the relatively low power level and the engineered safety features provided, the probability of even partial fuel melting is vanishingly small. Further, it can be shown that fuel melting is possible only if the tank is drained below the level of the core less than 30 minutes after reactor shutdown. If the time-to-drain is longer than 30 minutes, no melting will occur.[4-132]

A worst condition is envisioned as the case where the tank is drained within six minutes after shutdown. Calculations indicate that melting temperatures would not be reached until approximately 34 minutes later. If it is assumed that none of the engineered safety features are effective and that the operating crew takes no action in the 40 minutes before melting could begin, then some 8% of the fuel plates could be melted.

The short duration of the critical period and the low probability of draining the tank within that period, together with the availability of two independent and redundant spray systems to afford protection against core melting during the critical period following shutdown, make core melting following loss of coolant not credible. Because it is not considered to be credible, this accident will not be analyzed further, even though the releases could be greater than the releases from the maximum credible accident.

The melting of fuel as a result of flow blockage in one or more fuel elements is considered to have the highest probability of occurrence for the types of accidents possible. Accidents of this ature have occurred in at least three reactors of the same general type as the OWR.[4-135, 4-136, and 4-138] The flow blockage accident is taken to be the maximum credible accident for the Omega West Reactor because the potential release of fission products is greater than for any other accident considered credible. Although the vigorous boiling accompanying flow blockage produces detectable fluctuations in instrument readings, experience has shown that there is often considerable confusion and doubt in the interpretation of the indications so that corrective action is too long delayed and appreciable fuel melting could occur. Other protective measures as mentioned later are designed to counteract this anomaly.

During operation, the OWR is a closed system except for the surge tank vent normally open to the atmosphere. A solenoid valve is provided to switch this vent to the exhaust stack if activity is released into the water from any source. The exhaust stack has charcoal adsorbers and is 46 m (150 ft) above the mesa top south of the reactor site. This valve can be actuated from the control console by the operator. If the surge tank vent valve sticks in the open position, or if the operator fails to switch it, then the rare gases and some fraction of the iodines would escape to the atmosphere within the canyon.

Other mechanisms for the escape of fission products from the system could include, under some conditions: (1) over-and-under-pressure relief valves located on top of the surge tank; these are gravity- or spring-actuated caps that could easily be blocked open by debris; (2) the untimely opening of the hatches on tank top by the operating crew; (3) a simultaneous break in the cooling system; and (4) the inadvertent operation of system valves in such a way as to expel or release a large quantity of cooling water from an otherwise closed system.

Given one of these circumstances, the possibility exists for a large release of fission products, particularly iodines. Up to 100% of the xenons and kryptons might escape from the system over an extended period. If the surge tank was open to the atmosphere through the vent or pressure-relief valves, the tank's degasifying action could allow the complete escape of the gaseous products as water circulation was continued to allow cleanup by the deionizers. Estimation of the release of iodines to the atmosphere is difficult. For suppression-containment systems analyses, an escape fraction of 0.5% has sometimes been used for the escape of iodine from the pool.[4-139] It is reasonable to assume that a maximum of 10% of the iodines might escape from the water over a period of time, with the other 90% remaining in the water to be removed by the deionizers.

Summarizing the conditions for the maximum credible accident as postulated[4-132] the accident conditions are: (1) seven fuel elements suffer some degree of melting from flow blockage; (2) an average of 50% of the fuel in each of these elements melts; (3) the seven elements involved contain 24% of the total core fission product inventory; thus, the melt contains a maximum of 12% of the core inventory; (4) a 50% release of radioiodines and a 100% release of the rare gases contained in the melt is assumed; (5) six percent of the radioiodines in the core inventory and 12% of the rare gases are released into the water; (6) all of the xenons and kryptons in the water (12% of the core inventory) are released to the atmosphere over a period of time; and (7) ten percent of the radioiodines dissolved in water, or 0.6% of the core iodine inventory, is released to the atmosphere over a period of time.

Table 4.2.7-1 gives the total core fission product inventory. This inventory, combined with the above postulated accident conditions, yields the following atmospheric release for the maximum credible accident: (1) 8.22×10^2 Ci of ^{131}I, (2) 1.09×10^4 of Ci of other iodines, (3) 1.68×10^2 Ci of ^{131}Xe, and (4) 1.53×10^5 Ci of other rare gases.

Three distinct meteorological conditions can exist to transport the release (see Section 3.1.3). A down-canyon wind occurs from about two hours after sunset until sunrise. The wind is a shallow, low turbulence wind (Pasquill Type F) with a mean velocity of approximately 0.5 m/s (1 mph). An up-canyon flow occurs less frequently; locally driven circulation gives way to gradient flow influence as soon as vertical mixing is sufficient to result in coupling. This flow (Pasquill Type E) occurs from approximately two hours after sunrise throughout the day and has a mean velocity of 1 m/s (2.2 mph). A cross-canyon flow is common during about 25-35% of the daytime hours (Pasquill Type A and C). It is complicated by terrain interaction and has the highest mean velocity of all, 3 m/s (6.7 mph).

Three public areas could be affected by a release: (1) a residential area to the north (cross-canyon flow); (2) an ice skating rink to the west (up-canyon flow); and (3) State Road 4 to the east (down-canyon flow). Table 4.2.7-2 shows the thyroid and whole-body total integrated dose commitments for the specific locations and meteorological conditions mentioned above.

A considerable degree of conservatism is contained in the above results because no deposition or radioactive decay is assumed during the release period or during the cloud travel or passage. Therefore, the doses correspond to the infinite time dose, or that received by an individual exposed for the entire time of release and cloud passage.

The OWR has several features designed specifically to prevent melting. An antisiphon loop is designed to prevent the drainage or siphoning of the reactor tank water level to less than 115 cm (49 in) above the core as a result of leaks or ruptures in the cooling lines external to the shielding.

An automatic convective cooling loop is designed to allow reactor operation at low power levels without forced flow and to provide for the removal of core after-heat when cooling flow is lost by pump failure.

An emergency core spray system will deliver water at a rate of 3.8 to 6.8 ℓ/s (60 to 100 gpm), which is at least an order of magnitude greater than that estimated to be required to prevent core meltdown.

For an extra measure of protection, another emergency core spray system has been designed and installed. It has a source of pure reactor system water and will maintain a flow rate of 1.2 ℓ/s (18 gpm) for approximately 23.5 hours. These engineered safety features include a number of alarms and warnings to alert the operating crew.

4.2.8 Tritium Release

Several Los Alamos Technical Areas were examined for the possibility of tritium release. Two locations where large amounts of tritium are or will be handled are HP site and the new Tritium System Test Assembly at DP Site. It is difficult to postulate a mechanism not involving a major external force by which the entire inventory could be released at once. At HP-site the greatest release considered possible produced a maximum dose at the site boundary (State Road 4) of 0.6 rem. Because tritium is involved in the airplane crash accident analyzed in Section 4.2.11 for DP-site, no further discussion of tritium release is presented in this section.

TABLE 4.2.7-1

TOTAL CORE-FISSION-PRODUCT INVENTORY

Radioisotope	Core Inventory[a] (Ci)
^{131}I	1.37×10^5
^{132}I	3.04×10^5
^{133}I	4.51×10^5
^{134}I	5.16×10^5
^{135}I	4.19×10^5
^{131}Xe	1.4×10^3
^{133}Xe (2.3d)	9.2×10^3
^{133}Xe (5.3d)	3.39×10^5
^{135}Xe (15.6m)	1.22×10^5
^{135}Xe (9.13h)	4.02×10^5
^{83}Kr	9.35×10^4
^{87}Kr	5.23×10^4
^{88}Kr	2.64×10^5
Mixed Solids	1.15×10^7

a) Values for each isotope are adjusted to account for a 5-day operating week and for the fuel-addition cycle.

TABLE 4.2.7-2

DOSES EXPECTED FROM POSTULATED RELEASE OF MIXED FISSION PRODUCTS AT OMEGA SITE[a]

Location	Wind Direction	Distance (km)	Distance (mi)	Thyroid (rem)	Whole Body (rem)
Residential Areas	Cross Canyon	0.6	0.4	26	9.8
Skating Rink	Up Canyon	3.0	1.9	16	6.1
State Road 4	Down Canyon	6.5	4.0	57	22.0

a) Total integrated doses are given because of the short half-lives of the radionuclides involved.

4.2.9 Releases of Potentially Hazardous Biological Material

Biological materials are classified by their potential hazard. Class 1 agents are agents of no or minimal hazard under ordinary conditions of handling. These agents may be distributed to all users with no special competence or containment required. Class 2 agents are agents of ordinary potential hazard. This class includes agents that may produce disease of varying degrees of severity from accidental innoculation or injection or other means of cutaneous penetration but which are contained by ordinary laboratory techniques. They may be distributed to laboratories whose staffs have levels of competency equal to or greater than one would expect in a college department of microbiology.

There are currently no programs at LASL employing biological agents of greater risk than Class 2. It should be mentioned, also, that LASL operates an extensive animal colony in connection with its biomedical programs. There is the inherent possiblity of Class 2 or greater organisms being present in intact animals. All animal colony operations are administered by one group, which maintains a strict disease surveillance program including quarantine, viral screening, bacteriological testing, pathological examination, and other routine diagnostic procedures. Because many of the LASL Health Division activities use intact animals and some are centered around agricultural bioscience studies, a LASL Biohazards Committee was formed in 1973 to provide a formal mechanism for review of any experiments involving infectious agents or other potentially hazardous biological material.

This committee also published the LASL Biohazards Manual[4-140] which describes Laboratory practices and policies for handling these materials.

Until such time that biological materials of greater risk than Class 2 are handled (unforeseen in the near future) there is no threat of a release of hazardous biological material to the environment.

4.2.10 Release of Nonradioactive Toxic Chemicals

In considering potential hazards from nonradioactive toxic chemicals, three LASL facilities were examined; the Chemical Storage Facility, the Gas Plant and the Beryllium Shop. Release of chemicals such as chlorine from the first two facilities was not found to have consequences as great as those from a fire in the Beryllium Shop.

The Beryllium Shop located in the Main Shop Building (SM-39) contains large quantities of the highly toxic metal beryllium. If the oxide or other compounds of the metal are inhaled, they are capable of causing either an acute chemical pneumonia or a severely debilitating lung disease that can be fatal. For the protection of employees, the AEC in 1950 established a permissible exposure rate limit of 2 $\mu g/m^3$ for a maximum short time limit, usually interpreted as 30 minutes. They also set a limit of 0.01 $\mu g/m^3$, averaged over 30 days, as a permissible level of exposure to the offsite members of the general public. This value is the same as the New Mexico EIA Ambient Standards approved by EPA.[4-43] Most of the beryllium in the Beryllium Shop is in bulk form, which can only be ignited at very high temperatures and is adequately protected by the sprinkler system. Explosions in the beryllium shop are highly improbable from Be or other sources of materials. Explosions from Be operations have not occurred. Finely divided metal is produced by the machining, grinding, and polishing operations in the shop and is collected by the ventilation and air cleaning system. Because Sim-cool or water is used most of the time as a coolant, the probability of a fine metal particle fire is very low. No beryllium fire has ever occurred in SM-39. A stack sampler is operated continuously during any time the ventilation system is in operation. The sample is analyzed for Be monthly and, to date, the actual concentration of Be in the effluent air has been less than 0.01 $\mu g/m^3$. The larger metal chips are collected in the dynamic precipitator and deposited downstream on a bag filter, which prevents their escape to the environment. The filter bags are made of cotten with a maximum operating temperature of 250^{O}F with particulate efficiency of between 92 and 96%.

The accident postulated is a fire in the finely divided metal collected on the filter surface. The maximum amount of material found on the filter before it is cleaned is about 5 kg, only part of which is beryllium in a combustible form. It is assumed in this analysis that a fire can be sustained on the surface for one hour resulting in the formation of finely divided beryllium oxide containing 5 kg of beryllium and that this material is released into the air stream and then to the environment at an essentially constant rate. The source term, then, is an emission rate of 1.4 g/s.

Meteorological conditions are such that about 12% of the time the wind direction is toward the western area of the community. Assuming a 20 m release height and "worst case" conditions the relative concentration (χ/Q) at 1 km is 2.5×10^{-4} as seen from Figure 4.2.1-1. The 50% probable χ/Q at this distance is 3×10^{-5}. The worst case condition would produce a concentration of 350 $\mu g/m^3$. However, considering measured meteorological conditions at this site, there is about one chance in eight that the ground level air concentration in this area of the community could reach 40 $\mu g/m^3$. This is about twice the permissible short term occupational exposure limit. No specific limit exists for short term public exposure, but a factor of 10 to 50 below the occupational limit would not be unreasonable. Considerably higher exposures could be sustained by employees in the main technical area, including the Administration Building.

A set of very unfavorable and unlikely conditions have been assumed in this postulated accident analysis. It is difficult to see how a fire could start on the filter, which is downstream of the dynamic precipitator. The dust collected on the filter probably would not sustain steady combustion since it contains oxides and other inert material. A fire, when the fans were not operating, would extinguish itself because of lack of oxygen, and beryllium would not transfer to the air stream. If the filter burned through, most of the air would go through the opening created and not past the remaining filter deposit. As a result, a considerable fraction of the deposit would remain within the filter housing. The escape of 25% of the deposit seems a more reasonable assumption.

It is highly unlikely that a filter fire in the most heavily populated area of the Laboratory would go undetected for an hour during working hours. Nevertheless, heat or smoke detection devices do trip an alarm at a continuously occupied control point and results in control of the fire in a matter of minutes with little release to the atmosphere. In order to transfer beryllium oxide from the filter to the environment, it was assumed the exhaust ventilation fan continued to operate. A serious fire would probably render the fan inoperable and would also set off the sprinkler system in the fan room and ring an alarm.

The meteorological factors are conservative in that a very light northerly wind (1 m/s) was assumed, combined with the most stable conditions possible in daylight hours. Taking this and the maximized accident conditions into account, the actual air concentration in the offsite populated area is probably less than 10% of that calculated above. However, it is still possible for severe lung distress to result among members of the population or among those employed in the Main Technical Area who are susceptible to heavy metals allergy.

The chemical storage facility was considered for inclusion as a source of a nonradioactive toxic chemical release because it represents the maximum accumulations of most chemicals in the technical areas. A chemical storage facility is located on the western edge of the South Mesa technical area. The facility receives, stores, and dispenses various chemicals. The quantities stored at any other site are too small to present an environmental impact if accidentally released. Because of containment provided by the structure design, fire/temperature control, and isolated location, it is unlikely that the total chemical inventory would be involved in any accident that would release toxic or hazardous chemicals to the environment (see Section 3.3.4 for precautionary procedures).

Other facilities were considered, but each has a very low probability of releasing sufficient chemicals which are harmful to the environment. Those facilities include explosive storage areas that, if the explosive burned incompletely, would produce oxides of nitrogen. However, the isolation and limitation of quantity stored precludes any significant release of gases. The central gas storage facility has only small volumes of toxic or hazardous gases with the remaining quantity being primarily those gases common to the environment. A quantity of carbon monoxide is involved in the ICON facility; however, the release of all CO would involve only the immediate area and, in the event of fire, only CO_2 would be released.

4.2.11 Aircraft Accident

The Los Alamos Airport has a single east-west runway. Because of local conditions, all traffic enters from and leaves to the east. The west end of the strip is used only for runups or taxiing. Some small aircraft are excluded because of the altitude, 2180 m (7150 ft). Scheduled flights currently account for six landings and takeoffs each on weekdays and two landings and takeoffs on Sunday. Private plane landings and takeoffs average a total of 27 per day. There is little air traffic at Los Alamos because of the location of the field, the necessity for traffic to both enter from and leave to the east, and the need for advance permission to land. The accident record of the Los Alamos Airport has been quite good with an average of less than one accident per year since the airport began operation in 1946. (See Section 3.2.6 for previous discussion of the airport.)

The LASL installation nearest to the Los Alamos Airport is DP-Site. DP-Site lies 1 km (0.6 mi) due south of the middle of the runway across a deep arroyo. The local air traffic pattern avoids DP-Site since it is located in Restricted Air Space that is clearly indicated on all air charts.

A majority of aircraft accidents in the vicinity of landing strips occur through collisions in the traffic pattern, engine failure on takeoff, or undershooting the runway. Since the traffic avoids DP, any wreckage from such an accident is not likely to fall near DP.

Considering the above factors, the probability of an aircraft accident involving DP-Site is quite low. However, an aborted landing or takeoff attempt has a high degree of probability. An aircraft accident involving a LASL facility that may result in a major environmental incident is hypothesized to be the crash of an airplane into the proposed tritium system test assembly facility at DP-Site, rupturing distillation columns and/or transfer lines followed by the combustion of the aircraft fuel.

Other facilities at DP-site would not present as severe consequences in the event of an airplane crash. Plutonium operations currently conducted at DP-site West will soon move to the New Plutonium Facility. The only Pu remaining in the vault will be encapsulated Pu, such as Pu-Be sources. The vault is constructed of 20 cm (8 in) reinforced concrete which reduces the chances of an airplane crash generating a major hazard from that source.

Anticipated operations at the new Tritium System Test Assembly DP-site (east) may have as much as 200 g of tritium in inventory. In these operations, the tritium loop and the tritium storage containers will be confined to the experimental building. Approximately 50 g will be kept in reserve storage in a glovebox. The remaining ~150 g will normally be in various components of the tritium loop, with the largest amount in the distillation columns (~125 g). Except for one component which will be operated at negative pressure ($<10^{-3}$ torr), secondary containment will be incorporated in all components and interconnecting lines of the tritium loop.

In case of the highly unlikely double failure of any of the primary and secondary containments, coupled with failure of the tritium cleanup systems, decagram quantities of tritium gas could escape from the building. Should such a release be accompanied by fire, all or part of the gas could be converted to the oxide. The result would be significantly higher doses or potential doses than would result from a release of an equal quantity of tritium gas. A release of tritium into the building in elemental or oxide form would normally be contained by the Emergency Cleanup System. Failure of this system, which is connected to emergency power along with the ventilation system, is extremely unlikely to occur simultaneously with a release of a significant fraction of the tritium inventory, especially in an oxidized form. (In that event, it would be contained by the building.) An external cause may render the situation plausible, such as the crash of an aircraft through the composite roof of the building.

Penetration of a light aircraft through the steel-beam-supported roof is not considered plausible. A heavier twin-engine aircraft, of the type in commercial use between Albuquerque and Los Alamos, would have a higher probability of at least partial penetration. In the following scenario, such an accident is the postulated cause of a release of a major fraction of the total tritium inventory.

The postulated crash of the aircraft onto the roof tears the engines from their mounts, and one of them strikes the vacuum jacket housing the three tritium distillation columns. One-hundred grams of tritium are released and oxidized by the ensuing fire of some 800 liters (200 gal) of aviation fuel released during the impact.

The heat from the fire, lasting 10-20 min, causes the oxidized tritium to be carried upward, through the roof, to a maximum height of 30 m from ground level, providing the winds are relatively light (a few meters per second or less). The effective release height will be lower for higher winds, which will counteract with additional dilution the adverse effect of a lower release point on potential doses downwind. Thus, a release height of 30 m, with a wind speed of 1 m/s, is used. No credit is taken for any stacking (at 30 m) by the ventilation system or for partial recovery of the tritium by the cleanup system or for any beneficial results of any automatic fire-suppression systems or other fire-fighting efforts.

At the location where a crowd is most likely to gather to watch, the roadway 400 m (1300 ft) north, the dose to an individual is calculated to be 4.8 rem. At the nearest residence, 900 m (3000 ft) northwest, the dose is 3.7 rem. Figure 4.2.1-1 was used as a basis for the X/Q values in this case.

A short release produces little skin intake, whereas a longer release results in a lower average concentration at a receptor point because of increased lateral dispersion. The two tend to cancel each other, resulting in similar doses for both short releases and releases lasting many hours.

A ground release from the building is of questionable credibility. Should tritium escape into the building and not be vented or recovered by the cleanup system, it would permeate to the environment extremely slowly because of the ongoing efforts to make the building reasonably tight. Tritium gas released into the building would be converted to water vapor by oxidation and exchange very slowly (about 1% per day for a 100 g release). Whether in oxide or elemental form, the ground-level release to the environment (by leakage around doors and through cracks and other penetrations) would be slow enough to allow ample time to repair the ventilation and cleanup systems, or, if all else fails, to evacuate nearby persons.

A crash of a plane carrying 380 ℓ (100 gal) of fuel into a forested area could conceivably initiate a forest fire, particularly on a dry and windy day. This is typical of the larger aircraft that might be operated at the Los Alamos airport. Such a crash would not result in the release of any radioactive or toxic materials, but a large forest fire could produce a significant environmental insult. Under current guidelines, aircraft always take off to the east and land to the west, and the nearest forested area is 16 km (10 mi) west.

4.2.12 Accelerator Accident

The Los Alamos Meson Physics Facility (LAMPF) is a medium-energy, high-intensity, linear proton accelerator. The design criteria specified a proton beam of 800 MeV in energy, with a beam intensity of 1 milliamp (average current). This section describes the likelihood and consequences of the release of radioactive materials to the atmosphere from the operation of this accelerator.

Beam power (800 kw) dissipated in targets and beam stops is removed by a cooling water system 7.9×10^3 ℓ (2,100 gal), which contains radioactive spallation products. If a water leak should occur the accelerator is automatically shut down and the leakage is collected in one of two hold-up tanks 9.5×10^3 ℓ (2,500 gal) each and the contents analyzed before release. The spallation products, with the exception of ^3H and ^7Be, have half-lives measured in minutes or less. The cooling water system contains resin ion-exchange columns for continuous purification of a fraction of the stream, which effectively removes the ^7Be. The maximum calculated tritium concentration is 15 $\mu Ci/cm^3$ and studies show that if all the tritiated water were evaporated to the atmosphere a population exposure less than 0.13 man-rem per year would result.

On occasion kilocurie quantities of elemental tritium at cryogenic temperatures have been used as targets; however, the amounts involved have been much less than the quantities at risk at other LASL sites and an accidental release from LAMPF (in the absence of a fire) would be in the form of elemental gas. Thus, environmental effects will be lower than other potential areas.

The release of solid radioactive material from a target or beam stop to the atmosphere would result in some environmental impact; however, the mechanisms for such a release are limited. The targets are normally positioned within evacuated chambers and surrounded by massive shielding structures. The target and beam stop areas are further ventilated with the exhaust filtered by High Efficiency Particulate Air (HEPA) filters.

The release of any significant amount of radioactive materials from LAMPF to the environment will require an accident scenario rendering the ventilation system inoperative and supplying sufficient energy to disintegrate a target or beam stop and to propel the resulting material from the shielded experimental areas. One imaginary sequence of events, thus identified, involves a lost, confused, or deranged small-aircraft pilot attempting to land his plane on top of LAMPF (a half-mile-long structure) and crashing through the roof of the Experimental Building, the aviation fuel flowing through the cracks between the shielding blocks into the target area before being ignited, followed by loss of electric power, stopping the ventilation fans. The amount of aviation fuel available should be less than 150 ℓ (40 gal) and will likely spread over a sizeable area, thereby lessening its ability to affect any individual target. This limitation coupled with the low probability of such a chain of events makes additional refinement and detailed analysis of such an accident appear unwarranted.

Other radioactive material in this facility is in the form of activated shielding, accelerator components, etc., at a relatively low specific activity. An explosion, fire, or other accident would not release any significant quantities of material to the environment.

All accidents that have been postulated to occur at LAMPF are at least an order of magnitude less severe in their effect upon the environment than similar events postulated and analyzed for other facilities at the LASL.

4.2.13 Accident Summary

In preceding sections, a set of accidental release mechanisms have been postulated. In each case, the accident presented was the worst (most severe consequences to the public or the environment) of each accident type. The accident types were selected on the basis of potential for occurrence or consequence severity. The results of the analysis were presented in terms of the maximum dose (rem) to individual members of the general public, Table 4.2.13-1 summarizes these results for the accidents having significant radiological consequences. In addition, the table presents cumulative population dose estimates (man-rem) calculated as described in Section 4.2.1. The cumulative population doses for Los Alamos and White Rock represent worst case model estimates. The cumulative population doses for the region outside Los Alamos County shown in the table are based on the 95 percentile meteorological dispersion values, meaning they would be exceeded only 5 percent of the time assuming the total release described for the accident has occurred. For purposes of comparison, the estimated annual doses due to natural background are also included (see Section 4.1.3).

There are no standards against which these values may be directly compared. Tables 4.2.13-2 and 4.2.13-3 give the current dose limits for occupational workers and members of the general public recommended by the NCRP and the ICRP respectively. Comparison of these two tables with Table 4.2.13-1 shows that maximum doses to the public from accidents at LASL could be of the same order as the maximum permissible annual doses to occupationally exposed persons. The consequences of accidental releases are approximately ten times the recommended annual exposure of the public from routine operations, but are less than recommended emergency dose limits. Thus, even though there are no recommended limits for the accident situation, doses expected from accidents at LASL are about the same as the recommended limits for routinely occupationally exposed persons.

TABLE 4.2.13-1

SUMMARY OF RADIOLOGICAL CONSEQUENCES OF POSTULATED ACCIDENTS AT LOS ALAMOS

Accident Type	Maximum Dose Commitment[a] to Individual Members of the General Public (rem)		Worst Case Population Dose[b] Commitment in County (man-rem) Los Alamos Townsite	or	White Rock	95 Percentile Population Dose[c] Commitment in Region Outside County to 80 km Radium Plus Metropolitan Albuquerque (man-rem)
Explosion	26	(bone)	2.6×10^3		1.4×10^3	3.6×10^1
Criticality #1	0.5	(thyroid)	3×10^2		1×10^2	2×10^1
Criticality #2	0.001	(thyroid)	3×10^{-2}		1×10^{-2}	2×10^{-3}
Fission Product Release	57	(thyroid)	6×10^3		2×10^3	3×10^2
	22	(whole body)	5×10^3		2×10^3	3×10^2
Air Crash	4.8	(whole body)	7×10^3		2×10^3	5×10^2
Natural Back-ground	0.15		1.8×10^3		7.7×10^2	7.3×10^4

[a]Time integrated total dose commitments, except for bone-seeking nuclides (e.g., plutonium) where integration was for 50 years.

[b]Doses (rem) in Los Alamos Townsite and White Rock are not additive. Only one would actually occur depending on prevailing wind direction.

[c]Values (rem) are expected to be exceeded only 5% of the time; 50 percentile values are approximately 1/10 of those shown.

TABLE 4.2.13-2

CURRENT NCRP DOSE LIMITS

Maximum Permissible Dose Equivalent for Occupational Exposure	
Combined whole body occupational exposure	
Prospective annual limit	5 rems/year
Retrospective annual limit	10-15 rems/yr
Long term accumulation	(N - 18) x 5 rems, where N is age in years
Skin	15 rems/yr
Hands	75 rem/yr (25.quarter)
Forearms	30 rems/yr (10/quarter)
Other organs, tissues and organ systems	15 rems/yr (5/quarter)
Fertile women (with respect to fetus)	0.5 rem in gestation period
Dose Limits for the Public, or Occasionally Exposed Individuals	
Individual or Occasional	0.5 rem/yr
Students	0.1 rem/yr
Population Dose Limits	
Genetic	0.17 rem avg/yr
Somatic	0.17 rem avg/yr
Emergency Dose Limits-Life Saving	
Individual (older than 45 if possible)	100 rems
Hands and Forearms	200 rems, additional (300 rems, total)
Emergency Dose Limits-Less Urgent	
Individual	25 rems
Hands and Forearms	100 rems, total
Family of Radioactive Patients	
Individual (under age 45)	0.5 rem/yr
Individual (over age 45)	5 rems/yr

TABLE 4.2.13-3

CURRENT ICRP DOSE LIMITS

Organ or tissue	Maximum permissible doses for adults exposed in the course of their work	Dose limits for members of the public
Gonads, red bone-marrow	5 rems/yr	0.5 rems/yr
Skin, bone, thyroid	30 rems/yr	3 rems/yr[a]
Hands and forearms; feet and ankles	75 rems/yr	7.5 rems/yr
Other single organs	15 rems/yr	1.5 rems/yr

a)1.5 rems/yr to the thyroid of children up to 16 years of age.

4.2.14 Transportation of Radioactive Materials

Radiological Effects of Transportation to and from Los Alamos

Radiological effects from the transportation associated with LASL activities could come from two distinct sources. First, there is external penetrating radiation which may be received by humans in proximity to normally operating transport vehicles or packages held in storage; secondly, there may be internal exposure which may result from radionuclide releases caused by transportation accidents. The methodology used to evaluate radiological effects of LASL transportation activities is essentially that of the U.S. Nuclear Regulatory Commission's environmental statement on transportation of radioactive material and on the RADTRAN code provided by Sandia Laboratories.[4-140A,B]

For estimation of radiation exposures from normal and hypothetical accidents, the RADTRAN code uses population averages segmented by rural, suburban, and urban settings for a source of radioactivity moving over a specified distance. For estimation of releases of radionuclides during hypothetical accidents the RADTRAN categories accident severity by probability of occurrance and accident severity. The severity category includes the parameters of speed and type of the transport vehicle, crush forces, fire duration, and intensity along with the probability of such an accident occurring. The code provides an annual radiological risk which is the product of probability of a given accident and the maximum radiological consequences (expected value). Theses products are summed for all accidents and isotopes shipments for the distances travelled. Site specific data were used whenever the nationwide data of the NRC document were not applicable.

Normal Operations

Radiological effects of the normal transportation associated with LASL activities are not limited to the area surrounding the Laboratory, but are spread throughout the United States. Thus, it is appropriate to discuss the population dose to the entire United States rather than limiting the population to that immediately surrounding the Laboratory. This assessment includes material shipped to, within, and from the LASL site. In contrast to many facilities, transportation of radioactive waste is only a local hazard because radioactive disposal areas are located on site. Thus, transportation within the Laboratory includes waste transport as well as intra- and inter-site transfers of radioactive materials.

Radiation exposures resulting from LASL's incoming and outgoing common carrier shipments of radioactive material were encompassed in the assessment of radioactive material transport in the United States as a whole.[4-140A] Thus, normal transportation exposures are not in addition to those already assessed. Nor are the exposures additive to assessed exposures from other DOE facilities where those facilities have included exposures to shipments to Los Alamos as part of their assessment.

Dose integrated estimates are made for several portions of the population through the United States: the population sharing the transportation link; the population off, but near, the transportation link; the population surrounding the vehicle while stopped; warehouse personnel; and transportation vehicle crew. The dose estimates give 0.15, 1.4, and 1.1 man-rem for outgoing, incoming, and on-site shipments, respectively, for a total of 2.65 man-rem.

This population dose is insignificant when compared to the population dose received by the United States of 2.2×10^7 man-rem from natural radiation.

A special detailed analysis using the RADTRAN code was performed by another DOE contractor using actual data for transport of test devices (including high explosive and radioactive materials) from LASL to the Nevada Test Site using DOE operated Safe Secure Trailers (SST). Results indicated that the risk of expected number of latent cancer fatalities resulting from probable accidents to be less than 1.8×10^{-8} for accidents and less than 2.5×10^{-7} for normal non-accident transportation involving such transport. (Health effects were computed using risk coefficients from the BEIR report.[4-140C]) These risks are insignificant when compared to an individual's lifetime risk of one chance in eight of developing a fatal cancer.

Transportation Accidents

Packages used to transport materials in support of LASL operations are designed to prevent the loss or dispersal of their contents under both hypothetical accident and normal transport conditions. These packages include shipments of enriched, depleted, and natural uranium, plutonium, americium, tritium, and other radionuclides. See Table 3.3.5-1 for the input data. However, under certain abnormal conditions, releases of radionuclides to the environment could occur. The NRC provides guidance on various accident severity categories, their probability of occurrence, and the means to assess these accidents through the RADTRAN computer code developed by Sandia Corporation.[4-140A,B] RADTRAN was used and where necessary adjusted for input assumptions to reflect site specific information. Incoming, outgoing, and on-site transportation were all included in the analysis which covered all isotopes shipped. Maximium doses, regardless of the isotope causing this dose, for each of the three types of shipment are listed in Table 4.2.14-1, by three of eight accident severity categories. Accident severity categories run from the most probable accident which is least likely to release radioactive material (Category I) to a very severe, highly improbable accident (Category VIII) which would release material from most types of containers. The table is limited to three categories to prevent overlap of somewhat redundant information but yet provides the range of possible maximum doses from various accidents. Category II was chosen because Category I is assumed to release no material. Category IV was chosen as an intermediate category and Category VIII to give maximum possible doses. (Categories I-IV include 99.6% of all possible accidents in an overall accident rate of 1.06×10^{-6} accidents per km under normal circumstances.[4-140A]) Maximum individual doses in Category VIII are probably overestimated by RADTRAN because it assumes (for meteorological dispersion) a line source extending to 10 m above the surface. However, a true Category VIII accident [4-140A] includes a sustained fire (in addition to a high crush force) which would cause the effluent plume to rise considerably, thus ensuring significant dilution before the maximum dose to an individual is given. Accidents above Category IV were not included in assessment of on-site transportation because conditions do not exist for their occurrence at LASL. The combination of lower speeds, less traffic, no large volume fuel transport on site (which would be required for high intensity sustained fires required for the higher accident severity categories) and the ready availability of fire fighting equipment (<5 min to arrive on scene after notification) combine to make assessment of the possibility of on-site accidents above Category IV meaningless.

TABLE 4.2.14-1

SUMMARY OF RADIOLOGICAL CONSEQUENCES FROM POTENTIAL ACCIDENTS

INVOLVING TRANSPORTATION OF RADIOACTIVE MATERIALS

	Incoming	Outgoing	Onsite
		Category II	
Isotope	Depleted Uranium	^{60}Co	^{238}Pu
Quantity per Shipment	40 kg	0.25 Ci	15g
Maximum Individual Dose (rem)	0.0004	0.006	7.9
Critical Organ	Lung	Lung	Bone
Population Dose (man-rem)	0.006	0.08	620
Annual Radiological Risk (man-rem)[a]	0.002	1.2×10^{-5}	.01
		Category IV	
Isotope	^{192}Ir	^{60}Co	^{239}Pu
Quantity per Shipment	88 Ci	0.25 Ci	1 kg
Maximum Individual Dose (rem)	0.20	0.59	1680
Critical Organ	Whole Body	Lung	Bone
Population Dose (man-rem)	0.56[b]	8.3	13,200
Annual Radiological Risk (man-rem)[a]	0.0015[b]	1.9×10^{-5}	2.7
		Category VIII	
Isotope	^{238}Pu	$^{239}PuO_2$	
Quantity per Shipment	50 g	13.6 kg	
Maximum Individual Dose (rem)	18,600	2,340	
Critical Organ	Bone	Bone	
Population Dose (man-rem)	260,000	33,000	
Annual Radiological Risk (man-rem)[a]	0.14	0.0067	

[a]The total annual radiological risk from all accidents is 0.26, 0.16, and 6.3 man-rem for bone and 0.094, 0.039, and 2.2 man-rem for lung for incoming, outgoing, and onsite transportation, respectively, summed over Categories I through VIII.

[b]From accidents involving depleted uranium shipments, which provide a lower maximum individual dose than ^{192}Ir but provide a higher population dose (lung) and annual radiological risk than ^{192}Ir.

Included in Table 4.2.14-1 is an annual radiological risk value. This takes into account the total expected population dose from all accident severity categories and multiplies that value by the probability of that accident occurring to give an annual expected man-rem value from accidental releases caused by transportation accidents.

As illustrated by the data, maximum doses from the worse accidents in Categories II and IV for incoming and outgoing shipments lead to small maximum individual and population doses. Much larger doses are encountered in the highly improbable Category VIII accidents. When multiplied by the risk probabilities, however, Category VIII accident doses are not significantly different than Category IV accident doses. For on-site transportation, accident doses are higher than for incoming and outgoing shipments. This is caused in part by different packaging methods used for short and frequent material transfers between technical areas. When multiplied by accident probabilities, the annual radiological risk is considered acceptable. The primary population at risk for on-site transportation is Laboratory employees, members of the public who use Laboratory roads, and county residents who may be downwind of a plume from an accident. The population at risk for incoming and outgoing shipments theoretically includes the entire United States population.

4.3 SECONDARY IMPACTS

The secondary, or indirect, impact of LASL is greatest in Los Alamos County. The Los Alamos Townsite and White Rock communities are virtually the direct result of the operation of the Laboratory. The impact on the northern New Mexico region surrounding Los Alamos has been substantial. The contribution of LASL to the areas economic life is both to increase income directly and stimulate employment. The secondary impacts on water, air, land use, ecology, economy, demography, institutions, and community services are discussed both in terms of the adjacent communities and the northern New Mexico region.

4.3.1. Water Quality and Consumption

The water supply system in Los Alamos County serves LASL and the communities of Los Alamos, White Rock and Pajarito Acres (see Section 3.3.1.1). Water consumption during the last five years is given in Table 4.3.1-1. If trends continue, the communities will grow as the Laboratory grows. It is projected that the population in 1982 will be 21,000. If the 1978 per capita use of about 0.52 m^3/d (137 gal/person/day) continues, the projected community water demand would be about $4 \times 10^6 m^3$ (1.1×10^9 gal) in 1982 (see Section 3.3.1). Domestic water use approximately doubles during the summer months attesting to the impact of lawn irrigation. The projected community water demand could be reduced if there was a significant effort to encourage use of natural landscaping instead of lawns and if future building emphasis was directed toward multiple family dwellings instead of the present predominance of single family units. The housing shortage in Los Alamos County (see Section 4.3.3) has caused a large number of LASL/DOE/Zia employees to live "off the hill" in the surrounding counties of Santa Fe, Rio Arriba, Sandoval, Taos, and Bernalillo (see Section 3.2.3). If this trend continues, Laboratory growth will result in increased domestic water demands in these counties. This may in some cases have the beneficial impact of accelerating the upgrading of present water supply and sewage treatment systems in the surrounding communities involved. There is no anticipated need for acquisition of additional water rights until after the year 2000 in Los Alamos County.

TABLE 4.3.1-1

WATER CONSUMPTION FOR LOS ALAMOS COUNTY

Year	LASL/DOE/ZIA[a] $m^3 \times 10^6$	Community[b] $m^3 \times 10^6$	Community as % of Total	Total $m^3 \times 10^6$
1972	1.98	4.05	67	6.03
1973	2.01	3.54	64	5.55
1974	2.15	4.40	67	6.55
1975	2.07	3.80	65	5.87
1976	2.30	4.30	65	6.60
1977	2.16	3.70	63	5.85
1978	1.98	3.70	65	5.69

a) Includes steam and electrical power generation.

b) Includes residential and commercial use.

Waste management is always an important consideration when population growth is expected. Los Alamos County presently operates three waste-water treatment plants (see Section 3.3.3) with a design capacity to provide for a total population of 27,300. These plants treat all residential and commercial wastes generated outside the Laboratory boundaries.

The Pueblo and Bayo plants serving the Los Alamos townsite, based on trickling filter technology, are presently meeting the most recent EPA requirements for secondary treatment. Upgrading of these plants was completed in 1978. About one-third of the Pueblo plant effluent is used to irrigate the golf course. The Bayo plant will have to serve the North Mesa area, expected to be a principal location for new residential growth. Depending on the extent of development, the Bayo plant may require some expansion in the future. The White Rock trickling filter plant is now meeting all EPA standards including fecal coliform counts since the installation of chlorination equipment in September 1978. Los Alamos County has eliminated the Pajarito Acres stabilization ponds, and that sewage is pumped to the White Rock Treatment Facility. The combined capacity of the treatment plants is more than adequate for projected populations (see Section 3.3.3).

4.3.2 Air Quality

During 1976 approximately 5,000 automobiles were driven to work at LASL, DOE, and Zia Company. Using the population statistics and commuting distances from Section 3.3.2, an estimate of 64 million commuting kilometers (40×10^6 mi) per work year (230 days) was made (see Table 4.3.2-1). Using national average statistics and emission factors, [4-141] annual exhaust emissions for these vehicles is estimated in Table 4.3.2-1.

Residences and commercial buildings in Los Alamos use electricity generated by the LASL power plant and also purchase their natural gas from LASL. Lesser energy inputs are from gasoline, propane, wood, and fuel oil. About 40% of the LASL power plant emissions result from generation of electricity for the Los Alamos townsite. Therefore, approximately 40% of the power plant emissions listed in Table 4.1.2-3 are attributable to the townsite. Table 4.3.2-2 shows the estimated emissions from the combustion of natural gas for the townsite.

White Rocky and Pajarito Acres, with a combined population of about 5,000 and with about 1,500 residences, purchase their natural gas from the Gas Company of New Mexico. Each residence uses an average of 5,166 standard cubic meters (182,400 standard cubic feet) per year, [4-142] so that the total annual natural gas use is about 7.7 x 106 standard cubic meters (2.7×10^9 standard cubic feet). Thus, the emissions from burning natural gas in White Rock and Pajarito Acres are about one-third of those shown in Table 4.3.3-2.

White Rock and Pajarito Acres purchase their electricity from the Public Service Company of New Mexico (PSCNM). The PSCNM generates its electricity from 60% natural gas and 40% coal. An average residence uses 5,702 kwh per year,[4-143] so about 8.55×10^6 kwh per year are consumed by these two residential areas. Making the simplifying assumption that all this power is generated by the PSCNM's San Juan Power Plant, the estimates in Table 4.3.2-3 of emissions can be made.

Wood-burning in fireplaces in Los Alamos, Pajarito Acres and White Rock is popular. Assuming one-fourth of the 17,000 people in these communities burn one cord per year (1.36 metric tons/cord), 28,920 kg (63,750 lb) particulates, 3,760 kg (8,290 lb) nitride, 57,830 kg (127,500 lb) hydrocarbons,

TABLE 4.3.2-1

ESTIMATE OF TOTAL COMMUTING KILOMETERS DRIVEN PER DAY BY LASL, DOE, AND ZIA COMPANY EMPLOYEES

Percent of Work Force	Locale	Estimated Number of Vehicles	Estimated Kilometers Day/Vehicle	Total Kilometers[a] (in thousands)
66	Los Alamos, White Rock, Pajarito Acres	3,300	32	24,425
1	Albuquerque, Belen, Jemez Springs	50	322	3,700
19	Española, Santa Clara	950	80	17,580
14	Santa Fe	700	113	18,135
100		5,000		63,840

ESTIMTED ANNUAL EXHAUST EMISSIONS OF VEHICLES USED TO COMMUTE TO LASL, DOE, AND ZIA COMPANY FOR 1976

Gasoline Used[b]	11,041,900 liters
Distance	63,840,000 kilometers
CO (27 g/km)[c]	1,700 x 10^3 metric tons
HC - Exhaust (2.7 km)[c]	170 x 10^3 metric tons
Evaporation (2.08 g/km)[c]	52 x 10^3 metric tons
NO_x (3.0 g/km)[c]	190 x 10^3 metric tons
SO_x (0.12 g/km)[c]	8 x 10^3 metric tons
Particulates	
Exhaust (0.24 g/km)[c]	15 x 10^3 metric tons
Tire Wear (0.44 g/km)[c]	3 x 10^3 metric tons

a) A work year consists of 230 working days.

b) Assuming 13.6 mpg.

c) Average emission factors for highway vehicles based on 1976 nationwide statistics.

TABLE 4.3.2-2

ESTIMATED ANNUAL EMISSIONS FROM NATURAL GAS COMBUSTION IN THE LOS ALAMOS COMMUNITY TOWNSITE

		Fiscal Year (July 1 to June 30)				
		1972	1973	1974	1975	1976[a]
Natural Gas used (thousand standard cubic meters)		20,932	19,029	21,005	23,032	20,935
Particulates	(160)[b]	3,350	3,710	3,360	3,690	3,350
SO_2	(9.6)[b]	200	220	200	220	200
NO_2	(2880)[b]	60,300	66,780	60,500	66,330	60,300
HC	(1120)[b]	23,460	25,970	23,530	25,800	23,450
Organic Acids	(960)[b]	20,100	22,260	20,160	22,110	20,100
Aldehydes	(160)[b]	3,350	3,710	3,360	3,690	3,350
Ammonia	(8)[b]	170	190	170	190	170

[a] Average New Mexico residential gas consumption for 9/1/75 to 9/1/76 was 5.17 thousand standard cubic meters per year/dwelling.

[b] $kg/10^6 m^3$ natural gas.

TABLE 4.3.2-3

ESTIMATED ANNUAL EMISSIONS ATTRIBUTABLE TO WHITE ROCK AND PAJARITO ACRES FROM THE SAN JUAN POWER PLANT (SJPP)

	1976 Data
Electricity purchased from Public Service Company of New Mexico	85,500 MKWH
Fraction of SJPP annual power output consumed by White Rock[a]	0.02623
Annual Emissions	
Particulates (2.76)[b]	2,300 kg
SO_2 (54.5)[b]	45,100 kg
NO_x (234)[b]	193,600 kg

a)Total average annual output of the San Juan Power Plant is 326 megawatts.
b)Measured emissions at 80% capacity (g/s).

TABLE 4.3.2-4

ESTIMATED ANNUAL EMISSIONS ATTRIBUTABLE TO LASL FROM THE SAN JUAN POWER PLANT

	1976 Data
Electricity purchased from Public Service Company of New Mexico	140,600 MKWH
Fraction of SJPP annual power output consumed by LASL[a]	0.04925
Annual Emissions	
Particulates (2.76)[b]	4,200 kg
SO_2 (54.5)	84,800 kg
NO_x (234)	363,600 kg

a)Total average annual output of the San Juan Power Plant is 326 megawatts.
b)Measured emissions at 80% capacity (g/s).

1,1160 kg (2,560 lb) organic acids, and 5,210 kg (11,480 lb) aldehydes are released per year.[4-141] Suspended particulates are also generated by construction activity, automobile emissions, and natural processes such as dust storms.

LASL purchases roughly half the electricity it uses from the Public Service Company of New Mexico (PSCNM) and the Bureau of Reclamation. The purchased PSCNM power comes from various generating stations on their northern New Mexico power grid, but mainly from their San Juan Power Plant in the Four Corners Area. The Bureau of Reclamation power is hydroelectrically generated by the Colorado River Storage Project. Since no atmospheric emissions emanate from the hydroelectric power station, the only emissions to be considered are those from the PSCNM's San Juan Power Plant.

Presently the San Juan Power Plant has one unit in operation. This unit has a 100% capacity of 326 megawatts, but is operated at an annual average 80% capacity factor. Emissions from the San Juan Power Plant are measured by the PSCNM, so estimates of those attributable to electricity consumed by LASL can be made (see Table 4.3.2-4).

None of these emissions are believed to adversely affect the local air qualtiy. See Section 3.1.5 for information on ambient air quality in the area.

4.3.3 Land Use

Before LASL was developed, the previous land uses on the Pajarito Plateau were mainly farming, grazing, lumbering, and some hunting and trapping. As discussed in Section 4.1.4, the effects of these activities are still present. Almost all of the area previously cleared for farming outside the Laboratory reservation itself has been used for commercial, residential, or other community developments. Housing now also covers areas that were previously used for grazing and lumbering. This urbanization of previously agricultural and undeveloped lands is a principal secondary impact of the Laboratory's existence.

Some of the buildings built during the early years of LASL's history are still standing, as well as a few buildings from the Los Alamos Ranch School. These old barracks and quad housing were the core city during the wartime period. When the facilities were transferred to private ownership in the late 1960's, 1,938 residential, 33 nonprofit, and 44 commercial properties were sold. Two apartment buildings containing 64 units were retained for graduate student use under the administration of LASL. The book value (at cost) of the properties was $51.5 million, accumulated depreciation at the time of sale was $26.2 million, and the net book value at the time of sale amounted to $25.3 million. In 1975, an additional 5.76 km^2 (1,422.2 acres) were transferred to Los Alamos County, and 0.06 km^2 (15.5 acres) were sold to private parties. The transfer of facilities to Los Alamos County in 1967 included 0.04 km^2 (8.8 acres) of buildings and facilities used by the Zia Company for vehicle maintenance and repair and general office-warehousing activities. However, DOE retained use of these facilities through 1977. An additional 1.1 km^2 (280.7 acres) were transferred to the School Board. This property was valued at $16,542,772 and consisted of 13 installations: one high school, two junior high schools, ten elementary schools, and auxiliary facilities including offices, warehouses, a maintenance shop, and garage facilities.[4-103]

A County Planning Commission was created in 1962, and it immediately began preparing a comprehensive master plan for the community, retaining a consulting firm to prepare the plan. The Master Plan (1963) projected populations of 22,000 for 1970-1971, and longer range "low," "medium," and "high" population projections for 1985; 22,000, 26,000, and 31,000 respectively. A comprehensive land-use and circulation plan was developed. It provides the conceptual framework, basic land-use zoning, and utility and transportation requirements to provide for a total population of about 31,000. The plan is still considered the basic land-use and facility planning document for the county, and its recommendations have been followed for the most part with relatively few deviations. The county updated the basic plan to take into account new considerations in 1976. This revised plan should provide for orderly growth and development for the community up to nearly twice its present size.

Using the current County Planning Office factor of 2.94 persons per household and the average of building permits for the 1958-1978 period, the average annual population growth in the Los Alamos communities has been around 430 people per year, closely tied to the increases in Laboratory employment. (Earlier figures for persons per household were higher, 3.4 in 1970 for example.) Even though a substantial number of people living in the county are employed in business and service industries unrelated to the Laboratory operation, their growth and economic success is virtually locked to that of the Laboratory population. See Section 4.3.5 for further discussion of this close relationship between federal employment and the resultant impact on the community. Thus it can be anticipated that most future population growth will be related directly to Laboratory expansion, with some due to retirees remaining in the communities and some due to increases in businesses serving the communities. No new industries of any significance are anticipated, and, in fact, the recent Community '75 study recommends that new industry should not be encouraged. Thus, future planning by the county to handle population increases must be based largely on Laboratory plans which are ultimately set on a year-to-year basis by federal government decisions.

Since the Daly Plan was completed, the growth in population has fallen far short of the predicted levels (15,198 by 1970 census vs. 22,000 predicted). This fact reflects the extreme difficulty and risk involved in predicting population, especially in a small "pre-industry town" where the growth rate of the main industry is impossible to predict accurately.

The upsurge in Laboratory employment since 1975 was largely related to acceleration of federally augmented programs focusing on energy. Using the projected growth of Laboratory programs as discussed in Section 3.2.3 and assuming the total county population to grow in the same proportion, leads to a projected population of 21,000 in the end of 1982 and 26,000 by 1992. Thus the predicted 31,000 population may quite possibly never be reached, especially within the next 25 years. In addition, an assumption of total county growth proportionate to LASL employment is unlikely, based on recent trends. There are potential pressures for overall county growth not in proportion to LASL employment, such as a severe housing shortage forcing new employeees to live in surrounding counties. County population growth could eventually be accelerated because an expanded Lab-related population base may be able to support non-Lab-related retail and service businesses in proportions larger than at present.

Some future land use requirements are projectable on the basis of population levels while others are the result of the perceived needs of the community. As a result of the felt need for a junior college or university, 0.2 km^2 (40 acres) of Overlook Park in White Rock has been allocated for the construction of a new campus. A recreation center and cultural complex is planned in the Civic Center in townsite.

A survey of Los Alamos residents' attitudes indicated that they favor growth and development, but want it "to be controlled and kept within the present environmental and ecological setting...."[4-143] Since research and development operations are the only industries that would be attracted to Los Alamos as a result of the small labor force, remoteness from most markets, poor transportation connections, and the few raw materials locally available, this community decision not to encourage industrial growth will have a significant impact on future land use requirements.[4-144]

Projected acreage requirements by land use category for the projected populations of 21,000 in 1982, 26,000 in 1992 and 31,000 in 2002, if that level is reached, are shown in Table 4.3.3-1. This would mean an increase in the percentage of residential and commercial land in proportion to the other land use categories, and a decrease in the percentage of the government and general welfare and community service categories. Although this would entail a notable decrease in the amount of open space, the general welfare and community service proportion of the total urbanized area would still be a minimum of 26%. This is sufficient by most standards, especially since 11.2 km^2 (2,775 acres) of open space land is not included in the table, and since the Laboratory reservation amounts to vast areas of open space as well.

There are 4.8 km^2 (1,195 acres) of developable vacant land in the county. The projections in Table 4.3.3-1 indicate that this will be adequate land to accommodate a population of 26,000 as projected for 1992. If the population did eventually reach 31,000 there is a potential shortage of 2.8 km^2 (696 acres). The most likely alternatives to satisfy the demands for a potential population level of 31,000 are that the county will acquire more land, or increase the density of residential development. Future development has been considered in Rendija Canyon, Deer Trap Mesa and the Western Perimeter Tracts, which total 5.2 km^2 (1,281 acres). Bayo Canyon has also been considered for residential development. Each of these areas may be expensive to develop because of terrain problems. The density of present residential areas averages 790 units km^2 (3.2 units/acre). An increase of 26% to 996 units km^2 (4.0 units/acre) would satisfy land requirements for the 31,000 projected population and remain at a lower average density than a typical subdivision.

The most obvious impact induced in the community is a need for housing, and concomitant dedication of land to that use. Housing has been a continuing problem in Los Alamos over the years. Although the housing stock is virtually all less than 30 years old and in good condition, periodic shortages have occurred over the years, mainly when rapid spurts in LASL employment occurred faster than the local housing industry could respond.

The local industry has exhibited a fairly stable production capability over the years, mostly for single-family housing. Dips have occurred in response to national economic and local employment conditions, as Table 4.3.3-2 shows. As old government homes were acquired by private owners, they have been the subjects of considerable remodeling activity. Normal gross outmigration is essentially nil; therefore, no significant number of units from the existing stock are expected to become available.

There is not now sufficient nor adequate housing in the county to accommodate the present employment level or an increase and it appears that the traditional housing shortage will become more acute. There are several contributing factors. Because of the dependence of the housing market on LASL employment,

TABLE 4.3.3-1

PROJECTED LAND USE REQUIREMENTS IN LOS ALAMOS COUNTY

Land Use Activity	Present Area (km^2)	1982 Population 21,000	1992 Population 26,000	2002 Population[a] 31,000
Residential	7.03	2,275	2,802	3,330
Commercial	0.29	94	115	137
Industrial	0.08	23	28	32
Transportation, Communication and Utilities	0.43	138	169	200
Government	0.25	63	63	63
General Welfare and Community Services	4.79	1,226	1,267	1,309
Total	12.87	3,819	4,444	5,071
Increase	-	639	1,264	1,891

a)Source: Revised Comprehensive Plan, 1976.

TABLE 4.3.3-2

RESIDENTIAL BUILDING PERMITS, LOS ALAMOS COUNTY

Year	Building Permits Number of Units (Single family unless noted)
1958-66	863
1967	154
1968	116
1969	103
1970	84[a]
1971	87
1972	110
1973	139 + 168[b]
1974	149
1975	218
1976	196
1977	281
1978	248

a) A reduction in force (RIF) occurred at LASL in 1970.

b) 168 units built in 1973 were apartments, all by nonlocal builders.

NOTE: Three local builders have been responsible for nearly all single-family home construction.

contractors are unwilling to build speculatively - most houses are committed before they are built. Other factors include the need to expand utilites and roads; contractor difficulties with labor, materials, and transportation; the tight money for financing; and land speculation.[146]

Possible action could take the form of government-provided mortgage guarantees or possibly enticing outside contractors by helping to "package" a large number of units to be built at once, perhaps under the umbrella of a community housing corporation. Finally, if developed building sites were a limiting factor, DOE could consider its own ability to make land available or could encourage other land-owners to develop by, for example, guaranteeing them that DOE would not open up new land for development for a certain period of years.

There will be pressure to expand into Federal lands administered by the Forest Service and the General Services Administration. The General Services Administration lands are considered 'reserved' in the county land management plan. In addition, a large percentage of Los Alamos workers may decide to live outside the county.

Assuming that approximately one-third of the county's work force will live outside the county and will be distributed in northern New Mexico in roughly the same proportion as presently, the impact on the surrounding region can be estimated (see Table 4.3.3-3). The majority of the population should continue to concentrate in Santa Fe and Espanola. Thus the Santa Fe and Española area could expect to have another 1600 Los Alamos employees and dependents by 1982, 3200 by 1992, and 4700 by 2000.

Since some of the future growth in employment should be from hiring residents of the region, not all of this growth in employment will result in population growth. It has been projected that the region will have a steady but fairly moderate population growth in future years due to the assimilation of new people from outside areas regardless of the Laboratory's operation.

Land is a limited resource in northern New Mexico as in Los Alamos County. Although there is a large amount of land, its use is severely limited by factors of topography, water availability, and ownership. Often decision-making and coordination is beyond local control. Increased population pressures have resulted in an increased awareness of the necessity of land use controls. Present land use concerns center on the adverse effect of over-population in areas with sensitive ecological systems such as forests and river basins, which are the most desirable for development. There is no state or regional land use planning authority. The local county and municipal governments have zoning authority. The 1973 Subdivision Act gave counties the responsibility for managing subdivision activity, and all the counties in the region have adopted subdivision regulations.

Traditionally urban development in the region has been confined within well defined urban areas. However, over the past decade the demand for new housing and retail services has increased. As a result, urban communities such as Santa Fe and Española have begun to spread along their peripheries. Urbanization is beginning in many smaller communities such as Pojoaque, Chimayo, Santa Cruz, and Jemez Springs. Present water and sewage system development projects will certainly affect future urbanization and land use patterns.[4-147] Los Alamos workers have contributed to the trend toward residential development of the limited amount of agricultural lands in the region, especially in the Rio Grande Valley. These trends toward increasing urbanization, changes in land use patterns, and rising land prices can be expected to continue. Indian lands are adjacent to almost all other property ownerships. Development of utility corridors, easements, rights-of-way, or any other activity that may have a potential impact is to be considered in relation to the Native American Religious Freedom Act, PL 95-341

TABLE 4.3.3-3

DISTRIUTION IN NORTHERN NEW MEXICO OF PROJECTED POPULATION GROWTH DUE TO LOS ALAMOS

	1982	1992	2000
Rio Arriba	880	1,760	2,590
Santa Fe	730	1,460	2,150
Taos	40	80	120
Bernalillo	30	60	90
Sandoval	20	40	60
Mora	0	0	10
Total	1,700	3,400	5,020

The high percentage of federally owned lands in northern New Mexico was discussed in Section 3.2.1. The policy of retaining land in federal ownership, such as the LASL reservation, has an impact on regional land use. Large scale changes in land ownership or use can not be anticipated. Federal emphasis is on improved management of land. Conflicts arise from land adjacent to growing communities, isolated tracts of federal land which are surrounded by privately owned lands and isolated tracts of privately owned lands which are surrounded by federal lands. Expanding communities such as Los Alamos place demands on federal lands. Although federal land management agencies have provisions for the sale and leasing of their lands, the general policy is retention. As municipalities and counties begin to anticipate growth and the direction of expansion, an increasing number of request for use of federal lands will result. In Los Alamos County the need for residential land causes continual pressure for the release of federal lands, especially DOE and Forest Service property. Isolated tracts of privately owned land within federal property are under the jurisdiction of county subdivision regulations. It is thus possible for tracts of private land to be subdivided without regard for the impact on surrounding federal lands. The development may be in strong conflict with the land use planning of the federal agencies. The present subdivision of private lands in the Jemez Forest Reserve west of Los Alamos is a typical example, since many LASL employees find the mountain subdivision an excellent solution to their housing problem. In summary, the housing shortage in Los Alamos creates pressure on federal lands that can result in increasing interaction by federal agencies and municipal and county governments in evaluating and supporting land use policies.

Another land use issue in northern New Mexico is the revenue from federal lands. Since federal lands are tax exempt, the counties lose potential property tax revenue. However, federal agencies make payments to counties on the basis of lumber, oil, gas, minerals, and recreational receipts. Recent federal legislation has increased the amount of these payments. DOE's assistance payments to Los Alamos County (see Section 4.3.5) are another form of compensation for loss of property tax revenue.

As in Los Alamos County, there is a shortage of housing throughout the northern New Mexico region. 1970 Census data indicates a large number of houses lacking adequate plumbing facilities and a substantial percentage, 45%, of substandard housing. New housing and remodeling activity in the region varies proportionally with the amount of urbanization and the economic health of the county. Los Alamos, Santa Fe, and Bernalillo Counties have had the most remodeling and new construction while both activities in Mora County have been minimal. Taos County has experienced a large amount of second-home and recreation-oriented building. The average cost of construction in the state is rising at the annual rate of 9.35% or higher. In addition to the increases in the cost of building material and labor, the price of the land and the price of improvements is increasing, often because of terrain difficulties. The cost of rehabilitation has risen even faster. New housing and rehabilitation are also limited by the lack of mortgage money and high interest rates. Many of these problems are national in scope although the economically depressed state of the region aggravates the situation. The construction of low- and moderate-priced homes has been negligible in comparison to the needs.[4-146]

In some cases, the prices of land and housing may have been driven up by the increased demand created by Los Alamos workers who live outside the County.

The situation is complicated because of the land-title issue. Complicated land exchanges and confusing jurisdictions have entangled claims to land and water rights. Without proper proof of ownership, development capital is unavailable and the economic development process stagnates. Thus there will be a continued shortage of land for residential purposes.

4.3.4 Ecology

As mentioned earlier in Sections 4.1.5 and 4.3.3, the Los Alamos area was used previously and primarily for agriculture, grazing and lumbering. Most early residential development occurred in areas that had been cleared for farming earlier and thus was not in a natural state. As newer residential areas have been developed, previously uncleared areas were opened. This urbanization of previously agricultural and undeveloped lands is a principal secondary impact of the Laboratory's existence. The comments under Physical Impacts on Habitat and Wildlife in Section 4.1.5 are also applicable to the secondary impacts of housing construction on plant and animal communities. Thus, the proposed residential developments in the Northern and Western Perimeter tracts, Deer Trap Mesa, Rendija Canyon, and Bayo Canyon would result in a loss of habitat, displacement of the wildlife population and death of some animals. Clearing would benefit very few wildlife species because these areas would be occupied by people. The close proximity of humans will drive wildlife species, especially the larger animals, out of surrounding areas. The proposed development of Bayo Canyon for housing would represent an additional encroachment into habitat currently used by an endangered species, the peregrine falcon, for nesting and food gathering. The greatest danger is the increased likelihood of predation or vandalism by humans.

The ecological impact of residential development in other areas of northern New Mexico, as a secondary impact of the Laboratory's operation, cannot be predicted. The relative isolation, low human population density, and low industrial development of northern New Mexico has helped the region to maintain its high environmental quality. The natural resources of the area include clean streams and lakes, high visibility, undeveloped mountainous terrain, widespread forests, abundant game and fish, and significant historical sites. Since the game and fish in the region are an important economic asset as well as a valuable natural resource, both state and federal agencies have given a great deal of attention to the protection and conservation of wildlife.

Because of the high environmental quality of the region, recreation areas and urban growth centers are attracting increasing numbers of people. Population pressures especially threaten the integrity of the natural habitats. It should be noted that these development pressures are occurring independent of the operation of LASL and that the contribution of LASL-related employees is only incremental.

The comments regarding the ecological effect of radionuclides in Section 4.1.5 would also apply if any such material were to be found off the LASL reservation.

4.3.5 Economic

Los Alamos has an economic position unique in this locale, largely due to its technological base and its federal subsidy. This economic situation is perhaps most succinctly demonstrated by its being the only county in New Mexico with no bonded debt until late 1974. Unlike many other communities, this is not derived from a large assessed tax base; 17 other New Mexico counties have higher total assessed valuations and 19 have higher per capita assessed valuations.[4-48] Much of this is traceable to the input of federal support for the community.

Historically, the great bulk of the community facilities, all of which were originally constructed and owned by the AEC, were donated to the county pursuant to the 1962 "transfer" legislation. At that time municipal facilities were valued at some $22 million. A further condition of the transfer committed the government to spending some $8.7 million in municipal improvements and community construction. Some of the final stages of this transfer were completed in 1977.

As part of its support of the Laboratory, the federal government provides direct economic support to the Los Alamos County government and assistance payments to the Los Alamos School Board to offset the near-absence of taxes that would normally result from private business and industry in an equivalent-size community. In FY 76 this direct assistance totaled $4,564,000. The exact amount is negotiated yearly, and the funds must be appropriated by Congress. The contractual arrangement for county government support is presently being renegotiated. Other federal support in FY 75 included $270,000 for fire protection and community-related activities and $145,000 in construction undertaken toward completion of municipal improvements.

About one-third of the Laboratory employees live out of the county, reducing somewhat the quantity of services that Los Alamos County must provide. This means that Los Alamos County enjoys an effective industrial tax windfall for the same reason that the counties in which these commuters live suffer from the bedroom-community fiscal problem. On the other hand, this population distribution limits the spendable income going to Los Alamos businesses, and contributes to those in surrounding counties.

Some indirect subsidies are provided for residents of Los Alamos County by federal support, for example, transportation. Some federally owned and Zia-maintained roads, notably East Jemez and Pajarito Roads, are open to public use and carry a large portion of the commuting traffic.

The total expenditures for DOE, LASL, Zia, LACI, and EG&G in 1978 were about $515,000,000. Of this, $3,480,000 in state income tax payroll deductions directly benefited New Mexico. The total expenditures for capital equipment in 1976 were $14,949,000, and the total expenditures for construction were $39,563,000. Total operating costs for LASL, DOE-LAAO, and Zia-LACI for several years are summarized in Table 4.3.5-1.

The impact on the region's economy from DOE's operations in Los Alamos can be compared with other industries in terms of the number of employees. Direct employment by LASL, Zia, DOE/LAAO, EG&G, and Los Alamos County accounts for roughly 20% of the total employment in Northern New Mexico, excluding Sandoval and Bernalillo Counties. Additional jobs are estimated to be generated in the supporting commercial and industrial sectors through the secondary impacts of LASL's operations. Additionally, revenues are generated from taxes on gross receipts, gasoline, cigarettes, licenses, permits, motor vehicles, and property in Los Alamos County.

In effect, DOE plays the role of a major industry in northern New Mexico. In this sense LASL's funding is derived from outside the local area, drawing income into the region. In view of the generally depressed economy of the region, DOE's operations at Los Alamos are of major significance to the economy of northern New Mexico.

TABLE 4.3.5-1

TOTAL EXPENDITURES FOR LOS ALAMOS OPERATIONS
(in thousands)

	FY 1970	FY 1975	FY 1976	FY 1977
Operating Costs	$105,622	$166,932	$201,191	$247,700
Capital Equipment	19,047	19,490	14,949	42,600
Construction	16,251	34,358	39,563	*

*42,600 represents capital equipment and construction expenditurees.

If DOE's operations in the area were to be discontinued, 8650 jobs and $150 million in income would be lost to the region directly. The number of jobs and income lost indirectly remains to be calculated. An additional loss of money in value added and tax revenue would result, as well as a loss of school and university funding. Property values in Los Alamos County would plummet, amounting to a potential loss of money. The number of welfare recipients would probably increase. Almost all the residents of Los Alamos County, as well as some residents of the surrounding region, would leave the state to find jobs elsewhere. In summary, ceasing DOE operations at Los Alamos would have a devastating impact on northern New Mexico, already an economically depressed area.

As shown in Table 2.1, the proposed growth in LASL's activities could directly result in 927 new jobs in 1981, and an estimated additional 340 indirect jobs in supporting industries and local Los Alamos County employment. The total gain in income would be over $75 million with a potential increase in the value added. The tax revenues would increase, and schools and university would receive additional funding. This would be a clear economic benefit to northern New Mexico. This projected growth might necessitate parallel growth in various community services.

4.3.6 Demography

As mentioned in previous sections (3.2.3 and 4.3.3), the population of Los Alamos has grown in direct proportion to the level of LASL's research and development effort (see Figure 4.3.6-1).[4-149] In the early years of the Laboratory's history the population was regulated by LASL's personnel requirements. Housing assignments were strictly controlled, and only those employed in Los Alamos and their immediate families could reside in the community. Even after control was transferred to the county government and legal restrictions on housing were removed, residents would leave the community if they were no longer employed in the county. There were simply no other jobs available.[4-144]

After Los Alamos was opened, the commercial sectors expanded. Although this did not provide jobs for the highly specialized technical talent of Laboratory employees, it did affect the demography of the county. The proportion of non-Laboratory employees in the County increased. Likewise, the percentage of the family incomes that were directly from the Laboratory's payroll decreased somewhat. In addition, Laboratory employees began to retire and continue to reside in Los Alamos. The proportion of retired people in Los Alamos County is continuing to grow (see Section 3.2.3). As a result of the history of Los Alamos, the present population level is completely the direct and secondary effect of LASL's operation.

This population has grown from 904 in 1940, before the Laboratory's development, to 10,476 in 1950, 13,037 in 1960, and 15,198 in 1970. Even though a substantial number of people living in the county are employed in business and service industries unrelated to the Laboratory operation, their growth and economic success is virtually locked to that of the Laboratory population. Thus it can be anticipated that most future population growth will be related directly to Laboratory expansion, with some resulting from retirees remaining in the communities and some from increases in businesses serving the communities. No new industries of any significance are anticipated, and, in fact, the recent Community '75 study recommends that new industry should not be encouraged.[4-150] Thus, future planning by the county to handle population increases must be based largely on Laboratory plans, which are ultimately set on a year-to-year basis by federal government decisions. If DOE's operations were discontinued, there would be no base for the county's economy.

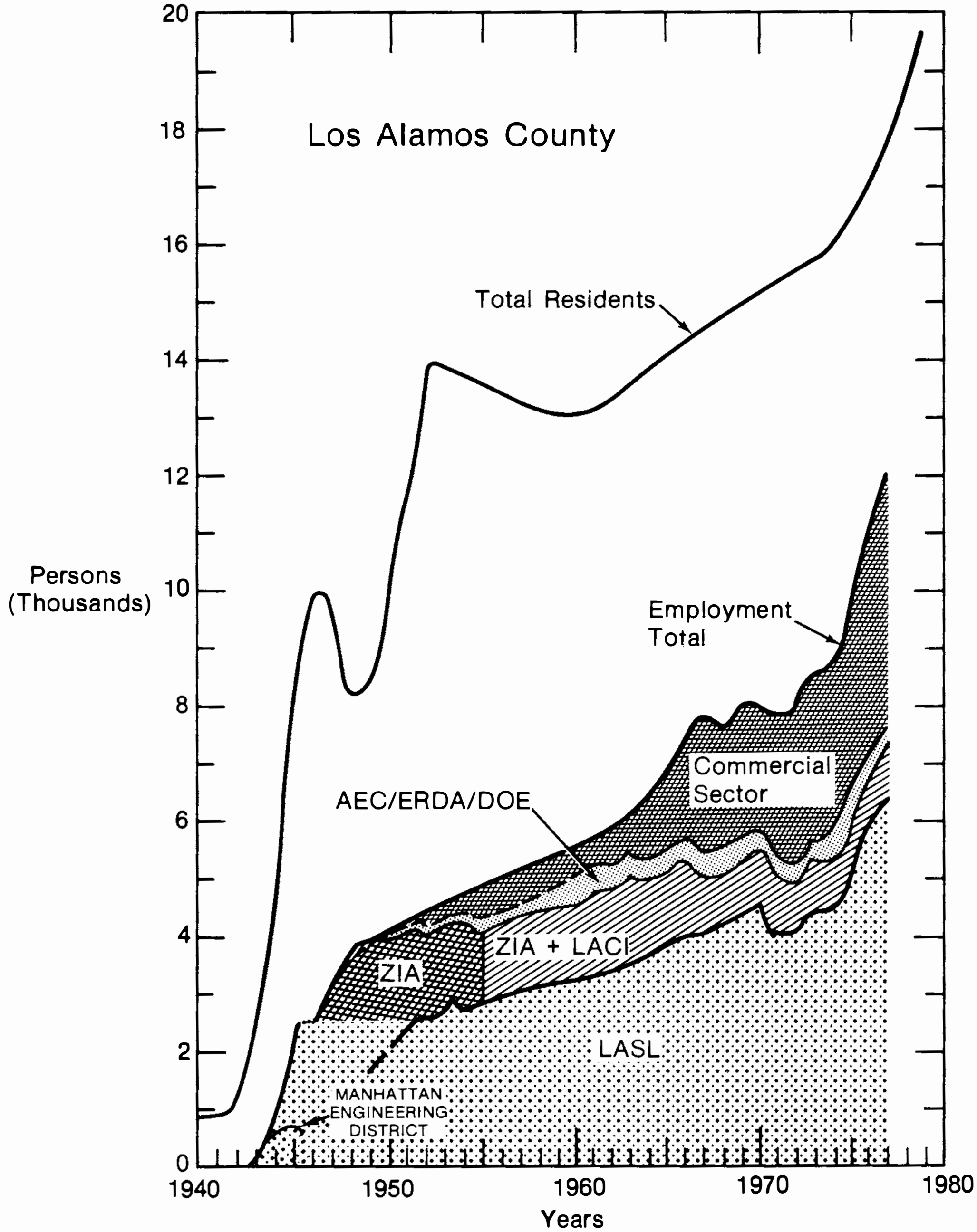


Figure 4.3.6-1

Employment and Population for Los Alamos County
1943-1977*

*LASL, ZIA, and DOE historic records best estimate compilation.

As discussed in Section 4.3.3, population levels of 21,000 can be expected in 1982, rising to 26,000 in 1992 and possibly 31,000 by 2000. The commercial sector should expand, with an increase in the ratio of commercial sector workers to Laboratory employees. This should improve the job outlook for the two chronically unemployed groups, women and young adults. The low unemployment rates typical of the county's history should continue. The other demographic factors that are unusual in Los Alamos can be expected to continue, such as the high family income, the high proportion of college graduates, and the high median age. The average family size will probably continue to drop, and the percentage of married couples continue to decrease, following the national trend. In view of the shortage of residential land, the population density should continue to increase. The crime index can be expected to remain below the national average.

The high cost of housing could cause a greater percentage of workers to live outside the county. However, a recent study indicates that the cost of commuting from outside the county offsets the difference in housing costs.[4-151] Transportation costs could well rise at a faster rate than housing costs. Therefore, it is extremely difficult to project population increases in northern New Mexico resulting from LASL's operations. Nevertheless, Table 4.3.3-3 presents the estimated distribution of Los Alamos workers in the region. Table 4.3.6-1 shows the historic and projected populations of the northern New Mexico region.[4-48 and 4-152] The percentage of Laboratory-related employees living in any one community outside the county is relatively small.

Because of its historical isolation and regionally atypical sociological makeup, Los Alamos has had less impact on the surrounding communities than would be expected in more interdependent community associations.[4-153] The main sociological impact of Los Alamos has been, and can be expected to be, economic. The employment opportunities at Los Alamos may have had a slight slowing effect on the out-migration pattern of many counties in the surrounding region (see Table 3.2.3-3). It should be noted that especially since the recent impetus toward equal opportunity employment, LASL is increasingly having an economic, educational, and technological impact in these areas through minority employment drawn largely from the locally available employable minority workforce of 46% in a 40-55 km (25-35 mi) radius; LASL, Zia and LACI, EG&G, and DOE minority employment showed 21%, 60%, 22%, and 45%, respectively, in early FY 75. In response to a chronic community need for more efficient use of the some 37% employable female workforce locally available, the Laboratory is additionally making a vigorous effort to provide employment opportunities for women. Table 4.3.6-2 reflects the January 1979 employment figures in various job categories for LASL.

LASL has had a significant influence in promoting educational advancement in the area. Because of the availability of outstanding educational facilities and teachers, the Laboratory has local course offersings from the University of New Mexico that provide college advancement for many Laboratory employees. The high value placed on education within the community and the vocational advantages of advanced training in terms of Laboratory employment have motivated many to extend their education. There has been, for example, an unexpectedly high level of participation in the Northern New Mexico Community College from nearby Indian and Spanish-American residents, and many Los Alamos youths decided to get their initial college experience here instead of immediately going off to more distant institutions.

TABLE 4.3.6-1

POPULATION, HISTORIC AND PROJECTED, FOR LOS ALAMOS AND SURROUNDING COUNTIES IN NEW MEXICO

	1960	1970	1980 BBR[a] - OBERS[b]	2000 BBR[a] - OBERS[b]
Sandoval County	14,201	17,492	20,200 - 14,300	26,000 - 18,500
Rio Arriba County	24,193	25,170	27,000 - 20,800	31,500 - 29,700
Española	1,976	4,528		
Taos County	15,934	17,516	19,300 - 19,500	23,000 - 26,000
Taos	2,475	3,505		
Santa Fe County	44,970	55,756	59,200 - 65,100	70,700 - 118,700
Santa Fe	33,394	41,167		
Bernalillo County	262,199	315,774	353,500 - 424,300	425,800 - 632,300
Albuquerque	201,189	243,751		
Los Alamos County	13,037	15,198	16,800 - 27,300	20,000 - 37,100
Los Alamos	12,584	11,310		
White Rock	--	3,861		

a)BBR - mid-1972 estimates made by Bureau of Business Research, UNM.[4-150]

b)OBERS - estimates published in 1972 by joint team of U. S. Depts. of Commerce and Agriculture.[4-48]

TABLE 4.3.6-2

LOS ALAMOS SCIENTIFIC LABORATORY EEO STATISTICS FOR JANUARY 1979

	TOTAL	MALES TOTAL	MALES OTHER	MALES BLACK	MALES HISPANIC	MALES ASIAN	MALES AMER. INDIAN	FEMALES TOTAL	FEMALES OTHER	FEMALES BLACK	FEMALES HISPANIC	FEMALES ASIAN	FEMALES AMER. INDIAN
EXECUTIVE ADMINISTRATIVE MANAGERIAL													
BELOW $ 7,500													
7,500 - 9,999													
10,000 - 12,999													
13,000 - 15,999													
16,000 - 18,999	1	1	1										
19,000 - 24,999	42	33	18		15			9	7		2		
25,000 - 29,999	55	54	48		6			1	1				
30,000 AND ABOVE	544	539	526	2	7	2	2	5	5				
PROFESSIONAL													
BELOW $ 7,500	1	1				1							
7,500 - 9,999													
10,000 - 12,999	7	1	1					6	5		1		
13,000 - 15,999	45	17	11	1	4	1		28	24	1	2	1	
16,000 - 18,999	162	115	88		20	7		47	41	1	4	1	
19,000 - 24,999	441	362	312	5	40	2	3	79	71	1	6	1	
25,000 - 29,999	694	662	622	4	25	10	1	32	30	1		1	
30,000 AND ABOVE	965	952	913	2	12	22	3	13	10	1	1		1
SECRETARIAL/ CLERICAL													
BELOW $ 5,000													
5,000 - 7,499	17							17	5		12		
7,500 - 9,999	377	71	10	1	57		3	306	137		155	1	13
10,000 - 12,999	311	47	5		40		2	264	151		107	3	3
13,000 - 15,999	153	40	4		34		2	113	86		27		
16,000 AND ABOVE	63	36	15		20		1	27	20		7		
TECHNICAL PARAPROFESSIONAL													
BELOW $ 5,000													
5,000 - 7,499	5	4			4			1			1		
7,500 - 9,999	189	100	26	1	72		1	89	46	1	41		1
10,000 - 12,999	297	185	66	2	106	1	10	112	81		28	2	1
13,000 - 15,999	384	291	142	2	136		11	93	64		26	1	2
16,000 AND ABOVE	1262	1190	887		287	3	13	72	55		15		2
SKILLED CRAFTS													
BELOW $ 5,000													
5,000 - 7,499													
7,500 - 9,999	20	18	8		8		2	2	2				
10,000 - 12,999	41	36	17		16		3	5	4		1		
13,000 - 15,999	23	20	7		11		2	3			3		
16,000 AND ABOVE	309	308	239		65		4	1	1				
SERVICE MAINTENANCE													
BELOW $ 3,000													
3,000 - 4,999													
5,000 - 7,499	2	2			2								
7,500 - 9,999	51	30	9		21			21	7	1	9	1	3
10,000 AND ABOVE	52	49	10		37		2	3	1		2		
GRAND TOTALS	6513	5164	3985	20	1045	49	65	1349	854	7	450	12	26
PART TIME													
1. EXEC/ADMIN/ MANAGERIAL	1							1	1				
2. PROFESSIONAL	44	3	3					41	39			2	
3. SECRETARIAL/ CLERICAL	99	1	1					98	79		19		
4. TECH/ PARAPROFESS	85	19	15		3		1	66	59		7		
5. SKILLED CRAFT	1							1	1				
6. SERVICE/MAINT	2	1	1					1	1				
GRAND TOTALS	232	24	20		3		1	208	180		26	2	

Its University of California affiliation permits the Laboratory to offer resident tuition rates at any University of California campus to members of the immediate family of any LASL employee. The Laboratory additionally supports a number of academic exchange and other programs benefiting its employees: an Advanced Study Program that encourages graduate studies by LASL reimbursement for half tuition, a stipend, and peripherally accrued educational expenses; a Graduate Thesis Program to encourage on-the-job completion of theses for those who have essentially completed all other requirements for the degree sought; on-site training programs including a Machinist Apprenticeship Program and various short-duration internal training courses; and a Professional Renewal Leave Program for management and senior staff members that may qualify for leave up to six months with continued salary and benefits.

The Laboratory also has several programs that promote scientific technological advancement on a broader scope. These include the Academic Cooperation Program, in which students from various colleges and universities are given short-term assignment to Laboratory projects; a Professional Research and Teaching Leave Program; a Summer Graduate Study Program; and a Postdoctoral Research Program. The J. Robert Oppenheimer Research Fellowships, established in honor of the first Director of the Laboratory, are awarded to a select number of recent recipients of doctoral degrees who show promise of becoming outstanding leaders in scientific research.

An extensive ongoing technology exchange is strongly encouraged by collaboration with other scientists in Guest Scientist, Visiting Staff Member, and Visiting Scientist programs. Attendance at scientific and technical meetings and presentation of papers are strongly supported, and there is a regular schedule of colloquia and seminars that is heavily attended by staff personnel.

Finally, one aspect of the Laboratory-Community relationship that is of great importance is the cooperative atmosphere that exists. Laboratory employees take an active role in community affairs, and in fact, make up the majority of the elected council and volunteer task forces. A recent example is the Community '75 Task Force, a voluntary effort by several dozen community people to define current and future problems and to suggest future directions to the County Council.[4-150] Many members of the task force were LASL/Zia/DOE employees working during their off-hours.

The community benefits by having access to LASL expertise, and the Laboratory in turn takes part in an unofficial dialogue with the community, to its own eventual benefit. There is, however, something of a negative aspect to this situation, in the sense that Los Alamos is a "one industry town," and may be overly influenced by the Laboratory in the opinion of some.

4.3.7 Institutional

All the schools in Los Alamos County were originally built for the community by the AEC. When title was transferred in 1966, there were one highschool, two junior highschools, and ten elementary schools. Since the transfer to the School Board, no major improvements or bond issues for expansion have been required. The total assistance payments (1967 through 1976) amounted to $18,503,319. The Los Alamos Schools Administration have closed two schools and anticipate the closing of another because of declining enrollment. Canyon Elementary was closed in the summer of 1971 and is now rented to EG&G, a DOE support contractor. Pajarito Elementary closed in the summer of 1973 and is rented to LASL. Aspen Elementary may close in 1978, if school enrollment continues to decline in that neighborhood. The schools have undeveloped land areas available for potential school sites. White Rock has a 0.51 km^2 (126 acres) elementary school site and a 0.10 km^2 (25 acres) junior high site. There is a 0.24 km^2 (60 acres) high school site available in Los Alamos townsite next to Cumbres Junior High School.

Other schools in the northern New Mexico region receive federal assistance money. Some of these funds are allocated on the basis of the number of DOE-related employees who have children in the school.

As discussed in previous sections (3.2.1, 3.2.4, and 4.3.3), the large percentage of federally-owned lands in the region affects the institutional structure. Since congressional legislation regulates the administration of federal property, increasing interaction between federal agencies and local governing groups can be expected. Population growth at Los Alamos will only be a portion of the pressure on the institutional structure of the region.

The main institutional impacts of future growth and development in northern New Mexico will focus on water allocation and land use. The increased water requirements for urban use hopefully will be met by the San Juan-Chama Project (see Sections 3.1.2 and 3.3.1) and by the retirement of irrigated agriculture.

Land-use issues related to any projected population resulting from LASL's operation will concentrate on residential development. Pressures for subdivision development and right-of-way acquisition on Indian lands will continue. The Indian tribes are protective of their sovereignty and oppose restraints on their land use or water. Recent court decisions have restated the sovereignty of Indian tribes to regulate administration of their lands. In several instances, leases to tracts of Indian land have been acquired by developers for subdivision. Likewise, residential developments of islands of private property in Forest Service lands may result in jurisdictional problems.

Land-title disputes have sometimes prevented the aggradation of tracts of land of developable size in urbanizing areas, and may be slowing the rate of development in rural areas. However, ranches of several thousand acres are being subdivided by developers. In addition to the above problems, lack of authority and overlapping jurisdictions will further impede the development of comprehensive growth management policy in the northern New Mexico region.

Several communities have finished "701" comprehensive land use plans through the US Department of Housing and Urban Development. In view of the population projections, the most pertinent of these are Albuquerque, Española, the city of Santa Fe, the County of Santa Fe, Taos, and, of course, Los Alamos County. All of the Indian pueblos have also completed comprehensive plans. The Farmers Home Administration has drafted water and sewer studies for many of the smaller communities in the region. The State Engineers Office and the New Mexico Department of Development have each prepared County and Community Profile Series for each county in the region that are valuable economic and water resource planning tools. Los Alamos County, the City of Santa Fe, Española, Taos, and Albuquerque are among the communities that have developed Section 201 Wastewater Facility Plans under the US Environmental Protection Agency and the New Mexico Environmental Improvement Agency.

Los Alamos County is a member of the North Central New Mexico Economic Development District, along with Rio Arriba, Taos, Mora, and Santa Fe Counties. This organization is also known as the Northern Area Planning Organization and performs various regional planning and coordination efforts. Sandoval and Bernalillo County are members of a parallel organization, the Middle Rio Grande Council of Governments. The State Engineer's Office also is active in regional planning.

Los Alamos and Santa Fe Counties are members of the Santa Fe-Pojoaque Natural Resource Conservation District. The entire northern New Mexico region is a Soil Conservation Service Administrative Area, and also part of the Four Corners Economic Development Region.

4.3.8 Community Services

The original community communication system started as one telephone on a rural line. During the early years at Los Alamos, the local system was developed by the government. The government sold its interest to the Mountain States Telephone and Telegraph Company in 1967 for $950,294. Since then, Mountain Bell has invested approximately $6 million in a new site, buildings, and an electronic switching system. Changes in the County's population will be reflected by changes in the telephone system, but should not have any adverse effects. No critical problems are expected to result from continued growth, largely because capacities are well above current needs and will permit ample time to plan for future needs if maximum growth trends materialize.

County solid waste management is based on a sanitary land fill operated in conformance with federal and state standards. The present landfill site is expected to be adequate for roughly 20 years, depending on the exact rates of growth experienced in the County.

Capacity expansion and extension of the road networks to accommodate growth will probably involve greater expense than the utilities. Because of the constraints of topography, some key arteries generally serve as sole access to sizeable sections of the community, since alternate routes are frequently much longer. As new areas are developed it may be necessary to provide new cross-canyon links. And, as noted earlier in Section 3.2.6, public transit may become a necessity to avoid the crush of traffic at the start and finish of the business day. Alternatively, staggered work hours may alleviate peak hour traffic problems.

Los Alamos workers that reside outside the County will have an impact on the County's transportation network as well. They will be commuting daily to the Laboratory, mostly following State Road 4 to either the Alternate Route of State Road 4, the East Jemez Road, or Pajarito Road (see Figure 3.2.6-2). The most serious consequence of this commuter load will be on State Road 4 from Pojoaque to East Jemez Road and on the intersection of Diamond Drive with Jemez Road. Plans to widen State Road 4 from Pojoaque to the Otowi Bridge are indefinitely delayed because of problems acquiring the right-of-way. State Road 4 is presently being widened from Totavi to the Bandelier Junction. East Jemez Road, Pajarito Road, and the intersection of Jemez Road with Diamond Drive are the responsibility of DOE. East Jemez Road should be quite adequate to handle additional traffic, and DOE is making some improvements on the Diamond Drive intersection. Improvements on the alternate route of State Route 4 may not be feasible because of the terrain.

The Los Alamos Police Department will need incremental increases in personnel in response to population growth. The County has just completed construction of a new Police Department building, and, therefore, adequate facilities will not be a problem.

The medical resources in Los Alamos are of a high quality, atypical of the northern New Mexico region. An increase in population would likely result in more specialists, thus further increasing the level of medical care. The growing number of retired people in Los Alamos indicates that a need for day-care facilities is developing.

If population growth results in additional commercial recreational facilities, such as movie theaters, bowling alleys, or miniature golf courses, the entertainment and employment opportunities for teenagers would improve.

The projections for possible population increases in the northern New Mexico area would result in only small additions to each community. Therefore, only small proportions of increased resource use, residual generation, transportation loads, or other factors will be attributable to any increase in LASL's employment levels.

References

4-1 R. L. Cushman and W. D. Purtymun, "Evaluation and Yield and Water Level Relations," Los Alamos Scientific Laboratory report LA-6086-MS (1975).

4-2 Herkenhoff and Associates, Inc., "Water System Improvements, Los Alamos, New Mexico," Cont. No. AT(29-1)-2201, prepared for U. S. Atomic Energy Commission, Gordon Herkenhoff and Associates, Inc., Engineers, Albuquerque, N. M. (1974).

