LA-UR-90-3216

Los Alamos National Laboratory

Environmental Restoration

A Department of Energy environmental clean up program

Annotated Bibliography of Geologic, Hydrogeologic, and Environmental Studies Relevant to Solid Waste Management Units at Los Alamos National Laboratory

CERTIFICATION

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Document Titles:

- Perched Zone Monitoring Well Installation
- Environmental Surveillance at Los Alamos During 1988
- Annotated Bibliography of Geologic, Hydrogeologic, and Environmental Studies Relevant to Solid Waste Management Units at Los Alamos National Laboratory

Name: J C Gunderson Date: 9/14/90
Deputy Division Leader
Health, Safety, and Environment
Los Alamos National Laboratory

Name: ______________________ Date: ____________
Acting Chief
Environment, Safety, and Health Branch
Los Alamos Area Office - DOE

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DATE: Sept. 17, 1990
IN REPLY REFER TO: HSE-DO:90/793
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Mr. Harry T. Season, Jr.
Acting Area Manager
US Department of Energy
Los Alamos Area Office
Los Alamos, NM 87544

Dear Mr. Season:

Special Conditions Numbers 1, 2, and 8 of the Hazardous and Solid Waste Amendments (HSWA) module of the Laboratory's Resource Conservation and Recovery Act (RCRA) operating permit require submittal of three deliverables within 120 days of its effective date. The 120 days will be reached September 19, 1990. These deliverables include

- a report and map describing the perched zone well installations required under permit Section C.1., "Perched Zone Monitoring,"

- a summary of the ongoing environmental monitoring program described under permit Section C.2., "Monitoring of Surface and Ground Water," and

- a reference of all known geologic, hydrogeologic, and environmental studies relevant to potential contaminant migration as described in permit Section C.8., "Identification and Summary of Previous Studies."

The deliverable required under C.1. is being met through the submittal of a report that includes the survey location of each well (northing, easting, ground level, top of casing, well pad), static water level, well construction data, and well development data. A map is included to illustrate the geographic location of the wells.

The deliverable required under Section C.2. is being met through submittal of the document, "Environmental Surveillance at Los Alamos During 1988." This is an annual report that is prepared by the Environmental Surveillance Group at the Laboratory. The 1989 report is currently at DOE-HQ for review before release. When it is released by DOE-HQ it will be forwarded to EPA.

The deliverable required under C.8. is a summary of previous studies that was generated solely to meet this permit requirement, entitled "Annotated Bibliography of Geologic, Hydrogeologic, and Environmental Studies Relevant to Solid Waste Management Units at Los Alamos National Laboratory".

Enclosed are five copies of the required documentation, including the required certification statement. Two copies, each, should be transmitted to

> Allyn M. Davis, Director, Hazardous Waste Management Division, U.S. Environmental Protection Agency, 1445 Ross Avenue, Dallas, TX 75202-2733, and
>
> Kathleen Sisneros, New Mexico Environmental Improvement Division, Hazardous and Radioactive Waste Bureau, Harold Runnels Bldg., 1190 St. Francis, Santa Fe, NM 87503.

The enclosed electronic copy of each deliverable should also be transmitted to Allyn M. Davis, EPA.

If I can be of further assistance, please do not hesitate to call.

Sincerely,

T Gunderson

Thomas Gunderson
Deputy Divison Leader
Health, Safety, and Environment

TG:SW:am

Enc. a/s

Cy: A. Tiedman, ADO, MS A120, wo/a
R. Sena, AL, MS A906, wo/a
S. McBee, DOE-AL, MS A609, w/a
B. Vocke, HSE-DO/ER, MS K481, w/a
S. Wagner, HSE-DO/ER, MS K481, wo/a
L. Soholt, HSE-DO/ER, MS K481, wo/a
K. Hargis, HSE-8, MS K490, w/a
S. Brown, LC-General, MS A187, wo/a
M. Janowski, Public Affairs, MS K481, w/a
M. Jones, EES-1, MS M707, w/a
CRM-4 (1), MS A150, wo/a

I. GEOLOGY

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A Time Domain Survey of the Los Alamos Region, New Mexico.

Abeele, W.V., 1978,
The Influence of Access Hole Parameters on Neutron Moisture Probe Readings,
LANL, LA-7241-MS.

Computing soil moisture content with a neutron probe requires use of a calibration curve that considers the thermal neutron capture cross section of the hole liner as well as the hole diameter. The influence of steel, polyvinyl chloride, and aluminum casings that fit 0.051 to 0.102-hole diameters was determined by comparison with neutron probe readings in uncased holes of corresponding diameters. Eccentricity of probe location was considered a potentially significant variable. The relationship between hole diameter and count rate also was investigated. The experiment was run in disturbed Bandelier tuff with an average dry density of 1.2 g/cubic cm and moisture content of 1.3 to 35.5% by volume. The casing material and hole diameter influenced the probe readings significantly, whereas eccentric location of the probe did not. Regression analyses showed an almost perfect inverse linear correlation between hole diameter and count rate.

Abeele, W.V., 1984,
Geotechnical Aspects of Hackroy Sandy Loan and Crushed Tuff,
LANL, LA-9916-MS.

Important geotechnical properties that should be tested before construction and operation of a low-level waste disposal site include hydraulic conductivity, consolidation, and shear strength of the soils of interest in that low-level waste disposal site. Because hydraulic conductivity of Bandelier tuff & adjacent soils has been the subject of exhaustive studies, this report will concentrate on consolidation and shear stress of the above-mentioned porous media.

Abeele, W.V., 1984,
Geotechnical Characteristics of Bentonite/Sandy Silt Mixes for Use in Waste Disposal Sites,
LANL, LA-10101-MS.

The coefficient of consolidation for bentonite/sandy silt ratios of 0.04 to 0.14 decreases inversely proportional with the square of that ratio, whereas the compression index, the swelling index, & the permeability change index increase with increasing bentonite ratio. A strong relationship also exists between the void ratio & the logarithm of the applied stress for any given bentonite ratio. The empirical linear relationship between the void ratio & the logarithm of the applied by Taylor, is excellent and enables us to limit the evaluation of conductivity at any void ratio to the measurement of the initial and the desired ratio, the initial conductivity, & the permeability change index. This allows us to read directly, for a given bentonite ratio, the void ratio (or compaction) needed so that a required hydraulic conductivity will prevail. This is crucial in the choice of materials or mixes to be used in a wick system where an established differentiation in hydraulic conductivity is desirable.

Abeele, W.V., 1985,
Consolidation and Shear Failure Leading to Subsidence and Settlement: Part I,
LANL, LA-10261-MS.

Subsidence and settlement are phenomena that are much more destructive than generally thought. In shallow land burials they may lead to cracking of the overburden and eventual exposure and escape of waste material. The primary causes are consolidation and cave-ins. Laboratory studies performed at Los Alamos permit us to predict settlement caused by consolidation or natural compaction of the crushed tuff overburden. We have also investigated the shear failure characteristics of crushed tuff overburden. Examples of expected settlement and subsidence are calculated based on known geotechnical characteristics of crushed tuff. The same thing is done for bentonite/tuff mixes because some field experiments were performed using this additive (bentonite) to reduce hydraulic conductivity of the crushed tuff. Remedial actions, i.e., means to limit the amount of settlement, are discussed. Finally, we briefly comment on our current field experiment, which studies the influence of subsidence on layered systems in general and on biobarrires in particular.

Abeele, W.V., and Nyhan, J.W., 1985,
Evaluation of Subsidence Constraints and Controls,
LANL, LA-UR-85-1694.

The objective of this task is to assess the subsidence danger and eventually determine experimentally if there is a consistent subsidence width to height ratio existing in the overburden for a certain set of degrees of compaction and moisture contents.

The primary effort is to field test the stability of crushed tuff and at least one other soil under varying W/h, void and saturation ratios. A total of 54 testing combinations will be performed without replication using two different media involved in SLB in Los Alamos (crushed tuff and sandy clay loam), with three different-W/h ratios each (0.2, 0.2, and 0.4) submitted to three different degrees of compaction (80, 90, and 100% of optimum) and at least three different moisture contents (20%, 30%, and 40% of saturation).

This program represents a unique and important contribution to the understanding of subsidence at problem and future SLB sites used for the disposal of hazardous waste. Knowledge of the critical W/h ratio and its influence on subsidence occurrence may determine how far from the surface big objects (and consequently big drawholes) should be located.

Abeele, W.V., et al., 1986,
Consolidation and Shear Failure Leading to Subsidence and Settlement,
LANL, LA-10576-MS.

Sudsidence and settlement are phenomera that are much more destructive than generally thought. In shallow land burials they may lead to cracking of the over burden and eventual exposure and escape of waste material. The primary causes are consolidation and cave-ins. Laboratory studies performed at Los Alamos permit us to predict settlement caused by consolidation or natural compaction of the crushed tuff overburden. We have also investigated the shear failure characteristics of crushed tuff that may lead to subsidence are calculated based on the known geotechnical characteristics of crushed tuff. The same thing is done for bentonite/tuff mixes because some field experiments were performed using this additive (bentonite) to reduce the hydraulic conductivity of the crushed tuff. Remedial actions, i.e., means to limit the amount of settlement, are discussed. We finally discuss our field experiment, which studies the influence of subsidence on layered systems in general and on biobarriers in particular. The share of the produced cavities is compared with cavities produced by idealized voids in an idealized environment. Study of root penetration at subsidence sites gives us an indication of the remaining degree integrity.

Abeele, W.V., Wheeler, M.L., and Burton, B.W., 1981,
Geohydrology of Bandelier Tuff,
LANL, LA-8962-MS.

The Los Alamos National Laboratory has been disposing of radioactive waste since 1944. Environmental studies and monitoring for radioactive contamination started concurrently. In this report, only two mechanisms and rates by which the radionuclides can enter the environment are studied in detail: subsurface transport of radionuclides by migrating water, and diffusion of tritiated water (HTO) in the vapor phase. The report also includes a section concerning the influence of moisture on shear strength and possible resulting subsidences occuring in the pit overburdens. Because subsurface transport of radionuclides is influenced by the hydraulic conductivity and this in turn is regulated by the moisture content of any given material, a study was also undertaken involving precipitation, the most important climatic element influencing the geohydrology of any given area. Further work is in progress to correlate HTO emanation to atmospheric and pedological properties, especially including thermal characteristics of the tuff.

Abrahams, J.H., Jr., 1963,
Geologic and Hydrologic Environment of Radioactive Waste Disposal Sites at Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

Liquids and solids containing radioactive materials have been discharged or buried at Los Alamos since about 1943. The U.S. Geological Survey began studies of the general geology and hydrology of the Los Alamos area in 1949 and began investigations of the movement of water and radioactive-waste materials in 1957.

Los Alamos is on the Pajarito Plateau which is part of the Jemez Mountain volcanic pile. The Sierra de los Valles immediately west of the Pajarito Plateau and the plateau itself are dissected by deep canyons that drain eastward to the Rio Grande. The Bandelier Tuff of Pleistocene age caps the plateau and is comprised of ash-flow rocks that drape over the older rocks. The tuff lies unconformably on the Santa Fe Group of middle Miocene to Pleistocene age and the Tschicoma Formation of Pliocene and Pleistocene age.

The main zone of saturation is about 800 to 1,200 feet below the land surface of most of the waste disposal sites in rocks of the Santa Fe and the Tschicoma Formation. The gradient on the piezometric surface of the zone of saturation is east-sotheast about 50 feet per mile toward the Rio Grande.

Processed liquid radioactive wastes were discharged into the 1940's into dry canyons or into pits dug into the tuff, and pits were partly backfilled with gravel. Liquid wastes were discharged into alluvium at one site. Solid wastes were dumped into pits and covered. After about 1950 the liquid wastes, except for laundry wastes, were treated to below off-site tolerances and discharged into canyons. Sludges left after the treatment of wastes were placed in barrels and mixed with cement or vermiculite and then buried systematically between layers of fill in pits dug into the tuff. Solid wastes containing radioactive materials also were buried between layers of fill. The fill over some of the pits containing sludge and solid wastes was compacted and mounded to prevent ponding of water. The main discharge area after 1962 will be into Mortandad Canyon. The movement of the wastes in alluvium and bedrock will be monitored closely.

Albright, J.N., 1979,
"Earthquake Monitoring", Summary of Talks, 2nd Annual Hot Dry Rock Geothermal Conference,
LANL, LASL-79-86, pp.20.

Although under certain conditions microearthquakes are known to have been induced in the Fenton Hill reservoir, none of these have been of sufficient magnitude, Mb-0.5, to be detected by the existing surface seismic array. Improvements in the array to be completed for Phase II testing will result in detection sensitivity and resolution maximized within practical limits. Included will be instrumentation installed at 750 m in a well penetrating basement rock at 1500 m from the experimental site.

Bailey, R.A., Smith, R.L., and Ross, C.S., 1969,
Stratigraphic Nomenclature of Volcanic Rocks in the Jemez Mountains, New Mexico, U.S. Geological Survey, Bulletin 1274-I.

Upper Tertiary and Quaternary volcanic rocks of the Jemez Mountains are subdivided into three groups-the Keres Group, in the south, the Polvadera Group, mainly in the north, and the Tewa Group, in the central and flanking parts of the mountains.

The Keres Group is divisible informally into two subgroups-an older subgroup, consisting of the basalt of Chamisa Mesa and the Canovas Canyon Rhyolite, and younger subgroup, consisting of the Paliza Canyon Formation and the Bearhead Rhyolite. The older subgroup is a basalt-rhyolite association; the younger subgroup is a more differentiated basalt-andesite-dacite-rhyolite association.

The Polvadera Group includes the Lobato Basalt; the andesites, dacites, and quartz latties of the Tschicoma Formation; and El Rechuelos Rhyolite. These formations constitute a still younger basalt-andesite-dacite-rhyolite association in the Jemez Mountains.

The Tewa Group includes the Bandelier Tuff, Cerro Rubio Quartz Latite, Cerro Toledo Rhyolite, and the Valles Rhyolite and represents the climax of rholitic volcanism in the Jemez Mountains.

Subdivision of the Bandelier Tuff is revised so that it consists of only two members-the Otowi Memeber, which includes the Guaje Pumice Bed, and the Tshirege Member, which includes the Tsankawi Pumice Bed. The Valles Rhyolite is subdivided into six members. Ages of many of the formations are defined by radiometric dating.

Balagna, J., Charles, R., and Vidale, R., 1976,
Geothermal Chemistry Activities at LASL, January-December 1975,
LANL, LA-6448-PR.

The nature of rock-filled interactions in the LASL Hot Dry Rock Geothermal System are being studied using both new and standard hydrothermal systems. Permeability measurements using a newly developed technique to allow measurements at elevated temperature and pressure (up to 200 degrees C. and 0.4 kb confining pressure) show GT-2 granite has minimum in situ permeability of a few tenths of a microdarcy. Noncirculating systems, rocking vessels and static vessels, are used to approximate the steady state reactions found in a slow moving geothermal system. Solutions in these systems approach steady state equilibrium in a matter of hours. Correlation of single mineral + solution reactions in static vessels have shown only slight agreement with existing PATHCALC modeling.

New circulating systems are operating which allow recirculation of the working fluid. Felsic rocks (granitoid) are more reactive than crystallized mafic rocks (amphibolite) but less reactive than glassy mafic rocks (kileaua basalt). The sequence of mineral reactivity is quartz>feldspar>>mafic minerals for all solutions used. Solution composition reached a steady state in a few days in the temperature range 200 degrees C to 300 degrees C. Working fluids such as distilled water and San Antonio river water, once reacted, yeilded a total solute inventory of at most 500 to 1000 ppm showing the dilute nature of these working fluids (i.e., they are not brines). Rock dissolution was enhanced compared to distilled water when using 0.1 N Na2CO3 as a working fluid. The preferential and prompt removal of quartz from the rock matrix in these experiments indicates Na2 CO3 solutions may be used to decrease impedance in the geothermal well.

Trace elememts are being examined as possible tracers for dissolution of minerals.

Baldridge, W.S., Perry, F.V., and Gladney, E.S., 1982,
Petrology and Geochemistry of the Cat Hills Volcanic Field, Central Rio Grande Rift, New Mexico,
Geological Society of America Bulletin, Vol. 93, pp. 635-643.

The Pleistocene Cat Hills volcanic field of the central Rio Grande rift consists of relatively homogeneous high-alkali olivine thoieiite, typical of late Cenozoic rift volcanism. Phenocrysts of olivine (Fo-64-84) (with abundant inclusions of Cr-spinel) and plagioclase (An-48-70) and partially resorbed xenocrysts of more sodic plagioclase (An-55-60) characterize these rocks. Chondrite-normalized rare earth data show high LREE/HREE (La/Yb =5.5) and a small positive europium anomaly. Modeling indicates that these high-alkali tholeiitic lavas evolved from parental composition with 100 X Mg/(Mg + Fe+2)=61, (Na2O + K2O)=4.3%, and SiO2=49.2% (equivalent to the most mafic Cat Hills lava) by fractional crystallization of 5 % to 6 % of olivine and a trace of Cr-spinel, and by addition of 3% to 6% of Na-plagioclase. We suggest that the plagioclase xenocysts are high pressure phenocysts which became out of equilibrium with the melt at shallow crustal conditions. Evolution of the lavas may have proceeded in isolated apophyses of a rising dike by sinking of olivine and included spinel and by floation of plagioclase.

The Cat Hills parent lava may have been derived from a primary (that is, unmodified mantle-derived) melt by crystallization and removal of 7.5% olivine or 17% augite, or a mixture of both, and by the simultaneous addition of 10% plagioclase. This inferred primary magma had a LREE-enriched composition very similar to that of the Cat Hills parent lava. Modeling of possible mantle compositions indicates that the source material for the Cat Hills magma, even if garnet was a residual phase, was also LREE-enriched.

Baltz, E.H., Abrahams, J.H., and Purtymun, W.D., 1963,
Preliminary Report on the Geology and Hydrology of Mortandad Canyon near Los Alamos, New Mexico, with Reference to Disposal of Liquid Low-Level Radioactive Waste,
U.S. Geological Survey, Open File.

The U.S. Geological Survey, in cooperation with the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory, selected the upper part of Mortandad Canyon near Los Alamos, New Mexico for a site for disposal of treated, liquid, low-level radioactive waste. This report summarizes the part of the study of the geology and hydrology that was done from October 1960 through June 1961. Additional work is being continued.

Mortandad Canyon is a narrow, east-southeast-trending canyon about 91/2 miles long that heads on the central part of the Pajarito Plateau at an altitude of about 7,340 feet. The canyon is tributary to the Rio Grande. The drainage area of the part of Mortandad Canyon that was investigated is about 2 miles, and the total drainage area is about 4.9 sqaure miles.

The Pajarito Plateau is capped by Bandelier Tuff of Pleistocene age. Mortandad Canyon is cut in the Bandelier, and alluvium covers the floor of the canyon to depths ranging from less than 1 foot to as much as 100 feet. The Bandelier is underlain by silt, sand, conglomerate, and interbedded basalt of the Santa Fe Group of Miocene, Pliocene, and Pleistocene age. Some ground water is perched in the alluvium in the canyon; however, the top of the main aquifer is in the Santa Fe Group at a depth of about 990 feet below the canyon floor.

Joints in the Bandelier Tuff probably were caused by shrinkage of the tuff during cooling. The joints range from hairline cracks to fissures several inches wide. Water can infiltrate along the open joints where the Bandelier is at the surface; however, soil, alluvial fill, and autochthonous clay inhibit infiltration on the top of the mesa, and probably in the alluvium-floored canyon, also.

Thirty-three test holes, each less than 100 feet deep, were drilled in 10 lines across Mortandad Canyon from the western margin of the study area to just west of the Los Alamos-Santa Fe County line. Ten of the holes were cased for observation wells to measure water levels and collect samples from the alluvium. Twenty-three of the holes were cased to seal out water and were used to access tubes to accomodate a neutron-neutron probe for determining the moisture content of the alluvium and tuff.

The source of recharge for the perched ground water body in the alluvium in Mortandad Canyon is the precipitation in the drainage area of the canyon. During the winter of 1960-1961, a snowpack 1-2 feet thick accumalated in the narrow shaded upper part of the canyon. The alluvium beneath the snowpack received some recharge because of diurnal melting during the winter. In March 1961 the snowmelt water saturated most of the thin alluvium in the upper part of the canyon, and a surface stream began to flow. The maximum flow of surface stream was about 250 gpm. Water from the stream infiltrated into alluvium at the front of the surface stream and in the reach upstream from the front. A ground water mound was formed beneath the channel by water infiltrating from the stream. The front of the surface stream and the front of the ground water mound advanced eastward, to about the middle of the study area. From this point eastward, the alluvium is thick enough to absorb and transmit the amount of flow in 1961. Late in April the front of the subsurface stream retreated, and by the first of May the surface flow had stopped. During and after this period the ground water mound decayed, and ground water levels dropped in the upper part of the canyon as water drained into the channel and downgradient through the alluvium.

The amount of recharge was small in the wide lower part of the canyon during the period of the study. The rise in ground water levels and the increase in moisture content of the alluvium in this lower part of the canyon indicate that water moved downgradient by underflow through alluvium from the recharge area in the upper part of the canyon. Moisture measurements indicate that only a little water moved into the underlying Bandelier Tuff from the saturated alluvium in the part of the canyon studied.

Borton, R.L., 1968,
General Geology and Hydrology of North-Central Santa Fe County, New Mexico,
New Mexico State Engineer Office, Report.

The purpose of this report is to present a general description of the geology and hydrology of north-central Santa Fe County, New Mexico. The report contains data and observations during approximately two months in the field during which 83 wells were visted and scheduled, locations and altitudes determined on topographic maps and water levels measured when possible. A geologic reconnaissance of the area was made and in early December a flight was made to make streamflow observations in inaccessible areas.

Brookins, D.G., et al., 1977,
Rb-Sr, K-Ar, and Fisson-Track Geochronological Studies of Samples from LASL
Drill Holes GT-1, GT-2 and EE-1,
LANL, LA-6829-MS.

Geochronological investigations using the Rb-SR, K-Ar, and fisson-track methods have been completed on core samples from three LASL deep drill holes, Gt-1, GT-2 and EE-1. This work indicates a complex history for these Precambrian rocks beginning with a metamorphic event at 1.66 b.y. which generated the gneisses and schists from older sedimentary and igneous rocks. The metamorphic complex was introduced by at least two different magmas at 1.3-1.4 b.y. producing thin felsic dikes and a major biotite granodiorite pluton. This igneous activity caused pervasive argon loss to occur, lowering the K-Ar ages to about 1.4 b.y. Plio-Pleistocene igneous activity related to the formation of the Valles Caldera increased the local geothermal gradient to 50-60 degrees C/km and produced fission track annealing in apatite and again argon loss from the biotite in deeper samples.

Brown, F., et al., 1988,
Site Geology and Hydrology of Technical Area 16, Area P,
LANL, LA-11209-MS.

Two distinct units of the Quarternary Upper Bandelier Tuff were encountered during a geological investigation of Technical Area 16, Area P, at Los Alamos National Laboratory, Los Alamos, New Mexico. Unit 3, the uppermost unit encountered, consists of four distinct ashflows, and is characterized by a high degree of welding and low-moisture content. Unit 2, the lowermost unit encountered, is densely welded, and noticeably impeded drilling operations. The Water Canyon Fault Zone, which lies approximately 500 ft to the east of Area P, exibits 10 to 15 ft of displacement in the subsurface with little surface expression apparent. No evidence for the existence of groundwater was detected.

Brown, M.C., et al., 1979,
Hot Dry Rock Geothermal Development Program Annual Report Fiscal Year 1978,
LANL, LA-7807-HDR.

During this period, Run Segment 1-3 were completed in the prototype reservior of the Phase I energy-extraction system at Fenton Hill, New Mexico. These tests yielded significant data on system flow parameters, water loss rates, geofluid chemistry, downhole flow impedance, operational constraints, mathematical modeling, technology and instrument capabilities and environmental effects of operation. The technical results indicated that energy (thermal or electrical) from hot dry rock may be feasible alternate energy source and prompted the Department of Energy to expand the project into a national Hot Dry Rock Geothermal Energy Development Program.

To further prove the concept, plans were prepared for a Phase II system with a commercial-size reservoir that will demonstrate the production lifetime of such a system. This deeper, hotter reservoir will require improved and new instruments and technology, which are being developed at the Los Alamos Scientific Laboratory and also by industry and other institutions. To expedite development of this promising energy resource, communication and information exchange on a national and international basis will continue.

Budding, A.J., 1978,
Gravity Survey of the Pajarito Plateau Los Alamos and Santa Fe Counties, New Mexico,
LANL, LA-7419-MS.

A Bouguer anomaly map of the Pajarito Plateau, based on more than 200 gravity stations, shows a NNE-trending low of 18 milligals centered 4.5 km southeast of Los Alamos. Interpretation based on geologic column, which includes Precambrian crystalline rocks, Carboniferous sediments, early Tertiary El Rito and Abiquiu Formations, late Teritary Santa Fe Group, and late Teritary and Quaternary volcanics and sediments, shows that the gravitational low could be the result of a NNE-trending graben, not expressed in the surface geology. The graben is about 10 km long and 5 km wide. It appears that the deepest part of the Espanola Basin of the Rio Grande rift zone is along the west side, where much as 2300 m of Santa Fe Group sediments could be present.

Budding, A.J., and Beers, C.A., 1973,
Faults in the Los Alamos Area and Their Relation to Seismicity,
LANL, Unpublished.

Faults in the vicinity of Los Alamos, New Mexico, offset members of the Bandelier Tuff, dated as 1.1 million years old. Fault lengths and displacements were determined from aerial photographs and field investigations. This information was used to estimate the seismicity of the area. It is concluded that the Los Alamos area may experience one shock of maximum magnitude 5 during a period of 100 years.

Budding, A.J., and Purtymun, W.D., 1976,
Seismicity of the Los Alamos Area Based on Geologic Data,
LANL, LA-6278-MS.

The seismicity of the Los Alamos area was determined by geologic data from four major faults that offset the Bandelier Tuff. The Bandelier Tuff was deposited as an ashflow about 1.1 million yr ago. From geologic data, fault length, displacement, and age of the Bandelier Tuff, it was concluded that the Los Alamos area may experience one shock of a maximum magnitude 5 during a period of 100 yr.

Burton, B.W., 1982,
Geologic Evolution of the Jemez Mountains and Their Potential for Future Volcanic Activity,
LANL, LA-8795-GEOL.

Geophysical and geochemical data and the geologic history of the Rio Grande rift and the vicinity of the Jemez Mountains are summarized to determine the probability of future volcanic activity in the Los Alamos, New Mexico area. The apparent cyclic nature of volcanism in the Jemez Mountains may be related to intermittent thermal inputs into the volcanic system beneath the region. The Jemez lineament, an alignment of late Cenozoic volcanic centers that crosses the rift near Los Alamos, has played an important role in the volcanic evolution of the Jemez Mountains. Geophysical data suggest that there is no active shallow magma body beneath the Valles caldera, through magma probably exists at about 15 km beneath this portion of the rift. The rate of volcanism in the Jemez Mountains during the last 10 million years has been 5 X 10-9/squared km/yr. Lava or ash flows overriding Laboratory radioactive waste disposal sites would have little potential to release radionuclides to the environment. The probability of a new volcano intruding close enough to a radioactive waste disposal site to effect radionuclide release is 2 X 10-7/yr.

Cabot, E.C., 1938,
Fault Border of the Sangre de Cristo Mountains North of Santa Fe New Mexico, Journal of Geolgy, Vol. 46, No.1.

The eastern prong of the southern Rocky Mountain province in New Mexico, called the Sangre de Cristo Mountains is usally described as a great anticlinal structure. Its eastern border and general internal structure conform to this definition but its western border is a fault-line scarp facing the down-faulted structural basin of the Rio Grande Depression.

This depression is underlain by partly consolidated fan deposits-the Santa Fe formation of Miocene or early Pliocene age. A water laid tuff, the Picuris formation, with interbedded basalt in places underlies the Santa Fe unconformably. These two formations are separated from the older rocks of the Sangre de Cristo both by erosional and by fault contacts. The fault pattern is irregular and consists largely of on echelon faults trending northwest, but so overlapping as to produce a north-south trend of the scarp from Santa Fe to Chimayo. North of this point the Picuris re-entrant forms an extension of the depression eastward, and the Picuris prong, bounded by a complex fault pattern, forms an extension of the mountain area westward.

The Rio Grande depression has been eroded in several successive stages. At the earliest stage the area of outcrop of the Santa Fe was reduced to a plain and the fault scarp was reduced to maturity by erosion. Later revival of streams has accentuated the topography and given the mountain front an apparent height about twice as great as it had in the early stages of erosion.

Crowe, B.M., et al., 1978,
Stratigraphy of the Bandelier Tuff in the Pajarito Plateau,
LANL, LA-7225-MS.

The Badelier Tuff within the Pajarito Plateau consists of a lower sequence of air-fall & ash-flow deposits (Otowi Member) disconformably overlain by an upper sequence of air-fall and ash-flow deposits (Tshirege Member). The ash-flow sequence of the Tshirege Member consists of three cooling units throughout much of the pajarito plateau. The lower cooling unit is formed by three to as many as six pyroclastic flow units; the middle and upper cooling units each consist of at least three pyroclastic flow units. The contact between the lower and the middle cooling units coincides with a pyroclastic flow unit contact. This horizon is a prominent stratigraphic marker within distal sections of the Tshirege Member.

Major and trace elememts analyses of unaltered and altered samples of the Bandelier Tuff were determined by neutron activation and delayed neutron activation techniques. Petrographic, granulometric and morphologic characteristics of the Bandelier Tuff were determined to provide background information on the suitability of the Tuff as a medium for radioactive waste disposal.

The hydrologic characteristics of the Bandelier Tuff are controlled primarily by secondary features of the Tuff (cooling zones). These features vary with emplacement temperature and transport distance of the Tuff. Primary depositional features provide second order control on transport pathways in distal sections of the Tuff.

Dames and Moore, 1972,
Report of Geologic, Foundation, Hydrologic and Seismic Investigation Plutonium Processing Facility Los Alamos Scientific Laboratory, Los Alamos, New Mexico, Dames & Moore, Los Angeles, Ca, Job Number: 0651-120-02.

This report describes a geological and engineering investigation of the proposed site for a new plutonium processing facility. The facility will be located at Los Alamos, New Mexico. The site is located on the Pajarito plateau situated on the eastern lanks of the Jemez Mountains. The site lies within the Rio Grande trough, which is a tectonic rift zone with bordering faults.

Evaluation of the geologic features within a radius of 200 miles of the site have been done. In addition, a detailed study of the immediate area of the site has been done. As a result of this investigation, it is concluded that TA-55 site is suitable, from a geologic standpoint, for the proposed plutonium processing facility. The risks of possible future surface ɜulting or volcanism are minimal. There is a risk of moderate future seismic ground motion at the site.

Dransfield, B.J., and Gardner, J.N., 1985,
Subsurface Geology of the Pajarito Plateau, Espanola Basin, New Mexico,
LANL, LA-10455-MS.

Integration of data from wells, geophysical surveys, and surface exposures has enabled construction of structure contour and paleogeologic maps of the pre-Bandelier Tuff surface beneath the Pajarito. Numerous faults of the Rio Grande rift system cut the pre-Bandelier Tuff surface, and most have down-to-the-west displacements. Cumulative down-to-the-west movements across these faults from the Rio Grande on the east to the Rendija Canyon fault zone on the west exceed 600 ft (185 m). All faults in the area show evidence of recurrent activity, with increasing displacements of progressively older rock units. The southern Pajarito fault zone has over 600 ft (185 m) of pre-Bandelier Tuff down-to-the-east movement. The pajarito fault zone and a major pre-Bandelier Tuff fault identified herein may constitute the local boundaries of the southern continuation of the intra-rift Velarde graben. The paleogeologic map shows that the three major rock units (Cerros del Rio basalts, Tschicoma Formation dacites, and Puye Formation gravels) underlie the Bandelier Tuff and interfinger beneath the central Pajarito Plateau.

Earth Environmental Consultants, 1978,
Soil Survey of the Bandelier National Monument,
Earth Environmental Consultants, Inc., Contract # CX70040199, PX7029-7-0838.

The Bandelier National Monument was surveyed to determine soil characteristics and conditions. That part of the Monument which occurs in Santa Fe County was mapped by the USDA Soil Conservation Service during the period of 1960-1968. and is published in the "Soil Survey of Santa Fe Area, New Mexico", 1975. This area comprises approximately 7 square miles. The southern two-thirds of the Monument was surveyed by Earth Environmental Consultants, Inc., (EECI) in the summer of 1974. This area comprises about 25 square miles. The remainder of the Monument was surveyed by EECI in April and May 1978. This includes the area north of Frijoles Canyon to State Highway 4 in Los Alamos County, the recently acquired lands on the Baca location in Sandoval County and the Upper Frijoles Canyon in Los Alamos County. These areas comprise about 25 square miles. The entire Monument comprises about 57 square miles and, except for the discrete area in Santa Fe County, is one contiguous unit comprising of Sandoval and Los Alamos Counties, New Mexico.

Soil names and classifications used in this report for areas in Sandoval and Los Alamos Counties are tentative as correlation is not yet complete. The soil names andclassifications used for the area in Santa Fe County were approved in 1971 and represent established soil series of the National Cooperative Soil Survey. Several unnamed soils in the EECI, 1974 report are tentatively named in this report to correspond to the tentative names being used by the USDA-SCS and FS in Los Alamos and Sandoval Counties. The soils are classified according to "Soil Taxonomy" USDA-SCS, Agricultural Handbook No. 436,1975.

Eichelberger, J.C., 1976,
Geosciences at Los Alamos Scientific Laboratory (LASL), July 1-December 31, 1975,
LANL, LA-6335-PR.

Research in the geosciences at LASL is focused primarily on the problem of understanding processes operating in the hot areas of the earth's crust, and the closely related applied problem of using the hot, dry rock of these regions as a source of geothermal energy. These studies include mass and heat transfer in the crust and upper mantle, phases in the crust and upper mantle rocks, near surface and surface behavior of magma (including eruption phenomenology), rock-water interaction at magmatic to surface temperatures, seismology, advanced drilling techniques applicable to hot rocks, geology and geophysics of the Fenton Hill geothermal experiment site, and evaluation of future sites. Many of the programs described here have begun to apply LASL's vast analytical and computational facilities to obtain solutions to major problems in the earth sciences.

Fisher, H.N., 1979,
"An Analysis of the Pressure Transient Testing of the Fenton Hill Reservoir",
Summary of Talks, 2nd Annual Hot Dry Rock Geothermal Conference,
LANL, LASL-79-86, pp. 24.

The Los Alamos Hot Dry Rock (HDR) Geothermal System which consists of fractures connecting two wellbores at Fenton Hill, New Mexico, was first established in October 1975. The fracture system, which is located in granite at a depth of approximately 2900 m, has been altered since then by two redrilling operations and subsequent hydraulic fracturing attempts. Many experiments involving the pressurization of one or both boreholes from which the fracture originates have also altered the flow characteristics of the system. These experiments have continued to give information on the permeation flow into surrounding rocks, the properties of the reservoir rock, the geometry and extent of the main fractures, and the flow-through properties of the heat exchange paths.

As in the analysis of conventional reservoirs the data analysis is in terms of a diffusion equation that determines the flow of water and hence the pressure in the main fracture system, associated joints, and the matrix permeability. The fits of the flow data to type curve solutions of the diffusion equation for various flow geometries are presented. The following points are considered in detail: 1) The limits on the fracture geometry, aperture and diffusing areas are determined from the diffusion parameters. 2) The parameters (impedance, diffusivity) of the flow-through systems are related to those governing the inflation of the main fractures. 3) The relationship of the rock properties to the reservoir compressibility and permeability are discussed. In particular, laboratory experiments show properties of all size of cracks from large single fractures to the microstructure and pressure dependent if the fluid pressure is near the confining stress. The effects of this on the form of the type curves are discussed. 4) The competition of flow into the various types of porosity (main fractures, joints, and microstructure) and the effect on the interpretation of the type curves are discussed.

Galuska, T., and Blick, J.C., 1971,
"Stratigraphy of the Santa Fe Group",
Bulletin of Am. Museum of Natural History, Vol. 144, Article 1, pp. 1-128.

The type area of the Santa Fe Group is in the region north of Santa Fe, New Mexico, between the Sangre de Cristo Mountains on the east and the Jemez Mountains on the west. This report proposes to restrict the use of the Santa Fe Group to the rocks of the type and contiguous areas. The middle Miocene to middle to upper Pliocene deposits of the type area, heretofore differentiated, are divided among five members of the Tesuque Formation, and the Chamita Formation. The division of the group is based upon results of field and laboratory studies since 1924 by Frick Laboratory of the American Museum of Natural History. The two formations from lowermost to uppermost are: (1) Tesuque Formation and (2) Chamita Formation. Formal names are proposed for the members of the Tesuque Formation.

Deposits of the Tesuque Formation, which is the lowest formation of the Santa Fe Group as here recognized, are divided into five members: (1) the Nambe Member, (2) the Skull Ridge Member, (3) the Pojoaque Member, (4) the Chama-el rito Member, and the (5) the Ojo Caliente Sandstone. Fossils collected from the Nambe and Skull Ridge members range in age from medial to late Miocene. The Pojoaque, the Chama-el rito, and the Ojo Caliente Sandstone have produced a large collection of early Pliocene mamalian fossils. These members are lithologically distinct, and, although they may have been deposited through the same general period of time, the beds are advisedly separated as members rather than as facies.

The Chamita Formation which is the uppermost formation of the Santa Fe Group, represents deposits from a markedly different sedimentary environment compared with the underlying Ojo Caliente Sandstone. Moreover, fossils of medial Pliocene age have been collected from the beds of the formation, with even a few fossils indicative of an early part of the late Pliocene.

The total thickness of the Santa Fe group, as restricted in this report, is at least 4500 feet and may be as much as 4800 ft. These figures were obtained by our measuring correlated fault blocks in the type area. The thicknesses assigned to the ideal sections of members or formations have been the basis for the estimates.

The sediments of the Santa Fe Group include alluvial-fan and eolian deposits, including conglomerates, gravel, lossely consolidated sandstones, siltstones, volcanic ash, bentonites, tuffaceous deposits, conglomeratic sandstones, intraformational breccias and conglomerates, concretions of various kinds, calcareous and cherty strata, and a small amount clay. Interbedded volcanic flows are few and of small extent.

Strata of the Santa Fe Group were deformed by high-angle, normal, strike faults during the post-Santa Fe deformation. The faults are closely spaced, and the strata in the resultant fault blocks in the Espanola Valley commonly dip westward 3 to 9 degrees. Maximum dip may be as much as 30 degrees. North of the Black Mesa dips may be easterly.

Detailed correlations in the Tesuque Formation were made from studies of the stratigraphic position of 38 differentiable volcanic-ash beds. Ash beds are particularly useful as horizon markers in the Skull Ridge Member. Small groups of volcanic-ash strata were used in comparable correlations in the Pojoaque Member of the Tesuque Formation. Two distinctive tuffaceous zones are useful for correlations in the Chamita Formation.

Gardner, J.N., and House, L., 1987,
Seismic Hazards Investigations at Los Alamos National Laboratory, 1984 to 1985,
LANL, LA-11072-MS.

The Pajarito fault system, part of which skirts the western boundary of Los Alamos National laboratory, is a major, active structural element of the Rio Grande rift. We have mapped over 100 km of interrelated fault zones and traces that constitute the fault system in the vicinity of Los Alamos; however, estimates of total fault system length are unrealistic because faults of the Pajarito system connect with regional structures that show no clear terminations. The style of deformation in the fault system gradually transforms from normal slip, to normal oblique slip, to dominantly right lateral strike-slip motions from south to north. Most significant movements (>100 m) on the fault system in the vicinity of Los Alamos have occurred within the last 1.1 million years. Portions of the fault system may have associated microseismic activity. Available evidence indicates that major movements have occurred on the fault system in the last 500,000 years and as recently as 350,000 years ago, 240,000 years ago, 42, 000 years ago, possibly <10,000 years ago, and 2, 000 years ago. Clearly the fault system is capable in the sense of the Code of Federal Regulations definitions. Some limited inferential field data imply the fault system generates characteristic earthquakes in the magnitude (Richter) range 6.5 to 7.8 (ideal correlation to Modified Mercalli Intensity VIII to X); however, these estimates need to better constrained, and the recurrence interval for these earthquakes remains to be determined. Extrapolation of frequency-magnitude relations, derived from the 10 years of data from the Los Alamos seismograph net, to estimate large expectable earthquakes is unrealistic, and based on the findings of other workers the result is most likely a substantial underestimate. The subsurface geology of Los Alamos and seismic properties of the Bandelier Tuff, over which the Laboratory lies, are so variable that the responses of different sites within the Laboratory should be analyzed individually for design purposes.

Gardner, J.N., et al., 1987,
Core Lithology Valles Caldera #1, New Mexico,
LANL, LA-10957-OBES.

Valles caldera #1 (VC-1) is the first Continental Scientific Drilling Program research core hole in the Valles caldera and the first continuously cored hole in the region. The hole penetrated 298 m of moat volcanics and caldera-fill ignimbrites, 35 m of volcaniclastic breccia, and 523 m of Paleozoic carbonates, sandstones, and shales with over 95% core recovery. The primary research objectives included coring through the youngest rhyolite flow within the caldera; obtaining structural and stratigraphic information near the intersection of the ring-fracture zone and the pre-caldera Jemez fault zone; and penetrating a high-temperature hydrothermal outflow plume near its source. This report presents a Compilation of lithologic and geophysical logs and photographs of core that were collected while drilling VC-1. It is intended to be a reference tool for researchers interested in caldera processes and associated geologic phenomena.

Giffels, and Rossetti, Inc., 1966,
Foundation Investigation (Subsurface Soil Borings) for Los Alamos Meson Physics Facility, Los Alamos, New Mexico,
Giffels, and Rosetti, Inc., Laboratory Number 6209.

This report gives tabular and graphic results obtained from test soil borings made at Los Alamos Meson Physics Facility project site. These test were conducted to obtain information on the degree of fusion of the underlying tuff and to obtain samples for visual inspection. Soil borings were used to determine unconfined compressive strength, grain-size classification, moisture content, dry densities, stress strain, and elasticity of the tuff.

Golombek, M.P., 1981,
Structural Analysis of the Pajarito Fault Zone in the Espanola Basin of the Rio Grande Rift, New Mexico,
University Microfilms International, Ann Arbor, MI, PH.D. Dissertation.

The Pajarito fault zone forms the western border of the Velarde graben, the presently active, central subbasin of the Espanola basin section of the Rio Grande rift in north-central New Mexico. The fault zone is a NNE-trending zone of predominantly down-to-the-east faults that cut Miocene to Pliocene volcanic rocks along the eastern flank of the Jemez Mountains. Where the fault zone cuts the 1.1 m.y. old Tshirege Member of the Bandelier Tuff, it has produced a steep, ~100 m high fault scarp. The total displacement across the fault zone during its 5 m.y. history is between 200-600 m. Detailed mapping along the Pajarito fault zone has revealed a fairly simple geometry. In the Tshirege Member, the faults follow numerous vertical joints. Below this member, fault dips are 60 degrees and are not listric at shallow depths. This simple geometry allows calculation of a ~0.05 mm/yr mean rate of extension across the Pajarito fault zone for the past 1.1 m.y. If extension is not perpendicular to the fault zone, the extension rate could be as great as ~0.07 mm/yr. Lack of transverse tilt of the Velarde garben wedge implies that the extension rate across the eastern margin is approximately the same as for the western margin. Comparsion with a published extension rate for the northern Albuquerque-Belen basin, immediately south of the Jemez Mountains, of 0.33 mm/yr (for both sides) since rifting began 26 m.y. ago indicates a slower opening for the Velarde graben during the past 1.1 m.y. If extension is localized along the margins of the Velarde graben with little activity along other fault zones in the Espanola basin, then both the mean rate of extension and the width of the actively extending region have decreased with time for this section of the Rio Grande rift.

Abrupt facies changes between older volcanics and volcaniclastic sediments of the Jemez Mountains appear to have controlled the local position, trend, and character of the Pajarito Fault zone. The fault zone bows and/or steps eastward where two large volcanic complexes are present, but is found further west in between and at either end of the volcanic complexes. One complex was sufficiently massive to interfere with the development of the Velarde graben.

Slickensides on mesoscopic faults in the Tshirege Member of the Bandelier Tuff indicate that the Pajarito fault zone has undergone extension in two directions during the past 1.1 m.y., approximately parallel and perpendicular to the local trend of the fault zone. These directions indicate that the Pajarito fault zone has reoriented the regional minimuum and intermediate stress directions to perpendicular and parallel, respectively , to the local trend of the fault zone and that both minimum and intermediate stress directions are tensional.

A tectonic history for the Pajarito fault zone area of the Espanola basin begins with relatively stable accumualtion of pre-rift and syn-rift sediments from Eocene and Oligocene time. Faulting, unrelated to the Pajarito fault zone but concomitant with sedimentation, filled deep central depressions within the Espanola basin. This faulting ceased prior to the end of the filling of the basin, around 10 m.y. ago in the local area. Jemez Mountains volcanism began about this time, before movement along the western-margin border faults of the Espanola basin caused west-tilting of old volcanics and sediments about 7.5-8.5 m.y. ago. Volcanism continued under relatively stable cobditions until ~5 m.y. ago. At this time, the Pajarito fault zone and Velarde graben formed. Faulting has continued to the present, localized along this central subbasin.

Griggs, R.L., 1955,
Geology and Ground Water Resources of the Los Alamos Area, New Mexico.,
U.S. Geological Survey, Open-File Report.

This report describes the geology and the occurrence and availability of ground water in an area surrounding Los Alamos, New Mexico. The study on which the report is based was made by the Ground Water Branch of the Geological Survey with funds furnished by the Atomic Evergy Commission.

The Los Alamos area is in north-central New Mexico, approximately 60 miles north-northeast of Albuquerque and 25 miles northwest of Santa Fe. As used in this report, the area is about 20 miles long in an east-west direction and about 10 miles wide in a north-south direction. The town of Los Alamos is near the center of the area.

The rocks of the area are of late Tertiary and Quaternary age. They consist of volcanic and sedimentary rocks that accumulated at the western side of the Rio Grande depression. For the most part, the area lies on the eastern flank of the Jemez Mountains, a volcanic eruptive center that stands athwart the zone of faulting at the western margin of the Rio Grande depression. The western edge of the area is near the center of these volcanic rocks and from there the area extends eastward across a segment of the interior mass of flows and an outlying apron of tuff that lies on the sedimentary and volcanic rocks of the Rio Grande depression.

The volcanic rocks of the Jemez Mountains consist mainly of the Tschicoma and Tewa groups with the former represented by two map units which consist of (1) latite and quartz latite and (2) pyroxene andesite; and the latter group represented by the (1) Bandelier tuff, (2) Cerro Toledo rhyolite, (3) Cerro Rubio quartz latite, and (4) Valles rhyolite. The Tschicoma group forms the interior mass of flows of the volcanic center. The Bandelier tuff forms the outlying apron of tuff. The Cerro Toledo rhyolite, the Cerro Rubio quartz latite, and Valles rhyolite are volcanic domes associated with the collapsed interior of the volcanic center. In addition, an unnamed body of sediments occurs in the Valles caldera, a portion of the collapsed interior of the volcanic center.

The suite of rocks of the Rio Grande depression are referred to as the Santa Fe group. Within the area this group is represented by three main map units. One is an undifferentiated sequence of arkosic sandstone and siltstone with some included basalt. Another, the Puye conglomerate, is composed mainly of latitic debris derived from the interior mass of the Jemez volcanic area, but it also includes some interbedded basalt and lentil of arkosic conglomerate. The third unit is a thick sequence of basalt.

Mapping and subsurface work indicate that the stratigraphic units are complexly interrelated. The mapping shows that the units of the Sant Fe group interfinger with each other. The subsurface work indicates that two units of the Santa Fe group, the undifferentiated sequence and the Puye conglomerate, interfinger with the Tschicoma group of the Jemez Mountains volcanic area.

Adequate water resources for the town of Los Alamos are not available in the immediate vicinity of the town. However, water in quantities adequate for the present population (14,000) occurs at both the eastern and western margins of the area. In both places the surface waters cannot be used because of legal restrictions. Water of the streams in the Valles Caldera, in the western part of the area, is utilized by Jemez Indians who have primordial rights to the flow. The flow of the Rio Grande, at the east margin of the area, also is completely appropriated by downstream users. Ground water in the sediments of the Valles caldera is unavailable as the present investigation has indicated that the small water bodies present are in close connection with the adjacent streams, and pumpage would decrease the stream flow. Ground water in the undifferentiated sequence of the Santa Fe group in the eastern part of the area represents the only source of supply available. Between 1946 and 1952 eleven supply wells were completed in these sediments. The study on which this report is based indicates that these wells are capable of supplying one billion gallons of water annually, the amount necessary for the town.

Grigsby, C.O., 1979,
"Hot Dry Rock Geochemistry", Summary of Talks, 2nd Annual Hot Dry Rock Geothermal Conference,
LANL, LASL-79-86, pp.26.

Analyses of fluids circulated through the prototype hot dry rock geothermal system at Fenton Hill indicate the importance of the combined effects of "pore" fluid displacement and rock dissolution in the total system chemistry. Changes in the fluid composition can be described by a simple mixing/dissolution model which accounts for addition of fresh fluid to replace permeation fluid losses in the reservoir. Changes in reservoir temperature, pressure and rates of water loss have an effect on the observed fluid composition.

Concentration variations of SIO2, HCO3, and Cl- Depict three patterns for geochemical behavior in the reservoir, and these species and others are used as internal tracers in the system. The SIO2 and Na-K-Ca geotheromometers are also used to study reservoir behavior.

Comparision between field circulation experiments and laboratory rock-water experiments are made to predict the compositions of geothermal fluids for the Phase II 20- to 50-MW(t) system at higher reservoir temperatures.

Gutschick, V., and Rea, K., 1978,
Environmental Assessment of Dissolved Gases in LASL's Hot Dry Rock Geothermal Source Demonstration Project,
Geothermal Resources Council, Transactions, Vol. 2.

Los Alamos Scientific Laboratory (LASL) Hot Dry Rock (HDR) Geothermal Energy Project basically involves drilling two deep holes by hydraulic fracturing, circulating water through the system, and bringing thermal energy to the surface in the form of superheated fluid. This paper focuses on the first examination of the fluid for dissolved gases. These gases can be emitted when fluid is vented during restarting of circulation or by inadvertent venting of the system during operation.

Analyses of the fluid for dissolved gases revealed the presence of hydrogen sulfide in amounts most likely higher than natural waters. Analyses with infared spectroscopy revealed the presence of a gas which did not match a standard spectrum. This "mystery gas" comprises 0.026 to 0.26% of the total gas. Ammonia was also detected, but in negligible amounts.

The fluid also contained 180 ppm by weight of silicon dioxide, 14 ppm of fluoride and small amounts of calcium and other ions.

Results therfore indicated that the only toxic gas detected was hydrogen sulfide, which at the levels found poses no hazard. The mystery gas is unassessed for toxicity but is not a recognized and potent substance.

Of the remaining fluid components, only fluoride at its elevated concentration (14 ppm) poses a moderate harzard in the event that fluid is released in very extensive amounts to drainage areas. The drinking water standard for fluoride is 2 ppm.

Heiken, G., 1975,
Solid Earth Geosciences Research Activities at LASL, January 1 - June 30, 1975, LANL, LA-6080-PR.

The Geoscience group at the Los Alamos Scientific Laboratory (LASL) supports existing geoscience-related programs and conducts a basic research program related to energy and earth resources.

Projects supporting the dry hot-rock geothermal energy program include study of drill cores, seismic activity associated with hydraulic fracturing at the drill site, and the thermal state of the Valles Caldera.

Research in igneous processes includes the modeling of large-scale volcanic eruptions such as the one which deposited the Bandelier Tuff around the Jemez Mountains, the petrology of those tuffs, and the dimensions of the magma chamber below the Valles Caldera. Report activity at Mt. Baker, WA, presented an opportunity to observe increasing fumarolic activity which may procede an eruption. The activity is continuously monitored by two sequence cameras. Samples of the tephra from around the vent have been studied, temperatures were measured, and ground observations were made of the new fumaroles. Every three months a flight is made over the volcano for aerial photography and infared scanning.

Field studies in the Southern Cascade Mountains were begun to determine the petrochemistry, mode of eruption, and volume of erupted materials for the last 0.5 million years. This study will be used to evaluate the present thermal state and composition of magmas below the range. Investigations of active volcanoes and their eruptions will provide data for geothermal research on the physical properties of the magma.

Heiken, G., 1985,
Workshop on Recent Research in the Valles Caldera; Los Alamos National Laboratory, Los Alamos, New Mexico, October 15-18, 1984,
LANL, LA-10339-C.

Over the last 5 years, there has been increased interest in the geology of the Jemez Mountains volacnic field, New Mexico. Of special interest is the Toledo-Valles caldera complex, which is targeted for research coring as a part of the Continental Scientific Drilling Program.

The abstracts in this document were prepared for distribution at this workshop. The general topics covered were (1) hydrothermal systems and rock-water interactions, (2) volcanology and structural framework of the Jemez volcanic field, (3) determining the presence or absence of melt below the Valles caldera, and (4) deep coring and drilling technology.

After the presentation of research results, the attendees spent 1 day addressing the problem of a research coring program in the Toledo-Valles caldera complex.

Hof, G.J., 1962,
The Effect of the Constant Natural Earth Movement on Numerically-Controlled Machine Tools,
LANL, TID-7024.

We were unable to find someone having machine tool problems caused by natural earth movement. Investigation with agencies having extremely sensitive equipment such as interferometers, ruling engines, or inertial guidance calibrating platforms also did not reveal any complaints about natural earth movements or microseisms. A study was made at the Los Alamos Scientific Laboratory to determine the extent of earth noise because there was indication that it was high. The study did not reveal any unusual conditions. We concluded that constant natural earth motions, usally called microseisms, are of such low frequency and amplitude and generate so little energy that they have no measurable effect on numerically-controlled machine tools.

House, L.S., and Cash, D.J., 1988,
A Reveiw of Historic and Instrumental Earthquake Activity and Studies of Seiemic Hazards near Los Alamos, New Mexico,
LANL, LA-11323-MS.

Los Alamos National laboratory is situated within an active tectonic feature, the Rio Grande rift. Numerous small to moderate magnitude earthquakes have occurred in the Los Alamos area within the past 100 years. The largest was the Cerrillos earthquake of 1918, for which felt reports imply a magnitude of 5 to 6. Several earthquakes of magnitude 3 to 4 have been felt in Los Alamos since the early 1950s. Instrumental information about earthquakes in northern New Mexico has been available for the past 14 years from the Los Alamos Seismograph Network. An estimate of future earthquake activity extrapolated from seiamicity recorded by the network suggests an earthquake of magnitude 4.5 to 5 could occur within 110 km (about 70 miles) of Los Alamos once per 100 years. Recent geologic and seismologic studies from other areas of the United States demonstrate such extrapolations may not be reliable, since earthquakes have occurred that are as muchas one to two magnitude units larger than those extrapolated. Additional studies, particularly geologic, are needed to better estimate the magnitude of the largest earthquakes that have affected the Los Alamos area and their reoccurrence intervals.

Several studies of seismic hazards and seismic risk have been done for the Los Alamos area. The most comprehensive one was completed in 1972 and was intended was intended for design engineering for the TA-55 Plutonium Facility. This study concluded that a peak horizontal acceleration of 0.33 g was appropriate for design of facilities at ta-55 since it was "unlikely to be exceeded". Progress in several areas of earthquake studies in the past 15 years has provided an improved understanding of earthquake occurrence and recurrence, as well as improved ability to estimate ground response resulting from possible local earthquakes. Because the results of the 1972 study are still being used for seismic design of new facilities at Los Alamos, the seismic hazards and risk for Los Alamos should be reevaluated in order to confirm that the 1972 results are still meaningful and valid. Such a reevaluation is however, beyound the scope of this report.

International Technology Corporation, 1987,
Geologic Assessment of Technical Area 54, Areas G and L, Los Alamos National Laboratory,
International Technology Corporation, Project NO. 301017.02.

This report presents a summary of the hydrogeology of Area G and L and other data and discussions relevant to the potential for migration of hazardous waste from the disposal ares. This report was prepared in response to a Compliance Order/Schedule, dated May 7, 1985, issued to the Laboratory by the New Mexico Environmental Improvement Division, pursuant to the New Mexico Hazardous Waste Act. Paragraph 25 of the Order mandated that certain tests and investigations be performed at Areas G and L to obtain information on the hydrologic characteristics of the waste disposal areas relevant to the potential migration of waste constituents into the area ground water.

Several specific conclusions, based on the hydrogeologic investigations performed at Mesita del Buey in 1985 and 1986 and on previous work, can be reached relative to the characteristics of Areas G and L and the potential for migration of contaminants from waste disposal units in these areas:

1. The Bandelier Tuff stratigraphy at Areas G and L is similar to that of the tuff throughout the western Pajarito Plateau.
2. Vertical and near-vertical fractures are common in the Bandelier Tuff on Mesita del Buey, through the degree of openness or pervasiveness of individual fractures is not well characterized.
3. No major fault zones that could serve as conduits from the shallow subsurface to the regional water table are known to exist at or near Areas G or L.
4. The combination of very low moisture content in the tuff, empirical determination that moisture from precipitation does not infiltrate below a depth of 10 to 25 feet, and very low calculated flux rates all suggest that aqueous transport of contaminants through Bandelier Tuff is not a viable mechanism for contaminant migration at Areas G and L.
5. Volatile organic waste constituents have migrated from land disposal units at Areas G and L based on the results of core and pore gas analyses conducted in 1985 and 1986.
6. Metals contamination from the land disposal units at Areas G and L was detected in only two samples from shallow depths (20 feet or less) at Area L.
7. Chemical data from the core and pore gas analyses (and information obtained from vadose zone charcterization) support vapor phase migration from Areas G and L as the dominant transport mechanism, based on the presence of volatile organic vapors at depths of up to 100 feet.
8. No perched bodies of water, which could be hydraulically connected to the main aquifer, have been detected beneath Areas G and L.
9. Perched water in Pajarito Canyon is confined to alluvium within the canyon and does not extend vertically or horizontally into the Bandelier Tuff which forms Mesita del Buey. No perched water was detected in Canada del Buey.
10. There is no evidence of migration of hazardous waste constituents from Areas G and L into perched water contained in the alluvium of Pajarito Canyon.

Izett, G.A., et al., 1978,
K-Ar and Fission-Track Zircon Ages of Cerro Toledo Rhyolite Tephra Units in the Jemez Mountains, North Central New Mexico,
U.S. Geological Survey, Open-File Report, 78-931.

Pumice units of the Cerro Tledo Rhyolite of early Pleistocene age in Pueblo Canyon in the eastern part of the Jemez Mountains of northcentral New Mexico lie stratigraphically between the Otowi (lower) and Tshirege (upper) Members of the Bandelier Tuff. The K-Ar ages of saidine, plagioclase, and hornblende from a lower unit of air-fall pumice of the Cerro Toledo are 1.46+/-0.03 m.y., 1.50+/-0.03 m.y., and 1.58+/-0.11 m.y., respectively, based on the newly recommended decay constants for K-40. A K-Ar isochron age for the three minerals is 1.47+/-0.04 m.y. The K-Ar age of sanidine from the uppermost pumice unit of the Cerro Toldedo is 1.23+/-0.11 m.y. These K-Ar ages are compatible with K-Ar ages of the lower and upper members of the Bandelier Tuff determined by G.B. Dalrymple in 1968. Zicron fission-tracks ages of the lower unit of the Cerro Toledo are 1.39 +/-0.11 m.y. and 1.46 +/-0.12 m.y.

Keller, M.D., 1968,
Deformation Characteristics of the Bandelier Tuff,
LANL, ENG-1-Rp-2.

The foundation material which must support the Los Alamos Meson Physics Linear Acceleration is a welded tuff of volcanic origin. Its physical properties are neither perfectly elastic nor inelastic, and its deformation characteristics were unknown to a satisfactory degree. Prior to design of critical components for the Meson Physics Linear Accelerator, it was necessary to determine these characteristics with sufficient reliability to provide for economical designs of buildings and critical machine components.

The two parameters that had to be determined for the Bandelier Tuff were the relationship of deformation to stress and to distance from a loaded area and the change in deformation with time (creep). These parameters then had to be correlated to analytical methods in order that reasonable accurate means of predicting deformation or creep could be devised.

Test medium used to obtain empirical results for deformation and creep consisted of a water tank which imposed 2180 pounds per square foot over an area of 5740 square feet and surplus Atlas counter-weights weighing 750 tons. The 750 ton load was imposed at two different locations, each location having a different subgrade configuration and on two different size foundations, thereby yielding four sets of data.

Analytical methods compared to this empirical data were Newsmark's Chart for determining vertical pressures and a computer program using the Boussinesq equation for vertical stress. Hooke's Law was used to determine deformation due to this vertical stress. The foundation material was assumed to be an isotropic uniform material.

Keller, M.D., 1968,
Geologic Studies and Material Properties Investigations of Mesita de Los Alamos,
LANL, LA-3728.

Investigations were conducted to verify the competence of the foundation material for the Los Alamos Meson Physics Facility and to provide relevant quantitative data for use by the architect-engineers in their facility design work. These investigations included geologic history, seismic probability, physical characteristics, and deformation characteristics.

Keller, M.D., Foster, E.S., and Werner, F.H., 1969,
Ground Vibration Characteristics of Mestia de Los Alamos,
LANL, ENG-1-RP-1.

The foundation material which must support the Los Alamos Meson Physics Linear Accelerator is a welded tuff of volcanic origin. Its physical properties are neither perfectly elastic nor inelastic, and its characteristics with respect to amplification or attenuation of vibrations were unknown to a satisfactory degree. Prior to design of critical components for the Meson Physics Linear Accelerator, it was necessary to determine these characteristics with sufficient reliability to provide for economical designs of buildings and critical machine components.

Those forces which could be duplicated, such as heavy truck traffic and impact loading, were duplicated and the vibrations resulting thereform were recorded. Natural microseisms were recorded. High explosives were detonated on Mesital de Los Alamos, and the relationship between size of charge, distance, frequency, velocity, acceleration, displacement and Fourierr Spectra coefficients was established. The results obtained from these tests will be used in the dynamic analysis of components comprising this facility. The tests conducted and the results obtained therefrom are described in this paper.

Kelley, V.C., 1948,
Los Alamos Project-Pumice Investigation-Field Survey; Geology and Pumice Deposits of the Pajarito Pateau, Sandoval, Santa Fe, and Rio Arriba Counties, New Mexico,
University of New Mexico, Contract No. At-(29-1)-553.

The rocks of the Pajarito Plateau consist of nearly horizontal volcanic and sedimentary beds which range in age from Middle Tertiary to Quaternary. The oldest rocks, known as Chicoma volcanic group, occur along the western edge of the plateau and in the Jemez Mountains. The late Tertiary Santa Fe Formation consisting of sand, silt, clay and gravel with some interbedded basalt crops out along the eastern escarpment of the plateau. The Bandelier rhyolite tuff is the youngest formation present, and it is the principal rock of the plateau. The bottom bed of the Bandelier formation consists of high quality pumice which is as much as 35 feet thick. This lower member of the Bandelier formation is here termed the Santa Clara pumice bed.

The best pumice of the Santa Clara bed underlies the plateau in a central, north-south band 5 miles wide and at least 20 miles long. In this band the pumice probably averages 25 feet in thickness and reserves amount over two billion cubic yards. In the northeastern part of the plateau the Santa Clara pumice forms surface blankets covering some 45,000,000 square yards. It is estimated that these surface deposits contain nearly 242,000,000 cubic yards of pumice.

The nearest of the blanket surface deposits to Los Alamos is at Guaje Flats where reserves of about 7,000,000 cubic yards are available.

Kelley, V.C., 1978,
Geology of Espanola Basin, New Mexico,
New Mexico Institute of Mining and Technology, Geologic Map 48.

This map was done as a companion to the geologic map of the Albuquerque Basin published in Memoir 33 (Kelley, 1977). These two maps cover most of the middle Rio Grande Depression. Most of the field work was done between September 1976 and September 1977. The prepared map gives detailed geologic mapping units for the basin as well as a description of those units.

Kelley, V.C., 1979,
"Tectonics, Middle Rio Grande Rift, New Mexico", Rio Grande Rift: Tectonics and Magmatism,
American Geophysical Union, Washington, D.C., pp. 57-70.

The Rio Grande rift, northward from Hatch, New Mexico on the south almost to Colorado, consists of about six north-trending basins which are translated easterly by right echeloning of the bordering uplifts. For the middle Rio Grande part of the rift the shift to the right of the eastern side of the Espanola basin with respect to that of Albuquerque basin is 55 km. Right echeloning occurs along both sides of the basins but is most pronounced along the eastern border. The geometry is accomplished by "ramping down" (plunging) of uplifts between faults arranged in relay. The shift to the right is such that the west side Los Alamos fault of the Espanola basin is nearly on line with the east-side Sandia fault of the Albuquerque basin. Direction of dips in adjoining basins is commonly opposite, e.g., northern Albuquerque, border beds as well as basin beds, dip east; in espanola basin, west; and in San Luis basin, east. Thus, basins appear to have deformed as units and diagonal faults involving twisting or pivotal movements occur. Between Albuquerque and Espanola it is La Bajada fault; between Espanola and Taos it is Embudo-Los Alamos fault. Maps by Cordell support with accentuated negative Bouguer gravity anomalies the structural and stratigraphic evidence for the deeply and aburtly downfaulted sides. Along the pivotal Los Alamos-Embudo fault the gravity basins cross near the pivot.

Left drag on several bounding faults, left oblique faults and folds in the basin, and left offset of two east-west Jurassic wedge edges across the Albuquerque basin indicate some left transcurrent motion along the rift in a field of counterclockwise rotational streaaes. This motion is also indicated by the abundance of the right echelon border uplifts, ramps, and relay faults.

The regional tectonic position of the rift is along the boundary between the Colorado Plateau on the west and the midcontinental cration on the east. This boundary underwent compressive deformation in the laramide to form the Eastern Rockies and later, just west of the orogenic belt, experienced neotectonic extensional activities which formed the Rio Grande rift. The rift may simply be the broken and foundered edge of the Plateau.

Kintzinger, P.R., et al., 1978,
Seismic Reflection Surveys Near LASL Geothermal Site,
LANL, LA-7228-MS.

Data and interpretations are presented for a seismic reflection survey in the Barley Canyon area of the Jemez Mountains, Sandoval County, New Mexico, on the north side of the Los Alamos Scientific Laboratory Hot Dry Rock Project, Fenton Hill Site.

Some results of an earlier (1974) seismic reflection of the south portion of the Hot Dry Rock Project area are included. Possible correlations of geologic structure between the two surveys are indicated.

Koopman, F.C., and Purtymun, W.D., 1965,
Preliminary Report on the MECHANICS OF AIR FLOW WITHIN THE BANDELIER TUFF with Special Reference to THE INJECTION DISPOSAL OF GASEOUS WASTES INTO UNSATURATED MEDIA.,
U.S. Geological Survey, Administrative Release.

Naturally occurring unsaturated porous media of great vertical and horizontal extent may have a holding capacity for radioactive gaseous waste. Present methods of radioactive gas disposal are expensive regardless of the quantities involved. Isolated disposal space for large quantities cannot be made mechanically without great expense. Gas wastes are present from many facets of our nuclear program and a search for safe storage space continues.

Observation of natural and artifically-imposed air-flow characteristics within natural porous media, tests on flow rates and directions, and degree of isolation of injected air have been proposed to determine if there is a safe space for gas at Los Alamos, New Mexico.

The investigations thus far have produced data on air flow exchange through wells in response to barometric pressure changes and artificially imposed low pressure tests on individual wells. Natural pressure changes can cause several thousand cubic feet of air to flow to or from a well depending upon the pressure balance. The air exchange to or from the tuff through a well can transfer several hundred thousand BTU per day.

The preliminary tests indicate that more than a million cubic feet per day can be forced into a well constructed in the tuff at a pressure not greater than one pound per square inch. The direction of air movement from deeper zones to the atmosphere is rather high. When a well is drilled into the tuff, the well becomes a dominating factor in air exchange by permitting large quantities of air to move through it with very small pressure differential. If the tuff characteristics were such that the air exchange through it to the surface took place rapidly by avenues other than the well, then there would be little or no differential between the atmosphere and tuff through the well, resulting in practically no air movement in the well.

Koopman, F.C., and Purtymun, W.D., 1966,
Volume and Energy Within Air Exchanged Through Test Holes in the Bandelier Tuff, Near Los Alamos, N. Mex.,
U.S. Geological Survey, Open-File Report.

Holes drilled into the Bandelier Tuff inhale or exhale air in response to atmospheric pressure changes. The rate of air exchanged, the groundwater levels, and the atmospheric pressure are correlative. Energy exhausted in the air ranges from 1.39 BTU/cubic ft (British thermal units per cubic foot) from a test hole completed in a dry tuff to 2.18 BTU/cubic ft from a test hole completed through the tuff and underlying conglomerate into the zone of saturation.

Kunkler, J.L., 1969,
Measurement of Atmospheric Pressure and Subsurface-Gas Pressure in the Unsaturated Zone of the Bandelier Tuff, Los Alamos, New Mexico,
U.S. Geological Survey, Prof. Paper, 650-D, pp. D283-D287.

Pressure transducers, power supplies, and potentiometric recorders were assembled into portable pressure-monitoring systems which measured pressures in the field with an accuracy of about 0.3 percent. The performance of some of the components was affected by fluctuations in field temperatures; hence these components were operated in a constant temperature chamber. The data from this study show that the subsurface-gas pressures to depths of 35 meters in the Bandelier Tuff; the response was completely attenuated at some depth between 35 and 89 m.

Kunkler, J.L., 1969,
The Sources of Carbon Dioxide in the Zone of Aeration of the Bandelier Tuff, Near Los Alamos, New Mexico,
U.S. Geological Survey, Prof. Paper, 650-B, pp. B185-B188.

Circulation of gas in the zone of aeration of the Bandelier Tuff in the vicinity of Los Alamos, N. Mex., has been under study for several years. Clues to the circulation pattern may be obtained from the carbon dioxide for composition and concentration in the zone of aeration. Techniques for collection of samples of samples of carbon dioxide for various analyses has been developed. Analyses of the data show that the carbon dioxide could not be determined because of contamination in the zone of aeration by artifically produced radiocarbon.

Larkin, K.P., and Speake, J.L., 1976,
Horizontal Monitoring Holes Los Alamos, New Mexico,
U.S. Energy Research & Development Administration, NVO-410-36.

The Horizontal Monitoring Holes were continously drilled holes. These were drilled in a horizontal plane in volcanic tuff and passed beneath a solid waste disposal pit in the vicinity of Los Alamos, New Mexico. The purpose of these holes was to determine the extent, if any, of radionuclide and moisture migration below the storage pits.

This report describes the drilling and completion operation of each hole and includes Daily Drilling Reports, Core Recovery Report, Operational Time Summary and Final Cost Report.

Laughlin, A.W., and Eddy, A., 1977,
Petrography and Geochemistry of Precambrian Rocks from GT-2 and EE-1,
LANL, LA-6930-MS.

During the drilling of GT-2 and EE-1, 27 cores totaling about 35 m were collected from the Precambrian section. Samples of each different lithology in each core were taken for petrographic and whole-rock major- and trace-element analyses. Whole-rock analyses are now completed on 37 samples. From these data we recognize four major Precambrian units at the Fenton Hill site. Geophysical logs and cuttings have been used to extrapolate between cores. The most abundant rock type is an extremely variable gneissic unit comprising about 75% of the rock penetrated. This rock is strongly foliated and may range compositionally from syenogranitic to tonalitic over a few centimeters. The bulk of the unit falls within the monzogranite field. Interlayered with the gneiss is a ferrohastingsite-biotite schist which compositionally resembles a basaltic andesite. A fault contact between the schist and gneiss was observed in one core. Intrusive into this metamorphic complex are two igneous rocks. A leucocratic monzogranite occurs as at least two 15-m-thick dikes, and a biotite-granodiorite body was intercepted by 338 m of drill hole. Both rocks are unfoliated and equigranular. The biotite granodiorite is very homogeneous and is characterized by high modal contents of biotite and sphene and by high K2O, TiO2, and P2O5 contents. Although all of the cores examined show fractures, most of these are tightly sealed or healed. Calcite is the most abundunt fracture filling mineral, but epidote, quartz, chlorite, clays or sulfides have also been ovserved. The degree of alteration of the essential minerals normally increases as these fractures are approached. The homogeneity of the biotite granodiorite at the bottom of GT-2 and the high degree of fracture filling ensure an ideal setting for the Hot Dry Rock Experiment.

Manley, K., 1979,
"Stratigraphy and Structure of the Espanola Basin, Rio Grande Rift, New Mexico",
Rio Grande Rift: Tectonics and Magmatism,
American Geophysical Union, Washington, D.C., pp. 71-86.

The Espanola basin, part of the Rio Grande rift in northern New Mexico, contains sedimentary and volcanic rocks of Eocene to Quaternary age. The onset of rifting, based on evidence from north and south basin, is generally considered middle to late Oligocene. Deposits of late Oligocene and early Miocene age extend beyound the margins of the present basin, offering no evidence that boundary faults existed at that time. The basin was probably a shallow depression between the eastward-tilting Nacimiento uplift and the westward-tilting Sangre de Cristo Mountains. Extensional faulting and volcanism near the western basin margin began in mid-Miocene time. Mid-Miocene to Pliocene rocks lap onto the Precambrian rocks of the Sangre de Cristo Mountains and have minor offsets along late Miocene to Pliocene faults.

The northeast-trending Velarde graben, with stratigraphic offset of as much as 360 m, formed in the central Espanola basin in early Pliocene time. The western side of the garben is partially bounded by the Pajarito fault zone, along which the Quaternary Bandelier Tuff has been offset. Early Pliocene deformation waned about 4 m.y. ago. A series of broad penecontemporaneous surfaces were cut across older basin-fill deposits; one of these surfaces is the Ortiz surface in the Santo Domingo subbasin. Overlying these surfaces are several formations 2.9 to 2.0 m.y. old. The Rio Grande was apparently established in conjunction with Pliocene erosion. Volcanic activity in the Cerros del Rio field 3 to 2 m.y. ago periodically dammed the river, which downcut in the late Quaternary until the present topographic Espanola basin was formed.

McGetchin, T.R., 1975,
Solid Earth Geosciences Research Activities at LASL, June1 - Dec 31, 1974,
LANL, LA-5956-PR.

Los Alamos Scientific Laboratory has had a continuing interest in the earth sciences because they relate directly to containment of radioactivity in underground weapons testing programs, facility siting, and environmental monitoring. The past emphasis has been in seismology, rock mechanics, and experimental high pressure geophysics. In response to national needs for energy resources, the Laboratory has expanded its interests. The present major efforts in energy related research are the hot dry rock geothermal energy project and the rock melting subterrene an electrically powered, high-temperature experimental drilling technique.

A geoscience group was formed at LASL in 1974 to support existing and future geo-related engineering programs, to maximize the scientific yield of the applied programs and to conduct a basic research program related to energy and earth resources. The primary interests of the group and igneous geology and solid earth geophysics - the origin, emplacement, and chemical evolution of plutons and volcanoes, and the nature of heat and mass transfer in the earth's interior. The research program includes seismology, rock mechanics, experimental high pressure geophysics, experimental geochemistry, observational petrology and geochemistry, field geology, and modeling by theoretical numerical and physical simulation.

Research activities in support of geothermal energy include: 1) geochemical and petrological investigations of drill cores; 2) physical and mechanical properties of the cores, in situ and in the laboratory, 3) seismology, 4) experimental and numerical investigation of the chemical interaction of granite and hot aqueous solutions, and 5) field and laboratory investigations of heat flow and the thermal properties of the cores. Investigations of solution geochemistry have proved to be especially interesting because they have possible applications in solution mining, suggesting coupled geothermal energy and mineral extraction operations.

Basic geoscience research activities in other divisions of LASL include preparation of high-purity crystals for experimental studies, thermochemistry, and the application of shock wave and other high-pressure techniques to investigations of the equation of state of rocks and minerals of the earth's interior.

Basic research of the geoscience group is focused on three field activities: 1) The Jemez Mountains-Rio Grande program provides information on the geothermal energy potential of the Rio Grande rift zone and problems of seismic risk to LASL facilities as well as probing interesting questions in volcanology such as caldera formation. Many investigators believe that the Rio Grande rift zone may be an incipient spreading center which may eventually split the American continent. 2) The Cascade program will deepen our understanding of andesite volcanoes, which are typical of the entire circum-Pacific volcano-seismic belt. Some andesitic volcanoes are known to contain important ore bodies and are a potential geothermal energy source. The andesitic volcanoes are also amoung the world's most dangerous and interesting in terms of their behavior and tectonic setting. 3) Investigations of active volcanoes and their eruptions provide data of interest in geothermal evergy research, such as the composition of the volcanic gas phase, and the basis for working models of magma chambers, their location, size and shape.

Newton, C.A., et al., 1976,
LASL Seismic Programs in the Vicinity of Los Alamos, New Mexico,
LANL, LA-6406-MS.

The Los Alamos Scientific Laboratory is located in north-central New Mexico within an area of geologically recent volcanic and tectonic activity. A network of twelve short period seismic stations within 150 kilometers of Los Alamos is telemetered to LASL, and recordings are mailed from similar stations at Lukachukaim, Arizona. These stations record most earthquakes having magnitudes (Ml) greater than one. The seismic data thus obtained are used to study the contemporary tectonic activity near the Valles Caldera and the Rio Grande Rift between 35 degrees and 37 degrees north latitude. The regional epicenter map for the period September 1973 through December 1975 shows earthquake concentrations (1) along the Nacimiento Uplift and its northward extension to Dulce, NM, (2) near Abiquiu, north of Los Alamos; (3) beneath the western part of the Taos Plateau; and (4) within the Rio Puerco fault zone, between Albuquerque and Grants. Almost no earthquakes are originating beneath the Valles Caldera, suggesting the presence of a hot shallow body where strain relief occurs by creep rather than by brittle fracture. The instrumental and historical seismicity and earthquake evidence from fault displacement consistently show the overall region to have moderate activity.

Short period seismic stations were installed within two kilometers of the LASL Hot Dry Rock Geothermal Demonstration site, but signals from the hydraulic fracturing of the granite body at depths of two and three kilometers were not observed. Other activities, such as building vibration studies, and future plans are also discussed.

Nyhan, J.W., 1978,
"Soil Survey Techniques Used to Characterize the National Environmental Research Park at Los Alamos", National Environmental Reserach Park Symposium: Natural Resource Inventory, Characterization, and Analysis,
Oak Ridge National Laboratory, ORNL-5304.

The techniques used to characterize the soils of the Los Alamos National Environmental Research Park are discussed. The selection of type of soil survey performed is explained, as well as the procedures necessary for the preparation for field work, for the examination and mapping of soils in the field, for the field and lab characterization of the soils, and for the completion of the survey.

Nyhan, J.W., and Miera, F.R., 1974,
"Characterization of Soil", Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division: January through December 1973, LANL, LA-5633-PR, pp. 35-36.

Ten core samples were taken of the alluvium at each of the 11 stations in Mortandad, DP-Los Alamos and Acid-Pueblo Canyons during the period May-July 1973. The samples were characterized as to their particle size distribution, cation exchange capacity and soil pH. The particle size distribution was used to characterize the erodibility of the soil profile. Severely eroded and moderately eroded soil profiles in all canyons contained less than 1-2% silt and clay in the top 2.5 cm of soil and less than 3-4% silt and clay in the remainder of the profile. Severely eroded soils contained up to 70% coarse fragments, whereas the dominant size fraction in most moderately eroded soils was very coarse sand. Very few stations contained soils with minimal water erosion; these soil profiles contained up to 54% silt and clay.

Cation exchange capacities of soil samples were correlated with increases in the smaller sized fractions. Thus, severely eroded, moderately eroded and minimally eroded soil profiles usually demonstrated cation exchange capacities of 2-4, 4-10, and 11-21 milliequivalents/100 g soil, respectively.

Soil pH fluctuated as a function of distance above and below the waste outfall areas, partially due to the dumping of alkaline waste solutions. Very little change in soil pH was found with depth in any soil profiles.

Nyhan, J.W., et al., 1978,
Soil Survey of Los Alamos County, New Mexico,
LANL, LA-6779-MS.

An intensive soil survey of about 79% of the 280,000,000 squared meters of Los Alamos County has been made to identify the kinds of soil in the area, where they are located and how they can best be used. A soil survey map is included, with detailed soils information presented in the report. Past and present land use in the Los Alamos area is discussed and general information about soils and their formation is evaluated, including the regional soil formation factors of geologic parent materials, climate, living organisms, topography, and time.

The soils of the area are classified according to the current system of soil classification and described in detail. The relationship of soil formation to classification is discussed and the current soil classification system is explained. General and detailed descriptions are given for each of the 61 soil mapping units, and include information on soil color, texture, structure, consistence, clay films, coarse and fine fragment distributions, permeability, depth hydrologic properties, pores, pH, and soil horizon boundaries. Soil mapping units are also described relative to their specific soil formation factors. The use and management of these soils for engineering and recreational purposes are also considered.

Olsen, K.H., Keller, G.R., and Stewart, J.N., 1978,
"Crustal Structure Along the Rio Grande Rift from Seismic Refraction Profiles",
1978 International Symposium on the Rio Grande Rift, October 8-17, 1978, Santa Fe, New Mexico, USA,
LANL, LA-7487-C.

A 40 station seismic refraction profile using large chemical explosions at the White Sands Missle Range as sources has been recorded along a 350 kilometer length extending north along the axis of the Rio Grande rift. The most detailed profile obtained in 1976-orginates about 40 km southeast of Socorro, NM, crosses the 1975 COCORP deep reflection profile at Abo Pass 80 km from the shot, and terminates near the Colorado-New Mexico border. Interpretation of the record section indicates a crustal thickness of about 34 kilometers and an apparent upper mantle (Pn) velocity of approximately 7.6 km/sec. In contrast, refraction and surface wave dispersion data of previous investigators in the Colorado Plateau province to the west and the Great Plains province to the east indicate somewhat thicker crust and higher Pn velocities (40 km, 7.8 - 8.0 km/sec and 45 km, 8.0 km/sec respectively). This implies a moderate crustal thinning under the Northern New Mexico segment of the Rio Grande rift.

The most notable feature of our 1976 record section is a strong reflection phase that exhibits a high degree of coherency over distances ranging from 20 to 130 kilomters. This phase arises from P waves reflected from a major intracrustual layer at a depth of approximately 21 kilomters, where the P wave velocity changes from 6.0 km/sec to 6.4 km/sec. Travel time and amplitude modeling with synthetic seismograms indicates the P wave velocity contrast of 0.4 km/sec alone is insufficient to explain the high reflection amplitude; an anomalously low shear wave velocity is required to match the observations. Thus, the data imply that the top of the lower crustal layer is in a zone of low rigidity. Micro-earthquakes studies by Sanford in the vicinity of Socorro have indicated the presence of a probable magma body whose upper surface lies at depths between 18 and 23 kilometers; this has been confirmed by COCORP observations west of Abo Pass. Our data, from reflection points mainly to the east and south of the Sanford and COCORP areas, suggest that the Socorro magma body may be associated with a more widespread intracrustal low rigidity layer.

Purtymun, W.D., 1966,
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. Geological Survey, Administrative Release.

White Rock Canyon along the Rio Grande from Otowi to the confluence of Frijoles Canyon is a discharge area for ground water that moves beneath the Pajarito Plateau, the site of the City of Los Alamos, New Mexico, and the Los Alamos Scientific Laboratories. The geology and hydrology of the water supply and waste-disposal problems of the Los Alamos area.

Two geologic units, the Tesuque Formation and the Totavi Lentil of the Puye Conglomerate, yield sbout 3 cfs (cubic feet per second) of ground water to the river through springs. Some water is accrited directly into the river from the Tesuque Formation and some water moves through alluvial fans at the mouths of Los Alamos and Frijoles Canyons, and possibly Canada Ancha, directly into the river. Seepage investigations indicate an average increase in flow of the Rio Grande, between Otowi and the confluence of Frijoles Canyon, of about 15 cfs of which about 3 cfs is added from springs.

The chemical quality of water from the springs, from streams fed by springs, and from the Rio Grande is good. The individual chemical constituents and total dissolved solids are below the maximum permissible limits as recommended for drinking water by the U.S. Public Health Service.

The radiochemical quality of the water in White Rock Canyon indicates that the water has not been contaminated by industrial effluents discharged at Los Alamos. Beta (gamma) activity and uranium content of the water is low, well below the maximum permissible concentrations.

