HISTORY OF LASL NEAR-SURFACE LAND BURIAL FACILITIES FOR SOLID RADIOACTIVE WASTES

INTRODUCTION

Purpose

The AEC's increased emphasis on determining the environmental impact of solid waste disposal led them to the conclusion a re-examination should be made of the use of land burial as a means of permanent disposal. An evaluation of site monitoring practices, both past and present, is in progress or planned for all major AEC sites. The United States Geological Survey under contract to the AEC is performing the evaluation in cooperation with AEC Contractors.

LASL's evaluation began in September, 1973, and included Materials Disposal Areas A,T,B,C,D,E,F, and G. (See Fig. 1) T. E. (Tim) Kelly of the U.S.G.S. Water Resources Division, Albuquerque and Margaret Anne Rogers are the investigators.

During the Fall of 1973 as the data were collected for the evaluation, it became apparent through discussion with LASL personnel that LASL had a need for a report which would parallel the one done by Kelly for the AEC but would include much more detail then Kelly's report would be expected to have.

This report is designed to be a readily available source of accurate, in depth information for LASL employees.

HISTORY OF LOS ALAMOS

From 1918 until late 1942[163] Los Alamos was the site of a boys ranch school. Because of its isolated location it was acquired by the Army, November 25, 1942, for the Manhattan

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Engineer District. As a patriotic gesture[163] the University of California accepted the contract to operate the new laboratory January 1, 1943. After the war Los Alamos continued as a site of government sponsored scientific research operated by the University.

Location

Los Alamos and the Los Alamos Scientific Laboratory are located on the Pajarito Plateau, which flanks the eastern side of the volcanic Jemez Mountains in north-central New Mexico. The plateau is 16-24 km (10-15 miles) wide and more than 48 km (30 miles) long. It is bounded on the west by the Sierra de los Valles, on the east by the Rio Grande, on the northeast by the Puye Escarpment, and on the southwest by Canada de Cochiti. (See fig. 2)

The plateau slopes eastward from an elevation of 7800 feet (2377m) abutting the Sierra de los Valles to an elevation of 6200 feet (1890m) adjacent to the Rio Grande. It is cut [200-400 feet (61-122 m) deep] by numerous southeast trending intermittent streams. The dissected eastern margin of the plateau rises 300-1000 feet (91-305 m) above the Rio Grande.

Los Alamos is 38.6 km (23 miles) northwest of Santa Fe and 92.8 km (58 miles) north-northeast of Albuquerque.

GEOLOGY

Stratigraphy

Introduction

The volcanic and sedimentary rocks cropping out in the Los Alamos area range in age from Tertiary to Quaternary. Stratigraphic nomenclature varies. There appears to be little or no disagreement on the unit definitions for the volcanic rocks whose origin is the Valles or Toledo Calderas. However, disagreement on unit definition and usage for the sedimentary rocks and basalt flows which form the basin fill for the Rio Grande Structural Trough appears to be great.

The oldest sedimentary sequence cropping out in the Los Alamos area has been referred to as the Santa Fe formation, a restricted usage, or as a part of the Santa Fe group, a usage which includes all basin fill rocks

regardless of origin. Spiegel and Baldwin (1963)[2] and Griggs (1964)[164] favor use of the Santa Fe group designation; Bailey, Smith and Ross (1969)[1] favor use of the older term Santa Fe formation. These three reports define stratigraphic nomenclature for the Los Alamos area since all use rock sequences in or adjacent to the area to define their unit usage. (The Los Alamos area, this report, means roughly the area bounded by the Rio Grande on the east, the Rito de los Frijoles on the south, the crest of the Sierra de los Valles on the west, and Guaje Canyon on the north.) Other authors such as Baltz, Abrahams, and Purtymun (1962),[166] have adopted the unit usage of one of these three reports. (See figures 3, 4, 5 and 6)

The same named unit does not necessarily refer to the same rock and/or include the same subunits. Spiegel and Baldwin (1963)[2] and Griggs (1964)[164] agree the term Santa Fe should have group status, but the two reports do not use the same subunits. The term Puye seems to be applied to the same sequence of rocks by all three reports although it receives different treatment by each. Spiegel and Baldwin (1963)[2] recognize the Puye gravel as used by Smith (1938, p. 937). Griggs (1964, p. 28)[164] gave the Puye formal status as a formation with a specified type locality, "the belt of exposures along Guaje Canyon between Guaje Mountain and the Puye Escarpment." He also changed the name from Puye gravel to Puye conglomerate because "the formation is sufficiently consolidated to stand in vertical cliffs" and separated it into two members of alluvial origin -- the Totavi Lentil and a fanglomerate member. Bailey, Smith, and Ross (1969, p. 12)[1] propose to call the Puye the Puye formation because "most of the constituent materials of the formation are of ultimate pyroclastic origin, and many of the component beds, especially those close to the source areas in the Jemez Mountains, are pumiceous tuffs and lithic lapilli tuffs that show only slight alluvial reworking."