4-3 W. D. Purtymun, "Water Supply at Los Alamos during 1975," Los Alamos Scientific Laboratory report LA-6461-PR (1976).

4-4 Herkenhoff and Associates, Inc., "North Mesa Water Supply Study, Los Alamos, New Mexico," Contract No. E(29-1)-2340, prepared for U. S. Energy Research and Development Administration, Gordon Herkenhoff and Associates, Inc., Engineers, Albuquerque, N. M. (1976).

4-5 Environmental Protection Agency Secondary Treatment Information, 40CFR133.102, Federal Register, Vol. 41, No. 144 (July 26, 1976).

4-6 Environmental Protection Agency, Water Programs, National Interim Primary Drinking Water Regulations, (Federal Register, Wednesday, Dec. 24, 1975, Vol. 40, No. 248).

4-6A W. D. Turtyman, "Hydrologic Characteristics of the Los Alamos Well Field with Reference to the Occurance of Arsenic in Well LA-6," Los Alamos Scientific Laboratory report LA-7012-MS (Nov. 1977).

4-8 J. F. Tribby and W. H. Kingsley, "Survey of Los Alamos and Pueblo Canyons for Radioactive Contamination in May 1947," Los Alamos Scientific Laboratory report LAMS-516A (June 20, 1947).

4-9 W. H. Kingsley, "Survey of Los Alamos and Pueblo Canyon for Radioactive Contamination and Radioassay Tests Run on Sewer-Water Samples and Water and Soil Samples Taken from Los Alamos and Pueblo Canyons," Los Alamos Scientific Laboratory report LAMS-516 (Feb. 20, 1947).

4-10 J. E. Weir, Jr., J. H. Abrahams, Jr., J. R. Waldon, and W. D. Purtymun, "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, 1949-1955," U. S. Geol. Survey Admin. report (1963).

4-11 J. H. Abrahams, Jr., "Geologic and Hydrologic Environment of Radioactive Waste Disposal Site at Los Alamos, New Mexico," U. S. Geol. Sruvey Admin. report (1963).

4-12 J. H. Abrahams, Jr., "Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, January, 1956 through June, 1975," U. S. Geol Survey Admin. report (1965).

4-13 J. H. Abrahams, Jr., and W. D. Purtymun, "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1957 through June, 1961," U. S. Geol. Survey Admin. report (1965).

4-14 W. D. Purtymun, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1961 through June, 1962," U. S. Geol. Survey Admin. report (1965).

4-15 W. D. Purtymun, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1962 through June, 1963," U. S. Geol. Survey Admin. report (1965).

4-16 W. D. Purtymun, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1963 through June, 1964," U. S. Geol. Survey Admin. report (1965).

4-17 W. D. Purtymun and E. A. Enyart, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1964 through June, 1965," U. S. Geol. Survey Admin. report (1966).

4-18 W. D. Purtymun and J. L. Kunkler, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1965 to June, 1966." U. S. Geol. Survey Admin. report (1967).

4-19 W. D. Purtymun and J. L. Kunkler, "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1966 to June, 1967," U. S. Geol. Survey Admin. report (1969).

4-20 G. C. Robeck, "Pueblo Canyon Survey," in U.S.A.E.C., "Meeting of AEC Waste Processing Committee at Los Alamos, New Mexico," Tech. Info. Ser., Oak Ridge, Tenn., TID-460 (Oct. 1950).

4-21 B. F. Schnap and J. F. Tribby, "Radioassay and Spectrochemical Analyses of Water and Soil Samples Collected from Los Alamos and Pueblo Canyons and Analyses of Water Samples from Technical Areas, DP Site, and Laundry Drains, December 1947," Los Alamos Scientific Laboratory report LAMS-709 Series A (Mar. 1948).

4-22 A. O. Dodd, "A Survey of Some Los Alamos County Canyons for Radioactive Contamination, Spring 1953 to Spring 1955," Los Alamos Scientific Laboratory report LAMS-2038 (April 1956).

4-23 K. J. Schiager and K. E. Apt, compilers, "Environmental Surveillance at Los Alamos During 1973," Los Alamos Scientific Laboratory report LA-5586 (1974).

4-24 W. D. Purtymun, "Plutonium in Stream Channel Alluvium in the Los Alamos Area, New Mexico," Los Alamos Scientific Laboratory report LA-4561 (1971).

4-25 T. E. Hakonson and K. V. Bostick, "Cesium-137 and Plutonium in Liquid Waste Discharge Areas at Los Alamos," in Radioecology and Energy Resources, Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pa. (1976).

4-26 J. W. Nyhan, F. R. Miera, Jr., and R. J. Peters, "The Distribution of Plutonium and Cesium in Alluvial Soils of the Los Alamos Environs," in Radioecology and Energy Resources, Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pa. (1976).

4-27 W. D. Purtymun, "Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County New Mexico," Los Alamos Scientific Laboratory report LA-5744 (1974).

4-28 T. E. Hakonson, J. W. Nyhan, and W. D. Purtymun, "Accumulation and Transport of Soil Plutonium in Liquid Waste Discharge Areas at Los Alamos," Transuranium Nuclides In the Environment, International Atomic Energy Agency, IAEA-SM-199/99, Vienna, Austria (1976).

4-29 W. D. Purtymun, G. L. Johnson, and E. C. John, "Distribution of Radioactivity in the Alluvium of a Disposal Area at Los Alamos, New Mexico," U. S. Geol. Survey Prof. Paper 550-D (1966).

4-30 W. R. Kennedy, "Los Alamos Environmental Monitoring Program," Los Alamos Scientific Laboratory report LA-3639-MS (1970).

4-31 W. R. Kennedy, W. D. Purtymun, and H. F. Schulte, "Los Alamos Environmental Monitoring Program, July through December, 1970," Los Alamos Scientific Laboratory report LA-4672-MS (1971).

4-32 J. E. Herceg, compiler, "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972," Los Alamos Scientific Laboratory report LA-5184 (March 1973).

4-33 J. E. Herceg, compiler, "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, July through December, 1971," Los Alamos Scientific Laboratory report LA-4970 (1972).

4-34 K. E. Apt and V. J. Lee, compilers, "Environmental Surveillance at the Los Alamos Scientific Laboratory During 1974," Los Alamos Scientific Laboratory report LA-5977-PR (1975).

4-35 K. E. Apt and V. J. Lee, compilers, "Environmental Surveillance at Los Alamos Scientific Laboratory," Los Alamos Scientific Laboratory report LA-6321-MS (1976).

4-36 Environmental Studies Group, "Environmental Surveillance at Los Alamos During 1976," Los Alamos Scientific Laboratory report LA-6801-MS (1977).

4-37 E. H. Baltz, J. H. Abrahams, Jr., and W. D. Purtymun, "Preliminary Report on the Geology and Hydrology of Mortandad Canyon near Los Alamos, New Mexico, with Reference to Disposal of Liquid Low-Level Radioactive Wastes," U. S. Geol. Survey Open-File report (1963).

4-38 W. D. Purtymun, "Progress Report on the Hydrology of Mortandad Canyon, Disposal System for Treated Low-Level Liquid Radioactive Wastes, July, 1961 to June, 1963," U. S. Geol. Survey Admin. report (1964).

4-39 W. D. Purtymun, "Dispersion and Movement of Tritium in a Shallow Aquifer in Mortandad Canyon at the Los Alamos Scientific Laboratory," Los Alamos Scientific Laboratory report LA-5716-MS (Sept. 1974).

4-40 W. D. Purtymun, J. R. Buchholz, and T. E. Hakonson, "Chemical Quality of Effluents and Their Influence on Water Quality in a Shallow Aquifer," Journal of Environmental Quality, Vol. 6, No. 1 (Jan-Mar 1977).

4-41 E. S. Gladney and J. W. Owens, "Determination of Mercury Using a Carrier-Free Combustion Separation and Flameless Atomic Absorption," Anal. Chim. Acta. (in press) (1977).

4-42 G. L. Voelz, Health Division Leader, LASL, personal communication to H. C. Donnelly, Albuquerque Operations Office, U. S. Atomic Energy Commission (November 13, 1973).

4-43 Environmental Protection Agency, "Regulations on National Emission Standards for Hazardous Air Pollutants," 40CFR Part 61.32, Subpart C, National Emission Standard for Beryllium (April 6, 1973).

4-44 Compiled from monthly internal reports, Zia Company, "Statements of Operations," Los Alamos, New Mexico (1972 through 1976).

4-45 R. G. bond, C. P. Straub, and R. Prober, eds., "Handbook of Environmental Control, 1, Air Pollution," CRC Press, Cleveland, Ohio (1972).

4-46 New Mexico Environmental Improvement Agency, New Mexico Air Quality Standards and Regulations," Section 604, Gas Burning Equipment, Nitrogen Dioxide (March 17, 1972).

4-47 U. S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," 2nd ed., U. S. EPA, AP-42, Office of Air and Water Programs, Research Triangle Park, N.C. (April 1973).

4-48 Bureau of Business and Economic Research, "New Mexico Statistical Abstract, 1975 Edition," University of New Mexico, Albuquerque, N. M. (1975).

4-49 Automobile Manufacturers Association, "Automobile Facts and Figures," Washington, D. C. (1971).

4-50 W. C. Hanson, "Ecological Considerations of Depleted Uranium Munitions," Los Alamos Scientific Laboratory report LA-5559 (1974).

4-51 International Committee on Radiological Protection, "Report of Committee II on Permissible Dose for Internal Radiation," ICRP Publication 2, Pergamon Press, Oxford, New York, pp. 12-13 (1960).

4-52 National Council on Radiation Protection and Measurements, "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," Handbook 69, U. S. Dept. of Commerce, National Bureau of Standards (U. S. Govt. Printing Office, June 1959).

4-53 National Council on Radiation Protection and Measurements, "Basic Radiation Protection Criteria," NCRP Report No. 39, NCRP Publications, Washington, D. C. (January 1971).

4-53A National Council on Radiation Protection and Measurements, "Tritium and Other Radionuclides Labeled Organic Compounds Incorporated in Genetic Material," NCRP Report 63, Washington, D. C. (in press).

4-54 United Nations Scientific Committee on the Effects of Atomic Radiation, "Ionizing Radiation: Levels and Effects," United Nations, New York, N. Y. (1972).

4-55 Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards," Federal Radiation Council Report #2, U. S. Govt. Printing Office (September 1961).

4-56 Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards. Protective Action Guide for Strontium-89, Strontium-90, and Cesium-137," Federal Radiation Council Report #7, U. S. Govt. Printing Office, Washington, D. C. (May 1965).

4-57 C. W. Francis, "Plutonium Mobility in Soil and Uptake in Plants: A Review," J. Environ. Qual. 2 (1), 67-70 (1973).

4-58 E. M. Romney, H. M. Mork, and K. H. Larsen, "Persistence of Plutonium in Soils, Plants, and Small Mammals," Health Phys. 19, 487-491 (1970).

4-58A M. F. Sullivan, "Gastrointestinal Absorption of Transuranic Elements by Rats," May 1977, Annual Report for 1976, BNWL-2100, Pt. 1.

4-58B M. F. Sullivan, "Gastrointestinal Absorption and Retention of ^{238}Pu in Neonatal Rats and Swine," Feb. 1978, Annual Report for 1977, PNL-2500, Pt. 1.

4-58C M. F. Sullivan, "Absorption of Transuranic Nitrates by Rats, Guinea Pigs, and Dogs," Feb. 1978, Annual Report for 1977, PNL-2500, Pt. 1.

4-59 K. C. Pillai, R. C. Smith, and T. R. Folsom, Nature 203 (4945), 568-571 (1964).

4-60 M. A. Wahlgren and J. S. Marshall, "Distribution Studies of Plutonium in the Great Lakes," CONF-740701 Proceedings of the 2nd Int'l. Conf. on Nuclear Methods in Environmental Research, Univ. of Missouri, Columbia, Mo. (July 24-31, 1974).

4-61 J. W. Healy, "An Examination of the Pathways from Soil to Man for Plutonium," Los Alamos Scientific Laboratory report LA-6741-MS (April 1977).

4-62 R. J. Engelmann, G. A. Schsnel, coordinators, "Atmospheric-Surface Exchange of Particulate and Gaseous Pollutants (1974)," CONF-740921, National Technical Information Service, U. S. Dept. of Commerce, Springfield, Va. (Jan. 1976).

4-63 U. S. Atomic Energy Commission, "Proposed Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program, Vol. II," U.S. AEC Report WASH 1535 (December 1974).

4-64 C. R. Richmond, "Current Status of Information Obtained from Plutonium Contaminated People," in Radiation Research, Biomedical, Chemical and Physical Perspectives. O. F. Nygaard, H. I. Adler and W. K. Sinclair, eds., Academic Press, New York (1975).

4-65 C. C. Lushbaugh and J. Langham, "A Dermal Lesion from Implanted Plutonium," Arch. Dermatol. 86, 461-464 (1962).

4-66 C. C. Lushbaugh, R. J. Cloutier, G. Humason, J. Langham, and S. Guzak, "Histopathologic Study of Intradermal Plutonium Metal Deposits: Their Conjectured Fate," Ann. N. Y. Acad. Sci. 145, 791-797 (1967).

4-67 International Commission on Radiological Protection - Task Group of Committee 2, "The Metabolism of Compounds of Plutonium and Other Actinides," ICRP Publication 19, Pergamon Press, New York, NY (1972).

4-68 M. Heller, "The Testis," in Histopathology of Irradiation from External and Internal Sources, W. Bloom, Ed., McGraw-Hill, New York (1948).

4-69 W. Bloom, "The Ovary," in Histopathology of Irradiation from External and Internal Sources, W. Bloom, Ed., McGraw-Hill, New York (1948).

4-70 A. L. Brooks, D. K. Mead, and R. F. Peters, "Distribution and Retention of Monomeric ^{239}Pu Citrate in the Chinese Hamster and Its Cytogenetic Effect on the Testes," Lovelace Foundation Report LF-46 (1974).

4-71 C. V. Beechey, D. Green, E. R. Humphreys, and A. G. Searle, "Cytogenetic Effects of Plutonium-239 in Male Mice," Nature 256 (1975).

4-72 D. Green, G. R. Howells, E. R. Humphreys, and J. Vennart, "Localization of Plutonium in Mouse Testes," Nature 255 (1975).

4-73 C. R. Richmond and R. L. Thomas, "Plutonium and Other Actinide Elements in Gonadal Tissues of Man and Animals," Health Physics 29 (1975).

4-73A D. Grahn, B. H. Frystak, C. H. Lee, Sel Russell, and K. Lindenbaum, "Dominant Lethal Mutations and Chromosome Aberrations Induced in Male Mice by Incorporated ^{239}Pu and by External Fission Neutron and Gamma Irradiation," International Symposium on Biological Implications of Radionuclides Released from Nuclear Industries, Vienna, March 26-30, 1979, IAEA-SM-237/50.

4-73B B. J. Barnhardt and S. H. Cox, "Mutagenicity and Cytotoxicity of 4.4 MeV Alpha Particles Emitted by Plutonium-238," Radiation Research, in press, 1979.

4-73C W. F. Brandon, et al., "Somatic Cell Chromosome Changes in Humans Exposed to ^{239}Pu and ^{222}Rn," Progress Report, July 1, 1976 to September 30, 1977," DOE Contract No. E(29-2)-363.

4-74 J. W. Healy, "The Origin of Current Standards," Health Physics 29, 490-491 (October 1975).

4-75 C. W. Mays, "Estimated Risk from ^{239}Pu to Human Bone, Liver and Lung," in Biological and Environmental Effects of Low-Level Radiation, Proceedings of IAEA/WHO Symposium (Chicago, Ill., Nov. 3-7, 1975), Vol. 11 (1976).

4-75A W. R. Wiley and Staff Members of Pacific Northwest Laboratory, "Pacific Northwest Laboratory Annual Report for 1978 to the DOE Assistant Secretary for Environment, Part 1, Biomedical Studies," Pacific Northwest Laboratories Report PNL-2850, Pt. 1, Feb. 1979.

4-76 R. C. Thompson, "Transuranium Element Toxicity - Dose-Response Relationships at Low Exposure Levels," in Radiation Research, Biomedical, Chemical and Physical Perspectives, O. F. Nygaard, H. I. Adler and W. K. Sinclair, Eds., Academic Press, New York (1975).

4-77 The Advisory Committee on the Biological Effects of Ionizing Radiations, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Division of Medical Sciences, National Academy of Sciences, National Research Council (November 1972).

4-78 U. S. Nuclear Regulatory Commission, "Reactor Safety Study. An Assessment of Accident Risks in U. S. Commercial Nuclear Power Plants," Doc. WASH-1400 (NUREG-75/014), Appendix VI. Calculation of Reactor Accident Consequences (1975).

4-79 U. S. Energy Research and Development Administration, "Draft Environmental Impact Statement, RockFlats Plant Site," ERDA-1545-D (September 1977).

4-80 A. R. Tamplin and T. B. Cochran, "Radiation Standards for Hot Particles," Natural Resources Defense Council, Washington, D. C. (1974).

4-81 W. J. Bair, C. R. Richmond, and B. W. Wachholz, "A Radiobiological Assessment of the Spatial Distribution and Radiation Dose from Inhaled Plutonium," WASH-1320 (1974).

4-82 G. W. Dolphin, "Hot Particles," Radiol. Prot. Bull. 1974 (8), 8-10 (1974).

4-83 G. W. Dolphin, "The Hot Particle Problem," Radiol. Prot. Bull. 1975 (12), 18-19 (1975).

4-84 Medical Research Council, "The Toxicity of Plutonium," Her Majesty's Stationery Office, London (1975).

4-85 Alpha-Emitting Particles in Lungs; NCRP Report No. 40 (August 15, 1975).

4-86 J. W. Gofman, "The Cancer Hazard from Inhaled Plutonium," Committee for Nuclear Responsibility, Dublin, Ca. (1975).

4-87 C. R. Richmond, "Review of John W. Gofman's Reports on Health Hazards from Inhaled Plutonium," Oak Ridge National Laboratory report ORNL/TM-5257 (February 1976).

4-88 J. W. Healy, E. C. Anderson, J. F. McInroy, R. G. Thomas, and R. L. Thomas, "A Brief Review of the Plutonium Lung Carrier Estimates by John W. Gofman," Los Alamos Scientific Laboratory report (unpublished).

4-89 E. A. Martell, "Basic Considerations in the Assessment of the Cancer Risks and Standards for Internal Alpha Emitters," in Proceedings of Public Hearings: Plutonium and the Other Transuranium Elements, Vol. 2, USEPA Doc. ORP/SCD-75-1 (1975).

4-90 K. Z. Morgan, "Suggested Reduction of Permissible Exposure to Plutonium and Other Transuranium Elements," Amer. Indust. Hyg. Assoc. J., 36, 567-575 (1975).

4-91 C. W. Mays, H. Spiess, G. N. Taylor, R. D. Lloyd, W. S. S. Jee, S. S. McFarland, D. H. Taysam, T. W. Brammer, D. Brammer, and T. A. Hollard, "Estimated Risk to Human Bone from ^{239}Pu," in Health Effects of Plutonium and Radium, W. S. S. Jee, Ed., Salt Lake City (1976).

4-92 F. W. Spiers and J. R. Whitwell, "Dosimetry of ^{239}Pu and ^{226}Ra in Man and Animals," in The Health Effects of Plutonium and Radium, W. S. S. Jee, ed., J. W. Press, Salt Lake City, Utah, p. 543 (1976).

4-93 F. W. Spiers and J. Vaughan, "Hazard of Plutonium with Special Reference to the Skeleton," Nature 259:533 (1976).

4-94 Naomi H. Harley and Bernard S. Pasternack, "A Comparison of the Dose to Cells on Trabecular Bone Surfaces from Plutonium-239 and Radium-226 Based on Experimental Alpha Absorption Measurements," Health Physics, 30:35-46 (1976).

4-95 H. Metivier, et al., "Excretion and Acute Toxicity of $^{239}PuO_2$ in Baboons," Health Physics, 27(5):513 (1974).

4-96 R. L. Thomas and J. W. Healy, "An Appraisal of Available Information on Uptake by Plants of Transplutonium Elements and Neptunium," Los Alamos Scientific Laboratory report LA-6460-MS (August 1976).

4-96A A. J. Vorwald, "Medical Aspects of Beryllium Disease," in Beryllium, Its Industrial Hygiene Aspects, H. E. Stokinger, Ed., Academic Press, New York (1966).

4-97 United States Nuclear Regulatory Commission Office of Standards Development, "Calculation of Annual Doses to Man From Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance With 10CFR Part 50, Appendix I," Regulatory Guide 1.109, U. S. Nuclear Regulatory Commission, Office of Standards Development, Washington, D. C. (March 1976).

4-98 D. T. Oakley, National Radiation Exposure in the U. S.," U. S. EPA report ORP/SID 72-1 (1972).

4-98A W. E. Martin and S. G. Bloom, "Model for Estimating Plutonium Transport and Dose to Man," in Transuranics in Natural Environments, M. G. White and P. B. Dunaway, Eds., Nevada Applied Ecology Group, U. S. ERDA, report NVO-178 (June 1977).

4-99 T. E. Hakonson, J. W. Nyhan, L. J. Johnson, and K. V. Bostick, "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos," Los Alamos Scientific Laboratory report LA-5282-MS (1973).

4-100 H. C. Paxton, "Safety Analysis of the Los Alamos Critical Experiments Facility," Volume II, Los Alamos Scientific Laboratory report LA-6206 (1976).

4-101 National Council on Radiation Protection and Measurements, "Review of the Current State of Radiation Protection Philosophy," NCRP Report #43 (1975).

4-101A ICRP Publication 26, Annals of the ICRP, Vol. 1, #3, 1977, Pegamon Press, Elmsford, New York.

4-101B Cancer Research and Treatment Center, University of New Mexico, Epidemiology Section, Albuquerque, NM

4-102 A. J. Ahlquist, A. J. Stoker, L. K. Trocki, Compilers, "Radiological Survey and Decontamination of the Former Main Technical Area (TA-1) at Los Alamos, NM," Los Alamos Scientific Laboratory report LA-6887 (1977).

4-103 U. S. Energy Research and Development Administration, "Los Alamos Community Operations: Background and Summary of Statistical Information," Los Alamos Area Office, U. S. Energy Research and Development Administration, Los Alamos, New Mexico (1975).

4-104 LASL Engineering Department in collaboration with LASL Health Research Division and Kamnitzer, Marks, Lappin & Vreeland, Inc., Planning Consultants, "Los Alamos Scientific Laboratory Sketch Master Plan," Los Alamos Scientific Laboratory, Los Alamos, N. M. (in preparation May 1977).

4-105 J. F. Johnson, "Deer Population Trend, Habitat Condition Evaluation and Harvest Information," Progress Report, Federal Aid Project W-93-14, New Mexico Department of Game and Fish, Santa Fe, N. M. (1972).

4-106 D. F. Petersen, E. C. Anderson, and E. M. Sullivan, compilers, "Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division, January through December 1976," Los Alamos Scientific Laboratory report LA-6313-PR (1977).

4-107 F. R. Miera, Jr., M. J. Romine, and L. E. Eberhardt, "Small Mammal and Vegetation Composition and Diversity Along a 1500 Meter Elevational Gradient in Los Alamos," draft to be submitted to Southwest Naturalist (1977).

4-108 T. E. Hakonson, L. J. Johnson, and W. D. Purtymun, "The Distribution of Plutonium in Liquid waste Disposal Areas at Los Alamos," Proc. Third Internl. Congress of the Radiation Protection Assoc. (1974).

4-109 T. E. Hakonson and K. V. Bostick, "Cesium-137 and Plutonium in Liquid Waste Disposal Areas at Los Alamos," in Radioecology and Energy Resources Fourth Natl. Symposium on Radioecology, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Pa. (1975).

4-110 J. W. Nyhan, F. R. Miera, Jr., and R. J. Peters, "The Distribution of Plutonium in Soil Particle Size Fractions of Liquid Effluent-Receiving Areas at Los Alamos," J. Environ. Qual. 5:50-56 (1976).

4-111 F. R. Miera, Jr., and T. E. Hakonson, "Radiation Exposure to Rodents Inhabiting a Low-Level Liquid Radioactive Waste Receiving Area," submitted for publication in Health Physics (1977).

4-112 W. C. Hanson and F. R. Miera, Jr., "Long-Term Ecological Effects of Exposure to Uranium," Los Alamos Scientific Laboratory report LA-6269 (1976).

4-113 "The Los Alamos National Environmental Research Park," Los Alamos Scientific Laboratory publication (1977).

4-114 Grumman Aerospace Conf., "Energy Utilization and Conservation Study Los Alamos Scientific Laboratory," prepared for U.S. ERDA/ALO (Sept. 1976).

4-114A Report of Ad Hoc Advisory Committee on Use of Sand-Salt Mixtures on Streets, submitted to Los Alamos County Council, September 1970.

4-114B H. O. Menlove, "Determination of NaCl Contamination in Pine Trees by Neutron Activation Techniques," in Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972, LA-5184, March 1973, pp. 52-53.

4-114C J. W. Walters, Biological Evaluation of Salt Damage, New Mexico State Highway 4 Adjacent to Bandelier National Monument, US Dept. of Agriculture, Southwest Region, Forest Service Report R-3 77-22, 1977.

4-114D Oct. 4, 1977, Wm. C. Francis to Distribution Memo: Snow and Ice Control Plan - Season 1977-1978, Zia-7817.

4-115 C. R. Steen, "Pajarito Plateau Archaeological Survey and Excavations," Los Alamos Scientific Laboratory report LASL 77-4 (1977).

4-116 U.S. Energy Research and Development Administration, Environmental Statement: Intense Neutron Source Facility, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, ERDA-1548 (July 1976).

4-117 U.S. Energy Research and Development Administration, Environmental Impact Assessment, Tritium Systems Test Assembly, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, EIA/MFE/77-1 (September 1977).

4-117A "Operational Accidents and Radiation Exposures Experienced Within USAEC," 1943-75, WASH-1192.

4-118 H. W. Church, R. E. Luna, and S. M. Milly, "Operation Roller Coaster: Near Ground-Level Air Sampler Measurements," Sandia Laboratories Research Report SC-RR-69-788 (February 1970).

4-119 Environmental Surveillance Group, "Radiological Conditions at Project Rollercoaster Sites - 1966," U. S. Atomic Energy Commission Report NVO-162-28 (January 1967).

4-120 W. H. Langham, P. S. Harris, and T. L. Shipman, "Plutonium Hazards Created by Accidental or Experimental Low-Order Detonation of Atomic Weapons," Los Alamos Scientific Laboratory report LA-1981 (December 1955).

4-121 US Environmental Protection Agency, "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment," US EPA Report 520/4-77-016 (September 1977).

4-121A US Environmental Protection Agency, "Selected Topics: Transuranium Elements in the General Environment," US EPA Technical Note ORP/CSD-78-1 (June 1978).

4-122 U. S. Army, "Army Material Command Regulations," AMCR 385-100 (April 1970).

4-123 Los Alamos Scientific Laboratory, Group CMB-11, "Final Safety Analysis Report for the Plutonium Processing Facility at TA-55," Los Alamos Scientific Laboratory internal document, undated.

4-124 H. C. Paxton, "Safety Analysis of the Los Alamos Critical Experiments Facility," Los Alamos Scientific Laboratory report LA-6206, Vol. 1 and 2 (1976).

4-125 K. J. Schiager and K. E. Apt, compilers, "Environmental Surveillance at Los Alamos During 1973," Los Alamos Scientific Laboratory report LA-5586 (May 1974).

4-126 W. J. Smith, II., E. B. Fowler, and R. G. Stafford, "Experience in the Cleanup of Plutonium-Contaminated Land," Los Alamos Scientific Laboratory Report LA-6731-MS (March 1977).

4-127 J. M. Selby, et al., "Considerations in the Assessment of the Consequences of Effluents from Mixed Oxide Fuel Fabrication Plants," Battelle Pacific Northwest Laboratories Report BNWL-1697 (June 1973).

4-128 J. Mishima, "Plutonium Release Studies. II. Release from Ignited, Bulk Metallic Pieces," Battelle Pacific Northwest Laboratories report BNWL-357 (November 1966).

4-129 K. Stewart, "The Particulate Material Formed by the Oxidation of Plutonium," Progress in Nuclear Energy, Pergamon Press, New York, Series IV, Vol. 5 (1963).

4-130 International Commission on Radiological Protection, "Report of Committee II on Permissible Dose for Internal Radiation, 1959," ICRP Publication 2, Pergamon Press, New York (1968).

4-131 U. S. Atomic Energy Commission, "Environmental Statement: Plutonium Facility Los Alamos Scientific Laboratory, New Mexico," WASH-1507 (January 1972).

4-132 H. T. Williams, et al., "1969 Status Report on the OWR with Revised Safety Analysis," Los Alamos Scientific Laboratory report LA-4192 (July 1969).

4-133 W. E. Neyer, "The Technology of Nuclear Safety, Vol. I," MIT Press, Cambridge Massachusetts (1964).

4-134 M. R. Ziessler, "Non-Destrictive and Destructive Transient Tests of SPERT I-D, Fully Enriched, Aluminum-Plate-Type of Core," Data Summary Report, Phillips Petroleum Co., Atomic Energy Division Report IDO-16886 (November 1963).

4-135 A. H. Spano, "Quarterly Technical Report, SPERT Project July, August, September 1959," Phillips Petroleum Co., Atomic Energy Division Report IDO-16606 (July 11, 1960).

4-136 J. W. Dykes, et al., "A Summary of the 1962 Fuel Element Fission Break in the MTR," Phillips Petroleum Co., Atomic Energy Division report IDO-17064 (1965).

4-137 T. M. Sims and W. H. Tabor, "Report on Fuel-Plate Melting at the Oak Ridge Research Reactor, July 1, 1968," Oak Ridge National Laboratory report ORNL-TM-627 (1964).

4-138 F. R. Keller, "Conference on Light-Water-Moderated Research Reactors Held at Gatlinberg, Tennessee, June 11-14, 1962," Oak Ridge National Laboratory report TID-7663, pp. 888-1283 (1963).

4-139 W. B. Cottrell and A. W. Savolainen, "U.S. Reactor Containment Technology, Vol. 1," Oak Ridge National Laboratory report ORNL-NSIC-5 (August 1965).

4-140 P. M. Kramer, P. L. Flynn, G. M. Talley, R. A. Tohey, and L. M. Holland, "Biohazards Manual," Los Alamos Scientific Laboratory report LA-5267-M (1974).

4-140A U.S. Nuclear Regulatory Commission, "Final Environmental Statement on Transportation of Radioactive Material by Air and Other Modes." U.S. Nuclear Regulatory Commission Document NUREG-0170, Volumes 1 and 2, (December 1977).

4-140B J. M Taylor and S. L. Daniel, "RADTRAN: A Computer Code to Analyze Transportation of Radioactive Material," Sandia Laboratories Report SAND76-0243 (April 1977).

4-140C National Academy of Sciences, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," National Academy of Sciences, National Research Council (November 1972).

4-141 U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," AP-42, second edition, U.S. EPA Office of Air and Waste Management, Office of Air Quality Planning and Standards, Research Triangle Park, N.C. (February 1976).

4-142 P. Blackman, Gas Company of New Mexico, personal communication (October 1976).

4-143 A. Carinci, Public Service Company of New Mexico, personal communication (October 1976).

4-144 Los Alamos County, "The Revised Comprehensive Plan of Los Alamos County," Los Alamos, N.M. (1976).

4-145 P. A. Lupsha and R. V. Anderson, "The Los Alamos Report: Citizen Attitudes Towards Their City, Its Services and Its Future," Institute for Social Research and Development, University of New Mexico, Albuquerque, N.M. (1974).

4-146 Los Alamos County Planning Department, "Population and Housing Study for Los Alamos County," Los Alamos, N.M. (May 1974).

4-147 New Mexico Water Quality Control Commission, "Upper Rio Grande Basin Plan (Draft)," Santa Fe, N.M. (August 1976).

4-148 North Central New Mexico Economic Development District, "Overall Economic Development Program, Section I," Santa Fe, N.M. (1975).

4-149 Los Alamos Scientific Laboratory Engineering Department in collaboration with LASL Health Research Division and Kamnitzer, Marks, Lappin & Vreeland, Inc., Planning Consultants, "Los Alamos Scientific Laboratory Sketch Master Plan," (in preparation May 1977).

4-150 Steering Committee, "Community '75 Goals Program," report of the Steering Committee, Los Alamos County, N.M. (1974).

4-151 Los Alamos County Administrative Services, "Analysis of Cost of Living in Los Alamos versus Surrounding Area," Special report to the County Administrator (September 1976).

4-152 L. B. Zink, "A Note on Population Projections," New Mexico Business, Bureau of Business and Economic Research, University of New Mexico, Albuquerque, N.M. (August 1972).

4-153 J. E. Holmes, "Science Town in the Politics of New Mexico," Division of Research, Department of Political Science, University of New Mexico, Albuquerque, N.M. (1967).

5. UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

Identification of the actual or potential unavoidable adverse environmental effects arising from the continued operation of LASL must reflect a subjective value judgment. For purposes of this summary, only the major results of Laboratory operations in the categories of resource consumption, release of effluents, and preemption of alternative land uses are included. The potential for accidents is another unavoidable environmental risk. Adverse effects are taken to include those increments of consuption or releases or commitments attributable to Laboratory operation that might be considered adverse to at least some interests, even if there are no measurable or discernable influences on the human population or biota of the area.

The use and consumption of natural resources including water and fuels for energy, both directly by the Laboratory and in the surrounding communities, are unavoidable, given continued operation. Such uses preempt other uses of such resources.

The annual Laboratory-related use of water amounted to approximately 2.3 x 10^6 m^3 (608 x 10^6 gal) in 1976. (The ERDA water system supplied 4.3 x 10^6 m^3 (1.1 x 10^9 gal) to the local communities.) Water use from the underground aquifer is managed so that the resource is apparently fully renewable and is well within the legal water rights limits that are designed to prevent adverse to effect on other water users in the Rio Grande Basin. The existing water rights would permit withdrawal of about 20% more water. This would not cause drawdown of the water table. In addition to present efforts at water conservation, some opportunities for further conservation exist, including mandatory rationing should it be necessary.

The annual Laboratory-related consuption of energy totaled approximately 5.6 x 10^{15} joules (5.3 x 10^{12} BTU) as a source energy. This total includes approximately 206 x 10^6 kwh of purchased electricity and the local combustion of approximately 89 x 10^6 m^3 (3.1 x 10^9 ft^3) of natural gas for direct heating or generation of steam or electricity. A major energy conservation study is underway, and preliminary results indicate a potential for savings of about 20% over projected consumption by 1985 depending on the effectiveness of required investments. In addition to the consumption of fossil fuels, the energy use results in a release of pollutants. The local releases, principally oxides of nitrogen because the major fuel is natural gas, are well within state approved limits and produce no discernable impacts. The remote release of pollutants attributable to Laboratory electricity consumption occur primarily in the Four Corners region (see Section 4.3.2) and are not within the direct control of DOE.

The release of some pollutants in liquid and airborne effluents from LASL facilities and treatment plants is an unavoidable result of continued operation. Present knowledge derived from the routine environmental surveillance program and special ecology studies indicates these releases result in impacts that are neither large nor significant.

Releases from sanitary sewage treatment facilities are all within the interim limits of current NPDES permits. Some of the effluents do not meet all EPA regulations for secondary treatment, but conceptual design is underway to upgrade the required facilities. The conditions of the final NPDES permits are still being worked out with EPA. The canyons into which the effluents are discharged are essentially dry through most of the year, and none of the water is used for municipal supply or recreation. Since present practices do not appear to be overloading natural assimilative capacity, the costs of additional technology will probably not help avoid any adverse impacts but will draw resources away from situations where real improvements could be made.

Industrial effluents are discharged at about 100 locations on the Laboratory site, including many of which are once-through cooling water or cooling-tower blowdown. Applications for NPDES permits for many of these are now in process, and others will be eliminated through procedural changes. Most such releases have resulted in minor impacts such as increases in total dissolved solids content of shallow alluvial aquifers.

As shown in Section 3, treated effluents from the two industrial waste treatment plants contain trace levels of radioactivity and are discharged into canyons on the Laboratory site. The concentrations of radioactivity are well below Concentration Guides[3-102] for water suitable for drinking (see Section 4.1.1). They are in conformance with DOE requirements that releases of radioactivity be as low as practicable. These releases will continue for at least several years. However, planning is underway to implement a major upgrading of the Central Waste Treatment Plant that through improved processing and ultimate evaporation of the final effluent will eliminate at least 90% of present radioactively contaminated liquid effluent. The smaller waste treatment plant that serves the present old plutonium processing facility will probably be nearly phased out when the new Plutonium Processing Facility becomes operational. The elimination of discharge from the Central Waste Treatment Plant will also reduce the nonradioactive pollutants, notably nitrates and fluorides, that have altered the chemical quality of water in the shallow canyon aquifers.

To date, environmental monitoring of liquid effluents released in canyon areas has not shown any adverse effects on canyon ecosystems. As mentioned previously, it is anticipated that release of liquid effluents containing pollutants will cease within a very few years to comply with anticipated federal regulations.

Atmospheric release of airborne effluents includes some radioactivity (see Section 3.3.3), but the effect of these releases in terms of added radiation dose received by the local population is small. The maximum potential dose at a Laboratory border is estimated to be about 22 mrem/yr (see Section 4.1.3). This is less than 15% of the natural background, which averages about 153 mrem/yr. The total dose to the population of 17,700 in Los Alamos County is estimated to be approximately 4.1 man-rem, essentially all attributable to tritium, ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O. This is less than 0.2% of the estimated 2,570 man-rem attributable to natural background. Projected operations are not expected to increase these levels.

Even though the atmospheric radioactivity has been a small fraction of the breathing air concentration guidelines, there are continuing efforts to reduce airborne releases as much as is feasible within technological and economic limits. As an example, releases of plutonium have been reduced by a factor of more than 200 over the last five years by improvements to air filtration systems.

Penetrating radiation from accelerators and the Critical Assembly Facility may contribute a small dose, estimated at less than 1 mrem/year, to people who regularly drive on the two DOE-controlled access roads that traverse the Laboratory site.

Some may consider the near-wilderness area placement of a major facility such as LASL to be an adverse impact because it precludes alternative land uses, largely on aesthetic grounds. The isolation itself was a major requirement for the original operation of Los Alamos and continues to mitigate the potential for risk from some types of accidents.

Continued operation of LASL requires dedication of the present Laboratory lands for the foreseeable future, excluding alternative land uses. This is necessary for reasons of security, safety, and contiguous land use. The exclusion is a mitigating measure that protects the public from the potential hazards of exposure to radioactive contamination, dangerous test activities such as high explosive detonations, and potential risks from accidental releases. Some people, such as hikers, campers, and hunters, may consider this an adverse environmental condition that prevents their access to areas generally acknowledged to be beautiful and rich in game and other resources. However, the Laboratory is not a unique area; similar landscape and opportunities for recreation are avilable in the Bandelier National Monument and nearby Forest Service lands. Also, the exclusion policy has preserved much of the reservation in the character of a wildlife refuge, as attested to by the variety and density of fauna in the area. Some lands used for cattle grazing in pre-Laboratory days are regaining carrying capacity for a variety of wildlife.

Loss of habitat through facility development may occur, contingent upon programmatic emphasis. The effect of these losses can be tempered by land-use practices attuned to wildlife considerations. The ecological studies currently underway will be instrumental in providing much of the information required to insure land-use practices that optimize wildlife aspects. Site clearing, if properly located and implemented, will create favorable edge effects that offset wildlife habitat losses caused by the facility. Consideration will be given to alternatives to barriers such as fences to insure free movement of wildlife. The continued restricted access and prohibition of hunting on Laboratory lands will also serve in tempering habitat loss caused by facility development. The lack of hunting and generally low human presence in large areas of the Laboratory will continue to benefit species that are intolerant of human disturbance. Continuing studies on mule deer will provide information for assessing Laboratory impacts on critical habitat, reproductive performance, movements, and densities. Mitigating efforts relative to mule deer will be commensurate with our ability to define and assign importance to the various impacts.

LASL performs the role of custodian of wildlife upon its environs and is responsible for its welfare. The endangered species are particularly important (see Section 3.1.4). Efforts to identify and protect all endangered species within the Laboratory will continue. Precautions are being taken to preserve their habitats, in accord with the Endangered Species Act of 1973 (P.L. 93-205. 87 stat. 884). In addition, a complete biotic inventory is currently being made of the environs to identify and characterize ecosystem components so that a comprehensive land-use plan may be developed. Close liaison is maintained with the U.S. Forest Service. The coordinator position that was recently established by contract with the Los Alamos Area Office of the DOE to provide forest management consultation to DOE and its contractors.

The expanded environmental monitoring program in conjunction with ecological studies insures a comprehensive view of chemical waste distributions throughout the Laboratory and adjacent region. Special emphasis has been given to sampling from trophic levels leading to man to insure compliance with existing regulations and to identify potential problem materials for which regulations do not exist. Ongoing studies in the treated-waste receiving areas of canyons are providing information on ways to control chemical distributions through planning for drainage and erosion in site construction activities. In-house review of plans and EIS's for new facility construction insure that compliance with these needs is attained whenever possible. It has always been and will continue to be a feature of Laboratory operations that the environmental quality be well within the legal requirements.

As new facilities are built at LASL, some of them will inevitably be in the vicinity of archaeological ruins. Because of the nature of early Indian settlements on the Pajarito Plateau, it is often not possible to find a construction zone that contains no traces of early occupation. Many of the larger ancient sites are surrounded by small one- and two-room ruins and small middens. With the LASL Archaeological Map as a guide for engineers and planners for siting new facilities, major clusters of Indian ruins can be avoided and salvage excavations minimized. When it is necessary to proceed with the construction, salvage archaeology is done to gain as much information as possible about the Indian site before it is destroyed. Future determinations of importance and salvage archaeology will be conducted in accord with new regulations entitled, "Protection of Historic and Cultural Properties," 36CFR800, effective March 1, 1979.

The LASL Sketch Master Plan will incorporate a number of ways in which some visual impacts can be mitigated or improved at relatively low cost without impairing the operation of the Laboratory. New facilities are now receiving more attention on an aesthetic and architectural design basis than has been typical of past structures; the National Security and Resources Study Center is an example. However, structures will remain basically utilitarian to keep costs as low as practicable.

Disposal of solid radioactive waste may well be the most significant unavoidable and adverse effect of the LASL operations. The adverse possibilities are largely due to the long-term commitment of disposal areas to that use because of the long half-lives and toxicities of some of the radioactive materials. Approximately 0.2 km^2 (50 acres) of land are dedicated to solid radioactive waste burial within the Laboratory boundaries. There are no known adverse effects of present or past solid waste disposal practices, aside from the land use, which precludes most alternative surface uses. The geologic characteristics of the Los Alamos area appear to be among the most suitable for the long-term confinement of these potentially hazardous materials. Continuing studies are designed to identify any deficiencies and problem areas so that necessary mitigating action can be taken. The studies themselves, although focusing on the immediate situation, have potential applicability to radioactive solid waste disposal problems that may arise in other locations. Some revegetation of areas disturbed for waste burial has been initiated to reduce the surface impact of such operations.

LASL management includes environmental impacts as a major element in evaluating and establishing policies and decisions on future modifications, improvements, and projects. As part of the evaluation procedure, appropriate groups within the Health Division review plans and specifications for all proposed projects to ensure minimal accident potential and environmental impact. Any high-risk operation with accident or environmental impact potential requires preparation of a formal Safety Analysis Report and the development of written Standard Operating Procedures before its initiation.

Construction presents certain unavoidable and often adverse short-term impacts such as noise, dust from land preparation and earthmoving, additional traffic, and visual changes. Some of these effects are temporary and terminate with the completion of the structure, other impacts such as increased traffic load for permanent employees and visual changes are more prolonged. Integral to the design process are efforts to anticipate special problems. Most of this is accomplished through an ongoing Quality Assurance Program that includes review of plans by various engineering and technical groups such as the Environmental Studies Group. Review considerations include structural and operational suitability for accomplishment of the missions, adequate health and safety protection, compatibility with environmental protection, reliability and continuity of operations, and decontamination or site restoration of obsolete facilities. If there is a question with respect to environmental impacts, an environmental assessment is prepared and submitted for DOE determination as to the need for an environmental impact statement. If it is clear that the action will require an environmental impact statement, it is prepared prior to initiating the action.

A number of other specific mitigating actions, underway or proposed, have already been discussed in other sections. Summarily, the most important of these are: (1) development of a LASL Master Plan to govern future Laboratory land use; (2) improvements in liquid waste treatment to effect greater removal of radioactivity and improve general chemical quality; (3) improvements in solid waste management including volume reduction and evaluation of the adequacy of past practices; (4) improvements in gaseous waste treatment including additional HEPA filtering and controls on tritium releases; (5) additional security measures especially relating to nuclear materials; (6) improvements in the fire protection system aimed at further risk reduction; (7) construction of a new plutonium facility consistent with more stringent safety standards; and (8) county-wide mapping of archaeological sites to ensure preservation of unque sites and adequate archaeological salvage and study of those areas where preservation and development conflict.

6. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Relatively few commitments of resources at LASL are absolutely irreversible and irretrievable. However, fuels for energy production, most construction materials, and other consumables used in the operation and maintenance of the research facilities are irretrievable. Water consumption is detailed in Section 4.1.1. The other resources consumed were discussed in Section 4.1.6. In a less tangible but equally real way, the human resources invested in establishing the Laboratory and its many research programs also represent an irretrievable commitment. At the present level of activity, this is about 7700 man-years per year.

A special emphasis on conservation of resources used in the operation of the Laboratory, starting in the fall of 1973, effected a savings in energy usage of electricity and natural gas. A major energy conservation study now in progress has identified a potential for energy savings of up to 20% by 1985. Although energy conservation in the Laboratory is considered mandatory, no direct controls have been placed on community uses of electricity and natural gas. Voluntary efforts in the community did reduce rates of increase in usage in spite of new home construction and population growth. Water conservation has also been encouraged. The water level drawdowns are not considered irreversible or irretrievable because withdrawal rates are within natural rates of recharge.

Other commitments of resources may be irreversible and irretrievable depending on assumptions about economics and technology. As discussed in relation to tradeoffs between short-term uses and long-term productivity, most of the present commitments of land resources are not absolutely irreversible and irretrievable. Buildings have been and presumably could be decontaminated and removed if other uses for the occupied land areas were considered sufficiently important. Such decommissioning itself would represent considerable cost and the irreversible and irretrievable investment of time and energy. Unless extremely pressing alternative uses are found for the site, it is unlikely that wholesale removal of structures could be economically justified. Within that perspective, most of the present land uses for structures would have to be considered irreversible.

Careful consideration must be given to land areas that have low levels of radioactive or chemical contamination such as the dynamic test areas and the three canyon areas described in Chapter 3. These locations are within the controlled areas of the site, and under present operating practices they present no known safety or health hazards. However, before the areas could be released for unrestricted alternative uses it would probably be necessary to accomplish decontamination in order to be conservative. This could be costly, depending on the degree of decontamination deemed necessary. Other areas with higher levels of contamination, or presenting severe engineering problems, would require much larger investments. If present operations in these areas are discontinued, plans for adequate decontamination would have to be formulated and implemented to permit unrestricted access. Or, it would also be reasonable to consider these areas for restricted uses where the low-level contamination presents no problem.

Most of the areas used for solid radioactive and hazardous chemical waste burial must probably be considered irreversibly and irretrievably committed to that use. Obvious exceptions are those areas used for retrievable radioactive waste storage. The near surface conditions at Los Alamos burial grounds are considered favorable for storage of radioactive and hazardous chemical wastes. The present land area involved is about 200,000 m^2 (50 acres). An additional 30 acres has been designated for this purpose if required. Future long-term waste management repositories, particularly for transuranic radionuclides, may enable LASL to transfer wastes in storage and thus reduce or eliminate such local commitments.

As described earlier, other minor irreversible commitments of resources have occurred and will probably occur in the future. Also, some minor archaeological sites have been destroyed as a result of construction. Salvage archaeological studies have been conducted at important or extensive sites in keeping with the provisions of Federal regulations. The now completed archaeological site evaluation and mapping will make it possible to avoid disturbing any significant sites in the future or will assure that adequate studies and excavation are conducted before construction. Small areas have had their topography altered by excavation for foundations and access so that it would be impossible to restore the original conditions by any practical means. However, none of these irreversible changes are considered environmentally significant.

No irreversible or irretrievable changes are known or thought to have occurred in the overall ecological patterns of the area as a result of the existence of the Laboratory and the adjacent communities. Some land has been removed from wildlife habitat because of the presence of structures, but other land previously used for grazing has been returned to more natural vegetation conditions capable of supporting a wider range of wildlife.

7. RELATIONSHIP OF PROPOSED ACTION TO LAND-USE PLANS, POLICIES, AND CONTROLS

The natural physical resources of the Laboratory site are finite, and many are nonrenewable. The 111 km^2 (27,500 acres) of the LASL reservation is constrained because of contiguous land use and characteristics. Such considerations require the assumption that current land resources must suffice for the foreseeable future of the Laboratory. Strict procedures are followed at LASL to protect and preserve pre-Columbian Indian sites in conformance with federal and state laws regarding archaeological and historic sites. Since the LASL reservation does not contain any prime agricultural land, there is no primary impact in conflict with federal or state laws. Adjacent Indian lands require review and compliance with the Native Religious Freedom Act, PL95-341.

A secondary impact consideration of LASL growth and expansion is the availability of land and other resources to accommodate proportionate community population growth.

The most obvious impact induced in the community is a need for more housing, and concomitant dedication of land to that use. There is not now sufficient nor adequate housing in the County to accommodate the present employment level, and it appears that the traditional housing shortage will become more acute. Existing land provisions for residential housing within existing community boundaries are adequate for a total population of 26,000, a 64% increase over the 1976 population. Other developable reserve lands would allow for another 5,000. This would mean an increase in the percentage of residential and commercial land in proportion to the other land use categories, and a decrease in the percentage of the government and general welfare and community service categories. Although this would entail a notable decrease in the amount of open space, the general welfare and community service proportion of the total urbanized area would still be a minimum of 26%. Basic utility resources are sufficient for any projected future time. Additional water rights from the Bureau of Reclamation's San Juan-Chama Diversion Project were negotiated in 1976 and will be sufficient for twenty years. The County has a basic design for future growth to a total population of 31,000 in the form of the Comprehensive Plan for Los Alamos adopted in 1963. A major County-wide review and updating of the plan was completed in 1976. Other land use planning tools for Los Alamos County include the Zoning Plan, the Subdivision Regulation, and the Building Codes.

The impact of future residential development in other areas of northern New Mexico as a secondary impact of the Laboratory's operation can not be accurately predicted. The main impacts of future growth and development in northern New Mexico will focus on water allocation and land use. LASL's growth will contribute a small proportion of the population pressures for subdivision development. The present trends towards increasing urbanization, changes in land use patterns, and rising land prices can be expected to continue. As in Los Alamos County, there is a shortage of housing throughout the northern New Mexico region.

Likewise, land is a limited resource in northern New Mexico as in Los Alamos County. Although there is a large amount of land, its use is severely limited by factors of topography, water availability, and ownership. Often decision-making and coordination is beyond local control. Increased population pressures have resulted in an increased awareness of the necessity of land-use controls. Present land-use concerns center on the adverse effect of overpopulation in areas with sensitive ecological systems such as forests and river basins, which are the most desirable for development. There is no state land or regional land-use planning authority.

The high percentage of federal-owned lands in northern New Mexico and the policy of retaining land in federal ownership, such as the LASL reservation, has an impact on regional land use. However, the LASL site represents only 1% of the federal-owned lands in the region. Large scale changes in land ownership or use can not be anticipated. Federal emphasis is on improved management of land. Conflicts arise from land adjacent to expanding communities such as Los Alamos that place demands on federal land. Development may be in strong conflict with the land-use planning of the federal agencies. In summary, population pressures on federal land can result in increasing interaction by federal agencies and municipal and county governments in evaluating and supporting land-use policies. Lack of authority and overlapping jurisdictions will further impede the development of comprehensive growth management policy in the northern New Mexico region.

Another land-use issue in northern New Mexico is the revenue from federal lands. DOE's assistance payments to Los Alamos County are a form of compensation for loss of property-tax revenue.

Land-title disputes have sometimes prevented the aggradation of tracts of land of developable size in urbanizing areas, and may be slowing the rate of development in rural areas.

Several communities have finished federal-funded comprehensive land-use plans through the US Department of Housing and Urban Development. All of the Indian pueblos have also completed comprehensive plans. The Farmers Home Administration has drafted water and sewer studies for many of the smaller communities in the region. The State Engineer Office and the New Mexico Department of Development have each prepared County and Community Profile Series for each county in the region that are valuable economic and water resource planning tools. Los Alamos County, the cities of Santa Fe, Española, Taos, and Albuquerque are among the communities that have developed Section 201 Wastewater Facility Plans under the US Environmental Protection Agency and the New Mexico Environmental Improvement Division.

LASL has cooperated with neighboring Indian Pueblos with regard to any activities or planned actions which mibht influence adjacent lands.

Los Alamos County is a member of the North Central New Mexico Economic Development District, along with Rio Arriba, Taos, Mora, and Santa Fe counties. This organization is also known as the Northern area Planning Organization and performs various regional planning and coordination efforts. Sandoval and Bernalillo County are members of a parallel organization, the Middle Rio Grande Council of Governments. The State Engineer Office also is active in regional planning.

Los Alamos and Santa Fe counties are members of the Santa Fe Pojoaque Natural Resource Conservation District. The entire northern New Mexico region is a Soil Conservation Service Administrative Area, and also part of the Four Corners Economic Development Region.

8. RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

Efforts at LASL are dedicated to improving and guaranteeing the nation's long-term productivity. Weapons research aids in assuring the national defense dedicated to preserving its position as a strong and independent world leader. Energy technology research is a foremost example of contributions toward improving efficiency of resource use and developing new energy resources to assure a secure future and improved quality of life. Biomedical research contributes to the alleviation and better treatment of diseases such as cancer. The Laboratory's use of resources must be considered in this perspective.

Short-term uses of the local environment for the operation of LASL do not generally preclude alternative future uses. For the purposes of this analysis, short-term is defined as the time that the Laboratory has existed and the projected lifetimes of its structures and facilities. During this period alternative uses of resources are precluded. Basic uses include commitment of land and natural resources, and the investment of human and economic resources.

Land used for structures housing nuclear research facilities can be, and has been, returned to alternative uses. It has been Laboratory practice to decontaminate and decommission excess or obsolete facilites. A prime example is the removal of structures used in the early effort of World War II, and the rededication of the land to community use. The decontamination and decommissioning of all existing Laboratory facilities could be carried out, but only with a large investment of human, material, and economic resources. This investment could be minimized by continuing the process of decontaminating as necessary and redirecting the basic facilities to other uses.

Land use for explosive testing would require decontamination before it could be considered for unrestricted alternative uses. Although it is theoretically possible to return such land to a near natural state, it is likely that in the foreseeable future economic and practical considerations would indicate a limited decontamination effort, one that will assure that remaining low levels of contamination present no safety or health hazards. Such an approach was taken in the previous cleanup operations.

Waste disposal areas, including zones in the canyons near effluent outfalls for radioactive liquid waste treatment plants and the roughly 0.2 km^2 (50 acres) in various sites used for solid radioactive waste burial, also present contamination problems for unrestricted future uses even though the levels present no health or safety problems under present operational practices. The canyon alluvial sediments where low levels of radioactive materials have been adsorbed from the treated effluent flows could be removed and transferred to solid waste burial. The sediments that might require removal are confined to a few hundred meters downstream from the outfalls; at greater distances the levels of radioactivity are low enough that they pose no problem to any unrestricted uses. The solid waste burial areas could be considered for return to unrestricted alternative uses only after expenditure of large sums of money because of the presence of quantities of potentially hazardous materials. Some other uses of certain disposal sites are possible, such as the two now paved over and used as parking areas. The main site, on Mesita del Buey, and others with relatively high amounts of radioactivity in them, will be maintained under appropriate controls for the foreseeable future to preclude uses that might involve excavation or significant introduction of water.

Some short-term uses of resources such as non-renewable fuel and mineral resources involved in the construction and operation of the research facilities must be considered an investment in long-term national productivity. Such consumed resources would not materially affect the present national productivity if applied to manufacturing, for example. However, if they contribute to reaching some of the research national goals, such as continued security and greater self sufficiency in energy, the potential benefits could be substantial.

Short-term uses of certain resources preserve potential future productivity. The main aquifer is managed so that current use of water is renewable and within the limits of natural recharge. The preservation of much of the land area in near-wilderness state by exclusion of the public makes virtually any future use possible if and when it is no longer needed for security and isolation. The return of other areas to more natural vegetation by elimination of grazing has resulted in increased carrying capacity for wildlife.

Continued operation of the Laboratory, including proposed expansions, will not change the qualitative nature of short-term uses of the environment and natural resources. There will be some additional land committed to structures, and there will be some additional consumption of fuel and other materials for construction and operation. The existing solid-waste disposal areas should suffice for anticipated operations for at least two decades. The canyon areas receiving effluent from radioactive liquid waste treatment plants will continue to receive low levels (only a few percent of appropriate concentration guides) of contamination, but at even lower than present levels when proposed process improvements are incorporated. These canyons, within the controlled areas of LASL, will continue to be used as study areas to provide knowledge about low levels of radionuclides and their interrelationships with vegetation and animals in the local ecosystems. Present levels of contamination within the controlled areas are not deleterious to health or safety. The levels are such that if it is deemed desirable in the future to open the areas to unrestricted use, prudence may direct the removal of some contaminated sediments within a few hundred meters of the effluent discharge points. None of the canyon areas further downstream in uncontrolled areas have ever had contamination at levels of any concern for unrestricted use. No future operations are expected to add significantly to such low-level, but still measurable, amounts of radioactivity.

The short-term uses of environment and resources at LASL are considered minor in relation to potential gains in long-term productivity resulting from research.

9. ALTERNATIVES

This environmental impact statement has been prepared to support DOE's decision with respect to the continuation of the Laboratory's operation with some further growth and evolution of research programs in new areas but with a scope of activity approximately the same as present. The Laboratory's general mission and activities, as described in detail in Section 2.2, Current Missions and Activities, are anticipated to remain essentially the same. Future directions, as detailed in Section 2.3, are based on current projections showing a 3% annual increase in personnel at LASL.

Since the Los Alamos Scientific Laboratory has been in operation more than 30 years, the range of reasonable alternatives is different than for an entirely new project. The most reasonable alternatives are those that would decrease the actual or potential adverse environmental impacts of current or probable future operation of the facility. The major categories of alternatives considered are: "no action," cessation or relocation of programs, modified future trends, limitation of adverse impacts, and institutional alternatives.

No Action

The no-action alternative (status quo) for the existing Los Alamos Scientific Laboratory means no change from present facilities and operations, with the consequence of no change in continuing environmental impacts. This also means no further construction or decommissioning of facilities, continued use of resources at current rates, no change in employment, and no change in the general nature of work performed. Because of the nature of work performed, i.e., applied and basic scientific research, the alternative is not tenable for more than a very short period. As phases of research are completed the work must change, frequently resulting in changes in the use of facilities and resources. The overall size of the Laboratory employment could be held constant and no new buildings constructed, permitting research work to continue by modifying existing facilities to accommodate program changes. This course of action would lead to a limitation on the types of research and productivity as facilities become totally obsolete.

This no-action alternative can be considered to incur a continuation of the present environmental impacts in terms of land use, consumption of non-renewable resources, release of effluents, long-term commitment of waste disposal areas, and associated secondary impacts. There would be no improvement by mitigation of impacts and there would be some impacts that could become cumulatively larger, e.g. the amount of land committed to waste disposal. However, this no-action alternative may be unreasonable because it is basically incompatible with the objectives and pursuit of research and it would not permit the implementation of various plans to minimize environmental impacts.

Cessation or Relocation of Programs

If the continuing and planned research programs were completely or partially discontinued or relocated, there could be reductions or changes in continuing environmental impacts. The discontinuation or relocation of all research programs would make other uses of the site possible, though not necessarily feasible. The discontinuation or relocation of some selected programs could result in the elimination of certain impacts associated with those programs.

Complete cessation of all research programs is not probable because of their importance to national policy and objectives. Complete cessation of research on nuclear weapons would reduce future impacts and waste burial requirements. Research on nuclear weapons constitutes a major portion of work at LASL and is an essential element of national security. Such work has a continuing national commitment by the Congress. Research on various energy technologies, from magnetic- and laser-fusion processes to solar and geothermal sources and improved power transmission, also has a high national priority. Thus, complete cessation of all programs at LASL would result in some loss of research and development in areas of national need.

Complete relocation of all research programs would almost totally eliminate environmental impacts at the LASL site without total loss of the benefits of research. However, such relocation would not be without cost. Small parts of current operations could be moved to other DOE laboratories without expansion of their facilities. But most research is closely tied to major LASL facilities that would have to be moved to, or reproduced at, other sites to permit continuation. Many of the special facilities, such as the Meson Physics Facility (LAMPF), PHERMEX, and the tandem Van de Graaff, would be both difficult and costly to relocate or rebuild. Research laboratories, the new Plutonium Processing Facility, and the large office buildings could not be moved, yet have long remaining economic lifetimes. The cost of relocating or rebuilding facilities would be much higher than the original cost. Additionally, the abandonment of many existing facilities would incur costs for decontamination before alternative uses or costs for demolition and site restoration. Decontamination is a painstaking and expensive process that is not normally undertaken lightly or before a facility has reached the end of its economic lifetime. For example, a laboratory-wide planning effort has tentatively identified nearly 20 decontamination or decommissioning projects that may be required in the next 10 years with an estimated total cost of about $12 million. The objectives range from decontamination sufficient for alternative programmatic uses of existing facilities to complete decommissioning and removal permitting unrestricted alternative uses. Complete decontamination and decommissioning of the entire physical plant could run to the hundreds of millions of dollars. Some radioactive waste disposal areas may be too costly to decontaminate sufficiently to allow unrestricted use. Exhumation technology would need to be developed to assure suitable decontamination of burial sites. At the new sites there would be environmental costs of new construction as well as the resource consumption and effluent discharges presently at Los Alamos. Thus, the removal of LASL activities to other locations would merely transfer environmental costs to other locations. Although reconstruction might lead to some reduced impacts at the new site in comparison with present operations, the equivalent expenditure on improvements to the existing site and facilities would be more productive.

The benefits derived from removal of research programs from Los Alamos by either termination or relocation would be partly dependent on the new uses of the existing facilities and site. The advantages of returning the site to its former uses of small subsistence farms and ranches, and possibly a school or resort, are dubious. The limited water supply precludes significant agricultural production. The Soil Conservation Service does not consider the site to include any prime agricultural land. Recreational opportunities afforded by the Laboratory are already available in surrounding Bandelier National Monument and Forest Service lands. The present economic base of Los Alamos County would be removed, and most people in residence would probably have to move, resulting in a ghost town. Removal of the Laboratory would delete at least $515 million annually in personal incomes and other Lab-related expenditures from the New Mexico economy. Additionally, the environmental envelope for radioactive waste containment at LASL has been shown to be effective and safe (Section 3.3.3). The waste burden protection suitability at future alternative sites is not known.

If the site and facilities were decontaminated but not demolished there could be some alternative uses. Some types of relatively light industry might be able to use the facilites, although there are serious limitations on water availability and on transportation access that would limit possibilities. There would probably be no fewer impacts of resource consumption, land use, and effluent release, except release of small quantities of radioactivity would cease and the risk of accidential releases would be eliminated. In fact, many industries might have a larger impact because of industrial wastes and larger consumption of energy and water. A change of employee composition could have a significant impact on the people living in the area. For example, a production industry could require a larger proportion of skilled workers but fewer scientific and engineering personnel, resulting in dislocation of many present residents.

An academic institution such as a moderate-size university might use some of the existing facilities. However, because of the great proportion of laboratory facilities and highly specialized research equipment many changes would be required. The scattered layout of facilities would not be well suited to the normal pattern of university interaction. There is insufficient and inappropriate housing to meet the needs of a university. The environmental impacts would be similar to present conditions with the exception, again, of lesser or eliminated release of small quantities of radioactivity. The socio-economic costs and benefits would not change drastically.

Other possibilities include a governmental administrative center or expanded residential use. However, the location is probably too isolated and most facilities are inappropriate for a government center. Expanded residential use would be predicated on greater employment opportunities in Los Alamos than are presently provided by DOE operations. It is inconceivable that Los Alamos could function as a residential suburb for Albuquerque, the nearest commercial and industrial center of any size, about 100 road miles (160 km) away. Some residents of Los Alamos do commute to Santa Fe for work.

In short, alternative uses of the site do not appear to be significantly better. The removal of Laboratory programs from Los Alamos would mean a great economic loss in terms of facilities that still have productive lifetimes and a great loss of human resources in terms of the many scientific teams assembled to conduct research. Any alternative uses would require considerable cost to recondition the site and would probably result in no fewer or lesser environmental impacts.

The termination or relocation of selected programs or facilities could reduce or eliminate some environmental impacts of the current operations without complete loss of benefits. Without attempting to cover all possibilities, some of the most significant programs or facilities in terms of contribution to current environmental impacts will be discussed briefly as examples.

The largest quantities of plutonium in effluents, both airborne and liquid, result from a variety of research programs carried out in the Chemistry and Metallurgy Research Building. These airborne effluents have always been controlled by filtration to meet appropriate guidelines, and total quantities have been substantially reduced in recent years due to augmentation of filtration systems. The liquid wastes are treated at the Central Waste Treament Plant and have met appropriate guidelines. Nonetheless, all effluents and contaminated solid wastes generated by effluent treatment would be eliminated by terminating the research and converting the building to some other purpose. The net result would be eliminating the release of about 40 μCi of plutonium in airborne effluents (approximately 58% of the total LASL airborne plutonium effluent based on 1976 data) and about 8 mCi of plutonium in liquid effluents (approximately 90% of the total LASL liquid plutonium effluent based on 1976 data). If the research programs were moved elsewhere, the releases would presumably be continued at about the same level but in another location. If the research programs were terminated these impacts would be eliminated but there would be major impairment of work on weapons programs and on programs related to power reactor safety, plutonium-based thermoelectric generators for applications ranging from pace makers to space vehicles, and basic chemistry and metallurgy research. The benefits of these programs are considered valuable and there are alternatives for reducing radioactivity in effluents other than program termination. Some of these alternatives will be covered below.

One of the largest sources of external penetrating radiation is the Critical Assembly Facility, where high intensity radiation fields are produced for extremely short periods. The facility is located adjacent to Pajarito Road, a DOE-owned road that traverses the Laboratory site and is normally open to the general public for passage to and from White Rock. At the edge of the roadway near the facility, external penetrating radiation doses of as much as 1120 mrem/yr in 1976 (about 1000 mrem/yr above the average background of about 140 mrem/yr) are recorded. Travelers along the road may be exposed to some fraction of this increment (see Section 4.1.3 for discussion) if they happen to pass the site when an experiment is in progress. If use of the facility were discontinued, or if the facility were relocated farther from the road, the potential for exposure would be eliminated or reduced. However, other obvious alternatives would cost much less and achieve the same result. Some of the these are discussed below. Similar considerations and arguments apply to the Meson Physics Facility (LAMPF) and to the Van de Graaff accelerator.

The new Plutonium Processing Facility completed in 1979 with much more modern facilities is a greater distance from the townsite and airport which has precluded the potential for some relatively consequential accidents. The new facility reduces the routine releases of radioactive effluent, thus minimizing continuing environmental impacts. It might have been physically possible to relocate such a new facility at a different DOE laboratory, but this would impair the interactive contact between scientists. It would simply transfer the impact and risk to another area.

The Meson Physics Facility (LAMPF) is the largest consumer of energy, accounting for about half of the electric power expended at LASL (FY 76), and a major savings in energy would be realized by discontinuing its use. If it were relocated anywhere else in the country the power consumption would be the same, so there would be no change from a national perspective. Thus the expenditure of energy is a direct cost for the benefits of research performed at LAMPF. This research includes basic physics as well as specific applications ranging from cancer therapy to weapons development, many of which can be carried on concurrently. The expenditure of energy, while large, is efficient.

Open dynamic experiments with high explosives are an uncontrolled source of airborne contaminants including toxic substances such as mercury, beryllium, lead, and uranium (see Section 4.1.2 for details).

Although these are not believed to cause a discernable impact off-site, it would be possible to eliminate even the potential for impact by discontinuing this type of experimenting at LASL. One alternative would be to relocate such work at an even more remote area such as the Nevada Test Site. This would require the relocation or replication of the flash radiographic facility (PHERMEX) to derive full information from the experiments. Carrying out such experiments at a different location would reduce the efficiency of interaction between theoretical and experimental scientists working on related research. Complete elimination of the experimentation is not a practical option because of its essential place in defining properties of materials. Exclusive reliance on computer simulation and theoretical models to replace actual experiments would unacceptably reduce the quality of information. A technical alternative in the form of containment of experiments will be discussed below.

Modification of Future Trends

The proposed action is continued operation of LASL with growth in employment of about 3% a year up to a maximum Full Time Equivalent (FTE) level of about 7,500. This is an increase of about 1,500 over the (FY 77) employment of 6,000. This increase is predicated on the likely expansion or addition of certain research programs. The no-action alternative discussed earlier was defined as no change in either employment or programs from the present. The possibility of elimination of the Laboratory has also been discussed conceptually.

However, other patterns of growth can be considered. These include accelerated growth at a rate higher than 3% a year; reaching a plateau or continued growth to a larger maximum employment. A final category would be a gradual reduction in total employment.

Any of these alternatives, although discussed in terms of employment, would change programmatic activities such as program emphasis, combinations of programs pursued, or speed of completion. Any major deviations from the proposed action would probably be tied to substantive changes in national policy made at the congressional or executive levels of federal government. As such, specific possibilities can not be elucidated because of their uncertainty. But, some broad speculations can be made. For example, it is conceivable that a major new federally supported program to develop new energy technologies at a faster pace could lead to rapid expansion of at least some LASL research activities. A consolidation of weapons research programs at LASL could lead to a significant expansion of many research activities. On the other hand, consolidation of weapons work at another laboratory could lead to a reduction at LASL.

These possible changes do not guarantee a reduction of environmental or human risk potential per se. For example, a change to nonnuclear research programs may carry potential hazards of another sort, such as the heavy metals or organics pollution which cause risk potentials in industry. While premature decommissioning and decontamination decreases the burial burden at LASL, continuation of the program at alternative facilities would increase the waste burden at the new sites, thus displacing not erasing risks.

Without a more accurate forecast of future national policy decisions, it is impossible to identify effects on LASL precisely, although certain types of impacts can be identified. Additional growth, either at a faster pace or to higher maximum employment levels, would induce both primary and secondary impacts. The primary impacts would include those of new construction and additional land use. There is ample developable space for a moderate growth without causing major impacts on total proportion of land used or greatly disturbing wildlife habitat. The Laboratory's long-range planning efforts have identified land areas suitable for development that would permit considerable expansion of facilities.

Possible growth plans would be tempered, however, because any expansion would likely increase consumption of water and energy resources in close proportion to the number of employees. Waste disposal requirements would also increase, but effluents might not necessarily increase because of better control and treatment. New construction and increases in employment would add greater economic input to the region.

Secondary impacts of accelerated or higher maximum levels of growth would be tied closely to housing and public service requirements. Housing in the Los Alamos area is in short supply because of recent growth. Accelerated growth would place even more pressure on the existing market and could push prices even higher. Water and energy use, as well as solid and liquid waste disposal for the community, would increase more or less in proportion to total population. The rate of growth will largely determine the difficulty in dealing with these problems, but planning is underway that would permit expansion of community size and municipal services.

Limitation of Adverse Impacts

The modification of laboratory procedures or facilities with the objective of reducing the environmental impact from present research operations can be accomplished productively and economically. New facilities are now being designed with more attention to environmental considerations than several years ago. Basic mechanisms operate at LASL with the goal of identifying and dealing with potential and real problems before they incur significant impacts. One major thrust is in the review of new project proposals by appropriate groups in the Health Division and Engineering Department, which include the Quality Assurance Program reviews of projects in the design stage. These systematic reviews identify potential problems and suggest alternatives or appropriate mitigating actions before work progresses. For any new proposals involving hazards or unusual risks, a formal Safety Analysis Report is undertaken to ensure that adequate attention is given to potential problems. The second major thrust is the ongoing environmental surveillance program designed to document actual performance and detect trends that could indicate the development of undesirable conditions so that corrective measures can be initiated before significant impacts occur.

Several basic approaches to implementing reductions in environmental impact are functioning or possible at LASL. These include replacement of facilities to permit continued operations with greater safety and better environmental controls, application of new or different technologies to existing operations, alteration of procedures, conservation, and long-range coordinated site planning. Several examples of these approaches that have been undertaken recently or that are being considered are discussed below.

A prime example of facility replacement is the new Plutonium Processing Facility. It will both reduce routine releases and risk of accidents. The old facility could not be economically upgraded to meet recent requirements for fire protection, ventilation, filtration, radiation protection, and protection from natural disasters such as tornado or earthquake. The total project cost was over $75 million and incorporated the most reliable designs for minimizing routine releases and the probability of an accidental release. Air filtration equipment will keep emissions so low that deposition of plutonium in soils in the vicinity should not be detectable above levels occurring from worldwide fallout. The building and emergency protection systems will ensure containment within the structure of the effects of any credible criticality accident or fire.[9-1] As noted earlier, the site of the new facility, which is now operational, is further from the townsite and the airport, thereby the risks from this operation are reduced.

Another facility replacement currently planned is the industrial waste sewer that collects liquid wastes contaminated with toxic materials or radioactivity from several technical areas and transports them to the Central Waste Treatment Plant. The current installation is old and of obsolete construction for hazardous wastes. Two leaks from the line in 1974 (which were cleaned up with no lasting impact) focused attention on the problem and led to temporary measures. The replacement line will incorporate double containment with provision for flow and leak monitoring to reduce the probability of future spills to a technological minimum. The entire project, which includes provision for removal and decontamination of the old line, is estimated to cost approximately $12.5 million.

Improvements to existing facilities for control of effluents have resulted in substantial decreases in the quantity of airborne plutonium during the last several years. A recently completed improvement was the upgrading of the air filtration system for the Chemistry and Metallurgy Research (CMR) laboratory building. The replacement of the old air filtration systems designed in the early 1950's with double stage High Efficiency Particulate Air (HEPA) filters reduced the amount of plutonium released by a factor of about 200 from 7,900 mCi in 1972 to about 40 mCi in 1976. This improvement cost approximately $3 million. Similar improvements were made in the releases from the present plutonium processing facility, and those releases will be further reduced when the new Plutonium Processing Facility is completed. Such improvements also illustrate the issue of costs versus benefits for further limitations of releases. The remaining largest source of airborne plutonium release is from one wing of the CMR building that emitted about 28 mCi in 1976. This release was about 41% of the Laboratory total airborne plutonium effluent in 1976, though five years ago would have been less than 0.5% of the total. To install HEPA filtration in this wing would cost an estimated $1 million. Thus the marginal costs of further cleanup necessitate consideration alongside other important improvements that could be made for an equivalent expenditure.

Major improvements to the liquid waste treatment facilities, in addition to the industrial sewer line replacement already discussed, have been proposed and are identified for probable funding in FY 81. Several supplementary processes including raw waste filtration, ion exchange, carbon adsorption, and effluent evaporation are to be added by facility additions to the Central Waste Treatment Plant. The supplementary processes as well as some changes in operating procedures are expected to reduce the various radioactivity contents of the plant effluent by factors of as much as 20 (see Section 4.1.1.) from current values. This effluent will then be directed to a series of solar evaporation ponds to completely eliminate the discharge of treated industrial effluent into Mortandad Canyon. There will be some increase in the amount and radioactivity content of resulting solid residues, which will be buried at the solid radioactive waste disposal site and there will be some atmospheric dispersal and dilution of tritium. This media trade off is preferable because there will be an elimination of additions to the canyon system subject to environmental transport and dispersal. The cost of the liquid waste treatment system upgrading is estimated at approximately $14 million.

Another example of a facility modification that could reduce effluents involves the decontamination of an old now-unused tritium glovebox line. Building ventilation requirements for occupational safety have resulted in the release of about 2000 Ci a year of tritium (roughly 34% of the total LASL airborne tritium releases in 1976). The decontamination and removal of this equipment would eliminate the effluent and would free some presently unusable laboratory space. This decontamination operation began in early 1979 and is expected to be completed by mid-summer of 1979. Estimated cost when completed will be about $300 thousand. Decommissioning and decontamination projects are reported in the Environmental Surveillance reports; the most recent activities are documented in Appendix H.

Nuclear reactions with air cause the largest radiation doses (calculated) to members of the public from Laboratory operations. Argon-41, a radioactive noble gas, is released by the Omega West research reactor, located in Los Alamos Canyon just south of the main townsite. It is produced by neutron activation of argon present in the reactor air. To reduce these emissions, all places in the reactor where practicable were sealed to prevent air infiltration. Carbon dioxide is injected to reduce the amount of air present in the reactor. Since the reactor is located on the canyon floor, ventilated gases are exhausted through a pipe up the side of the canyon and then up a 46 m (150 ft) stack on the top of Mesita del Buey. The transit time through this ventilation system is about one hour; this additional delay allows for decay of the ^{41}Ar (half-life 1.8 hours). These measures have reduced the ^{41}Ar emissions.

The effluents responsibile for the highest probable exposure to the public in Los Alamos are the short-lived isotopes ^{11}C, ^{13}N, and ^{13}O emitted from LAMPF operations. Air leaks in shielding around the target areas and beam channnels cause activated air to diffuse from these areas into experimental areas. To prevent experimental problems and unnecessary personnel exposure, and also to determine any source-term, the air in the target areas and beam channels is exhausted through a stack.

There is an ongoing program at LAMPF to reduce this source-term. Tops of target cells have been sealed with large sheets of metal. Cracks are being sealed with polyurethane foam. Air volumes around target cells may be able to be reduced. Isotope productions targets to be installed in the beam stop area will further reduce air volumes. With a better exhaust capability, it is anticipated, exhaust velocity may be reduced, allowing for longer decay times prior to release of exhaust gases. Thus, positive steps are being taken to reduce public exposure as far below the limits as is practicable.

In some cases the reduction of actual or potential environmental impacts would require substantive changes in research procedures, in contrast to modifications that can be made to the facilities in which research is conducted without any particular consequence for the research itself. One important example of this type of situation is the use of uncontained experiments with high explosives in materials research. The dynamic experiments permit the evaluation of properties of materials for various engineering programs. Data are collected by a variety of means including flash radiography and complex electronic sensing. Detonation of the high explosive disperses toxic materials such as mercury, beryllium, lead, and uranium into the atmosphere and onto the ground around the firing point (see Section 4.1.2 for data on atmospheric releases). It would be technologically feasible to perform all such experiments in a containment vessel so that no releases would result from the detonations. This would require some new facilities and some changes in the procedures. Data collection by radiography would be more difficult, and some of the advantages of the PHERMEX facility in particular would be lost. The time required for the experiments would be increased by as much as a factor of two. The extra time would in part be required for more difficult set up in confinement vessels and for cleanup of the vessels, after each use. Because no dilution of fine particulates would occur in the vessel considerable care would be required from an occupational health standpoint. The basic approach has been shown feasible and is in fact used for some experiments when plutonium is involved. The additional time required to conduct all experiments in containment has several implications. The most important is that it would stretch out the time required for engineering programs by about two years over the current three- to five-year period. Another possibility would keep the overall engineering period the same by expansion and construction of new facilities that would permit work on different experiments to proceed in parallel. An additional upgraded PHERMEX-type facility would permit test set up and cleanup operations to proceed concurrently. Such a facility is roughly estimated to cost in the tens of millions of dollars and would require a six- to eight-year lead time to become operational. Thus, while technically possible, the elimination of some airborne effluents that have produced no discernable effects and the elimination of some continuing contamination of relatively small land areas would be quite costly when compared to the relative environmental and human risk potential.

Conservation can be applied to various types of resource consumption. Some types of conservation can be effected by changes in operational practices, others would require some initial investment to realize gains. Water and energy use are the major areas in which conservation practices could reduce continuing impacts.

Water from the DOE supply system is distributed approximately one-third to Laboratory uses and two-thirds to the community. There are some direct water saving measures that have been and could be employed by lab operations; imposing conservation measures on the community is more complex. Within the lab it has been a practice to limit the use of landscaping that requires watering. A Southwest style of landscaping, employing rocks and gravel, has even been used to replace some areas previously in lawns. Cooling continues to be a major use of water in Laboratory operations. An estimated 12% of total Laboratory-used water goes to once-through non-contact cooling. This water is discharged with only the addition of some heat. An apparent conservation measure would be to replace once-through cooling systems with recirculating heat exchanger systems or refrigeration systems. In most instances, it is not possible to use air cooling because the minimum required temperatures are lower than summer air temperatures. The trade off is that these other cooling methods would involve significant capital expenditures. Additionally some of the once-through cooling involves numerous relatively small Laboratory cooling applications such as condensers. Such applications are often not amenable to being connected to centralized chiller systems, as program needs are constantly changing. However, cooling water use is reviewed and changes made whenever appropriate to limit once-through use both as a water conservation measure and to limit loads on waste-water treatment systems. The re-use of effluent from the sanitary sewage treatment plant serving the main technical area (see Section 3.3.1) for makeup water in the cooling towers of the power plant is an example of an effective conservation measure.

Energy conservation potential encompasses a range of possibilities from improvements and modifications in existing facilities to different methods of construction and energy supply in new facilities. Examples of energy conservation measures taken to date include the addition of extensive insulation to the new Plutonium Processing Facility, some reduction in lighting, and repair and maintenance of facilities to minimize unnecessary losses. A new facility, the National Security and Resources Study Center, derives a major fraction of its energy for heating and cooling from solar collectors. Additional measures for energy conservation in the future are the subject of a major study. Preliminary evaluations indicate the potential for total energy savings of approximately 20% over presently projected uses by 1985. The conservation measures being considered include improved insulation; changes in heating, ventilating, and air conditioning system equipment and operation; higher efficiency lighting and motors; use of waste energy from process heating; and a variety of smaller improvements. The capital and operating costs of such modifications also will be evaluated.

On a Laboratory-wide basis, minimization of impacts is a major factor in the long-range planning conducted by the Laboratory. A master plan is being developed to provide a coordinated basis for determining land use. As many elements as possible are being considered in this planning effort such as topography, site geology, transportation, existing waste-handling systems, energy and water requirements, and security. This planning will help to ensure that future Laboratory development minimizes impacts and takes full advantage of existing installations.

Institutional Alternatives

Some types of environmental impacts could be affected by institutional actions. The range of possibilities is wide and in many cases would provide administratively simple ways of avoiding or minimizing actual or potential environmental impacts. A few possibilities are outlined here.

Potential exposure of members of the general public from radiation near the Critical Assembly Facility, the Van de Graaff accelerator, and LAMPF could be reduced or eliminated by closing the roads running across the site to public access. This would require additional manned entrance gates at the Laboratory boundaries. There would be a substantial effect on transportation patterns, forcing more traffic onto the state roads and resulting in inconvenience for many residents of the area.

Some transportation-related impacts could be affected by administrative action. An implementation of mass transit for Laboratory employees in the local residential areas coupled with parking controls or other incentives to encourage car pooling could reduce gasoline consumption and the associated release of atmospheric pollutants.

Conservation of water might be extended into the realm of community use by modifications of the contract under which DOE supplies water to Los Alamos County. One possibility would be to require a strongly progressive rate structure that would be designed to limit high consumption. High consumption is a particular problem in summer months when extensive watering of home landscaping pushes the limits of capacity of the water supply system.

Additional sale of DOE-controlled land could ease some of the pressure on housing by providing more development opportunities. Release of land is pursued on a continuing basis. Judgment is carefully exercised to be certain that such land is truly excess to Laboratory operations.

Reference

9-1 U. S. Atomic Energy Commission, "Environmental Statement: Plutonium Facility, Los Alamos Scientific Laboratory, New Mexico," WASH-1507 (January 1972).

10. ENVIRONMENTAL TRADE-OFF ANALYSIS

This discussion is founded largely in qualitative and philosophical terms since it is impossible to set quantitative values on the benefits of national defense or the uncertain potential of basic research. It would be presumptuous to try to set an economic value on the cumulative and expected results of nuclear weapons research as they benefit the national defense posture. A strong nuclear capability is a matter of national policy, and the Los Alamos Scientific Laboratory has historically played an important role in carrying out that policy. Unique facilities at Los Alamos, such as the Clinton P. Anderson Meson Physics Facility (LAMPF), provide world-wide useful tools.

Other major areas in which benefits have been or are expected to be realized on a national scale by the proposed continued operation of the Laboratory include the development of alternative energy resources and applied energy technology, biomedical and environmental research, and physical research. Details of program goals within these areas are given in Chapter 2. Particularly important programs include those dealing with laser-initiated fusion, laser isotope separation, security of nuclear materials, various aspects of fission reactors, space nuclear systems, magnetic fusion, geothermal energy resources, solar energy resources, cryogenic energy storage and transmission technology, recovery of nuclear materials, biomedical research including radiobiology and cancer detection and treatment, environmental studies emphasizing the behavior of radionuclides in terrestrial ecosystems, waste management technology evaluation and development, and basic research in nuclear, molecular, and materials science. If the goals of such research are realized the benefits would encompass increased self-sufficiency of energy resources, maintained or improved quality of life, and reductions of environmental impact throughout the nation.

On a local scale, benefits are economically, physically, and socially significant. A total 1978 payroll of about $190 million is a substantial portion of household incomes in north-central New Mexico.

Much of the 111-km^2 (27,500-acre) land area reserved for Laboratory use functions as a wildlife and archaeologic preserve because of the exclusion of the general public for security and safety reasons. Certain areas used for grazing in pre-Laboratory times are regaining carrying capacity for wildlife. Employment by the Laboratory and related activities has provided significant opportunities for individuals considered as national minorities, drawn from surrounding communities. The presence of the Laboratory has made possible certain higher education opportunities in conjunction with the University of New Mexico.

Tens of thousands of man-years and hundreds of millions of dollars have already been invested in establishing the Laboratory and conducting its research programs to date. The existing physical plant has an estimated replacement value of $870 million, with most facilities having many useful years remaining. Total Laboratory-related employment FY 78 was about 8,000. Total federally funded expenditures related to the Los Alamos Project in FY 78 were about $325 million including LASL, Zia, LACI, EG&G, and the LAAO. Future expansion, especially in energy-related research areas, could require substantial increases in employment, operating budgets, and facilities.

Principal commitments of natural resources include land, water, natural gas, and electricity. The 124 major Laboratory structures are located in 31 designated technical areas within the 111-km^2

(27,500-acre) site reserved by the federal government for LASL. Only a small portion of the total land area is developed; most of it is less tangibly used to provide isolation for safety and security. Limited land areas are committed to toxic chemical and radioactive waste disposal; it may never be practical to return these areas to unrestricted alternative use. Other areas have low levels of radioactive or toxic material contamination resulting from test activities or waste disposal. These areas would probably have to be decontaminated should it be deemed desirable to release them to unrestricted alternative uses. Water for Laboratory and community use is produced from federally owned wells penetrating a deep ground water aquifer. Total production in 1978 was about 5.7 X $10^6 m^3$ (1.5 x 10^9 gal); about 35% was used by the Laboratory, with the balance sold to Los Alamos County. Natural gas is purchased from private utilities. Total consumption in 1978 was about 102 x $10^6 m^3$ (3.59 x 10^9 ft^3); about half was used to operate the federally owned electric generating plant, about 20% was distributed in the townsite by the County, and the balance was used directly by the Laboratory. Total Laboratory consumption of electricity in 1978 was about 310 x 10^6 kwh. About 30% of the electricity was produced by the generating plant, the balance was purchased.

Environmental costs are incurred as a result of managing wastes. Some land areas are committed to solid-waste burial and storage. Some radioactivity is released to the environment in filtered gaseous effluents or treated liquid effluents.

All releases are controlled to assure that radiation exposure to individuals and population groups will be limited to the lowest levels technically and economically practicable. The maximum increment of exposure, resulting from LASL operation, likely to be received by an individual in the general public in Los Alamos, is about 3.8 mrem/yr or about 1% of the DOE Radiation Protection Standard. The entire population of Los Alamos County received an estimated increment of radiation exposure of about 0.44% more than attributable to natural background.

Other secondary environmental costs are at least in part attributable to the presence of the Laboratory. These have to do with land and other natural resources committed to the resident community. Los Alamos, White Rock, and Pajarito Acres have a combined estimated 1978 population of about 19,600, the majority being employees of the Laboratory and their families. About 6,400 acres are held by private owners or the County of Los Alamos.

These largely short-term commitments and uses of the natural resources and the local environment of Los Alamos are considered minor in relation to the demonstrated and expected long-term benefits realized from such goals as maintaining national security, better and more self-sufficient use of energy resources, increased understanding in areas of basic research, and improved quality of life through biomedical research.