Purtymun, W.D., 1967,
Geology and Physical Properties of the Near-Surface Rocks at Mesita de los Alamos, Los Alamos County, New Mexico,
U.S. Geological Survey, Open-File Report.

The surface of Mesita de los Alamos is formed by units 2b and 3 of the Tshirege Member of the Bandelier Tuff. These units dip gently east-southeastward at 3 to 6 degrees. The units are faulted near the center of the mesa by a north-south trending normal spike slip fault, that is downthrown about 14 feet to the east. The units east of the fault have moved about 14 feet south relative to the units on the west side of the fault.

Units 2b and 3 have bulk density values ranging from 80 to 120 pounds per cubic foot. The moisture content of the tuff below the soil zone and near surface tuff was less than 5 percent by volume in five of the 25 test holes drilled during a foundation investigation for the Meson Facility. The temperature of the tuff in the bottom of three test holes (depth 16 to 43 feet) varied from 50 degrees F. to 54 degrees F. Temperature variations were a function of density and amount of solar radiation.

Purtymun, W.D., 1973,
Geology of the Jemez Plateau West of Valles Caldera,
LANL, LA-5124-MS.

The Jemez Plateau at the site proposed for a geothermal-energy study forms an apron around the west side of the Valles Caldera. Five test holes were drilled on the plateau for geologic information, temperature data, and to investigate drilling problems. Four of the test holes, ranging in depth from 500 to 750 ft, penetrated volcanic rocks of Cenozoic Age and were completed into the sediments of Permian Age. A deep test hole, drilled 2575 ft, penetrated the volcanic of Cenzoic Age and sediments of Permian and Pennsylvanian Age, and is completed into the rocks of Precambrian rocks. The basic part of the study is to be made in the Precambrian rocks. Test drilling and measured sections indicate a small north-south trending basin near the center plateau in which the sediments thicken. The basin may be structural in part or erosional where the upper surface of Precambrain rocks was cut to form a small valley before deposition of the sediments. The geologic logs of the five test holes are included.

Purtymun, W.D., 1973,
Underground Movement of Tritium from Solid-Waste Storage Shafts,
LANL, LA-5286-MS.

Tritium from contaminated wastes placed in storage shafts has been transported by moisture into adjacent tuff. A study made to determine the extent and geologic factors governing this movement indicates that 100 pCi/ml levels have moved westward a distance of 105 ft in 4 yr. Major movement has been along the contact between the two ashflows penetrated by the shafts, with secondary transport through open joints and through the tuff matrix. Evaporation from surface soil and tuff and transpiration from plants has been a contributing factor in the release of tritium to the atmosphere.

Purtymun, W.D., and Johansen, S., 1974,
"General Geohydrology of the Pajarito Plateau", New Mexico Geologic Society Guidebook, 25th Field Conference,
New Mexico Geologic Society, pp. 347-349.

The Pajarito Plateau, twenty miles northwest of Santa Fe in north-central New Mexico, forms an apron of volcanic and sedimentary rocks around the eastern flanks of the Jemez Mountains. The plateau slopes gently eastward from the mountains toward the Rio Grande where it terminates in steep slopes and cliffs formed by down cutting of the river. It is dissected into a number of narrow mesas by south-eastward trending intermittent streams.

The main aquifer lies at a depth of 600 to 1200ft beneath the surface of the plateau in rocks of the Santa Fe Group. This is the only aquifer in the area capable of municipal and industrial water supply.

The plateau is formed by rocks of the Santa Fe Group of middle to Pleistocene Age, and volcanic rocks of Pliocene and Pleistocene Age. The Santa Fe Group comprises the Tesuque and the Puye Formations and the basaltic rocks of Chimo Mesa. These formations crop out along the eastern margin of the Pajarito Plateau.

The upper surface of the main aquifer rises westward from the Rio Grande through the Tesuque into the lower part of the Puye Formation beneath the central and western parts of the plateau. The water in the aquifer moves from the major recharge area in the Valles Caldera eastward toward the Rio Grande where a part is discharged into the river through seeps and springs.

The first water-supply wells for Los Alamos municipal and industrial supply were developed along the eastern edge of the Pajarito Plateau in 1947. These wells are completed in the main aquifer and range in depth from 870 to 2000 ft.

Aquifer test of wells indicate an average coefficient of transmissibility of 20,000 g/d/ft of the aquifer. These wells yield an average of 500 gpm with a specific capacity of 8 gpm/ft of drawdown.

The chemical quality of water may vary within well fields due to local conditions within the aquifer. In general the quality of water is good; total dissolved solids range from 200 mg/l to less than 500 mg/l. Silica concentrations range from 35 to 80 mg/l while total hardness (as $CaCO_3$) ranges from 25 to 100 mg/l.

Purtymun, W.D., and Jordan, H.S., 1973,
Seismic Program of the Los Alamos Scientific Laboratory,
LANL, LA-5386-MS.

There are four areas of interest in seismic programs at Los Alamos; (1) Environmental studies, (2) Seismic studies in connection with the Geothermal Program, (3) Underground explosive test event studies, and (4) Strong motion studies. The purpose of this paper is to outline areas of study and their objectives and to propose a policy statement.

Purtymun, W.D., and Kennedy, W.R., 1971,
Geology and Hydrology of Mesita del Buey,
LANL, LA-4660.

Mesita del Buey is used for the disposal of wastes contaminated by radionuclides, of toxic or explosive chemicals, and of classified materials. These are buried in pits or shafts dug into the mesa surface. The mesa, covered by a clay-like soil, is underlain by a series of ashfalls of rhyolite tuffs from 240 to 590 ft thick. The tuffs are above the main aquifer of the Los Alamos area which lies at a depth of about 1000 ft.Stream flow in adjacent canyons is intermittent Water in the alluvium of the stream-connected aquifer in the canyon south of the mesa is recharged by storm runoff. The hydrologic characteristics and conditions of the soil, tuff and seal material used to cover the wastes indicate no recharge to the stream-connected aquifer or main aquifer through the soil, buried wastes, or tuff at Mesita del Buey.

Purtymun, W.D., and Koopman, F.C., 1965,
Physical Characteristics of the Tshirege Member of the Bandelier Tuff with Reference to Use as a Building and Ornamental Stone,
U.S. Geological Survey, Report to Comm. Act. Prog., Santa Clara Ind..

The suitability of the Tshirege Member of the Bandelier Tuff for insulation, ornament, building stone, and other uses is dependent on its availability, accessibility, and its physical properties. At the request of Mr. Paul Tofoya, Governor of Santa Clara Indian Pueblo and Mr. Williams, Advisor of the Community Action Program at Santa Clara, New Mexico, the information available as its geographical and geological accessibility and its physical properties are presented in this report. The information will be useful in the Community Action Program for developng and enlarging the Puye Cliff Dwelling area as a tourist facility and may also suggest other uses.

Results of this study and earilier studies suggest that the Tshirege Member of the Bandelier Tuff is well suited as a building and ornamental stone.

Purtymun, W.D., West, F.G., and Pettitt, R.A., 1974,
Geology of Geothermal Test Hole GT-2 Fenton Hill Site, July 1974,
LANL, LA-5780-MS.

The test hole GT-2, drilled at Fenton Hill Site, was completed at a depth of 6346 ft (1934.3 m) below land surface. The hole penetrated 450 ft (137.2 m) of Cenozoic volcanics, 1945 ft (592.8 m) of sediments of Permian and Pennsylvanian age and 3951 ft (1204.3 m) of granitic rocks of Precambrian age. This report presents the field geologic log of the hole and hydrologic data complied during the drilling phase of the program.

Purtymun, W.D., Wheeler, M.L., and Rogers, M.A., 1978,
Geologic Description of Cores from Holes P-3 MH-1 Through P-3 MH-5, Area G,
Technical Area 54,
LANL, LA-7308-MS.

Five horizontal holes were cored beneath Pit 3 near the southeast edge of Mesita del Buey at Area G. The pit, filled and covered by 1966, contains solid radioactive wastes. The holes were cored to obtain samples of the tuff underlying the pit to determine if there has been any migration of radionuclides by infiltration of water in the past 10 years. The five holes were collared in Unit 2b of the Tshirege Member of the Bandelier Tuff; three holes plunged by core holes and the joint characteristics observed. The locations of core samples selected for analyses are related to the floor of the pit.

Reynolds, C.B., 1977,
Experimental Shallow Seismic Reflection Survey Los Alamos Area, New Mexico,
Unknown, Letter Report.

During the period June 14-22 inclusive, an experimental shallow seismic reflection survey was carried out for Los Alamos Scientific Laboratory in the area of Los Alamos, Los Alamos and Santa Fe Counties, New Mexico. The purpose of the experimental survey was to determine whether usable shallow seismic reflection data could be obtained in this deeply dissected volcanic terrain.

Four seismic lines were recorded, each about a mile long: Line TA-49, Line TA-44, Line LAC-1, and Line SR-4. The first (TA-49) was recorded using explosives as a seismic energy source, using a receiver array of 12 geophones spaced 12 feet apart inline. It was later recorded again using a receiver array of 24 geophones spaced 12 feet apart inline, as a comparison. Line TA-44 was recorded using a dropped weight (150 lb. shot bag) and a drag cable receiver array of 6 geophones spaced four meters apart inline, as was Line LAC-1. Line SR-4 was recorded using a larger dropped weight (300 lbs.) and a receiver array of 12 geophones spaced 12 feet apart inline. Station spacing was 100 meters on lines TA-49 and SR-4, and 25 meters on lines TA-44 and LAC-1. All recording was single channel.

The test of explosives as a seismic reflection energy source was not successful, probably because (1) no good reflectors were present, (2) the line was recorded in the unfavourable setting of a ridgetop, (3) the recording frequency band pass used (8-40 Hz) may have been too low and (4) the charges used (1/3 lb.) may have been too large.

The test of the drag cable and shot bag system was successful, more especially in the case of the line recorded in Los Alamos Canyon, where there was no interference caused by vehicular traffic, power lines, or disposal pits. Geologically usable data to a depth of 600-800 feet were obtained.

The test of the 300 lb. weight-drop and 12-geophone system was also successful, yielding geologiclly useable data to about 1500 feet depth.

If in future explosives are used as a seismic reflection energy source in this area, smaller charges should be tried, 50 meter group (trace) spacing should be used, a higher frequency pass band should be used, including deconvolution and uniform filtering planned. Where possible, future drag-cable recording in the area should be done in canyons, rather than on ridgetops. Any future 300-lb. weight-drop recording in the area should use 50 m spacing.

Ross, C.S., Smith, R.L., and Bailey, R.A., 1961,
"Outline of the Geology of the Jemez Mountains, New Mexico",
New Mexico Geological Society, Twelfth Field Conference, pp. 139-143.

This paper gives a description of the geologic setting, volcanic stratigraphy, volcanic structures, and regional setting of the Jemez Mountains. The paper also outlines a historical geologic summary of the area based on the works of Bryan (1938), Smith (1938), and Stearns (1953).

Sanford, A.R., 1972,
Semismicity on the Los Alamos Region Based on Seismological Data,
New Nexico Institute of Mining and Technology, A Report to LANL.

Estimates of seismic risk in the Los Alamos area based on only seismological evidence are presented. The data used in the study and tabulated in this paper restricted to shocks occurring within 111 km of Los Alamos and included (1) noninstrumental reports of earthquakes prior to 1962, and (2) instrumental studies of shocks from 1962 to 1972.

The strongest earthquakes to occur within the region of study during the 100 year period, 1872-1972, had a probable magnitude of 5.5. 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 depending on the data set used.

The paper recommends that sesimic risk in the Los Alamos area be based on the reoccurrence of a magnitude 5.5 earthquake once every 100 years somewhere within the Rio Grande depression from Albuquerque to Questa. The seismicity of this part of the rift zone is (1) less than the Albuqerque to Socorro segment of the same structure and (2) substantially less than equivalent areas in Southern California.

Sanford, A.R., et al., 1972,
Seismicity of the Rio Grande Rift in New Mexico,
N. Mex. State Bureau of Mines & Mineral Resources, Circular 120.

The Rio Grande rift zone is the most probable are of New Mexico to have substantial seismic activity. The principal data used in establishing the seismicity of this region were: (1) reports of strong earthquakes before 1960, (2) instrumental studies of moderate shocks (Ml>2.7) after 1960, (3) analysis of fault scarps offsetting the Quaternary geomorphic surfaces in the Socorro area.

Historical reports indicate a moderately high seismic risk in a zone from Albuquerque to Socorro. In this region, particularly near Socorro, the largest shock in a 100-year period is likely to be magnitude 6. Instrumental data on earthquakes (M>2.7) since 1960 show that activity is highest near Socorro and Las Cruces. However, estimated seismic risk from these data is low, with a maximum magnitude shock of about 5 each 100 years over the entire extent of the rift zone. Analyses of microearthquakes (ML<2.7) also lead to low estimates of seismic risk in the rift zone, e.g. a maximum magnitude shock of 4.6 in the Socorro-Bernardo region each 100 years.

Historical reports, spanning a century are probably more reliable indicator of seismic risk than the relatively short-term instrumental data spanning only a decade. The historical data indicate probability of a magnitude 6 earthquake each 100 years. Both categories of data indicate seismic risk is not uniform and is greatest in the following regions: (1) Socorro-Bernardo, (2) Albuquerque-Belen, and (3) El Paso-Las Cruces.

In the region of highest seismic risk, Socorro-Bernardo, little direct correlation exists between the distribution of microearthquakes and faults. Analyses of data for faults offsetting recent geomorphic surfaces indicates seismic activity has been occurring in the Socorro-Bernardo region for thousands of years. Estimates of seismicity based on the fault scarps cover a farily wide range because of the uncertainty in the age of the scarps. However, the most reasonable estimates for the age yeild seismicity values comparable to those calculated from earthquake data.

Sanford, A.R., Olsen, K.H., and Jaksha, L.H., 1979, "Seismicity of the Rio Grande Rift", Rio Grande Rift: Tectonics and Magmatism, American Geophysical Union, Washington, D.C., pp. 145-168.

Earthquakes have been noted along the Rio Grande rift since 1849. During the period of non-instrumental reporting of earthquakes from 1849 through 1961, nearly all earthquakes occurred along a 150 km section of the rift from Albuquerque to Socorro. In the latter area, the most notable seismic activity was an intense and prolonged earthquake swarm from 1906-1907 which included three moderately strong shocks (felt areas from 125,000 to 245,000 sq km).

Instrumental studies starting in 1962 have revealed a low level of seismicity in the rift during the past 16 years, only an average of two shocks with Ml >= 2.4 each year. During the same period, a comparable level of seismicity was observed in the High Plains and Colorado Plateau, two neighboring physiographic provinces which geologic data indicate are more tectonically stable than the rift. An additional finding of the instrumental studies was large seismic gaps along the rift, e.g. from Socorro to Las Cruces, where no shocks with Ml >=2.4 have occurred since 1962.

Detailed seismic studies along the rift by New Mexico Institute of Mining and Technology, Los Alamos Scientific Laboratory, and Albuquerque Seismological Laboratory (U.S.G.S.) have shown that areas of concentrated microearthquake activity exist within the rift, notably from Belen to Socorro and 15 km west to Espanola. Both of these seismic regions may be associated with modern magma bodies at middle to upper crustal levels. An important finding of the LASL studies is an absence of microearthquake activity in a rather large area centered on the Valles caldera, a possible indication of high temperature at shallow depths in the crust. Composite fault plane solutions for microearthquakes in the rift suggest that both strikes-slip and normal faulting, and latter dominant, are currently occurring in the rift. The average direction of the T axis for all solutions is near east-west.

The small number of shocks in the rift, along with their spatial distribution, suggests the rift may not be spreading at this time. Geodetic measurements at one location, Socorro, are in agreement with this tentative conclusion.

Savage, W.U., Ely, R.W., and Tocher, D., 1977,
Review of the Los Alamos Seismic Monitoring Program in Relation to the Hot Dry Rock Geothermal Project,
Woodward-Clyde Consultants, UC-LASL Order No. L47-85930-1.

The following is review of the Los Alamos Scientific Laboratory's Seismic Monitoring program in relation to the Hot Dry Rock Geothermal Project. This review was prepared by Woodward-Clyde Consultants. The specific objectives of this review of the LASL seismic monitoring program are:

1. to evaluate the current seismic monitoring strategy;
2. to examine the adequacy of the operational aspects of the program as they relate to identified or desirable objectives; and
3. to provide recommendations for changes and alterations in the seismic monitoring program.

After this review it is recommended that a multifaceted program of seismic monitoring continue to be included as a part of the HDRG Project and associated projects and seismic monitoring studies related to the HDRG at Fenton Hill be upgraded in the light of the risk faced by the HDRG program due to the possible occurrence of either natural or induced earthquakes. It is also recommended that expansion of the regional seismic network in northern New Mexico be undertaken, with the addition of thirteen stations. Three recommendations are specific to Fenton Hill. One, optimization of the five station surface array to detect small high frequency natural or induced earthquakes that may occur in the vicinity of the thermal reservoir. Two, utilization of the test hole GT-1 for continuous downhole monitoring of the thermal reservoir during production tests. Three, inclusion of plans for deep subsurface monitoring at future HDRG sites.

Shankland, T.J., 1978,
"Simultaneous Consideration of Electrical and Elastic Anomalities in Rift Zones", 1978 International Symposium on the Rio Grande Rift, October 8-17, 1978, Santa Fe, New Mexico, USA,
LANL, LA-7487-C.

The mantle below continental rifts is usually a region of anomalously high electrical conductivity and low seismic velocity. Recent volcanism and high heat flow associated with rifts make it plausible to attribute these anomalies to the presence of partial melt. For a given melt fraction within a solid matrix it is possible to use theories of electrical and elastic properties of aggregates to interpret the anomalies. Lines of constant conductivity of velocity can be combined with plots of temperature vs. degree of partial melting from experimental petrology; these results can be used to estimate both temperatures and melt fractions in mantle zones having anomalous conductivity or velocity. Further, if the melt is assumed to be in flattened cracks, dikes, or lenses, then requiring that the same amount of melt produce both kinds of anomalies permits the calculation of the aspect ratio of crack thickness to diameter. An example of conditions approximating those within the Rio Grande Rift is that of an anomalous zone at 45 km depth having an electrical conductivity of 0.2 S/m (mhos/m) and a P-velocity 10% less than that of unmelted "dry" peridotite. Then a consistent physical description would be a temperature of 1300 degrees C, a melt fraction of 7%, and an aspect ratio of 0.03. This aspect ratio is more likely to be consistent with melt in dike or sill complexes rather than as a film of melt surrounding crystal grains.

Slemmons, D.B., 1975,
Fault Activity and Seismicity near the Los Alamos Scientific Laboratory Geothermal Test Site, Jemez Mountains, New Mexico,
LANL, LA-5911-MS.

The purpose of this study is to develop for evaluating geothermal sites for earthquakes hazards and for possibility siting on an active fault. These guidelines were used to minimize these risks for a specific geothermal test site of the Los Alamos Scientific Laboratory (LASL) on the Jemez Plateau, a few miles west of the Valles Caldera, at the center of the Jemez Mountains in north-central New Mexico.

The approach to the problem involves new methods of low-sun-angle aerial photography and photogeology, in combination with conventional geological and seismicity studies. The possibility of future surface faulting or occurrence of strong local earthquakes is analyzed by comparing the structural and seismic setting of the area of investigation with that of the Rio Grande depression and other active zones in the western United States. The evaluation includes identification, delination and characterization of faults in the region with conventional high-sun-angle aerial photographs, special low-sun-angle aerial photographs taken specifically for this project, Earth Resources Technology Satellite (ERTS) imagery, manned space satellite photography, search of the geological literature, and aerial and ground reconnaissance using both low and high sun angles of illumination at midday, early morning and late afternoon.

The site area is near the western edge of the Rio Grande depression, the most active seismic zone of new Mexico. The Rio Grande depression is marked in places by geologically youthful fault scarps and in places is known to have significant normal faults.

Topographically the site area is composed of mesas of Quarternary volcanic tuffs and ashes of the Bandelier Rhyolite unit, which dips gently to the southwest with a nearly uniform dip. The upper surface of the mesas have slightly steeper gradients near the source area for the volcanic rocks at the eastern edge of the area. The drainage lines also trend in a southwesternly direction, away from the source of the eruptions, and are of consequent origin. Four streams or valleys have segments that diverge from this general trend: (1) the northern end of the eastern branch of Rio Cebolla, along an arcuate fault mapped by Smith et al. in 1970, about 7 miles (11 km) north of the Gt-2 site; (2) a similar trending and concentric zone about 1.6 mile (2.5 km) to the northwest of the Rio Cebolla fault along the upper part of Calaveras Canyon; (3) a small fault along the upper reaches of Virigin Canyon, about 2.5 miles (4 km) southeast of the site; and (4) the Jemez Springs fault, a more important regional fault, about 4.4 miles (7 km) southeast of the site. Although these faults displace the Bandelier Rhyolites of 1.1-million-years age, they all have relatively small displacements (under about 100 ft or 30 m) and have rates of displacement that are 1 or 2 orders of magnitude smaller than those of the San Andreas fault system, or of major faults of the Basin and Range province of the western United States.

The very low seismic risk is indicated not only by the low-level of fault activity, but also by the low-level of earthquake activity for New Mexico, the low level activity in the Rio Grande structural depression (the most important fault zone in New Mexico), the general lack of any earthquakes of Richter magnitudes above 6, and the very sparse distribution of microearthquakes in the Jemez Mountains.

Spiegel, Z., 1961,
"Late Cenzoic Sediments of the Lower Jemez River",
New Mexico Geologic Society, Twelfth Field Conference, pp. 132-138.

Mapping of serveral important areas of late Cenozoic sediments in the Rio Grande trough has been accomplished by recent workers. However, four units mapped by Bryan and McCann in 1937 along the Rio Puerco had apparently had not been restudied in sufficient detail to assure definite correlations with the sections observed elsewhere. Therefore, this work was undertaken in August 1960, as part of a quantitative investigation of the relationships of aquifer systems in this area to streamflow in the Rio Grande drainage basin. A geologic map was made of the lower Jemez River basin proper but the "Lower Jemez River Region" as described here extends from White Rock Canyon to Alameda.

Stranford, A.R., 1976,
Seismicity of the Los Alamos Region Based on Seismological Data,
LANL, LA-6416-MS.

Estimates of seismic risk in the Los Alamos area based on only seismological evidence are presented. The data used in the study and tabulated in this paper were restricted to shocks occuring within 111 km of Los Alamos and included (1) noninstrumental reports of earthquakes prior to 1962 and (2) instrumental studies of shocks from 1962 to 1972.

The strongest earthquake to occur within the region of study the 100-yr period 1872-1972, had a probable magnitude of 5.5. Estimates of the strongest shock to occur in a 100 yr period based on extrapolation of the earthquake frequency-magnitude relation range from 3.9 to 5.4 depending on the data set used.

The report recommends that seismic risk in the Los Alamos area be based on the occurrence of a magnitude 5.5 earthquake once every 100 yr somewhere within the Rio Grande depression from Albuquerque to Questa. The seismicity of this part of the rift zone is (1) less than the Albuquerque-to-Socorro segment of the same structure and (2) substantially less than equilvalent areas in Southern California.

Theis, C.V., Conover, C.S., and Griggs, R.L., 1950,
Preliminary Report on the Geology and Hydrology of the Valle Grande Area, New Mexico,
U.S. Geological Survey, Administrative Release.

The following report gives the descriptive geology and stratigraphy of the Valle Grande Area. The report also discusses discharge test performed in the Valle Toledo, and the Valle Grande to determine hydraulic characteristics of the area. A water quality discussion is also included above the area. Emphasing that the water is of generally good quality with the exception of high fluoride concentration found in waters of the Valle Toledo.

Wachs, D., et al., 1988,
Evidence of Young Fault Movements on the Pajarito Fault System in the Area of Los Alamos, New Mexico,
LANL, LA-11156-MS.

Los Alamos lies along and upon the Pajarito system, a major intragraben structure of the Rio Grande rift. This fault system consists of over 100 km of interconnected fault zones and traces. Geomorphic evidence, including right-lateral steps in stream valleys and disrupted drainages, as well as apparent vertical offset of alluvial units determined by seismic refraction, strongly suggests that the Pajarito fault is active. To evaluate seismic hazards in the Los Alamos area, values for recurrence intervals and characteristic earthquakes of the faults must be determined. We recommend the trenching of young alluvium in Rendija and Guaje canyons to obtain information regarding recurrence of the characteristic earthquake.

Weir, J.E., and Purtymun, W.D., 1962,
Geology and Hydrology of Technical Area 49, Frijoles Mesa, Los Alamos County, New Mexico,
U.S. Geological Survey, Administrative Release.

Frijoles Mesa ia a part of the Pajarito Plateau, a dissected ash-flow field that laps onto the Sierra de los Valles to the west and terminates in cliffs along White Rock Canyon to the east. Technical Area 49 (TA-49) occupies about 2 square miles on the northern segment of the Frijoles Mesa near the center of the plateau, about 5 miles south of Los Alamos.

The rocks exposed at the surface at TA-49 are of the Bandelier Tuff of Pleistocene age. Subsurface rocks of the Santa Fe Group of Middle Miocene to Pleistocene age were penetrated by three deep test holes. The rocks of the Santa Fe Group, in ascending order, are: the undifferentiated unit, the Puye Conglomerate, and the basaltic rocks of Chino Mesa. Interbedded with rocks of the Santa Fe Group are rocks of the Tschicoma Formation.

The undifferentiated unit consist of sediments laid down as alluvial-fan and flood-plan deposits. Above the undifferentiated unit is the Puye Conglomerate, which consists of two members. The lower member is poorly consolidated channel-fill deposit called Totavi Lentil. Overlying the Totavi Lentil is the conglomerate member that is made up of volcanic debris. Interbedded with the fanglomerate member are the basaltic rocks of the Chino Mesa and latite and quartz-latite flow-rocks of the Tschicoma Formation.

The Bandelier Tuff overlies the fanglomerate member. It consist of ash-fall and ash flow rocks that are dropped over the older rocks, filling the lows and smoothing out the topography of the older rocks. The Bandelier Tuff consist of three members. In ascending order they are: the Guaje Member, an ash-fall pumice and water laid pumiceous tuff; the Otowi Member, a friable ash-flow tuff; and the uppermost Tshirege Member, a series of ash-flow tuffs with one thin water-laid bed near the top.

The Tshirege Member forms finger-like mesa at TA-49. It is the most important geologic unit because test operations will place contaminants in these rocks about 100 feet below the mesa surface. There, these contaminants could be removed by water and carried into the zone of saturation.

The X-ray and chemical analyses of the tuff from the Tshirege Member indicate that they are rhyolitic in composition. Hydrologic analysis of the tuff indicated the following ranges: porosity 19.3 to 54.7 percent; specific retention, 11.3 to 27.3 percent; specific yield, 0.6 to 42.6; permeability, 0.04 to 22 gpd (gallons per day) per square foot for consolidated samples, and 34 to 59 gpd per square foot for unconsolidated samples. Moisture content ranged from 0.2 to 8.7 percent by volume beneath the mesa, but moisture contents of tuff from a test hole in Water Canyon north of the mesa ranged from 13.3 to 36.3 percent by volume, which indicates some infiltration of water.

The soil cover on the mesa surface is characterized by a weathered zone, a water-laid pumice zone, and a soil zone. The top few feet of the Tshirege Member is composed of partly weathered tuff fragments in a matrix of clay. The weathered zone grades up into a brown clayey soil except along the northern edge of the mesa, where a layer of water-laid pumice occurs between the weathered zone and the soil zone.

Periodic moisture readings of the soil and underlying tuff, made by a neutron-scattering moisture probe, indicate little or no infiltration of water from precipitation through the soil zone. Other data collected during drilling, mapping, and hydrologic analysis of rocks of the Guaje, Otowi, and Tshirege Members of the Bandelier Tuff indicate that the soil forms a nearly perfect seal on the mesa surface and that the Bandelier Tuff has a large bulk permeability. Where the soil cover has been removed or disturbed, water in sufficient quantities would move almost vertically through the Bandelier Tuff into the Puye Conglomerate and eventually into the zone of saturation.

Stream-flow in a natural stream channel on the surface of the mesa was measured at two moisture holes about 700 feet apart. There was very little loss of flow between the two test holes after the channel and bank material had become saturated. No change in moisture content in channel materials or underlying tuff was detected below a depth of 3.5 feet in either of the test holes. The moisture content increased 16 percent by volume in the upper 3.5 feet while the stream was flowing. Six days after the flow ended, capillary return to the surface and evaporation had decreased this moisture content by as much as 13 percent.

The zone of saturation, or main aquifer, lies 1,000 to 1,200 feet below the mesa surface at TA-49 in rocks of the Santa Fe Group and Tschicoma Formation. No perched water was found above the zone of saturation. The gradient on the piezometric surface of the main aquifer is east-southeastward toward the Rio Grande about 50 feet per mile. Data indicated that the recharge area to the main aquifer is west of TA-49 on the slopes of the Sierra de Los Valles and the western part of the Pajarito Plateau. The specific capacity of three wells finished in the main aquifer range from 5.7 to 22 gpm per foot of drawdown. Pumping test indicate an average coefficient of permeability of 180 gpd per foot. The velocity of water in the main aquifer is approximately 400 feet per year. The quantity of water passing through the upper 650 feet of the aquifer beneath the test areas at TA-49 is approximately 370 acre-feet per year.

Tritium analyses indicate that the water in the main aquifer ranges in age from 13 to 20 years. The cause of differences in age could be that water deeper in the aquifer moves more slowly and is actually older, or that some young water is being added to the aquifer by local recharge from canyon sources.

West, F.G., 1973,
Regional Geology and Geophysics of the Jemez Mountains,
LANL, LA-5362-MS.

The western margin of the Rocky Mountain tectonic belt is the initial site for the Los Alamos Geothermal Project. Igneous activity in the area culminated with the formation of collapsed volcanic caldera and the deposition of thick beds of tuff. Geophysical studies indicate that the region is one of relatively high-terrestrial heat flow, low-crustal density, low-crustal magneto-electric impedance, and thin crust.

Williston, McNeil and Associates, 1979,
A Time Domain Survey of the Los Alamos Region, New Mexico,
LANL, LA-7657-MS.

A time domain electromagnetic sounding survey of the region surrounding the city of Los Alamos, New Mexico was carried out. The results show that a linear trough, trending northeast-southwest runs beneath the city. The southern boundary is somewhat to the south of the city, the northern boundary was not established. The geoelectric section consists of three layers and total thickness of the section is in excess of 3,000 m. The resistivities of the second layer are as low as 2.5 ohm per meter. If the salinities are in the region of 7,000 ppm, the resistivities could indicate that water with temperature of 150 degrees C may be found at a depth of 3,000 m.

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Weir, J.E., Jr., et al., 1963,
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Abeele, W.V., 1979,
Determination of Hydraulic Conductivity in Crushed Bandelier Tuff,
LANL, LA-8147-MS.

The unsaturated hydraulic conductivity in a sample of crushed Bandelier Tuff was evaluated using volumetric pressure plate extractors. The total impedance of the tuff sample is determined from the experimental outflow data for each pressure step applied. The determination of the membrane impedance is not compulsory and the varying contact impedances are taken into account at each pressure step. The results show that prediction of saturation ratios can be made based on knowledge of matric potentials just as predictions of hydraulic conductivities can be made based on knowledge of either matric potentials or saturation ratios. They are highly significant at the equivalent of a matric potential lower than -10kPa. These results are then compared to those obtained by means of the predictive methods promoted by Campbell and Millington-Quirk using moisture retention data.

Abeele, W.V., 1979,
Determination of Relative Hydraulic Conductivity from Moisture Retention Data Obtained in the Bandelier Tuff,
LANL, LA-7625-MS.

A method for calculating unsaturated hydraulic conductivity from measured values of matric potential and saturation ratio is applied to data for the Bandelier tuff. A method described by Campbell requires that the measured data satisfy a particular log-log relationship. The coefficient of correlation using the predictive formula in actual measurements is highly significant at matric potentials lower than -10 kPa (-0.1 bar). The decrease of the relative hydraulic conductivity with decreasing saturation ratio is more rapid for crushed tuff than undisturbed tuff.

Abeele, W.V., 1983,
Testing of Lateral Flow,
LANL, LA-UR-83-2993.

Small scale modeling has demonstrated that it was possible to maintain structures dry in porous media by using capillary barriers. These barriers are created by differences in particle size distribution. The phenomenon is due to the predominance of capillary suction, soil tension, or matric potential over gravity forces. The percolating liquid will only penetrate the coarser material after the overlying finer one is totally wetted. Consequently, the structure enclosed in the coarser material is maintained dry. As long as matric potential at the coarse-fine interface remains negative, water infiltrating into the finer layer will not cross the interface but will flow laterally within the finer layer until percolation reoccurs upon the edge of the coarser layer. This concept has been referred to as a "wick system". The lateral distance over which the water can be transported is limited and will be influenced by the slope of the interface.

Abeele, W.V., 1984,
Hydraulic Testing of Crushed Bandelier Tuff,
LANL, LA-10037-MS.

This report emphasizes large-scale testing, using the instantaneous profile method, for determination of unsaturated hydraulic conductivity. To allow for comparison, unsaturated conductivity was measured in the laboratory using the pressure plate method.

Laboratory techniques and large-scale testing for determination of unsaturated hydraulic conductivity using the instantaneous profile method have been studied. It was found in both cases the hydraulic conductivity could best be expressed as a power function of the water ratio by volume. Both graphical and analytyical methods were used to analyze the moisture and tensiometric data provided by the instantaneous profile method and led to the determination of the hydraulic conductivity values.

Abeele, W.V., and DePoorter, G.L., 1983,
Field Scale Determination of the Saturated and Unasaturated Hydraulic Conductivity of Porous Materials, I. Crushed Bandelier Tuff,
LANL, LA-UR-83-1279.

The hydraulic conductivity of crushed Bandelier tuff was measured as a function of moisture content. The instananeous profile method was used to calculate the conductivity from the experimental data. Large deviations from unit hydraulic head gradient were observed in this experiment. The effect of time of the experiment and calculational method used are discussed.

Abeele, W.V., and DePoorter, G.L., 1984,
Testing of Lateral Water Flow in a Moisture Barrier,
LANL, LA-10125-MS.

We have performed large-scale lateral-flow tests in a fine textured material overlying a coarser medium. The goal was to investigate the effectiveness of a moisture barrier where the finer material has the texture of a silty sand. When we tested for induced lateral flow, a geotextile inhibited penetration of two overlying materials of different particle sizes, our "wick" system provided data regarding time to failure of the barriers, but the data are qualitative because of the variance in mositure level around versus below the access tube.

Abeele, W.V., DePoorter, G.L., and Nyhan, J.W., 1986,
Laboratory and Large Scale Hydraulic Testing of a Sandy Silt Used in Shallow Land Burial,
LANL, LA-UR-86-2750.

Laboratory techniques and large-scale testing for determination of unsaturated hydraulic conductivity of crushed tuff using the instantaneous profile method have been studied. It was found that in all cases the hydraulic conductivity could best be expressed as a power function of water content. Both graphical and analytical methods were used to analyze the moisture and tensiometric data provided by the instantaneous profile method that led to the determination of the hydraulic conductivity values.

Accurate evaluation of the moisture content is more important than evaluation of the matric potential and inclusion of tensiometric values become less critical as testing time increases.

Abrahams, J., Jr., Weir, J., Jr., and Purtymun, W., 1961,
"Distribution of Moisture in Soil and Near-Surface Tuff on the Pajarito Plateau, Los Alamos County, New Mexico" Short Papers in the Geologic and Hydrologic Sciences, Articles 293-435,
Geological Survey Research, Article 339, D142-D145.

This paper describes the natural distribution of moisture on the Pajarito Plateau by as well as providing results from an infiltration study. Measurements of the rate and amount of water movement and of moisture content of the soil and tuff, both under natural conditions and in controlled infiltration experiments were made.

Results of this study indicated that although water not removed by surface drainage infiltrates into the soil of the Pajarito Plateau, the downward movement of this water is impeded or stopped by the dense transition zone between the soil and the tuff. Thus, it seems that where the normal soil cover is undisturbed, there would be little or no recharge to the zone of saturation from precipitation on the surface of the plateau.

Abrahams, J.H., Baltz, E.H., and Purtyman, W.D., 1962,
Movement of Perched Ground Water in Alluvium Near Los Alamos, New Mexico,
U.S. Geological Survey, Prof. Paper, 450-B.

The infiltration and underground movement of snowmelt water in Mortandad Canyon near Los Alamos, New Mexico, were studied March through June 1961. The part of the canyon studied has a drainage area of about 2 square miles and heads at an altitude of about 7,350 feet on the central part of the plateau, where the annual precipitation is about 17.5 inches.

The Bandelier Tuff of Pleistocene age caps the Pajarito Plateau and rests on the Santa Fe Group of middle Miocene to Pleistocene age. The principal ground water body is in the Santa Fe Group about 960 ft beneath the canyon floor. However, a small body of perched ground water, which was the subject of investigation, occcurs in alluvium resting on the Bandelier in the bottom of Mortandad Canyon.

The water in the alluvium was monitored by means of holes drilled in seven lines across Mortandad Canyon. Water levels were measured in observation wells and moisture content of the alluvium and underlying tuff was determined.

Results of the study revealed the building of a ground water mound during infiltration. Ground water moved at different rates due to the composition of the soil profile. This phenomenon probably occurs elsewhere and should be considered in other infiltration investigations, especially in the interpretation of rate of water movement, use of tracers, and studies of chemical quality of water.

Abrahams, J.H., Jr., 1959,
Production of Water and Changes in Water Level in the Los Alamos, New Mexico, Well Fields July through December 1958,
U.S. Geological Survey, Administrative Release.

During the last six months of 1958 the over-all changes in water levels were within or near the range of previous fluctuations. The lowering of the water levels in most of the wells during June and July 1958 was appreciable but generally within expected limits. A significant abnormality in the trend in Guaje well 5 occurred, however, because of the greatly increased discharge rate. In many wells the long-term trend of the water levels was downward.

The nonpumping water level in the lower part of the Los Alamos Canyon well field shows a generally rising trend due to decreased pumping of Los Alamos well 2. The trend of the nonpumping water levels in the upper part of the well field continued downward, with the July 1958 water levels near or at record lows in Los Alamos wells 4,5,and 6. The average discharge rates of most wells during the period July through December 1958 were generally within or near the range of previous seasonal fluctuations.

The trend of the water levels in most wells in the Guaje Canyon well field continued downward, except for a slight upward trend of the pumping level in Guaje well 4. The sharp decline of the pumping level in Guaje well 5 was caused by the installation of a new pump in the well and a greatly increased average discharge rate. The June and July 1958 water levels for most wells were near the record lows with the greatest declines in Guaje wells 1A and 5. The average discharge rates during the period July through December 1958 were within or near the range of previous seasonal fluctuations but were somewhat lower than average in Guaje well 2 and somewhat higher than average in Guaje well 5.

The pumping time and the production in both well fields were considerably higher during the period July through December 1958 than for the same period in 1957. This increase reflects the relatively low production during 1957.

The pumping schedule suggested in the past should be continued in order that water levels in all wells will decline at approximately a uniform rate. Sufficient time has not elapsed since the new pumping schedule was started or since the new pump was installed in Guaje well 5 to justify a reevaluation of this schedule.

Abrahams, J.H., Jr., 1963,
Physical Properties of and Movement of Water in the Bandelier Tuff, Los Alamos and Santa Fe Counties, New Mexico,
U.S. Geological Survey, Water Supply Paper.

Radioactive wastes from the Los Alamos on the Pajarito Plateau in north-central New Mexico are released onto the surface and in the subsurface within the area. In the 1940's liquid wastes were processed for the removal of some radionuclides but the quantity of radioactivity discharged into open infiltration pits on the plateau or into natural drainage in deep canyons were not recorded. After waste treatment plants were built in 1951, supernatant liquids, separated from sludges containing most of the radioactivity, were treated below off-site tolerances and discharged. The sludges are buried on the plateau after being mixed with concrete or vermiculite and placed in metal barrels.

The Pajarito Plateau is part of the Jemez Mountains volcanic complex. The altitude of the plateau ranges from about 7,800 feet at the base of the Sierra de los Valles on the west to about 6,200 feet at an escarpment overlooking the Rio Grande on the east. The plateau has been dissected by east-west trending canyons as much as 1,000 feet deep.

The plateau is capped by the Bandelier Tuff of Pleistocene age that is at least 1,000 feet thick near the western margin of the plateau and thins eastward to less than 100 feet near White Rock Canyon. The Bandelier Tuff is divided, in ascending order, into the Guaje, Otowi, and Tshirege Members. In much of the plateau, the Tshirege comprises about three-fourths of the thickness of the Bandelier Tuff.

The Santa Fe Group of middle Miocene and Pleistocene age underlies the Bandelier Tuff and forms the main aquifer in the Los Alamos area.

Disposal of radioactivity wastes have been, for the most part, on the surface of or buried in the Tshirege Member. Most of the studies described in this report are with the Tshirege Member of the Bandelier Tuff, and reference to tuff in this report are to the Tshirege unless the Guaje and Otowi Memebers are mentioned specifically.

The Tshirege Member of the Bandelier Tuff contains sub-units that probably are individual beds of tuff. Water moving through the tuff is temporarily perched by variations in vertical permeability. The permeability varies from one bed to another, from one member to another, and from the Bandelier Tuff to underlying beds of the Santa Fe group.

Joints are common throughout the Tshirege Member. The joints which are not filled with sediments or alteration products may interconnect across the contacts of the sub-units and may provide paths for rapid movement of water which negate the effects of differences in the rock permeability. Nuclides in water moving through the open joints would have a relatively limited opportunity to be absorbed into the tuff, as compared to radionuclides in water that moved through the pores of the tuff.

Most of the gross alpha (plutonium) activity discharged into disposal pits was retained in the tuff at a depth less than 15 or 20 feet beneath the bottom of disposal pits, except for isolated areas where water carried the activity through joints to greater depth. There was an inverse relationship between gross alpha activity and the pH of water percolation through the tuff.

The porosity of the tuff ranged from about 20 percent to about 60 percent. The porosity is inversely related to the moisture content at one-third atmospheric tension, which is roughly the average field capacity of the tuff. About 20 to 25 percent of the total pore space transmits most of the water which moves through the tuff. The average permeability is low--about 1/2 to 6 gal/d/sq ft.

The moisture content after 99 days of infiltration into a pit that penetrated above one-half foot of a 5 ft thick soil zone overlying tuff ranged from about 39 percent by volume in the soil zone to less than 4 percent within a foot below the top of the underlying tuff. Soil cover reduces the amount of water that would infiltrate the tuff. The moisture content ranged from less than 1 percent

Abrahams, J.H., Jr., 1966,
Equipment Used to Study the Movement of Water in the Bandelier Tuff at Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

Equipment used to study water movement in the Bandelier Tuff in the Los Alamos area consisted of neutron-scattering moisture and gamma-ray density probes and scalers (counting devices) to obtain moisture and density measurements of subsurface material, a porous cup-vacuum system for collecting samples of water from subsurface material in which the cup is embeded, and a "tipping bucket" to meter small rates of flow to an infiltration pit.

The moisture and density probes were lowered into test holes cased with plastic tubes instead of seamless steel tubes recommended by the manufacturer of the probes. Difference in diameter and wall thickness of the plastic tubes used to case the test holes affected the count rate of the probes (the count decreased as wall thickness or diameter increased) and made it necessary to construct calibration curves for each of three different types of plastic tubes used.

Coors porous cup P-3 having an air entry value of 21 pounds per square inch collected water at a rate 10 times that of cup No. 5, which has an air entry value of 43 pounds per square inch -- when each cup was under the same vacuum pressure.

The tipping bucket and the associated device that counted the number of times the bucket dumped water was successful in measuring water entering the pit at rates of about 50 gallons per day and less.

Abrahams, J.H., Jr., 1966,
The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, January 1956 through June 1957,
U.S. Geological Survey, Administrative Release.

This is the third of a series of reports by the U.S. Geological Survey describing the hydrologic conditions in the Los Alamos area. Los Alamos, in north-central New Mexico, is on the Pajarito Plateau, which is formed by the Bandelier Tuff of Pleistocene age.

Several holes 11 to 73 feet deep were drilled in lines across the middle and lower reaches of Pueblo Canyon near where the canyon cuts the conglomerate underlying the tuff. Water perched in the alluvium and within the conglomerate was sampled.

Acid and Pueblo Canyons were the major disposal areas for radioactive waste effluents for the period of investigation. Most of the radioactivity in liquid wastes discharged into the Acid Canyon were retained in deposits within one foot of the upper surface of the alluvium and did not reach Pueblo Canyon. The chemical quality of surface and ground water improved downgradient in Acid Canyon and Pueblo Canyons due to dilution by storm runoff and by treated sewage effluents.

Streamflow in Pueblo Canyons and changes in water levels in the wells that tap the alluvium in Pueblo Canyon are the result of precipitation and discharges from the waste and sewage treatment plants in Acid and Pueblo Canyons. Changes in water levels and the quality of water from the shallow test wells indicate hydraulic interconnection between the aquifers and surface water in Pueblo Canyon. The slight decline of water levels in the deep test wells may be due to a long-term trend.

The quality of water from the supply wells in Los Alamos and Guaje Canyons is good, and water levels are relatively stable. There are slight differences in water quality from different wells. The concentrations of dissolved solids in samples of water from springs downgradient from the Acid-Pueblo Canyon disposal system was some what higher than in samples from other springs in the Los Alamos area.

Abrahams, J.H., Jr., and Purtymun, W.D., 1966,
The Hydrology and Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1957 through June 1961,
U.S.Geological Survey, Administrative Release.

Low-flow measurements of perennial streams in Santa Clara, Guaje, Los Alamos, and Frijoles Canyons indicated gains in flow in the upper third reach of the streams and losses in flow downstream. Streamflow in Acid and Pueblo Canyons is maintained principally by effluent discharges from the waste treatment plant in Acid Canyon and sewage treatment plants in Pueblo Canyon. Effluent from the waste treatment plant has a low level (below off-site tolerance) of radioactivity; effluent from the sewage plant has only background radioactivity. Water from the sewage plants mixes with and dilutes the radioactive waste from the waste treatment plant.

Total dissolved solids in the water from sewage plants generally is low; the specific conductance normally is less than 600 micromhos at 25 degrees C. The water is of the sodium bicarbonate type.

Changes in the chemical quality of water from shallow wells in the alluvium of Pueblo Canyon suggest that the stream recharges the alluvium. The chemical quality of the water from deep test wells in Pueblo Canyon, which are open to and bottom in tuff and basalt, show no indication that recharge from the stream has carried plant effluents to hundreds of feet below land surface. There was no significant change in the chemical quality of water from springs and from supply wells in Los Alamos and Guaje Canyons. Small qunatities of radioactivity in water from the Rio Grande and Rio Chama may be due to fallout; apparently little or no contamination was added to Rio Grande from waste and sewage disposal at Los Alamos, except possibly that transported in summer flood flows in the tributaries crossing the Los Alamos area.

Radioactivity in the alluvium decreases with distance from the waste treatment plant in Acid Canyon and most activity is retained in Acid Canyon before reaching Pueblo Canyon. Radioactivity in the alluvium in Los Alamos Canyon is small and is confined chiefly near areas of waste discharge. Radioactivity in the alluvial material near Ten Site decreased with time and distance.

Abrahams, J.H., Weir, J.E., and Purtymun, W.D., 1961,
Distribution of Moisture in Soil and Near Surface Tuff in the Pajarito Plateau, Los Alamos, New Mexico.,
U.S. Geological Survey, Prof. Paper, No. 434.

The Pajarito Plateau is underlain by pumice deposits, ash falls and ash flows of welded rhyolite tuff. Three soil zones are identified: an A zone from which most of the clay has been leached, a B zone containing montmorillionite, and a C zone with a high clay content. Measurements of the moisture content of soil was made under natural and controlled conditions. Moisture measurements under natural conditions, indicate that the moisture content was found to increase from surface to a depth of about 3 feet then decrease to a depth of 4 to 12 feet below which the moisture content remained relatively constant. Moisture content in soil ranged from 10% to 50% as a function of depth and time. The tuff's moisture content range from 4% to 30% as a function of depth and time. Under controlled conditions, the moisture content of the tuff, below 8 feet, never exceeded 4%.

Becker, N.M., Purtymun, W.D., and Ballance, W.C., 1981,
Aquifer Evaluation at Fenton Hill, October and November 1980,
LANL, LA-8964-MS.

An aquifer test at the Fenton Hill Geothermal Site was performed on a volcanic aquifer used for water supply. The test was made to determine the yield from the aquifer and to predict the amount of depletion that would occur with increased production during the period 1981-1985. A step-discharge test indicated the aquifer would comfortably yield 100 gal per min (gpm) without excessive water level drawdown in the pumping well. Drawdown test results indicated that the average aquifer transmissivity and storage coefficient are 5000 gal per day per foot (gpd/ft) and 0.07, respectively. Using thses parameters, a drawdown was estimated to be at least 42 ft at the pumping well due to a withdrawal of 500 acre-ft of water over 5 yr. However, the presence of ground water boundaries indicates the aquifer is of limited extent, and because of this, the water level decline would probably be much greater. Past water level data indicate that there is little recharge to the aquifer and that the ground water is being depleted.

Cooper, J.B., Purtymun, W.D., and John, E.C., 1965,
Records of Water Supply Wells Guaje Canyon 6, Pajarito Mesa 1, and Pajarito Mesa 2, Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

This report contains pertinent data on the geology, hydrology and construction of three water wells drilled in 1964-65 to supplememnt the water supply of Los Alamos, New Mexico. The wells vary in depth from 1530 feet to 2300 feet and tap a common aquifer--the Tesuque Formation of the Santa Fe Group. The formation is Tertiary in age. The Tesuque Formation consists of slightly consolidated beds of silty sand and minor gravel and conglomerate. Basalt flows and volcanic breccia are interbedded with the sediment at places.

Ground water in the Tesuque Formation moves west to east beneath Los Alamos. Depth to water in the three wells drilled in 1964-65 ranged from 560 to 820 feet Yields of the wells ranged from about 400 gpm (gallons per minute) to about 1,500 gpm.

The drilling and construction of each of the three wells was divided into 2 main phases: 1) Drilling an approximate 10-inch diameter pilot hole to a predetermined depth; sampling the formations penetrated; and logging the hole electrically; 2) reaming the pilot hole to the optimum depth of permeable material as determined from examination of drill cuttings and electric logs; casing; gravel-packing; developing swabbing, bailing, and pumping.

The first of the three wells drilled in 1964-65 was in Guaje Canyon well field Specific capacity of well was determined to be 4.5 gpm per ft of drawdown. Transmissibility of aquifer calculated from drawdown measurements was 6,500 gpd per ft and calculated from recovery measurement was 6,000 gpd per ft.

The second well drilled in 1964-65 was in the Sandia Canyon about 2 1/2 miles north of White Rock. Specific capacity of the well from tests is about 17 gpm per ft of drawdown. Transmissibility of aquifer calculated from drawdown measurements was about 55,000 gpd per ft. Both of these values were thought to be high because an absolute static water level was not established and because water levels in the aquifer were in a state of drawdown at time of tests, due to prior pumping.

The last well drilled in 1964-65 was in the Pajarito Canyon a few hundred feet east of technical area known as Pajarito site. Specific capacity determined from well test was about 24 gpm per ft of drawdown. Transmissibility of aquifer calculated from drawdown measurements was about 40,000 gpd per ft.

Cushman, R.L., 1965,
An Evaluation of Aquifer and Well Characteristics of Municipal Well Fields in Los Alamos and Guaje Canyons, Near Los Alamos, New Mexico,
U.S. Geological Survey, Water Supply Paper, 1809-D.

The main aquifer tapped by the municipal supply wells of Los Alamos, N. Mex., is the Tesuque Formation and younger rocks of the Santa Fe Group of middle Miocene to Pleistocene age. These rocks comprise a series of unconsolidated to slightly consolidated sedimentary rocks consisting of silt, sand, gravel and conglomerate having a saturated thickness of more than 2,000 feet. Recharge to the aquifer is principally by seepage from streamflow in the canyons. Water in the aquifer moves from west to east in the Los Alamos area. The principal area of natural discharge, the Rio Grande, is a hydrologic boundary for the aquifer, ground water in the Los Alamos area does not move eastward beyound the river.

The main aquifer terminates on the west aganist relatively impermeable latites of the Tschicoma Formation. The exact position of this geologic boundary is not known. There are no known geologic or hydrologic boundaries to the north and south that are close enough to the Los Alamos area to influence the movement of ground water near the municipal well fields. Water in the main aquifer is under water-table conditions except near the eastern hydrologic boundary where artesian conditions occur. In this latter area the water in the aquifer is under increasing pressure with depth, and water levels in deep wells rise to higher altitudes than levels in shallow wells at the same location. Wells 19.7.13.114 (LA-1), 13.114b(LA-1B), 14.221(LA-3), and 14.222(LA-2) flowed when they were completed.

Average values for hydraulic coefficients of the aquifer determined from pumping test of wells are T (transmissibility) = 15,000 gallons per day per foot and S (storage) = 0.0003. These aquifer coefficients may not be uniform throughout the Los Alamos area; basaltic rocks in the central and western parts of the plateau probably cause higher transmissibility. The coefficient of storage probably is larger throughout the area than that computed from aquifer tests, and probably is as much as 0.005, the lowest range for water-table conditions.

A method of estimating transmissibility and storage is described whereby the Theis nonequilibrium formula is adapted for computations of water-level changes using past pumping expressed in cycles of one-half year duration and boundary conditions simulated with image wells. Computation of water-level decline by trial-and-error use of assumed values for transmissibility and storage and assumed locations of the western boundary of the aquifer would continue until the computed declines coincide with the amount of decline measured at each well. These computations were not carried to completion in this report because the large number of combinations of assumed conditions would require reasonable length of time. Additional wells should not be placed in Los Alamos and Guaje Canyons with the possible exception of one additional well that should be at least 2,500 feet upgradient from well 5.112(G-5). The water-level decline might accelerate and substantially reduce the life of the well fields if additional wells were added. This restriction does not preclude the placement of other supply wells on the Pajarito Plateau but additional wells should be at distances more than 2 miles south of the Los Alamos and Guaje Canyons well fields.

Wells in Los Alamos and Guaje Canyons having specific capacities of less than 10 gpm (gallons per minute) per ft probably can be rehabilitated to attain specific capacities above 10. A properly constructed supply well in the main aquifer should have a specific capacity of 10 to 15 gpm per foot of drawdown.

Cushman, R.L., and Purtymun, W.D., 1975,
Evaluation of Yield and Water-Level Relations,
LANL, LA-6086-MS.

Yield and water relations in the Los Alamos supply wells were evaluated because of the increasing demand for water. Water-level declines were extrapolated for 10 yr, to 1983, on the basis of past records. On the basis of current pumpage, the extrapolations indicate that nonpumping water level in individual wells will decline from 10 to 30 ft. Well characteristics were complied to provide an individual history of each well, and recommendations for improving water production are presented.

Daniel B. Stephens and Associates, Inc., 1988,
Final Data Report on Laboratory Analyses of Soil Hydraulic Properties of Welded Tuffs at Los Alamos National Laboratory,
Daniel B. Stephens and Associates, Inc., Report to LANL.

Daniel B. Stephens and Associates, Inc. was requested by Los Alamos National Laboratory of Los Alamos, New Mexico, to perform laboratory analyses for properties of soil. Included in this report are summary tables, graphs, and raw laboratory data concerning the samples of cores of welded tuff.

Devaurs, M., 1985,
Core Analyses and Observation Well Data From Mesita Del Buey Waste Disposal Areas and in Adjacent Canyons,
LANL, LA-UR-85-4003.

This document provides the necessary information to comply with Task 5 and 6 of Paragraph 25 of the Compliance order/Schedule issued to the Los Alamos National Laboratory on May 7, 1985. The Compliance Order/Schedule (Docket No. 001007) was issued by the New Mexico Environmental Improvement Division (EID) under the authority of New Mexico's Hazardous Waste Management Act. Paragraph 25 requires the Laboratory to submit to EID, by November 30, 1985, core analyses (Task 5) and analyses of perched water (Task 6). This report presents data obtained from seven test holes near waste disposal sites (Area L and G) on Mesita del Buey and from seven observation wells in the adjacent canyons (Pajarito Canyon and Canada del Buey).

Water from observation wells in Pajarito Canyon was analyzed for volatile organics, chemical and radiochemical constituents. No volatile organics were found. All chemical and radiochemical constituents were at concentrations below primary and secondary maximum contaminant levels specified for drinking water, with the exception of two manganese measurements. Radionuclides present in observation well water are naturally occurring and do not indicate radioactive contamination. Core from seven test holes near Area L and G were analyzed for volatile organics and Extraction Process (EP) toxicity constituents. All inorganic constituents were below EP toxic regulatory standard. No "target" volatile organic compounds were found in the samples. However, a number of non-target volatile organic compounds, primarily common organic solvents, were detected at low concentration in some samples.

This report provides data to further substantiate the Laboratory's ground water monitoring waiver application under New Mexico's Hazardous Waste Management Regulations Section 206.C.1.a(3). No data interpretation is provided; this is forthcoming in the March 31, 1986 submittal, required under Paragraph 25 of the Compliance Order/Schedule (Docket No. 001007).

Devaurs, M., and Purtymun, W.D., 1985,
Hydrologic Characteristics of the Alluvial Aquifers in Mortandad, Canada del Buey and Pajarito Canyons,
LANL, LA-UR-85-4002.

Water in the alluvium in Mortandad and Pajarito Canyons is perched on the underlying tuff. Both are recharged from surface flow from upper reaches of their watersheds and/or effluent flows into the canyon. Occurrence of water in both of the canyons is similar. The alluvium is confined to the stream channel and does not extend under the adjacent mesas. No water is found between the base of the alluvium and the top of the main aquifer. Studies made in Mortandad Canyon indicate that the water is confined to the alluvium and does not extend under the mesas adjacent to the canyon bottom. Based on data from test holes drilled in Canada del Buey (dry), in Pajarito Canyon into the alluvium, and from those holes drilled below the alluvium into underlying volcanic sediments, water in the alluvium in Pajarito Canyon does not extend under adjacent mesas.

This report has summarized the applicability of research in Mortandad Canyon to Canada del Buey and Pajarito Canyons, as required in Task 6, Paragraph 25 of the Compliance Order/Schedule issued to the Laboratory by the EID on May 7, 1985. Canada del Buey and Pajarito Canyons are adjacent to Mesita del Buey where the Laboratory's waste disposal sites, Area G and L, are located. This report further substantiates the Laboratory's ground water monitoring wavier application because it documents, as required by New Mexico's Hazardous Waste Management Act (NM HWMA) Section 206.C.1.a(3), that there is no, or at worst, low potential for migration of hazardous waste or hazardous waste constituents from the waste disposal facilities on top of the mesa to water supply wells or to surface water.

Enyart, F.A., and Purtymun, W.D., 1966,
Movement of Water Injected into Tuff,
U.S. Geological Survey, Annual Review.

Behavior of liquid injected at depth into a moderately-welded dry tuff at Los Alamos, New Mexico, was investigated.

Concentration and movement of the moisture was monitored by neutron-neutron probe. With porosities of about 50 percent, the highest degree of concentration of moisture was about 34 percent, by volume. Over a period of 5 months (during which water was injected for the first 3 months) the zone of maximum concentration after an initial expansion in size, decreased to about 32 percent water content, shrank in volume, and slowed its downward movement from an early rate of 30 feet per month to about 0.6 feet per month.

Rate of intake of water after an initial adjustment period of a week, during which it declined from 10 gpm to 1.5 gpm, increased from a low of 1.5 gpm to 6 gpm in a month and then steadily declined to 0.4 gpm at the end of three months of injection. The amount of water injected was about 335,000 gallons.

Fuentes, H.R., and Polzer, W.L., 1987,
Interpretative Analysis of Data for Solute Transport in the Unsaturated Zone,
LANL, LA-10817-MS.

In this report, the movement of iodide, bromide, and lithium under unsaturated flow conditions is modeled using the computer code CFITIM. This code is a solution of the one-dimensional convective-dispersive equation when steady-state flow exists and when interactions between the solute and Bandelier tuff can be described by the linear isotherm. The model predicts well the transport of the solutes iodide, bromide, and lithium when flow conditions are near steady-state. When assuming average steady-state flow conditions, the model predicts dispersion factors for unsteady flow within one to two orders of magnitude of the predictions at steady-state flow; retardation factors, on the other hand, are predicted much better than the dispersion factors. Differences in the estimated dispersion coefficients for solutes of two steady-state pulses indicate that the intended replication of those steady-state flow pulses was not achieved during experimentation. A comparison of breakthrough curves of solutes from one depth to another in the 3-m X 6-m field experimental cassion indicates poor conservation of solute mass during transport.

Fuentes, H.R., Polzer, W.L., and Springer, E.P., 1987,
Effects from Influent Boundary Conditions on Tracer Migration and Spatial Variability Features in Intermediate-Scale Experiments,
LANL, LA-10981-MS.

In previous unsaturated transport studies at Los Alamos dispersion coefficients were estimated to be higher close to the tracer source than at greater distances from the source. Injection of tracers through discrete influent outlets could have accounted for those higher dispersions. Also, a lack of conservation of mass of the tracers was observed and suspected to be due to spatial variability in transport. In the present study experiments were performed under uniform influent (ponded) conditions in which breakthrough of tracers was monitored at four locations at each of four depths. All other conditions were similar to those of the unsaturated transport experiments. A comparison of results from these two sets of experiments indicates differences in the parameter estimates. Estimates were made for the dispersion coefficient and the retardation factor by the one dimensional steady flow computer code, CFITIM. Estimates were also made for mass and for velocity and the dispersion coefficient by the method of moments. The dispersion coefficient decreased with depth under discrete influent application and increased with depth under ponded influent application. Retardation was predicted better under the discrete influent application than under ponded influent application. Differences in breakthoughs and in estimated parameters among locations at the same depth were observed under ponded influent application. Those differences indicate that there is a lack of conservation of mass as well as significant spatial variability across the experimental domain.

Gruber, J., 1988,
"Natural Geochemical Isolation of Neutron-Activated Waste: Scenarios and Equilibrium Models",
Nuclear and Chemical Waste Management, Vol. 8, pp. 13-32.

A coupled geochemical/geohydraulic model is used to discuss and interpret possible mechanisms for contaminant transport and accumulation in inorganic environments. The geochemical part of the code, the triple layer model for adsorption allows one to estimate the variation of the contaminant distribution coefficient with solution composition. The hydraulic part of the model establishes a deterministic correlation of the spatial variation of the distribution coefficient. Scenarios are constructed incorporating computed system behavior. A comparison of potential contaminant concentrations with acceptable ones allows one to quantify the degree of geochemical isolation of the contaminant which a chosen environment provides. Long lived waste, activated in the thermal neutron flux of a lightwater reactor, is classified using the proposed methodology and a very conservative scenario: beryllium, lead, molybdenium, selenium, tin, and zinic activated in the bulk of the reactor decommissioning waste (the bioshied) might be sufficiently isolated by the chemistry in common soils. The concentration of nickel in oxidizing inorganic noncomplexing drinking water has an upper limit given by the the precipitation of nickel minerals. Above pH = 7 is an effective geochemical barrier for nickel activated anywhere in the reactor, except the high neutron flux region.

Hakonson, T.E., 1981,
"Hydrological Transport of Sediments", Environmental Surveillance at Los Alamos During 1980,
LANL, LA-8810-ENV, pp. 60.

During 1979, three runoff events occurred in Mortandad Canyon at the Los Alamos National Laboratory after placement of labeled soil in the stream channel. The results of sampling indicated that particle sorting by rainstorm runoff does occur and is characterized by large downstream movement of silt-clay particles with relatively smaller movement of coarser particle sizes. Furthermore, the maximum transport distance of silt-clay particles coincides with the maximum distance downstream that surface water runoff occurs. Transport of labeled soil particles from a point source is most rapid for silt-clay particles; however, after as few as three relatively small runoff events, less than 3% of any of the labeled particles remained at the label locations. Thus, contaminants, particularly those associated with the silt-clay fractions that are released to an intermittent stream channel would be rapidly transported downstream in a runoff event.

HSE Division, Facilities Eng. Division, 1988,
Long-Range Water Supply Plan: A Program to Develop Water Resources for Los Alamos County and the Laboratory to Year 2030,
LANL, Final Draft.

Los Alamos County residents and the Laboratory are provided water from three well fields owned by DOE. Theses wells have a finite life, and the first two well fields, developed about forty years ago, are reaching the end of their usable life spans.

The Los Alamos and Guaje well field must be replaced during the next 7-10 years in order to meet expected peak-day demand, and to perclude putting a critical burden on our relatively new pajarito field and transmission system.

At least two wells are needed immediately. Because the County uses two-thirds of the water, this report proposes financing new wells in a two-to-one ratio with the Lab's constructing the first two wells with existing Line Item funding, and the County's paying for the following four wells through a capital development fund, probably with the need for special rate increases. Thereafter, wells would be financed on the two to one ratio. Three alternative funding schedules are suggested within report.

The water rights issue, although not as urgent as the water supply, is also covered in this report. Various approaches to increasing water rights are presented. The main objective of ensuring future rights is stressed. Actions should be implemented now to ensure the additional rights before we reach our limit.

HydroGeoLogic, Inc., 1989,
Pathway Analysis at Material Disposal Area T Los Alamos National Laboratory (LANL) Los Alamos, New Mexico,
HydroGeologic, Inc., Working Draft submitted to LANL.

The primary objectives of this pathway analysis are to (1) estimate unsaturated flow conditions and contaminant transport using available data, and (2) define data requirements necessary for completing a remedial investigation at Material Disposal Area T (MDA T). This pathway analysis has been instrumental in developing a conceptual model for MDA T that may be tested and refined during the remedial investigation. This model, with minor refinements, may be applied to other sites at LANL that are characterized by similar hydrogeologic properties and settings. Furthermore, remedial investigation activities and technologies developed for MDA T may also be transferred to other LANL sites.

The conceptual model for MDA T describes a heterogeneous system where the addition of both liquid waste and waste-free water provides a contaminant source and a driving force for at least limited downward migration of radionuclides. Fracture systems in the Bandelier tuff are considered to play an important role in moisture migration. The rate and depth of contaminant migration is largely controlled by the rate of water movement and retardation caused by adsorption of radionuclides within the vadose zone matrix. It is estimated that the volume of water discharged to adsorption bed number 1 during the period between 1945 and 1967 has already passed through the vadose zone system. The distribution coefficient values, would have severely retarded the migration of radionuclides. In the case of fracture-dominated flow, matrix diffusion may have acted to significantly retard the movement of dissolved constituents.

It is recognized that some of the parameters controlling flow and transport today and into the future may be quite different compared to conditions that goverened flow transport during the application of water and liquid waste in the past. Natural recharge is presently the primary force for migration. Its magnitude is not considered sufficient to induce measurable transport of radionuclides through fractures or the rock matrix. Other processes, such as lateral migration, canyon recharge, or groundwater flow, may affect the distribution of any contaminants that may pass through the vadose zone with moisture pulses associated with past input. Fractures were probably the predominant avenue for flow and transport during the application of large volumes of water and liquid waste in the past. Under ambient recharge conditions the same fractures are thought to behave as natural barriers to flow and migration.

Distinguishing whether the flow and transport processes are primarily controlled by rock and fracture permeabilities or by other chemical or physical properties is critical to the design of a characterization program at MDA T. If observed subsurface peaks in moisture content and radionuclide concentration reflect downward migration of pulses from past discharges, then water flux and travel times can be computed on that basis. If subsurface peaks reflect instead remnants of water and solutes retained by higher retention and adsorption capacity, then entirely different interpretations result. Migration pathway analysis results indicate that the bulk of the moisture applied to bed number 1 has migrated through the vadose zone within an estimated 10-year period, and represent remnants of past applications of water and liquid waste that have been retained by the adsorption capacity of the tuff.

Pathway analysis results also indicate uncertainty in some input parameters compared tp previous estimates, particularly hydraulic conductuctivities and distribution coefficients. To explain available data and modeling results, either the matrix saturated hydraulic conductivity is substantially greater than previously estimated by Abeele and others (1983), or fractures add considerably to secondary permeabilities and play a significant role in flow processes occurring at the time of liquid waste application in the past.

In order to match subsurface radionuclide concentrations measured by Nyhan and others in 1984, distribution coefficients (Kd) must be considerably lower than those measured for other tuff to allow for faster transport. One of two conclusions may be drawn; either the sorptive characteristics of the Bandelier tuff are considerably different than those reported for other tuffs, or other factors involving physical or chemical characteristics of the wastes cause a reduced Kd.

Two-dimensional simulation result suggest that increase in saturation could occurr in the vadose zone at substantial lateral distances from adsorption beds at MDA T. The possibility of lateral flow and migration to points of release along the wall of Los Alamos Canyon to the north is addressed as a remedial investigation data requirement.

Other data requirements for a remedial investigation at MDA T are listed and remedial investigation activities recommended. The relationship between lithology, water saturation, contaminant concentrations and geographic setting is emphasized. Four recommended phases consist of further background research to obtain a more-detailed waste inventory, bench-scale studies to observe waste chemistry behavior in tuff samples, field investigation activities designed to obtain moisture and contaminant profiles at depth, and confirmatory modeling to integrate collected data into the migration pathway analysis and refine the current conceptual model. Potential remedial measures are presented that address both source removal and plume stabilization. A description of each technology includes benefits and constraints.

John, E.C., 1966,
Pumpage and Water levels in Los Alamos Supply Wells, 1965,
U.S. Geological Survey, Water Supply Correspondence.

Pumpage from the supply wells amounted to 1,119 million gallons in 1965, or about 173 million gallons less than that of 1964. The wells in Guaje Canyon supplied about 51.2 percent of the total pumpage. A decrease in pumping of about 92 million gallons in the Los Alamos well field and about 180 million gallons in the Guaje well field occurred during 1965 as compared to 1964.

The specific capacity shows whether or not the condition of the well is changing. Significant decrease in the specific capacity of wells G-1 and LA-3 was indicated by a progressive loss of production to about one half gallons per foot of drawdown. Decline in specific capacity in these wells is believed to be due to sanding of productive zones.

Water levels in the supply wells fluctuate in response to pumping in the well fields. Highest levels occur from January to March, when the pumping load is at a minimum; the lowest levels occur from June to September when the pumping load is at a maximum. The long-term trend of water levels in wells supplying Los Alamos is a slow-decline.

The first well, PM-1 in the Pajarito Mesa well field was completed and equipped during 1965. The well was put into production during June at a pumping rate of 644 gallons per minute. A second well, PM-2 was drilled in the Pajarito Mesa well field, but was not equipped during 1965.

Water quality has shown no significant change from 1964. Dissolved solids content of the water from all of the wells is near or below the 500 parts per million maximum recommended by the U.S. Public Health Service for drinking water. Average hardness ranges from 30 parts per million to 90 parts per million.

Radiochemical analyses for plutionium show only background concentration. Uranium concentrations are below background in all wells except LA-1B, LA-6, G-4 and G-5, where natural formation uranium occurs in the amounts which are well below the established limits for drinking water. The chemical and radiochemical analyses indicate no contamination from industrial waste effluent at Los Alamos.

Kearl, P.M., Dexter, J.J., and Kautsky, M., 1986,
Vadose Zone Characterization of Technical Area 54, Waste Disposal Areas G and L, Los Alamos National Laboratory, Los Alamos, New Mexico, Report 3: Preliminary Assessment of the Hydrologic System,
Bendix Field Engineering Corporation, GJ-44.

The hydrologic characteristics of the vadose zone in Areas G and L, Technical Area 54, at Los Alamos National Laboratory were investigated in response to the Compliance Order/Schedule issued to the Laboratory by the State of New Mexico's Environmental Improvement Division under the authority of New Mexico's Hazardous Waste Management Act. This report summarizes an assessment of the hydrologic system.

The most significant conclusion resulting from this investigation is that vapor-phase transport is the predominant mechanism controlling the potential subsurface movements of contaminants in the study area. Evidence for this conclusion includes the low moisture content of the underlying rock and the high-moisture retention values observed in the moisture characteristics curves. These results indicate that there is no interconnection or movement of liquid water in the interval of Bandelier Tuff examined in this study.

Permeability measurements were made by two field methods, vacuum-test method and borehole injection. Laboratory determinations were made using both the Klinkenberg Correction and the Dynamic methods. Agreement among the various methods was generally good, yeilding an intrinsic permeability for the Bandelier Tuff in the range 10^-8 to 10^-9 squared centimeters.

Determination of the water distribution in the tuff was determined. Gravimetric results indicate a moisture content of 2 to 4 percent for the center portion of the profile, with generally higher contents in the lower portion of Unit 1b. Preliminary data from the thermocouple psychrometers indicate that water potentials range from -1 to -15 bar, suggesting low moisture conditions in the tuff.

The various field and laboratory activities conducted during this study permit an evaluation of the effects of porosity, pumice content, and degree of welding on the unsaturated transport processes. As expected, porosity and pumice content are highly correlated. The high porosity demonstrates that the tuff acts like a sponge: A quantity of water equal to approximately one-quarter of the rock volume is required to satisfy the capillary forces and permit the movement of water in the liquid phase. Permeability, on the other hand, is inversely proportional to porosity due to significant amount of dead-end pore space which occurs in pumice. Finally, a high degree of welding apparently reduces the average radii of pores, the result being an increase in the capillary forces and the residual moisture content.

Another major objective of this study was to evaluate the role of fractures as avenues of transport in the Bandelier Tuff. Results obtained thus far, however, are inconclusive. Although predominant northeasterly trends were measured, a bias in the data resulted from sampling limitations imposed by available exposures. The permeability of fractured zones, where fractures are filled, is not significantly greater than that of the surrounding rock. Certain fractured zones exhibit a higher moisture content and may be indicative of open fractures. Petrex survey results indicate that ion counts of volatile organic compounds are not distributed uniformly in a radial pattern around the source. Instead, the distribution of volatile organic compounds is apatially variable, as if venting occurs in discrete zones whose fracture apertures and/or intensities may be locally elevated. Transport of contaminants from the source probably follows tortuous routes determined by a combination of fractures orientations and degree of dialation, and interconnections of fractures related to position of infill materials. It is anticipated that results of the pore-gas sampling and analysis will be of particular benefit to the definition of the role of fractures in the vadose zone. In addition, more extensive Petrex surveys just under the rim of Mesita del Buey and in Area L may also better define the role of fractures relative to contaminant transport.

Kearl, P.M., Dexter, J.J., and Kautsky, M., 1986,
Vadose Zone Characterization of Technical Area 54, Waste Disposal Areas G and L, Los Alamos National Laboratory, Los Alamos, New Mexico, Report 4: Preliminary Assessment of the Hydrologic System through Fiscal Year 1986,
UNC Technical Services, GJ-54.

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Kelly, T.E., 1971,
Pumpage and Water Levels in Supply Wells, 1970,
U.S. Geological Survey, Administrative Report.

Pumpage from the Los Alamos, Guaje, and Pajarito well fields increased 41 million gallons, from 1,334 million gallons in 1969 to 1,375 million gallons in 1970. Production was from 6 wells in the Los Alamos field, 7 wells in the Guaje field, and 3 wells in the Pajarito well field. The total amount of water pumped from the three fields, from 1950 through 1970, is about 21.5 billion gallons. The average yearly pumping rate for the three fields decreased 130 gpm (gallons per minute) from 9,080 gpm in 1969 to 8,950 gpm in 1970.

In general, during 1970, the highest water levels occurred during the winter when pumpage was at a minimum and the lowest water levels occurred during the late spring and summer when pumping was at a maximum. Excessive sanding probably was responsible for limited production from wells PM-1 and G-4.

Kelly, T.E., 1974,
Reconnaissance Investigation of Ground Water in the Rio Grande Drainage Basin - With Special Emphasis on Saline Ground-Water Resources,
U.S. Geological Survey, Atlas, HA-510.

At the present time (1973), the surface water resources of the Rio Grande drainage basin are fully appropriated and insufficient to meet present needs in the most of the basin. Ground water supplies have been extensively developed for irrigation and for almost all municipalities. In areas of heavy ground water use, withdrawals often substantially exceed annaul recharge; therefore the ground water in storage is being depleted steadily, with accompying deterioration in quality. Because of the increasing demands for ground water by the 1,250,000 people of the United States part of the basin, fundamental knowledge of both fresh and saline ground water resources is needed to serve as a guide for future development.

This report describes the distribution and availability of ground water resources of the Rio Grande basin, surface water drainage and use, the geohydrology of the basin, saturated thickness of the aquifers and estimated yeild of wells in the Rio Grande basin. The report also details the chemical quality of water from wells, including saline waters, as well as mapping the saline waters of the basin.

Koopman, F.C., and Purtymun, W.D., 1965,
Hydrologic Characteristics of the Tshirege Member of the Bandelier Tuff with Reference to the Injection of Treated Low-level Radioactive Liquids, U.S.Geological Survey, Open File.

The U.S. Geological Survey in cooperation with the Los Alamos Scientific Laboratory and the U.S. Atomic Energy Commission began a study in February 1964 to determine the feasibility of using the Tshirege Member of the Bandelier Tuff to store or to arrest indefinitely radioactive effluents produced by the laboratories at Los Alamos.

The initial phase of the study is to summarize by this report data related to waste disposal at Los Alamos as well as techniques of injecting liquids and monitoring the effects of the injection.

Los Alamos is located on the Pajarito Plateau which is underlain by the Bandelier Tuff. The Bandelier is composed of ash fall, and pumice of rhyolite tuff. Heat and pressure has welded the tuff into a consolidated mass. Rocks of the Santa Fe Group underlie the Bandelier Tuff and consist of siltstone and sandstone, conglomerate, and interbedded basalt. The geologic and hydrologic setting of the Pajarito Plateau is most favorable for retention of radioactive wastes. The plateau is not unique; other areas in the western half of the United States have thousands of square miles of similar geologic settings. The information gained by an injection pilot study in the Pajarito Plateau could be used in other areas.

The Santa Fe Group is the main aquifer of the Los Alamos area and it lies 600 to 1,000 feet below the surface of the plateau. Above the main aquifer and the rocks of the Santa Fe Group are about 1,000 feet of rhyolite tuff of the Bandelier Tuff. The Bandelier Tuff is composed of three members which in ascending order are: the Guaje Member, a pumice fall 20 to 35 feet thick; the Otowi Member a nonwelded rhyolite tuff 140 to 385 feet thick; and the Tshirege Member, a series of nonwelded to welded units of rhyolite tuffs that is as much as 800 feet thick.

The degree of welding affects porosity, specific yield, specific retention, and permeability. It also determines the density of jointing and the degree of opening of joints in the various units.

The matrix of nonwelded units is more permeable than that of the welded units; however, more joints tend to form and remain open in the welded units, and these joints transmit water readily.

The upper surface of the plateau is covered with a clayey soil that is derived by weathering of the underlying Tshirege Member. This soil cover prevents most of the precipitation from infiltrating into the underlying tuff and forms an apparent airtight seal on the mesa surfaces.

Water moves as unsaturated flow downward by gravity and outward by capillary forces in the tuff beneath test infiltration pits and waste-disposal pits. Water occurs in open joints beneath some of the waste-disposal pits.

Injection of liquids should be into moderately welded to welded unit of tuff overlying a nonwelded unit. Open joints in the moderately welded to welded unit will increase the effective size of the injection well and the underlying nonwelded unit will tend to arrest the downward movement of the liquid.

Hydraulic injection procedures that borehole pressure during injection into a 100-foot well should be at less than 67 psi (pounds per square inch measured at land surface). An injection well 100 feet deep, 1 foot in diameter, and with a 20 foot section of tuff penetrated will take about 28,400 gallons of liquid per day. Tension forces (capillary in the tuff matrix) will move liquid in all directions; the vertical movement influenced by gravity. After six months of injecting liquid at a rate of 28,400 gpd, the liquid will have moved to about 75 feet from the injection well.

Three sites proposed for a pilot study were chosen because of availibility of waste effluent and the geological conditions.

Koopman, F.C., and Purtymun, W.D., 1969,
Pumpage and Water Levels in Supply Wells, 1968,
U.S. Geological Survey, Los Alamos Water Supply File.

Pumpage from the Los Alamos, Guaje, and Pajarito well fields increased 82 million gallons, from 1,319 million gallons in 1967 to 1,401 million gallons in 1968. Production was from 6 wells in the Los Alamos field, 7 wells in the Guaje field, and 3 wells in the Pajarito field. The total amount of water pumped from the three fields, from 1950 through 1968, is about 18.7 billion gallons.

The average pumping rate for the three fields increased 1,256 gpm (gallons per minute) from 8,003 gpm in 1967 to 9,259 gpm in 1968. The increased in the average pumping rate was due to the addition of well PM-3 to the Pajarito field in January 1968.

In general, during 1968, the highest water levels occurred during the winter when pumpage was at a minimum and the lowest water levels occurred during the late spring and summer when pumping was at a maximum.

Lane, L.J., 1983,
Preliminary Report on Water and Contaminant Transport in the Subsurface Zone--A Joint Los Alamos/USDA-Agricultural Service Study,
LANL, LA-UR-83-2994.

During August 1983, a cooperative research project involving scientists from Los Alamos and from the USDA-ARS US Water Conservation Laboratory in Phoenix, Arizona was initiated. The cooperative study, hereafter called the Caisson B Tracer Study, was designed to provide data on subsurface movement of contaminants in the unsaturated zone. Earlier in the summer a steady-state, but unsaturated flow condition was established in Cassion B by applying an input rate of 200 ml/min = 0.04 m/d of water until the subsequent outflow from the bottom of the 3 X 6 m cassion equaled the input rate. This steady-state flow condition was reached and the profile-average volumetric water content of the crushed tuff stabilized at about 0.28 to 0.30.

Starting on August 10, 1983 and continuing for six days, three tracers were added to the 200 ml/min inflow rate. The tracers were potassium bromide (KBr) at 326 +/- 11 ppm, potassium iodide (KI) at 310 +/- 20 ppm and potassium thiocyanate (KSCN) at 282 +/- 6 ppm. Water traces were added through a drip irrigation system and solute samples were collected in a porous cup water samplers at six positions (0.4, 1.16, 1.91, 2.72, 3.47 and 4.23 m below the surface). These samples were then analyzed for tracer content to determine solute transport.

The inflow of water was applied with a drip irrigation system consisting of 24 outlets arranged nearly uniformly over the surface of the cassion. The surface was covered with two layers of plastic sheets to prevent evaporation and entry of precipitation. Unfortunately, 7 of the 24 outlets were plugged and failed at unknown times between August 10 and September 27, 1983. Therefore, the input application rates were not uniform in space.

The results were analyzed with the aid of a simple computer program to evaluate the analytic solution for the one-dimensional, convective-dispersive, solute transport equation.

Comparison of the computed concentrations and measured concentrations of the conservative tracers (KBr and KI) reveal 1) at shallow depths the computed concentration occurs earlier than was measured, while better agreement was achieved in time of greater depths, 2) observed concentrations show two peaks while the computed curves do not. The nonuniform application of traces and water (plugged outlets) could contribute to complex distribution of tracers in time and space. This would explain why the observed concentration data would more closely approach the theoretical curves as depth increased.

Comparison of the result of the computed and observed concentrations for the nonconservative tracer (KSCN) exhibit characterisitics similar to those shown for the conservative tracer, with the exception that the nonconservative tracer did not show a secondary peak. This is consistent with the assumption of first order decay assumed in the simulation.

Model limitations and departures of experimental conditions from model assumptions were used to interpret the observed tracer movement. These observed data and their departures from the theoretical tracer movement patterns are being used to design improved unsaturated flow and contaminant transport studies at Los Alamos.

Lane, L.J., 1984,
Surface Water Management: A User's Guide to Calculate a Water Balance Using the CREAMS Model,
LANL, LA-10177-MS.

The hydrologic component of the CREAMS model is described and discussed in terms of calculating a surface water balance from a shallow land burial system used for waste disposal. Parameters estimates and estimation procedures are presented in detail in the form of a user's guide. Use of method is illustrated with three examples based on analysis of data from Los Alamos, New Mexico and Rock Valley, Nevada. Use of the model in design of trench caps for shallow land burial systems is illustrated with example applications at Los Alamos.

Lane, L.J., and Hakonson, T.E., 1982,
"Influence of Particle Sorting in Transport of Sediment Associated Contaminants", Proceedings of the Symposium on Waste Management,
Waste Management, Volume 1, pp. 543-557.

