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LOS ALAMOS SCIENTIFIC LABORATORY
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Compiled by

L. J. Johnson
H. M. Lewis

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description was developed of a reference burial site, located in a humid climate, receiving waste typical of the current nuclear power fuel cycle. The impacts of radionuclide releases during both the operational and post-operational periods were evaluated using generic models. These impacts were compared with those resulting from existing commercial radioactive waste burial sites. The report concluded that known releases from existing commercial sites have not produced any health hazard to off-site individuals and that, with proper site selection and operation, the already low environmental concentrations of radioactivity could be reduced even further.

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XVIII. LASL WASTE BURIAL SITES STUDIES

(M. A. Rogers, W. V. Abeele)

The solid radioactive waste disposal facilities at LASL are considered to provide excellent containment of radionuclides. This has been demonstrated repeatedly by short-term or one-time studies at various disposal sites. However, there is a continuing need to substantiate this through routine monitoring programs conducted at both operationally active and closed disposal areas. This is being accomplished in several phases; evaluation of all existing data regarding the environmental setting and use history of the various areas, surface reconnaissance to determine distribution of radionuclides in plants and soils, subsurface sampling for moisture and radionuclide distributions, and installation of access tubes for measurement of moisture distributions within the burial area. These efforts are augmented by special sampling studies.

A source document[1] was published during the year, summarizing existing knowledge and previous work at the principal LASL disposal sites for radioactive waste. Information on the sites varies markedly, from rather complete knowlege of the radionuclide inventory and environmental setting, to very scanty knowledge of both. This latter condition is especially true for older

sites, used in the 1940s, when little attention was given to documenting waste management activities. Environmental studies at these disposal sites have identified no significant radionuclide migration, but in some instances, information is too scarce to support quantification of release rates.

Review of existing information shows a need for additional geologic data on the disposal sites. As a result, a major geological stratigraphic and structural mapping program was begun for the disposal sites. The resulting geologic map will permit identification of significant hydrologic properties of the rocks underlying disposal sites, leading to a more thorough evaluation of the containment potential of LASL sites. This detailed environmental geology will also assist in establishing monitoring schemes for each disposal site.

Previous work reviewed during compilation of the source document[1] revealed little about the distribution of radionuclides within the disposal sites, either in the surface plants and soils or in the subsurface. Work was begun to define surface contamination, which included (1) field environmental radiation surveys with a LASL-developed portable phoswich gamma-ray detector, (2) soil and vegetation sampling, (3) screening of all samples for gross-α, gross-β, ^{3}H, ^{137}Cs, (4) analysis of selected samples for plutonium, strontium, uranium-thorium series elements, americium, and fission products, and (5) geophysical work to define pit boundaries. A report describing the reconnaissance results is currently in preparation; results for the two largest inactive disposal sites, Areas B and C (Fig. 1), are summarized below.

The initial screening of all samples served to identify those that might be contaminated. The expected values of the screening parameters for uncontaminated soils in the Los Alamos area are listed in Table I. Samples showing higher values were assumed contaminated. These samples were then submitted for additional analysis as described in (4) above.

Area B was the first major solid radioactive waste disposal area at LASL, and was used from 1944 through 1948. Engineering drawings do not show the location of the disposal pits, but there may be as many as six within the area. Asphalt paving covers the western 70% of the area, and DOE leases this portion to the county of Los Alamos, which in turn rents spaces for vehicle storage. A phoswich survey of this paved area located only one small contaminated zone, at the base of a utility pole installed after the area was paved.

A small unpaved area to the southwest of the paved area was sampled on a grid system and results were uniformly low, as shown by the data summarized in Table II. Sampling of the unpaved area east of the pavement on a 10-m by 15-m grid revealed numerous areas of surface contamination. Maximum values observed from sample analyses are given in Table II. Geophysical work at Area B included both seismic and resistivity surveys. Surface conditions interfered with both and no conclusive results are yet available.