With reference to some of the alternatives considered in Chapter 9.0, a further comparison of costs, risks, and benefits can be summarized. The alternatives of either complete or partial termination of the Laboratory could only be implemented at great cost. The cost involved would be the loss of the benefits of the research to the nation. The resulting benefits would include only the elimination of relatively minor and controlled environmental costs. In either case, the economic costs to the local region would be severe through loss of employment, and there would be major nonproductive costs to the nation for unrealized use of existing expensive facilities with remaining useful lifetimes, for extensive decontamination and demolition, and possibly for expensive reconstruction of new facilities.

Implementation of alternative actions to reduce the environmental impacts of certain Laboratory operations could in most cases achieve the same environmental benefits as termination or relocation, with much lower costs and no loss in productivity. Some of these alternatives, such as replacement of the Plutonium Processing Facility and the industrial waste sewer, upgrading the Central Waste Treatment Plant, further conservation of energy and water, and decontamination of the tritium glove box line, were discussed in Chapter 9 and are summarized in Table 10-1. Each such alternative must be individually considered as to its monitoring and environmental cost effectiveness. Several of them are actively being planned and will be implemented if funding is made available. Others are only formulated as conceptual possibilities and will have to receive further study to determine desirability or cost effectiveness.

In summary, the anticipated benefits of the proposed continued operations at the Los Alamos Scientific Laboratory site appear to be great. Continued operation would retain the benefits of research and realize the full use of existing unique installations while minimizing specific environmental costs through suitable improvements in procedures and facilities.

TABLE 10-1

SUMMARY OF PLANNED AND POTENTIAL MITIGATING MEASURES TO REDUCE ENVIRONMENTAL IMPACTS OF THE PRESENT LASL OPERATIONS, FY 1978

Alternative	Benefit	Approximate Cost
Replacement of Plutonium Processing Facility (completed in 1978)	Reduction of risk from accident; reduction of some airborne radioactive effluents	$75 million capital cost
Replacement of Industrial Waste Sewer	Virtual elimination of potential for leak or spill of untreated radioactive liquid waste, removal of existing contaminated line	$12.5 million capital cost
Install HEPA filter on one wing of CMR Building	Eliminate release of approximately 28 μCi/yr of airborne plutonium (41% of 1976 total)	
Upgrading of Central Waste Treatment Plant	Eliminate release of approximately 90% of radioactive liquid effluent	$8.7 million capital cost
Decontamination of Tritium Glove Box Line (completed in 1979)	Elimination of airborne release of approximately 2000 Ci/yr of Tritium (34% of 1976 total)	
Decrease Release of ^{11}C, ^{13}N, and ^{13}O from LAMPF	Reduce effluents causing largest estimated incremental radiation dose. maximum about 4 mrem/year.	No unique costs since sealing cracks will be covered by operational budget.
Change from Uncontained to Contained Dynamic Experiments	Eliminate some airborne release of uranium and heavy metals, eliminate further land contamination	Increase time required for experimentation unacceptably or Ten's of millions of capital cost in duplicated facilities to permit work in parallel
Full Energy Conservation	Reduce energy consumption by 20% from projected usage by 1985	Under continuing implentation; some large capital costs expected for upgrading existing facilities
Limit Public Access to Roads Traversing Site	Reduce or eliminate increment of external radiation dose from accelerators and critical assemblies, estimated at <1 mrem/year for regular traveler	Operating cost for additional guard stations; inconvenience for local residents
Encourage Water Conservation in Community by Change in Rate Structure	Reduced water consumption	Administrative
Mass Transit/Car Pooling	Reduced gasoline consumption; reduced atmospheric emissions	Not evaluated; some capital and operational cost

11. COMMENTS

On June 27, 1978, the Department of Energy (DOE) issued for public review and comment a Draft Environmental Statement (DEIS) that assessed the environmental impact associated with the current and continuing activities at the Los Alamos Scientific Laboratory. Comment letters were received from 15 individuals and organizations which are reproduced in Appendix I of this document. The substantive concerns raised in the written comments pertained to: (1) the mission and location of the Laboratory, (2) the biological behavior of radionuclides, (3) water supply for Los Alamos, (4) waste management, (5) accident analysis, (6) radiological doses and dose interpretations, (7) radioactive materials in the environment, (8) transportation of radioactive materials, and (9) additional details desired. The following discussion has been prepared to clarify and summarize the areas of substantive concern which were raised and to indicate the general nature of the modifications which have been made in the EIS in response thereto.

1. Mission and Location of the Laboratory

There were several comments requesting that the EIS include an evaluation of the environmental effects of nuclear war, the design and testing of nuclear weapons, and that it generally be expanded so as to address the U.S. Nuclear Weapons Program. One comment in particular requested a more detailed analysis of the environmental impacts of closing or relocating the Laboratory.

This environmental impact statement was prepared to provide input for decisions on the continued operation of DOE's Los Alamos Scientific Laboratory. Nuclear weapons research and development, which is conducted in support of U.S. nuclear weapons requirements, has been and continues to be a principal mission of LASL operations. Requirements for nuclear weapons are imposed on DOE by Congress and the President as part of the overall national defense policy. The scope of the EIS, therefore, is limited to addressing the site specific environmental impacts of LASL operations and does not include assessing the potential environmental impacts of U.S. policy to develop and test nuclear weapons.

The options of terminating or completely relocating the Laboratory are not considered realistically available. Accordingly, the discussion of the environmental consequences for these alternatives has been left somewhat general in scope. A more detailed or site-specific treatment of the Laboratory relocation alternative is not considered justified. Rather, the emphasis was left on those alternatives that could be considered feasible, albeit subject to the directions of Congress for funding, and that offer potential for minimizing or eliminating adverse impacts of continued operations.

2. Biological Behavior of Radionuclides

A number of comments focused on the General Biological Behavior of radionuclides portion of Section 4.1.3, which is a brief summary of background information on the effects of radionuclides in biological organisms including man. The comments suggested a number of more current references, some published after the DEIS, and amplifications to avoid misunderstandings.

Suitable changes were made in the text and appropriate references were added in this section and the section on accidents.

3. Water Supply for Los Alamos

Comments and questions were raised with regard to the issues of adequacy of future water supply for Los Alamos, effects on the quantity and quality of the ground water aquifer, and effects on the Rio Grande river as a consequence of continued or increased pumpage of wells for the Laboratory and community water supply.

Additional information on the geohydrology of the area, data from test wells at a distance from the pumped fields, elaboration on the relationship between pumped ground water and recently acquired surface water, and updated use trends were included in Sections 3.1.2, 3.3.1, 4.1.1, and 4.3.1. In summary, given the estimated thickness of the fresh water aquifer (about 1200 m or 3900 ft) and drawdown of less than 1 m (3 ft) since 1960 at a distance of several km from the pumping fields, there is virtually no indication of physical effect on the aquifer on a regional basis. The surface water available from Los Alamos will be useful to offset any effect on the Rio Grande from increased pumpage in the future. Reduced consumption of water during the last two years led to an annual rate for 1978 that was about 30% lower than in 1976. Thus, the projections made in the DEIS now appear too high and it is likely that the physically and legally available water will suffice for several decades unless drastic unanticipated changes in growth occur. Detailed data on the quality of surface and ground water is included in the new Appendix H.

4. Waste Management

The wide variety of questions regarding management of radioactive wastes at LASL generally fit into three subcategories: additional detail on operations, environmental conditions and effects related to current and historic waste disposal, and plans for future management of solid waste disposal or retrievable storage areas.

Many changes, additions, updates, and new references were incorporated into Section 3.3.3 and other appropriate portions of the text regarding liquid, solid, and airborne radioactive wastes. The portion of Section 3.3.3 on solid wastes was completely revised to avoid some apparent confusion introduced by the prior organization of the discussion. Additions were made to indicate the extent of the continuing environmental and technology development studies conducted at LASL, especially in relation to solid waste management. References to numerous publicly available reports documenting the detailed results of such studies were added. Additional detail on the nature and location of current liquid and airborne releases, and their associated environmental consequences, has been incorporated into the document by addition of the 1978 monitoring report for LASL as Appendix H.

Future plans for managing solid waste disposal areas are now under study. This major effort, initiated after the DEIS was published, will examine all aspects of historic and current solid waste disposal areas at LASL in an effort to formulate and evaluate alternatives that range from continuation of present practices to various engineered improvements and possible retrieval of some previously buried wastes. It is expected that this effort will take several years to complete and will include extensive consideration of environmental consequences of such alternatives.

One area of particular concern expressed by some commentors related to the limited amount of information regarding waste disposal practices at LASL during the 1940s and early 1950s. Some of the wording in the DEIS could have been interpreted to indicate that there was no information at all available for certain periods with the implication that there might be numerous unknown locations containing radioactive wastes. This is not the case. There are sufficient records and historic documents from the early years of the Laboratory to identify the areas used for waste disposal and the general nature of wastes placed in the areas. It is often true that for such areas there is no detailed documentation on the precise amounts, forms, and location of the radioactive wastes within these disposal areas. However, these limitations on records do not detract materially from our understanding or analysis of the associated environmental impacts. Environmental monitoring data is available to indicate the satisfactory containment of solid wastes, or, in the case of former liquid waste disposal areas, residual environmental levels that are low enough to preclude the inference of any significant, or even measurable, dose increments. More information is desirable, and is currently being collected by the continuing waste management research and future alternatives studies, to ensure the best possible decisions regarding actions that may be desirable to preclude or responsibly limit potential long-term consequences.

5. Accident Analysis

Comments on the accident analysis in the DEIS (Section 4.2) included requests for historic information, additional detail regarding bases for individual accident evaluations, and responses to accidents including emergency plans and decontamination procedures.

The accident section was updated to reflect changes in procedures and facilities that have eliminated the possibility of some accidents previously considered. New descriptions were included of the scope of standard operating procedures designed to reduce the possibility of accidents and of the range of emergency response plans including means for coordinating with the local government. Some additional information on historic accidents, more detailed bases for evaluations, and decontamination procedures and costs were incorporated by brief summary and highlighting the availability of other publicly available documents and some new references. The basis for certain dose calculations was clarified as appropriate in the text and tables. Related information on flood hazards was incorporated into Section 3.1.2.

6. Radiological Doses and Dose Assessment

Several comments indicated the desirability of including information on occupational exposure doses received by workers at LASL. Several specific comments related to clarification of the basis for some of the measurements and calculations for doses received by the public under current normal operating conditions. One comment requested additional interpretation of the calculated and measured doses in terms of health consequences.

Summary information for occupational exposures during the last three years and a breakdown of occupational exposures during 1978 have been provided in Section 4.1.3.

The portion of Section 4.1.3 entitled "Calculated and Measured Doses" has been completely revised. It was updated, and additional discussion was included regarding assumptions for dose calculations. Supplementary and more detailed information is also now available by reference to Appendix H which provides details of the environmental measurements made during 1978, including full information on sampling procedures, analytical techniques, quality control of results, statistical methodology, and interpretation. An interpretation of the doses was provided in the form of calculated individual risk expressed as a probability of injury. This approach was chosen as being more easily understood than numbers of estimated health effects.

Estimates of radiological risks were made based on the risk factors for total stocastic risk provided by the International Commission on Radiological Protection (ICRP) in ICRP Publication 26.[4-101A] The risk can be expressed as a probabilty of injury to an individual in the exposed population. Use of the dose equivalent for the maximum individual in the population provides an upper bound for probability of injury. For example, using the ICRP risk factors the probability of injury for a Los Alamos resident due to whole body irradiation from natural sources is 1 in 83,000 per year. For the average whole body dose attributable to LASL operations for an individual living in the Los Alamos townsite the added risk of injury by cancer is estimated as between zero and 1 in 12,000,000 per year. Other risks of injury can be calculated from tables of dose equivalents using the following ICRP factors:

Uniform whole body irradiation	
1. Cancer mortality	10^{-4} per rem
2. Hereditary effects	4×10^{-5} per rem
Tissues at Risk	
1. Gonads-Hereditary risk	10^{-4} per rem
2. Red bone marrow - leukemia	2×10^{-5} per rem
3. Bone cancer	5×10^{-6} per rem
4. Lung cancer	2×10^{-5} per rem
5. Thyroid	5×10^{-6} per rem
6. Breast cancer	2.5×10^{-5} per rem
7. All other tissues	5×10^{-5} per rem

Differences in age structure can alter the risk factors used. However, at the time of this writing the full report of the Advisory Committee on the Biological Effects of Ionizing Radiations, Division of Medical Sciences, National Academy of Sciences, referred to as BEIR III, other than the summary, is not available. Considerations in the forthcoming BIER III report may provide different risk factors.

7. Radioactive Materials in the Environment

Some comments expressed concern that there were radioactive materials in the environment as a result of past and current operations at LASL.

It is true that past and current operations at LASL have contributed or continue to contribute some radioactivity to the environment. The additional information included in this final Environmental Impact Statement, particularly the data for interpreting incremental health risks, the detailed environmental monitoring data in Appendix H, and the discussions of additional investigations as the Formerly Utilized Sites Remedial Action Program, and the waste management alternatives studies, provides an improved perspective for assessing significance. It is believed that there are no unacceptable risks being imposed on the public. Nevertheless, considerable effort is being expended to further reduce the risks of continuing operations and limit the long-term effects of past, present, and future operations.

8. Transportation of Radioactive Materials

Several comments indicated the desirability of addressing the transportation of radioactive materials associated with the operation of LASL both on and off the Laboratory site.

Two completely new sections were developed and have been included in the final Environmental Impact Statement. Section 3.3.5 includes a description of procedures, regulations, and actual operations for transportation of radioactive materials at LASL as well as shipments to and from Los Alamos made by government and commercial carriers. Data is presented to summarize the transportation activity during 1978. Section 4.2.14 provides an evaluation of both routine normal transportation and potential accidents. The evaluation was performed using a statistical methodology developed for the Nuclear Regulatory Commission's Environmental Impact Statement on Transportation of Radioactive Material by Air and Other Modes (NUREG-0170, December 1977).

9. Additional Details Desired

Numerous comments were received requesting additional detail be included in the final Environmental Impact Statement. Often an answer to such comments already appeared elsewhere in the document. Additional cross-referencing has been utilized to remedy these difficulties wherever possible. In cases where additional information was available in other documents every attempt was made to include the most up-to-date references cited at appropriate points in the text. In some cases, summarized or more current information has been incorporated at an appropriate location in the text.

One substantial addition to the document was the incorporation of the annual monitoring report, "Environmental Surveillance at Los Alamos During 1978," as Appendix H in this document. References to this appendix were noted in the text at numerous locations where it could be consulted for additional or updated details.

APPENDIX A

VEGETATION SPECIES FOUND IN THE LOS ALAMOS VICINITY

		COMMUNITY TYPE (ELEVATION IN METERS)[a]					
		2850	Meadow 2850	2550	2250	1950	1650
Aceraceae	Maple Family						
Acer glabrum	Rocky Mountain maple	X					
Acer negundo	boxelder						X
Amaranthaceae	Amaranth Family						
Amaranthus retroflexus	redroot amaranth						X
Anacardiaceae	Cashew Family						
Rhus trilobata	skunk-bush sumac				X	X	X
Berberidaceae	Barberry Family						
Berberis fendleri	Colorado barberry				X		
Berberis repens	creeping mahonia				X		
* Betulaceae	Birch Family						
Betula occidentalis	water birch						
Boraginaceae	Borage Family						
Cryptantha fendleri	Fendler cryptantha				X	X	
Cryptantha jamesii	James cryptantha					X	
Lappula Redowskii	stickseed			X			
* Lithospermum multiflorum	many-flowered stoneseed			X	X		
* Lithospermum incisum	gromwell						
* Mertensia franciscana	blue bell						
Cactaceae	Cactus Family						
Echinocereus viridiflorus	varied hedgehog cactus					X	
* Mammillaria vivipara	ball cactus						
Opuntia compressa var. macrorhiza	tuberous pricklypear						X
Opuntia erinacea var. xanthostemma	Grizzlybear pricklypear					X	X
Opuntia imbricata	walking stick cholla						X
Opuntia phaeacantha	purple-fruited pricklypear						X
* Opuntia polyacantha	plains pricklypear						
Campanulaceae	Bell Flower Family						
Campanula rotundifolia	bluebell		X	X			
Capparidaceae	Caper Family						
Cleome serrulata	Rocky Mountain beeplant						X

[a]Samples were collected at given elevation; see Table 3.1.4-1 for community type.

*Presumed, not verified; no community association given.

			COMMUNITY TYPE (m)				
		2850	Meadow 2850	2550	2250	1950	1650
Caprifoliaceae	Honeysuckly Family						
* Lonicera involucrata	bearberry honeysuckle						
Virburnum lentago	black haw			X			
Caryophyllaceae	Pink Family						
Arenaria fendleri	Fendler sandwort		X				
Celastraceae	Bitter-sweet Family						
Pachystima myrsinites	myrtle boxleaf	X					
Chenopodiaceae	Goosefoot Family						
Atriplex canescens	four-winged saltbush						X
Chenopodium cycloides	goosefoot				X		
Chenopodium fremontii	Fremont goosefoot		X				
Chenopodium leptophyllum	slimleaf goosefoot		X		X		
Chenopodium incisum	goosefoot					X	
Chenopodium watsoni	goosefoot						X
* Kochia scoparia	summer cyprus						
Salsola kali	Russian thistle						X
Compositae	Sunflower Family						
Achillea lanulosa	western yarrow	X	X	X			
Agoseris aurantiaca	orange agoseris		X				
Agoseris glauca	pale agoseris						X
Ambrosia artemisiifolia	common ragweed						X
Antennaria parvifolia	pussytoes		X	X	X		
Artemisia cana	silver sagebrush				X		
Artemisia dracunculoides	false-tarragon sagebrush				X	X	X
Artemisia filifolia	sand sagebrush						X
Artemisia franseriodes	ragweed sagebrush	X		X			
Artemisia frigida	fringed sagebrush		X		X	X	
Artemisia ludoviciana	Louisiana wormwood	X					X
Artemisia tridentata	big sagebrush						X
Aster arenosus	sand aster						X
Aster Bigelovii	Bigelow aster				X		
* Aster glaucodes	aster						

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
*	Aster hirtifolius	baby aster						
	Aster occidentalis	western aster		X		X		
	Aster pauciflorus	aster				X	X	X
	Bahia dissecta	ragleaf bahia				X	X	
	Bidens cernua	beggartick						X
	Brickellia californica	California brickellia						X
	Brickellia grandiflora	tasselflower brickellia						X
*	Chrysopsis villosa var. foliosa	leafy goldaster			X	X	X	X
	Chrysopsis villosa	hairy goldaster						
	Chrysothamnus nauseosus	rubber rabbitbrush					X	X
	Chrysothamnus parryi howardi	rabbitbrush			X	X	X	X
*	Cirsium neomexicanum	New Mexico thistle						
	Cirsium pallidum	thistle		X				
	Cirsium undulatum	wavyleaf thistle				X		
	Conyza canadensis	horseweed						X
*	Coreopsis tinctoria	tickseed						
*	Dyssodia pappos a	dogweed						
	Erigeron divergens	spreading fleabane						X
	Erigeron flagellaris	trailing fleabane		X		X		
*	Erigeron divergens var. nudiflorus	fleabane						
	Erigeron peregrinus	aster fleabane	X	X				
	Erigeron speciosus	Oregon fleabane			X	X		
	Erigeron subtrinervis	three-nerve fleabane		X	X			
	Erigeron superbus	pale erigeron	X					
	Eupatorium herbaceum	white thoroughwort			X			
*	Gaillardia pulchella	Blanket-flower						
	Gnaphalium chilense	cottonbatting cudweed						X
*	Grindelia aphanactis	gumweed						
	Grindelia fastigiata	rayless gumweed						X
	Gutierrezia Sarothrae	broom snakeweed				X	X	X

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Haplopappus gracilis	star goldenweed					X	X
	Haplopappus parryi	Parry goldenweed	X		X			
	Helianthus annuus	sunflower				X	X	X
	Hieracium sp.	hawkweed		X	X			
	Hymenopappus filifolius	thread-leaved hymenopappus					X	
	Hymenoxys acaulis	stemless hymenoxys				X	X	
*	Hymenoxys argentea	Perky Sue						
*	Hymenoxys Brandegei	actinea						
	Hymonoxys richardsonii	pingue				X		
	Liatris punctata	dotted gayfeather				X		
	Pericome caudata	tailleaf pericome						X
*	Psilostrophe tagetina	wooly paper flower						
	Rudbeckia laciniata	black-eyed Susan		X				
	Senecio ambrosioides	western golden groundsel		X	X			
	Senecio crassulus	thick-leaf groundsel		X				
*	Senecio fendleri	Fendler groundsel						
*	Senecio longilobus	threadleaf groundsel						
	Senecio multicapitatus	ragwort groundsel						X
*	Senecio neomexicanus	New Mexico groundsel						
	Senecio wootonii	Wooten groundsel	X		X			
	Solidago spathulata	decumbent goldenrod		X	X	X		
	Solidago nana	baby goldenrod			X			
*	Sonchus asper	prickly sowthistle						
	Taraxacum officinale	common dandelion						X

		COMMUNITY TYPE (m)					
		2850	Meadow 2850	2550	2250	1950	1650
Thelesperma megapotamicum	Hopi-tea greenthread				X		X
Thelesperma trifidum	greenthread				X	X	
* Townsendia excapa	ground daisy						
Tragopogon dubius	goatsbeard		X	X	X		
* Verbesina encelioides	golden crownbeard						
Viguiera multiflora	showy goldeneye				X		
Xanthium strumarium	cocklebur						X
Convolvulaceae	Morning Glory Family						
* Convolvulus arvensis	field bindweed						
Cruciferae	Mustard Family						
Descurainia obtusa	tansy mustard				X	X	
* Draba spectabilis	whitlow grass						
Erysimum argillosum	wallflower		X				
* Erysimum inconspicuum	smallflower						
Lesquerella intermedia	bladderpod					X	
* Sisymbrium linearifolium	tumblemustard						
Sisymbrium altissimum	tumblemustard						X
Thelypodium integrifolium	thelypody					X	
Thlaspi fendleri	wild candytuft			X			
Cupressaceae							
Juniperus monosperma	one-seed juniper				X	X	X
Juniperus scopulorum	Rocky Mountain juniper				X	X	X
Cyperaceae	Sedge Family						
Cyperus fendlerianus	Fendler flatsedge			X	X		
Elaeagnaceae	Oleaster Family						
Elaeagnus angustifolia	Russian-olive						X
Equisetaceae	Horsetail Family						
Equisetum laevigatum	smooth horsetail						X
Ericaceae	Heath Family						
Arctostaphylos uva-ursi	bearberry	X		X			

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Vaccinium myrtillus	myrtle whortleberry	X					
	Euphorbiaceae	Spurge Family						
	Croton texensis	Texas doveweed						X
	Euphorbia geyeri	Euphorbia					X	X
	Euphorbia serpyllifolia	thymeleaf spurge					X	X
	Fagaceae	Beech Family						
	Quercus gambelii	Gambel oak			X	X		
*	Quercus grisea	gray oak						
	Quercus turbinella	shrub live oak				X	X	
	Fumariaceae	Fumitory Family						
*	Corydalis aurea	golden corydalis						
	Gentianaceae	Gentian Family						
	Gentiana Bigelovii	Bigelow gentian				X		
	Gentiana plebeia	Rocky Mountain gentian	X	X				
	Swertia radiata	deer's ears	X					
	Geraniaceae	Geranium Family						
	Erodium cicutarium	Alfileria storksbill			X			
	Geranium Fremontii	Fremont geranium		X	X			
	Geranium Richardsonii	Richardson geranium	X			X		
	Gramineae	Grass Family						
*	Agropyron cristatum	crested wheatgrass						
	Agropyron latiglume	wheatgrass	X	X				
	Agropyron trachycaulum	slender wheatgrass		X		X		
	Agrostis semiverticillata	waterbentgrass						X
*	Andropogon scoparius	little blue-stem						
	Aristida adscensionis	six-weeks three-awn						X
	Aristida arizonica	Arizona three-awn				X		
	Aristida Fendleriana	Fendler three-awn					X	
	Aristida longiseta	red three-awn						X

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
*	*Aristida oligantha*	prairie three-awn						
	Blepharoneuron tricholepis	pine dropseed		X	X	X		
	Boutelous aristidoides	needle grama						X
	Bouteloua curtipendula	side-oats grama						X
	Bouteloua eriopoda	black grama					X	
	Bouteloua gracilis	blue grama						X
*	*Bromus ciliatus*	Fringed bromegrass						
*	*Bromus frondosus*	weeping bromegrass						
	Bromus marginatus	mountain brome		X	X	X		
*	*Bromus japonicus*	Japanese bromegrass						
	Bromus purgans	Canada brome	X		X			
*	*Bromus tectorum*	cheatgrass						
*	*Eragrostis barrelieri*	lovegrass						
	Festuca sororia	ravine fescue	X					
	Festuca Thurberi	Thurber fescue		X				
	Hilaria jamesii	galleta grass					X	
	Koeleria cristata	prairie junegrass		X	X			
	Muhlenbergia montana	mountain muhly		X	X	X		
*	*Muhlenbergia pulcherrima*	muhly						
*	*Panicum capillare*	witchgrass						
	Panicum obtusum	vine-mesquite						X
	Phleum alpinum	alpine timothy		X				
*	*Poa fendleriana*	mutton grass						
	Poa nevadensis	Nevada bluegrass		X				
*	*Poa Pattersoni*	Patterson bluegrass						
	Poa pratensis	Kentucky bluegrass				X		
	Polypogon monspeliensis	rabbitfoot grass						X
*	*Schedonnardus paniculatus*	tumblegrass						
*	*Setaria geniculata*	bristle grass						
	Sitanion hystrix	bottlebrush squirreltail		X		X		

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
*	*Sporobolus asper*	dropseed						
	Sporobolus contractus	spike dropseed						X
	Sporobolus cryptandrus	sand dropseed					X	X
*	*Stipa neomexicana*	New Mexico feathergrass						
	Tridens pulchellus	fluffgrass						X
	Trisetum spicatum	spike trisetum	X					
	Iridaceae	Iris Family						
	Iris missouriensis	Rocky Mountain iris	X	X				
	Sisyrinchium montanum	blue-eyed-grass		X				
	Labiatae	Mint Family						
*	*Agastache pallidiflora*	giant hyssop						
	Hedeoma drummondii	false pennyroyal					X	
	Mentha sp.	mint			X			
	Monarda austromontana							
	Leguminosae	Bean Family						
	Astragalus insularis	milkvetch						X
*	*Astragalus amphioxys*	milkvetch						
*	*Astragalus crassicarpus*	ground plum milkvetch						
*	*Astragalus emoryanus*	milkvetch						
	Astragalus missouriensis	milkvetch					X	
*	*Astragalus shortianus*	milkvetch						
*	*Glycyrrhiza lepidota*	American licorice						
	Lathyrus sp.	sweetpea	X	X	X			
*	*Lupinus argenteus*	silvery lupine						
*	*Medicago lupulina*	black medick						
*	*Medicago sativa*	alfalfa						
	Melilotus alba	white sweetclover						X
*	*Melilotus officinalis*	yellow sweetclover						
*	*Petalostemon compactus*	prairie clover						

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Petalostemon villosus	prairie clover						X
	Robinia neomexicana	New Mexico locust						X
	Phaseolus leiospermus	wildbean						X
	Thermopsis montanum	goldenpea						
*	Thermopsis pinetorum	goldenpea	X		X			
	Trifolium hybridum	alsike clover		X				
	Trifolium pratense	red clover	X					
	Trifolium procumbens	low hop clover						X
	Trifolium repens	white clover						X
	Vicia americana	American vetch		X		X		
	Vicia producta	vetch	X					
	Liliaceae	Lily Family						
	Allium cernuum	nodding onion		X		X	X	
*	Androstephium breviflorum	funnellily						
	Calochortus gunnisonii	Gunnison mariposalily		X				
	Smilacina racemosa	false Solomonplume	X					
	Smilacina stellata	starry Solomonplume	X	X	X			
	Yucca baccata	datil yucca						X
	Yucca glauca	soapweed yucca					X	
	Zygadenus elegans	mountain deathcamas	X					
	Linaceae	Flax Family						
	Linum puberulum	yellow flax				X	X	
	Loasaceae	Blazing Star Family						
	Mentzelia pumila	golden blazing-star						X
*	Mentzelia rusbyi	blazing star						
	Malvaceae	Mallow Family						
*	Sphaeralcea cocinea	scarlet globe mallow						
*	Sphaeralcea fendleri	globe mallow						
*	Sphaeralcea incana	globe mallow						

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Nyctaginaceae	Four-O'clock Family						
	Boerhaavia coulteri	Coulter spiderling						X
	Mirabilis linearis	four-o'clock						X
	Mirabilis multiflora	Colorado four-o'clock					X	X
	Oleaceae							
	Forestiera neomexicana	New Mexico forestiera					X	X
	Onagraceae	Evening-primrose Family						
	Epilobium angustifolium	fireweed	X					
*	Gaura parviflora	butterfly weed						
*	Oenothera albicaulis	evening primrose						
	Oenothera caespitosa eximia	tufted evening-primrose				X		
	Oenothera coronopifolia	evening-primrose				X		
	Oenothera harwegii var. toumeya	evening-primrose					X	
*	Oenothera Hookeri	evening primrose						
*	Oenothera primiveris	evening primrose						
	Orchidaceae	Orchid Family						
	Goodyera oblongifolia	western rattlesnake plantain	X					
	Malaxis Soulei	addersmouth				X		
	Oxalidaceae	Wood-sorrel Family						
	Oxalis violacea	violet wood-sorrel	X					
	Pinaceae	Pine Family						
	Abies concolor	white fir	X		X			
	Picea engelmanni	Engelmann spruce	X					
	Picea pungens	blue spruce	X					
	Pinus edulis	piñon pine				X	X	
	Pinus flexilis	limber pine	X		X			
	Pinus ponderosa	ponderosa pine			X			
	Pseudotsuga taxifolia	Douglas-fir			X			
	Polemoniaceae	Phlox Family						
	Gilia aggregata	skyrocket gilia			X	X		
*	Gilia calcarea	gilia						

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Gilia longiflora	gilia					X	X
*	Gilia texana	gilia						
	Polygonaceae	Buckwheat Family						
*	Eriogonum pauciflorum	umbrella plant						
	Eriogonum racemosum	redroot buckwheat	X					
	Eriogonum jamesii	antelope sage				X	X	
	Portulacaceae	Purslane Family						
	Portulaca oleracea	common purslane						X
	Primulaceae	Primrose Family						
*	Androsace septentrionalis	rock jasmine						
	Pyrolaceae	Wintergreen Family						
	Pyrola secunda	sidebells wintergreen	X					
	Pyrola virens	wintergreen	X					
	Ranunculaceae	Buttercup Family						
	Actaea arguta	western baneberry	X		X			
*	Aquilegia elegantula	red columbine						
	Clematis ligusticifolia	western virginsbower						X
*	Clematis pseudoalpina	virgin's bower						
*	Pulsatilla ludoviciana	pasque flower						
*	Thalictrum fendleri	meadowrue						
	Rhamnaceae	Buckthorn Family						
*	Ceanothus fendleri	buckbush						
	Rosaceae	Rose Family						
	Amelanchier alnifolia	Saskatoon serviceberry						X
*	Amelanchier utahensis	Utah serviceberry						
	Cercocarpus montanus	true mountain mahogany	X					
	Fallugia paradoxa	Apache-plume					X	X
	Fragaria americana	American strawberry	X		X	X		
	Fragaria bracteata	bracted strawberry	X					
	Fragaria ovalis	wild strawberry	X	X	X			

			COMMUNITY TYPE (m)					
			2850	Meadow 2850	2550	2250	1950	1650
	Geum sp.	avens		X				
	Potentilla anserina	silverweed cinquefoil		X	X	X	X	
	Potentilla crinita	cinquefoil					X	
	Potentilla fruticosa	shrubby cinquefoil		X				
	Potentilla gracilis	goldcup cinquefoil	X	X				
	Potentilla hippiana	horse cinquefoil		X		X		
	Potentilla pulcherrima	beauty cinquefoil	X	X	X	X		
	Prunus americana	American plum			X			
	Prunus virginiana	common chokecherry			X			
*	Rosa neomexicana	New Mexico rose						
*	Rosa woodsii	Wood's rose						
	Rubus parviflorus	western thimbleberry	X					
	Rubus strigosus	American red raspberry	X		X			
	Rubiaceae	Madder Family						
	Galium boreale	northern bedstraw		X				
	Galium triflorum	sweetscented bedstraw	X					
	Rutaceae	Rue Family						
*	Ptelea trifoliata	hoptree						
	Salicaceae	Willow Family						
	Salix bebbiana	bebb willow	X					
*	Salix irrorata	willow						
*	Salix lasiandra	Pacific willow						
	Populus angustifolia	narrowleaf cottonwood						X
	Populus tremuloides	quaking aspen	X		X			
	Saxifragaceae	Saxifrage Family						
*	Jamesia americana	cliffbush waxflower						
	Ribes cereum	wax currant			X	X		
	Ribes inerme	whitestem gooseberry				X		
	Ribes montigenum	gooseberry currant			X			
	Scrophulariaceae	Figwort Family						
	Castilleja integra	wholeleaf paintbrush					X	X

		COMMUNITY TYPE (m)					
		2850	Meadow 2850	2550	2250	1950	1650
Castilleja linariaefolia	Wyoming paintbrush	X		X			
Castilleja rhexifolia	splitleaf paintbrush		X				
Orthocarpus luteus	yellow owlclover		X				
Orthocarpus purpureo albus	purplewhite owlclover				X		
Verbascum thapsus	flannel mullein						X
* *Penstemon barbatus*	scarlet beardtongue						
* *Penstemon jamesii*	beardtongue						
* *Penstemon oliganthus*	beardtongue						
Penstemon virgatus	wandbloom penstemon				X		
Solanaceae	Nightshade Family						
Datura meteloides	Indian apple						X
Physalis fendleri	groundcherry						X
Solanum sp.	nightshade						X
Solanum elaeagnifolium	white horsenettle						X
Tamaricaceae	Tamarisk Family						
* *Tamarix gallica*	salt cedar						
Typhaceae	Cat-tail Family						
* *Typha latifolia*	cattail						
Umbelliferae	Carrot Family						
* *Foeniculum vulgare*	fennel						
Harbouria trachypleura	whiskbroom parsley			X			
Pseudocymopterus montanus	mountain parsley		X	X	X	X	
Valerianaceae	Valerian Family						
* *Valeriana capitata*	valerian						
Violaceae	Violet Family						
* *Viola canadensis*	Canada violet						
* *Viola nephrophylla*	violet						
Vitaceae	Grape Family						
Vitis vulpina	wild grape						X
Zygophyllaceae	Caltrop Family						
Kallstroemia hirsutissima	caltrop						X
Tribulus terrestris	puncturevine						X

APPENDIX B

PRELIMINARY LIST OF INVERTEBRATE TAXONOMIC GROUPS IN THE LOS ALAMOS ENVIRONS

Phylum	Class	Order	Estimated No. Species
Annelida	Oligochaeta (segmented worms)		1
Nematomorpha	Gordiaceae (round worms)		2
Arthropoda	Chilopoda (centipedes)		5
	Diplopoda (millipedes)		1
	Arachnida	Acarina (ticks and mites)	>80
		Solpugida (sun "scorpions")	1
		Chelonethida (false scorpions)	1
		Phalangida (Harvestment)	1
		Araneida (spiders) 16 families	74-100
	Insecta	Thysanura	1
		Collembola	32-37
		Orthoptera	4-6
		Psocoptera	3-4
		Thysanoptera	4-6
		Hemiptera	28-33
		Homoptera	18-23
		Coleoptera	46-51
		Mecoptera	1
		Neuroptera	3-5
		Rhaphidioidea	1
		Trichoptera	1
		Lepidoptera	9-12
		Diptera	50-57
		Siphonaptera	2-3
		Hymenoptera (Formicidae 22-25)	54-65
		Protura	1
		Diplura	3
		Total No. Species	430-535

APPENDIX C

MAMMALS IN LOS ALAMOS ENVIRONS

		Verified to be in Area	Presence Reported or Suspected	Threatened[a] or Endangered
Cervidae				
Odocoileus hemionus	Rocky Mountain Mule Deer	X		
Cervus canadensis	Rocky Mountain Elk	X		
Erethizontidae				
Erethizon dorsatum	Porcupine	X		
Sciuridae				
Tamiasciurus hudsonicus	Red Squirrel	X		
Sciurus aberti	Tassel-eared Squirred	X		
Spermophilus variegatus	Rock Squirrel	X		
Spermophilus spilosoma	Spotted Ground Squirrel		X	
Spermophilus lateralis	Golden Mantled Ground Squirrel	X		
Eutamias dorsalis	Cliff Chipmunk	X		
Eutamias quadrivittatus	Colorado Chipmunk	X		
Eutamias minimus	Least Chipmunk	X		
Cynomys gunnisoni	White-tailed Prairie Dog		X	
Leporidae				
Sylvilagus nuttallii	Mountain Cottontail	X		
Lepus californicus	Black-tailed Jackrabbit	X		
Ochotonidae				
Ochotona princeps	Pika	X		
Muridae				
Mus musculus	House Mouse	X		
Heteromyidae				
Dipodomys ordii	Ord's Kangaroo Rat		X	
Perognathus flavus	Silky Pocket Mouse		X	
Cricetidae				
Peromyscus leucopus	White-Footed Mouse		X	

a) Presently classified as Group (Endangered Species) or Group 2 (Threatened Species) as defined by the State of New Mexico Game Commission Regulation No. 563, as adopted January 24, 1975.

		Verified to be in Area	Presence Reported or Suspected	Threatened[a] or Endangered
Cricetidae (cont.)				
Peromyscus maniculatus	Deer Mouse	X		
Peromyscus boylii	Brush Mouse	X		
Peromyscus truei	Piñon Mouse	X		
Reithrodontomys megalotis	Western Harvest Mouse	X		
Clethrionomys gapperi	Gappers Red-Backed Vole	X		
Microtus montanus	Montane Vole	X		
Microtus longicaudus	Long-tailed Vole		X	
Microtus pennsylvanicus	Meadow Vole	X		
Geomyidae				
Thomomys bottae	Valley Pocket Gopher	X		
Thomomys talpoides	Northern Pocket Gopher	X		
Soricidae				
Sorex nanus	Drawf Shrew	X		
Sorex vagrans	Vagrant Shrew	X		
Procyonidae				
Procyon lotor	Raccoon	X		
Mustelidae				
Taxidea taxus	American badger	X		
Martes americana	Pine Marten		X	
Mustela erminea	Ermine/Short-tail Weasel		X	
Mustela nigripes	Black-footed Ferret		X	X
Mephitis mephitis	Striped Skunk	X		
Canidae				
Urocyon cinereoargenteus	Grey Fox	X		
Vulpes fulva	Red Fox	X		
Canis latrans	Coyote	X		
Ursidae				
Ursus americanus	Black Bear	X		
Felidae				
Lynx rufus	Bobcat	X		

		Verified to be in Area	Presence Reported or Suspected	Threatened[a] or Endangered
Felis concolor	Mountain Lion	X		
Castoridae				
Castor canadensis	Beaver		X	
	AMPHIBIANS AND REPTILES			
Plethodontidae				
Plethodon neomexicanus	Jemez Mountain Salamander		X	X
Teiidae				
Chemidophorus spp.	Whiptail	X		
Iquanidae				
Phrynosoma spp.	Horned Lizard	X		
Crotaphytus collaris	Collared Lizard	X		
Sceloporus magister	Desert Spiny Lizard	X		
Viperidae				
Crotalus viridis	Prairie Rattlesnake	X		
Colubridae				
Pituophis melanoleucas	Bull Snake	X		
Thamnophis sirtalis	Common Garter Snake	X		
Thamnophis elegans	Western Garter Snake	X		
Lampropeltis getulus	Common King Snake	X		
	FISH			
Catostomidae				
Catostomus commersoni	White sucker	X		
Carpoides carpio	Carp-sucker	X		
Cyprinidae				
Cyprinus carpio	Carp	X		
Hybopsis sp.	Chub	X		
Salmonidae				
Salmo trutta	Brown trout	X		

APPENDIX D

BIRDS KNOWN OR EXPECTED TO OCCUR IN THE ENVIRONS OF THE LOS ALAMOS SCIENTIFIC LABORATORY

		Nest in area	Summer resident[a]	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Gaviiformes								
Gavia immer	Common loon						X	
Podicipiformes								
Podiceps caspicus	Eared grebe						X	
Anseriformes								
Branta canadensis	Canada goose					X		
Anas platyrhynchos	Mallard					X		
Anas strepera	Gadwall					X		
Anas acuta	Pintail					X		
Anas carolinensis	Green-winged teal					X		
Anas discors	Blue-winged teal					X		
Anas cyanoptera	Cinnamon teal					X		
Mareca americana	American widgeon					X		
Spatula clypeata	Shoveler					X		
Aythya collaris	Ring-necked duck					X		
Aythya affinis	Lesser scaup					X		
Bucephala albeola	Bufflehead					X		
Oxyura jamaicensis	Ruddy duck						X	
Mergus merganser	Common merganser	X	X					
Falconiformes								
Cathartes aura	Turkey vulture		X					
Accipiter gentilis	Goshawk			X				
Accipiter striatus	Sharp-shinned hawk			X				
Accipiter cooperii	Cooper's hawk	X	X					
Buteo jamaicensis	Red-tailed hawk			X				
Buteo albonotatus	Zone-tailed hawk[c]	X	X					
Buteo lagopus	Rough-legged hawk				X			
Buteo regalis	Ferruginous hawk[c]			X				
Aquila chrysaetos	Golden eagle	X	X			X		
Circus cyaneus	Marsh hawk				X			
Pandion haliaetus	Osprey[c]					X		
Falco mexicanus	Prairie falcon[c]			X				
Falco peregrinus	Peregrine falcon[b]			X				
Falco columbarius	Merlin (pigeon hawk)				X			
Falco sparverius	American kestrel			X				

a)This category only covers summer residents that nest in the area. Clearly yearlong residents also nest in the area.

b)Presently classified as Group I (Endangered Species) as defined by the State of New Mexico Game Commission Regulation No. 563, as adopted January 24, 1975.

c)Presently classified as Group II (Threatened Species) as defined above.

		Nest in area	Summer resident[a]	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Galliformes								
Dendragapus obscurus	Blue grouse			X				
Callipepla squamata	Scaled quail			X				
Lophortyx gambelii	Gambel's quail			X				
Melagris gallopavo	Wild turkey			X				
Gruiformes								
Grus americana	Whooping crane[b]					X		
Grus canadensis	Sandhill crane					X		
Rallus limicola	Virginia rail						X	
Porzana carolina	Sora						X	
Charadriiformes								
Charadrius vociferus	Killdeer					X		
Capella gallinago	Common snipe					X		
Actitis macularia	Spotted sandpiper					X		
Catoptrophorus semipalmatus	Willet					X		
Steganopus tricolor	Wilson's phalarope					X		
Recurvirostra americana	American avocet						X	
Larus delawarensis	Ring-billed gull						X	
Larus pipixcan	Franklin's gull					X		
Columbiformes								
Columba fasciata	Band-tailed pigeon	X	X					
Zenaida macroura	Mourning dove	X	X					
Cuculiformes								
Coccyzus americanus	Yellow-billed cuckoo					X		
Geococcyx californianus	Roadrunner				X		X	
Strigiformes								
Otus asio	Screech owl		X					
Otus flammeolus	Flammulated owl	X	X					
Bubo virginianus	Great horned owl	X	X					
Glaucidium gnoma	Pygmy owl			X				
Strix occidentalis	Spotted owl		X					
Aegolius acadicus	Saw-whet owl				X			
Caprimulgiformes								
Phalaenoptilus nuttallii	Poor-will	X	X					
Chordeiles minor	Common nighthawk	X	X					

		Nest in area	Summer[a] resident	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Apodiformes								
Aeronautes saxatalis	White-throated swift	X	X					
Archilocus alexandri	Black-chinned hummingbird	X	X					
Selasphorus platycercus	Broad-tailed hummingbird	X	X					
Selasphorus rufus	Rufous hummingbird		X					
Stellula calliope	Calliope hummingbird					X		
Piciformes								
Colaptes auratus	Common flicker			X				
Melanerpes formicivorus	Acorn woodpecker			X				
Melanerpes erythrocephalus	Red-headed woodpecker[c]		X					
Sphyrapicus varius	Yellow-bellied sapsucker			X				
Sphyrapicus thyroideus	Williamson's sapsucker	X	X					
Dendrocopos villosus	Hairy woodpecker			X				
Dendrocopos pubescens	Downy woodpecker			X				
Dendrocopos scalaris	Ladder-backed woodpecker		X					
Asyndesmus lewis	Lewis' woodpecker					X		
Passeriformes								
Tryannus vociferans	Cassin's kingbird	X	X					
Myiarchus cinerascens	Ash-throated flycatcher	X	X					
Sayornis saya	Say's phoebe	X	X					
Empidonax traillii	Traill's flycatcher	X	X					
Empidonax hammondii	Hammond's flycatcher	X	X					
Empidonax oberholseri	Dusky flycatcher		X					
Empidonax wrightii	Gray flycatcher	X	X					
Empidonax difficilis	Western flycatcher	X	X					
Contopus sordidulus	Western wood pewee							
Nuttallornis borealis	Olive-sided flycatcher	X	X					

		Nest in area	Summer resident[a]	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Passeriformes (cont)								
Eremophila alpestris	Horned lark					X		
Tachycineta thalassina	Violet-green swallow	X	X					
Iridoprocne bicolor	Tree swallow						X	
Cyanocitta cristata	Blue jay						X	
Cyanocitta stelleri	Steller's jay			X				
Aphelocoma coerulescens	Scrub jay			X				
Corvus corax	Common raven			X				
Corvus brachyrhynchos	Common crow			X				
Nucifraga columbiana	Clark's nutcracker	X	X					
Gymnorhinus cyanocephalus	Piñon jay			X				
Parus atricapillus	Black-capped chickadee					X		
Parus gambelli	Mountain chickadee			X				
Parus inornatus	Plain titmouse			X				
Psaltriparus minimus	Common bushtit					X		
Sitta carolinensis	White-breasted nuthatch			X				
Sitta canadensis	Red-breasted nuthatch				X			
Certhia familiaris	Brown creeper				X	X		
Sitta pygmea	Pygmy nuthatch			X				
Cinclus mexicanus	Dipper						X	
Troglodytes aedon	House wren	X	X					
Catherpes mexicanus	Canyon wren	X	X					
Salpinctes obsoletus	Rock wren			X				
Dumetella carolinensis	Catbird					X		
Toxostoma rufum	Brown thrasher				X			
Oreoscoptes montanus	Sage thrasher				X			

		Nest in area	Summer[a] resident	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Passeriformes (cont)								
Turdus migratorius	Robin			X				
Hylocichla guttata	Hermit thrush		X					
Hylocichla ustulata	Swainson's thrush		X				X	
Seiurus noveboracensis	Northern waterthrush							
Sialia mexicana	Western bluebird			X				
Sialia currucoides	Mountain bluebird			X				
Myadestes townsendi	Townsend's solitaire			X				
Polioptila caerulea	Blue-gray gnatcatcher		X					
Regulus satrapa	Golden-crowned kinglet			X				
Regulus calendula	Ruby-crowned kinglet			X				
Anthus spinoletta	Water pipit					X		
Bombycilla garrulus	Bohemian waxwing				X			
Bombycilla cedrorum	Cedar waxwing				X			
Lanius excubitor	Northern shrike				X			
Lanius ludovicianus	Loggerhead shrike			X				
Sturnus vulgaris	Starling			X				
Vireo solitarius	Solitary vireo	X	X					
Vireo olivaceus	Red-eyed vireo						X	
Vireo gilvus	Warbling vireo					X		
Vermivora celata	Orange-crowned warbler					X		
Vermivora ruficapilla	Nashville warbler					X		
Vermivora virginiae	Virginia's warbler	X	X					
Dendroica petechia	Yellow warbler							
Dendroica caerulescens	Black-throated blue warbler							

Passeriformes (cont)		Nest in area	Summer[a] resident	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Dendroica coronata	Yellow-rumped warbler			X				
Dendroica nigrescens	Black-throated gray warbler		X					
Dendroica townsendi	Townsend's warbler							
Dendroica virens	Black-throated green warbler					X	X	
Dendroica graciae	Grace's warbler		X					
Dendroica pennsylvanica	Chestnut-sided warbler						X	
Oporornis tolmiei	MacGillivray's warbler						X	
Icteria virens	Yellow-breasted chat					X		
Wilsonia pusilla	Wilson's warbler					X		
Setophaga ruticilla	American redstart					X		
Passer domesticus	House sparrow			X				
Sturnella neglecta	Western meadowlark						X	
Xanthocephalus zanthocephalus	Yellow-headed blackbird					X		
Agelaius phoeniceus	Red-winged blackbird					X		
Icterus bullockii	Bullock's oriole		X					
Euphagus carolinus	Rusty blackbird						X	
Euphagus cyanocephalus	Brewer's blackbird	X	X					
Quiscalus quiscula	Common grackle		X					
Molothrus ater	Brown-headed cowbird		X					
Piranga ludoviciana	Western tanager	X	X					
Piranga flava	Hepatic tanager		X					
Piranga rubra	Summer tanager	X	X					
Pheucticus ludovicianus	Rose-breasted grosbeak						X	
Pheucticus melanocephalus	Black-headed grosbeak	X	X					
Guiraca caerulea	Blue grosbeak		X					

Passeriformes (cont.)		Nest in area	Summer[a] resident	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Passerina cyanea	Indigo bunting					X		
Passerina amoena	Lazuli bunting		X					
Hesperiphona vespertina	Evening grosbeak			X				
Carpodacus cassinii	Cassin's finch		X					
Carpodacus mexicanus	House finch			X				
Pinicola enucleator	Pine grosbeak					X		
Leucosticte tephrocotis	Gray-crowned rosy finch					X		
Spinus pinus	Pine siskin	X	X					
Spinus psaltria	Lesser goldfinch			X				
Loxia curvirostra	Red crossbill			X				
Pipilo chlorurus	Green-tailed towhee	X	X					
Pipilo erythrophthalmus	Rufous-sided towhee			X				
Pipilo fuscus	Brown towhee			X				
Calamospiza melanocorys	Lark bunting					X		
Pooecetes gramineus	Vesper sparrow					X		
Chondestes grammacus	Lark sparrow	X	X					
Amphispiza belli	Sage sparrow					X		
Junco hyemalis	Dark-eyed junco				X			
Junco caniceps	Gray-headed junco			X				
Spizella arborea	Tree sparrow					X		
Spizella passerina	Chipping sparrow	X	X					
Spizella pallida	Clay-colored sparrow							
Spizella breweri	Brewer's sparrow					X		
Spizella pusilla	Field sparrow							
Zonotrichia querula	Harris' sparrow				X			
Zonotrichia leucophrys	White-crowned sparrow					X		
Zonotrichia atricapilla	Golden-crowned sparrow							

		Nest in area	Summer[a] resident	Yearlong resident	Winter resident	Migrant	Casual or irregular	Uncommon
Passeriformes (cont)								
Zonotrichia albicollis	White-throated sparrow						X	
Passerella iliaca	Fox sparrow						X	
Melospiza lincolnii	Lincoln's sparrow				X			
Melospiza georgiana	Swamp sparrow						X	
Melospiza melodia	Song sparrow			X				

APPENDIX E

SUMMARY OF ANNUAL ATMOSPHERIC RADIOACTIVITY MONITORING IN LOS ALAMOS VICINITY

		1973		1974		1975	
Number and Type of Sampling Locations	Type of Analysis Performed	Mean Radioactivity Concentration	% CG[e]	Mean Radioactivity Concentration	% CG[e]	Mean Radioactivity Concentration	% CG[e]
11 regional[a]	gross α	1.2×10^{-15} mCi/mℓ	1.9	1.4×10^{-15} mCi/mℓ	2.3	1.0×10^{-15} mCi/mℓ	1.8
10 perimeter[b]	gross α	1.0×10^{-15} mCi/mℓ	1.6	1.3×10^{-15} mCi/mℓ	2.2	1.1×10^{-15} mCi/mℓ	1.9
5 on-site[c]	gross α	1.0×10^{-15} mCi/mℓ	0.05	1.3×10^{-15} mCi/mℓ	0.1	1.1×10^{-15} mCi/mℓ	0.01
11 regional	gross β	39×10^{-15} mCi/mℓ	0.13	175×10^{-15} mCi/mℓ	0.6	76×10^{-15} mCi/mℓ	0.3
10 perimeter	gross β	39×10^{-15} mCi/mℓ	0.13	173×10^{-15} mCi/mℓ	0.6	80×10^{-15} mCi/mℓ	0.3
5 on-site	gross β	38×10^{-15} mCi/mℓ	0.004	167×10^{-15} mCi/mℓ	0.02	77×10^{-15} mCi/mℓ	0.01
11 regional	tritiated H_2O	12×10^{-12} mCi/mℓ	0.01	17×10^{-12} mCi/mℓ	0.01	20×10^{-12} mCi/mℓ	0.01
10 perimeter	tritiated H_2O	37×10^{-12} mCi/mℓ	0.02	35×10^{-12} mCi/mℓ	0.02	42×10^{-12} mCi/mℓ	0.02
5 on-site	tritiated H_2O	49×10^{-12} mCi/mℓ	0.001	84×10^{-12} mCi/mℓ	0.002	104×10^{-12} mCi/mℓ	0.002
11 regional	^{238}Pu	15×10^{-18} mCi/mℓ	0.01	2.1×10^{-18} mCi/mℓ	0.003	0.8×10^{-18} mCi/mℓ	0.001
10 perimeter	^{238}Pu	18×10^{-18} mCi/mℓ	0.02	1.5×10^{-18} mCi/mℓ	0.002	0.6×10^{-18} mCi/mℓ	0.001
5 on-site	^{238}Pu	10×10^{-18} mCi/mℓ	0.0004	1.3×10^{-18} mCi/mℓ	0.0001	0.5×10^{-18} mCi/mℓ	0.00003
11 regional	^{239}Pu	21×10^{-18} mCi/mℓ	0.03	27×10^{-18} mCi/mℓ	0.05	19×10^{-18} mCi/mℓ	0.03
10 perimeter	^{239}Pu	26×10^{-18} mCi/mℓ	0.04	27×10^{-18} mCi/mℓ	0.05	24×10^{-18} mCi/mℓ	0.04
5 on-site	^{239}Pu	15×10^{-18} mCi/mℓ	0.0007	26×10^{-18} mCi/mℓ	0.001	20×10^{-18} mCi/mℓ	0.001
11 regional	Uranium	110 pg/m^3	0.001	80 pg/m^3	0.001	45 pg/m^3	0.0005
10 perimeter	Uranium	110 pg/m^3	0.001	90 pg/m^3	0.001	37 pg/m^3	0.0004
5 on-site	Uranium	140 pg/m^3	0.0001	90 pg/m^3	0.00004	45 pg/m^3	0.00002
4 regional	^{241}Am	8×10^{-18} mCi/mℓ	0.004	---	---	4×10^{-18} mCi/mℓ	0.02
5 perimeter	^{241}Am	5×10^{-18} mCi/mℓ	0.002	---	---	8×10^{-18} mCi/mℓ	0.004
2 on-site	^{241}Am	5×10^{-18} mCi/mℓ	0.0001	---	---	5×10^{-18} mCi/mℓ	0.0001

a)0.5 - 50 km from the LASL boundary.
b)<0.5 km from the LASL boundary.
c)Within the LASL boundary.
d)16 off-site, 10 perimeter, and 10 on-site stations for this year only.
e)Percent of Concentration Guides.

APPENDIX F
GLOSSARY OF TERMS

The following brief glossary of terms used in this report is intended to aid the reader to understand special technical terms with particular meanings. It is not a comprehensive listing and does not include technical terms which are readily found in standard commonly used dictionaries. A selected list of units of measurement with symbols and conversions and common metric prefixes is included at the end.

ACTIVATION - the induction of radioactivity in material by irradiation with neutrons.

ACTIVITY - a measure of the rate at which a material is emitting nuclear radiations, usually given in terms of the number of nuclear disintegrations occuring in a given quantity of material over a unit of time. The common unit of activity is the curie (Ci)

ALPHA RADIATION - an emission of particles (helium nuclei) from a material undergoing nuclear transformation; the particles have a nuclear mass number of four and a charge of plus two (symbol. a).

AQUIFER - a subsurface formation containing sufficient saturated permeabile material to yield significant quantities of water.

ARKOSIC - pertaining to arkose, a quartz-feldspar sandstone usually formed in desert areas by rapid erosion and deposition of feldspar-rich igneous rocks.

BACKGROUND (RADIATION, LEVELS) with respect to radiation, the amounts that are produced by naturally occurring radioactive materials in the crust of the earth, cosmic radiations, and the fallout from nuclear weapons tests. (In the U.S. natural radiation backgrounds vary from place to place by roughly a factor of two.)

BETA RADIATION - essentially weightless charged particles (electrons and positrons) emitted from the nucleus of an atom undergoing nuclear transformation (symbol: b).

BIOME - a major regional ecological community of plants and animals extending over large natural areas. The plants of land biomes comprise the "formations" of plant ecologists.

BREEDER REACTOR - a reactor having the capability of both producing consumable power and usable fuel.

CONCENTRATION GUIDE - the average concentration of a radionuclide in air or water to which a worker or member of the general population may be continuously exposed without exceeding acceptable radiation dose standards.

CONDUCTANCE (CONDUCTIVITY) - a common way to express general mineral content of water. It is literally the specific electrical conductance (or electrical conductivity); a measure of the capacity of water to conduct an electrical current under standard test conditions. Conductivity increases as concentrations of dissolved and ionized constituents increase. It is actually measured as resistance (in millionths of an ohm) but reported as micromhos (the reciprocal of millionths of an ohm). As a rule of thumb, dissolved solids concentration (in mg/ℓ) is 60-70 percent of specific conductance (in mocromhos). Metric units for conductance are milliSiemens/meter (mS/m) where 1 mS/m = 10μmho/cm.

COOLING TOWER - a structure designed for the evaporative cooling of heated water.

CREEP - a process for migration of surface soil particles under the influence of wind. Loose soil particles in the millimeter size range may roll and bounce along the surface when wind speeds are strong enough.

CRITICAL - capability of fissionable nuclear material to sustain a chain reaction at a constant level.

DACITIC - pertaining to dacite, a fine-grained extrusive rock with the same general composition as andesite but having a less calcic feldspar.

DAUGHTER - the nuclide formed in the radioactive disintegration of a first nuclide (parent).

DECAY - with respect to radiation, the disintegration from one nuclide to another until a stable (nonradioactive) daughter is reached.

DEPLETED URANIUM - uranium consisting primarily of ^{238}U and depleted of the ^{235}U isotope. Depleted uranium generally contains less than 0.2 wt % ^{235}U.

DOSE COMMITMENT - the integrated dose that results from an intake of radioactive material, evaluated from the beginning of intake to a later time (usually 50 years); also used for the longer term integrated dose to which people are considered committed because radioactive material has been released to the environment.

ECOTONE - a fairly broad transition region between adjacent biomes.

ENRICHED-URANIUM - uranium treated to increase the concentration of the ^{235}U isotope.

EVAPOTRANSPIRATION - loss of water from the soil both by evaporation from the surface and by transpiration from the plants growing therein.

EXTERNAL PENETRATING RADIATION - see penetrating radiation.

FECAL COLIFORMS - a group of bacteria common to the intestinal tracts of man and other animals. The presence of fecal coliforms in water is an indicator of domestic sewage pollution and of potentially dangerous bacterial contamination, although they themselves are not disease causing.

FIREBREAK - a barrier from which fuels have been removed and utilized to stop or check fires.

FUELBREAK - a selected strategically located strip or block of land, normally 2 to 7 chains wide, where esthetic values have been maintained or enhanced by fuel modifications. Vehicular access is provided where possible. Fuelbreaks provide a safe location from which firefighters can attack and control a fire. It may or may not have a cleared fireline constructed in it prior to fire occurrence.

GALLERY - a horizontal storage reservoir constructed for the purpose of intercepting ground water for distribution.

GAMMA RADIATION - electromagnetic energy emitted during a nuclear transition (symbol: γ).

GAUSSIAN (PLUME, MODEL) - a class of atmospheric turbulent diffusion estimation schemes in which pollutant material is assumed to be distributed as a normal, or gaussian function about its average downwind trajectory. The models typically conserve mass and require inputs of plume spread rate with travel distance as a function of meteorological conditions.

GROSS-ALPHA - total alpha radiation activity with no discrimination between specific radionuclides.

GROSS-BETA - total beta radiation activity with no discrimination between specific radionuclides.

GROSS-GAMMA - total gamma radiation activity with no discrimination between specific radionuclides.

HARDNESS - derived largely from contact with soil and rock formations, hardness in water is caused by divalent metallic cations, principally calcium, magnesium, strontium, ferrous iron, and manganour ions. Hard waters are as satisfactory for human consumption as soft waters. Because of their adverse action with soap, however, the use for cleaning purposes is quite unsatisfactory, and they produce scale in hot water pipes, heaters, boilers, and other units in which the temperature of water is increased materially.

HEATING DEGREE DAYS - *the departure of the mean daily temperature below a given standard (in this case, 65°F or 18.3°C). One degree-day is counted for each degree of departure below the standard during one day. Degree days are usually accumulated over a month, season, or year.

*from Glossary of Meteorology, R. E. Hushke, ed., AMS, Boston, 1959.

HEPA FILTER - a high efficiency particulate air filter having a fibrous medium which produces a particulate removal efficiency of at least 99.97% for all measurable (0.3 microns and larger) particles on a count basis.

HYDRAULIC CONDUCTIVITY - the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

ION EXCHANGE - a process for selectively removing a constituent (for example, a hard water softener) from a waste stream by reversibly transferring ions between an insoluble solid and the waste stream. The exchange medium (usually a column of resin or soil) can then be washed and the waste collected or taken to a disposal site.

LATITIC - pertaining to latite, a porphyritic extrusive rock having plagioclose and potassium feldspar (probably mostly feldspar) present in nearly equal amounts as phenocrysts, little or no quartz, and a finely crystalline to glassy groundmass, which may contain obscure potassium feldspar, the extrusive equivalent of monzonite.

LIMBURGITIC - pertaining to limburgite, a dark-colored porphyritic extrusive igneous rock having olivine and clinopyroxene as phenocript minerals in an alkali-rich glassy groundmass which may have microlites of clinophropene, olivene, and opaque oxides; some nepheline and/or analcime may be present, and feldspars are typically absent.

MAN-REM - a unit of population dose, often the average dose per individual expressed in rems times the population affected.

MESIC - pertaining to a soil's water relationships intermediate between dry (xeric) and wet (hydric).

NUCLIDE - a species of atom having a specific mass, atomic number, and nuclear energy state.

OVERSTORY - the layer of foliage in a forest canopy; also, its trees.

PARENT - a nuclide which disintegrates radioactively to form a second nuclide (daughter).

PASCAL - a measure of pressure in units of N/m^2 (newtons per square meter).

PENETRATING RADIATION - forms of radiant energy capable of passing through significant thickness of solid material; these usually include gamma rays, xrays, and neutrons.

PERCHED AQUIFER - unconfined ground water separated from the underlying main aquifer by an unsaturated zone.

PIEZOMETRIC SURFACE - imaginary surface representing the static head of ground water.

population dose - the total ionizing radiation dose received by the entire population in question. It is the sum of the doses received by each member of the population.

rad - a unit of measure for the absorbed dose of radiation; one rad equals 100 ergs absorbed per gram of material.

radionuclide - a radioactive nuclide.

radiation protection standards - the radiation protection standards are a set of maximum external and internal radiation dose equivalents (rem) for individuals in controlled and uncontrolled areas and populations. The standards are stated for calendar quarters and annual exposure periods for the whole body and specific organs or tissues.

radio-telemetry - a process involving the attachment to an animal of a small radio transmitter that emits long wave frequencies permitting investigators to pinpoint location of the animal.

rem - a unit of measure for the dose of ionizing radiation that has the same biological effect as one roentgen of xrays. One rem is approximately equal to one rad for X, gamma, or beta radiation.

SANIDINE - a high-temperature mineral of the alkali feldspar group. It is a highly disordered, monoclinic form of orthoclase occurring in clear, glassy, often tabular crystals embedded in unaltered acid volcanic rocks.

SCINTILLATION (COUNTING) - light flashes produced in crystalline material by ionizing radiation; measurement of the level of activity of the source.

SHERD - variation of shard. A fragment of a brittle substance, as of an earthen vessel (pottery).

STORAGE COEFFICIENT - the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

THERMOLUMINESCENT DOSIMETER - a passive detector, usually containing a phosphor material, used to cumulatively measure incidental ionizing radiation (in this case, terrestrial gamma and cosmic radiation). Upon heating, the detector emits visible photons in a quantity proportional to the amount of ionizing radiation to which the detector was exposed.

TRANSMISSIVITY - a coefficient relating the volumetric flow through a unit width of groundwater to the driving force (hydraulic potential). It is a function of the porous medium, fluid properties, and saturated thickness of the aquifer.

TRANSURANIC WASTE - those wastes contaminated with long-liver alpha-emitting radionuclides including ^{233}U and its daughter products, plutonium and transplutonium nuclides (those with atomic number ≥ 94) except ^{238}Pu and ^{241}Pu.

TRICKLING FILTER - a biological sewage treatment technology consisting of a bed of "filter" medium, an underdrainage system, and a mechanism for distributing the sewage evenly over the surface of the "filter." The word "filter" is a misnomer. There is no straining or filtering involved. Actually, the "filter" is a bed of gravel, broken stone, etc., on which a film of growth develops. As sewage percolates through the bed, the organisms in the film of growth utilize the organic matter in the sewage for growth.

UNDERSTORY - a layer of foliage in a forest below the level of the main canopy; also, the trees forming such a layer.

WIND ROSE - a diagrammatic representation of the distribution of prevailing wind directions at a given location; some variations include wind speed groupings by direction.

APPENDIX G

UNITS OF MEASUREMENT WITH SYMBOLS AND SELECTED METRIC-ENGLISH CONVERSIONS

Unit	Symbol	Conversion
British thermal unit	BTU	1056 joules
Cubic Centimeter	cm^3 (cc)	0.034 ounce (fluid)
Cubic meter	m^3	264 gallons, 35.3 ft^3
Curie	Ci	3.7×10^{10} disintegraions/sec
Gallons per minute	gpm	3.78 liters/min
Gram	g	0.035 ounce (avoirdupois)
Kilogram	kg	2.2 lb
Kilometer	km	0.621 mile
Kilowatt hour	kwh	3.6×10^6 joules
Liter	ℓ	0.264 gallon
Meter	m	3.28 feet
Million electron volts	MeV	
Million gallons per day	MGD	3785 m^3/day
Thousand cubic feet	MCF	
Thousand kilowatt hours	MKWH	3.6×10^9 joules
Thousand standard cubic feet	MSCF	28.3 m^3
Metric ton	MT	1000 kg
Parts per million	ppm	
Pascal	Pa	0.021 lb/ft^2
Pounds per square inch	pse	6895 Pa
Roentgen	R	

METRIC PREFIXES

Prefix	Symbol	Multiplier
mega	M	10^6
kilo	k	10^3
deca	da	10^1
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	P	10^{-12}

APPENDIX H

LA-7800-ENV
UC-41
Issued: April 1979

Environmental Surveillance at Los Alamos During 1978

Environmental Surveillance Group

The four most recent reports in this series, unclassified, are LA-5977-PR, LA-6321-MS, LA-6801-MS, and LA-7263-MS.

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

CONTENTS

APPENDIXES

FIGURES

TABLES

ENVIRONMENTAL SURVEILLANCE AT LOS ALAMOS DURING 1978

Environmental Surveillance Group

ABSTRACT

This report documents the environmental surveillance program conducted by the Los Alamos Scientific Laboratory (LASL) in 1978. Routine monitoring for radiation and radioactive or chemical substances is conducted on the Laboratory site and in the surrounding region to determine compliance with appropriate standards and permit early identification of possible undesirable trends. Results and interpretation of the data for 1978 on penetrating radiation, chemical and radiochemical quality of ambient air, surface and ground water, municipal water supply, soils and sediments, food, and airborne and liquid effluents are included. Comparisons with appropriate standards and regulations or with background levels from natural or other non-LASL sources provide a basis for concluding that environmental effects attributable to LASL operations are minor and cannot be considered likely to result in any hazard to the population of the area. Results of several special studies provide documentation of some unique environmental conditions in the LASL environs.

I. INTRODUCTION

This report documents results of the environmental monitoring program conducted at the Los Alamos Scientific Laboratory (LASL) during 1978. In keeping with Department of Energy (DOE) and Laboratory intent to describe and document possible influences of operations on the environment, this report provides data and interpretation of environmental conditions in the vicinity of LASL.

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

Since its inception in 1943, the Laboratory's primary mission has been nuclear weapons research and development. National security programs include weapons development, laser fusion, nuclear materials research, and laser isotope separation, as well as basic research in the areas of physics, chemistry, and engineering that support such programs. Research on peaceful uses of nuclear energy has included space applications, power reactor programs, magnetic fusion, and radiobiology and medicine. In more recent years other programs have been added in astrophysics, earth sciences, energy resources, nuclear fuel safeguards, lasers, and biomedical and environmental research.

A unique combination of facilities, which contribute to the various research programs, exists at Los Alamos. These facilities include the 800 MeV proton accelerator, a tandem Van de Graaff accelerator, the Laser Laboratory, the Magnetic Fusion Laboratory, a flash radiographic facility, and a 10 megawatt research reactor. Some of these facilities encourage participation and joint projects by researchers from other laboratories and research facilities.

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

A. Physical Setting

The Los Alamos Scientific Laboratory and adjacent residential areas of Los Alamos and White Rock are located in Los Alamos County in north-central New Mexico, about 100 km NNE of Albuquerque and 40 km NW of Santa Fe by air (Fig. 1). The 111 km^2 Laboratory site and adjacent communities are situated on the Pajarito Plateau. The Plateau consists of a series of mesas separated by deep canyons cut by intermittent streams that trend eastward from an altitude of about 2400 m at the flank of the Jemez Mountains to about 1800 m at the eastern margin where it terminates above the Rio Grande valley. Most Laboratory and community developments are confined to the mesa tops (see Fig. 2 and inside front cover). The surrounding land is essentially undeveloped with large tracts of land north, west, and south of the Laboratory site held by the U.S. Forest Service and U.S. Park Service (see land ownership map inside back cover). San Ildefonso Indian lands border the Laboratory to the east.

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

B. Geology-Hydrology

The canyons and mesas in the Laboratory area are underlain by the Bandelier Tuff composed of ashfall and ashflow pumice and rhyolite tuff that form the surface of the Pajarito Plateau. The tuff ranges from nonwelded to welded and is in excess of 300 m thick in the western part of the Pajarito Plateau and thins to about 80 m toward the east above the Rio Grande. It was deposited as a result of a major eruption of a volcano in the Jemez Mountains to the west about 1.1—1.4 million years ago.

The tuffs lap onto the older volcanics of the Tschicoma Formation, which form the Jemez Mountains along the western edge of the Plateau and are underlain by the fanglomerate of the Puye Formation in the central and eastern edge along the Rio Grande. The Chino Mesa basalts interfinger with the fanglomerate along the river. These formations overlie the siltstone/sandstone Tesuque Formation, which extends across the Rio Grande Valley, and are in excess of 1000 m thick.

Los Alamos area surface water is primarily intermittent stream flow. Springs on the flanks of the Jemez Mountains supply base flow to the upper reaches of some canyons, but the amount is insufficient to maintain surface flows across the Laboratory area before it is depleted by evaporation, transpiration, and infiltration. Runoff from heavy thunderstorms or heavy snowmelt reaches the Rio Grande several times a year. Effluents from sanitary sewage, industrial waste treatment plants, and cooling tower blowdown are released to some canyons at rates sufficient to maintain surface flows for as long as 1.5 km.

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

Intermittent stream flows in canyons of the Plateau have deposited alluvium that ranges from less than 1 m to as much as 30 m in thickness. The alluvium is quite permeable in contrast to the underlying volcanic tuff and sediments. The intermittent runoff in the canyons infiltrates the alluvium until its downward movement is impeded by the less permeable tuff and volcanic sediment. This results in a shallow alluvial ground water body that moves

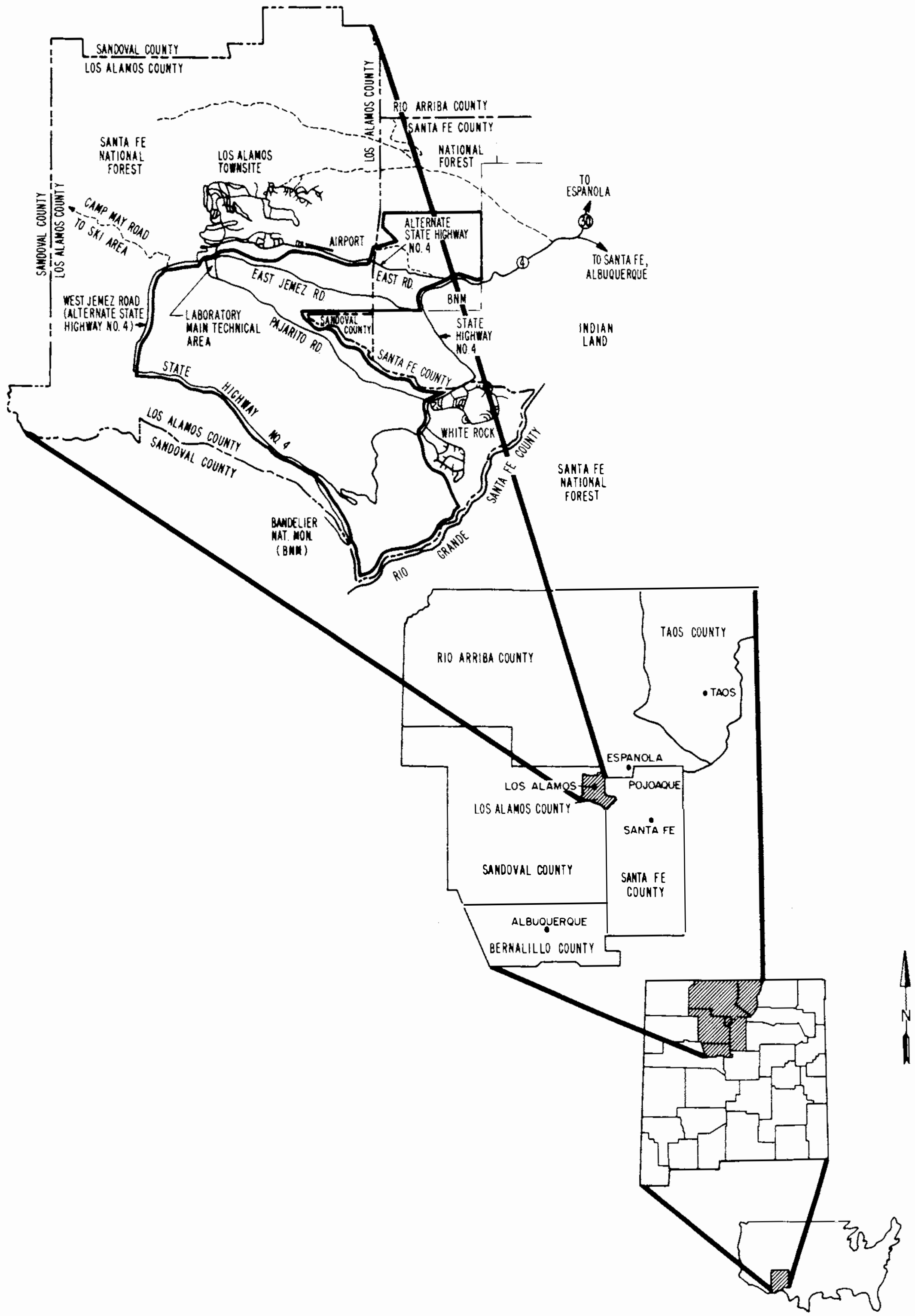


Fig. 1.

Regional location of Los Alamos.

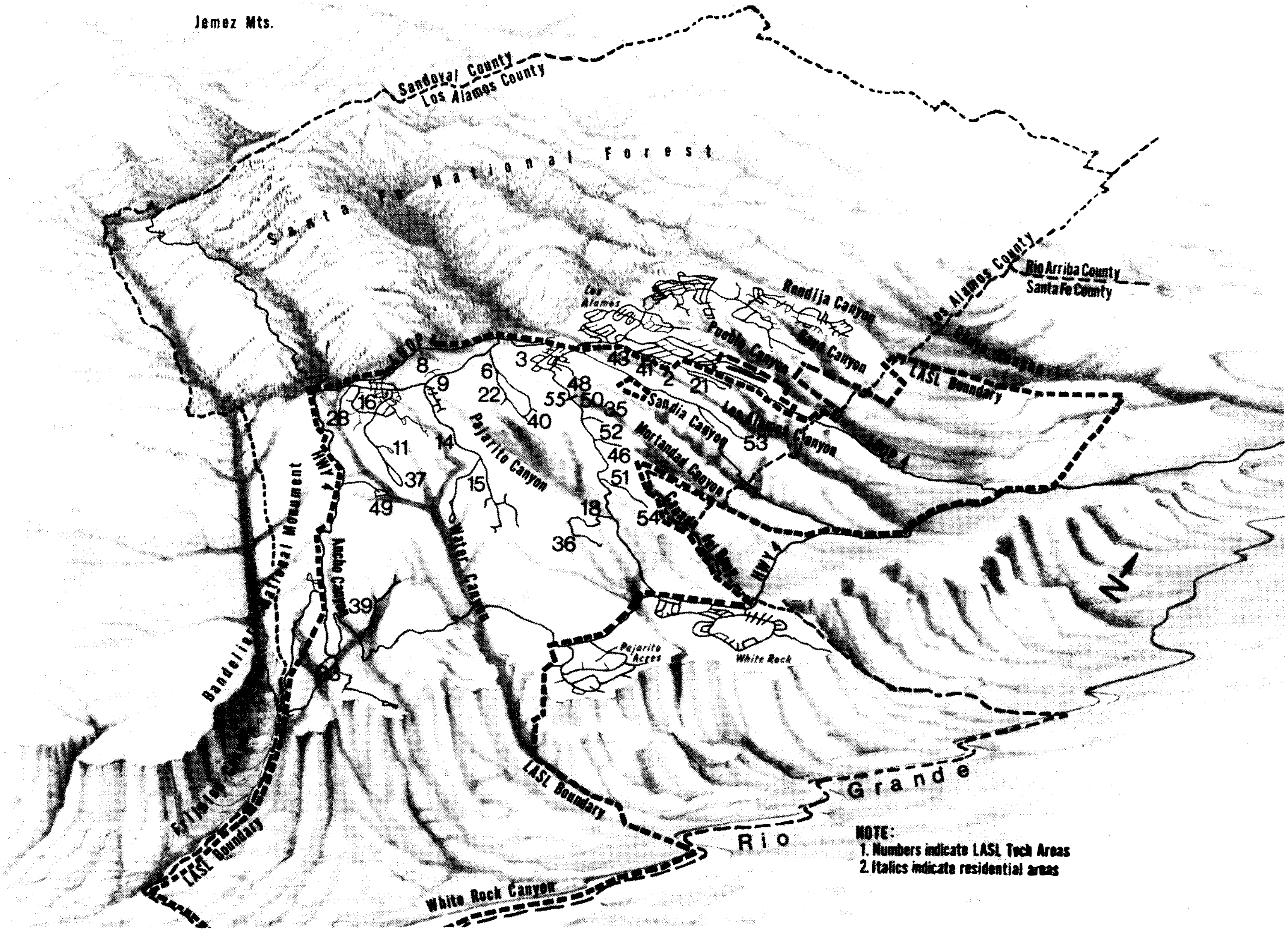


Fig. 2.

Topography of the Los Alamos, New Mexico area.

downgradient in the alluvium. As water in the alluvium moves downgradient, it is depleted by evapotranspiration and movement into underlying volcanics.[1]

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

The main aquifer of the Los Alamos area is the only aquifer in the area capable of serving as a municipal water supply. The surface of the aquifer rises westward from the Rio Grande within the Tesuque Formation into the lower part of the Puye Formation beneath the central and western part of the plateau. Depth to the aquifer decreases from 360 m along the western margin of the Plateau to about 180 m at the eastern margin. The water is under water table conditions in the western and central part of the plateau and under artesian conditions in the eastern part and along the Rio Grande.[2]

The major recharge area to the main aquifer is the intermountain basin of the Valles Caldera. The water table in the caldera is near land surface. The underlying lake sediment and volcanics are highly permeable and recharge the aquifer through Tschicoma Formation interflow breccias and the Tesuque Formation. The Rio Grande receives ground water discharge from springs fed by the main aquifer. The 18.4 km reach of the river between Otowi Bridge and the mouth of Rito de Frijoles receives an estimated 5.3 to 6.8 $\times$ 10^6 m^3 annually from the aquifer.

C. Meteorology

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

Summers are cool and pleasant. Maximum temperatures are generally below 32°C, and a large diurnal variation keeps nocturnal temperatures in the 12-15°C range. Winter temperatures are typically in the range from −10°C to 5°C. Many winter days are clear with light winds, and strong solar radiation makes conditions quite comfortable even when air temperatures are cold. A single heating degree day equals 18.3°C minus the average of the daily maximum and minimum temperatures. The average total heating degree days per year between 1951 and 1978 was 3528°C days, with January accounting for over 622°Cdays. Summaries of the 1978 weather and climatological data from 1951 through 1978 are presented in Table E-I and Fig. 3.

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

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

D. Demographics

Los Alamos County is demographically different from the surrounding area. With a population estimated at 19 600, it is characteristically urban in nature, surrounded by more rural communities relying on farming and cattle and sheep herding, primarily in the valley areas. Two residential and related commercial areas exist in the county (see Fig. 4 and inside back cover). Los Alamos, the original area of development, has an estimated population of 13 300, while White Rock has about 6300 residents. Commuting and general traffic are served by State Road 4, which runs through White Rock, and Loop 4, which runs through Los Alamos (see Fig. 4). Two federally owned roads, East Jemez and Pajarito Roads, cross this site and are normally open to public use. About one third of those employed in Los Alamos commute from other counties. Population estimates for 1978 place 105 000 people within an 80 km radius of Los Alamos.

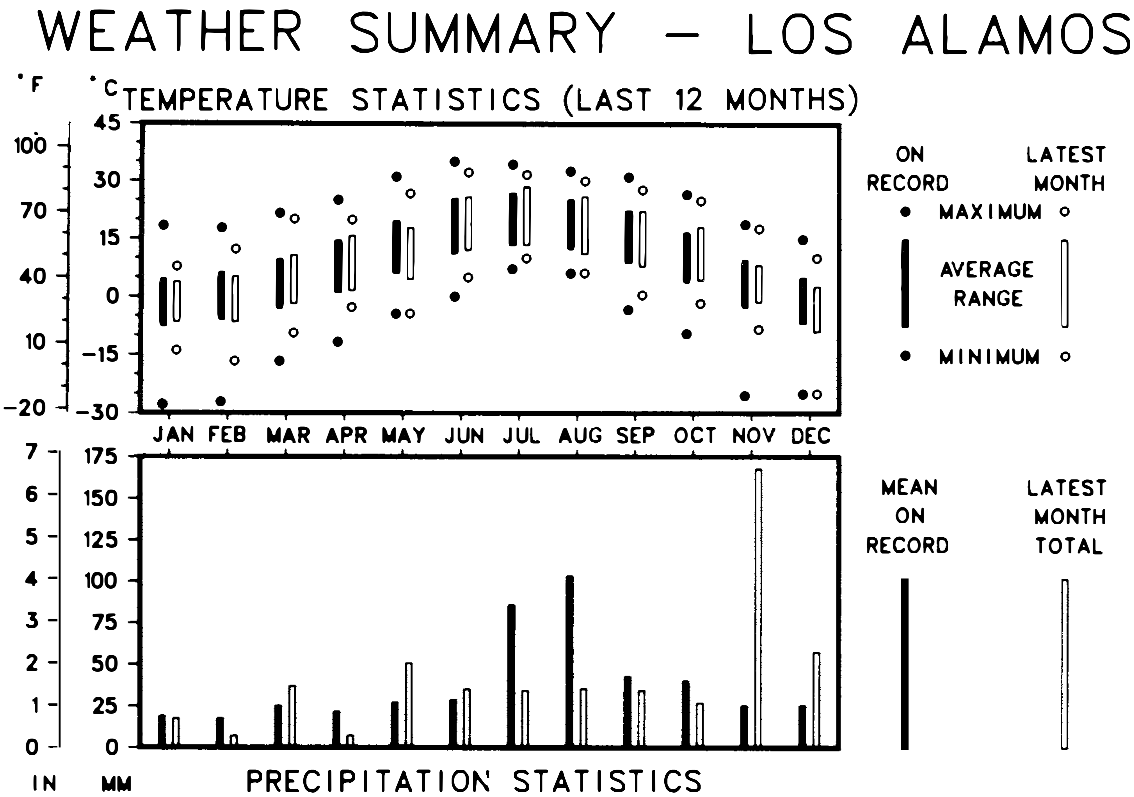


Fig. 3.

Summary of 1978 weather in Los Alamos.

E. Waste Disposal

LASL's activities are carried out in 30 active technical areas (TA) distributed over the site (see Fig. 4). Wastes requiring disposal are generated at virtually all these locations. Sanitary sewage is treated by a number of plants employing conventional secondary treatment processes or by septic tanks. Uncontaminated solid waste is disposed in a County-operated landfill located within the Laboratory boundary. Nonradioactive airborne effluents include combustion products from the power and steam plants, vapors of fumes from numerous local exhaust systems such as chemistry laboratory hoods, and burning of high explosives wastes.

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

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

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

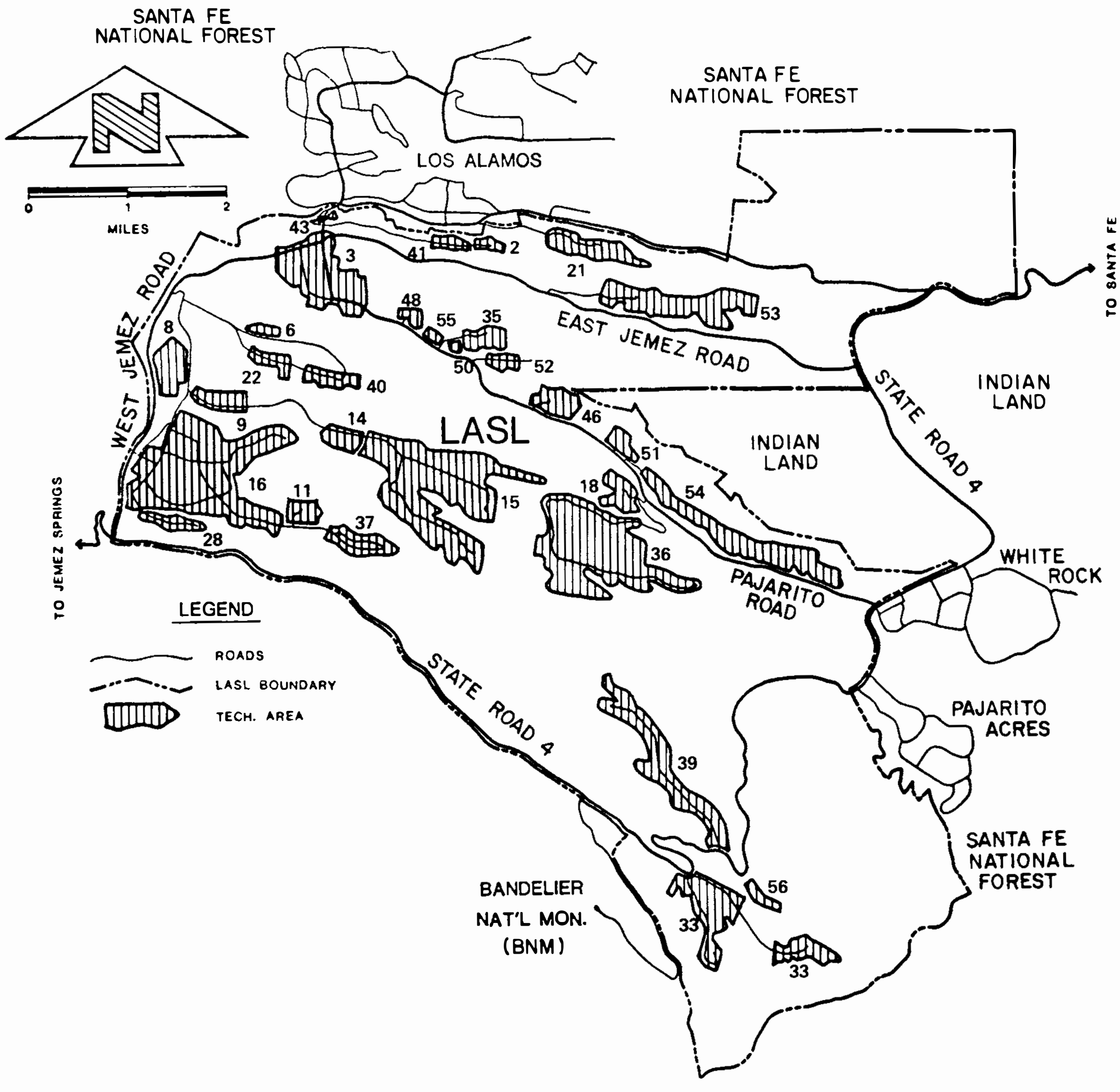


Fig. 4.