Hydrologic and sediment transport models are developed to route the flow of water and sediment (by particle size classes) in alluvial stream channels. A simplified infiltration model is used to compute runoff from upland areas and flow is routed in ephemeral stream channels to account for infiltration or transmission losses in the channel alluvium. Hydraulic calculations, based on the normal flow assumption and an approximating hydrograph, are used to compute sediment transport by particle size classes. Contaminants associated with sediment particles are routed in the stream channels to predict contaminant transport by particle size classes. An empirical adjustments factor, the enrichment ratio, is shown to be a function of the particle size distribution of stream bed sediments, contaminant concentrations by particle size, differential sediment transport rates, and the magnitude of the runoff event causing transport of sediment and contaminants. This analysis and an example application in a liquid effluent-receiving area illustrate the significance of particle sorting in transport of sediment associated contaminants.

Lane, L.J., and Nyhan, J.W., 1984,
Water and Contaminant Movement: Migration Barriers,
LANL, LA-10242-MS.

Migration Barriers are used in shallow land burial facilities to stop or slow the movement of water and contaminants are discussed here as a single component embedded in a complex environmental system. Analytical solutions to solute transport equations are used to approximate the behavior of migration barriers and derive design criteria for control of subsurface water and contaminant migration. Various types of migration barriers are compared and design recommendations are made for shallow land burial trench caps and liners. Needed improvements and suggested field experiments for future designs of migration barriers are then discussed relative to the management of low-level radioactive wastes.

Lane, L.J., Purtymun, W.D., and Becker, N., 1982,
Development of Procedures to Estimate Surface Runoff, Sediment Yield, and Contaminant Transport at Los Alamos, New Mexico,
Rough draft, unpublished.

Simplified procedures are developed to predict runofff, sediment yield, and contaminant transport from semiarid watersheds with alluvial stream channels. The procedures represent a synthesis of simplified models to approximate the complex processes of runoff generation, streamflow-routing and hydrograph development, sediment transport and yield, particle sorting and enrichment, and transport of sediment-associated contaminants.

The procedures are applied to complex watershed-channel system at Los Alamos, New Mexico, and are used to compute the transport and redistribution of plutonium in alluvial stream channels. Mass-balance calculations are used to compute plutonium outflows from the channel system, and to compute the amount of plutonium remaining in storage in the channel alluvium.

Lane, L.J., Purtymun, W.D., and Becker, N.M., 1985,
New Estimating Procedures for Surface Runoff, Sediment Yield, and Contaminant Transport in Los Alamos County, New Mexico,
LANL, LA-10335-MS.

Procedures are developed tp predicted runoff, sediment yield, and contaminant transport from semiarid watersheds with alluvial stream channels. The procedures represent a sythesis of mathematical models to approximate the complex processes of runoff generation, streamflow routing and hydrograph development, sediment transport and yield, particle sorting and enrichment, and transport of sediment-associated contaminants.

The procedures are applied to a complex watershed-channel system at Los Alamos New Mexico, and are used to compute plutonium transport and redistribution in alluvial stream channels. Mass-balance calculations are used to compute the amount of plutonium discharge from the channel system and to compute the plutonium remaining in storage in the channel alluvium.

McLin, S., McInroy, D., and Grieggs, A., 1988,
"Vadose Zone Characterization at TA-16, Area P", Los Alamos National Laboratory Environmental Surveillance 1987,
LANL, LA-11306-ENV, pp. 96-97.

The hydrologic transmitting characteristics of the vadose zone in Area P are presently under investigation. These efforts will support the ground water waiver as required under 40CFR 265, Subpart F. The contaminate of major concern leaching from the landfill is soluble barium nitrate. Results from recent survey of locations adjacent to the landfill, indicate barium nitrate concentrations did not exceed 3 mg/l. In an attempt to numerically simulate the potential barium nitrate migration from the landfill through the Bandelier Tuff continuous core samples were laboratory tested for determination of saturated and unsaturated hydraulic conductivity, moisture retention characteristics, bulk density, porosity. Five neutron moisture wells, and nine ground water monitoring wells were also installed around the landfill as well as boreholes to verify suspected stratigraphic unit correlations within the unsaturated Bandelier Tuff.

New Mexico Environmental Improvement Division, 1984,
A Reasonable Worst-Case Water Balance for LANL Hazardous Waste Disposal Areas, with Emphasis on TA-54,
New Mexico Environmental Improvement Division, Memo to Los Alamos National Laboratory.

This paper gives the New Mexico's Environmental Improvement Divisions water balance scenarios for TA-54. Four different scenarios are used, with one illustrating a worst-case situation.

Nyhan, J.W., 1989,
A Hydrologic Modeling Study of Water Balance Relationships at the Area P Landfill in Los Alamos, New Mexico,
LANL, LA-11521-MS.

The water balance relationships of the Area P landfill in Los Alamos were studied in a preliminary attempt to hydrologically characterize and successfully close shallow land burial site. The current Resource Conservation and Recovery Act status of the site is discussed, and plans to reach site closure are presented along with the waste use history and description of the site. The precipitation and temperature at the Area P landfill are evaluated and soil volumetric water content data collected at the site are presented, along with calculations of water inventories in the backfill and underlying tuff. The results of hydrologic modeling studies are presented for various scenarios at the landfill, for both those with and without a final closure cover. A final set of design recommendations is presented relative to improving the final approved closure plan for this landfill.

Nyhan, J.W., 1989,
Hydrologic Modeling to Predict Performance of Shallow Land Burial Cover Designs at the Los Alamos National Laboratory,
LANL, LA-11533-MS.

The water balance relatioships of two shallow land burial (SLB) cover configurations were studied using a hydrologic model in a preliminary attempt to design waste disposal site covers for successful long term closure at Los Alamos. Burial site performance requirements for site closure are first discussed, along with the role of hydrologic models in assessing the dynamics of the hydrology of the SLB cover. The calibration of a hydrologic model using field data from two SLB cover designs is then described, followed by an analysis of long-term climatic model input parameters across Los Alamos National Laboratory.

These two calibrated models are then used to evaluate the influence of vegetation, precipitation, and runoff curve numbers on the design of SLB covers within Los Alamos County. Future directions of field resesarch efforts and subsequent hydrologic modeling activities were recommended in terms of their usefulness for waste management decisions to be made at Los Alamos.

Nyhan, J.W., and Drennon, B., 1989,
The Measurement of Soil Water Tension in a Hydrologic Study of Waste Disposal Site Design,
LANL, LA-11460-MS.

Commercially available differential pressure transducers, tensiometers and a data aquisition system were combined to study soil water tension changes with time within two trench cap designs used for shallow land burial (SLB) of waste materials. Apparent diurnal variations in soil water tension measured with this system in these field plots are evaluated relative to field variations in temperature, atmospheric pressure and soil water content.

Isolated variable experiments were then performed in the field and in the laboratory to evaluate the measurement of soil water tension with the acquisition system. A background tensiometer was used to measure the temperature and soil water induced effects independent of soil matric potential, and was evaluated under field conditions. The reliability of soil water tension data collected in the field is discussed, and future research needs for tensiometry are identified.

Nyhan, J.W., and Drennon, B.J., 1990,
"Tensiometer Data Acquaition System for Hydrologic Studies Requring High Temporal Resolution",
Soil Sci. Soc. Am. J., Vol. 54, pp. 293-296.

Commerically available differential pressure transducers, tensiometers, and a data aqusisition system were combined to evaluate soil water tension changes with time within two landfill cover designs used for the shallow land burial of waste materials. A typical error for the differential pressure transducers in the voltage-pressure transducers in the voltage-pressure calibration curve was estimated to be 0.14 V at a transducer output of 4 V. Tensiometer data collected simultaneously using the data acquisition system and a hand-held manual pressure transducer system agreed well (r squared = 0.994). The utility of the tensiometer data acquisition system to collect field data was demonstrated successfully using reference tensiometers with known hydraulic heads. Diurnal fluctuations in tensiometer data collected in the field are discussed relative to future experiments to be performed with the system. In addition, tensiometers with unknown and variable hydraulic heads were used to determine tensiometer response times of approximately 50 min.

Nyhan, J.W., Drennon, B.J., and Gaylor, R.M., 1987,
Field Evaluation of a Tensiometer Data Aquisition System for Hydrologic Studies of Waste Disposal Site Design,
Environmental Science Group, LANL, unknown.

Commercially available differential pressure transducers, tensiometers and a data aquisition system were combined to study soil water tension changes with time within two trench cap designs used for shallow land burial of waste materials. Apparent diurnal variations in soil water tension measured with this system are evaluated relative to field variations in temperature, atmospheric pressure and soil water content. On-going research is described which should improve the reliability of future soil water tension data collected in the field.

Nyhan, J.W., et al., 1983,
"Environmental Migration of Long Lived Radionuclides Beneath a Former Los Alamos Liquid Waste Disposal Site After 33 years",
LANL, LA-UR-83-1199.

The distribution of plutonium, Am-241 and water in Bandelier tuff beneath a former liquid waste disposal site at Los Alamos was investigated. The waste use history of the site was described, as well as the previous field and laboratory studies of radionuclide migration performed at this site. One of the adsorption beds studied had 20.52 m of water added to it in 1961 in an agressive attempt to change the distribution of radionuclides in the tuff beneath the bed. Plutonium and Am-241 inventory were detected to sampling depths of 30 m in this bed, but only found depths of 6.5-13.41 m in adjacent adsorption bed (bed 2) not receiving additional water in 1961. After 17 years of migration of the slug of water added to bed 1, 0.3-5.1% of the plutonium inventory and 3.0-49.6% of the Am-241 inventory was mobilized within 30 m sampling depth, as less than one column volume of water moved out of the tuff profile under the bed.

The results of similar lab and field studies performed since 1953 were compared with our 1978 data and site geohydrologic data, as well as the implications of our results to nuclear waste management.

Nyhan, J.W., et al., 1983,
"Transport of Soil Particles by Overland Flow from Trench Caps Used to Cover Low-Level Radioactive Wastes",
Agronomy Abstracts, 84.

A joint study was made by the Los Alamos National Laboratory and USDA-ARS to examine water erosion of soil particles from a typical Los Alamos trench cap using USLE plots. Overland flow of soil particles was studied from plots with bare soil, tilled, and vegetated surface treatments using a rotating boom rain simulator. Transport of nondispersed and dispersed soil particles was studied from soil surfaces with three initial soil water contents, ranging from air dry to near saturated conditions, and at various times during the runoff events. The implications of these research results are discussed relative to management alternatives an nuclear waste management.

Nyhan, J.W., et al., 1986,
A Joint DOE/NRC Field Study of Tracer Migration in the Unsaturated Zone,
LANL, LA-10575-MS.

The results of a joint DOE/NRC field experiment to evaluate leaching and transport of solutes in a sandy silt backfill used for shallow land burial operations at Los Alamos are presented for steady-state and unsteady-state flow conditions. The migration of iodide, bromide, and lithium through the backfill material is studied as functions of depth and time and they are compared with one another.

The bromide and iodide tracer data are used to estimate the distribution coefficient, tortuosity factor, and dispersivity. These values are used to calculate effective dispersion coefficients for subsequent analyses of the retardation factor and the distribution coefficients for subsequent analyses of the retardation factor and the distribution coefficient for lithium using least squares procedures.

Our preliminary findings were that iodide and bromide migration seem to be enhanced under unsteady-state flow conditions, while lithium transport demonstrated just the opposite pattern. This behavior, along with similar NRC data on cesium and strontium transport, will provide real challenges to current transport codes, many of which will probably only work successfully under steady-state flow conditions. Because most transport in the field, such as liquid waste spills and leaching buried wastes in landfills, probably occurs within the unsteady-state flow regime, or ultimate goal is to be able to model chemical transport under these transient conditions.

Nyhan, J.W., Hakonson, T.E., and Drennon, B.J., 1990,
"A Water Balance Study of Two Landfill Cover Designs for Semiarid Regions",
J. Environ. Qual., Vol. 19, No. 2, pp. 281-288.

The results from several field experiments on methods to control soil erosion, biointrusion, and water infiltration were used to design and test an enhanced landfill cover that improves the ability of the disposal site to isolate buried wastes. The performance of the improved cover design in managing water and biota at the disposal site was compared for 3 yr with that obtained from a more conventional cover design that has been widely used in the industry. The conventional cover design consisted of 20 cm of sandy loam topsoil over 108 cm of a sandy silt backfill, whereas the improved design consists of 71 cm of topsoil over a minimum of 46 cm of gravel, 91 cm of river cobble, and 38 cm of sandy silt backfill. Each plot was lined with an impermeable liner to allow for mass balance calculation of water dynamics. Results over a 3-yr period, including 2 wet yr, demonstrated that the improved design reduced percolation of water through the landfill cover by a factor of >4 over the conventional design. This decrease in percolation was attributed to a combination of increased evapotranspiration from the plant cover and the effect of a capillary barrier embedded in the enhanced cover profile in diverting water laterally in the cover. The field data are finally discussed in terms of its usefulness for waste management decisions to be made in the future for both new and existing landfills at Los Alamos, NM, and at other semiarid waste disposal sites.

Pearson, C.F., 1981,
Investigation of a Shallow Aquifer Near the Fenton Hill Hot Dry Rock Site Using DC Resistivity,
LANL, LA-8999-MS.

This study investigated a shallow aquifer in the base of the Tertiary volcanic sequence using a series of 9 DC Schlumberger soundings taken within 10 km of the Fenton Hill hot dry rock geothermal site. The aquifer dips to the southwest following the top of the Abo formation, which acts as an aquiclude. Depth increases from 130 m in the eastern part of the study area to 260 m at 1.5 km west of the Fenton Hill site. Aquifer resistivities varied from 13 ohms-m to 126 ohms-m, which could be caused by variable permeability in the aquifer. Using results from empirical studies the study estimated permeabilities ranging from 40 darcies to less than 0.3 darcies with the highest values occurring nearest to the Fenton Hill site.

Penrose, W.R., et al., 1990,
"Mobility of Plutonium and Americium through a Shallow Aquifer in a Semiarid Region",
Environ. Sci. Technol., Vol. 24, pp. 228-234.

Treated liquid wastes containing traces of plutonium and americium are released into Mortandad Canyon, within the site of Los Alamos National Laboratory, NM. The wastes infiltrate a small aquifer within the canyon. Although laboratory studies have predicted that the movement of actinides in subsurface environments will be limited to less than a few meters, both plutonium and americium are detectable in monitoring wells as far as 3390 m downgradient from the discharge. between the first and last monitoring wells (1.8 and 3.4 km from the discharge), plutonium concentrations decrease exponentially from 1400 to 0.55 mBq/L. Americium concentrations ranged between 94 and 1240 mBq/L, but did not appear to vary in a systematic way with distance. Investigation of the properties of the mobile actinides indicates that the plutonium and part of the americium are tightly or irreversibly associated with colloidal material between 25 and 450 nm in size. The colloidally bound actinides are removed only gradually from groundwater. The fraction of the americium not associated with colloids exists in a low molecular weight form (diameter, <= 2 nm) and appears to be a stable, anionic complex of unknown composition. The mobile forms of these actinides defeat the forces that normally act to retard their movement through groundwater systems.

Perkins, B., Travis, B., and DePoorter, G., 1985,
Validation of the TRACR3D Code for Soil Water Flow Under Saturated/Unsaturated Conditions in Three Experiments,
LANL, LA-10263-MS.

Validation of the TRACR3D code in a one-dimensional form was obtained for flow of soil water in three experiments. In the first experiment, a pulse of water entered a crushed-tuff soil and initially moved under conditions of saturated flow, quickly followed by unsaturated flow took place. In the final experiment, two slugs of water entered crushed tuff under field conditions. In all three experiments, experimentally measured data for volumetric water content agreed, within experimental errors, with the volumetric water content predicted by the code simulations.

The experiments and simulations indicated the need for accurate knowledge of boundary and initial conditions, amount and duration of moisture input, and relevant material properties as input into the computer code. During the Validation experiments, limitations on monitoring of water movement in waste burial burial sites were also noted.

Perkins, B.L., and Cokal, E.J., 1986,
Subsurface Moisture Regimes and Tracer Movement Under Two Types of Trench-Cap Designs for Shallow Land Burial Sites,
LANL, LA-10449-MS.

The Los Alamos work has focused on proper design of shallow land burial (SLB) sites in arid and semiarid regions and in applying corrective measures to existing sites.

One of the most important design features affecting the probability of movement of radionuclides in SLB sites is the type of trench cap placed over the waste. The cap influences such interdependent parameters as erosion, water infiltration and percolation and biointrusion.

To obtain experimental data for arid and semiarid sites, two different designs of trench caps, one topsoil underlain with a cobble/gravel biobarrier and one with topsoil underlain with crushed tuff, were compared with respect to (1) seasonal changes in volumetric soil water content and (2) downgradient migration of tracers emplaced directly below each type of trench cap.

Due to the holdup of moisture (because of the differences in matric potential at the topsoil/biobarrier interface) until breakthough occurred, the use of the biobarrier design resulted in a pulse of water entering the underlying tracer layer. Because breakthough would be expected to occur more easily in some regions than others (due to nonuniformities at the interface), water probably did not move uniformly into the region below the biobarrier. In contrast, the use of crushed tuff allowed water to percolate down through the topsoil profile. The buildup of moisture in the topsoil and rapid, large increase in moisture at the tracer layer was not observed. Moreover, soil water probably moved more uniformly through a given horizon.

After one growing season, with the addition of approximately 81 cm of precipitation, downward tracer movement had occurred. The movement of cobalt and strontium was greater in the biobarrier design than in the crushed tuff design. Under both trench cap designs, strontium was more mobile than cobalt, which was more mobile than cesium for the high concentrations added to the tracer layer. In a given horizon into which tracer had moved, nonumiform concentrations of tracer were found in both treatments. There was much greater nonuniformity across each horizon, particularly for strontium, in the biobarrier containing trench cap. Tracer inhomogeneity was probably related to the observed nonuniform distributions of soil moisture and perhaps channeling along instrumentation tubes.

After two growing seasons and the addition of a total of 178 cm of precipitation, significant strontium was found in the outflow water from the experimental columns utilizing the biobarrier treatment, whereas little strontium was found in the outflow water from the columns having the tuff cover.

This large-scale-type experiment indicates that under some conditions some contaminants may have greater subsurface migration using a biobarrier as compared to a crushed-tuff-only design. The nonuniform concentrations of tracer found at a given horizon perhaps indicate perferred pathways for movement, particularly for the biobarrier design. Nonuniform covers or inhomogeneities in the soil may greatly influence preferred pathway movement. At SLB sites, under the conditions of unsaturated flow that generally occur at near-surface depths in air and semiarid sites, nonuniform structures may make both modeling and monitoring difficult, and mobilization of a contaminant may be greater than expected.

The causes for the large differences in concentrations found in this experiment need to be investigated further. Problems in environmental modeling and monitoring of arid and semiarid SLB sites because of heterogeneities in the soil profiles and their implications for SLB waste management need to be better understood. More work in trench cap design and its influence on the many pathways available for mobilization is needed.

Polzer, W.L., and Essington, E.H., 1983,
Mobility of Waste Actinides in the Shallow Aquifer of Mortandad Canyon, Los Alamos, New Mexico,
Upublished, Rough Draft.

Treated waste effluents are released to the shallow aquifer of Mortandad Canyon at the Los Alamos National Laboratory. About 1% of the released actinides remains in solution (<0.45 um in diameter). An investigation of the relatiive mobilities of those plutonium and americum species indicate similar mobilities in the upper reaches of the canyon, but considerably different mobilities in the lower reaches; americium being more mobile than plutonium. The sorption of the of the actinides to the sediments in Mortandad Canyon tends to be less than that observed for many other environmental systems; however sorption is still substantial. The lower sorption is attributed to the characteristics of both the aquifer water and the canyon sediments.

The mobile plutonium is predominantly associated with inorganic colloidal material. Both the plutonium and the colloidal material posses neutral charge characteristics. On the other hand, the mobile americium appears to be associated with a low molecular weight complex and with colloidal material. The colloidal material probably predominates in the upper reaches of the canyon and the low molecular weight complex probably predominates in the lower reaches of the canyon. The charge characteristics of americium are predominatly neutral, but a significant factor of the charge is negative in the lower reaches of the canyon. Both the plutonium and americium appear to equilibrate rather slowly with their aqueous environment.

Polzer, W.L., and Fuentes, H.R., 1985,
Coupling Equilibrium Sorption to Flow Dynamics in Porous Media.,
LANL, LA-UR-85-4457.

In this paper a chemical sorption model is presented which describes the sorption of solutes under batch equilibrium conditions. The derivation of the isotherm equation from statistical mechanics and kinetic theories suggest that the empirical constants calculated from the isotherm can be used to predict the influence of the sorption processes on the transport of solutes under dynamic flow and equilibrium sorption conditions. A technique is presented for the coupling of the sorption model to an advective-dispersion model to show the influence of sorption processes on solute transport.

Polzer, W.L., and Fuentes, H.R., 1985,
Field Studies and Modeling of Chemical Processes in the Unsaturated Zone,
LANL, LA-UR-85-3489.

Technical assistance is being provided to Nuclear Materials Safety and Safeguards of the Nuclear Regulatory Commission to evaluate the validity of several guidelines listed in 10 CFR Part 61 for the future burial of low-level radioactive waste. Those guidelines include the requirement that the burial site shall be capable of being modeled.

Both laboratory- and field-scale studies are being conducted under unsaturated moisture conditions and under steady-state and unsteady-state flow conditions. This paper reviews the kinds of experiments in low-level radioactive waste disposal in development at the Los Alamos National Laboratory. Major emphasis is on some of the inital analyses of data for laboratory sorption experiments and for field transport tests. Brief reference is made to leaching and transport studies.

Laboratory batch equilibrium sorption studies suggest that adsorption of nonconservative tracers can be described in terms of two empirical constants; one gives an indication of the average K(d) for all adsorption sites and the other gives an indication of the spread of individual K(d)'s about the average K(d). This information can be translated into a "chemical dispersion" under dynamic flow and equilibrium sorption conditions that is in addition to the traditionally accepted physical disperson.

Laboratory nonequilibrium sorption studies suggest that nonequilibrium models may be needed to model the transport of the nonconservative tracers cobalt and cesium; equilibrium models should be suitable to model strontium transport.

Analyses from field-scale studies indicate that conservative tracers can reasonably be modeled with a one-dimensional advective-dispersive equation for steady flow.

Polzer, W.L., and Fuentes, H.R., 1987,
The Use of a Heterogenity-Based Isotherm to Interpret the Transport of Reactive Radionuclides in Volcanic Tuff,
LANL, LA-UR-87-2901.

The sorption of cesium and strontium has been modeled with a heterogeneity-based isotherm equation for various tuff materials including those within a sequence of geologic stratigraphic units. The theory of the isotherm forsees the relative retardation and the "chemical dispersion" of the studied radionuclides during transport. The concepts of heterogeneity of sites and variablity in the maximum number of sites available for sorption are incorporated into the model.

Polzer, W.L., and Lane, L.J., 1984,
Field Studies and Modeling of Chemical Processes in the Unsaturated Zone: Test Plan for Technical Support Studies,
LANL, LA-UR-84-445.

Los Alamos has been asked to conduct preliminary field and /or laboratory studies as technical support to assist Nuclear Regulatory Commission (NRC) in improving estimated leaching and transport scenarios used to assess the performance of low-level waste disposal sites. The studies will investigate four major areas related to the leaching processes in the unsaturated zone: (1) comparison of the amount of radionuclides leached from the waste forms during passage of wetting fronts with the amount of radionuclides leached continuously due to moisture movement in partially saturated soils; (2) determination of the contribution of radionuclides diffusing into static interstitial soil moisture that is subsequently removed by the passage of the wetting front; (3) determination of the increase in dilution of leachate caused by increased frequency or volume of water passing through successive wetting fronts; and (4) determination of the amount of error introduced by the assumption of continuous distributed evenly rather than sporadic infiltration. The results of this leaching study will also include recommendations of appropriate scenarios for leaching to be incorporated in existing computer models.

In a closely related transport study, Los Alamos is to perform preliminary investigations of the chemical and physical processes which affect the transport of reactive solutes in the unsaturated zone. The objectives of this investigation will be to evaluate the effects of other chemical processes compared to adsorption processes and to provide the NRC with improved means of evaluating the adequacy of the use of "lumped" coefficients in modeling studies. The results of this investigation will be used to assist the NRC staff in improving estimates of the interaction between soil moisture and the soil matrix that lead to retardation of waste contaminants. That, in turn, will assist the NRC staff in identifying either favorable siting characteristics or potential remedial actions to control waste contaminant migration. In addition, this study will identify areas where research may be needed to define the effects of specific, important chemical processes.

Polzer, W.L., et al., 1984,
"Geochemical Mechanisms of Contaminant Transport ", Environmental Surveillance at Los Alamos During 1983,
LANL, LA-10100-ENV, pp. 71-72.

Treated waste at Los Alamos has been released into the environment in Mortandad Canyon since 1963. This study was initiated to investigate (1) the relative mobilities of the actinides in the shallow aquifer of Mortandad Canyon and (2) the influence of physiochemical characteristics of those mobilities.

The results from this study suggest the following conclusions. Plutonium is associated with mobile colloidal material and americium is associated with both mobile colloidal and low molecular weight materials; neither species equilibrates readily with its aqueous environment. As the effluent moves through the aquifer, the colloidal material is removed from "solution". In the lower reaches of the canyon the low molecular weight americum complex becomes the predominant americum species and it is not adsorbed readily by sediment.

Polzer, W.L., et al., 1986,
Modeling Study of Solute Transport in the Unsaturated Zone: Information and Data Sets,
LANL, LA-10730-MS, Vol. 1.

The Environmental Science Group (HSE-12) is conducting a study to compare various approaches of modeling water and solute transport in porous media. Various groups representing different approaches will model a common set of transport data so that the state of the art in modeling and field experimentation can be discussed in a positive framework with an assessment of current capabilities and future needs in this area of research. This paper provides information and sets of data that will be useful to the modelers in meeting the objectives of the modeling study. The information and data sets include (1) a description of the experimental design and methods used in obtaining solute transport data, (2) supporting data that may be useful in modeling the data set of interest, and (3) the data set to be modeled.

Polzer, W.L., et al., 1987,
Characterization of Crushed Tuff for the Evaluation of the Fate of Tracers in Transport Studies in the Unsaturated Zone,
LANL, LA-10962-MS.

Results of field-scale (cassion) transport studies under unsaturated moisture and steady and nonsteady flow conditions indicate variability and a lack of conservation of mass in solute transport. The tuff materials used in that study were analyzed for the presence of tracers and of freshly precipitated material to help explain the variability and lack of conservation of mass. Selected tuff samples were characterized by neutron activation analysis for tracer identification, by X-ray diffraction for mineral identifcation, by petrographic analysis for identification of freshly precipitated material, and by x-ray fluorescence analysis for identification of major and trace elements.

The results of these analyses indicate no obvious presence of freshly precipitated material that would retard tracer movement. The presence of the nonsorbing tracers (bromide and iodide) suggest the retention of these tracers in immobile water. The presence of sorbing and nonsorbing tracers on the tuff at the same locations (even cesium at the 415-cm depth) and not at others suggests variability in transport.

Porzucek, C., and Springer, E., 1987,
VAPTOC - Vapor Phase Transport of Organic Chemicals I. Model Development,
LANL, LA-UR-87-3773.

A model has been formulated to predict the vapor phase flow of a single organic component in soils. The contaminant is assumed to have volatilized from an aqueous solution which is trapped in unsaturated porous media. Equilibrium is assumed between the liquid and vapor phases. The gaseous organic contaminant migrates due to diffusion and free convection. In addition, an energy balance has been incorporated to account for the thermal effects at the soil-air interface as well as the latent heat of vaporization of the organic contaminant. Species balance equations, an energy balance and other constitutive relationships are presented. Some details of the solution technique are also presented.

Purtymun, W.D., 1962,
The Distribution of Moisture in the Soil and Underlying Tuff at Technical Area 49, Frijoles Mesa, Los Alamos County, New Mexico,
U.S. Geological Survey, Administrative RElease.

Twenty-three moisture test holes were constructed in February and March 1960 to study the moisture distribution in the soil and underlying tuff at Technical Area 49, on the northern segment of Frijoles Mesa, in north-central New Mexico. Radioactive contaminants are buried within the tufff in this area, and sufficient infiltration of water from precipitation could cause them to move into nearby surface and ground-water supplies.

Moisture measurements, tabulated in this report, indicate that only small and insignificant amounts of water infiltrate the soil and underlying tuff in Technical Area 49, except at sites where construction work has disturbed the natural soil cover or changed the pattern of surface drainage.

The periodic moisture measurements, made by a neutron-scattering moisture probe for a 2-year period, indicated the moisture content of the soil and transition zone varied due to weather conditions. The mositure content of the tuff remained the same, varied due to weather conditions, or increased slightly in the upper few feet of tuff in 21 of the test holes. The moisture content in the tuff, up to a depth of 16 feet, in two test holes increased from 13 1/2 to 28 percent by volume, indicating some infiltration of water.

Purtymun, W.D., 1964,
Progress Report on the Hydrology of Mortandad Canyon, Disposal System for Treated Low-level Liquid Radioactive Wastes; July 1961 to June 1963,
U.S. Geological Survey, Administrative Release.

The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory collected hydrologic data in Mortandad Canyon prior to the discharge of low-level radioactive effluents into the canyon from an industrial waste-treatment plant at technical area TA-50. The plant began operation on June 28, 1963. Prior to and following June 1963 waste water also was discharged into Effluent Canyon, a tributary to Mortandad Canyon, from technical area TA-48 and from the New Sigma Building of the head of Mortandad Canyon.

Nine observation wells finished in the alluvium and nine access tubes to study the moisture distribution in the alluvium and tuff were constructed in the canyon during the period from July 1961 to June 1963. Two gaging stations were built, and equipped with semicontinuous recorders to monitor surface flow in the canyon.

Waste water from the plants in TA-48 and New Sigma Building and storm runoff constitute the surface flow on the canyon floor. The alluvium in the canyon is highly permeable and accepts recharge readily; the Tshirege and Otowi Members of the Bandelier Tuff are much less permeable and accept recharge very slowly, the Tshirege more slowly than the Otowi. The chemical quality of water in the alluvium changes slightly as the water moves eastward downgradient. The change may be related to differences in the bedrock beneath the alluvium; the Tshirege underlies the alluvium on the west, the Otowi on the east.

Chemical and radiochemical analyses of water provide background radioactivity data. Analyses of samples of alluvium and tuff provide background-radioactivity data of materials on the canyon floor. Gamma-radiation logs of observation well access tubes, and a test well provide additional background monitoring information and aid in computing storage for the effluents in the alluvium.

Purtymun, W.D., 1966,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1961 through June 1962,
U.S. Geological Survey, Administrative Release.

Chemical and radiochemical analyses of water samples and of alluvium collected in the Los Alamos area downgradient from industrial waste and sewage treatment plants during July 1961 through June 1962 were made by the H-6 and H-7 Groups of the Health Division of the Los Alamos Scientific Laboratory. The analyses were made to monitor the amount and extent of contamination resulting from the operation of the Los Alamos Scientific Laboratory at Los Alamos, New Mexico.

Radioactive contaminants were present in Acid and Pueblo Canyons below the points of radioactive-waste discharge, but the radioactivity was below the maximum permissible limits and was confined mainly to Acid Canyon, which contains the major disposal area for liquid low-level radioactive effluents. The chemical quality of the water showed no significant change from that during the previous monitoring period 1956-1957 and indicated that the quality in Pueblo Canyon improved downstream through ion exchange and by dilution with treated sewage effluent.

The chemical quality of water from shallow test wells 1A and 2A in Pueblo Canyon was good and had changed only slightly from 1956-57 to 1961-62. The quality of water from three deep test wells in Pueblo and Los Alamos Canyons and supply wells in Los Alamos and Guaje Canyons was good and had not changed significantly from 1956-57 to 1961-62. Radiochemical analyses of water from test wells and supply wells showed no contamination.

The quality of water from springs, the Rio Chama, and the Rio Grande varied because of seasonal changes and discharge. The plutonium contamination reported in the Rio Grande at Otowi may have been caused by contaminated samples bottles, contamination in the laboratory, or from fallout and is not the result of low-level radioactive waste effluents discharged into Acid and Pueblo Canyons. High gross beta-gamma activity was reported in the Rio Grande at Cochiti and may have been caused by fallout or contamination from Acid and Pueblo Canyons.

Radioactivity in the alluvium occurred in Acid and Pueblo Canyons in the highest concentrations in Acid Canyon. Working of the alluvial material by the streams tends to disperse the contaminants along the stream throughout the Acid and Pueblo. In this latter, the decrease in concentration downgradient verifies this. The radioactivity of alluvium near Ten Site has decreased in intensity.

Purtymun, W.D., 1966,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1962 through June 1963,
U.S. Geological Survey, Administrative Release.

Chemical and radiochemical analyses of water samples and of alluvium collected in the Los Alamos area downgradient from industrial from industrial waste and sewage treatment plants during July 1962 through June 1963 were made by the H-6 and H-7 Groups of the Health Division of the Los Alamos Scientific Laboratory. The analyses were made to monitor the amount and extent of contamination resulting from the operation of the Los Alamos Scientific Laboratory at Los Alamos, New Mexico.

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The chemical quality of water from shallow test wells 1A and 2A in Pueblo Canyon was good and had changed only slightly from 1961-62 to 1962-63. The quality of water from three deep test wells in Pueblo and Los Alamos Canyons and supply wells in Los Alamos and Guaje Canyons was good and had not changed significantly from 1961-62 to 1962-63. Radiochemical analyses of water from test wells and supply wells showed no contamination.

The quality of water from springs, the Rio Chama, and the Rio Grande varied because of seasonal changes and discharge. Radiochemical analyses indicated no plutonium, minor amounts of uranium and some beta-gamma activity. Concentrations of uranium were low and probably are naturally occurring constituents. Beta-gamma activity was low and may be due to fallout or background in the laboratory when the sample was analyzed.

The quality of water from the Scared, Indian, Los Alamos, Basalt, Ancho, Doe and Sandia Springs; surface water from Pajarito at the gravel pit; surface water from Frijoles Canyon showed no significant change from prior analyses. Radiochemical analyses indicated no contamination by radionuclides. The concentration of uranium detected in Los Alamos Spring is natural for the aquifer.

Purtymun, W.D., 1966,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1963 through June 1964,
U.S. Geological Survey, Administrative Release.

Chemical and radiochemical analyses of water samples and of alluvium collected in the Los Alamos area downgradient from industrial from industrial waste and sewage treatment plants during July 1963 through June 1964 were made by the H-6 and H-7 Groups of the Health Division of the Los Alamos Scientific Laboratory. The analyses were made to monitor the amount and extent of contamination resulting from the operation of the Los Alamos Scientific Laboratory at Los Alamos, New Mexico.

Radioactive contaminants were present in Acid and Pueblo Canyons below the points of radioactive-waste discharge, but the radioactivity was below the maximum permissible limits and was confined mainly to Acid Canyon, which contains the major disposal area for liquid low-level radioactive effluents. The chemical quality of the water showed no significant change from that during the previous monitoring period 1962-1963. The volume of industrial effluents discharged into the Acid did decline which resulted in a more chemically stable water in Acid Canyon (near neutral pH).

The chemical quality of water from shallow test wells 1A and 2A in Pueblo Canyon was good and had changed only slightly from 1962-63 to 1963-64. The quality of water from three deep test wells in Pueblo and Los Alamos Canyons and supply wells in Los Alamos and Guaje Canyons was good and had not changed significantly from 1962-63 to 1963-64. Radiochemical analyses of water from test wells and supply wells showed no contamination.

The quality of water from springs, the Rio Chama, and the Rio Grande varied because of seasonal changes and discharge. Radiochemical analyses indicated minor amounts of plutonium in water samples from the Rio Chama for April through June 1964 and beta- gamma emmitters, above background , in water from the Rio Grande at Cochiti in April-June 1964 samples. Minor amounts of uranium occur naturally in the water. Concentrations of radioactivity are below MPC.

The quality of water from the Scared, Indian, Los Alamos, Basalt, Ancho, Doe and Sandia Springs; surface water from Pajarito at the gravel pit; surface water from Frijoles Canyon showed no significant change from prior analyses. Radiochemical analyses indicated no contamination by radionuclides. The concentration of uranium detected in Los Alamos Spring is natural for the aquifer.

Purtymun, W.D., 1967,
Pumpage and Water Levels in Supply Wells, 1966,
U.S. Geological Survey, Water Supply Correspondence.

Pumpage increased 72 million gallons from 1,119 million gallons in 1965 to 1,191 million gallons in 1966. Distribution of pumpage from the three well fields in 1966 was 450 million gallons from the Los Alamos field, 614 million gallons from the Guaje field and 127 million gallons from the Pajarito field. The amount of water produced from the well fields since 1950 is about 15.9 billion gallons.

The combined pumping rate from the three fields with all wells operational is about 7,738 gpm, or an increase of about 1,420 gpm from the combined yearly average pumping rate of 6,318 gpm in 1965. The increase is due to the addition of well PM-2.

Declining specific capacity in well G-1 indicates well deterioration due to sanding which has covered or is covering some of the screen sections of the well. The specific capacity of well G-4 increased slightly with the removal of 46 feet of sand from the well. There were no significant trends or changes in specific capacities of the other wells.

Water level fluctuation in wells responded to the amount of pumpage in the well fields. Highest water levels occurred in January through April when pumpage was at a minimum and lowest in May through July when pumpage was at maximum. The water levels continue to decline in the Guaje well field and there are sporadic water level declines in the Los Alamos well field. These water levels are following their anticipated trends under the present amount of pumpage.

Purtymun, W.D., 1967,
Record of Water-Supply Well PM-3 Los Alamos, New Mexico,
U.S.Geological Survey, Open-file Report.

This report contains data on the geology and hydrology at the site of construction of supply well PM-3 which was drilled in 1966 to supplement the water supply at Los Alamos, New Mexico. The well is in Sandia Canyon about 7,000 ft west of the junction of the Laboratory Truck Route and State Highway 4.

The well was completed at a depth of 2,552 feet and based on interpretations of geologic and geophysical logs a high yield well (1,000 to 1,500 gpm) could be developed. The data collected during the step test indicate that the well can supply a pump capable of producing 1,400 gpm. The methods used in the construction (size of gravel, size of louver openings in casing, and development by swabbing, bailing and pumping), were satisfactory. Little or no sand was produced with the water pumped during the aquifer and step test, thus sand should cause no difficulties when water from the well is added to the supply system.

The water is of good quality for domestic and most industrial use; however, the relatively high concentrations of silica, calcium, and magnesium will contribute scale formation when water is heated and may be objectionable for some industrial use.

Purtymun, W.D., 1967,
The Disposal of Industrial Effluents in Mortandad Canyon, Los Alamos County, New Mexico,
U.S. Geological Survey, Administration Release.

The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commission and Groups H-6 and H-7 of the Los Alamos Scientific Laboratory made a study of the disposal area for low-level radioactive industrial effluents in Mortandad Canyon. The study was made to determine the movement of effluents in the disposal area and to evaluate the possibility of contamination of surface and ground water outside the disposal area.

Mortandad Canyon is cut into the Bandelier Tuff, which forms the Pajarito Plateau. The drainage area above and within the disposal area is small. The alluvium is thin in the upper canyon but thickness eastward into the middle and lower canyon.

The canyon has no natural perennial streamflow. Surface water entering the disposal area is storm runoff, waste water from cooling process at New Sigma and TA-48 and industrial effluents from the waste treatment plant at TA-50. The storm runoff, waste water and effluents infiltrate into the alluvium to recharge a body of water perched in the alluvium overlying the tuff. As the water moves through the alluvium some is lost to evapotranspiration while the remainder infiltrates into the tuff.

An inventory of surface water and water in the alluvium from July 1963 to June 1965 indicated that a greater amount of water was lost into the tuff in the upper canyon than in the middle and lower canyon of the disposal area because the alluvium overlying the tuff in the upper canyon is more permeable (silty sand) than the alluvium overlying the tuff in the middle and lower canyon (sandy silt). The movement of water in the tuff is downward beneath the disposal area into the unsaturated volcanic rocks and sediments of the Puye Conglomerate.

The upper part of the main aquifer in the Los Alamos area is in the Puye Conglomerate, about 1,000 feet beneath the canyon floor. The waterin the mian aquifer is moving at about 70 feet per year toward the Rio Grande. The Rio Grande, about 6 miles east of the disposal area, is the natural dischrage area for the main aquifer.

The chemical and radiochemical quality of the water in the alluvium improves downgradient in the disposal area due to dilution of the effuent by storm runoff and waste water, and by adsorption of certain ions and radionuclides by clay minerals. Water in the main aquifer showed no sign of contamination.

The geology and hydrology of Mortandad Canyon is ideal for the disposal of low-level radioactive effluents. The small drainage area and the volume of alluvium (to adsorb the storm runoff) reduces the chances for storms to flush contaminates to the Rio Grande. Chemical and radiochemical contamination is confined to the disposal area. The disposal area has an environment that reduces the contamination in the effluents and the slow movement of water in the main aquifer beneath the disposal area would allow ion-exchange and half-life decay of nay radionuclides that should reach the aquifer so that no contamination would remain in the water when it reached its natural discharge area.

Purtymun, W.D., 1968,
Pumpage and Water Levels in Supply Wells, 1967,
U.S. Geological Survey, Administrative Report.

Water production during 1967 was from 6 wells in the Los Alamos field, 7 wells in the Guaje field, and 2 wells in the Pajarito field. Pumpage from the three fields increased 128 million gallons from 1,191 million gallons in 1966 to 1,319 million gallons in 1967. Total amount of water produced from the three well fields since 1950 is about 17.2 billion gallons.

Water level fluctuations respond to the amount of pumpage from the well. In general, during 1967 the highest water levels occurred from January through March when pumpage was at a minimum and lowest from May through July when pumpage was at the maximum.

The total pumping rate for the three well fields was about 8,000 gpm (gallons per minute) in 1967. This will increase to 9,450 gpm in 1968 when well PM-3 is added to the Pajarito field.

Specific capacity showed no significant changes during the year. Changes in specific capacities indicate either deterioration in well construction or aquifer conditions in the vicinity of the well.

The yearly average specific capacity in the individual wells in the Los Alamos field ranged from 1.7 to 14.4 with an average of 6.4 gpm per ft of drawdown; Guaje field ranged from 2.3 to 11.9 with an average of 6.8 gpm per ft of drawdown; and the Pajarito field from 14.6 to 26.3 with an average of 20.4 gpm per ft of drawdown. The specific capacity also indicates wells or fields with the greater yield due to either greater permeability of the aquifer or better well construction or a combination of both factors.

Total pumpage for 1968 is estimated to be about 1,500 million gallons. As a matter of conservation and management of the well fields, pumpage from the Los Alamos and Guaje fields could be regulated to prolong the life of the fields by decreasing the rate of water level decline. During the coming year the pumpage should be limited, if possible, to or below 400 million gallons from the Los Alamos field and 500 million from the Guaje field. Limiting the pumpage should slow down water level declines in both fields. The remaining 600 million gallons of the 1,500 million gallons to total production can be made up from wells in the Pajarito field. Even with added pumpage from the Pajarito field the production from wells PM-1 and PM-2 will probably decline during the coming year to below that of 1967 due to the addition of high yield well PM-3 to the system.

Purtymun, W.D., 1969,
Chemical and Radiochemical Analyses of Water in Los Alamos Area, New Mexico, Made by the U.S. Geological Survey, 1960 through 1968,
U.S. Geological Survey, Administrative Realease.

The U.S. Geological Survey, in cooperation with the U.S. Atomic Energy Commission and the Los Alamos Scientific Laboratory of the University of California, began in 1949 to monitor the chemical and radiochemical quality of surface and ground water in the Los Alamos area. Chemical and radiochemical analyses of water samples collected between 1949 and 1968 were made by Group H-6 and H-7 of the Los Alamos Scientific Laboratory, except for the period July 1957 to June 1960 when the chemical analyses were made by the Geological Survey. The results of these analyses have been transmitted in various reports to the Atomic Energy Commission and the Los Alamos Scientific Laboratory.

A few chemical and radiochemical analyses of selected water samples have been made by the Geological Survey since 1960. As a number of analyses were few, they were transmitted informally. This report is a compilation of chemical and radiochemical analyses of water from the Los Alamos area that were made by the Geological Survey from 1960 through 1968.

The chemical and radiochemical analyses made by the Geological Survey were made in compliance with Contract No. AT(29-1)-1739, Title 1B (4) between the Survey and the Atomic Energy Commission.

Purtymun, W.D., 1969,
Schedule for the Collection and Analyses of Surface and Ground-water Samples in the Los Alamos Area, New Mexico,
U.S. Geological Survey, Letter Report.

The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commis-ion and Los Alamos Scientific Laboratory has operated a monitoring net of wells, springs, and surface-water stations to determine if and what extent industrial effluents have affected the hydrologic environment in the Los Alamos area. In operation of the monitoring net the Geologic Survey has assumed the role of an impartial agency in collection, synthesis, and analyses of data related to the disposal of wastes.

The purpose of this report is to update the previous sampling schedule. The schedule submitted is based on the results of previous monitoring reports and is necessary for the maintenance of an adequate monitoring net.

Purtymun, W.D., 1973,
Regional Survey of Tritium in Surface and Ground Water in the Los Alamos Area, New Mexico; August 1966 through May 1969,
LANL, LA-5234-MS.

Surface and ground water samples were analyzed for tritium from 113 sampling stations during the period August 1966 through May 1969. Tritium was detected only in surface and ground water in the stream-connected aquifers in the alluvium of DP, Los Alamos, and Mortandad Canyons which are controlled areas. These canyons receive treated low-level radioactive effluents. The tritium in DP and Los Alamos Canyon is from old seepage pits that contained tritium. The tritium concentrations decrease downgradient in the canyons due to dilution with other waste water, sewage effluent, and storm runoff. Tritium in the alluvium in Lower Mortandad Canyon is residual from a release into the canyon prior to August 1966. The concentrations decreased with time due to dilution by effluents and storm runoff. The surface and ground water in the alluvium is not a source of municipal or industrial supply.

Purtymun, W.D., 1973,
Water Supply at Los Alamos During 1972,
LANL, LA-5296-MS.

The Los Alamos water supply for 1972 consisted of production of 1510 X 10^6 gal from 16 wells in 3 fields, with an addition of 40 X 10^6 gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Los Alamos and Guaje well field pumpage was restricted to less tha 400 and 500 million gallons, respectively. These restrictions were instituted in 1967 in an effort to halt water-level declines and prolong life of the well fields. The restrictions have beeb successful, and we recommend their continuance. Previous report (LA-5039-MS) recommendations for a replacement well for well G-4 and a new well in the Pajarito field are still valid. Monthly pumping and production data are included for each of the 16 wells for 1970, 1971 and 1972. Corrected pumping and production records are also included for Wells LA-6 and G-1, and supersede those given in LA-5040-MS.

Purtymun, W.D., 1974,
Dispersion and Movement of Tritium in a Shallow Aquifer in Mortandad Canyon at the Los Alamos Scientific Laboratory,
LANL, LA-5716-MS.

Twenty [20] Ci of tritium discharged into Mortandad Canyon in November 1969 were used to determine the dispersion and movement of the tritium in a shallow aquifer in the alluvium. It took 388 days for the peak concentration to move 3027 m from the effluent outfall to the eastern end of the aquifer. The concentration decreased from 77,700 pCi/ml to 310 pCi/ml in that distance. Ground water in transit storage contained about 0.9Ci of tritium prior to the release of the 20 Ci. About 3.9 Ci of tritium remained in transit storage at the end of 1970. The remaining 17.0 Ci were lost with evapotranspiration, infiltration with ground water into the underlying tuff or suspended with soil moisture above the aquifer.

Purtymun, W.D., 1974,
Storm Runoff and Transport of Radionuclides in DP Canyon, Los Alamos County, New Mexico,
LANL, LA-5744.

Effluents from the waste treatment plant at Los Alamos Scientific Laboratory's Technical Area 21 are released into DP Canyon. The radionuclides remaining in the effluents are bound to stream-channel sediments which are later carried out of the canyon by storm runoff.

A study was made to determine the runoff volume, the suspended-sediment load, and the amount of radioactivity carried out of DP Canyon by storm runoff. During the summer of 1967, precipitation resulted in 23 runoff events that carried approximately 88,000 kg of suspended sediments out of the canyon in 36,8000 cubic meters of water. Less than 74 uCi of gross alpha emitter and 40,000 uCi of gross beta were carried out of the canyon in solution. The suspended sediments carried out 70,000 uCi of gross alpha emitters and 11,300 uCi of gross beta emitters. About 31,000 uCi of Sr-90 left the canyon in solution, as did traces of Pu-238, Pu-239 and Am-241.

Purtymun, W.D., 1974,
Water Supply at Los Alamos During 1973,
LANL, LA-5636-MS.

The Los Alamos water supply for 1973 consisted of production of 1566 million gal from 16 wells in 3 fields, with an addition of 49 million gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Recommendations previously made in Los Alamos Scientific Laboratory reports LA-5039-MS and LA-5296-MS for a new well for the Pajarito field and a replacement well in Guaje field are still valid. An exceedingly dry summer, or outage of a high yield well during a peak production period, could result in a water shortage. Monthly pumping and production data are presented for each of the 16 wells and the gallery in Water Canyons for the years 1971, 1972, and 1973.

Purtymun, W.D., 1975,
Geohydrology of the Pajarito Plateau with Reference to Quality of Water, 1949-1972,
LANL, Informal Report.

The facilities of Los Alamos Scientific Laboratory are located on the Pajarito Plateau in North-Central New Mexico. The plateau is formed by ashfall and ash-flow units of the bandelier Tuff. The tuff is underlain by volcanic debris of the Puye Formation which in places interfingers with the Basaltic Rocks of Chino Mesa. The Puye Formation is underlain by sediments of the Tesuque Formation.

Southeastward intermittent streams that drain into the Rio Grande have cut deep canyons into the Bandelier Tuff. The intermittent runoff in the canyons occur from storm runoff and the release of treated sewage or industrial effluents. The effluents do not reach the Rio Grande as surface flow.

There are two major ground water systems in thecanyons. A near surface ground water systems occur in the larger canyon in the alluvium which is underlain by the tuff. This system is recharged by the intermittent storm runoff or release of effluents. A deep ground water system, the main aquifer, occurs in the lower part of the volcanic debris and sediments of Puye and Tesuque Formation.

The movement of water from the recharge area in the Valles Caldera and canyons cut into flanks of the mountains and western part of the plateau eastward toward the Rio Grande, where a part is discharged into the river.

There are sixteen drainage areas on the plateau that emcompass the Laboratory Reservation. Hydrogeologic data have been collected in twelve of these areas. The remaining four areas are small with no well defined drainage, thus, have not warranted study.

Treated sewage effluents are released into Drainage Area 4 (Acid-Pueblo Canyon), 5 (Dp-Los Alamos Canyon), 6 (Sandia Canyon), 10 Pajarito Canyon), and 11 (Water Canyon). Pueblo Canyon receives the largest volume of effluents from the two community sewage treatment plants. The volume released into the remaining drainage areas are small. The chemical quality of the sewage effluents released into the canyons have dominated the chemical quality of the water in the stream and shallow ground water aquifer in the alluvium of the canyons.

Two drainage area, 5 (Los Alamos Canyon) and 7 (Mortandad Canyon) are currently receiving effluents from tratment plants that operate to reduce radionuclide concentrations. Drainage Area 6 (Sandia Canyon) receives some effluents as the result of blow-down from the power plant at TA-3. Drainage Area 11 (Water Canyon)receives some water from industrial process at nearby technical areas. These canyons also receive sewage effluent as previously mentioned.

The chemical quality of water in the streams or shallow aquifers in the alluvium of these canyons reflect the chemical quality of the type of effluent released, such as sewage or industrial effluents. The base flow in these canyons are from the release of effluents. In general, the chemical quality of the water improves downgradient from the effluent outfall as the chemical ions in the effluent adjust to the environment.

Drainage Area 4 (Acid-Pueblo Canyon) received industrial effluents containing radionuclides until 1964. Drainage Area 5 (DP-Los Alamos Canyon) received this type of effluents from 1952 to present, and Drainage Area7 (Mortandad Canyon) also received this type of effluents from 1963 to present.

Residual radionuclides remain in the Acid-Pueblo Canyon drainage although the release of effluents ceased in 1964. The radionuclide concentration decreased downgradient in the canyon from the old effluent outfall. The radioactive materials are attached to the alluvial materials in the stream channel. They, in part, are suspended in water in the stream.

Radionuclides in solution inthe stream and shallow aquifer in alluvium and attached alluvial material are found in DP-Los Alamos Canyon. The concentrations generally decrease down stream from the outfall in DP Canyon and below the junction of DP with Los Alamos Canyon. The radionuclides have an affinity for the alluvial material in the channels of both streams. There is no high build up of

Purtymun, W.D., 1975,
Water Supply at Los Alamos During 1974,
LANL, LA-5998-MS.

The Los Alamos water supply for 1974 consisted of 1624 million gal from 16 wells in three well fields, with an additional 35 million gal from a gallery in Water Canyon. Water-level trends are as anticipated under current pumpage practices. Recommendations for a new well in the Pajarito field and a replacement well in the Guaje field are still valid. An exceedingly dry spring and summer, or an outage of a high-yield well, could result in a shortage of supply for an indefinite period of time.

Monthly pumping and production data are presented for the years 1972, 1973, and 1974 for each of the 16 wells and the Water Canyon gallery.

Purtymun, W.D., 1976,
Water Supply at Los Alamos During 1975,
LANL, LA-6461-PR.

The Los Alamos water supply for 1975 consisted of production of 1536 million gal from 16 wells in 3 fields, with an addition of 42.5 million gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Rehabilitation of wells G-3 and G-4 has increased the production capabilities of the Guaje field. Construction of a new well will begin in 1976 and should be completed in 1977 or 1978. Until the well is operational, an exceedingly dry summer, or outage of a high yield well during a peak production period, could result in a water shortage. Rehablilitation of older wells should be continued to ensure a dependable supply and efficient use of already established booster stations and transmission lines. Annual production and water level statistics are presented on hydrographs, for the period of record, for the 16 supply wells, 1 observation well, and the gallery in Water Canyon. Monthly production and water-level statistics are also included for the years 1973, 1974 and 1975.

Purtymun, W.D., 1977,
Hydrologic Characteristics of the Los Alamos Well Field, with Reference to the Occurrence of Arsenic in Well LA-6,
LANL, LA-7012-MS.

The Los Alamos well field is composed of six wells ranging in depth from 870 to 1965 ft, that are completed in the Tesuque Formation, the main aquifer of the Los Alamos area. The water from the field is used for industrial and municipal supply to Los Alamos Scientific Laboratory and the community of Los Alamos. The quality of water from individual wells varies slightly, with only three wells of the same general type.

The occurrence and increase of arsenic in well LA-6 during the latter part of 1974 and early in 1975 now precludes use of water from this well. Studies were made using a combination of wells and restricting pumpage from well LA-6 and on dilution by other wells in the system to determine if acceptable arsenic levels could be obtained. An attempt was also made to determine which zone of the aquifer was yielding the high arsenic concentration to the well. Water samples collected at selected depths within the well were analyzed and compared to geophysical logs. These data were then applied to select zones to be blocked at below depths of 1550,1440, 1210 and 825 ft. within the well. These test failed to isolate the arsenic bearing waters.

The high concentration of arsenic occurs throughout the aquifer adjacent to the well. The average arsenic concentration at well LA-6 for nine tets ranged from 159 to 201 ug/l. Arsenic concentrations measured after blocking selected zones ranged from 141 to 203 ug/l. It was calculated that the arsenic level from the well would have to be reduced to 100 ug/l at a pumping rate of 300 gpm for dilution in the system to reach the acceptable limits of 50 ug/l for municipal use. Therefore, the well was placed on "standby" to be used only in extreme emergency.

This report summarizes the hydrologic characteristics of the wells in the Los Alamos well field for necessary background material. It also presents a summary and interpretation of data related to arsenic concentrations in wells in the field, with special reference to tests made of well LA-6 during the period August 1975- June 1976.

Purtymun, W.D., 1977,
Water Supply at Los Alamos During 1976,
LANL, LA-6814-PR.

The Los Alamos water supply for 1976 consisted of production of 1691 million gal from 15 wells in 3 fields, with an addition of 41 million gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Well LA-6 is on standby status to be used only in emergency. The loss of this well has resulted in greater production from wells LA-1B, 4 and 5 in the field. The construction of a new well in the Pajarito Field has been delayed. An exceedingly dry summer, or outage of a high yield well during a peak production period, could result in a water shortage. Rehablilitation of older wells should be continued to ensure a dependable supply and efficient use of established booster stations and transmission lines.

Purtymun, W.D., 1978,
Water Supply at Los Alamos During 1977,
LANL, LA-7436-MS.

The Los Alamos water supply for 1977 consisted of production of 1474 million gal from wells in 3 fields, with an addition of 57 million gal from the gallery in Water Canyon. The production from the well field was the lowest volume since 1970. Water level trends were as anticipated under current pumping practices. Well rehabilitation should be continued to ensure an adequate and reliable supply from wells that are 10 to 25 yr old.

Purtymun, W.D., 1979,
Water Supply at Los Alamos During 1978,
LANL, LA-8075-PR.

The Los Alamos water supply for 1978 consisted of production of 1436 million gal from wells in 3 fields, with an addition of 45 million gal from the gallery in Water Canyon. An additional 1.1 million gal of water were pumped to waste during testing of well LA-6. About 3.3 million gal of water in the Guaje Reservoir were used for irrigation, thus the total use was about 1485 million gal. Water level trends in the wells were as anticipated under current pumping practices. Projected water level declines or recoveries were made to 1983. Suggestions are presented to reduce the rate of decline in the lower part of the Los Alamos well field. Quality of water from wells, gallery, five stations on the distribution system, and Guaje Reservoir is presented. Quality of water is good and meets standards for municipal supply. Well and distribution system rehabilitation and replacements should be continued to ensure an adequate and reliable water supply from the wells and systems.

Purtymun, W.D., 1980,
Water Supply at Los Alamos During 1979,
LANL, LA-8075-PR.

The Los Alamos water supply for 1979 consisted of production of 1407 million gal from wells in 3 fields, with an addition of 44 million gal from the gallery in Water Canyon. An additional 0.2 million gal of water were pumped to waste during testing of well LA-6. About 3.7 million gal of water in the Guaje Reservoir and 1.3 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1456 million gal. Water level trends in the wells were as anticipated under current production practices. Well and distribution system rehabilitation should be continued. The rehabilitation of older wells and drilling and development of new wells are necessary to ensure an adequate and reliable water supply for municipal and industrial use at Los Alamos.

Purtymun, W.D., 1984,
Hydrologic Characteristics of the Main Aquifer in the Los Alamos Area: Development of Ground Water Supplies,
LANL, LA-9957-MS.

Deeps wells completed into the main aquifer have furnished 40.5 billion gal of water for the Los Alamos National Laboratory and for the communities of Los Alamos & White Rock from 1947 through 1982. The main aquifer is within the siltstones & sandstones of the Tesuque Formation along the Rio Grande, and rises westward into the lower part of the Puye Conglomerate beneath the central and western part of the Pajarito Plateau. The laboratory & communities of Los Alamos and White Rock are located on the Pajarito Plateau.

Supply, test and stock wells have been used to collect hydrologic data from the aquifer beneath the Pajarito Plateau and to the east along the Rio Grande. Hydrologic characteristics of springs along the Rio Grande, which are in discharge area from the main aquifer, are included to supplement the data from the wells. Hydrologic characteristics of the aquifer determined from tests and observations are the saturated thickness, pumping or production rates of the wells, drawdown, specific capacity, field coefficient of permeability, transmissivity, rate of water movement in the aquifer, production from wells and fields, water-level trends of the aquifer, rates of water-level decline, and production per foot of water-level decline.

Chemical quality of water in the aquifer varies according to the formations yielding water to the wells. Based on hydrologic characteristics of existing wells, suggested locations for four additional wells were made in areas to develop high-yield low-drawdown (1000-gpm/100ft) supply wells. These locations are recommended in long-range planning for future water supply as the demand for water increases at the Laboratory and in the communities. A well to replace well G-4 in the Guaje Field is recommended to offset declining production in the field.

Purtymun, W.D., Adams, W.H., and Owens, J.W., 1975,
Water Quality in the Vicinity of Fenton Hill Site, 1974,
LANL, LA-6093.

The water quality at nine surface stations, eight ground water stations, and drilling operations at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal experimental studies in the Jemez Mountains. Surface water quality in the Jemez River drainage area is affected by the quality of the inflow from thermal and mineral springs. Ground water discharges from the Cenozoic Volcanics are similar in chemical quality. Water in the main zone of saturation penetrated by test hole GT-2 is highly mineralized, whereas water in the lower section of the hole, which is granite, contains a higher concentration of uranium.

Purtymun, W.D., Adams, W.H., and Stoker, A.K., 1978,
Water Quality in the Vicinity of Fenton Hill Site, 1976,
LANL, LA-7307-MS.

The water quality at nine surface stations, 11 ground water stations, and 3 ponds at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal site experimental studies in the Jemez Mountains. Insignificant changes (within expected normal seasonal flucuations) in the chemical quality of water at individual stations were observed during the year. Predominant ions and total dissolved solids remained essentially stable.

Purtymun, W.D., and Abrahams, J.H., Jr., 1963,
Hydrologic Characteristics of an Ash Flow Tuff at Frijoles Mesa, Los Alamos County, New Mexico,
U.S. Geological Survey, Open-File Report.

The specific yield of ash flow tuff under study is related to porosity while the coefficient of permeability is independent of the porosity and is related to the pore size distribution. Fluid movement in the lower third of the flow as it cools could result in larger horizontal permeability in direction of movement than vertical permeabilities.

Purtymun, W.D., and Adams, H., 1980,
Geohydrology of Bandelier National Monument, New Mexico,
LANL, LA-8461-MS.

Bandelier National Monument is located on the eastern slopes of the Sierra de los Valles and the Pajarito Plateau. The Pajarito Plateau was formed by a series of ashflow and ashfall of rhyolite tuff. Perennial and intermittent streams have cut the surface of the plateau into a number of narrow southeast-trending mesas separated by deep canyons. Perennial surface flow occurs in Canon de los Frijoles and in the upper and middle reaches of Alamo, Capulin, Medio, and Sanchez Canyons. Of the five springs in and adjacent to the Monument, three discharge from perched aquifers and two from the main aquifer. Water in the deep main aquifer moves south to southeast in the Monument. Along the western edge of the Monument, the intrusion of volcanic rock of the San Miguel Mountains forms a barrier to the movement of water from the recharge area in the Valles Caldera. About 46.4 square km of drainage area in the upper and middle reaches of Canon de los Frijoles, Alamo, Lummis and Capulin Canyons were burned over by a wildfire (La Mesa Fire) in June 1977. The geohydrology of the area was determined to assess the availability of surface and ground water in the Monument and to determine the impact of the wildfire on these water resources.

Purtymun, W.D., and Cooper, J.B., 1965,
Locations for Five Water-Spply Wells at Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

Locations for five water-supply wells at Los Alamos, New Mexico are suggested with consideration given to geologic and hydrologic conditions and to the existing water-utility system amd proposed expansion of the system. Two of the locations are in the the Pajarito Canyon area where wells are expected to yield 1,000 gpm (gallons per minute) with less than 100 ft drawdown. A third location is in the Sandia Canyon area where a well is anticipated to yield about 700 gpm with less than 100 feet of drawdown. Depth of the pilot holes of these wells will be about 2,5000 feet. A fourth location is for a well to replace water-supply well G-4 in the Guaje Canyon well field. A well at this location should yield 500 gpm with less than 100 feet drawdown. The depth of the pilot hole will be 2,000 feet.

Four alternative locations are presented for a fifth well. A well at location "A" would replace wells at LA-2 and LA-3 in the Los Alamos Canyon well field and would yield 500 gpm with less than 100 feet drawdown; the pilot hole would be 2,000 feet deep. A well at location "B", in Pueblo Canyon, would yield 700 to 1,000 gpm with less than 100 feet of drawdown; the pilot hole would be 2,500 feet deep. A well at either location "C" or "D", in the Pajarito Canyon area, would yield 1,000 gpm with less than 100 feet of drawdown; the pilot hole would be 2,500 feet deep. Final selection of the location for this fifth well would be based on future production demand.

The main aquifer is within the Puye Conglomerate and the Tesuque Formation in the Pajarito Plateau (Pajarito and Sandia Canyon areas and at locations "B", "C", or "D"). The physical characteristics of the sediments of the Tesuque Formation and the Puye Conglomerate will allow moderate-to-high-yield (700 to 1,000 gpm) wells to be developed on the Pajarito Plateau. In the Guaje Canyon well field and at location "A" in the Los Alamos Canyon well field the main aquifer is in the Tesuque Formation. Because sediments of the Tesuque Formation in Guaje Canyon and Los Alamos Canyon well field are fined-grained, transmissibility is reduced and the maximum yield to be expected of wells in these areas is 500 gpm. The depth to the main aquifer varies from about 1,200 feet along the western margin of the Pajarito Plateau to about 600 feet near the Rio Grande. Water in the aquifer is under artesian pressure in some areas. Ground water at the suggested well locations is low in dissolved solids and is of good chemical quality

Depth at which to complete the water-supply wells will be determined by examination of lithologic and geophysical logs outlined from the pilot holes.

Gravel-pack well construction is necessary to minimize the entry of fine material into the well. Perforated pipe or screen should be placed through the entire saturated section penetrated by the wells. Rotary-drilling methods are commonly used to construct wells in the Los Alamos area; however, circulation often is lost in the unsaturated section of rocks above the main aquifer and basalt flows tend to cause crooked holes. Cable-tool methods of drilling have been used successfully to drill the upper section of unsaturated material.

Purtymun, W.D., and Cooper, J.B., 1969,
Development of Ground-Water Supplies on the Pajarito Plateau, Los Alamos County, New Mexico,
U.S. Geological Survey, Prof. Paper, 650B, pp. B149-B153.

The Pajarito Mesa well field, completed in 1966 on the Pajarito Plateau, contributed 37 percent of the total water supply to Los Alamos in 1967. Two wells in the field are capable of yeilds of 1,400 gallons per minute each. This yield is about three times that of any of the other 13 supply wells in the water supply system. The high yield of the two wells is attributed to the occurrence of coarse volcanic debris and arkosic sediment in the Puye and Tesuque Formations of the Santa Fe Group that make up the Main aquifer beneath the Pajarito Plateau.

Purtymun, W.D., and Cushman, R.L., 1961,
Site Location for a Los Alamos Supply Well Near the 10-inch Water Main that Parallels State Highway 4 Between Pueblo Canyon and White Rock,
U.S. Geological Survey, Administrative Release.

A study was made to select a site for a water-supply well for the town of Los Alamos, New Mexico along a 10-inch water main between the Pueblo-Los Alamos Canyon junction and White Rock. The well must be capable of yielding about 500 gallons per minute and have a specific capacity of at least 5 gallons per minute per foot of drawdown.

The most favorable site for the supply well is in the Sandia Canyon, because waste products are not being discharged into that canyon. The depth of a supply well in this canyon should be about 2,600 to 2,700 feet.

Purtymun, W.D., and Cushman, R.L., 1963,
Site Location for a Municipal Supply Well in Guaje Canyon or Rendija Canyon near Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

The site of a new municipal well for Los Alamos, New Mexico could be either in Guaje Canyon about 2,500 to 3,500 feet northwest of well G-5 or in Rendija Canyon about 2,600 to 3,600 feet west of booster pump station No.1. The Rendija Canyon site might be preferred because of power and water transmission lines in that canyon near the site.

A well that could be pumped at a rate of at least 500 gallons per minute with a drawdown less than 100 feet (at time of completion) would be between 1,500 and 2,000 feet deep provided that massive latite flows are not encountered before reaching those depths. Latite flows present at depths appreciably less than 1,500 ft probably would make it impossible to construct a well that would have the required discharge-drawdown relationship. Ground water will be encountered in the main zone of saturation probably under water-table conditions at a depth 50 feet below land surface.

Drilling will be predominantly in conglomerate, siltstone, silty sandstone, and basaltic rocks (flows and breccias). The combined thickness of the basaltic rocks may comprise as much as 400 feet of the section drilled.

Purtymun, W.D., and Enyart, E.A., 1966,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1964 through June 1965,
U.S. Geological Survey, Administrative Release.

Chemical and radiochemical analyses of water samples and of alluvium collected in the Los Alamos area downgradient from industrial waste and sewage treatment plants during July 1964 through June 1965 were made by the H-6 and H-7 Groups of the Health Division of the Los Alamos Scientific Laboratory. The analyses were made to monitor the amount and extent of contamination resulting from the operation of the Los Alamos Scientific Laboratory at Los Alamos, New Mexico.

Analyses of water samples collected at Los Alamos, New Mexico, during 1964-65, show that contamination (chemical and radiochemical) was confined to surface water and to the water in the alluvium of canyons receiving low-level radioactive effluent (DP-Canyon and Mortandad Canyon) or canyons which have received low-level radioactive effluent in the past (Acid and Pueblo Canyons). The chemical concentration was generally low, with most analyses indicating that water is acceptable for domestic use, according to the limits recommended by the U.S. Public Health Service. Radiochemical quality was generally below the MPC. The degree of contamination decreases downgradient in the canyons.

Analyses of water samples collected from surface flow, springs, supply wells and test wells show no indication of chemical or radiochemical contamination.

Purtymun, W.D., and Herceg, J.E., 1972,
Summary of Los Alamos Municipal Well-Field Characteristics, 1947-1971,
LANL, LA-5040-MS.

Basic data concerning monthly pumpage, aquifer condition and well characteristics for wells of the Los Alamos water supply system from 1947 through 1971 have been prepared to interpret data for an annual report and determine future aquifer conditions. This report presents a historical record of this data. Annual summaries of pumpage statistics are also included.

Purtymun, W.D., and Herceg, J.E., 1972,
Water Supply at Los Alamos During 1971,
LANL, LA-5039-MS.

The Los Alamos water supply for 1972 consisted of production of 1553 million gal from 16 wells in 3 fields, with an addition of 37 million gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Limiting pumpage in the Los Alamos and Guaje well fields has slowed or reversed water-level decline in most wells and will thus prolong their lives.

The pumping rate at well LA-2 declined owning to increased production. The pumping at well G-6 declined owning to pump wear and subsequent failure. The pump at well G-6 was replaced in March. The pumping rate at well G-4 is held to about 200 gpm because of casing deterioration and entry into well of part of the gravel pack. The well cannot be repaired but must be replaced. An additional well in Pajarito well field is necessary to provide adequate supply during periods of peak demand and to meet increasing water needs.

Monthly pumping and production data for each of the 16 wells for 1969, 1970, and 1971 are included in this report

Purtymun, W.D., and John, E., 1964,
Site for a Municipal Supply Well in Pajarito Canyon near Los Alamos, New Mexico, U.S. Geological Survey, Administrative Release.

A site for the first of four new municipal supply wells for Los Alamos was selected in the NE1/4SW1/4NW1/4 sec. 36, T. 19 N., R. 6 E. The well site is Pajarito Canyon at an altitude of 6,720 feet above mean sea level and only a few hundred feet east of a technical area known as Pajarito Site.

The well depth might have to be as much as 2,600 feet to obtain the required 500 gallons per minute with a drawdown less than 100 feet; however, the well could be finished at a shallow depth if the lower 160 feet of the conglomerate and basalt is a part of the main aquifer at the site. The conglomerate and basalt sequence generally is highly permeable, and would yield more water to the well per foot of aquifer thickness than any other section of aquifer beneath the site. If the conglomerate and basalt sequence is a part of the aquifer, the well should be screened throughout that part of the aquifer to obtain the most favorable specific capacity to well depth ratio. If this section is not screened, the depth of the finished well must be increased to compensate for lower average permeability. The section of screen settings in the siltstone and silty sandstone can be made on the basis of lithologic and geophysical logs of the pilot hole. The top of the main aquifer probably will be at a depth about 870 feet at the site. The aquifer may be artesian and the water might rise in the well to a level about 5 feet above the top of the aquifer.

Purtymun, W.D., and Kunkler, J.L., 1967,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1965 through June 1966,
U.S. Geological Survey, Administrative Release.

This report discusses the water quality results of surface and ground water samples taken at Los Alamos during 1965-1966. As in previous reports, analyses of water samples collected at Los Alamos during 1965-66 show that chemical and radiochemical contamination is confined to surface and ground water in the alluvium of canyons receiving loe-level radioactive effluents (DP, Los Alamos, and Mortandad Canyons) or canyons that received low-level radioactive effluents in the past (Acid Canyon). The chemical contamination was generally low, with most analyses indicating that water is acceptable for domestic use according to the limits recommended by the U.S. Public Health Service. Radiochemical analyses show that plutonium, and uranium were below MPC. Beta-gamma emitters were also below MPC except in surface water in Mortandad Canyon. The degree of contamination decreases downgradient in the canyon. The results of tritium analyses indicate that the tritium content of water in the alluvium of Los Alamos and Mortandad Canyons is near the maximum permissible concentrations. Further investigations are being made to determine the extent and amounts of tritium cntamination.

Purtymun, W.D., and Kunkler, J.L., 1969,
The Chemical and radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1966 through June 1967,
U.S. Geological Survey, Administrative Release.

This report discusses the chemical and radiochemical quality of surface and ground water at Los Alamos during July 1966 through June 1967. Analyses of water samples collected at Los Alamos during 1966-1967 indicate that radiochemical contamination of surface and ground water is confined to water in the alluvium of canyons (DP, Los Alamos, Mortandad) which receive low-level radioactive effluents from waste disposal plants. Concentrations of plutonium and uranium in the water are below MPC. Beta-gamma emitters are also below MPC except for samples of surface water collected from Mortandad Canyon in November of 1966. Chemical contamination is also indicated in water samples from surface and ground water sources in DP, Los Alamos, and Mortandad Canyons, as well as from Mortandad Canyon to the Rio Grande (treated-sewage effluent) and perhaps Canada del Buey below TA-46. The chemical contamination is minor; most analyses indicate the water is acceptable for domestic use.

Surface water entering Mortandad Canyon during 1966-67 infiltrated into alluvium within the disposal area. A decrease in the amount of surface flow (coolant and storm runoff) from March 1966 to February 1967 caused a general decline in the volume of ground water in storage in the alluvium. Loss of surface and ground water in the alluvium by evapotranspiration and infiltration into the underlying tuff average about 2 million gallons per month.

Ground water in the alluvium in Los Alamos Canyon is recharged by coolant water, sewage effluent, low-level radiochemical effluents and seasonal runoff. Chemical and radiochemical analyses of water samples from wells penetrating the alluvium indicate the movement of low-level radioactive effluents through the alluvium from DP Canyon into Los Alamos Canyon.

Purtymun, W.D., and Stoker, A.K., 1988,
Water Supply at Los Alamos: Current Status of Wells and Future Water Supply, LANL, LA-11332-MS.

The municipal and industrial use of groundwater at the Los Alamos National Laboratory and Los Alamos County was about 1.5 billion gallons during 1986. From a total of 19 wells that range in age from 5 to 41 years, the water was pumped from 3 well fields. The life expectancy of a well in the area ranges from 30 to 50 years, dependent on the well construction and the rate of corrosion of the casing and screen. Twelve of the wells are more than 30 years old and, of these four cannot be used for production, three because of well damage (LA-1, LA-4, and G-3) and one (LA-6) because quality of water is not suitable for use. Eight (LA-2, LA-3, LA-5, G-1, G-2, G-4, G-5, and G-6) of the twelve oldest wells are likely to be unsuitable for use in the next 10 years because of well deterioration and failure. The remaining 7 wells include 2 (LA-1B, G-1A) that are likely to fail in the next 20 years. Five younger wells in the Pajarito well field are in good condition and could serve for another two or three decades.

The program of maintenance and rehabilitation of pumps and wells has extended production capabilities for short periods of time. Pumps may be effectively repaired or replaced; however, rehabilitation of the well is only short-term correction to increase the yeild before it starts to decline again. The two main factors that prevent successful well rehabilitation are: (1) chemicals precipitated in the gravel pack and screen restrict or reduce the entrance of water to the well, which reduces yeild of the well, and (2) the screen and casing become corroded to a point of losing structural strength and subsequent failure allows the gravel pack and formation sand to enter the well. Both factors are due to long-term use and result in extensive damage to the pump and reduce the depth of the well, which in turn causes the yield to decline. Once such well damage occurs, rehabilitation is unlikely top be successful and the ultimate result is loss of the well. Two wells (LA-4 and G-3) were lost in 1987 because of such damage.

It is essential to implement a program to replace wells that have failed or will fail in the next 10 years to ensure a continued and reliable water supply. Any change in operation of the Laboratory or county that will require additional water adds to the urgency to develop a system of new wells. Rehabilitation of the older wells will not ensure a continued or reliable supply, or meet additional demands for water. This report presents the history of the wells and well fields, briefly describes the geology and hydrology of the area, includes a section on production and production capacity, and outlines development of additional water supply.

Purtymun, W.D., Becker, N.M., and Maes, M., 1983,
Water Supply at Los Alamos During 1981,
LANL, LA-9734-PR.

The municipal and industrial water supply for Los Alamos during 1981 consisted of 1506 X 10^6 gal from wells in three well fields and 45 X 10^6 gal from the gallery in Water Canyon. Another 0.08 X 10^6 gal of water were pumped to waste during testing of Well LA-6. About 2.6 X 10^6 gal of water from Guaje Reservoir and 2.1 X 10^6 gal of water from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1556 X 10^6 gal. Water level trends in the wells were as anticipated under current production practices. Pumps in several wells that failed in 1981 are now being repaired or have been repaired. The new well, PM-4, was placed in service in the early summer of 1982. Chemical qulaity of water from wells and distribution system is in compliance with state and federal regulations related to municipal use.

Purtymun, W.D., Becker, N.M., and Maes, M., 1984,
Water Supply at Los Alamos During 1982,
LANL, LA-9896-PR.

Municipal and industrial water supply for Los Alamos during 1982 consisted of 1512 million gal from wells in three well fields and 46 million gal from the gallery in Water Canyon. Less than 30,000 gal of water were pumped to waste during testing of well LA-6. About 3.4 million gal of water from Guaje Reservior and 2.8 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1564 million gal. The failure of pumps in several of the wells in 1982 did not result in water shortage because of a low peak demand period in the summer, and some of the lost production was offset as supply well PM-4 began production in July 1982. Well PM-5 was completed in 1982; however, equipping the well and construction of the pump station & transmission line will probably not be completed until early 1984. The primary and secondary chemical quality of water from wells and distribution systemis in compliance with federal regulations. Radioactivity in the water is low and naturally occurring.

Purtymun, W.D., Becker, N.M., and Maes, M., 1985,
Water Supply at Los Alamos During 1983,
LANL, LA-10327-PR.

The Los Alamos water supply for 1983 consisted of production of 1463 million gal from wells in 3 fields, with an addition of 38.3 million gal from the gallery in Water Canyon. About 3.4 million gal of water from Guaje Reservoir and 1.4 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1506 million gal. High-yield Well PM-4 produced 452 million gal or about 30% of the total production at Los Alamos during 1983. The primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations.

Purtymun, W.D., Becker, N.M., and Maes, M., 1986,
Water Supply at Los Alamos During 1984,
LANL, LA-10584-PR.

The Los Alamos water supply for 1984 consisted of production of 1566 million gal from wells in 3 fields, with an addition of 34 million gal from the gallery in Water Canyon. About 3 million gal of water from Guaje Reservoir and 1.3 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1604 million gal. Well field operations were satisfactory with pumping schedules resulting in a uniform decline of water level in the fields. Primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations. Fluoride in water from Well LA-1B and arsenic in water from well G-2 exceeded the standards; however, mixing of water from these wells with water pumped from other wells in the field reduced the concentration to below the acceptable level in the distribution system.

Purtymun, W.D., Becker, N.M., and Maes, M., 1986,
Water Supply at Los Alamos During 1985,
LANL, LA-10835-PR.

The Los Alamos water supply for 1985 consisted of production of 1587 million gal from wells in 3 fields, with an addition of 37 million gal from the gallery in Water Canyon. About 2.8 million gal of water from Guaje Reservoir and 0.9 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1628 million gal. Well field operations were satisfactory with pumping schedules resulting in a uniform decline of water level in the fields. Primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations.

Purtymun, W.D., Buchholz, J.R., and Hakonson, T.E., 1977,
Chemical Quality of Effluents and Their Influence on Water Quality in a Shallow Aquifer,
J. Environ. Qual., Vol. 6, No. 1, pp. 29-32.

The chemical quality of liquid effluent released from an industrial waste treatment plant at the Los Alamos Scientific Laboratory controls the quality of water in a shallow aquifer in the alluvium of Mortandad Canyon. The dilution the effluent with surface flow in the canyon reduces the concentrations of the chemicals as they move down gradient into the aquifer. Mass estimates of residual chemicals in solution in the aquifer average 1-6% of the total chemicals released to the canyon from 1963-1974. The average annual concentration of sodium nitrate, chloride, and total dissolved solids in the aquifer through a 12 year period was directly correlated with annual average concentrations in the effluent. This relationship provides a means of predicting the impact of the chemical effluents on the quality of water in the aquifer.

Purtymun, W.D., Buchholz, J.R., Hakonson, T.E., 1975,
Chemical Quality of Effluents and Their Influence on Water Quality in Mortandad Canyon,
LANL, LA-UR-75-2076.

The chemical quality of liquid effluents released from an industrial waste treatment plant at the Los Alamos Scientific Laboratory controls the quality of water in a shallow aquifer in the alluvium of Mortandad Canyon. The dilution of the effluent with the waste water and storm runoff, uptake of ions by plants, base exchange with alluvium and losses from the aquifer into the underlying strata reduce the concentrations of chemicals as they move downgradient in the canyon into the aquifer. Mass estimates of residual chemicals in the solution in the aquifer were about 1% of the total released to the canyon from 1963-1974. The average annual concentration of sodium, nitrate, chloride, and total dissolved solids in the aquifer through a 12 year period was directly correlated with the average annual concentration in the effluent. This relationship provides a means of predicting the impact of the chemical effluents on the quality of water in the aquifer.

Purtymun, W.D., Enyart, E.A., and McLin, S.G., 1989,
Hydrologic Characteristics of the Bandelier Tuff as Determined Through an Injection Well System,
LANL, LA-11511-MS.

Injection wells were used to determine some of the hydrologic transmitting characteristics of the unsaturated Bandelier Tuff. At site 1, a 60-ft injection well with a 5-ft injection zone was used to conduct four tests. These preliminary tests were made in order to design an injection well monitoring system that could track the movements of fluids in the tuff.

At site 2, a second injection well with a 10-ft injection zone and seven observation holes was used to monitor the movement of 335,000 gallons of water injected into the tuff. The initial injection rate at site 2 was 5.8 gallons per minute (gpm), but that rate gradually declined to 0.4 gpm after 89 days of the test; 289 days after the test ended, the pear-shaped nephol (the shape of moisture injected into the tuff) reached a maximum depth of 210 ft and had a diameter of about 120 ft.

A second test at site 2 indicated that intermittent use of an injection system would allow for short periods of higher injection rates, thereby extending the life of the system. Finally, a third test at site 2 was made using a 50 ft injection zone, which resulted in an injection rate of 15.8 gpm, or about 3 times the initial rate achieved when a 10 ft injection zone was used.

Purtymun, W.D., et al., 1974,
Air Volume and Energy Transfer Through Test Holes and Atmospheric Pressure Effects on the Main Aquifer,
LANL, LA-5725-MS.

Air volumes and energy transfer through test holes completed in the Bandelier Tuff and/or Puye Formation were monitored for 95 h at test hole DT-10 and for 34 h at test hole DT-10 and Alpha. Air transfer caused by atmospheric pressure changes at DT-10 during the 95-h study consisted of four cycles of four intake periods and four exhaust periods. The total volume of air taken into the reservoir was 2910 cubic meters while 1425 cubic meters of air were released from the reservoir. The largest volume of air transferred was 2400 cubic meters during intake period of 40 h with an atmospheric pressure change of 0.46 cm Hg. The average energy in the air transferred during the intake period was 14400 g-cal/cubic meter while the average energy in the air exhaust period was 19300 g-cal/cubic meter.

The 24-h study test holes DT-10 and Alpha was made near the end of an exhaust period. About 1160 cubic meters of air were released from the reservoir rocks at DT-10 with about 10,500 cubic meters of air released from Alpha. A construction in the casing to accommodate instrumentation reduced the volume of air transferred from DT-10. Energy in air transferred from DT-10 was 19300 g-cal/cubic meter and 12300 g-cal/cubic meter from Alpha.