Area C contains six disposal pits used from 1948 to 1964, and 107 disposal shafts used from 1958 through 1974. The waste in the pits is contaminated with uranium, plutonium, americium, tritium, and minor amounts of other radionuclides. The disposal shafts contain tritium, ^{60}Co, ^{90}Sr, other fission products, activation products, and uranium. The entire surface area was surveyed with a phoswich detector and samples collected for further analysis from spots showing high readings. In addition, samples were collected on a 15- by 20-m grid system from over the disposal pits and on a smaller grid from around the disposal shafts. The results of these analyses are summarized in Table III. All samples contained one or more radionuclides in concentrations above background, with tritum being the most common radionuclide in that category. Plutonium and americium contamination were also present.

A pathway of concern, and the most difficult to quantify in an arid environment, is that resulting from water movement into or through buried waste. The dynamics of such movement are depicted in Fig. 2. The combination of low precipitation, high evaporation and runoff, and low permeability of the tuff results in little infiltration into the ground at the LASL disposal sites. Previous evidence indicates that the "deep seepage" illustrated in Fig. 2 is vanishingly small.

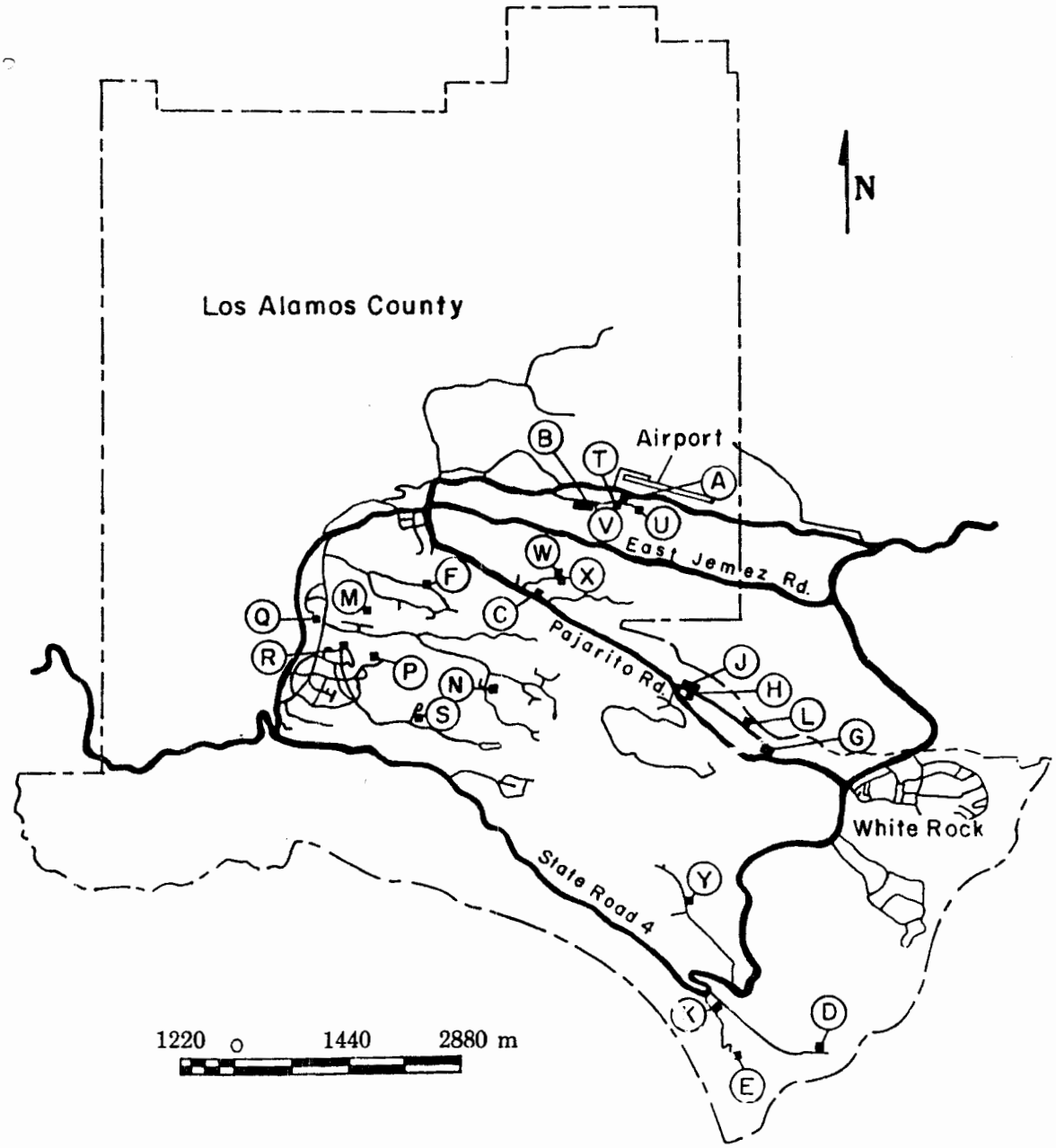

Fig. 1.
Map of LASL Materials Disposal Areas.

TABLE I

AVERAGE AND EXTREME VALUES OF SELECTED ANALYSES OF UNCONTAMINATED SOILS IN THE LASL AREA

Analysis	Units	Average	Extreme*
Gross-α	pCi/g	4.7	10.7
Gross-β	pCi/g	4.8	8.4
Cs^{137}	pCi/g	2.3	3.0
H^3	nCi/ℓ	7.9	10.3

*Average + 3σ (99.9% confidence level).

TABLE II

SUMMARY OF SURFACE RECONNAISSANCE AT AREA B

Location	Area (m^2)	Maximum Values Observed			
		Gross-α	Gross-β (pCi/g)	^3H	^{137}Cs
Unpaved eastern portion	8000	6200	560	35 *	130
Unpaved southwestern portion	800	46	31	2 *	---