LASL technical areas and adjacent community areas.

F. Environmental Monitoring

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

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

II. SUMMARY

This report presents the results of LASL environmental monitoring programs for 1978. Data and interpretive comparisons are included for:

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

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

Penetrating radiation in the Los Alamos area outside the LASL boundary averaged 108 mrem/yr from multiple sources of natural radiation; LASL operations did not contribute to the total. Penetrating radiation at onsite locations near facilities emitting radiation reached a maximum of about 700 mrem/yr. The annual mean concentration of tritiated water vapor in air at perimeter locations was 13×10^{-12} μ Ci/mℓ, about 9×10^{-12} μCi/mℓ higher than background measured at regional stations, showing some effect of laboratory effluents. The mean concentration at perimeter locations is about 0.007% of the applicable uncontrolled area concentration guide (CG).

Uncontrolled area concentration guides represent levels of radioactivity considered acceptable in air breathed or water consumed by members of the public and were derived to insure that continuous breathing of air or drinking of water containing radioactivity at the CG levels would not cause human radiation doses exceeding the Radiation Protection Standards (see Appendix A). However, the CGs do not account for concentration mechanisms that may exist in environmental media. Consequently, other media such as sediments, soils, and foods are monitored.

Atmospheric long-lived gross alpha and gross beta mean concentrations in the LASL environs were 1.5×10^{-15} and 86×10^{-15} μCi/mℓ, respectively, 2.4% and 0.09% of their respective uncontrolled area CGs. Gross beta activity was elevated during March and December, shortly after detonations of atmospheric nuclear devices by the People's Republic of China. The maximum beta activity concentrations were less than 0.6% of the appropriate CG. The atmospheric ^{239}Pu mean concentration offsite in the LASL environs was about 80×10^{-18} μCi/mℓ, which was 0.13% of the uncontrolled area CG. The airborne radioactive effluents of possible concern were the air activation products ^{41}Ar, ^{11}C, ^{13}N, and ^{15}O, released from the research reactor (TA-2) and the linear accelerator at the Los Alamos Meson Physics Facility (LAMPF, TA-53). Concentrations for these isotopes at occupied locations were theoretically calculated using atmospheric dispersion models in order to estimate doses. Measured doses at the Laboratory boundary north of LAMPF indicate that the theoretically calculated concentrations probably overestimate actual concentrations.

Radiation doses to members of the public (~0.1 mrem/yr or greater) attributable to radioactive airborne effluents from LASL operations were calculated from these measured or theoretically estimated concentrations or from penetrating radiation measurements. Such calculations indicate that maximum doses to people at occupied locations could be as high as 0.7 mrem/yr from ^{41}Ar [0.14% of the DOE Radiation Protection Standard (RPS), see Table A-II], and 3.8 mrem/yr from combined ^{11}C, ^{13}N, and ^{15}O (0.76% of the RPS). The estimated total whole body population dose attributable to LASL operations for residents of Los Alamos County was 10.5 man-rem or about 0.44% of the population dose due to normally present background radiation and about 0.52% of the population dose received from medical radiation (diagnostic x-rays only).

No pathways to humans were identified for radioactivity in treated liquid effluents. All water affected by such effluents contained radioactivity at levels well below appropriate CGs. No pathways for sediments in liquid waste discharge areas were identified. Analyses of fish from the Cochiti Reservoir showed no measurable concentrations of activity attributable to Laboratory operations.

Commuters making 15 round trips a week on one federally owned road (Pajarito Road) crossing the site would have received <0.5 mrem/yr from one technical area where radiation emitting experiments are carried out. Two possible food pathways, involving honey and venison, could have resulted in doses of <4 mrem/yr to a few people.

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

Nonradioactive airborne effluents from sources including a power plant, steam plants, an asphalt plant, a beryllium shop, and experiments utilizing high explosives were well within environmental quality standards. Effluents from 6 of 10 sanitary sewage plants operating under provisions of EPA permits exceeded one or more permit limits during at least one month of the year. Industrial effluents from 104 sources came under provisions of an EPA NPDES permit during October 1978. Data on the quality of these effluents are presented.

III. MONITORING RESULTS

A. Radiation and Radioactivity

1. Penetrating Radiation

Levels of penetrating radiation, including x and gamma rays from cosmic, terrestrial, and man-made sources in the Los Alamos area are monitored with thermoluminescent dosimeters deployed in two independent networks. The environmental network consists of 50 locations divided into three groups (Fig. 5). Three of these locations are 28 to 44 km from the Laboratory boundaries in the neighboring communities of Española, Pojoaque, and Santa Fe, and form the regional group (Fig. 1). The perimeter group consists of 16 dosimeters placed within 4 km of the boundary. Thirty-one locations within LASL boundaries are classed as the onsite group. The dosimeters are changed each calendar quarter. The second network consists of 25 locations, all within LASL boundaries. This network was established to monitor radioactivity of the gaseous effluent from LAMPF at ground level approximately 1 km from the stack. The dosimeters are changed in accordance with the operating schedule of LAMPF. No measurements at regional or perimeter locations in the environmental network for any calendar quarter showed any statistically discernible increase in radiation levels that could be attributed to LASL operations. The LAMPF network showed an increase of 13.7 ± 1.4 mrem/yr at the LASL boundary north of the LAMPF facility. Table I summarizes the annual total doses by the regional, perimeter, onsite, and LAMPF groups for 1978.

Natural penetrating radiation background has two components. The natural terrestrial component results from the decay of ^{40}K and the radioactive daughters from the decay chains of ^{232}Th and ^{238}U. The cosmic component includes both photon radiation and neutrons. The thermoluminescent dosimeters used in the LASL monitoring program (TLD-100®) are insensitive to neutrons so neutron contribution to natural background radiation was not measured and, therefore, will be excluded from this discussion. The cosmic ionizing radiation level increases with elevation because of reduction in the shielding effect of the atmosphere. At sea level it averages between 25 and 30 mrem/yr. Los Alamos, with a mean elevation of about 2.2 km, receives about 60 mrem/yr from the cosmic component. The regional monitoring locations, ranging from about 1.7 km elevation at Pojoaque to about 2.1 km at Santa Fe, receive from 50-60 mrem/yr.[3]

In contrast to this fairly constant cosmic component, the dose from the natural terrestrial component in the Los Alamos area is highly variable. The

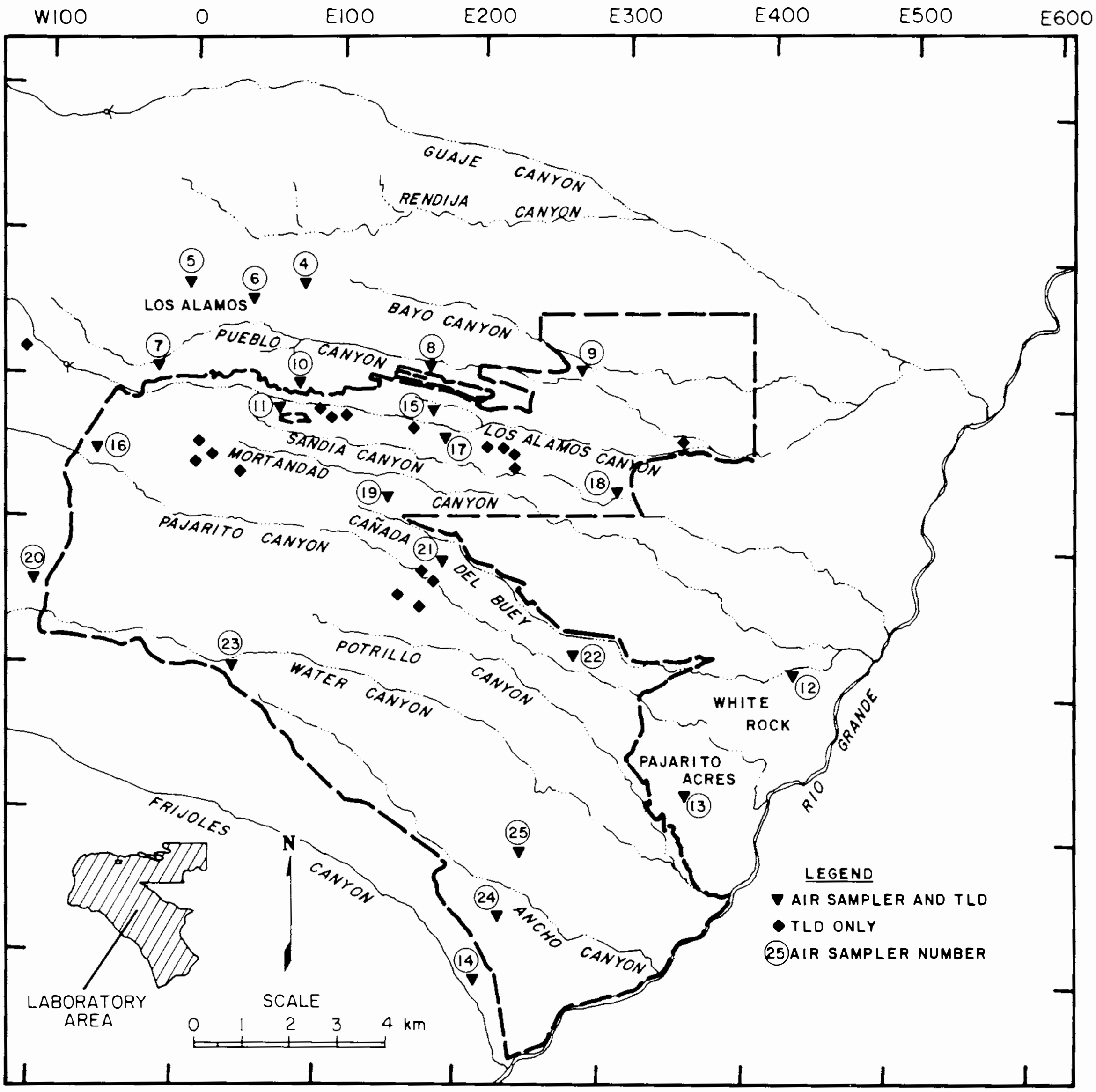


Fig. 5.

Thermoluminescent dosimeter (TLD) and air sampler locations on or near the LASL site.

temporal variation at any particular location (Fig. 5) is about 15-25% because of variations in soil moisture content and snow cover.[3] There is also spatial variation because of different soil and rock types in the area.[4] These natural sources of variation make it difficult to detect any increases in the radiation level from man-made sources, especially if the magnitude of such an increase is small compared to natural fluctuations.

In order to discriminate between these man-made and natural components of variation, data were used from two different dosimeter configurations at each LAMPF network location. One measures total penetrating radiation, both cosmic and terrestrial. The second is shielded from below with enough lead to eliminate about 90% of the direct terrestrial gamma-ray component and from above by enough Lucite to eliminate virtually all beta particles and positrons (whether from natural sources or from LAMPF operations). Gamma rays from annihilation of positrons and electrons can penetrate the Lucite.

TABLE I

EXTERNAL PENETRATING RADIATION DURING 1978

	Dose (mrem)		
Group	**Minimum**	**Maximum**	**Average**
Regional	74.± 5	96.± 6	84.± 22
Perimeter	82.± 6	135.± 6	108.± 29
Onsite	97.± 5	681.± 13	160.± 212
LAMPF[a]	81.± 5	127.± 7	110.± 10

[a]Extrapolated from data obtained during the fourth calendar quarter when the LAMPF network was completed.

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

Because the TLD dosimeters used in the LAMPF network are insensitive to neutrons, independent neutron measurements with sensitive portable equipment were made at the nearest boundary to LAMPF (0.8 km north). With all LAMPF targets in use and a beam current of about 40% of the maximum planned current, the neutron dose rate increase at this location is less than 0.1 mrem/yr. When full power is eventually reached, the dose rate due to LAMPF produced neutrons will be less than 0.2 mrem/yr.

2. Air

Worldwide background atmospheric radioactivity is composed of fallout from atmospheric nuclear weapons tests, natural radioactive constituents in dust from the earth's surface, and radioactive materials resulting from interactions with cosmic radiation. Air is routinely sampled at several locations on Laboratory land, along the Laboratory perimeter, and in distant areas to determine the existence and composition of any contributions to radionuclide levels from Laboratory operations. During 1978, no statistically significant difference was observed between the atmospheric concentrations of gross alpha, gross beta, americium, plutonium, and uranium measured at sampling locations along the Laboratory perimeter and those measured in distant areas. This indicates Laboratory contributions to concentrations of these contaminants were less than the local variability in background levels. Tritiated water vapor (HTO) concentrations at perimeter and onsite stations were about three and four times higher, respectively, than regional background HTO levels and are attributable to the Laboratory's HTO stack effluents. Elevated levels of airborne activity from short-lived fission products were detected for short periods of time following nuclear atmospheric detonations by the People's Republic of China on March 14 and December 14.

a. General. Atmospheric radioactivity samples were collected at 25 continuously operating air sampling stations in Los Alamos County and vicinity. Onsite and perimeter station locations are shown in Fig. 5 and identified by map coordinates (Table E-VI). Perimeter stations are 0 to 4 km from the Laboratory boundary. The regional monitoring stations, located 28 to 44 km from the Laboratory at Española, Pojoaque, and Santa Fe (Fig. 6), serve as reference points in determining the regional background for atmospheric radioactivity.

When interpreting data from this air sampling program, one must first be aware of natural and fallout radioactivity levels and their fluctuations. Worldwide background atmospheric radioactivity is largely composed of fallout from atmospheric nuclear weapons tests, natural radioactive constituents in dust from the decay chains of ^{232}Th, ^{238}U, and materials resulting from interactions with cosmic radiation, such as tritiated water vapor. Because suspended particulates are mostly from soil resuspension, there are large temporal fluctuations in radioactivity concentrations as a result of changing meteorological conditions. Periods of high winds, resulting in relatively high suspended particulate concentrations, contrast with periods of heavy precipitation, which remove much of the suspended mass. Spatial variations may be dependent on these same factors. Previous measurements of background atmospheric radioactivity concentrations are summarized in Table E-III and are useful in interpreting the air sampling data.

b. Chinese Fallout Monitoring. Two atmospheric nuclear tests by the People's Republic of China were conducted over their Lop Nor testing area in southwest China. Both tests (March 14 and December 14) were reported to be nuclear devices with explosive power equivalent to approximately 20 000 tons of TNT. Radioactive materials were injected into the troposphere and stratosphere over the mid-latitudes of the northern hemisphere by the above-ground detonations. Prevailing air currents then carried the airborne radioactive materials to the North American continent where the radioactive debris slowly dropped to the earth's surface as fallout.

After each explosion, supplementary sampling was initiated to measure the fallout. Daily particulate samples were taken at the Occupational Health Laboratory (N050 E040) and at the offsite station at Española, 28 km distant from the Laboratory (see Fig. 6). The highest observed long-lived (counted after 7 to 10 days), gross beta concentration for the March 14 test was 570 ($\pm$70) $\times 10^{-15}$ μCi/mℓ and for the December 14 test was 190 ($\pm$20) $\times$ 10^{-15} μCi/mℓ. These concentrations are 0.6% and 0.2%, respectively, of the uncontrolled area CG for ^{131}I. Qualitative gamma spectral analyses of the atmospheric particulate samples showed the presence of fresh fission products (e.g., ^{141}Ce, ^{131}I, ^{95}Zr) from the detonations. Tables E-IV and E-V contain all data collected during the special Chinese fallout monitoring programs.

c. Annual Gross Alpha and Gross Beta Radioactivity. The annual average 4-wk gross alpha and gross beta concentrations are summarized in Table II and are shown in detail in Table E-VII. Temporal variations in long-lived gross beta concentrations (Fig. 7) were observed during the year. The elevated activity during the spring was typical of that observed during most springs when mixing of the stratosphere with the troposphere causes increased fallout of particulates.

Data plotted in Fig. 7 also show that there were no significant differences in atmospheric gross beta concentrations among the regional, perimeter, and onsite sampling stations this year. There have been no statistically significant differences over the past six years. This lack of statistically significant differences in concentrations indicates that Laboratory operations have negligible influence on the ambient atmospheric radioactivity in the Los Alamos vicinity and suggests that this radioactivity originates from widespread sources—fallout from nuclear test detonations and naturally occurring materials—and not from a localized source such as the Laboratory.

d. Tritium. Atmospheric tritiated water concentrations for each station for 1978 are summarized in Table II and shown in detail in Table E-VIII. The relatively higher levels observed at the Los Alamos airport (station 8) and TA-21 (station 15) are similar to those observed in previous years and are attributable to stack effluents from nearby TA-21. The relatively higher concentrations at TA-54 (station 22) result from evapotranspiration of buried tritium-contaminated wastes at this site. The annual mean for the onsite stations is statistically higher (at a >99% confidence level) than the regional and perimeter means. The higher value reflects tritium releases from Laboratory operations (see Sec. III.A.6). The annual mean atmospheric tritium concentrations for the perimeter and onsite stations are shown in Fig. 8. The highest annual mean of 57 ($\pm$74) pCi/m^3 was at TA-54 (station 22).

e. Plutonium. The annual average ^{238}Pu and ^{239}Pu concentrations for each station are summarized in Table II and listed in Table E-IX. Practically all ^{238}Pu concentrations were less than the minimum detectable limit of 2 $\times$ 10^{-18} μCi/mℓ; ^{239}Pu concentrations were comparable to 1977 data and showed no anomolies. The regional, perimeter, and onsite group ^{239}Pu means are statistically indistinguishable from one another, indicating Laboratory contributions of ^{239}Pu to the atmosphere are at background levels.

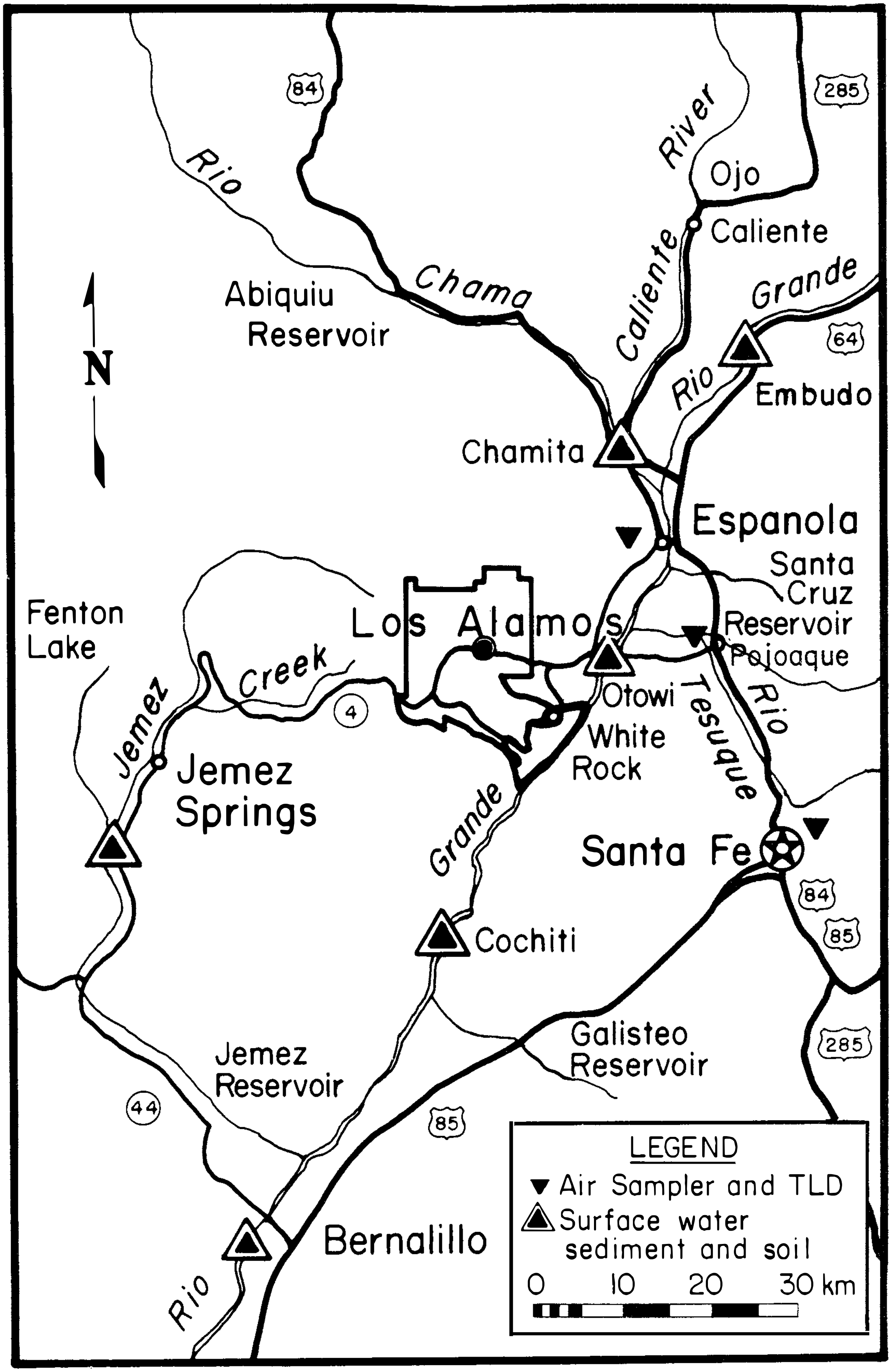
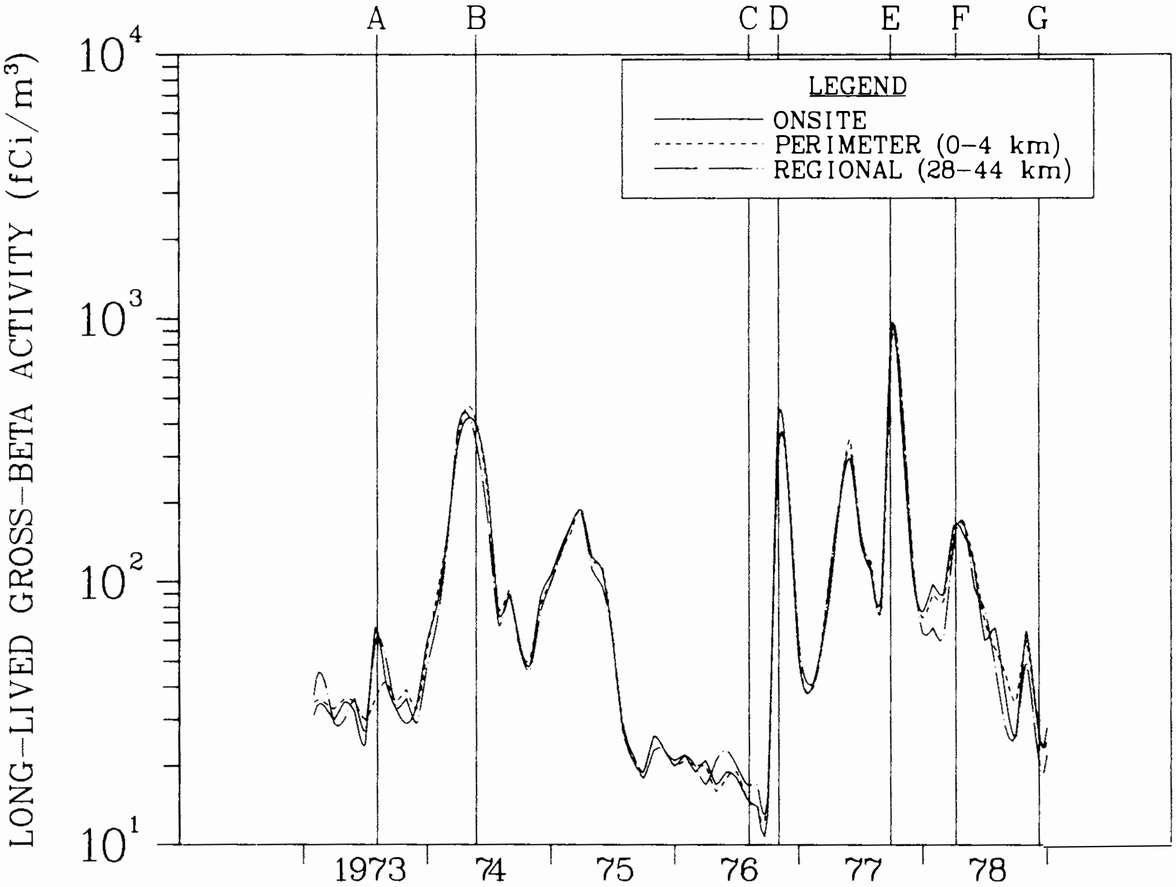


Fig. 6.
Regional surface water, sediments, soil, and air sampling stations.



CHINESE NUCLEAR ATMOSPHERIC TESTS

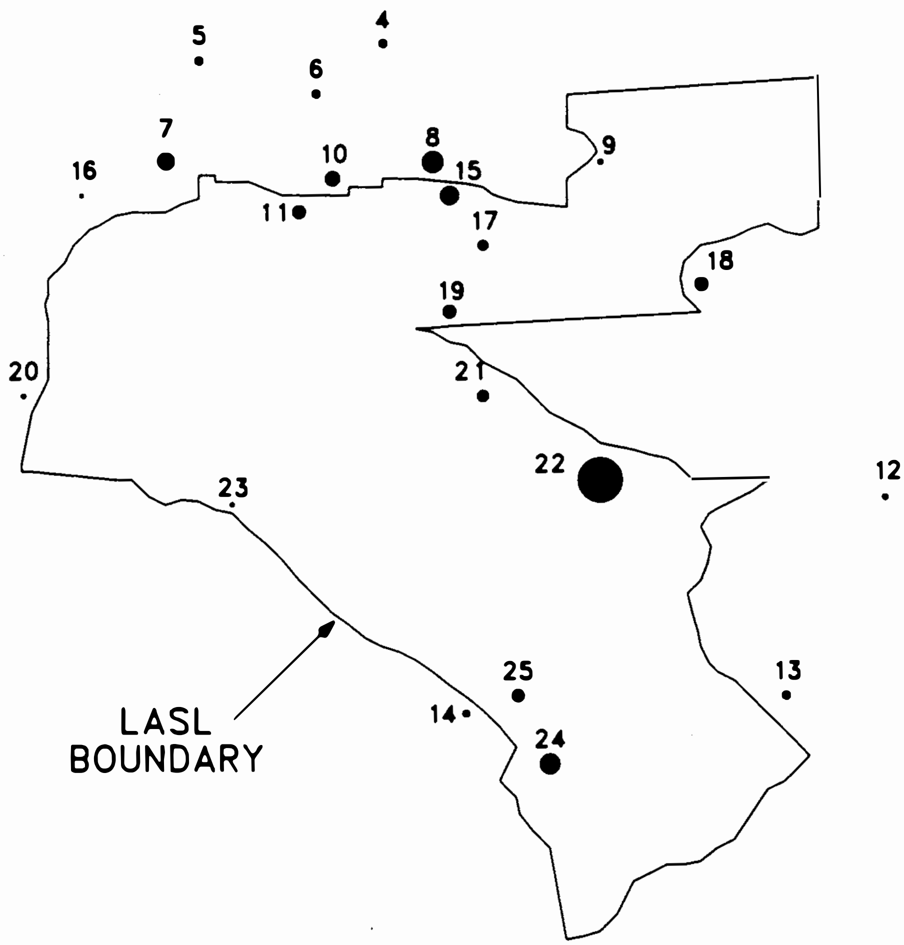
A.	26	JUNE 1973	2-3 MT
B.	17	JUNE 1974	0.2-1 MT
C.	26	SEPTEMBER 1976	~ 0.2 MT
D.	17	NOVEMBER 1976	~ 4 MT
E.	17	SEPTEMBER 1977	~ 0.02 MT
F.	14	MARCH 1978	~ 0.02 MT
G.	14	DECEMBER 1978	~ 0.02 MT

Fig. 7.

Monthly average long-lived gross beta radioactivity, 1973-1978, by sampling station groups.

f. Uranium and Americium. The 1978 atmospheric uranium concentrations are summarized in Table II and listed in Table E-X. The uranium concentrations are dependent on the immediate environment of the sampling station. Those stations with higher annual averages and maximum values were all located in dusty areas where a higher filter dust loading accounts for the collection of more natural crustal-abundance of uranium. The annual averages of the stations are typical of regional average background atmospheric uranium concentrations (Table E-III). There were no statistically significant (at a >99% confidence level) temporal or geographical differences among the regional, perimeter, and onsite station groups.

The 1978 atmospheric americium concentrations are summarized in Table II and listed in Table E-XI. All data were below the analytical detection limit, so no statistical analysis was made. Only 0.034 μCi of ^{241}Am (Table E-XXI) was released to the atmosphere from LASL during 1978.



LEGEND

EACH CIRCLE IS LOCATED AT A SAMPLING STAION
AND IS PROPORTIONAL TO TRITIUM CONCENTRATION.

X
• – REPRESENTS 10 pCi/m³ AT STATION X

Y
● – REPRESENTS 50 pCi/m³ AT STATION Y

Fig. 8.

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

TABLE II

SUMMARY OF ANNUAL ATMOSPHERIC RADIOACTIVITY MONITORING

Analysis	Composite Group	Units	Maximum Observed	Minimum Observed	Annual Mean	Mean As % CG
Gross Alpha	Regional	10^{-15} μCi/mℓ	1.9 ± 0.8	−0.3 ± 0.1	0.9 ± 0.9	1.6
	Perimeter	10^{-15} μCi/mℓ	6.8 ± 3.2	−0.0 ± 0.1	1.5 ± 1.9	2.4
	Onsite	10^{-15} μCi/mℓ	4.6 ± 2.0	−0.1 ± 0.6	1.5 ± 2.0	0.1
Gross Beta	Regional	10^{-15} μCi/mℓ	200 ± 60	9 ± 2	72 ± 102	0.07
	Perimeter	10^{-15} μCi/mℓ	240 ± 60	13 ± 3	86 ± 108	0.09
	Onsite	10^{-15} μCi/mℓ	440 ± 120	4 ± 1	83 ± 109	0.002
Tritiated Water Vapor	Regional	10^{-12} μCi/mℓ	19 ± 6	0.2 ± 0.6	4 ± 9	0.002
	Perimeter	10^{-12} μCi/mℓ	107 ± 34	0.6 ± 0.2	13 ± 33	0.007
	Onsite	10^{-12} μCi/mℓ	118 ± 38	0.1 ± 0.6	18 ± 48	0.0004
^{238}Pu	Regional	10^{-18} μCi/mℓ	−1.1 ± 1.6	−4.5 ± 4.8	−2.3 ± 1.3	0.00
	Perimeter	10^{-18} μCi/mℓ	−0.1 ± 1.9	−4.7 ± 3.9	−1.8 ± 1.3	0.00
	Onsite	10^{-18} μCi/mℓ	8.8 ± 3.2	−4.7 ± 2.3	−1.2 ± 3.7	0.00
^{239}Pu	Regional	10^{-18} μCi/mℓ	44 ± 81	1.2 ± 1.5	20 ± 39	0.034
	Perimeter	10^{-18} μCi/mℓ	79 ± 14	−0.6 ± 1.4	27 ± 43	0.044
	Onsite	10^{-18} μCi/mℓ	153 ± 13	−0.5 ± 1.3	32 ± 67	0.0016
^{241}Am	Regional	10^{-18} μCi/mℓ	0.3 ± 3.6	−2.0 ± 9.1	−0.5 ± 2.2	0.00000
	Perimeter	10^{-18} μCi/mℓ	7.4 ± 15	−2.7 ± 6.4	0.5 ± 6.7	0.00026
	Onsite	10^{-18} μCi/mℓ	4.2 ± 4.8	−3.3 ± 4.8	0.1 ± 4.2	0.000002
Uranium (total)	Regional	pg/m^3	184 ± 38	34 ± 18	102 ± 94	0.0011
	Perimeter	pg/m^3	238 ± 49	19 ± 22	74 ± 88	0.0008
	Onsite	pg/m^3	177 ± 40	16 ± 21	68 ± 66	0.00003

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

3. Radioactivity in Surface and Ground Waters

Surface and ground waters are monitored to provide routine surveillance of potential dispersion of radionuclides from LASL operations. The results of these analyses are compared to DOE CGs (see Appendix A) as an indication of the very small amounts of radionuclides in the environment. The results of the 1978 radiochemical quality analyses of water from regional, perimeter, water supply, and onsite non-effluent release areas indicate no effect from effluent releases from LASL. Waters in the onsite liquid effluent release areas contain trace amounts of radioactivity. These onsite waters are not a source of industrial, agricultural, or municipal water supplies.

*a. **Regional and Perimeter Waters.*** Analyses of surface and ground waters from regional and perimeter stations reflect base line levels of radioactivity in the areas outside the LASL boundaries. However, the CGs do not account for concentration mechanisms that may exist in environmental media. Consequently, other media such as sediments, soils, and foods are monitored. Regional surface waters were collected within 75 km of LASL from six stations on the Rio Grande, Rio Chama, and Jemez River (Fig. 6, Table E-XII). Samples were also collected from five perimeter stations located within about 4 km of the LASL boundaries and from 26 stations in White Rock Canyon of the Rio Grande (Fig. 9, Table E-XII). Excluded from this discussion is Acid-Pueblo Canyon, a former release area for industrial liquid waste, which has four offsite stations and three onsite stations (Fig. 9). As a known release area and for hydrologic continuity, the monitoring results in Acid-Pueblo Canyon are discussed in the following section concerning onsite surface and ground waters. Detailed data from the regional and

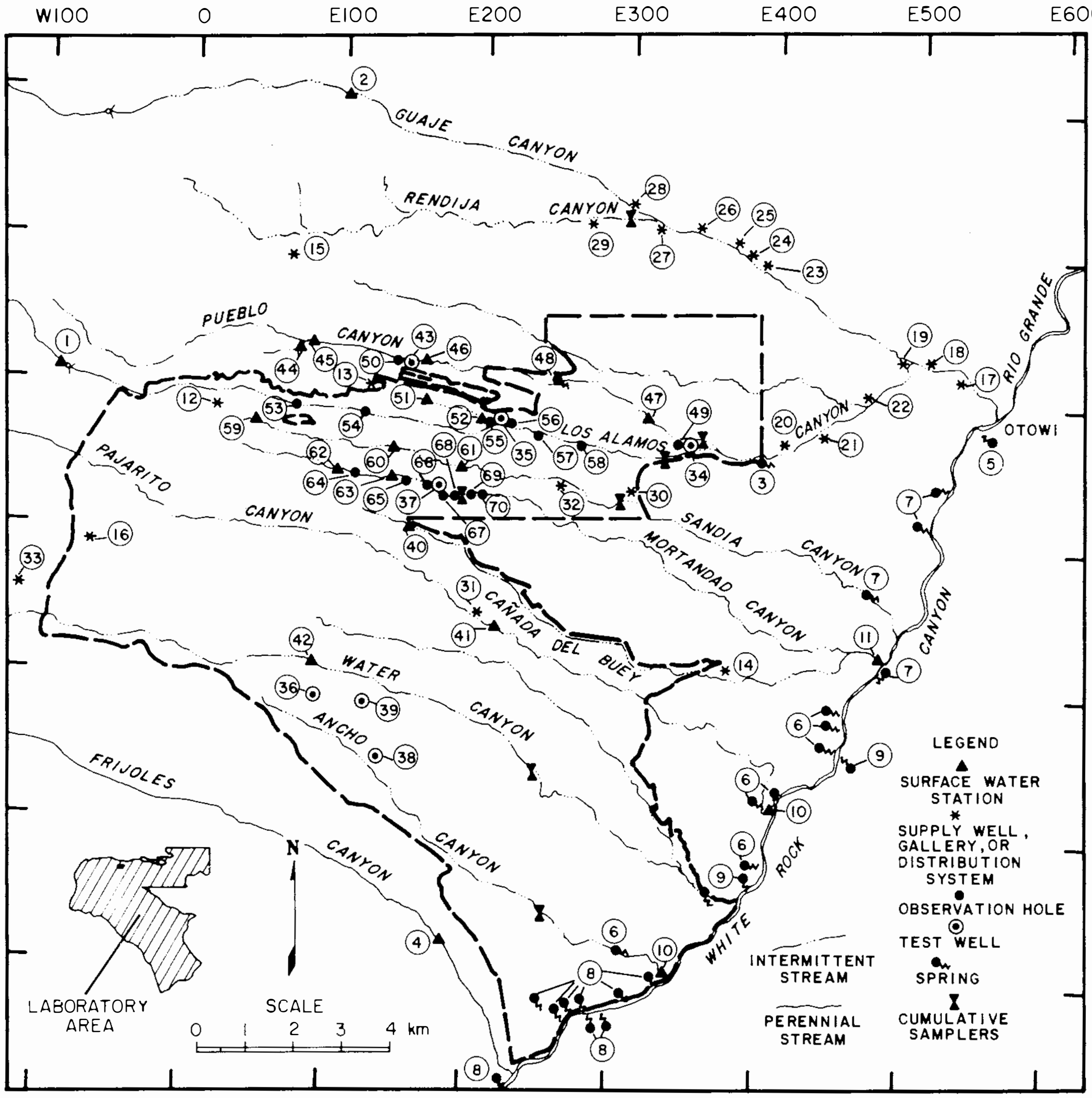


Fig. 9.

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

perimeter stations are in Tables E-XIII and E-XIV, respectively (see Appendix B.3 for methods of collection, analyses, and reporting of water data). A comparison of the maximum concentrations found in these waters with CGs for uncontrolled areas is given in Table III.

Radionuclide concentrations in surface and ground waters from the six regional and five perimeter stations are low and have shown no effect from release of liquid effluents at LASL. Plutonium concentrations are near detection limits. The concentrations are well below CGs for uncontrolled areas.

b. Water Supply. The municipal and industrial water supply for the Laboratory and community is from 15 deep wells (in 3 well fields) and one gallery (underground collection basin for spring discharge). The wells are located on the Pajarito Plateau and in canyons east of the Laboratory (Fig. 9). The water is pumped from the main aquifer, which lies at a depth of about 350 m below the surface of the plateau. The gallery discharges from a perched water zone in the volcanics west of the plateau. During 1978 production from the wells and gallery was about 5.6 × $10^6 m^3$, with the wells furnishing about 97% of the total production and the gallery about 3%. Water samples were collected from the wells and gallery and at 5 stations on the distribution system. The 5 stations on the distribution system are located within the Laboratory and community (Fig. 9, Table E-XII).

Detailed radiochemical analyses from the wells, gallery, and distribution system are presented in Table E-XV. A comparison of maximum concentrations found in these waters with the EPA National Interim Primary Drinking Water Standards[9] is given in Table IV.

Radioactivity occurring in the water supply is low and naturally occurring. Plutonium is below detection limits. Samples from the water distribution system showed gross alpha activity lower than the EPA screening limit (see Appendix A) even though one well (LA-1B, Los Alamos field) contained natural alpha activity about 40% greater than the screening limit. Dilution by water from the wells results in concentrations at points of use that meet the EPA criteria for municipal supply without requiring further detailed analyses.

c. Onsite Surface and Ground Waters. The onsite sampling stations are grouped according to areas that are not located in effluent release areas and those located in areas that receive or have received industrial liquid effluents. The onsite noneffluent release areas consist of seven test wells completed into the main aquifer, and three surface water sources (Fig. 9; Table E-XII). Detailed radiochemical analyses are shown in Table E-XVI. The maximum concentration of radioactivity at the ten stations is in Table V. The concentrations were low, near or below detection limits, and well below CGs for controlled areas.

TABLE III

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN REGIONAL AND PERIMETER WATERS

Analyses	Units μCi/mℓ	Regional	Perimeter: Five Stations	Perimeter: White Rock Canyon	CG for Uncontrolled Areas
^{3}H	10^{-6}	3.6	1.4	1.3	3000
^{137}Cs	10^{-9}	<140	<100	<120	30 000
^{238}Pu	10^{-9}	<0.03	<0.02	<0.02	5000
^{239}Pu	10^{-9}	<0.02	<0.03	<0.02	5000
Gross Alpha	10^{-9}	5.2	6.3	13	5000
Gross Beta	10^{-9}	24	8.7	18	300
Total U	μg/ℓ	4.5	14	20	1800

TABLE IV

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATER SUPPLY

Analysis	Units μCi/mℓ	Wells and Gallery	Distribution System	EPA NIPDWR[a]
^{3}H	10^{-6}	0.6	1.2	20
^{137}Cs	10^{-9}	<80	<80	200
^{238}Pu	10^{-9}	<0.01	<0.01	7.5
^{239}Pu	10^{-9}	<0.01	<0.01	7.5
Gross Alpha	10^{-9}	7.0	2.9	5
Gross Beta	10^{-9}	5.2	5.9	---
Total U	μg/ℓ	6.3	4.2	1800

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

TABLE V

MAXIMUM RADIOACTIVITY IN ONSITE WATERS IN AREAS NOT RECEIVING EFFLUENTS

Analysis	Units (μCi/mℓ)	Onsite Non-Effluent Area	CGs for Controlled Areas
^{3}H	10^{-6}	4.2	100 000
^{137}Cs	10^{-9}	70	400 000
^{238}Pu	10^{-9}	<0.01	100 000
^{239}Pu	10^{-9}	0.01	100 000
Gross Alpha	10^{-9}	2.3	100 000
Gross Beta	10^{-9}	17.0	10 000
Total U	μg/ℓ	2.4	60 000

Canyons that receive or have received industrial effluents are Acid-Pueblo, DP-Los Alamos, Sandia, and Mortandad. Samples were collected from surface water stations or shallow observation holes completed in the alluvium. Surface water in these canyons infiltrates into the alluvium before leaving the LASL boundaries (Fig. 9, Table E-XII). The maximum concentration of radioactivity in each of the four canyons is given in Table VI. Radioactivity observed in Acid-Pueblo Canyon (7 stations) results from residuals of treated and untreated radioactive liquid waste effluents released into the canyon before 1964 (Table E-XVI). Radionuclides that were adsorbed by channel sediments are now being resuspended by runoff and municipal sanitary effluents.

Sandia Canyon (3 stations) receives cooling tower blowdown from the TA-3 power plant and some sanitary effluent from the TA-3 areas. Analyses of samples from this canyon show no release of radionuclides to the environment (Table E-XVI).

DP-Los Alamos Canyon (8 stations) receives industrial effluents that contain low levels of

TABLE VI

MAXIMUM RADIOACTIVITY CONCENTRATIONS IN WATERS IN AREAS RECEIVING EFFLUENTS

Analysis	Units $\mu Ci/m\ell$	Acid-Pueblo	DP-Los Alamos	Sandia	Mortandad	CGs for Controlled Areas
^{3}H	10^{-6}	21.5	93.4	8.4	464	100 000
^{137}Cs	10^{-9}	110	<100	29	960	400 000
^{238}Pu	10^{-9}	0.04	13.1	0.02	8.60	100 000
^{239}Pu	10^{-9}	4.22	5.49	0.01	5.13	100 000
^{90}Sr	10^{-9}	77	197	0.90	137	10 000
Gross Alpha	10^{-9}	15	3100	5.0	560	100 000
Gross Beta	10^{-9}	220	1220	25	1230	10 000
Total U	$\mu g/\ell$	50	1160	7.9	143	60 000

radionuclides and some sanitary effluents from TA-21. Mortandad Canyon (8 stations) receives industrial effluent containing radionuclides (Table E-XVI).

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

4. Radionuclides in Soil and Sediments

The number of soil and sediment stations was increased this year over the number in 1977. A sample from one soil station in the regional net contained ^{137}Cs and ^{239}Pu in excess of natural fallout. Three soil samples from perimeter stations contained ^{137}Cs and one station contained ^{239}Pu in excess of natural fallout. The concentrations were less than 10 times worldwide fallout levels. Eight other perimeter sediment samples, all from a former release area, contained concentrations of ^{241}Am, ^{238}Pu, and ^{239}Pu above fallout levels. Five onsite soil stations contained activity above normal fallout and are near Laboratory activities. Sediment samples that contained activity greater than fallout were from effluent release areas.

a. Regional Soils and Sediments. Regional soils are collected in the same general locations as the regional waters (Fig. 6). Regional sediments are also collected at the same locations with additional samples collected on the Rio Grande downgradient from the station at Otowi (Fig. 6). The exact locations are presented in Table E-XVII (see Appendix B.3 for methods of collection, analysis, and reporting of soil and sediment data). These samples provide a baseline for comparison with samples collected in and adjacent to the Laboratory. The maximum concentrations of radionuclides in the regional samples for 1978 were compared with maximum concentrations in soils for 1970 and in soils and sediments for 1974-77 in Table VII. Cesium and ^{239}Pu in soil from Otowi were slightly elevated from previous levels. The remainder of analyses in 1978 were comparable to previous analyses. Four sediment samples collected from the Rio Grande to Otowi (Fig. 6, Table E-XVIII) showed only background concentrations of radionuclides.

b. Perimeter Soils and Sediments. Eight perimeter soil stations were sampled in areas >4 km from the Laboratory. Twenty sediment samples were collected from major intermittent streams that cross the Plateau. Locations of the stations are described in Table E-XVII and mapped in Fig. 10. The maximum concentrations are summarized in Table VIII and are grouped into those above background and background.

Soil analyses indicated ^{137}Cs was above background in three samples and ^{239}Pu in one (see Table E-XIX for detailed analyses). The above background concentrations in soils are due to Laboratory activities. Cesium and ^{239}Pu were only slightly above background. Concentrations of ^{241}Am, ^{238}Pu, and ^{239}Pu were found in sediments from Acid-Pueblo Canyon (offsite), which are due to release of industrial effluents into the canyon before 1964 (Table E-XIX). The concentrations in lower Los Alamos Canyon (Totavi to Rio Grande) reflect transport by intermittent storm runoff from Acid-Pueblo Canyon and from onsite release of liquid effluents into DP-Los Alamos Canyon. The concentrations decrease downgradient in the canyons and are only slightly higher than the regional baseline concentrations (Table E-XVIII).

c. Onsite Soils and Sediments. Onsite soil samples were collected from 19 stations within Laboratory boundaries. Sediment samples were collected from 32 stations within the boundaries (Fig. 10, Table E-XX). Ten of the sediment samples are from areas that receive or have received liquid effluents. The detailed analyses are shown in Table E-XX, while descriptions of locations are noted in Table E-XVII. The maximum concentrations are in Table IX.

Concentrations of ^{3}H (1 station), ^{137}Cs (2 stations), ^{238}Pu (1 station), ^{239}Pu (5 stations), and gross beta (1 station) in the onsite soils were above background levels. These levels are probably due to deposition of airborne effluents from past Laboratory operations. Above background levels of ^{137}Cs, ^{90}Sr, ^{241}Am, ^{238}Pu, ^{239}Pu, gross alpha , and gross beta were found mainly in sediments of canyons that are now receiving treated effluents. They

TABLE VII

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

	1978		1970	1974-77
Analysis	**Soils**	**Sediments**	**Soils**	**Soil and Sediments**
$^{3}H^{a}$	29.5	---	---	---
^{137}Cs	1.02[b]	0.26	---	1.00
^{90}Sr	---	---	0.87	1.06
^{238}Pu	<0.016	<0.020	0.004	0.010
^{239}Pu	0.053[b]	<0.014	0.012	0.045
Gross Alpha	4.8	16		18
Gross Beta	7.6	14		13

[a] pCi/mℓ.

[b] Maximum value except for Otowi analyses: 1.73 pCi/g ^{137}Cs; ^{239}Pu 0.15 pCi/g.

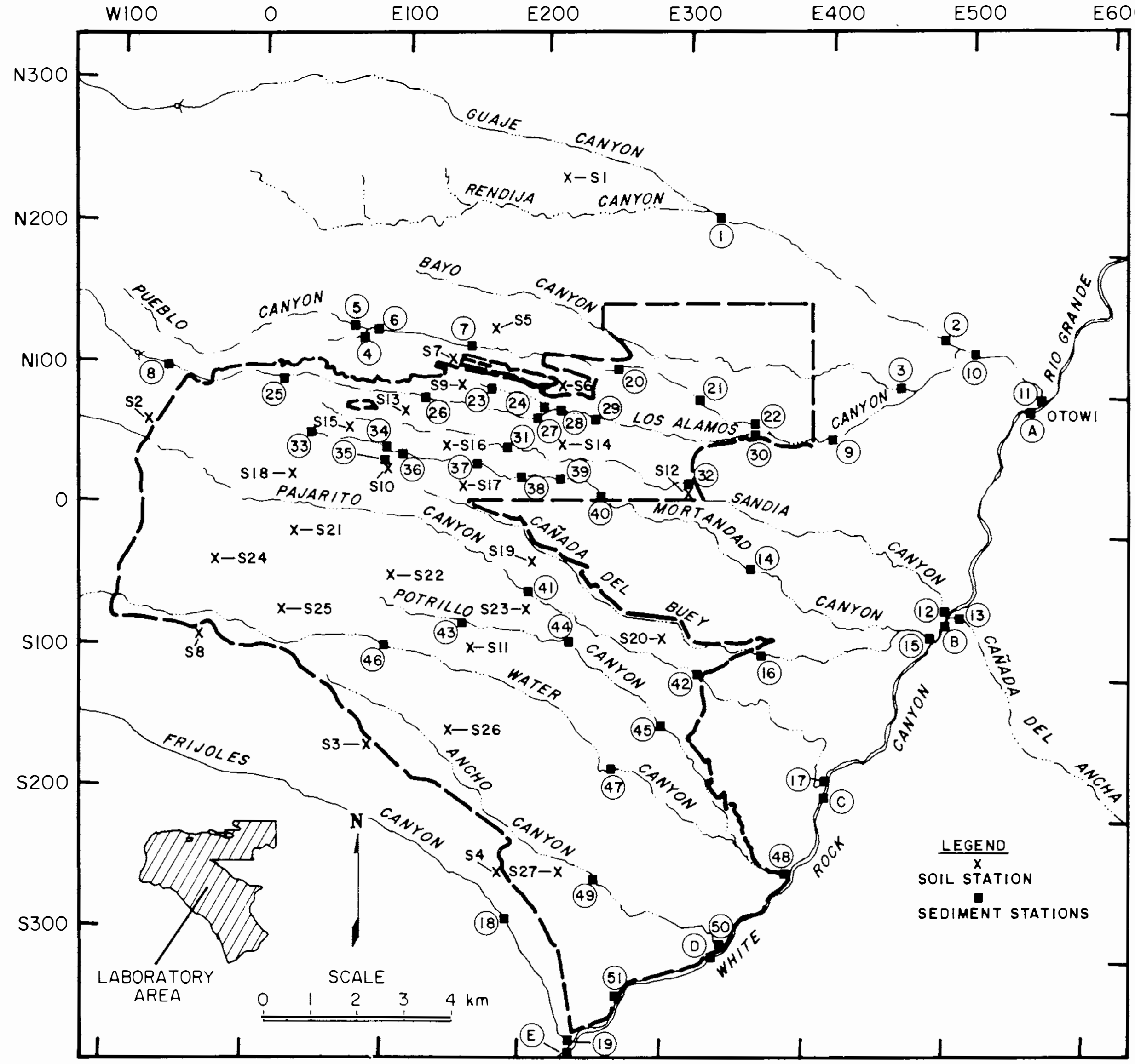


Fig. 10.

Soil and sediment sampling stations on or near the LASL site.

are Acid-Pueblo, DP-Los Alamos, and Mortandad Canyons. The radionuclides in the treated effluents are adsorbed or attached to sediment particles in the alluvium. Concentrations are highest near the effluent outfall and decrease downgradient in the canyon as the sediments and radionuclides are transported and dispersed by other industrial effluents, sanitary effluents, and periodic storm runoff.

The ^{238}Pu in sediments from Mortandad Canyon near the CMR laboratory (station 33, Fig. 10) is from an acid sewer spill in 1974. The bulk of the contamination was removed. Above background levels of ^{137}Cs and ^{239}Pu were reported from two stations in Water Canyon. The ^{137}Cs is slightly above background, while ^{239}Pu is about a factor of 2 above normal levels (Table E-XX).

TABLE VIII

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

Analysis	Soil: Above Background	Soil: Background	Sediments: Above Background	Sediments: Background
$^{3}H^{6}$	---	12.2(8)	---	---
^{137}Cs	1.6(3)	1.08(5)	---	0.81(25)
^{90}Sr	---	0.92(4)	---	0.90(6)
^{241}Am	---	---	0.590(3)	<0.024(8)
^{238}Pu	---	<0.020(8)	0.040(2)	<0.009(17)
^{239}Pu	0.460(1)	0.041(7)	6.46(6)	<0.022(13)
Gross Alpha	---	6.2(8)	---	7.4(23)
Gross Beta	---	8.9(8)	---	74(19)

[a] Parentheses indicate number of stations in group with the maximum value noted. See Table E-XVII and Fig. 11 for description of location.

[b] 10^{-6} μCi/mℓ.

TABLE IX

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

Analysis	Soil: Above Background	Soil: Background	Sediments: Above Background	Sediments: Background
$^{3}H^{b}$	157(1)	29.7(18)	---	---
^{137}Cs	1.50(2)	1.10(17)	1260(12)	1.15(20)
^{90}Sr	---	0.83(7)	17(6)	1.05(8)
^{241}Am	---	0.003(1)	---	0.016(12)
^{238}Pu	0.700(1)	0.015(18)	35.2(8)	<0.027(24)
^{239}Pu	2.52(5)	0.026(14)	11.6(14)	0.056(18)
Gross Alpha	---	11(19)	52(3)	8.5(29)
Gross Beta	22(1)	14(8)	1710(8)	12(24)

[a] Parentheses indicate number of stations in group with the maximum value noted. See Table E-XVII and Fig. 11 for description of location.

[b] 10^{-6} μCi/mℓ.

d. Study of Radionuclide Transport in Storm Runoff. The major transport mechanism for radionuclides from canyons receiving treated liquid radioactive effluent is in storm runoff (solution and suspended sediments). Cumulative samplers were set up in intermittent streams to collect samples of runoff for analyses (see Appendix B.3 for methods of collection, analyses, and reporting of data). Rendija Canyon was used as a control. Pueblo, Los Alamos, and Mortandad Canyons receive liquid waste effluent, while Sandia Canyon receives sanitary effluents. Water and Ancho Canyons drain small areas that were burned during the June 1977 La Mesa fire (Fig. 10). All sampler locations were within Laboratory boundaries except for the control sampler in Rendija Canyon.

Analyses were performed for ^{137}Cs, ^{238}Pu, and ^{239}Pu in solution and for ^{238}Pu and ^{239}Pu in the suspended sediments. In addition, chemical analyses were performed for Ca, Mg, Cl, F, and total dissolved solids (TDS) when enough sample was collected. The runoff volume of each event varied, so if there was low volume, the sample collected may have been too small for particular analyses. In addition, due to localized rainfall on the Plateau, one stream might run, while the adjacent stream might not. All streams sampled are tributary to the Rio Grande; however, in Mortandad Canyon, storm runoff infiltrates into the alluvium within the Laboratory boundary. The average radiochemical and chemical concentrations for a number of flow events are in Table X.

Runoff from Rendija Canyon (used as a control) shows little radioactivity, while runoff from Pueblo, Los Alamos, and Mortandad Canyons contains plutonium both in solution and suspended sediments. The plutonium in Pueblo Canyon is mainly ^{239}Pu, while that in Los Alamos and Mortandad Canyons is both ^{238}Pu and ^{239}Pu. The $^{239}Pu/^{238}Pu$ ratios are 742, 3, and 0.3, respectively, in the suspended sediment. The three canyons have or are now receiving treated effluents. Trace amounts of

TABLE X

RADIOCHEMICAL AND CHEMICAL ANALYSES OF STORM RUNOFF (average concentrations)

		Radiochemical				
		Solution (pCi/ℓ)			Suspended Sediments (pCi/g)	
Canyon	No. of Events	^{137}Cs	^{238}Pu	^{239}Pu	^{238}Pu	^{239}Pu
Rendija near G-6	3	12 ± 29	−0.003 ± 0.004	−0.004 ± 0.015	−0.042 ± 0.053	−0.012 ± 0.023
Pueblo near SR-4	4	12 ± 12	0.002 ± 0.013	0.051 ± 0.046	−0.014 ± 0.069	10.4 ± 8.8
Los Alamos near SR-4	7	7 ± 16	0.026 ± 0.058	0.074 ± 0.104	1.38 ± 1.05	4.59 ± 2.28
Sandia near SR-4	3	128 ± 186	−0.012 ± 0.006	−0.001 ± 0.005	−0.004 ± 0.012	0.079 ± 0.044
Mortandad near MCO-7	2	25 ± 35	0.521 ± 0.578	0.092 ± 0.124	31.6 ± 37.3	8.9 ± 10.0
Water at SR-4	7	6 ± 21	−0.008 ± 0.008	0.011 ± 0.003	0.003 ± 0.164	0.119 ± 0.298
Ancho at SR-4	3	20 ± 28	−0.021 ± 0.034	−0.019 ± 0.028	0.001 ± 0.001	0.075 ± 0.042
		Chemical (solution concentrations in mg/ℓ)				
Canyon		Ca	Mg	Cl	F	TDS
Rendija near G-6	3	16 ± 2	4.4 ± 3.1	4 ± 3	0.4 ± 0.1	184 ± 84
Pueblo near SR-4	4	11 ± 2	2.1 ± 0.6	10 ± 10	0.7 ± 0.4	242 ± 83
Los Alamos near SR-4	8	10 ± 2	1.4 ± 0.9	7 ± 3	3.4 ± 3.6	277 ± 86
Sandia near SR-4	3	14 ± 6	3.0 ± 1.8	20 ± 28	0.4 ± 0.2	265 ± 217
Mortandad near MCO-7	2	8 ± 1	1.8 ± 0.5	5 ± 1	0.9 ± 0.1	172 ± 54
Water at SR-4	8	14 ± 9	3.9 ± 1.8	3 ± 3	0.2 ± 0.1	164 ± 64
Ancho at SR-4	4	14 ± 6	2.6 ± 0.7	3 ± 1	0.3 ± 0.1	132 ± 99

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

^{239}Pu are found in suspended sediments of Sandia, Water, and Ancho Canyons, which may be from Laboratory operations or fallout.

The calcium, magnesium, and chloride analyses of runoff show no trends. Fluorides are high (3.4 ± 3.6 mg/ℓ) in runoff from Los Alamos Canyon, while the remainder shows no particular trends. The relatively higher TDS in runoff from Pueblo, Los Alamos, and Sandia Canyons may reflect the release of sanitary effluents into the canyons.

The seven canyons contain intermittent streams that flow only during storm runoff. It is evident that in three canyons—Pueblo, Los Alamos, and Mortandad—transport of radionuclides occurs during storm runoff events both in solution and in suspended sediments.

5. Radioactivity in Foodstuffs

Fruit and vegetable samples collected in the vicinity of LASL showed no apparent influence from Laboratory operations except for peach tree leaves collected at an onsite location near a facility that emits tritium.

Fruit and vegetable samples were collected during the fall to monitor foodstuffs for possible radioactive contamination from Laboratory operations. Collection was made in the Los Alamos area and in the Rio Grande Valley above and below the confluences of intermittent streams crossing the Laboratory and the Rio Grande. Samples were cleaned but not washed. Moisture was distilled from them for HTO analyses and the remaining fraction dried, ashed, and chemically digested for ^{238}Pu, ^{239}Pu, total uranium and ^{90}Sr analyses. A study completed in 1978 analyzed the 1977 piñon nut crop for radioactivity. Additionally, fish muscle samples from a 1976 ecological research project were analyzed for ^{137}Cs, $^{238,239}Pu$, and total uranium.

The data presented in Table XI summarize the tritium content in fruit and vegetable samples from the 1978 harvest according to different water supplies. Sample moisture ranged from 64 to 96% of the total sample weight. With the exception of the TA-35 sample, there is no significant difference in HTO content between any batches of samples analyzed. Observed concentrations are within the range of values measured in local surface water and atmospheric water vapor. Thus, there is no indication of any measurable offsite contribution from Laboratory operations. The peach trees of TA-35 produced a small crop, which was gone before we were able to sample, so leaves were analyzed as being representative of the HTO content of peaches.

TABLE XI

TRITIATED WATER CONTENT OF FOODSTUFFS

Location	Irrigation Water Source	No. of Samples	Tritium Concentration (pCi/mℓ) Averge (± 1σ)	Range
Española	Rio Chama[a]	5	1.3 ± 1.5	−0.8 to 3.1
Española, San Juan	Rio Grande[a]	6	1.2 ± 0.8	0.4 to 2.2
Peña Blanca	Rio Grande[b]	4	0.4 ± 0.5	−0.3 to 1.0
White Rock	LA County	4	−0.7 ± 0.1	−0.8 to 0.6
Los Alamos	LA County	5	−0.1 ± 0.4	−0.6 to 0.3
TA-35	LA County	1	17	---

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

As expected, there was some Laboratory contribution to the tritium content of those leaves because the trees are within 20 m of a 23 m high stack where tritium is released. The few peaches do not represent a significant pathway to man because they are within a Laboratory fence, represent a very small volume of ingestible water, and have considerably less tritium than the uncontrolled area CG (3000 pCi/mℓ) for water.

As can be seen in Table XII, uranium concentrations in all cases are low and consistent with results reported earlier. The three highest values, 247, 184, and 20 pCi/g, are from samples of lettuce (LA County), peach leaves (TA-35), and spinach (White Rock), respectively. Samples of non-leafy vegetables from the Los Alamos and White Rock areas did not show such concentrations of uranium, which indicates the uranium was from soil on the leaf surface and not from the water supply.

Plutonium 238 and 239 analyses were made on all the samples. Only four samples had detectable activity, as indicated in Table XIII. Ingestion of 1 kg of lettuce contaminated to 1.2×10^{-3} pCi/g would result in a 50 yr dose commitment of 1.4×10^{-4} mrem to the critical organ (bone). Contamination and doses of this magnitude indicate they are due to fallout or soil contamination on the plant surface and not to Laboratory related effluents.

Results of ^{90}Sr analyses (Table XIV) show two samples with slightly elevated ^{90}Sr concentrations—lettuce leaves in Los Alamos and peach leaves from TA-35. The lettuce (which has a high surface to volume ratio) had the highest uranium and plutonium concentrations. The contamination was likely due to external contamination from fallout, which would be removed by washing. Eating 1 kg of unwashed lettuce would give a 50 yr dose commitment to the bone of 0.56 mrem. Contamination at TA-35 is likely due to elevated concentrations of ^{90}Sr in the vicinity, caused by early work at TA-35 on radioactive lanthanum sources in which ^{90}Sr is a contaminant. Obviously, the peach leaves are not a route of ingestion for man and ingestion of peaches from TA-35 would not have as much ^{90}Sr contamination as the leaves because of the lower surface to volume ratio of the peaches.

Analysis of bees and honey for radioactive contamination was established in 1972 (phased out in 1974) as part of the ongoing environmental research program at the Laboratory. Results were reported elsewhere.[5-8] Three stations from this network (DP outfall; Effluent Canyon, and Mortandad Canyon) were reestablished and a new station (TA-54) added in September 1978 to monitor radioactive and nonradioactive contaminants in waste disposal areas.

TABLE XII

URANIUM CONCENTRATIONS IN FOODSTUFFS

Location	Irrigation Water Source	No. of Samples	Uranium Concentration (ng/g)[c] Average (± 1σ)	Range
Española	Rio Chama[a]	5	8.0 ± 4.6	4.1 to 13
Española, San Juan	Rio Grande[a]	6	1.4 ± 2.2	0 to 4.5
Peña Blanca	Rio Grande[b]	4	6.1 ± 6.6	0 to 15
White Rock	LA County	4	5.4 ± 9.6	0 to 20
Los Alamos	LA County	5	49.4 ± 110	0 to 247
TA-35	LA County	1	184	---

[a] Upstream from Laboratory stream confluence.

[b] Downstream from Laboratory stream confluence.

[c] Concentrations are given in ng/g of dry weight. After collecting water for tritium analysis, samples were dried at 100°C for 48-72 h.

TABLE XIII

^{238}Pu and ^{239}Pu CONCENTRATIONS IN FOODSTUFFS

Location	Foodstuff	pCi/g (dry weight) ^{238}Pu	^{239}Pu
Peña Blanca	Cucumbers	---	3.6×10^{-4}
Los Alamos	Lettuce	---	1.2×10^{-3}
Los Alamos	Squash	3.2×10^{-4}	---
TA-35	Peach Leaves	---	8.5×10^{-4}

TABLE XIV

^{90}Sr CONTENT IN FOODSTUFFS

Location	Irrigation Water Source	No. of Samples	^{90}Sr Concentration (pCi/g)[c] Average ($\pm 1\sigma$)	Range
Española	Rio Chama[a]	5	0.021 ± 0.015	0.005 to 0.040
Española, San Juan	Rio Grande[a]	6	0.028 ± 0.032	0.0016 to 0.077
Peña Blanca	Rio Grande[b]	4	0.020 ± 0.009	0.008 to 0.031
White Rock	LA County	4	0.029 ± 0.039	0.007 to 0.086
Los Alamos	LA County	5	0.058 ± 0.088	0.008 to 0.215
TA-35	LA County	1	1.58 ± 0.06	---

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

Several of these disposal areas could be readily accessible to bees from privately-owned hives that might be placed near Laboratory boundaries. Because the honey producing season was over at the time hives were placed by the Laboratory, no samples were available for 1978. However, the hives should be well established and productive for samples during 1979. Estimates of the maximum exposure to an individual from eating honey were made from data collected during the research portion of this program. The maximum individual dose was calculated to be 0.12 mrem/yr from eating honey slightly contaminated with tritium, which theoretically would come from nectar made from clover growing over a contaminated solid waste disposal site.

Over half the Laboratory land area of 111 km^2 is covered with the piñon pine tree (*pinus edulis*), which yields a southwestern speciality food—the piñon nut. A study was made of the 1977 crop to determine possible radionuclide intake through piñon nut consumption, because many employees and some of the public harvest nuts on Laboratory lands. In this initial study, unwashed whole nuts were analyzed because some people eat unwashed, whole nuts (although most people prefer to remove the shell). Nuts were harvested by picking them off the ground. Results are summarized in Table XV.

Slightly elevated concentrations (above background sample concentrations) of ^{90}Sr, total uranium, and tritium occurred in several technical

TABLE XV

RADIOACTIVITY CONTENT OF PIÑON NUTS

	Units[a]	Background Composite[b]	Six Technical Areas Average	Range
^{90}Sr	fCi/g	3.0 ± 1.1	13.5 ± 15.6	0.2 to 42
^{238}Pu	fCi/g	0.12 ± 0.18	−1.3 ± 1.2	−3.2 to −0.056
^{239}Pu	fCi/g	0.051 ± 0.18	0.11 ± 2.9	−4.8 to 4.4
U	ng/g	1.4 ± 0.35	14.± 28	1.6 to 71
^{137}Cs	fCi/g	0.070 ± 0.28	0.30 ± 0.41	0.00 to 1.1
^{7}Be	fCi/g	0.40 ± 0.21	0.57 ± 0.47	0.09 to 1.1
^{3}H	pCi/mℓ	4.9 ± 0.4	12.6 ± 7.7	5.6 to 24.2

[a] Units are per gram of wet weight.
[b] Collected from Nambe, Santa Fe, and Abiquiu.

areas. For ^{90}Sr and total uranium we believe this increase is due to greater external soil contamination that contains fallout ^{90}Sr and to naturally occurring uranium, because the nuts were harvested in areas with no record of contamination and no noticed increase of these contaminants in the soil. The sample with elevated tritium concentrations comes from a waste disposal area where there is known tritium contamination. We plan to study this pathway further by examining whether contamination is internal or external and by analyzing the soil from which the nuts are removed.

If one were to eat 1.5 kg of whole, unwashed nuts from the areas with maximum concentrations, one would receive a 50 yr dose commitment to bone from ^{90}Sr of 0.45 mrem and a whole body dose of 2×10^{-3} mrem from HTO.

As part of the environmental research program, fish samples were collected from three locations at Cochiti Reservoir on the Rio Grande in 1976, and at Heron and Costilla Lakes in northern New Mexico in 1976 and 1973, respectively. These samples (muscle only) were analyzed in 1978 for ^{137}Cs, total uranium, and ^{238,239}Pu. Results are summarized in Table XVI.

As can be seen from the data, there are no significant differences between Cochiti and the background stations at Heron and Costilla Lakes. Species chosen for analysis were mostly bottom feeders (e.g., suckers), which are more likely to ingest any contamination present in sediments than species of higher trophic levels.

6. Radioactive Effluents

Airborne radioactive effluents released from LASL operations in 1978 were typical of releases during the last several years. The greatest change was an increase in activation products from higher power operation of the linear accelerator at LAMPF. Liquid effluents from three waste treatment plants contained radioactivity at levels well below controlled area concentration guides.

Effluents containing radioactivity are discharged at LASL in the form of airborne materials in stack exhausts at twelve of the technical areas and as liquid discharges from two industrial waste treatment plants and one sanitary sewage lagoon. The airborne effluents consist principally of filtered ventilation exhausts from gloveboxes, other experimental

TABLE XVI

RADIOACTIVITY IN FISH

Location	No. of Samples	^{137}Cs (pCi/g[a]) Average	^{137}Cs (pCi/g[a]) Range	U(ng/g[a]) Average	U(ng/g[a]) Range
Cochiti[b]	5	−0.0082 ± 0.049	−0.067 to 0.056	2.0 ± 2.1	0.0 to 4.5
Herron	2	0.0040 ± 0.078	−0.051 to 0.059	1.5 ± 2.1	0.0 too 3.0
Costilla	2	0.013 ± 0.11	−0.065 to 0.091	2.6 ± 3.6	0.0 to 5.1

Location	No. of Samples	^{238}Pu (fCi/g[a]) Average	^{238}Pu (fCi/g[a]) Range	^{239}Pu (fCi/g[a]) Average	^{239}Pu (fCi/g[a]) Range
Cochiti[b]	5	−0.064 ± 0.067	−0.16 to 0.010	−0.044 ± 0.028	−0.090 to 0.020
Herron	2	−0.075 ± 0.120	−0.16 to 0.010	−0.060.± 0.11	−0.14 to 0.020
Costilla	2	−1.0 ± 1.4	−2.0 to −0.06	−1.2 ± 1.7	−2.4 to 0.040

[a]Radionuclide concentration in muscle tissue based on tissue weight after oven drying.
[b]Below confluence of the Rio Grande with intermittent Laboratory streams.

facilities, and some process facilities such as the liquid waste treatment plants; exhausts from the research reactor (TA-2); and exhausts from the linear accelerator at LAMPF (TA-53). The releases of various isotopes from the technical areas are detailed in Table E-XXI. The quantities of radioactivity released depend on the research programs conducted and result in significant year-to-year variations. For example, the amount of air activation products, especially ^{11}C, ^{13}N, and ^{15}O, was higher by a factor of about 2 in 1978 compared to 1977 (Fig. 11) because the linear accelerator was operating at higher power levels in 1978. However, these short-lived (2 to 20 min) isotopes decay rapidly. For instance, 4 h after a release of a quantity of ^{11}C (half-life of 20 min), <0.1% of the original amount discharged would remain. A Task Force on Radioactive Air at LAMPF has been formed to explore ways to reduce radioactive airborne effluents from LAMPF. Airborne tritium releases at TA-33 in 1978 were higher by a factor of about 30 compared to 1977 releases (Fig. 12) because of increased research activity. Other releases showed variation expectable from programmatic differences (Figs. 13 and 14).

Treated liquid effluents containing low levels of radioactivity are released from the Central Liquid Waste Treatment Plant (TA-50), a smaller plant serving the old plutonium processing facility (TA-21), and the sanitary sewage lagoon serving LAMPF. Detailed results of the effluent radioactivity monitoring are presented in Table E-XXII and Figs. 12-14. A total of 1.3×10^7 ℓ of effluent was discharged from the TA-53 sanitary lagoon containing 0.05 Ci of ^7Be and 2.4 Ci of ^3H. The source of the radioactivity was leaks of activated beam stop cooling water. None of the isotopes were at concentrations higher than about 2.6% of CGs for water in controlled areas. The amount of radioactive liquid waste processed at the smaller plant (TA-21) has declined through the year as research operations have moved to the new plutonium facility (TA-55) and is expected to continue to decline in 1979. Design work is underway for an upgrading of the larger plant (TA-50), which will further reduce the amount of contaminants released in the effluent.

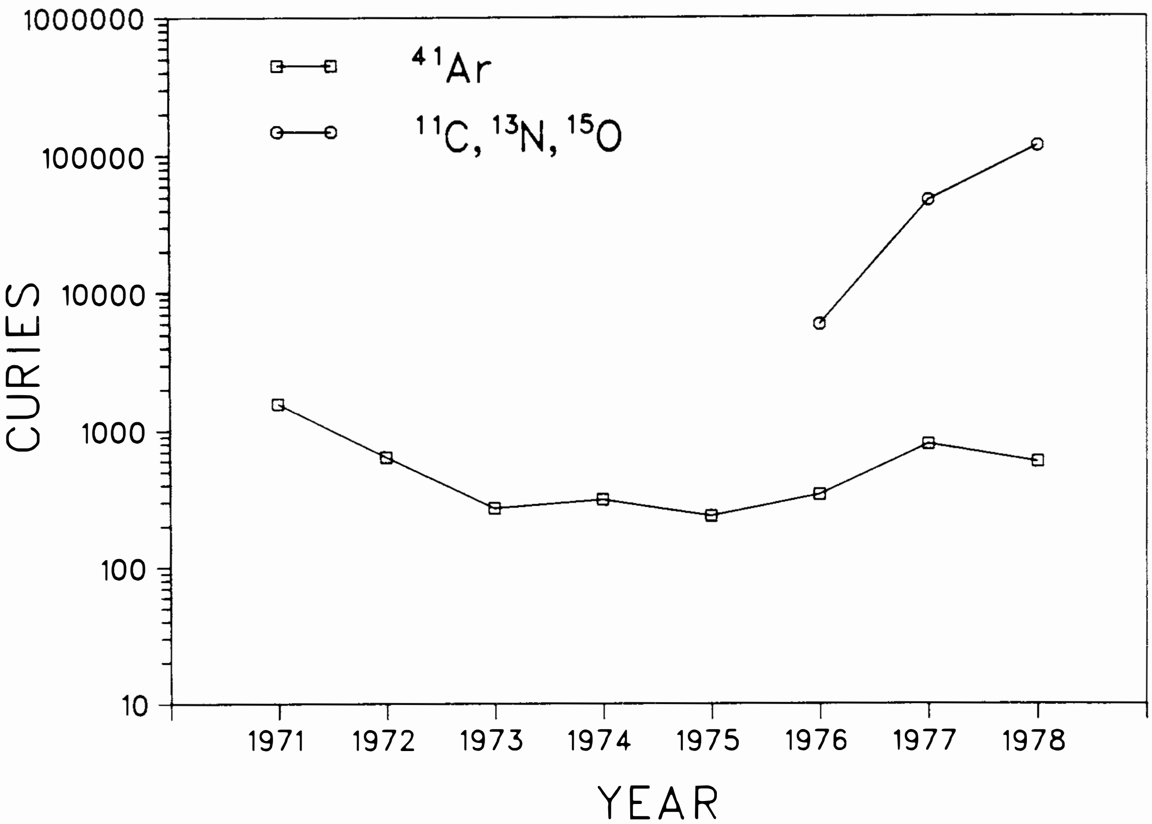
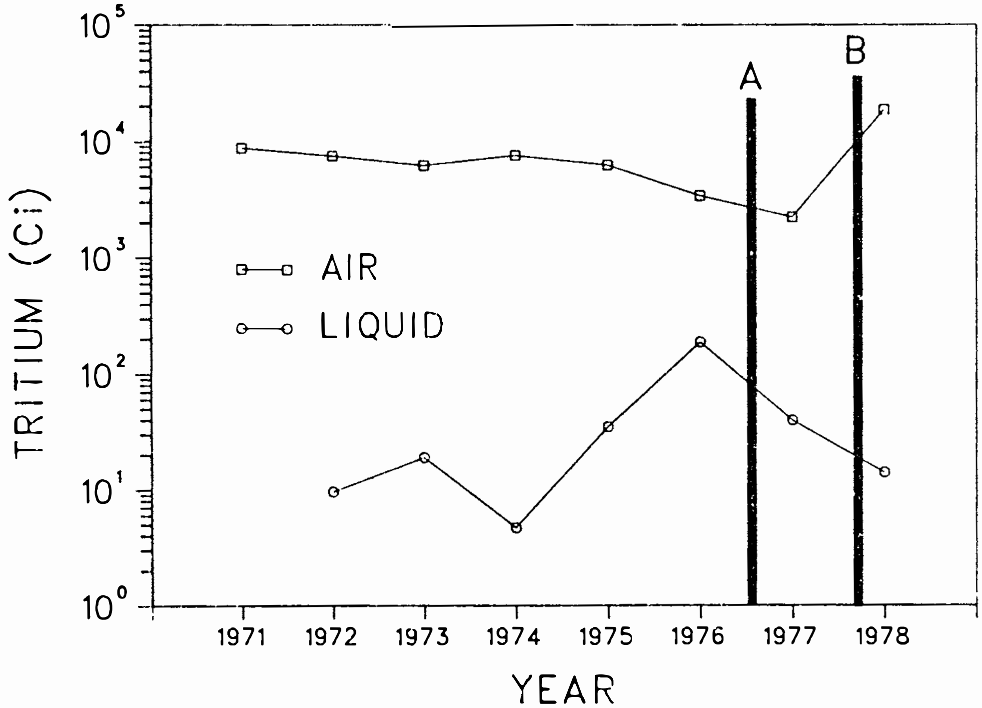


Fig. 11.

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

The releases from the large plant (TA-50) are discharged into a normally dry stream channel (Mortandad Canyon) in which surface flow has not passed beyond the Laboratory boundary since before the plant began operation. The discharges from the smaller plant (TA-21) are made into DP Canyon, a tributary of Los Alamos Canyon where runoff does at times flow past the boundary and transports some residual activity adsorbed on sediments.

In addition to the airborne releases from stacks, some depleted uranium (uranium consisting almost entirely of ^{238}U) is dispersed by experiments employing conventional high explosives. In 1978 about 1371 kg of depleted uranium were used in such experiments. Based on known isotopic composition, this mass is estimated to contain approximately 0.51 Ci of activity. Most of the debris from these experiments is deposited on the ground in the vicinity of the firing point. Limited experimental information indicates that no more than about 10% of the depleted uranium is aerosolized. Approximate dispersion calculations indicate that resulting airborne concentrations at site boundaries would be in the same range as attributable to natural crustal-abundance uranium in resuspended dust. This theoretical evaluation is compatible with the concentrations of atmospheric uranium measured by the continuous air sampling network (see Sec. III.A.2). Estimates of nonradioactive releases from these experiments are discussed in Sec. III.B.3.



A. Accidental airborne tritium release of 22 000 Ci from TA-3-34 on July 15, 1976.
B. Accidental airborne tritium release of 30 800 Ci from TA-33-86 on October 6, 1977.

Fig. 12.
Summary of tritium effluents (air and liquid).

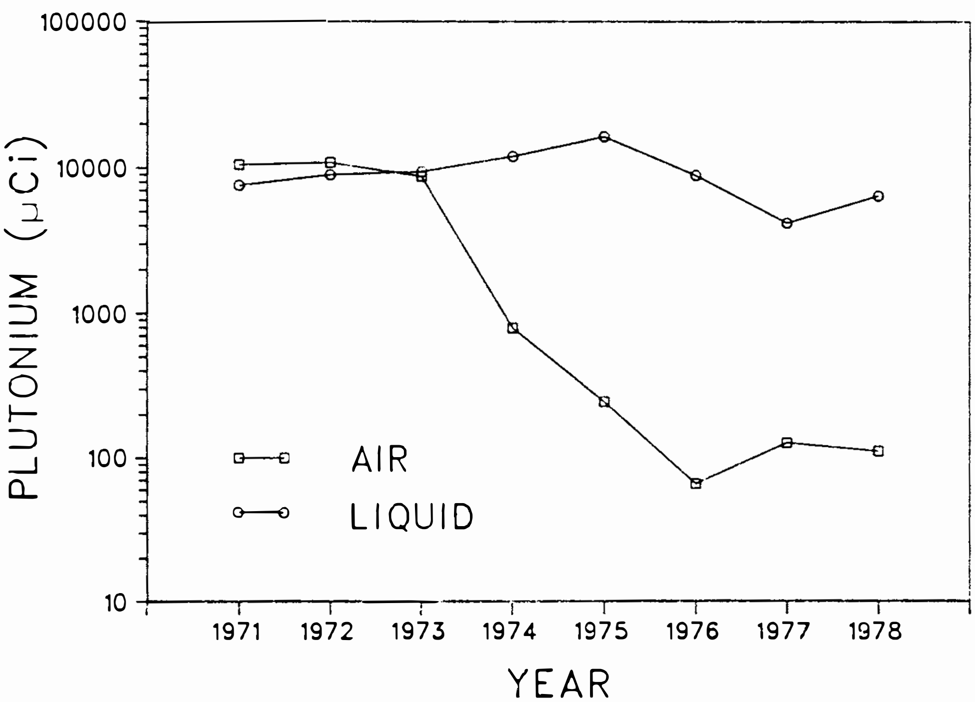


Fig. 13.
Summary of plutonium effluents (air and liquid).

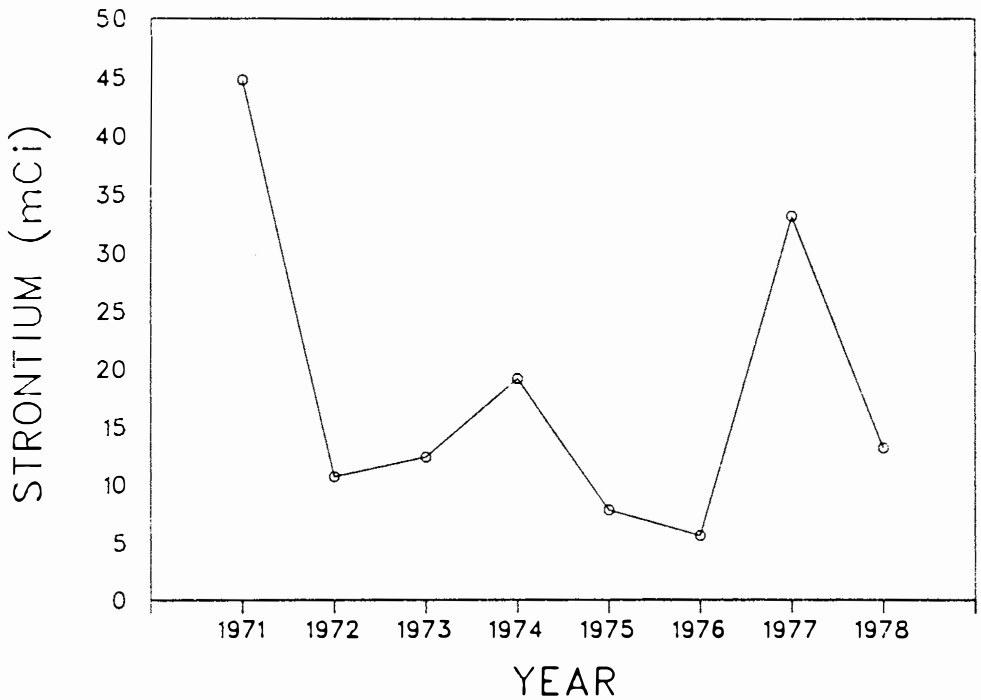


Fig. 14.
Summary of strontium liquid effluents.

B. Chemical Constituents

1. Chemical Quality of Surface and Ground Waters

Chemical analyses of surface and ground waters from regional, perimeter, and onsite non-effluent release areas varied slightly from previous years, but showed no significant change. The chemical quality of water from the municipal supply for the Laboratory and community meets the standards set by the EPA and NMEID. Analyses from onsite effluent release areas indicated that some constituents were higher than in naturally-occurring waters; however, these waters are not a source of municipal, industrial, or agricultural supply. Analyses were performed for 33 parameters related to water quality.

a. Regional and Perimeter. Regional and perimeter surface and ground waters were sampled at the same locations as were used for radioactivity monitoring (Table E-XII). The regional surface waters were sampled at six stations, with perimeter waters sampled at seven stations plus 26 stations in White Rock Canyon (Fig. 9). Detailed analyses from the regional and perimeter stations are presented in Tables E-XIII and E-XIV, respectively. (See Appendix B.3 for methods of collection, analyses, and reporting of water data). The maximum concentrations for 12 parameters are in Table XVII.

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

TABLE XVII

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

		Perimeter		
Analysis	Regional	Five Stations	White Rock Canyon	Standard or Criteria
Ag	0.02	<0.01	---	0.05
As	0.08	<0.01	---	0.05
Ba	0.4	0.49	---	1.0
Cd	<0.010	0.010	---	0.010
Cl	82	9	29	250
Cr	<0.01	<0.01	---	0.05
F	0.9	0.6	1.0	2.0
Hg	<0.001	<0.001	---	0.002
NO_3	<2	8	60	45
Pb	<0.01	<0.01	---	0.05
Se	<0.005	<0.005	---	0.01
TDS	540	286	552	1000

b. Onsite Surface and Ground Waters. Water samples were collected from three surface water stations and seven wells completed in the main aquifer (Table E-XII). They are located in onsite areas that do not receive industrial effluents (Fig. 9). Detailed results of analyses are given in Table E-XVI. The maximum concentrations for selected constituents are in Table XVIII.

Water quality at the surface water stations also varies slightly as base flow is diluted with varying amounts of storm runoff. Two surface water stations contained above normal amounts of barium (Water Canyon) and fluorides (Cañada del Buey), which may result from release of cooling or process water at sites upgradient from the stations. The quality of surface and ground waters has not changed significantly from previous analyses.

Table E-XVI details the chemical quality analyses of surface and ground water from 21 stations located in canyons that receive sanitary and/or industrial effluent (Fig. 10, Table E-XII). The maximum concentrations of selected constituents found in each canyon are summarized in Table XIX.

Acid-Pueblo Canyon received industrial effluents from 1943 to 1964 and currently is receiving treated sanitary effluents, which are now the major part of the flow. Sandia Canyon receives cooling tower blowdown and some treated sanitary effluents. DP-Los Alamos and Mortandad Canyons receive treated industrial effluents that contain some radionuclides and residual chemicals used in the waste treatment process. The high TDS and chlorides reflect effluents released into the canyons. Cadmium in Acid-Pueblo; chromates in Sandia and DP-Los Alamos; fluorides in DP-Los Alamos and Mortandad; and nitrates in the four canyons were above drinking water standards;[9] however, these onsite waters are not a source of municipal, industrial, or agricultural supply (Table XIX). The maximum concentrations occurred near the effluent outfalls. The chemical quality of the water improves downgradient from the outfall. There is no surface flow to the Rio Grande in these canyons except during periods of heavy precipitation.

Baseline data were collected from the main aquifer upgradient (location 41, Fig. 9) and at the discharge from the aquifer (location 6, Fig. 9) downgradient from a solid waste disposal site, which has been proposed to be used for disposal of organic wastes. The analyses are compared to EPA drinking water standards[9] and are in Table XX.

TABLE XVIII

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

Analysis	Surface Water	Ground Water	Standard or Criteria
Ag	0.03	<0.01	0.05
As	<0.01	0.01	0.05
Ba	8.15	0.72	1.0
Cd	<0.010	<0.010	0.010
Cl	95	6	250
Cr	<0.01	<0.01	0.05
F	4.2	1.2	2.0
Hg	<0.001	<0.001	0.002
NO_3	<2	<2	45
Pb	<0.01	<0.01	0.05
Se	<0.005	<0.005	0.01
TDS	440	290	1000

TABLE XIX

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

Analysis	Acid-Pueblo	Sandia	DP-Los Alamos	Mortandad	Standard or Criteria
Ag	<0.01	0.07	0.01	0.02	0.05
As	0.01	<0.01	<0.01	<0.01	0.05
Ba	<0.3	<0.3	<0.2	<0.3	1.0
Cd	0.240	0.017	0.007	0.014	0.010
Cl	102	62	104	44	250
Cr	<0.01	5.38	0.11	0.04	0.05
F	0.9	1.9	25	2.7	2.0
Hg	<0.001	<0.001	<0.001	<0.001	0.002
NO_3	46	33	68	276	45
Pb	<0.01	<0.01	<0.01	<0.01	0.05
Se	<0.005	0.005	0.005	<0.005	0.01
TDS	558	916	1908	1340	1000

TABLE XX

BASELINE DATA FOR ORGANIC CHEMICALS
(concentrations in mg/ℓ)

	Location			
Analysis	**41 PM-2**	**6 Spr 3**	**6 Spr 4A**	**Standard**
PCBs	<0.0001	<0.0001	<0.0001	---
Chlordane	<0.003	<0.003	<0.003	---
Endrin	<0.0002	<0.0002	<0.0002	0.0002
Heptachlor	<0.0001	<0.0001	<0.0001	---
Heptachlor Epoxide	<0.0001	<0.0001	<0.0001	---
Lindane	<0.004	<0.004	<0.004	0.004
Methoxychlor	<0.1	<0.1	<0.1	0.1
Toxaphene	<0.005	<0.005	<0.005	0.005
2,4-D (acid)	<0.1	<0.1	<0.1	0.1
2,4,5-TP Silver (acid)	<0.01	<0.01	<0.01	0.01

2. Water Supply

The federally-owned well field produced water for the Laboratory and County, which met all applicable EPA standards.