Atmospheric pressure changes cause water-level fluctuations in test holes penetrating the main aquifer. The changes in water-levels, atmospheric pressure and rates of air transferred during the 95-h study were correlatable. The barometric efficiency of the aquifer during the four cycles ranged from 51 to 88 percent. Large barometric efficiencies resulted with smaller volumes of air transferred and smaller pressure changes.

Purtymun, W.D., et al., 1976,
Water Quality in the Vicinity of Fenton Hill Site, 1975,
LANL, LA-6511-MS.

The water quality at nine surface stations, 14 ground water stations, and drilling operations at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal experimental studies in the Jemez Mountains. Slight variations in the chemical quality of the water at individual stations were observed during the year. Predominant ions and total dissolved solids in the surface and ground water declined slightly in comparison to previous data. These variations in quality are not considered significant considering seasonal and annual stream flow variations. Surface water discharge records from three U.S. Geological Survey gaging station on the Rio Guadalupe and Jemez River were analyzed to provide background data for the impact study. Direct correlations were determined between mean annual discharge at each of two stations in the upper reach of the drainage and at the station in the lower reach.

Purtymun, W.D., et al., 1978,
Water Quality in the Vicinity of Fenton Hill Site, 1977,
LANL, LA-7468-PR.

The water quality at nine surface stations, 11 ground water stations, and 3 ponds at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal site experimental studies in the Jemez Mountains. There have been slight variations in chemical quality at individual stations during the year however, these variations in water quality are within expected normal seasonal fluctuation and are not considered significant. In addition to the 14 routine chemical analyses performed twice annually, 17 trace metal analyses were run on one set of samples collected during the year.

Purtymun, W.D., et al., 1980,
Water Quality in the Vicinity of Fenton Hill Site, 1978,
LANL, LA-8217-PR.

Water quality data have been collected from surface and ground water stations and from ponds at the Fenton Hill Site located in the Jemez Mountains, as part of a continuing program of environmental studies. There have been slight variations in the chemical quality at individual stations; however, these variations in water quality are within normal seasonal fluctuations. Evaluation of the aquifer furnishing water to the Fenton Hill Site indicates a transmissivity of about 1200 squared meters/day. The specific capacity over a five day test was 28 l/s/m of drawdown. There was a slight increase in total dissolved solids in the well between 1977 to 1978. Water quality and soluble fluoride and chloride in sediments in the canyon that receives excess water from the ponds indicate that these constituents decrease to background within 300 m of the ponds. A water balance of amount produced at the sites indicate 7% of the water lost to evaporation from the ponds, 31% lost by infiltration into tuff beneath the ponds 21% of the water discharged from the ponds, and 41% used for downhole experiments, drilling operations, and general site use.

Purtymun, W.D., et al., 1980,
Water Quality in the Vicinity of Fenton Hill Site, 1979,
LANL, LA-8424-PR.

Water quality data have been collected from surface and ground water stations and from ponds and pond discharges at the Fenton Hill Site located in the Jemez Mountains, as part of a continuing program of environmental studies. There have been slight variations in the chemical quality at individual stations; however, these variations in water quality are within normal seasonal fluctuations. Water in the ponds is highly mineralized because drilling operations and circulation tests at the site. Water quality in the ponds deteriorates further as it is re-used. Most notable increases were in sulfates and total dissolved solids (TDS) in 1979. Discharge and overflow from the ponds infiltrates into alluvium of the dry canyon within 300 m below the ponds. Monitoring of surface water and spring discharge downgradient from the ponds in the release area failed to detect any effects from release of water from the ponds. Analyses of water from the supply well at the site indicated metallic and nonmetallic ions were below the U.S. Environmentao Protection Agency (USEPA) and State of New Mexico standards of criteria for domestic or municipal uses.

Purtymun, W.D., et al., 1983,
Water Quality in the Vicinity of Fenton Hill Site, 1981 and 1982,
LANL, LA-9854-PR.

Water quality data have been collected from surface and ground water stations and from ponds and pond discharges at the Fenton Hill Site located in the Jemez Mountains, as part of a continuing program of environmental studies. There have been slight variations in the chemical quality at individual stations; however, these variations in water quality are within normal seasonal fluctuations. Water in the ponds is highly mineralized because drilling operations and circulation tests in the fractured reservoir of the deep geothermal holes. Water from the ponds or direct discharges from the circulation tests are discharged into an adjacent dry canyon. The discharges infiltrate into alluvium of the canyon within 400 m of the ponds. Monitoring surface water and spring discharge down-gradient from the ponds failed to detect any effects resulting from the release of water from the ponds. Total dissolved solids and calcium have increased in water from well FH-1, which furnishes the water supply for the site. This increase is caused by the decreasing water level in the well resulting in yield from beds with a slightly different quality than has been found in previous years.

Purtymun, W.D., et al., 1988,
Water Quality in the Vicinity of Fenton Hill, 1985 and 1986,
LANL, LA-11210-PR.

Water quality data have been collected since 1974 from established surface and groundwater stations at and in the vicinity of Fenton Hill (Hot Dry Rock Geothermal Demonstration Site) located in the Jemez Mountains. This is part of a continuing program of environmetal studies. Data on chemical quality of water were determined for samples collected from 13 surface water and 19 groundwater stations in 1985 and 1986. There were slight variations in the chemical quality of the ground and surface water in 1985 and 1986 as compared with previous analyses; however, these variations are within normal seasonal fluctuations. Chemical uptake in soil, roots and foilage is monitored in the canyon, which receives intermittent effluent release of water from tests in the geothermal circulation loop and occasional fluids from drilling operations. The chemical concentrations found in soils, roots, and vegetation as the results of effluent release have shown a decrease in concentration down-canyon and also have decreased in concentration with time since the larger releases that took place in the late 1970s and early 1980s.

Purtymun, W.D., Ferenbaugh, R.W., and Maes, M., 1988,
Quality of Surface and Ground Water at and Adjacent to the Los Alamos National Laboratory: Reference Organic Compounds,
LANL, LA-11333-MS.

Surface and ground water supplies were collected from 43 stations representing the major occurrences of natural and municipal water and industrial and sanitary effluents in the Los Alamos area. The samples were analyzed for volatile organics (35 compounds), semivolatile organics (65 compounds), base neutral acid fraction, pesticides (20 compounds), herbicides (3 compounds), polychlorinated biphenyls (7 compounds), and cyanides. The investigation was performed to find possible areas of organic contamination for further study; however, the impact of organic contamination in surface and ground water is minimal. A limited program of organic monitoring maybe incorporated into the annual surveillance program for monitoring the quality of surface and ground water at and adjacent to the Los Alamos National Laboratory.

Purtymun, W.D., Hansen, W.R., and Peters, R.J., 1983,
Radiochemical Quality of Water in the Shallow Aquifer in Mortandad Canyon 1967-1978,
LANL, LA-9675-MS.

Mortandad Canyon receives treated industrial liquid effluents that contain trace amounts of radionuclides. The effluents, other waste water, and storm run-off recharge of a shallow aquifer in the alluvium of the canyon. The aquifer lies within the Los Alamos National Laboratory boundaries. Analyses for gross alpha, gross beta, Cs-137, Pu-238, Pu-239, Am-241, Sr-90, H-3 and total U have been made of water in the aquifer from 1967 through 1978. Average concentrations the radionuclides in solution decrease downgradient in the canyon with the exception of H-3. Average H-3 concentrations were the highest in the Middle Canyon. Inventories of most radionuclides in the water indicate that in 1978 less than 1% of the total amount released with the effluents in the canyon from 1963 through 1978 remained in solution. The amount of total U in solution in 1978 was about 16 % of the total amount released. If there is no significant change in the amounts received at the treatment plant and methods of treatment remain the same, the projected estimates of radionuclide concentrations in the aquifer will increase about 80% from 1978 to 1990. The average concentrations in 1978 and projected concentrations in 1990 of gross alpha, Cs-137, Pu-238, Pu-239, Am-241, Sr-90, H-3 and total U are less than 1% of the Department of Energy's concentration guides (CG) for areas with controlled public access. Gross beta radioactivity in 1978 was 2% of the CG and is projected to increase to 3% of the CG by 1990.

Purtymun, W.D., Maes, M.N., and Peters, R., 1984,
"Distribution of Moisture, Tritium and Plutonium in the Alluvium, Aquifer and Underlying Tuff in Mortandad Canyon", Environmental Surveillance at Los Alamos During 1984,
LANL, LA-10100-ENV, pp. 69-71.

Mortandad Canyon received industrial effluents containing trace amounts of radionuclides from the treatment plant at TA-50. An experiment was designed to determine the distribution of moisture content and concentrations of tritum and plutonium in the Mortandad Canyon aquifer.

At observation well MC-6, three core holes were drilled at right angles to the stream channel. Two other holes were cored to obtain background information. Cores taken from five holes were analyzed to determine moisture content and concentrations of tritium and plutonium.

Results of the study indicate some infiltration of water into the underlying tuff. This infiltration was accompanied by similar movement of tritium. The concentrations of plutonium on the sediments in the aquifer were low when compared to the high concentrations in solution in the aquifer or on sediments in the stream channel. It appears that most of the plutonium in the aquifer is in solution in an ionic complex that does not readily exchange or is adsorbed by clay minerals in the alluvium.

Purtymun, W.D., Peters, R.J., and Owens, J.W., 1980,
Geohydrology of White Rock Canyon of the Rio Grande from Otowi to Frijoles Canyon,
LANL, LA-8635-MS.

Twenty-seven springs discharge from the Totavi Lentil and Tesuque Formation in White Rock Canyon. Water generally acquires its chemical characteristics from rock units that comprise the spring aquifer. Twenty-two springs are separated into three groups of similar aquifer-related chemical quality. The five remaining springs make up a forth group with a chemical quality that differs due to localized conditions in the aquifer. Localized conditions may be related to recharge or discharge in or near basalt intrusion or through faults. Streams from Pajarito, Ancho and Frijoles Canyons discharge into the Rio Grande in White Rock Canyon. The base flow in the stream is from springs. Sanitary effluent in Mortandad Canyon from the treatment plant at White Rock also reaches the Rio Grande.

Purtymun, W.D., Stoker, A.K., and Maes, M.N., 1987,
Water Supply at Los Alamos During 1986,
LANL, LA-11046-PR.

Water supply during 1986 were satisfactory with muncipal and industrial usage supplied by 1497 million gal from wells in three well fields and 28 million gal from the spring gallery in Water Canyon. About 2.4 million gal of water from Guaje Reservoir and 1.5 million gal from Los Alamos Reservoir were used for irrigation; thus the total usage in 1986 was about 1529 million gal. The total water usage was down in 1986 about 99 million gal from the total usag of 1628 million gal in 1985. Primary and secondary chemical quality of water in the distribution system was in compliance with federal regulations.

Purtymun, W.D., West, F.G., and Adams, W.H., 1974,
Preliminary Study of the Quality of Water in the Drainage Area of the Jemez River and Rio Guadalupe,
LANL, LA-5595-MS.

A preliminary study of the quality of surface and ground water was made in the area of a proposed geothermal test hole and experiment by Los Alamos Scientific Laboratory. The study was made to establish background data prior to the geothermal experiment by the Laboratory. The data compiled prior to 1971 were taken from literature search while data from 1971 through 1973 were collected from field surveys. Analyses are reported from 17 surface water stations, 15 mineral and thermal springs, and 53 ground water stations (wells, test holes, and springs). A general description of sampling stations is presented with a brief description of the chemical quality of the water based on concentrations of dissolved solids.

The dissolved solids concentrations in surface water in the area are generally low and increase downstream as would be expected. A rapid increase in concentrations of dissolved solids in the upper reach of the Jemez River is due to the inflow of highly mineralized water from thermal springs associated with the Jemez fault. Surface water during low flow along Sulphur Creek contains high concentrations of dissolved solids due to the inflow of water from thermal and mineral springs. The concentrations of dissolved solids of surface water in San Antonio Creek, Vallecitos Creek, Fenton Lake, Rio de las Vacas, and Rio Guadalupe are low and show a normal increase downstream.

Thermal and mineral springs associated with the Jemez fault in the interior of the caldera contain water with moderate to high concentrations os dissolved solids. Those thermal and mineral springs associated with the recent volcanic rocks along the outer rim of the caldera yield water with low concentrations of dissolved solids.

The concentrations of dissolved solids in ground water in the area vary from low to high depending on the area of recharge and type of rocks in contact with the ground water.

The concentrations of dissolved solids in ground water in the Valle Toledo and Valle Grande are low, but in geothermal test holes along Sulphur Creek the concentrations are high. In the area of La Cueva and to the north and west, test holes and wells pentetrating the alluvium and rocks of Permian age yield ground water with low to moderate concentrations of dissolved solids. Ground water in the alluvium and rocks of Permian or Pennsylvanian age along the Jemez River contain moderate to high concentrations of dissolved solids. Shallow wells completed in the alluvium at Jemez Springs and at the Jemez Pueblo are probably recharged in part from the Jemez River and in part from thermal and mineral springs associated with the Jemez fault. Ground water discharges from springs in the Bandelier Tuff have low concentrations of dissolved solids.

Rodgers, J.C., et al., 1984,
Maintenance Free Vegetative Systems for Landfill Covers,
LANL, LA-UR-84-3407.

The overall objective of this EPA funded project is to investigate water balance relationships in hazardous landfill cover treatments, with the aim of identifying soil/vegetation systems that have promise for long-term stability. We are evaluating the utility of using the USDA CREAMS model as a hydrology modeling tool to assess the performance of site specific vegetation treatments and soil properties when applied to cover designs under local climatic regimes.

A successful cover system must be designed to minimize long-term migration of liquids from the waste, minimize erosion, accommodate subsidence, retain vegetation cover integrity, and be relatively maintenance free. These constraints require a cover design that eliminates deep percolation, controls erosion, and utilizes native plant species that are pre-adapted to local climate and are successful competitors.

The fraction of precipitation input that results in percolation below the root zone is substantially affected by the evapotranspiration component of the water balance in the cover. Thus, our focus has been on quantifying and evaluating those attributes of native species that directly affect evapotranspiration: leaf area index (LAI), rooting depth and distribution and phenology. There are a number of aspects of the vegetation component of the CREAMS model apparently tuned to agricultural plant species, which are being reevaluated for application to native plant species.

Simulation of cover treatments in a humid climate have indicated that even the native plant species offering the greatest potential for removal of normal precipitation inputs over the entire year are not successful in fully controlling percolation. In semiarid ecosystems, the situation is more complex. Percolation is apparently effectively eliminated in normal precipitation cycles and amounts. But timing and quantities can be such that deep percolation will not precluded by native plants.

A second phase of the research is currently being implemented. It involves a field scale experimental test of semi-arid ecosystem trench cap cover treatments initially investigated by model simulation. The test facility is a closed shallow land burial site at Los Alamos that has both several experimental multi-layer soil cover treatments on it. These soil profiles have been planted with plots consisting of two warm season native plant species (a shurb and a grass) at two different densities. Those should produce quantitatively different plant canopies, rooting profiles, and water use strategies. The experimental design and data collection methods will be presented.

Smith, M.C., 1971,
A Preliminary Study of the Nuclear Subterrene,
LANL, LA-4547.

The rock-melting drill was invented at Los Alamos Scientific Laboratory in 1960. Electrically heated, laboratory-scale drills were subsequently shown to penetrate igneous rocks at usefully high rates, with moderate power comsumptions. The development of compact nuclear reactors and of heat pipes now make possible the extension of this technology to much larger melting penetrators, potentially capable of producing holes up to several tens of kilometers long or deep.

Development of a rapid, versatile, economical method of boring large, long shafts and tunnels offers solutions to many of man's most urgent ecological, scientific, raw-materials, and energy-supply problems. A melting method appears to be the most promising and flexible means of producing such holes. It is relatively insensitive to the composition, hardness, structure, and temperature of the rock, and offers the possibilities of producing self-supporting, glass-lined holes in almost any formation and (using a technique called lithofracturing) of eliminating the debris-removal problem by forcing molten rock into cracks created in thr bore wall.

Large rock-melting penetrators, called Electric Subterrenes or Nuclear Subterrenes according to the energy source used, are discussed in this report, together with problems anticipated in their development. It is concluded that this development is within the grasp of present technology.

Soholt, L., Jacobsen, K., and Brown, F., 1987,
"Storm Water Run-Off Sampling", Environmental Surveillance at Los Alamos During During 1986,
LANL, LA-10992-ENV, pp. 111.

In September 1984, the EPA promulgated regulations that could require NPDES permitting of some of the Laboratory's outfalls that receive storm water run-off from conveyance systems. Due to this, during August and September runoff samples were obtained at 17 outfalls around the Laboratory. Samples were analyzed for approximately 30 inorganic pollutants and 145 organic pollutants.

The majority of organic pollutants occurred at levels below the minimum limits of detection of analytical methods used. However, methylene chloride, fluoranthene and pheno' were detected, but none of these pollutants exceeded EPA's criteria for repo. . ng in the NPDES permit application. Levels of chloroform were found to exceed the reporting criteria in one sample and general phenolic levels were at or above the reporting criteria in all but one sample. Three samples were found to be near the reporting criteria for oil and grease.
Inorganic pollutants were commonly detected in storm water run-off. Most metals and anions anlayzed for exceed the reporting criteria in one or more samples. Aluminum and iron were the most abundant metals in runoff, which probably reflects their natural abundance in the geosphere.

Soholt, L., Jacobsen, K., and Brown, F., 1988,
"Storm Water Runoff Sampling", Health, Safety and Environment Division Annual Report 1987,
LANL, LA-11257-PR, pp. 74.

In September 1984, the EPA promulgated regulations that could require the NPDES to permit some of the Laboratory's outfalls that receive storm-water runoff from conveyance systems, for example channels or culverts. This application must contain results of analyses from runoff samples that the Laboratory has reason to believe contain certain nonconventional priority pollutants in concentrations in excess of 10 ug/l (100 ug/l for some pollutants). During August and September, runoff samples were obtained once each at all 17 outfalls around the Laboratory. Samples were analyzed for approximately 30 inorganic pollutants and 145 organic pollutants.

The majority of organic pollutants occurred at levels below the minimum limits of detection by the analytical methods used. However, methylene chloride was detected in two samples from TA-35 and from TA-50 and exceeded 8 ug/l. Fluoranthene phenol were also detected in one sample from TA-35. These organics are found with a frequency of > 10% of urban runoff. Done of these detected pollutants exceeded EPA criteria for reporting in the NPDES permit application. Levels of chloroform exceeded these criteria in all but one sample. Oil and grease were present in three samples from TA-3 at level near the reporting criteria.

Inorganic pollutants were commonly detected in storm-water runoff. Most metals and anions we analyzed exceeded reporting criteria in one or more samples. For several elements, the analytical level of detection exceeded the reporting criteria, but this cannot be determined from the data. Aluminum and iron were the most abundant metals in runoff. This probably reflects their natural abundance in the geosphere.

Stearns, H.T., 1948,
Ground-Water Supplies for Los Alamos, New Mexico,
LANL, unpublished.

This report deals with the geology and hydrology of the area west of Los Alamos. The goal of this project was to locate a underground supply of 10 million gallons of water per day to meet the growing needs of Los Alamos.

A brief synopsis of the geologic history is given together with a stratigraphic table and the water-bearing character of each formation. Geologic and hydrologic traverses were made of each canyon behind Los Alamos. It was found that most of the springs issue from fractured andesite lava or from welded tuff overlying baked tuff beds. The springs are perched and do not indicate a thick zone of saturation at high levels. The prospects for developing additional water in these canyons is poor, especially for the large quantities desired.

The search for ground-water led to the upper parts of the valleys of Jemez and San Antonio Streams. Test holes revealed an artesian basin in each of these valleys. Nearly all the rocks there are permeable and recharge is heavy because the precipitation has been estimated to average about 27 inches per annum. The water table is close to the surface throughout the year and the area is uninhabited, hence pollution is controlled. The quality of the water, as determined by preliminary tests, is excellant with hardness of only 30 ppm. The quantity of groundwater recoverable is estimated to be 5 to 10 million gallons per day. Drilled wells 100 to 500 feet deep are recommended to recover this water from highly permeable pumiceous sands and gravels. The water lies 1200 feet or more above Los Alamos, due to a mountain ridge intervening, the water would have to be pumped up about 1000 feet and then dropped 2000 feet. Sufficient power might be generated from the drop to pump the water over the divide. The water could be obtained by gravity by tunnelling thru the divide into the zone of saturation. The Jemez Valley offers a better site for such a tunnel because a mass of tuff with low permeability lies at the head of San Antonio Valley.

Theis, C.V., and Conover, C.S., 1962,
Pumping Tests in the Los Alamos Canyon Well Field Near Los Alamos, New Mexico,
U.S. Geological Survey, Water-Supply Paper, 1619-I.

The town of Los Alamos, New Mexico, founded in 1943, obtained its first water supply from surface sources in canyons draining the eastern slopes of the Sierra de los Valles, a part of the Jemez Mountains. The water demands of the town soon outgrew the water supply available from these sources, and explorations began early in 1946 to find a supply of ground water in the recent alluvium of the Rio Grande about 9 miles east of town and in rocks of the Santa Fe group of middle(?) Miocene to Pleistocene(?) age in lower reaches of Los Alamos Canyon, about 7 miles east of town. The Los Alamos Canyon site proved to be more favorable and six supply wells ranging in depth from 870 ft to 1,975 ft were constructed in the period 1946-48.

The growth in the demand for water was such, however, that it became apparent that the surface sources and the six wells would become inadequate by 1950, so additional wells would be required. The rapid search for a ground water supply leading to the 1946-48 drilling was not accomplished by a quantitative evaluation of the water-production potential of the Santa Fe group. Additional wells probably will be constructed in nearby Guaje Canyon, and their position relative to the Los Alamos Canyon well field should be soundly planned. The pumping tests described in this report were a first step toward this planning.

The pumping tests were not made under ideal conditions because the pumping operation in the well field could not be completely regulated to eliminate irregular water-level fluctuations in the wells during the tests, and the results, therefore, are considered only approximate. The results of the test indicated that the coefficient of transmissibility probably is about 2,500 gpd/ft in the uppermost 1,000 ft of the Santa Fe group in the Los Alamos Canyon area; the aquifers in the next 1,00 ft may be separate from those in the upper 1,000 ft; and the coefficient of transmissibility for the uppermost 2,000 ft may be at least 9,000 gpd/ft.

Predictions of water-level trends in the well field indicated that,at the 1950 rate of pumping, the levels might decline about 100 feet between 1950 and 1988. The predictions were based on the assumption that the average pumping rate from the well field would be about 1,000 gpm after 1950- the coefficient of transmissibility is about 5000 gpd/ft, all the water would be withdrawn from storage and the boundary of the aquifer would not affect water levels in the period.

Travis, B.J., 1984,
TRACR3D: A Model of Flow and Transport in Porous/Fractured Media,
LANL, LA-9967-MS.

This report describes the TRAC3D computer code, which solves the equations of transient two-phase flow and multicomponent transport in deformable, heterogeneous reactive porous/fractured media. Solution is obtained by an implicit finite difference scheme for flow and a semi-implicit approach for transport. This report describes the equations of the model, defines the numerical solution procedure, presents partial verification and validation of the model, and includes a user's guide.TRACR3D can be used to study radioactive waste migration from repositories in unsaturated and saturated geology, chemical waste storage, soil water movement, and tests that define hydrocarbon reservoir structure.

Weir, J.E., et al., 1963,
The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

Treated liquid waste and sewage from the Los Alamos Scientific Laboratories at Los Alamos are discharged into canyons eroded in the volcanic rocks and sediments of the Pajarito Plateau. Liquids containing waste and sewage constitute the perennial flow of the upper reaches of the Acid and Pueblo Canyons.

Four deep and two shallow wells were drilled to determine the transmissibility of the perched aquifers and to monitor the chemical and radiochemical quality of ground water. Values of transmissibility range from 200 to 7,800 gallons per day per foot for the deep perched aquifer, and 50 to 8,300 gallons per day per foot for the shallow perched aquifers. The velocities of ground water in these range from about 150 feet per year to 4,500 feet per year.

Shallow wells 2 to 10 feet in depth were constructed in Acid and Pueblo Canyons in order that data could be collected on the chemical and radiochemical nature of water in the alluvium. They consisted of four wells cased with corrugated culvert pipe in Acid Canyon and 10 drivepoint wells in Pueblo Canyon.

Surface flow in Acid and Pueblo Canyons was observed to determine seepage losses or gains. Seepage losses are high during high flow in Acid Canyon, and seepage gain may occur at low flow. In Pueblo Canyon, streamflow diminishes downstream from the confluence with Acid Canyon, except for a gain in flow at the outfall of the Central Sewage Plant, and disappears into the pumiceous material of the Bandelier Tuff which underlies the upper part of the middle reach of the stream. Stormflow may carry some waste and sewage effluent into the lower reaches of the canyon or the Rio Grande. Precipitation and streamflow in Pueblo Canyon may correlate with water levels in some test wells. Radioactive contaminants probably are retained in Acid Canyon. Plutonium concentrations in Acid Canyon were sometimes equal to the limits for off-site tolerance, but in Pueblo Canyon were considerably below this limit. Uranium concentrations were not significantly high except in a few samples from Acid Canyon. Nitrate, chloride, and fluoride concentrations in samples from shallow test wells suggest a possible hydraulic connection between perched aquifers and the contaminated streamflow in Pueblo Canyon. Analyses of samples from the Rio Grande and Rio Chama show no significant amounts of contaminants.

Weir, J.E., Jr., et al., 1963,
The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, 1949-55.,
U.S. Geological Survey, Administrative Release.

Treated liquid wastes and sewage from the Los Alamos Scientific Laboratory at Los Alamos are discharged into canyons eroded in the volcanic rocks and sediments of the Pajarito Plateau. Liquids containing waste and sewage constitute the perennial flow of the upper reaches of Acid and Pueblo Canyons.

Four deep and two shallow test wells were drilled to determine the transmissibility of the perched aquifers and to monitor the chemical and radiological quality of ground water. Values of transmissibility range from 200 to 7,800 gallons per day per foot for the deep perched aquifer, and 50 to 8,300 gallons per day per foot for the shallow perched aquifers. The velocities of ground water in these aquifers range, from about 150 feet per year to about 4,500 feet per year.

Shallow wells 2 to 10 feet in depth were constructed in Acid and Pueblo Canyons in order that data could be collected on the chemical and radiochemical nature of water in the alluvuim. They consisted of four wells cased with corrugated culvert pipe in Acid Canyon and 10 drivepoint wells in Pueblo Canyon.

Surface flow in Acid and Pueblo Canyons was observed to determine seepage losses or gains. Seepage losses are high during high flow in Acid Canyon, and seepage gain may occur at low flow. In Pueblo Canyon, streamflow diminishes from the confluence with Acid Canyon, except for a gain in flow at the outfall of the Central Sewage Plant, and disappears into the pumiceous material of the Bandelier Tuff which underlies the upper part of the middle reach of the stream. Stormflow may carry some waste and sewage effluent into the lower reaches of the canyon or to the Rio Grande. Precipitation and streamflow in Pueblo Canyon may correlate with water levels in some of the test wells.

Radioactive contaminants probably are retained in Acid Canyon. Plutonium concentrations in Acid Canyon were sometimes equal to about one-tenth the limits for off-site tolerance, but in Pueblo Canyon were considerably below this limit. Uranium concentrations were not significantly high except in a few samples from Acid Canyon. Nitrate, chloride, and fluoride concentrations in samples from shallow test wells suggest a possible hydraulic connection between perched aquifers and the contaminated streamflow in Pueble Canyon. Analyses of samples from the Rio Grande and Rio Chama show no significant amounts of contaminants.

Purtymun, W.D., Adams, W.H., and Owens, J.W., 1975,
Water Quality in the Vicinity of Fenton Hill Site, 1974,
LANL, LA-6093.

The water quality at nine surface stations, eight ground water stations, and drilling operations at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal experimental studies in the Jemez Mountains. Surface water quality in the Jemez River drainage area is affected by the quality of the inflow from thermal and mineral springs. Ground water discharges from the Cenozoic Volcanics are similar in chemical quality. Water in the main zone of saturation penetrated by test hole GT-2 is highly mineralized, whereas water in the lower section of the hole, which is granite, contains a higher concentration of uranium.

Purtymun, W.D., Adams, W.H., and Stoker, A.K., 1978,
Water Quality in the Vicinity of Fenton Hill Site, 1976,
LANL, LA-7307-MS.

The water quality at nine surface stations, 11 ground water stations, and 3 ponds at the Fenton Hill Site have been studied as a measure of the environmental impact of the Los Alamos Scientific Laboratory geothermal site experimental studies in the Jemez Mountains. Insignificant changes (within expected normal seasonal flucuations) in the chemical quality of water at individual stations were observed during the year. Predominant ions and total dissolved solids remained essentially stable.

Purtymun, W.D., and Abrahams, J.H., Jr., 1963,
Hydrologic Characteristics of an Ash Flow Tuff at Frijoles Mesa, Los Alamos County, New Mexico,
U.S. Geological Survey, Open-File Report.

The specific yield of ash flow tuff under study is related to porosity while the coefficient of permeability is independent of the porosity and is related to the pore size distribution. Fluid movement in the lower third of the flow as it cools could result in larger horizontal permeability in direction of movement than vertical permeabilities.

Purtymun, W.D., and Adams, H., 1980,
Geohydrology of Bandelier National Monument, New Mexico,
LANL, LA-8461-MS.

Bandelier National Monument is located on the eastern slopes of the Sierra de los Valles and the Pajarito Plateau. The Pajarito Plateau was formed by a series of ashflow and ashfall of rhyolite tuff. Perennial and intermittent streams have cut the surface of the plateau into a number of narrow southeast-trending mesas separated by deep canyons. Perennial surface flow occurs in Canon de los Frijoles and in the upper and middle reaches of Alamo, Capulin, Medio, and Sanchez Canyons. Of the five springs in and adjacent to the Monument, three discharge from perched aquifers and two from the main aquifer. Water in the deep main aquifer moves south to southeast in the Monument. Along the western edge of the Monument, the intrusion of volcanic rock of the San Miguel Mountains forms a barrier to the movement of water from the recharge area in the Valles Caldera. About 46.4 square km of drainage area in the upper and middle reaches of Canon de los Frijoles, Alamo, Lummis and Capulin Canyons were burned over by a wildfire (La Mesa Fire) in June 1977. The geohydrology of the area was determined to assess the availability of surface and ground water in the Monument and to determine the impact of the wildfire on these water resources.

Purtymun, W.D., and Cooper, J.B., 1965,
Locations for Five Water-Spply Wells at Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

Locations for five water-supply wells at Los Alamos, New Mexico are suggested with consideration given to geologic and hydrologic conditions and to the existing water-utility system amd proposed expansion of the system. Two of the locations are in the the Pajarito Canyon area where wells are expected to yield 1,000 gpm (gallons per minute) with less than 100 ft drawdown. A third location is in the Sandia Canyon area where a well is anticipated to yield about 700 gpm with less than 100 feet of drawdown. Depth of the pilot holes of these wells will be about 2,5000 feet. A fourth location is for a well to replace water-supply well G-4 in the Guaje Canyon well field. A well at this location should yield 500 gpm with less than 100 feet drawdown. The depth of the pilot hole will be 2,000 feet.

Four alternative locations are presented for a fifth well. A well at location "A" would replace wells at LA-2 and LA-3 in the Los Alamos Canyon well field and would yield 500 gpm with less than 100 feet drawdown; the pilot hole would be 2,000 feet deep. A well at location "B", in Pueblo Canyon, would yield 700 to 1,000 gpm with less than 100 feet of drawdown; the pilot hole would be 2,500 feet deep. A well at either location "C" or "D", in the Pajarito Canyon area, would yield 1,000 gpm with less than 100 feet of drawdown; the pilot hole would be 2,500 feet deep. Final selection of the location for this fifth well would be based on future production demand.

The main aquifer is within the Puye Conglomerate and the Tesuque Formation in the Pajarito Plateau (Pajarito and Sandia Canyon areas and at locations "B", "C", or "D"). The physical characteristics of the sediments of the Tesuque Formation and the Puye Conglomerate will allow moderate-to-high-yield (700 to 1,000 gpm) wells to be developed on the Pajarito Plateau. In the Guaje Canyon well field and at location "A" in the Los Alamos Canyon well field the main aquifer is in the Tesuque Formation. Because sediments of the Tesuque Formation in Guaje Canyon and Los Alamos Canyon well field are fined-grained, transmissibility is reduced and the maximum yield to be expected of wells in these areas is 500 gpm. The depth to the main aquifer varies from about 1,200 feet along the western margin of the Pajarito Plateau to about 600 feet near the Rio Grande. Water in the aquifer is under artesian pressure in some areas. Ground water at the suggested well locations is low in dissolved solids and is of good chemical quality

Depth at which to complete the water-supply wells will be determined by examination of lithologic and geophysical logs outlined from the pilot holes.

Gravel-pack well construction is necessary to minimize the entry of fine material into the well. Perforated pipe or screen should be placed through the entire saturated section penetrated by the wells. Rotary-drilling methods are commonly used to construct wells in the Los Alamos area; however, circulation often is lost in the unsaturated section of rocks above the main aquifer and basalt flows tend to cause crooked holes. Cable-tool methods of drilling have been used successfully to drill the upper section of unsaturated material.

Purtymun, W.D., and Cooper, J.B., 1969,
Development of Ground-Water Supplies on the Pajarito Plateau, Los Alamos County, New Mexico,
U.S. Geological Survey, Prof. Paper, 650B, pp. B149-B153.

The Pajarito Mesa well field, completed in 1966 on the Pajarito Plateau, contributed 37 percent of the total water supply to Los Alamos in 1967. Two wells in the field are capable of yeilds of 1,400 gallons per minute each. This yield is about three times that of any of the other 13 supply wells in the water supply system. The high yield of the two wells is attributed to the occurrence of coarse volcanic debris and arkosic sediment in the Puye and Tesuque Formations of the Santa Fe Group that make up the Main aquifer beneath the Pajarito Plateau.

Purtymun, W.D., and Cushman, R.L., 1961,
Site Location for a Los Alamos Supply Well Near the 10-inch Water Main that Parallels State Highway 4 Between Pueblo Canyon and White Rock,
U.S. Geological Survey, Administrative Release.

A study was made to select a site for a water-supply well for the town of Los Alamos, New Mexico along a 10-inch water main between the Pueblo-Los Alamos Canyon junction and White Rock. The well must be capable of yielding about 500 gallons per minute and have a specific capacity of at least 5 gallons per minute per foot of drawdown.

The most favorable site for the supply well is in the Sandia Canyon, because waste products are not being discharged into that canyon. The depth of a supply well in this canyon should be about 2,600 to 2,700 feet.

Purtymun, W.D., and Cushman, R.L., 1963,
Site Location for a Municipal Supply Well in Guaje Canyon or Rendija Canyon near Los Alamos, New Mexico,
U.S. Geological Survey, Administrative Release.

The site of a new municipal well for Los Alamos, New Mexico could be either in Guaje Canyon about 2,500 to 3,500 feet northwest of well G-5 or in Rendija Canyon about 2,600 to 3,600 feet west of booster pump station No.1. The Rendija Canyon site might be preferred because of power and water transmission lines in that canyon near the site.

A well that could be pumped at a rate of at least 500 gallons per minute with a drawdown less than 100 feet (at time of completion) would be between 1,500 and 2,000 feet deep provided that massive latite flows are not encountered before reaching those depths. Latite flows present at depths appreciably less than 1,500 ft probably would make it impossible to construct a well that would have the required discharge-drawdown relationship. Ground water will be encountered in the main zone of saturation probably under water-table conditions at a depth 50 feet below land surface.

Drilling will be predominantly in conglomerate, siltstone, silty sandstone, and basaltic rocks (flows and breccias). The combined thickness of the basaltic rocks may comprise as much as 400 feet of the section drilled.

Purtymun, W.D., and Enyart, E.A., 1966,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1964 through June 1965,
U.S. Geological Survey, Administrative Release.

Chemical and radiochemical analyses of water samples and of alluvium collected in the Los Alamos area downgradient from industrial waste and sewage treatment plants during July 1964 through June 1965 were made by the H-6 and H-7 Groups of the Health Division of the Los Alamos Scientific Laboratory. The analyses were made to monitor the amount and extent of contamination resulting from the operation of the Los Alamos Scientific Laboratory at Los Alamos, New Mexico.

Analyses of water samples collected at Los Alamos, New Mexico, during 1964-65, show that contamination (chemical and radiochemical) was confined to surface water and to the water in the alluvium of canyons receiving low-level radioactive effluent (DP-Canyon and Mortandad Canyon) or canyons which have received low-level radioactive effluent in the past (Acid and Pueblo Canyons). The chemical concentration was generally low, with most analyses indicating that water is acceptable for domestic use, according to the limits recommended by the U.S. Public Health Service. Radiochemical quality was generally below the MPC. The degree of contamination decreases downgradient in the canyons.

Analyses of water samples collected from surface flow, springs, supply wells and test wells show no indication of chemical or radiochemical contamination.

Purtymun, W.D., and Herceg, J.E., 1972,
Summary of Los Alamos Municipal Well-Field Characteristics, 1947-1971,
LANL, LA-5040-MS.

Basic data concerning monthly pumpage, aquifer condition and well characteristics for wells of the Los Alamos water supply system from 1947 through 1971 have been prepared to interpret data for an annual report and determine future aquifer conditions. This report presents a historical record of this data. Annual summaries of pumpage statistics are also included.

Purtymun, W.D., and Herceg, J.E., 1972,
Water Supply at Los Alamos During 1971,
LANL, LA-5039-MS.

The Los Alamos water supply for 1972 consisted of production of 1553 million gal from 16 wells in 3 fields, with an addition of 37 million gal from the gallery in Water Canyon. Water-level trends are as anticipated under current pumping practices. Limiting pumpage in the Los Alamos and Guaje well fields has slowed or reversed water-level decline in most wells and will thus prolong their lives.

The pumping rate at well LA-2 declined owning to increased production. The pumping at well G-6 declined owning to pump wear and subsequent failure. The pump at well G-6 was replaced in March. The pumping rate at well G-4 is held to about 200 gpm because of casing deterioration and entry into well of part of the gravel pack. The well cannot be repaired but must be replaced. An additional well in Pajarito well field is necessary to provide adequate supply during periods of peak demand and to meet increasing water needs.

Monthly pumping and production data for each of the 16 wells for 1969, 1970, and 1971 are included in this report

Purtymun, W.D., and John, E., 1964,
Site for a Municipal Supply Well in Pajarito Canyon near Los Alamos, New Mexico, U.S. Geological Survey, Administrative Release.

A site for the first of four new municipal supply wells for Los Alamos was selected in the NE1/4SW1/4NW1/4 sec. 36, T. 19 N., R. 6 E. The well site is Pajarito Canyon at an altitude of 6,720 feet above mean sea level and only a few hundred feet east of a technical area known as Pajarito Site.

The well depth might have to be as much as 2,600 feet to obtain the required 500 gallons per minute with a drawdown less than 100 feet; however, the well could be finished at a shallow depth if the lower 160 feet of the conglomerate and basalt is a part of the main aquifer at the site. The conglomerate and basalt sequence generally is highly permeable, and would yield more water to the well per foot of aquifer thickness than any other section of aquifer beneath the site. If the conglomerate and basalt sequence is a part of the aquifer, the well should be screened throughout that part of the aquifer to obtain the most favorable specific capacity to well depth ratio. If this section is not screened, the depth of the finished well must be increased to compensate for lower average permeability. The section of screen settings in the siltstone and silty sandstone can be made on the basis of lithologic and geophysical logs of the pilot hole. The top of the main aquifer probably will be at a depth about 870 feet at the site. The aquifer may be artesian and the water might rise in the well to a level about 5 feet above the top of the aquifer.

Purtymun, W.D., and Kunkler, J.L., 1967,
The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1965 through June 1966,
U.S. Geological Survey, Administrative Release.

This report discusses the water quality results of surface and ground water samples taken at Los Alamos during 1965-1966. As in previous reports, analyses of water samples collected at Los Alamos during 1965-66 show that chemical and radiochemical contamination is confined to surface and ground water in the alluvium of canyons receiving loe-level radioactive effluents (DP, Los Alamos, and Mortandad Canyons) or canyons that received low-level radioactive effluents in the past (Acid Canyon). The chemical contamination was generally low, with most analyses indicating that water is acceptable for domestic use according to the limits recommended by the U.S. Public Health Service. Radiochemical analyses show that plutonium, and uranium were below MPC. Beta-gamma emitters were also below MPC except in surface water in Mortandad Canyon. The degree of contamination decreases downgradient in the canyon. The results of tritium analyses indicate that the tritium content of water in the alluvium of Los Alamos and Mortandad Canyons is near the maximum permissible concentrations. Further investigations are being made to determine the extent and amounts of tritium cntamination.

Purtymun, W.D., and Kunkler, J.L., 1969,
The Chemical and radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1966 through June 1967,
U.S. Geological Survey, Administrative Release.

This report discusses the chemical and radiochemical quality of surface and ground water at Los Alamos during July 1966 through June 1967. Analyses of water samples collected at Los Alamos during 1966-1967 indicate that radiochemical contamination of surface and ground water is confined to water in the alluvium of canyons (DP, Los Alamos, Mortandad) which receive low-level radioactive effluents from waste disposal plants. Concentrations of plutonium and uranium in the water are below MPC. Beta-gamma emitters are also below MPC except for samples of surface water collected from Mortandad Canyon in November of 1966. Chemical contamination is also indicated in water samples from surface and ground water sources in DP, Los Alamos, and Mortandad Canyons, as well as from Mortandad Canyon to the Rio Grande (treated-sewage effluent) and perhaps Canada del Buey below TA-46. The chemical contamination is minor; most analyses indicate the water is acceptable for domestic use.

Surface water entering Mortandad Canyon during 1966-67 infiltrated into alluvium within the disposal area. A decrease in the amount of surface flow (coolant and storm runoff) from March 1966 to February 1967 caused a general decline in the volume of ground water in storage in the alluvium. Loss of surface and ground water in the alluvium by evapotranspiration and infiltration into the underlying tuff average about 2 million gallons per month.

Ground water in the alluvium in Los Alamos Canyon is recharged by coolant water, sewage effluent, low-level radiochemical effluents and seasonal runoff. Chemical and radiochemical analyses of water samples from wells penetrating the alluvium indicate the movement of low-level radioactive effluents through the alluvium from DP Canyon into Los Alamos Canyon.

Purtymun, W.D., and Stoker, A.K., 1988,
Water Supply at Los Alamos: Current Status of Wells and Future Water Supply,
LANL, LA-11332-MS.

The municipal and industrial use of groundwater at the Los Alamos National Laboratory and Los Alamos County was about 1.5 billion gallons during 1986. From a total of 19 wells that range in age from 5 to 41 years, the water was pumped from 3 well fields. The life expectancy of a well in the area ranges from 30 to 50 years, dependent on the well construction and the rate of corrosion of the casing and screen. Twelve of the wells are more than 30 years old and, of these four cannot be used for production, three because of well damage (LA-1, LA-4, and G-3) and one (LA-6) because quality of water is not suitable for use. Eight (LA-2, LA-3, LA-5, G-1, G-2, G-4, G-5, and G-6) of the twelve oldest wells are likely to be unsuitable for use in the next 10 years because of well deterioration and failure. The remaining 7 wells include 2 (LA-1B, G-1A) that are likely to fail in the next 20 years. Five younger wells in the Pajarito well field are in good condition and could serve for another two or three decades.

The program of maintenance and rehabilitation of pumps and wells has extended production capabilities for short periods of time. Pumps may be effectively repaired or replaced; however, rehabilitation of the well is only short-term correction to increase the yeild before it starts to decline again. The two main factors that prevent successful well rehabilitation are: (1) chemicals precipitated in the gravel pack and screen restrict or reduce the entrance of water to the well, which reduces yeild of the well, and (2) the screen and casing become corroded to a point of losing structural strength and subsequent failure allows the gravel pack and formation sand to enter the well. Both factors are due to long-term use and result in extensive damage to the pump and reduce the depth of the well, which in turn causes the yield to decline. Once such well damage occurs, rehabilitation is unlikely top be successful and the ultimate result is loss of the well. Two wells (LA-4 and G-3) were lost in 1987 because of such damage.

It is essential to implement a program to replace wells that have failed or will fail in the next 10 years to ensure a continued and reliable water supply. Any change in operation of the Laboratory or county that will require additional water adds to the urgency to develop a system of new wells. Rehabilitation of the older wells will not ensure a continued or reliable supply, or meet additional demands for water. This report presents the history of the wells and well fields, briefly describes the geology and hydrology of the area, includes a section on production and production capacity, and outlines development of additional water supply.

Purtymun, W.D., Becker, N.M., and Maes, M., 1983,
Water Supply at Los Alamos During 1981,
LANL, LA-9734-PR.

The municipal and industrial water supply for Los Alamos during 1981 consisted of 1506 X 10^6 gal from wells in three well fields and 45 X 10^6 gal from the gallery in Water Canyon. Another 0.08 X 10^6 gal of water were pumped to waste during testing of Well LA-6. About 2.6 X 10^6 gal of water from Guaje Reservoir and 2.1 X 10^6 gal of water from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1556 X 10^6 gal. Water level trends in the wells were as anticipated under current production practices. Pumps in several wells that failed in 1981 are now being repaired or have been repaired. The new well, PM-4, was placed in service in the early summer of 1982. Chemical qulaity of water from wells and distribution system is in compliance with state and federal regulations related to municipal use.

Purtymun, W.D., Becker, N.M., and Maes, M., 1984,
Water Supply at Los Alamos During 1982,
LANL, LA-9896-PR.

Municipal and industrial water supply for Los Alamos during 1982 consisted of 1512 million gal from wells in three well fields and 46 million gal from the gallery in Water Canyon. Less than 30,000 gal of water were pumped to waste during testing of well LA-6. About 3.4 million gal of water from Guaje Reservior and 2.8 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1564 million gal. The failure of pumps in several of the wells in 1982 did not result in water shortage because of a low peak demand period in the summer, and some of the lost production was offset as supply well PM-4 began production in July 1982. Well PM-5 was completed in 1982; however, equipping the well and construction of the pump station & transmission line will probably not be completed until early 1984. The primary and secondary chemical quality of water from wells and distribution systemis in compliance with federal regulations. Radioactivity in the water is low and naturally occurring.

Purtymun, W.D., Becker, N.M., and Maes, M., 1985,
Water Supply at Los Alamos During 1983,
LANL, LA-10327-PR.

The Los Alamos water supply for 1983 consisted of production of 1463 million gal from wells in 3 fields, with an addition of 38.3 million gal from the gallery in Water Canyon. About 3.4 million gal of water from Guaje Reservoir and 1.4 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1506 million gal. High-yield Well PM-4 produced 452 million gal or about 30% of the total production at Los Alamos during 1983. The primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations.

Purtymun, W.D., Becker, N.M., and Maes, M., 1986,
Water Supply at Los Alamos During 1984,
LANL, LA-10584-PR.

The Los Alamos water supply for 1984 consisted of production of 1566 million gal from wells in 3 fields, with an addition of 34 million gal from the gallery in Water Canyon. About 3 million gal of water from Guaje Reservoir and 1.3 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1604 million gal. Well field operations were satisfactory with pumping schedules resulting in a uniform decline of water level in the fields. Primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations. Fluoride in water from Well LA-1B and arsenic in water from well G-2 exceeded the standards; however, mixing of water from these wells with water pumped from other wells in the field reduced the concentration to below the acceptable level in the distribution system.

Purtymun, W.D., Becker, N.M., and Maes, M., 1986,
Water Supply at Los Alamos During 1985,
LANL, LA-10835-PR.

The Los Alamos water supply for 1985 consisted of production of 1587 million gal from wells in 3 fields, with an addition of 37 million gal from the gallery in Water Canyon. About 2.8 million gal of water from Guaje Reservoir and 0.9 million gal from Los Alamos Reservoir were used for irrigation; thus, the total use was about 1628 million gal. Well field operations were satisfactory with pumping schedules resulting in a uniform decline of water level in the fields. Primary and secondary chemical quality and radioactivity in water from wells and distribution system are in compliance with federal regulations.

Purtymun, W.D., Buchholz, J.R., and Hakonson, T.E., 1977,
Chemical Quality of Effluents and Their Influence on Water Quality in a Shallow Aquifer,
J. Environ. Qual., Vol. 6, No. 1, pp. 29-32.

The chemical quality of liquid effluent released from an industrial waste treatment plant at the Los Alamos Scientific Laboratory controls the quality of water in a shallow aquifer in the alluvium of Mortandad Canyon. The dilution the effluent with surface flow in the canyon reduces the concentrations of the chemicals as they move down gradient into the aquifer. Mass estimates of residual chemicals in solution in the aquifer average 1-6% of the total chemicals released to the canyon from 1963-1974. The average annual concentration of sodium nitrate, chloride, and total dissolved solids in the aquifer through a 12 year period was directly correlated with annual average concentrations in the effluent. This relationship provides a means of predicting the impact of the chemical effluents on the quality of water in the aquifer.

Purtymun, W.D., Buchholz, J.R., Hakonson, T.E., 1975,
Chemical Quality of Effluents and Their Influence on Water Quality in Mortandad Canyon,
LANL, LA-UR-75-2076.

The chemical quality of liquid effluents released from an industrial waste treatment plant at the Los Alamos Scientific Laboratory controls the quality of water in a shallow aquifer in the alluvium of Mortandad Canyon. The dilution of the effluent with the waste water and storm runoff, uptake of ions by plants, base exchange with alluvium and losses from the aquifer into the underlying strata reduce the concentrations of chemicals as they move downgradient in the canyon into the aquifer. Mass estimates of residual chemicals in the solution in the aquifer were about 1% of the total released to the canyon from 1963-1974. The average annual concentration of sodium, nitrate, chloride, and total dissolved solids in the aquifer through a 12 year period was directly correlated with the average annual concentration in the effluent. This relationship provides a means of predicting the impact of the chemical effluents on the quality of water in the aquifer.

Purtymun, W.D., Enyart, E.A., and McLin, S.G., 1989,
Hydrologic Characteristics of the Bandelier Tuff as Determined Through an Injection Well System,
LANL, LA-11511-MS.

Injection wells were used to determine some of the hydrologic transmitting characteristics of the unsaturated Bandelier Tuff. At site 1, a 60-ft injection well with a 5-ft injection zone was used to conduct four tests. These preliminary tests were made in order to design an injection well monitoring system that could track the movements of fluids in the tuff.

At site 2, a second injection well with a 10-ft injection zone and seven observation holes was used to monitor the movement of 335,000 gallons of water injected into the tuff. The initial injection rate at site 2 was 5.8 gallons per minute (gpm), but that rate gradually declined to 0.4 gpm after 89 days of the test; 289 days after the test ended, the pear-shaped nephol (the shape of moisture injected into the tuff) reached a maximum depth of 210 ft and had a diameter of about 120 ft.

A second test at site 2 indicated that intermittent use of an injection system would allow for short periods of higher injection rates, thereby extending the life of the system. Finally, a third test at site 2 was made using a 50 ft injection zone, which resulted in an injection rate of 15.8 gpm, or about 3 times the initial rate achieved when a 10 ft injection zone was used.

Purtymun, W.D., et al., 1974,
Air Volume and Energy Transfer Through Test Holes and Atmospheric Pressure Effects on the Main Aquifer,
LANL, LA-5725-MS.

Air volumes and energy transfer through test holes completed in the Bandelier Tuff and/or Puye Formation were monitored for 95 h at test hole DT-10 and for 34 h at test hole DT-10 and Alpha. Air transfer caused by atmospheric pressure changes at DT-10 during the 95-h study consisted of four cycles of four intake periods and four exhaust periods. The total volume of air taken into the reservoir was 2910 cubic meters while 1425 cubic meters of air were released from the reservoir. The largest volume of air transferred was 2400 cubic meters during intake period of 40 h with an atmospheric pressure change of 0.46 cm Hg. The average energy in the air transferred during the intake period was 14400 g-cal/cubic meter while the average energy in the air exhaust period was 19300 g-cal/cubic meter.

The 24-h study test holes DT-10 and Alpha was made near the end of an exhaust period. About 1160 cubic meters of air were released from the reservoir rocks at DT-10 with about 10,500 cubic meters of air released from Alpha. A construction in the casing to accommodate instrumentation reduced the volume of air transferred from DT-10. Energy in air transferred from DT-10 was 19300 g-cal/cubic meter and 12300 g-cal/cubic meter from Alpha.

Atmospheric pressure changes cause water-level fluctuations in test holes penetrating the main aquifer. The changes in water-levels, atmospheric pressure and rates of air transferred during the 95-h study were correlatable. The barometric efficiency of the aquifer during the four cycles ranged from 51 to 88 percent. Large barometric efficiencies resulted with smaller volumes of air transferred and smaller pressure changes.

III. HAZARDOUS WASTE MANAGEMENT

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Development of Corrective Measures Technologies for the Long-Term Stabilization of Shallow Land burial Sites in Semiarid Environments.

Nyhan, J.W., Hakonson, T.E., and Lopez, E.A., 1986,
Corrective Measures Technology for Shallow Land Burial at Arid Sites: Field Studies of Biointrusion Barriers and Erosion Control.

Perkins, B.L., 1982,
Disposal of Liquid Radioactive Waste Through Wells or Shafts.

Perkins, B.L., 1982,
Evaluation of Environmental Control Technologies for Commercial Nuclear Fuel Conversion (UF6) Facilities.

Perkins, B.L., 1983,
Evaluation of Environmental Control Technologies for Commercial Uranium Nuclear Fuel Fabrication Facilities.

Rodgers, J.C., and Hansen, W.R., 1982,
On the Feasibility of Various Disposal Techniques for Selected Los Alamos Store and Buried TRU Wastes.

Walker, L.J., et al., 1981,
Alternative Transuranic Waste Management Strategies at Los Alamos National Laboratory.

Warren, J.L., and Zerwekh, A., 1985,
TRU Waste-Sampling Program.

WESTON, 1986,
Surface Geophysical Investigations Ultilizing Magnetometry and Ground Penetrating at Area F, Technical Area 6.

Wheeler, M.L., and Smith, W.J., II, 1975,
"Considerations for the Long-Term: Perpetual is not Forever".

Wheeler, M.L., and Warren, J.L., 1975,
Tritium Containment After Burial of Contaminated Solid Waste.

White, J., et al., 1988,
"Underground Storage Tanks", Environmental Surveillance at Los Alamos During 1987.

Williams, J.A., 1986,
Results of the Geophysical Investigation Conducted at Los Alamos Labs Facility, Los Alamos, New Mexico.

Zerwekh, A., and Warren, J.L., 1986,
Gas Generation and Migration Studies Involving Recently Generated 238-Pu-Contaminated Waste for the TRU Waste Sampling Program.

Zerwekh, A., Kosiewicz, S., and Barraclough, B., 1978,
Experimental studies of the Degradation of RAD-Wastes for the Sandia Laboratories Waste Isolation Pilot Project (WIPP).

Abeele, W.V., et al., 1986,
Low-Level Integrated System Test,
LANL, LA-10572-MS.

An unusually wet season permitted us to test the integrity of our biobarrier installed in the improved or modified plots on our integrated system. Although the modified plots had a reduced water-holding capacity, they delivered leachate only at the drain installed above the biobarrier, demonstrating once more that the biobarrier is behaving successfully as a capillary barrier in rerouting the subsurface flow around the tuff beneath the biobarrier. As a result of vertical water flow impedance, more water was made available to plot vegetation, enhancing its growth dramatically. The capillary barrier theory was backed up by the tensiometer results showing saturation at the upper biobarrier interface.

Burton, B.W., et al., 1982,
Overview Assessment of Nuclear Waste Management.,
LANL, LA-9395-MS.

After reviewing the environmental control technologies associated with Department of Energy nuclear waste management programs, we have identified the most urgent problems requiring futher action of follow-up. They are listed, in order of decreasing importance, below.

1. Shallow Land Disposal Technology Development

There is insufficient understanding of radionuclide release and transport mechanisms, which is compounded by the location of many burial sites in areas of complex geology. Regulatory standards and criteria seem to be conflicting and may not be adequate to provide safe disposal. In addition, there seems to be no coherent plan for ensuring site integrity after enclosure. We recommend further research in the areas of hydrogeologic conditions at existing sites and radionuclide release and transport mechanisms. A close evaluation of limiting concentrations in burial grounds (maximum and minimum allowable concentrations) is needed. Also needed are programs to address waste treatment and volume reduction. Land use evaluation schemes to be used in new facility siting should be developed, as well as a specific definition of low-level waste.

2. Active Uranium Mill Tailings Piles

Remedial action and the new Nuclear Regulatory Commission (NRC) licensing requirements addressing old and new tailings piles are promising, but their long-term effectiveness has yet to be proven. Environmental controls for currently active piles are not adequate, but these facilities are licensed and needed improvements may not be required. It is reasonable to assume that successful developments in the remedial action programs and NRC regulations regarding stabilization/rehabilitation at the close of operations will be applied to these active piles. However, currently active milling operations, which were not subject to the new NRC requirements at the time they were licensed, should be comprehensively studied to determine the extent to which their current practices are affecting the environment and to determine the cost/feasibility of ameliorative action.

3. Uranium Mine Dewatering

Pumpage of uranium mine water in changes in the aquifer, dispersal of contaminants (both radioactive and toxic), and loss of water, itself a valuable resource. Mine water control is not very effective and these activities are poorly documented. Environmental health and safety regulations and division of authority are not clear. Carefully coordinated field studies to determine the overall potential health and environmental impact of current uranium mining practices with particular attention to implications of the gaps in regulatory authority and enforcement capacity of both state and federal authorities should be undertaken.

4. Site Decommissioning

Some of the decontamination and site decommissioning activities scheduled for the near future (that is, decommissioning of the Gunite tanks at Oak Ridge National Laboratory and the plutonium facilities at Mound National Laboratory) are potentially quite hazardous. They will involve large quantities of radionuclides, will take place in populated areas, and are novel. Relevant documents do not address methods for disposal of the waste. These issues must be addressed before operations are allowed to begin.

5. Exhumation/Treatment of Transuranic Waste at Idaho National Engineering

Laboratory.

This activity is discussed in some documents but not in others, so the current status of the project is not clear. The operations will be novel, the quantity of radionuclides involved is large, and the environmental controls are not known. This activity is potentially hazardous and, if it is still scheduled, the US Department of Energy (DOE) should ensure careful planning and adequate environmental controls before exhumation is allowed to begin.

6. Uranium Mine Spoils

Mine spoils piles are a potential source of wind-and waterborne contamination (both radioactive and toxic). There are very little data available regarding mine spoils. Although spoils piles are poorly regulated, an effective reclamation program can probably be developed under the Resource Conservation and Recovery Act (RCRA). These spoils piles are outside DOE jurisdiction, but DOE should pay close attention to devedopments in this area.

7. Medical/Institutional Wastes

Large volumes of very low activity wastes are produced by the medical/institutional community. Enforcement of environmental controls has been ineffective, and much of the waste is disposed to municipal sewer and refuse systems. Because of the low activities involved, the hazards of institutional wastes are biological and chemical rather than radiological. Large volumes of toxic and organic liquids are buried in commercial low-level burial grounds, presenting the potential hazard of chelating and mobilizing radionuclides. Although these waste generators are not under DOE jurisdiction, there is a compelling need for increased development of waste treatment and volume reduction systems.

We feel that the following areas need not be of immediate concern:

-Conversion/Enrichment/Fabrication.

-Reactor/Fuel Storage Operations.

-Terminal Isolation.

Devaurs, M., 1985,
Use of CREAMS Model in Experimental Designs for Shallow Land Burial of Low Level Wastes,
LANL, LA-UR-85-663.

A state of the art model developed by the U.S. Department of Agriculture called CREAMS (A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems) is used to simulate the hydrologic processes in soil and rock covers at shallow land waste disposal sites. Application of the CREAMS model in management of soil moisture and percolation at waste disposal sites is discussed for diverse topsoil-backfill-cobble-gravel trench cap designs tested at different field scales.

Results from the study indicate that the CREAMS model predicts observed soil moisture best in the summer and fall; maximum divergence between observed and predicted soil moisture occurs in the winter with snow cover, snowmelt and freeze/thaw. The cassion data shows the closest agreement of field data and model predictions. CREAMS simulates the major increases and decreases in soil moisture. At the larger field scale of Area B there is more variablity between the observed and CREAMS-predicted soil moisture. However, CREAMS still tracks increases and decreases in soil moisture in soil moisture. The greatest discrepancies between observed and predicted moisture occur in the winter.

Generally CREAMS has been shown to predict soil moisture under more humid conditions where flow is dominated by gravity. Under drier conditions where capillary forces become important, CREAMS modeling of soil moisture is less accurate. Correlation coefficients indicates that for Area B less than 50% percent of the variation in observed soil moisture is explained by CREAMS.

Dreesen, D.R., 1981,
Biogeochemistry of Uranium Mill Wastes Program Overview and Conclusions,
LANL, LA-8861-MS.

The major findings and conclusions are summarized for research on uranium mill tailings for the US Department of Energy and the US Nuclear Regulatory Commission. An overview of results and interpretations is presented for investigations of 222Rn emissions, revegetation of tailings and mine spoils, and trace element enrichment, mobility, and bioavailability. A brief discussion addresses the implications of these findings in relation to tailings disposal technology and proposed uranium recovery processes.

Elder, J., et al., 1986,
Radioactive Liquid Waste Lines Removal Project at Los Alamos (1981-1986),
LANL, LA-10821-MS.

This report describes the abondoned liquid waste lines removal operations conducted at Los Alamos in the period 1981-1986. Particular emphasis has been placed on as left conditions,that is, on the location of sections of waste lines or contamianted soil which were left in place on the basis of ALARA decisions. Contaminated items were left when interfering utilities, roads, structures, or great depth made complete removal not cost effective or not safe. Left items were either not highly contaminated or they were not near the surface.

Total cost of the project was $4.2 million. Approximately 5800 cubic meters of contaminated waste was placed in the Solid Waste Management Site at TA-54, Area G. The project accomplished the removal of approximately 34,500 ft (6.5 miles) of abandoned waste lines under carefully controlled conditions.

Procedures for excavation, waste disposal, personnel protection, and radiation monitoring are described. Environmental monitoring criteria and methods for determining acceptable levels of contamination in soils and on surface are discussed.

Environmental Science Group, 1975,
Transuranic Waste Management Programs: July - December 1974,
LANL, LA-6100-PR.

Progress is reported for three transuranic solid waste management programs funded at the Los Alamos Scientific Laboratory (LASL) by the Energy Research and Develpment Administration (ERDA) Division of Waste Management a Transportation (DWMT). Under the Transpleted evaluation of stainless steel drums showed that although the material has superior corrosion-resistant properties, its higher cost makes a thorough investigation of other container systems mandatory. A program to investigate more economical, nonmetallic containers is proposed. Preliminary fire tests in mild steel drums have been completed with fire propagation not appearing to be a problem unless container integrity is lost. Investigation of the corrosion of mild steel drums and the evaluation of potential corrosion inhibitors, in a variety of humid environments, continues. Experimental results of both laboratory and field investigations on radiolysis of transuranic elements in hydrogenous waste are discussed. Progress in the development of instrumentation for monitoring and segregating low-level wastes is described.

New plans and developments for the Transuranic-Contaminated Solid Waste Treatment Development Facility are presented. The current focus is on a comparison of all alternative waste reduction systems toward a relative Figure of Merit with universal application. Drawings, flowsheets, and building layouts are included, and the proposed incinerator device is detailed.

The release mechanisms, inter- and intraregional transport mechanisms, and exhumation studies relevant to the Evaluation of Transuranic-Contaminated Radioactive Waste Disposal Areas Program are defined and analyzed. A detailed description is given of the formulation of the computer simulation scheme for the intraregional biological transport model.

Environmental Science Group, 1990,
"Calibration of the CREAMS Model for Landfill Cover Designs Limiting Infiltration of Precipitation at Waste Repositories",
Hazardous Waste and Hazardous Materials, Volume 7, Number 2, pp. 169-184.

The water balance relationships of two shallow land burial (SLB) cover configurations were studied using a hydrologic model in an attempt to design waste disposal site covers for successful long-term closure at Los Alamos. Burial site performance requirements for site closure are discussed, along with the role of hydrology of the SLB cover. The calibration of a hydrologic model using field data from two SLB cover designs is then described, followed by evaluation of the influence of vegetation, precipitation, and runoff curve number on the design of the SLB covers at Los Alamos. Future directions of field research efforts and subsequent hydrologic modeling activities are recommended in terms of their usefulness for waste management decisions to be made at Los Alamos.

Environmental Studies Group, 1973,
Quarterly Report Transuranic Waste Research Development Program March-June 1973 and Annual Report FY 1973 Transuranic Contaminated Solid Waste Treatment Program,
LANL, LA-5451-PR.

This report reviews the progress during the period of March-June 1973 for the Transuranic Solid Waste Research and Development program and for FY 1973 for the Transuranic Contaminated Solid Waste Treatment Program. All of the solid waste management activities at LASL have been consolidated into one group, and research and development activities will now be reported in a single quarterly report. During this period, the Criteria for the Interim Storage of AEC-Generated Transuranic Wastes have progressed to a rough draft stage with initial review by DWMT. The experimental programs on corrosion, radiolysis, combustion, and leaching, designed to provide data for the criteria and for optimization of the storage procedures, have continued. The Conceptual Design Report for the Waste Volume Reduction Development Facility neared completion at the end of the year. Preliminary studies were made in evaluating the progress of the candidate processes to be used in this facility. These processes include incineration, molten salt combustion, pyrolysis, pressurized oxygen combustion, and acid digestion, all of which are under study by various laboratories of the AEC or commercial operations.

Environmental Studies Group, 1974,
Transuranic Solid Waste Management Research Programs: April-June 1974,
LANL, LA-5762-PR.

Progress is reported on the three transuranic solid waste management research programs funded by the AEC Division of Waste Management and Transportation. The report covers the period of April-June 1974. Corrosion of mild steel drums and effectiveness of potential corrosion inhibitors are under going continued investigation in a variety of humid environs. One 11-year-old waste container was opened and examined. Exterior corrosion was negligible but substantial interior corrosion had resulted from acid residues in the contained waste materials. Interesting results were obtained from radiolysis studies; total pressurization rate from radiolytic gases appears to diminish as total absolute pressure increases. Almost no Cl or HCL was detected in gas samples from radiolysis of chlorinated plastics. The reasons for these phenomea are being investigated. The Facility Design Criteria Report for the waste treatment development facility has been published and an architect-engineer selected for Title I design work. An incinerator was selected and ordered for prefacility testing with nonradioactive materials; it is anticipated that the same type incinerator will ultimately be installed in the facility.

A generalized structure for the environmental risk analysis has been defined so as to facilitate its application to disposal sites at LASL and elsewhere. The analytical methods allow for any degree of refinement, from rough approximations to quantitative detail; the methods also are adaptable to manual as well as computerized calculations. A variety of computer codes are being incorporated into the risk analysis to account for various transport mechanisms and distribution parameters. Atmospheric transport and inhalation dose codes are nearly complete; substantial work is still required on the hydrologic and biologic transport and the ingestion dose code.

Environmental Studies Group, 1974,
Transuranic Solid Waste Management Research Programs: January-March 1974,
LANL, LA-5666-PR.

The following report reviews the progress for three transuranic solid waste management research programs funded by the AEC Division of Waste Management and Transportation during the period of January-March 1974. The interim storage criteria have been redesigned as guidelines and will be issued as a Los Alamos Scientific Laboratory documents after incorporation of final revisions. Studies of corrosion of mild steel in humid air have shown that Zinic Chromate Underseal, Chemical and Water-Resistant Rustoleum Industrial Coating, and Rust Gard do not prevent corrosion. Analyses of the gaseous products of radiolysis of cellulosics contaminated with 1.2 mg 238-Pu/g waste matrix have shown hydrogen and carbon dioxide to be the major products. Waste production is being evaluated on an individual process basis, and flowsheets are being prepared to show material input and waste output for each plutonium handling process. The Transuranic Contaminated Solid Waste Treatment Development Facility has been redesigned to permit increased research ability and flexibility. The program to evaluate past burial practices has been redirected to empasize local burial areas. Fluid dynamics computer codes are being evaluated for use in soil transport, atmospheric dispersion, and resuspension models. Agricultural and population data are being obtained for the areas surrounding Los Alamos.

Environmental Studies Group, 1974,
Transuranic Solid Waste Management Research Programs: July-September 1973,
LANL, LA-5512-PR.

The following report reveiws the progress during the period of July-September 1973 for three transuranic solid waste management research programs funded by the AEC Division of Waste Management and Transportation. The three programs include transuranic solid waste management research and development, the contaminated waste treatment development facility, and the burial ground evaluation. The interim storage criteria are now ready to be issued for general review. Experiments in radiolysis and container corrosion have been reorganized and expanded to provide information for optimization of interim storage, while waste sorting experiments have begun to determine more accurately the character of wastes being produced at LASL. Several task forces have been organized for the waste treatment facility to evaluate incinerators and determine a satisfactory operational size for the facility. Work has begun on developing a model for the risk analysis of radioactive burial grounds. A questionaire has been developed to obtain the necessary information for the analysis.

Environmental Studies Group, 1974,
Transuranic Solid Waste Management Research Programs: October - December 1973,
LANL, LA-5614-PR.

The following report reviews the progress for three transuranic solid waste management research programs funded by the AEC Division of Waste Management and Transportation during the period of October - December 1973. The interim storage criteria, which were reviewed by AEC administrative and contractor personnel, will be revised and submitted to AEC Headquaters for further comment. The experimental conditions for the studies of corrosion in humid air have been revised to better simulate conditions expected in closed-pad storage. In addition to bare mild-steel and stainless-steel samples, mild-steel coupons coated with several rust-inhibiting compounds are being studied. Radiolysis studies of typical waste materials contaminated with Pu-238 have thus far produced between 0.56 and 41.01 kPa of gas per simulated year. Waste sorting studies are being used to evaluate the newly developed Multi-Energy Gamma Assay System (box counter). Incinerator type and design feed rate have been selected for the Transuranic-Contaminated Solid Waste Treatment Development Facility, and operational parameters selected. The risk analysis method to be used in the evaluation parameters has been described. Several parameters have been evaluated from literature sources, and equations to estimate organ doses have been derived. A radionuclide inventory of the Los Alamos Scientific Laboratory (LASL) disposal areas has been compiled.

Environmental Studies Group, 1976,
Transuranic Solid Waste Management Research Programs: January - June 1975,
LANL, LA-6264-PR.

Progress is reported for the transuranic solid waste management programs funded at the Los Alamos Scientific Laboratory by the Energy Research and Development Administration's Division of Nuclear Fuel Cycle and Production.

Under the Transuranic Waste Research and Development Program, tests continued to evaluate less costly fiber drums as alternative storage containers for low-level wastes. Tests completed to date indicate that the factory-applied fire retardants were not satisfactory; however, investigations of more promising coatings have been undertaken. The fiber drums were more satisfactory in other aspects. Expanded laboratory and field radiolysis experiments were performed. These were accompanied by investigations of H2 diffusion through common waste packaging materials and through Los Alamos soils. Radiolysis studies were also initiated on wastes typical of Mound Laboratory. All results to date show that while H2 is being slowly generated, the quantities are not excessive and should diffuse rapidly away.

Construction of the TDF facility began and was 14% complete at the end of this reporting period. The incinerator was received, installed and checked out, and is operational. Additional specifications were developed and equipment procurement continued.

Progress is reported on development of a system for evaluating radioactively contaminated solid waste burial sites. Source term data are summarized for some Los Alamos areas along with waste composition and configuration considerations. Physical and biotic transport pathways are discussed and development of modeling methods for projecting the environmental fate of transuranic materials is detailed.

Environmental Studies Group, 1976,
Transuranic Solid Waste Management: July - December 1975,
LANL, LA-6481-PR.

Progress is reported for three transuranic solid waste management programs funded at Los Alamos Scientific Laboratory (LASL) by the Energy Research and Development Administration (ERDA) Division of Fuel Cycle and Protection (NFCR).

Under the Transuranic Waste Research and Development Program, continued studies have shown the potential attractiveness of fiber drums as an acceptable substitute for the current mild steel storage containers. Various fire retardants have been evaluated, with one indicating significant ability to inhibit fire propagation. Continued radiolysis studies, under laboratory and field conditions, continue to reaffirm earlier LASL results indicating no significant hazard from radiolytic reactions reactions, assuming no change in current allowable loadings. Care must be exercised to differentiate between radiolytic and chemical reactions. Other efforts have identified a modification of chemical processing to reduce the amounts of plutonium requiring retrievable storage. Studies are also in progress to enhance the sensitivity of the LASL MEGAS assay system.

The Transuranic-Contaminated Solid Waste Treatment Development Facility building was 72% complete as of December 31, 1975, which is in accord with the existing schedule. Procurement of process components is also on schedule. Certain modifications to the facility have been made, and various pre-facility experiments on waste container handling and processing have been completed.

The program for the Evaluation of Transuranic-Contaminated Radioactive Waste Disposal Areas continued development of various computer modules for simulation of radionuclide transport within the biosphere. In addition, program staff contributed to an ERDA document on radioactive waste management through the prepartion of a report on burial of radioactive waste at ERDA-contractor and commercial sites.

Environmental Studies Group, 1977,
Development Activities on Shallow Land Disposal of Solid Radioactive Waste:
January-December 1976,
LANL, LA-6856-PR.

This report summarizes progress on projects focused on problems of shallow land burial of radioactively contaminated solid waste. Developments on a system to evaluate the containment adequacy of existing burial sites are described. Efforts to describe the environmental factors in monitoring the LASL disposal sites are discussed. The aim of a new program on radioactive waste burial technology is outlined.

Essington, E.H., et al., 1986,
Leaching of Solutes from Ion-Exchange Resins Buried in Bandelier Tuff,
LANL, LA-10707-MS.

Prediction of solute transport at shallow land burial facilities requires a knowledge of the rates of release of solutes (source term) from the buried wastes and of those processes affecting transport through surrounding media.

The leaching (removal) of lithium, strontium and cesium from a resin/tuff mixture (Bandelier Tuff) was conducted under unsaturated steady and unsteady conditions in both laboratory columns and large scale field caissons to approximate the conditions of buried contaminated-waste resins.

Lithium was leached most rapidly and strontium least rapidly. Stopping the flow for a period of 40 to 60 days to create drainage (unsteady flow) conditions had very little effect on the concentrations of solutes leached from the resin/tuff layer. Leaching of these solutes in laboratory columns simulated the large-scale (cassion) leaching very well. Thus, laboratory studies may be reasonable predictors of leaching under certain large-scale field conditions. Also, leaching appears to be a kinetics-controlled process that, for the experimental conditions of this study, may be represented by first-order kinetics.

Further work should concentrate on understanding the effect of environmental factors such as solute mixtures, concentrations, and temperature, as well as those mechanisms that control leaching of solutes. Also, the evaluation and development of alternative mathematical models for describing the source term are needed.

Essington, E.H., Polzer, W.L., and Fowler, E.B., 1983,
Estimation of Ionic Charges Associated with Radionuclides in Waste Burial Solutions,
LANL, LA-UR-83-1615.

Knowledge of the distribution of ionic species of radionuclides is important in the evaluation of the potential migration of radionuclides from waste burial trenches and for their interaction with the surrounding soil. That information can be of value in predicting the degree of sorption of the various species of radionuclides from the complex wastes by the medium through which the waste migrates.

The distribution of ionic species can be evaluated from charge distribution determinations using ion exchange resins. Usually in that method a sample of a solution is passed through cation and anion exchange resin columns; both the leachate and the resins are analyzed for the radionuclide. The charge distribution is based on the relative concentrations of the radionuclide in the various fractions. The procedures are well suited for stable non-labile radionuclide species of cesium and strontium. However, the labile species of plutonium and uranium can change in charge distribution as they interact with the resin.

Careful control of the exchange conditions is necessary for the proper seperation of plutonium and uranium charge species. For example, it is important to balance the pH of the effluent to that of the influent of a resin column in order not to change the distribution of the species in the resin column.

Fowler, E.B., Essington, E.H., and Polzer, W.L., 1979,
Interactions of Radioactive Wastes with Soils - A Review,
LANL, LA-UR-79-2910.

Four soils of different physical and chemical characteristics have been reacted in both the batch and column mode with two different radioactive wastes to determine the soil's degree of retention for waste radionuclides. Two of the soils are of the same type found at two commercial waste burial grounds. The raw and treated liquid wastes were obtained from the stream at a large laboratory complex.

Three fractions were demonstrated in each waste as (1) insoluble, (2) soluble and sorbabic by the soil, and (3) soluble but nonsorbable by the soil. Although the soluble fraction (<0.05 um) in both waste increased with storage time, that increase did not directly relate to the degree of retention by the soil.

Differences in degrees of retention for the same radionuclide were demonstrated among the soils. Retention of the same radionuclide from different wastes, but by the same soil, also differed.

Ninety-five to one hundred per cent of raw waste Cs-137 was retained by all soils. Plutonium isotopes and Am-241 were the least retained by the soils; uranium isotope retention was intermediate.

A Fuquay soil from South Carolina dissolved plutonium and americium from the insoluble fraction of the waste. The net retention of those two nuclides was negative, i.e., more plutonium was brought into solution than was sorbrd by the Fuquay soil.

Two of the factors that could influence the degree of retention by the soil was investigated. Those factors are (1) charge on the radionuclide in solution and (2) degree of calcium carbonate saturation.

All investigated radionuclides and their isotopes were predominately negatively charged within the pH range of about 4 to 12 with the exception of Cs-137; that isotope was positively charged at a pH value as low as 2. Theoretical calculations based on analytical data demonstrated a shift from negative to positive charge in the presence of soil. As a result, some fraction of the observed retention could occur through an ion exchange mechanism.

Calcium carbonate precipitates were shown, by autoradiographic techniques to occlude alpha emitting radionuclides. The degree of calcium carbonate saturation calculations showed that where sorption of plutonium and americium occurred, the liquid fraction was at or above saturation. In the case of the Fuquay soil, the liquid fraction was undersaturated with respect to calcium carbonate. Post precipitation of aluminum also removed radionuclides from solution. Removal of radionuclides by algal growth was demonstrated; however, biological mechanism are probably undesirable.

Removal of radionuclides from wastes by filtration of the insoluble fraction is an important mechanism in retention. Ion exchange and calcium carbonate precipitation will attenuate radionuclides and inhibit transport. Of the three fractions, the soluble nonsorbable fraction is of immediate importance because it has the greater potential for mobility.

Fowler, E.B., Essington, E.H., and Polzer, W.L., 1981,
"The Interactions of Low-Level Liquid Radioactive Wastes With Soils: 1. Behavior of Radionuclides in Soil-Waste Systems",
Soil Science, Vol. 132, No. 1, pp. 2-12.

The characteristics of radioactive wastes and soils vary over a wide range. Liquid radioactive waste entering the environment will eventually contact the soil geological matrix; interactions will be determined by the chemical and physical nature of the liquid, as well as the soil matrix. We report here the results from an investigation of certain of those characteristics as they relate to retention of radionuclides by soils. Three fractions were demonstrated in the waste as filterable, soluble-sorbable, and soluble-nonsorable; the physical nature of each fraction was demonstrated using autoradiographic techniques. Isotopes of plutonium and americium-241 in the soluble fraction of the waste were shown to have a negative charge as determined by ion exchange techniques. In the soil-waste systems, the net charge for those radionuclides was shown to change from predominantly negative to predominantly positive. Nevertheless, cesium-137 was shown to be predominantly positively charged. The change in charge and the redistribution of radionuclides among the various fractions is important in assessing the degree of mobility of radionuclides in soil.

Fowler, E.B., et al., 1973,
Transuranic Waste Research and Development Program,
LANL, LA-5281-MS.

This report reviews the progress of the Transuranic Waste Research and Development Program at the Los Alamos Scientific Labortaory for the period November 1, 1972 - March 1, 1973. The results of a survey of transuranic waste management practices at six major AEC installations indicated the wide variety of waste and waste handling practices in existence and the need for some uniformity in record keeping. Preliminary results of experimental studies on corrosion sources and mechanisms using 17C 55-gallon drums suggest that unrelieved stress may be a major contributor to the corrosion of the drum. Combustion studies of typical waste types demonstrated the production of large quantities of smoke and gases but failed to produce a flame at temperatures up to 450 degrees C. Leaching studies showed that plutonium is removed from the waste by water at a rate that decreases after the first few hours of contact. Progress on the development of an assay system to detect radioactive contaminants in very low concentrations in waste is reported.

Fowler, E.B., Polzer, W.L., and Essington, E.H., 1978,
Characteristics of Wastes and Soils Which Affect Transport of Radionuclides Through the Soil and Their Relationship to Waste Management,
LANL, LA-7311-PR.

Knowledge of the rate and degree of movement of radioactive nuclides through soil and geologic media is an important adjunct to the conduct of radioactive waste management. The Environmental Sciences Group of the Los Alamos Scientific Laboratory (LASL) is studying the interactions of various radioactive wastes with a wide variety of soils in order to establish a predictive range of radionuclide retention values to be used by the Nuclear Regulatory Commission (NRC) for the evaluation of waste handling, storage, and burial practices.

This report covers field and laboratory efforts for the period July 1976 through September 1977. During that period, a total of five large-volume soil samples were classified and collected from the eastern, central and western United States. Two radioactive liquid wastes were also collected at LASL.

Results of the laboratory studies on waste/soil interactions indicate that over the initial four-month period of waste storage no sorption of plutonium and only slight sorption of americium by soils occurred when they were interacted with a raw waste; about 50% of the soluble uranium was sorbed by the soils (the soluble fraction may contain particulates up to 0.05 um in diameter). An increase in the concentration of radionuclides in the soluble fraction occurred with increased time and storage.

In the case of the treated waste no increase in the concentration of plutonium was observed during the same time period. However, a change from no sorption by soils was observed for Pu-238. The waste and waste/soil solution were also characterized with respect to their chemical and physical properties.

Coordination of this project by LASL personnel with correlative projects at the University of California, Los Angeles; the University of California, Berkeley, and the Savannah River Ecology Laboratory, Savannah River, South Carolina, was accomplished through informational meetings. Projected future work includes continuation of present studies and extensions to include additional waste and soils. Column studies will be initiated to evaluate the mobility, per se, of radionuclides through soils.

Fowler, E.B., Polzer, W.L., and Essington, E.H., 1981,
Characteristics of Wastes and Soils Affecting Transport of Radionuclides Through the Soil and Their Relationship to Waste Management,
LANL, LA-8563-PR.

Investigations of waste/soil interactions have continued. Studies on the attenuation of plutonium species, uranium species, Am-241 and Cs-137 by four different soils for two different wastes have been completed.

The degree of attenuation for a specific radionuclide varies among soils. A specific soil attenuates different radionuclides to different degrees; Cs-137 is attenuated to the highest degree by all soils.

Soils from the Ap and A2 horizon of a South Carolina Fuquay soil when reacted with waste dissolve plutonium, americium, iron, and aluminum from the insoluble fraction of the waste. The dissolved plutonium and americium are not sorbed by the soil thus are potentially mobile and are considered to be complexed, possibly by an organic chelate from the soil metabolic pool.

When the degrees of sorption for horizon soils from Fuquay and Fayette soil profiles are compared, the ability to solubilize was found to be unique to the Fuquay Ap and A2. The lower horizons, B2t and C, of the Fuquay soil have a high sorptive capacity for all of the radionuclides studied.

Emphasis will be placed on a field study in FY '80 at the Maxey Flats, Kentucky shallow land burial site. Soil solution samples will be obtained at various depths and locations using porous cups. Soil will be obtained for analyses from the same locations. Sampling of the soil solutions will provide data relative to the presence and concentration of mobile radionuclides.

Dr. Fobert Schulz, University of California, Berkeley, will implant electric soil moisture sensors for the determination of soil moisture movement. Those data will be correlated with results from chemical, physical, and radiochemical analyses.

Hakonson, T.E., 1986,
Evaluation of Geologic Materials to Limit Biological Intrusion into Low-Level Radioactive Waste Disposal Sites,
LANL, LA-10286-MS.

This report describes the results of a three-year research program to evaluate the performance of selected soil and rock trench cap designs in limiting biological intrusion into simulated waste. The report is divided into three sections including a discussion of background material on biological interactions with waste site trench caps, a presentation of experimental data from field studies conducted at several scales, and a final section on the interpretation and limitations of the data including implications for the user.

In the first section the fact is established that the importance of biological processes, including plant root intrusion and animal burrowing, in contributing to radionuclide transport at low-level waste sites, cannot be dismissed out of hand. In fact, model simulations by others suggest that the biological processes may contribute significantly to dose-man compared to other transport pathways including percolation of leachates to groundwater. Despite emerging data on the relative importance of biological processes on waste site integrity, this report is not intended as an endorsement for or aganist the use of biointrusion barriers in trench cap designs. Rather, experimental evidence is presented and interpreted on barrier performance as a function of experimental scale, configuration, and a variety of extreme moisture conditions to identify operational limits should the use of a biointrusion barrier be deemed necessary.