Paved portion	16 000	(phoswich survey showed one contaminated spot—5 times background—no samples of asphalt paving were collected)			

*At 10% soil water content.

Direct measurement of the infiltration, or collection of water samples from migrating soil solutions, is exceptionally difficult under the low moisture conditions prevailing at LASL sites. The strategy used is that of measuring soil moisture distributions and hydraulic conductivity values and computing moisture transport from known relationships. Samples of the tuff or backfill are collected periodically for radionuclide analysis. From these data the rate of radionuclide migration can be estimated.

Measurements are made monthly in 10 access holes with a neutron moisture probe, providing an essentially continuous record of soil moisture variations. Data from Hole S50-1 are presented in Fig. 3. The data show no significant variation below 8 m. At all levels, the moisture conditions are well below saturation throughout the year (saturation is about 40% water content).

Additional work in support of the moisture probe and monitoring program included extensive calibration of the moisture probe and calibration of thermocouple psychrometers. The moisture probe calibration extends the sensitivity of the probe beyond the calibration data supplied by the manufacturer. The thermocouple psychrometers are being used to measure moisture distributions at moisture levels below the detection limit of the moisture probe. Preliminary

TABLE III

SITE RECONNAISSANCE DATA FOR AREA C

Sample Category	Maximum Observed Values - pCi/g			
	Gross-α	Gross-β	^{137}Cs	^{3}H
Pit Grid	220 (34%)	32 (12%)	8 (6%)	7,3 60* (100%)
Shaft Grid	300 (32%)	64 (14%)	- (0%)	5,0 90* (100%)
Phoswich Survey "hot spots"	18 000 (73%)	69 000 (42%)	41 000)12%)	not analyzed

*At 10% soil water content.
(Number in parentheses is per cent of samples showing above background concentration).