Municipal and industrial water supplies for the Laboratory and community were sampled at 15 deep wells, one gallery, and at five stations on the distribution system (Table E-XII, Fig. 9). Detailed analyses are in Table E-XV. Appendix A gives the federal and state standards and criteria for municipal water supplies. The maximum concentrations of chemical constituents from wells, gallery, and distribution system stations are compared to criteria in Table XXI. The concentrations of naturally-occurring arsenic in the Guaje Well Field (G-2), and fluoride and silver in the Los Alamos Well Field (LA-1B and LA-5, respectively) were slightly above standards[9] for drinking water; however, dilution in the distribution system reduces the concentrations to acceptable levels. All constituents met the criteria for water supply in the distribution system. There has been no significant change in chemical constituents from individual wells from previous years.

TABLE XXI

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

Analysis	Supply Wells and Gallery	Distribution	Standard or Criteria
Ag	0.07	0.02	0.05
As	0.08	0.01	0.05
Ba	0.1	0.1	1.0
Cd	0.008	0.006	0.010
Cl	13	7	250
Cr	0.03	0.02	0.05
F	2.2	1.1	2.0
Hg	<0.001	<0.001	0.002
NO_3	<2	1	45
Pb	0.02	0.01	0.05
Se	0.001	0.001	0.01
TDS	624	274	1000

3. Nonradioactive Effluents

Nonradioactive effluents include airborne and liquid discharges. Airborne effluents from the asphalt plant; beryllium shop; gasoline storage and combustion; power plant; gases and volatile chemicals; waste explosive burning; lead pouring; and dynamic testing did not result in any measurable or theoretically calculable degradation of air quality. A single NPDES permit for 104 industrial discharge points and 10 sanitary sewage treatment facilities took effect in mid-October. After the new permit took effect, 6 of the 10 sanitary sewage treatment facilities exceeded one or more of the EPA permit limits in one or more months and 18 of the 104 industrial outfalls exceeded one or more limit.

a. Airborne Discharges. Particulate concentrations in the Los Alamos and White Rock areas are routinely measured by the state. Table E-XXIII summarizes these data for 1978. The highest 24 h averages and the annual averages are compared to the New Mexico Ambient Air Quality Standards for particulates in Table XXII. Both the 24 h averages and annual geometric means are well within state standards. Although true 7 day and 30 day averages cannot be calculated, there is no indication that they would exceed state standards.

The state does not routinely monitor the Los Alamos area for any air contaminants other than particulate matter. As reported last year, a series of SO_2 (sulfur dioxide) measurements was made by the state in October and November of 1976 to establish background levels. None of the hourly SO_2 measurements were above the minimum detectable level of 0.01 ppm. The state standard for SO_2 is a 24 h average of 0.10 ppm and an annual arithmetic average of 0.02 ppm.

During 1978 the Laboratory was surveyed to identify air pollution sources and quantify amounts of materials emitted from these sources. Sources investigated to date include the asphalt plant operated by the Zia Company, beryllium shop, gasoline storage and combustion, TA-3 power plant, volatile chemical and gas emissions, waste explosive burning, and dynamic experiments. These sources are discussed separately in the following paragraphs.

As reported last year,[4] a consultant evaluated the emissions from the asphalt plant operated by the Zia

TABLE XXII

SUMMARY OF ATMOSPHERIC PARTICULATE CONCENTRATIONS IN LOS ALAMOS AND WHITE ROCK DURING 1978

	New Mexico Ambient Air Quality Standards for Particulates ($\mu g/m^3$)	Los Alamos ($\mu g/m^3$)	White Rock ($\mu g/m^3$)
Maximum 24 hour average	150	111	172
Maximum 7 day average	110	---	---
Maximum 30 day average	90	---	---
Annual Geometric Mean	60	36	22

Company in 1977. The state particulate emission standard for asphalt plants specifies a maximum allowable particulate emission rate as a function of the aggregate process rate of the plant. At the time of the study, the aggregate production rate of the asphalt plant was 68 metric tons per h. The allowable particulate emission rate for a plant of this size is 16 kg/h. The measured emission rate of 0.8 kg/h was only about 5% of the standard.[10]

Beryllium emissions from the beryllium shop are continuously monitored. A total of about 20 mg of beryllium were emitted during 1978, and measured stack gas concentrations ranged from 0.000 to 0.009 $\mu g/m^3$. All stack gas concentrations were below the state ambient air standard of 0.01 $\mu g/m^3$.

A large fleet of cars and trucks is maintained for the Laboratory complex by the Zia Company. During fiscal year 1978, a total of $2.4 \times 10^6 \ell$ of gasoline were used by this fleet. Carbon monoxide, hydrocarbons, nitrogen oxides, sulfur oxides, and particulates are emitted during automobile operation. There are also gasoline evaporative losses associated with gasoline storage and vehicle refueling. By breaking down total gasoline usage among the size classes of vehicles and by applying the most appropriate EPA emissions factors[11] to these data, air pollution emissions associated with maintenance and operation of the vehicle fleet (Table XXIII) were estimated.

The TA-3 power plant is fueled with natural gas and thus comes under state regulations for gas burning equipment. These regulations specify maximum allowable nitrogen oxide emissions but also contain a provision exempting facilities that have a heat input of less than 1×10^{12} Btu/year/unit. The heat input for the TA-3 power plant boilers during 1978 were 0.82×10^{12} Btu (Boiler No. 1), 0.77×10^{12} Btu, (Boiler No. 2), and 0.86×10^{12} Btu (Boiler No. 3). Total heat input for the power plant is 2.45×10^{12} Btu, but inputs for the individual boilers are below the exemption threshold. Measured NO_x (nitrogen oxide) concentrations in the stack gases range from 30 to 50 ppm, or no more than about 20% of the limit that would apply were the heat input threshold exceeded. Using EPA emission factors[11] and volume of natural gas burned, the following estimates of stack gas emissions were made (Table XXIV).

The Laboratory complex uses large quantities of various volatile chemicals and gases that are released into the atmosphere by evaporation or exhaust. Using data from stock records and estimates of actual losses to the atmosphere by large users (>680 kg/yr) of these chemicals, a preliminary estimate of total releases during 1978 was compiled and is given in Table XXV. There are also many small users of chemicals throughout the Laboratory, and other chemicals released to the atmosphere will be added to this list as the smaller users are inventoried.

During 1978 about 26 480 kg of high explosives wastes were disposed by open burning at the Laboratory. Estimates of emissions (Table XXVI) were made by using data from experimental work carried out by Mason & Hangar-Silar Mason Co., Inc.[12] Open burning of high explosives wastes is permitted by the New Mexico Air Quality Control regulations.

TABLE XXIII

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

Pollutant	Estimated Amount (metric tons)
Gasoline Evaporative Losses	28.3
Carbon Monoxide	213
Hydrocarbons	21
Nitrogen Oxides	29
Sulfur Oxides	1.1
Particulates, Exhaust	0.6
Particulates, Tires	1.2

TABLE XXIV

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

Pollutant	Estimated Amount (metric tons)
Sulfur oxides	0.6
Hydrocarbons	1.1
Carbon monoxide	17.9
Particulates	10.5
Nitrogen oxides	739

TABLE XXV

ESTIMATED LOSSES OF GASES AND VOLATILE CHEMICALS

Chemical	Estimated Amount (kg)
Acetone	2700
Carbon Monoxide	4100
Ethyl Acetate	1600
Freons	3300
Helium	6800 - 13 600
Methyl Ethyl Ketone	3500
Methylene Chloride	800
Sulfur Hexafluoride	8200
Trichloroethane	13 700
Trichloroethylene	2000

TABLE XXVI

ESTIMATED EMISSIONS FROM BURNING OF EXPLOSIVE WASTES

(Using data from Mason & Hanger-Silas Mason Co., Inc.[12])

Pollutant	Estimated Amount (kg)
Carbon Monoxide	205
Particulates	477
Nitrogen Oxides	800
Total Waste Burned	26 480 kg

Dynamic experiments employing conventional explosives are routinely conducted in certain test areas at LASL and may contain quantities of potentially toxic metals, including beryllium, lead, and uranium. Some limited field experiments, based on aircraft sampling of debris clouds, provided information on the proportion of such materials aerosolized. This information was employed to prepare estimates of concentrations at the LASL boundary based on the current year's utilization of the elements of interest. The results are presented in Table E-XXIV along with comparisons to applicable air quality regulations. The average concentrations are all less than 5×10^{-4}% of applicable standards.

b. Liquid Discharges. Nonradioactive liquid wastes are released from 104 industrial discharge points and 10 sanitary sewage treatment facilities subject to NPDES requirements. A single NPDES permit issued by the EPA took effect in mid-October 1978, placing specific effluent limits for the first time on 10 categories of industrial waste outfalls. Ten sanitary sewage treatment facilities, 9 of which previously had separate NPDES permits, were also included in the new permit. Under the new permit only two of the sanitary outfalls were assigned fecal coliform limits; all other parameters, including 5-day biochemical oxygen demand total suspended solids, and pH, were the same as in the individual permits. Tables E-XXV and E-XXVI summarize the effluent quality and compliance status of the sanitary sewage and industrial waste outfalls, respectively.

After the new permit took effect, four of the sanitary sewage outfalls met all limits, and two others (lagoons) exceeded only flow limits because of far above normal precipitation during the last three months of 1978. Eighteen of the 104 industrial outfalls exceeded one or more limit during the period the permit was in effect. Eight of those responsible for the largest number of deviations are scheduled for already-funded corrective measures to be carried out in 1979-80. The two radioactive waste treatment plants have the largest number of limits with which to comply, and only one of those plants exceeded one limit by about 5% on one day. Details of the effluent quality from these two plants are given in Table E-XXII for both non-radioactive (including several not regulated by the NPDES permit), and for radioactive parameters.

4. Herbicide Damage

During the spring and summer of 1978, many reports of dead and dying trees along Laboratory roads were received by the Environmental Surveillance Group. An initial estimate placed the damage at about 2400 dead and dying trees. The most probable causes of damage were insects, road salt, herbicides, or some combination of these factors. To check for the possibility of salt damage, samples of both healthy and damaged needles were analyzed for chloride content. Although the chloride content of the damaged needles was slightly higher than that of the healthy needles, both were within the range of concentrations previously associated with healthy needles. The damage symptoms also were not characteristic of salt damage. Forest Service specialists were called in to assess the possibilities of insect and herbicide damage. No evidence of insect damage was found, but the symptoms were characteristic of damage from bromacil, an herbicide which was applied to the roadsides in the fall of 1977 to control roadside vegetation. Subsequent gas chromatographic analyses established the presence of bromacil residues in the needles from damaged trees. These residues were not present in the needles from healthy trees. As the incident was reconstructed, bromacil, which was applied in the fall, was washed laterally away from the roadside by unusually heavy rains in the spring following a winter with little snowfall. Normally, the herbicide is leached into lower soil horizons by melting snow. Some trees may have been weakened somewhat by road salt, but the herbicide was ultimately responsible for their death.[13]

To prevent future recurrences of this problem, the Laboratory has formed two committees to review its policies and procedures regarding use and application of herbicides. The Vegetation Control Policy Committee will formulate guidelines for herbicide use, while the Vegetation Control Procedure Committee will determine how to implement these guidelines.

IV. ENVIRONMENTAL EVALUATION

A. Radiation Doses

Some increments of radiation doses above natural and worldwide fallout background levels are received by Los Alamos County residents as a result of LASL operations. The largest estimated dose at an occupied location was 3.8 mrem or 0.76% of the radiation protection standard. This estimate is based on boundary dose measurements of airborne effluents from the proton accelerator at TA-53. Other minor exposure pathways such as direct radiation from an experimental facility and two unlikely food pathways may result in doses to several mrem/yr. No significant exposure pathways are believed to exist for radioactivity released in treated liquid waste effluents. The radioactivity is absorbed in the alluvium before leaving the LASL boundaries and some is transported offsite with stream channel sediments during heavy runoff. The total population dose received by residents of Los Alamos County in 1978 was estimated to be 10.5 man-rem or about 0.4% of the 2400 man-rem to the same population from background radiation and 0.5% of the population dose due to medical exposure. As no significant pathways could be identified outside the County, the 10.5 man-rem dose also represents the population dose to the inhabitants living within an 80 km radius of LASL who receive an estimated 11 900 man-rem dose from background radiation.

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

1. Maximum dose at a site boundary,

2. dose to individual or population groups where highest dose rates occur, and

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

Exposure to airborne ^{3}H (as HTO) was determined by actual measurements with background correction based on the assumption that natural and worldwide fallout activity was represented by the average data from the three regional sampling locations at Española, Pojoaque, and Santa Fe.

Exposures to ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar from LAMPF were inferred from direct radiation measurements (see Sec. III.A.1). Exposure from ^{41}Ar released from the TA-2 stack was theoretically calculated from measured stack releases and standard atmospheric dispersion models.

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

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

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

TABLE XXVII

CALCULATED BOUNDARY AND MAXIMUM INDIVIDUAL DOSES FROM AIRBORNE RADIOACTIVITY

		Maximum Boundary Dose		Maximum Individual Dose		
Isotope	Critical Organ	Location	Dose (mrem/yr)	Location	Dose (mrem/yr)	% RPS
^{3}H (HTO)	Whole Body	TA-54	0.071	Airport	0.029	0.0058
^{11}C, ^{13}N, ^{15}O	Whole Body	Restaurant N. of TA-53	14 [a]	Restaurant N. of TA-53	3.8	0.76
^{41}Ar	Whole Body	Boundary N. of TA-2 Stack	1.2	Apts. N. of TA-2 Stack	0.7	0.14
^{239}Pu	Lung	TA-54	0.024	Bandelier	0.0079 [b]	0.00053

[a] Estimated from TLD measurements June-Dec 1978.
[b] For a 50 yr dose commitment, bone becomes the critical organ. A maximum individual would receive a 50 yr dose commitment to bone of 0.53 mrem.

Liquid effluents, as such, do not flow beyond the LASL boundary but are absorbed in the alluvium of the receiving canyons; excess moisture is lost primarily by evapotranspiration. These effluents are monitored at their point of discharge and their behavior in the alluvium of the canyons below outfalls has been studied.[14-17] Small quantities of radioactive contaminants transported during periods of heavy runoff have been measured in canyon sediments beyond the LASL boundary. However, no significant exposure pathways from the sediments to humans have been identified.

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

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

Measurements of external penetrating radiation showed no statistically distinguishable doses at any offsite locations that could be attributed to LASL operations. Variations among stations or over time were all within expectable ranges.

As was stated in Sec. III.A.1, no measurements of external penetrating radiation at regional and perimeter stations in the environmental network indicated any discernable increase in radiation levels that could be attributed to LASL operations. The special network at the Laboratory boundary north of TA-53 indicated a 13.7 mrem increase above background due to ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar emissions from LAMPF. The increase is considerably less than the 126 mrem dose theoretically estimated for that location from concentrations and cloud size calculated from standard atmospheric dispersion models. To reach the boundary, the effluent must cross a large canyon, which has a pronounced effect on plume dispersion, and for which there are no adequate theoretical models to predict cloud concentrations and size, which are the basis of dose calculations.

Onsite measurements of above background doses were expected and do not represent potential exposure to the public except in the vicinity of TA-18. Members of the public regularly utilizing the DOE-controlled road passing by TA-18 would likely receive no more than 0.5 mrem/yr of direct gamma and neutron radiation. This value was derived from 1975 data[18] on total dose rates using 1978 gamma doses measured by TLDs and estimating exposure time by assuming a person made 15 round trips per week at an average speed of 40 mph past TA-18 while tests were being conducted. The onsite station near the Laboratory boundary at State Highway 4 recorded a dose of 216 mrem/yr. This is caused by a localized accumulation of ^{137}Cs on sediments transported from a treated effluent release point upstream.

Cumulative 1978 whole body doses to Los Alamos County residents from LASL operations with comparison to exposure from natural radiation and medical radiation are indicated in Table XXVIII. Population data are based on Los Alamos County Planning Department figures of 13 300 residents in the Los Alamos townsite and 6300 in White Rock.

The calculated 8.4 man-rem from atmospheric ^{11}C, ^{13}N, and ^{15}O is probably high because it is subject to many of the same uncertainties that caused boundary dose calculations to overestimate actual doses from these isotopes by a factor of 9. The whole-body population dose to the estimated 105 000 inhabitants[21] of the 80 km circle around Los Alamos because of LASL operations is estimated to be 10.5 man-rem, which is the population dose to Los Alamos County inhabitants. This is because other population centers are far enough away that dispersion, dilution, and decay in transit (particularly for ^{11}C, ^{13}N, ^{15}O, and ^{41}Ar) make exposure undetectable and theoretically a very small fraction of the estimated 10.5 man-rem. By contrast, natural radiation exposure to the inhabitants within the 80 km circle is 11 900 man-rem.

Thus, doses potentially attributable to releases of effluents contribute about 0.44% of the total dose received by Los Alamos County residents from

TABLE XXVIII

1978 WHOLE BODY POPULATION DOSES TO LOS ALAMOS COUNTY RESIDENTS

Exposure Mechanism	Whole-Body Population Dose (man-rem)
Atmospheric Tritium (as HTO)	0.23
Atmospheric ^{11}C, ^{13}N, ^{15}O	8.4
Atmospheric ^{41}Ar	1.9
Total Due to LASL Atmospheric Releases	10.5
Cosmic and Terrestrial Gamma Radiation[a]	1570
Cosmic Neutron Radiation (~17 mrem/yr/person[19])	330
Self Irradiation from Natural Isotopes in the Body (~24 mrem/yr/person[3])	470
Average Due to Airline Travel (0.22 mrem/hr at 9 km[3])	13
Total Due to Natural Sources of Radiation	2383
Medical Exposure (~103 mrem/yr/person[20])	2020

[a]Calculations are based on measured (TLD) data. The indicate a 10% reduction in cosmic radiation due to shielding by structures and a 40% reduction in terrestrial radiation due to shielding by structures and self-shielding by the body.

natural radiation, about 0.52% to the same residents from medical radiation (diagnostic x-rays only), and about 0.088% of the dose from natural radiation received by the population within an 80 km radius of the Laboratory.

B. Environmental Protection Programs at LASL

1. LERC/EEC Program

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

Projects that may require an EA or EIS are screened by the EEC to determine level of data needed for the report. Various resource persons are identified to assist in preparation of the draft environmental document for the proposed construction or programmatic project. High-visibility or high-risk projects that may require added attention are passed through an *ad hoc* committee, chaired by the EEC and comprised of representatives of the Engineering Department, Health Division, the user group(s), and other expert members as needed.

The EEC also coordinates input on environmental matters for other official documents and the Quality Assurance (QA) program (see next section). The EEC works with those responsible for construction or programs and the Environmental Surveillance Group representative to the QA program to assure that the environmental considerations are included in the assessments and that they are implemented in the QA program.

2. Quality Assurance Program

In compliance with DOE Manual Chapter 0820, LASL has a QA program[22] for engineering, construction, modification, and maintenance of DOE-owned facilities and installations. The purpose of the program is not only to minimize chance of deficiencies in construction, but also to improve cost effectiveness of facilities' design, construction, and operation, and to protect the environment. QA is implemented from inception of design through completion of construction by a project team approach. The project team consists of individuals from the DOE program division, the DOE Albuquerque Operations Office and Los Alamos Area Office, the LASL operating group(s), the LASL Engineering Department, the design contractor, the inspection organization, and the construction contractor. Under the project team approach each organization having responsibility for some facet of the project is likewise responsible for its respective aspects of the overall QA program. For example, it is the inspection organization's responsibility to provide assurance that the structures, systems, and components have been constructed or fabricated in accordance with the approved drawings and specifications.

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

3. Archeology

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

A survey of more than 450 archeological sites in LASL environs was made between March 1973 and July 1975. This survey of the pre-Columbian Indian ruins is summarized in a report,[23] which is used during construction planning to avoid damage to such sites if possible, or to provide the lead time necessary to conduct required salvage archeology. Several unique sites were recommended for registration as national historic sites and formal nomination procedures are underway. This will ensure their preservation for future generations by establishing formal responsibility and authority to protect the sites.

Ten additional archeological sites were located and added to the map of all archeological sites at LASL in 1978. Also, four sites were salvaged. One site was salvaged after it was uncovered by the La Mesa fire and found to have been damaged many years ago. Three others were excavated in advance of construction activity. Research now underway includes analysis and identification of food plant remains recovered in archeological salvage activities; plant pollen identification in mesa-top soils to ascertain farming practices of ancient civilizations associated with the archeological sites; identification of ancient crop field locations via analysis of trace soil minerals; a study of minerals in pottery to determine the pottery's origin; and a study of ancient food preparation methods.

4. Decontamination and Decommissioning Work

During the spring and summer of 1978, all facilities at a small abandoned site (TA-42) built to incinerate plutonium contaminated waste were demolished. To monitor for possible airborne release of radioactive contaminants during operations, filters at two special air sampling stations (TA-50 and TA-55) were collected weekly. There was no indication of airborne contamination from these operations. After the facilities were removed, the soil in the vicinity was decontaminated to levels determined to be as low as practicable. Final sampling results will be available in a forthcoming comprehensive report on the decontamination and decommissioning of TA-42.

An ^{227}Ac-contaminated filter building at TA-21 (TA-21-153) was demolished in the summer and fall of 1978. Routine airnet sampling stations located at the airport, DP-East, and LAMPF and a special station established at Acorn Street provided documentation of any possible release of airborne material during demolition operations. Air samples were changed weekly. There was no indication of any airborne radioactivity from these operations.

C. Related Environmental Studies

The Environmental Studies Group (H-12) at LASL conducts research and experimental studies under auspices of the DOE. Some of the research programs conducted by H-12 complement routine monitoring carried out by the Environmental Surveillance Group (H-8) in providing a better understanding of the ecosystem surrounding LASL in relation to the Laboratory's operations. Following are highlights of several of these research programs.

1. Ecological Investigation of Dry Geothermal Energy at Fenton Hill

[Ken Rea (H-12)]

LASL is currently evaluating the feasibility of extracting thermal energy from hot dry rock (HDR) geothermal reservoirs. The concept involves drilling two deep holes into HDR, connecting these holes by hydraulic fracture, and bringing thermal energy to the surface by circulating water through the system.[24]

LASL's HDR project provides an opportunity to study the environmental impact of this new energy resource from its infancy. This study is designed to describe quantitatively the ecosystem surrounding the HDR site, to identify the types and amounts of chemicals and/or materials released during the various phases of development, and to evaluate potential impacts from site operations and effluents. Specific objectives include (a) development and maintenance of an environmental resource data base at the site, (b) periodic examination of permanent transects adjacent to the facility and at nearby control sites to determine changes in composition and quantity of ecosystem components, and (c) identification and evaluations of chemicals in effluent waste waters and stored residues.[25]

Biological investigations include biomass, relative cover, and relative density measurements on the plant species of the three vegetative complexes surrounding the HDR site. Within each vegetative type, relative densities of small mammal populations are examined by live trapping techniques, and, within the grass forb complex, pellet group counting transects have been established to determine change in utilization patterns of the resident Rocky Mountain elk (*Cervus canadensis*) population.

Table XXIX is a brief summary of the small mammal trapping program for the 1967-1977 field seasons. The 1978 data have not been analyzed; however, the deermouse (*Peromyscus maniculatus*) was the most trappable species encountered in all vegetative types. Variations between trapping locations within and/or between vegetative complexes fall within the bounds of natural variability and are not considered significant for the two years of analyzed data. Examination of the 1978 data shows no unexpected deviations from these previous collections.

The first extensive (10 000 h) run of the HDR system was accomplished during the summer of 1978. Though the system is a closed loop with no apparent releases to the atmosphere, the gaseous component of the fluid was examined to determine what problems might arise during an accidental venting of the system. Minute quantities of H_2S were detected. This was the only toxic gas detected, and at the levels found, it should pose no environmental hazard, even for major releases of the fluid under emergency venting.[26]

Noise pollution has been considered one of the major problems of geothermal energy development. The major source of noise at the HDR site is the heat exchanger, and during the 10 000 h test, noise levels at the heat exchanger under full load conditions averaged less than 95 dB(A), with frequencies less than 1000 Hz.

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

[R. Ferenbaugh and W. D. Purtymun (H-8)]

Studies have been carried out to determine the extent to which water discharged from geothermal holding ponds at the Fenton Hill site (LASL's HDR Project) penetrates into the canyon below the site. A series of 1-2 m holes were drilled down-canyon of the site, and soil samples from these holes analyzed for fluoride, chloride, and uranium. Four of the holes at distances of 20, 60 295, and 915 m from the point of discharge were cased. Water samples obtained from these holes after holding pond discharge were collected and analyzed for several chemical constituents in which the water from the geothermal

TABLE XXIX

RELATIVE TRAPPING DENSITIES AND TRAPPING SUCCESS FOR SMALL MAMMALS IN VARIOUS VEGETATIVE COMPLEXES (expressed in per cent)

	Grass Forb		Aspen		Mixed Conifer	
Species	**1976**	**1977**	**1976**	**1977**	**1976**	**1977**
Deermouse						
Peromyscus maniculatus	99	100	51	65	63	83
Chipmunk						
Eutamias minimus	1	0	44	35	28	17
Other species	0	0	5	0	9	0
	100	100	100	100	100	100
Trapping Success %[a]	72	28	23	63	41	33

[a] Calculated as total captures vs total traps.

pond is enriched. Fluoride concentration, chloride concentration, and strontium isotope ratio were investigated as tracers to determine the extent of penetration of discharged water down the canyon. Chloride concentration proved to be the most informative, and the results of these analyses indicate that the discharged water is completely absorbed into the alluvium by the time it has moved 295 m down the canyon. Wells have been drilled around the holding ponds themselves to determine the extent to which water infiltrates the soil surrounding the ponds. Samples from these wells indicate that most water movement from the ponds is vertical; there is little if any horizontal movement.

Certain elements, which are present in the holding pond discharge, are of particular interest because of the low allowable levels specified in the proposed National Pollution Discharge Elimination System permit. These are arsenic, boron, cadmium, fluoride, and lithium. Soils and vegetation in the canyon into which the water is being discharged consequently are being monitored to determine if these elements are accumulating in the canyon. Plant growth studies and soil adsorption studies also are being carried out using water from the holding ponds.

The canyon below the geothermal site into which water is discharged ultimately opens into Lake Fork Canyon (Fig. 15). Although there is no flow of geothermal water into Lake Fork Canyon, wells and streams in the canyon are monitored for water quality. Other water sources in the vicinity of Fenton Hill are also monitored (Fig. 15). Table E-XXVII summarizes the results of this monitoring during 1978. There has been no significant change in the quality of these waters from previous analyses.

3. The Comparative Distribution of Stable Mercury, Cesium-137, and Plutonium in an Intermittent Stream at Los Alamos

[T. E. Hakonson (H-12), G. C. White (H-12), E. S. Gladney (H-8), and Mona Driecer (H-12)]

Mortandad Canyon has been used for disposal of liquid wastes since 1963. Past studies in this canyon have emphasized the distribution and transport of ^{137}Cs, ^{238}Pu, and ^{239,240}Pu. Stable mercury is also a component of the waste released to Mortandad Canyon as a result of loss of the metal from chemical laboratories into drain systems. Records maintained over the past few years show that a few tens to hundreds of grams of mercury are released annually to this canyon.[27] The quantity of plutonium and cesium released annually to the canyon averages about 10 and 100 mCi, respectively. Although long term records are not available, we suspect that the isotopic composition of the waste has been varied considerably.

Core samples were collected from 10 stream channel and 10 stream bank locations randomly selected along a 100 m segment of Mortandad Canyon about 500 m below the effluent outfall. A total of 10 stream channel cores and 40 stream bank cores (four per location) were collected. Frozen core samples were sectioned into 0-2.5, 2.5-7.5, and 7.5-30 cm segments; 142 aliquots were then taken for Hg analysis. The remaining sample was oven-dried and counted for ^{137}Cs on a NaI detector coupled to a multichannel analyzer. Sample aliquots were analyzed for ^{238}Pu, ^{239}Pu, and Hg using wet chemistry followed by instrumental analysis.[28] Elemental concentrations in all cases were sufficient to limit instrumental uncertainties to less than 10% ($p<0.05$).

The results of this study demonstrate the importance of stream banks as deposition locations for stable mercury, cesium, and plutonium continuously released to an intermittent stream channel over a 13 yr period. The movement of contaminants from channel to bank results in concentrations that are generally equivalent or exceed those measured in the channel sediments (Table XXX). These findings have implications on the long term distribution of contaminants in intermittent streams because stream banks not only retard downstream movement of the contaminants but may be a source of these materials to biota.

4. Mule Deer Movement

[G. White and L. Eberhardt (H-12)]

Studies continue on the populations of elk and deer that inhabit the Los Alamos National Environmental Research Park (LA/NERP), and cross its boundaries into other protected and/or unprotected areas in Bandelier National Monument, Santa Fe National Forest, and on private lands. Movements of mule deer (*Odocoileus hemionus*) have been studied on the site since January 1975 in an effort to obtain baseline data on this species and to define important deer habitats within the

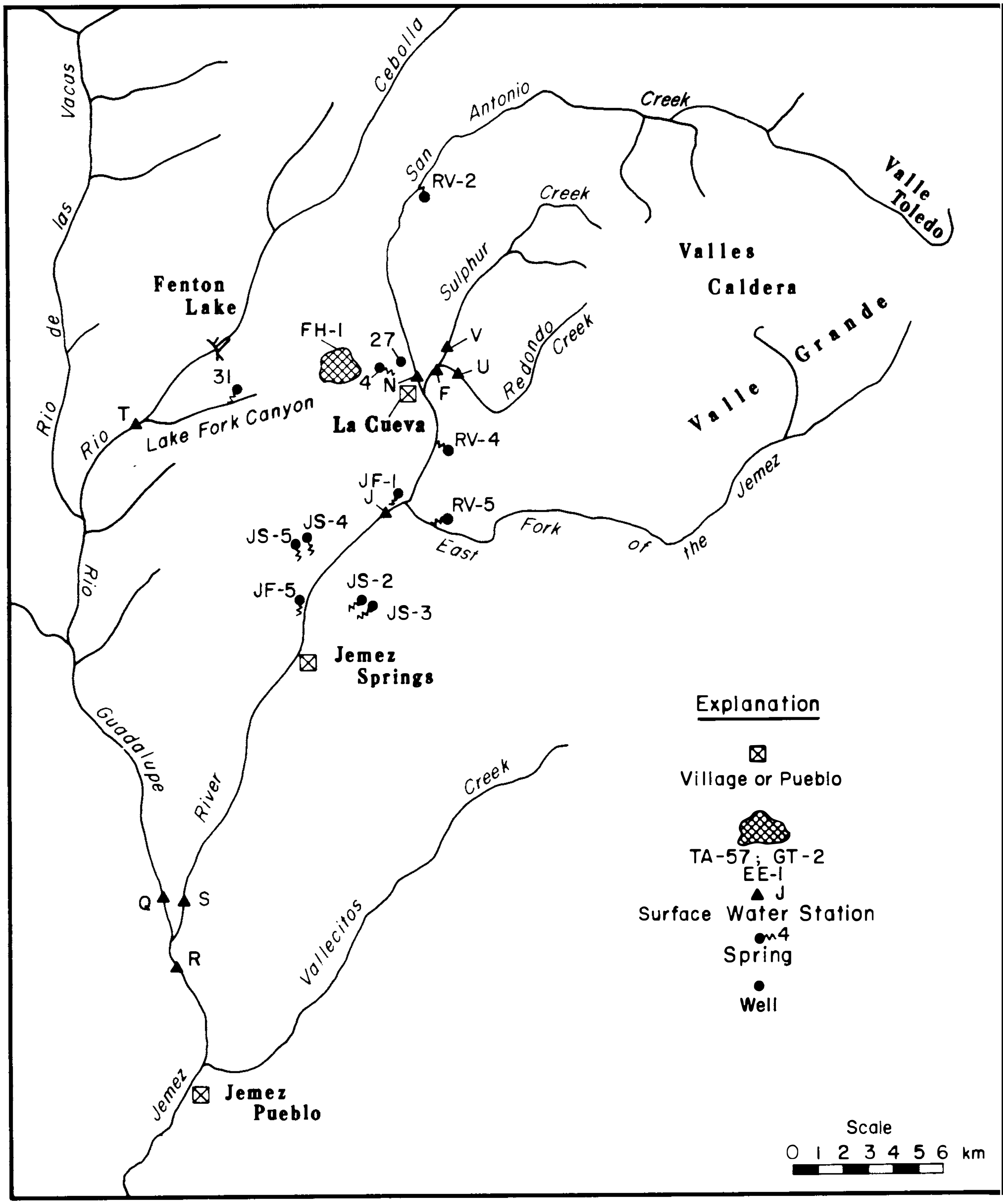


Fig. 15.

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

TABLE XXX

ARITHMETIC MEAN CONCENTRATIONS AND COEFFICIENTS OF VARIATION OF MERCURY, CESIUM, AND PLUTONIUM AS A FUNCTION OF LOCATION IN MORTANDAD CANYON SOILS[a]

	Stream Channel			Stream Bank		
	Number of Samples	Mean	Coefficient of Variation	Number of Samples	Mean	Coefficient of Variation
Hg (ppb)	27	79	1.0	115	160	1.6
^{137}Cs (pCi/g)	28	370	0.35	120	197	1.7
^{238}Pu (pCi/g)	29	26	0.32	120	23	1.9
^{239}Pu (pCi/g)	30	5.2	1.5	119	5.8	1.7

[a]Background concentrations in soils averaged about 10 ppb Hg, 0.5 pCi ^{137}Cs/g and 0.05 pCi Pu/g.

LA/NERP. A total of 34 deer have been live-trapped (Fig. 16), marked with collars and ear tags, and released.[29] Both visual and radiotelemetry techniques have been used to determine deer movements. A total of 254 resightings have been made on 20 of the marked deer since their release. In addition, weekly locations of six radio equipped deer have been determined since March 1977.

Deer movements generally paralleled the east-west oriented canyon systems. A few deer moved to lower elevations on the LA/NERP during the winters, but this was not a consistent trait in all deer studied. Adult female deer generally tended to concentrate their activities in specific areas, while both adult and juvenile male movements were usually more scattered. Longest movement observed during this study was made by an adult female captured at TA-16 in the LA/NERP and relocated one year later 21.4 km to the east across the Rio Grande. Average home range of the six radio collared deer was ~14 km^2 (standard deviation = 5 km^2), which is considerably larger than that reported for mule deer elsewhere.

Security fences on the LA/NERP probably affect deer movements, but several marked animals successfully circumvented the western boundary fence by moving around it or by passing through manned security gates. Specific individual deer consistently walked in and out of the unmanned security gate at TA-9.

Pellet group plots are being used as an index to deer and elk densities, as well as indicators of distribution. A summary of the LA/NERP pellet group data for deer and elk is presented in Tables XXXI and XXXII. For deer, there is a decline in pellet group counts since 1975 in the ponderosa pine and piñon-juniper habitats. There does not appear to have been a significant decline in deer in the mixed conifer habitat type. Not enough data are available to test for time differences in the other three habitats. No significant changes in elk density have occurred in the mixed conifer habitat type. Not enough data are available to test for differences in the other three habitats.

5. Botanical Survey for Critical Habitats in the LA/NERP

[T. Foxx and G. Tierney, Consulting Botanists (H-12)]

Presently, there are 37 candidate plant species on the federal Threatened and Endangered Species list for New Mexico. Examination of the list provided by the New Mexico Heritage Program of the State Fish and Game Department showed only one species, grama grass cactus (*Pediocactus paprycanthus*), that was likely to be found within the LA/NERP. This species was located and photographed in various stages, including the reproductive stage.[30]

Fig. 16.

Capture of an elk at LASL.

TABLE XXXI

SUMMARY OF LA/NERP PELLET GROUP DATA FOR DEER

	Habitat					
Period	Conifer	Burn	Meadow	Alfalfa	Ponderosa Pine	Piñon Juniper
Winter 75-76	0.73	---	---	---	3.80	1.81
Summer 76	1.38	---	---	---	1.45	0.94
Winter 76-77	1.00	---	---	---	1.49	0.76
Summer 77	0.46	---	---	---	1.04	0.39
Winter 77-78	0.53	0.38	0.31	0.75	0.51	0.73
Summer 78	0.58	0.76	0.54	3.13	0.51	0.12
Probability level of test for changes with time	0.34	---	---	---	<0.01	0.03

TABLE XXXII

SUMMARY OF LA/NERP PELLET GROUP DATA FOR ELK

	Habitat			
Period	Mixed Conifer	Burn	Meadow	Alfalfa
Winter 75-76	0.60	---	---	---
Summer 76	0.50	---	---	---
Winter 76-77	0.96	---	---	---
Summer 77	0.21	---	---	---
Winter 77-78	0.94	3.76	2.77	12.63
Summer 78	0.89	0.43	1.23	6.88
Probability level of test for change with time	0.23	---	---	---

Although the site location is outside the LA/NERP boundaries *per se*, the species is very likely to occur within undisturbed sites where grama grass predominates.

Most of the species presently on the list occur in the southern part of the state. This is due, in large part, to the paucity of floristic studies in the northern part of the state. Our survey was designed to identify any of the listed species and to locate other species that were rare to the area or perhaps endemic. During the course of the floristic search, several species were located that had not been noted by other LASL studies, by the present investigators, or by previous investigators. They are not necessarily rare, threatened, or endangered at the present time, but in areas sampled, they have a very low population number. An example of such a plant is the larkspur violet (*Viola pedatifida*).

The federal list consists only of candidate species; the list is not yet static. Species are being added and deleted. A number of species are very loosely protected under New Mexico Statute 45-11. Special attention was given to the occurrence of these latter plants within the area. An annotated list of species ennumerated under the Statute and which are known to be found within the LA/NERP or adjacent areas has been compiled. If these species are subsequently added to the federal list or the New Mexico law becomes more stringent, this information will be readily available to DOE managers.

Because the federal list is not yet static, we realized that a comprehensive plant survey would be the most useful. Therefore, a more complete collection was made than originally anticipated. As of May 1, 1978, 160 plants had been identified; 65 of these had not been reported previously. This indicates that, at the completion of the 1978 field season, the number of newly recorded species can be expected to increase considerably.

From previous experience through contracts for the Museum of New Mexico, the University of New Mexico, and the National Park Service, a number of species have been found that are known to be of ethnobotanical significance. They were possibly utilized by the prehistoric inhabitants of the Pajarito Plateau as food, clothing, medicine, or for ceremonial purposes. Such species as white stem stickleaf (*Mentzelia albicaulis*) are of special ethnobotanical significance and have been located in the study area. These observations have been useful in seed analysis studies done for archeological salvage studies at LASL.

Finally, an unanticipated by-product of the study is a checklist of over 1000 plants compiled by Foxx and Tierney.[30] This checklist is to be published as a LASL report and will give information such as plant distribution, synonyms, and references. Because no such publication now exists for the area, this report will be valuable to the Park Service, Forest Service, Department of Energy, naturalists, teachers, students, and interested laymen.

6. La Mesa Fire

[T. Foxx, Consulting Botanist (H-12)]

The La Mesa fire burned from June 16-23, 1977, ultimately consuming 62 km^2 of Santa Fe National Forest, Bandelier National Monument, and LASL land (10.6 km^2).

Subsequent to the fire 9.9 km^2 of LASL land were reseeded with a mixture of native grass species (slender wheatgrass, western wheatgrass, hard fescue, blue grama, spiked muhley, and sand dropseed) and 0.7 km^2 were set aside for natural succession studies.

In October 1978, paired 20 by 50 m plots with fifty 1 m by 2 m shrub plots and one hundred 5 decimeter by 5 decimeter plots were established in the seeded and unseeded area of the ponderosa pine zone. Relative foliage cover for herbaceous plants and shrubs was determined for each plot. Plots in the seeded area had 6.7% total foliage cover. Grass comprised 56.5% of the total foliage cover; 41.5% was the reseeded grass species *Agropyron trachycaulum* (slender wheatgrass). In the unseeded plots there was 5.2% coverage. Less than 1% was grass and over 99% was forbs. *Chenopodium* (lambsquarters) species made up 78.5% of the total foliage cover.

Biomass was based on ten 1 m by 1 m plots. The biomass in the seeded area was 850.1 g/m^2 and in the unseeded area 10 g/m^2. Grass represented 31.3% of the total biomass on the seeded side, whereas only 5.8% on the unseeded side. Forbs made up 94.2% of the total biomass on the unseeded side and only 68.7% on the seeded side. Reseeded grasses made up 69.3% of the total biomass on the seeded side and 0% on the unseeded side.

7. Long-Term Ecological Effects of Exposure to Uranium

[G. C. White and T. E. Hakonson (H-12)]

An estimated 75 000 to 100 000 kg of uranium were expended during conventional explosive tests at several LASL testing areas during 1949-1970. Of this, about 35 000 to 45 000 kg of natural uranium were used during 1949-1954, and 40 000 to 50 000 kg of depleted uranium (depleted of ^{235}U) were used during 1955-1970. The principal concern about depeleted uranium is the effect of its chemical toxicity and pyrophoric properties on terrestrial ecosystems. Methods to ascertain environmental transport are necessary. Also, rapid analysis for uranium in various matrices has become increasingly important with the advent of the energy crisis. Decontamination of uranium contaminated areas may be necessary because of the chemical toxicity aspects of that element. A fourth year of study of the transport of depleted uranium in the terrestrial ecosystem at LASL was completed, with emphasis on evaluation of the portable phoswich survey instrument as a uranium field survey instrument.

A firing site at LASL was resampled with the phoswich survey instrument at the same locations that were sampled in the 1976 soil uranium field survey.[31] The initial sampling grid was systematically placed on a polar coordinate system radiating from the detonation point every 45° with concentric circles at 10, 20, 30, 40, and 50 m from the detonation point.

Soil samples collected on the grid system during the 1976 uranium survey at the firing site were obtained with a polyvinylchloride coring tube with a 2.5 cm inside diameter. Field instrument measurements from the grid were compared with the uranium concentration in the 0 to 2.5 cm depth segment of each core.

Correlation between the phoswich measurements and previous soil samples taken in 1976 at the site was excellent (Fig. 17), with $r = 0.95$ ($p<0.0001$), even though the respective measurements were taken two years apart. Changes in the distribution of uranium during the interval between samplings must have been minor relative to the total inventory of uranium in the soil.

D. Resurvey Program

For the past two years LASL's Environmental Surveillance Group has conducted some intensive radiological surveys as part of DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP). The results of these surveys will be utilized by DOE to determine whether any remedial measures are desirable to further reduce any residual effects from previous uses of the areas. In the Los Alamos Area, Bayo Canyon and the Acid-Pueblo Canyon system were investigated. A final report on the radiological survey of Bayo Canyon has been completed and is expected to be published by DOE's Division of Environmental Control Technology in 1979. The summary from that report is included in this section. A draft report on Acid-Pueblo Canyon is expected to be submitted to DOE for review in 1979. A brief summary of the status of that work follows the Bayo Canyon summary.

1. Bayo Canyon

A portion of Bayo Canyon (Fig. 5) was used between 1944 and 1961 as a site for experiments employing conventional high explosives in conjunction with research on nuclear weapons development initially under auspices of the US Army Manhattan Engineer District and later the Atomic Energy Commission (AEC). The explosive test assemblies usually included components made from natural or depleted uranium and a radiation source for blast diagnostics. The sources contained several hundred to several thousand curies of ^{140}La (half-life 40.2 h) and a small proportion of ^{90}Sr (half-life 28.1 yr). The explosive detonation resulted in the dispersion of radioactive materials—uranium, ^{140}La and ^{90}Sr—in the form of aerosols and debris to the atmosphere and onto the ground around the firing points. Radiochemistry operations conducted at the site resulted in the generation of liquid and solid radioactive wastes, which were disposed into the subsurface pits and leaching fields.

The site was decommissioned by 1963 with the removal or demolition of structures, cleanup of surface debris, and excavation of contaminated waste disposal facilities. Radiological surveys resulted in the conclusion that the site was sufficiently free of contamination to permit the land to be released from Federal government control. The land was transferred to Los Alamos County by quit claim deed on July 1, 1967.

In 1976 the Energy Research and Development Administration (ERDA) identified the Bayo Canyon Site as one of the locations to be reevaluated as part of the FUSRAP using modern instrumentation and analytical methods as a basis for determining whether any further corrective measures would be desirable.

The resurvey utilized information from a number of routine and special environmental surveillance studies conducted previously by LASL as well as extensive new instrumental measurements, soil sampling, and radiochemical analyses. Results showed that residual surface contamination due to ^{90}Sr averaged about 1.4 pCi/g or approximately 3 times the level attributable to worldwide fallout. Surface uranium averaged about 4.9 μg/g or about 1.5 times the amount naturally present in the volcanic-derived soils of the area. Subsurface contamination associated with the former waste disposal locations is largely confined within a total area of about 10 000 m^2 and down to depths of about 5 m. Of 378 subsurface samples, fewer than 12% exceeded 13 pCi/g of gross beta activity, which is comparable to the upper range of activities for uncontaminated local soils.

Health physics interpretation of the data indicates that the present population of Los Alamos living on mesas adjacent to Bayo Canyon is not receiving any incremental radiation doses due to the

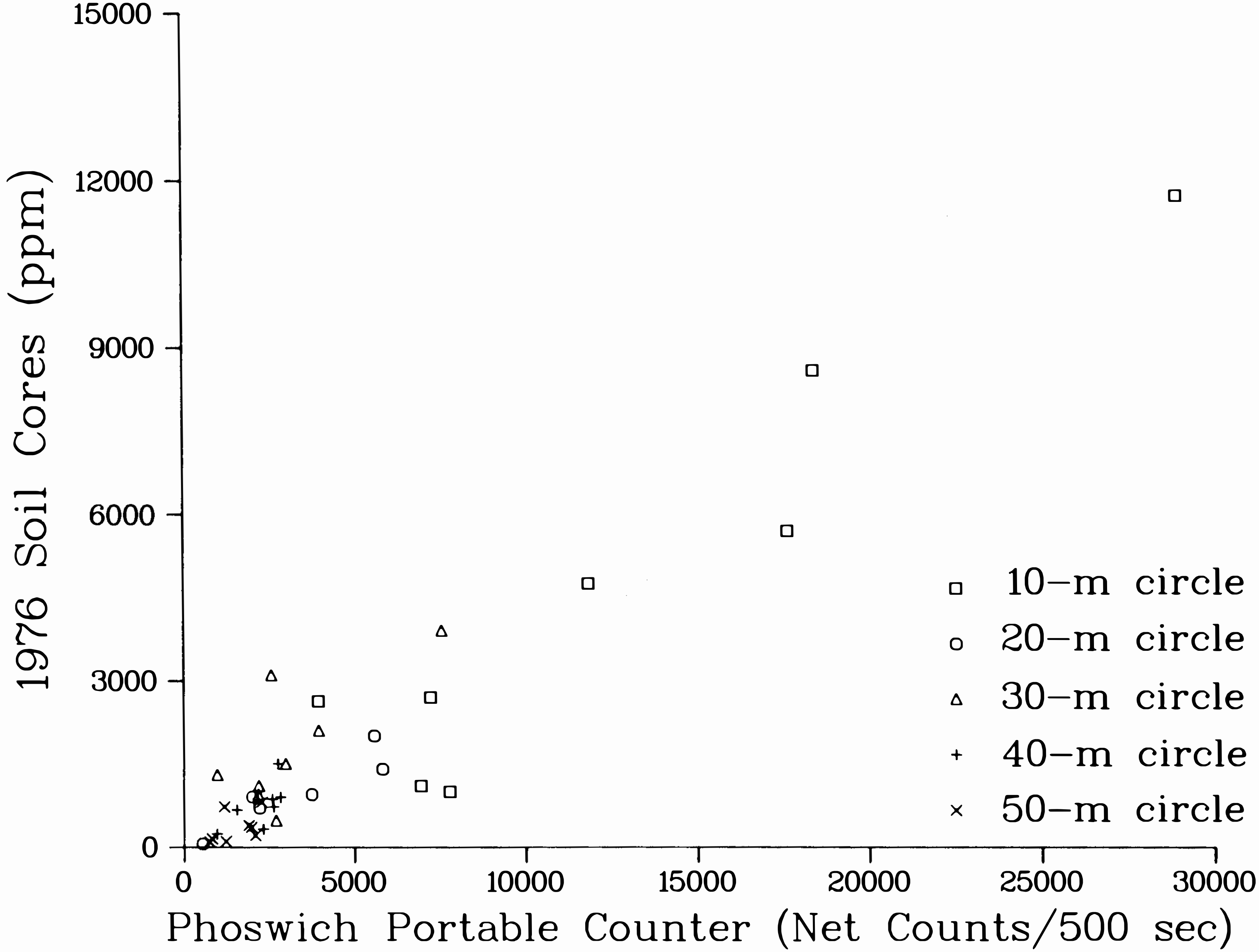


Fig. 17.

Graph of the 1976 0-2.5 cm depth segment soil uranium concentration and the phoswich portable survey instrument counts in 1978.

residual contamination. Potential future land uses of Bayo Canyon include development of a residential area.

Theoretical evaluation of such potential uses by means of exposure scenarios (including inhalation of contamination with dust by construction workers or residents) indicates that increments of radiation exposure due to residual contamination attributable to Bayo test operations would be small in comparison with either radiation protection guidelines or natural background.

The worst case evaluations for maximum individual exposures under these hypothetical conditions were calculated as 50 yr dose commitments, which represent the dose accumulated over 50 yr from exposure to radioactive material in the first year. Only several radionuclides are capable of irradiating an individual for years after exposure to that radionuclide. This occurs when these long-lived radioactive materials are inhaled or ingested and are incorporated into body tissues where they remain, such as incorporation of ^{90}Sr into bone. These dose commitments are compared to the current DOE Radiation Protection Standards for annual doses to individuals in the general public and to average doses of radiation received from natural radiation in the area. Comparing 50 yr dose commitments to annual exposure guidelines is considered conservative because the actual dose received in any one year from a radioisotope capable of irradiating the individual for years after exposure is considerably less than the 50 yr dose commitment.

The largest dose an average resident of Bayo Canyon would receive from present contamination levels would be 0.43 mrem/yr due to external penetrating radiation, which is 0.086% of DOE Guidelines and 0.24% of the dose received from natural radiation in Bayo Canyon. For maximum exposure it is assumed an individual consumes 50 kg/yr of vegetables and fruits produced from garden plots located in contaminated soil in Bayo Canyon. This individual could receive a 50 yr dose commitment of 45.6 mrem to the bone, which is 3.0% of the guidelines for annual exposure and 25% of annual exposure from natural radiation in the Canyon. Another exposure pathway is inhalation of contaminated dust due to construction activity in contaminated soil. The maximum postulated 50 yr dose commitment to a construction worker is 23 mrem to the bone from installation of underground structures or utilities. This would likely by a one-time exposure and would be only 1.5% of the DOE guidelines for annual exposure and 13% of the annual dose due to background radiation in the Canyon.

2. Acid-Pueblo Canyon System

These deep canyons (Fig. 5) were the discharge area for untreated radioactive liquid wastes between 1943 and 1951 resulting from research and processing at LASL. Starting in 1951, treated radioactive effluents were discharged into the canyon from TA-45, the liquid waste treatment facility which operated until 1964. The TA-45 waste treatment plant was sited on the mesa forming the south side of Acid Canyon. Acid Canyon is a deep canyon cut into soft volcanic rock, and is tributary to Pueblo Canyon. Intermittent stream flow is ultimately tributary to the Rio Grande.

Acid Canyon and part of Pueblo Canyon were transferred to the incorporated County of Los Alamos subject to recognition of an easement with AEC. This easement was generally a strip along the stream channel. The right of access was to permit the construction and operation of test wells and to permit the collection of earth and water samples. The property was transferred by a quit claim deed on July 1, 1967.

Plutonium, americium, and fission products were discharged into the canyons in liquid effluents from 1943 to 1964. The first survey of Acid Canyon, for purposes of cleanup, was made on August 31, 1965. On October 4, 1966, work commenced on removing the TA-45 structures. Five hundred truckloads of demolition debris and dirt from this location were removed to the dump. Ninety-four loads of debris from Acid Canyon were placed in a solid waste disposal area within the currently operational LASL site. This decontamination activity included the removal of all drain pipes, wires, rocks, tuff, and other debris found contaminated in Acid and Pueblo Canyons. This work was completed in 1967, and it was reported that a small amount of contamination remained in inaccessible places.

Some radioecological and environmental surveillance evaluations have been completed and documented for Pueblo Canyon as reported in previous surveillance reports.[4-6,27] Several hundred soil and sediment samples were collected for the present detailed radiological survey during 1977. Data show some limited areas at the TA-45 site and in the canyons that exceed EPA proposed soil screening guides for plutonium concentrations. Measurements of penetrating radiation showed no areas that exceed radiation protection standards. A draft report will be completed in 1979.

ACKNOWLEDGMENTS

This report was compiled by the staff of the Environmental Studies Group of the LASL Health Division. Principal contributors included A. J. Ahlquist, M. Driecer, L. Eberhardt, T. Foxx, R. Ferenbaugh, E. S. Gladney, T. C. Gunderson, T. E. Hakonson, W. R. Hansen, W. D. Purtymun, K. Rea, D. L. Mayfield, J. G. Salazar, S. Smith-Sanclare, A. K. Stoker, A. D. Talley, G. Tierney, and G. C. White. Much of the sampling and data collection was carried out by F. R. Craven, D. Lacombe, M. N. Maes, E. Rahrig, R. Romero, E. Sagon, D. M. Van Etten, and C. Wardlow. Analytical chemistry was performed by C. E. Burns, C. Conley, W. M. Eberhardt, W. E. Goode, P. L. Johnson, D. Knab, G. M. Martinez, L. Ortiz, J. W. Owens, R. J. Peters, D. R. Perrin, and W. H. Schweitzer. Word processing and assembly of this report done by M. Lewis.

REFERENCES

1. W. D. Purtymun, J. R. Buchholz, and T. E. Hakonson, "Chemical Quality of Effluents and Their Influence on Water Quality in a Shallow Aquifer," J. of Environmental Quality, 6, No. 1, Jan-Mar 1977.

2. W. D. Purtymun and S. Johansen, "General Geohydrology of the Pajarito Plateau," N.M. Gol. Soc. Guidebook, 25th Field Conference, Ghost Ranch, New Mexico (1974).

3. National Council on Radiation Protection and Measurements, "Natural Background Radiation in the United States," NCRP Report No. 45 (November 1975).

4. Environmental Surveillance Group, "Environmental Surveillance at Los Alamos During 1977," Los Alamos Scientific Laboratory report LA-7263-MS (April 1978).

5. J. E. Herceg, compiler, "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory—1972," Los Alamos Scientific Laboratory report LA-5184 (March 1973).

6. K. J. Schiager and K. E. Apt, compilers, "Environmental Surveillance at Los Alamos During 1973," Los Alamos Scientific Laboratory report LA-5586 (May 1974).

7. T. E. Hakonson, J. W. Nyhan, L. J. Johnson, and K. V. Bostick, "Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos," Los Alamos Scientific Laboratory report LA-5282-MS (1973).

8. T. E. Hakonson and K. V. Bostick, "The Availability of Environmental Radioactivity to Honey Bee Colonies at Los Alamos," J. of Environmental Quality, 5, No. 3, July-Sept 1976, pp. 307-310.

9. Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," EPA-570/9-76-003, US Government Printing Office, Washington, DC (1976).

11. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors," Parts A and B, Supplements 1 through 7, Third Edition, Research Triangle Park, North Carolina (1977).

10. New Mexico State Ambient Air Quality Standards and Air Quality Control Regulations, Section 703, "Regulation of Air Contaminant Sources," (July 29, 1972).

12. Mason and Hanger-Silas Mason Co., Inc., "Disposal of Waste or Excess High Explosives," Quarterly Progress Reports from Jan 1971 through March 1976.

13. A. K. Stoker, T. E. Lough, and L. J. Walker, "Report of the Investigation into Tree Mortality Along Certain LASL Site Roads," Los Alamos Scientific Laboratory report HRD-78-9 (1978).

14. W. D. Purtymun, "Plutonium in Stream Channel Alluvium in the Los Alamos Area, New Mexico," Los Alamos Scientific Laboratory report LA-4561 (1971).

15. T. E. Hakonson and K. V. Bostick, "Cesium-137 and Plutonium in Liquid Waste Discharge Areas at Los Alamos," in *Radioecology and Energy Resources* (Dowden, Hutchinson, & Ross, Inc., Stroudsburg, Pennsyvania; F. R. Miera, Jr., and R. J. Peters, "The Distribution of Plutonium and Cesium of Alluvial Soils in the Los Alamos Environs," in *Radioecology and Energy Resources* (Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pennsylvania, 1976).

16. W. D. Purtymun, "Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County, New Mexico," Los Alamos Scientific Laboratory report LA-5744 (1974).

17. T. E. Hakonson, J. W. Nyhan, and W. D. Purtymun, "Accumulation and Transport of Soil Plutonium in Liquid Waste Discharge Areas at Los Alamos," Proc. Transuranium Nuclides in the Environment, International Atomic Energy Agency, IAEA-SM-199/99 (Vienna, Austria, 1976).

18. H. C. Paxton, "Safety and Analysis of the Los Alamos Critical Experiments Facility," Los Alamos Scientific Laboratory report LA-6206, Vol. II (October 1975).

19. D. T. Oakley, "Natural Radiation Exposure in the United States," US EPA and ORP/SID 72-1 (1972).

20. US Environmental Protection Agency, "Radiological Quality of the Environment in the United States, 1977," US EPA report EPA-520/1-77-009 (Sept 1977).

21. J. M. Voltin and J. M. Graf (H-1), private communication (Feb 1979).

22. LASL Engineering Dept. of Quality Assurance, "LASL Quality Assurance Manual for Engineering and Construction," Los Alamos Scientific Laboratory report LA-5220-M (May 1974).

23. C. R. Steen, "Pajarito Plateau Archaeological Survey and Excavations," Los Alamos Scientific Laboratory report LASL-77-4 (May 1977).

24. J.J. Mortensen, "The LASL Hot Dry Rock Geothermal," Los Alamos Scientific Laboratory mini-review 77-8 (1977).

25. K. H. Rea, "Environmental Investigations Associated with the LASL Hot Dry Rock Geothermal Energy Development Project," Los Alamos Scientific Laboratory report LA-6972 (1977).

26. V. Gutschick and K. H. Rea, "Environmental Assessment of Dissolved Gases in LASL's Hot Dry Rock Geothermal Source Demonstration Project," Geothermal Resources Council, TRANSACTIONS, **2**, pp. 249-252 (1978).

27. K. E. Apt and V. J. Lee, "Environmental Surveillance at Los Alamos During 1974," Los Alamos Scientific Laboratory report LA-5977-PR (May 1975).

28. G. C. White and T. E. Hakonson, "Statistical Considerations and Survey of Plutonium Concentration Variability in Some Terrestrial Ecosystem Components," J. of Environmental Quality (in press).

29. L. E. Eberhardt, T. E. Haksonson, and E. M. Karlen, "Methodology of Mule Deer Studies in the Los Alamos National Environmental Research Park," in *National Environmental Research Park Symposium: natural Resource Inventory, Characterization, and Analysis*, J. T. Kitchings and N. E. Tarr, Eds., Oak Ridge National Laboratory report ORNL-5304, pp. 1-9 (February 1978).

30. T. S. Foxx and G. D. Tierney, "Status of the Flora of the National Environmental Research Park," (in preparation).

31. W. C. Hanson and F. R. Miera, Jr., "Continued Studies on Long-Term Ecological Effect of Exposure to Uranium," Los Alamos Scientific Laboratory report LA-6742, AFATL-TR-77-35 (June 1977).

APPENDIX A

STANDARDS FOR ENVIRONMENTAL CONTAMINANTS

The concentrations of radioactive and chemical contaminants in air and water samples collected throughout the environment are compared with pertinent standards contained in the regulations of several Federal and State agencies in order to verify the Laboratory's compliance with these standards. LASL operations pertaining to environmental quality control are conducted in accordance with the directives and procedures contained in DOE's Health and Safety Manual, Chapters 0510, 0511, 0513, 0524, and 0550.

In the case of radioactive materials in the environment, the guides contained in Manual Chapter 0524 are used as a basis for evaluation. However, the DOE standard for uranium in water (1500 and 60 mg/ℓ for controlled and uncontrolled areas, respectively) does not consider chemical toxicity. Therefore, for the purposes of this report, the more restrictive standards[A1] of the International Commission on Radiological Protection (ICRP) for uranium in water (60 mg/ℓ for an occupational 40-h week) are were used as a point of comparison. For atmospheric uranium, the DOE and ICRP standards are in agreement. The standards are listed in Table A-I in the form of a Radioactivity Concentration Guide (CG). A CG is the concentration of radioactivity in the environment that is determined to result in whole body or organ doses equal to the Radiation Protection Standards (listed in Table A-II) for internal and external exposures. Obviously, there are uncertainties in relating the CG to the Radiation Protection Standards. Thus, common practice and stated DOE policy in Manual Chapter 0524 are that operations shall be "conducted in a manner to assure that radiation exposure to individuals and population groups is limited to the lowest levels technically and economically practicable."

Because some radioisotopes remain in the body and cause exposure long after intake has occurred, it is common practice to consider the 50 yr dose commitment caused by ingestion of such isotopes. At present, there are no standards for 50 yr dose commitments.

For chemical pollutants in water supply, the controlling standards are those promulgated by either the EPA or the NMEID (Table A-III).

Radioactivity in public water supply is governed by EPA regulations contained in 40CFR141. These regulations provide that combined radium-226 and radium-228 shall not exceed 5 pCi/ℓ and gross alpha activity (including radium-226, but excluding radon and uranium) shall not exceed 15 pCi/ℓ. A screening level of 5 pCi/ℓ is established as part of the monitoring requirements to determine whether specific radium analyses must be performed.

For man-made radionuclides the EPA drinking water regulations specify that concentration be limited to levels that would result in doses of 4 mrem/yr calculated according to a specified procedure. The EPA calculated value for tritum (^{3}H) is 20×10^{-6} μCi/mℓ and for cesium (^{137}Cs) is 200×10^{-9} μCi/mℓ.[A2] The calculated concentration using bone as the critical organ and the EPA prescribed methods[A2] for ^{238}Pu or ^{239}Pu is 7.5×10^{-9} μCi/mℓ.

REFERENCES

A1. International Commission on Radiological Protection (ICRP), *Recommendations of the International Commission on Radiological Protection*, ICRP Publ. 6, Pergamon Press, New York (1964).

A2. Environmental Protection Agency, "National Interim Primary Drinking Water Regulations," EPA-570/9-76-003, US Govt Printing Office, Washington, DC (1976).

TABLE A-I

DOE RADIOACTIVITY CONCENTRATION GUIDES (CGs)

CONCENTRATION GUIDES FOR UNCONTROLLED AREAS[a,b]

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

CONCENTRATION GUIDE FOR CONTROLLED AREAS[a,b]

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

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

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

[c]One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses may be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

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

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

TABLE A-II

DOE RADIATION PROTECTION STANDARDS FOR EXTERNAL AND INTERNAL EXPOSURES

Individuals and Population Groups in Uncontrolled Areas

	Annual Dose Equivalent or Dose Commitment (rem)[a]	
Type of Exposure	**Based on dose to individuals at points of maximum probable exposure**	**Based on an average dose to a suitable sample of the exposed population[b]**
Whole body, gonads, or bone marrow	0.5	0.17
Other organs	1.5	0.5

Individuals in Controlled Areas

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

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

[b]A beta exposure below a maximum energy of 700 keV will not penetrate the lens of the eye; therefore, the applicable limit for these energies would be that for the skin (15 rem/year).

[c]In special cases with the approval of the Director, Division of Safety, Standards, and Compliance, a worker may exceed 5 rem/year provided his/her average exposure per year since age 18 will not exceed 5 rem per year.

[d]All reasonable effort shall be made to keep exposure of forearms and hands to the general limit for the skin.

TABLE A-III

MAXIMUM CONTAMINANT LEVEL (MCL) IN WATER SUPPLY FOR INORGANIC CHEMICALS AND RADIOCHEMICALS[a]

Inorganic Chemical Contaminant	MCL (mg/ℓ)
As	0.05
Ba	1.0
Cd	0.010
Cl	250
Cr	0.05
F[b]	2.0
Pb	0.05
Hg	0.002
NO_3	45
Se	0.01
Ag	0.05
TDS	1000

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

[a]USEPA National Interim Primary Drinking Water Regulations (EPA-570/9-76-003), EPA, Office of Water Supply (1976) and NMEID Water Supply Regulations (Regulations Governing Water Supply, N.M. Environmental Improvement Agency, Santa Fe, N.M., Dec. 9 1977).

[b]Based on annual average of the maximum daily air temperature of 14.6 to 17.7°C.

APPENDIX B

SAMPLING PROCEDURES AND STATISTICAL TREATMENT OF DATA

1. Thermoluminescent Dosimeters

Harshaw High Sensitivity TLD-100® LiF (lithium fluoride) chips, 6.4 mm square by 0.9 mm thick, are used in both the environmental and LAMPF networks. The chips are annealed at 400°C for 1 h and then cooled rapidly to room temperature. In order for the annealing conditions to be repeatable the chips are put into rectangular borosilicate glass vials that hold 48 LiF chips each. These vials are slipped into rectangular holes formed by stacking machined stainless steel blocks inside an oven maintained at 400°C. After 1 h the vials are removed from the oven and placed between massive copper blocks at room temperature.

The TLD reader is an Eberline model TLR-5 set for 15s, 140°C preheat and 15s, 240°C integration cycles. Incandescent lighting is used exclusively during all phases of annealing, dosimeter preparation, and readout to prevent ultraviolet-induced spurious TL (thermoluminescence). Four chips are placed in a molded nylon acorn nut, size 3/8-16, then closed with a 3/8-16 × 1/4 in. nylon set screw. This assembly constitutes one dosimeter.

For each annealed batch, two calibration sets are exposed. One set is read at the beginning of the dosimetry cycle along with field and calibration sets from the previous cycle. The second is read at the end of the cycle to detect possible sensitivity drift. Each calibration set consists of 20 dosimeters irradiated at the following levels: 3 at 0 mR are stored as laboratory controls, 3 at 0 mR accompany the set to the irradiation facility and serve as calibration controls, 3 at 0 mR accompany the field set as transit controls, 4 at 10 mR, 4 at 20 mR, 1 each at 40, 80, and 160 mR. A factor of 1 rem (tissue) = 1.061 R is used in evaluating the dosimeter data. This factor is the reciprocal of the product of the roentgen to rad conversion factor of 0.957 for muscle for ^{60}Co (the isotope used for TLD calibrations) and the factor 0.985, which corrects for attenuation of the primary radiation beam at electronic equilibrium thickness. A rad-to-rem conversion factor of 1.0 for gamma rays is used as recommended by the International Commission on Radiation Protection.[B1] A method of weighted least squares linear regression is used to determine the relationship between TLD reader units and dose (weighting factor is the reciprocal of the variance).[B2]

The TLD chips used are all from the same production batch and were selected by the manufacturer so that the measured standard deviation in TL sensitivity is 2.0 to 4.0% of the mean at 10 R exposure. At the end of each field cycle, whether calendar quarter or LAMPF operation cycle, the dose at each network location is calculated along with the upper and lower limits at the 95% confidence level.[B3] At the end of the calendar year, individual field cycle doses are summed for each location. Uncertainty is calculated as the square root of the sum of squares of the individual standard deviation by assuming that the 95% confidence interval closely approximates the same interval as ±2 standard deviations. The dose at the LASL boundary north of LAMPF is calculated differently. Here 12 locations are in close proximity and the dose at the end of each cycle is calculated as the mean for these locations. Because there is a dosimeter containing four chips at each location, this is actually a grand mean (or mean of means) and the standard deviation is therefore smaller by a factor of almost a third ($1/\sqrt{12}$) than that of any of the individual dosimeters.

In order to calculate the magnitude of the component of the total dose caused by LAMPF operations, three locations along the south boundary of LASL are used for background values. These locations are distant from and unaffected by LAMPF or any other laboratory source of radiation. They are close enough in elevation to the LAMPF site to experience similar climatic conditions such as rain and snowfall. The geologic formation along the south boundary is different from that near the north boundary and has a smaller terrestrial gamma component. However this causes an overestimate of the LAMPF contribution so that the calculated values are conservative.

The rationale for this calculation is based on the ratio of the dose recorded by the unshielded dosimeter to that for the lead and Lucite-shielded dosimeter. This ratio should be the same for dosimeters at both the north and south boundaries because the cosmic gamma component is quite stable (and is responsible for nearly 90% of the dose recorded by the shielded dosimeters) and because the terrestrial conditions are nearly the same. Any decrease in the ratio at the north boundary is assumed to be caused by LAMPF operations. The actual method of calculation follows. Let z be the dose component from LAMPF, u and v be the unshielded and shielded dose means, respectively, at the north boundary, u' and v' be their counterparts at the south boundary, and S_u, S_v, $S_{u'}$, $S_{v'}$ be the standard deviation of these means. Then

$$z = u-(v[u'/v']).$$

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

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

The doses at the other 10 locations in the LAMPF network are reported in the same manner as those in the environmental network. The ratios of unshielded to shielded doses are calculated for comparison purposes only. They serve as a check on the ratios at the north boundary and background locations.

An independent comparison study between an integrating high-pressure ionization chamber and the TLD system was also made to try to verify the ability of the TLD network to measure the north boundary dose. The ion chamber and TLDs were placed on top of a 10 m tower located on the boundary north of LAMPF from 16 Nov 1978 through 15 Jan 1979. The integrated total dose recorded by the ion chamber for this period was 23.7 mrem. The TLDs recorded 22.7 ± 0.4 (2σ) mrem. An estimated dose of 2.1 mrem due to LAMPF activities using data from the ion chamber compares with 3.6 ± 2.4 (2σ) mrem measured by the LAMPF network TLDs placed 1 m above ground in the vicinity of the tower. This close agreement between the two methods of dose measurement indicates that the TLD system is capable of measuring the boundary dose due to LAMPF activities with reasonable accuracy.

2. Air Sampling

Samples are collected monthly at 25 continuously operating stations during 1978. High volume positive displacement air pumps with flow rates of approximately 3 ℓ/s are used. Atmospheric aerosols are collected on 79 mm diam polystyrene filters. Part of the total air flow (~2 mℓ/s) is passed through a cartridge containing silica gel to adsorb atmospheric water vapor for tritium analyses. Air flow rates through both sampling cartridges are measured with variable-area flow meters, and sampling times recorded.

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

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

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

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

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

Measurements of the air particulate samples require that chemical or instrumental backgrounds be subtracted to obtain net values. Thus, net values lower than the minimum detection limit (MDL) of the system were sometimes obtained (see Table C-IV). Individual measurements often result in values of zero or negative numbers because of statistical fluctuations in the measurements. Although a negative value does not represent a physical reality, a valid long-term average of many measurements can be obtained only if the very small or negative values are included in the population. For this reason, the primary value given in the tables of air sampling results is the actual value obtained from an individual measurement or group of measurements. These primary values are those used in making subsequent statistical analyses and in evaluating the real environmental impact of Laboratory operations.

Station and group means are weighted for the length of each sampling period and for the air volume sampled. The means were calculated using the following equation.[B4]

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

where

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

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

N = total number of samples during 1978 for a station or group,

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

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

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

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

where

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

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

3. Water, Soil, and Sediment Sampling

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

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

Water is collected for chemical analyses at the same time as for radiochemical analysis and returned to the laboratory for filtration through a Whatman #2 filter. Samples for trace constituents in the water supply are collected and acidified in the field and returned immediately to the laboratory for filtration.

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

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

Cumulative samplers are set in a dry stream to collect samples of intermittent storm runoff. The sampler consists of a heavy angle iron driven into the channel with a heavy polyethylene bottle attached by a strap. The intake nozzle to the bottle, consisting of a 1 cm diam copper tube fitted through the plastic bottle cap, faces upstream and is placed about 4 cm above the channel. A vent hole (0.4 cm diam) is drilled into the bottle neck to vent air during initial filling of the sampler and to allow some continuous circulation of water and sediments into the bottle. The average time to fill the sampler is about 3 min; however, this can vary considerably, depending on the volume and velocity of flow.

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

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

REFERENCES

B1. H. E. Johns and J. R. Cunningham, *The Physics of Radiobiology*, 3rd edition. (C. C. Thomas, Springfield, Illinois, 1974) and International Commission on Radiological Protection (ICRP), "Protection Against Ionizing Radiation from External Sources," ICRP Report No. 15 (Pergamon Press,New York, 1970).

B2. P. R. Bevington, *Data Reduction and Error Analysis for the Physical Sciences* McGraw-Hill, New York (1969).

B3. National Bureau of Standards Handbook 91, *Experimental Statistics*, National Bureau of Standards (August 1, 1963).

B4. N. C. Barford, *Experimental Measurements: Precision, Error and Truth*, Addison-Wesley Publishing Co., Inc., London, p. 32 (1962).

APPENDIX C

ANALYTICAL CHEMISTRY METHODS

1. Procedures

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

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

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

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

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

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

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

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

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

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

Air filters are mounted directly on counting planchets.

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

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

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

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

Samples are counted in a Beckman LS-200 liquid scintillation counter for 50 min or 10 000 counts, whichever comes first. Standards and blanks are counted in conjunction with each set of samples.

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

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

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

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

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

For samples with U concentrations greater than 100 ppm, another epithermal irradiation may be used. Following a 5 min irradiation and 10 min decay, the 75 keV gamma ray from ^{239}U may be observed directly rather than waiting for the total decay to ^{239}Np. Results from both epithermal methods have been reported in the literature.[C1]

In the second method, samples are irradiated in a thermal neutron port and pneumatically transferred to a neutron counter where the delayed neutrons produced by the fission of ^{235}U are measured.[C2] The technique is very manpower efficient and has a lower limit of detection than does the epithermal irradiation method. However, total U is calculated assuming a $^{235}U/^{238}U$ ratio of 0.0072. Variations in this ratio will produce inaccuracies in the result, hence samples likely to contain depleted U were not analyzed by this method because of the lower limits of detection. Most of our U analyses are done by this method because it is the more sensitive.

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

A comparison of these methods with the more traditional fluorometric technique for U analysis in soils has been published.[C3]

2. Stable Elements

Four instrumental methods are used for a wide variety of stable element determinations. Neutron activation and atomic absorption are the principal techniques with ion chromatography and ion selective electrodes used in a supplementary role. Elements and anions determined by the various methods are summarized in Table CI. In addition, standard chemical methods are used for HCO_3^{2}, total dissolved solids (TDS), and total hardness. It should be noted that our Hg method of choice is cold vapor atomic absorption using the standard Perkin-Elmer technique.

3. Analytical Chemistry Quality Evaluation Program

Control samples are analyzed in conjunction with the normal analytical chemistry workload. Such samples consist of two general types. Blanks are matrix materials containing quantities of analyte below the detection limit of the analytical procedure. Standards are materials containing known quantities of the analyte. Analyses of control samples fill two needs in the analytical work. First, they provide quality control over the analytical procedures so that problems that might occur can be identified and corrected. Secondly, data obtained

TABLE C-I

ANALYTICAL METHODS FOR VARIOUS ELEMENTS AND ANIONS

Technique	Elements/Anions Measured	References
Neutron Activation		
Instrumental Thermal	Al,Sb,As,Ba,Br,Ca,Ce,Cs,Cl,Cr, Co,Dy,Eu,Au,Hf,In,I,Fe,La,Lu, Mg,Mn,K,Rb,Sm,Sc,Se,Na,Sr,S, Ta,Tb,Th,Ti,W,V,Yb,Zn	C4,5,6,7
Instrumental Epithermal	Al,Sb,As,Ba,Br,Cs,Cr,F,Ga,Au, In,I,La,Mg,Mn,Mo,Ni,K,Sm,Se, Si,Na,Sr,Th,Ti,W,U,Zn,Zr	C8,9,10,11
Thermal Neutron Capture–Gamma Ray	Al,B,Ca,Cd,C,Gd,H,Fe,Mg N,P,K,Si,Na,S,ti	C12,13,14
Radiochemical	Sb,As,Bi,Cu,Au,Ir,Hg,Mo,Os,Pd P,Pt,Ru,Se,Ag,Te,Th.W,U	C15,16,17,18 19,20
Atomic Absorption	Sb,As,Ba,Be,Bi,Cd,Ca,Cr,Co,Cu F,Ga,In,Fe,Pb,Li,Mg,Mn,Hg,Mo, Ni,K,Se,Si,Ag,Na,Sr,Te,Tl,Sn, Ti,V,Zn	C21,22,23,24, 25,26,27
Ion Chromatography	F^-,Cl^-,Br^-,NO_2^-, NO_3^-,SO_3^{2},SO_4^{2},PO_4^{3},NH_4^+	C28
Ion Selective Electrodes	F^-,NO_3^-,NH_4^+	C29

from the analysis of control samples permits the evaluation of the capabilities of a particular analytical technique under a certain set of circumstances. The former function is one of analytical control, the latter is called quality assurance.

Quality control samples are obtained from outside agencies and prepared internally. The EPA provides water, foodstuff, and air filter standards for analysis of gross alpha, gross beta, ^{3}H, ^{137}Cs, and ^{239}Pu as part of the ongoing laboratory intercomparison program. The Environmental Measurements Laboratory (EML) provides soil, water, bone, tissue, vegetation, and air filter samples each containing a wide variety of radionuclides. These are part of a laboratory intercomparison of DOE-supported facilities. Uranium standards obtained from the Canadian Geological Survey (CGS) and the International Atomic Energy Agency (IAEA) are used to evaluate the uranium analysis procedures. Internal standards are prepared by adding known quantities of analyte to blank matrix materials.

Quality assurance for the stable element analysis program is maintained by the analysis of certified or well-characterized environmental materials. The National Bureau of Standards (NBS) has a large set of silicate, water, and biological Standard Reference Materials (SRM). The EPA distributes mineral analysis and trace analysis water standards. Rock and soil certified standards have been obtained from the CGS and the United States Geological Survey (USGS). Other trace elemental standards have been purchased from Kodak.

No attempt is made to make control samples unknown to the analyst. However, they are submitted to the laboratory at regular intervals and analyzed in association with other samples; i.e., they are not normally handled as a unique set of samples. We feel that it would be difficult for the analyst to give the samples special attention even if they were so inclined. We endeavor to run at least 10% of the stable element analyses as quality assurance samples using the materials described above. A more detailed description of our Quality Assurance Program using SRM is in preparation.

The capabilities of the analytical procedures are evaluated from the quality control samples. Accuracy and precision are evaluated from results of analysis of standards. These results are normalized to the known quantity in the standard to permit comparison between standards containing different quantities of the analyte:

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

A mean value of $(\bar{x})$ of R for all analyses of a given type is calculated by weighting each value (x_i) by the uncertainty associated with it (σ_i).

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

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

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

These calculated values are presented in Table C-II. The weighted mean of the R is a measure of the accuracy of the procedure. Values of R greater than unity indicate a positive bias and values less than unity, a negative bias in the analysis. The standard deviation is a measure of the precision. The precision is a function of the quantity of analyte; i.e., as the absolute quantity approaches the limit of detection, the precision increases. For instance, the precision for ^{137}Cs determinations is quite large because many of the standards approached the limits of detection of the measurement. Conversely, the precision for the uranium analyses is unrealistically small because the standards contained quantities of uranium significantly above the detection limits.

Analysis of blanks provides a criterion to judge the probability that samples were contaminated during the analysis. Table C-III presented weighted means and standard deviations of the absolute quantity of analyte reported in blank materials analyzed during 1978.

4. Limits of Detection

Data from the analysis of blanks also provide a means of calculating limits of detection for the various procedures. Table C-III presents detection limits for analyses of various constituents in several environmental matrices. The limits for $^{238,239}Pu$, ^{241}Am, ^{137}Cs, and U are calculated from the

TABLE C-II

ANALYTICAL CAPABILITIES EVALUATED FROM QUALITY CONTROL AND QUALITY ASSURANCE STANDARDS

Analysis	No. of Samples	R (Weighted Mean) $\bar{x} \pm \sigma^a$	Analysis	No. of Samples	R (Weighted Mean) $\bar{x} \pm \sigma^a$
^{90}Sr	9	1.53 ± 0.57	F	43	1.06 ± 0.20
^{3}H	30	0.70 ± 0.39	Hf	4	1.19 ± 0.12
^{226}Ra	6	1.09 ± 0.13	Hg	15	1.03 ± 0.04
^{137}Cs	14	0.92 ± 0.61	Fe	6	0.96 ± 0.07
^{238}Pu	23	0.84 ± 0.23	La	9	0.91 ± 0.04
^{239}Pu	37	0.90 ± 0.19	Lu	2	1.12
^{241}Am	25	0.96 ± 0.14	Mg	4	0.91 ± 0.08
Gross alpha	21	0.86 ± 0.23	Mn	12	1.07 ± 0.23
Gross beta	21	1.07 ± 0.08	K	15	1.01 ± 0.04
U	87	0.99 ± 0.06	Rb	2	0.94
Al	17	1.11 ± 0.27	Sm	7	1.18 ± 0.02
Sb	1	0.90	Sc	2	0.98
As	10	0.97 ± 0.05	Se	15	0.91 ± 0.20
Ba	12	0.98 ± 0.13	Na	22	1.02 ± 0.10
Br	2	0.87	Sr	5	0.91 ± 0.10
Ca	7	1.08 ± 0.12	Ta	3	0.98 ± 0.07
Ce	2	1.05	Th	9	0.98 ± 0.04
Cs	1	0.99	Ti	3	1.02 ± 0.02
Cl	35	0.99 ± 0.11	W	6	0.99 ± 0.01
Cr	2	1.08	V	12	0.94 ± 0.12
Co	1	1.00	Yb	5	1.09 ± 0.08
Eu	5	1.11 ± 0.07			

[a]Three or more samples are required to calculate σ.

weighted mean plus two standard deviations of the analysis of blanks (Table C-IV). For tritium, the detection limit is merely 2σ of repetitive determinations of the instrumental blank. Gross alpha and gross beta are measured simultaneously by counting on a gas proportional counter and electronically discriminating the output pulses. As there is crosstalk generated by the detection of the two types of emissions, the detection limit of one is a function of the counting rate of the other. Detection limits in Table C-III are calculated assuming that counting rates for both alpha and beta are at background levels. The detection limit for alpha increases 10% above the limit for every count per minute (cpm) of beta activity emitted by the sample. Similarly, the detection limit for beta increases 40% for every 10 cpm of alpha.

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

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

TABLE C-III

QUANTITY OF CONSTITUENT REPORTED IN BLANKS

Analyses	No. of Samples	Quantity (Weighted Mean) $\bar{x} \pm \sigma$	Units
^{90}Sr	15	0.0055 ± 0.06	pCi
^{137}Cs	26	1.2 ± 11	pCi
^{238}Pu	23	-0.0064 ± 0.069	pCi
^{239}Pu	23	0.0010 ± 0.029	pCi
^{241}Am	18	0.021 ± 0.020	pCi
Uranium (Delayed neutron)	4	15 ± 6	ng
Uranium (Epithermal activation)	153	25 ± 12	ng
Gross α	9	0.032 ± 0.35	pCi
Gross β	9	0.57 ± 0.93	pCi

TABLE C-IV

DETECTION LIMITS FOR ANALYSES OF TYPICAL ENVIRONMENTAL SAMPLES

Parameter	Approximate Sample Volume or Weight	Count Time	Concentration
Air Sample			
Tritium	3 m	100 min	10^{-12} μCi/mℓ
^{238}Pu	1.2×10^4 m^3	8×10^4 sec	2×10^{-12} μCi/mℓ
^{239}Pu	1.2×10^4 m^3	8×10^4 sec	10^{-12} μCi/mℓ
^{241}Am	2.5×10^4 m^3	8×10^4 sec	2×10^{-12} μCi/mℓ
Gross-alpha	3.8×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Gross-beta	3.8×10^3 m^3	100 min	3×10^{-16} μCi/mℓ
Uranium (Delayed neutron)	2.5×10^4 m^3		1 pg/m^3
Water Sample			
Tritium	0.005 ℓ	100 min	7×10^{-7} μCi/mℓ
^{137}Cs	0.5 ℓ	5×10^4 sec	4×10^{-8} μCi/mℓ
^{238}Pu	0.5 ℓ	8×10^4 sec	9×10^{-12} μCi/mℓ
^{239}Pu	0.5 ℓ	8×10^4 sec	3×10^{-11} μCi/mℓ
^{241}Am	0.5 ℓ	8×10^4 sec	2×10^{-10} μCi/mℓ
Gross-alpha	0.9 ℓ	100 min	1×10^{-9} μCi/mℓ
Gross-beta	0.9 ℓ	100 min	5×10^{-9} μCi/mℓ
Uranium (Delayed neutron)	0.025 ℓ		1 μg/ℓ
Soil Sample			
Tritium	1 kg	100 min	0.003 pCi/g
^{137}Cs	100 g	5×10^4 sec	10^{-1} pCi/g
^{238}Pu	10	8×10^4 sec	0.003 pCi/g
^{239}Pu	10	8×10^4 sec	0.002 pCi/g
^{241}Am	10	8×10^4 sec	0.01 pCi/g
Gross-alpha	2	100 min	0.8 pCi/g
Gross-beta	2	100 min	0.003 pCi/g
Uranium (Epithermal activation)	2		0.03 μg/g

REFERENCES

C1. E. S. Gladney, J. W. Owens, and J. W. Starner, "Simultaneous Determination of Uranium and Thorium on Ores by Instrumental Epithermal Neutron Activation Analysis," Anal. Chim. Acta, **104**, 121 (1979).

C2. B. A. Amiel, "Analytical Applications of Delayed Neutron Emission in Fissionable Elements," Anal. Chem. **34**, 1683 (1962).

C3. E. S. Gladney, W. K. Hensley, and M. M. Minor, "Comparison of Three Techniques for the Measurement of Depleted Uranium in Soils," Anal. Chem. **50**, 652 (1978).

C4. G. E. Gordon, K. Randle, G. G. Goles, J. B. Corliss, M. H. Beeson, and S. S. Oxley, "Instrumental Activation Analysis of Standard Rocks with High Resolution γ-Ray Detectors," Geochim. et Cosmochim. Acta **32**, 369 (1968).

C5. R. Dams, J. A. Robbins, K. A. Rahn, and J. W. Winchester, "Nondestructive Neutron Activation Analysis of Air Pollution Particulates," Anal. Chem. **42**, 861 (1970).

C6. B. Salbu, E. Steinnes and A. C. Pappas, "Multielement Neutron Activation of Fresh Water Using Ge(Li) Gamma Spectrometry," Anal. Chem. **47**, 1011 (1975).

C7. G. R. Van der Linden, F. DeCorte, and J. Hoste, "Activation Analysis of Biological Materials with Ruthenium as a Multi-Isotopic Comparator," Anal. Chim. Acta **71**, 263 (1974).

C8. H. E. Steinnes, "Epithermal Neutron Activation Analysis of Geological Materials," in ***Activitation Analysis in Geochemistry and Cosmochemistry***, A. O. Brumfelt and E. Steinnes, Eds., UNIVERSITETSFORLAGET, Oslo, Norway, pp. 113-128 (1971).

C9. E. S. Gladney, L. E. Wangen, and R. D. Aquilar, "Comparison of Three Techniques for Rapid Determination of Sr in Soils and Vegetation," Anal. Lett., **10**, 1083 (1977).

C10. L. E. Wangen and E. S. Gladney, "Determination of As and Ga in Standard Materials by Instrumental Epithermal Neutron Activation Analysis," Anal. Chim. Acta, **96**, 271 (1978).

C11. E. S. Gladney, J. W. Owens, M. L. Marple, and D. R. Dreesen, "A Comparison of Thermal and Epithermal Neutron Activation for the Measurement of Se in Vegetation," Anal. Lett., **A11**, 1001 (1978).

C12. E. S. Gladney, E. T. Jurney, and D. B. Curtis, "Nondestructive Determination of Boron and Cadmium in Environmental Materials by Thermal Neutron Prompt Gamma-Ray Spectrometry," Anal. Chem., **48**, 2139 (1976).

C13. E. T. Jurney, D. B. Curtis, and E. S. Gladney, "Nondestructive Determination of Sulfur in Environmental Materials by Thermal Neutron Prompt Gamma-Ray Spectroscopy," Anal. Chem., **49**, 1741 (1977).

C14. E. S. Gladney, D. B. Curtis, and E. T. Jurney, "Multielement Analysis of Major and Minor Elements by Thermal Neutron Capture Gamma-Ray Spectrometry," J. Radioanal. Chem., **46**, 299 (1978).

C15. E. S. Gladney and H. L. Rook, "Determination of Tellurium and Uranium in Environmental Materials," Anal. Chem., **47**, 1554 (1975).

C16. E. S. Gladney, J. W. Owens, and J. W. Starner, "The Determination of Uranium in Natural Waters by Neutron Activation Analysis," Anal. Chem., **48**, 973 (1976).

C17. E. S. Gladney, "Copper Determination in Standard Materials Using Neutron Activation and Srafion NMRR Anion Exchange Resin," Anal. Chim. Acta, **91**, 353 (1977).

C18. E. S. Gladney, "Determination of As, Sb, Mo, Th, and W in Silicates by Thermal Neutron Activation and Inorganic Ion Exchange," Anal. Lett., **A11** 429 (1978).