Results of studies at several scales, ranging from 25-cm-diameter columns to 1560 squared meter field plots, demonstrated that a minimum of 75 cm of cobble covered with 25 cm gravel all covered with 60 cm of topsoil reduces plant root and animal intrusion through the cap profile over conventional design constructed of soil over crushed tuff. Plant root intrusion for the soil and rock cap designs was reduced by a factor of two to eight as evaluated by a simulated cesium waste. The field scale study, which was the final test of an optimized soil/rock cap design for Los Alamos conditions, revealed that both the conventional and soil/rock designs were preventing root intrusion after one growing seasonal. Unfortunately, the termination of the experiment precluded obtaining longer term data vital for a more rigorous evaluation of field performance.

An added benefit of using soil/rock trench cap design is the reduction in percolation afforded by the capillary barrier inherent in the cap design. Water percolating through the topsoil is impeded at the soil/rock interface due to the difference in hydraulic conductivities of the two materials. Only when the topsoil becomes saturated does percolation occur into and through the rock. The benefit of the capillary barrier inherent in the soil/rock cap designs is that water stored in the topsoil can be removed by evaporation and transpiration, thereby reducing the potential for percolation deeper in the profile.

The topsoil and plant cover placed over the rocks are critical components of the soil/rock intrusion barrier design since they function as the primary barrier to biointrusion and deep percolation. The CREAMS model, developed by the US Department of Agriculture has been applied to designing optium configurations of topsoil and plant storage to reduce erosion and percolation through the trench cap. While the soil and plant components serve as primary barriers to biological intrusion and deep percolation, rock material provides a secondary barrier should the primary components fail.

Several limitations on recommending the use of a soil/rock cap design are presented including the effect of time on barrier performance. Observation periods of less than two years on individual experiments leaves serious unanswered questions about the continued barrier performance over decade to century time scales. Attendant with the question of time scale are the uncertainties in barrier performance as plant and animal species change due to sucessional processes.

For arid sites, the probability seems high that the soil/rock design will perform over extended time scales when proper attention is given to all the important interrelationships between biological and physical processes acting on the cap. For example, if the cap is designed to manage soil water in topsoil over the rock barrier, then the probability of failure of the rock barrier in preventing biointrusion and percolation will be greatly reduced. Saturation of the topsoil, with resulting percolation through the rock, can result in greater percolation into deeper regions than that associated with a conventional cap design of soil and tuff.

Hakonson, T.E., 1987,
Trench Cover Systems for Manipulating Water Balance on Low-Level Radioactive Waste Site,
LANL, LA-UR-87-1971.

This paper discusses the results of Los Alamos National Laboratory's research to measure, model and manipulate water balance on low-level radioactive waste sites. Results from this study indicate that a light covering of gravel (60-70% cover, one stone thick), a gentle slope (<1) and a dense cover of native grasses (70-80%) effectively eliminated runoff and erosion over a three year period despite the occurrence of several intense rainstorms. Likewise, the use of a combination capillary wick-biotrusion barrier reduced percolation by a factor of 5-6 over the conventional cover design and diverted a significant amount of percolating water laterally, reducing the amount of deep percolation. The cobble component of the rock barrier also completely prevented plant root intrusion through the cover into simulated waste.

A secondary, an important, benefit of the capillary barrier is the influence it has on plant growth. The retention of moisture in the soil above the barrier caused an increased of a factor of 2-3 in plant biomass. Since leaf area is correlated with biomass for many species, transpiration would be expected to be higher too. Higher transpiration is evident in the modifieo cover design because of the lower water content of the soil following moisture input. Of course, the drier the soil is, the greater the capacity to absorb incoming precipitation.

Hakonson, T.E., and Gladney, E.S., 1982,
"Biological Intrusion of Low-Level Waste Trench Covers", The Scientific Basis For Nuclear Waste Management,
Elsevier Science Publishing Company, Incorporated, pp. 519-523.

The long-term integrity of low-level waste shallow land burial sites is dependent on the interaction of physical, chemical, and biological factors that modify the waste containment system. Past research on low-level waste shallow land burial methods has emphasized physical (i.e., water infiltration, soil erosion) and chemical (radionuclide leaching) processes that can cause waste site failure and subsequent radionuclide transport.

The purpose of this paper is to demonstrate the need to consider biological processes as being potentially important in reducing the integrity of waste burial site cover treatments. Plants and animals not only can transport radionuclides to the ground surface via root systems and soil excavated from the cover profile by animal burrowing activities, but they modify physical and chemical processes within the cover profile by changing the water infilteration rates, soil erosion rates and chemical composition of the soil.

One approach to limiting biological intrusion through the waste cover is to apply a barrier within the profile to limit root and animal penetration with depth. Experiments in the Los Alamos Experimental Engineered Test Facility were initiated to develop and evaluate biological barriers that are effective in minimizing intrusion into waste trenches. The experiments that are described employ four different candidate barrier materials of geologic origin. Experimental variables that will be evaluated, in addition to barrier type, are barrier depth and soil overburden depth. The rate of biological intrusion through the various barrier materials is being evaluated through the use of activatable stable tracers.

Hakonson, T.E., Cline, J.F., and Rickard, W.H., 1982, "Biological Intrusion Barriers For Large Volume Waste Disposal Sites", Low-Level Waste Disposal; Facility Design, Construction and Operating Practices., U.S. DOE, NUREG/CP-0028, pp. 289-308.

Intrusion of plants and animals into shallow land burial sites with subsequent mobilization of toxic and radiotoxic materials has occurred. Based on recent pathway modeling studies, such intrusions can contribute to the dose received by man. This paper describes past work on developing biological intrusion barrier systems for application to large volume waste site stabilization. State-of-the-art concepts employing rock and chemical barriers are discussed relative to long term serviceability and cost of application. The interaction of bio-intrusion barrier systems with other processes affecting trench cover stability are discussed to ensure that trench cover designs minimize the potential dose to man.

Hakonson, T.E., et al., 1982,
Remedial Action Technology-Arid,
LANL, LA-UR-82-2534.

A summary is presented of the low-level waste remedial action program at Los Alamos. The experimental design and progress is described for the experiments on second generation intrusion barriers, subsidence effects on SLB components, moisture cycling effects on chemical transport, and erosion control methodologies.

The soil moisture data from bio-intrusion and moisture cycling experiments both demonstrate the overwhelming importance of vegetation in minimizing infiltration of water through trench covers and backfill. Evaporation, as water loss component in trench covers, is only effective in reducing soil moisture within 40 cm of the trench cover surface. Moisture infiltrating past the zone of evaporation in unvegetated or poorly vegetated trench covers is in storage and accumulates until drainage out of the soil profile occurs. Judicious selection of vegetation species for revegetating a low level waste site may prevent infiltration of moisture into the trench and, when coupled with other design features (i.e. trench cover slope, tilling and seeding practice), may greatly reduce problems with erosion.

Standard U.S. Department of Agriculture erosion plots, when coupled with a state-of-the-art water balance and erosion model (CREAMS) promises to be highly useful in screening proposed remedial action cover designs for low-level waste sites. The erosion plot configuration allows for complete accounting of the water balance in a soil profile. This features enables the user to optimize cover designs to minimize erosion and infiltration of water into the trench.

Hansen, W.R., and Rodgers, J.C., 1983,
"Risk Analyses for Shallow Land Burial and Greater Confinement of Alpha-Contaminated Wastes",
Nuclear and Chemical Waste Management, Vol. 4, pp. 81-94.

To evaluate the possible disposal techniques for Los Alamos stored and buried TRU wastes, several risk scenarios are analyzed. For several inactive waste areas, intrusion scenarios are summarized from previous work. The effect of deeper burial reduces the number of scenarios for intrusion by man, eliminates intrusion by biotic communities, and reduces concerns for surface erosion. However, transport of uranium and neptunium daughter products of plutonium isotopes to groundwater could occur in approximately one million years. This latter pathway needs further calculational refinement to narrow the uncertainties in time estimates and adsorption characteristics of the involved geological media at Los Alamos. At sites with high rainfall or water tables located close to buried wastes, an analysis of the transport of daughter products from decay of transuranic elements should be performed.

Healy, J.W., and Rodgers, J.C., 1979,
Limits for the Burial of the Department of Energy Transuranic Wastes,
LANL, LA-UR-79-100.

Potential limits for the shallow earth burial of transuranic elements were examined by simplified models of the individual pathways to man. Pathways examined included transport to surface streams, transport to ground water, intrusion, and people living on the burial ground area after the wastes have surfaced. Limits are derived for each pathway and operational limits are suggested based upon a dose to the organ receiving the maximum dose rate of 0.5 rem/y after 70 years of exposure for the maximum exposed individual.

Healy, J.W., et al., 1972,
Transuranic Waste Repository Studies,
LANL, LA-5127-MS, Vol. 1.

This report reviews the progress of the Los Alamos Scientific Laboratory's effort related to the Transuranic Waste Repositories studies for the period July 1-November 1, 1972. Literature values reporting thermal and radiolytic degradation of certain wastes, and waste storage problems related to products of degradation are discussed. Preliminary data on the chemical characterization of several waste types and their implications in storage of transuranic wastes are reported. The rational for screening stations and monitoring of large volumes of solid waste is developed as well as preliminary radiological consideration for the twenty year storage of transuranic waste. Dose rates and heat loads are probably of small concern with Pu-241 a possible exception, however, package integrity (under shallow earth burial) poses serious problems which are being investigated.

Johnson, L.J., 1980,
Los Alamos Scientific Laboratory Waste Management Technology Development Activities: Summary Progress Report 1979,
LANL, LA-8243-PR.

Summary reports on the Department of Energy's Nuclear Energy-sponsored waste management technology development projects at the Los Alamos Scientific Laboratory describe progress for calendar year 1979. Activities in airborne, low-level, and transuranic waste management areas are discussed. Work progress on waste assay, treatment, disposal, and environmental monitoring are reviewed.

Johnson, L.J., and Desilets, B.H., 1979,
Nuclear Waste Management Technology Development Activities: January - December 1978,
LANL, LA-7921-PR.

Summary reports describe progress in Los Alamos Scientific Laboratory (LASL) Health Research Division managed programs by the nuclear waste management task area for calendar year (CY) 1978. Development and application of assay instrumentation for measuring radioactivity content of waste packages is reported. Work in developing test materials and laser-based instrumentation for in-place testing of high-efficiency particulate aerosol filters is discussed. Development and demonstration of a controlled air incinerator for treatment of radioactively contaminated combustible waste is described. Field data from the environmental geology and hydrology aspect of shallow earth disposal of radioactively contaminated waste are reviewed and related to improvements of land burial technology.

Johnson, L.J., and Lewis, H.M., 1978,
Nuclear Waste Management Technology Development Program: January-December 1977,
LANL, LA-7501-PR.

Summary reports describe progress by nuclear waste mangement task area for calendar year 1977. Development and demonstration of a controlled air incinerator for treatment of radioactively contaminated combustible waste is described. Development and application of assay instrumentation for measuring the radioactivity content of waste packages is reported. Work in developing test materials and laser-based instrumentation for inplace testing of high-efficiency particulate aerosol filters is discussed. Field data from the environmental geology and hydrology aspect of shallow earth disposal of radioactively contaminated waste are reviewed and related to improvement of land burial technology.

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.

Burial of solid radioactive waste began at Los Alamos, N. Mex. in 1943. Most of this waste contained a low level of radioactivity; consequently, only limited monitoring of the hydrogeologic environment has been done in the past. This study was based on a file-and-literature search in order to determine the effectiveness of these monitoring activities.

Insufficient data are available to design an effective monitoring program at the present time. Various geologic and hydrologic parameters need to be defined more accurately if an effective system of monitoring is to be designed.

Kosiewicz, S., et al., 1979,
Studies of Transuranic Waste Storage Under Conditions Expected in the Waste Isolation Pilot Project (WIPP),
LANL, LA-7582-PR.

This is the fourth quarterly report describing progress in an experimental program to determine the effects of radiolytic, thermal, and catalyzed pyrolytic degradation of various forms of existing or proposed transuranic (TRU) wastes. Thermal degradation of paper and composite (35% cellulosics, 23% polyethylene, 12% polyvinyl chloride, 15% neoprene, and 15% Hypalon) at 70 and 100 degrees celcius is occurring. Some radiolytic gas evolution appears to be occurring at a dose of 4 x 10 to the fifth nCi/g. The rates of sludge dewatering at 25, 40, 70, and 100 degrees celcius have been determined. Several high-pressure (1.5 x 10 to the fourth kPa, or 150 atm) experiments are in progress. In addition, an assessment of Los Alamos Scientific Laboratory (LASL) retrievably stored TRU waste for the calendar years 1971 to 1977 is in progress. The total volume of TRU waste stored at LASL during these years is 1589 meter cubed, or about 3.5% of the national Department of Energy total. Progress is reported for the first quarter of the project designed to assess potential microbial interaction with plutonium and other transuranics in low-level radioactive waste as it is expected to occur in the Waste Isolation Pilot Project (WIPP). In the two months this project has been funded, we have compiled an extensive body of pertinent literature, ordered and received equipment and laboratory expendables, initiated the enumeration, isolation, and identification of bacteria performed the abiotic alkylation of a heavy metal (mercury) and identified the methylated product in preparation for subsequent abiotic and biological alkylation reaction of europium and plutonium.

Kosiewicz, S.T., Barraclough, B., and Zerwekh, A., 1979,
Studies of Transuranic Waste Storage Under Conditions Expected in the Waste Isolation Pilot Plant (WIPP),
LANL, LA-7649-PR.

This is the fifth quarterly report describing progress in an experimental program to determine the effects of radiolytic, thermal and catalyzed pyrolytic degradation of various forms of existing or proposed transuranic contaminated wastes. Preliminary data appear to indicate that G(gas) is dose-rate independent. The rate of evolution of radiolytically generated gases decreases with increasing exposure time. More gas is evolved by radiolysis at 70 degrees celsius than at 20 degrees celsius. A summary of other work on alpha radiolysis of organics is provided. The rates of cement paste dewatering have been determined at 40 and 100 degrees celsius. Characterization of (1) waste types, (2) waste containers, and (3) radionuclide occurrences are presented in detail in the Los Alamos Scientific Laboratory TRU waste inventory assessment.

Nelson, D.C., and West, J.L., 1980,
Contamination Control Demonstration for Radioactive Pipeline Decommissioning,
LANL, LA-UR-80-1210.

The inside surface of vitrified clay tile was coated with ultraviolet powder to simulate radioactive contamination. The tile was then filled with different materials to evaluate their effectiveness for confining contamination during decommissioning operations. The test materials were roofing asphalt, road asphalt mixed with kerosene and latex, and thermosetting foam. Each of the materials tested showed a substantial improvement over the reference case where no material was used to confine the contamination.

Nyhan, J.W., 1989,
Development of Technology for the Long-Term Stabilization and Closure of Shallow Land Burial Sites in Semiarid Environments,
LANL, LA-11283-MS.

The eight-year field research program involving the development of technology for the closure and stabilization of shallow land burial (SLB) sites is described. Results of field testing of biointrusion barriers at active waste disposal areas at Los Alamos and Los Alamos Experimental Engineered Test Facility (EETF) are reported. Field experiments performed in 6-m-deep cassions with a diameter of 3 m at the EETF are described in which performances of migration capillary barriers were tested. Finally, the results of model verification and validation efforts associated with hydrologic and chemical trasport processes in the field experiments are described.

Nyhan, J.W., and Abeele, W.V., 1983,
Corrective Measures Technology Program: Arid Sites Used for the Shallow Land Burial of Low-Level Radioactive Wastes,
LANL, LA-UR-83-2870.

The overall purpose of the Los Alamos part of Corrective Measures Technology task of the National Low-Level Waste Management Program (NLLWMP) is to develop and test methods that can be used to correct any actual or anticipated problems with new and existing SLB sites in arid environment.The approach taken in developing remedial action technology for low-level waste sites is to recognize that physical and biological processess affecting site integrity are interdependent, and therefore, cannot be treated as seperate problems.

Specifically, the research performed for this task will continue to identify, evaluate and model erosion control technologies, field test second generation biointrusion barriers, determine by field experiments the extent of upward radionuclide migration due to moisture cycling, and measure the effects of subsidence on remedial action or other system components. The CREAMS model, (A Field Scale Model for Chemicals, Runoff, and Erosion from Agricultural Management Systems) is being used to model the surface processes and will be validated for soil profiles typical of that in SLB facilities.

Nyhan, J.W., and Barnes, F., 1989,
Development of a Prototype Plan for the Effective Closure of a Waste Disposal Site in Los Alamos, New Mexico,
LANL, LA-11282-MS.

The purpose of this study was to develop a prototype plan for the effective closure and stabilization of a semiarid low-level waste disposal site. This prototype plan will provide demonstrated closure techniques for a trench in a disposal site research both at the Los Alamos Experimental Engineered Test Facility (EETF), and at a waste disposal area at Los Alamos.

The accuracy of modeling soil water storage by two hydrologic models was tested by comparing simulation results with field measurements of soil moisture in eight experimental landfill cover systems at Waste Disposal Area B having a range of well-defined soil profiles and vegetative covers. Regression analysis showed that one of the two models tested represented soil moisture more accurately than the second model.

The accuracy of modeling all of the parameters of the water balance equation was then evaluated using field data from the Integrated Systems Demonstrated plots at EETF. Optimized parameters were developed for one model to describe observed values of deep percolation, evapotranspiration, and runoff from the field plots containing an SLB trench cap configuration.

Precautions for determining parameter values for model input and for interpreting simulation results are discussed. Several examples are presented showing how the field-validated hydrologic models developed in this endeavor can be used to develop a final research efforts and subsequent hydrologic modeling activities are recommended in terms of their usefulness for waste management decisions to be made at Los Alamos.

Nyhan, J.W., and Barnes, F.J., 1987,
"Development of an Arid Site Closure Plan", Proceedings of the Ninth Annual DOE Low-Level Radioactive Waste Management Conference,
EG & G Idaho, pp. 21.

The purpose of this task is to develop a prototype plan for the effective closure and stabilization of an arid low-level waste disposal site. This prototype plan will provide demonstration closure techniques for a trench in a disposal site at Los Alamos based on previous NLLWMP-sponsored SLB field research both at Los Alamos Experimental Engineered Test Facility, and at two waste disposal areas at Los Alamos.

The accuracy of modeling soil water storage by two hydrologic models. CREAMS and HELP, was tested by comparing simulation results with field measurements of soil moisture in eight experimental landfill cover systems having a range of well-defined soil profiles and vegetative covers. Regression analysis showed that CREAMS generally represented soil moisture more accurately than HELP simulations.

Precautions for determing parameter values for model input and for interpreting simulation results are discussed. A specific example is presented showing how the field-validated hydrologic models developed in this endeavor can be used to develop a final prototype closure plan.

Nyhan, J.W., and Lane, L.J., 1986,
Erosion Control Technology: A User's Guide to the Use of the Universal Soil Loss Equation at Waste Burial Facilities,
LANL, LA-10262-M.

The Universal Soil Loss Equation (USLE) enables the operators of shallow land burial sites to predict the average rate of soil erosion for each feasible alternative combination of plant cover and land mangement practices in association with a specified soil type, rainfall pattern, and topography. The equation groups the numerous parameters that influence erosion rate under six major factors, whose site-specific values can be expressed numerically. Over a half century of erosion research in the agricultural community has supplied information from which approximate USLE factor values can be obtained for shallow land burial sites throughout the United States. Tables and charts presented in this report make this information readily available for field use.

Extensions and limitations of the USLE to shallow land burial systems in the West are discussed, followed by a detailed description of the erosion plot research performed by the nuclear waste management community at Los Alamos, New Mexico. Example applications of the USLE at shallow land burial sites are described and recommendations for applications of these erosion control technologies are discussed.

Nyhan, J.W., Drennon, B., and Hakonson, T., 1989,
Field Evaluation of Two Shallow Land Burial Trench Cap Designs for Long-Term Stabilization and Closure of Waste Repositories at Los Alamos, New Mexico,
LANL, LA-11281-MS.

The results from several field experiments on methods to control soil erosion, biointrusion and water infiltration were used to design and test a burial site cover which improves the ability of the disposal site to isolate the wastes. The performance of the improved cover design in managing water and biota at the disposal site was compared for three years with that obtained from a more conventional design widely used in the industry. The conventional trench cover design consists of 15 cm of sandy loam topsoil over 75 cm of sandy silt back-fill, whereas the improved trench cover design consists of 75 cm of topsoil over a minimum of 25 cm of gravel and 90 cm of river cobble.Each plot was lined with an impermable liner to allow for mass balance calculation of water dynamics and contains hydrologic tracer ions (iodide and bromide) to demonstrate movement of water through the various zones of the trench cap. Cesium was emplaced beneath the trench cap to indicate root penetration through the trench cap, observed by sampling plant samples collected on the plots and assaying them for cesium.

The field data are finally summarized and discussed in terms of its usefulness for waste management decisions to be made in the future for both new and existing landfills at Los Alamos and at other semiarid waste disposal sites.

Nyhan, J.W., et al., 1982,
"Use of USLE Plots to Evaluate Management Alternatives for Trench Caps Used to Cover Low Level Radioactive Wastes at Los Alamos.",
Agronomy Abstracts, 1982 Annual Meetings, p. 35.

A joint study was made by the Los Alamos National Laboratory and USDA-ARS to examine soil erosion and water balance relationships for a simulated trench cap, similar to that used for the shallow land burial of low level radioactive wastes at Los Alamos. A 67 x 15 m trench cap with a 7% slope was first constructed with 15 cm of topsoil overlying 91 cm of crushed tuff backfill, and then eight 3.05 x 10.7 m USLE plots were installed. Each plot was equipped with three 1.8 m-deep neutron moisture gauge access tubes and bare soil, tilled and vegetated surface treatments applied to the plots. A rotating boom rain simulator was then used in an effort to determine the soil erodibility and cover management factors of the USLE for this trench cap. Water balance relationships were determined simultaneously on each plot using a neutron moisture gauge to obtain evapotranspitation and percolation estimates and flume to obtain runoff estimates. The implications of the results of this study are discussed relative to management alternatives for low level waste disposal.

Nyhan, J.W., et al., 1984,
"Development of Corrective Measures Technology for Shallow Land Burial Facilities at Arid Sites", Proceedings of the Sixth Annual Participants' Information Meeting DOE Low-Level Waste Management Program, EG&G Idaho, Inc., DOE Contract # DE-AC07-76ID01570, pp. 277-300.

The field research program involving corrective measure technologies for arid shallow land burial sites is described. Soil erosion and infiltration of water into a simulated trench cap with various surface treatments was measured and compared with similar data from agricultural systems across the United States. Field testing of biointrusion barriers at closed-out waste disposal sites at Los Alamos and in the experimental clusters are reported. The final results of an experiment designed to measure the extent of contaminant transport to the surface of a SLB facility, and the influence of plants on this relationship, are presented. An experiment designed to determine the effects of subsidence on the performance of a cobble-gravel biobarrier system is described and current field data are presented.

Nyhan, J.W., et al., 1984,
"Erosion of Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico",
J. Environ. Qual., Vol.13, No. 3, pp. 361-366.

The Los Alamos National Laboratory and the USDA-ARS examined soil erosion and water balance relationships for a trench cap used for the shallow land burial of low-level radioactive wastes at Los Alamos, NM. Eight 3.05 by 10.7 m plots were installed with bare soil, tiled, and vegetated surface treatments on a 15 by 63 m trench cap constructed from soil and crushed tuff layers. A rotating boom rain simulator was used to estimate soil erodibility and cover-management factors of the Universal Soil Loss Equation (USLE) for this trench cap and for two undisturbed plots with natural vegetative cover. The implications of the results of this study are discussed relative to management of infiltration and erosion processes at waste burial sites and compared with similar USDA research performed throughout the USA.

Nyhan, J.W., et al., 1985,
Development of Technology for the Design of Shallow Land Burial Facilities at Arid Sites,
LANL, LA-UR-85-3278.

The Los Alamos field research program involving technology development for arid shallow land burial sites is described. Field data are presented for an integrated field experiment, which was designed to test individual SLB component experiments related to erosion control, biobarriers and subsurface capillary and migration barriers. Field tests of biointrusion barriers at waste disposal sites and experimental plots are reported. The results of a joint DOE/NRC experiment to evaluate leaching and transport of sorbing (Cs, Sr, Li) and nonsorbing (I, Br) solutes in sandy silt backfill are presented for steady state flow conditions. A capillary barrier experiment performed in a large cassion (3 m diameter, 6.1 m deep) is described and year's worth of field data is presented.

Nyhan, J.W., et al., 1986,
Technology Development for the Design of Waste Repositories at Arid Sites: Field Studies of Biointrusion and Capillary Barriers,
LANL, LA-10574-MS.

The field research program involving the development of technology for arid shallow land burial (SLB) sites is described. Results of the field testing of biointrusion barriers installed at an active low-level radioactive waste disposal site (Area G) at Los Alamos are presented. A second experiment was designed to test the ability of a capillary barrier to effectively convey water infiltrating a SLB trench around and away from underlying buried wastes. The performance of the capillary barrier was tested in the field for a barrier of known thickness (2m), slope (10%), and slope length (2m), and for one combination of porous materials [a crushed tuff-clay (2% w/w) mixture overlying Ottawa sand] subjected to a known water addition rate. The waste management implications of both studies are also discussed.

Nyhan, J.W., et al., 1989,
Development of Corrective Measures Technologies for the Long-Term Stabilization of Shallow Land burial Sites in Semiarid Environments,
LANL, LA-10778-MS.

The five-year field research program involving corrective measures technologies for semiarid shallow land burial (SLB) sites is described. Soil erosion and infiltration of water into a simulated trench cap with various surface treatments were measured and compared with similar data from agricultural systems across the United States. Results of field testing of biointrusion barriers at closed-out waste disposal sites at Los Alamos and in experimental clusters are reported. The final results of an experiment designed to measure the extent of contaminant transport of the surface of an SLB facility and the influences of plants on this relationship are presented. An experiment designed to determine the effects of subsidence on the performance of a cobble/gravel biobarrier system is described and current field data are presented.

Nyhan, J.W., Hakonson, T.E., and Lopez, E.A., 1986,
Corrective Measures Technology for Shallow Land Burial at Arid Sites: Field Studies of Biointrusion Barriers and Erosion Control,
LANL, LA-10573-MS.

The field research program involving corrective measures technologies for arid shallow land burial (SLB) sites is described. Results of field testing of a bio-intrusion barrier installed at a close-out waste disposal site (Area B) at Los Alamos are presented.Soil erosion and infiltration of water into simulated trench cap with various surface treatments were measured, and the interaction between erosion control and subsurface water dynamics is discussed relative to waste management.

The monitoring study designed for Area B addressed two questions: 1) Does the cobble-gravel biointrusion barrier-cap design perform any better than the soil-crushed tuff cap (control cap design) at field scale, under natural precipitation regimes and native grass cover? 2) Does the cobble-gravel trench-cap design act as a capillary barrier to percolating water?

The major results from the monitoring study at Area B can be summarized as follows: 1) both cap designs (cobble-gravel design and soil/crushed tuff design) prevented plant root intrusion to the simulated waste underlying the caps, 2) snowmelt dominated rainfall in soil water recharge and led to all the observed incidences of percolation into the backfill underlying the cap designs, 3)The cobble-gravel barrier system appeared to function as a capillary barrier that resulted in a lower incidence of percolation and in lower soil moisture in the backfill under the cap than in the backfill under the soil/tuff design and 4) Evapotranspiration effectively prevented percolation into backfill during summer months regardless of cap design.

Perkins, B.L., 1982,
Disposal of Liquid Radioactive Waste Through Wells or Shafts,
LANL, LA-9142-MS.

This report describes disposal of liquids and, in some cases, suitable solids and/or entrapped gases, through (1) well injection into deep permeable strata, bounded by impermeable layers, (2) grout injection into an impermeable host rock forming fractures in which the waste solidifies, and (3) slurrying into excavated subsurface cavities.

Radioactive materials are presently being disposed of worldwide using all three techniques. However, it would appear that if the techniques were verified as posing minimum hazards to the environment and suitable site-specific host rock were identified, these disposal techniques could be more widely used.

Perkins, B.L., 1982,
Evaluation of Environmental Control Technologies for Commercial Nuclear Fuel Conversion (UF6) Facilities,
LANL, LA-9397-MS.

At present in the United States, there are two commercial conversion facilities. These facilities uranium concentrate into UF6 for shipment to the enrichment facilities. One conversion facility uses a "dry" hydrofluor process, whereas the other facility uses a process known as the "wet solvent extraction-fluorination" process. Because of the different processes used in the two plants, waste characteristics, quantities, and treatment practices differ at each facility. Wastes and effluent streams contain impurities found in the concentrate (such as uranium daughters, vanadium, molybdenum, selenium, arsenic, and ammonia) and process chemicals used in the circuit (including fluorine nitrogen, and hydrogen), as well as small quantities of uranium. Studies of suitable disposal options for the solid wastes and sludges generated at the facilities and the long-term effects of emissions to the ambient environment are needed.

Perkins, B.L., 1983,
Evaluation of Environmental Control Technologies for Commercial Uranium Nuclear Fuel Fabrication Facilities,
LANL, LA-9398-MS.

At present in the United States, there are seven commerical light-water reactor fuel fabrication facilities. Effluent wastes from these facilities include uranium, nitrogen, fluorine, and organic-containing compounds. These effluents may be either discharges to the ambient environment, treated and recycled internally, stored or disposed of off-site, sent off site for treatment and/or recovery, or sent off-site for disposal (including disposal in low-level waste burial sites). Quantities of wastes generated and treatment techniques vary greatly depending on the facility and the circuits used internally at the f acility, though in general all of the fluorine entering the facility as UF6 is discharged as waste. Further studies to determine techniques and procedures that might minimize dose (ALARA) and to give data on possible long-term effects of effluent discharge and waste disposal are needed.

Rodgers, J.C., and Hansen, W.R., 1982,
On the Feasibility of Various Disposal Techniques for Selected Los Alamos Store and Buried TRU Wastes,
LANL, LA-UR-82-3071.

To evaluate the possible disposal techniques for Los Alamos stored and buried wastes, several risks scenarios are analyzed. For several inactive waste areas, intrusion scenarios are summarized from previous work. The effect of deeper burial reduces the number of scenarios for intrusion by man, eliminates intrusion by biotic communities, and reduces concerns for surface erosion. Transport of uranium and neptunium daughter products of plutonium isotopes to ground water could occur in approximately one million years. This later pathway needs further calculational refinement to narrow the uncertainties in time estimates and adsorption characteristics of the involved geological media.

Walker, L.J., et al., 1981,
Alternative Transuranic Waste Management Strategies at Los Alamos National Laboratory,
LANL, LA-8982-MS.

As an integralpart of the ongoing U.S. Department of Energy (DOE) waste management programs, several strategies have been identified and evaluated for the long-term management of defense transuranic (TRU) waste now buried or stored at the Los Alamos National Laboratory. The 14 alternatives evaluated are combinations of the following operations: (1) Continue present practices (CPP), (2) Engineered improvements (EI), (3) Exhume the buried waste and retrieve the stored waste, (4) Segregate the TRU from the low-level (LL) wastes with reburial of the LL wastes, (5) Resize and package the TRU wastes, (6) Process the TRU wastes, and disposal either by (7) Burial in a deeper pit or pits at Los Alamos, or (8) Emplacement in a federally owned deep geological repository.

TRU wastes are located in six waste disposal areas with an estimated volume of wastes, backfill materials and projected accumulations to the year 1990 totalling approximately 330,000 cubic meters (12,000,000 cubic feet).

Estimated cost in dollars, environmental, radiological and other impacts are generally proportional to the amount of handling, processing, transportation over the short term (15 yr), and the institutional control period (100 yr). Possible long-term impacts, over several thousands of years, are dependent upon the possible uses of the disposal site lands over these prolonged time periods. The higher estimates of impacts relate to urbanization and commercial uses and the lower estimatesstem from agricultural and undeveloped land uses. Man-caused changes in erosion produce the greatest long-term contact possibility of waste by humans and release of waste to the biosphere.

This document provides the public and goverment agencies with possible alternative waste management strategies and serve as the basis for discussion and comment.

Warren, J.L., and Zerwekh, A., 1985,
TRU Waste-Sampling Program,
LANL, LA-10479-MS.

As part of a TRU waste-sampling program, Los Alamos National Laboratory retrived and examined 44 drums of 238-PU and 239-Pu-contaminated waste. The drums ranged in age from 8 months to 9 years.

The majority of drums were tested for pressure, and gas samples withdrawn from the drums were analyzed by a mass spectrometer. Real-time radiography and visual examinations were used to determine both void volumes and waste content. Drum walls were measured for deterioration, and selected drum contents were reassayed for comparison with original assays and WIPP criteria.

Each drum test at atmospheric pressure. Mass spectrometry revealed no problem with 239-Pu contaminated waste, but three 8-month-old drums of 238-Pu-contaminated waste contained a potentially hazardous gas mixture. Void volumes fell with in the 81-97% range. Measurements of drum walls showed no significant corrosion or deterioration. All reassayed contents were within WIPP waste acceptance criteria.

Five of the drums opened and examined (15%) could not be certified as packaged. Three contained free liquids, one had corrosive materials, and one had too much unstabilized particulate. Eleven drums had the wrong (or not the most appropriate) waste code. In many cases, disposal volumes had been inefficiently used.

WESTON, 1986,
Surface Geophysical Investigations Ultilizing Magnetometry and Ground Penetrating at Area F, Technical Area 6,
WESTON, Inc., Report to Los Alamos National Laboratory.

This report documents the geophysical survey activities conducted by Roy F. Weston, Inc. at the Los Alamos National Laboratory Facility, Los Alamos, New Mexico. The investigation was centered around the location of the Site F waste disposal area. It was suspected that specific areas within Site F were underlain by trenches containing waste materials. It was the desire of Los Alamos to locate and map possible subsurface waste areas based on the anomalies detected using geophysical sensing techniques. The geophysical field survey activities were conducted by WESTON betwenn 16 and 19 June 1986 at the direction of the Los Alamos environmental group.

The geophysical survey completed at Site F at Los Alamos has identified several suspect areas where the burial of waste material may have occurred in the past. Suspect areas are those areas where identified anomalies cannot be explained by known site subsurface features such as foundations or buried utilities. Areas showing correlation between magnetic anomalies and the location the sink hole area and the metal standpipe area. These areas should be considered of special interest because they may contain metal objects. Two strong subsurface anomalies were identified by GPR with no magnetic anomalies.

The results of this survey indicate thet surface geophysics is a useful technology for investigating sites similar to Site F where waste may have been buried in the past and where surface indicators and background information are lacking. Geophysical data is most useful when correlated to historical records, aerial photographs and direct physical data obtained by selective test pits and soil borings.

Wheeler, M.L., and Smith, W.J., II, 1975,
"Considerations for the Long-Term: Perpetual is not Forever",
Unknown, pp. 13-30.

Shallow land burial is intened to provide a waste emplacement with low probability for the release of radionuclides to the environment, and to provide a barrier aganist encroachment on the waste by man or his activities. Additionally, the emplacement conditions are designed to insure that a potential release cannot result in unacceptable radionuclide concentrations in man's environment. Site control requirements are intended to prevent unacceptable use or accidental excavation of the waste disposal site. Evaluation procedures generally provide definition of the contaminant capability of the site under present environmental conditions. Long-term care requirements can continue site control measures, and provide a continuing check on the containment capability. However, significant changes in climate, hydrology, plant cover and land use which might alter the containment potential can occur in a time frame of tens to hundreds of years, and true "perpetual" care cannot be guaranteed. This paper considers the possible long-term consequences of radionuclide uptake by plants and burrowing animals, of changes in site hydrology, and of inadvertent excavation of the buried waste by man at some distant future date.

Wheeler, M.L., and Warren, J.L., 1975,
Tritium Containment After Burial of Contaminated Solid Waste,
Remote Systems Technology, Proceedings of 23rd Conference.

Asphalt has been used since 1979 as a means of containing tritium in solid waste disposed of by shallow earth burial in volcanic tuff. As applied, the asphalt has been ineffective in limiting or preventing tritium migration from the waste burial site. Similarities observed between tritium distribution patterns and orientations of joints in the tuff indicate that the migration occurs primarily as movement of tritiated water vapor through joint systems. Modified asphalt-containment techniques now being implemented are described.

White, J., et al., 1988,
"Underground Storage Tanks", Environmental Surveillance at Los Alamos During 1987,
LANL, LA-11306-ENV, pp. 93-95.

In response to new RCRA regulations, underground storage tanks (USTs) at the Laboratory were inventoried and the results submitted to New Mexico's Environmental Improvement Division. Leak tests were performed on 27 of the 105 tanks, and several leaks were found. The leaks were corrected. Further mitigation will be implemented as the need is identified in development of the tank management plan.

During 1987, 32 inactive USTs that were used to store petroleum products were identified at the laboratory. The majority of these tanks were installed in the mid-1940's. These tanks were prioritized for removal according to age, tank size and overall environmental concern. Tank removal began in August 1987 and will continue into 1988.

Williams, J.A., 1986,
Results of the Geophysical Investigation Conducted at Los Alamos Labs Facility,
Los Alamos, New Mexico,
WESTON, Inc., Task Order # 003-86.

This report documents the geophysical survey activities conducted by Roy F. Weston, Inc. at the Los Alamos National Laboratory Facility, Los Alamos, New Mexico. The investigation was centered around the location of the Site F waste disposal area. It was suspected that specific areas within Site F were underlain by trenches containing waste materials. It was the desire of Los Alamos to locate and map possible subsurface waste areas based on the anomalies detected using geophysical sensing techniques. The geophysical field survey activities were conducted by WESTON betwenn 16 and 19 June 1986 at the direction of the Los Alamos environmental group.

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Zerwekh, A., and Warren, J.L., 1986,
Gas Generation and Migration Studies Involving Recently Generated 238-Pu-Contaminated Waste for the TRU Waste Sampling Program,
LANL, LA-10732-MS.

This study is part of the multicontractor TRU Waste Sampling Program. Radiolytically generated gases were vented through a filtering device to determine its effectiveness in maintaining hydrogen concentrations within acceptably safe levels.

In the second part of the study measurements were made to determine the ability of these gases, particularly hydrogen, to migrate through sealed rigid polyethylene drum liner.

Void volumes in these drums were found to be generally in excess of 90%. The carbon composite filter was found to satisfactorily vent hydrogen up to moderate high levels of aplha activity in the waste substrate. The sealed 90-mil liner was found to inhibit, but not prevent, the migration of hydrogen and other radiolytically generated gases.

Zerwekh, A., Kosiewicz, S., and Barraclough, B., 1978,
Experimental studies of the Degradation of RAD-Wastes for the Sandia Laboratories Waste Isolation Pilot Project (WIPP),
LANL, LA-7478-PR.

This is the third quarterly report describing progress in an experimental program to determine the effects of radiolytic, thermal, and catalyzed pyrolytic degradation mechanisms on various forms of existing or proposed transuranic wastes. The low pressure (1 atm, or 1x10 to the 2nd kPa) experiments planned to date to investigate gas yields generated by radiolysis and thermal and catalytic degradation are in progress. There has been no measurable radiolytic gas evolution from any of the materials. However, some thermal degradation of paper at 70 and 100 degrees Celcius has occurred. An experiment involving radiolytic degradation of cellulose at WIPP lithostatic pressure (150 atm, or 1.5 x 10 to the fourth kPa) is in progress.

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A Survey of Some Los Alamos County Canyons for Radioactive Contamination.

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Future Credible Precipitation Occurrences in Los Alamos, New Mexico,
LANL, LA-8523-MS.

Many factors thought to influence past climatic change have been studied. Because they might recur, they are possible suspects for future climatic alterations. Most of these factors are totally unpredictable; therefore, they cast a shadow on the validity of derived climatic predictions. Changes in atmospheric conditions and in continental surfaces, variations in solar radiation, and in the earth's orbit around the sun are among the influential mechanisms investigated. Even when models are set up that include the above parameters, their reliability will depend on unpredictable variables totally alien to the model (like volcanic eruptions).

Based on climatic records, however, maximum precipitation amounts have been calculated for different probability levels. These seem to correspond well to past precipitation occurrences, derived from tree ring indices. The link between tree ring indices and local climate has been established through regression analysis.

Abeele, W.V., 1982,
Diurnal Variability of Wind Velocity Increase with Height,
LANL, LA-9601-MS.

All indications are that wind velocity increase with height is a strong function of temperature stratification. The stronger the inversion, the greater the increase in wind velocity with height, whereas the more superadiabatic the lapse rate, the less the increase. Because superadiabatic lapse rates are most likely to be found about noon, it is expected that the wind speed increase will reach a minimum about that time. Inversions are predominantly night and morning phenomena; thus, a maximum increase in wind speed with height will be obtained at those times.

Abeele, W.V., 1982,
Emanation of Tritiated Water from Disposal Sites at Los Alamos, New Mexico,
LANL, LA-9148-MS.

The level of contamination induced by the presence of tritiated water (HTO) on the Bandelier tuff near Los Alamos, New Mexico has been seen to decrease vertically and horizontally at the same rate. This decrease in radioactivity with distance from the source has been measured around three different disposal shafts and found to be somewhat slower than the decrease in emanation rate with distance from the source.

Physical factors, suspected of influencing HTO emanation, were entered as independent variables in a regression equation including measurements taken over a 14 month period. The physical variables studied were of thermal, hydrological and meteorological origin or a combination of the above. Only four variables were retained as significant although they explained only 71% of the variation in HTO flux.

Abeele, W.V., and Nyhan, J.W., 1986,
The Influence of the Emanation and Dispersal of Tritiated Water on the Concentration of Tritium in the Atmosphere,
LANL, LA-UR-86-492.

The source level of contamination induced by the presence of tritiated water (HTO) on the Bandelier Tuff near Los Alamos, New Mexico has been seen to decrease in all directions at the same rate. This decrease in radioactivity with distance from the source has been measured around three different disposal shafts and found to be somewhat slower than the decrease in emanation rate with distance from the source.

Physical factors, suspected of influencing HTO emanation, were entered as independent variables in a regression equation including measurements taken over a 14 month period. The physical variables studied were of thermal, hydrological, and meteorological origin. Only four variables were retained as significant.

Air concentrations of HTO show a maximum during the warmer months and an overall minimum during the month of December. Emanation of HTO, shown to be strongly associated with daily heat flux amplitude, also at a maximum in summer and at noon, more than counterbalances higher dissipation due to increased turbulence occurring during the same period.

More than 76% of the variation in air concentration of HTO was associated with the regression on emanation, wind direction and velocity.

Abeele, W.V., and Nyhan, J.W., 1987,
"Emanation and Dispersal of Tritiated Water from Disposal Shafts",
Nuclear and Chemical Waste Management, Vol. 7, pp. 217-226.

The source level of contamination induced by the presence of triated water (HTO) in the Bandelier Tuff near Los Alamos, New Mexico has been seen to decrease in all directions at the same rate. This decrease in radioactivity with distance from the source has been measured around three different disposal shafts and found to be slower than the decrease in emanation rate with distance from the source.

Physical factors, suspected of influencing HTO emanation, were entered as independent variables in a regression equation including measurements taken over a 14-month period. The physical variables studied were of thermal, hydrological, and meteorological origin. Only four variables were retained as significant.

Air concentrations of HTO show a maximum during the warmer months and an overall minimum during the colder months. Emanation of HTO, shown to be strongly associated with the daily heat flux amplitude, also at a maximum in summer and at noon, more than counterbalances higher dissipation due to increased turbulence occurring during the same period.

More than 76% of the variation in air concentration of HTO was associated with the regression on emanation, wind direction, and wind velocity and turbulence.

Ahlquist, A.J., Stoker, A.K., and Trocki, L.K., 1977,
Radiological Survey and Decontamination of the Former Main Technical Area (TA-1) at Los Alamos, New Mexico,
LANL, LA-6887.

A radiological survey was conducted on the undeveloped portions of the site of the former Main Technical Area (TA-1) of the Los Alamos Scientific Laboratory in north-central New Mexico. Between 1943 and 1965, research work on nuclear weapons was carried out in TA-1. The area was decontaminated and demolished in stages, and beginning in 1966 the land was given to Los Alamos County or sold to private interests. The survey disclosed traces of radioactive contamination undected or considered insignificant during original demolition in the 1950s and 1960s. The remaining contamination was removed in 1975 and 1976 to levels considered practicable.

Methods used in the survey included measurement techniques for detecting alpha emitters such as uranium and plutonium, extensive surface and subsurface soil sampling, and use of conventional health physics instrumentation to provide detailed information on 16 hectares (40 acres) of land. As a result of decontamination efforts 15,000 cubic meters of contaminated or potentially contaminated material was removed to an approved radioactive waste disposal site on ERDA property. Full details in the methods, findings, decision criteria, and as-left conditions are documented. (ERDA was succeded by the Department of Energy (DOE) in October 1977.)

Anspaugh, L.R., et al., 1982,
A Study of the Potential Health and Environmental Impacts from the Development of Liquid-Dominated Geothermal Resources,
LANL, LA-9407-P.

This document describes seven programs to provide scientific input, understanding, and forecasting capability for hydrothermal energy areas needing resolution. The three major areas addressed are (1) the impacts on living components of the aqueous and terrestrial ecosystems, (2) the impacts on the quality of the abiotic environment itself, and (3) the techniques needed to measure releases from hydrothermal activities.

Apt, K.E., and Lee, V.J., 1976,
"Radionuclide in Rio Grande Sediments and Fish", Environmental Surveillance at Los Alamos During 1975,
LANL, LA-6321-MS, pp.31.

A sampling program was initiated in 1973 to measure the concentrations of selected radionuclides in fish and sediments from the Rio Grande, and preliminary results are presented here. Sampling locations were chosen along the river at the outfalls of the major canyons draining the Laboratory area and at about 2-km intervals downstream to the Cochiti Reservoir.

Sediments cores were obtained along the river and reservoir edges. Fish samples consisted of three species, namely carp (Cyprinus carpio), western white sucker (Catostomus commersoni) and Rio Grande chub (Gila nigrescens).

Results from sediments samples indicated that plutonium concentrations were generally not significantly above the analytical detection limit of 0.005 pCi/g. Cesium-137 concentrations in sediment samples are not currently available.

Concentrations of Cs-137 in the three species from the sampling area generally were not significantly above the detection limit of 0.4 pCi/g dry tissue. Most of the plutonium data for fish are not available, with the exception of the September 1974 collection. Plutonium-238 was not detected in any of the fish samples. However, a mean concentration of 0.9 fCi/g of Pu-239 was measured in fish with individual concentration ranging from 0 to 7 fCi/g Pu-239.

Archuleta, J., et al., 1978,
Some Atmospheric Tracer Experiments in Complex Terrain at LASL.,
LANL, LA-7198-MS, Vol. 1.

Two series of atmospheric tracer experiments have been conducted in complex terrain situations in and around the Los Alamos Scientific Laboratory. Fluorescent particle tracers were used to investigate nighttime drainage flow in Los Alamos Canyon and daytime flow across the local canyon-mesa complex. This report describes the details of these experiments and presents a summary of the data collected. A subsequent report will discuss the analysis of these data.

IV. ENVIRONMENTAL STUDIES

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Future Credible Precipitation Occurrences in Los Alamos, New Mexico.

Abeele, W.V., 1982,
Diurnal Variability of Wind Velocity Increase with Height.

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Emanation of Tritiated Water from Disposal Sites at Los Alamos, New Mexico.

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"Emanation and Dispersal of Tritiated Water from Disposal Shafts".

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Some Atmospheric Tracer Experiments in Complex Terrain at LASL..

Archuleta, J.A., et al., 1978,
Northwest New Mexico Boundary Layer Experiment.

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Population Dynamics and Mortality Factors in a Colony of Mexican Free-Tailed Bats (Tadarida brasiliensis) in Bandelier National Monument.

Barnes, F., et al., 1984,
Designing Stable Vegetative Cover Systems For Shallow Land Burial of Hazardous Waste.

Barr, A., Grieggs, A., and McInroy, D., 1988,
"Vadose Zone Characterization at Areas L and G", Environmental Surveillance at Los Alamos During 1987.

Barr, S., and Clements, W.E., 1977,
"Terrian Influence on Low-Level Meteorological Transport", Biomedical and Environmental Research Program of the LASL Health Division: January - December 1976.

Barr, S., and Gedayloo, T., 1979,
Proceedings of the Atmospheric Tracers and Tracer Application Workshop, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, May 22-24, 1979.

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Barton, L.L., et al., 1988,
Plasmids in Sulfur-Reducing Bacteria.

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"Heavy Metals in Runoff", Environmental Surveillance at Los Alamos During 1985.

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"Movement of Depleted Uranium by Storm Runoff", Environmental Surveillance at Los Alamos During 1984.

Bendix Field Engineering Corporation, 1985,
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Measurements and Modeling of Gamma Absorbed Doses Due to Releases from a Linear Proton Acceletor: Experimental Design and Preliminary Results.

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"Uncertainty in Predictions of Fallout Radionuclides in Food and of Subsequent Ingestion".

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The Comparative Uptake and Interaction of Several Radionuclides in the Trophic Levels Surrounding the Los Alamos Meson Physics Facility (LAMPF) Waste Water Ponds.

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"Movement of Plutonium Through Los Alamos Tuff".

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"Soil Adsorption of Radioactive Wastes at Los Alamos".

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Composition of the E-F Site Ground Water.

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A Survey of Some Los Alamos County Canyons for Radioactive Contamination.

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"Plant Uptake Assay to Determine Bioavailability of Inorganic Contaminants".

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Effect of Soil and Weather on the Decomposition of Explosives.

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Movements of Mule Deer on the Los Alamos National Environmental Research Park.

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Environmental Surveillance Group, 1978,
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"Archeology", Environmental Surveillance at Los Alamos During 1978.

Archuleta, J.A., et al., 1978,
Northwest New Mexico Boundary Layer Experiment,
LANL, LA-7525-MS.

A 24-hour meteorological experiment was performed in the San Juan Basin of northwestern New Mexico with an emphasis on the diurnal variations of boundary layer wind, temperature, and turbulence structure. Hourly profiles of wind and temperature were observed to an altitude of 3 km above ground concurrently with photographs of a nearby power plant plume. The plume behavior is consistent with the meteorological conditions at its elevation, which, because of phase differences in a continually time varying field, may not agree with surface based meteorological observations.

Arganbright, K., 1987,
Population Dynamics and Mortality Factors in a Colony of Mexican Free-Tailed Bats (Tadarida brasiliensis) in Bandelier National Monument,
Bandelier National Monument, Final Report.

A study was under taken to look at population dynamics and mortality factors in a colony of mexican free-tailed bats (Tadarida brasiliensis) in Bandelier National Monument, located approximately eight miles west of White Rock, New Mexico in Frijoles Canyon. Bats were collected by two methods. Young were caught in catch nets as they fell from the cave after losing their grip and adult flying bats were trapped upon exiting the cave using a modified Constantine harp trap. Vital statistics were taken on all bats collected and those caught in the modified Constantine harp trap were banded. Individuals caught in the catch nets were wrapped in aluminium foil, labeled and frozen. These bats were submitted for pesticide analysis at the end of the summer.

Barnes, F., et al., 1984,
Designing Stable Vegetative Cover Systems For Shallow Land Burial of Hazardous Waste,
LANL, LA-UR-84-3090.

The design of toxic waste burial sites is constrained by the requirements of having to minimize long term migration of liquids from landfills, minimize erosion, accommodate settling and subsidance so that cover integrity is maintained, and accomplished all this in such a way that the site is essentially maintenance-free after a few decades post-closure. The water balance relationships of landfill cover treatments can be significantly altered by different vegetative covers and soil types. The purpose of this research was to study the use of the USDA modes CREAMS as a possible predictive tool to assess soil/vegetation system performance under a variety of environmental conditions, with the aim of facilitating the choice of the optimum system to minimize erosion and percolation.

Two regions in the United States were studied as hypothetical locations for hazardous waste sites (Houston, TX and Fresno, CA) in addition to a closed nuclear waste disposal site at Los Alamos. The various soil covers for the sites were assumed to be of local origin, and the vegetative covers modeled were assumed to be either native or introduced species that are locally abundant. Soil parameters required by CREAMS were obtained from soil survey reports. Vegetative parameters (leaf area indices, LAI; rooting depth) were obtained from data, literature, or more commonly, estimated from allometric relationships, biomass data, and/or comparisons with well studied species or ecosystems.

The precipitation inputs in humid climates (Houston, TX) are so large that simulations indicate that vegetated soil covers will not prevent percolation below the rooting zone even in normal years. A combination of climax tree cover and impermeable cap liner may be an effective and stable combination. In semi-arid settings the situation is more complex and variable. Simulations of the Fresno, CA and the Los Alamos, NM settings indicate that zero percolation is attainable for average precipitation quantities and timing. But an occasional percolation event is predicated with high precipitation, particularly in normally dry seasons. Whether or not liner technology is indicated would depend on the specifics of the hazardous waste and the exact site hydrology.

The semi-arid case is being investigated experimentally at Los Alamos. A closed shallow land burial site recently received multi-layer soil cover treatments as a part of DOE site renovation. As part of this project, these soils have been planted in a set of 25′ x 80′ plots with two warm season native plants, a grass and a shrub which differ in rooting depth and canopy structure. Two different planting densities were used, which will result in different LAI's. Data to be collected from these plots include not only water redistribution in the profile and water balance, but also rooting depth and distribution and directly determined evapotranspiration based on infra-red thermometry methods.

Barr, A., Grieggs, A., and McInroy, D., 1988,
"Vadose Zone Characterization at Areas L and G", Environmental Surveillance at Los Alamos During 1987,
LANL, LA-11306-ENV, pp. 83.

A vadose zone characterization program was initiated to substantiate the Laboratory's request for ground water monitoring wavier. The zone above the aquifer (the vadose zone) was studied to characterize its hydrogeology and evaluate the potential for contaminant migration.

Conclusions reached from this study are: (1) the dominant mechanism of subsurface transport is through vapor phase migration--aqueous phase migration is unlikely; (2) perched water is confined in the adjacent canyon and does not extend beneath the mesa or connect hydraulically to the main aquifer; (3) some metal contamination exists at shallow depths in Area L; (4) organic vapor contamination exist in Area L and G; (5) no contamination was evident in the perched canyon water; and (6) vertical cooling fractures are present in disposal areas but their ability to transport contaminants and water has not been determined

Barr, S., and Clements, W.E., 1977,
"Terrian Influence on Low-Level Meteorological Transport", Biomedical and Environmental Research Program of the LASL Health Division: January - December 1976,
LANL, LA-6898-PR, pp. 96-72.

The objectives of the project are to define and document the major effects of terrain irregularities on the transport, dispersion and deposition of effluents released to the atmosphere. Initial efforts have been directed toward studying the processes in a single canyon and their interactions with mesa-level wind. This local problem has been addressed with simple slope-flow theory, wind and temperature data analysis, visual tracers, fluorescent particle tracers, and hydrodynamic codes.

Barr, S., and Gedayloo, T., 1979,
Proceedings of the Atmospheric Tracers and Tracer Application Workshop, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, May 22-24, 1979, LANL, LA-8144-C.

The workshop on Atmospheric Tracers and Tracer Applications was held at Los Alamos Sciebtific Laboratory on May 23 and 24, 1979. In addition to presentations by participating members a general discussion was held in order to summarize and outline the goals and objectives of the workshop. A number of new low level background tracers such as heavy methanes, perflurocarbons, multiply labeled isotopes such as 13^C 18^02, helium 3, in addition to sample collection techniques and analytical methods for various tracers were discussed. This report is a summary of the discussions at the workshop.

Barr, S., et al., 1978,
"Fluorescent Particle Tracer Experiment", Biomedical and Environmental Research Program of the LASL Health Division January - December 1977,
LANL, LA-7254-PR, pp. 23-26.

Atmospheric tracer experiments using fluorescent particles has begun at Los Alamos Scientific Laboratory (LASL). These studies are beginning to identify driving phenomena and are providing a much needed data base upon which to develop and test models. Tracer investigations are being conducted currently on fairly common flow regimes at LASL: (1) nocturnal drainage flow in a single canyon; and (2) day-time flow across a canyon-mesa complex.

A total of seven nocturnal canyon experiments and 6 daytime experiments have been performed to date. However, the bulk of the data is still being processed.

Barton, L.L., et al., 1988,
Plasmids in Sulfur-Reducing Bacteria,
LANL, LA-UR-88-3377.

Chemical similarities between elements of sulfur and selenium have led many investigators to consider that selenium is metabolized by the enzymes that transform sulfur compounds. An increasing body of information implies that distinct metabolic pathways actually operate in sulfur and selenium transformations. The resistance to heavy metals by bacteria has been attributed to plasmids. The resistance to selenium compounds shown by sulfur-reducing bacteria could be encoded in plasmids. Since the literature contains little reference to plasmids in Desulfovibrio species, we examined several strains of this genus for large and small plasmids. Preliminary evidence shows that several types of plasmids are found in these bacteria. There appear to be plasmids that are very large (>20 kb), and also some small ones (<10kb). Ongoing research is attempting to correlate plasmid expression with selenium metabolism in these bacteria.

Becker, N.M., 1986,
"Heavy Metals in Runoff", Environmental Surveillance at Los Alamos During 1985, LANL, LA-10721-ENV, pp. 90.

Snowmelt runoff samples were collected in four canyons within the Laboratory boundary; Pajarito Canyon, Water Canyon, Potrillo Canyon and Fence Canyon. Runoff samples were collected about once a week during snowmelt runoff.
The samples were analyzed four beryllium, lead and mercury.

The limits of detection in the analysis of metals in solution presented difficulty in interpreting the data. Lead in solution, when taking into account the standard deviation of the results could exceed primary drinking water standards. However, none of the water is used for municipal, agricultural or industrial purposes.

Mercury in solution is below drinking water standards. There is no standard for beryllium in water; all concentrations are below 50 ug/g.

Results of metals in suspended sediments indicate that beryllium is less than 10 ug/g in all instances. Background levels of beryllium in soil samples in northern New Mexico is about 1 ug/g. Lead in suspended sediment in runoff ranges from less than 34 to 130 ug/g. This compares with an average background sample of 23 ug/g in Sigma Mesa. Mercury in suspended sediment in runoff is less than 1 ug/g. This compares with an average background sample of 0.02 ug/g.

Becker, N.M., Purtymun, W.D., and Maes, M., 1985,
"Movement of Depleted Uranium by Storm Runoff", Environmental Surveillance at Los Alamos During 1984,
LANL, LA-10421-ENV, pp. 75.

Field studies were begun in the spring of 1983 to determine the extent of movement of depleted uranium from test firings at some of the Laboratory's dynamic testing areas. Airborne depleted uranium from test shots settles on the ground surface and is washed into onsite stream channels by precipitation and snowmelt. Onsite channels and alluvium were sampled for uranium to help trace its movement by storm runoff process.

Background uranium levels were measured in Pajarito Plateau stream channels in the vicinity of the Laboratory that are not drainage area of the firing sites and in sediments collected from the Rio Grande.

Onsite studies were concentrated on stream channel sediments in Potrillo Canyon, which drains four firing sites. Studies indicate that samples collected in Potrillo Canyon had relatively higher uranium concentrations near the main sources of uranium and decreased with distance from the firing sites. The concentrations ranged from 112 ppm below Firing Site E-F to 2.5 ppm at the intersection of Potrillo Canyon and New Mexico State Rd 4. Background uranium levels measured in Mortandad Canyon were 4.6 ppm. Channel bank samples showed the same uranium distribution pattern as the sediment samples.

Sediment samples were sieved into sand and silt-clay fractions. The silt-clay fractions were consistely greater in uranium content than the sand fractions. Storm runoff, which carrys a high silt-clay fraction, deposits some suspended sediments on channel banks during receding flow. This deposition accounts for relatively higher uranium concentrations in channel bank samples versus concentrations in channel sediments.

Leach test were also performed on selected channel sediment samples. Results indicated that uranium binds closely with some minerals and does not leach out readily.

Bendix Field Engineering Corporation, 1985,
Vadose Zone Characterization of Technical Area 54, Waste Disposal Areas G and L, Los Alamos National Laboratory, New Mexico, Report 2: Downhole Instrumentation and Pore-Gas-Sampling/Data-Collection Procedures,
Bendix Field Engineering Corporation, GJ-43.

This report describes the instrument installations and procedures for sample and data collection conducted in support of the vadose zone characterization of waste Disposal Areas G and L. Technical Area 54, Los Alamos National Laboratory, New Mexico. The study was initiated in response to a Resource Conservation Recovery Act (RCRA) Compliance Order/Schedule issued to the Laboratory by the Environment Improvement Division of the State New Mexico.

This report is the second in a series of reports documenting the vadose zone characterization of the study area. This report presents the instrument-completion diagrams for the nine bore holes in which instruments were installed and describes the procedures to be used in the collection of samples and other data.

Bendix Field Engineering Corporation, 1985,
Vadose Zone Characterization of Technical Area 54, Waste Disposal Areas G and L, Los Alamos National Laboratory, Report 1: Drilling and Logging Activities, Bendix Field Engineering Corporation, GJ-37.

This report presents preliminary lithologic and geophysical data for Waste Disposal Areas G and L, located in Technical Area 54 at Los Alamos National Laboratory (LANL), New Mexico. These data, obtained via drilling and logging operations, will be used to aid in characterizing the vadose zone in Area G and L. The study is being conducted by Bendix Field Engineering Corporation.

The overall objective of this study of Area G and L is twofold: to characterize the hydrology of the vadose zone at the site and to evaluate the potential for contaminant migration from these two waste disposal areas, both of which are still actively used. Initial field activities for this study consisted of drilling and logging conducted over the period of 30 July to 22 August 1985. The resulting lithologic and geophysical logs were completed on 13 September 1985. Due to the time constraints imposed on this first report, its scope is limited to a summary of these initial activities and presentation of the preliminary data with very little interpretation.. A thorough interpretation of these data, including their integration with other results, will be prepared in the comprehensive final report on this study.

Bohn, R., and Nylander, C., 1988,
"Biomonitoring of the Laboratory's Liquid Effluents", Environmental Surveillance at Los Alamos During 1987,
LANL, LA-11306-ENV, pp. 95-96.

HSE-8 has initiated a biomonitoring program at the Laboratory in support of its NPDES program. Biomonitoring is used as a strategy to evaluate the overall toxic impact of effluents without specifically identifying individual contaminants.

NPDES outfalls were segregated into nine basic categories according to wastewater source. Biomonitoring assay using the test organism Daphnia pulex are conducted for each representative effluent. To date each outfall has been sampled three times and preliminary results indicate that overall water quality of the effluent is good.

Bowen, B.M., 1990,
Los Alamos Climatology,
LANL, LA-11735-MS.

The report presents Los Alamos climate data and analyses of basic meteorological variables beginning in late 1910 and continuing into 1989. The first section summarizes Los Alamos climate. Temperature, humidity, and precipitation analyses are given, with daily temperature and precipitation records listed and analyzed from late 1910. More-detailed records of temperatures and humidity, as well as winds, pressure, insolation, and other weather phenomena, are analyzed and discussed for the years 1980-1988, historical climate trends in Los Alamos are also given. This report also gives weather extremes, present climate records and variability, and air pollution meteorology.

Bowen, B.M., et al., 1982,
Measurements and Modeling of Gamma Absorbed Doses Due to Releases from a Linear Proton Acceletor: Experimental Design and Preliminary Results,
LANL, LA-UR-82-3681.

External radiation levels due to positron annihilation radiation from C-11, N-13 and O-15 released by the 800 MeV linear proton accelerator at the Los Alamos Meson Physics Facility (LAMPF) have been monitored at a fence-line location both by thermoluminescent dosimeters (TLDs) and high pressure ionization chambers (HPICs). The accelerator is located in irregular terrin consisting of mesas and canyons. Fifteen minute, accumulated external radiation levels were recorded with the HPICs. Instruments on a nearby meteorological tower concurrently measured wind speed and direction at three levels, temperature at two levels, solar radation and rainfall. Real-time radionuclide release rates and stack velocities were measured at the release point with in-stack monitors. This paper presents analyses of short-term radiation levels using HPICs and long-term levels using TLDs. Work being done to develop a computer model to predict external radiation levels based on meteorological data is also discussed.

Bowen, B.M., et al., 1987,
Measurement and Modeling of External Radiation During 1985 from LAMPF Emissions, LANL, LA-11150-MS.

An array of three portable, pressurized ionization chambers (PICs) continued to measure external radiation levels during 1985 caused by radionuclides emitted from Los Alamos Meson Physics Facility (LAMPF). The monitoring was at the closest offsite location, averaging 800 m north and northeast of the source, just across a 120-m-deep canyon. A Gaussian-type atmospheric dispersion model, using onsite meteorological and stack release data, was tested during this study. A more complex finite model, which takes into account the contribution of radiation at a receptor from different locations of the passing plume, was also tested.

Monitoring results indicate that, as in 1984, a persistent wind up the Rio Grande Valley during the evening and early morning hours is largely responsible for causing the highest external radiation levels to occur to the northeast an north-northeast of LAMPF. Daytime winds are more southerly, transporting more radionuclides toward the north and north-northeast. However, because of increased trubulent mixing during the day, external radiation levels are generally much less during the day than at night. External radiation levels during 1985 show approximately a 75% reduction over 1984 levels. This resulted from a similar percentage reduction in LAMPF emissions caused by newly implemented emission controls.

Comparison of predicted and measured daily external radiation levels indicates a high degree of correlation. The model also gives accurate estimates of measured concentrations over longer time periods. Comparison of predicted and measured hourly values indicates that the model generally tends to overpredict during the day and underpredict at night.

Bowker, R.G., and Ferenbaugh, R.W., 1983,
"Temperature Regulation and Energetics of Lizards at Los Alamos National Environmental Park", Environmental Surveillance at Los Alamos During 1982, LANL, LA-9762-ENV, pp. 66-68.

Although reptiles are generally most abundant in low elevation habitats, the area around Los Alamos National Laboratory nonetheless has a variety of reptile species. Preliminary surveys of the area indicate the presence of nine lizard species representing three families. During the summer of 1981, a study of aspects of the physiology and ecology of two lizard species (Cnemidophorus velox, Sceloporus undulatus) was begun and this research was expanded during the summer of 1982 to include three additonal species (C. exanguis, Crotaphytus collaris, Urosaurus ornatus). The physiological studies primarily involved a comparison of the abilities of the five species to regulate body temperature (BT). Directly related to this, the energy requirements of the species also were being determined.

The lizards typically regulated BT by shuttling between the sun and shade in the thermal gradient enclosure. There were species-specific differences in their behavior in the thermal gradient. Certain species tended to be more active than did other species. Regardless of the frequency of movement in the temperature gradient, all of the species maintained relatively high body temperatures (between 36 to 38 degrees C) and did so with considerable precision (standard deviations less than 2 degrees C). Thus, the five species of lizards examined to date maintain BTs comparable to those of mammalian species.

A preliminary analysis of the lizard energetic data provides some surprising findings. Although the metabolic rate did generally increase as body temperature increased from 20 to 38 degrees C, the relationship was not strongly temperature dependent for any of the species. In fact, most species showed either a plateau or a decrease in metabolic rate when their body temperature was near their preferred temperature (for example, for Urosaurus ornatus the metabolic rate at 30 degrees C averaged 0.50 ml CO_2/g-h and declined to 0.35 ml CO_2/g-h at 38 degrees C.)

Breshears, D.D., et al., 1989,
"Uncertainty in Predictions of Fallout Radionuclides in Food and of Subsequent Ingestion",
Health Physics, Vol. 57, No. 6, pp. 943-953.

Uncertainty in predictions from the PATHWAY food-chain model was estimated using Monte Carlo simulation. Uncertainty estimates, measured by the geometric standard deviation (GSD), were obtained for median values of time-integrated concentrations of I-131, Cs-136, and Cs-137 in foods and for corresponding time-integrated intakes resulting from ingestion of all foods. The GSDs associated with a given food for short-lived radionuclides, I-131 and Cs-136, were not significantly different, but they differed from the GSDs for the longer-lived radionuclide. The GSDs for integrated concentrations of radionuclides in milk varied with the time of year fallout was deposited, but uncertainty for nondairy products was relatively independent of the date of fallout deposition. The estimated GSDs were applied to other radionuclides of interest based on physical half-life and ranged from 1.7 to 2.7 for time-integrated intake across all foods for radionuclides with physical half-lives less than 30 d, from 1.8 to 2.3 for half-lives ranging from 30 to 500 d, and from 1.9 to 2.1 when half-lives were greater than 500 d.

Brooks, G.H., 1989,
The Comparative Uptake and Interaction of Several Radionuclides in the Trophic Levels Surrounding the Los Alamos Meson Physics Facility (LAMPF) Waste Water Ponds,
LANL, LA-11487-T.

A study was undertaken to examine the uptake, distribution, and interaction of five activation products (Co-57, Be-7, Cs-134, Rb-83, and Mn-54) within the biotic and abiotic components surrounding the waste treatment lagoons of the Los Alamos Meson Physics Facility (LAMPF). The study attempted to ascertain where, and what specific interactions were taking place among the isotopes and the biotic/abiotic components. A statistical approach, utilizing Multivariate Analysis of Variance (MANOVA),was conducted testing the radioisotopic concentrations by 1) the trophic levels (TROPLVL) in each position sampled on the grid, 2) where sampled on the grid (TRAN), 3) where sampled with-in each grid line (PLOT), and 4) the side with which sampled (SIDE). This provided both the dependent and independent variables that would be tested. The Null Hypothesis (Ho) tested the difference in the mean values of the isotopes within/between each of the four independent variables.

The Rb-83 statistic indicated an accumulation within the TRAN and PLOT variables within the sampled area. The Co-57 test statistic provided a value which indicated that accumluation was also taking place. Mn-54 test values indicated that accumulation was also taking place at the higher trophic levels within the PLOT, TRAN and SIDE positions. Cs-134 was found to accumulate to third level in this trophic structure (TROPLVL-(vegetation)), and then decrease from there. The Be-7 component provide no variance from known compartmental transfers.

Many factors, such as soil moisture, cation exchange capacity, percent organic matter, nutrient percent in the soil, and the interaction of the radioisotopes, are most probably the cause of the results which have been found in this study.

Buhl, T.E., and Hansen, W.R., 1984,
Estimating the Risks of Cancer Mortality and Genetic Defects Resulting from Exposures to Low Levels of Ionizing Radiation,
LANL, LA-9893-MS.

Estimators for calculating the risk of cancer and genetic disorders induced by exposure to ionizing radiation have been recommended by the U.S. National Academy of Sciences Committee on the Biological Effects of Ionizing Radiations, the U.N. Scientific Committee on Radiological Protection, and the International Committee on Radiological Protection. These groups have also considered the risk of somatic effects other than cancer. The U.S. National Council on Radiation Protection and Measurements has discussed risk estimate procedures for radiation induced health effects.

The recommendations of these national and international advisory committees are summarized and compared in this report. Based on this review, two procedures for risk estimation are presented for use in radiological assessments performed by the U.S. Department of Energy under the National Environmental Policy Act of 1969 (NEPA). In the first procedure, age and sex-averaged risk estimators calculated with U.S. average demographic statistics would be used with estimates of radiation dose to calculate the projected risk of cancer and genetic disorder that would result from the operation being reviewed under NEPA. If more site specific risk estimators are needed, and the demographic information is available, a second procedure is described that would involve direct calculation of the risk estimators using recommended risk-rate factors. The computer program REPCAL has been written to perform this calculation and is described in this report.

We have discussed somatic effects other than cancer, such as developmental effects resulting from irradiation in utero and nonstochastic effects that may occuring the dose range considered in NEPA documents. No risk estimation procedures are given in this report for these effects because none have been recommended by any of the national and international committees reviewed here.

Carlson, S.R., 1988,
Influence of Western Harvester Ants on Vegetation and Soils in a Semi-Arid Mountain Ecosystem,
New Mexico State University, Master Thesis.

Vegetation patterns and soil properties associated with western harvester (Pogonomyrmex occidentalis) mounds were examined in a pinon-juniper community and a ponderosa pine community near Los Alamos, New Mexico. Plant-clearing habits of the ants exerted only a minor influence on total plant cover. Denuded areas around the mounds represented 1.2% and 1.0% of the total surface area that caused reductions in plant cover of 0.35% and 0.49%, respectively, in the pinyon-juniper and ponderosa sites. Vegetation near the perimeter of the cleared discs had decreased species richness and lower percent cover compared with adjacent control areas (sampled 3.0 m from discs). Comparisons of plant species occurrences around the colonies revealed that 1) most species, including dominant understory plants, were evenly dispersed in relation to nest discs; 2) two species--one in each site--were significantly associated with areas near the cleared discs; and 3) six species--4 in the pinyon-juniper site and 2 in the ponderosa pine site--were significantly associated with control areas. Vegetation on abandoned mounds and remnant discs also had decreased species richness, reduced cover, and altered species composition.

Active mounds occurred at densities at 17/ha and 14/ha and had an average mass of 38 kg and 48 kg, respectively, in the pinyon-juniper and ponderosa sites. Particle size analysis indicated that ants construct mounds primarily of gravel and sand fractions. Mound soils at both sites had elevated concentrations of NO3, P, and K, increased conductivity, and lower H2O content compared with soils on the denuded perimeter of the mounds (disc) and control soils. Disc soils in both sites had lower organic matter content but were otherwise similar to control soils.

Activities of P. occidetalis caused localized accumulations of nutrients that are unavailable to plants until colony abandonment. Colony influences on vegetation patterns beyond the denuded areas and lingering affects of abandoned nests contribute to plant heterogeneity.

Christenson, C.W., and Thomas, R.G., 1962,
"Movement of Plutonium Through Los Alamos Tuff",
U.S. Dept. Commerce, TID-7628, pp. 248-281.

Early work at Los Alamos resulted in the disposal of liquid radioactive waste in seepage pits constructed in the porous tuff. This report gives a general geologic description of the area and the results from test performed at DP West Site in Los Alamos to characterize the movement of plutonium through the tuff. Core sampling, moisture study and experiments involving raw waste application were conducted.

Results can only be interpreted in a general sense and indicate that under field conditions, plutonium species can penetrate to at least 28 feet in Los Alamos tuff. This penetration takes place along fissures as indicated by moisture data, rates of flow of liquid and physical inspection. The amount of activity sorbed at any point in depth is dependent upon the chemical and physical nature of the sub-structure in that area. High penetration of clays, deposited by local weathering, will sorb plutonium species and result in a localized area of high alpha activity. As the species percolates through the soil changes in valence state may also occur with changes in chemical environment; sorption or even solution may result. These results indicate, however general, the dangers associated with the practice of uncontrolled and uncontained ground disposal of radioactive waste.

Christenson, C.W., et al., 1958,
"Soil Adsorption of Radioactive Wastes at Los Alamos",
Sewage and Industrial Wastes, Vol. 30, No. 12, pp. 1478-1489.

A laboratory study was undertaken to determine the soil adsorption of radionuclide waste at Los Alamos. The study utilized cylindrical cores of tuff enclosed in a neoprene jacket and various solutions of nuclides. The nuclides used were Pu-239, Cs-137, Sr-90 and mixed nuclides (Sr-90+Cs-137 and Sr-90+Cs-137+Pu-239). The tuff cores were contaminated with solutions of nuclides so that 100-200 ml/hr of effluent was collected. Samples were collected at a 24-hr interval. Appropriate volumes of samples were counted for alpha, beta and gamma emmiters. Radiographs were also made of the cores when breakthrough of a nuclide was indicated. Results indicated that Cs-137 is apparently very tightly bound to the tuff and resist leaching by any common agent. Pu-239 likewise is readily retained by the tuff. However Sr-90 is not retained by the tuff nearly as well as cesium and plutonium and it is much more readily released. Therefore Sr-90 is the controlling isotope in the disposal of radioactive waste.

Clements, W.E., Barr, S., and Fowler, M.M., 1980,
Effective Transport Velocity and Plume Elongation in Nocturnal Valley Wind Fields,
LANL, LA-UR-80-791.

Using three different atmospheric tracers effective transport velocity and plume elongation produced from nocturnal wind drainage was investigated in three different valleys: (1) Los Alamos Canyon, NM; a narrow steep mountain canyon, (2) Anderson Creek Valley, Ca; a relatively small air shed, and (3) Grants Basin, NM; two converging air sheds. Tracer was released in each valley in a well defined drainage wind field and sequentially sampled at downvalley locations. The effective transport velocity was determined from the elapsed time from the start of the release to the time when the plume concentration reached 10% of the peak value and the distance from the release site. The plume elongation factor was determined from the ratio of the width (time) of the plume at 10% of its peak value to the duration of the release.

In Los Alamos Canyon and Grants Basin it was found that the mean surface wind velocity was a fairly good indicator of effective transport velocity. The data obtained from the Anderson Creek Valley gave mixed results. Some areas the mean surface wind velocity was on the average of 50% higher than the effective transport, while other areas were in reasonable agreement. The Anderson Creek Valley had the more complicated terrain and these differences were not unexpected.

Mean elongation factors showed a wide variation in values. Plume elongation is tied to shear structure. It may be unreasonable to relate surface measurements to elongation effects. More knowledge is required about shear flows in valleys and the effect of the canopy before lateral plume elongation problems in valleys will be well tractable. Here we have observed some elongation factors that one might expect in similar valleys under similar conditions.

Cokal, E.J., and Rodgers, J., 1985,
Composition of the E-F Site Ground Water,
LANL, Memorandum, Firing Site Project File, 3/26/85.

Samples were collected on March 13, 1985 from ground water at E-F site. The samples were analyzed for dissolved metals. There were two reasons for obtaining this information. Firstly, this information was to establish the concentration of the major cations in the water, since these are the ions which will be effective in mobilizing trace heavy metals. The second reason for determining the metals is to establish the absence of the anion-forming metals.

Cokal, E.J., and Rodgers, J., 1985,
Data Analysis of the E-F Site Soil Samples,
LANL, Memorandum, Firing Site Project File, 3/22/85.

The uranium, beryllium, and lead data from the nine soil samples reported on March 21 and Feb. 28, 1985 were subjected to a brief statistical analysis. The purpose was to form an estimate of the maximum and minimum values expected at the site, as well as the most probable value. This information is to be used in selection of additional sampling locations to characterize the contaminant loading of the site soils.

The data for uranium have a range of 408 to 3359 ppm. The most probable value of the set is 1160 ppm. For lead, the range of values found was 23 ppm to 198 ppm, with the most probable value being 57 ppm. The range of beryllium results was 14.4 to 2.3 ppm. The most probable value was 5.5 ppm.

One obvious conclusion from this analysis is that the immediate vicinity of the firing site is quite elevated in all three elements. Of the three elements, neither beryllium or lead appears to be at levels for which phytotoxicity is expected. Uranium on the other had, is known to be substantially elevated and levels found are potentially toxic to the plants growing at the site.

Cokal, E.J., and Rodgers, J., 1985,
Series of Memos Describing Uranium, Beryllium, and Lead in E-F Site Water Samples Collected 4 March, 1985,
LANL, Memorandum.

On March 4, 1985 water samples were taken from surface waters collected at E-F site. The samples were analyzed for uranium, beryllium, and lead. All samples analyzed for dissolved uranium were within the New Mexico drinking water standards of 5.0 ppm.

Beryllium is not listed among the U.S.P.H.S., WHO, EPA, or New Mexico drinking water standard controlled elements. However, beryllium is known to be toxic to plants. Review of the literature indicates that no biological effects should be apparent at the 100 ppb level, and a level of 50 ppb as a proposed standard would provide an adequate margin of safety. Therefore all samples collected at E-F site were far below 50 ppb and indicated that beryllium in the samples tested was of no present environmental concern.

Lead was measured in the dissolved and suspended sediment fractions of the surface water collected on March 4, 1985. The dissolved fraction was less than 5 ppb in all cases. No evidence was obtained that soluble lead was present in the waters. On the other hand, the suspended sediment fraction contained lead in measurable amounts, in some cases exceeding the accepted drinking water standards for this element.

Cokal, E.J., and Rodgers, J., 1985,
Soil Moisture Uranium, 22 March Samples,
LANL, Memorandum, Firing Site Project File, 3/26/85.

Hollow fiber moisture samplers were used to collect soil moisture samples on March 22, 1985. Previous samples were taken on March 13, 1985. The uranium values found on March 22 were much higher than those found on March 13, when the soil was saturated with snowmelt. Apparently, as the soil dries or drains, air oxidation and carbonate complexing occur at the rather high soil pH, and thus additional uranium becomes solubilized. This suggect that eventually, all of the available uranium in the uppermost soil layers at E-F may become solubilized and transported into the canyon systems.

Results of the March 22 samples indicate the concentration of the uranium is comparable to that of the calcium in the soil water near the firing site. The data suggest that at times of snowmelt and perhaps summer runoff, significant movement of uranium may be produced. The observed uranium concentrations have now risen to levels at which phytotoxicity is expected.

Dahlman, R.C., Garten, C.T., and Hakonson, T.E., 1980,
"Comparative Distribution of Plutonium in Contaminated Ecosystems at Oak Ridge, Tennessee, and Los Alamos, New Mexico", Transuranic Elements in the Environment, U.S. DOE, pp. 371-380.

The distribution of plutonium was compared in portions of forest ecosystems at Oak Ridge, Tenn., and Los Alamos, N. Mex., which were contaminated by liquid effluents. Inventories of plutonium in soil at the two sites were generally similar, but a larger fraction of the plutonium was associated with biota at Los Alamos than at Oak Ridge. Most (99.7 to 99.9%) of the plutonium was present in the soil, and very little (0.1 to 0.3%) was in biotic components. Comparative differences in distributions within the two ecosystems appeared to be related to individual contamination histories and greater physical transport of plutonium in soil to biotic surfaces at Los Alamos.

Daniels, W.R., 1981,
Laboratory and Field Studies Related to the Radionuclide Migration Project:
October 1, 1979 - September 30, 1980,
LANL, LA-8670-PR.

Fy-1980 laboratory and field studies related to the Radionuclide Migration project are described. Results are presented for radiochemical analyses of water samples collected from the RNM-1 well and the RNM-2S satellite well at the Cambric site. Data are included for tritium, Kr-85, Sr-90, Cs-137, I-129 and what is tentatively identified as Ru-106. The time of arrival of the maximum concentration tritium peak at RNM-2S is estimated as August 1,1981 with an uncertainity of 45 days. Laboratory studies emphasize the sorptive behavior of tuff and its dependence on atmosphere, groundwater composition, and mineralogy. Results from batch measurements and crushed rock and whole-core column studies are presented.

Daniels, W.R., 1982,
Laboratory and Field Studies Related to the Radionuclide Migration Project: October 1, 1980 - September 30, 1981,
LANL, LA-9192-PR.

FY-1981 laboratory and field studies related to the Radionuclide Migration project are presented for radiochemical analyses of water samples collected from the RNM-1 well and the RNM-2S satellite well at the Cambric site. Data are included for tritium, Kr-85, I-129 and Cl-36. The maximum-concentration tritium peak appears to have arrived at RNM-2S near the end of behavior of alluvium and tuff and its dependence on mineralogy. Results from batch measurements and crushed-rock and whole-core column studies are presented.

Daniels, W.R., 1983,
Laboratory and Field Studies Related to the Radionuclide Migration Project,
LANL, LA-9691-PR.

FY 1982 laboratory and field studies related to the Radionuclide Migration Project are described. Results are presented for radiochemical analyses of water samples collected from the RNM-1 well and the RNM-2S satellite well at the Cambric site. Data are included for tritium, Cl-36, Kr-85, Sr-90, I-129 and Cs-137. Laboratory studies emphasize the sorptive behavior of tuff and its dependence on mineralogy.

Daniels, W.R., and Thompson, J.L., 1984,
Laboratory and Field Studies Related to the Radionuclide Migration Project:
October 1, 1982 - September 30, 1983,
LANL, LA-10121-PR.

The FY 1983 laboratory and field studies related to the Radionuclide Migration project are described. Results are presented for radiochemical analyses of water samples collected from the RNM-1 well and the RNM-2S satellite well at the Cambric site. Data are included for tritium, 36-Cl, 85-Kr, 90-Sr, 129-I, and 137-Cs. Preliminary results from water collection at the Cheshire site are reported. Laboratory studies emphasize the sorptive behavior of tuff and its dependence on mineralogy.

Devaurs, M., 1989,
Modeling of Radionuclide Transport at Inactive Material Disposal Area T, TA-21, LANL, LA-11544-MS.