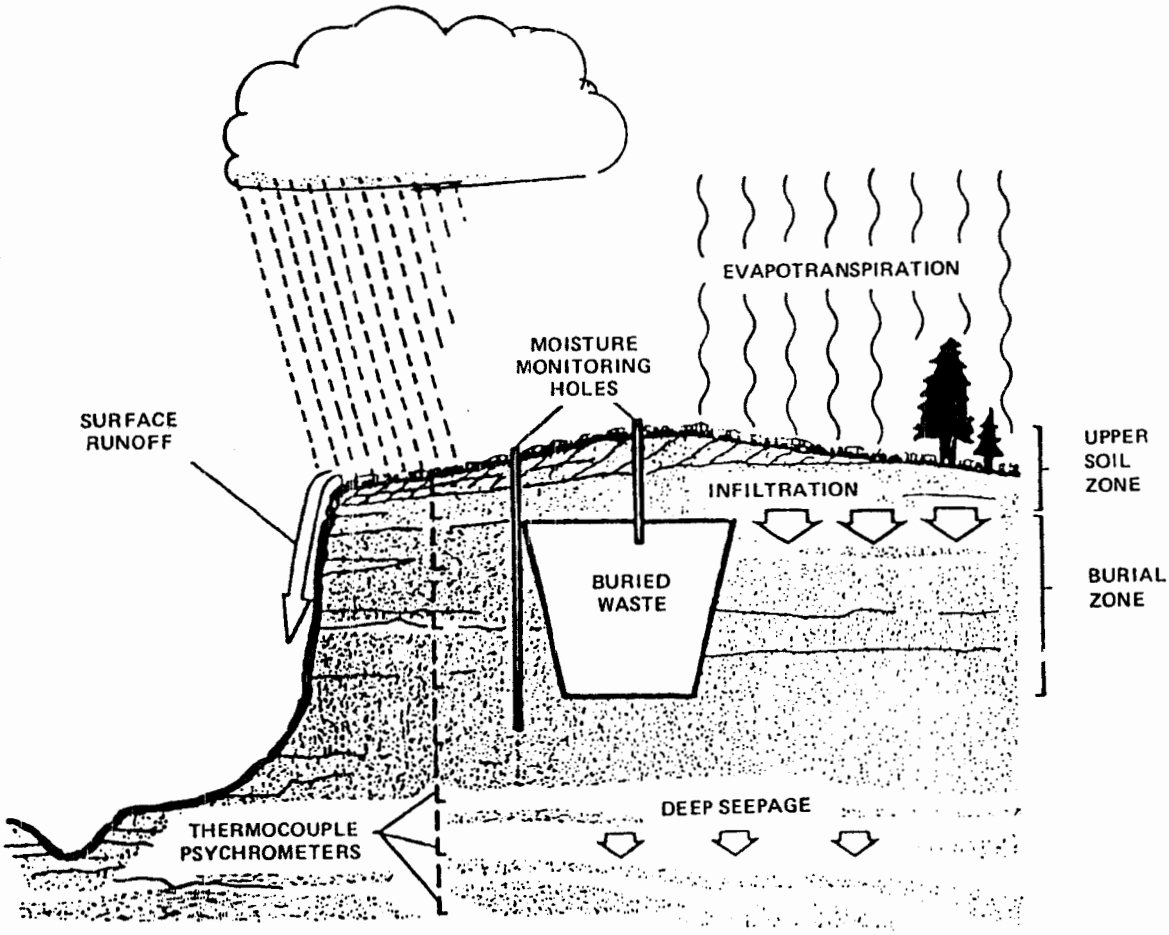

Fig. 2.
Dynamics of water movement into or through buried waste.