C19. E. S. Gladney and J. W. Owens, "Determination of As, W, and Sb in Natural Waters by Neutron Activation and Inorganic Ion Exchange," Anal. Chem., **48**, 2220 (1976).

C20. R. A. Nadkarni and G. H. Morrison, "Determination of the Noble Metals in Geological Materials by Neutron Activation Analysis," Anal. Chem. **46**, 232 (1974).

C21. Perkin-Elmer Corporation, "Analytical Methods Using the HGA Graphite Furnace," Perkin-Elmer, Norwalk, Connecticut (1977).

C22. R. D. Ediger, "Atomic Absorption Analysis with the Graphite Furnace Using Matrix Modification," At. Absorption Newslett. **14**, 127 (1975).

23. J. W. Owens and E. S. Gladney, "Determination of Beryllium in Environmental Materials by Flameless Atomic Absorption Spectrometry," Atomic Absorption Newsletter **14**,76 (1975).

C24. J. W. Owens and E. S. Gladney, "Lithium Metaborate Fusion and the Determination of Trace Metals in Fly Ash by Flameless Atomic Absorption," Atomic Absorption Newsletter **15**,95 (1976).

C25. J. W. Owens and E. S. Gladney, "The Determination of Arsenic in Natural Waters byFlameless Atomic Absorption," Atomic Absorption Newsletter **15**, 47 (1976).

C26. E. S. Gladney, "Matrix Modification for the Determination of Bi by Flameless Atomic Absorption, "Atomic Absorption Newsletter **16**, 114 (1977).

C27. E. S. Gladney and J. W. Owens, "Determination of Hg Using a Carrier-Free Combustion Separation and Flameless Atomic Absorption," Anal. Chim. Acta **90**, 271 (1977),

C28. F. C. Smith and R. A. Wetzel, "Operation and Maintenance Manual for Sionex Model 10 and Model 14 Ion Chromatographs," Dionex Corp., Sunnyvale, California (1978).

C29. American Society for Testing and Materials, *1977 Annual Book of ASTM Standards: Part 31: Water*, ASTM, Philadelphia, Pennsylvania (1977).

APPENDIX D

METHODS FOR DOSE CALCULATIONS

A. Airborne Tritium and Actinides

Measured annual average concentrations in air, after subtracting background, are multiplied by standard breathing rates[D1] to determine annual intake via inhalation. This intake is then multiplied by appropriate dose conversion factors[D2] to convert intake into annual dose and 50 year dose commitments for various organs. Dose commitment factors for tritium include an increase by a factor of 2 over inhalation intake to account for skin absorption of tritium.

B. Airborne Air Activation Products

Nuclear reactions with air in the target areas at LAMPF cause the air activation products ^{11}C, ^{13}N, and ^{15}O to be formed. These isotopes are all positron emitters and have 20.4-min, 10-min, and 122-sec half-lives, respectively. Neutron reactions with air at the Omega West Reactor and LAMPF form ^{41}Ar (1.8 h half-life). The concentrations of these isotopes at the appropriate site boundary are calculated using the annual average meteorological dispersion coefficient

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

and the source term Q $X(r,\theta)$ is determined from Gaussian plume dispersion models. The dose calculated using semi-infinite cloud assumptions and then corrected for cloud size. The gamma dose rate in a semi-infinite cloud can be represented by the equation[D3]

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

where

γ_∞ (x,y,o,t) = gamma dose rate (rad/sec) to a person located at point x,y at ground level and time t,

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

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

Dose rate corrections for estimated plume size (if the cloud cannot be construed to be semi-infinite) is taken from standard graphical compilations.[D3] $\overline{E}\gamma$ is 1.02 MeV for the positron emitters (two 0.511 MeV gammas are produced in the positron annihilation process) and 1.29 MeV for ^{41}Ar. For maximum individual doses, a shielding factor (because of structure shielding) of 0.7 is used.[D4]

REFERENCES

D1. International Commission on Radiation Protection, "Report of the Task Group on Reference Man," ICRP Report No. 23 (1975).

D2. G. R. Hoenes and J. K. Soldat, "Age-Specific Radiation Dose Commitment Factors for a One-Year Chronic Intake," U.S. Nuclear Regulatory Commission Report NUREG-0172 (1977).

D3. D. H. Slade, Ed., "Meteorology and Atomic Energy 1967," U.S. AEC document TID-24190 (1968).

D4. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 (1977).

APPENDIX E

ENVIRONMENTAL DATA TABLES

TABLE E-I

MEANS AND EXTREMES OF TEMPERATURE AND PRECIPITATION

CLIMATOLOGICAL SUMMARY 1951-1978[a]

	Temperature (°C)							Precipitation (mm)										Mean No. of Days		
	Means			Extremes				Rain[b]					Snow/Frozen Precipitation							
Month	Max	Min	Mo. Mean	High	Year	Low	Year	Mean	Daily Max	Year	Mo. Max	Year	Mean	Daily Max	Year	Mo. Max	Year	Precip ≥2.5 mm	Max Temp ≥32°C	Min Temp ≤0°C
Jan	4.4	−7.5	−1.6	18.3	1953	−27.8	1963	19.0	24.9	1952	47.8	1952	230	360	1974	590	1974	2	0	30
Feb	6.1	−5.9	0.1	17.8	1962	−27.2	1951	17.6	24.4	1975	47.5	1964	200	270	1975	490	1964	2	0	26
March	9.4	−3.0	3.2	21.7	1971	−16.7	1971	25.1	41.7	1973	104.4	1973	250	410	1973	910	1973	3	0	23
April	14.4	1.0	7.7	25.0	1965	−11.7	1973	21.4	50.8	1975	82.0	1975	130	510	1975	850	1958	2	0	13
May	19.7	6.1	12.9	31.1	1956	−4.4	1976	26.9	34.3	1952	88.9	1952	20	300	1978	410	1978	3	0	2
June	25.4	11.3	18.4	35.0	1952	0.0	1975	28.7	29.7	1969	86.4	1960	0	0	---	0	---	3	0	0
July	26.8	13.3	20.1	34.4	1952	7.2	1961	85.6	62.7	1968	167.6	1968	0	0	---	0	---	8	1	0
Aug	25.2	12.4	18.8	32.8	1977	6.1	1957	103.1	57.4	1951	284.0	1952	0	0	---	0	---	9	0	0
Sept	22.3	9.0	20.7	31.1	1952	−3.3	1971	42.5	47.2	1973	115.6	1975	2	40	1971	40	1971	4	0	0
Oct	16.7	3.7	10.2	26.7	1952	−9.4	1976	39.8	52.3	1957	172.0	1957	40	180	1972	230	1959	3	0	7
Nov	9.5	−2.6	3.5	18.9	1952	−25.6	1976	25.0	45.0	1978	167.6	1978	130	300	1976	880	1957	2	0	22
Dec	4.9	−6.8	−1.0	15.0	1965	−25.0	1978	25.2	40.6	1978	72.4	1965	300	560	1978	1050	1967	2	0	30

CLIMATOLOGICAL SUMMARY 1978[a]

	Temperature (°C)					Precipitation (mm)				No. of Days		
	Means			Extremes		Rain[b]		Snow/Frozen Precipitation				
Month	Max	Min	Mo. Mean	High	Low	Total	Daily Max	Total	Daily Max	Precip ≥2.5 mm	Max Temp ≥32°C	Min Temp ≤0°C
Jan	3.7	−6.5	−1.4	7.8	−13.9	17.5	8.4	150	50	2	0	31
Feb	5.1	−6.5	−0.7	12.2	−16.7	7.1	2.8	50	50	1	0	28
March	10.8	−1.7	4.6	20.0	−9.4	36.8	12.2	130	130	6	0	22
April	15.8	1.4	8.6	20.0	−2.8	7.1	4.3	0	0	1	0	10
May	17.8	4.4	11.1	26.7	−4.4	50.5	31.5	410	300	3	0	7
June	25.9	12.1	19.0	32.2	5.0	35.1	19.6	0	0	4	1	0
July	28.5	13.4	21.0	31.7	10.0	34.3	17.0	0	0	5	0	0
Aug	26.0	11.1	18.6	30.0	6.1	35.3	12.7	0	0	6	0	0
Sept	22.3	8.0	15.2	27.8	0.6	34.3	19.8	0	0	3	0	0
Oct	18.0	4.4	11.2	25.0	−1.7	26.7	13.2	30	30	4	0	6
Nov	8.1	−1.4	3.4	17.8	−8.3	167.6	45.0	180	150	7	0	18
Dec	2.6	−9.1	−3.3	10.0	−25.0	57.1	40.6	640	560	4	0	31

[a]Los Alamos, New Mexico; latitude 35°32' north, longitude 106°19' west; elevation 2260 m.
[b]Includes liquid water equivalent of frozen precipitation.

TABLE E-II

ANNUAL THERMOLUMINESCENT DOSIMETER MEASUREMENTS

Station Location	Coordinates	Annual Dose: Dose (mrem)	95% Conf Interval (mrem)	95% Conf Interval (per cent)
Regional Stations	**(28-44 km)**	**Uncontrolled Areas**		
Española		74.3	5.2	7.0
Pojoaque		81.7	5.2	6.4
Santa Fe		95.5	5.7	5.9
	Regional Average	83.8 ± 21.5		
Perimeter Stations	**(0-4 km)**	**Uncontrolled Areas**		
Barranca School	N180 E130	111.8	5.6	5.0
Cumbres School	N150 E090	106.8	5.5	5.1
Golf Course	N160 E060	109.6	5.5	5.0
Arkansas Avenue	N170 E020	135.4	5.4	4.1
Diamond Drive	N130 E020	104.9	5.5	5.2
48th Street	N110 E000	128.2	5.5	4.2
Fuller Lodge	N110 E090	128.5	5.5	4.2
Acorn Street	N100 E110	102.6	5.6	5.5
LA Airport	N110 E160	113.7	5.5	4.8
Bayo Canyon S.T.P.	N110 E260	98.6	3.8	3.8
Bandelier Lookout	S270 E200	105.5	5.6	5.3
Pajarito Acres	S210 E370	82.4	5.6	6.8
White Rock S.T.P.	S090 E430	87.7	5.2	6.0
Pajarito Ski Area	N130 W180	111.2	5.2	4.7
Gulf Station	N100 E100	101.0	5.2	5.2
Royal Crest	N080 E080	91.3	5.2	5.7
	Perimeter Average	107.5 ± 29.1		

Station Location	Coordinates	Annual Dose: Dose (mrem)	95% Conf Interval (mrem)	95% Conf Interval (per cent)
Onsite Stations	**(28-44 km)**	**Controlled Areas**		
TA-21	N090 E170	111.4	5.5	4.9
State Hwy 4	N070 E350	217.1	5.6	2.6
Well PM-1	N030 E310	120.6	5.4	4.5
TA-53	N040 E230	113.9	5.5	4.8
TA-53	N070 E160	121.0	5.5	4.5
TA-53	N060 E190	143.4	5.5	3.8
TA-53	N060 E200	185.7	5.4	2.9
TA-53	N060 E220	680.8	13.3	2.0
TA-53	N050 E230	159.3	5.5	3.4
TA-2	N080 E100	119.7	5.4	4.6
TA-2	N080 E110	138.0	5.5	4.0
TA-2	N080 E120	153.3	5.5	3.6
TA-6	N060 W050	106.7	5.2	4.9
TA-16	S030 W080	117.9	5.5	4.7
TA-49	S100 E040	115.6	5.4	4.7
TA-33	S250 E230	105.8	5.7	5.3
Booster P-1	S100 E300	121.0	5.6	4.6
TA-18	S040 E190	173.6	5.2	3.0
TA-18	S030 E190	251.7	5.7	2.3
TA-18	S040 E200	207.1	5.3	2.6
TA-18	S060 E190	161.4	5.3	3.3
TA-18	S050 E170	114.9	5.2	4.5
TA-52	N020 E170	105.8	5.2	4.9
TA-35	N040 E110	123.4	5.1	4.2
TA-35	N030 E110	119.2	5.2	4.4
TA-39	N030 E100	132.5	4.0	3.0
TA-3	N040 E010	117.0	5.2	4.4
TA-3	N060 E010	219.5	5.4	2.5
TA-3	N050 E020	142.6	5.2	3.6
TA-3	N050 E040	97.2	5.0	5.2
TA-54	S080 E260	112.2	5.2	4.7
	Onsite Average	159.9 ± 211.9		

TABLE E-III

REGIONAL AVERAGE BACKGROUNDS ATMOSPHERIC RADIOACTIVITY CONCENTRATIONS

Radioactive Constituent	Activity (10^{-15} μCi/mℓ)		
	EPA[a]	LASL[b]	CG[c]
Gross α[d]	Not reported	1.4 ± 0.2	60
Gross β[e]	83	105 ± 25	1×10^5
^{241}Am	Not reported	0.004 ± 0.004	2×10^2
^{238}Pu	0.0018 ± 0.0018	0.0012 ± 0.0026	70
^{239}Pu	0.0199 ± 0.0100	0.014 ± 0.007	60
Tritium	Not reported	11 000.± 3500	2×10^8
Uranium	0.0408 ± 0.0300 (120 ± 88)[f]	0.034 ± 0.017 (105 ± 54)[f]	7×10^4

[a] "Radiological Quality of the Environment," (EPA-520/1-76-010), US EPA, Office of Radiation Programs, Washington, DC (1976).

[b] Annual averages for 1973-1977.

[c] Concentration Guide for uncontrolled areas.

[d] Gross alpha activity compares to CG for ^{239}Pu.

[e] Gross beta activity compared to CG for ^{131}I.

[f] pg/m^3.

TABLE E-IV

LONG-LIVED ATMOSPHERIC GROSS BETA CONCENTRATIONS FOLLOWING CHINESE NUCLEAR TEST ON MARCH 14, 1978

Sampling Period	Gross Beta (10^{-15} μCi/mℓ) OHL (Onsite)	Española (28 km from LASL)
3/13 - 3/17	---	180 ± 20
3/7 - 3/20	100 ± 10	114 ± 15
3/20 - 3/21	310 ± 40	170 ± 20
3/21 - 3/22	830 ± 110	500 ± 60[a]
3/22 - 3/23	200 ± 30	170 ± 20
3/23 - 3/24	150 ± 20	170 ± 20
3/24 - 3/27	430 ± 50	460 ± 60
3/27 - 3/28	320 ± 40	260 ± 30
3/28 - 3/29	400 ± 50	240 ± 30
3/29 - 3/30	460 ± 60	330 ± 40
3/30 - 3/31	590 ± 80	570 ± 70[b]
3/31 - 4/3	190 ± 20	190 ± 20
4/3 - 4/4	320 ± 40	230 ± 30

[a] First pass of the fallout cloud.
[b] Second pass of the fallout cloud.

TABLE E-V

LONG-LIVED ATMOSPHERIC GROSS BETA CONCENTATIONS FOLLOWING CHINESE NUCLEAR TEST ON DECEMBER 14, 1978

Sampling Period	Gross Beta (10^{-15} μCi/mℓ) OHL (Onsite)	Española (28 km from LASL)
12/15 - 12/18	48 ± 6	77 ± 10
12/18 - 12/19	16 ± 3	37 ± 5
12/19 - 12/20	83 ± 14	39 ± 5
12/20 - 12/21	45 ± 6	40 ± 6
12/21 - 12/22	53 ± 7	20 ± 3
12/22 - 12/26	148 ± 19	190 ± 20[a]
12/26 - 12/27	91 ± 12	78 ± 11
12/27 - 12/28	80 ± 11	95 ± 13
12/28 - 12/29	63 ± 8	55 ± 8
12/29 - 1/2/79	37 ± 5	44 ± 6
1/2 - 1/3	74 ± 10	77 ± 10

[a] Peak.

TABLE E-VI

LOCATION OF AIR SAMPLING STATIONS

Station	Latitude or N-S Coord	Longitude or E-W Coord
Regional (28-44 km)		
1. Española	36°00'	106°06'
2. Pojoaque	35°52'	106°02'
3. Santa Fe	35°40'	106°56'
Perimeter (0-4 km)		
4. Barranca School	N180	E130
5. Arkansas Avenue	N170	E020
6. Cumbres School	N150	E090
7. 48th Street	N110	E000
8. LA Airport	N110	E160
9. Bayo STP	N110	E260
10. Gulf Station	N100	E100
11. Royal Crest	N080	E080
12. White Rock	S090	E430
13. Pajarito Acres	S210	E370
14. Bandelier	S270	E200
Onsite		
15. TA-21	N090	E170
16. TA-6	N060	W050
17. TA-53 (LAMPF)	N060	E190
18. Well PM-1	N030	E310
19. TA-52	N020	E170
20. TA-16	S030	W080
21. Booster P-2	S030	E190
22. TA-54	S080	E260
23. TA-49	S100	E040
24. TA-33	S250	E230
25. TA-39	S210	E210

TABLE E-VII

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

		Gross Alpha Concentrations-fCi/m³ (10^{-15}μCi/mℓ)						Gross Beta Concentrations-fCi/m³ (10^{-15} μCi/mℓ)					
Station Location	Total Air[b] Volume (m³)	No. 4-wk Samples	No. Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]	No: 4-wk Samples	No: Samples <MDL[c]	Max[d]	Min[d]	Mean[d]	Mean as % CG[e]
Regional Stations (28-44 km) - Uncontrolled Areas													
1. Española	81 596	13	3	1.9 ± 0.9	0.3 ± 0.1	0.6 ± 0.7	0.9	13	0	145 ± 38	9 ± 2	64 ± 10	0.06
2. Pojoaque	66 352	13	0	1.9 ± 0.8	0.6 ± 0.3	1.3 ± 1.0	2.2	13	0	200 ± 60	23 ± 6	81 ± 9	0.08
3. Santa Fe	88 083	13	0	1.7 ± 0.8	0.5 ± 0.3	1.0 ± 0.8	1.6	13	0	160 ± 40	13 ± 3	73 ± 104	0.07
Regional Group Summary	236 391	39	3	1.9 ± 0.8	0.3 ± 0.1	0.9 ± 0.9	1.6	39	0	200 ± 60	9 ± 2	72 ± 102	0.07
Perimeter Stations (-04 km) - Uncontrolled Areas													
4. Barranca School	94 684	13	2	2.9 ± 1.2	0.0 ± 0.1	1.4 ± 1.7	2.3	13	0	200 ± 60	24 ± 6	84 ± 113	0.08
5. Arkansas Avenue	83 139	13	0	3.2 ± 1.4	0.5 ± 0.3	1.8 ± 1.9	2.9	13	0	180 ± 40	23 ± 6	91 ± 86	0.09
6. Cumbres School	79 786	13	0	2.8 ± 1.2	0.5 ± 0.3	1.4 ± 1.4	2.3	13	0	180 ± 40	24 ± 6	79 ± 101	0.08
7. 48th Street	79 472	13	2	2.7 ± 1.2	0.2 ± 0.1	1.2 ± 1.6	2.0	13	0	190 ± 40	15 ± 4	71 ± 119	0.07
8. LA Airport	89 099	13	2	3.2 ± 1.4	0.0 ± 0.1	1.5 ± 2.2	2.5	13	0	160 ± 40	21 ± 6	75 ± 102	0.07
9. Bayo Stp	86 190	13	3	3.0 ± 1.4	0.0 ± 0.1	1.1 ± 2.0	1.9	13	0	190 ± 40	21 ± 6	86 ± 114	0.09
10. Gulf Station	91 868	13	1	4.3 ± 1.8	0.3 ± 0.2	1.4 ± 2.1	2.3	13	0	147 ± 38	22 ± 6	81 ± 77	0.08
11. Royal Crest	89 726	13	0	2.6 ± 1.2	0.4 ± 0.2	1.5 ± 1.5	2.5	13	0	190 ± 40	24 ± 6	94 ± 119	0.09
12. White Rock	81 501	13	4	3.5 ± 1.6	0.1 ± 0.2	1.1 ± 2.1	1.8	13	0	180 ± 40	13 ± 3	76 ± 111	0.08
13. Pajarito Acres	82 750	13	1	3.3 ± 1.4	0.1 ± 0.2	1.6 ± 2.0	2.7	13	0	220 ± 60	31 ± 8	99 ± 125	0.10
14. Bandelier	67 895	13	0	6.8 ± 3.2	0.5 ± 0.3	2.3 ± 2.7	3.8	13	0	240 ± 60	40 ± 10	116 ± 145	0.11
Perimeter Group Summary	926 110	143	15	6.8 ± 3.2	0.0 ± 0.1	1.5 ± 1.9	2.4	143	0	240 ± 60	13 ± 3	86 ± 108	0.09
Onsite Stations - Controlled Areas													
15. TA-21	63 527	13	2	3.2 ± 1.4	−0.1 ± 0.6	1.8 ± 2.3	0.09	13	0	440 ± 120	4 ± 1	80 ± 133	0.002
16. TA-6	92 343	13	2	3.1 ± 1.4	0.2 ± 0.2	1.5 ± 1.7	0.08	13	0	160 ± 40	26 ± 6	81 ± 85	0.002
17. TA-53 (LAMPF)	81 513	13	2	2.2 ± 1.0	0.0 ± 0.4	1.1 ± 1.7	0.06	13	0	160 ± 40	4 ± 1	59 ± 114	0.001
18. Well PM-1	92 388	13	2	3.2 ± 1.4	0.3 ± 0.2	1.5 ± 1.8	0.07	13	0	170 ± 40	25 ± 6	89 ± 111	0.002
19. TA-52	94 496	13	1	3.4 ± 1.6	0.2 ± 0.1	1.3 ± 1.8	0.06	13	0	200 ± 60	6 ± 2	85 ± 122	0.002
20. TA-16	94 899	13	2	2.4 ± 1.0	0.1 ± 0.1	1.1 ± 1.5	0.05	13	0	135 ± 34	6 ± 1	69 ± 82	0.002
21. Booster P-2	95 138	13	1	3.1 ± 1.4	0.2 ± 0.2	1.4 ± 1.9	0.07	13	0	160 ± 40	21 ± 6	83 ± 102	0.002
22. TA-54	97 610	13	3	3.5 ± 1.6	0.2 ± 0.2	1.6 ± 2.1	0.08	13	0	190 ± 40	31 ± 8	87 ± 109	0.002
23. TA-49	94 556	13	2	2.6 ± 1.2	0.1 ± 0.1	1.4 ± 1.8	0.07	13	0	190 ± 40	27 ± 6	81 ± 93	0.002
24. TA-33	93 452	13	0	3.9 ± 1.6	0.3 ± 0.3	1.9 ± 2.3	0.09	13	0	220 ± 60	35 ± 8	103 ± 125	0.003
25. TA-39	94 665	13	1	4.6 ± 2.0	0.3 ± 0.2	1.8 ± 2.5	0.09	13	0	210 ± 60	33 ± 8	91 ± 116	0.002
Onsite Group Summary	994 587	143	18	4.6 ± 2.0	−0.1 ± 0.6	1.5 ± 2.0	0.07	143	0	440 ± 120	4 ± 1	83 ± 109	0.002

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

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

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

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

[e]Of the possible radionuclides released at LASL, ^{239}Pu and ^{131}I are the most restrictive. The CGs for these species are used for the gross alpha and gross beta CGs, respectively.

Controlled Area Radioactivity Concentration Guide = 2×10^{-12} μCi/mℓ (α)
= 4×10^{-9} μCi/mℓ (β)

Uncontrolled Area Radioactivity Concentration Guide = 6×10^{-14} μCi/mℓ (α)
= 1×10^{-10} μCi/mℓ (β)

TABLE E-VIII

ANNUAL ATMOSPHERIC TRITIATED WATER VAPOR CONCENTRATIONS

Station Location	Total Air Volume (m^3)[a]	No. 4-wk Samples	No. Samples <MDL[b]	Concentrations - pCi/m^3 (10^{-12} $\mu Ci/m\ell$)			
				Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas							
1. Española	113	13	3	18 ± 6	0.9 ± 0.8	5 ± 11	0.003
2. Pojoaque	121	13	0	9 ± 3	1.1 ± 1.0	4 ± 4	0.002
3. Santa Fe	121	13	2	19 ± 6	0.2 ± 0.6	5 ± 10	0.002
Regional Group Summary	356	39	5	19 ± 6	0.2 ± 0.6	4 ± 9	0.002
Perimeter Stations (0-4 km) - Uncontrolled Areas							
4. Barranca School	121	13	1	26 ± 8	0.7 ± 0.6	10 ± 15	0.005
5. Arkansas Ave	121	13	1	36 ± 14	0.6 ± 0.2	10 ± 21	0.005
6. Cumbres School	120	13	0	27 ± 8	2.0 ± 1.0	10 ± 15	0.005
7. 48th Street	113	13	0	106 ± 34	1.9 ± 1.0	21 ±.60	0.010
8. LA Airport	113	13	0	107 ± 34	3.5 ± 1.2	26 ± 63	0.013
9. Bayo STP	113	13	0	23 ± 8	1.4 ± 0.8	7 ± 14	0.003
10. Gulf Station	121	13	0	43 ± 14	4.2 ± 1.6	18 ± 27	0.009
11. Royal Crest	121	13	0	67 ± 22	4.0 ± 1.4	16 ± 35	0.008
12. White Rock	121	13	0	25 ± 8	1.9 ± 1.8	7 ± 14	0.004
13. Pajarito Acres	120	13	0	36 ± 12	2.6 ± 1.2	10.± 20	0.005
14. Bandelier	111	13	0	26 ± 8	2.6 ± 1.4	9 ± 15	0.004
Perimeter Group Summary	1300.	143	2	107 ± 34	0.6 ± 0.2	13 ± 33	0.007
Onsite Stations - Controlled Areas							
15. TA-21	114	13	0	118 ± 38	1.5 ± 1.0	23 ± 40	0.0005
16. TA-6	117	13	1	15 ± 4	0.5 ± 0.4	5 ± 10	0.0001
17. TA-53 (LAMPF)	114	13	0	33 ± 10	1.9 ± 0.8	13 ± 21	0.0003
18. Well PM-1	115	13	1	95 ± 30	1.2 ± 1.6	15 ± 53	0.0003
19. TA-52	121	13	0	39 ± 12	3.1 ± 1.2	16 ± 21	0.0003
20. TA-16	121	13	1	24 ± 8	0.6 ± 0.6	6 ± 15	0.0001
21. Booster P-2	121	13	0	85 ± 28	2.3 ± 1.0	14 ± 45	0.0003
22. TA-54	123	13	0	114 ± 36	9.1 ± 3.0	57 ± 74	0.0011
23. TA-49	120	13	1	19 ± 6	0.1 ± 0.6	5 ± 10	0.0001
24. TA-33	120	13	0	92 ± 30	6.5 ± 2.2	25 ± 54	0.0005
25. TA-39	122	13	0	68 ± 22	2.7 ± 1.0	15 ± 38	0.0003
Onsite Group Summary	1311	143	4	118 ± 38	0.1 ± 0.6	18 ± 48	0.0004

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 1×10^{-12} $\mu Ci/m\ell$.
[c]Uncertainties for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample standard deviations). Uncertainties for station and group means are ±2 standard deviations.
[d]Controlled area radioactivity concentration guide = 5×10^{-6} $\mu Ci/m\ell$.
Uncontrolled area radioactivity concentration guide = 2×10^{-7} $\mu Ci/m\ell$.

TABLE E-IX

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

		^{238}Pu (10^{-18} μCi/mℓ[a])						^{239}Pu (10^{-18} μCi/mℓ[a])					
Station Location	Total Air[a] Volume (m^3)	Number of Quarterly Samples	No. <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]	Number of Quarterly Samples	No. Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas													
1. Española	89 457	4	4	−1.1 ± 1.6	−2.4 ± 3.0	−1.9 ± 0.9	0.00	4	1	26 ± 7.7	1.2 ± 1.5	15 ± 30	0.025
2. Pojoaque	65 350	4	4	−2.0 ± 1.9	−4.5 ± 4.8	−3.0 ± 1.8	0.00	4	0	41 ± 6.3	7.0 ± 3.9	21 ± 47	0.035
3. Santa Fe	93 421	4	4	−1.1 ± 1.3	−3.4 ± 2.2	−2.2 ± 1.3	0.00	4	0	44 ± 8.1	6.2 ± 2.1	24 ± 46	0.040
Regional Group Summary	248 228	12	12	−1.1 ± 1.6	−4.5 ± 4.8	−2.3 ± 1.3	0.00	12	1	44 ± 8.1	1.2 ± 1.5	20 ± 39	0.034
Perimeter Stations (0-4 km) - Uncontrolled Areas													
4. Barranca School	95 009	4	4	−0.7 ± 2.0	−3.0 ± 2.4	−1.8 ± 1.6	0.00	4	0	37 ± 8.1	6.5 ± 2.3	25 ± 44	0.041
5. Arkansas Avenue	80 130	4	4	−1.2 ± 1.8	−2.4 ± 1.7	−1.9 ± 0.5	0.00	4	0	40 ± 5.2	8.6 ± 3.7	27 ± 43	0.045
6. Cumbres School	80 511	4	4	−1.0 ± 1.5	−4.0 ± 2.3	−2.1 ± 2.2	0.00	4	1	49 ± 10	2.0 ± 2.3	24 ± 47	0.040
7. 48th Street	78 886	4	4	−0.8 ± 2.1	−4.2 ± 5.0	−1.7 ± 1.5	0.00	4	0	79 ± 14	4.9 ± 2.3	28 ± 52	0.046
8. LA Airport	92 171	4	4	−0.9 ± 1.3	−3.7 ± 3.4	−2.0 ± 1.9	0.00	4	0	33 ± 10	5.9 ± 2.9	20 ± 41	0.034
9. Bayo STP	100 456	4	4	−1.2 ± 1.4	−2.5 ± 1.8	−1.8 ± 0.4	0.00	4	1	62 ± 7.6	−0.6 ± 1.4	27 ± 61	0.045
10. Gulf Station	112 845	4	4	−1.2 ± 1.3	−2.3 ± 1.7	−1.6 ± 0.3	0.00	4	0	46 ± 7.7	10 ± 3.5	22 ± 33	0.037
11. Royal Crest	89 941	4	4	−0.9 ± 1.3	−1.8 ± 1.8	−1.3 ± 0.4	0.00	4	0	56 ± 9.9	11 ± 3.9	32 ± 52	0.053
12. White Rock	74 695	4	4	−1.0 ± 2.7	−4.7 ± 3.9	−1.9 ± 1.8	0.00	4	0	26 ± 4.6	6.9 ± 4.3	19 ± 35	0.031
13. Pajarito Acres	82 758	4	4.	−0.1 ± 1.9	−2.8 ± 2.1	−1.4 ± 1.9	0.00	4	0	52 ± 8.6	7.3 ± 3.0	31 ± 53	0.052
14. Bandelier	67 406	4	4	−1.2 ± 2.0	−3.6 ± 2.4	−2.1 ± 1.1	0.00	4	0	67 ± 10	14 ± 3.7	40 ± 66	0.066
Perimeter Group Summary	954 808	44	44	−0.1 ± 1.9	−4.7 ± 3.9	−1.8 ± 1.3	0.00	44	2	79 ± 14	−0.6 ± 1.4	27 ± 43	0.044
Onsite Stations - Controlled Areas													
15. TA-21	72 942	4	4	−0.2 ± 2.5	−4.7 ± 2.3	−2.0 ± 2.5	0.00	4	0	44 ± 5.7	3.6 ± 2.9	23 ± 51	0.0011
16. TA-6	95 604	4	4	−1.5 ± 1.7	−2.3 ± 1.7	−1.8 ± 1.4	0.00	4	1	43 ± 6.6	−0.5 ± 1.3	27 ± 53	0.0013
17. TA-53 (LAMPF)	81 191	4	4	−1.2 ± 1.4	−2.6 ± 3.5	−1.7 ± 0.5	0.00	4	0	33 ± 5.5	4.2 ± 2.7	17 ± 51	0.0009
18. Well PM-1	92 806	4	4	−2.3 ± 1.9	−3.1 ± 2.6	−2.6 ± 2.8	0.00	4	0	40 ± 5.8	7.4 ± 2.9	26 ± 42	0.0013
19. TA-52	94 693	4	4	−1.2 ± 1.5	−2.8 ± 1.7	−1.7 ± 1.5	0.00	4	0	55 ± 7.5	5.7 ± 2.7	29 ± 58	0.0015
20. TA-16	94 752	4	4	−1.2 ± 1.7	−1.6 ± 1.8	−1.4 ± 0.7	0.00	4	0	59 ± 6.7	7.9 ± 2.8	36 ± 77	0.0018
21. Booster P-2	96 446	4	4	−1.1 ± 1.5	−2.6 ± 1.8	−1.6 ± 0.6	0.00	4	0	37 ± 5.3	7.1 ± 2.6	24 ± 41	0.0012
22. TA-54	99 251	4	3	8.8 ± 3.2	0.3 ± 1.8	3.0 ± 6.8	0.0002	4	0	153 ± 13	15 ± 3.6	80 ± 120	0.0040
23. TA-49	94 524	4	4	−1.0 ± 2.7	−2.2 ± 1.6	−1.5 ± 1.2	0.00	4	0	50 ± 9.7	7.1 ± 2.9	26 ± 41	0.0013
24. TA-33	102 442	4	4	−0.6 ± 1.3	−2.2 ± 2.0	−1.2 ± 1.1	0.00	4	0	41 ± 5.4	8.9 ± 2.9	28 ± 46	0.0014
25. TA-39	95 298	4	4	−0.6 ± 1.7	−2.5 ± 1.5	−1.4 ± 1.3	0.00	4	0	54 ± 6.6	6.4 ± 2.5	35 ± 70	0.0018
Onsite Group Summary	1 019 949	44	43	8.8 ± 3.2	−4.7 ± 2.3	−1.2 ± 3.7	0.00	44	1	153 ± 13	−0.5 ± 1.3	32 ± 67	0.0016

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

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

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

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

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

TABLE E-X

ANNUAL ATMOSPHERIC URANIUM CONCENTRATIONS

Station Location	Total Air[a] Volume (m^3)	Number of Quarterly Samples	No. Samples <MDL[b]	Uranium - pg/m^3 Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas							
1. Española	89 457	4	0	147 ± 29	34 ± 18	105 ± 138	0.0012
2. Pojoaque	65 350	4	0	184 ± 38	128 ± 25	155 ± 38	0.0017
3. Santa Fe	93 421	4	0	91 ± 18	44 ± 16	63 ± 34	0.0007
Regional Group Summary	248 228	12	0	184 ± 38	34 ± 18	102 ± 94	0.0011
Perimeter Stations (0-4 km) - Uncontrolled Areas							
4. Barranca School	95 009	4	0	92 ± 19	59 ± 18	73 ± 36	0.0008
5. Arkansas Ave	80 130	4	0	134 ± 21	43 ± 9	73 ± 59	0.0008
6. Cumbres School	80 511	4	1	69 ± 15	19 ± 22	42 ± 51	0.0005
7. 48th Street	78 886	4	0	159 ± 21	28 ± 6	74 ± 80	0.0008
8. LA Airport	92 171	4	0	107 ± 22	37 ± 18	73 ± 133	0.0008
9. Bayo STP	100 456	4	1	120 ± 23	20 ± 21	58 ± 60	0.0006
10. Gulf Station	91 940	4	0	177 ± 40	30 ± 20	84 ± 93	0.0009
11. Royal Crest	89941	4	0	236 ± 40	44 ± 20	101 ± 127	0.0011
12. White Rock	74 695	4	0	238 ± 49	56 ± 12	115 ± 145	0.0013
13. Pajarito Acres	82 758	4	0	79 ± 17	45 ± 9	58 ± 28	0.0006
14. Bandelier	67 406	4	0	113 ± 33	38 ± 24	61 ± 37	0.0007
Perimeter Group Summary	954 808	44	2	238 ± 49	19 ± 22	74 ± 88	0.0008
Onsite Stations - Controlled Areas							
15. TA-21	72 942	4	1	149 ± 30	23 ± 27	96 ± 159	0.00005
16. TA-6	95 604	4	0	177 ± 40	36 ± 19	72 ± 89	0.00003
17. TA-53 (LAMPF)	81 191	4	1	61 ± 21	16 ± 21	40 ± 58	0.00002
18. Well PM-1	92 806	4	0	103 ± 21	40 ± 8	59 ± 45	0.00003
19. TA-52	94 693	4	1	94 ± 18	19 ± 19	61 ± 61	0.00003
20. TA-16	94752	4	1	80 ± 18	20 ± 19	48 ± 45	0.00002
21. Booster P-2	96 446	4	0	86 ± 19	59 ± 12	72 ± 21	0.00003
22. TA-54	99 251	4	0	134 ± 18	78 ± 16	103 ± 42	0.00005
23. TA-49	94 524	4	0	78 ± 18	32 ± 18	61 ± 54	0.00003
24. TA-33	102 442	4	0	81 ± 19	43 ± 10	61 ± 29	0.00003
25. TA-39	95 298	4	0	135 ± 19	52 ± 11	82 ± 40	0.00004
Onsite Group Summary	1 019 949	44	4	177 ± 40	16 ± 21	68 ± 66	0.00003

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

[b]Minimum detectable limit = 2 pg/m^3.

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

[d]Controlled area radioactivity concentration guide = 2.1×10^8 pg/m^3.
Uncontrolled area radioactivity concentration guide = 9×10^6 pg/m^3.

Note: One curie of natural uranium is equivalent to 3000 kg of natural uranium. Hence, uranium masses can be converted to the DOE "uranium special curie" by using the factor 3.3×10^{-13} μCi/pg.

TABLE E-XI

ANNUAL ATMOSPHERIC ^{241}Am CONCENTRATIONS

Station Location	Total Air Volume (m^3)[a]	Number of Quarterly Samples	No. Samples <MDL[b]	Max[c]	Min[c]	Mean[c]	Mean as % CG[d]
Regional Stations (28-44 km) - Uncontrolled Areas							
3. Santa Fe	73 671	3	3	0.3 ± 3.6	−2.0 ± 9.1	−0.5 ± 2.2	0.00000
Regional Group Summary	73 671	3	3	0.3 ± 3.6	−2.0 ± 9.1	−0.5 ± 2.2	0.00000
Perimeter Stations (0-4 km) - Uncontrolled Areas							
6. Cumbres	61 855	3	3	7.4 ± 15	−1.0 ± 5.9	3.1 ± 13	0.00156
8. LA Airport	76 020	3	3	2.6 ± 3.6	−2.7 ± 6.4	0.3 ± 5.9	0.00014
9. Bayo STP	68 754	3	3	0.6 ± 3.8	−1.9 ± 5.5	−0.3 ± 2.8	0.00017
12. White Rock	74 695	4	4	1.9 ± 6.0	−2.0 ± 5.9	−0.6 ± 4.0	0.00029
Perimeter Group Summary	281 324	13	13	7.4 ± 15	−2.7 ± 6.4	0.5 ± 6.7	0.00026
Onsite Stations - Controlled Areas							
16. TA-6	71 249	3	3	1.4 ± 3.5	−1.2 ± 5.2	0.3 ± 2.8	0.000006
17. TA-53 (LAMPF)	67 161	3	3	1.1 ± 6.0	−0.7 ± 3.8	0.0 ± 1.9	0.000000
20. TA-16	94 752	4	4	1.3 ± 5.2	−2.0 ± 4.8	−0.4 ± 2.7	0.000000
21. Booster P-2	96 446	4	4	1.6 ± 4.7	−3.3 ± 4.8	−1.5 ± 5.1	0.000000
22. TA-54	99 251	4	4	4.2 ± 4.8	−0.9 ± 5.0	2.2 ± 4.1	0.000036
23. TA-49	73 746	3	3	2.4 ± 3.8	−2.7 ± 5.2	0.0 ± 5.4	0.000000
Onsite Group Summary	502 605	21	21	4.2 ± 4.8	−3.3 ± 4.8	0.1 ± 4.2	0.000002

[a]Air volumes (m^3) at average ambient conditions of 77 kPa barometric pressure and 15°C.
[b]Minimum detectable limit = 2×10^{-12} μCi/mℓ.
[c]Uncertainties for maximum and minimum concentrations are counting uncertainties at the 95% confidence level (±2 sample deviations). Uncertainties for station and group means are ±2 standard deviations.
[d]Controlled area radioactivity concentration guide = 5×10^{-6} μCi/mℓ.
Uncontrolled area radioactivity concentration guide = 2×10^{-7} μCi/mℓ.

TABLE E-XII

LOCATIONS OF SURFACE AND GROUND WATER STATIONS

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Regional[c]				
Chamita—Rio Chama	36°05'	106°07	---	SW
Embudo—Rio Grande	36°12'	105°58'	---	SW
Otowi—Rio Grande	35°52'	106°08'	---	SW
Cochiti—Rio Grande	35°37'	106°19'	---	SW
Bernalillo—Rio Grande	35°17'	106°36'	---	SW
Jemez River	35°40'	106°44'	---	SW
Perimeter				
Los Alamos Reservoir	N105	W090	1	SW
Guaje Canyon	N300	E100	2	SW
Basalt Spring	N060	E395	3	GWS
Frijoles Canyon	S280	E180	4	SW
La Mesita Spring	N080	E550	5	GWD
White Rock Canyon[d]				
Puye Formation	---	---	6	GWD
Tesuque Fm (F.G. Sed)	---	---	7	GWD
Tesuque Fm (C.G. Sed)	----	---	8	GWD
Tesuque Fm (Basalts)	---	---	9	GWD
Surface Water	---	---	10	SW
Surface Water (Sanitary effluents)	---	---	11	SW
Water Supply				
Distribution				
Fire Station 1	N080	E015	12	D
Fire Station 2	N100	E120	13	D
Fire Station 3	S085	E375	14	D
Fire Station 4	N185	E070	15	D
Fire Station 5	S010	W065	16	D
Los Alamos Field				
LA-1B	N115	E530	17	GWD
LA-2	N125	E505	18	GWD
LA-3	N130	E490	19	GWD
LA-4	N070	E405	20	GWD
LA-5	N076	E435	21	GWD
LA-6	N105	E465	22	GWD
Guaje Field				
G-1	N190	E385	23	GWD
G-1A	N197	E380	24	GWD
G-2	N205	E365	25	GWD
G-3	N215	E350	26	GWD
G-4	N213	E315	27	GWD
G-5	N228	E295	28	GWD
G-6	N215	E270	29	GWD

TABLE E-XII (continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Pajarito Field				
PM-1	N030	E305	30	GWD
PM-2	S055	E202	31	GWD
PM-3	N040	E255	32	GWD
Water Canyon Gallery	S040	W125	33	GWD
Noneffluent Areas				
Test Well 1	N070	E345	34	GWD
Test Well 3	N080	E215	35	GWD
Deep Test-5A	S110	E090	36	GWD
Test Well-8	N035	E170	37	GWD
Deep Test-9	S155	E140	38	GWD
Deep Test-10	S120	E125	39	GWD
Cañada del Buey	N010	E150	40	SW
Pajarito Canyon	S060	E215	41	SW
Water Canyon	S090	E090	42	SW
Test Well 2	N120	E150	43	GWD
Effluent Release Area				
Acid-Pueblo Canyon (Former Release Area)				
Acid Weir	N125	E070	44	SW
Pueblo 1	N130	E080	45	SW
Pueblo 2	N120	E155	46	SW
Pueblo 3	N085	E315	47	SW
Hamilton Bend Spring	N110	E255	48	GW
Test Well 1A	N070	E335	49	GWS
Test Well 2A	N120	E140	50	GWS
DP-Los Alamos Canyon				
DPS-1	N090	E160	51	SW
DPS-4	N080	E200	52	SW
Obs. Hole LAO-C	N085	E070	53	GWS
Obs. Hole LAO-1	N080	E120	54	GWS
Obs. Hole LAO-2	N080	E210	55	GWS
Obs. Hole LAO-3	N080	E220	56	GWS
Obs. Hole LAO-4	N070	E245	57	GWS
Obs. Hole LAO-4.5	N065	E270	58	GWS
Sandia Canyon				
SCS-1	N080	E040	59	SW
SCS-2	N060	E140	60	SW
SCS-3	N050	E185	61	SW

TABLE E-XII (continued)

Station	Latitude or N-S Coordinate	Longitude or E-W Coordinate	Map Designation[a]	Type[b]
Mortandad Canyon				
GS-1	N040	E200	62	SW
MCS-3.9	N040	E140	63	SW
Obs. Hole MCO-3	N040	E110	64	GWS
Obs. Hole MCO-4	N035	E150	65	GWS
Obs. Hole MCO-5	N030	E160	66	GWS
Obs. Hole MCO-6	N030	E175	67	GWS
Obs. Hole MCO-7	N025	E180	68	GWS
Obs. Hole MCO-7.5	N030	E190	69	GWS
Obs. Hole MCO-8	N030	E205	70	GWS

[a]See Fig. 9 for numbered locations.

[b]SW = surface water; GWD = deep or main aquifer; GWS = shallow or alluvial aquifer; D = water supply distribution system.

[c]See Fig. 8 for regional locations.

[d]Puye Formation 7 stations; Tesuque Fm (F.G. Sed) 4 stations; Tesuque Fm (C.G. Sed) 9 stations; Tesuque (basalts) 3 stations; surface water 2 stations; surface water (sanitary effluents) 1 station.

TABLE E-XIII

RADIOCHEMICAL AND CHEMICAL QUALITY OF SURFACE WATER FROM REGIONAL STATIONS

Station	No. of Analyses	Radiochemical (average of a number of analyses) ^{3}H 10^{-6} μCi/mℓ	^{137}Cs 10^{-9} μCi/mℓ	^{238}Pu 10^{-9} μCi/mℓ	^{239}Pu 10^{-9} μCi/mℓ	Gross α 10^{-9} μCi/mℓ	Gross β 10^{-9} μCi/mℓ	Total U μg/ℓ
Chamita	2	2.4 ± 3.5	25 ± 42	−0:01 ± 0.000	−0.01 0.07	1.7.± 0.3	6.4 ± 6.9	2.1 ± 3.5
Embudo	2	2.0 ± 3.5	65 ± 156	0.01 ± 0.02	−0:01 ± 0.00	2.2.± 6.3	2.8 ± 8.9	2.1 ± 0.4
Otowi	2	1.4 ± 1.8	15 ± 99	−0.01 ± 0.02	0.01 ± 0.03	0:9 ± 1.0	5.2 ± 3.5	3.0 ± 1.8
Cochiti	2	0.8 ± 0.8	10 ± 28	−0:02 ± 0.03	−0.00 ± 0.02	1.5 ± 0.9	5.9 ± 1.1	3.0 ± 3.5
Bernalillo	2	1.1 ± 8.5	−5 ± 14	−0.02 ± 0.03	−0.01.± 0.01	3.4 ± 0.1	7.7 ± 4.7	3.3 ± 3.4
Jemez River	2	0.9 ± 0.0	−5 ± 14	−0.01 ± 0.04	−0.02 ± 0.05	4.6 ± 1.7	20 ± 11	0.9 ± 0.4
No. of Analyses		12	12	12	12	12	12	12
Minimum		0.5 ± 0.6	−20 ± 160	−0.01 ± 0.02	−0:04 ± 0.02	−0.8 ± 1.0	−0.3 ± 1.0	0.7 ± 0.2
Maximum		3.6 ± 0.6	120 ± 140	0.02 ± 0.03	C:02 ± 0.02	5.2 ± 3.0	24 ± 6.0	4.5 ± 0.8
Average		1:4 ± 2.0	18 ± 77	−0.01 ± 0.02	−0.01 ± 0.03	2.3 ± 3.5	8.0 ± 12.7	2.4 ± 2.6

Stations	Chemical (one analysis) Si_2O	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond mS/m
Chamita	13	55	13	3	33	4	149	<2	133	10	0.4	<2	508	191	8.5	52
Embudo	21	26	6	3	19	4	112	<2	35	4	0.5	<2	314	91	8.5	27
Otowi	18	38	9	3	24	0	139	<2	68	6	0.5	<2	394	131	8.5	35
Cochiti	27	36	8	3	25	5	156	<2	53	2	0.5	<2	410	123	8.3	35
Bernalillo	25	41	8	4	41	3	144	<2	70	9	0.6	<2	400	137	8.6	45
Jemez River	39	38	5	12	61	0	178	<2	28	82	0.9	<2	540	116	8.6	52
No. of Analyses	6	6.	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	13	26.	5	3	19	0	112	<2	28	2	0.4	<2	314	91	8.3	27
Maximum	39	55.	13	12	61	5	178	---	133	82	0.9	---	540	191	8.6	52
Average	24 ± 18	39.± 18	8 ± 6	5 ± 8	34 ± 30	3 ± 4	146 ± 44	<2	65 ± 75	19 ± 62	0.6 ± 0.4	<2	428 ± 165	132 ± 66	8.5 ± 0.2	41 ± 20

Stations	Metal Ion (concentrations in μg/ℓ, one analysis) Ag	Al	As	Ba	Br	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pd	Se	Zn
Chamita	19	33	<5	420	<2	3	<5	<3	<300	<300	<0.2	<300	<10.	7	5	<5	<300
Embudo	24	<10	<5	190	<2	3	<5	<3	<300	<300	<0.2	<300.	15	7	<3	<5	<300.
Otowi	20	20	<5	320	<2.	6	<5	<3	<300	<300	<0.2	<300	13	8	4	<5	<300
Cochiti	16	16	<5	270	<2.	3.	<5	<3	<300	<300	<0.2	<300	12	8	4	<5	<300
Bernalillo	20	11	<5	260	<2.	3	<5	<3	<300.	<300	<0.2	<300	27	9	7	<5	<300
Jemez River	18	49	75	210	<2	4	<5	<3	<300	<300	<0.2	<300	25	10.	8	<5	<300
No. of Analyses	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Minimum	16	<10	1	190	<2	3	<5	<3	<300	<300	<0.2	<300	<10	7	<3	<5	<300.
Maximum	24	49	75	420	---	€	---	---	---	---	---	---	27	10	8	---	---
Average	20 ± 5	23 ± 30	17 ± 57	278 ± 167	<2	4 ± 2	<5	<3	<300	<300	<0.2	<300	17 ± 14	8 ± 2	5 ± 4	<5	<300

Note: ± value represents twice the standard deviation of the distributions of observed values unless only one analysis is reported. Then the value represents twice the error term for that analysis. One sample used for chemical and metal ion analysis.

TABLE E-XIV

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

Stations	No. of Analyses	Radiochemical (average of a number of analyses)						
		^{3}H 10^{-6} μCi/mℓ	^{137}Cs 10^{-9} μCi/mℓ	^{238}Pu 10^{-9} μCi/mℓ	^{239}Pu 10^{-9} μCi/mℓ	Gross α 10^{-9} μCi/mℓ	Gross β 10^{-9} μCi/mℓ	Total U μg/ℓ
Los Alamos Reservoir	2	1.2 ± 0.5	1 ± 31	−0.02 ± 0.00	0.01 ± 0.03	−0.3 ± 0.7	4.7 ± 0.0	<0.1 ± 0.2
Guaje Canyon	2	0.9 ± 1.0	59 ± 88	−0.02 ± 0.06	0.00.± 0.01	0.7 ± 1.8	5.7 ± 7.2	0.3 ± 0.8
Basalt Spring	2	0.8 ± 1.0	−1 ± 55	−0.01 ± 0.02	−0.02 ± 0.02	0.8 ± 2.1	4.1 ± 0.4	1.7 ± 0.3
Frijoles Canyon	2	1.1 ± 0.3	13 ± 20	−0.01 ± 0.00	−0.01 ± 0.04	0.9 ± 2.7	6.0 ± 7.6	0.1 ± 0.3
La Mesita Spring	2	1.0 ± 0.3	−6 ± 16	0.00 ± 0.02	0.00 ± 0.02	5.6 ± 2.1	6.9 ± 0.3	14 ± 1.0
No. of Analyses		10	10	10	10	10	10	10
Minimum		0.4 ± 0.6	−20 ± 80	−0.04 ± 0.03	−0.03 ± 0.04	−0.5 ± 1.0	3.1 ± 1.6	<0.1 ± 0.2
Maximum		1.4 ± 0.6	90 ± 100	0.01 ± 0.02	0.03 ± 0.03	6.3 ± 3.0	8.7 ± 2.0	14 ± 2.0
Average		1.0 ± 0.6	13 ± 62	−0.01 ± 0.02	0.00 ± 0.03	1.5 ± 4.6	5.5 ± 4.1	3.2 ± 11
White Rock Canyon								
Puye Formation	7	0.2 ± 0.6	14 ± 21	0.00 ± 0.01	−0.01 ± 0.02	1.4 ± 2.1	2.7 ± 2.3	0.8 ± 1.4
Tesuque Fm (F.G. Sed)	4	0.1 ± 0.8	8 ± 38	−0.01 ± 0.02	−0.00 ± 0.01	1.8 ± 5.2	3.6 ± 2.4	3.3 ± 6.4
Tesuque Fm (C.G. Sed)	9	0.3 ± 0.8	5 ± 51	0.00 ± 0.02	−0.01 ± 0.01	0.6 ± 1.9	2.3 ± 2.2	0.4 ± 1.1
Tesuque Fm (basalt)	3	<0.1 ± 0.2	7 ± 28	−0.01 ± 0.03	−0.01 ± 0.02	5.3 ± 14	6.6 ± 7.5	7.2 ± 23
Surface Water (2 stations)	2	<0.1 ± 0.8	−20 ± 84	−0.01 ± 0.03	−0.01 ± 0.04	1.1 ± 4.0	3.3 ± 3.0	0.3 ± 0.4
Surface Water (sanitary eff)	1	0.1 ± 0.3	10 ± 80	0.00 ± 0.02	0.00 ± 0.02	−0.2 ± 2.0	18 ± 4.0	0.5 ± 0.2
No. of Analyses		26	26	26	26	26	26	26
Minimum		<0.1 ± 0.6	−50 ± 120	−0.01 ± 0.02	−0.03 ± 0.03	−0.5 ± 0.8	0.2 ± 1.4	<0.1 ± 0.2
Maximum		1.3 ± 0.6	60 ± 120	0.01 ± 0.02	0.00 ± 0.02	13 ± 6.0	18 ± 4.0	20 ± 4.0
Average		0.1 ± 0.7	6 ± 42	−0.01 ± 0.03	−0.01 ± 0.03	1.5 ± 5.4	3.8 ± 7.0	1.7 ± 8.2

TABLE E-XIV (continued)

Chemical
(concentrations in mg/ℓ, one analysis)

Station	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	Cond mS/m
Los Alamos Reservoir	50	4	3	3	9	4	61	<2	2	1	0.2	<2	182	18	8.3	8.0
Guaje Canyon	44	3	2	2	6	5	54	<2	2	1	0.3	<2	122	16	7.7	8.0
Basalt Spring	36	17	7	3	14	2	98	<2	18	9	0.6	7	250	72	8.2	24.0
Frijoles Canyon	48	5	3	2	10	2	185	<2	18	9	0.6	7	162	27	8.2	12.0
La Mesita Spring	19	27	<1	3	29	4	222	<2	12	6	0.3	8	286	70	8.1	27.0
No. of Analyses	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Minimum	19	3	<1	2	6	2	54	<2	2	1	0.2	<2	122	16	7.7	8.0
Maximum	50	27	7	3	29	5	222	---	18	9	0.6	8	286	72	8.3	24.0
Average	39 ± 25	11 ± 21	3 ± 5	3 ± 1	14 ± 18	3 ± 3	124 ± 151	<2	10 ± 16	5 ± 8	0.4 ± 0.4	5 ± 6	200 ± 133	41 ± 56	8.1 ± 0.5	15.8 ± 18.2
White Rock Canyon					15	0	94	<2	5	3	0.4	<2	159	60	---	19.0
Puye Formation	55	13	3	---	38	0	150	<2	7	3	0.7	<2	228	63	---	28.5
Tesuque Fm (F.G. Sed)	37	19	2	---	12	0	90	<2	3	2	0.4	<2	173	53	---	14.0
Tesuque Fm (C.G. Sed)	57	8	3	---	52	0	198	<2	9	4	0.4	3	296	71	---	35.0
Tesuque Fm (Basalts)	50	18	3	---	12	0	98	<2	4	4	0.4	<2	173	67	---	17.0
Surface Water (2 stations)	66	12	4	---	75	5	132	40	37	29	0.9	60	552	95	---	60.0
Surface Water (sanitary eff)	88	16	8	---												
No. of Analyses	26	26	26	---	26	26	26	26	26	26	26	26	26	26	---	26
Minimum	30	3	<1	---	10	0	63	<2	2	2	0.2	<2	112	20	---	12.0
Maximum	88	35	5	---	126	5	388	40	37	29	1.0	60	552	105	---	62.0
Average	54 ± 32	13 ± 13	3 ± 3	---	24 ± 52	1 ± 8	115 ± 128	8 ± 18	6 ± 14	4 ± 10	0.4 ± 0.4	5 ± 22	206 ± 210	61 ± 8	---	22.0 ± 25.3

Metal Ions
(concentrations in μg/ℓ, one analysis

Station	Ag	Al	As	Ba	Br	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Se	Zn
Los Alamos Reservoir	<10	32	<5	30	<2000	5	<5	<3	<300	<300	---	<300	<10	8	5	<5	<300
Guaje Canyon	<10	71	<5	30	<2000	7	<5	<3	<300	500	---	<300	<10	8	4	<5	<300
Basalt Spring	<10	<10	<5	110	<2000	5	<5	4	<300	<300	<0.2	<300	15	8	<3	<5	<300
Frijoles Canyon	<10	48	<5	60	<2000	4	<5	<3	<300	<300	<0.2	<300	<10	8	3	<5	<300
La Mesita Spring	<10	<10	<5	490	<2000	10	<5	4	<300	<300	<0.2	<300	13	8	4	<5	<300
No. of Analyses	5	5	5	5	5	5	5	5	5	5	3.	5	5	5	5	5	5
Minimum	<10	<10	<5	30	<2000	4	<5	<3	<300	<300	<0.2	<300	<10	8	<3	<5	<300
Maximum	---	71	---	490	---	10	---	4	---	500	---	---	15	8	5	---	---
Average	<10	34 ± 51	<5	144 ± 392	<2000	6 ± 5	<5	3 ± 1	<300	340 ± 180	<0.2	<300	12 ± 4	8 ± 8	4 ± 2	<5	<300

Note: ± value represents twice the standard deviation of the distribution of observed values unless only one analysis is reported. Then the value represents twice the error term for that analysis. One sample chemical and metal ion analysis.

TABLE E-XV

RADIOCHEMICAL AND CHEMICAL QUALITY OF WATER FROM MUNICIPAL SUPPLY AND DISTRIBUTION

Station	No. of Analyses	Radiochemical (average of a number of analyses)						
		^{3}H 10^{-6} $\mu Ci/m\ell$	^{137}Cs 10^{-9} $\mu Ci/m\ell$	^{238}Pu 10^{-9} $\mu Ci/m\ell$	^{239}Pu 10^{-9} $\mu Ci/m\ell$	Gross α 10^{-9} $\mu Ci/m\ell$	Gross β 10^{-9} $\mu Ci/m\ell$	Total U $\mu g/\ell$
Los Alamos Field (5 wells)	5	0.3 ± 0.4	40 ± 48	−0.02 ± 0.04	−0.01 ± 0.03	2.5 ± 5.3	3.3 ± 1.7	3.8 ± 4.7
Guaje Field (7 wells)	7	0.3 ± 0.5	17 ± 70	−0.01 ± 0.02	0.2 ± 0.4	2.4 ± 1.7	0.6 ± 0.5	
Pajarito Field (3 wells)	3	0.4 ± 0.3	−34 ± 116	−0.01 ± 0.01	−0.01 ± 0.02	1.0 ± 1.2	3.7 ± 4.0	1.2 ± 1.7
Water Canyon (gallery)	1	0.5 ± 0.7	−10 ± 40	−0.03 ± 0.02	−0.02 ± 0.02	−0.1 ± 1.0	1.9 ± 1.6	<0.1 ± 0.2
Distribution (5 stations)	10	0.6 ± 0.8	1 ± 54	−0.01 ± 0.03	0.00 ± 0.2	0.8 ± 2.4	3.5 ± 2.6	1.2 ± 2.3
No. of Analyses		26	26	26	26	26	26	26
Minimum		<0.2 ± 0.6	−100 ± 80	−0.04 ± 0.03	−0.03 ± 0.03	−0.4 ± 1.4	1.0 ± 1.4	<0.1 ± 0.2
Maximum		1.2 ± 0.6	80 ± 80	0.01 ± 0.02	0.01 ± 0.02	7.0 ± 4.0	5.9 ± 2.0	6.3 ± 1.2
Average		0.4 ± 0.7	19 ± 117	−0.02 ± 0.03	−0.01 ± 0.02	0.9 ± 3.1	3.1 ± 2.4	1.5 ± 3.4
Los Alamos Well LA-6[a]	1	0.2 ± 0.6	50 ± 80	−0.02 ± 0.03	−0.02 ± 0.02	1.6 ± 1.6	4.6 ± 1.8	1.6 ± 0.4

Station	Quality Required for Municipal Use (average concentrations in mg/ℓ)									
	Ag	As	Ba	Cd	Cr	F	Hg	NO_3	Pb	Se
Los Alamos Field (5 wells)	0.031	0.017	0.100	0.004	0.018	1.0	<0.0002	<2	0.010	0.005
Guaje Field (7 wells)	0.011	0.014	0.059	0.005	0.007	0.5	<0.0002	<2	0.005	0.005
Pajarito Field (3 wells)	<0.010	0.001	0.097	0.004	0.005	0.4	<0.0002	<2	0.004	0.005
Water Canyon (gallery)	<0.010	0.001	0.030	0.007	0.002	0.2	<0.0002	<2	0.005	0.005
Distribution (5 stations)	0.018	0.004	0.090	0.004	0.008	0.6	<0.0002	<2	0.007	0.005
No. of Analyses	21	21	21	21	21	21	19	21	21	21
Minimum	<0.010	<0.005	0.020	0.003	0.002	0.2	<0.2	<2	0.003	---
Maximum	0.074	0.078	0.150	0.008	0.032	2.2	<0.0002	---	0.020	<0.005
Average	0.017 ± 0.030	0.010 ± 0.037	0.080 ± 0.080	0.004 ± 0.003	0.009 ± 0.015	0.6 ± 0.8	<0.2	<2	0.006 ± 0.007	---
USEPA and NMEIA MPL	0.05	0.05	1.0	0.010	0.05	2.0	0.002	45	0.05	0.01
Los Alamos Well LA-6[a]	0.007	0.211	0.040	<0.003	0.019	1.8	<0.0002	<2	0.010	<0.005

TABLE E-XV (continued)

Chemical
(average concentrations in mg/ℓ)

Stations	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	TDS	Hard	pH	Cond mS/m
Los Alamos Field (5 wells)	27	7	<1	1.8	65	0	178	<2	12	6	318	19	8.7	30.6
Guaje Field (7 wells)	65	9	1	2.3	23	0	100	<2	4	2	229	29	8.6	17.0
Pajarito Field (3 wells)	75	12	6	3.0	17	4	124	<2	4	4	314	54	8.2	20.3
Water Canyon (gallery)	34	5	3	1.8	6	2	54	<2	2	<1	176	25	8.1	12.0
Distribution (5 stations)	55	9	3	2.5	24	2	141	<2	5	3	249	35	8.2	19.0
No. of Analyses	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Minimum	26	5	<1	1.3	6	0	49	<2	<1	166	14	8.0	8.0	10.0
Maximum	84	16	8	3.8	152	5	376	---	34	13	624	71	8.8	64.0
Average	54 ± 40	9 ± 7	2 ± 5	2.3 ± 1.5	32 ± 66	1 ± 3	130 ± 148	<2	6 ± 14	4 ± 7	265 ± 206	31 ± 34	8.4 ± 0.5	21.0 ± 12.0
Los Alamos Well LA-6[a]	29	3	<3	1.1	74	0	163	<2	4	2	324	7	9.1	30.0

Metal Ions
(average concentrations in μg/ℓ)

Station	Al	Be	Co	Cu	Fe	Mn	Mo	Ni	Zn
Los Alamos Field (5 wells)	<10	<2000	<5	<300	<300	<300	<10	8	<300
Guaje Field (7 wells)	<10	<2000	<5	<300	<300	<300	<10	7	<300
Pajarito Field (3 wells)	11	<2000	<5	<300	<300	<300	40	7	<300
Water Canyon (gallery)	35	<2000	<5	<300	<300	<300	<10	8	<300
Distribution (5 stations)	26	<2000	<5	<300	<300	<300	<10	11	<300
No. of Analyses	21	21	21	21	21	21	21	21	21
Minimum	<10	<2000	<5	<300	<300	<300	<10	6	<300
Maximum	83	---	---	---	---	--	---	12	---
Average	14 ± 34	<2000	<5	<300	<300	<300	<10	8 ± 4	<300
Los Alamos Well LA-6[a]	10	<2000	<5	<300	<300	<300	<10	8	<300

Note: ± value represents twice the standard deviation of the distribution of observed values unless only one analysis is reported. Then the value represents twice the error term for that analysis. One sample for chemical and metal ion analysis from each well and distribution station.

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

TABLE E-XVI

RADIOCHEMICAL AND CHEMICAL QUALTY OF WATER FROM ONSITE STATIONS

Station	No. of Analyses	Radiochemical (average of a number of analyses) ^{3}H $10^{-6}\mu$Ci/mℓ	^{137}Cs $10^{-9}\mu$Ci/mℓ	^{238}Pu $10^{-9}\mu$Ci/mℓ	^{239}Pu $10^{-9}\mu$Ci/mℓ	^{90}Sr $10^{-9}\mu$Ci/mℓ	Gross α $10^{-9}\mu$Ci/mℓ	Gross β $10^{-9}\mu$Ci/mℓ	Total U μg/ℓ
Noneffluent Areas									
Test Well 1	1	1.3 ± 0.3	−19 ± 16	−0.1 ± 0.02	0.00 ± 0.01	---	0.0 ± 1.6	5.2 ± 2.0	0.1 ± 0.2
Test Well 3	2	1.0 ± 0.1	30 ± 57	−0.1 ± 0.02	−0.1 ± 0.06	---	0.7 ± 0.7	1.8 ± 0.6	0.2 ± 0.2
Deep Test-5A	2	0.7 ± 0.3	32 ± 52	−0.2 ± 0.02	−0.01 ± 0.04	---	1.3 ± 3.0	3.0 ± 3.0	0.5 ± 0.2
Test Well 8	2	1.5 ± 0.6	25 ± 14	−0.02 ± 0.04	0.00 ± 0.03	---	0.9 ± 1.0	2.5 ± 0.1	0.1 ± 0.1
Deep Test-9	2	1.9 ± 1.8	15 ±14	−0.03 ± 0.06	0.00 ± 0.02	---	0.9 ± 0.0	3.6 ± 2.6	1.0 ± 0.7
Deep Test-10	1	0.5 ± 0.6	50 ± 40	−0.03 ± 0.02	0.00 ± 0.03	---	0.4 ± 1.2	4.5 ± 1.8	0.4 ± 0.2
Cañada del Buey	1	3.6 ± 0.8	50 ± 32	−0.04 ± 0.03	−0.05 ± 0.04	---	1.8 ± 1.6	6.4 ± 2.2	2.4 ± 0.4
Pajarito Canyon	1	4.2 ± 0.8	60 ± 100	−0.04 ± 0.04	0.00 ± 0.03	---	0.0 ± 2.2	17.0 ± 4.0	0.4 ± 0.2
Water Canyon	1	1.3 ± 0.6	−3 ± 32	−0.02 ± 0.03	−0.01 ± 0.03	---	0.4 ± 1.6	13.0 ± 3.2	1.5 ± 0.2
Test Well 2	2	0.6 ± 0.3	12 ± 20	−0.03 ± 0.02	−0.01 ± 0.01	---	0.1 ± 1.8	1.5 ± 0.9	0.2 ± 0.3
No. of Analyses		14	15	15	15	---	15	15	13
Minimum		4.2 ± 0.8	−19 ± 16	−0.05 ± 0.03	−0.05 ± 0.04	---	−0.6 ± 0.5	1.2 ± 1.6	<0.1 ± 0.2
Maximum		4.2 ± 0.8	70 ± 40	−0.00 ± 0.02	0.01 ± 0.03	---	2.3 ± 0.9	17.0 ± 4.0	2.4 ± 0.4
Average		4.2 ± 2.3	27 ± 50	−0.02 ± 0.02	−0.02 ± 0.04	---	0.7 ± 1.5	4.7 ± 9.0	0.6 ± 1.4
Effluent Release Area									
Acid Pueblo Canyon (former release area)									
Acid Weir	2	1.3 ± 0.4	15 ± 71	0.02 ± 0.06	2.11 ± 5.96	77 ± 6.0	3.2 ± 5.1	118 ± 290	0.4 ± 0.7
Pueblo 1	2	1.8 ± 0.8	1 ± 3	−0.00 ± 0.03	0.10 ± 0.26	3.70 ± 0.80	1.1 ± 1.8	56 ± 102	0.9 ± 1.4
Pueblo 2	2	1.1 ± 0.0	69 ± 117	−0.01 ± 0.06	0.04 ± 0.01	4.60 ± 0.80	2.5 ± 3.4	24 ± 1.4	0.2 ± 0.4
Pueblo 3	2	0.9 ± 0.4	20 ± 57	−0.03 ± 0.04	0.03 ± 0.06	1.70 ± 1.00	12 ± 31	55 ± 112	2.1 ± 5.8
Hamilton Bend Spr	1	1.6 ± 0.6	40 ± 60	−0.03 ± 0.02	−0.01 ± 0.02	−0.70 ± 0.80	15 ± 6.0	25 ± 6.0	50 ± 10
Test Well 1A	1	0.9 ± 0.6	30 ± 40	−0.08 ± 0.03	−0.03 ± 0.02	−0.30 ± 0.80	0.1 ± 1.8	7.1 ± 2.4	0.9 ± 0.2
Test Well 2A	2	18.9 ± 4.4	−10 ± 14	−0.02 ± 0.02	0.00 ± 0.00	0.30 ± 1.00	0.7 ± 1.4	3.3 ± 0.0	0.1 ± 0.3
No. of Analyses		12	12	12	12	7	12	12	12
Minimum		0.8 ± 0.6	−20 ± 60	−0.08 ±0.03	−0.02 ± 0.02	−0.07 ± 0.80	0.1 ± 0.9	3.3 ± 1.6	<0.1 ± 0.2
Maximum		21.5 ± 1.1	110 ± 80	0.04 ± 0.04	4.22 ± 0.32	77 ± 6.0	15 ± 6.0	220 ± 40	50 ± 10
Average		4.2 ± 13.9	22 ± 70	−0.01 ± 0.06	0.38 ± 2.42	12 ± 57	45 ± 14	45 ± 126	4.9 ± 29
DP-Los Alamos Canyon									
DPS-1	2	81.2 ± 34.5	35 ± 42	6.81 ± 18	3.26 ± 6.29	197 ± 12	1885 ± 3450	835 ± 1090	698 ± 1300
DPS-4	2	21.4 ± 16.7	1 ± 115	0.14 ± 0.19	0.42 ± 0.86	185 ± 14	11 ± 27	675 ± 71	4.3 ± 4.0
LAO-C	2	1.0 ± 1.8	10 ± 57	−0.01 ± 0.04	0.02 ± 0.07	1.0 ± 0.6	5.3 ± 7.8	9.3 ± 6.4	3.5 ± 7.5
LAO-1	2	21.3 ± 10.5	4 ± 44	−0.01 ± 0.01	0.08 ± 0.20	73 ± 6.0	3.0 ± 5.8	184 ± 74	0.4 ± 0.8
LAO-2	2	14.8 ± 26.9	21 ± 25	0.00 ± 0.07	0.17 ± 0.42	111 ± 8.0	3.5 ± 4.1	222 ± 249	1.5 ± 1.4
LAO-3	2	12.9 ± 26.2	13 ± 14	0.01 ± 0.07	0.15 ± 0.40	22 ± 2.2	6.6 ± 9.8	84 ± 35	4.2 ± 4.2
LAO-4	2	10.3 ± 1.7	40 ± 57	−0.01 ± 0.03	0.26 ± 0.72	2.0 ± 0.4	5.5 ± 3.5	18 ± 11	0.4 ± 0.8
LAO-4.5	1	10.8 ± 0.8	40 ± 40	−0.01 ± 0.03	0.00 ± 0.02	3.0 ± 1.2	2.2 ± 2.0	8.9 ± 2.6	2.9 ± 0.6
No. of Analyses		15	15	15	15	15.	15	15	15
Minimum		0.4 ± 0.6	−40 ± 40	−0.02 ± 0.02	0.01 ± 0.02	1.0 ± 0.6	1.0 ± 6.0	8.9 ± 2.6	<0.1 ± 0.2
Maximum		93.4 ± 3.2	60 ± 100	13.1 ± 0.60	5.49 ± 0.34	197 ± 6.0	3100 ± 1200	1220 ± 240	1160 ± 232
Average		22.4 ± 51.5	19 ± 51	0.92 ± 6.74	0.58 ± 2.79	74 ± 164	256 ± 1600	271 ± 690	95.1 ± 600
Sandia Canyon			−35 ± 156	−0.02 ± 0.03	−0.01 ± 0.00	0.30 ± 0.40	2.2 ± 7.9	23 ± 7	3.1 ± 46
SCS-1	2	8.1 ± 0.8	15 ± 41	0.00 ± 0.04	−0.01 ± 0.01	0.60 ± 1.2	0.9 ± 5.9	22 ± 6	2.2 ± 0.9
SCS-2	2	7.3 ± 1.7	6 ± 7	−0.01 ± 0.03	0.00 ± 0.00	0.90 ± 1.2	2.5 ± 1.4	24 ± 0	5.3 ± 7.3
SCS-3	2	6.9 ± 2.7							
No. of Analyses		6	6	6	6	3	6	6	6
Minimum		6.0 ± 0.8	−90 ± 100	−0.03 ± 0.02	−0.01 ± 0.02	0.30 ± 0.40	−1.2 3.4	20 ± 4	1.4 ± 0.2
Maximum		8.4 ± 0.8	29 ± 16	0.02 ± 0.02	0.01 ± 0.02	0.90 ± 1.2	5.0 ± 6.0	25 ± 6	7.9 ± 1.6
Average		7.4 ± 1.8	−5 ± 86	0.00 ± 0.02	−0.01 ± 0.01	0.60 ± 0.60	1.9 ± 4.7	23 ± 4	3.5 ± 4.9
Mortandad Canyon									
GS-1	2	8.8 ± 3.0	845 ± 325	4.94 ± 5.18	2.24 ± 4.84	137 ± 12	48 ± 113	1155 ± 212	0.8 ± 0.3
MCS-3:9	1	22.0 ± 1.2	319 ± 38	8.60 ± 0.40	2.37 ± 0.20	---	14 ± 8.0	600 ± 120	1.6 ± 0.4
MCO-3	2	95.4 ± 33.5	35 ± 41	5.37 ± 2.07	0.59 ± 0.54	36 ± 3.0	20 ± 7.0	304 ± 413	4.3 ± 2.0
MCO-4	2	303 ± 114	75 ± 42	19.10 ± 18.10	3.76 ± 3.89	80 ± 6.0	325 ± 665	790 ± 1200	10.4 ± 4.7
MCO-5	2	239 ± 164	−50 ± 15	0.78 ± 1.10	0.19 ± 0.38	2.6 ± 1.0	14 ± 17	66 ± 21	13.6 ± 12.2
MCO-6	2	303 ± 455	21 ± 18	2.16 ± 2.81	0.28 ± 0.63	2.8 ± 1.2	17 ± 29	58 ± 27	32 ± 90
MCO-7	2	105 ± 28	15 ± 14	0.06 ± 0.07	0.02 ± 0.06	0.2 ± 1.4	12 ± 24	18 ± 18	8.2 ± 18
MCO-7.5	1	388 ± 12	−40 ± 140	0.29 ± 0.08	0.06 ± 0.04	1.6 ± 0.8	22 ± 14	42 ± 10	143 ± 14
No. of Analyses		14	14	14	14	7	14	14	14
Minimum		7.8 ± 0.8	−60 ± 80	0.03 ± 0.02	0.00 ± 0.02	0.2 ± 1.4	2.9 ± 2.8	11 ± 3.0	0.7 ± 0.2
Maximum		464 ± 14	960 ± 80	8.60 ± 0.40	5.13 ± 0.34	137 ± 12	560 ± 240	1230 ± 240	143 ± 14
Average		180 ± 295	154 ± 619	5.26 ± 13.8	1.19 ± 3.28	37 ± 106	65 ± 290	387 ± 929	20 ± 78

TABLE E-XVI (continued)

Station	No. Analyses	SiO_2	Ca	Mg	K	Na	CO_3	HCO_3	PO_4	SO_4	Cl	F	NO_3	TDS	Hard	pH	mS/m
		Chemical (concentrations in mg/ℓ)															
Noneffluent Areas																	
Test Well 1	1	44	32	2	5.0	21	14	115	<2	2	6	0.8	<2	290	88	8.3	27.0
Test Well 3	1	70	9	6	2.3	12	2	107	<2	2	3	0.5	<2	268	45	8.1	18.0
Deep Test-5A	1	60	4	2	1.8	11	3	73	<2	<2	1	0.3	<2	200	20	8.1	11.0
Test Well 8	1	46	6	4	1.8	11	0	88	<2	<2	1	0.3	<2	221	32	8.5	13.0
Deep Test-9	1	56	5	3	1.2	11	5	66	<2	<2	1	0.4	<2	160	24	8.2	12.0
Deep Test-10	1	50	6	4	1.6	11	0	110	<2	<2	1	1.2	<2	206	30	8.3	12.0
Cañada del Buey	1	48	3	2	3.1	20	4	56	<2	13	7	4.2	<2	228	31	7.5	15.0
Pajarito Canyon	1	39	25	11	6.6	27	4	61	<2	18	95	0.3	<2	440	111	7.4	41.0
Water Canyon	1	19	17	6	5.2	21	0	122	<2	12	5	0.3	<2	322	69	8.3	23.0
Test Well 2	2	47	9	3	1.2	9	4	105	<2	6	6	0.4	<2	163	67	7.9	16.5
No. of Analyses		11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Minimum		19	3	2	1.2	9	0	56	<2	<2	1	0.3	<2	160	20	7.4	11.0
Maximum		70	32	11	6.6	27	14	122	---	18	95	4.2	8	440	111	8.5	41.0
Average		48 ± 26	12 ± 20	4 ± 6	3.0 ± 3.8	15 ± 12	4 ± 8	90 ± 50	<2	<6 ± 12	13 ± 58	0.9 ± 2.4	<4 ± 6	250 ± 170	52 ± 62	8.1 ± 0.8	19.0 ± 18.0
Effluent Areas																	
Acid-Pueblo Canyon (former release area)																	
Acid-Weir	2	27	117	3	7.9	63	5	116	4	16	60	0.3	13	393	110	7.3	43.0
Pueblo 1	2	60	8	3	14	75	7	79	30	34	43	0.6	40	463	85	8.4	48.5
Pueblo 2	2	49	9	3	13	73	12	95	24	33	30	0.6	36	472	65	8.0	45.0
Pueblo 3	2	47	10	3	14	81	3	157	24	14	3	0.8	20	471	64	8.0	48.0
Hamilton Bend Spr	1	50	7	4	9.3	74	5	120	22	29	40	0.9	26	464	356	8.1	44.0
Test Well 1A	1	44	10	5	7.9	69	7	137	17	27	33	0.9	26	482	98	7.8	44.0
Test Well 2A	2	4	14	3	2.4	18	3	62	<2	22	19	0.3	<2	184	89	8.7	20.5
No. of Analyses		12	12	12	7	12	12	12	12	12	12	12	12	12	12	12	12
Minimum		4	7	2	2.4	18	2	56	<2	<2	<1	0.2	<2	162	34	7.3	19.0
Maximum		66	223	5	14	82	12	190	32	37	102	0.9	46	558	356	8.8	54.0
Average		42 ± 35	28 ± 123	3 ± 2	9.9 ± 8.7	63 ± 46	6 ± 7	106 ± 75	17 ± 24	24 ± 21	32 ± 56	0.6 ± 0.5	23 ± 33	409 ± 252	107 ± 182	8.1 ± 1.0	41.5 ± 22.9
DP-Los Alamos Canyon																	
DPS-1	2	22	11	2	60	407	1	514	237	42	58	21	11	1739	4048	9.6	195.0
DPS-4	1	17	18	3	31	131	2	205	2	24	64	2.8	<2	694	1148	8.3	76.0
LAO-C	2	32	14	5	4.4	51	2	79	<2	9	51	0.2	<2	329	146	8.2	39.0
LAO-1	2	40	16	5	7.2	83	6	146	<2	18	45	0.6	5	454	90	8.1	51.0
LAO-2	2	32	9	2	34	90	3	134	<2	19	40	3.2	3	507	154	7.8	54.0
LAO-3	2	23	9	3	29	78	2	177	<2	18	24	2.6	39	452	190	7.8	48.0
LAO-4	1	36	16	6	---	51	7	124	<2	18	25	1.4	31	320	76	7.6	38.0
LAO-4.5	1	32	9	5	4.3	40	2	73	<2	18	28	0.4	4	280	336	8.1	30.0
No. of Analyses		13	13	13	7	13	13	13	13	13	13	13	13	13	13	13	13
Minimum		17	4	1	4.4	40	0	73	<2	7	12	0.1	<2	258	20	7.1	30.0
Maximum		44	18	6	60	429	7	600	474	49	104	25	68	1908	8057	10.3	200.0
Average		29 ± 18	13 ± 8	4 ± 3	24 ± 41	126 ± 256	3 ± 5	192 ± 305	<39 ± 260	21 ± 22	43 ± 58	4.5 ± 15	<12 ± 38	635 ± 1030	834 ± 4380	8.2 ± 1.7	706 ± 1040
Sandia Canyon																	
SCS-1	2	107	13	5	18	94	2	189	12	50	44	1.3	28	676	136	8.7	59.0
SCS-2	2	96	18	6	17	149	2	241	11	119	62	1.5	10	832	236	8.6	85.0
SCS-3	2	89	17	5	15	134	1	213	12	114	57	1.5	8	761	107	8.6	76.0
No. of Analyses		6	6	6	3	6	6	6	6	6	6	6	6	6	6	6	6
Minimum		74	11	4	15	68	0	134	10	39	36	0.8	2	656	78	8.6	50.0
Maximum		134	22	6	18	150	5	275	13	138	62	1.9	33	916	29.2	8.9	86.0
Average		97 ± 44	16 ± 8	5 ± 2	16 ± 3.0	125 ± 121	2 ± 4	214 ± 95	12 ± 2	94 ± 75	54 ± 19	1.4 ± 0.9	16 ± 24	756 ± 179	160 ± 158	8.6 ± 0.1	73.0 ± 27.0
Mortandad Canyon																	
GS-1	2	60	9	2	3.5	181	0	165	<2	14	9	1.3	28	407	144	8.5	38.0
MCS-3.9	1	42	23	2	---	321	0	400	<2	82	23	1.8	276	1258	68	8.1	140.0
MCO-3	2	43	12	1	3.7	203	1	326	<2	41	18	2.0	112	836	1010	8.7	94.0
MCO-4	2	31	15	2	6.5	271	20	403	<2	61	29	2.6	12	1087	437	8.5	135.0
MCO-5	2	25	19	5	7.5	188	4	287	<2	61	34	0.9	68	851	140	8.0	90.0
MCO-6	6	23	20	6	9.8	264	0	393	<2	76	39	1.6	95	1109	240	8.4	120.0
MCO-7	2	31	11	4	4.6	87	6	15	4	17	12	0.3	32	462	155	8.0	48.5
MCO-7.5	1	25	25	8	8.7	229	9	390	<2	83	29	0.6	<2	1340	333	8.7	54.0
No. of Analyses		14	14	14	7	14	14	14	14	14	14	14	14	14	14	14	14
Minimum		21	4	2	3.5	49	0	107	<2	10	5	0.3	<2	390	34	7.2	34.0
Maximum		62	25	8	9.8	321	9	468	8	84	44	2.7	276	1340	1961	8.8	140.0
Average		35 ± 27	16 ± 13	4 ± 4	6.3 ± 5.0	209 ± 179	6 ± 3	303 ± 238	<2	50 ± 54	24 ± 23	1.5 ± 1.5	<70 ± 192	864 ± 697	332 ± 1032	8.4 ± 0.9	89.0 ± 80.4

TABLE E-XVI (continued)

Station	Ag	Al	As	Ba	Br	Cd	Co	Cr	Cu	Fe	Hg	Mn	Mo	Ni	Pb	Se	Zn
	Metal Ions (concentrations in $\mu g/\ell$, one analysis)																
DP-Los Alamos Canyon																	
DPS-1	<10	1440	7	160	<2000	6	<5	16	<300	1600	<0.2	<300	56	19	6	<5	<300
DPS-4	<10	196	7	160	<2000	5	<5	<3	<300	<300	<0.2	<300	17	12	6	5	<300
LAO-C	<10	32	<5	110	<2000	4	<5	<3	<300	<300	<0.2	<300	<10	10	6	5	<300
LAO-1	<10	<10	<5	110	<2000	7	<5	113	<300	<300	<0.2	<300	24	13	6	5	<300
LAO-2	11	43	<5	140	<2000	5	<5	<3	<300	<300	<0.2	<300	<10	16	6	<5	<300
LAO-3	<10	55	<5	130	<2000	4	<5	5	<300	<300	<0.2	<300	<10	11	6	5	<300
LAO-4.5	12	53	<5	40	<2000	7	<5	<3	<300	<300	---	<300	<10	9	4	<5	<300
No. of Analyses	7	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7	7
Minimum	2	9	<5	40	<2000	4	<5	1	<300	<300	<0.2	<300	<10	9	4	<5	<300
Maximum	12	1440	7	160	---	7	---	113	---	1600	---	---	56	19	6	5	---
Average	<10 ± 2	261 ± 1047	3 ± 6	121 ± 83	<2000	5 ± 3	<5	21 ± 82	<300	<486 ± 983	<0.2	<300	<20 ± 34	13 ± 7	6 ± 2	<5	<300
Sandia Canyon																	
SCS-1	14	25	5	30	<2000	17	<5	5380	<300	800	<0.2	<300	<10	34	6	<5	<300
SCS-2	21	41	9	30	<2000	13	<5	34	<300	700	<0.2	<300	<10	27	4	<5	<300
SCS-3	74	10	6	20	<2000	11	<5	21	<300	400	<0.2	<300	11	25	3	5	<300
No. of Analyses	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Minimum	14	10	5	20	<2000	11	<5	21	<300	400	<0.2	<300	10	25	3	<5	<300
Maximum	74	41	9	30	---	17	---	5380	---	800	---	---	11	34	6	---	---
Average	36 ± 66	25 ± 31	7 ± 4	27 ± 12	<2000	14 ± 6	<5	1812 ± 6181	<300	633 ± 416	<0.2	<300	<10 ± 1	29 ± 9	4 ± 3	<5	<300
Mortandad Canyon																	
GS-1	10	39	<5	<20	<2000	9	<5	6	<300	800	0.6	<300	<10	13	3	<5	<300
MCO-3	14	350	<5	<20	9700	6	<5	4	<300	500	0.2	<300	30	18	6	<5	<300
MCO-4	14	140	<5	20	180 000	9	<5	13	<300	400	0.3	<300	73	26	6	<5	<300
MCO-5	20	25	<5	120	173 000	6	<5	11	<300	<300	0.2	<300	96	8	6	<5	<300
MCO-6	12	59	<5	100	234 000	9	<5	21	<300	<300	<0.2	<300	196	9	6	<5	<300
MCO-7	<10	40	<5	70	21 000	14	<5	8	<300	<300	<0.2	<300	16	14	7	<5	<300
MCO-7.5	17	43	<5	220	173 000	8	<5	41	<300	<300	<0.2	<300	51	18	7	<5	<300
No. of Analyses	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Minimum	<10	25	<5	<20	<2000	6	<5	4	<300	<300	<0.2	<300	<10	8	3	<5	<300
Maximum	20	350	---	220	234 000	14	---	41	---	800	0.6	---	196	26	7	---	---
Average	14 ± 7	99 ± 234	<5	81 ± 147	113 000 ± 196 000	9 ± 5	<5	15 ± 26	<300	<414 ± 373	0.3 ± 0.3	<300	67 ± 129	15 ± 12	6 ± 3	<5	<300
Nonaffluent Areas												500	<10	12	4	<5	<300
Test Well 1	10	<10	<5	720	<2000	4	<5	<3	<300	<300	---	<300	<10	9	4	<5	<300
Test Well 3	<10	12	<5	90	<2000	6	<5	3	<300	<300	---	<300	<10	8	8	<5	400
DT-54	<10	11	<5	70	<2000	6	<5	3	<300	<300	<0.2	<300	<10	8	9	<5	400
Test Well 8	<10	<10	<5	40	<2000	4	<5	<3	<300	<300	---	<300	<10	8	5	<5	<300
DT-9	<10	11	<5	70	<2000	4	<5	3	<300	<300	---	<300	<10	9	5	<5	<300
DT-10	<10	10	<5	20	<2000	8	<5	<3	<300	<300	---	<300	<10	14	<3	<5	<300
Cañada del Buey	29	1700	<5	130	<2000	5	<5	4	<300	2400	---	1110	<10	9	5	<5	<300
Pajarito Canyon	<10	10	<5	1890	<2000	7	<5	<3	<300	900	<0.2	<300	<10	8	4	<5	<300
Water Canyon	<10	20	<5	8150	<2000	3	<5	<3	<300	<300	---	<300	<10	9	7	<5	<300
Test Well 2	<10	11	10	50	<2000	6	<5	5	<300	<300	---						
No. of Analyses	10	10	10	10	10	10	10	10	10	10	2.	10	10	10	10	10	10
Minimum	<10	<10	<5	20	<2000	3	<5	<3	<300	<300	<0.2	6300	<10	8	<3	<5	<300
Maximum	29	1700	10	8150	---	8	---	5	---	2400	---	1100	---	14	9	---	400
Average	<12 ± 12	<180 ± 1040	<5 ± 4	1120 ± 5070	<2000	5 ± 4	<5	<3 ± 2	<300	<570 ± 1340	<0.2	<370 ± 570	<10	9 ± 4	5 ± 4	<5	<320 ± 84
Effluent Areas																	
Acid-Pueblo Canyon (former release area)																	
Acid Weir	<10	18	<5	110	17 500	240	2	<3	<300	<300	<0.2	<300	<10	7	5	<5	<300
Pueblo 1	<10	18	11	60	<2000	4	<1	4	<300	<300	<0.2	<300	<10	10	4	<5	<300
Pueblo 2	<10	10	10	60	<2000	9	1	3	<300	<300	<0.2	<300	<10	10	3	<5	<300
Pueblo 3	<10	10	8	30	<2000	7	<1	4	<300	<300	<0.2	<300	<10	9	5	<5	<300
Hamilton Bend Spr	<10	56	7	250	<2000	12	1	<3	<300	<300	---	<300	<10	5	3	<5	<300
Test Well 1A	<10	11	10	120	<2000	90	<5	<3	<300	<300	<0.2	<300	<10	11	7	<5	<300
Test Well2A	<10	16	<5	200	<2000	11	<5	<3	<300	<300	---	<300	<10	10	6	<5	<300
No. of Analyses	7	7	7	7	7	7	7	7	7	7	5	7	7	7	7	7	7
Minimum	<10	10	<5	30	<2000	4	<1	<3	<300	<300	<0.2	<300	<10	5	3	<5	<300
Maximum	---	56	11	250	---	240	<5	4	---	---	---	---	---	11	7	---	---
Average	<10	20 ± 32	8 ± 4	119 ± 160	<2000	53 ± 175	2 ± 4	<3 ± 1	<300	<300	<0.2	<300	<10	9 ± 4	5 ± 4	<5	<300

TABLE E-XVII

LOCATION OF SOIL AND SEDIMENT STATIONS

Station	Latitude or N-S Coordinate	Longtiude or E-W Coordinate	Map Designation (Figure 10)[a]
Regional Soils[b]			
Regional Sediments			
Rio Chama			
Chamita	36°05'	106°07	---
Rio Grande			
Embudo	36°12'	105°58'	---
Otowi	N085	E550	A
Sandia	S060	E490	B
Pajarito	S185	E410	C
Ancho	S305	E335	D
Frijoles	S375	E235	E
Cochiti	35°37'	106°19'	---
Bernalillo	35°17'	106°36'	---
Jemez River	35°40'	106°44'	---
Perimeter Soils			
Sportsman's Club	N240	E215	S1
TA-8	N060	W075	S2
TA-49	S165	E085	S3
Frijoles	S245	E180	S4
North Mesa	N135	E165	S5
East of Airport	N095	E220	S6
West of Airport	N115	E135	S7
South SR-4 near S-Site	S085	W035	S8
Perimeter Sediments			
Guaje near G-4	N215	E325	1
Guaje at SR-4	N135	E480	2
Bayo at SR-4	N100	E455	3
Pueblo at Acid Weir	N125	E070	4
Pueblo at PC-1	N130	E070	5
Pueblo at Pueblo 1	N130	E085	6
Pueblo at Pueblo 2	N120	E145	7
Los Alamos at Reservoir	N100	W065	8
Los Alamos at Totatvi	N065	E405	9
Los Alamos at LA-2	N125	E510	10
Los Alamos at Rio Grande	N095	E555	11
Sandia at Rio Grande	S055	E490	12
Cañada del Ancha	S060	E505	13
Mortandad at SR-4	S030	E350	14
Mortandad at Rio Grande	S075	E480	15
Cañada del Buey at SR-4	S090	E360	16
Pajarito at Rio Grande	S175	E410	17
Frijoles at Park Hdq	S280	E185	18
Frijoles at Rio Grande	S365	E235	19

TABLE E-XVII (continued)

LOCATION OF SOIL AND SEDIMENT STATIONS

Station	Latitude or N-S Coordinate	Longtiude or E-W Coordinate	Map Designation (Figure 10)[a]
Onsite Soils			
TA-21	N095	E140	S9
TA-50	N035	E095	S10
TA-36	S090	E150	S11
PM-1	N020	E310	S12
West of TA-53	N070	E105	S13
East of TA-53	N050	E220	S14
East of New Sigma	N060	E065	S15
Sigma Mesa	N050	E135	S16
East of TA-52	N020	E145	S17
2-Mile Mesa	N025	E030	S18
Near TA-51	S030	E200	S19
East of TA-54	S080	E295	S20
R-Site Road	S015	E030	S21
R-Site Road East	S040	E100	S22
Potrillo Drive	S065	E195	S23
S-Site	S035	W025	S24
Near TA-11	S070	E020	S25
Near DT-9	S150	E140	S26
TA-33	S245	E225	S27
Onsite Sediments			
Pueblo at Hamilton Bend Spr	N105	E255	20
Pueblo at Pueblo 3	N090	E315	21
Pueblo at SR-4	N070	E350	22
DP Canyon at DPS-1	N090	E160	23
DP Canyon at DPS-4	N075	E205	24
Los Alamos Canyon at Bridge	N095	E020	25
Los Alamos at LAO-1	N080	E120	26
Los Alamos at GS-1	N075	E200	27
Los Alamos at TW-3	N075	E215	28
Los Alamos at LAO-4	N075	E240	29
Los Alamos at SR-4	N065	E355	30
Sandia at SCS-2	N050	E175	31
Sandia at SR-4	N025	E315	32
Mortandad near CMR	N060	E035	33
Mortandad West of GS-1	N045	E095	34
Mortandad near MCO-2	N035	E090	35
Mortandad at GS-1	N040	E105	36
Mortandad at MCO-5	N035	E155	37
Mortandad at MCO-7	N025	E190	38
Mortandad at MCO-9	N030	E215	39
Mortandad at MCO-13	N015	E250	40
Pajarito at TA-18	S055	E195	41
Pajarito at SR-4	S105	E320	42

TABLE E-XVII (continued)

LOCATION OF SOIL AND SEDIMENT STATIONS

Station	Latitude or N-S Coordinate	Longtiude or E-W Coordinate	Map Designation (Figure 10)[a]
Potrillo at TA-36	S075	E150	43
Potrillo East of TA-36	S085	E225	44
Potrillo at SR-4	S145	E295	45
Water at Beta Hole	S090	E095	46
Water at SR-4	S170	E260	47
Water at Rio Grande	S240	E385	48
Ancho at SR-4	S255	E250	49
Ancho at Rio Grande	S295	E340	50
Chaquihui at Rio Grande	S335	E265	51

[a]See Fig. 10 for numbered locations.
[b]Locations are the same as for surface water stations (Table E-XII).