Existing Area T data are used to extract information on radionuclide movement to assist in design of future characterization studies. Spatial moment estimation was used in conjunction with the one-dimensional convective-dispersive solute transport equation to describe radionuclide transport. With available data and conservative assumptions, we obtained gross estimates of radionuclide movement rates. Recommendations are made on how this information could guide further drilling/sampling for contamination at Area T.

Dodd, A.O., 1956,
A Survey of Some Los Alamos County Canyons for Radioactive Contamination,
LANL, LAMS-2038.

This doucument is a survey analysis of soil samples from Los Alamos, Pueblo, Bayo and Mortandad canyons to determine the presence and activities of radioactive contaminants. Also included are the results of analyses of a few samples of grass and of surface water. This survey covers the period from spring 1953 to spring 1955.

Dreesen, D.R., and Cokal, E.J., 1984,
"Plant Uptake Assay to Determine Bioavailability of Inorganic Contaminants",
Water, Air, and Soil Pollution, Vol. 22, pp. 85-93.

A laboratory technique has been developed to rapidly assess the potential uptake of contaminants plants growing into waste burial sites. A soil-less media was used to provide rapid plant growth and reproducible growing conditions. The uptake of contaminants by several plant species grown on uranium mill tailings materials has been examined. The bioavailability of Mo, Se, Cl, and other trace metals in tailings was greater than in a surface soil from uranium mining area. Significant differences in nutrient and contaminant contents in aboveground biomass were found between species.

Dreicer, M., et al., 1984,
"Rainsplash as a Mechanism for Soil Contamination of Plant Surfaces",
Health Physics, Vol. 46, No. 1, pp. 177-187.

We characterized the physical transport of soil, and therefore contaminants attached to the soil, onto vegetable surfaces due to rainsplash. Soil accumulation by tomato plants (Lycopersicon esculentum) was investigated as a function of soil particle size, rainstorm characteristics, foliage height, surface area, and canopy cover of the plants. No soil particles greater than 105 um in diameter were detected on the plants. Most of the soil was splashed no higher than 40 cm above the ground surface. Linear relationships were observed for concentrations of <53 um of soil on vegetation and certain rainfall characteristics. Data from this study, as well as ancillary calculations, provide evidence that a significant fraction of surficial contamination of foliage may be attributed to the rainsplash mechanism.

DuBois, F.W., and Baytos, J.F., 1972,
Effect of Soil and Weather on the Decomposition of Explosives,
LANL, LA-4943.

Twelve high-explosive materials were buried in soil and exposed to the elements to determine their rate of disappearance from the environment. Only those explosives that contained TNT, barium nitrate, and boric acid disappeared at a useful rate.

Eberhardt, L.E., and White, G.C., 1979,
Movements of Mule Deer on the Los Alamos National Environmental Research Park, LANL, LA-7742.

The movements of mule deer (Odocoileus hemionus) on the Los Alamos National Environmental Research Park (LA/NERP) in north-central New Mexico were studied during 1975-1978. A total of 36 deer were live-trapped, marked, and released; 25 of these were equippped with visual markings including ear tags, ear streamers, and neck collars, and 11 were fitted with radio transmitters. Disturbance caused by trapping may have caused some unusual movements.

Deer home ranges tended to be elongated in shape, possibly because the deer tended to move parallel to the steep canyon-mesa systems and along the elevational gradient. The average home range size for six deer radio tracked for 18-20 months was 13.7 +/- 5.0 kilometers squared. There was no indication that marked deer made extensive seasonal elevational migrations.

Resident deer appeared to be habituated to much of the human activity on the LA/NERP and did not appear to avoid areas of high human use within their home ranges. However, the 2.6-m high security fences did affect deer movements on the LA/NERP.

Environmental Science Group, 1977,
"Radiation Exposures Measured in Rodents Inhabiting a Liquid Radioavtive Effluent Receiving Area at Los Alamos", Environmental Surveillance at Los Alamos During 1976,
LANL, LA-6801-MS, pp. 28.

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

A 50 x 50 m site near the effluent outfall in DP Canyon was chosen for this study. It has measurable, but variable levels of Cs-137 in the soil, which have accumulated from the release of treated effluent. Rodents in the study area were trapped, implanted with thermoluminescent dosimeters, and released for subsequent recapture and TLD retrieval.

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

Environmental Studies Group, 1973,
Environmental Monitoring in the Vincity of the Los Alamos Scientific Laboratory: Calender Year 1972,
LANL, LA-5184.

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

Environmental Studies Group, 1975,
Omnibus Environmental Assessment,
LANL, R.P. 12.

Environment assessment of the continuing operations at the Los Alamos Scientific laboratory (LASL), Los Alamos, New Mexico, has been carried out in accordance with Federal Regulations. This assessment describes the activities at the Laboratory and assesses actual and possible impacts of these activities on the surrounding environment. Federally-funded operations at Los Alamos began in 1943 during World War II as Project Y of the Manhattan Engineer District of the U.S. Army Corps of Engineers for the War Department. Most of the existing plant was constructed and operational prior to the enactment of the National Environmental Policy Act (NEPA) of 1969 which requires evaluation of environmental impacts.

This Omnibus Environmental Assessment addresses the whole LASL site; the level of detail is general with special emphasis reserved for those areas which have or might be considered to have potential for environmental impacts. The cumulative environmental results of Laboratory activities to date are covered insofar as current knowledge permits. Many long-term environmental studies are underway as part of ongoing research and monitoring programs designed to continually document interactions of Laboratory activities with the environment and permit re-evaluations of significance as knowledge increases.

Environmental Studies Group, 1976,
Environmental Surveillance at Los Alamos During 1975,
LANL, LA-6321-MS.

This report documents the CY 1975 environmental monitoring program of the Los Alamos Scientific Laboratory (LASL). Data are presented for concentrations of radioactivity measured in air, ground and surface waters, sediments, soils and foodstuffs, and are compared with relevent U.S. Energy Research and Development Administration guides and/or data from other reporting periods. Levels of external penetrating radiation measured in the LASL environs are given. The average whole body radiation dose to residents of Los Alamos County resulting from LASL operations is calculated. Chemical qualities of surface and ground waters in the LASL environs have been determined and compared to applicable standards. Results of related environmental studies are summarized.

Environmental Surveillance Group, 1974,
Environmental Surveillance at Los Alamos During 1973,
LANL, LA-5586.

The Fy 73 environmental monitoring program of the Los Alamos Scientific Laboratory (LASL) is described. Data are presented for concentrations of radioactivity measured in air, ground and surface waters, liquids effluents, sediments, and soils and are compared with those of AEC guides and/or data from other reporting periods. Levels of external penetrating radiation measured in LASL environs are given. The average whole body radiation dose to residents of Los Alamos County resulting from LASL operations was calculated. Chemical and biological qualities of liquid effluents and surface and ground waters of LASL environs were determined, and are compared to applicable standards. Results of related environmental studies are presented. Ecological investigations include (a) an environmental inventory of LASL and environs, (b) the honeybee as a potential tritium indicator organism, (c) radionuclides in Los Alamos area canyon ecosystems, and (d) physical and chemical characterization of Los Alamos area soils. Results are given of meteorological investigations of Los Alamos climatological records, rainfall distributions, and wildfield patterns. There are also data pertaining to the geo-hydrological determination of flood frequencies and maximum discharges of Los Alamos area canyons. Environmental control activities are described which should be benefit to LASL planning.

The results of the monitoring program for this report confirm the generally low radiation levels previously noted in the Los Alamos Environs. Measurements of gross radioactivity in air and precipitation revealed concentrations similar to those at other locations in the northern hemisphere where activity is entirely attributable to the presence of worldwide fallout. Airborne plutonium and tritium measurements revealed that Laboratory activities have slightly elevated the levels of both materials above the concentrations expected from global fallout.

Environmental Surveillance Group, 1975,
Environmental Surveillance at Los Alamos During 1974,
LANL, LA-5977-PR.

This report documents the environemtal monitoring program at the Los Alamos Scientific Laboratory (LASL) in 1974. Data are presented for concentrations of radioactivity measured in air, ground and surface waters, sediments, soils, and foodstuffs, and are compared to relevant U.S. Energy Research from other reporting periods. Levels of external penetrating radiation were measured and the average level for off site locations was 128 mrem/yr. Radioactivity in surface and ground water, soils and sediments in the LASL environs were below applicable Concentration Guides (CGs). The chemical quality of most surface and ground waters sampled in LASL environs met standards set for drinking water.

Environmental Surveillance Group, 1977,
Environmental Surveillance at Los Alamos During 1976,
LANL, LA-6801-MS.

This report documents the environmental monitoring program at the Los Alamos Scientific Laboratory (LASL) in 1976. Data are presented for concentrations of radioactivity measured in air, ground and surface waters, sediments, soils, a foodstuffs, and are compared to relevant U.S. Energy Research from other reporting periods. Levels of external penetrating radiation were measured and the average level for off site locations was 118 mrem/yr. Radioactivity in surface and ground water in the LASL environs was below applicable Concentration Guidelines (CGs). The chemical quality of most surface and ground waters sampled in LASL environs met standards set for drinking water.

Environmental Surveillance Group, 1978,
"Radionuclide Uptake by Vegetable Crops in the Mortandad Canyon Garden Plot During 1976", Environmental Surveillance at Los Alamos During 1977, LANL, LA-7263-MS, pp. 38.

A garden study was initiated in 1976 to determine the availability of radionuclides to vegetables grown in contaminated soil in Mortandad Canyon. The garden was located on an alluvial fan in an area which has received runoff-transported industrial liquid effluents since 1963. An area of 200 square meters was fenced off and diked to prevent animal intrusion and further flooding from stream channel water. The garden was rototilled to a depth of 30 cm and fertilized with chemical fertilizers and manure. Soil samples were taken prior to planting to determine radionuclide distribution. In 1976, radish, onion, corn, squash and tomato crops were planted. The crops were sampled at various times in the growing season and soil samples collected at the rooting zone for each sample. Preliminary data for tomatoes and radishes have been summarized.

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

Environmental Surveillance Group, 1978,
Environmental Surveillance at Los Alamos During 1977,
LANL, LA-7263-MS.

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

Environmental Surveillance Group, 1979,
"Archeology", Environmental Surveillance at Los Alamos During 1978,
LANL, LA-7800-ENV, pp. 43-44.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977).

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Ten additional archeological sites were located and added to the map of all archaeological 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.

Environmental Surveillance Group, 1979,
Environmental Surveillance at Los Alamos During 1978,
LANL, LA-7800-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos Scientific Laboratory during 1978. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1978 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment. Results of several special studies describe some unique environmental conditions in the Laboratory environs.

Environmental Surveillance Group, 1980,
"Archeology", Environmental Surveillance at Los Alamos During 1979,
LANL, LA-8200-ENV, pp. 50-51.

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More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977).

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Twenty additional archeological sites were located at LASL in 1979 and have been added to the inve ɔry of historic sites. During the year one pre-Columbian ruin was excavated.

Two local boys made an important find of two 15th century pottery vessels sealed with lime plaster. The pots were brought to LASL where test were performed. Neutron radiography revealed feathery-looking contents inside the pot. A small hole was drilled through the top pot and the contents were futher determined. Small bits of feathers were removed from the pot and sent to the Smithsonian Institute for ornithological and other analyses. The pots have been placed in the Bradbury Science Hall.

Five log cabins, which date from early years of this century are located within LASL boundaries. All are deteriorating rapidly, and the National Park Service is preparing a preservation plan for the structures. Boring of logs will be done to estimate construction dates.

Environmental Surveillance Group, 1980,
Environmental Surveillance at Los Alamos During 1979,
LANL, LA-8200-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos Scientific Laboratory during 1979. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1979 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment. Results of several special studies describe some unique environmental conditions in the Laboratory environs.

Environmental Surveillance Group, 1981,
"Archeology", Environmental Surveillance at Los Alamos During 1980,
LANL, LA-8810-ENV, pp. 50-51.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977).

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Environmental Surveillance Group, 1981,
Environmental Surveillance at Los Alamos During 1980,
LANL, LA-8810-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1980. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1980 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1982,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1981,
LANL, LA-9349-ENV, pp. 61-62.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977). A further report summarizing excavations on the Laboratory between 1975 and 1978 is in process.

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Nine new sites, both pre-Columbian and historic, were located this year and added to the inventory of sites.

Environmental Surveillance Group, 1982,
Environmental Surveillance at Los Alamos During 1981,
LANL, LA-9349-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1981. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1981 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment. Results of several special studies describe some unique environmental conditions in the Laboratory environs.

Environmental Surveillance Group, 1983,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1982,
LANL, LA-9762-ENV, pp. 59-60.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977). A further report summarizing excavations on the Laboratory between 1975 and 1978 was issued later (Steen, 1982).

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

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Environmental Surveillance Group, 1983,
Environmental Surveillance at Los Alamos During 1982,
LANL, LA-9762-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1982. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1982 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment. Results of several special studies describe some unique environmental conditions in the Laboratory environs.

Environmental Surveillance Group, 1984,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1983,
LANL, LA-10100-ENV, pp. 63-64.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977). A further report summarizing excavations on the Laboratory between 1975 and 1978 was issued later (Steen, 1982).

Several unique pre-Columbian ruins were recommended for registration as national historic sites, and formal nomination procedures are underway. Registration will ensure their preservation for future generations by establishing formal responsibility for their protection.

Environmental Surveillance Group, 1984,
Environmental Surveillance at Los Alamos During 1983,
LANL, LA-10100-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1983. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1983 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1985,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1984,
LANL, LA-10421-ENV, pp. 73.

Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

More than 450 archaeological sites at the Laboratory were surveyed between March 1973 and July 1975. This survey of the pre-Columbian Indians is summarized in a Laboratory report (Steen, 1977). A further report summarizing excavations on the Laboratory between 1975 and 1978 was issued later (Steen, 1982).

The Laboratory donated an onsite homesteader's cabin, the Romero Cabin, to the Los Alamos Historical Society. A historical architect was employed to dismantle and store the structure for reconstruction at the Los Alamos County Historical Museum.

The Laboratory's archaeologist has begun field surveys of associated outlying features and analysis of recovered artifacts for the homestead. Certain site features will be excavated. Botanical analysis of vegetation patterns has also been started. This project is the first professional investigation of homesteading on Pajarito Plateau. Los Alamos Historical Society is conducting interviews of people who lived on Pajarito Plateau during the homesteading effort, in a cooperative research effort with the Laboratory.

Environmental Surveillance Group, 1985,
Environmental Surveillance at Los Alamos During 1984,
LANL, LA-10421-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1984. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1984 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1986,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1985,
LANL, LA-10721-ENV, pp. 72-73.

Laboratory lands contain more than 450 known archaeological and historical sites. Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance.

Mitigation of unavoidable adverse impact to cultural resources is determined in consultation with the New Mexico State Historical Preservation Office (SHPO) and the National Advisory Council on Historic Preservation. During 1985, two principal mitigative actions occurred. The SHPO determined that the World War II explosives subassembly site of the Fat Man Bomb (Building TA-22-1) was of sufficient historical significance to prohibt demolition. Major mitigation of adverse impact to the Romero Homesteading Complex, begun in 1984, continued. The Romero cabin was dismantled and restored at a site near the Los Alamos County Historical Museum. The Laboratory archaeologists completed fieldwork at the original homesteading site; analysis of artifacts continues.

Environmental Surveillance Group, 1986,
Environmental Surveillance at Los Alamos During 1985,
LANL, LA-10721-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1985. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well a in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1985 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1987,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1986,
LANL, LA-10992-ENV, pp. 91-95.

Laboratory lands contain about 500 known archaeological and historical sites. Protection of cultural resources is mandated by numerous laws and regulations. The Laboratory's archaeologist survey construction sites in advance to determine the presence or absence of cultural resources.

During 1986, the Laboratory conducted 32 cultural surveys, monitored construction at 3 sites, had permanent protective fencing erected at 1 site, and undertook adverse impact mitigation at 2 sites. Archaeologists and botanists continued data analysis of artifacts from historic Romero Cabin complex. A historic cabin, the Pond Cabin, was given emergency stabilization, and grates were placed over two unique cavates to provide protection from vandalism.

Environmental Surveillance Group, 1987,
Environmental Surveillance at Los Alamos During 1986,
LANL, LA-10992-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1986. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potenially undesirable trends. Results and interpretation of 1986 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1988,
"Archaeological and Historical Protection", Environmental Surveillance at Los Alamos During 1987,
LANL, LA-11306-ENV, pp.72-75.

Laboratory lands contain about 900 known archaeological and historical sites. Protection of cultural resources is mandated by numerous laws and regulations. Laboratory archaeologists survey project sites in advance of construction to determine the presence or absence of cultural resources.

During 1987, the Laboratory conducted 28 cultural resource surveys, monitored construction at 7 sites, had permanent protective fencing erected at 1 site, and undertook adverse impact mitigation at 2 sites. During surveys of one project in Mortandad Canyon, archaeologists discovered a pit house that indicates earlier prehistoric occupation of the area than thought.

The New Mexico State Historic Preservation Office (SHPO) and Advisory Council on Historic Perservation approved stabilization and restoration work on the historic Pond Cabin at TA-18. The Laboratory completed work on this project during 1987. The cabin will be nominated for inclusion on the State Register of Cultural Properties. Surveys of prehistoric Indian cavates along the south slope of Mesita del Buey using volunteer Laboratory staff supervised by Laboratory archaeologists were completed, and a report was submitted to the Laboratory. Analysis of archaeological and botanical data recovered from the Romero Cabin homesteading site was conducted and draft reports prepared.

Environmental Surveillance Group, 1988,
Environmental Surveillance at Los Alamos During 1987,
LANL, LA-11306-ENV.

This report describes the environmental surveillanvce program conducted by Los Alamos National Laboratory during 1987. Routine monitoring for radiation and radioactive or chemical materials is conducted on the Laboratory site as well as in surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of 1987 data cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not impact the public, Laboratory employees, or the environment.

Environmental Surveillance Group, 1989,
Environmental Surveillance at Los Alamos During 1988,
LANL, LA-11628-ENV.

This report describes the environmental surveillance program conducted by Los Alamos National Laboratory during 1988. Routine monitoring for radiation and radioactive or chemical material is conducted on the Laboratory site as well as in the surrounding region. Monitoring results are used to determine compliance with appropriate standards and to permit early identification of potentially undesirable trends. Results and interpretation of data for 1988 cover: external penetrating radiation; quantities of airborne emissions and liquid effluents; concentrations of chemicals and radionuclides in ambient air, surface and ground waters, municipal water supply, soils and sediments, and foodstuffs; and environmental compliance. Comparisons with appropriate standards, regulations, and background levels provide the basis for concluding that environmental effects from Laboratory operations are insignificant and do not pose a threat to public, Laboratory employees, or the environment.

Erdal, B.R., 1979,
Sorption-Desorption Studies on Granite I. Initial Studies of Strontium, Technetium, Cesium, Barium, Cerium, Europium, Uranium, Plutonium, and Americium, LANL, LA-7456-MS.

Distribution ratios were determined for sorption-desorption of radioactive tracers between the Climax Stock granite (quartz monzonite porphyry) obtained at Nevada Test Site and a water prepared to be reasonably representative of the natural composition of water in equilibrium with the Climax Stock granite. The measurements were performed at 22 degrees C. and 70 degrees C. under atmospheric oxygen conditions. Elements given in order of increasing distribution coefficient at ambient temperature are: U(VI), Sr, Tc(VII), Ba, Ce(III), Cs, Eu(III), Pu, and Am. At 70 degrees C. the order is: Tc(VII), Sr, Ce(III), Eu(III), Ba, Cs, Pu, Am. The effects of surface area mineralogy on sorption were also investigated.

Erdal, B.R., et al., 1979,
Sorption-Desorption Studies on Argillite I. Initial Studies of Strontium, Technetium, Cesium, Barium, Cerium and Europium,
LANL, LA-7455-MS.

Distribution ratios were determined for sorption-desorption of radioactive tracers between Eleana argillite available from Nevada Test Site and water prepared to be representative of the natural groundwater composition. The measurements were performed at 22 degrees C. and 70 degrees C. under atmospheric oxygen conditions. The order of increasing distribution coefficients by element at both temperatures is Tc(VII), Sr, Cs, Ba, Eu, and Ce. The effects of surface area and mineralogy were also investigated.

Felthauser, M., and McInroy, D., 1982,
"Mapping Pocket Gopher Systems with Expanding Polyurethane Form", Environmental Surveillance at Los Alamos During 1981,
LANL, LA-9349-ENV, pp.65-66.

In a Los Alamos study of barrier materials that inhibit burrowing by pocket gophers (Thomomys spp.) into waste material, it was necessary to map tunnel systems as a function of depth and soil profile type. A method of mapping burrow systems was needed that would be economical, portable, useful in a variety of soil types and give accurate, permanent records of burrow configurations.A method for injecting an expanding polyurethane foam to map burrow systems was chosen

The polyurethane foam injection technique provided a relatively easy, accurate method of mapping pocket gopher burrow systems. Features of the burrows that were readily identified or measured included the length, depth, and volume of the length, depth and volume of the tunnel system as well as food storage and nesting chambers.

Labor required to map a burrow system in detail was minimal over conventional excavation methods that employ archeological procedures. The foam injection method was particularly appropriate for cohesive soil types with limited pore space. The method did not work well in loosely structured gravel or cobble soil soil profiles. Although this technique was tested only on tunnel systems, it could be adapted to map tunnel systems from a wide array of burrowing organisms.

Ferenbaugh, R.W., and Purtymun, W.D., 1980,
"Special Study of Radionuclides from LAMPF Lagoons", Environmental Surveillance at Los Alamos During 1979,
LANL, LA-8200-ENV, pp. 61-63.

Cooling system at the Los Alamos Meson Physics Facility (LAMPF) discharge water with activation product radionuclides, primarily H-3, Be-7, and Na-22, into lagoons below the facility. Samples of the water and sediment, and transpirate from trees adjacent to the effluent stream from the lagoons have been collected every 1 to 1.5 months since the effluent began flowing in the Spring of 1979. The purpose of the sampling program is to ascertain the extent to which radionuclides are being dispersed from the lagoons.

Sampling results indicate that radionuclide concentrations decrease with progression down the canyon. In general, the data show that while there has been some dispersal of radionuclides down the canyon into which the discharge occurs, there has been no detectable dispersion beyond the point at which the discharge stream sinks into the alluvium.

Ferenbaugh, R.W., et al., 1982,
Environmental Analysis of Acid/Middle Pueblo Canyon, Los Alamos, New Mexico,
LANL, LA-9409-MS.

The radiological survey of the former radioactive waste treatment plant site (TA-45), Acid Canyon, and Pueblo Canyon found residual radioactivity at the site itself and in the channels and banks of Acid, Pueblo, and lower Los Alamos Canyon all the way to the Rio Grande. The largest reservoir of the radioactive material is in the lower Pueblo Canyon, which is on DOE property. The only areas where residual radioactivity exceeds the proposed cleanup criteria are at the former vehicle decontamination facility, located between the former treatment plant site and Acid Canyon, around the former untreated waste outfall and for a short distance below, and in two small areas farther down in Acid Canyon. Three altrnatives proposed are (1) to take no action, (2) to fence the areas where the residual radioactivity exceeds the proposed criteria (minimal action), and (3) to clean up the former vehicle decontamination facility and around the former untreated waste outfall. Calculations based on actual measurements indicate that the annual dose at the location having the greatest residual radioactivity would be about 12% the applicable guideline. Most doses are much smaller than that. No environmental impacts are associated with either the no-action or minimal action alternatives. The impact associated with the clean up alternative is very small. The preferred alternative is to clean up the areas around the former vehicle decontamination facility and the untreated waste outfall. This course of action is recommended not because of any real danger associated with the residual radioactivity, but rather because cleanup operations is a minor effort and would conform with the ALARA (as low as reasonably achievable) philosophy.

Ferenbaugh, R.W., et al., 1982,
Environmental Analysis of the Bayo Canyon (TA-10) Site, Los Alamos, New Mexico,
LANL, LA-9252-MS.

The radiological survey of the old TA-10 site in Bayo Canyon found low levels of surface contamination in the old waste disposal area. The three alternatives proposed for the site are (1) to take no action, (2) to restrict usage of the area of subsurface contamination to activities that cause no surface disturbance (minimal action), and (3) to remove the subsurface contamination to levels below the working criteria. Dose calculations indicate that doses from surface contamination for recreational users of the canyon, permanent residents, and construction workers and doses for workers involved in excavation of contaminated soil under the clean up alternative are only small percentages of applicable guidelines. No environmental impacts are associated with either the no-action or minimal alternatives. The impact associated with the cleanup alternative is small, especially considering that the area already has been affected by the original TA-10 decommissioning action, but nevertheless, the preferred alternative is the minimal action alternative, where 0.6 hectare of land is restricted to surface activities. This leaves the rest of the canyon available for development with up to 400 homes. The restricted area can be used as a park, tennis courts, etc., and the Sr-90 activity will decay to limits permitting unresticted usage in about 160 yr.

Ferenbaugh, R.W., Spall, W.D., and LaCombe, D.M., 1981,
Detection of Bromacil Herbicide in Ponderosa Pine,
Bull. Environm. Contam. Toxicol., Vol. 27, pp. 268-273.

Bromacil is a substituted uracil herbicide, 5-bromo-3-secbutyl-6-methyluracil. It is a photosynthesis inhibitor, which apparently affects the Hill reaction in photosystem II (Hilton et al. 1964, Hoffman et al. 1964). It has a low oral toxicity and causes minimal effects on soil microorganisms (Sherman & Kaplan 1975, Weed Science Society of America 1974). Because it is readily absorbed through the root system of plants, bromacil usually is applied to the soil as an aqueous solution or suspension during or just before periods of active plant growth. It is not readily adsorbed onto soil particles and may be persistent in the soil for more one than growing season, having a half-life of five to six months (Gardiner et al. 1969, Weed Science Society of America 1974).

Foster, G.R., and Hakonson, T.E., 1987,
"Erosional Losses of Fallout Plutonium", Dynamics of Transuranics and Other Radionuclides in Natural Environments,
Nevada Applied Ecology Group, NVO-272.

Plutonium from fallout after atmospheric explosion of nuclear weapons in the 1950's and 1960's is being redistributed over the landscape by soil erosion and carried on sediment by streams to oceans. Erosion rates computed with the Universal Soil Loss Equation for more than 200,000 sample points on nonfederal land across the United States were used to estimate plutonium removal rates by soil erosion. On the average, only about 4 percent of the eroded sediment reaches the outlet of a major river. The remaining sediment is deposited en-route, and since deposition is a selective process, the sediment is enriched in fine particles, ones having the highest concentration of plutonium because of its strong association with clay and silt sized sediment. Estimated enrichment ratios, sediment delivery ratios, and erosion rates were used to estimate annual delivery of fallout plutonium. These estimates ranged from 0.002 percent of the initial fallout plutonium inventory for the Savannah River Basin, to 0.01 percent of the Columbia River basin to 0.02 perecent for the Hudson and Rio Grande River Basins to 0.08 percent for the Mississippi River Basin. If the deposition of plutonium had been uniformly 1 mCi/squared km, the estimated plutonium activity on suspended sediments ranged from about 7 fCi/g of sediment of the Savannah River basin, to 9 fCi/g for the Mississippi River Basin, to 12 fCi/g for the Hudson River basin, to 14 fCi/g for the Columbia and the Rio Grande River basins. Erosion does not rapidly remove plutonium; after 100 years, about 60 to 85 percent of the initial inventory will remain in United States' soils. Much of the plutonium on eroded sediment will travel only a short distance from its origin before its host sediment particles are deposited permanently located, at least for a few hundred years. Therefore, 90 percent of the initially deposited plutonium will remain but redistributed over the landscape by erosion and deposition. Although the delivery rate of plutonium by rivers will not decrease greatly in the next 200 years, a significant decrease will likely occur by 1000 years.

Foster, G.R., et al., 1983,
Modeling the Effectiveness of On-Site Sediment Controls.,
American Society of Agricultural Engineers, Paper #83-2092.

Equations are presented that may be used with modifications of the USLE and fully dynamic hydrology models to model the effectiveness of on-site sediment controls.

Foster, G.R., Neibling, W.H., and Natterman, R.A., 1982,
A Programmable Rainfall Simulator,
American Society of Agricultural Engineers, Paper #82-2570.

A programmable rainfall simulator was designed and built for field studies on plots 4 x 11 m and longer. The simulator uses oscillating nozzles and recirculates excess water within individual trough units. Since each trough is independent of other troughs, variable intensities in time and space can be programmed on the industrial process controller controlling the simulator. Although spray from the nozzles is intermittent, the 0.5 s delay between spray applications at a 60 mm/h intensity is sufficiently short to have minimal effects on infiltration, runoff, and erosion. The simulator is reliable and easy to use, but is more expensive than other similar simulators.

Fowler, E.B., Gilbert, R.O., and Essington, E.H., 1974,
Sampling of Soils for Radioactivity: Philosophy, Experience, and Results,
LANL, LA-UR-74-1339.

In many cases, the methods of sampling a soil matrix have not received the attention required when data derived therefrom are to be applied to problems associated with analysis of radionuclides. The import of the soil surface as one ultimate receptor, and hence source, of particulate debris in the atmosphere surface exchange system will be discussed.

This paper will review aspects of one approach to sampling of soils which has proved sucessful in a study of extensive areas where contamination with plutonium exists at a wide range of levels. The practical application of the work presented by Gilbert, et al., is reported as well as data identifying one source term to be reported by Anspaugh, et al.

The development and field application of sampling techniques based on a designed random sampling scheme and on knowledge of contaminant distribution are discussed.

Typical results from participating laboratories are presented which indicate the degree of success experienced when the approach described is used to obtain data relative to inventory, horizontal and vertical distribution, and species of radionuclide.

Problems associated with the requirement to obtain a "most probably representative sample" as well as the need for a common expression of extent of contaminant, are emphasized. The particle problem as it relates to sampling, analyses, and interpretation of data is discussed.

Foxx, T., and Tierney, G., 1979,
"Botanical Survey for Critical Habitats in the LA/NERP", Environmental Surveillance During 1978,
LANL, LA-7800-ENV, pp. 48-51.

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, gramma grass catctus (Pediocactus paprycanthus), that was likely to be found within the LA/NERP. Although no gramma grass cactus has been found inside the LA/NERP boundaries per se, the species is very likely to occur within undisturbed sites where gamma grass predominates.

Most of the species on the list occur in the southern portion of the state. This is partially due to the paucity of floristic studies in the northern part of the state. Therefore, this survey was designed to identify any of the listed species and to locate other species that were rare to the area or endemic. During the course of the survey several species were located that had not been noted on other LANL studies. They are not necessarily rare, threatened or endangered at the present time, but in areas sampled, they nave very low population numbers. An example of such a plant is the larkspur violet (Viola pedatifida).

The federal list consist only of candidate species; the list is not yet static Species are being added and deleted. Therefore a more complex collection was made than originally anticipated. As of May 1, 1978, 160 plants had been identified; 65 of these had not been reported previously. A number of species found are known to be of ethnobatanical significance. They were possibly utilized by the prehistoric inhabitants of the Pajarito Plateau as food clothing, medicine, or for ceremonial purposes. 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. This list is published as a LASL report and will give information such as plant distribution, synonyms, and references.

Foxx, T.S., 1982,
Use of a Computer Generated Movie to show the Sequence in Fire History Interpretation,
LANL, LA-UR-82-1569.

Fire history interpretation has been done with conventional graphing techniques. However, when a fire history spans over several hundred years, these traditional graphing techniques have several limitations in interpretation presentations. A dendrochronological study was conducted in Bandelier National Monument, New Mexico to determine fire frequency before major land use changes occurred in this area. A fire history sequence from 1986-1977 was illustrated using a computer generated movie. The study showed before major land use changes a major fire burned over the meas tops ever 12-25 years; however, after 1894 there had been no major conflagrations for 84 years. Fire frequencies for the period 1797-1893 were one fire every 15 years but for the period 1894-1977 the frequency was one fire every 63 years. The movie visually shows the difference in fire frequency prior to major land use changes and the total fire suppression policy.

Foxx, T.S., and Tierney, G.D., 1980,
Status of the Flora of the Los Alamos Environmental Research Park,
LANL, LA-8050-NERP Vol. I.

Under the Endangered Species Act of 1973, it became necessary to locate critical habitats of plant species in danger of extinction on State/Federal lands. In 1976 the Los Alamos National Environmental Research Park (LA/NERP) was established to provide a study area that would contribute to the understanding of how man can best live in balance with nature while enjoying the benefits of technology. Under this mandate, a study to provide information regarding the locations of possible endangered, threatened, protected, and rare species within the LA/NERP was initiated in August 1977.

Foxx, T.S., and Tierney, G.D., 1982,
Vegetational Analysis of a Canyon Ecosystem at Los Alamos,
LANL, LA-9576-MS.

During the fall of 1981, a vegetative analysis was done on a canyon ecosystem at Los Alamos in a disturbed area immediately below an endangered falcon nesting site. The primary objective was to determine if any plants found within the disturbed area were key food species for either doves or rodents.

The results indicate that the disturbed site does not have an abundance of key food species that are reportly used by doves and rodents.

Foxx, T.S., and Tierney, G.D., 1984,
Status of the Flora of the Los Alamos National Environmental Research Park: A Historical Perspective,
LANL, LA-8050-NERP, Vol. II.

Studies of the flora of the Los Alamos National Environmental Research Park (LA/NERP) are continued in Water and Pajarito Canyons and their extensions to natural boundaries outside the LA/NERP . Six plant communities and sixteen plant habitats are described for the study area. The status of endangered, threatened and rare species is reviewed and landuse history of the Pajarito Plateau is related to the levels of apparent anthropengic distrubance in the study areas' six plant communities.

Results of the study revealed their are approximately 436 vascular plant species 67 families. Very few of these species are presently regarded as endangered, threatened or even rare; however, 39 of them receive limited protection under New Mexico laws, and the status of some potentially endangered or threatened plants may change when current reviews by state and federal agencies are completed.

Vegetation patterns on the LA/NERP and its immediate surroundings have been affected by former land use on the Pajarito. Some evidence of disturbances dates to the pre-Spanish period. The strongest agents of disturbance in recent times have been fir, logging and insect pest.

Foxx, T.S., and Tierney, G.D., 1985,
Status of the Flora of the Los Alamos National Environmental Research Park: Checklist of Vascular Plants of the Pajarito Plateau and Jemez Mountains, LANL, LA-8050-NERP, Vol. III.

This report lists all taxonomic recorded from the Pajarito Plateau, Valles del los Sierros, Valles Caldera, and portions of the Jemez Mountains in north-central New Mexico. Approximately 900 plants representing more than 80 families are documented.

Foxx, T.S., Tierney, G.D., and Williams, J.M., 1984,
Rooting Depths of Plants on Low-Level Waste Disposal Sites,
LANL, LA-10253-MS.

In 1981-1982 an extensive biblographic study was done to reference rooting depths of native plants in the United States. The data base presently contains 1034 different rooting citations with approximately 12,000 data elements. For this report, data analyzed for rooting depths related to species found on low-level waste (LLW) sites at Los Alamos National Laboratory. Average rooting depth and rooting frequencies were determined and related to present LLW maintenance.

The data-base was searched for information on rooting depths of 53 species found on LLW sites at Los Alamos National Laboratory. The study indicates 12 out of 13 grasses found in LLW sites root below 91 cm. June grass [Koeleria cristata (L.) Pers.] (76 cm) was the shallowest rooting grass & side-oats grama [Bouteloua curptipendula (michx.) Torr.] was the deepest rooting grass (396 cm). Forbs were more variable in rooting depths. Indian paintbrush (Castelleja spp.) (30 cm) was the shallowest rooting forb and alfalfa (Medicago sativa L.) was the deepest (>3900 cm). Trees and shrubs commonly rooted below 457 cm. The shallowest rooting tree was elm (Ulmus pumila L.) (127 cm) and the deepest was one-seed juniper [Juniperus monosperma (Engelm) Sarg.] (>6000 cm). Apache plume [Fallugia paradoxa (D. Don) Endl.] rooted to 140 cm, whereas fourwing saltbush [Atriplex canecens (Pursh) Nutt.] rooted to 762 cm.

Foxx, T.S., Tierney, G.D., and Williams, J.M., 1984,
Rooting Depths of Plants to Biological and Environmental Factors,
LANL, LA-10254-MS.

In 1981-1982 an extensive bibliographic study was completed to document rooting depths of native plants in the United States. The data base presently contains 1034 citations with approximately 12,000 data elements. In this paper the data were analyzed for rooting depths as related to life form, soil type, geographical region, root type, family, root depth to shoot height ratios, and root depth to root lateral ratios. Average rooting depth and rooting frequencies were determined and related to present low-level waste site maintenance.

Fuentes, H.R., 1987,
Preliminary Report on Sorption Modeling,
LANL, LA-10952-MS.

The generic objective of this study is to inventory and model batch sorption data obtained for the Nevada Nuclear Waste Storage Investigations Project by the Los Alamos National Laboratory. This report addresses three main topics: the modeling by various isotherms of data sets inventoried from about 1500 data entries, potential occurrence of precipitation in the sorption experiments, and the evaluation of a computer code to study changes in chemical isolation caused by changes in the chemistry of the porous media.

In general the sorption data for strontium, cesium, barium, and europium were found to be modeled best by the Freundlich and Modified Freundlich isotherms, followed by the linear isotherm; the poorest fits were usually observed with the Langmuir isotherm. The effect of particle size of tuff material on modeling was found to be relatively insignificant for the available size ranges and data sets. Thus, in general, modeling of combined data for different fractions of the same tuff sample remained as effective as before combining data of different sizes. Modeling combined data from samples within the same stratigraphic unit of Yucca Mountain indicates that simple models having acceptable statistical correlation may be found. Best modeling results were obtained for the Topopah Spring and Calico Hills units; poorest results were obtained for the Tram, Prow Pass, and Bullfrog units. In every case, however, at least one isotherm modeled the data from each stratigraphic unit with acceptable statistical correlation.

The analysis of sorption data for the potential precipitation of strontium and barium indicates that the precipitation of $SrSO_4$ may have occurred in experiments with the YM-22 and G1-2840 tuff samples at the high initial concentrations of strontium. The precipitation of BaSO also potentially occurred in experiments with the YM-22 tuff samples at the high initial concentrations of barium.

Because of the large CEC of the YM-38 tuff sample, both strontium and barium were probably removed from solution by the cation exchange process rather than by precipitation.

The modeling of microscopic processes on metal oxide surfaces suggests that the intrusion into the isolated environment of a contaminant by a water of different chemical composition can mobilize that contaminant. The intrusion of that water causes the release of protons from oxide surfaces together with the adsorption or desorption of electrolyte ions. As a result the contaminant may be desorbed and mobilized; thus the isolation of the contaminant is breached.

Fuentes, H.R., et al., 1984,
Nonequilibrium Behavior of Cobalt, Cesium, and Strontium in Competitive Sorption on Bandelier Tuff,
LANL, LA-UR-84-3607.

Information is presented on the nonequilibrium competitive sorption of cobalt, cesium and strontium on Bandelier Tuff. These solutes were studied because of prime concern by regulators on their fate in the shallow land disposal of low level radioactive waste and because of their suspected differences in sorptive characteristics. Both adsorption and desorption were studied in the batch mode at 25 degrees C. with constant mixing.

Adsorption equilibrium appears to occur almost instananeously for strontium, somewhat more slowly for cesium and very slowly for cobalt. The degree of adsorption varied between about 20% for strontium and 90% for cobalt, with approximately 40% for cesium. Data from the sampling of solutes in solution as a function of time indicate various regions in which sorption kinetics reflect temporary steady state conditions.

The simultaneous sorption of solutes in groups of two or three indicates that competition among solutes may affect either kinetics or the equilibrium concentrations or both.

The results of this study provide some insight into the theoretical and practical evaluation of equilibrium/nonequilibrium patterns of solute sorption for the improvement of modeling of solute transport in the unsaturated zone.

Gallegos, A.F., and Wenzel, W.J., 1984,
HUMTRN: Documentation and Verification for an ICRP-BASED Age-and Sex-Specific Human Simulation Model for Radionuclide Dose Assessment,
LANL, LA-9994-MS.

The dynamic human simulation model HUMTRN is designed specifically as a major module of BIOTRAN to integrate climatic, hydrologic, atmospheric, food crop, and herbivore simulation with human dietary and physiological characteristics, and metabolism of radionuclides to predict radiation doses to select organs of both sexes in different age groups. The model is based on age and weight specific equations developed for predicting human radionuclide transport from metabolic and physical characteristics. These characteristics are modeled from studies documented by the International Commission on Radiological Protection (ICRP 23). HUMTRN allows cumulative doses from uranium or plutonium radionuclides to be predicted by modeling age specific anatomical, physiological, and metabolic properties of individuals between 1 and 70 years of age and can track radiation exposure and radionuclide metabolism for any age group for specified daily or yearly time periods. The simulated daily dose integration of eight or more simultaneous air, water, and food intakes gives a new, comprehensive, dynamic picture of radionuclide intake, uptake, and hazard analysis for complex scenarios. A detailed example using site-specific data based on the Pantex studies is included for verification.

Gallegos, A.F., Garcia, B.J., and Sutton, C.M., 1980,
Documentation of TRU Biological Transport Model,
LANL, LA-8213-MS.

Inclusive of Appendices, this document describes, rationale, construction, and operation of a biological transport model (BIOTRAN). This model is used to predict the flow of transuranic elements (TRU) through specified plant and animal environmets using biomass as a vector. The appendices are:

A) Flows of moisture, biomass, and TRU
B) Intermediate variables affecting flows
C) Memonic equivalents (code) for variables
D) Variable library (code)
E) Biotran code (Fortan)
F) Plants simulated
G) BIOTRAN code documentation
H) Operating instructions for BIOTRAN code

The main text is presented with a specific format which usese a minimum of space, yet is adequate for tracking most relationships from their first appearance to their formulation into code. Because relationships are treated individually in this manner, and rely heavily on Appendix material for understanding, it is advised that the reader familiarize himself with these materials before proceeding with the main text.

Gedayloo, T., et al., 1979,
Behavior of a Tall Stack Plume in Flow over a Ridge.,
LANL, LA-7632-MS.

A study of ground level sulfur dioxide concentration due to effluent from the Four Corners Power Plant in northwestern New Mexico was conducted from December 1976 to August 1978. An array of sulfation plates was installed on a hogback ridge northwest of the power plant. Data were analyzed to determine the existence and effect of and eddy current on the lee side of the hogback.

Gedayloo, T., et al., 1979,
Summertime Nocturnal Drainage Flow in the San Mateo and Ambrosia Lake Sheds of the Grants Basin.,
LANL, LA-7628-MS.

An initial study of some fundamental meteorological properties of two major air sheds in the Grants Basin of northwestern New Mexico was conducted from May 18 to September 19, 1978. Three mechanical weather stations were used in conjunction with a few vertical wind soundings to develop a data set for the summer regime. Data collected between May 18 and July 30 is analyzed to investigate nocturnal drainage flows, daytime flows, and channeling of synoptic wind. Drainage wind averaging 2.5 m/s was found to exist in a surface layer not greater than 200 m deep on 60% of the nights investigated. This frequently occurring drainage flow is characterized by a strong decoupling from the upper level winds. Daytime winds, on the other hand, are representative of the synoptic flow patterns suggesting a rather rapid coupling after sunrise.

Gonzales, G.J., 1984,
The Potential Effects of Hydrogen Sulfide Gas from Geothermal Energy Conversion on Two Plant Species Native to Northern New Mexico,
LANL, LA-9984-T.

Dry weight of topgrowth. water content of topgrowth, leaf nitrogen content, and leaf chlorophyll content was measured in well-watered, field-exposed little bluestem (Schizachyrium scoparium Nash.) and mountain brome (Bromus marginatus Nees.) plants fumigated with various mean levels of H2S ranging from 0.05 to 3.58 ppm. The youngest fully expanded leaves were sampled for chlorophyll content after 60, 80, 100, and 140 and 60, 80, 120, and 140 h total of fumigation for little bluestem and mountain brome, repectively. All other responses were measured after 140 h total of fumigation. The plants received a 7-day fumigation free period prior to the seventh week (140 h) of fumigations.

Dry weight of little bluestem plants which received low concentrations of H2S (0.11 ppm) increased by 94% of the control. Dry weight of little bluestem plants which received higher concentrations of H2S (0.12 to 0.48 ppm) was reduced to the control level. At the highest H2S concentration (2.39 ppm) dry weight of little bluestem was reduced by 44% of the control. There was no evidence that the reduction in nitrogen content (38%) at low H2S levels (<=0.11 ppm) was determental to plant growth. The productivity increase at these low concentrations may have been partially due to increase in leaf chlorophyll content (28%) and decrease in water content (16%). The linear dependence of dry weight on leaf chlorophyll content diminished as H2S stress increased. The productivity increase may have partially reflected the usage of sulfur from H2S as a nutrient source.

Mountain brome was relatively unaffected at the different concentrations of H2S until 3.58 ppm H2S was received where dry weight was reduced by 37% of the control.

There was evidence that changes in leaf chlorophyll content as total exposure time increased was partially due to air temperature changes. The decline of leaf chlorophyll content for both little bluestem and mountain brome appeared to be elastic strain because fumigated plants recovered to control or above-control levels. The mechanisms behind H2S-caused stimulation of inhibition of chlorophyll systhesis or destruction of chlorophyll are complex.

Graham, E.R., 1963,
Plant as Monitors of Radioactive Contamination of the Environment of Los Alamos, New Mexico,
LANL, LAMS-2879.

A study of the radioactive contamination of plants of Los Alamos, New Mexico, revealed them to be suitable monitors of the environment.

The results of an analysis of the beta activity found in the ash of grass samples from the area showed that the beta activity in the ash due to potassium-40 was in no case more than 10 percent of the observed activity. The low values obtained on most of the samples obtained at Los Alamos were higher than values obtained on samples from Espanola and Santa Fe.

Gammma-ray spectrum analysis of the grass and pine needle pellets along with analysis of digested air filters reveled the principal gamma activity to be due to the fission products zirconium-niobium, ruthenium-rhodium, and cerium-praseodymium. There were some samples which contained amounts of iodine-131.

Graham, E.R., 1964,
Strontium-90, Cesium-137, and Radioactive Rare Earths in Environmental Rain and Air at Los Alamos, New Mexico, 1958-June 1963,
LANL, LAMS-2878.

A study was made of the strontium-90, cesium-137 and the radioactive rare earths in the environmental rain and air at Los Alamos, New Mexico. Samples of rain and air were collected continuously from January 1958 through June 1963

The results of the study showed the activity of the strontium-90 to be the highest during the summer of 1958; the activity then decreased slowly reaching the lowest level during September of 1961. Starting in October of 1961 the activity started to rise, however, never reaching the level of 1958.

The observed results of the environmental concentration of cesium-137 and rare earth radioactivity were similar to those for strontium-90. The results of the activity measured in the air and that in the rain followed the same monthly distribution. The results of the study would indicate that the rain-held activity is just a wash out of the activity present in the Los Alamos air.

Graham, E.R., 1965,
Strontium-90, Cesium-137, and Radioactive Rare Earths in Environmental Rain and Air at Los Alamos, New Mexico: 1963-1964,
LANL, LA-3382-MS.

The report is a continuation of work reported in LAMS-2878. The study was determination of the strontium-90, cesium-137, and radioactive rare earths in environmental rain and air at Los Alamos, New Mexico.

The results of the study show the activity of the strontium-90 to be the highest during the summer months. The activity then decreases slowly reaching the lowest level during December and January.

The observed results of the environmental concentration of cesium-137 and rare earth radioactivity were similar to those for strontium-90. The results of the activity measured in the air and that in the rain followed the same monthly distribution. The results of the study would indicate that the rain-held activity is just a wash out of the activity present in the Los Alamos air.

Gunderson, T., et al., 1983,
Radiological Survey Following Decontamination Activities Near the TA-45 Site,
LANL, LA-9831-MS.

Three areas at the site of a former radioactive liquid waste treatment plant at Los Alamos National Laboratory were decontaminated during 1982 by Bechtel Corporation, with health physics support provided by Eberline Instrument Corporation., under the Department of Energy's Formerly Utilized Sites Remedial Action Program (FUSRAP). Before decontamination, there were above-background concentrations of gross alpha, gross beta, Pu-238, Pu-239,240, Am-241, Sr-90 and Cs-137 in the surface soils. These combined concentrations were above operational decontamination guidelines for surface soil contamination. After cleanup operations, radionuclide concentrations in surface soils at all three sites were within decontamination guidelines.

Gunderson, T.C., et al., 1983,
An Environmental Study of Emissions from Testing of Shaped-Charged, Depleted Uranium Munitions,
LANL, LA-UR-83-373.

The U.S. Army Missle Command, Redstone Arsenal, Alabama, requested assistance in an environmental study of emissions from testing of shaped-charge, depleted uranium munitions. This study was done at Los Alamos National Laboratory in Technical Area 36 at IJ Firing Site. The IJ Firing Site is in a controlled area where public access is restricted. The Laboratory's Environmental Surveillance Group (H-8) and Detonation Physics Group (M-3) participated in the study.

The environmental assessment involved sampling air, fallout and soil. Air samples based on either radiological or chemical toxicity considerations, measured average airborne concentrations of uraniums in clouds resulting from testing shaped-charged, depleted uranium munitions did not exceed airborne uranium standards at IJ Firing Site. Sampling results also indicated that after testing hundreds of uranium munitions at one firing site the soil at the site became extensively contaminated. Results revealed dose from exposure to any one test firing of a shaped-charged, depleted uranium munition is relatively insignificant. However, the doses are additive for repeated exposures.

From the results obtained from this investigation it appears that more environmental data are needed to adequately assess the health and environmental consequences of testing shaped-charged, depleted uranium munitions.

Guthrie, D.A., and Large, N., 1980,
Mammals of Bandelier National Monument, New Mexico,
Bandelier National Monument, PX7029-7-0807.

This paper presents a list of the mammals of Bandelier National Monument, along with brief accounts of the distribution and status of each species. Knowledge of the mammals of Bandelier is by no means complete. We hope that this report, which summarises all past mammal work, will serve to point gaps in our knowledge and indicate where future work is needed. The nomenclature followed here is that of Findley, et al., 1975.

Gutschick, V.P., 1977,
Long-Term Strategies for Supplying Nitrogen to Crops.,
LANL, LA-6700-MS.

Raising food for present population requires nitrogenous fertilizers in addition to indirect management of the biosphere's nitrogen cycle. The Haber process for making the ammonia base of fertilizers is increasingly pressed by shortages of energy, while only minor improvements are still possible. I discuss the Haber process and 15 alternatives for increasing the nitrogen available to crops using less fossil energy. These alternatives span technology of fertilizer synthesis, farm management and technology, crop genetics, and market management. They were selected by criteria of energy-efficiency and of meeting the numerous biological/physical constraints posed by soils and plants. The alternatives vary in scope and efficiency due to scientific, economic, and political constraints which need be appreciated by policy-makers and researchers alike. I conclude that the Haber process will be the mainstay for nitrogen-nutrition of crops for 50 years, and a few alternative strategies--especially in farm management, but little in crop genetics--will slowly achieve a partial replacement of the Haber process. Full replacement in the longer run requires commitment within a few decades to developing the strongest alternatives.

Hakonson, T.E., 1975,
"Environmental Pathways of Plutonium into Terrestrial Plants and Animals",
Health Physics, Vol. 29, pp. 583-588.

Attempts to assess the relative hazards (or lack of hazards) associated with plutonium dissemination to the environment emphasize the need for quantative data to resolve the many unanswered queations regrading environmental plutonium behavior. This review summarizes most available data on plutonium in native terrestrial plants and animals and discusses some of the known and speculative mechanisms by which plutonium moves into the biota. Factors which require consideration in preparing environmental plutonium safety evaluations are discussed.

Hakonson, T.E., 1987,
Environmental Surveillance of Low-Level Radioactive Waste Management Areas at Los Alamos During 1985,
LANL, LA-UR-87-139.

This report was obtained from Environmental Science Groups as a part of the DOE sponsored radioactive waste site surveillance program at Los Alamos National Laboratory. This report contains information on active (Area G) and 11 inactive (Areas A, B, C, E, F, K, T, U, V, W, and X) radioactive waste management areas at Los Alamos.

Hakonson, T.E., and Bostick, K.V., 1975,
"Honeybees as Biological Indicators of Radionuclide Contamination", Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division: January through December 1974,
LANL, LA-5883-PR, 50-51.

As an extension of previous studies of honeybees, a study was conducted to assess the ultility of honeybees as indicators of tritium (as HTO) released to the environment from a single source. Technical Area 33 was chosen as the study area because relatively large amounts of tritium (3500 Ci/yr) are released from a single stack to the atmosphere surrounding the facility. Samples of stack air, environmental air, vegetation, and soils were collected each week to relate the tritium concentrations in each sample type to corresponding data for bee and honey samples.

Some tentative conclusions can be drawn from the limited amount of data which is available at this time. First, the rapid initial increase in tritium concentrations in bees which was observed in this experiment and in a previous study demonstrated the ability of the insect to respond rapidly to changes in environmental tritium concentrations. Second, there appears to be an inverse relationship between tritium levels in bees and the distance from the stack source. Finally there appears to be little relationship between air concentrations of tritium and levels measured in honeybees, a finding which was also observed previously. If further analysis of the data substantiates this observation, then it would appear that air monitoring data would have little use in predicting tritium concentrations in nectivorous and perhaps herbivorous species.

Hakonson, T.E., and Bostick, K.V., 1976,
"Cesium-137 and Plutonium in Liquid Waste Discharge Areas at Los Alamos", Radioecology and Energy Resources,
Ecol. Soc. Am., Special Publication, No. 1, pp. 40-48.

The results of an ecological investigation of plutonium and Cs-137 are described for three canyons which have received liquid wastes at Los Alamos. Stream channel sediments were identified as the major reservoir of waste radioactivity based on the relatively high radionuclide concentrations measured in this component. Hydrological sediment transport processes in the respective canyons play a major role in the downstream movement of radioactivity. Statistically significant correlations between plutonium and 137-Cs in sediments downstream from the waste outfalls support a physical transport mechanism in the redistribution of sediment radioactivity. Substantially higher plant:sediment activity ratios were calculated for plutonium in the canyons than corresponding ratios derived by others through laboratory experimentation. Significant positive correlation between plutonium and 137-Cs concentrations in vegetation were observed in two canyons which currently receive wastes but not in the third canyon which has not received wastes for 10 yr. Highest average concentrations of plutonium in small ground-dwelling rodents living adjacent to the contaminated streams were observed in lung and pelt tissue, indicating that resuspension is likely a major mechanism in the contamination of the rodents.

Hakonson, T.E., and Johnson, L.J., 1973,
"Distribution of Environmental Plutonium in the Trinity Site After 27 Years",
Proc. 3rd Inter. Congress Rad. Protection Assoc., Conf. 730907, pp. 242-247.

The results are presented for radioecological survey of the Trinity Site environs, where the world's first (July 1945) atomic bomb was detonated. The temporal behavior of the low environmental levels of the plutonium produced by this detonation are discussed. The data from this study were compared with similar data obtained in the Trinity Site environs nearly 20 years ago. The major change which was observed was an increased migration of Pu into soil. Concentrations of Pu in vegetation and rodents were too low to make valid comparisons.

Hakonson, T.E., and Miera, F.R., Jr., 1976,
"Ecological Studies of Non-Nuclear Materials in the Los Alamos Environs",
Biomedical and Environmental Research Program of the LASL Health Division:
January - December 1975,
LANL, LA-6313-PR, pp. 29.

The Los Alamos Scientific Laboratory has several on site areas which contain various nonradioactive elements typically found as effluents or by-products of geothermal and coal field development and their associated energy production facilities. Studies on natural uranium, depleted uranium and mercury were initiated recently in a conventional explosives test areas and in three canyon liquid effluent receiving areas where radionuclides studies are underway to gather data on ecological distribution and transport of these metals.

Results for uranium-depleted uranium indicate soils contain most of the residual depleted uranium with vegetation and small mammals containing relatively minor amounts. Mercury studies are still underway and procedures for mercury analysis in soils and biota are being developed. From the mercury data comparisons will be made with radionuclide concentration data to identify any similarities in distribution.

Hakonson, T.E., and Nyhan, J.W., 1980,
"Ecological Relationships of Plutonium in Southwest Ecosystem", Transuranic Elements in the Environment,
U.S. DOE, pp. 402-419.

A comprehensive summary of the results was prepared on plutonium distribution and transport in Los Alamos and Trinity Site study areas. Despite differences in ecosystems and plutonium source, there are several similarities in plutonium distribution between Los Alamos and Trinity Site study areas. First, the soils/ sediment component contains virtually all the plutonium inventory, with vegetation and rodents containing less than 0.1% of the total in all cases.

Plutonium has penetrated to considerable soil depths at both locations, although it has occurred much more rapidly and to a greater degree in the alluvial soil at Los Alamos than in the arid terrestrial system at Trinity Site. However, in all cases less than 50% of soil-column plutonium inventories was found in the surface 2.5 cm. The plutonium penetration depth appears to correspond to the moisture penetration depth at Trinity Site. This is probably the governing factor at Los Alamos, although storm runoff and accompanying turblent mixing processes complicate the process. In Acid-Pueblo Canyon, the bulk of the soil column inventory lies in the lower profiles, an indication of the loss of the plutonium from surface layers due to sediment transport.

Soil plutonium in most cases, was associated with relatively coarse-size fractions. The silt-clay (<53 um) fraction contained relatively little (<15%) of the plutonium; this reflects the small amounts of this size fraction in study area soils. An exception was in Area 21 at Trinity, where the <53 um soil size fraction contained about 73% of soil plutonium inventories. The importance of these distributional differences was demonstrated for Trinity Site, where Bagnold dust samples from Area 21 contained 54% silt-clay material and samples from Area Ground Zero (GZ) contained less than 10% of this material.

Concentrations in herbaceous vegetation were generally related to those in soils from all sites. Our belief, although unsubstatiated, is that external contamination of the plant surfaces is the major contaminating mechanism in these arid systems. The plutonium concentrations in certain rodent tissues from all the study areas were related to corresponding soil concentrations. Over 95% of the plutonium body burden in rodents was associated with the pelt and gastrointestinal tract samples, indicating the dominance of physical processes at the contaminating mechanism.

Horizontal transport of soil plutonium is dominated by physical processes. At Los Alamos water governs the downstream transport of soil plutonium, and indications are that wind is relatively more important transport vector at the Trinity Site.

In no cases was there evidence for trophic-level increase due to physiological processes as plutonium passes from the soil to vegetation to the rodents, although food habits of rodents are not known sufficiently to perclude a trophic-level increase. We believe, however, that rodents most likely come into contact with environmental plutonium directly from the soil and water and not through the food-web intermediary.

Hakonson, T.E., and Whicker, F.W., 1969,
"Uptake and Elimination of Cs-134 by Mule Deer", Symposium on Radioecolgy,
U.S. Atomic Energy Commission, CONF-670503, pp. 616-622.

To establish some basis for predicting cesium accumulation in wild mule deer (Odocoileus hemionus hemionus), studies were undertaken to determine uptake and elimination rates under various conditions. In several separate experiments, up to 14 deer were given an 85 uCi acute oral dose of 134-CsCl. Excretion estimates were made by daily whole body counting.

Throughout the various experiments, biological half times associated with the two component retention curves averaged about 0.5 day and 14 days, and value of the slow elimination component extrapolated to the time of dosing averaged 77% of the initial dose.

It was found that cesium elimination rates of yearling and adult deer were not significantly different. However, fawns (<5 months old) eliminated cesium more rapidly than adults. Sex per se had no significant effect on cesium elimination rates. Reduced feed intake and larger body weights significantly increased the cesium elimination half times. Cesium uptake and elimination rates in deer fed dietary levels of 0.8% and 6.0% potassium and 9.6% and 24.1% crude fiber were not significantly different. Deer confined to 3 X 6 foot and 12 X 20 foot pens did not have significantly different cesium elimination rates.

Hakonson, T.E., and Whicker, F.W., 1971,
"The Contribution of Various Tissues and Organs to Total Body Mass in the Mule Deer",
J. of Mammalogy, Vol.52, No. 3, pp. 628-630.

During the course of studies on radionuclide metabolism conducted in our laboratory, data were gathered on the relative contribution of various tissues to total body mass in the mule deer (Odocoileus hemionus hemionus). Such information was used in assessing burdens of radioactive contaminants within particular compartments of the animal's body.

Five unbled deer carcasses were weighed and then dissected to determine the quantity of muscular and skeletal tissue. An additional nine deer, six adults and three near-term fetuses, were weighed and dissected to determine the relative weight contribution of some of the organs. Deer numbered 2-5 were road-killed animals; all remaining deer were from a captive colony. Skeletal muscle was separated from all extraneous connective and ligamentous tissue prior to weighing. The contribution of long bone marrow to the total skeletal weight was estimated by sampling respresentative bones of this type from four deer and determining the average per cent marrow (8.5 per cent of long bone weight). The total weight for all long bones (49 per cent of skeleton weight) was then corrected for weight of bone marrow. Red marrow was not removed from the flat and vertical bones (for example, in ribs, vertebrae, and skull). In man, red bone marrow accounts for about 2 percent of the total body weight (International Commission on Radiological Protection). Organs were also separated from connective tissues prior to weighing.

Average values for total muscle and bone in the deer, excluding the 22-day-old fawn, were 46.9 per cent and 10.3 per cent, respectively. Comparable values for the standard man are 43.0 per cent and 10.0 per cent (ICRP,1980). The 22-day-old fawn carcass contained 35.4 per cent and 17.7 per cent muscle and bone, respectively. Stara (1965) observed the percentage muscle and bone in the guinea pig to be 45.0 per cent and 5 per cent, respectively.

The range of values for total muscle varied from 35.4 percent in deer no. 1 (the 22-day-old fawn) to 52.4 per cent in deer no. 5. These data seem to indicate that young deer (22 days old) have relatively less muscle and bone than older deer (4-5 months older). In addition, there may be a greater proportion of muscle in larger deer. The limited amount of data, however, disallows an adequate comparison.

This relative size of several adult deer organs and, in general fetal organs, appear to exhibit a relationship to total body mass which is similar to standard man. Noteworthy exceptions were the adrenals, brain, heart, and thyroid. The relative masses of adrenals, brain, and thyroid in man appear to be several times the respective masses in deer. The deer heart, however, is approximately twice the relative mass of the human heart.

Hakonson, T.E., and White, G.C., 1981,
"Effect of Rotilling on the Distribution of Cesium-137 in Trinity Site Soil",
Health Physics, Vol. 40, pp. 735-739.

This paper presents results of an experiment to determine changes in spatial distributions of Cs-137 in nuclear fallout contaminated soil in south central New Mexico after vigorous, shallow, mechanical rototilling. The scale of the experiment and tilling method were chosen to simulate conditions normally used in establishing and preparing a small garden plot.

Results of this study demonstrate that shallow cultivation of soil with a garden rototiller was ineffective in reducing surface soil concentrations of Cs-137. Thus, the effectiveness of this tilling procedure in reducing soil contaminant transport across the land surface by wind and water would be minimal assuming that Cs-137 and soil particle size relationships were not greatly altered. However, rototilling did reduce variability in Cs-137 concentrations in surface soils. Thus considerable benefit could be realized by designing sampling programs in similarly treated areas since sample size requirements and, thus, cost are related as a square function to variability.

Hakonson, T.E., Cline, J.R., and Rickard, W.H., 1982,
"Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers",
Health Physics, Vol. 42, No.6, pp. 868-871.

This paper presents the results of the study to characterize the amount of disturbance of a low-level waste cover resulting from the burrowing activities of (Thomomys bottae) at Los Alamos. Data are presented on the amount of soil excavated from the cover profile, the amount of tunnel system created by these soil mining activities, and the particle distribution and radionuclide content of the cast soil.

The results of the study indicate that the amount of soil brought to the surface of low-level waste site is small relative to the volume of cover material. Gamma emitting radionuclides at levels exceeding worldwide fallout, were not detected in any of the mound soil samples. The lack of waste radionuclides in the mound samples would suggest that the gophers have not penetrated into the waste trench in the four years subsequent to closure of the site. However, the void space created by their burrowing activities represents a substantial network of tunnel system within the waste cover profile. Burrowing animals not only directly alter the soil profile through digging activities but also change the physical and chemical processes within the profile that can mobilize buried contaminants.

Hakonson, T.E., et al., 1973,
Ecological Investigation of Radioactive Materials in Waste Discharge Areas at Los Alamos for the Period July 1,1972 through March 31, 1973,
LANL, LA-5282-MS.

This report describes the ecological research program at the Los Alamos Scientific Laboratory and, in addition, summarizes the progress which has been made on current project activities between July 1,1972 and March 31, 1973.

Information is presented on an environmental inventory of the Los Alamos area, a radionuclide inventory in three liquid waste disposal areas, studies to determine the applicability of the honeybee as an indicator of environmental radiocontamination and a resurvey of the Trinity area to determine the bioavailability of the plutonium from the world's first nuclear detonation.

Hakonson, T.E., et al., 1979,
"The Comparative Distribution of Stable Mercury, Cesium-137 and Plutonium in an Intermittent Stream at Los Alamos", Environmental Surveillance at Los Alamos During 1978,
LANL, LA-7800-ENV, pp. 46.

Mortandad Canyon has been used for disposal of liquid wastes since 1963. Past studies in this canyon have emphasized the distribution and transport of Cs-137, Pu-238, and Pu-239/240. Stable mercury is also a component of the waste release to Mortandad Canyon as a result of loss of the metal from chemical laboratories into drain systems.

Core samples were collected from 10 stream channels and 10 stream bank locations randomly selected along a 100 m segment of Mortandad Canyon about 500 m below the effluent outfall. Samples were analyzed for mercury and/or Cs-137, Pu-238 and Pu-239. Elemental concentrations were sufficient in all cases to limit instrumentation uncertainties to less than 10% ($p<0.05$).

The results of this study demonstrate the importance of stream banks as deposition locations for mercury, cesium and plutonium continuously released to an intermitttent stream channel over a 13 year period. The movement of contaminants from channel to banks results in concentrations that are generally equivalent or exceed those measured in the channel sediments. 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.

Hakonson, T.E., et al., 1980,
"The Distribution of Mercury, Cesium-137 and Plutonium in an Intermittent Stream at Los Alamos",
Journal of Environmental Quality, Vol. 9, No. 2, pp. 289-292.

This paper summarizes the results of a study on the distribution of Hg, Cs-137, Pu-238, and Pu-239,240 in channel sediments and adjacent bank soils in an intermittent stream used for treated liquid effluent disposal since 1963.

Concentrations of three radionuclides and Hg in stream bank soils were compared to adjacent channel sediments demonstrating that the stream bank serves as a deposition site for chemicals released to the channel. This finding has important implications on the long-term behavior of effluent contaminants since other studies at Los Alamos have shown that vegetated stream banks retard downstream movement of chemicals bound to soils and provide a pathway for transport of these materials to biota.

Concentrations of the radionucludes and Hg were more uniformly distributed with distance and depth in the channel sediments than in bank soils. The action of periodic surface waves in the channel partially explains these differences. Statistical analysis of the data revealed that 50 to 85% of the variability in contaminant concentrations in bank and channel locations was due to variation with distance while depth contributed relatively little variability.

Hakonson, T.E., Johnson, L.I., and Purtymun, W.D., 1972,
The Distribution of Plutonium in Liquid Waste Disposal Areas at Los Alamos,
LANL, Internal Report.

The article reports the results from a survey conducted during 1972 to determine the concentration of radionuclides in alluvial sediments, water, and some of the natural biota in Mortandad Canyon.

Hakonson, T.E., Martinez, J.L., and White, G.C., 1982,
"Disturbance of a Low-level Waste Burial Site by Pocket Gophers", Environmental Surveillance at Los Alamos During 1981,
LANL, LA-9349-ENV, pp. 64.

A study was done at Los Alamos to characterize the amount of disturbance of a low-level waste cover resulting from activities of pocket gophers. Pocket gophers modify the soil matrix in many ways. Perturbations to the soil profile that may be detrimental to low-level waste containment systems include excavation of soil from within the cover profile to the ground surface, increasing water infiltration rates into soil profile, displacing chemicals vertically within the profile, altering rates of erosion, and penetrating into waste burial trenches and mobilizing radionuclides.

The results of this study indicate that the amount of soil brought to the surface of low-level waste site is small relative to the volume of cover material. However, the void space created by their burrowing activity represents a substantial network of tunnel system within the waste cover profile.

The effects plant and animals have in altering the soil profile must be considered in developing reclamation procedures that have long-term effectiveness. Burrowing animals not only alter the soil profile through digging activities but also change the physical and chemical processes within the profile that can mobilize buried contaminants.

Hakonson, T.E., Nyhan, J.W., and Purtymun, W.D., 1976,
Accumulation and Transport of Soil Plutonium in Liquid Waste Dischare Areas at Los Alamos,
International Atomic Energy Agency, IAEA-SM-199/99.

Plutonium inventory estimates for the surface 12.5 cm of soil in Mortandad Canyon did not reflect all plutonium added to the canyon during a 7 month interval. The methods used in this study indicated that about 2 mCi Pu-238 and 0 mCi Pu-239/240 were added to the canyon during this interval, compared with known additions of 5.5 mCi Pu-238 and 0.4 mCi Pu-239/240. This discrepancy likely was the result of the large sampling variability, indicating that inventory changes in this order (i.e. up to 17%) are not detectable with any certainty. However, factors other than sampling variability may be involved, incliuding losses of plutonium to depths exceeding 12.5 cm. The relative distribution of plutonium within the canyon demonstrates that transport has occurred beyond the extent of surface water and that runoff from summer rainstorms can serve as a radionuclide transport vector in landscapes exhibiting these hydrologic features. There was a highly significant relationship between suspended sediment concentrations and total amounts of radioactivity in water. The flow rates achieved during the runoff event play an important part in determining the total amount of sediment and thus radioactivity transport downstream. The storm runoff event sampled during this study resulted in the downstream transport of about 1-2% of the sediment inventories of plutonium.

Hakonson, T.E., Watters, R.L., and Hanson, W.C., 1981,
"The Transport of Plutoniumin Terrestrial Ecosystem",
Health Physics, Vol. 40, pp. 63-69.

Data from several field studies of plutonium were evaluated to identify environmental factors that result in redistribution of this element within ecosystems.

When released to terrestrial ecosystems, plutonium is almost quantitively transferred to and retained in soils. Thus, processes which transport soil within ecosystems predominate in the transport of environmental plutonium.

Erosion of soils by wind and water is the principal means of translational movement of plutonium within terrestrial ecosystems. Soil erosion processes also dominate in the transport of soil plutonium to biological surfaces particularly in arid and semi-arid regions of the U.S. Understanding the relationships between soil erosional processes and plutonium transport within ecosystems is essential for prediction of plutonium fate and effects.

Halford, D.K., Markham, O.D., and White, G.C., 1983,
"Biological Elimination Rates of Radioisotopes by Mallards Contaminated at a Liquid Radioactive Waste Disposal Area",
Health Physics, Vol. 45, No. 3, pp. 745-756.

The biological elimination of nine gamma emitting radioisotopes was studied in mallards (Ana platyrhynchos) which were released onto liquid radioactive waste ponds in sotheastern Idaho. After 68, 75, or 145 days, the ducks were removed from the contaminated environment and placed in metabolic cages. Whole-body and feces-urine counts were made for 51 days and then the ducks were sacrificed and dissected for tissue analyses.

The biological elimination of radioisotopes were fit to two compartment models using nonlinear least squares estimation. Fecal-urine data substantiated two-carpartment elimination of all radionuclides. Biological half-lives in mallards were 10 days (I-131), 22 days (Ba-140), 86 days (Cr-51), 32 days (Co-58), 26 days (Se-75), 67 days (Zn-65), 10 days (Cs-134), 67 days (Co-60) and 11 days (Cs-137). Body burdens in ducks were at 90% of equilibrium with the radioactive waste pond water at the time of removal from the waste ponds. Tissue distributions of radionuclides on the day of removal from the ponds showed gut to have greatest radionuclide concentrations followed by liver, muscle and gut. Liver contained the greatest variety of radionuclides and muscle the smallest. Biological elimination rates for the major dose-contributing nuclides (Cs-134 and Cs-137) to humans consuming contaminated waterfowl tissue indicate that the dose to man could de reduced substantially due to the rapid elimination of these radionuclides by mallards. Contaminated waterfowl would receive most of the internal dose in the first month after leaving the contaminated environment indicating that long-term doses would be inconsequential.

Hansen, W.C., and Ponton, D.A., 1978,
"Observations and Activities Related to Peregrine Falcons", Biomedical and Environmental Research Program of the LASL Health Division: January-December, 1977,
LANL, LA-7254-PR, pp. 88-89.

A third year of formal observations and investigations of the single eyrie of peregrine falcons (Falco peregrinus anatum) located in the Los Alamos environs was conducted during the period of mid-March through mid-October. The major focus of the study was to aid in the successful nesting of the peregrine falcons and to determine if eggshell thickness was related to the decline in reproduction of the peregrine falcons.

The peregrine falcons were observed to copulate on April 23 and were found incubating 2 eggs on May 21. The Rocky Mountain Southwest Peregrine Falcon Recovery team was alerted. The team removed the two eggs from the nest and replaced them with artifical eggs. The falcon eggs were placed in an incubator and to a control laboratory for observation; both eggs were infertile. The artifical eggs were replaced with 2 prairie falcon (Falco mexicanus) nestlings, and were later replaced with 2 peregrine falcons nestlings when the adult birds proved tracable. Two additional peregrine nestlings were later added to the nest from another nest which had been deserted. The four young birds were sucessfully fledged. This represented the first successful nesting of the peregrine falcons at the Los Alamos eyrie since 1973.

Eggshell fragments were collected from 1969-1973. The thickness of these fragments were measured to try to determine if eggshell thickness was related to the decline in peregrine falcon reproduction. The mean eggshell thickness was below the pre-1947 average eggshell thickness for unhatched peregrine falcon eggs from eastern U.S. No significant trend of mean shell thickness was exhibited over the 10 yr period suggesting the importance of some unknown factor as the cause of embryo mortality.

Hansen, W.R., Mayfield, D.L., and Walker, L.J., 1980,
Interim Environmental Surveillance Plan for LASL Radioactive Waste Areas,
LANL, LA-UR-80-3110.

This documents describes the surveillance plan being implemented to monitor and assess environmental conditions at radioactive waste mangement sites of the Los Alamos Scientific Laboratory (LASL). This report documents the methodology for assessing the surface conditions and subsurface conditions at radioactive waste sites. The execution of the plan may vary slightly for specific waste sites due to individual differences.

The general surveillance of the Los Alamos Scientific Laboratory and area includes food sampling, air sampling, soil and sediment sampling and water sampling. The sampling locations are situated to detect migration from the waste areas as well as the operating facilities at the Laboratory.

In 1979, the Department of Energy (DOE) issued interim operational criteria for radioactive waste areas owned or operated by DOE and its contractors. This document is meant to be responsive to the surveillance requirements listed in the DOE interim criteria.

Hanson, W.C., 1974,
Ecological Considerations of Depleted Uranium Munitions,
LANL, LA-5559.

Ecological consequences of depleted uranium (DU) released to the environment as a result of military use of DU munitions were appraised by reviewing pertinent literature. Estimates were based upon ecosystem responses to natural uranium which is more soluble and more toxic than DU. It was concluded that the major ecological hazard from expended uranium munitions will be chemical toxicity rather than radiation. The alloy nature of the munitions will substantially decrease the mobility of DU and mitigate the problem. However, the ecological aspects of the chemical toxicity of DU in terrestrial ecosystems is expected to be a major consideration of expended munitions.

Hanson, W.C., 1974,
Particle Size Distribution of Fragments from Depleted Uranium Penetrators Fired Aganist Armor Plate Targets,
LANL, LA-5654.

This report describes particle size distributions of fragments of depleted uranium (DU) penetrators fired against armor plate targets. The experiments were conducted at the request of the U.S. Air Force Armament Laboratory, Eglin Air Force Base, Florida, to provide information needed to evaluate the environmental impact of such munitions. These data will serve as input to a model for evaluation of human exposures to aerosols generated by the pyrophoric action of DU penetrators.

Fragments produced by four DU penetrators fired into armor plate targets showed a higher concentration of large particles in the exit chamber than in the entrance chamber. Compounded samples of the six size fractions from the exit chamber contained nearly three times the uranium found in similar aggregate samples from the entrance chamber. An average of 41% of the penetrator uranium mass was accounted for in the size fractions. This mass was distributed in a 1:4 ratio between entrance and exit chambers, indicating that much of the penetrator pierced the armor plate unfragmented.

Aerosol data collected by impactors were positively correlated with larger fragment sizes. Production of uranium aerosol was low when a greater uranium concentration was observed in fragments in the 105 to 500 and 500 to 2000 um ranges, compared to high aerosol production when the greatest occurred in >5660 um fragments.

The relatively small (0.27 and 0.25 cubic meter) volumes of the collection chambers apparently caused fusion and agglomeration of particles. This constraint on the data is not serious, but it should be borne in mind in applying the results to field situations. We conclude that these results provide a reasonable estimate of a potential hazard to personnel frequently exposed in test areas or in combat.

Hanson, W.C., 1975,
"Ecological Considerations of the Behavior of Plutonium in the Environment",
Health Physics, Vol. 28, pp. 529-537.

Radiological considerations of plutonium released to the environment are logically based upon an understanding of ecosystem structure and function. Studies of Pu in the atmosphere, lithosphere, terrestrial ecosystem of the biosphere, and in the hydrosphere are reviewed to evaluate areas for consideration of environmental consequences of nuclear wastes. Soil is the major reservoir of deposited Pu in most terrestrial ecosystems. Resuspension of Pu into the air mass above the contaminated soil occurs over a highly variable range of 0.01 to 10 x -11 per meter, reflecting important effects of several physical and biological variables. Uptake by most natural plant species is of the order of 0.0001 (acceptor/precursor). Appreciable external deposition of Pu upon plants through resuspension is a complicating factor in interpretation of field data. Pu concentrations in small terrestrial mammals also emphasize the greater importance of physical processes rather than physiological or chemical processes in the movement of Pu through terrestrial ecosystems. Freshwater and marine investigations indicate that Pu is generally concentrated over ambient levels in water but with decreases of about a factor of ten at each trophic level of a food chain. An apparent change in availability of Pu-238 is indicated by several studies and physical processes that may account for this are discussed.

Hanson, W.C., and Miera, F.R., Jr., 1976,
Long-term Ecological Effects of Exposure to Uranium,
LANL, LA-6269.

The consequences of releasing natural and depleted uranium to terrestrial ecosystems during development and testing of depleted uranium munitions were investigated. At Eglin Air Force Base, Florida, soil at variuos distances from armor plate target butts struck by depleted uranium penetrators was sampled. The upper 5 cm of soil at the target bases contained an average of 800 ppm of depleted uranium, about 30 times as much as soil at 5 to 10 cm depth, indicating some vertical movement of depleted uranium. Samples collected beyond about 20 m from the targets showed near-background natural uranium levels, about 1.3 +/- 0.3 ug/g or ppm.

Two explosives-testing areas at the Los Alamos Scientific Laboratory (LASL) were selected because of their use history. E-F Site soil averaged 2400 ppm of uranium in the upper 5 cm and 1600 ppm at 5-10 cm. Lower Slobovia Site soil from two subplots averaged about 2.5 and 0.6% of the E-F Site concentrations. Important uranium concentration differences with depth and distance points ascribed to the different explosive tests conducted in each area.

E-F Site vegetation samples contained about 320 ppm of uranium in November 1974 and about 125 ppm in June 1975. Small mammals trapped in the study areas in November contained a maximum of 210 ppm of uranium in the gastrointestinal tract contents, 24 ppm in the pelt, and 4 ppm in the remaining carcass. In June, maximum concentrations were 110, 50, and 2 ppm in similar samples and 6 ppm in the lungs. These data emphasized the importance of resuspension of respirable particles in the upper few millimeters of soil as contamination mechanism for several components of the LASL ecosystem.

Hanson, W.C., and Miera, F.R., Jr., 1977,
Continued Studies of Long-Term Ecological Effects of Exposure to Uranium,
LANL, LA-6742.

Studies of the long-term consequences of exposing terrestrial ecosystem to natural and depleted uranium dispersed during explosive tests at Los Alamos Scientific Laboratory (LASL) and test firing at Eglin Air Force Base (EAFB), Florida, were continued. Soils from EAFB, sampled before and after firing of depleted uranium penetrators aganist armor plate targets, indicated that the upper (0-to 5-cm-deep) soil usually contained more unranium than the lower (5-to 10-cm-deep) soil. However, no significant changes were apparent in samples taken before and after the test firing.

E-F explosive testing site at LASL was selected for intensive study of uranium redistribution during its 33-yr use. Highest surface soil (0- to 2.5-cm-deep) uranium concentrations occurred 0 and 10 m from the detonation point and averaged 4500 ppm. Concentrations in surface soil 50 and 200 m from the firing point were usually < 15% of that value. The uranium distribution to 30-cm depth showed significant penetration into the soil.

Alluvium collected 250 m from the E-F detonation area in Potrillo Canyon indicated that surface (0- to 2.5-cm-deep) uranium concentrations were about 10% of those at the detonation point, and at 2.8 km they were twice background levels.

Hanson, W.C., and Miera, F.R., Jr., 1978,
Further Studies of Long-Term Ecological Effects of Exposure to Uranium,
LANL, LA-7162.

A third year study of the ecological consequences of exposure of terrestrial ecosystems at the Los Alamos Scientific Laboratory to elevated soil concentrations of natural and depleted uranium was completed. A uranium analytical technique that uses instrumental epithermal neutron activation analysis was developed and tested. It provided more accurate and expeditious results for soil and biota samples that contain >10-ng total uranium than did our other two techniques.

Spatial variability in sampling for soil uranium distribution by a polar coordinate system was evaluated in randomly selected soil cores. Variations for surface (0- to 2.5-cm-deep) soils were 0.18 at 10 m from the detonation point and 0.96 at 50 m. Results were strongly influenced by past uranium dispersal patterns, variable leaching of uranium debris, and surface water runoff.

A total surface (0- to 5-cm) soil uranium inventory within a 12.6-ha circle centered on the E-F detonation point was estimated to be 3000 kg when calculated by soil uranium concentration isopeths and 4500 kg when using annuli polar coordinate sampling system.

Uranium concentrations in tissue of deer mice (Peromyscus maniculatus) and pocket gophers (Thomomys bottae) were sufficiently different to conclude that the greater bioavailability of uranium in the top few millimeters of soil at E-F Site, combined with the difference in grooming and food habits of the animals, resulted in greater contamination of deer mice than of pocket gophers.

Invertebrate populations inhabiting areas of high and medium soil uranium concentrations at LASL sites were sampled by pitfall trapping and insect net sweeps. There was no conclusive evidence of a differential population response to areas of relatively high uranium concentrations and to control areas.

Harper, J.R., and Garde, R., 1981,
The Decommissioning of TA-21-153, A-227 Ac Contaminated Old Filter Building, LANL, LA-9047-MS.

An exhaust air filter building contaminated with Ac-227 was decommissioned at the Los Alamos National Laboratory, Los Alamos, New Mexico, in 1978. The building was constructed in the late 1940s at TA-21, DP Site. It was in service until March 1970.

The project involved preliminary decontamination, dismantling the building, and burying the debris at an on-site waste disposal/storage area.

This report presents the details on the decommissioning procedures, the health physics, the waste management, the environmental surveillance, and the costs for the operation. No measurable elevation in gross alpha activity was detected from air samples taken during the period of decommissioning. At the end of the decommissioning period the soil was sampled for radioactivity. A value of <30pCi gross alpha/gm of soil was determined to be as low as practicable (ALAP).

Harris, D.R., and Beyer, W.A., 1972,
BIOTA2, a Program for Monte Carlo Simulation of Population Interactions in a Biome,
LANL, LA-4865.

BIOTA2 is a computer program for Monte Carlo simulation of complex population interactions in a biome. The program is variably dimensioned so that any number of species, and any number of age groups for any given species, can be followed. BIOTA2 employs a useful and novel simulation technique which we refer to as the event-consequence technique. At any time during the simulation the current rates of immigration, emigration, death and offspring production events are computed, and the time to the next event is chosen pseudorandomly. Another pseudorandom number determines the event type, e.g., offspring production by a unit in age group IA of species IS. Then another pseudorandom number determines the consequence of the event, e.g., production of a litter of IL units. The event-consequence technique is fast, avoids instability and other problems associated with the more conventional time-differencing of coupled differential equations and permits great flexibility in BIOTA2 in choice of algorithms used in computation of event rates and consequences. These alogrithms involve crowding, competition, predation and physical condition of the organism. Seasonal and other environmental effects are treated. These features are illustrated by a simple test problem which appears to achieve a stochastic limit cycle. By suitable choice of "species", sex, location, and other properties can be included. BIOTA2, in Fortran-IV for the CDC-6600, CDC-7600, and UNIVAC-1108 computers, requires for many problems a field length less than 608K and a running time of 0.5-2 msec per event on the CDC-6600 and UNIVAC-1108 computers, and 0.1-0.4 msec/event on the CDC-7600 computer.