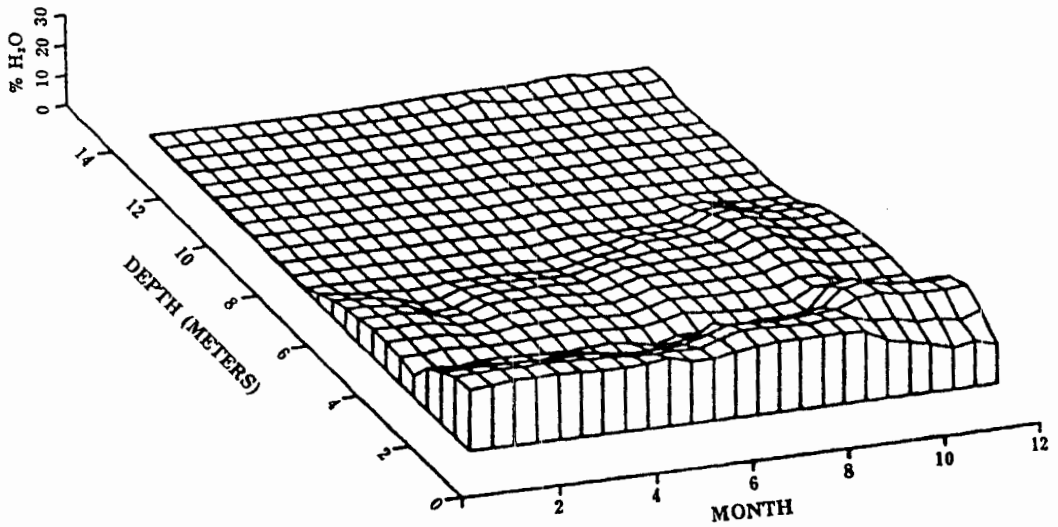

Fig. 3.
Moisture profile for Hole S50-1.

calculations show that moisture flux below about 5 m is on the order of 1 cm/yr, with a m ment uncertainty of equal magnitude. Longer term measurements, coupled with imp measuring techniques, are expected to refine that value.

Another approach to detecting possible movement of radionuclides away from a disposal pit or shaft is that of sampling the material by way of a drill hole. Samples are collected routinely when a new shaft or pit is constructed and when moisture monitoring holes are drilled. In addition, some holes are constructed specifically for establishing radionuclide distributions.

One such effort consisted of drilling several horizontal core holes beneath an existing, filled, waste pit, as shown in Figs. 4 and 5.[2] Samples of the tuff recovered from the coring were submitted for radionuclide analysis. The samples were analyzed for gross-α, gross-β, ^{90}Sr, ^{137}Cs, ^{238}Pu, ^{239}Pu, and ^{241}Am. All results returned to date have shown radionuclide concentrations similar to, or less than, those to be expected in an uncontaminated area. These data further substantiate that there is little or no migration of radionuclides from subsurface water movement at the LASL burial sites.

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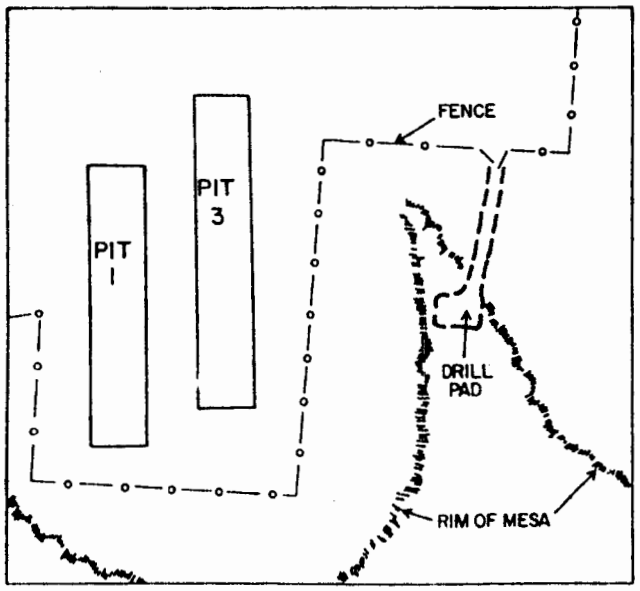

Fig. 4a
Southeastern part of Area G showing location of waste pits and drill pad.