TABLE E-XVIII

RADIOCHEMICAL ANALYSES OF REGIONAL SOILS AND SEDIMENTS

	^{3}H $10^{-6}\mu Ci/m\ell$	^{137}Cs pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Gross α pCi/g	Gross β pCi/g
Regional Soils						
Chamita	5.8 ± 0.8	0.68 ± 0.12	0.000 ± 0.002	0.013 ± 0.004	3.4 ± 1.6	4.9 ± 1.4
Embudo[a]	144 ±42.7	1.17 ±0.40	0.001 ± 0.010	0.061 ± 0.129	3.9 ± 1.8	5.8 ± 1.4
Otowi[a,b]	4.9 ± 3.4	1.35 ± 1.07	0.001 ± 0.003	0.102 ± 0.137	4.8 ± 2.2	7.6 ± 1.8
Cochiti	4.9 ± 0.8	0.62 ± 0.16	0.000 ± 0.003	0.004 ± 0.004	3.6 ± 1.8	5.4 ± 1.4
Bernalillo	4.7 ± 0.8	0.15 ± 0.10	−0.001 ± 0.002	0.000 ± 0.003	3.1 ± 1.6	3.4 ± 1.0
Jemez	13.6 ± 1.0	0.06 ± 0.28	−0.002 ± 0.002	0.001 ± 0.002	4.4 ± 2.2	5.7 ± 1.4
No. of Analyses	7	7	7	7	6	6
Minimum	4.8 ± 0.8	0.06 ± 0.28	−0.001 ± 0.02	0.000 ± 0.003	3.1 ± 1.6	3.4.± 1.0
Maximum	29.5 ± 1.4	1.73 ± 0.32	0.005 ± 0.016	0.150 ± 0.040	4.8 ± 2.2	7.6.± 1.8
Average	8.1 ± 9.3	0.67 ± 1.04	0.000 ± 0.002	0.03 ± 0.084	3.9 ± 1.3	5.5.± 2.7
Regional Sediments						
Rio Chama						
Chamita	---	0.00 ± 0.06	0.000 ± 0.002	−0.002 ± 0.004	2.4 ± 1.2	2.8 ± 1.0
Rio Grande						
Embudo[a]	---	0.26 ± 0.16	−0.002 ± 0.002	−0.006 ± 0.004	1.9 ± 1.0	1.7 ±0.8
Otowi	---	0.08 ± 0.03	0.000 ± 0.001	0.000 ± 0.003	1.4 ± 0.8	0.9 ± 0.6
Sandia	---	0.13 ± 0.06	−0.005 ± 0.016	−0.013 ± 0.016	11 ± 2	8.5 ± 1.2
Pajarito	---	0.07 ± 0.06	−0.005 ± 0.016	0.009 ± 0.014	10 ± 2	8.6 ± 1.3
Ancho	---	0.13 ± 0.06	−0.006 ± 0.026	0.003 ± 0.020	16 ± 3	14 ± 1.7
Frijoles	---	0.15 ± 0.06	0.012 ± 0.020	−0.003 ± 0.020	7.3 ± 1.7	6.0 ± 1.0
Cochiti	---	0.03 ± 0.10	−0.001 ± 0.003	0.001 ± 0.004	1.5 ± 0.8	1.5 ± 0.8
Bernalillo	---	0.24 ± 0.06	−0.001 ± 0.003	−0.001 ± 0.003	2.4 ± 1.4	4.9 ±1.4
Jemez River						
Jemez Pueblo	---	0.26 ± 0.14	0.000 ± 0.003	0.002 ± 0.003	4.6 ± 1.2	4.6 ± 2.2
No. of Analyses	---	10	10	10	10	10
Minimum	---	0.00 ± 0.06	−0.001 ± 0.003	−0.001 ± 0.030	1.4 ± 0.8	0.9 ± 0.6
Maximum	---	0.26 ± 0.16	0.012 ± 0.020	0.009 ± 0.014	16 ± 3.0	14 ± 1.7
Average	---	0.14 ± 0.19	0.000 ± 0.00	−0.001 ± 0.012	5.8 ± 10	5.4 ± 8.2

[a]Two analyses for ^{137}Cs, ^{238}Pu, and ^{239}Pu.

[b]^{137}Cs and ^{239}Pu slightly above background.

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

TABLE XIX

RADIOCHEMICAL ANALYSES OF PERIMETER SOILS AND SEDIMENTS

	^{3}H 10^{-6} μCi/mℓ	^{137}Cs pCi/g	^{90}Sr pCi/g	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Gross α pCi/g	Gross β pCi/g
Soils								
Sportsmen's Club	3.0 ± 0.8	1.08 ± 0.18	0.87 ± 0.26	---	0.000 ± 0.006	0.021 ± 0.008	6.2 ± 2.8	7.9 ± 1.8
TA-8[b]	9.0 ± 0.8	1.56 ± 0.26	---	---	0.001 ± 0.006	0.041 ± 0.016	5.1 ± 2.4	8.9 ± 2.0
TA-49	5.9 ± 0.8	0.53 ± 0.10	---	---	−0.001 ± 0.004	0.008 ± 0.006	5.2 ± 2.4	6.2 ± 1.6
Frijoles	4.0 ± 0.8	1.37 ± 0.34	---	---	0.000 ± 0.002	0.029 ± 0.006	5.7 ± 2.4	7.1 ± 1.6
North Mesa	8.6 ± 0.8	0.51 ± 0.10	0.87 ± 0.26	---	−0.002 ± 0.003	0.015 ± 0.010	4.3 ± 2.0	6.1 ± 1.4
East of Airport	12.2 ± 1.0	0.59 ± 0.05	0.92 ± 0.26	---	0.000 ± 0.003	0.030 ± 0.001	5.1 ± 2.2	6.2 ± 1.6
West of Airport[a,b]	10.5 ± 3.1	1.44 ± 0.51	---	---	0.010 ± 0.026	0.284 ± 0.498	4.5 ± 2.0	7.9 ± 1.8
South SR-4 & Near S-site[b]	3.4 ± 0.8	1.32 ± 0.20	0.85 ± 0.26	---	0.002 ± 0.004	0.018 ± 0.008	5.1 ± 2.2	6.9 ± 1.6
No. of Analyses	8	9	4		9	9	8	8
Minimum	3.0 ± 0.8	0.51 ± 0.10	0.85 ± 0.26		−0.002 ± 0.003	0.008 ± 0.006	4.3 ± 2.0	6.1 ± 1.6
Maximum	12.2 ± 1.0	1.6 ± 0.24	0.92 ± 0.26		0.019 ± 0.020	0.460 ± 0.080	6.2 ± 2.8	8.9 ± 2.0
Average	7.1 ± 7.0	1.5 ± 0.88	0.88 ± 0.06	---	0.001 ± 0.007	0.056 ± 0.19	5.1 ± 1.2	7.2 ± 2.0
Sediments								
Guaje near G-4	---	0.09 ± 0.12	---	0.002 ± 0.014	0.000 ± 0.002	0.003 ± 0.003	2.3 ± 0.8	1.4 ± 0.8
Guaje at SR-4	---	0.22 ± 0.08	0.17 ± 0.12	0.002 ± 0.014	0.001 ± 0.002	0.000 ± 0.002	2.2 ± 1.2	2.5 ± 0.8
Bayo at SR-4	---	0.10 ± 0.04	0.10 ± 0.11	0.002 ± 0.012	0.001 ± 0.002	0.006 ± 0.002	3.0 ± 1.4	2.3 ± 0.8
Pueblo at Acid Weir[a,b]	---	0.68 ± 0.06	---	0.351 ± 0.024	0.034 ± 0.018	5.62 ± 2.39	7.5 ± 3.2	4.5 ± 1.2
Pueblo at PC-1[a]	---	0.19 ± 0.10	---	0.001 ± 0.012	0.001 ± 0.001	0.026 ± 0.068	1.2 ± 0.8	1.0 ± 0.6
Pueblo at Pueblo 1[a,b]	---	0.50 ± 0.30	---	---	0.022 ± 0.011	3.72 ± 1.30	4.1 ± 2.0	2.1 ± 0.8
Pueblo at Pueblo 2[a,b]	---	0.18 ± 0.03	---	0.590 ± 0.016	0.007 ± 0.009	1.07 ± 1.93	3.1 ± 1.4	2.9 ± 1.0
Los Alamos at Reservoir	---	0.80 ± 0.18	---	0.003 ± 0.012	−0.001 ± 0.002	0.011 ± 0.006	10.0 ± 4.0	13.3 ± 3.0
Los Alamos at Totavi[a,b]	---	0.35 ± 0.34	---	---	0.002 ± 0.005	0.053 ± 0.041	2.9 ± 1.4	2.7 ± 1.0
Los Alamos at LA-2[a,b]	---	0.52 ± 0.82	---	---	0.001 ± 0.002	0.068 ± 0.076	2.6 ± 1.2	3.3 ± 1.0
Los Alamos at Rio Grande[a,b]	---	0.36 ± 0.50	0.30 ± 0.11	0.005 ± 0.012	−0.000 ± 0.001	0.062 ± 0.02	2.5 ± 1.2	3.3 ± 1.0
Sandia at Rio Grande	---	0.12 ± 0.04	---	---	0.002 ± 0.020	0.012 ± 0.008	7.4 ± 1.7	7.4 ± 1.1
Cañada del Ancha	---	0.09 ± 0.06	---	---	0.003 ± 0.022	0.007 ± 0.028	6.6 ± 1.6	5.6 ± 1.0
Mortandad at SR-4	---	0.10 ± 0.04	0.90 ± 0.40	0.001 ± 0.012	0.000 ± 0.002	0.001 ± 0.004	5.0 ± 2.2	4.4 ± 1.2
Mortandad at Rio Grande	---	0.11 ± 0.06	---	---	0.000 ± 0.006	0.002 ± 0.008	2.7 ± 0.8	2.9 ± 0.8
Cañada del Buey at SR-4	---	0.06 ± 0.24	0.41 ± 0.38	---	−0.002 ± 0.002	0.003 ± 0.004	4.7 ± 2.2	4.3 ± 1.2
Pajarito at Rio Grande	---	0.17 ± 0.06	---	---	−0.003 ± 0.010	0.007 ± 0.008	3.4 ± 0.9	6.0 ± 1.0
Frijoles at Park Hdq	---	0.35 ± 0.12	−0.15 ± 0.22	0.006 ± 0.012	−0.002 ± 0.003	0.003 ± 0.004	2.5 ± 1.2	1.8 ± 0.8
Frijoles at Rio Grande	---	0.33 ± 0.08	---	---	0.002 ± 0.018	0.020 ± 0.022	6.9 ± 1.6	6.1 ± 1.0
No. of Analyses		25	6	10	25	25	19	19
Minimum		0.09 ± 0.12	−0.15 ± 0.22	0.001 ± 0.012	−0.003 ± 0.010	0.000 ± 0.002	2.5 ± 1.2	2.7 ± 1.0
Maximum		0.81 ± 0.26	0.90 ± 0.40	0.590 ± 0.016	0.040 ± 0.006	6.46 ± 0.28	7.4 ± 1.7	7.4 ± 1.1
Average		0.28 ± 0.43	0.12 ± 0.71	0.096 ± 0.41	0.003 ± 0.018	0.56 ± 3.0	4.2 ± 4.7	4.1 ± 5.7

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

[a]Two analyses for ^{137}Cs, ^{238}Pu, and ^{239}Pu.

[b]^{137}Cs, ^{241}Am, ^{238}Pu, or ^{239}Pu slightly above background.

TABLE E-XX

RADIOCHEMICAL ANALYSES OF ONSITE SOILS AND SEDIMENTS
(pCi/g and one analysis except as noted)

Soils	^{3}H 10^{-6} µCi/ml	^{137}Cs pCi/g	^{90}Sr pCi/g	^{241}Am pCi/g	^{238}Pu pCi/g	^{239}Pu pCi/g	Gross α pCi/g	Gross β pCi/g
Soils								
TA-21[a]	15.6 ± 31.1	0.07 ± 0.00	---	---	−0.003 ± 0.008	0.022 ± 0.052	4.1 ± 1.8	5.0 ± 1.2
TA-50[a,b]	29.9 ± 69.3	0.49 ± 0.72	---	---	0.008 ± .025	0.085 ± 0.004	6.2 ± 1.4	9.4 ± 2.2
TA-36	22.3 ± 1.2	0.36 ± 0.10	---	---	−0.001 ± 0.004	0.006 ± 0.006	4.4 ± 2.0	5.3 ± 1.4
PM-1	29.7 ± 1.4	0.41 ± 0.12	---	---	−0.002 ± 0.003	0.011 ± 0.006	5.8 ± 2.6	7.5 ± 1.8
West of TA-53	17.6 ± 1.0	1.03 ± 0.20	---	---	−0.001 ± 0.004	0.02 ± 0.008	6.0 ± 2.6	8.0 ± 1.8
East of TA-53[a,b]	8.2 ± 14.6	1.29 ± 0.39	0.82 ± 0.26	---	0.013 ± 0.034	0.15 ± 0.385	4.5 ± 2.0	6.7 ± 1.6
East of New Sigma I	22.2 ± 1.2	0.60 ± 0.14	---	---	0.000 ± 0.003	0.008 ± 0.003	4.5 ± 2.0	5.8 ± 1.4
East of New Sigma II	17.7 ± 1.0	0.60 ± 0.14	0.42 ± 0.22	---	0.000 ± 0.006	0.012 ± 0.006	5.3 ± 2.4	7.5 ± 1.8
East of TA-52	17.7 ± 1.0	−0.11 ± 0.12	−0.05 ± 0.20	---	−0.002 ± 0.002	−0.001 ± 0.002	4.6 ± 2.2	5.7 ± 1.4
2-Mile Mesa	7.1 ± 0.8	0.90 ± 0.16	0.61 ± 0.34	---	−0.002 ± 0.010	0.023 ± 0.010	5.8 ± 2.6	7.9 ± 1.8
Near TA-51[a,b]	7.4 ± 13.3	0.87 ± 1.75	---	---	−0.004 ± 0.017	0.118 ± 0.262	5.8 ± 2.6	12.3 ± 2.6
East of TA-54[a,b]	157 ± 374	0.26 ± 0.35	---	---	0.448 ± 0.714	1.35 ± 3.32	5.5 ± 2.4	6.3 ± 1.6
R-Site Road	6.2 ± 0.8	0.73 ± 0.20	0.63 ± 0.22	---	−0.002 ± 0.003	0.013 ± 0.006	6.1 ± 2.6	7.5 ± 1.8
R-Site Road East[b]	10.5 ± 0.8	0.84 ± 0.18	0.83 ± 0.14	---	0.001 ± 0.003	0.020 ± 0.001	11 ± 4.0	22 ± 4.0
Potrillo Drive	6.8 ± 0.8	0.57 ± 0.12	---	---	−0.003 ± 0.002	0.010 ± 0.006	3.8 ± 1.8	14 ± 1.6
S-Site[a,b]	4.0 ± 4.2	1.46 ± 0.11	---	---	0.015 ± 0.044	0.086 ± 0.181	5.3 ± 2.4	8.5 ± 2.0
Near TA-11	5.3 ± 0.8	0.65 ± 0.28	---	---	−0.002 ± 0.002	0.008 ± 0.008	5.3 ± 2.4	6.6 ± 1.6
Near DT-9	3.8 ± 0.8	1.10 ± 0.22	0.27 ± 0.28	0.003 ± 0.012	−0.001 ± 0.002	−0.021 ± 0.006	7.1 ± 3.0	9.1 ± 2.0
TA-33	28.6 ± 1.4	0.51 ± 0.10	---	---	−0.002 ± 0.004	0.003 ± 0.006	6.5 ± 2.8	8.5 ± 2.0
No. of Analyses	19	24	7.	1	24	24	19	19
Minimum	3.8 ± 0.8	−0.11 ± 0.12	−0.05 ± 0.20	0.003 ± 0.012	−0.003 ± 0.008	−0.001 ± 0.002	3.8 ± 1.8	5.0 ± 1.2
Maximum	157 ± 374	1.60 ± 0.40	0.83 ± 0.14	---	0.700 ± 0.100	2.52 ± 0.220	11 ± 4.0	22 ± 4.0
Average	22 ± 68	0.65 ± 0.80	0.60 ± 0.63	0.003 ± 0.0	0.025 ± 0.21	0.10 ± 0.61	5.7 ± 3.1	8.6 ± 7.9
Sediments								
Pueblo at Hamilton Bend Spr[a,b]		0.12 ± 0.01	---	0.016 ± 0.014	0.001 ± 0.002	0.432 ± 0.133	2.5 ± 1.2	1.5 ± 0.8
Pueblo at Pueblo[a,b]		0.14 ± 0.17	---	0.015 ± 0.014	0.001 ± 0.001	0.440 ± 0.177	2.1 ± 1.0	1.1 ± 0.8
Pueblo at SR-4[a,b]		0.16 ± 0.11	1.05 ± 0.32	---	0.001 ± 0.001	0.521 ± 0.421	2.7 ± 1.4	3.1 ± 1.0
DP Canyon at DPS-1[a,b]		20 ± 1.8	8.7 ± 0.80	---	6.71 ± 17..8	1.72 ± 2.80	9.1 ± 3.8	30 ± 6.0
DP Canyon at DPS-4[a,b]		12 ± 7.8	2.4 ± 0.30	---	0.092 ± 0.064	0.304 ± 0.204	1.6 ± 0.8	12 ± 2.4
Los Alamos at Bridge		0.07 ± 7.8	2.4 ± 0.30	0.009 ± 0.014	−0.002 ± 0.004	−0.003 ± 0.003	3.1 ± 1.4	1.9 ± 0.8
Los Alamos at LAO-1[a,b]		1.15 ± 0.20	---	---	0.001 ± 0.004	0.490 ± 0.040	2.0 ± 1.2	3.0 ± 1.0
Los Alamos at GS-1[a,b]		0.22 ± 0.04	---	---	0.000 ± 0.002	0.237 ± 0.091	2.3 ± 1.2	2.5 ± 0.8
Los Alamos at TW-3[a,b]		14 ± 9.5	---	---	0.091 ± 0.066	0.323 ± 0.303	2.6 ± 1.2	16 ± 3.4
Los Alamos at LAO-4[a,b]		17 ± 9.2	---	0.008 ± 0.012	0.104 ± 0.018	0.35 ± 0.127	2.7 ± 1.2	17.± 3.6
Los Alamos at SR-4[b]		21 ± 2.8	0.71 ± 0.26	0.001 ± 0.012	0.010 ± 0.027	0.056 ± 0.065	2.4 ± 1.2	2.9 ± 1.0
Sandia at SCS-2		0.42 ± 0.32	---	0.006 ± 0.012	−0.001 ± 0.002	0.003 ± 0.004	1.6 ± 0.8	1.6 ± 0.8
Sandia at SR-4		0.05 ± 0.08	---	---	0.001 ± 0.002	0.001 ± 0.004	2.8 ± 1.4	1.7 ± 0.8
Mortandad near CMR[a]		0.23 ± 0.12	0.22 ± 0.14	---	0.101 ± 0.020	0.025 ± 0.012	2.0 ± 1.0	2.5 ± 0.8
Mortandad West of GS-1[a,b]		0.24 ± 0.40	0.08 ± 0.14	---	0.008 ± 0.014	0.023 ± 0.034	3.3 ± 1.4	3.7 ± 0.8
Mortandad near MCO-2[a]		1280 ± 180	9.9 ± 0.8	---	3.52 ± 1.20	11.6 ± 0.400	52 ± 22	1710 ± 340
Mortandad at GS-1[a,b]		755 ± 1090	17 ± 1.2	---	17.6 ± 15.3	5.69 ± 4.43	39 ± 16	450 ± 100
Mortandad at MCO-5[a,b]		76.5 ± 26.9	8.9 ± 0.8	---	2.71 ± 3.44	4.14 ± 9.42	11 ± 4	105 ± 22
Mortandad at MCO-7[a,b]		62.5 ± 12.7	4.2 ± 0.4	---	3.27 ± 0.25	0.76 ± 0.01	7.6 ± 3.2	67 ± 14
Mortandad at MCO-9[b]		0.96 ± 1.4	---	0.004 ± 0.012	0.002 ± 0.007	0.018 ± 0.008	6.3 ± 2.8	8.9 ± 2.0
Mortandad at MCO-13[b]		1.32 ± 0.24	0.46 ± 0.26	0.001 ± 0.012	0.002 ± 0.001	0.020 ± 0.044	4.4 ± 2.0	7.1 ± 1.6
Pajarito at TA-18		−0.03 ± 0.10	---	---	0.000 ± 0.001	0.000 ± 0.004	3.3 ± 1.6	2.8 ± 1.0
Pajarito at SR-4		0.90 ± 0.34	−0.11 ± 0.22	−0.001 ± 0.012	−0.002 ± 0.004	0.009 ± 0.008	8.5 ± 3.8	7.3 ± 1.8
Potrillo at TA-36		0.14 ± 0.08	---	0.001 ± 0.012	−0.001 ± 0.002	−0.001 ± 0.002	2.6 ± 1.2	3.2 ± 1.0
Portillo East of TA-36		0.17 ± 0.08	---	0.004 ± 0.014	0.001 ± 0.002	0.002 ± 0.004	2.7 ± 1.4	4.3 ± 1.2
Potrillo at SR-4		−0.08 ± 0.20	−0.10 ± 0.24	---	−0.001 ± 0.002	0.003 ± 0.004	2.7 ± 1.2	2.3 ± 0.8
Water at Beta Hole[b]		3.4 ± 0.99	---	0.006 ± 0.012	0.002 ± 0.004	0.056 ± 0.027	6.6 ± 2.8	12 ± 2.6
Water at SR-4		0.36 ± 0.16	0.85 ± 0.34	---	−0.001 ± 0.001	0.006 ± 0.004	3.2 ± 1.4	3.3 ± 1.0
Water at Rio Grande[b]		1.39 ± 0.20	---	---	0.007 ± 0.018	0.109 ± 0.038	17.0 ± 4.0	21 ± 2
Ancho at SR-4		0.54 ± 0.08	---	---	0.001 ± 0.002	0.009 ± 0.004	3.9 ± 1.8	5.3 ± 1.4
Ancho at Rio Grande		0.29 ± 0.08	---	---	0.008 ± 0.018	0.018 ± 0.024	7.8 ± 1.9	11 ± 1.4
Chaquihui at Rio Grande		0.11 ± 0.04	---		−0.002 ± 0.008	0.012 ± 0.010	3.7 ± 1.0	4 4 ± 0.9
No. of Analyses		47	14	12	47	47	32	32
Minimum		−0.08 ± 0.20	−0.11 ± 0.22	−0.001 ± 0.012	−0.002 ± 0.004	−0.003 ± 0.003	1.6 ± 0.8	1.1 ± 0.8
Maximum		1260 ± 180	17 ± 1.2	0.016 ± 0.014	35.2 ± 1.20	11.6 ± 0.400	52 ± 22	1710 ± 340
Average		70 ± 510	3.9 ± 11	0.008 ± 0.011	2.1 ± 14	0.86 ± 4.6	7.1 ± 22	79 ± 620

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

[a] ^{3}H, ^{137}Cs, ^{238}Pu, ^{239}Pu, Gross α, or Gross β above background.
[b] Two analyses for ^{137}Cs, R^{238}Pu, and ^{239}Pu.

TABLE E-XXI

ATMOSPHERIC RADIOACTIVE EFFLUENT TOTAL FOR 1978

Location	^{238}Pu ^{239}Pu (μCi)	^{241}Am (μCi)	^{235}U ^{238}U (μCi)	^{234}Th (mCi)	MFP[a] (μCi)	^{131}I (μCi)	^{41}Ar (Ci)	^{32}P (μCi)	^{3}H (Ci)	^{11}C,^{13}N,^{15}O[b] (Ci)	^{7}Be (μCi)
TA-2	---	---	---	---	---	---	239	---	---	---	---
TA-3	58.3	---	185	1.9	403	81	---	---	100	---	---
TA-9	---	---	---	---	---	---	---	---	2.6	---	---
TA-15	---	---	---	---	---	---	---	---	---	---	---
TA-21	30.8	0.034	305	---	1.0	---	---	---	72	---	---
TA-33	---	---	---	---	---	---	---	---	17 780	---	---
TA-35	2.0	---	---	---	---	---	---	---	676	---	---
TA-43	1.5	---	---	---	---	---	---	85	---	---	---
TA-46	---	---	25	---	---	---	---	---	---	---	---
TA-48	1.9	---	11.2	---	1169	---	---	---	---	---	---
TA-50	17.4	---	---	---	39	---	---	---	---	---	---
TA-53	---	---	---	---	---	---	350	---	---	116 449	0.19
TA-54	0.026	---	---	---	---	---	---	---	---	---	---
TA-55	0.40	---	---	---	---	---	---	---	---	---	---

[a]Mixed fission products.

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

TABLE E-XXII

QUALITY OF EFFLUENTS FROM LIQUID RADIOACTIVE WASTE TREATMENT PLANTS

	Waste Treatment Plant Location			
	TA-50		TA-21	
Radioactive Isotopes	Activity Released (mCi)	Average Concentration (μCi/mℓ)	Activity Released (mCi)	Average Concentration (μCi/mℓ)
^{239}Pu	4.05	0.099×10^{-6}	0.313	0.10×10^{-6}
^{238}Pu	1.83	0.045×10^{-6}	0.223	0.072×10^{-6}
^{241}Am	1.73	0.043×10^{-6}	2.30	0.738×10^{-6}
^{89}Sr	2.64	0.065×10^{-6}	0.026	0.008×10^{-6}
^{90}Sr	10.4	2.57×10^{-7}	0.10	0.321×10^{-7}
^{3}H	12 300	0.30×10^{-3}	1780	0.57×10^{-3}
^{137}Cs	317	0.78×10^{-5}	1.40	0.045×10^{-5}
U-Total	176 grams	4.34×10^{-3} mg/ℓ	10.8 grams	3.46×10^{-3} mg/ℓ

Nonradioactive Constituents	TA-50 Average Concentration (mg/ℓ)	TA-21 Average Concentration (mg/ℓ)
Cd[a]	0.003	0.06
Ca	26.0	10.1
Cl	48.4	70.5
Cr[a]	0.04	0.49
Cu[a]	0.27	0.11
F	3.8	345
Hg[a]	0.009	0.002
Mg	1.4	2.0
Na	354	1650
Pb[a]	0.044	0.064
Zn[a]	0.46	0.26
CN	0.04	---
COD[a]	51	73
NO_3 (N)	90	423
PO_4	0.44	1.96
TDS	1345	5440
pH[a]	6.8-12.3	6.3-13.1
Total Effluent Volume	4.058×10^{7} ℓ	3.118×10^{6} ℓ

[a]Constituents regulated by NPDES permit.

TABLE E-XXIII

ESTIMATED CONCENTRATIONS OF TOXIC ELEMENTS AEROSOLIZED BY DYNAMIC EXPERIMENTS

Element	1978 Total Usage (kg)	Percent Aerosolized (%)	Annual Avg. Concentration (ng/m^3) 4 km	8 km	Applicable Standard (ng/m^3)
Uranium	1371	10	0.1	0.05	9000[a]
Be	29.4	2	0.0008	0.0002	10[b] (30 day avg)
Pb	16.5	100[c]	0.03	0.008	10 000[b] (for total heavy metals, N>21)

[a]DOE Manual Chapter 0524.
[b]Section 201 of the Ambient Air Quality Standards and Air Quality Control Regulations adopted by the New Mexico Health and Social Services Board, April 19, 1974.
[c]Assumed percentage aerosolization.

TABLE E-XXIV

TOTAL SUSPENDED PARTICULATES AT LOS ALAMOS AND WHITE ROCK DURING 1978
(Data from New Mexico Environmental Improvement Agency)
All Concentrations in $\mu g/m^3$

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
				Los Alamos (Annual Geometric Mean = 36)								
No. of Samples	5	4	6	5	4	5	5	5	5	2	2	2
Maximum	63	47	63	111	40	60	45	58	98	30	38	29
Minimum	13	35	18	10	14	33	27	25	33	7	34	20
Mean ± 1 Standard Deviation	25 ± 21	42 ± 6	38 ± 15	61 ± 40	30 ± 13	51 ± 11	37 ± 7	46 ± 15	69 ± 37	18 ± 16	36 ± 3	25 ± 6
				White Rock (Annual Geometric Mean = 22)								
No. of Samples	5	5	4	0	0	0	0	0	2	5	4	
Maximum	32	24	172	---	---	---	---	---	---	23	38	32
Minimum	10	15	18	---	---	---	---	---	---	20	13	21
Mean ± 1 Standard Deviation	21 ± 9	20 ± 3	59 ± 76	---	---	---	---	---	---	21 ± 2	21 ± 11	26 ± 6

TABLE E-XXV

SANITARY SEWAGE TREATMENT FACILITIES
EFFLUENT QUALITY SUMMARY

Facility Location	NPDES Identification: Permit Number[a]	NPDES Identification: Outfall Serial No.[b]	Biochemical Oxygen Demand (BOD_5)[c]: Observed Range (mg/ℓ)	Biochemical Oxygen Demand (BOD_5)[c]: No. of Months Limits Exceeded	Total Suspended Solids[d]: Observed Range (mg/ℓ)	Total Suspended Solids[d]: No. of Months Limits Exceeded	Fecal Coliform Bacteria[e]: Observed Range (mg/ℓ)	Fecal Coliform Bacteria[e]: No. of Months Limits Exceeded	pH[f]: Observed Range	pH[f]: No. of Months Limits Exceeded
TA-3	NM0024210	01S	10-84	5	5-46	5	0-430000[g]	7	6.3-8.1	0
TA-9	NM0024295	02S	1-22	0	1-16	0	0-100[h]	0	6.7-8.8	0
TA-16	NM0024236	03S	4-22	0	3-44	1	40-15000[h]	3	6.6-8.3	0
TA-18	NM0024244	04S[i]	21-68	6	28-204	6	0-120[h]	0	6.8-10.3	6
TA-21	NM0024252	05S	9-103	7	9-137	6	0-37600[g]	5	6.1-7.8	0
TA-41	NM0024261	06S	1-28	0	7-43	1	0[h]	0	6.0-8.4	0
TA-46	NM0024341	07S[i]	3-26	0	1-14	0	0-640[h]	1	6.7-7.8	0
TA-48	NM0024741	08S	3-25	0	1-20	0	0-1200[h]	2	6.0-7.8	0
TA-53	NM0024279	09S[i]	37-67	4	28-143	4	1-1500[h]	1	8.9-10.5	5
TA-35	---	010S[i]	52	1	56	1	---[h]	---	9.2-9.7	3

[a]Individual permits effective 1/1/78 - 10/15/78.

[b]Single permit, NM 0028355, with separately designated outfalls effective 10/16/78.

[c]BOD_5 limits 30 mg/ℓ (20-day avg), 45 mg/ℓ (7-day avg).

[d]TSS limits 30 mg/ℓ (20-day avg), 45 mg/ℓ (7-day ave).

[e]Fecal coliform limits 200/100 mℓ for all individual permits through 10/15/78. Starting 10/16/78 limits of 2000/100 mℓ (daily max. and 1000/100 mℓ (geometric mean) apply only to outfall 01S (TA-3) and 05S (TA-21).

[f]pH limits not less than 6.0 or greater than 9.0 standard units.

[g]See footnote e for change in limit as of 10/16/78, new limit exceeded only by outfall 05S during one month.

[h]No fecal coliform limit for these outfalls after 10/15/78.

[i]Flow limits exceeded by these outfalls from lagoons during last quarter when far above average precipitation occurred.

TABLE XXVI

INDUSTRIAL LIQUID EFFLUENT QUALITY SUMMARY[a]

Dischage Category	No. of Outfalls	Permit Constituents	No. of Deviations	Range of Deviation/Limit Ratios or pH[b]	No. of Outfalls Causing Deviations
Power Plant	6	TSS	4	1.5.- 55	2[c]
		Free Cl	0	---	0
		pH	4	9.6.- 11.9	2[c]
Boiler Blowdown	4	TSS	0	---	0
		Fe	0	---	0
		Cu	2	1.3.- 42	1[c]
		P	0	---	0
		pH	10	10.4.- 12.4	3[c]
Treated Cooling Water	32	TSS	2	1.3.- 1.34	2
		Free Cl	0	---	0
		P	0	---	0
		pH	5	9.1.- 9.8	3
Non-contact Cooling Water	23	pH	0	---	0
Radioactive Waste Treatment Plant Discharges	2	NH_3	0	---	0
		COD	0	---	0
		TSS	0	---	0
		Cd	0	---	0
		Cr	0	---	0
		Cu	1	1.05	1
		Fe	0	---	0
		Pb	0	---	0
		Hg	0	---	0
		Zn	0	---	0
		pH	0	---	0
High Explosives Waste Discharges	20	COD	4	1.2.- 87	3[d]
		TSS	0	---	0
		pH	1	4.8	1
Photo Waste Discharges	14	CN	0	---	0
		Ag	0	---	0
		pH	1	9.6	1
Printed Circuit Board Development Wastes	1	COD	0	---	0
		Cu	0	---	0
		Fe	1	1.1	1
		Ni	0	---	0
		P	0	---	0
		pH	0	---	0
Acid Dip Tank Rinse	1	Cu	1	1.01	1[c]
		pH	1	5.3	1[c]
Gas Cylinder Cleaning Waste	1	TSS	0	---	0
		P	0	---	0
		pH	0	---	0

[a]Summary of reports to EPA or NPDES Permit NM0028355, which was effective starting 10/16/78.
[b]pH range limit on all outfalls is not less than 6.0 or greater than 9.0 standard units.
[c]Outfalls responsible for deviations to be corrected during 1979-80 by funded projects.
[d]One of the 3 outfalls scheduled for funded corrective measures.

TABLE E-XXVII

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

	Surface Water	Water Supply	Springs (Jemez Fault)	Springs (Volcanics)	Abandoned Well	Fenton Hill (Pond Fluids)
No. of Stations[a]	9	4	2	1	1	2
No. of Analyses	9	4	2	1	1	2
Chemical (mg/ℓ)						
SiO_2	33 ± 9	66 ± 15	47 ± 0.7	52	67	115 ± 13
Ca^{2+}	17 ± 5	17 ± 9	137 ± 59	12	26	64 ± 30
Mg^{2+}	3 ± 0.7	3 ± 1	12 ± 0	4	9	6 ± 1
Na^{+}	13 ± 8	14 ± 1	595 ± 494	10	120	411 ± 267
CO_3^{2-}	0 ± 0	0 ± 0	0 ± 0	0	0	0 ± 0
HCO_3^-	40 ± 28	78 ± 21	633 ± 284	58	370	337 ± 120
SO_4	20 ± 23	9 ± 9	32 ± 3	<1	5	120 ± 109
Cl^-	11 ± 13	6 ± 3	921 ± 785	4	9	657 ± 655
F^-	0.4 ± 0.2	0.4 ± 0.1	2.9 ± 0.2	0.9	1.2	8 ± 14
NO_3^-	0.4 ± 0.0	0.5 ± 0.3	0.4 ± 0	0.2	0.4	0.4 ± 0
TDS	143 ± 45	226 ± 76	2234 ± 1646	114	480	2013 ± 1322
Hard	55 ± 14	56 ± 27	392 ± 146	44	102	184 ± 82
pH	6.7 ± 1.2	7.4 ± 0.2	7.2.± 0.2	7.2	7.8	7.8 ± 0.1
Conductance mS/m	20.1 ± 7.5	24.5 ± 13.7	384.0 ± 255.3	12.0	74.0	333.0 ± 248.3
Total U μg/ℓ	0.9 ± 0.7	1.0 ± 0.9	1.3 ± 0.1	1.2	<0.1	1.2 ± 0.2

[a]Sampling locations key on Fig. 15 as follows:

Surface Water—Locations F, J, N, Q, R, S, T, U, V.
Water Supply—Locations JS 2-3, JS 4-5, FH-1, 4.
Spring (Jemez Fault)—Locations JF-1, JF-5.
Spring (Volcanics)—Location 31.
Abandoned Well—Location 27.
Fenton Hill (pond fluids)—Two ponds TA-57.

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

DISTRIBUTION LIST

Department of Energy
- Assistant Secretary for Environment
  - R. L. Clusen
  - H. Hollister
  - J. L. Liverman
- Office of Environmental Compliance and Overview
  - R. J. Catlin
  - W. J. McCool
  - W. E. Mott
  - R. J. Stern
- Office of Health and Environmental Research
  - W. W. Burr, Jr.
  - W. S. Osburn, Jr.
  - D. H. Slade
  - J. Swinebroad
  - R. L. Watters
- Office of Military Applications
  - Major General J. K. Bratton
- Office of Technology Impacts
  - P. W. House
- Albuquerque Operations Office (12)
  - J. R. Roeder
- Los Alamos Area Office
  - K. R. Braziel
  - W. Crismon, Jr.
- Environmental Measurements Laboratory, New York
  - J. H. Harley
  - E. P. Hardy, Jr.
- Idaho Operations Office
  - M. M. Williamson
- Nevada Operations Office
  - P. B. Dunaway
- Oak Ridge Operations Office
  - J. F. Wing

Department of Energy Conractors
- Argonne National Laboratory
  - J. Sedlet
  - D. P. O'Neil
- Battelle, Pacific Northwest Laboratories
  - D. A. Waite
  - E. C. Watson
- Rockwell Hanford Operations
  - J. V. Panesko
- Brookhhaven National Laboratory
  - A. P. Hull
- Rockwell International - Rocky Flats Plant
  - M. V. Werkeme
  - R. Bistline
  - D. Bokowski
- GE-Pinellas Plant
  - E. P. Forest
- Lawrence Livermore Laboratory
  - W. J. Silver
  - C. L. Lindeken
  - V. Noshkin
- Mound Laboratory
  - A. G. Barnett
  - D. G. Carfagno
  - H. E. Meyer
  - C. T. Bishop
- Oak Ridge National Laboratory
  - J. A. Auxier
- Pantex Plant
  - R. E. Alexander
- Sandia Laboratories, Albuquerque
  - L. W. Brewer
  - T. Simmons
  - W. B. Burnett
- Savannah River Laboratory
  - J. L. Crandall
  - J. E. Johnson
  - J. A. Harper

Other External
- Environmental Protection Agency
  - W. A. Mills, ORP, Washington, DC
  - D. Smith, ORP, Washington, DC
  - F. L. Galpin, ORP, Washington, DC
  - D. T. Wruble, EMSL, Las Vegas, NV
  - A. W. Bush, Region 6, Dallas, TX
  - H. May, Region 6, Dallas, TX
- New Mexico Health and Environment Dept., Environmental Improvement Division
  - T. E. Baca, Director
  - K. M. Hargis
  - J. Pierce
  - T. Wolff
- Individuals
  - B. Calkin, Sierra Club, Santa Fe, NM
  - W. E. Hale, US Geological Survey, Albuquerque, NM
  - W. Schwarts, LFE, Richmond, CA
  - J. Mueller, CEP, Santa Fe, NM

New Mexico State Engineer, Santa Fe, NM
Supervisor, Santa Fe National Forest, Santa Fe, NM
Superintendent, Bandelier National Monument, Los Alamos, NM

Local Media
Los Alamos Monitor, Los Alamos, NM
Santa Fe New Mexican, Santa Fe, NM
Albuquerque Journal, Albuquerque, NM
KRSN Radio, Los Alamos, NM
KGGM TV, Albuquerque, NM
KOAT TV, Albuquerque, NM
KOB TV, Albuquerque, NM

New Mexico Congressional Delegation
Senator Pete V. Domenici
Senator Harrison H. Schmidt
Representative Manuel Lujan, Jr.

APPENDIX I
COMMENTS RECEIVED CONCERNING THE
DRAFT ENVIRONMENTAL IMPACT STATEMENT DOE/EIS-0018-D

On June 27, 1978, the Department of Energy (DOE) issued for public review and comment the Draft Environmental Statement, DOE/EIS-0018-D that assessed the environmental impact associated with the current and continuing activities at the Los Alamos Scientific Laboratory. Comment letters were received from 15 individuals and organizations which are reproduced in this appendix. The substantive concerns raised in the written comments pertained to: (1) the mission and location of the Laboratory, (2) the biological behavior of radionuclides, (3) water supply for Los Alamos, (4) waste management, (5) accident analysis, (6) radiological doses and dose interpretations, (7) radioactive materials in the environment, (8) transportation of radioactive materials, and (9) additional details desired.

These are discussed in Section 11 of this final EIS where directions are given to those portions of the text that were changed to accommodate these concerns.

Letters of views and comments were received from:

1. Mr. Peter L. Cook, Acting Director, Office of Federal Activities, United States Environmental Protection Agency, Washington, DC 20460

2. Ms. D. Feldman, 1821 Meadowview Northwest, Albuquerque, New Mexico 87104

3. Dr. William H. Foege, Assistant Surgeon General, Director, Department of Health, Education and Welfare, Public Health Service, Center for Disease Control, Atlanta, Georgia 30333

4. Mr. A. W. Hamelstrom, State Conservationist, United States Department of Agriculture, Soil Conservation Service, Box 2007, Albuquerque, New Mexico 87103

5. Mr. Robert M. Hawk, Vice-Chairman, Board of County Commissioners, County of Bernalillo, State of New Mexico, 620 Lomas N. W., Albuquerque, New Mexico 87102

6. Mr. Daniel Hunt, Deputy Assistant Director, Office of the Assistant Director for Astronomical, Atmospheric, Earth, and Ocean Sciences, National Science Foundation, Washington, DC 20550

7. Mr. Grant W. LaPier, Product Manager, The Babcock & Wilcox Company, Nuclear Materials Division, 609 North Warren Avenue, Apollo, Pennsylvania 15613

8. Mr. Larry E. Meierotto, Deputy Assistant Secretary, Office of the Secretary, United States Department of the Interior, Washington, DC 20240

9. Mr. Jack M. Mobley, Planning Bureau, State of New Mexico, Department of Finance and Administration, State Planning Division, 505 Don Gaspar Avenue, Sante Fe, New Mexico 87503

10. Dr. Peter Montague, P. O. Box 4524, Albuquerque, New Mexico 87106

11. Mr. Voss A Moore, Assistant Director for Environmental Projects, Division of Site Safety and Environmental Analysis, United States Nuclear Regulatory Commission, Washington, DC 20555

12. Mr. Donald A. Neeper, Chairman, Los Alamos Chapter, New Mexico Citizens for Clean Air and Water, P. O. Box 5, Los Alamos, New Mexico 87544

13. Mr. Harold F. Olson, Director, State Game Commission, State of New Mexico, Department of Game and Fish, State Capitol, Santa Fe, New Mexico 87503

14. Mr. R. Max Peterson, Deputy Chief, United States Department of Agriculture, Forest Service, P. O. Box 2417, Washington, DC 20013

15. Mr. Craig Simpson, War Resisters League, 201 Pine S. E., Albuquerque, New Mexico 87106

Copies of the letters received and DOE staff responses are contained in the following pages of this section.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

26 OCT 1978

OFFICE OF THE ADMINISTRATOR

Mr. W.H. Pennington
Mail Station E-201
GTN
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

The Environmental Protection Agency (EPA) has reviewed the Department of Energy's draft environmental impact statement (EIS) on the Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico (DOE/EIS-0018-D). Our detailed comments are enclosed.

As a result of our review, we have identified two major concerns with the draft EIS. First, EPA believes that the discussion of public health impacts from activities at the laboratory is inadequate. We note that in the past DOE has provided health effects estimates in their EIS's. However, in this EIS no health effects estimates are given because the DOE staff states that the linear dose hypothesis method does not provide accurate risk estimates. We feel that the Department of Energy should provide EPA and the public with health effects estimates and not just estimates of radiation doses. We suggest that DOE use any other method or model that it considers more suitable and include the results of such analysis in the final EIS.

In addition, we believe that there is a lack of relevant radiation information in the "potential impacts section" of the EIS. Many of the references used need to be updated and EPA's proposed Federal Radiation Guidance on transuranics in the general environment should be included in the discussion of transuranics in the environment. We are enclosing, those documents pertinent to this proposed guidance for your convenience.

In accordance with EPA procedures and as a result of our review, we have rated this draft EIS on the Los Alamos Laboratory 2 (Insufficient Information) and have categorized the proposed action LO (Lack of Objections). If you or your staff have any questions concerning our comments, please contact Florence Munter of my staff (755-0770).

Sincerely yours,

Peter L. Cook
Acting Director
Office of Federal Activities (A-104)

Enclosures

- EPA Comments on DOE/EIS-0018-D
- Proposed Guidance on Dose Limits
- Selected Topics
- Parameters for Estimating the Uptake of Transuranic Elements

EPA COMMENTS ON DOE/EIS-0018-D, THE DRAFT ENVIRONMENTAL IMPACT STATEMENT ON THE LOS ALAMOS SCIENTIFIC LABORATORY SITE

General Comments

There are several documents which we feel are pertinent to the draft EIS and which should be reviewed and used by DOE in preparing the final EIS. Some of these documents have been enclosed for your information and include the following: "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment" (especially Annex III, "The Dose and Risk to Health Due to Inhalation and Ingestion of Transuranium Nuclides") and "Selected Topics: Transuranium Elements in the General Environment" (specifically pages 281-309, "The Physiological Basis of Transuranic Element Dose Estimates"). Other documents which we believe should be included in your revision of the draft EIS have been noted in our specific comments.

Although it would not be economically feasible to terminate or relocate operation of the Los Alamos Laboratory, we believe DOE is still obligated under NEPA to include a complete analysis of alternatives to the present facility. Therefore, the discussion on alternatives should consider the option of termination and the option of relocation separately. The socio-economic as well as radiological impacts are quite different for these two alternatives from both a national and regional perspective. As an example, in the case of relocation, the regional impacts (both beneficial and adverse) at the Los Alamos area would be very different from the regional impacts at a new location. Differences such as this appear to justify a more in-depth analysis than presently appears in the EIS.

Specific Comments

1. Page 3-129: The use of Area B as a trailer/camper storage area allows an opportunity for exposure of the public. What measures are being taken to assure that such exposure is not taking place? If this is an exposed area, why is public access allowed? The DOE should describe in the final EIS the measures that will be taken to eliminate public access.

2. Page 4-42, second paragraph, 13th sentence: "The radiation doses calculated from this material are those in a mass of free water, since most tissues are primarily water." The possibility of ^3H being incorporated in DNA or RNA molecules should be considered--especially if the ^3H is "tagged" on one of the nucleotides, such as Thymidine, as is often the case in biological experiments.

3. Page 4-42, second paragraph, seven lines from the bottom: The statement is made that "...at a high enough exposure, various types of cancers and possible genetic effects in later generations may occur." Documentation should be provided for this statement in the final EIS.

4. Page 4-42, three lines from the bottom: The final EIS should reference the statement that transmutations of genes from tritium incorporated in a molecule are unimportant compared to direct radiation.

5. Page 4-42: The next to the last sentence is not true--the induction of nonsolid tumors (leukemia) and indeed some solid tumors has occurred at doses as low as 15 rem/yr to 30 rem/yr which are, incidently, the present occupational limits. See ICRP-26.

6. Page 4-43, third paragraph, last sentence: The notion of "the primary effect of sufficient quantities in the body" is obsolete. This implies that there is a threshold dose for cancer induction; such an implication is not acceptable according to the latest public health research and should not be made. See UNSCEAR, BEIR, and Annex III (Attachment I).

7. Page 4-44, fifth paragraph, third to the last sentence: "At the occupational level in humans, the chemical toxicity and effect on kidney function predominate." In addition to needing clarification, this is obsolete--See N. Adams and N.L. Spoor, 1974. "Kidney and Bone Retention Functions in the Human Metabolism of Uranium." Phys. Med. Biol. 19(4): 460-471.

8. Page 4-45, first paragraph: Reference 4-51, ICRP #2, is obsolete. There are many other acceptable, more recent references such as ICRP 19, Annex III, or BEIR. The latest information should be incorporated wherever possible.

9. Page 4-45, first paragraph: Reference 4-57 could be further substantiated by statements on page 192 of D.E. Bernhardt's and G.G. Eadies' enclosed Technical Note ORP/LV-76-2, entitled "Parameters for Estimating the Uptake of Transuranic Elements by Terrestrial Plants."

10. Page 4-45, ninth line from the bottom of the first paragraph: The sentence ending with "previously thought" needs a reference to document the statement that, "data that indicate that ingestion may contribute a somewhat higher fraction."

11. Page 4-45, sixth line from the bottom of the first paragraph: "There is some speculation that the small fraction of plutonium incorporated into meat or plant foods may be more readily absorbed from the gut." Recent reports suggest that organically-bound, or biologically-incorporated (protein-bound), plutonium is absorbed up to ten times as readily as inorganically-bound plutonium. M.F. Sullivan and A.L. Crosby, Battelle Annual Report, pp. 91-93, (1976).

12. The following three references also apply to the preceding four comments:

M. F. Sullivan, "Gastrointestinal Absorption of Transuranic Elements by Rats," May 1977, Annual Report for 1976, BNWL-2100 Pt. 1.

M. F. Sullivan, "Gastrointestinal Absorption and Retention of ^{238}Pu in Neonatal Rats and Swine," Feb. 1978, Annual Report for 1977, PNL-2500 Pt. 1.

M. F. Sullivan, "Absorption of Transuranic Nitrates by Rats, Guinea Pigs, and Dogs," Feb. 1978, Annual Report for 1977, PNL-2500, Pt. 1.

13. Page 4-47, first and second sentences, fourth paragraph: Even though References 4-68 and 4-69 may be correct, they are thirty years old. This may be why the quotation implies that chromosome aberrations are the only genetic effects evident in the gonads. This is not true, there are many other effects which may occur upon exposure to radiation. These effects should be evaluated in the final EIS. See page 36 (Section 3.8.1) of EPA 520/4-77-016.

14. Page 4-47, first sentence of the last paragraph: Plutonium-239 should be compared to radium-224 not radium-226. See enclosed documents.

15. Page 4-47: The paragraphs discussing plutonium and radon should include some discussion of Brandom's work on somatic cell chromosome changes. This work presents new information on the subject and discusses significant new findings. Brandom, W. F., et al., "Somatic Cell Chromosome Changes in Humans Exposed to ^{239}Pu and ^{222}Rn," Progress Report, July 1, 1976 to September 30, 1977," DOE Contract No. E(29-2)-363.

16. Page 4-48, first paragraph: "Additional dogs at lower exposure levels are now being observed." The final EIS should substantiate this sentence with a citation and provide some additional information as to the results or estimates from these observations.

17. Page 4-48, first paragraph, next to last sentence: Reference 4-76 suggests the results are from low doses whereas this sentence implies the results were obtained with high levels of plutonium. Please rectify this apparent conflict.

18. Page 4-48, last paragraph: In the statement, "In conclusion, the present standards are well supported...." please identify to which standards you are referring.

19. Page 4-49, second paragraph: "There is some evidence of a smaller effect for some types of cancers when the radiation is received at low dose rates ...." There is some evidence of a greater effect also, such as an inverse effect for alpha emitters. See Archer, V.E., Radford, E.P., and Axelson, O., 1978, "Radon Daughter Cancer in Man: Factors in Exposure Response Relationships." Presented at the Health Physics Society Meeting, June 19-23, 1978.

20. Page 4-53, Table 4.1.3-2: A column should be added showing to which organ the dose to the individual corresponds. Further, calculating the population dose for only Los Alamos county may underestimate the impact on the population of northern New Mexico. Population does estimates are generally based on the population within a 50-mile radius of the facility. From the map on pages 3-61, this would include most of Sandoval and Santa Fe counties and portions of Bernalillo, Rio Arriba, Taos, and Mora counties. While inclusion of these areas may not produce a large increase in the population dose, it is necessary in order that the analysis give a comprehensive picture of the regional impact and assure that those portions of the public are included.

21. Page 4-55, last paragraph: EPA does not at this time agree with the point of view expressed in this paragraph concerning the linear dose hypothesis. We maintain that it is currently the most reasonable model to use in estimating health effects arising from low dose and low dose rate exposure of the general public. If the Department of Energy wishes to dispute the accuracy of this model, that is its prerogative. However, we do not believe that this is sufficient reason to eliminate estimates of health effects altogether whatsoever. EPA strongly encourages DOE to include such estimates in the final EIS.

22. Page 4-82, third and fourth paragraphs and Page 4-86, third paragraph: These paragraphs each mention a different level of contamination to which accidental spills have been either cleaned up or would have to be cleaned up. While this information is interesting, it is confusing and has left out the most pertinent information. The statement on p. 4-86

which says that, following a particular accident, the contaminated area "...would probably be contaminated with plutonium to levels above 65 ug/m^2 and would require decontamination" implies that a level of 65 ug/m^2 is a set level below which no action is necessary. This is misleading since this level of radiation has no official sanction. The guidance which is applicable to plutonium in the general environment is that which has been proposed by EPA. The following text is from Section 1 of EPA's guidance (EPA report # 520/4-77-016) which is enclosed with these comments:

> 1. The annual alpha radiation does rate to members of the critical segment of the exposed population as the result of exposure to transuranium elements in the general environment should not exceed either:
>
> a. 1 millirad per year to the pulmonary lung, or
> b. 3 millirad per year to the bone.
>
> 2. For newly contaminated areas, control measures should be taken to minimize both residual levels and radiation exposures of the general public. The control measures are expected to result in levels well below those specified in paragraph one. Compliance with the guidance recommendations should be achieved within a reasonable period of time.

23. Page 4-90, first paragraph: In this paragraph and elsewhere in the EIS, when presenting dose equivalents from accidents involving long-lived radioactive material, the length of time over which the dose equivalents are calculated must be stated to insure complete understanding of the estimate.

24. Page 4-49, last paragraph: In referring to acute beryllium poisoning, "complete recovery" does not occur in "most cases", according to J. Schubert in his article, "Beryllium and Beryllosis," in Scientific American (199(2): 27-33(1958)). Please reference your source or amend the statement.

DOE Staff Responses to EPA Comments on the Draft Environmental Impact Statement for the Los Alamos Scientific Laboratory DOE/EIS-0018-D

General

In regard to EPA's concern about the discussion of estimates of public health impacts from radioactivity, we note the revision of the discussion on page 4-62 to include estimates of probability individual risk of injury due to natural background and the incremental probability of risk theoretically attributable to Los Alamos operations. Also, a general discussion of interpretation of radiation doses was included in section 11 (pages 11-3 and 11-4) and gives risk factors that can be used to aid in interpretation of other dose estimates and measurements throughout the statement.

A number of changes were incorporated into the text at appropriate points in response to your detailed comments, especially in the section on biological behavior of radionuclides. Responses to these detailed comments are explained below.

Because the options of terminating or completely relocating the laboratory are not considered realistically available, the discussions of the environmental consequences for such alternatives have been left somewhat general in scope. A more detailed or site-specific treatment of the laboratory relocation alternative(s) would be so dependent on the myriad available choices of possible relocations sites, including the various multiple sites, which would be likely candidates for the many combinations of partial relocations that it would be too speculative to be meaningful. While such an analysis may have merit when considering the proper location for a yet-to-be-started facility or project, it would be of questionable value with respect to evaluating an ongoing, multi-program facility such as LASL. We believe that the statement does adequately address the realistic alternatives which could be implemented within the constraints of national policy and congressional funding.

Specific

1. Routine monitoring and surveys indicate no radiation levels above natural background are present in the fenced trailer/camper storage area of Area B. Pavement is routinely maintained to prevent any direct access to wastes. Text was modified on page 3-136.

2. The possibility was discussed later in the same paragraph. An additional reference was included (4-53A).

3. The intent of the statement was to indicate that observable effects would occur or risks would be higher at higher exposures. The phrase that might have been misconstrued to indicate a threshold was deleted and two additional references (4-54 and 4-77) were added.

4. See comment No. 2 above.

5. We do not find any reference in ICRP-26 to leukemia or solid tumors having been observed at dose equivalent rates of 15-30 rems/yr. However, the controversial sentences were deleted.

6. Concur. The sentence was reworded to reflect frequency of effects expected to increase with increasing accumulation.

7. We concur that, under conditions of continued exposure at the Maximum Plutonium Concentration (MPC) for long periods of time, the dose rate to the bone appears to be limiting. However, under the more realistic conditions of occasional exposure, the toxicity aspects are of concern.

8. We cannot concur that ICRP-2 is obsolete in that it has not been replaced and the numerical values are still the basis of several U.S. regulations. The BEIR report is unsatisfactory because it does not discuss uptake in quantitative terms. A citation to ICRP-19 (ref. 4-67) was included.

9. There are many other studies that could be referenced here. We are not certain of exactly what was intended by the comment as our copy of the document has no page 192.

10. A new citation (ref. 4-66) was included at the appropriate location.

11. and 12. New references were added (refs. 4-58A, 4-58B, and 4-58C).

13. Two new paragraphs and two new references (refs. 4-73A and 4-73B) were added on pages 4-51 and 4-52.

14. The limits for ^{239}Pu were derived by biological comparison with the results of ^{226}Ra exposures. The more recent data from ^{224}Ra administrations have been used to extend and confirm the original comparisons with ^{226}Ra. The sentence was modified to include both radium isotopes.

15. A brief summary of Brandon's work and a citation (ref. 4-73C) was added on page 4-52.

16. A summary of more recent results from the continuing studies at Pacific Northwest Laboratories and a citation (ref. 4-75A) was added on page 4-52.

17. Reference 4-76 is subtitled "Summary and Speculative Interpretation Relative to Exposure Limits." The paper uses cancer incidence resulting from relatively high doses, compared to those used in establishing limits, and speculated on effects at lower doses.

18. Sentence modified to make clear that the conclusion was in fact referring to the preceding several pages of discussion on plutonium.

19. Sentence revised to indicate lack of consistency in current information.

20. Table 4.1.3-2 was updated and indication of type of dose included. A new paragraph was added on page 4-59 to indicate quantitatively the lack of importance of doses theoretically calculable for populations outside Los Alamos County.

21. A paragraph was added on page 4-62, which indicates values for probability of injury based on ICRP risk factors. A discussion and compilation of risk factors was included in section 11 to aid in interpretation of other radiation doses included in the statement.

22. Discussions of past cleanup practices have been retained as important facts. The discussion of potential soil contamination from an explosion accident (pages 4-98 and 4-99) has been revised to include the proposed EPA guidance and its implication for the extent of potential contamination that might require cleanup.

23. Text and tables at various locations in the statement have been clarified to indicate whether annual doses or dose commitments are being discussed.

24. The statement is believed to be correct. A new citation (ref. 4-96A) was added on page 4-54.

NEW MEXICO STATE CLEARINGHOUSE

I-13

REVIEW CERTIFICATION

MIS-5

JUDI ROSS
[illegible]
State Planning Officer

STATE PLANNING OFFICE
505 Don Gaspar, Greer Building
Santa Fe, New Mexico 87503
(505) 827-2073

Jerry Apodaca
Governor

TO: U. S. Department of Energy
Mail Station E 201 GNT
Washington, D. C. 20545

DATE: August 9, 1978

Att: W. H. Pennington

SUBJECT: Review of SAI No.: 79 07 1 014

REVIEW ACTION ON:	PROJECT TITLE: Los Alamos Scientific Laboratory Site
__ Pre-application	
X Final Application	Applicant: U. S. Department of Energy
__ State Area Plan	
X EIS	SOURCE OF FUNDS REQUESTED
TYPE FUNDS:	Federal Agency: Federal Energy Administration
__ Grant	Federal Program Title: State Energy Conservation Program
__ Loan	Federal Catalog No.: 80001
__ State Block	State Agency:
__ State Appropriation	
__ State Funds Only	Funds Requested: $ N/A Federal $____ State

REVIEW RESULTS

X The Application is supported.

__ The Application is not in conflict with State, Areawide, or Local plans.

X Comments are attached for submission with this application.

__ The Application has no review requirements. Thank you, however, for providing this courtesy information.

You may now submit your Application package, MIS-5 and all review comments to the Federal or State Agency(s) from whom action is being requested.

Please notify the State Clearinghouse of any changes in this project. Refer to the SAI number on ALL correspondence pertaining to this project.

2-1

DDC

Anita Desenberg for
State Planning Officer
JUDI ROSS

State of New Mexico
DEPARTMENT OF FINANCE AND ADMINISTRATION

State Planning Division
505 Don Gaspar Avenue

Coordination Bureau (505) 827-2073
Planning Bureau (505) 827-5191

Santa Fe, New Mexico 87503

August 9, 1978

Mr. W. H. Pennington
Mail Station E-201, GTN
Department of Energy
Washington, D. C. 20545

Reference: DOE/EIS-0018-D, Los Alamos Scientific Laboratory Site,
Los Alamos, N. M.; SAI #79-07-1-014

Dear Mr. Pennington:

The following are our comments on the referenced document:

- The report clearly states that radioactive effluents are released into the environment; however, we are assured in the report that "...it is clear that neither the direct atmospheric releases nor any possible pathways resulting from release of liquid effluents have any significant impact." pages 4-56. We urge DOE and LASL to continue every effort to reduce radioactive effluent release wherever possible.

- Section 4.2 covers Potential Impacts of Accidents but fails to discuss possible costs of clean-up activity in event of such accidents. For instance, how much would it cost to decontaminate a 650 acre area such as the one discussed on pages 4-86? We deem it advisable to discuss these costs and possible length of time to clean up contaminated areas.

- In section 3.2.6 Transportation, some discussion of the Los Alamos Airport is provided. Are there any shipments of radioactive materials transported by aircraft to or from this airport?

We have submitted the document to the following state agencies for review: the Department of Energy & Minerals, the Department of Health & Environment, the Department of Natural Resources, and the State Geologist. You will find Energy & Minerals Department's comments

Mr. W. H. Pennington
August 9, 1978

attached. The other agencies will file their reviews with you directly.

Thank you for the opportunity to review this DEIS.

Sincerely,

Jack M. Mobley
Planning Bureau

JMM:rr

Attachment

I-16 STATE OF NEW MEXICO

ENERGY AND MINERALS DEPARTMENT

OFFICE OF THE SECRETARY

JERRY APODACA
GOVERNOR

NICK FRANKLIN
SECRETARY

August 8, 1978

POST OFFICE BOX 2770
113 WASHINGTON AVENUE
SANTA FE, NEW MEXICO 87501
(505) 827-2471

Ms. Kate Wickes
Planning Bureau
State Planning Division
Department of Finance and Administration
505 Don Gaspar Avenue
Santa Fe, NM 87503

Dear Ms. Wickes:

Thank you for giving the Energy and Minerals Department an opportunity to review the Draft Environmental Impact Statement for the Los Alamos Scientific Laboratory Site. I am enclosing comments which were prepared by my staff.

Some of these comments may or may not be relevant but are based on the information available in the report. If you feel further information might be helpful, please feel free to contact me.

Sincerely,

for Ernest Ortiz Asst.
NICK FRANKLIN
Secretary

NF/cw

Enc.

COMMENTS: LASL DRAFT EIS

p. 1-5 - Hasn't the plutonium facility already been moved?

p. 1-5 - How is it known that there has been no change in the chemical or radiochemical quality of water in the main aquifer?

p. 1-5 - The concentration of Pu and other radionuclides in the sediments of intermittent streams feeding into the Rio Grande should be mentioned. Radiation levels above background in the canyons should be discussed. Other radionuclides such as Am, Sr and Cs should be mentioned in addition to Pu. Gamma levels at the outfall points should be indicated. Though the adverse effects may be small, there are certainly adverse effects.

p. 1-5 - How were numbers given in Table 1-1 obtained? Non-routine releases
1-6 - should be indicated. Releases should be separated as to source.

p. 1-5 - How were numbers given in Table 2-1 obtained? Non-routine air
1-8 releases should be indicated. What sources do these numbers include?

p. 1-7 - Withdrawal of land for waste disposal sites and at outfall points and other contaminated land is an environmental impact.

It would be thought that LASL might look at melt down at the uncontained reactor site and loss of solid fission products as well as iodine and gases in looking at "worst accidents." A fire and explosion in the TRU storage site might also be possible. A truck accident for a truck carrying a bomb or an airplane crash in which the airplane was carrying plutonium should be mentioned.

p. 1-9 - Table 1-3 or a similar Table should include curie amounts of radionuclides discharged to sorption beds and to the canyons. Subsurface disposal and retrievable storage should be given as separate numbers.

p.1-12 - There have been irreversible changes in the ecological patterns of the area as vegetation and animal populations have changed, due to surface water availability, human activities, etc.

p. 2-4 - LASL is presently not involved with metallic vapor lasers or chemical lasers. LASL is looking at fusion reactions in deuterium and tritium not just deuterium.

p. 2-4 - Uranium is mainly a health hazard as a heavy metal - the decay daughters have hazards as radionuclides.

p. 2-6 - Scyllac is no longer being used.

p.2-10 - Techniques to separate tritium gas from the molten lithium blanket are being thought about (not "developed").

p.2-11 - Subterrene drill program has had few practical applications so far. It would not appear to "have opened a whole new perspective."

p.2-13 - The high energy gas laser facility is scheduled for completion in October 1983. This facility should reach "break even." The facility is going to explore the possibility of laboratory simulation of weapons effects.

p.2-14 - The plutonium facility is essentially complete.

p. 3-8 - Cerro Toledo rhyolite also crops out in the town site.

p.3-12 - Couldn't LASL buildings be located on faults not exposed on the surface?

p.3-50 - Drainage from disturbed areas in Los Alamos should be discussed in relation to increased sediment load in the Rio Grande.

p.3-50 - Quality of water from the Los Alamos sewer treatment plants and the influence of this discharge on water quality in the Rio Grande should be discussed.

p.3-50 - Increase in population in the Northern New Mexico communities due to Laboratory employment and the effects of this increase on Rio Grande water consumption and quality should be indicated.

p.3-51 - Has improvement of the Los Alamos treatment facilities occurred. (August 1976 is two years ago).

p.3-51 - Emissions to the atmosphere of CO , NO_x , SO_2, etc., can be calculated for the boiler plants, from the number of cars employees use in getting to work and distance employees travel, from any heavy equipment and other laboratory vehicles used, from the chemicals and their amounts purchased by the laboratory, from the amount of natural gas used for space heating, etc. The major emissions are probably from commuter cars. The emissions should be discussed and listed together.

p.3-55 - Have the levels of penetrating radiation (beta and gamma) been measured using a PIC or similar instrument? Should LASL begin an extensive baseline survey to determine background levels? How is it known that 5-15% of the total is due to fallout? Has LASL measured Ra-226, K-40, and other naturally occurring radionuclides in its soils to obtain background levels of these?

p.3-58 - Gross alpha numbers appear to be slightly too low. Are these leaching numbers or measurements "in situ?" In an appendix, how the measurements in soils, air and water were obtained should be briefly described and compared, if possible, with measurements other groups have taken.

p.3-72 - "Land use in Los Alamos" region should be shown on map to indicate what region this is.

p.3-87 - Northern New Mexico is the only school above the high school level.

p.3-89 - There is a County Extension agent and a public library. There is also a home for girls.

p.3-89 - Should mention any taxi service or aid to elderly.

p.3-93 - Has LASL done a comprehensive survey to know how many prehistoric sites are within its boundaries?

p.3-95 - Is Puye Cliffs really under the National Park Service?

p.3-100 Museums of Indian life, art, etc., include:

1. Palace of the Governors
2. The Wheelwright Museum, and special shows in the Museum of Fine Arts and Folk Art Museum. The School of American Research and the Institute of American Indian Arts have collections.

p.3-105 Transmission lines and their rating should be shown on a map.

p.3-116 Are there any heavy metals not listed in Table 1-1 which are discharged? Has anything been done to reduce the nitrate level? When will zero discharge occur? How are contaminants in discharge monitored? What are the sampling errors? Are gamma levels above background at the discharge (outfall) points? What are the gross alpha levels in soils at the outfall? Do radionuclides not treated for, ever enter the waste water treatment system? What radioactive effluents have been emitted from the Omega West Reactor in non-routine cooling water blow down? Does the meson facility ever have radionuclides in liquid discharges? Are there other liquid discharges not mentioned in the DEIS which have occurred? What happens to cooling water blow down for the power plant? What contaminants has this cooling water contained?

p.3-122 The types and locations of the 91 discharges should be listed and described.

p.3-123 Isn't it 10 n Ci/gm gross α?

p.3-125 What is meant by "low amounts" of radioactive contamination?

p.3-125 Is either internal or external corrosion occurring for any of the 55 gallon or 30 gallon drums in retrievable storage?

p.3-125 What specific safety measures are taken in transportation of wastes to the burial site? Are swipe tests taken of the outside of drums before transport?

p.3-126 What prevents contamination of the waste delivery trucks? How is this monitored? How is blowing of wastes from the disposal site prevented? What protections are given to workers at the disposal site? How close are disposal areas to the edge of the mesas? Are any disposal areas located in tuff which contains cooling fractures?

p.3-127 Can plant roots penetrate into the waste material zone? How long does a site have bare soil before plants are established? What is the rate of surface erosion? Do animals which disturb soil such as coyotes and gophers live in the waste areas? Can migration of radionuclides occur in the tuff cooling joints? What will be the curie amount of radionuclides disposed of when Mesita del Buey is full? How will the hazard presented by this site decrease with time? (One way of showing this would be to show for each 100 year interval the amount of dilution water which would be required to achieve MPC's). How do the hazards at other sites decrease with time?

p.3-127 How will the corrugated metal pipe sections be removed when a TRU disposal facility is ready to handle retrievably stored waste? What hazards will retrieval of all retrievable wastes present? Since wastes are stored for only 20 years and storage was started in 1972, what happens if a facility for disposal is not available by 1992?

p.3-128 Is there any evidence of seepage along any of the cliff faces of any of the mesa disposal sites?

p.3-128 How does "special containment" restrict tritium movement?

p.3-128 What happens to the rate of erosion if the amount of rainfall increases?

p.3-129 Is it possible that there are any unknown waste disposal sites?

p.3-130 Is there any evidence of movement of radionuclides from pits and sorption beds?

p.3-130
p.3-131 If Sr, Am, and U are present other radionuclides would also be expected to be present such as I-129 and Np. A complete list of radionuclides (not just fission products and activation products) should be given and ingrowth of other radionuclides discussed. For example, uranium-238 has a long half life with toxic daughters such as Th-230 and Ra-226.

p.3-130 If no records were kept, what are the errors associated with this table?

p.3-134 What is planned for cleanup of the septic tanks?

p.3-136 What is planned for cleanup of the sodium containing tanks?

p.3-136 How many curies of activation products would be expected in the vessel? How are the long-lived products prevented from migrating?

p.3-136 Why aren't some of the hazardous chemical wastes incinerated so they would not need burial? Are these wastes ever contaminated with radionuclides? What will happen to these hazardous chemical wastes in future years?

p.3-136 How many facilities not in active use are contaminated? To what extent are they contaminated? What will be done with the land having surface contamination of U-238? How many acres are known to have surface soils having gross alpha, gross beta or gamma levels above background outside the disposal areas? What was done to decontaminate Acid Canyon and the area behind the Los Alamos Inn? What more needs to be done to reduce contamination to background? Will any other of the Los Alamos canyons having radionuclide contamination be cleaned up? What level of contamination will these be cleaned up to? Is there any evidence that surface contamination is present at any of the burial sites? What is being done about this problem. Have all sites been monitored for surface contamination? Have all sites been monitored for subsurface radionuclide migration? What does this monitoring indicate? What will be done with the contaminated incinerator and its site and associated contaminated wastes? How will buildings and contaminated soils be decontaminated? How will equipment be decontaminated?

p.3-137 Non-routine releases of gaseous effluents in the last ten years should be listed, their curie amounts given and their fate discussed.

p.3-137 How are the releases "monitored?" What are the sampling errors? Is carbon released? Is Kr released? Since HEPA filters do not remove gases, what gases are released from the various facilities? What is released from the reactor? For gaseous and particulate emissions to the atmosphere each source should be listed and the quantity of each contaminate listed. The stack height, diameter, gas temperature, and concentration in ppm of each pollutant should be given. Modeling of pollutant dispersion should be included, (while the terrain is rugged, stack height may be low enough to assume flat terrain). This, in turn, should be tied into the location of ambient monitors.

General - Does the Omega West Reactor meet NRC licensing requirements?

General - More information on quality control is needed. For example, how does LASL know that explosives don't get into combustible waste? How is "hot material" prevented in the low level waste?

Is every piece of waste taken to the radioactive dump monitored? How accurate are monitoring devices? How well does LASL even now know Ci amounts in storage? Is any thought being given to separating long-lived radionuclides from short-lived ones? What is the possibility that radioactive material finds its way into the county dump? Do employees ever take contaminated equipment? What is the level of contamination on equipment which goes to salvage? How many times have contaminated employees "tracked" radioactivity into the town site? What is being done to detect spills and prevent spread of radioactivity? How are leaks in the sewer detected? What is done when a leak in the sewer occurs? What is done with spent reactor and critical assembly fuel? How is this material transported for storage and/or reprocessing? How are other radioactive materials transported to Los Alamos?

p.3-139 What type of badges are used? Are OSHA inspections carried on? Are outside consultants asked to review standard operating procedures? What types of accidents have occurred? What is being done to prevent similar accidents? How often is lung counting and urinalysis performed on employees working in the Plutonium Reprocessing Facitiy, etc. Do LASL employee checks meet NRC regulations for workers in uranium mills, reactors, etc.?

p.3-140 Sources of gamma radiation at LASL should be listed and it should be shown that the location of the TLD stations is reasonable. Gamma surveys of the canyons, waste disposal areas, fence line and individual sites should be conducted routinely with a PIC or similar instrument to detect any increase in gamma levels. Surface soil α levels should be checked. Sources of radioactive particulate should be given and it should be shown by modeling that the air sampling network is suitably located.

p.3-142 How were the surface water run-off sample sites selected? Why isn't there a surface water sampling station in Ancho and Canyon del Buey? Shouldn't surface water sites also include sediment sampling? How were ground water sites selected? Were any special wells drilled?

p.3-147 From the BP ID data, what is the maximum amount of radioactive materials which could have gone to the waste disposal areas since the BP ID system has been in operation? This should be given as to each radionuclide in Ci amounts and compared with the LASL reported numbers for the disposal sites.

p.4-5 Does F pose a problem for drinking water? What levels of Pu were found in the wells in the Los Alamos Field? What were the levels of nitrates?

p.4-5 Non-routine effluent releases should be described.

p.4-8 What is the time frame for upgrading water treatment? Is the money available? What will happen to the evaporated tritium?

p.4-13 Why has the ^{3}H concentration in Pueblo increased?

p.4-14 Wasn't some of the Pu contaminated soil in Acid Canyon removed?

p.4-14 Are there any plans for cleaning up Acid-Pueblo particularly at the 2.56 km distance? Is Acid Pueblo open to the public?

p.4-18 What is the level of extenal gamma radiation at the DP out fall?

p.4-16 How many curies has the operation of reactors in Los Alamos canyon contributed to radioactivity in the canyon?

p.4-18 What are the measurement errors?

p.4-25 What are surface external gamma measurements in Mortandad?

p.4-25 When the radionuclides go into the perched water in Mortandad what happens? If there is downward movement in the tuff could these radionuclides reach the main aquifer? What would be the maximum concentrations expected in this aquifer?

p.4-28 What data is available to indicate aquifers in the Puye Conglomerate contain no radionuclides that can be attributed to the releases of industrial effluents? Nitrate data and Cs data should be given for these various aquifers and springs for these (i.e. one at Totavi and one in Pueblo Canyon).

p.4-28 How are beryllium emissions monitored? How were the levels of NO_x in the power plant effluent obtained? These appear low. Has EIA measured this effluent also; if not, why not?

p.4-28 What future improvements in effluent controls are planned? (are these all discussed on p. 4-29?)

p.4-29 Since monitoring is on a long-term basis, how are sudden unexpected releases detected?

p.4-37 How many Kg of beryllium and mercury have been used in dynamic experiments during the history of LASL?

p.4-55 What do TLD's read near LAMPF?

p.4-55 What hazard to the public does the U-238 deposited on the ground present after hundreds of years when the uranium daughters are present?

p.4-56 What dose to residents did the 22,000 Ci release of tritium give?

p.4-56 What are the neutron emissions from the reactor, critical assemblies, Van de Graaf and Meson facility? What hazards do these emissions represent?

p.4-56
4-68 Has the Cs in deer had any observable effect on the deer (i.e. observable tumors, etc.)? Do rodents show any adverse effects?

p.4-56 What external radiation doses are the workers at LAMPF and Pajarito site receiving? What external doses do workers at the Plutonium Facility receive? Have there ever been any cases of Be poisoning? How many workers have been killed in criticality accidents? In how many cases have special procedures been necessary to decontaminate workers? Have there ever been any deaths due to handling explosives? (workers and non-workers).

p.4-56 Are there any explosives available to the public in old sites now open to the public?

p.4-56 Has plant uptake of radionuclides been observed in plants growing on old burial sites? Do plants respire tritium?

p.4-62 How does LASL intend to protect its disposal areas from disturbance for the times necessary for the radionuclides to decay? What is the time frame for clean up of contaminated sites not located in disposal areas? What long-term monitoring of disposal sites is planned?

p.4-68 How did Sr distribute in the soils. What levels of Sr do the deer have? What levels of Sr do rodents have in their bones? Have radionuclides affected micro organisms in the soils in the canyons?

p.4-68 Even if 9 R/yr does not cause observable effects it should be noted that this dose is above the allowable dose for human occupational exposure even in controlled areas.

p.4-68 What has been the biological uptake of the other beta-gamma emitters in Table 4.1.1-10 and Table 4.1.1-19?

p.4-76 What energy requirements do the workers have in getting to and from work?

p.4-77 What effect has putting salt on the roads had?

p.4-83 If specific meteorological data is not available how will evacuation procedures be determined?

p.4-86 What would happen if there were a natural gas explosion at the reactor? Is sabotage possible for reactor core melt down?

p.4-86 Are there any wooden buildings containing tritium, Pu, Be, or recycling facilities which could explode releasing hazardous materials? What would happen if there were a fire in the old contaminated plutonium processing buildings? How much tritium is stored in Los Alamos?

p.4-93 Has a fire ever occurred in a glovebox containing Pu at the old plutonium site?

p.4-93 What happens if there is a fire in the HEPA filter system also?

p.4-98 Could there ever be a Be fire in a hood in the Beryllium shop? What are the bags in the bag filter made out of? Is an explosion in the beryllium shop possible? How is a hole in the filter detected?

p.4-100 Do LASL aircraft ever carry Pu? If so, what would happen if such an aircraft crashed in Albuquerque or Los Alamos?

p. 4-126 Only Northern New Mexico is located in Los Alamos for education open to the public above the high school level.

p.9-9 A list of the necessary cooling uses and temperatures needed should be given and a discussion of why in each case air cooling (fin-fans) is not feasible.

General Comments

The EIS for LASL should include the following information:

1. More details on the stack monitoring systems. The details of monitoring, the radionuclides and trace elements monitored for, the errors associated with the monitoring, and the materials emitted from the stack and not monitored should be included.

2. More details on the detection of malfunction of HEPA filters, baghouses, etc. The details of detection of channeling around roughing and HEPA filters, holes in the bags, defects in tritium retention systems, etc., should be given.

3. On the occupational exposure. The occupational exposure influences not only the worker but may influence the population for those workers who have not yet had their children. Thus the topic of occupational exposure is a topic which should be included in the EIS. Total exposure over the lifetime of the laboratory, number of deaths from over-exposure, average exposure of workers in the plutonium facility, Meson facility and critical assembly and reactor facility should be included along with maximum individual exposure for 1976 and 1977. Measurement of both internal and external radiation exposure to individuals should be discussed.

4. More details on contaminated buildings not in active use, the possibility for fire in these, and details on other contaminated but not used facilities, is needed. Details on decontamination, time schedules, possible effects on decontamination workers, etc., should be included. Details of decontamination when the laboratory finishes these operations of the uranium surface contaminated areas should be included.

5. More details on how LASL intends to stabilize, maintain, and monitor radioactive waste disposal areas for long time periods should be indicated.

6. More details on hazards associated with removal of waste from retrievable storage and its transport from LASL should be given.

Comments: LASL Draft EIS

p. 2-4 What quantities of fission products from tests in Nevada are shipped to LASL for radiochemical analysis and how are they shipped?

p. 3-55 What are the levels of plutonium and strontium in the soil for the Los Alamos, Espanola and Santa Fe area? Were the studies for Colorado, Ohio and New York done on soils collected in the vicinity of nuclear facilities?

p. 3-112 Is there a regulation which liquid wastes and what amounts (activities) may be transported by pipe? Is there a possibility of chemical reactions in the sewer line that might cause the release of toxic or radioactive gases?

Since part of the industrial sewer line runs across land accessible by the public, how are the pipes protected against willful or accidental destruction?

How is the industrial sewer line monitored for leaks, and how fast would a leak be detected?

p. 3-116 What determines the "lowest practicable level"?

p. 3-120 Is there a contamination of ground water from the disposal of waste oil?

Is the oil used in vacuum pumps included in the figures?

p. 3-123 Type 4 materials: what are recoverable quantities of uranium or plutonium.

p. 3-125 What safety measures are provided for the transport of waste material?

p. 3-129 What are the radiation levels in areas B and V that are accessible by the public?

p. 3-132 How are the 239 Pu contaminated liquid wastes moved from the tanks in Area A to the plutonium processing facility?

How thick is the cover over area A and B?

3-133 How will the waste containers be retrieved?

3-134 Septic tanks release some of the received liquid to the environment. How much uranium and plutonium is expected to have leaked from the septic tanks?

3-134 A list of the radionuclides contained in the paste should be given. (Area T)

3-134 Were these "very low" levels in area V actually measured, or were they assumed from the decay times involved? What means "very low" quantitativly?

3-136 Is the sodium stored in area W stored in dry form (what moisture content?) or in solution? What corrosion problems are anticipated?

3-136 What are the fire explosion hazards associated with the waste in area Y?

3-137 There should be a complete list of accidental releases of radioactive or toxic gases that occured in the past and a comparison of those to the routine releases.

3-140 Are the burial and disposal sites for radioactive and toxic waste specifically monitored? Are samples and measurements taken around the active and inactive disposal sites to detect movement of hazardous material into the environment? If so, how frequent? What will be done if a severe leakage occured at one of the disposal sites?

3-147 How is the source and special material transported to LASL?