This report does not propose to solve the stratigraphic nomenclature problems which have been briefly outlined in the preceding paragraphs.

A comparison of unit usage by Bailey, Smith, and Ross (1969),[1] Griggs (1964),[164] and Spiegel and Baldwin (1963)[2] is shown in Figure 7. Descriptions of all stratigraphic units in use follows.

Santa Fe Group

Spiegel and Baldwin (1963)[2] proposed the term Santa Fe be raised to group status. They considered the Santa Fe group to include sedimentary and volcanic rocks which ranged in age from middle(?) Miocene to Pleistocene (?) and were related to the Rio Grande trough. They placed all rocks above the latitic and limburgitic flows and breccias exposed in the Cienega area in the Santa Fe group. This definition includes the terrace deposits and alluvium of present valleys.

Tesuque Formation

The Tesuque formation (Spiegel and Baldwin, 1963, p. 39)[2] is middle (?) Miocene to early Pliocene in age. It consists of several thousand feet of pinkish - tan soft arkosic, silty sandstone and minor conglomerate and with two minor volcanic units. Most of the sediments were derived from siltstone Precambrian rocks. Named for the town of Tesuque its arbitrary type section is along the north boundary of T. 17 N., extending 9 miles westward from Tesuque Creek (NE 1/4 sec. 5, T. 17 N., R. 10 E.) to a point three-fourths of a mile east of the Buckman Road (NE 1/4 NW 1/4 sec. 2, T. 17 N., R. 8 E.). It crops out in the eastern part of the Los Alamos area along the Rio Grande.

Andesite Flows

Basaltic andesite makes up part of the high mesas of Cerros del Rio. These flows are considered older (Spiegel and Baldwin, 1963, p. 50)[2] than the flows several hundred feet below which form the main level of the lava mesa. The andesite flows intertongue with the Ancha formation along Cañada Ancha.

Ancha Formation

The Ancha formation (Spiegel and Baldwin, 1963, p. 45)[2] rests with angular unconformity on the Tesuque formation. A late Pliocene or

Pleistocene age is inferred for the Ancha from physiographic relations. It consists of up to 300 feet of arkosic gravel, sand, and silt. The formation is named for Cañada Ancha. In the Los Alamos area, (defined as west of the Rio Grande), it has never been mapped.

Puye Conglomerate

Late Pliocene (?) in age the Puye conglomerate (Griggs, 1964, p. 28)[164] consists of well-rounded pebbles, cobbles, and small boulders of quartzite, quartz and granite with some volcanic debris in a matrix of arkosic sand. The type locality is Guaje Canyon between Guaje Mountain and the Puye Escarpment. The Puye conglomerate is divided into two members, the Totavi lentil and the fanglomerate. Outcrops of the Puye conglomerate are found in the northeastern part of the Los Alamos area and along the Rio Grande.

Totavi Lentil

The Totavi lentil (Griggs, 1964, p. 29)[164] is the lower member of the Puye conglomerate. The type locality is a quarry north of State Highway 4 and about a quarter mile west of the community of Totavi from which it derives its name. As much as 75 feet thick, the Totavi is a channel deposit of poorly consolidated conglomerate composed of Precambrian rocks.

Fanglomerate Member

The upper member of the Puye conglomerate is a fanglomerate composed of latitic debris derived from the Tschicoma formation. The fanglomerate member (Griggs, 1964, ~~1964~~, p. 31)[164] ranges in thickness up to 600 feet. It thins southward and wedges out southwest of Otowi Bridge.

Basaltic Rocks of Chino Mesa

Those flows which form the steep walls of White Rock Canyon and cap the high mesas to the east are the basaltic rocks of Chino Mesa (Griggs, 1964, p. 37).[164] The sequence of flows, erupted from centers in the Cerros del Rio, is greater than 1,300 feet (340 m) thick at Chino Mesa. Their age is late Pliocene to middle or late Pleistocene.

The basaltic rocks of Chino Mesa have been divided into five units. Unit 1 rests unconformably on the undifferentiated unit (Griggs, 1964, p. 20)[164] and interfingers with ~~to~~ the Totavi lentil. Unit 2 conformably overlies unit 1, interfingers with the upper tongue of the undifferentiated unit, rests on the Totavi lentil, and abuts the fanglomerate member. Unit 3 is disconformable on unit 2, rests on the fanglomerate member, and interfingers with the old alluvium unit (Griggs, 1964, p. 41). Unit 4 rests unconformably on the undifferentiated unit, the Puye conglomerate and unit 2. In some places unit 4 abuts unit 2 and unit 3. Unit 5 consists of cinder cones and local flows which unconformably overlie all older rocks with which they are in contact.