Health Research Division, 1976,
Status and Plans Report for Former Technical Area One at Los Alamos Scientific Laboratory,
LANL, Unknown.

Because of increased official and public concern over low-level radioactive contamination of private lands or former ERDA (AEC) lands released to the public, the undeveloped part of the former main technical area of LASL (TA-1) was surveyed in 1974 at the request of ERDA (AEC). This effort was to determine whether any of the land (approximately 40 acres) was contaminated above fallout levels by uranium, transuranmic elements, or other radioisotopes, and to estimate costs of decontamination.

The initial survey (1974) identified an area with low levels (approximately 250 pCi/g) of plutonium contamination on the surface. Futher investigation devealed a subsurface pocket of high-level (>100,000 pCi/g) plutonium concentration. On the basis of this information a more extensive resurvey and a major decontamination operation were undertaken.

Results from this extensive resurvey found contaminated lines 50-60 feet from their indicated location on drawings. An uncharted septic tank was accidentally found. On general area surveys surface contamination was found behind Warehouse 19 and on the hillside below septic tank 138, and there are no clues as to the source. Construction debris (concrete supports, steam pipe insulation, etc.) in the fill in the D-building area has been found to be contaminated. Due to topography, it is believed that debris from other areas was pushed in over D-building debris. About 1000 to 2000 cubic yards of fill and debris from the southwestern portion of the filled area near D and D-2 were used for fill along Trinity Drive from the Los Alamos Inn to the Trinity Village Apartments during the 1966 widening-repaving project as recalled by the Zia Road Section Field Superintendent. Based on experience gained during this operation it is considered likely that pockets of highly contaminated soil would have been greatly diluted by construction activities involved in the gathering and spreading the backfill for road construction.

All likely sources of contamination have been or are being investigated. All known contamination has been or is being reduced to levels meeting ALAP criteria. It is conceivable that other people or agencies might, in the future, find contamination, although it is unlikely that any health hazard would be encountered.

In the absence of accepted standards for plutonium and uranium contamination in soil, professional judgement has been used to defining the concentrations of these contaminants in soil meeting ALAP criteria and the extent of required excavation in different areas.

Health, Safety and Environment Division, 1986,
Occupational Health and Environment Research 1984: Health, Safety and Environment Division,
LANL, LA-10642-PR.

The primary responsibility of the Health, Safety and Environment (HSE) Division at the Los Alamos National Laboratory is to provide comprehensive occupational health and safety programs, waste processing and environment protection. These activities are designed to protect the workers, the public and the environment. Many disciplines are required to meet the responsibilities, including radiation protection, industrial hygiene, safety, occupational medicine, environmental science, epidemiology and waste management. New and challenging health and safety problems arise occasionally from the diverse research and development work of the Laboratory. Research programs in the HSE Division often stem from these applied needs. These programs continue but are also extended, as needed to study specific problems for the Department of Energy (DOE) and to help develop better occupational health and safety practices.

Two supplied-air suits tested for their functional protection were considered to be unacceptable because of low fit factors. Respiratory protective equipment testing for the US Air Force, Navy and Army was performed during 1984. Several laser methods were evaluated to find noninvasive techniques for sampling tracer aerosols that penetrate into the facepiece of a respirator. Two practical methods were developed that achieve reproducible data on fit factors up to 5000. An environmental chamber was constructed for determining the effects of temperature and humidity on respirator fit under simulated work conditions. Test showed that submicron oil-droplet aeresol penetrated all respirator filters tested to a greater extent than did a fibrous chrysotile aerosol.

The laser aerosol spectrometer (LAS-X) has been shown to operate successfully for measuring and sizing aerosols used for quality assurance testing of high-efficiency particulate air filters used at DOE facilities.

Radioanalyses for Pu-239 and Am-241 are presented for the complete skeletal parts of two persons. The studies demonstrate more active turnover of cancellous bone surfaces than of compact bone surfaces and more rapid redistribution of americium than of plutonium.

Environmental surveillance at Los Alamos during 1984 showed the highest estimated radiation dose to an individual at or outside the Laboratory boundary to be about 25% of the natural background radiation dose. Surveillance studies on water and sediment transport of radionuclides, depleted uranium and silver are described. Studies of impacts on flora in the Los Alamos area throughout its settlement by man were published in 1984. The strongest agents of distrubance in recent times have been fires, logging and insect pests. Further development of the BIOTRAN and HUMTRN models are described. These models are designed to predict and to assess the impact of acute and chronic releases of pollutants on people.

Bibliographic reveiw of the rooting depth of native plants indicates that even many grass species will root to depths greater than the earth overburden depths to cover low-level radioactive waste sites. These overburdens are usually between 30 to 90 cm. The findings of these studies should be helpful in selecting specific species of plants for site stabilization.

Health, Safety and Environment Division, 1988,
Health, Safety and Environment Division Annual Report 1987,
LANL, LA-11257-PR.

The primary responsibility of the Health, Safety and Environment Division at the Los Alamos National Laboratory is to provide comprehensive occupational health and safety programs, waste processing and environment protection. These activities are designed to protect the worker, the public and the environment. Many disciplines are required to meet the responsibilities, including radiation protection, industrial hygiene, safety, occupational medicine, environmental science, epidemology and waste management. New and challenging health and safety problems arise occasionally from the diverse research and development work of the Laboratory. Research programs in HSE Division often stem from these applied needs. These programs extended, as needed to study specific problems for the Department of Energy and to help develop better occupational health and safety practices.

Healy, J.W., 1971,
"Some Thoughts on Plutonium in Soils", Proceedings of Environmental Plutonium Symposium: Held at LASL, August 4-5, 1971,
LANL, LA-4756, pp. 113-115.

The resuspension of particles by wind or meachanical disturbance is one of the major routes of potential intake from plutonium in soils. The actual air concentrations resulting from resuspension depended upon many variables including the characteristics of the source, the degree of disturbance, the nature of the terrain, and the meteorological dispersion and deposition processes operating. Although little data are available to characterize these variables and to provide a general solution, some factors involved are discussed.

Healy, J.W., 1974,
A Proposed Interim Standard for Plutonium in Soils,
LANL, LA-5483-MS.

Current standards for controlling health effects from plutonium in the body are discussed. Available information on possible sources of exposure of people living in an area where soils are contaminated with plutonium is analyzed to a arrive at estimates of intake. From these estimates, a recommended interim standard for the upper limit of concentration of plutomium in the soils in inhabited areas is derived. The recommendation is based upon conservative assumptions where information is lacking and further studies should result in revision. The subjects of resuspension, deposition velocity of particles and effectiveness of radioactive particulates in producing lung cancer are discussed in appendices.

Healy, J.W., 1977,
An Examination of the Pathways from Soil to Man for Plutonium,
LANL, LA-6741-MS.

The data available on resuspension and ingestion as pathways of plutonium from soil to man were reviewed and a recommended limit based upon conservative interpretation of the National Council on Radiation Protection and Measurement (NCRP) recommendations for limiting values was derived. Wind resuspension appeared to be the least limiting value with mechanical resuspension and pica in children among the more important. Ingestion of foodstuffs could also be an important pathway if it is assumed that all food is produced in the contaminated area.

Healy, J.W., and Rodgers, J.C., 1978,
A Preliminary Study of Radium-Contaminated Soils,
LANL, LA-7391-MS.

A preliminary study was made of the potential radiation exposures to people from radium contaminated in the soil in order to provide guidance on limits applied in decontaminating land. Pathways included were inhalation of radium from resuspension; ingestion of radium with foods; external gamma radiation from radium daughters; inhalation of radon and daughter, both in the open air and in houses; and the intake of Pb-210 and Po-210 from both inhalation and ingestion. The depth of the contaminated layer is of importance for external exposure and especially for radon emanation. The most limiting pathway was found to be emanation of the radon into buildings with limiting values comparable to those found naturally in many areas.

Heaton, R.C., et al., 1985,
Long-Term Exposure of 238-PuO2 to a Terrestrial Environment,
LANL, LA-9487-MS, Vol. III.

A plutonium oxide source consisting of a single piece of 83% 238-PuO2 and weighing 38 g was exposed for 2.9 yr to a humid temperate terrestrial environment in a environmental simulation chamber. The soil tray of the chamber was divided into four compartments so that different soil types could be studied under identical conditions. Soils examined in this experiment included loam, silt loam, sand, and humus. Plutonium released into the soils, the soil drainages, and the condensates from the dehumidifier was monitored throughout the experiment. The total plutonium release rate from the 238-PuO2 source was approximately 2 ng/sq m/s. The generation of short-ranged airborne plutonium, able to travel from a few centimeters to half a meter, was one of the most significant release pathways. The amount of plutonium released in this way was 10 times that washed directly off the source by rainwater and 20 times that from the fully airborne (longer ranged) release. Of the 200 ug of plutonium deposited in the soils, less than 0.1 ug was released into the soil percolates. In fact, the soil percolates constituted the least significant release pathway. Within the uncertainties in deriving the plutonium inventories of the soil compartments, we found no discernible differences among the behavior of the four soil types towards plutonium. There was little or no seasonal effect on the release of plutonium from the soil.

Henderson, R.W., and Larson, O.W., 1966,
Radiation Measurements of the Effluent from the NRX A-2 and NRX A-3 Reactors,
LANL, LA-3394-MS.

Compilation of data resulting from the collection of samples of the effluent clouds from the NRX A-2 and A-3 reactors during full power operation is presented. Data are presented concerning the magnitude and isotopic composition of the airborne and ground deposited material. The environmental impact of these tests has been calculated for hypothetical conditions of land use and occupancy, and these data are included. A brief description of equipment and techniques is also given.

Herceg, J.E., 1972,
Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory January through June, 1971,
LANL, LA-4871-MS.

A description is given of the environmental monitoring program in effect at the University of California Los Alamos Scientific Laboratory during the first half of calendar year 1971. Results of programs designed to monitor radiation levels in the Laboratory environs, including the atmosphere, local surface and ground waters, sediments and soils are presented. These measurements are used to make estimates of the dose commitments due to plutonium and tritium concentrations in the air.

Appendices describe the boundaries of the Laboratory site, the programs associated with various Laboratory technical areas, geologic, climatologic and economic characteristics of the Los Alamos area, and laboratory procedures used for the analysis of samples.

Herceg, J.E., 1972,
Environmental Monitoring in the Vincity of the Los Alamos Scientific Laboratory: July through December 1971,
LANL, LA-4970.

The environmental monitoring program in effect at the Los Alamos Scientific Laboratory of the University of California for the last half of calender year 1971 is described. Results of programs designed to monitor radiation levels in the Laboratory environs, including the atmosphere, the Los Alamos water supply, local surface and ground water, sediments, and soils. These measurements are used to make estimates of the dose commitments due to plutonium and tritium concntrations in the air.

Heyser, J.W., Warren, R.S., and Fink, N.F., 1985,
Adaption to NaCl Followed by in vivo NMR,
LANL, LA-UR-85-4457.

Suspension cultures of saltgrass (Distichlis spicata) were studied for their adaption to NaCl. In vivo Na-23 and C-13 NMR were performed to follow Na+ transport and proline accumulation in cells uplifted to 260 mm NaCl. Respiration was measured with an oxygen electrode. Both Na+ uptake and efflux were partially inhibited by 1 mM KCN. Respiration was increased 40% over that of controls when cells were shifted from 0 to 200 mM NaCl medium. After a lag of a few hours, proline accumulation increased linearly up to 30 mm at 48 hours when cells were shifted from 0 to 260 mm NaCl. The expenditure of metabolic energy on Na+ and Cl- transport, plus the use of energy for the accumulation of proline may account for the temporary reduction in growth by this halophytic grass when shifted to levels of NaCl greater than 200 mM. Data correlating the advent of increased respiration, Na+ transport, and proline accumulation in upshifted cells will be presented.

International Technology Corporation, 1989,
Interim Status Closure Plan, "Technical Area 35 TSL-85 Surface Impoundment Los Alamos National Laboratory Los Alamos, New Mexico",
IT Corporation, IT report for the Laboratory (LANL).

This Closure Plan is submitted in accordance with the requirements of NMHWMR-5, Part VI, Section 265.110 through 120, 265.197, and 265.228. This plan is a revision of the previous closure plan prepared for the TA-35-TSL 85 surface impoundment. Initial investigations of the surface impoundment resulted in findings and ovservations that warrant this revision. First, an inactive underground storage tank has been found to connect to the surface impoundment, and the Laboratory intends to address decontamination and removal of the tank as part of the surface impoundment closure. Second, the surface impoundment is located on the rim of Mortandad Canyon and, depending on the extent of any contamination associated with the unit(s), soil removal undertaken to attain "clean" closure potentially impacts the stability of the canyon wall. To minimize destabilization of the site, it is desirable to maintain the existing slope and allow as much native vegetation currently extablished to remain undisturbed. To this end, if contamination at the site is found to be really extensive, the Laboratory intends to follow EPA-published guidance to establish "health-based" clean levels for any hazardous wastes or constituents closure. The EPA states that closure to these levels is considered sufficient to meet the requirements of paragraph 265.228(a)(1) with regard to clean closure.

International Technology Corporation, 1990,
Interim Closure Plan: Technical Area 35 TSL-125 Surface Impoundment Los Alamos National Laboratory, Los Alamos, New Mexico,
IT Corp., Project No. 301215, January 1990, Rev. 2.0.

This closure plan is submitted for the TA-35 TSL-125 surface impoundment in accordance with the requirements of the New Mexico Hazardous Waste Management Regulations (NMHWMR-5, as amended 1989), Part VI, 40 CFR Part 265 Subpart G and section 265.228. As a revision to the October 1988 Closure Plan for this unit, this plan incorporates the U.S. Environmental Protection Agency's (U.S. EPA) March 19. 1987 guidance on the use of risk assessments to establish "clean" levels of closure, that is, concentrations of contaminants below which no threat to human health or the environment is considered to exist. The surface impoundment is located on a rim of the Ten Site canyon and, depending on the extent of any contamination associated with the unit, soil removal undertaken to attain "clean" closure potentially impacts the stability of the canyon wall. To minimize destabilization of the site, it is desirable to maintain the existing slope and allow as much vegetation currently established to remain undisturbed. To this end, if contamination at the site is found to be really extensive, the Laboratory intends to follow U.S. EPA guidance to establish health-based levels for any hazardous waste or constituents that analytical results show to have been released from the unit. The U.S. EPA states that closure to these levels is considered sufficient to meet the requirements of 40 CFR Section 265.228(a)(1) with regard to clean closure.

The structures associated with the surface impoundment include a floor trough and piping in addition to a curbed staging area near the impoundment. The Laboratory will perform clean closure by removing standing liquids, wastes and waste residue from the surface impoundment and associated structures; removing any underlying and/or surrounding soil contaminated with hazardous constituents; and taking all necessary steps to ensure that these closed areas will not become hazardous waste in the future. In the event removal of soil to reach contamination levels below the analytical detection limit ("background") proves impractical, the results of a risk assessment will be used to determine the extent of soil removal necessary to achieve acceptable closure.

John, E.C., Enyart, E., and Purtymun, W.D., 1966,
Records of Wells, Test Holes, Springs, and Surface-Water Stations in the Los Alamos Area, New Mexico,
U.S. Geological Survey, Open File Report.

The U.S. Atomic Energy Commission, the Los Alamos Scientific Laboratory and the U.S. Geological Survey have jointly conducted investigations of the geology hydrology of the Los Alamos area related to water supply and to disposal of low-level radioactive effluents. These investigations covering the period 1950-1965 required the drilling of many test holes, some for special problems, others to obtain data concerning areal geologic and hydrologic characteristics.

Sampling points to obtain quality of water data for ground and surface water of the area were established at several springs and at stations along the streams of the area.

Records of the data collected from the test holes and sampling stations are scattered among several reports. This report is a compliation of the geology and hydrologic data collected in the Los Alamos area.

Johnson, L.J., 1972,
Los Alamos Land Areas Environmental Radiation Survey; 1972,
LANL, LA-5097-MS.

The details of an environmental radiological evaluation on about 5,000 acres in eight parcels of land owned by the United States Atomic Energy Commission (USAEC) in Los Alamos County, New Mexico, are presented in this reported. The environmental assessment of these real properties included a careful search of the administrative records of the Los Alamos Scientific Laboratory (LASL) to determine the extent the land might have been used or involved in the Laboratory's activities, extensive measurements of the radiation levels in the field, and radiochemical analysis of numerous soil and vegetation samples. A new portable radiation measurement instrument, designated as the Los Alamos Field Pulse Height Analyzer, was developed and used for this study. This analyzer proved to be valuable in documenting the low level of radioactivity encountered. The results of the study showed that all measured values were comparable to reported worldwide levels, and that no radiation or radioactive contamination observations were encountered that are of radiological health or environmental concern. The study therefore supports the conclusion that no abnormal environmental hazard as a result of past Laboratory activities, exists on the surveyed parcels of land.

Kasunic, C.A., Ferenbaugh, R.W., and Gladney, E.S., 1985,
"Silver Transport in Canon de Valle", Environmental Surveillance at Los Alamos During 1984,
LANL, LA-10421-ENV, pp. 82.

Beginning in the 1940's the Los Alamos National Laboratory began discharing spent photographic solutions containing silver thiosulfate into a small canyon tributery in Canon de Valle. The practice continued until the late 1970's when silver recovery was implemented using ion exchange columns.

The purpose of this study was to determine the extent of silver contamination in the canyon receiving the solution drainage. Samples of water, vegetation, sediment and soil were collected along the canyon channel and analyzed for silver.

Results indicate that silver concentrations decreased with progression down the canyon. At approximately 300 m distance from the discharge point, the silver levels in vegetation approached background levels. Silver concentrations in sediments and soils, however, remained significantly higher than background for about 420 m.

The maximum silver concentrations detected were 20,000-25,000 ppm in sediment, 10,000-15,000 ppm in soil and 8-10 ppm in grass and trees. In the area of highest silver concentrations in soil, above background silver concentrations were found to a depth of about 1m.

Kaufman, E.L., and Siciliano, C.L.B., 1979,
Environmental Analysis of the Fenton Hill Hot Dry Rock Geothermal Test Site,
LANL, LA-7830-HDR.

Techniques for the extraction of geothermal energy from hot dry rock within the earth's crust were tested at the first experimental system at Fenton Hill and proved successful. Because new concepts were being tried and new uses of the natural resources were being made, environmental effects were a major concern. Therefore, at all phases of development and operation, the area was monitored for physical, biological, and social factors. The results were significant because after several extended operations, there were no adverse environmental effects, and no detrimental social impacts were detected. Although these results are specific for Fenton Hill, they are applicable to future systems at other locations.

Kennedy, W.R., 1960,
Radioactivity in Environmental Air at Los Alamos, New Mexico for the period November 17, 1958 through December 31, 1959,
LANL, LAMS-2397.

The report is a continuation of work reported in the Los Alamos section of "Radioactive Fallout Data Collected from Eleven Atomic Energy Installations for 1958". The beta activities measured were not identified. However, since the measurements were made in the same manner, the values are relative to one another. The monthly average "per day" figures show in general the same peaks reported by other stations, i.e., in the spring months.

Kennedy, W.R., 1961,
Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1960,
LANL, LAMS-2499.

This report is a continuation of work reported in the Los Alamos section of "Radioactive Fallout Data Collected from Eleven Atomic Energy Installations for 1958", and in LAMS-2397. The beta activities measured were not identified. however, since the measurements were made in the same manner, the values are relative to one another.

The monthly average "per day" figures show in general the same peaks reported by other stations, i.e., in the spring months. The values found for 1960 are down by factors of 15 to 20 from those found in 1959, and are approaching the limits of dectectability with the system in use.

Kennedy, W.R., 1962,
Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1961,
LANL, LAMS-2702.

The report is a continuation of work reported in the Los Alamos section of "Radioactive Fallout Data Collected from Eleven Atomic Energy Installations for 1958". The beta activities were not identified. However, since the measurements were made in the same manner, the values are relative to one another.

The monthly average "per day" and per sample" show in general the same peaks reported by other stations, i.e., in the spring months, with marked peaking in the fall as a result of the Russian tests. Definite increase of a factor of 5-8 were noted from the second week in September onward.

Kennedy, W.R., 1970,
Los Alamos Environmental Monitoring Program,
LANL, LA-3639-MS.

The Los Alamos Scientific Laboratory complex includes accelerators, research reactors, radioactive materials separation facilities, and other experimental installations using radiation or radiaoactive wastes are generated and must be disposed of.

An outline is given of the surveillance methods used throughout Los Alamos County and outside restricted areas to determine the effect of Laboratory operations on the environmental radioactivity. Gamma radiation measurements are routinely made. Scheduled samples of air and water are taken, assayed for gross alpha and beta activity, and also for certain specific nuclides which may be present in some concentration. Soil samples are taken when considered necessary.

Kennedy, W.R., and Aeby, J., 1971,
Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1970,
LANL, LA-4661.

Beta activity of particulate matter of both air and precipitation for 1970 are reported for Los Alamos, New Mexico. The lower monthly average levels found in precipitation collections and the slightly higher levels found in the air samples indicate that 1970 was dryer year than 1969 with 14.93 and 25.67 in of precipitation, respectively.

Kennedy, W.R., and Aeby, J.W., 1966,
Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1965,
LANL, LA-3516-MS.

The report is a continuation of work reported in the Los Alamos section of "Radioactive Fallout Data Collected from Eleven Atomic Energy Installations for 1958". The beta activities were not identified. However, since the measurements were made in same manner, the values are relative to one another.

The monthly average "per day" graphs continue their lower trend this year. No atmospheric testing was reported during 1965.

Kennedy, W.R., and Aeby, J.W., 1967,
Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1966,
LANL, LA-3663.

Beta activity of particulate matter in both air and precipitation for 1966 are reported for Los Alamos, New Mexico. The decline in activities that began in the last half of 1963 continued until the middle of 1966. Increases in May, November, and December can perhaps be attributed to the Chinese atmospheric tests.

Kennedy, W.R., and Aeby, J.W., 1968,
Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1967,
LANL, LA-3887.

Beta activity of particulate matter in both air and precipitation for 1967 are reported for Los Alamos, New Mexico. The declining activities found in January through April seem to be residual fallout from the 1966 foreign nuclear weapons tests, and the December high to late 1967 efforts. The May through September increases reflect the increasing rainfall of that period.

Kennedy, W.R., and Aeby, J.W., 1970,
Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1969,
LANL, LA-4388.

Beta activity of particulate matter in both air and precipitation for 1969 are reported for Los Alamos, New Mexico. The gradually increasing levels in both air and water samples from January through July reflect a contribution from foregin fallout arriving at our station as well as greater than average rainfall. The slight upward trend in October is a normal seasonal upswing.

Kennedy, W.R., and Purtymun, W.D., 1971,
Plutonium and Strontium in Soil in the Los Alamos, Espanola, and Santa Fe, New Mexico, Areas,
LANL, LA-4562.

Analyses for plutonium isotopes Pu-238 and Pu-239 and Strontium isotope Sr-90 were made of soil samples collected from the Los Alamos, Espanola and Santa Fe areas to determine concentration levels considered as originating from world-wide fallout from atmospheric tests. On the basis of the limited number of samples it was concluded that the concentrations in soils from the area of study were similar to but no greater than those reported by others for soil samples from Colorado, Ohio, and New York.

Kennedy, W.R., and Purtymun, W.D., 1971,
Plutonium and Strontium in Soil Near Technical Area 21, Los Alamos Scientific Labortory, Los Alamos, New Mexico,
LANL, LA-4563.

A study was made of plutonium in soil around TA-21 to determine amounts of plutonium deposited from a laboratory ventilation stack emission. In general the plutonium concentrations decrease with increased distance from the stacks.

Results are similar insofar as locations of maximum concentrations to those found by Jorden and Black in 1956. Calculations as to total amounts deposited within a radius of approximately 1 mile give approximately 2% of the total released from the stacks in the 24 year period of operation.

Strontium analyses were made to possibly distinguish fallout from atmospheric tests from stack emisson material by use of the Pu-239/Sr-90 ratio method. The method proved invalid due to trace deposition of Sr-90 in the soil from past activities in the area.

Kennedy, W.R., Purtymun, W.D., and Schulte, H.F., 1971,
Los Alamos Environmental Monitoring Program: July through December 1970,
LANL, LA-4672-MS.

The Los Alamos Scientific Laboratory complex includes accelerators, research reactors, radioactive materials separation facilities, and other experimental installations using radiation, chemicals and radioactive materials. In operation of the Laboratory, certain wastes are generated and must be disposed of safely.

This report is a six month summary (July through December, 1970) of results of a surveillance program in the area to determine the effect of Laboratory operations upon the environment. Gamma radiation measurements are routinely made. Scheduled samples of air and water are taken and assayed for certain chemical and radioactive materials which may be present in some concentration. Soil samples may be taken when considered necessary.

Kingsley, W.H., 1947,
Survey of Los Alamos and Pueblo Canyon for Radioactive Contamination and Radioassay Test Runs on Sewer-Water and Soil Samples Taken from Los Alamos and Pueblo Canyons.,
LANL, LAMS-516.

Chemical sewers and sanitary sewer lines draining the Tech Area, DP Site, CMR-12 Laundry, and surrounding residential areas flow into Pueblo and Los Alamos streams. The water flow formed in these two canyons winds southeastward to the Rio Grande River after joining beside the old Loudermilk camp site east of the junction of Route 4 and the Road to Post 1. In order to determine the extent and source of the radioactive contamination in these localities it is necessary to collect and radioassay fluid samples from each of the sewers, soil samples from the ground surrounding the sewer exits, and water and soil samples from selected spots in or near each of the two canyon streams. Some preliminary radioassay work was carried out in July, 1945 and previously reported, but because of the importance of the work and the possibility of increasing amounts of radioactive materials accumulating in the area the analyses and surveys were repeated using more exacting methods.

Four groups of radioassay determinations were run. The first group of assays was made on water samples from all sanitary and chemical sewer outlets. Samples were collected and assayed in July, 1946 and in September, 1946. The second group of assays (October and November, 1946) was made on soil samples taken from the ground surrounding all sewer outlets that were found contaminated when surveyed with a portable alpha survey instrument. In some cases, however, soil samples were collected from the ground surrounding exits where the presence of radioactive contaminants, by instrument survey, was not indicated but was suspected.This was done to insure a complete and accurate survey of the entire area and to insure a positive check of spots where any possible contamination might be present even though it might not be detectable by direct instrumentation. Pictures were taken of most of these sample sources. The third group of assays (September, 1946) was made on samples of water taken from stagnant pools in both Pueblo and Los Alamos Canyons. These samples were collected from pools as far down as the Rio Grande River. The fourth group of assays (October and November, 1946) was made on soil samples taken from points in the stream beds in Pueblo and Los Alamos Canyons. As in the case of the soil samples taken from near the sewer exits, pictures were taken of the sources of the soil samples in the canyons where alpha contamination was found to be appreciable by survey with a portable alpha survey meter.

Analyses for polonium and plutonium in the sewers in July, 1946 and in September, 1946 showed quite a wide differential margin.

All sewer water samples were analyzed for uranium content, but no uranium was detected by the fluorimetric method. Since no amount of uranium was detected by the method used, the analysis for uranium was not continued on the soil and canyon water samples.

The greatest activity due to polonium was found in fluid samples taken from number 22 sewer which drains DP East filter house. The July, 1946 analysis showed 46,640 d/m/L for polonium. The September analysis gave 1,854 d/m/L for polonium. The reason for the appreciable drop from 46,640 d/m/L to 1,854 d/m/L may be partially accounted for by the fact that precipitron oil was once eliminated through this exit. This practice was halted in December, 1945 and the polonium from this source is gradually disintegrating. The second and most probable reason for this drop is the fact that the summer rains have diluted the active products and have washed material over a greater area. The second highest polonium activity was found in fluid samples from sewer number 18 which drains most of the sewage from building number 52, DP East. The analysis showed 20,560 d/m/L in July, 1946, and 19,968 d?m?L in September, 1946.

The highest plutonium result was found in fluid samples taken in July, 1946 from the sewage pits (number 25 sewer) of DP West. The result showed 6,780 d/m/L. In September of 1946, however this figure had dropped to about 100 d/m/L. The second highest plutonium result was found in fluid sample taken from number 3 acid sewer which drains contaminated operations in Tech Area. The analysis of this sample showed 1900 d/m/L in July, 1946. The figure showed a drop to 124 d/m/L in September, 1946. This drop is unexplained.

The soil samples collected from the Los Alamos and Pueblo Canyons and ground surrounding the sewer exits showed contamination to a varying degree. The two sources of samples showing the highest polonium disintegration rates were from soil surrounding number 18 sewer at DP East (70,000 c/m/50 gms. soil), and from soil surrounding the outlet into seepage pits near DP East. This last soil sample was assayed as 24,907 d/m/50 gm of soil.

The highest plutonium activity was found in the sewer exit soil samples taken from the ground surrounding the exit of number 3 acid sewer which showed 17,806 d/m/50 gm of soil. The second highest plutonium activity found from samples collected from ground surrounding sewer exits was 3,082 d/m/50 gm of soil at sanitary 4 sewer exit. This high count near a sanitary sewer draining a residential areas may be attributed to the fact that the contaminated sewer, number 3 draining Tech Area chemical drains, is so near the number 4 exit.

The highest soil activity found in either Canyon was found in Los Alamos Canyon near where the sump solutions from the CMR-12 laundry drain into the Los Alamos Canyon stram. The analysis exhibited 10,000 d/m/50 gm of soil for plutonium.

The highest count recorded by survey with the portable alpha survey meter was 16,000 d/m on the surface ground found in Los Alamos Canyon near the drain exit from DP East filter house.

Kovacic, D.A., et al., 1985,
Biomass Estimates in New Mexico Ponderosa Pine Following Wildfire,
LANL, Rough Draft.

Biomass of forbs, shrubs, grasses, and sedges was estimated to species level on ponderosa pine sites that represented successional postfire sequence of from 4 to 80 years. Sites represented moderate-and high-intensity burns at two elevations (2290 and 2590 m). Biomass at 2290 m ranged from 32 to 161 g/squared meter, while at 2590 m ranged from 34 to 194 g/squared meter. Postfire biomass prediction equations were developed for forb, shrub, grass, sedge, and total biomass on both elevations.

Kovacic, D.A., et al., 1986,
"Immediate Effects of Prescribed Burning on Mineral Soil Nitrogen in Ponderosa Pine of New Mexico",
Soil Science, Vol. 141 No. 1, pp. 71-76.

Three 0.1-ha ponderosa pine (Pinus ponderosa Dougl. ex Laws) sites were burned in the fall of 1981. The burn was mainly a ground fire. Burn intensity was 980, 1760, and 2280 kJ per sec per meter on sites 1, 2, and 3, respectively. The mineral soils on each of these sites were analyzed for total N, NO2, NO3, and NH4 prior to burning, 1 d postburn and 30 d postburn. On the most intense burn, NH4 levels increased threefold from preburn (10 ppm) to 1 d postburn (32 ppm), but declined somewhat 30 d following the burn (24 ppm). Concentrations of NO2+NO3 on site 3 rose from 1 ppm preburn and 1 d postburn to 5 ppm 30 d postburn. There were no significant differences in soil total N after burning. Immediate postburn inorganic N values for ponderosa pine mineral soils have not been previously reported in the literature. It is important to investigate burned soils immediately after burning to better understand sequential processes involved in postfire inorganic N dynamics.

Lane, L., 1981,
Estimated Rainfall Frequencies for Los Alamos,
LANL, Memorandum, LS6-81-285.

Based on the isopluvials in NOAA atlas for 6-hr and 24-hr precipitation depths, rainfall frequency estimates have been computed. From original records the maximum 24-hr precipitation depths for Los Alamos were also tabulated.

The NOAA Atlas-2 estimates are some 20 % higher than the observations suggest. However, the relationship is linear and very close to straight line. This suggest that although there are differences in the absolute amounts of maximum 24-hr precipitation for the return periods, the relationships between amounts for the various return periods are very well represented by the NOAA Atlas-2 estimates.

In view of the differences between observed data and NOAA Atlas-2 estimates, the NOAA-Atlas-2 estimates may be high for the 24-hr period. However, since no data were available on shorter time periods (1 hr, 6 hr, etc.) the quality of these estimates are unknown.

Langham, W.H., Harris, P.S., and Shipman, T.L., 1955,
Plutonium Hazards Created by Accidental or Experimental Low-Order Detonation of Atomic Weapons,
LANL, LA-1981.

Accidental or experimental detonation of small atomic weapoms under conditions such that the degree of criticality produced is insignificant may create an immediate and a residual or delayed plutonium health hazard. The immediate hazard is associated with the inhalation of plutonium during cloud passage and on the basis of theoretical considerations appears to be relatively significant. The delayed hazard results from residual plutonium deposited in the fall-out pattern, which may produce chronic contamination over a long period of time. The magnitude of the residual hazard is not easily evaluated on a theoretical curves for maximum allowable air concentrations as a function of time of exposure, based on the assumption of a maximum permissible level of 0.008 uc of plutonium in the lung and a maximum permissible total body level of 0.5 ug, have been developed. These curves may be quite useful in assessing the magnitude of the immediate and residual hazards. Suggestions are made as to the course of action that should be followed in the event of an accidental detonation of the type under consideration.

Langhorst, G.J., 1980,
Preliminary Study of the Potential Concerns Associated with Surface Waters and Geothermal Development of the Valles Caldera.,
LANL, LA-8398-MS.

This report is a preliminary evaluation of possible and probable problems that may be associated with hydrothermal development of the Valles Caldera Known Geothermal Resource Area (KGRA), with specific reference to surface waters. Because of the history of geothermal development and its associated environmental impacts, this preliminary evaluation indicates the Valles Caldera KGRA will be subject to these concerns. Although the exact nature and size of any problem that may occur is not predictable, the baseline data accumulated so far have delineated existing conditions in the streams of the Valles Caldera KGRA. Continued monitoring will be necessary with the development of geothermal resources. Futher studies are also needed to establish guidelines for geothermal effluents and emissions.

LANL, 1975,
Summary of Records Search and Discussions with LASL Pioneers Concerning Building and Drain Lines in TA-1 where Radioactive Materials were Processed,
LANL, Internal Document.

The following internal Los Alamos Scientific Laboratory document summarizes the history of the buildings and operations at TA-1 with reference to location and removal of drain lines. The information presented was obtained from records search and discussions with LASL pioneers.

LANL, 1981,
Formerly Utilized MED/AEC Sites-Remedial Action Program: Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, NM, LANL, May 1981.

Potential exposure to radiation was evaluated for current and future land uses. The report includes a detailed compilation of data pertinent to the canyons (water quality, sediment analysis, effluent quality, etc.) which is very similar to that found by Purtymun in an unpublished report. Nearly 300 soil samples were taken in the two canyons of depths of 25 cm. Results for selected samples are given in the report.

Lopez, E.A., 1982,
The Effects of Coal Fly Ash on Rainbow Trout (Salmo gairdneri),
LANL, LA-9605-T.

Regardless of the environmental impacts from coal utilization, coal is most reliable resource capable of supplying our increasing energy needs. However, with the increase in coal consumption, coal fly ash has become a potential threat to some aquatic organisms. The contents of this report examines some effects of coal fly ash on Rainbow Trout (Salmo gairdneri) under laboratory conditions. An attempt was made to determine the quantities of fly ash that would result in a 50% mortality rate. Other objectives were to design and develop the most effective procedures for these types of studies and test them for adequacy.

Testing conditions, procedures, dietary plans and techniques for administration of a controlled substance was developed. Other results from this research indicate that a good filtering system and a supplementary diet may reduce mortalities in these type of tests. Absence of these requirements may cause trout to excrete a toxic substance. Some problems that were beyond the scope of this study were uncovered and should be investigated further. The pathway and exchange of the toxic substance by trout maintained strictly on fly ash remain to be investigated and identified thoroughly. It is also recommended that a long term study be conducted to evaluate possible accumulations of trace elements on trout over extended time periods.

Los Alamos National Laboratory, 1977,
The Los Alamos National Environmental Research Park,
LANL, LA/NERP.

In November 1976, the Los Alamos Scientific Laboratory and its adjacent lands, encompassing 111 squared kilometers, were designated as a National Environmental Research Park by the U.S. Energy Research and Development Administration. This technical information booklet provides a brief history of past and present land use in the Los Alamos area and an overview description of the Park's environmental setting and resources, including summary characterization information on geology, soils, hydrology, meteorology, ecology, and archaeology. Current research is described in relation to the operation of the Park.

Los Alamos National Laboratory, 1981,
Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo and Los Alamos Canyons, Los Alamos, New Mexico,
LANL, LA-8890-ENV.

Current radiological conditions were evaluated for the site of a former radioactive liquid waste treatment plant and the interconnected canyons that received both treated and untreated effluents between 1944 and 1951. The liquid radioactive wastes were generated by research with nuclear materials at Los Alamos, New Mexico, for World War II Manhattan Engineer District atomic bomb project and subsequently by work conducted for the Atomic Energy Commission. After decommissioning of the treatment plant and decontamination of the site and part of one canyon, ownership of some land in question was transferred to Los Alamos County by the Federal Goverment in 1967. Some residual radioactivity attributable to the effluents remained and is found in the soils and sediments at the former plant site and in channels of the canyons. The study considered all relevant information including historical records, environmental data extending back to the 1940s, and new data acquired by special field sampling and measurements. Potential exposures to radiation were evaluated for conditions of current and possible land uses. Maximum estimated doses were about 12% of radiation protect ion standards, and most were less than 2%. Detailed data and interpretations are given in extensive appendixes.

Markham, O.D., et al., 1983,
"Iodine-129 in Mule Deer Thyroids in the Rocky Mountain West",
Health Physics, Vol.45, No. 1, pp. 31-37.

Thyroids from mule deer (Odocoileus hemionus) were collected in New Mexico, Colorado, Wyoming and Idaho and I-129/I-127 atom ratios were determined. Iodine-129/127 atoms were significantly ($P<0.005$) different among states. Ratios in Wyoming and Idaho control thyroids were significantly ($P<0.05$) larger than ratios in New Mexico and Colorado. Fallout from past atmospheric nuclear tests at the Nevada Test Site is suggested as a possible explanation for the differences in ratios. Average I-129/I-127 ratios in thyroids of other large mammals collected 54 km west and 116 km northeast of the Idaho National Engineering Laboratory (INEL) in south eastern Idaho were up 15 times those found in control thyroid samples from Idaho. Atomospheric effluents from the Idaho Chemical Processing Plant located on the INEL were likely responsible for the increased ratios in animals collected in the INEL vicinity. Although of no health consequence to the animals, I-129 in deer thyroids may be a sensitive indicator of contaminants from nuclear fuel reprocessing plants and atmospheric nuclear test or accidents.

Mayfield, D., and Hansen, W.R., 1983,
Surface Reconnaissance through 1980 for Radioactivity at Radioactive Waste Disposal Area G at the Los Alamos National Laboratory,
LANL, LA-9656-MS.

Surface transport of waste residues was investigated at Waste Disposal Area G by sampling soil, air, and water at the site surface. Sampling locations for soil and vegetation were deliberately selected at (1) the most likely points of occurrence of radionuclides or (2) likely points of occurrence with theoretically the highest concentrations of radionuclides if radionuclides were transported from burial to the site surface. Data obtained from this reconnaissance showed H-3, Pu-239/240, and Gamma-emitting radionuclide concentrations occasionally increase modestly above regional background levels. The data also indicated that H-3 is migrating from waste repositories, whereas Pu-239/240 and Gamma-emitters are not migrating out of repositories. The latter were probably deposited on the surface by occasional spills during disposal operations or as a result of surface storage and holding practices. However, all radionuclide concentrations remain orders of magnitude below applicable standards and guides used to assure that their concentrations in environmental media would not lead to unnecessary or unsafe levels of exposure to the public.

Meadows, S., 1980,
"A Reference Elk Model for Calculating Contaminant Dose to Rocky Mountain Elk",
Environmental Surveillance at Los Alamos During 1980,
LANL, LA-8810-ENV, pp. 61.

The objective of this study was to devise a Reference Elk Model for the use in radioactive and stable contaminant dose assessments in elk (Cervus elphus nelsoni). It was conducted at Los Alamos National Environment Research Park. A large population of elk winter in a ponderosa pine habitat on and near Laboratory technical areas. These animals could potentially obtain radioactive and stable contaminants from areas contaminated by Laboratory activities.

Five elk were collected in an abandoned Laboratory technical area. Each carcass was dissected and and all tissues weighed. Information obtained from the dissection was used to calculate the Reference Elk Model.

Certain tissue percentages are similar for man and elk such as muscle and lung tissue. Differences occur with the proportionally larger brain of man, and larger gastrointestinal tract of the elk. Mule deer and elk have similar proportions of muscle tissue and whole skeleton, but show important differences in proportions of lung, liver and heart mass. The latter is possibly related to differences in metabolism and total body size. The Reference Elk model is expected to provide reliable baseline data for studies of environmental contaminates and their effects on mammalian system.

Meadows, S.D., and Salazar, J.G., 1982,
"An Investigation of Radionuclide Concentrations in Tissues of Elk Utilizing Los Alamos National Laboratory Land",
Health Physics, Vol. 43, No. 4, pp. 595-598.

The Los Alamos National Laboratory, located in north-central New Mexico, is responsible for monitoring the impact of its activities on local biota. Fulfillment of this responsibility requires sampling of air, water, soil, flora and fauna for chemical analyses. Radiotelemetry data were gathered on 30 radio-collared elk from 1978-80. The movements of these animals were followed with a yagi hand-held antennae. The position of each animal was determined at least once a week and was plotted on a USGS topographical map using UTM coordinates.

In the spring of 1980 tissue samples of 10 elk were collected in geographically distinct areas. Five elk were collected in an abandoned Laboratory technical area where radioactivity had been reported above natural or worldwide fallout concentrations in 1979. Four elk were sampled approximately 35 miles northwest of Los Alamos near Cuba, New Mexico. Since this sampling area is separated from Los Alamos by the Jemez and Naciamento mountain ranges, the Cuba samples were collected for background data. A fifth elk was sampled for background data in the Valle San Antonio, approximately 10 miles northwest of Los Alamos.

The results of this study indicate that concentrations of radionuclides found in various tissues are not generally different in Jemez Mountain elk utilizing Los Alamos National Laboratory lands in winter and Jemez Mountain elk that do not. Although Sr-90 concentrations were higher in elk bone sampled on Laboratory lands, as a result of differences in fallout in the 2 areas, these concentrations would result in negligible dose to a human consumer of elk meat.

Miera, F.R., and Hakonson, T.E., 1978,
"Radiation Doses to Rodents Inhabiting a Radioactive Waste Receiving Area",
Health Physics, Vol. 34, pp. 603-609.

A study was conducted of the gamma ray doses to four species of native rodents inhabiting a low level radioactive waste disposal area. Absorbed doses of radiation were measured with lithium fluroide thermoluminescent dosimeters that were significantly higher for western harvest mice (Reithrodontomys megalotis) than for deer mice (Peromyscus maniculatus), pinon mice (P.truei) and the least chipmunk (Eutamias minimus), reflecting differences in mobility and habitat preferences of the respective species. The average dose received by harvest mice was 26 mrad/day, which was 26% of the highest gamma dose detected at the ground surface in the study plot, although the maximum dose received by individual mice was high as 45% of the maximum dose rates in the plot.

Miera, F.R., Jr., 1975,
"Small Mammal Studies in Los Alamos Waste Disposal Areas", Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division: January through December 1974,
LANL, LA-5883-PR, pp. 53-56.

Small mammal studies were undertaken at Los Alamos Scientific Laboratories in areas associated with waste disposal areas. Small-mammal trapping was conducted and animals were marked by toe amputation. Data recorded on all captures included station number where caught, genus and species, sex, age class, reproductive condition, and weight. Data obtained was used to estimate population densities, species diversity and movement patterns.

Results indicated that 10 species of mammals were captured with the pinon mouse (Peromyscus truei) being the predominant species. The pinon mouse and the western harvest mouse (Reithrodontomys megalotis) were found at all sites, indicating that they are distributed through most canyon systems. Data suggest that the highest rodent densities and mass were generally associated with the ponderosa pine/pinon-juniper woodland and they were to the lowest in pinon-juniper woodlands. More trapping data is needed before conclusions concerning the movement patterns of the small mammals can be drawn.

Miera, F.R., Jr., et al., 1977,
Biotic Survey of Los Alamos Radioactive Liquid Effluent Receiving Areas,
LANL, LA-6503-MS.

A preliminary study was completed of the vegetation and small mammal communities and associated climatology in three canyon liquid waste receiving areas at the Los Alamos Scientific Laboratory. Data gathered on plant and animal composition, distribution, and biomass, along with air temperature, humidity, and precipitation, as a function of elevation and where data was available with season. Initial studies of the understory vegetation in the spring of 1974 indicate grass species to be dominant at higher elevations, with forb species becoming dominant at lower elevations. Generally, the highest total mass estimates for standing green vegetation were obtained in the study sites located in the upper portions of the canyons where precipitation is greatest, and where the terrain and intermittent stream flow result in a wetter habitat.

Fourteen species of small mammals were trapped or observed in canyon study areas during two trapping seasons of May-June 1974 and December 1974-February 1975. A greater number of species and the highest rodent biomass estimates in the spring were generally associated with the ponderosa pine/pinon-juniper woodland in the upper reaches of the canyons, and were the lowest in the pinon-juniper woodland at the lower portions of the canyons. This trend was observed in only one of the canyons during the winter season.

Climatological data gathered in the three canyons since 1973 are also presented to serve as a data base for future reference.

Miera, F.R., Jr., et al., 1979,
"Environmental Monitoring of Hot Dry Rock Development", Summary of Talks, 2nd Annual Hot Dry Rock Geothermal Conference,
LANL, LASL-79-86, pp.21.

The development of hot dry rock (HDR) geothermal as an alternative energy technology is being evaluated simultaneously by a comprehensive environmental surveillance program. The objective of these studies is to identify areas potential environmental impact and determine appropriate means for mitigation as the technology is developing. With Phase I completed, some of the operational stages of HDR development can now be assessed as to their potential for impact to the environment. Areas of concern or possible impacts include water quality, air quality, ecology, solid waste, seismicity and natural resources (land use). Extensive baseline data have been collected in these areas for preoperational characterization and for purposes of comparison to measurements made during and at the conclusion of operations. Results of these data are discussed and their significance evaluated.

Miera, F.R., Jr., Montoya, C.S., and Schofield, T., 1980,
"Seedling Germination Affected by Chemical Agents Used in Solar Applications",
Biomedical and Environmental Research Program of the LASL Life Sciences and
Health Divisions: January-December 1979,
LANL, LA-8577-PR, pp. 71-73.

Presently in the solar industry, numerous chemical agents are available as heat transfer media. Potential effects of theses agents on ecosystem components need to be evaluated. Last year, we reported results from research on the effects of glycol based fluids on seedling germination. Data were obtained that suggested that ethylene glcol does indeed inhibit seedling germination in elevated concentrations. This report presents results from more sensitive germination tests with four agents; ethylene glycol, silicone oil, diphenyl/ diphenyl oxide, and lithium chloride.

The seed varities selected for these test, sweet corn (Zea mays), wheat (Triticum aestirum), and pea (Pisum sativum), were those that required similar environmental germination conditions. One hundred seeds were used for each trial. All test were conducted in an environmental chamber for control of temperature, humidity and photoperiod. Emerging seedlings were counted through day 8.

Of the agents tested, lithium chloride most severely affected seedling germination even at the lowest concentration tested. Although diphenyl/diphenyl oxide does not apparently inhibit germination, seedlings at the lowest concentration of 250 ppm exhibited burning, dehydration and stunting effects on both the primary root tip and hypocotyl, all of which would prevent normal plant maturation. Silcone oils inhibited germination at the 8000 ppm levels. Germination was completely inhibited for all seed varieties at glycol concentrations of 8000 ppm and greater. Concentrations of 2000 ppm and less generally exhibited little effect on germination, with some variation between seed types.

Neibling, W.H., and Foster, G.R., 1983,
Modeling Shallow-flow Sediment Transport of Naturally Eroded Sediment,
American Society of Agricultural Engineers, Paper #83-2159.

Sediment transport calculated by six existing sediment transport equations was compared to observed transport rates from a concave-slope deposition study. A computer model developed and verified for sand and coal experiments on concave slopes adequately predicted deposition profile development when rainfall was not present on the deposition area.

Nyhan, J.W., 1975,
"Decomposition of Carbob-14 Labeled Plant Materials in a Grassland Soil Under Field Conditions",
Soil Sci. Soc. Am. Proc., Vol. 39, pp. 643-648.

A study was made of decomposition of plant materials under field conditions using carbon-14 labeled blue grama (Bouteloua gracilis [H.B.K.] Lag. x Steud.) A grassland soil was amended with blue grama herbage and roots in February 1971 and sampled at intervals until March 1972. For ground blue-grama herbage buried in the top 2.6 cm of soil at two admendment levels (128 and 1,280 kg/ha) 54-57% of initially added carbon-14 was lost in 412 days. For plant-root material at amendment levels of 384 and 1,920 kg/ha, only 26-37% of the carbon was lost in this time period. Rates of carbon loss were significantly affected by season of burial; plants buried in February and May exhibited losses of 56% in 335 days and 42% in 314 days, respectively. Segments of blue-grama herbage mixed with soil and placed on the soil surface for 412 days showed carbon losses of 39 and 50%, respectively. Additions of fresh, blue-grama herbage to soil containing partially degraded, labeled plant material had no significant effect on radiocarbon loss rates.

The experimental technique used to estimate blue grama carbon losses under field conditions is evaluated and the decomposition results are discussed relative to decay patterns of native blue grama.

Nyhan, J.W., 1975,
"Sampling Mixtures of Soil and Carbon-14-Labeled Plant Materials",
Soil Science Society of America Proceedings, Vol. 39, No. 2, pp. 380-382.

An automated commercial Dumas apparatus was converted to burn soil samples amended with Carbon-14-labeled plant material for radiocarbon assay. The changes necessary for this conversion are described as well as experiments to determine the efficiency of radiocarbon recovery in combusted samples.

A procedure was developed for mixing labeled plant material with soil and sampling the soil-plant mixture. The radiocarbon content of a mixture of 2.250 kg of soil and 0.5 g of radioactive herbage was determined on 500-mg subsamples taken from composite mixture subsamples. The average radiocarbon recovery value in this experiment was 107% with a coefficient of variation of 13%.

Nyhan, J.W., 1976,
"Influence of Soil Temperature and Water Tension on the Decomposition Rate of Carbon-14 Labeled Herbage",
Soil Science, Vol. 121, No. 5, pp. 288-293.

The relation of decomposition rate of carbon-14 labeled blue grama (Bouteloua gracilis) to soil water content and temperature was examined in laboratory studies. Soil samples amended with ground herbage were incubated at various temperatures (3, 10, 25, 40, 50 and 60 degrees C) and water contents (.009, .03, .06, 5.8, and 113 atm water tension). The oxygen concentrations in the decomposition vessels were determined to evaluate the possibility that oxygen became limiting in the experiments. Radicarbon losses were assessed and the results used to develop a multiple regression equation , which predicted percent carbon loss per hour as an exponential function of water tension, time, temperature and the inverse temperature.

Nyhan, J.W., 1981,
Sampling Soils for Cs-137 Using Various Field Sampling Volumes,
LANL, LA-8951-MS.

The sediments from a liquid effluent receiving area at the Los Alamos National Laboratory and soils from an intensive study area in the fallout pathway of Trinity were sampled for Cs-137 using 25, 500, 2500 and 12,500 cubic cm field sampling volumes. A highly replicated sampling program was used to determine the mean concentrations and inventories of Cs-137 at each site, as well as estimates of spatial, aliquoting, and counting variance components of the radionuclide data. The sampling methods were also analyzed as a function of soil size fractions collected in each field sampling volume and of the total cost of the program for a given variation in the radionuclide survey results.

Coefficients of variation (CV) of Cs-137 inventory estimates ranged from 0.063 to 0.14 for Mortandad Canyon sediments, whereas CV values for Trinity soils were observed from 0.38 to 0.57. Spatial variance components of Cs-137 concentration data were usually found to be larger than either the aliquoting or counting variance estimates and were inversely related to field sampling volume at the Trinity intensive site. Subsequent optimization studies of the sampling schemes demonstrated that each aliquat should be counted once and that only 2-4 aliquots out of as many as 30 collected need be assayed for Cs-137. The optimization studies showed that as sample costs increased to 45 man-hours of labor, the variance of the mean Cs-137 concentration decreased dramtically, but decreased very little with additional labor.

Nyhan, J.W., and Hakonson, T.E., 1976,
"Soil Plutonium in the Los Alamos Environs and at the Trinity Site", Proceedings of an Actinide-Sediment Reactions Working Meeting,
Battelle, BNWL-2117, pp. 103-173.

Soil plutonium concentrations were determined as a function of distance from either the liquid effluent outfalls at Los Alamos or from Ground Zero at Trinity Site and soil depth. Although most of the soil plutonium inventory in the intermittent streams at Los Alamos was located within about 2 km of the waste outfalls, runoff events were important in downstream transport of radioactivity beyond this point into the normally dry portion of these intermittent streams. Vertical mixing to the alluvium by hydrologic transport processes at Los Alamos were also responsible for the inconsistent plutonium-soil depth relationships observed at most sampling locations. In contrast, the horizontal distribution of plutonium in Trinity soils was related to the 1945 fallout deposition pattern and plutonium concentrations generally decreased with soil depth.

The distribution of plutonium was determined for a variety of size fractions as large as 2-23 mm in Los Alamos alluvium and Trinity soils. The 2-23 mm fractions of Los Alamos and Trinity soils generally had at least 10-fold lower Pu concentrations than smaller soil size fraction. The <105 um size fractions in the coarse-textured alluvium at Los Alamos accounted for up to 96% of the soil mass and 80% of the plutonium. Although Trinity soils close to Ground Zero also fit this pattern, up to 90% of the plutonium was associated with the smaller (<105 um) size fractions with increases in soil depth and distances from Ground Zero. The distribution of plutonium in Los Alamos and Trinity soils were also compared with several physical, chemical and hydrologic properties of soil. Increase cation exchange capacities and levels of soil organic carbon and calcium carbonate were significantly correlated with elevated plutonium levels in the alluvium at Los Alamos. The fractional distribution of plutonium was correlated with surface area in Los Alamos soils, but this relationship did not hold true for most of the Trinity soils, signifying that other unidentified causal factors were influencing the distribution of plutonium in soil separates at Trinity Site. The maximum penetration depths of Pu-239,240 into Trinity soils were related to carbonate accumulations in the subsoil and the maximum extent of rainwater penetration into these soil profiles.

Temporal changes in the distribution of plutonium in the Los Alamos and Trinity Site soils were also considered. After the isotopic composition of the effluents added to Effluent-Mortandad Canyon was changed in 1968, soil size fractions could still be collected in this canyon 5 years afterwards, which reflected the isotopic composition of the pre-1968 liquid effluents. The spatial distribution of plutonium in the alluvium of Acid-Pueblo Canyon indicates that dilution and loss of plutonium in the alluvium of Acid-Pueblo Canyon indicates that dilution and loss of plutonium from the upper soil layers has occurred since the liquid effluents were last added to this canyon in 1963. Whereas the plutonium in Trinity soils was only detected in the upper 5 cm of soil nearly 20 years ago, plutonium had migrated as far as 33 cm into these soils at some sampling locations.

Nyhan, J.W., and Lane, L.J., 1986,
"Rainfall Simulator Studies of Earth Covers Used in Shallow Land Burial at Los Alamos, New Mexico", Erosion on Rangelands: Emerging Technology and Data Base, Proc. of the Rainfall Simulator Workshop,
Soc. Range Mgmt, ISBN:0-9603692-4-4, pp. 39-42.

Ten 3.05 by 10.7 m experimental plots were established and subjected to simulated rainfall in a study of erosion of trench caps similar to those used for disposal of low-level radioactive wastes at Los Alamos, NM. Treatments included natural, tilled, bare soil, gravel mulch, vegetated, and vegetated plus gravel mulch plots. Measured soil loss data were used to estimate soil erodibility and cover-management factors for the Universal Soil Loss Equation (USLE).

Nyhan, J.W., and Trujillo, G., 1978,
"Soil Plutonium and Cesium in Stream Channels and Banks of Los Alamos Liquid Effluent-Receiving Areas",
Am. Soc. Argon, Annual Meeting: 32 (Abstract).

As part of the continuing ecological studies in three liquid radioactive waste disposal areas at Los Alamos, the distribution of various radionuclides in and near the stream channel at nine intensive study areas was studied. A set of soil samples was collected at each intensive study area at locations 0, .02, .1, .38, .50, and 10 m from the stream channel, as well as on the adjacent mesa tops. These 12 cores were cut up into various segments for each sampling location and analyzed for Pu-238, Pu-239,240 and Cs-137. Data relating to the concentrations and inventories of these radionuclides was analyzed for differences due to the varying waste use histories of the three waste disposal areas, differential migration rates of radionuclides into stream bank and channel soils, varying distances from the waste outfall, and the various hydrologic-physiographic characteristics of each intensive study area.

Nyhan, J.W., Beckman, R., and Bowen, B., 1989,
An Analysis of Precipitation Occurrences in Los Alamos, New Mexico, for Long-Term Predictions of Waste Repository Behavior,
LANL, LA-11459-MS.

This study describes precipitation as an uncontrolled natural input influencing the hydrology of waste repositories in terms of their ultimate long-term closure. The general climatology of the western states, including that of New Mexico and Los Alamos is first described. An analysis of the precipitation patterns at Los Alamos is then presented to be used for predicting long-term precipitation occurrences and shallow land burial site behavior. The waste management implications of this precipitation analysis are then discussed and future meteorological research needs are identified.

Nyhan, J.W., et al., 1978,
Temporal Changes in the Distribution of Cs-137 in Alluvial Soils at Los Alamos,
LANL, LA-7298-MS.

The alluvial soils of three liquid-effluent receiving areas at Los Alamos were sampled to determine Cs-137 temporal distributional relationships. Soil radionuclide concentrations were determined as a function of soil depth and distance from the waste outfall, and discussed relative to runoff transport of Cs-137-contaminated alluvium. The inventories of soil Cs-137 in various segments of each effluent-receiving area were calculated for two sampling periods and compared with amounts of Cs-137 added to canyons in the liquid wastes. The distribution patterns of soil cesium were compared with the waste-use history of the three study areas and the hydrologic characteristics of the canyons.

Nyhan, J.W., et al., 1983,
"An Evaluation of Soil Sampling for Cs-137 Using Various Field-Sampling Volumes",
Health Physics, Vol. 44, No. 5, pp. 541-552.

The sediments from a liquid effluent receiving area at the Los Alamos National Laboratory and soils from an intensive study area in the fallout pathway of Trinity were sampled for Cs-137 using 25, 500, 2500, and 12,000 cubic meter field sampling volumes. A highly replicated sampling program was used to determine mean concentrations and inventories of Cs-137 at each site, as well as estimates of spatial, aliquoting, and counting variance components of the radionuclide data. The sampling methods were analyzed as a function of soil size fraction collected in each field sampling volume and of total cost of the program for a given variation in the radionuclide survey results.

Coefficients of variation (CV) of Cs-137 inventory estimates ranged from 0.063 to 0.14 for Mortandad Canyon sediments, whereas CV values for Trinity soils were observed from 0.38 to 0.57. Spatial variance components of Cs-137 concentration data were usually found to be larger than either the aliquoting or counting variance estimates and were inverseley related to field sampling volume at the Trinity intensive site. Subsequent optimization studies of the sampling schemes demonstrated that each aliquot should be counted once, and that only 2-4 aliquots out as many as 30 collected need be assayed for Cs-137. The optimization studies showed that as sample costs increased to 45 man-hours of labor per sample, the variance of the mean Cs-137 concentration decreased dramatically, but decreased very little with additional labor.

Nyhan, J.W., et al., 1984,
Distribution of Radionuclides and Water in Bandelier Tuff Beneath a Former Los Alamos Liquid Waste Disposal Site After 33 Years,
LANL, LA-10159-LLWM.

The distribution of radionuclides and water in Bandelier Tuff beneath a former liquid waste disposal site at Los Alamos was investigated. The waste use history of the site was described, as well as several pertintent laboratory and field studies of water and radionuclide migration in Bandelier Tuff. The distribution of plutonium, Am-241,and water was determined in a set of about 800 tuff samples collected to sampling depths of 30 m beneath two adsorption beds. These data were related to site geohydrologic data. Water and radionuclide concentrations found after 33 years were compared with the results of similar studies previosly performed at this site, and the implications of these comparisons are discussed relative to nuclear waste management.

Nyhan, J.W., Miera, F.R., Jr., and Neher, R.E., 1976,
"Distribution of Plutonium in Trinity Soils After 28 Years",
J. Environ. Qual., Vol. 5, No. 4, pp. 431-437.

The soils of four intensive study areas located along the fallout pathway of Trinity, the first nuclear detonation, were sampled to determine soil plutonium concentrations as a function of distance from Ground Zero and soil depth.

About half of the Pu-239,240 in Trinity Soils was found at the 5-20 cm depth in 1973 compared to total plutonium inventories found only in the upper 5 cm of soil about 20 years ago. Soil plutonium concentrations of samples collected at the same depth of each study area generally exhibited coefficients of variation >1.2. Maximum penetration depths of Pu-239,240 into Trinity Site soils were related to the pesence of subsoil horizons containing carbonate accumulations and the maximum extent of rainwater penetration into these soil profiles.

Increased amounts of plutonium were associated with <100 um fractions as distance from Ground Zero and soil depth increased. The < 100 um fraction contained 1.2 and 89% of the plutonium in the topsoil at the study areas located 1.6 and 44 km from Ground Zero, respectively. Total amounts of Pu-238,239 in the <100 um soil fractions also generally increased with depth; at 1.6 km from Ground Zero, this size fraction contained 1.2% and 13% of the Pu-239,240 found at the 0-2.5 and 5.0-10 cm depths, respectively.

The soil plutonium data collected at the Trinity Site is discussed relative to the sizes of Trinity fallout particles, setting meaningful health standards for plutonium in the soils, and the distribution of plutonium in the biota of Trinity ecosystems.

Nyhan, J.W., Miera, F.R., Jr., and Peters, R.J., 1976,
"Distribution of Plutonium in Soil Particle Size Fractions of Liquid Effluent-Receiving Areas at Los Alamos",
J. Environ. Qual., Vol. 5, No. 1, pp. 50-56.

The alluvial soils of three liquid effluent-receiving areas at Los Alamos, New Mexico were sampled to determine the distribution of Pu-238 and Pu-239/240 in soil size fractions as a function of soil depth, distance from the waste outfall and soil physical-chemical properties. Although the plutonium concentrations in the <53 um soil size fraction were 10 times higher than plutonium levels in the 2-13 mm fraction, the largest portion of the plutonium inventory in the average soil sample was found in size fractions >105 um. Plutonium concentrations decreased curvilinearly with distance from the waste outfall and with soil depth in the soils of discharge areas currently receiving treated liquid wastes. The <53 um size fractions contained 7-fold larger surafce areas and 3-fold larger cation exchange capacities than the 2-23 mm size fractions; plutonium concentrations in the size fractions were collected with surface area in all three discharge areas.

Significant differences in the distribution of Pu-238 and Pu-239/240 were found in the soil size fractions from Mortandad Canyon. Most soil separates from this canyon exhibted an approximate doubling of the Pu-239,240/ Pu-238 ratio with increased soil depth and within 40 m from the waste outfall. The <53 um soil size fraction had a 2-fold higher average Pu-239,240/Pu-238 ratio for each sampling station than the 2-23 mm size fraction.

The distribution of plutonium in the soil size fraction is discussed as a function of changing isotopic composition of the liquid wastes added to the canyons, movement of soil and plutonium in these intermittent streams, and potential isotopic differences in the behavior of Pu-238 and Pu-239/240.

Nyhan, J.W., Miera, F.R., Jr., and Peters, R.J., 1976,
"The Distribution of Plutonium and Cesium in Alluvial Soils of the Los Alamos Environs", Proceedings of the Fourth National Symposium on Radioecology, The Ecological Society of America, Special Publication No. 1, pp. 49-57.

The alluvial soils of three liquid waste disposal areas at Los Alamos were sampled to determine plutonium and cesium distributional relationships and correlations with soil physical-chemical properties. Radionuclide concentrations were determined for soil samples as a function of soil depth and distance from the waste outfall. The cesium-plutonium data were collected with levels of organic-carbon, carbonates, exchangeable and water soluble cations, pH, cation exchange capacity, bulk density, surface area and geometric particle size of these soils. The distribution pattern of soil plutonium and cesium were compared to the waste use history of the three study areas.

Nyhan, J.W., White, G., and Schofield, T., 1978,
"Sampling Los Alamos and Trinity Site Soils for Cesium-137", Biomedical and Environmental Research Program of the LASL Health Division: January-December 1977,
LANL, LA-7254-PR, pp. 43-45.

The concentrations and inventories of soil Cs-137 were studied as a function of radionuclide source and volume of soil collected in a canyon (Mortandad Canyon) that serves as treated effluent-receiving area at the Los Alamos Scientific Laboratory and in the fallout zone at Trinity Site. A metal template was used to collect the soil samples at 4 different volumes (12,000, 25000, 500, 25 cubic centimeters). The results of the sampling indicate that Cs-137 concentration and inventories were a function of site-source factors and volume of soil collected in the field.

Nyhan, J.W., White, G.C., and Trujillo, G., 1980,
Soil Plutonium and Cesium in Stream Channels and Banks of Los Alamos Liquid Effluent-Receiving Areas,
LANL, LA-UR-80-1184.

Stream channel sediments and adjancent bank soils found in three intermittent streams used for treated liquid effluent disposal at Los Alamos, New Mexico were sampled to determine the distribution of Pu-238, Pu-239/240 and Cs-137. Radionuclide concentrations and inventories were determined as a function of distance downstream from the waste outfall and from the center of the stream channel-bank physiography, and the waste use history of each disposal area.

Radionuclide concentration in channel sediments were inversely related to distances up to 10 km downstream from the outfalls. Contaminant concentrations in bank soils severely decreased with perpendicular distances greater than 0.38 m from the stream channel and stream bank sampling depths greater than 20-40 cm. Concentrations and total inventories of radionuclides in stream bank soils generally decrease as stream bank height increased. Inventory estimates of radionuclides in channel sediments exhibited coefficients of variation that ranged from 0.41 to 2.6 reflecting the large variation in radionuclide concentrations at each site.

Several interesting temporal relationships of these radionuclides in intermittent streams were gleaned from the varying waste use histories of the three effluent-receiving areas. Eleven years after liquid wastes were added to one canyon, the major radionuclide inventories were found in the stream bank soils, unlike most of the other currently-used receiving areas. A period of time greater than six years seems to be required before the plutonium in liquid wastes currently added to the canyon is approximately equilibrated with the plutonium in the bank soils. These observations are discussed relative to the waste management practices in these southwestern intermittent streams.

Nyhan, J.W., White, G.C., and Trujillo, G., 1982,
"Soil Plutonium and Cesium in Stream Channels and Banks of Los Alamos Liquid Effluent-Receiving Areas",
Health Physics, Vol. 43, No. 4, pp. 531-541.

Stream channel sediments and adjacent bank soils found in three intermittent streams used for treated liquid effluent disposal at Los Alamos, New Mexico were sampled to determine the distribution of Pu-238, Pu-239/240 and Cs-137. Radionuclide concentrations and inventories were determined as functions of distance downstream from the waste outfall and from the center of the stream channel, soil sampling depth, stream channel-bank physiography, and the waste use history of each disposal area. Radionuclide concentrations in channel sediments were inversely related to distances up to 10 km downstream from the outfalls. For sites receiving appreciable waste effluent additions, contaminant concentrations in bank soils decreased with perpendicular distance greater than 0.38 m from the stream channel, and with stream bank sampling depths greater than 20-40 cm. Concentrations and total inventories of radionuclides in stream bank soils generally decreased as stream bank height increased. Inventory estimates of radionuclides in channel sediments exhibited coefficients of variation that ranged 0.41-2.6, reflecting the large variation in radionuclide concentrations at each site. Several interesting temporal relationships of these radionuclides in intermittent streams were gleaned from the varying waste use histories of the three effluent-receiving areas. Eleven years after liquid wastes were added to one canyon, the major radionuclide inventories were found in the stream bank soils, unlike most of the other currently-used receiving areas. A period of time greater than 6 yr seems to be required before the plutonium liquid wastes currently added to the canyon is approximately equilibrated with the plutonium in the bank soils. These observations are discussed relative to waste management practices in these southwestern intermittent streams.

Owens, J.W., 1976,
Fluorometric Determination of Uranium in Environmental Materials.,
LANL, LA-6338-MS.

This report describes the fused fluoride pellet fluorometric method of uranium determination used at the Los Alamos Scientific Laboratory for the measurement of uranium in environmental samples with concentrations as low as 0.1 ppb total U. These analytical techniques are routinely used in the analysis of thousands of samples of soils, natural waters, and various biological materials.

Patterson, J.H., Nelson, G.B., and Matlack, G.M., 1974,
The Dissolution of Pu-238 in Environmental and Biological Systems,
LANL, LA-5624.

Results from our experiments on dissolution rates of 238-PuO2 and 239-PuO2 in distilled water and normal saline solution were compared with rates calculated from data in the literature on various PuO2 dissolution experiments. The initial comparatively rapid dissolution rates were found to vary widely, even between experiments performed ostensibly under the same conditions. In contrast, the lower rate of dissolution, which began a few hours after contact of the oxide with the aqueous medium, was found to be constant and fell within a range of 1 to 6 ng/cubic meter * s under widely varying conditions.

Perkins, B.L., and DePoorter, G.L., 1985,
Plants and Their Relationship to Soil Moisture and Tracer Movement,
LANL, LA-10216-MS.

To obtain a better understanding of the mechanisms for possible movement of radionuclides or other toxic materials from waste burial sites in arid to semi-arid regions, changes in soil moisture and tracer (Co, Cs, Sr, and tritium) movement were compared for bare vs vegetated soils.

During the course of two growing seasons, comparing vegetated with bare soils, plant transpiration processes significantly reduced the soil moisture. In the vegetated soils, most of the Co, Cs, and Sr remained in the region of original emplacement. In bare soils, Co and Cs underwent minimum movement, but the peak concentration of Sr moved downward. For all tracers in the vegetated soils, there was some evidence that slight amounts of tracer had been adsorbed in the plant roots and brought to the surface through plant translocation processes. In all cases, there was no significant upward movement of Co, Cs, and Sr. For tritum, the vegetated soils, compared with the bare soils, retained the maximum inventories near the original emplacement location. Although all soils showed some tritium loss, it was greatest in the vegetated soils.

A literature review associated with the experiment indicated that plant species alone does not determine rooting depth, rate of transpiration, nutrient uptake, and other plant associated processes. Environmental conditions are just as important as plant species and must be included in modeling plant-related effects.

More data are needed on the effects of tracer concentration, soil water composition, variations in precipitation with time and intensity, evaporation rates, variations in soil composition, soil microorganisms, other invertebrates and vertebrates that inhabit the soils, litter decay, and colloid movement on contaminant movement under conditions of saturated flow.

Pettitt, R.A., 1976,
Environmental Monitoring for the Hot Dry Rock Geothermal Energy Development Project: Annual Report for the Period July 1975-June 1976,
LANL, LA-6504-SR.

For the last four years, the Los Alamos Scientific Laboratory has been investigating the feasibility demonstration of a technique for extracting geothermal energy from hot dry rock existing at moderate depths beneath the surface of the earth. In the hot dry rock (HDR) concept, a manmade geothermal reservoir would be formed by drilling an intial borehole into a region of hot dry rock, creating a large fracture at the bottom of the hole, then intersecting the fractured area with a second borehole. The heat contained in this underground reservoir would then be brought to the surface by the circulation of water through the system.

The objectives of this environmental monitoring report are to provide a brief conceptual and historical summary of the Hot Dry Rock Geothermal Project, a brief overview of the environmental monitoring responsibilities and activities of the Los Alamos Scientific Laboratory, and descriptions of the studies, problems and results obtained from various monitoring programs. Included are descriptions of the work that has been done in three major monitoring areas: (1) water quality, both surface and subsurface; (2) seismicity, with a discussion of the monitoring strategy of regional, local, and close-in detection networks; and (3) climatology. The purpose of these programs is to record baseline data, define potential effects from the project activities and determine and record any impacts that may occur.

The development of the hot dry rock geothermal energy resource and associated energy extraction technology is a new field of endeavor, with no established environmental guidelines. It is doubtful if the problems encountered and solutions devised in traditional geothermal systems will apply directly to hot dry rock development. Therefore, the impacts that are encountered in this project will be of particular value in making future environmental assessments for this type of energy resource developemnt in other locations in different geologic settings.

By the end of the reporting period, there had been no unacceptable impacts on the environment in any of the three monitoring areas.

Pippin, W.F., 1977,
Preliminary Check List, Arthopods of Bandelier National Monument, NM,
Bandelier National Monument, Bandelier Library, Accession No. 1480.

A survey of Arthropods found in Bandelier National Moument was initiated as a VIP Program, in May, 1977. The following list is limited to specimens collected and identified in 1977. This list represents identifications of approximately 52% of all specimens submitted to specialists for determination. Collections are continuing.

Many new distributions records for New Mexico are undoubtedly represented in the collection. However, insect distribution records in New Mexico are not well documented, but are currently being organized on a systematic basis at New Mexico State University, Las Cruces.

Several specimens collected were kept by specialists for inclusion in the National Museum Collection in Washington, DC. Two species new to science were collected: a syrphid or flower fly and a cuterbird or robust bot fly.

Polzer, W.L., and Essington, E.H., 1984,
A Modified Adsorption Equation for Modeling of Ion Exchange Reactions in Soils,
LANL, LA-UR-84-2512.

Many mathematical relationships are used to quantify or describe the sorption of reactive solutes by soil. Most of those relationships do not have theoretical basis and may be limited to a restricted range in solute concentrations. Sposito (1980) derived the Freundlich equation for ion exchange reactions on the basis that the exchanger surface is heterogeneous and each class of exchange sites adsorbs individually according to the Langmuir isotherm. Sposito also showed that the empirical parameters in the derived equation can be related in a precise manner to nonuniformity in the surface characteristics of the exchanger. One limitation of the Freundlich equations as derived by Sposito is that the equation aplies only to trace quantities of solute.

In this work we have converted the desired Langmuir equation into a modified Freundlich equation that extends the concentration of the solute to greater than trace quantities and also considers the competitive nature of the ion exchange reactions. Data for the competitive adsorption of the solutes strontium, cesium and cobalt relative to calcium in a calcium-saturated Bandelier Tuff are applied to the the modified Freundlich equation to demonstrate the equations applicability. An interpretation of the numerical values of the empirical parameters for the three solutes is presented on the basis of the meaning given to those parameters by Sposito (1980).

Adsorption data for strontium, cesium and cobalt were plotted according to the modified Freundlich equation. The data for all the solutes appeared to follow a straight line. Using emperical constants, the frequency distribution of the relative affinity parameters was plotted. That plot indicates that the exchanger has the greatest distribution of affinity parameters for cesium and the least for strontium. Those results suggest that in a dynamic system, e.g., a column of Bandelier Tuff where adsorption equilibrium exist, cesium should show the greatest chemical dispersion and strontium the least.

Historically solute dispersion has been attributed to physical dispersive processes. However, the above results suggest that chemical dispersion could be an important factor in solute transport through porous media. Its significance needs to be evaluated.

Polzer, W.L., et al., 1984,
Equilibrium Adsorption of Cobalt, Cesium, and Strontium on Bandelier Tuff:
Analysis of Alternative Mathematical Modeling,
LANL, LA-UR-84-2940.

Adsorption isotherm are derived from batch equilibrium data for cobalt, cesium and strontium on Bandelier Tuff. These three solutes were selected because of prime concern of the fate of their radioactive isotopes in the shallow land disposal of low level radioactive waste.

The adsorption experiments were conducted at an average temperature of 25 degrees C. and equilibrium was defined at 48 hr. The exchange sites of the tuff had been previously saturated with calcium by leaching with 0.01 N CaCl2 solution. The solute concentrations ranged from 0 to 500 ppm and were added to the tuff in solutions of 0.01 N CaCl2. The radioactive isotopes Co-60, Cs-137 and Sr-85 were used to trace the adsorption of the stable solutes on the tuff.

Various common isotherm models were used to evaluate the adsorption data. A modified expression is validated as a preferred general mathematical tool for representing radionuclide adsorption. This validation covers a wide range in solute adsorption characteristics as well as concentrations.

The empirical constants, can be used to determine the frequency distribution of the affinity of the solute relative to the affinity of calcium for the exchange sites. The relative affinities give an indication of the "relative chemical dispersion" of solutes in a dynamic, e.g. a column of Bandelier Tuff, where adsorption equilibrium exists. The results suggest that cesium should show the greatest "chemical dispersion" and strontium the least.

The conclusions reached in this study indicate the importance of understanding of the adsorptive behavior of solutes. Also, the modified Freundlich model is suggested for representing adsorption in the solute transport codes.

Polzer, W.L., et al., 1986,
Compilation of Field-Scale Caisson Data on Solute Transport in the Unsaturated Zone,
LANL, LA-10798-MS.

Los Alamos National Laboratory has conducted technical support studies to assess siting requirements manadated by Nuclear Regulatory Commission in 10CFR Part 61. Field-scale transport studies were conducted under unsaturated moisture conditions and under steady and unsteady flow conditions in large caissons located and operated in a natural (Field) environment. Moisture content, temperature flow rate, base-line chemical, and tracer influent migration studies in the caisson are compiled in tables and graphs. Data suggest that the imposition of a period of drainage (influent solution flow was stopped) may cause an increase in tracer concentration in the soil solution at various sampling points in the caisson. Evaporation during drainage and diffusion of the tracers from immobile to mobile water are two phenomena that could explain the increase. Data also suggest that heterogeneity of sorption sites may increase the variability in transport of sorbing tracers compared with nonsorbing tracers.

Polzer, W.L., Fowler, E.B., and Essington, E.H., 1979,
Characteristics of Wastes and Soils Which Affect Transport of Radionuclides Through the Soil and Their Relationship to Waste Management,
LANL, LA-UR-79-1025.

Knowledge of the rate and degree of movement of radioactive nuclides through soil and geologic media is an important adjunct to the conduct of hazardous waste management. The environmental science group of the Los Alamos Scientific Laboratory (LASL) is studying the interactions of various radioactive waste with a wide variety of soils in order to establish a predictive range of radionuclide retention values to be used by the Nuclear Regulatory Commission (NRC) for the evaluation of waste handling, storage and burial practices.

This report covers field and laboratory efforts for the period October 1977 through September 1978. During that time one large-volume soil sample was classified and collected from Beatty, NV. Three other large-volume soil samples were obtained from the University of California, Los Angeles/University of California, Berkeley (UCLA/UCB) project and include two soils from California and Nebraska.

Results of the laboratory studies on waste/soil interactions indicate that waste radionuclides can be categorized into three broad forms; filterable (insoluble) and sorable and nonsorbable (soluble). The relative distribution of the three depends on the storage time of the waste and on the soil which is interacted with the waste. In the filterable (insoluble) fraction, the radionuclides are associated with both organic and inorganic particulates. The primary inorganic particulate was identified as calcium carbonate. The soluble nonsorbable waste radionuclides posses a negative charge with the exception of Cs-137; that species is positively charged. The presence of negatively charged species is attributed to complexing with either carbonate or chelating compounds.

Changes in the soluble fraction of waste radionuclides on storage of waste are attributed in part to the dissolution or precipitation of calcium carbonate and perhaps the degradation of organic material or growth of microorganism in the waste. Slight changes in the chemical and physical constituents or interaction of the waste with the different soils could account for changes in the sorbed fraction of waste radionuclides. Algal growth and the dissolution or precipitation of constituents such as calcium carbonate could also affect the sorbed fraction of waste radionuclides as observed in the laboratory.

The three forms of waste radionuclides and changes in their realtive distribution with storage can be expected to occur in waste burial pits. An understanding of the factors affecting the relative distribution of the three forms is important in predicting the movement of those forms from a source to the open environment.

Two coordinating meetings were held with correlative projects at University of California, Los Angeles; the University of California, Berkeley; and the Savannah River Ecology Laboratory, Savannah River, South Carolina. Those meetings dealt with coordinating plant uptake and waste/soil interaction studies. A third meeting was held with personnel of Rockwell International at Rocky Flats, Colorado to discuss the identification of particulate material in waste.

Projected future work includes continuation of present batch and column studies with emphasis on the affect of microbiological activity and their end products on waste/soil interaction.

Polzer, W.L., Fowler, E.B., and Essington, E.H., 1981,
"The Interactions of Low-Level Liquid Radioactive Wastes With Soils:
3. Interaction of Wates Radionuclides With Soil From Horizons of Two Soil Series",
Soil Science, Vol. 132, No.1.

We interacted a low-level radioactive waste with the respective horizons of two soils series, the Fuquay and the Fayette. The sorption of the soluble radionuclides was determined by batch reaction methods. Cesium-137 was sorbed to a very high degree, greater than 95 percent, and that degree of sorption was independent of both the soil horizon and the soil series. Uranium also was sorbed to a high degree by all horizons, with sorption by the Fuquay A2 and Fayette Ap soils at 60 to 70 percent and at 90 percent or more by the other horizons. The lower degress of sorption were attributed to the presence of a negatively charged uranium species, probably a uranium carbonate complex. Soluble plutonium and americium were sorbed to a high degree, greater than 75 percent, by all horizons except for Fuquay AP and A2. Those two horizons solubilized, at least part, the plutonium and americium associated with the insoluble fraction of the waste. The complexing of those radionuclides into a nonsorable form was attributed to an organic complex.

Potter, L.D., and Foxx, T., 1984,
"Postfire Recovery and Mortality of the Ponderosa Pine Forest After La Mesa Fire", La Mesa Fire Symposium; Los Alamos, New Mexico October 6 and 7, 1981, LANL, LA-9236-NERP.

The recovery of ponderosa pine after a fire is complex and depends on a variety of factors during and after the fire. Of the 14,361 acres burned in La Mesa fire, the area of stands in categories 5 and 6, within which few or no seed trees were found, amounts to 5209 acres or 36% of the total. Except for about 211 acres of unburned patches, the rest of the trees with foliar damage classification of 1-4 (1% to 99% foliage singed).

After the fire, 897 trees, 393 of which were in categories 1-4, were tagged and their foliar classifications were recorded. Observations after one, two and three growing seasons provided the information for improvement or deterioration. Category-1 trees had 1-25% foliar singeing: category-2, 26-50%; category-3, 51-75%; and category 4, 76-99%. Category-5 trees had all needles singed, and category-6 trees were all consumed.

In the various categories, the following percentages of trees improved or remained the same: category-1, 91%; category-2, 83%; category-3, 74%; and category-4, 83%. Approximately 6% of category-5 trees improved, mostly sapling trees in open stands. All trees in categories 3 and 4 had less than 50% green foilage after the burn and, according to previous reports, most of all of these trees would be expected to die; however, after two growing seasons, 80% were still alive. Perhaps the slightly-above rainfall after the fire and the deep snowfall of 1978-79 resulted in excellant recovery. Among the category-4 trees, the larger trees showed greater recovery percentages. In general, the severity of foilage damage decreased with decreasing time since the last burn, and was negligible in areas burned 27 years earlier (the mean fire interval for the area before fire control is 17 years). The actual recovery percentage was much greater than that anticipated based on previously published data for ponderosa pine.

Recovery of immature trees damaged by fire was little affected by density of trees in the stand until the density reached about 100 trees per acre. There was a rapid decline in the percentage of recovery of mature trees as the density increased from 16 to about 100 trees per acre.

Although there was a positive relationship between severity of foliar damage and length of time since the previous burn, the relationship was negative between recovery of surviving trees and the last fire interval. However, the trees in the plots that were least dense, which previously had low fuel loads (mostly flash fuels), showed the maximum percentage improvement.

Potter, L.D., Foxx, T.S., and Barnes, F.J., 1982,
Natural Regeneration of Ponderosa Pine as Related to Land Use and Fire History on the Pajarito Plateau,
LANL, LA-9293-NERP.