4-5 Has it been determined where the high arsenic content in well water from LA-6 originates from?

4-8 What amounts of tritium are expected to be evaporated from solar ponds?

4-28 There have been non-routine releases of tritium that were not contained.

4-34 The 1976 release rate of tritium was about 25400 curies, taking the accidental t-release into account.

4-37 Are the emissions from vacuum system pumps and compressors used at LASL significant?

4-42 What is the exchange rate between tritium gas and hydrogen in water? How far would tritium gas travel if it were released during a heavy rainstorm?

Would it be converted to tritiated water immediately and fall to the ground?

4-53 How are these doses calculated? Do the ^3H figures include the accidental ^3H release of 22 000 Ci?

4-60 & 4-61 What were the radiation levels at the former TA-1 and Bayo Canyon area before removal of the contaminated material and what are they now? Average and maximum readings?

4-82 How was the leak in the industrial sewer line detected? Is this the only spill that ever occured from the line?

4-86 Could an explosion accidentally bring together a critical mass of plutonium?

The chemical toxicity of plutonium and the resulting hazards should be evaluated and discussed in addition to the radiological hazards.

Would the area be decontaminated to a level of 65 $\mu g/m^2$? What radiation levels would be received from the ground contiminated with 65 $\mu g/m^2$ Pu? How large would be the potential risk of Pu-poisoning in animals and persons from this Pu concentration?

4-94 What is the probability for core melting following a loss of coolant accident and why is it incredible?

4-95 What is the justification for the figures postulated as conditions for the maximum credible accident? The figures appear to be too low!

4-96 Tritium could be released through fire, explosion and sabotage also.

4-98 Have there been experiments conducted at LASL in the past that involved biological agents of risk greater than class 1?

(see also comment to p. 4-42): What would happen if the release of tritium to the atmosphere took place during a rainstorm?

Could a tritium release in the building result in an explosion inside the building? What would the consequences be?

General Comments on the Discussion of Accidents

The discussion of possible accidents in chapter 4.2 is considered inadequate.

The data base used in the calculations for accident consequences is not shown to be credible or reasonable, and it is impossible for the reader to determine whether the accident scenarios presented indeed are the worst cases, or credible. Possible, but highly improbable accidents are not discussed.

The concept of discussion of the worst accidents is useful, but accidents with less severe consequences should also be discussed, since they can and will happen with a much higher probability than the worst case accidents.

The whole paragraph (4.2) on accidents lacks a detailed discussion of the possible consequences of the different scenarios. In most cases, the consequences merely are expressed in figures for population exposures. Emergency procedures to follow in case of accidents are not mentioned, do they exist? Restoration, clean up and decontamination after an accident will be a necessity in most of the postulated accidents, but are not discussed. Are there any plans for an evacuation of Los Alamos or White Rock in case of a serious accident affecting these towns.

Is flooding of facilities located in canyon bottoms considered to be impossible? The possiblity of sabotage should also be discussed.

Contrary to the statement on page 11-1 it is thought that off-site transportation of nuclear materials and occupational health exposures should be discussed in the DEIS. The off-site transportation of nuclear materials and radioactive wastes is clearly associated with the activities at LASL and is, therefore, an environmental impact caused by the laboratory.

OMB Approval No. 29-R0218

FEDERAL ASSISTANCE

1. TYPE OF ACTION (Mark appropriate box)
- [ ] PREAPPLICATION
- [x] APPLICATION
- [ ] NOTIFICATION OF INTENT (Opt.)
- [ ] REPORT OF FEDERAL ACTION

2. APPLICANT'S APPLICATION
a. NUMBER:
b. DATE Year month day 19

Leave Blank

3. STATE APPLICATION IDENTIFIER
a. NUMBER: NM 79 07 1 014
b. DATE ASSIGNED Year month day: 1978 07 10

4. LEGAL APPLICANT/RECIPIENT
- a. Applicant Name : U.S. Department of Energy
- b. Organization Unit :
- c. Street/P.O. Box : Mail Station E-201 GNT
- d. City : Washington
- e. County :
- f. State : D.C.
- g. ZIP Code: 20545
- h. Contact Person (Name & telephone No.) : W. H. Pennington 301 353-4241

5. FEDERAL EMPLOYER IDENTIFICATION NO. N/A

6. PROGRAM (From Federal Catalog)
a. NUMBER: 81.001
b. TITLE: State Energy Conservation Program

7. TITLE AND DESCRIPTION OF APPLICANT'S PROJECT

LOS ALAMOS SCIENTIFIC LABORATORY SITE

Draft Environmental Impact Statement DOE EIS 0018 D. The statement assesses the potential comulative environmental impact associated with current 7 continuing activities at the LASL site.

8. TYPE OF APPLICANT/RECIPIENT
A-State, B-Interstate, C-Substate District, D-County, E-City, F-School District, G-Special Purpose District, H-Community Action Agency, I-Higher Educational Institution, J-Indian Tribe, K-Other (Specify):
Enter appropriate letter: E

9. TYPE OF ASSISTANCE
A-Basic Grant, B-Supplemental Grant, C-Loan, D-Insurance, E-Other
Enter appropriate letter(s): A

10. AREA OF PROJECT IMPACT (Names of cities, counties, States, etc.)
City of Los Alamos
Los Alamos County - New Mexico

11. ESTIMATED NUMBER OF PERSONS BENEFITING N/A

12. TYPE OF APPLICATION
A-New, B-Renewal, C-Revision, D-Continuation, E-Augmentation
Enter appropriate letter: A

13. PROPOSED FUNDING

a. FEDERAL	$ .00
b. APPLICANT	.00
c. STATE	.00
d. LOCAL	.00
e. OTHER	.00
f. TOTAL	$ .00

14. CONGRESSIONAL DISTRICTS OF:
a. APPLICANT 01
b. PROJECT 01

15. TYPE OF CHANGE (For 12c or 12e)
A-Increase Dollars, B-Decrease Dollars, C-Increase Duration, D-Decrease Duration, E-Cancellation, F-Other (Specify):
Enter appropriate letter(s):

16. PROJECT START DATE Year month day 19

17. PROJECT DURATION Months

18. ESTIMATED DATE TO BE SUBMITTED TO FEDERAL AGENCY Year month day 19

19. EXISTING FEDERAL IDENTIFICATION NUMBER N/A

20. FEDERAL AGENCY TO RECEIVE REQUEST (Name, City, State, ZIP code)
Federal Energy Administration

21. REMARKS ADDED [ ] Yes [ ] No

22. THE APPLICANT CERTIFIES THAT ▶
a. To the best of my knowledge and belief, data in this preapplication/application are true and correct, the document has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.
b. If required by OMB Circular A-95 this application was submitted, pursuant to instructions therein, to appropriate clearinghouses and all responses are attached:

	No response	Response attached
(1) Technical Assistance & Research	[ ]	[x]
(2)	[ ]	[ ]
(3)	[ ]	[ ]

23. CERTIFYING REPRESENTATIVE
a. TYPED NAME AND TITLE
b. SIGNATURE
c. DATE SIGNED Year month day 19

SECTION I—APPLICANT/RECIPIENT DATA
SECTION II—CERTIFICATION
SECTION III—FEDERAL AGENCY ACTION

24. AGENCY NAME

25. APPLICATION RECEIVED Year month day 19

26. ORGANIZATIONAL UNIT

27. ADMINISTRATIVE OFFICE

28. FEDERAL APPLICATION IDENTIFICATION

29. ADDRESS

30. FEDERAL GRANT IDENTIFICATION

31. ACTION TAKEN
- [ ] a. AWARDED
- [ ] b. REJECTED
- [ ] c. RETURNED FOR AMENDMENT
- [ ] d. DEFERRED
- [ ] e. WITHDRAWN

32. FUNDING

a. FEDERAL	$ .00
b. APPLICANT	.00
c. STATE	.00
d. LOCAL	.00
e. OTHER	.00
f. TOTAL	$ .00

33. ACTION DATE ▶ Year month day 19

34. STARTING DATE Year month day 19

35. CONTACT FOR ADDITIONAL INFORMATION (Name and telephone number)

36. ENDING DATE Year month day 19

37. REMARKS ADDED [ ] Yes [ ] No

38. FEDERAL AGENCY A-95 ACTION
a. In taking above action, any comments received from clearinghouses were considered. If agency response is due under provisions of Part 1, OMB Circular A-95, it has been or is being made.
b. FEDERAL AGENCY A-95 OFFICIAL (Name and telephone no.)

I-30

STATE CLEARINGHOUSE

GRANT AWARD NOTIFICATION

MIS-7

JUDI ROSS
State Planning Officer

STATE PLANNING OFFICE
505 Don Gaspar, Greer Building
Santa Fe, New Mexico 87503
(505) 827-2073

Jerry Apodaca
Governor

TO: State Clearinghouse
State Planning Office
505 Don Gaspar, Greer Building
Santa Fe, New Mexico 87503

DATE: August 8, 1978

FROM: U. S. Department of Energy
Mail Station E 201 GNT
Washington, D. C. 20545

Complete and return this form to the State Clearinghouse upon receipt of federal action.

STATE APPLICATION IDENTIFIER (SAI): 79 07 1 014

TYPE FUNDS:	
__ Grant	Applicant: U. S. Department of Energy
__ Loan	Project Title: Los Alamos Scientific Laboratory Site
__ State Block	Federal Catalog No.: 80001
__ State Appropriation	State Agency:
__ State Funds Only	Funds Requested: $ ________ Federal $ ________ State

ACTION

__ Grant Funded as Submitted __ Grant Amount Increased __ Grant Amount Decreased __ Application Cancelled

IF APPLICATION FUNDED

	Mo.	Day	Yr.
Effective Date of Grant			
Starting Date of Grant			
Ending Date of Grant			

Duration of Grant ________ Months

Federal Basic Amount $________
Federal Supp. Amount $________
State Contribution $________
Local Contribution $________
Other Contribution $________
TOTAL $________

____
Authorized Signature for Project Application

DOE Staff Response to the State of New Mexico's Comments on the Draft Environmental Impact Statement for the Los Alamos Scientific Laboratory Site
DOE/EIS-0018-D

INTRODUCTION. In order to respond to the comments in an orderly fashion that will permit easy cross-referencing between the comments and the Final Environmental Impact Statement (FEIS), two conventions have been employed. First, all comment provided by the Energy and Minerals Department Staff were collated into sequence according to page numbers in the Draft Environmental Impact Statement (DEIS), and these page numbers are used to identify the comments. In many cases, this collation indicated several questions or comments on the same substantive topic or issue. In these cases, these notes generally address only the issue as a whole and may not specifically respond to each variant of the question. Second, all references in the text of these notes are to pages in the FEIS, regardless of whether the information was contained in the DEIS or was added in response to comments received.

A number of comments were addressed to Chapter 1, Summary. That chapter is a brief summary intended to highlight the key issues addressed by the document. Therefore, it is impossible to include numerous details on a given topic. There are acknowledged differences of opinion regarding selection of key topics and extent of detail. Most of the comments were addressed in greater detail in subsequent sections of the DEIS. The notes on chapter 1 comments basically indicate locations in the FEIS where more detail can be found.

Comment Identification (DEIS page no.)	Response
p. 1-5	At the time of publication of the DEIS some operations had been moved to the new plutonium facility, others had not. However, the move is now nearly complete and the text was modified to read "... will continue at least until decontamination of the old plutonium processing facility is completed."
p. 1-5	The chemical and radiochemical quality of the main aquifer is addressed by the routine monitoring program of LASL. Detailed coverage is found in section 4.1.1 of the EIS with the accompanying references. Additional information is included in appendix H, (page H-35).
p. 1-5	Radiation levels and radionuclide concentrations are covered throughout the text. We would refer your comments to sections 4.1.1, 4.1.3 (pages 4-56 through 4-61), and 4.1.5 with their references.
p. 1-5 1-6 1-8	The information found in tables 1-1 and 1-2 is a product of the LASL routine monitoring program. This program is based upon DOE and EPA regulations and guidelines. Details about the monitoring program are found in appendix H, with pages H-102, -103, -106, and -107 giving breakdowns by source.
p. 1-7	We agree that withdrawal of land for various purposes is an environmental impact. As pointed out on page 1-9 of the FEIS, "Unavoidable environmental effects resulting from the continued operation of LASL <u>include land use</u>, resource consumption, and effluent release." All possible combinations of accidents could not be covered in this summary, but rather a spectrum of "worst case" events, which have a potential of occurrence within the framework of LASL operations. Section 4.2.4 addresses a serious onsite transportation accident of the nature requested, but points out that the serious transportation accident discussed in the DEIS could no longer happen. Page 3-162 shows that air shipments of plutonium were terminated in 1977.

Comment Identification (DEIS page no.)	Response
p. 1-9	Radionuclide content of material placed in disposal pits and sorption beds are shown in tables 3.3.3-2 and 3.3.3-3. Releases to the canyon systems are covered in detail by individual canyon in section 4.1.1.
p. 1-12	The comment that "irreversible changes in the ecological patterns of the area as vegetation and animal populations have changed, due to surface water availability, human activities, etc.,..." is true. However, these are localized phenomena adjacent to stream channels or located on land areas which have undergone construction activities. The major patterns evident within ecosystems established by the southwestern climatic and edaphic conditions have not changed. No major shift in these patterns would occur without a change in climatological conditions and/or a major catastropic event that altered the fundamental nature of the local environs.
p. 2-4	Text additions show all fission products from Nevada are shipped to LASL "in accordance with current Department of Transportation regulations."
	Discussion on health hazards of uranium begins on page 4-48.
p. 2-6	The text was modified to point out historical value of Scyllac.
p. 2-10	The text was modified to read "..., and techniques to separate tritium gas from the molten lithium blanket in fusion reactors are being considered."
p. 2-11	The text was modified to indicate actual use of subterrene drill program in a historical context.
p. 2-13	The high energy gas laser facility is covered in a new paragraph which addresses current programmatic goals.

Comment Identification (DEIS page no.)	Response
p. 2-14	The plutonium facility "... was completed in 1979."
p. 3-8	The text was modified to read "In the Los Alamos area, the Cerro Toledo Rhyolite and the Bandelier Tuff are the only formations of the Tewa group that crop out."
p. 3-12	Laboratory facilities are not located across any known fault zones.
p. 3-50	A rather extensive section of the EIS, section 4.1.1, covers both water quality and quantity for LASL and the surrounding region. We would refer your comments on drainage, water quality, and water consumption to this section.
p. 3-51	The text was modified to show that the county waste-water treatment facilities "meet the most recent EPA requirements for secondary treatment facilities and have been upgraded to be in full compliance with the National Pollutant Discharge Elimination System (NPDES)."
	Atmospheric emissions are covered in section 4.1.2, and we would refer your comments to this section with its accompanying references.
p. 3-55 3-58	These comments on radiation monitoring address the two areas of monitoring methodology and monitoring results. As suggested, an appendix has been added, and we refer your comments specifically to pages H-20, H-21, and H-61 through H-72.
p. 3-72	Land ownership in the Los Alamos region by county is presented in table 3.2.1-3, see figure 3.2-1 for location of counties.
p. 3-87	The sentence was changed to read "... a branch of the Northern New Mexico Community College."
p. 3-89	A new paragraph was inserted to point out the various community services and service organizations that exist.

Comment Identification (DEIS page no.)	Response
p. 3-93	The text was modified to read "A Laboratory report, LASL 77-4, 'Pajarito Plateau Archaeological Survey and Excavations' documents the sites within LASL boundaries."
p. 3-95	"Under the jurisdiction of the National Park Service" was deleted from the text.
p. 3-100	Museum of Navajo Ceremonial Art was replaced with Wheelwright Museum.
p. 3-105	Power transmission lines are discussed in the new material added to the text (pages 3-65 through 3-68) and transmission lines are shown on fig. 3.3.1-1.
p. 3-112	The concentrations of radionuclides which may be transported by sewer pipe are limited by administrative controls and standard operating procedures as stated on page 3-125.
	The possibility of chemical reactions in the sewer line is remote in that waste chemicals are appropriately neutralized at several neutralization stations tied to the system. This information is on page 3-118.
	The industrial sewer lines do cross DOE lands open to the public and the remote possibility exists for their willful destruction. However, these lines are buried and routinely patrolled by the DOE security force. A monitoring system does exist which would detect gross leaks in the lines (page 3-125); however, a slow leak was discovered in 1974 as described on pages 4-94 and 4-103. A replacement for the existing system is planned. The new system will be an electronically monitored double-encased industrial system and is described on pages 2-14 and 4-90.
p. 3-116	Table 4.1.2-4 lists the maximum potential releases of cadmium and beryllium to the atmosphere and page 4-43 mentions releases of uranium due to dynamic experimentation. Also, see the section on nonradioactive effluents in Appendix H, starting on page H-36.

Comment Identification (DEIS page no.)	Response
	The nitrate levels should be reduced with the completion of the planned upgrading of the treatment plant, and zero discharge could occur if the proposed solar ponds are funded. Sample monitoring is accomplished by taking both proportional and grab samples in accordance with the guidelines set forth in the NPDES permit.
	Radiation levels at the discharge or outfall points are discussed on page 4-77, detailed measurements were reported in ref. 4-23.
	Tritium is the only radionuclide not treated by the waste water treatment system. Tritium and its associated problems are discussed on pages 3-132, -135, -136, and 4-46.
	Emissions from the Omega West Reactor are discussed in the new paragraph on page 4-19.
	Discharges from the Meson Facility and other liquid discharges are covered on pages 3-129, H-28, and H-29, section 4.3.1, and H-36 through H-39.
	Page H-33 points out that Sandia Canyon receives cooling tower blowdown and page H-107 shows the effluent quality summary for the cooling water.
	Lowest practicable level is defined as "as low as technically and economically achievable."
p. 3-120	The text was modified to point out that most motor vehicle oil is taken by a commercial firm for reprocessing. No contamination of ground water from disposal at the county-operated landfill has been detected by the LASL ground water monitoring network.
p. 3-122	The types and general locations of the discharges are covered in section III.B.3.b of appendix H.
p. 3-123	The 10 nCi/g applies only to transuranics.

Comment Identification (DEIS page no.)	Response
p. 3-125	Section 3.3.3 of the EIS was completely rewritten to cover solid wastes in more detail. Transportation procedures are also addressed in section 3.3.5. We believe all comments from your staff are addressed by this improvement.
p. 3-126	All trucks are monitored before and after waste hauling, as pointed out on page 3-132. Workers at the waste disposal site are protected by the continuous monitoring and the health physics technician who is always present. Some disposal areas are located in tuff with fractures as mentioned on page 3-135. We are aware of this and are monitoring.
p. 3-127	The general subject area of biological uptake of radionuclides, soil-biota interface, and ecological fate of radioactive contaminants is covered on pages 4-76 through 4-79. Comments on the rate of surface erosion and subsequent exposure of buried wastes are referred to page 3-136. As previously mentioned, tritium has migrated through the tuff following fractures, areas of high porosity, and along interfaces between ashflows (page 3-135). The radioactive waste capacity of the Mesita del Buey disposal area and the curie amount of radionuclides buried is covered on pages 3-129 and 3-130. The comment was made that one way to show the decrease in the hazard presented by this site through time would be to "show for each 100 year interval the amount of dilution water which would be required to achieve Maximum Plutonium Concentrations (MPC's)." This method is not considered useful for this locale because the tuff is too dry. Long-term waste management alternatives for the buried and retrievably stored wastes is the topic of a recently initited study by the LASL Health Division. A new paragraph has been added to the EIS covering this topic on page 3-134.

Comment Identification (DEIS page no.)	Response
p. 3-128	Seepage from the mesa disposal sites is not occurring because there is insufficient moisture for saturated flow to occur. See pages 3-135 and 3-136 for related discussion.
	Comments on tritium are referred to on page 3-132.
	Comments on erosion of the waste sites are referred to on page 3-136.
p. 3-129	Radiation levels in Area B are not above background. Area V is not accessible and is posted with "No Trespassing" signs. See table 3.3.3-2 and page 3-136.
	The probability that there are any unknown waste disposal sites is vanishingly small; see new discussion on pages 11-2 and 11-3.
p. 3-130	Comment on movement of radionuclides is referred to pages 3-135 and 3-136.
	Comment on errors associated with the table are referred to page 11-2 and reference 3-111B.
p. 3-130 p. 3-131	For additional information on radionuclides, see pages 3-140 and 3-143. If the ingrowth of other radionuclides is significant, it will be addressed in the management alternatives.
p. 3-132	The movement of the contaminated liquid wastes is through an underground pipe. See page 3-141.
	For more detailed information on Areas A and B, see reference 3-111B.
p. 3-133	The waste management alternatives study (page 3-134) will address and evaluate options for waste container retrieval.
p. 3-134	These tanks will be removed when funds become available. Until they are excavated, there is no specific data on contamination levels.

Comment Identification (DEIS page no.)	Response
	The radionuclide content of the paste is "^{90}Sr, ^{238}Pu, ^{241}Am, ^{132}Cs, and Uranium" (page 3-144). See the tables on pages 3-138, 3-139, and 3-140 for more detail.
	Text modified to read "Based on their short half-lives, these nuclides have decayed to an undectable level." (page 3-144).
p. 3-136	Comments on sodium are referred to the new material on Areas W and X (page 3-145).
	Incineration of chemical wastes is not considered practical. If these wastes are radioactively contaminated, they are put in Area G.
	All wastes in Area Y are buried, and no associated fire hazards are known to exist.
	The comments on contamination are referred to pages 3-145 and 3-146.
	For details on Acid Canyon and the area behind the Los Alamos Inn, see section 4.1.4 and reference 4-102.
	For information about ongoing evaluations, see the discussions on the Formerly Utilized Sites Remedial Action Program (FUSRAP) program included in sections 4.1.1 and 4.1.4.
	Comments on contamination in regard to the burial sites are being addressed by the waste management alternatives study in progress (page 3-134).
	Comments on the incinerator and its site are referred to page 3-146, and references 3-112 and 3-112A.
p. 3-137	Comments on nonroutine gaseous effluents are addressed in the new material on page 3-148.
	Details on gaseous radioactive effluents are found on page H-102.
	Comments on pollutant dispersion are referred to the material on pages 3-147 and 3-148 and the section on air monitoring starting on page H-11. Monitors are located so as to intercept dispersion in many directions.

Comment Identification (DEIS page no.)	Response
p. 3-139	Two types of badges are used: film and thermoluminescent dosimeters (page 3-150). General protective measures for workers are discussed on page 3-150. The dosimetry requirements of DOE regulations meet the Federal radiation protection standards incumbent on all Federal agencies (pages 4-62 and 4-63).
p. 3-140	The comments on radiation sources and monitoring are referred to Appendix H and the section on waste management alternatives on page 3-134.
p. 3-142	Monitoring site selection criteria are addressed briefly in the new material (page 3-153). appendix H provides much more detail on all aspects of monitoring procedures. Comments on Ancho and Canyon del Buey are referred to appendix H. In addition, see section 4.1.1 and pages 4-13 and 4-15 and associated references regarding monitoring.
p. 3-147	Comments on Book Physical Inventory Difference (BPID) are referred to the new material on page 3-158. Comments on Special Nuclear Material transportation are referred to the new section 3.3.5.
p. 4-5	Comments on drinking water are referred to H-91 and H-92. See pages H-39 for an explanation of the NPDES permit which covers all industrial releases and page H-107 for deviations from permit conditions. In addition, see page 4-93 for accidents. Comments on the high arsenic content of Well LA-6 are referred to reference 4-6A.
p. 4-8	These comments are referred to the new material (page 4-11) on the planned treatment plant upgrading and the proposed solar ponds.

Comment Identification (DEIS page no.)	Response
p. 4-13	Tritium concentration has remained in the same range over time. See the correction and additions to table 4.1.1-6 on page 4-17.
p. 4-14	Comments on Acid-Pueblo are referred to pages 4-69 and H-54.
p. 4-16	See the discussion on the three reactors on page 4-19.
p. 4-18 p. 4-25	These comments on external gamma radiation are referred to reference 4-23 (page 30) and Appendix H.
p. 4-25	The new material on page 4-29 shows that no plutonium or cesium migration was detectable, and that tritium was measurable to depths of 8 m.
p. 4-28	Comments on the aquifers are referred to page 4-15 and detailed data in appendix H. (pages H-89, -90, -93, -94, and -95). Comments on beryllium emissions are referred to H-37. The New Mexico Environmental Improvement Division (EID) does not monitor this emission as the plant heat input is below the regulatory threshold. See page H-37. Comments on the future improvements in effluent controls are referred to the summaries in Chapter 9.
p. 4-29	For more detail on detection of unexpected releases, refer to the discussion on monitoring at the new plutonium facility (page 3-148) and the material on accident response (page 4-93).
p. 4-34	The 25,400 curies mentioned in your comment is the total for the year. For more information about the accident, see page 4-94.
p. 4-37	Comments on emissions from the vacuum pumps and compressors are referred to the new material on page 4-43. Total use of beryllium and mercury in dynamic testing is unknown; however, recent years are documented. See pages 4-45 and H-104.

Comment Identification (DEIS page no.)	Response
p. 4-42	Due to the slow oxidation rate of tritium, a heavy rainfall should make little difference. See page 4-46 and the associated references.
p. 4-53	See the new tables 4.1.3-2 and 4.1.3-3. See page 4-94 regarding accidental release.
p. 4-55	For details on monitoring near the Los Alamos Meson Production Facility (LAMPF), see pages H-9 through H-11.
	Comments on the health hazard of ^{238}U are referred to pages 4-48 and 4-79, and specifically reference 4-112.
p. 4-56	Comments on worker radiation doses are referred to the material on pages 4-62 and 4-64.
	Comments on accidents causing death are referred to page 4-95 and reference 4-117A.
	Comments on protection of workers are referred to the new material on pages 4-62 and 4-63.
	Plant uptake of radionuclides is discussed on pages 4-76 and 4-77 and in reference 4-25.
	Discussions of the effects of contamination on natural fauna is found on pages 4-76 and 4-77, and in the associated references.
	The comment on tritium is referred to page 4-94 and reference 4-36.
	The comments on neutron emissions are referred to the discussions on LAMPF on page H-11, and in reference 4-124.
p. 4-60 p. 4-61	These comments on TA-1 and the Bayo Canyon area are referred to the new material on pages 4-67 through 4-69 and reference 4-102.
p. 4-62	These comments are referred to the ongoing waste management alternatives study. See page 3-134.
p. 4-68	Comment on rodent populations. See page 4-77 and reference 4-111.

Comment Identification (DEIS page no.)	Response
	For some data on strontium, see page H-101. There have not been any extensive studies on this subject to date.
	The regulations are for dosages received. See the new material on page 4-77.
	The comments on biological uptake are referred to the two studies mentioned on page 4-77 and the results in reference 3-66A.
p. 4-76	Comments on energy requirements for travel by workers are referred to the table on page 4-123.
p. 4-77	Details on the use of salt and the subsequent impacts of this practice are discussed in the new material on page 4-86 and references 4-114A, B, C, and D.
p. 4-82	For further information on the leak from the industrial sewer line, see reference 4-126.
p. 4-83	For discussion of evacuation procedures, see section 4.2 on potential impacts of accidents (page 4-93).
p. 4-86	It would be impossible to bring together a critical mass due to an accidental one-point explosion. See page 4-98.
	Comments on the chemical toxicity of plutonium are referred to pages 4-48 through 4-53 and their accompanying references.
	The EPA proposed guidance as it relates to accidental dispersions of plutonium has been included on page 4-98.
	The probability of a reactor core meltdown is vanishingly small. Sabotage would even be more improbable due to security measures.

Comment Identification (DEIS page no.)	Response
	The comment on tritium is referred to on pages 4-106 and 4-110.
p. 4-93	Due to the nature of the material handled by glove boxes, some fires are to be expected. They have occurred without release to the environment, and the new facility is especially designed for this contingency. See page 4-103 for discussion on this and the HEPA filter system fire protection.
p. 4-94 p. 4-95	Comments on core melting and the maximum credible accident are referred to pages 4-104, 4-105, and the reference 4-132.
p. 4-96	Possible release by various causes is covered in the accident section on page 4-95.
p. 4-98	Biological agents can fall into class 2. See page 4-108.
	Due to the slow oxidation rate of tritium, a heavy rainfall should make no difference. See page 4-46 and the associated references.
	We assume your comment refers to the accident in section 4.2.11. It is theoretically possible that a tritium release inside a building could lead to an explosion. However, the accident analysis included assumes that all tritium would be oxidized and subsequent consequences would be no worse than stated.
	See new material on pages 4-108 and 4-109 for comments on beryllium shop.
p. 4-100	Air shipments of plutonium to or from Los Alamos were terminated in 1977. See page 3-162.
p. 4-126	See new material on education on page 4-139.
p. 9.9	Comments on cooling uses and practices are referred to the new discussion on page 9-9.

GENERAL COMMENTS

Several pages of general comments were received. Most of the issues raised have been addressed in the preceding notes. However, to insure that key issues are not bypassed, the following detailed referencing is included.

The Omega West Reactor is under the jurisdiction of DOE and meets DOE standards for research reactors. These are equivalent to the Nuclear Regulatory Commission (NRC) standards (page 2-10).

For the series of questions on quality control and safeguards in handling radioactive wastes, a detailed discussion can be found on pages 3-130 and 3-132.

The question is raised about how much contamination is present on material going to salvage. See page 3-147.

For information on employees "tracking" radioactivity into the townsite, see page 4-93.

For details on the industrial sewer line and accidents with the system, see pages 3-125, 4-94, and 4-103.

A new section has been added (section 3.3.5), which addresses transportation of radioactive materials.

As previously mentioned, all possible combinations of accidents could not be covered in this statement, but rather a spectrum of "worst case" events possible within the framework of LASL operations. See the material on pages 4-94, 4-95, and 11-3, and note the many referenced documents as well as the Standard Operating Procedures (SOP's) and safety studies which could not be included in any detail in this statement.

The Final EIS contains more material on accidents in section 4.2. This information answers several questions posed by your staff.

We would again refer questions about cleanup and restoration to the discussions of decontamination and decommissioning (pages 3-145 and -148) and the accidental spill covered on pages 4-94 and 4-103.

Possible accidents are discussed on page 4-95, and flooding is discussed in section 3.1.2. Sabotage would be very unlikely due to the security measures taken.

Both on and offsite transportation of nuclear material is documented. See sections 3.3.5, 4.2.14, and page 11-5.

The comments on the stack monitoring system and gaseous wastes are referred to the new material on pages 3-147, 3-148, and H-102.

The comments on occupational exposure are referred to the new dicussion of laboratory-wide exposure experience described on pages 4-62, 4-63, and the table on 4-64.

Several comments were made about decontamination procedures. These comments are answered by the section on decontamination (starting on page 3-145) and its references.

The comments on long-term monitoring of the waste disposal areas and the removal of waste from retrievable storage are being addressed by the long-term waste management alternatives study currently underway at LASL. See page 3-134.

State of New Mexico

DEPARTMENT OF GAME AND FISH

STATE CAPITOL
SANTA FE
87503

September 5, 1978

Mr. W. H. Pennington, Director
Division of Program Review
and Coordination
Office of NEPA Affairs
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

I have reviewed the Draft Environmental Impact Statement, Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico. I have the following comments pertaining to wildlife.

The discussions and data concerning wildlife are very good. Prior to establishment of the Laboratory, the area supported an abundance of deer, turkey, bear, small mammals, birds and other wildlife. Construction of facilities and the influx of people have placed adverse effects upon wildlife, and populations are greatly reduced from their previous numbers.

Administrators of the Laboratory have always recognized that wildlife is a valuable resource to the State of New Mexico and, in particular, to the County of Los Alamos and have demonstrated many efforts to preserve the well-being of the wildlife concomitant with the requirements of the Laboratory. Continuance of past studies, initiation of new studies as they become needed and the implementation of mitigating measures should provide for the continuance of this faction of the natural environment.

The New Mexico Department of Game and Fish is charged with the responsibility to provide an adequate and flexible system for the protection of the game and fish of New Mexico and for their use and development for public recreation and food supply, and to provide for their propagation, planting, protection, regulation and conservation. Because of this responsibility, I request that close coordination be maintained between our agencies to achieve the above goals.

Mr. W. H. Pennington September 5, 1978

Find attached: Suggested Corrections on Wildlife Species and Editing; a list of Plants in New Mexico that are Official Candidates for the Federal Endangered(E)/Threatened(T) Species List; and the State Game Commission's Regulation No. 563 for Protection of Endangered Species and Subspecies of New Mexico.

Thank you for the opportunity to review and comment upon the Draft Statement.

Sincerely,

Harold F. Olson

Harold F. Olson
Director

Enc. 3

STATE GAME COMMISSION'S
REGULATION NO. 563

As adopted January 24, 1975, and amended March 7, 1975, December 5, May 21, 1976, and February 10, 1978

Pursuant to the authority vested in the State Game Commission by the provisions of Section 53-2-54, New Mexico Statutes Annotated, 1953 Compilation, the following regulation is hereby made and adopted concerning:

PROTECTION OF ENDANGERED SPECIES AND SUBSPECIES OF NEW MEXICO

The following forms of wildlife indigenous to New Mexico are found to be endangered within the state, as the term "endangered" is defined by Section 53-2-51 D, and are therefore declared to be subject to the provisions of Section 53-2-50 through 53-2-59, New Mexico Statutes Annotated, 1953 Compilations:

ENDANGERED SPECIES AND SUBSPECIES OF NEW MEXICO

Group No. 1. Species and subspecies whose prospects of survival or recruitment in New Mexico are in jeopardy (species marked with asterisk are on the federal list).

Mammals

white-sided jackrabbit, *Lepus callotis gaillardi*
*(Mexican) wolf, *Canis lupus baileyi*
*black-footed ferret, *Mustela nigripes*
river otter, *Lutra canadensis sonora*
*jaguar, *Felis onca arizonensis*

Birds

little blue heron, *Florida caerulea*
gray hawk, *Buteo nitidus maximus*
*bald eagle, *Haliaeetus leucocephalus*
caracara, *Caracara cheriway audubonii*
*peregrine falcon, *Falco peregrinus anatum*
aplomado falcon, *Falco femoralis septentrionalis*
white-tailed ptarmigan, *Lagopus leucurus altipetens*
sharp-tailed grouse, *Pedioecetes phasianellus columbianus*
sage grouse, *Centrocercus urophasianus*

Birds (Contd.)

*whooping crane, *Grus americana*
coopery-tailed trogon, *Trogon elegans canescens*
buff-breasted flycatcher, *Empidonax fulvifrons pygmaeus*
sulphur-bellied flycatcher, *Myiodynastes luteiventris swarthi*

Reptiles

Gila monster, *Heloderma suspectum suspectum*
(New Mexican) ridge-nosed rattlesnake, *Crotalus willardi obscurus*

Fish

American eel, *Anguilla rostrata*
*Gila trout, *Salmo gilae*
blue sucker, *Cycleptus elongatus*
gray redhorse, *Moxostoma congestum*
bonytail chub, *Gila elegans*
Gila chub, *Gila intermedia*
Chihuahua chub, *Gila nigrescens*
*Colorado River squawfish, *Ptychocheilus lucius*
southern redbelly dace, *Phoxinus erythrogaster*
bluntnose shiner, *Notropis simus*
silverband shiner, *Notropis* cf. *shumardi*
Arkansas River shiner, *Notropis girardi*
*Pecos gambusia, *Gambusia nobilis*
*Gila topminnow, *Poeciliopsis occidentalis occidentalis*

Crustaceans

Socorro isopod, *Exosphaeroma thermophilum*

Group No. 2. Species and subspecies whose prospects of survival or recruitment within the state are likely to be in jeopardy within the foreeseeable future.

Mammals

Arizona shrew, *Sorex arizonae*
southern yellow bat, *Lasiurus ega xanthinus*
(Tularosa) black-tailed prairie dog, *Cynomys ludovicianus* ssp.
southern pocket gopher, *Thomomys umbrinus emotus*
Nelson's pocket mouse, *Perognathus nelsoni canescens*

Mammals (Contd.)

coatimundi, *Nasua narica molaris*
marten, *Martes americana origenes*
mink, *Mustela vison energumenos*

Birds

olivaceous cormorant, *Phalacrocorax olivaceus* sspp.
Mississippi kite, *Ictinia mississippensis*
zone-tailed hawk, *Buteo albonotatus*
black hawk, *Buteogallus anthracinus anthracinus*
osprey, *Pandion haliaetus carolinensis*
(Mexican) turkey, *Meleagris galloprvo mexicana*
(inland) least tern, *Sterna albifrons athalassos*
buff-collared nightjar, or Ridgway's whip-poor-will, *Caprimulgus ridgwayi*
blue-throated hummingbird, *Lampornis clemenciae* sspp.
violet-crowned hummingbird, *Amazilia violiceps elliotti*
white-eared hummingbird, *Hylocharis leucotis borealis*
broad-billed hummingbird, *Cynanthus latirostris*
red-headed woodpecker, *Melanerpes erythrocephalus caurinus*
Gila woodpecker, *Melanerpes uropygialis uropygialis*
thick-billed kingbird, *Tyrannus crassirostris pompalis*
beardless flycatcher, *Camptostoma imberbe ridgwayi*
Bell's vireo, *Vireo bellii* sspp.
varied bunting, *Passerina versicolor* sspp.
Baird's sparrow, *Ammodramus bairdii*
yellow-eyed junco, *Junco phaeonotus palliatus*
McCown's longspur, *Calcarius mccowni*

Reptiles

smooth softshell turtle, *Trionyx muticus muticus*
(western) spiny softshell turtle, *Trionyx spiniferus hartwegi*
(Texas) slider turtle, *Chrysemys concinna texana*
bunchgrass lizard, *Sceloporus scalaris*
(sanddune) sagebrush lizard, *Sceloporus graciosus arenicolous*
mountain skink, *Eumeces callicephalus*
giant spotted whiptail lizard, *Cnemidophorus burti stictogrammus*

rough green snake, *Opheodrys aestivus*
(Sonora) coachwhip, *Masticophis flagellum cingulum*
(blotched) plain-bellied water snake, *Natrix erythrogaster transversa*
narrow-headed garter snake, *Thamnophis rufipunctatus*
(Pecos) western ribbon snake, *Thamnophis proximus diabolicus*
Trans-Pecos rat snake, *Elaphe subocularis*
Sonora mountain kingsnake, *Lampropeltis pyromelana pyromelana*
lyre snake, *Trimorphodon biscutatus*
Arizona coral snake, *Micruroides euryxanthus euryxanthus*
(mottled) rock rattlesnake, *Crotalus lepidus lepidus*
(Arizona black) western rattlesnake, *Crotalus viridis cerberus*
Mojave rattlesnake, *Crotalus scutulatus scutulatus*

Amphibians

Jemez Mountains salamander, *Plethodon neomexicanus*
Sacramento Mountain salamander, *Aneides hardyi*
(eastern) barking frog, *Hylactophryne augusti latrans*
Colorado River toad, *Bufo alvarius*
western (boreal) toad, *Bufo boreas boreas*
(Blanchard's) cricket frog, *Acris crepitans blanchardi*

Fish

Mexican tetra, *Astyanax mexicanus*
Zuni mountain sucker, *Pantosteus discobolus yarrowi*
roundtail chub, *Gila robusta*
loach minnow, *Tiaroga cobitis*
suckermouth minnow, *Phenacobius mirabilis*
roundnose minnow, *Dionda episcopa*
("Canadian") speckled dace, *Hybopsis aestivalis tetranemus*
spikedace, *Meda fulgida*
rainwater killifish, *Lucania parva*
Pecos pupfish, *Cyprionodon* sp.
"Chihuahua" pupfish, *Cyprinodon* sp.
White Sands pupfish, *Cyprinodon tularosa*
bigscale perch, *Percina macrolepida*
greenthroat darter, *Etheostoma lepidum*
brook stickleback, *Culaca inzanslans*

Suggested Corrections on Wildlife Species and Editing

Page 3-43

para. 5 - kestral = kestrel

para. 6 - table 3.1.4-2, and appendices C and D. The list of endangered species is inaccurate (see our attached list), i.e.

Spotted bat - has never been listed by the New Mexico Department of Game and Fish or the U. S. Fish and Wildlife Service.

Mexican duck - has been delisted by the New Mexico Department of Game and Fish and will be by the U. S. Fish and Wildlife Service about August 24, 1978.

Southern bald eagle - is now simply bald eagle.

Prairie falcon, merlin, and ferruginous hawk - have never been listed by the New Mexico Department of Game and Fish or the U. S. Fish and Wildlife Service.

Jemez Mountains salamander - not shown in table.

Rio Grande cutthroat trout - has never been listed by the New Mexico Department of Game and Fish or the U. S. Fish and Wildlife Service.

Proserpine shiner - the species in question should be the bluntnose shiner, which has occurred near Cochiti Lake.

Suckermouth minnow - does not occur in Rio Grande.

Appendix A

p. A-2 Atriplex canescens is in the Chenopodlaceae - not the Caryophyllaceae.
Achilla = Achillea
Antennaria paruifolia = parvifolia

p. A-8 Iradaceae = Iridaceae
add Monarda austromontana under Labiatae
Petalostemun = Petalostemon (also on p. A-9)

p. A-12 Rubus perviflorus = parviflorus

p. A-13 Penstemon lentus not known from N.M.

Appendix B

p. B-1 The 9-12 members of the order Lepidoptera is a mere fraction of the total species present at LASL.

Appendix C

p. C-1 Cynomys leucorus = gunnisoni

p. C-2 Are there voucher specimens available of Microtus pennsylvanicus?

p. C-3 Carpoides spp. = carpio

Appendix D

p. D-3 The rufous hummingbird is not known to nest in N.M.
The western wood pewee is not a yearlong resident anywhere in N.M.

p. D-4 Aphelocona - Aphelocoma

p. D-5 The northern waterthrush is a warbler, not a thrush.
The blue-gray gnatcatcher is not a yearlong resident.
The red-eyed vireo is casual or irregular.
The yellow and black-throated gray warblers are not winter residents.

P. D-6 Dendroica vireni = virens
Molothrus alter = ater
The Townsend's warbler is not a winter resident.
The chestnut-sided warbler is casual or irregular.

p. D-7 Chlorua chlorua = Pipilo chlorurus
The clay-colored, field, and golden-crowned sparrows casual and irregular.

Plants in New Mexico that are Official Candidates for the Federal Endangered(E)/Threatened(T) Species List

APIACEAE
- Aletes filifolius - T[3]

ASTERACEAE
- Chaetopappa hershyi[1] - T
- Erigeron rhizomatus - E[2]
- Helianthus paradoxus - E
- Helianthus praetermissus - E
- Perityle (Laphamia) cernua - T
- Perityle lemmonii - T[3]
- Perityle staurophylla - T[3]
- Plummera floribunda - E[2]
- Senecio quaerens - T

BORAGINACEAE
- Cryptantha paradoxa[1] - T

BRASSICACEAE
- Draba mogollonica - T[3]
- Lesquerella aurea - E[2]
- Lesquerella goodingii - T[3]
- Lesquerella lata - E[3]
- Lesquerella valida - E[3]

CACTACEAE
- Coryphantha scheeri var. uncinata[1] - E
- Coryphantha sneedii var. leei - T
- Coryphantha sneedii var. sneedii - E
- Echinocereus triglochidiatus var. inermis[1] - E
- Echinocereus fendleri var. kuenzleri - E
- Echinocereus lloydii - G
- Mammillaria orestera - T
- Opuntia arenaria[1] - T
- Pediocactus papyracanthus - T
- Pediocactus knowltonii - E
- Sclerocactus mesae-verdae - E

CAPRIFOLIACEAE
- Symphoricarpos guadalupensis[1] - T

CARYOPHYLLACEAE
- Silene planlkii - E[2]

CHENOPODIACEAE
- Atriplex griffithsii - E[3]

COMMELINACEAE
- Tradescantia wrightii - T

CRASSULACEAE
- Graptopetalum (Echeveria) rusbyi[1] - E[2]

FABACEAE
- Astragalus accumbens - T
- Astragalus altus - T
- Astragalus castetteri - E[3]
- Astragalus oocalycis[1] - E
- Astragalus puniceus var. gertrudis - T
- Astragalus siliceus - T
- Dalea (Petalostemum) scariosa - T[3]
- Sophora (formosa) arizonica[1] - E
- Sophora gypsophila var. guadalupensis -

HYDROPHYLLACEAE
- Nama xylopodum[1] - T[3]

LILLIACEAE
- Allium gooding[i]i - T

ONAGRACEAE
- Oenothera organensis - T

PAPAVERACEAE
- Argemone pleiacantha var. pinnatisecta -

PLUMBAGINACEAE
- Limonium limbatum - T[3]

POACEAE
- Muhlenbergia villosa[1] - T
- Puccinellia parishii[1] - T

POLEMONIACEAE
- Phlox caryophylla[1] - T

POLYGALACEAE
- Polygala rimulicola - T
- Eriogonum densum - T
- Eriogonum gypsophilum - E[2]

POLYPODIACEAE
- Cheilanthes pringlei[1] - T
- Notholaena lemmonii[1] - T

RANUNCULACEAE
- Aquilegia chaplinei - E[2]

ROSACEAE
- Potentilla sierra-blancae - E[2]
- Rosa stellata - T[3]
- Vauquelinia pauciflora - T

SAXIFRAGACEAE
Philadelphus ernestii[1] - T

SCROPHULARIACEAE
Scrophularia (coccinea) macrantha - E[2]

VALERIANACEAE
Valeriana texana[1] - T

VISCACEAE
Arceuthobium apachecum - T[3]

[1]May not occur in N.M.
[2]Probably should be threatened
[3]Probably should be delisted

DOE Staff Responses to State of
New Mexico Department of Game and Fish
on the Draft Environmental Impact Statement
for the Los Alamos Scientific Laboratory
DOE/EIS-0018-D

With regard to the comment on maintaining coordination, there is full intention of continuing cooperation in all appropriate ways. Furthermore, we wish to express our appreciation to your department for assistance afforded the LASL environmental groups from time to time in the collection of samples. Detailed corrections and comments on species lists were considered and appropriate changes made in the document.

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

ER 78/589

AUG 3 0 1978

Mr. W. H. Pennington, Director
Division of Program Review
and Coordination
Office of NEPA Affairs, EV
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

Thank you for your letter of June 27, 1978, transmitting copies of the draft environmental statement for the Los Alamos Scientific Laboratory site, Los Alamos and Santa Fe Counties, New Mexico. Our comments are arranged by subject or according to the format of the statement.

Water Resources

The draft statement adequately addresses the aspects of water supply, water use and waste water disposal. It also indicates that surface flow from intermittent streams occasionally reaches the Rio Grande River. This flow transports sediment-bound radioactive wastes to downstream areas. In view of the planned increase in facilities at the site and possible corresponding increases in storm runoff, we believe it is important to continue the surveillance program along the Rio Grande and its tributaries for monitoring water quality and sediment as it relates to radioactive waste.

On page 3-16 of the draft statement, it is stated that 500 acre feet/year of water will be lost to evaporation from the permanent pool at Cochiti Reservoir. We suggest this figure be checked. Based on a pool size of 50,000 acre feet with 1,250 surface acres and a net evaporation rate of about 4 feet/year, it is estimated that the water loss would be about 5,000 acre feet/year.

Hydrologic Aspects

The disposal of liquid radioactive wastes to Acid Pueblo, Los Alamos, and Mortandad Canyons is discussed in commendable detail in the draft statement showing the considerable body of work done over the years to define the fate of the released radionuclides. The same cannot be said for the disposal of solid and liquid wastes buried or placed in disposal pits and shafts and on sorption beds. The draft statement discusses the hydrologic conditions of the 15 areas where wastes are known to have been disposed only in a general way. However, there is no indication that hydrologic conditions have been studied in detail at these areas or that such studies are planned. We note that the evaluation of the potential radionuclide releases from these areas, on pages 3-128 and 3-129 of the draft statement, is based essentially on a single study that is clearly indicated to be of a preliminary nature.[1/] It is not clear whether more in-depth studies to validate the preliminary conclusions are planned. Another report, not cited in the draft statement, concluded that in 1975 insufficient data were available to design an effective monitoring system and that the necessary geologic and hydrologic parameters were not adequately defined at the burial sites.[2/] Therefore, we recommend the final statement acknowledge the limited amount of information and recognize the preliminary nature of any evaluation of such effects as reported.

Recreational Resources

Although the recreation resources in the area have been adequately discussed, the final statement should address the impacts, if any, that continued use and possible expansion of the Los Alamos facility will have on these resources.

1/ Wheeler, M.L., et. al, 1977, "A Preliminary evaluation of the potential for plutonium release from burial grounds at Los Alamos Scientific Laboratory," LASAL informal report LA-6694-MS, 19 p.

2/ Kelly, T.E., 1975, "Evaluation of monitoring of radioactive solid-waste burial sites at Los Alamos, New Mexico," U.S. Geological Survey Open-File report 75-406, 82 p.

Cultural Resources

In general, the cultural resources in the area are adequately discussed but there are procedural omissions that should be included in the final statement.

The draft statement has omitted the fact that the Los Alamos Scientific Laboratory is listed on the National Register of Historic Places and is also a National Historic Landmark. The final statement should indicate that these designations will be accounted for when planning for construction or expansion of facilities.

The final statement should contain evidence of contact with the State Historic Preservation Officer (SHPO) and a copy of his comments concerning the effect of the undertaking upon historical and archeological resources. The SHPO in New Mexico is Mr. Thomas W. Merlan, Historic Preservation Program (c/o New Mexico State Library, P.O. Box 1629, Santa Fe, New Mexico 87503).

The final statement should contain a sentence indicating that no National Register properties will be affected by the project, or a listing of the properties to be affected, an analysis of the nature of the effects, a discussion of the ways in which the effects were taken into account, and an account of steps taken to assure compliance with Section 106 of the National Historic Preservation Act of 1966 (80 Stat. 915) in accordance with procedures of the Advisory Council on Historic Preservation as they appear in the Federal Register, February 10, 1976.

Since this area is rich in cultural resources, contract specifications for any construction should include a sentence to the effect that if any archeological resources are encountered during construction, operations will cease at the discovery site and a professional archeologist will be consulted as to the significance of the material.

Fish and Wildlife Resources

It appears that, for the most part, the concerns of the Fish and Wildlife Service, which were submitted to ERDA in a letter dated August 24, 1976, have been adequately addressed in the draft statement. However, we note that the draft statement seems to be lacking information on fish resources which may occur in the upper reaches of the Guaje, Los Alamos and Pajarito streams as well as in Water Canyon and Canyon del Valle. Since the draft statement indicates, on page 3-18, that these canyons have a small perennial flow for approximately one-third of their length, we recommend that the final statement include a discussion of the effects on fish resources in these canyons.

We also recommend that the final statement show evidence of compliance with Executive Orders 11988, titled "Floodplain Management" and 11990, "Protection of Wetland."

Fish and Wildlife Coordination

Pursuant to the Fish and Wildlife Coordination Act, the comments of the Fish and Wildlife Service on the environmental analysis and draft statement, do not preclude additional and separate evaluation and comments as may be required on a permit application under Section 404 of Public Law 92-500. Under these or other responsibilities, the Service may recommend prevention, mitigation, or compensation for fish and wildlife habitat losses.

Minor Comments

On pages 3-18, 3-21 and 4-23, the term "hydrologic conductivity" is used; we believe that the customary term in this context is hydraulic conductivity; hydraulic conductivity should be defined in the glossary because of its importance to environmental impact considerations.

An error on page 3-66 should be corrected in the final statement. The draft statement indicates that the Bureau of Outdoor Recreation controls Federal land in Los Alamos County. The Bureau of Outdoor Recreation (now the Heritage Conservation and Recreation Service) is an administrative agency and does not control or manage any Federal lands.

On page 3-44 and again on page D-3, red-headed woodpeckers are listed as summer residents of the LASL environs. It is questionable whether red-headed woodpeckers are summer residents or breed in the area. Their appearance is believed to be accidental only.

On page 3-120, the statement mentions the use of 30 septic tanks. Maintenance and/or monitoring of these facilities to assure efficient operation and disposal should be at least briefly addressed.

We think that the section on impacts, which begins on page 4-1, should include an assessment of the calculated magnitude and extent of drawdown of water levels in cased wells versus distance from well fields. Representative supporting measurements, if available, should also be included.

The aquifer supplying water to the Water Canyon Gallery, mentioned on page 4-3, should be identified.

We suggest that figure 4.1.1-2 be enlarged and revised to make it easier to read.

The section on aesthetics, which begins on page 4-77, does not address the possible impacts on archeological sites and cliff faces from accidental explosions or the routine explosive testing that occurs near Bandelier National Monument.

On page F-5, the glossary defines transmissivity in general terms; we recommend that the glossary also define storage coefficient, because the two aquifer characteristics are important in assessing impacts on the main aquifer; values for storage coefficient should also be given along with those transmissivity values which were listed on page 3-21.

As a final comment, we recommend the final statement be revised to make the proposed mitigation measures more easily understood by the layperson in the region of the study.

We hope these comments will be helpful to you in the preparation of a final statement.

Sincerely,

Larry E. Meierotto
Deputy Assistant SECRETARY

DOE Staff Response on DOI Comments on DOE/EIS-0018-D,
the Draft Environmental Impact Statement
on the Los Alamos Scientific Laboratory Site

With regard to the concerns about water resources and continuing the surveillance program, be assured that a thorough environmental monitoring program for LASL will continue. Please see the new appendix H in the document which provides complete documentation of the environmental surveillance at LASL during 1978.

The hydrologic aspects of the waste disposal areas are the subject of continuing research and monitoring studies at LASL. The discussion in section 3.3.3 was expanded to include some of the more recent important results and several additional references to study reports have been included. The section indicates that some of the continuing studies were initiated specifically in response to recommendations of the U.S. Geological Survey. While there is more knowledge that will be important to have for long-range waste management planning, we believe that the basic conclusions regarding the integrity of the waste disposal areas at present are much better than "preliminary."

There has been a continuing misunderstanding about the National Historic Landmark at Los Alamos. The description of the site has been summarized on page 3-103 of the statement. The title as shown in the Federal Register listing (43 CFR 5255), "Los Alamos Scientific Laboratory" refers to a plaque commerorating the site of the original technical area and is now located on land of the Incorporated County of Los Alamos. The entire Landmark District, as verified for inclusion in the National Register in January 1976, and consisting of three Historical Tracts, is on land not controlled by the Department of Energy; it is all on County or privately owned land. This has been true since April 28, 1975, when the Quitclaim Deed to the Incorporated County of Los Alamos from the Bureau of Outdoor Recreation was recorded to complete the transfer of lands in the Landmark District.

The only fish occurring in the upper reaches of Guaje, Los Alamos, Pajarito, and Water Canyons are those in the Los Alamos Reservoir located to the west of the DOE-controlled site. The streams are too small to support any fish.

We believe all of your other minor comments and suggestions including those on Cochiti Reservoir and Executive Order 11988 and 11990 have been considered at appropriate points in the statement.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SEP 22 1978

Mr. W. H. Pennington, Director
Office of NEPA Coordination
U. S. Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

Subject: Draft Environmental Impact Statement, Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico, DOE/EIS-0018-D

This office has reviewed the Draft Environmental Impact Statement for the Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico (DOE/EIS-0018-D) as requested in your letter of June 27, 1978. In consideration of this draft environmental impact statement, our comments on DOE/EIS-0018-D are enclosed for your use.

Sincerely,

Voss A. Moore

Voss A. Moore, Assistant Director
for Environmental Projects
Division of Site Safety and
Environmental Analysis

Enclosure:
Los Alamos Scientific
Laboratory Site DEIS

cc: Mr. Thomas Sheckells (5)
Environmental Protection Agency
Room 537, West Tower
401 M Street, S. W.
Washington, D. C. 20460

NRC COMMENTS ON THE LOS ALAMOS SCIENTIFIC LABORATORY SITE
DRAFT ENVIRONMENTAL IMPACT STATEMENT (DOE/EIS-0018-D)

Section	Comment
Summary	The discussion (page 1-7) of Table 1-4 should clarify whether Laboratory effluents include all routine onsite operations for both airborne and liquid radioactive releases. Why was only the Los Alamos County population considered (Table 1-4)?
3.1.5	Ambient Environmental Quality (Natural and Fallout Radioactivity), page 3-56 The exclusion of gross gamma and ^{131}I background concentration from Table 3.1.5-4 is not discussed in this section. Were grab water samples used to obtain the results in Table 3.1.5-6.
3.2.1	Land Use, page 3-57 The milk animals, meat animals, residences and residences with gardens within 5 miles of the LASL site should be identified to determine existing exposure pathways. Food crops, milk and meat produced in the area within 50 miles of the site should also be tabulated and considered in the population dose analysis. Present or anticipated municipal surface water intake locations downstream of LASL should be described. For each intake, river distance from the laboratory, travel time, dilution and population served should be given. Downstream irrigation locations, food production and water use should be shown.
3.2.3	Demography, page 3-81, paragraph 4 The six counties that encompass the area within a 50 mile radius of LASL should be identified in this section. Projected population should be estimated to the year 2000 for the area within a 50 mile radius of LASL.
3,3.3	Waste Disposal Liquid Wastes, page 3-112, paragraph 2 It is not clear how the radioactive waste from the 1951 waste treatment plant was packaged, or what method of final disposal was used.

Section Comment

A discussion should be provided of the methods used to handle spent resins used at the ion-exchange facility.

Liquid Wastes, page 3-112, paragraph 3

Are there controls placed on the activity levels of waste collected from holding tanks and transported to the Central Waste Treatment Plant for processing? A discussion should be included of the precautions used to prevent spills and keep personnel exposure to a minimum.

Liquid Wastes, page 3-112, paragraph 4

What criteria are used to determine whether dewatered sludge will be buried or placed in retrievable storage? The reasons why dewatered sludge that contains a high water content is not processed into a solid matrix should be discussed. A discussion should be provided of the methods used to process regenerant solutions.

Liquid Wastes, page 3-116, paragraph 1

It is recommended that a discussion outlining the methods of waste treatment for the facility at "east plant" be included.

Liquid Wastes, page 3-116, paragraph 2

A discussion should be provided of the methods used to assure complete solidification of the sludge/cement mixture pumped into the asphalt-lined burial shafts.

Liquid Wastes, page 3-116, paragraph 3

A discussion should be provided of the methods used to assure that strontium and cesium in normal industrial waste are kept at a very low level. The method employed to keep tritium out of this waste stream should also be discussed. What method of disposal is used for the liquid tritium waste treated separately at the east plant? A discussion should be provided of the methods used to assure complete solidification of strontium-cesium/cement waste.

<u>Section</u> <u>Comment</u>

Liquid Wastes, page 3-116, paragraph 4

The continuing efforts mentioned in this paragraph to minimize plutonium releases should be discussed.

Liquid Wastes, page 3-116, paragraph 5

In cases where waste drains directly into the industrial sewers, the monitors and administrative procedures used to assure that this waste does not exceed specified activity levels should be described.

Solid Wastes, page 3-123, paragraph 1

The solidification process used to contain the "estimated 30,000 Ci" of tritium to be buried annually should be discussed.

Solid Wastes, page 3-123, paragraph 2

What is the expected fraction of plutonium, uranium, mixed fission and activation products and tritium contained in radioactive solids waste generated at LASL?

Solid Wastes, page 3-125, paragraph 2

A description should be provided of the methods used to bury retrievable waste; in particular the procedure used to assure container integrity for the twenty-year burial period should be discussed.

Solid Wastes, page 3-125, paragraph 3

A description should be provided of the intent of "low amounts of radioactive contamination" referred to in this paragraph. What is the significant level of tritium in trash type waste or other that determines use of special packaging?

Solid Wastes, page 3-126, paragraph 1

The container used to compact solid waste should be described.

Section	Comment
3.3.3	Waste Disposal

Solid Wastes, Page 3-126, paragraph 2

From the description, it appears that there is no shroud around the top of the container used to compact solid waste. Describe the methods used to prevent the accumulation of high concentrations of radioactive dust in the vicinity of the compactor during compaction of waste.

Solid Wastes, page 3-129, paragraph 4

The developmental monitoring program underway for radioactive waste migration should be described (i.e., type of sample, sampling frequency, sampling locations and analysis planned). What monitoring is used to determine that disposed chemical waste does not migrate into solid waste disposal areas.

Gaseous Wastes, page 3-137

After reviewing this portion of the statement, we find that there is insufficient information for us to provide specific comments. It is recommended that the gaseous radioactive waste treatment systems be described in more detail. The plant or operational sources of routine releases and annual changes of radionuclides released, should be discussed. Plant stack locations and heights should be given.

3.3.4 Precautionary Procedures, Monitoring, pages 3-141, 3-143

A summary of the current radiological monitoring program, listing indicator and background stations, sampling media, analyses performed, analyses frequencies and analyses detection limits should be included for use with Figures 3.3.4-1 and 3.3.4-2. This section should reference Figure 4.1.1-2 and Tables in 4.1.1 on water and sediment monitoring. What was used as the basis for selecting foodstuff sampling locations?

4.1.3 Chemical Measurements and Assessment, Calculated and Measured Doses, page 4-53

It is not clear what pathways are included in the site boundary individual doses given in Table 4.1.3-2. What doses in Table 4.1.3-2 were calculated using measured releases, and which doses are based on monitoring results? It is not clear whether ingestion of food crops was included in individual or population doses tabulated. The calculated individual dose at the controlling residential location considering all existing pathways should be included in this section.

Section	Comment
General	The annual occupational radiation exposure for current laboratory site operations and estimated exposure due to future operations should be included in the environmental statement.

DOE Staff Response on NRC Comments on DOE/EIS-0018-D,
the Draft Environmental Impact Statement
on the Los Alamos Scientific Laboratory Site

Extensive additional detail has been added to the document through the incorporation of the 1978 environmental surveillance report for LASL as appendix H. It contains considerable additional detail on effluents, radioactive effluent release points, sampling locations, and methodologies.

Section 3.3.3 on waste disposal practices was largely reworked and incorporated additional information in response to your comments regarding pages 3-112 through 3-129 of the draft EIS.

The section on calculated and measured doses was revised to be based on more recent information and clarify pathway considerations.

Material was added in section 4.1.3 (see especially table 4.1.3-4) regarding laboratory-wide occupational radiation exposure experience.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CENTER FOR DISEASE CONTROL
ATLANTA, GEORGIA 30333
TELEPHONE: (404) 633-3311

September 20, 1978

Mr. W. H. Pennington
Director, Division of Program Review
and Coordination
Office of NEPA Affairs, EV
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

We have reviewed the draft environmental impact statement on the Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico. We are responding on behalf of the Public Health Service.

The DEIS for the Los Alamos Scientific Laboratory (LASL) site is intended to consider long-range cumulative environmental impacts of future LASL projects. Individual assessments and environmental impact statements will be issued for individual projects as they develop (page 2-15, last paragraph). The DEIS, however, does not always achieve its goal; environmental data are abundant but long-range impact assessments are scarce.

We understand from the statement that water rights are used by the State of New Mexico to control the quantity of water removed from its resources. LASL has two water rights, 6.8 million cubic meters per year of groundwater and 1.48 million cubic meters per year of surface water. The surface water rights were granted in 1976 when it was apparent that the demand for groundwater would exceed LASL's groundwater rights. However, LASL does not plan to use surface water to meet its needs, all projections for increased water requirements will be satisfied by the groundwater source. The DEIS projects that the natural discharge of water from the aquifer to the Rio Grande will be reduced by LASL's increased use of groundwater, and surface water will be used to replace the lost groundwater (page 4-3, last paragraph, and page 4-5, first paragraph). We feel both groundwater and surface water will be impacted by the LASL water needs as related to the following information retrieved from the DEIS:

1. <u>Impacts on the quantity of water stored in the aquifer</u>

   Data presented in the DEIS project a continual reduction in the quantity of water stored in the aquifer. LASL groundwater demand will increase until 1995 when it will equal the water rights limit. The water table is expected to continue dropping at approximately the same rate as it

Mr. W. H. Pennington

has in the past (page 4-3, last paragraph and page 4-4, first paragraph).

The significance of this impact can be measured by the length of time it will take to deplete the aquifer under current conditions compared to how long it will take with LASL increased demand for groundwater. The DEIS mentions that neighboring communities will increase their demand for water, but it does not calculate the volume or compare it to the LASL demand (page 4-108, second paragraph).

Since depletion will mean expensive alternative sources, it is important to know the expected life span of the aquifer. A mass balance calculation taking account of the volume of water in the aquifer, natural recharge and loss rates, and human demands would provide an estimate.

2. Impacts on the quality of water produced by the aquifer

As the volume of water in the aquifer continues to decrease, water will be drawn from successively lower strata where unknown deposits may contaminate the water. The DEIS does not consider this impact. An examination of the history of groundwater quality and chemical examination of aquifer samples indicates how the quality may change in the future. The DEIS reports that one well (LA-6) produces water contaminated with arsenic (page 4-5, third paragraph), but the history of this well is not provided.

3. Impact on the flow in the Rio Grande

As previously mentioned LASL plans to increase its demand on the aquifer reducing its discharge to the Rio Grande. This impact will be mitigated by using surface water to replace the lost water (page 4-3, last paragraph and page 4-5, first paragraph).

4. Impact on the quality of Rio Grande water

The exchange of surface water for groundwater (see impact #3) will affect the quality of the Rio Grande. The DEIS does not compare the quality of the two sources, but it may be assumed that they differ. The net result, therefore, will be a change in river water quality.

5. Secondary impacts on populations that depend on the water resources used by LASL

Changes in groundwater quantity and quality will affect communities around Los Alamos County. Impacts on these communities are not considered by the DEIS, nor does the DEIS indicate if the aquifer has been designated a sole source water supply under the Safe Drinking Water Act (P.L. 93-523).

Changes in surface (Rio Grande) water quantities have been considered by the DEIS, but the issue of quality is not addressed. This impact should be assessed since communities in New Mexico, Texas, and Mexico may be affected. The statement should also determine if any international agreements apply to the quality of the Rio Grande and the impact of the proposed facility upon this watercourse.

The only alternative for groundwater use considered by the DEIS is conservation; for example: by charging domestic users more for water (page 10-4, table 10-1), by stopping irrigation practices, by recycling treated wastewater (page 4-1, fourth paragraph), by using mechanical cooling in place of non-contact cooling (page 9-9, second paragraph), and by mandatory rationing (page 5-1, second paragraph). The DEIS does not consider alternatives for water sources after the water rights are exceeded in 1995. Long-range planning that recognizes depletion of the aquifer would consider alternatives that control the growth of LASL, develop construction designs that minimize water use, and give high priority to low water using research projects.

Wastewater Effluents

LASL wastewater discharges both industrial and sanitary create intermittent flows that discharge to essentially dry stream beds (page 3-19, figure 3.3.2-2). These flows remain on the surface for short distances and are absorbed by the soil prior to reaching the Rio Grande. The National Pollutant Discharge Elimination System only considers flow, biological oxygen demand, and total suspended solids in treated sanitary sewage (page 4-9, table 4.1.1-4). Heavy metals or other toxic compounds are not considered. Industrial wastewater effluent quality, however, is considered in detail (page 4-7, table 4.1.1-3), but concentrations are not related to animal usage. One study reported concentration of mercury in stream banks (page 4-24, table 4.1.1-18), but did not relate the mercury to wastewater. The DEIS should consider plant and animal populations that depend on the intermittent flows and determine if any effects in the food chain are caused by wastewater contaminants. Currently, only geographic plant and animal distribution are considered without relating to the surface water supply.

The discussions and presentation of radiological data in Chapter 4, Potential Impact of the Proposed Action, has adequately addressed the issues that impact on public health and safety from the activities at the LASL. It is noted that the radiological assessment of LASL operations indicates that the dose to the population offsite is well within current radiation protection standards. However, the discussion of health and safety on page 3-139 states that there is a health physics program for measurement and control of occupational exposure. It would be helpful if appropriate data on the dose to workers could be included in the statement.

Mr. W. H. Pennington

This DEIS acknowledges that low but measurable levels of long-lived radionuclides, such as Sr-90, Cs-137, Pu-239, and AM-241, are being released from the Los Alamos facilities into neighboring terrestrial and aquatic environments. The Food & Drug Administration is concerned about the potential for such radionuclides to accumulate in aquatic and terrestrial plants and animals which become a part of the human food supply.

Therefore, we recommend that the Department of Energy broaden the base of its monitoring program to include measurements of the above radionuclides in components of plants and animals located downstream and downwind from the research facilities, waste burial sites, and other locations known to be used as human food sources.

Thank you for the opportunity of reviewing this document. We would appreciate receiving three copies of the final when it is issued.

Sincerely yours,

William H. Foege, M.D.
Assistant Surgeon General
Director

DOE Staff Response on HEW Comments on DOE/EIS-0018-D,
the Draft Environmental Impact Statement
on the Los Alamos Scientific Laboratory Site

With regard to the concerns about water resources, the revisions and additions to the text at appropriate locations, especially in sections 3.1.2, 3.3.1, and 4.4.1, should provide adequate answers. However, some specific points can be highlighted. The impacts on the quantity of water in the aquifer are believed to be minimal. The aquifer from which the municipal supply is drawn is at least 3,900 feet thick. The water level in a test well in the aquifer about 2.2 miles from the largest producing well has declined less than 3 feet since 1960 and may be due to gradual long-term variation in recharge. This supports the belief that current, as well as projected pumpage, has no measurable physical effect on the regional aquifer and is within the amount of natural recharge. The drawdown at the pumped wells is not an indication of overall effect on the aquifer but rather on local well-bore conditions resulting from pumping. Even the largest drawdowns are small proportions of the well depths and no more than a few percent of the aquifer thickness. While some new wells will be required to offset effects of decreased capacity in older wells or larger demands, there are no expectations of ever needing to consider "expensive alternative sources." or a finite lifetime for the aquifer as a whole.

The only well in which significant quality changes have occurred over a long period of time is well LA-6. Arsenic concentrations in that well increased sufficiently (about 30 percent) over a 4-year period to require removing it from regular production. A new reference (4-6A) was added for the report of a detailed hydrogeologic study of the occurrence of arsenic in that well.

Impacts on both the flow and quality of the Rio Grande will be insignificant and almost certainly unmeasurable. Even if the full effect of increased pumping were realized in the Rio Grande, it would amount to about 0.15 percent of the average flow at Otowi Bridge. Detailed analyses of regional surface waters and springs in White Rock Canyon are included in appendix H (see pages H-88 and H-90), indicating that water flowing in the Rio Chama (which includes San Juan-Chama Diversion water) is generally more mineralized than the ground water discharged into White Rock Canyon. Even assuming the replacement surface water is twice the mineral content of the reduced ground water inflow to the Rio Grande, general water quality in the Rio Grande downstream would be changed less than 0.1 percent. This is much less than natural variation.

Thus, we do not believe that there have been or will be any significant effects on either the surface or ground water in the region. The aquifer is not a designated sole source water supply. Additions to the text at several points also indicate that conservation measures have been effective in Los Alamos with about a 30 percent reduction in total use realized in the last two years. Accordingly, the projections made in the draft EIS were considerable overestimates. It is unlikely that LASL demands will reach the legal limits for water use for several decades at the earliest.

Additional information on nonradioactive constituents in wastewaters has been included in the statement, especially in appendix H which contains data on effluent monitoring and summaries of some of the ongoing ecological studies in the Los Alamos area. At this point, information is still limited, but the general conclusion is that the greatest impacts are related to the variations in the amount of water available rather than contaminants. As more information on uptake or other biological effects is available, it will be reported through the annual monitoring reports issued by LASL.

New information has been added in section 4.1.3 (see especially table 4.1.3-4) summarizing laboratory-wide occupational radiation exposure experience in the last several years.

Extensive additional detail on water and foodstuff monitoring in the vicinity of Los Alamos is included in appendix H. Foodstuffs in the area, including fish from the Rio Grande, are discussed on pages H-25 through H-28. Discussions of possible foodchains in Los Alamos Canyon and the Rio Grande were expanded in section 4.1.3 (see especially pages 4-56 through 4-62).

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

P.O. Box 2417
Washington, DC 20013

SEP [illegible]

1950

Mr. W. H. Pennington, Director
Department of Energy
Division of Program Review
and Coordination
Office of NEPA Affairs, EV
Washington, DC 20545

Dear Mr. Pennington:

We have reviewed the Draft Environmental Statement for the Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico, DOE/EIS-0018-D.

Page 2-7, 3rd paragraph. Geothermal Demonstration Project

We concur that a separate Environmental Statement will probably be necessary before a generating facility is constructed and should be determined by an environmental assessment.

Page 3-36. Flora and Fauna

3-149 fire protection, 4-102 accidents, and 4-11 wood burning all point out a need to further develop the management of the woodlands (B. the pinon/juniper and ponderosa pine) within the LASL site. This management should be tied to fire protection (reduction of fuels - fuelbreaks, etc.) and the sustained production of wood products such as fuelwood, poles, and sawtimber. The Forest Service is willing and able (through the professional consulting services noted on page 3-149, 6th paragraph) to assist in developing a management program for the LASL site lands.

Page 4-117 (center of page)

We suggest rewording for clarification as follows: "There will be pressure to expand into Federal lands administered by the Forest Service and the General Services Administration. The General Services Administration lands are considered 'reserved' in the county land management plan."

We appreciate the opportunity to review and comment on this Environmental Statement.

Sincerely,

for R. MAX PETERSON
Deputy Chief

DOE Staff Response on DOA Comments on DOE/EIS-0018-D,
the Draft Environmental Impact Statement
on the Los Alamos Scientific Laboratory Site

With regard to the comment about land management cooperation, note that there is a continuing arrangement for cooperation between the Forest Service and Los Alamos Area Office of the DOE. One-half of the costs of a Forest Service staff person are borne by DOE to provide a direct liaison and consulting function, assuring coordination of management practices at LASL and the adjoining forest lands.

September 22, 1978

Mr. W. H. Pennington, Director
Division of Program Review & Coordination
Office of NEPA Affairs
Department of Energy
Washington, D.C. 20545

Dear Sir,

The purpose of this letter is to request that you hold a well-publicized public hearing on the Environmental Impact Statement for the Los Alamos Scientific Laboratories' site, DOE/EIS-0018-D. Your EIS does not contain adequate assessment of the problem of radioactive wastes generated by LASL and resultant hazards to the public. This is an important public policy issue and needs to be explored in great detail.

In addition, your section on alternatives seems woefully inadequate.

Only through a well-publicized public hearing can you learn about the alternatives that the public might consider feasible and desirable. A well-publicized public hearing is also the only way to learn about the public's concerns, which are very real, very soundly based, and very much ignored traditionally by D.O.E. and its predecessor agencies. Thank you.

Sincerely,

Peter Montague

Peter Montague, Ph.D.
P.O. Box 4524
Albuquerque, NM 87106

PM/vp

M FELDMAN
1821 MEADOWVIEW NORTHWEST
ALBUQUERQUE NM 87104

I-81 western union Mailgram

UNITED STATES POSTAL SERVICE U.S.MAIL

4-039789E269 09/26/78 ICS IPMMTZZ CSP WSHB
5052421997 MGM TDMT ALBUQUERQUE NM 167 09-26 0123P EST

W H PENNINGTON
DIRECTOR
OFFICE OF NEPA
MAIL STATION E 201 U.S. DEPT OF ENERGY
WASHINGTON DC 20545

COMMENT ON LOS ALAMOS SCIENTIFIC LABS ENVIRONMENTAL IMPACT STATEMENT:
LASL EIS LACKING IN THE FOLLOWING RESPECTS:
INADEQUATE TREATMENT OF DANGERS OF TRANSPORTATION OF RADIOACTIVE WASTE TO DUMPS WITHIN FACILITY
INADEQUATE DOCUMENTATION THAT PLUTONIUM IN PUEBLO CANYON HARMLESS AND THAT RADIOACTIVE EFFLUENCE DO NOT EFFECT RIO GRANDE OR WATER FOR CONSUMPTION
NO MENTION OF PAST SECURITY INCIDENTS AT THE LAB
INADEQUATE CONSIDERATION OF OCCUPATIONAL SAFETY FOR EMPLOYEES; NO MENTION OF EMPLOYEE SUITS VS. LASL FOR RADIATION DAMAGE
INADEQUATE CONSIDERATION OF LASL'S CONVERSION TO ALTERNATIVE ENERGY FACILITIES
EIS BASED ON DENIAL OF DANGERS OF LOW LEVEL RADIATION WITHOUT PROOF THAT THIS THEORY IS FALSE

IN ADDITION, I AM WORRIED ABOUT RADIOACTIVE WASTE DUMPED IN CANYONS WITHOUT RECORDS BEFORE 1959, THE HANDLING AND ESCAPE OF TRITIUM, AND THE NON-RETRIEVABILITY OF MOST WASTES STORED. WE NEED PUBLIC HEARINGS TO CONSIDER THESE AND OTHER QUESTIONS

DEDE FELDMAN
1821 MEADOWVIEW NORTHWEST
ALBUQUERQUE NM 87104

13:23 EST

MGMCOMP MGM

201 PineSE
Albuquerque, N.M. 87106
September 25, 1978

Mr. W.H. Pennington
Director of the Office NEPA
Mail Station E 201
Washington D.C. 20545

Dear Mr. Pennington,

I have just discovered after calling your office this morning that comments on the "Draft Environmental Impact Statement for the Los Alamos Scientific Laboratory site- Los Alamos , New Mexico" is due on September 27 - in two days. I just received a copy of the impact statement a week ago from a friend although I am a member and organizer for the local War Resisters League chapter and was not contacted on this paper though we have been involved and critical of Los Alamos's activities for many years.

Just a brief going over of the report shows that a hearing is necessary for the many unclear and unresearched areas in the statement.

1) The breakdown of whites and nonwhite minoirities working at LASL and the pay scale of those employees

2) No history of problems in security and violations and if the signs are in Spanish and Native American lanuages in wooded areas which are less frequently patroled.

3) No history of accidents and problems of the transportation and storage of nuclear waste in Los Alamos. It would be important that these accidents be well known and documented so that they not occur in the future.

4) Also in the social are there is no mention of the crime of lab employees and alcoholism problem being a major prcblems among the adult population of the community.

5) Another completelyneglected area which needs major research is the effect on the community and the labs if major programs are cut, especially those involving nuclear weapons and energy. Because of the unstable political environment on these particular issues makes a strong effect on the future of the labs and the town of Los Alamos. More discussion on conversion of labs to more socially acceptable and helpful programs is absolutely necessary.

6) More detailed study must be done on workers safety and occupational health. It is necessary to have more detailed information and breakdown on training and safety precautions taken by the labs to protect employees. The impact statement should also have a history of the accidents to lab employees and the hazards they have faced in the past.

Just these short comments and faults in the report make it obvious a hearing must be held. I would be able to work on getting testimony for such a hearing and the War Resiters League as well as other organizations could provide information for the impact statement.

I hope that a hearing will be set up in the near future and that I and my organization be contacted well in advance to prepare adequate testimony and input.

Thank you for your consideration.

Sincerely,

Craig Simpson

Craig Simpson
War Resisters League

DOE Staff Response to Dr. Peter Montague,
Ms. Dede Feldman, and Mr. Craig Simpson

These three commentators requested that public hearings be held on the draft statement. DOE felt that public hearings on the draft EIS would not result in receiving additional information that would significantly supplement that already received, since the subject EIS is for an existing facility which has been a significant and an integral part of the local and state environment for 35 years. Comments are on hand regarding: (1) the draft EIS, (2) the Omnibus Environmental Assessment for LASL, which was published in 1975 and served as one of the background documents that were made publicly available when it was first announced that an EIS was to be prepared, and (3) the issues which have been previously raised by these commentators and other public interest groups regarding the nuclear cycle, generally, during the several public hearings that DOE has held around the state in conjunction with the proposed Waste Isolation Pilot Plant project. We also believe the public has been kept informed about the environmental aspects and consequences of LASL operations over recent years through the distribution of annual environmental monitoring reports.

Furthermore, as a result of the substantive comments received on the draft statement, numerous changes and additons have been made in the statement. A summary of the changes made in the text as a result of these concerns is presented in section 11.

Other Letters

The following letters require no staff response. A summary of the changes made in the text as a result of these concerns is presented in section 11.

We wish to thank them for their interest in the DOE activities at the Los Alamos Scientific Laboratory.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

September 28, 1978

OFFICE OF THE
ASSISTANT DIRECTOR
FOR ASTRONOMICAL,
ATMOSPHERIC, EARTH,
AND OCEAN SCIENCES

Mr. W. H. Pennington, Director
Division of Program Review
and Coordination
Office of NEPA Affairs
Department of Energy
Washington, DC 20550

Dear Mr. Pennington:

The Department of Energy's draft Environmental Impact Statement, Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico, DOE/EIS-0018-D, has been reviewed by the appropriate National Science Foundation staff. We have no comments to offer on this statement.

Sincerely yours,

Daniel Hunt
Deputy Assistant Director

County of Bernalillo

State of New Mexico
620 LOMAS, N.W.
ALBUQUERQUE, NEW MEXICO 87102

July 27, 1978

W. H. Pennington, Director
Division of Program Review
and Coordination
Office of NEPA Affairs
Department of Energy
Washington, D.C. 20545

Dear Mr. Pennington:

On behalf of the County of Bernalillo I wish to acknowledge our receipt of your letter of July 7, 1978 and the enclosed Environmental Impact Statement for the continuation of activities at the Los Alamos Scientific Laboratory site.

As part of the review and comment process let this letter convey our strong support and endorsement of LASL's activities now and in the immediate future. In justification we can only echo one of their important statements, namely:

> "....The essence of the environmental trade-off analysis lies in national policy decisions that the work done at LASL is essential. If the goals of research are realized, the benefits would encompass maintenance of National defense, increased national self-sufficiency of energy resources, improved quality of life, and reductions of environmental impact throughout the nation....(page 1-14)"

Obviously as we approach the commencement of a new decade our attention turns toward new problems (or renewal of past problems) e.g. upstream and downstream water contamination, storage of irreversible radioactive substances. However, we trust that within the confines of LASL's operations there are a number of talented and concerned individuals who will provide the necessary safeguards and future technology to overcome the above concerns.

In closing, we strongly endorse the conservations of this program within Los Alamos County and would greatly appreciate the Department of Energy's approval of the program as presented.

Sincerely yours,

Robert M. Hawk

Robert M. Hawk
Vice-Chairman

RMH:br

Babcock & Wilcox

Nuclear Materials Division

609 North Warren Avenue, Apollo, Pa. 15613

Telephone: (412) 842-0111

July 28, 1978

W. H. Pennington, Director
Division of Program Review
and Coordination Office of Nepa Affairs
Department of Energy
Washington, D. C. 20545

Dear Mr. Pennington:

NMD's Health/Safety Personnel, as well as management personnel involved with the Mo_x program, have no comments to the Draft, Los Alamos E.I.S. (DOE/EIS 0018D).

Thank you for the opportunity to examine the draft issue.

Yours very truly

Grant W. LaPier chs

Grant W. LaPier
Product Manager

GWL/chs

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

Box 2007, Albuquerque, NM 87103

August 2, 1978

Mr. W. H. Pennington
Mail Station E-201
U.S. Department of Energy
Washington, DC 20545

Dear Sir:

The draft environmental impact statement for the Los Alamos Scientific Laboratory Site, Los Alamos, New Mexico, has been received at this office for review and comment.

The draft statement describes the potential for environmental impacts of continuing the operation of LASL. We find that most, if not all, of the impacts described may be categorized as being in fields of technology for which this agency has no competence.

Consequently, we are unable to provide substantive comments.

Sincerely,

A. W. Hamelstrom
State Conservationist

cc:
Director, Office of Federal Activities, EPA, Washington, DC (5 copies)
Administrator, USDA-SCS, Washington, DC

New Mexico Citizens for Clean Air and Water

PO Box 5
Los Alamos
New Mexico 87544
4 October 1978

Alan Stoker
Los Alamos Scientific Laboratory
Los Alamos
New Mexico 87545

Dear Alan:

The LASL draft impact statement did not specifically request responses, or give an address to which responses should be sent. I am guessing that you can forward our response to the correct person.

While the appropriate deadline for responses is long past, I thought someone might like to see our review of the draft statement. We simply could not mobilize manpower to get the review done in time. I am enclosing a copy of the comments of our reviewers, which were favorable but non-specific. Our column on September 24 in the Los Alamos Monitor acknowledged the favorable review and listed various facts from the statement which we thought might be of interest to the local people. As I scanned the statement in preparation for the column, I came across a few items which I will mention below, in case they might be of help to anyone still working on the statement.

The personnel figures were generally difficult to understand and seemed to be in conflict in different parts of the statement. This may simply be due to separating LASL, DoE, and Zia figures at one place, and lumping them together elsewhere.

Page 4-93 has a misprint in the exponent of curies released. Near this same page, there is a statement that air traffic departs eastward, although in fact Ross may depart to the west. Page 4-114 states that the town's growth is 250/year. The 1970 census was 15198, and the growth figure would therefore extrapolate to about 17000 now. However, I believe the current population is above this, and that the town is growing at about 250 families per year at this time. Finally, page 9-5 has a misprint in which "LASL" is given as "LAS ".

Sincerely,

Donald A. Neeper, chairman
Los Alamos Chapter

New Mexico Citizens for
Clean Air and Water
P. O. Box 5
Los Alamos, NM 87544

31 August 1978

Comments on the Draft Environmental Impact Statement (DEIS) for the Los Alamos Scientific Laboratory (LASL) site, Los Alamos, New Mexico, dated May, 1978

I. General Comments

The DEIS is thorough and comprehensive, adequately addressing the impact to the environment resulting from past and continuing operation of LASL.

The Preface contains a statement of purpose, "to determine the environmental impacts of continuing its [DoE's] activities at the Los Alamos Scientific Laboratory," and defines the area covered (LASL site) and the areas not covered (Nevada Test Site and Fenton Hill Geothermal Site). But it is not made clear that the LASL site is loosely meant to include the residential and commercial areas of Los Alamos County also.

II. Comments on Specific Sections

Section 1, Summary, is particularly well-written and well-placed in the Statement. It serves a dual purpose, to introduce and summarize LASL activities and associated environmental impact.

Section 2, Background, serves a useful purpose for both the technical and lay reader, providing the necessary historical information, description of current programs, and future activities.

Sections 3 and 4 and the appendices provide a wealth of information, in text, tabular, and graphic forms. Both beneficial and adverse impacts regarding continued operation of LASL are discussed. The Glossary in Appendix F should be especially useful to the lay reader.

The secondary impacts upon the residential and commercial areas in and near Los Alamos County are sufficiently discussed to make clear the vital ties these areas have with LASL.

Sections 5 through 8 appear to be straightforward, with no attempt to avoid discussion of less facorable impacts on the environment.

III. Summary

In view of the Section 9 alternatives to continued operation of LASL with the expected short-term uses of the environment and long-term productivity, the final summarizing statement of the DEIS is reasonable:

The anticipated benefits of the proposed continued operations at LASL appear to be great. Continued operation would retain the benefits of research and realize the full use of existing unique installations while minimizing specific environmental costs through suitable improvements in procedures and facilities.

APPENDIX J
LIST OF PREPARERS

The principal preparers of the LASL EIS are listed alphabetically, with a brief tabulation of their qualifications, in the list that follows:

A. John Ahlquist, M.S., Certified Health Physicist, 14 years experience in health physics

Sumner Barr, Ph.D., 19 years experience in meteorology

Jerry Buchholz, Ph.D., 16 years experience in chemistry

Evan Campbell, M.S., Certified Industrial Hygienist, 31 years experience in chemistry, industrial hygiene

Joyce Freiwald, M.S., 14 years experience in environmental planning, technology assessment, and system studies

Joe Graf, Ph.D., 7 years experience in nuclear engineering, health physics and environmental assessment

Tom Cunderson, Ph.D., Registered Professional Engineer (N.M.), 5 years experience in environmental engineering

Tom Hakenson, Ph.D., 12 years experience in radiation ecology and environmental science

Wayne R. Hansen, Ph.D., Certified Health Physicist, 16 years experience in radiation protection, environmental science, and environmental assessment

Wayne C. Hanson, Ph.D., Certified Wildlife Biologist, 30 years experience in radiation ecology and artic ecology

Jack Healy, B.S., Certified Health Physicist, 35 years experience in radiation protection and reactor safety

LaMar Johnson, Ph.D., Certified Health Physicist, 21 years experience in radiation biology and health physics

Harry S. Jordan, M. ENG., Certified Health Physicist, Registered Industrial Hygienist, 32 years experience in sanitary engineering, health physics, and industrial hygiene

Valerie McCabe, B.S., 20 years experience in behavioral science and technical writing

Jack W. Nyhan, Ph.D., 15 years experience in soil microbiology, soil radiochemistry, radioecology, and systems ecology

William D. Purtymun, B.S., Registered Prof. Geologist, 21 years experience in geology and hydrology

Shelby Smith-Sanclare, Ph.D., 8 years experience in landscape architecture, environmental planning, and assessment

Charlie R. Steen, B.A., 46 years experience in archeology, including regional archeologist for National Park Service, Southwest Region

Alan K. Stoker, ENG., 8 years experience in environmental engineering and environmental assessment

Daniel Talley, B.S., 12 years experience in mechanical engineering and biology

Allen Valentine, M.S., Certified Health Physicist, 15 years experience in health physics

John Warren, Ph.D., 9 years experience in chemistry and radiochemistry

Merlin Wheeler, Ph.D., 16 years experience in hydrology and geology

*U.S. GOVERNMENT PRINTING OFFICE : 1979 0-310-912/157