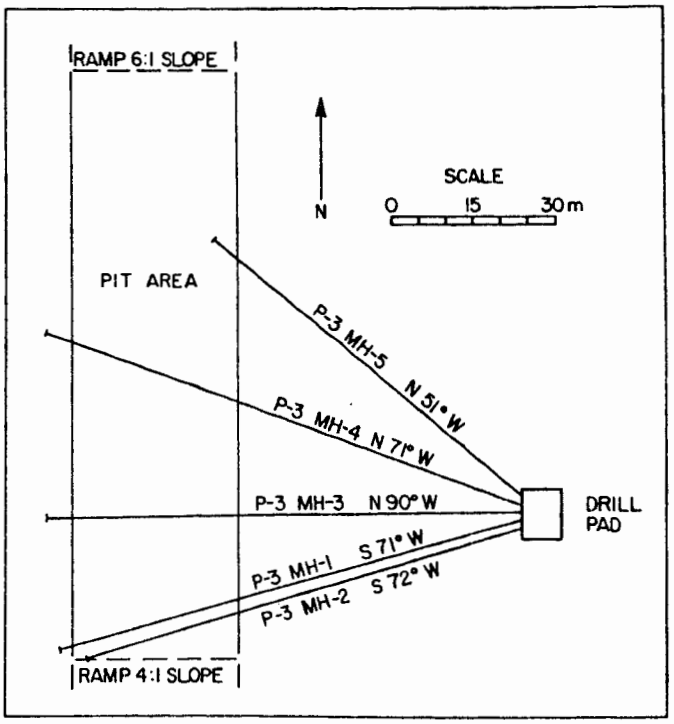

Fig. 4b.
Orientation of core holes beneath Pit 3, Area G.

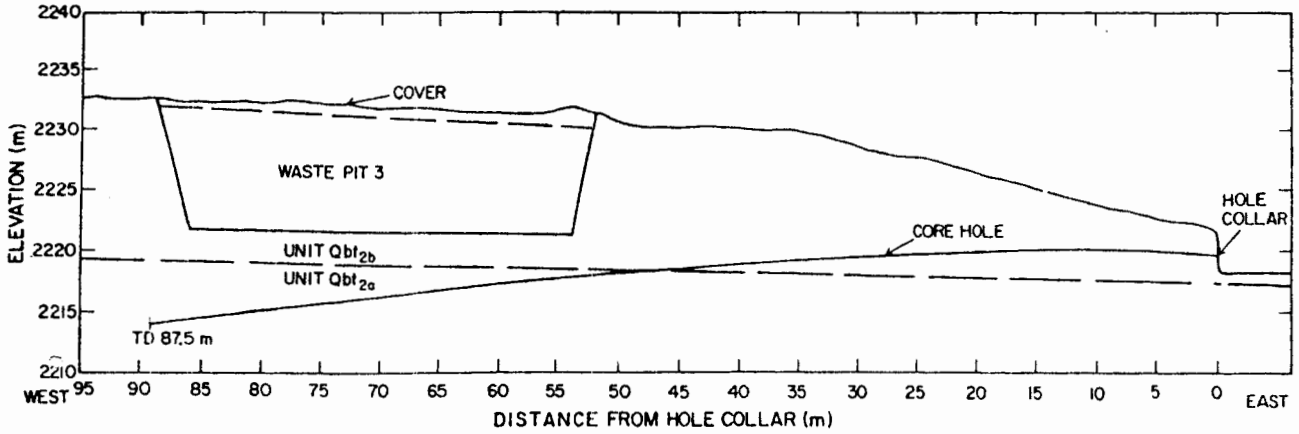

Fig. 5.
Cross section of the mesa showing the geologic units, Waste Pit 3, and the trace of core hole P-3 MH-1, Area G.