Problems of ponderosa pine regeneration have been of concern in the Southwest for years. When sources of seeds are removed either by fire or logging, problems of regeneration become paramount. In 1977 a major wildfire (La Mesa Fire) burned over land under control of the National Park Service, US Forest Service and Department of Energy. Each of these agencies, because of their mandates, have a different concept of management of burned land. This study was designed to look at natural regeneration of pine after fire as related to the various types of land management and restoration processes. This study had various aspects.

*Using aerial photo coverage the total area burned by the La Mesa fire was calculated and the amount of area devoid of seed trees was determined. The total acreage burned was 60.7 squared km with a total of 21 squared km (36.3%) devoid of seed trees.

*Leaf water potentials (LWP) of three grass species, two seeded [slender wheatgrass (Agropyron trachycaulum) and sheep fescue (Festuca ovina)] and one naturally occurring [Mountain muhly (Muhlenbergia montana)] were measured periodically. Soil samples at two sites were taken from 10, 20, 30, and 40 cm depths whenever LWP was measured. The results indicate that ponderosa pine seedlings would experience severe competition for water from sheep fescue early in the growing season, and continued competition with slender wheatgrass through summer Mountain muhly seems to have a water usage pattern and phenology that coordinates well with known requirements for ponderosa pine seedlings survival. The results indicate that artifical or natural regeneration of pine seedlings can be facilitated by seeding undercover species that will stabilize soils yet have niche requirements that are complimentary to those of regenerating tree seedlings.

*A population of 1431 seedlings with heights of 1 to 150 cm was examined for microsite characteristics such as soil texture, litter depth, litter composition living ground cover, phylogeny of ground cover, growth form of ground cover, vertical canopy, potential tree shade, seedling proximity, need for protective objects, relation to trees, distance to trees, slope, and slope direction.

The best ponderosa pine seedling survival was in fine soils: conifer litter less than 1 cm, sparse gound cover with some shade or ground cover of bearberry or mountain muhly with no shade. Overhead canopy is not required.

Purtymum, W.D., and Adams, H., 1980,
"Changes in Quality of Surface Water Related to La Mesa Fire, 1977",
Environmental Surveillance at Los Alamos During 1979,
LANL, LA-8200-ENV, pp. 53-54.

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

Samples of base flow and storm runoff were collected in Canon de los Frijoles and Capulin Canyon. Samples of base flow and storm runoff in Canon de los Frijoles and Capulin Canyon indicated barium, calcium, iron, and manganese concentrations were elevated in storm runoff when compared to base flow concentrations. Also in Canon de los Frijoles bicarbonate, lead, phenol and zinic concentrations were elevated while Capulin samples showed no significant trends in bicarbonate concentrations and phenols and lead were below limits of detection. Presence of phenols in runoff is from decay of vegetation in the drainage area. Lead concentrations found in the runoff in Canon de los Frijoles may be due to automobile emissions since the Monument Headquatersin Frijoles is subject to heavy vehicle traffic.

Purtymun, W.D., 1971,
Plutonium in Stream Channel Alluvium in the Los Alamos Area, New Mexico,
LANL, LA-4561.

A survey of plutonium isotopes Pu-238 and Pu-239 in the alluvium of major canyons in the Los Alamos Area was made to determine concentrations and movement of soil-bound plutonium. Trace concentrations of plutonium were found in the alluvium in those canyons which have received or are receiving treated effluents from operations of the Laboratory. The concentration of plutonium in the alluvium of the remainder of the canyons was no greater than those concentrations attributed to world-wide fallout from atmospheric tests.

Purtymun, W.D., and Kennedy, W.R., 1966,
Distribution of Moisture and Radioactivity in the Soil and Tuff at the Contaminated Waste Pit Near Technical Area 21, Los Alamos, New Mexico, U.S. Geological Survey, Open-File Report.

The contaminanted waste pit near Technical Area 21 was investigated to determine if waterborne radioactive contaminants had migrated from the pit into adjacent soil and tuff. Thirteen test holes, ranging in depth from 25 to 50 ft, were drilled through the soil into the underlying tuff in the vicinity of the waste pit. No holes were drilled through the base of the pit as only surface of the pit and adjacent land is considered for commercial use. The distribution of moisture in the soil and tuff penetrated by the test holes was determined by a neutron-scattering moisture probe. Samples of drill cuttings of the soil and the tuff were analyzed for gross alpha and gross beta-gamma radioactivities, and plutonium and uranium.

The moisture content of the tuff adjacent to the test holes indicated that the tuff was not saturated. Radiochemical analyses of soil and tuff indicated no radioactive contamination.

Purtymun, W.D., and Maes, M., 1987,
"Survey of Sediments in Major Stream Channels for Toxic and Hazardous Waste",
Environmental Surveillance at Los Alamos During 1986,
LANL, LA-10992-ENV, pp. 113-114.

Treated industrial and sanitary effluents from the Laboratory are released into the canyons that transverse the Pajarito Plateau. Some inorganic and organic compounds in the effluents have an affinity for attachment to the sediments by ion exchange or adsorption. The presence of inorganic and organic compounds in the sediment of the intermittent stream channel could indicate potential for transport of contaminants offsite.

A survey to determine if there has been major transport of organic or inorganic contamination from the Laboratory was made by collecting sediment from 10 canyons that cross the Laboratory and 4 canyons near or adjacent to the Laboratory. The Guaje and Frijoles Canyons data can be considered background data since they are offsite. The two canyons Bayo and Pueblo, drain former Laboratory areas. The sediment samples were analyzed for metals, pesticides, herbicides and volatile organics.

The sediments from the 14 stations were analyzed for 13 metals and anions as well as pH. The eight constituents (As, Ba, Cd, Cr, Pb, Hg, Se, Ag) which EPA has limits set for toxic concentrations, were below detectable limits and well below EPA toxic limit in sediments. The remaining constituents which EPA has set no guidelines, were analyzed for additional information. Concentrations of beryllium and nickel were below detectable limits. Nitrate and Sulfate concentrations were within the same range as background levels. The pH was variable ranging from 5.1 to 7.6, but background levels also ranged from pH 5.1 to 7.5.

Sediments were also analyzed for four pesticides and two herbicides. All pesticides and herbicides were below detectable limits and well below the maximum EPA toxic concentrations.

The sediments from the fourteen stations were analyzed for 36 priority pollutants, volatile organic compounds. Only two were detected. The two compounds (1,1,2,2-tetrachloroethane, 1,1,1,2-tetrachloroethane) were only slighlty above detection limits. Although their concentrations were low, additional investigation will be conducted.

Purtymun, W.D., and Maes, M., 1988,
"Survey of Sediments in Major Stream Channels for Toxic and Hazardous Waste",
Health Safety and Environment Division Annual Report 1987,
LANL, LA-11257-PR, pp. 74-76.

A survey to determine if there has been major transport of organic or inorganic contamination from the Laboratory was made by collecting sediment from 10 canyons that cross the Laboratory and 4 canyons near or adjacent to the Laboratory. Two of the off-site canyons (Guaje and Frijoles canyons) could be considered as background data because they do not drain the Laboratory. The other two (Bayo and Pueblo canyons) drain former Laboratory areas. The sediment samples were leached and the leachate was analyzed for metals, pesticides, herbcidies, and volatile organics. In all, 14 samples were taken and 55 analyses performed on each.

The sediments from the 14 stations were analyzed for 13 metals and anions as well as pH. Eight of the constituents (arsenic, barium, cadmium, chromium, lead mercury, selenium, and silver) have limits set for EPA toxic concentrations. Sediment concentrations were below detectable limits and well below detectable toxic limits as described by EPA. The concentrations of beryllium and nickel were below detectable limits. Sulfate concentrations ranged from 1.1 to 1.9 mg/l in sediments from all stations. Nitrate concentrations ranged from <0.2 to 1.0 mg/l and are within the same range as background. The pH was considerly variable from 5.1 to 7.6. The two background canyons contained sediments with pH 5.1 to 7.5. Hence the variations are probably related to normal variation among the canyon.

Pesticides analyses were performed on sediments from 4 stations. The results were below detectable limits and well below the maximum EPA toxic concentrations.

The sediments from 14 stations were analyzed for 36 priority pollutant, volatile organic compounds. Of the 36 organic compounds, only two were identified in the sediments. The compound 1,1,2,2,-tetrachloroethane was detected in Canada del Buey, Pajarito and Water canyons. The concentrations are only slightly above the detection limits of 5 ug/kg. A similar compound,1,1,1,2,-tetrachloroethane was also found in sediments from the Canada del Buey and Water canyons. Although the concentrations are low, additional investigations will be conducted.

Purtymun, W.D., and Maes, M.N., 1988,
Environmental Investigation of the Pueblo of San Ildefonso: Reference to Water, Soil, and Sediments,
LANL, Unpublished.

A cooperative agreement with the Pueblo of San Ildefonso (Pueblo), the Bureau of Indian Affairs (BIA), and the Department of Energy (DOE) was made to evaluate the possible environmental impact of Los Alamos National Laboratory (LANL) operations on the Pueblo. The LANL, as prime contractor for the DOE, represented the DOE in this investigation. There were 16 water, 4 soil, and 11 sediments collected and analyzed as part of the investigation.

The analytical results were compared with the United States Environmental Protection Agency's (EPA) radiochemical, primary, and secondary drinking water standards. The comparison, however,is not designed to determine acceptability under regulatory compliance. The comparison is made only to give perspective to the analytical results.

The maximum concentrations of radioactive and chemical constituents were below the EPA's drinking water standards. The water from the west side artesian well exceeds the EPA's primary standards for fluoride, while arsenic concentrations from the same well was equal to the primary standards. Other parameters from this and the other water sources were in compliance with the primary standards. The EPA secondary standards for chloride, iron, manganese, total dissolved solids, and pH were exceeded at some locations. The chemicals that exceed the standard occur in similar concentrations in the environment or may originate in the water supply system. There were no detectable volatile organics, pesticide, herbicide, or polychlorinated biphenyis (PCB) compounds in waters from the seven wells. Two semivolatile phthalate compounds were found in water from six of the seven wells. The phthalates, also found in blanks, are ubiquitous in the environment and are common artifacts in the laboratory that are reflected in the analysis.

Radiochemical analysis of four soil samples indicated the maximum concentrations were below regional background for soils. Radiochemical analysis of eleven sediment samples indicated that plutonium was above regional background for sediment at four stations in Los Alamos Canyon. The plutonium reflects the transport of plutonium in runoff from former effluent release area in the Laboratory. The concentrations are well below the EPA proposed screening level indicating that the plutonium is not an environmental problem. The cesium concentrations was above regional sediment background at one station in Los Alamos Canyon. The cesium is also due to transport from former effluent release areas. Concentrations of cesium at the six sampling stations in Mortandad Canyon were low above regional river sediment background; however, below the regional background level for soils. Because of the absence of runoff in this canyon, the background level for soils rather than sediments is the appropriate background level to use for comparison. The absence of other radionuclides indicate that the cesium is from world-wide fallout and not transport by storm runoff from the effluent release are in upper Mortandad Canyon. No chemical contamination was found in the soil and sediments.

Purtymun, W.D., and Stoker, A., 1987,
"Environmental Studies of TA-49", Environmental Surveillance at Los Alamos During 1986,
LANL, LA-10992, pp. 117.

Hydronuclear experiments were conducted in underground shafts at the Los Alamos National Laboratory in an area known as TA-49 in 1959-1961. The hydronuclear experiments and directly related operations deposited various residuals and wastes in the immediate vicinity of TA-49. Plutonium, enriched uranium, depleted uranium and beryllium were dispersed in the bottom of the shafts by detonation of the conventional (chemical) high explosives.

Some plutonium contamination was measured at the surface in one experimental area in December, 1960 and was traced to cuttings from a shaft drilled during October and November. All surface soil associated with the contamination (determined by standard procedures and instruments of the time) was cleaned up and placed back in the shaft from which it originated.

Routine monitoring has not shown any migration of contaminants from TA-49. Routine monitoring of ground water, surface water runoff and sediments will be continued as part of a routine annual environmental surveillance program.

Purtymun, W.D., and Stoker, A., 1988,
"Environmental Studies of TA-49", Health, Safety and Environment Division Annual Report 1987,
LANL, LA-11257-PR, pp. 76-77.

Hydronuclear experiments were conducted in underground shafts at the Los Alamos National Laboratory in Area TA-49 in 1959-1961. The hydronuclear experiments and directly related operations deposited various residuals and waste in the immediate vicinity of TA-49. A total of about 41 kg of plutonium, 93 kg of enriched uranium, 82 kg of depleted uranium and 15 kg of beryllium was used. These materials were dispersed in the bottoms of the shafts by detonation of the conventional high explosives.

Some plutonium contamination was measured at the surface in one experimental area in December 1960 and traced to cuttings from a shaft drilled October and November. Plutonium had apparently been dispersed through fractures in the tuff by the detonation of an experiment in an adjacent experimental shaft. All surface soil contamination ascertainable by standard procedures and instruments of the time was cleaned up and placed back in the shaft from which it originated.

Routine monitoring has not shown any migration of contaminants from TA-49. All monitoring of ground water in the main aquifer, surface-water-runoff and sediments will be continued as part of the routine annual environmental surveillance program carried out by Group HSE-8.

Purtymun, W.D., and Stoker, A.K., 1987,
Environmental Status of Technical Area 49, Los Alamos, New Mexico,
LANL, LA-11135-MS.

In 1960 and 1961 a series of experiments involving high explosives and radioactive materials were conducted at Los Alamos, New Mexico, primarily to understand certain safety aspects of operational nuclear weapons. The experiments were conducted underground in large diameter holes as deep as 120 ft. The experiments were conducted in an area that was extensively studied in advance by the U.S. Geological Survey. The location was selected because it had geologic and hydrologic characteristics that assured complete containment of the experiments and precluded any possible contamination of groundwater. Important features verified by the USGS included the absence of any recharge and about 1200 ft of dry rock above the groundwater aquifer.

Residual materials dispersed by detonation of the high explosives remain at the bottom of the experimental holes. The materials of significance from an environmental standpoint include about 40kg of plutonium, 93kg of enriched uranium, at least 82kg of depleted uranium, 13kg of beryllium, and an undetermined amount of lead. The area is presently identified as a radioactive and hazardous material disposal area for purpose of compliance with DOE and EPA requirements.

Environmental monitoring has been carried out regularly since the time of the experiments. Results of measurements confirm that there has been no contamination of groundwater. Minor surface soil contamination dating from the time of the experimental operations has been detected in small surface drainages near the experimental area. None of the surface contamination has been measurable at Laboratory boundaries or points of public access on a state highway. Additional environmental studies will be conducted in the future under auspices of Department of Energy programs designed to assure appropriate management of buried transuranic waste and full compliance with requirements of the Comprehensive Environmental Response, Compensation, and Liability Act.

Purtymun, W.D., Buchholz, J.R., and Hakonson, T.E., 1975,
Chemical Quality of Effluents and their Influence on Water Quality in Mortandad Canyon,
LANL, LA-UR-75-2076.

The chemical quality of liquid effluent released from an industrial waste treatment plant at the Los Alamos Scientific Laboratory controls the quality of water in a shallow aquifer in the alluvium of Mortandad Canyon. The dilution of the effluent with the waste water and storm runoff, uptake of ions by plants, base exchange with alluvium and losses from the aquifer into the underlying strata reduce the concentrations of the chemicals as they move down gradient in the canyon into the aquifer. Mass estimates of residual chemicals in solution in the aquifer were about 1% of the total released to the canyon from 1963-1974. The average annual concentration of sodium, nitrate, chloride, and total dissolved solids in the aquifer through a 12 year period was directly correlated with annual average concentration in the effluent. This relationship provides a means of predicting the impact of the chemical effluents on the quality of water in the aquifer.

Industrial liquid wastes resulting from some of the scientific programs at the Los Alamos Scientific Laboratory (LASL) were collected and processed at a waste treatment plant located adjacent to Mortandad Canyon in Technical Area (TA) 50. The plant which became operational in June 1963, has been the sole source of treated effluents to Mortandad Canyon. Hydrologic studies which were initiated in 1960 have continued as a part of an overall evaluation of the impact of the effluents on the environment. The purpose of this study was to investigate annual changes in the chemical quality of water in the canyon resulting from the release of effluents through the period 1963-1974. An annual mass inventory was made of chemical additions to the canyon and the residual chemicals in storage in the aquifer. Empirical data were used in developing a predictive model for estimating the concentrations of selected constituents in the aquifer.

Purtymun, W.D., et al., 1983,
"Plutonium in Reservoir Sediments", Environmental Surveillance at Los Alamos During 1982,
LANL, LA-9762-ENV, pp. 80.

Sediment samples were collected from four reservoirs in northern New Mexico. Three of these reservoirs, Heron, El Vado and Abiquiu are in the drainage above Los Alamos, whereas Cochiti Reservoir is in the drainage below Los Alamos. The study was made to determine fallout concentration of plutonium in the sediments and evaluate possible transport of plutonium from the Laboratory.

The Pu-238 concentrations ranged from 0.0001 to 0.0012 pCi/g with an average of 0.0007 pCi/g. There was no significant difference in plutonium concentrations in the reservoir sediments when compared to the river sediments. However, when plutonium concentrations in reservoirs and rivers were compared to those in soils, the soil plutonium concentrations were about a factor of 2X greater than the sediment plutonium concentrations.

In comparing the amount of the two isotopes of Pu, the ratio Pu-239/PU-238 was about 20 in reservoir sediments. The ratio Pu-239/Pu-238 decreased to about 6 in river sediments and to about 2.5 in soils.

There was no significant difference in the Pu-238 concentration in sediments from the four reservoirs. The Pu-239/Pu-238 ratio in sediments from the four reservoirs indicated that there was only regional concentrations in the reservoir sediments.

Purtymun, W.D., et al., 1983,
"Plutonium in Soil Near Technical Area 21", Environmental Surveillance at Los Alamos During 1982,
LANL, LA-9762-ENV, pp. 68-69.

Technical Area 21 (TA-21) was used as a plutonium processing area from 1944 until mid 1978. Air exhaust systems at TA-21 contained filters that removed the majority of the plutonium. Studies were made in 1970 to determine the deposition of plutonium in soil around TA-21. The stations sampled in 1970 were resampled in 1982 using the same sampling technique.

From 1972 to 1982 the average concentration of Pu-238 about doubled, whereas the average concentration of Pu-239 increased about 8 times. The ratio of Pu-239/Pu-238 increased from about 50 to 187. The ratio of Pu-239/Pu-238 shown by regional analysis is about 2.8.

The distribution in both sets of samples shows a nonuniform deposition of plutonium with a general decrease in concentration with increase distance from the stacks.

Purtymun, W.D., et al., 1983,
"Storm Transport of Radionuclides from Area G, Technical Area 54", Environmental Surveillance at Los Alamos During 1982,
LANL, LA-9762-ENV pp. 73-74.

In 1956, Area G was designated for the disposal of radioactive waste. The waste were buried in pits or placed in shafts. The pit or shaft serves as containment for the radionuclides. After burial, the major means of potential transport of contamination to the environment are in the hydrologic cycle.

Hydrologic characteristics and conditions of the soil, seal material and tuff underlying the waste indicate no recharge from the mesas to the main aquifer. Since the waste are buried surface runoff seems unlikely transport mechanism for radionuclides. However, transport and handling of waste at the site could result in surface contamination. Therefore this contamination would be subject to transport from surface runoff.

Results of the study indicate there is some transport of surface contamination from Area G. Concentrations of the radionuclides are low and pose no problem. Area G is well within the confines of the Laboratory.

Purtymun, W.D., et al., 1987,
Background Concentrations of Radionuclides in Soils and River Sediments in Northern New Mexico, 1974-1986,
LANL, LA-11134-MS.

This report documents the range and the upper limit for background concentrations of radionuclides and radioactivity in soils and river sediments that occur as natural rock-forming minerals and worldwide fallout from atmospheric nuclear weapons tests. Documentation is based on collection of soil and sediment in Northern New Mexico and analyzed for Cs-137, Pu-238, Pu-239,249, Sr-90, total uranium, gross gamma and tritium. The data were used to establish the statistical range and upper limit of background concentration cover a 9 or 13 year period ending in 1986. The knowledge of background levels is necessary to interpret soil and sediment data collected for the annual environmental surveillance report and other reports relating to radionuclides or radioactivity in soils and sediments.

Purtymun, W.D., et al., 1987,
Water Quality in the Vicinity of Fenton Hill Site, 1983 and 1984,
LANL, LA-10892-PR.

Water quality data have been collected from surface and ground water stations and from ponds and pond discharges at the Fenton Hill Site located in the Jemez Mountains, as part of a continuing program of environmental studies. There have been slight variations in the chemical quality at individual stations; however, these variations in water quality are within normal seasonal fluctuations. Water supply at the site is pumped from the aquifer in the Abiquiu Tuff. Cumulative production from 1976 through 1984 has been 41.5 million gal. The water level in the supply well declined from 365 ft in 1976 to 379 ft in 1984.

Purtymun, W.D., Ferenbaugh, R.W., and Adams, W.H., 1981,
Water Quality in the Vicinity of Fenton Hill Site, 1980,
LANL, LA-9007-PR.

Water quality data have been collected from surface and ground water stations and from ponds and pond discharges at the Fenton Hill Site located in the Jemez Mountains, as part of a continuing program of environmental studies. There have been slight variations in the chemical quality at individual stations; however, these variations in water quality are within normal seasonal fluctuations. Water in the ponds is highly mineralized because drilling operations and circulation tests in the fractured reservoir of the deep geothermal holes. Water from the ponds or direct discharges from the circulation tests are discharged into an adjacent dry canyon. The discharges infiltrate into alluvium of the canyon within 400 m of the ponds. Monitoring surface water and spring discharge down-gradient from the ponds failed to detect any effects resulting from the release of water from the ponds. Analyses of water from the supply well at the site indicated the chemical concentration were below the U.S. Environmental Protection Agency (USEPA) and State of New Mexico standards or criteria for domestic or municipal uses.

Purtymun, W.D., Garde, R., and Peters, R., 1978,
Movement of Fluids and Plutonium from Shafts at Los Alamos, New Mexico,
LANL, LA-7379-MS.

The movement of fluids and plutonium from wastes disposed in shafts drilled into rhyolite tuff were studied under normal and test conditions. During normal operations of a waste treatment plant at Los Alamos Scientific Laboratory (LASL) a Fe(OH)3 (ferric hydroxide) sludge is mixed with cement to form a paste and disposed into shafts. Under these conditions there was no indication of movement of fluid into the tuff; however, there was movement of paste into open joints that intersected the shaft. As a special test, some Fe(OH)3 sludge without cement was put into an experimental shaft. In this case, fluids moved a few meters from the shaft. The fluids carried trace amounts of plutonium from the shaft, but an inventory indicated more than 99% remained adsorbed or attached to the sludge in the shaft.

Purtymun, W.D., Johnson, G.L., and John, E.C., 1966,
Distribution of Radioactivity in the Alluvium of a Disposal Area at Los Alamos, New Mexico.,
U.S. Geological Survey, Prof. Paper 550-D, pp. D250-D252.

Fine particles in alluvial material in a disposal area for liquid radioactive wastes at Los Alamos have greater affinity for radionuclides than coarse particles; however, most of the radioactivity is in the coarse material, which is more abundant. The radioactivity in the alluvium is dispersed by waste water and storm runoff and decreases with distance from the point of effluent outfall.
Most of the radionuclides are very little change in the quality of the ground water perched in the alluvium.

Purtymun, W.D., Peters, R.J., and Stoker, A.K., 1980,
Radioactivity in Soils and Sediments in and Adjacent to the Los Alamos Area, 1974-1977,
LANL, LA-8234-MS.

Soil and sediment are analysed for gross alpha, gross beta. Pu-238, Pu-239, Cs-137, Sr-90, and total uranium as part of the continuing Environmental Monitoring Program at the Los Alamos Scientific Labortory. This report documents the levels of radioactivity of radionuclides in soils and sediments in northern New Mexico from natural sources and worldwide fallout as well as at seven on-site soil and sediment stations which contain radioactivity contributed by the Laboratory for the period 1974 through 1977.

Purtymun, W.D., Rogers, M.A., and Wheeler, M.L., 1980,
Radiochemical Anaylses of Samples from Beneath a Solid Radioactive Waste
Disposal Pit at Los Alamos, New Mexico,
LANL, LA-8422-MS.

Solid radioactive waste are disposed of by burial in pits excavated in rhyolite tuff at the Los Alamos Scientific Laboratory (LASL). Contaminants in the waste include fission products, uranium, and transuranic elements. In 1976, horizontal core holes were drilled beneath a waste disposal pit that was used from 1963 to 1966. Samples of core were analyzed for gross alpha, gross beta, total uranium, Sr-90, Cs-137, Pu-238, Pu-239,240, and Am-241. The measured gross alpha, gross beta, and uranium concentrations were below minimum detection limits; concentrations of remaining radionuclides, all of which are man-made isotopes, were below the minimum detection limits. Statistical comparisons were made of the gross alpha, gross beta, and uranium data to identify any significant variations from natural concentrations in the tuff. The comparisons demonstrated that none of the radioactivity detected in the samples can be attributed to migration from the disposal pit.

Ramotnik, C.A., and Scott, N.J., Jr., 1988,
"Habitat Requirements of New Mexico's Endangered Salamanders", Management of Amphibians, Reptiles, and Small Mammals in North America: Proceedings of the Symposium,
U.S. Forest Service, General Technical Report RM-166.

We measured a habitat components for two state-listed endangered salamanders in New Mexico in 1986 and 1987. Both species are restricted to mesic environments within high elevation, mixed coniferous forests. Steep slope and high elevation were the most useful variables for predicting the occurrence of Jemez Mountains salamanders and Sacramento Mountain salamanders, respectively. Although the discriminant models show some predictive value in detecting salamanders based on habitat variables, we believe that the best survey technique is ground-truth surveys in wet weather. A better fit of the discriminant models might be obtained by including variables not measured e.g. fire and logging history, and soil characteristics. We offer interim management guidelines as a result of our analysis.

Rea, K.H., 1977,
Environmental Investigation Associated with the LASL Hot Dry Rock Geothermal Energy Development Project,
LANL, LA-6972.

The Los Alamos Scientific Laboratory (LASL) is currently evaluating the feasibility of extracting thermal energy from hot dry rock (HDR) geothermal reservoirs. The concept being tested involves drilling two deep holes into the HDR, connecting these holes by hydraulic fracture, and bringing thermal energy to the surface by circulating water through the system.

This report is an overview of the environmental studies that LASL had conducted relative to its HDR Geothermal Energy Development Project. Because HDR geothermal technology is a new field of endeaver, environmental guidelines have not benn established. We anticipate that LASL's research will lead to the techniques necessary to mitigate undesirable environmental impacts.

To date, results of environmental investigations have been positive in that we have found no undesirable environmental impacts.

Rich, P.M., 1988,
Video Image Analysis of Hemispherical Canopy Photography,
LANL, LA-UR-88-1535.

A video image analysis system for rapid interpretation of hemispherical canopy photography was developed. The system estimates potential penetration of light through openings in plant canopies. Canopy photographs are taken through a hemispherical (fisheye) lens pointed upward through beneath a plant canopy. Backlit negatives are input through a solid-state video camera and digitized. A thresholding alogrithm is ultilized to isolate canopy openings. An image combination algorithm merges the threshold image with distributions of reflected skylight and indirect sunlight to calculate indirect and direct site factors. Long-term monitoring of direct sunlight and reflected skylight in the open allow calibration of predicted values for a given site. Desirable enhancements to the technique include 1) video image acquistion in the field; 2) direct field digitization and analysis; and 3) miniaturization of the optics using fiber optics to allow use under short canopies and at greater heights in tall canopies. The design of the dedicated video image analysis system, with its interactive user interface and efficient computional algorithms, can be used as a model for the design of other systems for analysis of video remote imagery.

Richmond, C.R., 1958,
Retention and Excretion of Radionuclides of the Alkali Metals by Five Mammalian Species,
LANL, LA-2207.

Large-volume liquid-scintillation counters were used to measure invivo the biological half-time (BT1/2), whole body retention, and excretion of several gamma-emitting alkali-metal radionuclides in five species of animals.

Tracer amounts of the radionuclides were administered to mice, rats, monkeys, dogs, and men by oral, intraperitoneal/intravenous administration. Radioactivity levels in the excreta were determined at subsequent intervals and the whole body retention was followed, where possible, until the retained body burden fell to 1.0 to 0.1 per cent of the administered dose.

The logarithms of the retention and excretion levels were plotted as functions of time after administration, and standard first-order kinetics were applied to determine the biological half-times and retention equations. Whole-body retention curves were best fitted by a single or multiple-component exponential function of the form: R = a(1)e(-k(1)t) = a(2)e(-k(2)t) + ... a(n)e(-k(n)t), where a(1), a(2), ...a(n) are the intercepts constants; k(1), k(2),...k(n) are the rate constants; and R is the whole-body retention at time t. Values for the BT1/2 of K-42 in the mouse, rat and dog were 1.3, 4.0, and 0.8 days respectively Respective values for Na-22 in the mouse, rat, monkey, dog andman were 1.7, 2.9, 7.5,9.5, and 11.0 days; for Rb-86, 3.8, 8.6, 15.0, 20.0, and 80.0 days; and for Cs-134 and Cs-137, 1.2, 6.5, 19.0, 25.0, and 110.0 days. Calculations based on these data suggest reduction in the maximum permissible concentrations of radiocesium and radiorubidium in air, food and water.

A first approximation for an interspecies correlation between BT1/2 and body surface area of the form: BT1/2 = k(SA)raised to the b power, where k and b are constants was demonstrated for the radionuclides investigated. Data on the naturally occurring K-40 in laboratory animals and on the distribution of Group I radionuclides in various tissues of the rat were also obtained.

Rodgers, J.C., 1982,
Radiological Hazards of Alpha-Contaminated Waste,
LANL, LA-UR-82-3001.

The radiological hazards of alpha-contaminated wastes is discussed in this overview in terms of two components of hazard: radiobiological hazard, and radioecological hazard. Radiobiological hazard refers to human uptake of alpha-emitters by inhalation and ingestion, and the resultant dose to critical organs of the body. Radioecological hazard refers to the processes of release from buried wastes, transport in the environment, and translocation to man through the food chain. Besides detailing the sources and magnitude of hazards, this brief review identifies the uncertainties in their estimation, and implications for the regulatory process.

Rogers, M.A., 1977,
History and Environmental Setting of LASL Near-Surface Land Disposal Facilities for Radioactive Wastes (Areas A, B, C, D, E, F, G and T),
LANL, LA-6848-MS, Vol. I and II.

The Los Alamos Scientific Laboratory (LASL) has been disposing of radioactive wastes since 1944. The LASL Materials Disposal Areas examined in this report, Areas A, B, C, D, E, F, G and T, are solid radioactive disposal areas with the exception of Area T which is a part of the liquid radioactive waste disposal operation. Areas A, G and T are currently active. Environmental studies of and monitoring for radioactive contamination have been done at LASL since 1944.

Romine, M.J., and Eberhardt, L.E., 1975,
"Understory Vegetation Analysis", Annual Report of the Biomedical and Environmental Research Program of the LASL Health Division: January-December 1974,
LANL, LA-5883-PR, pp. 47-48.

Analysis of understory vegetation was begun in August 1974 as part of the integrated ecological study of small mammals, carnivores and vegetation along a 1500 m elevational gradient from the Rio Grande to the Jemez Mountains and centered on the main canyons that receive liquid waste effluents that contain plutonium and other radionuclides.

Vegetation collections of understory species within the five major vegetation types of the region (juniper, pinon-juniper, ponderosa pine-fir, and fir-aspen-spruce) and a subalpine meadow have been made. These data will be used to develop a map of understory species for the area. The collections include representatives of 36 families with 164 species.

Salazar, J.G., 1984,
Produce and Fish Sampling Program of Los Alamos National Laboratory's
Environmental Surveillance Group,
LANL, LA-10186-MS.

This report describes produce and fish sampling procedures of the Environmental Surveillance Group at the Los Alamos National Laboratory. The program monitors foodstuffs and fish for possible radioactive contamination from Laboratory operations. Data gathered in this program on radionuclide concentrations help to estimate radiation doses to Laboratory personnel and the public.

Smith, W.J., II, Fowler, E.B., and Strafford, R.G., 1977,
Experience in the Cleanup of Plutonium-Contaminated Land,
LANL, LA-6731-MS.

During the summer of 1974, two accidential releases from a radioactive liquid-waste line at Los Alamos Scientific Laboratory (LASL) resulted in plutonium contamination of a small area of land, a portion of a Laboratory parking lot, and a strip along a adjacent street. This report documents the immediate control actions and radiation surveys made in response to these leaks, and the subsequent exhumation and decontamination processes, including the physical operations, operational health physics, and soil samples analyses. The cost and results of the decontamination and restoration are also covered.

Springer, E.P., 1986,
Modeling of Organic Vapor Movement at Area L Disposal Site Los Alamos, New Mexico,
LANL, LA-UR-86-4359.

A three-dimensional model for simulating vapor diffusion through porous media was developed to simulate the movement of organic vapors beneath the waste disposal site at Area L, TA-54, Los Alamos, NM. Movement of organic compounds by gaseous diffusion was determined to be the most probable mechanism because of the low moisture content of the tuff material beneath the disposal area and the concentrations of various organic chemicals found by the current surveillance program.

The computer aide that was developed can accomodate heterogeneous diffusion coefficients, anisotropy in the diffusion coefficient tensor in the principal coordinate directions, and spatially and temporally variable source-sink terms. The three-dimensional equation is solved using line successive over relaxation and a Picard time stepping algorithm. Heterogeneous diffusion coefficients are arithmetically averaged. Three types of boundary conditions, constant concentration, constant flux, and a third boundary condition , were incorporated into the formulation. The computer code was verified by comparing the numerical solution to two analytical solutions.

The organic chemical used in the simulation was trichloroethylene (TCE) because it was found in most of the pore gas sampling events and it was found not to readily adsorbed to tuff material in laboratory experiments. The first requirement for simulating the organic vapor movement in the mesa beneath Area L was to ascertain source concentrations. The use of homogeneous and isotropic diffusion coefficient and continuous source concentrations resulted in a linear problem. Using superposition, the concentration for any increase or decrease in source strength can be found by multiplying the concentration from the base simulation by the factor of adjustment for the source concentration. The results of the analysis indicated that a source concentration between 100 and 1000 ug/l was appropriate. But due to the uncertainity, the source concentrations used were increased by a factor of ten to 1000 and 10000 ug/L/d.

These source concentrations were used in a 10000 day simulation of the site. Using a continuous line source representing each disposal shaft continuing organic wastes, it was found that at the end of the simulation concentrations greater than 1000 ug/l can be found at a 195 m depth. Concentrations at 305 m were less than 10 ug/l for all simulations.

Another simulation was conducted which assumed that the source concentration will decrease to zero after 7300 days after initiation. By the end of the 1000 d simulation, all of the shafts were not contributing. The effect of decreasing contribution was more notable in the areas near the disposal shafts, but concentrations away from the shafts remained close to the values for the continuous source. This result is due to the relatively large concentrations in the areas near the source and the concentration gradients established during the period. There is still sufficient chemical in the source areas to maintain the concentrations away from the source location.

The simulations presented are as good as the assumptions made to frame the simulation. There is no doubt that simulations can reveal an increase or decrease in concentrations over those found in this set of simulations. These results must be viewed in conjunction with the current conditions at Area L and any goals.

Stahlecker, D.W., et al., 1989,
"Breeding Birds Assemblages in the Rio Grande Wild and Scenic River Recreation Area, New Mexico",
The Southwestern Naturalist, Vol. 34, No. 4, pp. 487-498.

Breeding bird assemblages were quantified on a 7,600-ha study area in northern New Mexico. Birds were censused on spot-mapping grids within six or eight habitats during the spring and summer of 1985. Population estimates were made for 43 species in at one habitat while 113 confirmed and potential breeding species were documented in the study area. The riparian habitat had the highest density of breeding birds (203.3 pairs/40 ha) while sagebrush-grasslands had the lowest density (75.6 pairs/40 ha). Sagebrush-grassland habitat had the lowest species richness, and wooded canyon benches had the highest species richness. The greatest similarity in breeding bird species occurred in adjacent and structurally similar habitats.

Steen, C.R., 1977,
Pajarito Plateau Archaeological Survey and Excavations,
LANL, LASL-77-4.

Los Alamos Scientific Laboratory lands were surveyed to locate pre-Columbian Indian ruins. The survey results will permit future construction to be planned so that most of the ancient sites in the area can be preserved.

Indian occupation of the area occurred principally from late Pueblo III times (late 13th century) until early Pueblo V (about the middle of the 16th century). There are evidences of sporadic Indian use of the area for some 10,000 years - one Folsom point has been found, as well as many other archaic varieties of projectile points. Continued use of the region well into the historic period is indicated by pictographic art that protrays horses.

In addition to an account of the survey, the report contains summaries of excavations made on Laboratory lands between 1950 and 1975.

Steen, C.R., 1979,
The Mortandad Style of Rock Art, Pajarito Plateau, New Mexico,
LANL, LA-UR-79-1259.

This paper summarizes the style and kinds of rock art found around the Pajarito Plateau. The style is termed Mortandad because the best preserved examples are in a cavate kiva in Mortandad Canyon. The style is found in a limited area: from Bayo Canyon to Ancho Canyon. Figures were drawn onto walls probably by using a sharpened stake. Most of the figures created are static and the greatest number of figures, by far, are of life forms; only a few geometric figures were made. Although most of the figures are static, motion was indicated (eg. the bear and the hunter) in some figures.

This style of rock art lasted only a short time, as little as fifty years, probably late in the 14th and early 15th centuries. The style shows a strong Mexican influence.

Steen, C.R., 1982,
Pajarito Plateau Archaeological Surveys and Excavations, II,
LANL, LA-8860-NERP.

Los Alamos National Laboratory continues its archaeological program of data gathering and salvage excavations. Sites recently added to the archaeological survey are described, as well as the results of five excavations. Among the more interesting and important discoveries are (1) the apparently well-established local use of anhydrous lime, and (2) a late pre-Columbian use of earlier house sites and middens for garden plots. Evidence indicates that the local puebloan population was the result of an expansion of upper Rio Grande peoples, not an influx of migrants.

Thomas, R.L., and Healy, J.W., 1976,
An Appraisal of Available Information on Uptake by Plants of Transplutonium Elements and Neptunium,
LANL, LA-6460-MS.

A critical review was made of reported information from laboratory studies of plant uptake of transplutonic elements plus neptunium. The available data are meager but indicate that the uptake of Np is the greatest followed by Am and Cm. The data are not sufficient to provide recommended values for use in hazard calculations but they do indicate that the actinides other than plutonium will be accumulated in plants to a greater degree than plutonium.

Thompson, J.L., 1985,
Laboratory and Field Studies Related to the Radionuclide Migration Project:
October 1, 1983 - September 30, 1984,
LANL, LA-10372-PR.

Laboratory and field work performed in FY 1984 in connection with the Radionuclide Migration Project are reviewed in this report. We have continued to monitor the migration of tritium, krypton, and iodine from the Cambric cavity region to the pumped satellite well RNM-2S at the Nevada Test Site. So far, no radioactive cations have appeared in the RNM-2S water. The concentrations of lithium, tritium, and a number of fission product and other radioactive elements have been measured at the Cheshire site. The tritium concentration at Cheshire is anomalously low. It appears that retention at radionuclides by the rhyolite of Pahute Mesa is comparable to that by the alluvium of Frenchman Flat. We are continuing our studies of sorption phenomena, chemical speciation, and colloid behavior. Computational work on chemical equilibria and colloid transport is progressing. We have improved our capabilities in the areas of gamma spectroscopy and mass spectrometry.

Thompson, J.L., 1986,
Laboratory and Field Studies Related to the Radionuclide Migration Project:
October 1, 1984 - September 30, 1985,
LANL, LA-10644-PR.

In this report we review work performed in FY 1985 for the Radionuclide Migration Program. Monitoring of water pumped from the satellite well at Cambric site shows the continuing elution of tritium and krypton from the cavity but no appearence of fission-product cations. Water samples taken from two different depths in the re-entry hole at Cheshire have rather similar concentrations of radionuclides. This result, along with anomolously low tritium concentrations, makes the interpretation of data from Cheshire somewhat uncertain. We have made significant progress in laboratory studies of radionuclide sorption, actinide speciation, and colloid detection and migration.

Thompson, J.L., 1987,
Laboratory and Field Studies Related to the Radionuclide Migration Project: October 1, 1985 - September 30, 1986,
LANL, LA-11081-PR.

In this report we describe the work done at Los Alamos in support of the Radionuclide Migration Project during fiscal year 1986. We have continued to monitor the transport of tritium and 85-Kr from the Cambric explosion zone to the satellite well, which is pumped at 600 gal/min. Corresponding movement of catonic radionuclides such as 137-Cs and 90-Sr has not yet been observed after 12 yr of pumping, nor have we seen evidence that these strongly sorbing ions move in conjunction with colloids. We have analyzed more data from the Cheshire study site but have not resolved uncertainties regarding the distribution and movement of radioactive materials at this location. Our attempts to improve our analytical capability for 36-Cl and 99-Tc have resulted in some progress. Similarly, we have increased our understanding of radionuclide transpot phenomena such as channeling in fracture flow and anion exclusion in zeolites and clays. A sample exchange with Lawrence Livermore National Laboratory has helped us identify critical steps in out procedures for collecting and analyzing large-volume water samples. We have surveyed potential sites on Pahute Mesa at the Nevada Test Site for future radionuclide migration studies and conclude that there are none other than Cheshire presently available, and none are likely to be created in the near future. The Laboratory has engaged recently in radionuclide migration studies sponsored by our weapons program; we review this work in an appendix to the annual report.

Tierney, G.D., and Foxx, T.S., 1982,
Floristic Composition and Plant Succession on Near-Surface Radioactive Waste Disposal Facilities in the Los Alamos National Laboratory,
LANL, LA-9219-MS.

Since 1946, low-level radioactive waste has been buried in shallow landfills within the confines of the Los Alamos National Laboratory. Five of these sites were studied for plant composition, successional patterns by reconnaissance and vegetation mapping.

The data show a slow rate of recovery for all sites, regardless of age,in both the pinon-juniper and ponderosa pine communities. The sites, are not comparable in succession or composition because of location and previous land use. The two oldest sites have the highest species diversity and the only mature trees. All sites allowed to revegetate naturally tend to colonized by the same species that originally surround the sites. Sites on historic fields are colonized by the old field flora, whereas in areas disturbed only by grazing are revegetated by the local native flora.

Tierney, G.D., and Foxx, T.S., 1987,
Root Lengths of Plants on Los Alamos National Laboratory Lands,
LANL, LA-10865-MS.

Maximum root lengths of 22 plant species occurring on Los Alamos National Laboratory lands were measured. An average of two longest roots from each species were dug up and their lengths, typical shapes & qualitative morphologic were noted along with overstory dimensions of the plant individual with which the roots were associated. Maximum root lengths were compared with overstory (height times width) dimensions. Among the life forms studied, the shurbs tend to show the longest in relation to overstory size. Measurements of tree roots suggest only that immature trees on the Pajarito Plateau may have root-length to overstory ratios near one.

Tribby, J.F., 1945,
Report on the Contamination of Creek Water,
LANL, Memorandium.

Waste water from the Technical Area empties into Los Alamos Creek to the southeast of the area and into Pueblo Creek to the north of the area. Both streams ultimately empty into the Rio Grande River. Since the waste water contains plutonium and polonium it is desirable to check these streams to determine the concentration of these substances in the water at various points from the Technical Area to the Rio Grande River, and perhaps, the Rio Grande itself. The principal source of plutonium is from the old contaminated laundary, D, Sigma, U, V, and M buildings in the Technical Area, and D.P. Site West. The principal source of polonium are N Building in the Technical Area and D.P. Site East. The waste water from the new contaminated laundary, highly contaminated with Pu and Po, empties into a sump, which filters a great deal of the contamination from the water before it reaches Los Alamos Creek.

Near the drain exit of the old Technical Area laundry, counts ran between 200,000 and 800,000 d/m/L of water for polomium and 2,000 and 13,000 d/m/L for plutonium. Roughly, this corresponds to a daily rate of 2 mg of Pu in 300 gal of water emptied into Los Alamos Creek from the old laundry alone. In Los Alamos Canyon the d/m/L were much smaller, 300 to 20,000 on Po and 100 to 3,000 on Pu. Near the entrance of Los Alamos Creek into the Rio Grande River the valuse were 12 d/m/L for Pu and 0 d/m/L for Po. In the Rio Grande River the total counts were 18 d/m/L for both agents. This indicates that both contaminating substances are very rapidly deposited from the water. However, it should be noted that the analyses were made in D Building, under semi-contaminated conditions and values under 100 d/m/L are probably not too reliable.

U.S. Department of Energy, 1979,
Final Environmental Impact Statement: Los Alamos Scientific Laboratory, Los Alamos, New Mexico,
U.S. Department of Energy, DOE/EIS-0018.

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.

Van Etten, D., and Scoggins, W., 1988,
"Development of the Mobile Ranger Radiation Mapping System", Health, Safety and Environment Annual Report 1987,
LANL, LA-11257-PR, pp.77-78.

The Ranger Radiation Mapping System is being developed and deployed to map radioactive material-principally transuranic-cocentrations over areas of potentially contaminated land. Ranger uses a commercial microwave ranging and tracking system interfaced with computer graphics to provide isopleths of radioactive material concentrations on the soil surface. A new detector for transuranic contamination, Violinist II, is used to measure the radiation levels.

The system was first field tested in August 1987 and again in December 1987 as part of the DOE Accident Response Group Functions.

Voelz, G.L., 1983,
Occupational Health, Waste Management, and Environmental Research Program of the Health Division 1981,
LANL, LA-9779-PR.

The primary responsiblity of the Health Division at the Los Alamos National Laboratory is to provide effective programs in health, safety, waste processing and environmental protection for the Laboratory. These activities are designed to protect the workers, the public and the environment. Many disciplines are required to meet these responsibilities, including health physics, industrial hygiene, safety, occupational medicine, environmental science, epidemiology, and waste management. The diverse research and development activities of the Laboratory provide new and challenging health and safety problems. These programs continue but are being extended also as needed to meet specific problems for the Department of Energy in its development of various energy technologies.

During 1981, evaluations of respiratory protective equipment included 3 special DOE contractor supplied-air suits or hoods and 10 commercial supplied-air devices. Preliminary results of chemical permeation tests of different protective garment materials are reported.

Industrial hygiene field studies of oil shale work were conducted at the Geokinetics true in situ facility and the Rio Blanco modified in situ facility. An occupational medical survey of workers at the Geokinetics, Inc., facility was completed. Research on the generation and characterization of aerosols was continued for inhalation studies of man-made mineral fibers and oil shale aerosols.

Environmental Surveillance at Los Alamos during 1981 showed the highest estimated dose due to Laboratory operations is about 4% of the dose due to the natural radioactivity here. A study was completed in alternative strategies for long-term management of Los Alamos transuranic wastes. A successful 10-day test burn of pentachlorophenol-contaminated wastes was conducted in the Controlled Air Incinerator. Decontamination factors for five fission products in the off-gas handling system of the incinerator were measured.

Voelz, G.L., 1984,
Occupational Health and Environmental Research Program of the Health Division 1982,
LANL, LA-9958-PR.

The primary responsibility of the Health Division at the Los Alamos National Laboratory is in health, safety, waste processing, and environmental protection for the Laboratory. These activities are designed to protect workers, the public and the environment. Many disciplines are required to meet these responsibilities, including health physics, industrial hygiene, safety, occupational medicine, environmental science, epidemology and waste management. New and challenging health and safety problems surface occasionally from the diverse research and development work of the Laboratory. Research programs in the Health Division often stem from these applied needs. These programs continue but are being extended, also, as needed to study specific problems for the DOE and to help develop various energy technologies.

Worker protection studies primarily involve investigating respirators, protective clothing and radiation dosimetry. Evaluations of respiratory protective equipment in 1982 included 3 special DOE contractor devices, 10 commercial supplied-air devices, 2 military respirators, and 3 powered air-purifying respirator systems that will be used in nuclear facilities. Permeation rates for a number of different chemicals were determined in 11 materials. Estimates of plutonium deposition in workers were calcualted from urine excreation data, and they were compared with plutonium measurements in autopsy tissues, so that estimates from bioassay results could be improved.

Field industrial hygiene studies of oil shale processes were continued at the Rio Blanco and the Occidental facilities in Colorado and the Geokinetics facility in Utah. Reasearch in generating and characterizing aerosols was continued for manmade mineral fibers and oil shale aerosols inhalation studies.

Studies of Los Alamos and Rocky Flats plutonium workers have shown no increased mortality compared with US vital statistics. The total number of deaths from cancer was not elevated, but a tripled brain cancer incidence was noted in the Rocky Flats group. A case-control study of brain cancer at Rocky Flats showed no association of these cases with radiation, plutonium, specific jobs or work locations.

A summary of analytical-chemistry methods used for environmental measurments is provided. Developments in analytical methods are discussed for beryllium, PCBs, uranium, plutonium, and americium. Instrumentation development was completed on a portable computer system and a portable neutron spectrometer/dosimeter.

Environmental surveillance at Los Alamos during 1982 showed the highest estimated dose from Laboratory poerations is about 7% of the natural radiation background dose. Surveys at the Los Alamos waste disposal areas measured external radiation levels and potential subsurface migration contaminants. Other environmetal studies included plutonium measurements in soil amd canyon sediments at Los Alamos; measurement of radionuclide transport away from the lagoons at the Clinton P. Anderson Meson Physics Facility (LAMPF); gamma-ray absorbed doses owing to gaseous releases from LAMPF; airborne emissions resulting from depleted uranium munitions tests, and chemical analyses of surface and ground waters at a hot dry rock, geothermal facility.

Controlled-air incineration of combustible wastes continued to contain fission and activation products well and to reduce feed material volume efficiently. A continuous slurry-feed system for ion-exchange resins and decomposition of PCBs were both demonstrated successfully in the incinerator. Methods and alternate test aerosols were evaluated for QA testing of HEPA filters.

Voelz, G.L., 1985,
Occupational Health and Environmental Research 1983: Health, Safety, and Environmental Division,
LANL, LA-19365-PR.

The primary responsibility of the Health, Safety, and Environment (HSE) Division at the Los Alamos National Laboratory is to provide comprehensive occupational health and safety programs, waste processing, and environmental protection. Theses activitites are designed to protect the workers, the public and the environment. Many disciplines are required to meet the responsibilities, including radiation protection, industrial hygiene, safety, occupational medicine, environmental science, epidemiology, and waste management. New and challenging health and safety problems arise occasionally from the diverse research and development work of the Laboratory. Research programs in the HSE Division often stem from these applied needs. These programs continue but are also extended, as needed, to study specific problems for the DOE and to help develop better occupational health and safety practices.

Worker protection studies involve investigating respirators and protective clothing. Evaluation of respiratory protective equipment in 1983 included three devices for DOE contractors, the XM-30 and M17A1 military masks, use of MAG-1 spectacles in respirators, and eight self-contained units.. The latter units were used in an evaluation of test procedures used for Bureau of Mines approval of breathing apparatuses. Preliminary results of studies on the penetration of selected respirator filters by asbestos fibers showed two of six respirators tested allowed penetration of 0.1% or more. A two-volume report on guidelines for the selection of chemical protective clothing was published.

Analyses of air samples from field studies of a modified in situ oil shale retorting facility were performed for total cyclohexane extractables and selected polynuclear aromatic hydrocarbons (PAH). Levels of vapor-phase PAH in the mine and at the surface were generally less than 20 ug/cubic meter except near areas where retort products were being handled or stored. Aerosol generation and characterization of effluents from oil shale processing were continued as part of an inhalation toxicology study.

Additional data on plutonium excretion in urine are presented and point up problems in using the Langham equation to predict deposition in the body from long-term excretion data. Preliminary results are given on the distribution of plutonoium in the whole body of a plutonium worker exposed 36 yr earlier. Relative risk of death was found to be no greater in persons with plutonium depositions of 2 nCi or more than among unexposed workers.

Environmental surveillance at Los Alamos during 1983 showed the highest estimated radiation dose from Laboratory operations to be about 26% of the natural background radiation dose. Several studies on radionuclides and their transport in the Los Alamos environment are described. The chemical quality of surface and ground water near the geothermal hot dry rockfacility is described. Short and long-term consequences to man from releases of radionuclides into the environment can be simulated by the BIOTRAN computer model, which is discussed briefly.

Several studies measured the penetration of high efficiency paticulate air filters by aerosols, including an evaluation of four different test aerosol materials. Preliminary data indicate that a laser aerosol spectrometer is a practical instrument for making aerosol measurements.

Wallwork-Barber, Ferenbaugh, R., and Gladney, E., 1982,
The Use of Honey Bees as Monitors of Environmental Pollution,
Agricultural Research, Vol. 122 (11), pp. 770-772.

Concern about the increase of world-wide pollution and radionuclide contamination has caused an increase in monitoring efforts. This study is an overview of the use of honey bees, Apis mellifera L., as monitors of environmental pollution with emphasis on research done at Los Alamoa National Laboratory. Bee colonies are discussed as a feasible long-term, self-sustaining system for environmental monitoring. Past studies are briefly surveyed. The success of these investigations indicates that the use of bee hives to assess environmental impact of potential sources deserves further investigation.

Wallwork-Barber, M., Lyall, K., and Ferenbaugh, R., 1985,
Thallium Movement in a Simple Aquatic Ecosystem,
J. Environ. Sci. Health, A20(6), pp. 689-700.

Very little is known about the behavior of thallium in an aquatic system. Because of its toxicity and pollution potential a greater understanding of thallium transport pathways in aquatic system is needed. This study examined the transport of thallium among four basic aquatic components: water, sand, vegetation, and fish. Concentrations of thallium decreased slowly in the water and increased tenfold in the vegetation and fish. Definite transport of thallium occurred among water, fish, and vegetation, but no significant transport was seen between the sand and the other ecosystem components. Thallium concentration in the sand remained essentially constant throughout the experiments.

Wallwork-Barber, M.K., and Hakonson, T.E., 1981,
"Accumulation and Retention of Soil Particles on Plants", Environmental Surveillance at Los Alamos During 1980,
LANL, LA-8810-ENV, pp. 59-60.

A study was conducted to measure accumulation and retention of soil particles on tomato plant surfaces as a function of soil particle size, surface of deposition, height of foliage above ground, rainfall characteristics, and time.

Two studies were conducted, one involved accumulation of particles on foliage by rain splash-up of soil from ground surface, and the other involved retention of particles that were applied directly to the surface foliage. A burlap covering over the ground surface prevented rain splash-up of soil from occurring in the retention plot. The number and size of particles per unit area of leaf surface were measured with a scanning electron microscope (SEM).

Results based on SEM analysis indicated that no particle greater than 200 um in diameter was accumulated or retained by tomato plant surfaces. The number of particles present on plant surfaces decreased with an increase in height of foliage above ground surfaces for all particle sizes.

Distribution of particles on the plant as a function of location (upper leaf surface, lower leaf surface, stem) was uniform for all particle sizes with the exception of clays which were most abundant on upper leaf surfaces.

Accumulation of particles increased by a factor of 2, and retention of particles decreased by a factor of 1.5 as a function of time.

Wangen, L.E., and Jones, M.M., 1984,
The Attenuation of Chemical Leachates from Coal Mineral Wastes by Soils,
LANL, LA-10161-MS.

The chemical attenuation of acidity and selected elements (aluminum, arsenic, cadmium, cobalt, chronium, copper, fluorine, iron, maganese, nickel, and zinic) in acidic leachates from coal mineral wastes by four natural subsurface soils has been investigated by using laboratory column methods. Leachate solutions were allowed to percolate through the soils under simulated natural flow conditions, and the elemental concentrations in the influents and effluents were measured periodically. Elemental retentions were substantial for all species except manganese, which was eluted in excess from all soils except the most calcareous. Two processes appeared to operate in decreasing influent concentrations: (1) precipitation of solid phases caused by increased pH of the leachate as it percolated through the soil, and (2) adsorption of elements onto exchange and sorption sites naturally present in the soil and on iron and aluminum oxide precipitates formed in situ from leachate components because of the increased in pH. The soil property most important in retention was its alkalinity. Thus, carbonaceous soils provide the best control material for acidic leachates from mineral wastes. Results show that natural soils can substantially reduce pollutant fluxes to the environment from acidic coal waste dumps and should be considered when selecting waste disposal sites.

Wangen, L.E., and Stallings, E.A., 1984,
Surface Transport of Contaminants From Energy Process Waste Leachates: January 1 - December 31, 1982,
LANL, LA-10011-PR.

This report describes progress during calendar year 1982 on research into the processes and mechanisms controlling the aqueous movement of inorganic solutes through soils and predominant soil mineral components. The reported research, which is ultimately designed to develop capabilities for predicting the transport of inorganic and organics solutes through subsurface geologic materials, is coordinated with that at three other institutions. Los Alamos is studying solute movement using mainly laboratory column methods designed to simulate one-dimensional transport through porous media. Trace elements being studied are As, B, Cd, Mo, Ni, and Se. Matrix species include Ca, K, No3, and So4. Presently, 0.01M KClO4 is being used as an ionic strength buffer. Solids adsorbents being or to be studied are goethite, kaolinite, illite, montmorillonite, in addition to soils collected in the field.

Presented in this report are soil and soil mineral components to be used in the experimental program, the chemical and physical properties determined for some of the adsorbents being used, results of studies into the speciation of selenium in influent and effluent from previously completed soil column experiments, and results of column transport experiments for selected inorganic elements (As, B, Cd, Mo, Ni and Se) in a calcareous soil and the mineral goethite (alpha-FeOOH).

Wangen, L.E., and Turner, F.B., 1980,
"Trace Elements in Vegetation Downwind of a Coal-Fired Power Plant",
Water, Air and Soil Pollution, Vol. 13, pp. 99-108.

Concentrations of As, B, Br, Co, Cu, F, Ga, Li, Mo, Ni, Sr, V and Zn were measured in samples of four different kinds of plants at distances 8, 12, 16, 24, 40, 70 and 120 km downwind of a large coalfired power plant in New Mexico. Concentrations of B, Br, Co, Li, and Sr decreased with distance from the power plant in grasses, but not in shurbs. Fluorine concentrations decreased in stems of a shrub. These decreases taken with concentration enrichment and solubility considerations, provide circumstantial evidence that at least B and F may be due to power plant stack emissions.

Wangen, L.E., Martinez, A.M., and Jones, M.M., 1985,
The Subsurface Transport of Contaminants from Energy Process Waste Leachates: Final Report,
LANL, LA-10502.

This report describes recent progress in research related to the subsurface transport of inoragnic solutes through soils and soil mineral components. The purposes of this research are to assist in the development of capabilities for predicting subsurface solute transport of chemically complex mixtures and to investigate the effects of chemical speciation on the transport of chemical components. This report includes results of studies on the adsorption of nickel and cadmium by a high iron oxide soil, effects of cyanide on adsorption and transport through goethite of nickel, and effect of oxidation state on selenium mobility.

Watson, C.W., and Barr, S., 1976,
Monte Carlo Simulation of the Turbulent Transport of Airborne Contaminants,
LANL, LA-6103.

A gerneralixed three-dimensional Monte Carlo model and computer code (SPOOR) are described for simulating atmospheric transport & dispersal of small pollutant clouds. A cloud is represented by a large number of particles that we "track" by statistically sampling simulated wind and turbulence fields. These data are based on generalized wind data for large scale flow and turbulent energy spectra for the micro and mesoscales. The large-scale field can be input from a climatological data base, or by means of real time analyses, or from a separate, subjectively defined data base. We introduce the micro and mesoscale wind flucuations through a power spectral density, to include effects from a broad spectrum of trubulent-energy scales. The role of turbulence is simulated in both meander and dispersal. Complex flow fields and time-dependent diffusion rates are accounted for naturally and shear effects are simulated automatically in the ensemble of particle trajectories. An important adjunct has been the development of the computer-graphics display. These include two and three dimensional (perspective) snapshots and color motion pictures of particle ensembles, plus running displays of differential and integral cloud characteristics. The model's versatility makes it a valuable atmospheric research tool that we can adapt easily into broader, multicomponent systems-analysis codes. Removal, transformation, dry or wet deposition, and resuspension of contaminant particles can be readily included.

Wenzel, W., et al., 1986,
Los Alamos Low-Level Waste Performance Assessment Status,
LANL, LA-10768-MS.

This report reviews the documented Los Alamos studies done to assess the containment of burial hazaradous wastes. Five sections logically present the environmental studies, operational source terms, transport pathways, environment dosimetry, and computer model development and use. This review gives a general picture of the Los Alamos solid waste disposal and liquid effluent sites and is intended for technical readers with waste management and environmental science but without a detailed familiarization with Los Alamos.

The review begins with a wide perspective on environmental studies at Los Alamos. Hydrology, geology, and meteorology are described for the site and region. The ongoing Laboratory-wide environmental studies are presented. The next section describes the waste disposal sites and summarizes the current source terms for these sites. Hazardous chemical waste and liquid effluents are also addressed by describing the sites and canyons that are impacted. The review focuses on the transport pathways addressed mainly in reports by Healy and the Formerly Utilized Sites Remedial Action Program. Once the source terms and potential pathways are described, the dose assessment methods are addressed. Three major studies, the waste alternatives, Hasen and Rogers, and the Pantex Environmental Impact Statement, contributed to the current Los Alamos dose assessment methodology. Finally, the current Los Alamos groundwater, surface water, and environmental assessment models for these mesa top and canyon sites described.

Wenzel, W.J., and Gallegos, A.F., 1985,
EFFECTS: Documentation and Verification for a BEIR III Cancer Risk Model Based on Age, Sex, and Population Dynamics for BIOTRAN,
LANL, LA-10371-MS.

The computer code EFFECTS is coupled with the radionuclide uptake and environmental transport strategies of the BIOTRAN code to predict cancer risks and deaths in a dynamic human population. Included in the EFFECTS model is a generalized population dynamics portion representative of the current US population mortality and natality characteristics. The population characteristics are integrated with BEIR III radiation cancer mortality estimates. Males and females between 1 and 85 years are treated separately. Natality for both sexes is simulated by using current US population birth rates on an annual basis. Total mortalities due to all causes are incorporated with projected radiation-induced cancer mortalities caused by all previous chronic or acute radiation exposures of the population as a function of age and sex. Superpositioning radiation-induced cancer mortalities on current total mortalities in each group allows a realistic and dynamic estimate of cancer risks for complex radiation exposure scenarios. EFFECTS was developed on the CDC 7600 and can be executed on the Cray computer system at Los Alamos National Laboratory. EFFECTS can simulate the upper boundary of cancer risk estimates where population exposures occur over many years and where organ burdens are integrated over the lifetime of the individual.

This report gives new insight on age-specific cancer risks. As part of the code verification, the simulated impacts to a small population from natural background uranium and an accidential release of air-borne plutonium are compared. For the long-term continuous exposure to natural background uranium, the impact to the population is very small (2 X 10-6 to 7 X 10-6 deaths/10,000 people) with young adults receiving the largest bone doses and risks. For the long-term intakes following a simulated accidental air release of plutonium, young teenagers receive the largest risk. Simulating these two scenarios, using BIOTRAN/HUMTRN/EFFECTS, illustrates sufficient resolution to predict the age/sex specific response from human populations from contaminants in our environment.

The 3-D color graphics are a major addition, developed to help visualize and interpret cancer risk by age group and exposure period for a population. EFFECTS has retained flexible input, which is characteristic of all BIOTRAN codes. Because it uses the systematic graphics verification techniques developed for BIOTRAN, EFFECTS has made possible for the first time the dynamic simulation of the release and the movement of contaminants in a simulated environment and the visualization of the impacts on plants, animals, and human populations. With the ability to plot over 20,000 lines of output in one 3-D graph, it is now possible to rapidly understand and verify complex scenarios.

Wenzel, W.J., et al., 1987,
Cesium-137, Plutonium-239/240, Total Uranium, and Scandium in Trees and Shrubs Growing in Transuranic Waste at Area B,
LANL, LA-11126-MS.

A unique radioecological study was carried out at a Los Alamos National Laboratory (LANL) shallow land burial site called Area B. Area B was the first common transuranic waste burial site for LANL from 1944 to 1948 and had lain fallow for 34 years. During this time secondary succession resulted in invasion of many native trees, shrubs, forbs, and grasses. The purpose of this study was to determine whether any trees or shrubs were rooting directly in waste material, to examine rooting patterns in a shallow land burial site, and to study the distribution patterns of different radionuclides by dissecting vegetative samples into representative compartments.

Scandium, Cs-137, Pu-239/240 and total Ur were measured in soil, litter, leaf, bark, wood, and root samples from excavated trees and shrubs. Several trees and shrubs were found rooted in transuranic waste material. The radiochemical data were used to calibrate the UPTAKE subroutine of the BIOTRAN model for the Los Alamos environs.The simulation results indicated that higher resolution sampling is needed for Cs-137 and Pu-239/240 to interpret surveillance data and to produce reliable risk assessments.

This study attempted to draw together and interpret the radionuclide data for Area B from several investigations. There is a need to standardize the grid methods and sampling site markers to develop a permanent system where sampling sites can be accurately relocated and tied to engineering drawings. This would allow subsequent studies to use the existing temporal data and hence produce reliable assessements, especially for sites where heterogeneous source terms require high resolution sampling on small grids over long time frames.

Wheeler, W.L., Smith, W.J., and Gallegos, A.F., 1977,
A Preliminary Evaluation of the Potential for Plutonium Release from Burial Grounds at Los Alamos Scientific Laboratory,
LANL, LA-6694-MS.

In this report an analysis is made of a number of natural phenomena which could result in the release of plutonium from radioactive waste buried at the Los Alamos Scientific Laboratory (LASL). Background information concerning the history and practice of radioactive waste disposal at LASL is provided. The potential impact of buried radioactive waste on the environment is addressed through the mechanisms and rates by which the radionuclides can enter the environment. Only mechanisms independent of human activity are considered. They are divided into two classes, acute and chronic. The acute release mechanisms considered are earthquakes, meteorite impacts, and tornadoes. These have been typified by low occurrence probabilities (10 -6 - 10 -7yr.). The chronic mechanisms that have been considered are release through uptake by plant roots, exposure by soil erosion, and transport by soil water. The rates of these processses are low, but may result in radionuclide release over long time periods. The analysis of uptake by plant roots was made using an environmental model currently under development; the model is discussed in some detail.

Whelan, G., et al., 1982,
Annual Report, October 1980 - September 1981; Multimedia Radionuclide Exposure Assessment Modeling,
Pacific Northwest Laboratory, PNL-4545.

Pacific Northwest Laboratory (PNL) and Los Alamos National Laboratory (LANL) are jointly developing a methodology for assessing exposures of the air, water, plants to radionuclides as part of an overall development effort of a radionuclide disposal site evaluation methodology. The assessment methodology will predict radionuclide exposure levels in the environment by simulating dominant mechanisms of radionuclide migration and fate. The methodology is more sophisticated than those for a basic worst case scenario analysis, but less sophisticated than a full-scale, extremely detailed, and expensive and time-consuming onsite survey. The methodology encompasses five different environments (i.e., atmospheric, terrestrial, overland, groundwater, and surface water) and combines them to a highly flexible tool. The purpose of the work in FY-1981 was to continue the development of the Multimedia Contaminant Environmental Exposure Assessment (MECA) methodology and to initiate an assessment of radionuclide migration in Los Alamos and Pueblo Canyons, New Mexico, using the methodology.

The scope of the work performed in FY-1981 consisted of four elements. The first involved the atmospheric component in which AIRTRAN model was completed for its development, briefly tested and documented. In addition, a literature search for existing validation data for AIRTRAN was performed. The second element involved the terrestriak and groundwater components of the methodology. This study was performed to assess the feasibility and advisibility of including the UNSAT moisture flow model as a submodel of the terrestrial code BIOTRAN. The third element discussed a preliminary application of the proposed MECA methodology, as it related to the Mortandad-South, Mortandad Canyon site in New Mexico. This preliminary application represented a scaled-down version of the methodology in which only the terrestrial, overland, and surface water components were used. Lastly, an update describing the progress in the assessment of radionuclide migration in Los Alamos and Pueblo Canyons is presented. The overland and surface water components of the methodology will be used to simulate the migration and fate of radionuclides in these two canyons in Los Alamos, New Mexico.

This study is part of a long-term effort to define an assessment tool for describing the migration and fate of radionuclides in multimedia environment. The study revealed (1 that a significant amount of atmospheric information exists at the DOE Rocky Flats Plant in Colorado, which has been identified as a promising site for validation of AIRTRAN; (2) that UNSAT in its present form should not be included directly as a subprogram of BIOTRAN; (3) that the scaled-down version of the MECA methodology, as resulted to the Mortandad-South, Mortandad Canyon site, demonstrated its usefulness for providing a reasonably accurate assessment of the ability of radioactive waste sites to confine the release of radionuclides.

Whelan, G., Thompson, F.L., and Yabusaki, S.B., 1983,
Multimedia Contaminant Environmental Exposure Assessment Methodology as Applied to Los Alamos, New Mexico,
Pacific Northwest Laboratory, PNL-4546.

Pacific Northwest Laboratory (PNL) used a methodology for predicting the migration and fate of radionuclides in the environment to assess Pu-239 migration in the vicinity of Los Alamos National Laboratory (LANL). The MECA (Multimedia Contaminant Environmental Exposure Assessment) methodology, which was jointly developed by PNL and LANL, assesses exposure to air, water, soil and plants from contaminants released into the environment by simulating dominant mechanisms of contaminant migration and fate. The methodology is more sophisticated than those for a worst-case scenario analysis, but less sophisticated than a full-scaled, extremely detailed, expensive and time-consuming onsite survey. The methodology encompasses five different pathways (i.e., atmospheric, terrestrial, overland, subsurface, and surface water) and combines them into a highly flexible tool. The flexibility of the MECA methodology is demonstrated in this study by encompassing two of the pathways (i.e., overland and surface water) into an effective tool for simulating the migration and fate of radionuclides into the Los Alamos, New Mexico region.

The purpose of this study was to assess the potential migration and fate of radionuclides in Los Alamos and Pueblo Canyon. Specifically, a precipitation-generated flood event with a recurrence interval of 50 yr was simulated in Los Alamos and Pueblo Canyons to simulate the degree to which radionuclides would migrate into lower Los Alamos Canyon. PNL performed this work in cooperation with LANL.

The MECA methodology was employed to simulate the resuspension, desorption, sorption, migration, and fate of Pu-239 adsorbed onto bed sediments. The scenario studied herein assumed the Pu-239 concentrations currently existing at the modeling site as the initial conditions. A temporally varying, spatially uniform precipitation event representing a possible 50-yr flood event was used in the modeling scenario. The 50-yr event was chosen in an attempt to simulate a critical event (i.e., one which may transport significant amounts of Pu-239 downstream and deposit them into lower Los Alamos Canyon). Overland flow events transported water and sediment to the channel's edge as lateral flow. The movement of water and sediment along with contaminated bed sediment entrained into the flow were simulated for the precipitation-generated flood event.

The study revealed that a) the Pu-239 inventory in lower Los Alamos Canyon increased approximately 1.1 times for the 50-yr flood event; b) the average contaminant Pu-239 concentrations (i.e., weighted according to the depth of the respective bed layer) in lower Los Alamos Canyon for the 50-yr flood event decreased by 5.4%; c)~27% of the total Pu-239 contamination resuspended from the entire bed (based on the assumed cross sections) for the 50-yr flood event oringinated from the lower Pueblo Canyon; d) an increase in the Pu-239 contamination of the bed followed the general deposition patterns experienced by the sediment in Pueblo-lower Los Alamos Canyon; likewise, a decrease in the Pu-239 contamination of the bed followed general sediment resuspension patterns in the canyon; e) 55% of the Pu-239 reaching the San Idelfonso Pueblo in lower Los Alamos Canyon originated from lower Los Alamos Canyon; and f) 56% of the Pu-239 contamination reaching the San Ildefonso Pueblo in lower Los Alamos Canyon was carried through towards the Rio Grande.

White, G.C., 1978,
Estimation of Expected Value and Coefficient of Variation for Lognormal and Gamma Distributions,
LANL, LA-7393-MS.

Concentrations of environmental pollutants tend to follow positively skewed frequency distributions. Two such density functions are the gamma and lognormal. Minimum variance unbiased estimators of the expected value for both densities are available. The small sample statistical properties of each of these estimators were compared for their own distributions, as well as for the other distributions, to check the robustness of the estimator of expected value when the underlying density of the sample is either lognormal or gamma, and results indicated the achieved coverage of the confidence interval is greater than 75 percent for coefficients of variation less than two. Further Monte Carlo simulations were conducted to study the robustness of the above estimators by simulating a lognormal or gamma distribution with the expected value of a particular observation selected from a uniform distribution before the lognormal or gamma observation is generated. Again, the arithmetic mean provides an unbiased estimate of expected value, and the achieved coverage of the confidence interval is greater than 75 percent for coefficients of variation less than two.

Additional Monte Carlo studies were conducted to study the estimation of the coefficient of variation, c. Three estimators of c and their associated confidence intervals were simulated: (1) the usual estimate of c, s/mean; (2) an estimator derived from the gamma distribution; and (3) an estimator derived from the lognormal distribution. Both the gamma and lognormal estimators of c performed satisfactorily when the underlying distribution was the one from which the estimator was derived. Neither of these estimators performed satisfactorily when the other distribution was substituted. The estimator s/mean was negatively biased for all cases simulated.

White, G.C., 1979,
"Computer Generated Movies to Display Biotelemetry Data",
Proceedings 2nd Inter. Conf. Wildlife Biotelemetry, pp. 210-214.

The three dimensional nature of biotelemetry data (x, y, time) make them difficult to comprehend. Graphic displays provide a means of extracting information and analyzing biotelemetry data. The extensive computer graphics facilities at Los Alamos Scientific Laboratory have been utilized to analyze elk biotelemetry data. Fixes have been taken weekly for 14 months on 14 animals. The inadequacy of still graphics displays to protray the time dimension of this data has lead to the use of computer generated movies to help grasp time relationships. A computer movie of the data from one animal demonstrates habitat uses a function of time, while a movie of 2 or more animals illustrates the correlations between animals' movements. About 2 hours of computer time were required to generate the movies for each animal for 1 year of data. The cost of the movies is quite small relative to the cost of collecting the data, so that computer generated movies are a reasonable method to depicit biotelemetry data.

White, G.C., 1981,
Biotelemetry Studies on Elk,
LANL, LA-8529-NERP.

The movements of Rocky Mountain elk (Cerus elaphus nelsoni) in the eastern Jemez Mountains in north-central New Mexico were studied from 1978 to 1980. Thirty-six elk were trapped, marked, and released, and 30 of these animals were radio-collared.

The June 1977 La Mesa fire created a wintering habitat that was used heavily by the radio-collared elk. The 10-year-old clear cuts on Cerro del Medio on the Baca Land and Cattle Company property were used for calving and nursing areas. In general, radio-collared elk used areas in an early successional state, and they did not use areas at the Los Alamos National Laboratory where there was human activity.

White, G.C., 1982,
Estimation of Survival Rates from Band Recovery and Biotelemetry Data,
LANL, LA-UR-82-847.

The estimation of survival rates from tagging or banding data has been well developed by Brownie, et al. (1978). However, problems occur when sparse data sets result in undefined estimates, when estimates are greater than one, and when a hypothesis about the data cannot be tested by any of the available models. This paper extends the banding analysis models of Brownie et al. to a more general framework. Models are specified algebraically as cell probabilities consisting of functions of the survival rates and other parameters to be estimated. These algebraic expressions and the observed cell values are input to the computer program SURVIVAL to estimate the unknown parameters and perform hypothesis tests about the data. The generality of the model specification also allows the estimation of survival rates from biotelemetry data.

White, G.C., and Hakonson, T.E., 1979,
"Statistical Considerations and Survey of Plutonium Concentration Variability in Some Terrestrial Ecosystem Components",
J. Environ. Qual., Vol. 8, No. 2, pp. 176-182.

Statistical aspects of the use of the coefficient of variation (c) in the design of environmental plutonium studies are considered. Small sample properties of the estimate of c are studied for both normal and log-normal populations with Monte Carlo simulations. A minimum sample size of 50 is necessary to estimate of c from a sample size of less than 5 is nearly worthless. The difficulty of achieving good estimates of c increases as the true value of c increases.

In addition, some of the available data on the variability of plutonium concentrations in terrestrial ecosystem components is summarized. The data were pooled to achieve better estimates of the coefficient of variation than might be available from individual studies. Pooled estimates of c are: soils, 1.35; vegetation, 0.70; and rodent tissues, 1.10. The estimates of c presented should be useful in designing a field sampling program for plutonium.

White, G.C., and Lissoway, J., 1980,
Research Plan for Elk in the Eastern Jemez Mountains,
LANL, LA-8079-MS.

In June 1977, the holocaustic La Mesa Fire occurred in the eastern Jemez Mountains of New Mexico. The fire and the subsequent reseeding of the area have created a potential 15,000-acre winter range for elk. Winter range generally is considered the limiting factor in control of elk populations; this abundance may allow a large increase in the eastern Jemez Mountains elk population. The Los Alamos Scientific Laboratory (LASL), located in the area, is interested in elk over population because of the effect on the vegetation, because increased numbers of elk on the roads would increase traffic hazards and because of the possibility of elk becoming contaminated with effluents released by the Laboratory The elk population is difficult to control here because LASL and Bandelier Monument do not allow hunting on their lands.

A 1-day workship, held June 12, 1979, to discuss problems that might occur with elk population changes, resulted in the research plan outlined here. Participants, including experts on elk and regional land and wildlife managers, are listed in the Appendix.

White, G.C., et al., 1979,
Studies of Long-Term Ecological Effects of Exposure to Uranium IV,
LANL, LA-7750.

Research performed by the Los Alamos Scientific Laboratory for the Air Force Armament Laboratory, Eglin Air Force Base, Florida, is reported. The phoswich portable survey instrument was evaluated as a uranium field-survey instrument and seems to be useful for doubling sampling as well as for the quick field surveys for which it was originally designed.

Three methods used to measure uranium concentrations in soils were also compared. Eglin personnel have determined approximate concentrations by analyzing soils in an ND-100 gamma counter. Thermal-neutron-induced delayed neutron activation and instrumental epithermal neutron activation analysis are the methods used at the Los Alamos Scientific Laboratory. Comparison of the three analytical techniques indicates differences; only part of the lack agreement is explainable by the heterogenity of aliquots taken from the same soil sample. There seems to be a basic difference in what each of the three techniques measures.

White, G.C., et al., 1982,
Capture-Recapture and Removal Methods for Sampling Closed Populations,
LANL, LA-8787-NERP.

The problem of estimating animal abundance is common in wildlife management and environmental impact assessment. Capture-recapture and removal methods are often used to estimate population size. Statistical Inference From Capture Data on Closed Animals Populations, a monograph by Otis et al.(1978), provides us with a comprehensive systhesis of much of the wildlife and statistical literature on the methods, as well as some extensions of the general theory. In our program we focus on capture-recapture and removal methods for trapping studies in which a population is assumed to be closed and do not treat open-population methods, such as the Jolly-Seber model, or catch-effort methods in any detail.

White, G.C., Simpson, J.C., and Bostick, K.V., 1980,
Studies of Long-Term Ecological Effects of Exposure to Uranium V,
LANL, LA-8221.

Research performed by the Los Alamos Scientific Laboratory (LASL) for the Air Force Armament Laboratory, Eglin Air Force Base, Florida, is reported. A statistical technique called kriging was used to analyze the uranium concentrations in surface soil at E-F Site (LASL). Kriging provided a much more realistic contour surface for uranium concentrations than either a polynomial trend analysis or contouring the original data. The major advantages of kriging are that a measure of the uncertainity of the contoured surface is provided, and that the nonparametric nature of the method allows very irregular surfaces to be fitted. A function relating the uranium counting efficiency of the phoswich portable survey instrument to ambient temperature (10-30 degrees C) was developed. Counting efficiency is maximum at approximately 10 degrees C and declines significantly at higher sample temperatures. The counting efficiency of the phoswich was not affected by soil moisture or relative humidity.

Williams, J.M., 1982,
A Study of the Potential Health and Environmental Impacts from the Development of Liquid-Dominated Geothermal Resources.,
LANL, LA-9407-MS.

This document describes seven programs to provide scientific input, understanding, and forecasting capability for hydrothermal energy areas needing resolution. The three major areas addressed are (1) the impacts on living components of the aqueous and terrestrial ecosystems, (2) the impacts on the quality of the abiotic environment itself, and (3) the techniques needed to measure releases from hydrothermal activities.

Williams, J.M., and Wewerka, E.M., 1980,
Workshops to Rate and Assign Air and Water Issues for Hydrothermal Energy Development,
LANL, LA-8613-C.

This report briefly describes the presentations, discussions, and recommendations associated with a semiformal, 2-day workshop organized and hosted by Los Alamos Scientific Laboratory personnel at Los Alamos, NM, from March, 11-12, 1980, and an informal 2-day workshop hosted at Lawrence Livermore Laboratory at Livermore and Konocti Harbor, CA, from April 15-16, 1980. These workshops were not conducted to determine what the problems are, but rather to determine which ones should be addressed and who should address them. Brief reviews of issues identified by previous workshops are included as background.

Worman, F.C., 1959,
"1957 Archeological Salvage Excavations at Los Alamos, New Mexico: A Preliminary Report",
El Palacio, February, 1959.

This report is the result of a cooperative archeological project arising from an agreement between the Los Alamos Scientific Laboratory, the U.S. Atomic Energy Commission, and the U.S. Department of the Interior. It is the desire of the participating agencies to obtain all possible information from archeological sites. It is the policy of both the Los Alamos Scientific Laboratory and the Atomic Energy Commission to cooperate fully with the regulations specified by the Antiquities Act of 1906 and the Historical Act of 1935. The technical areas of the Laboratory are located in a region rich in archeological sites. The interest in the importance of such resources has caused the salvage of sites to be included as an integral part of the construction program.

More space was needed at the Laboratory for the disposal of contaminated material. The Mesita del Buey satisfied the requirements of geological structure and space for disposal. With site salvage in mind the ruins on Mesita were inspected on January 23, 1957. Sites were located by numbers, by reference to the 100 foot contour map of Ramon Vigil Grant.

Request to excavate the ruins in the path of construction was made to the Department of Interior on February 21, 1957. Permission was granted on March 6 and excavation were begun on March 11.

During the course of the project, three ruins were completely and one partially excavated. Standard excavation methods were used so far as possible within the time allowed. The main digression was the elimination of screening the fill. Exploratory trenches were dug to establish the outer limits of the ruins. Excavation was by rooms, which were numbered consecutively in the order of removal. All materials were placed in bags and indentified with date, site number and room number. Photographs were taken before and after excavation and features were photographed as they appeared during the progress of the excavation. All ruins were mapped at the completion of the work. A pottery analysis was made of each ruin. Lithic and other nonceramic materials were classified according to type, described, and identified with the Laboratory of Anthropology site number.

Pottery recovered from the four excavated ruins indicates that all were occupied, with a beginning date of A.D. 1175-1200. The sites may be assigned to the Early Black-on-White period on the basis of the local trade wares. Abandonment occurred previous to or during the general movement from mesa-top small house sites to the larger communal type dwellings such as that in Frijoles Canyon, where a different and latter pottery sequence is encountered.

Worman, F.C., 1967,
Archeological Salvage Excavations on the Mesita del Buey, Los Alamos County, New Mexico,
LANL, LA-3636.

This report is the result of a cooperative archeological project arising from an agreement between the Los Alamos Scientific Laboratory, the U.S. Atomic Energy Commission, and the U.S. Department of the Interior. It is the desire of the participating agencies to obtain all possible information from archeological sites. It is the policy of both the Los Alamos Scientific Laboratory and the Atomic Energy Commission to cooperate fully with the regulations specified by the Antiquities Act of 1906 and the Historical Act of 1935. The technical areas of the Laboratory are located in a region rich in archeological sites. The interest in the importance of such resources has caused the salvage of sites to be included as an integral part of the construction program.

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Worman, F.C., and Steen, C.R., 1978,
Excavations on Mesita de los Alamos,
LANL, LA-7043-MS.

When the Clinton P. Anderson Meson Physics Facility was in the planning stage, several pre-Columbian Indian sites were discovered in the project area. The late Frederick C.V. Worman of the Los Alamos Scientific Laboratory (LASL) staff was asked to make salvage excavations at the sites. The digs were undertaken in 1965 and 1968. At the time of Worman's death in 1971, he was working on a report of excavations. Unfortunately, the only portion of his manuscript to be found was the analysis of pottery sherds and a few notes concerning the sites. This report includes the pottery analysis made by Worman. Brief discussions about the sites and about the recovered artifacts are by Steen, made from Worman's notes.