Polvadera Group

Polvadera Group is the name proposed by Smith, Bailey, and Ross (1969, p. 10)[1] for the sequence of basaltic, andesitic, dacitic, and rhyolitic rocks, 5000 feet (1524 m) thick, which form part of the central and most of the northern Jemez Mountains. The group is divided into three formations: the Lobato basalt, the Tschicoma formation, and El Rechuelos rhyolite. The Tschicoma formation is the only one which crops out in the Los Alamos area.

Tschicoma Formation

The Tschicoma formation (Griggs, 1964, p. 42)[164] of the Polvadera Group consists of andesites, dacites, rhyodacites, and quartz latites. Radiometric dates of 6.7 to 3.7 m.y. [G. B. Dalrymple, written commun., 1967 (Bailey, Smith and Ross, 1969, p. 11)][1] on the rocks indicate an age of middle to late pliocene. The Tschicoma formation crops out along the western margin of the area in the Sierra de los Valles. It is greater than (792 m) 2600 feet thick in the Los Alamos area.

Puye Formation

Penecontemporaneous with the Tschicoma formation is the Puye formation (Bailey, Smith, and Ross, 1969, p. 12).[1] The Puye formation

is described as essentially a broad alluvial and pyroclastic fan flanking the east side of the northern Jemez Mountains. It interbeds with the Tschicoma formation and the basalts of Chino Mesa (Cerros del Rio) and unconformably overlies the Santa Fe formation.

Tewa Group

The name Tewa group was given by Griggs (1964, p. 45)[164] to the rhyolitic tuff and the rhyolite and quartz latite domes which constitute the latest eruptive rocks of the Jemez Mountains. The group consists of the Bandelier Tuff, Cerro Toledo rhyolite, Cerro Rubio quartz latite, and the Valles rhyolite. In the Los Alamos area the Bandelier tuff is the only formation which crops out.

Bandelier Tuff

In the Los Alamos area the Bandelier tuff can be subdivided into three members (Griggs, 1964, p. 46).[164] These members are from bottom to top: (1) The Guaje member, a bedded pumice-fall deposit, (2) The Otowi member, a massive pumiceous tuff breccia of ash-flow origin, and (3) the Tshirege member, a succession of cliff-forming welded ash flows. Away from the Los Alamos area, the subdivision of the Bandelier into three units is not used. The Otowi member (Bailey, Smith and Ross, 1969, p. 13)[1] is defined to include a basal pumice fall the Guaje pumice bed, (Guaje member of Griggs) and the overlying ash-flow units (Otowi member of Griggs). The Tshirege member (Bailey, Smith and Ross, 1964, p. 13) is defined to include a basal pumice fall, the Tsankawi pumice bed, and the overlying ash-flow units (Tshirege member of Griggs). Due to the lack of detailed stratigraphic mapping, it is unclear whether we in the Los Alamos area will continue to subdivide the Bandelier into three units or adopt the more general usage outside the immediate area of two units.

The Los Alamos area is also unique in that the Tshirege member has been subdivided into seven numbered units, unit 1a; unit 1b; unit 2; unit 3; unit 4; unit 5 and unit 6, by Weir and Purtymun (1962)[167] and into

five numbered units, unit 1a; unit 1b; unit 2a; unit 2b; and unit 3 by Baltz, Abrahams and Purtymun (1963).[166] Weir and Purtymun (1962) give the type section for their units as the South wall of Water Canyon - NW 1/4 NE 1/4 sec. 3 (projected) T. 18 N., R. 6 E. Units 1a and 1b of Baltz, Abrahams and Purtymun (1963 p. 29) correlate with unit 1b of Weir and Purtymun (1962). Unit 2 (Weir and Purtymun 1962 p. 121) seems to correlate with units 2a and 2b (Baltz, Abrahams, and Purtymun, 1963, p. 26-27); and unit 3 (Weir and Purtymun, 1962, p. 124) seems to correlate with unit 3 (Baltz, Abrahams and Purtymun, 1963 p. 28). It is not clear with which unit the Tsankawi pumice bed of Bailey, Smith and Ross (1969, p. 14) correlates.

The Bandelier tuff is Pleistocene in age. The basal unit of the Tshirege member, the Tsankawi pumice bed, has been dated radiometrically as 1.1 m.y. old (Doell and others, 1968).[165]

In the Los Alamos area the Bandelier tuff, (260-1050 feet thick),[164] crops out on the Pajarito Plateau. See Table 1 for a chemical analysis of the tuff.

Recent Alluvium

Recent Alluvium is found in the canyons cutting the Pajarito Plateau. For those canyons which head in the Sierra de los Valles the Alluvium consists mainly of detritus derived from the Tschicoma formation. For those canyons which head on the Pajarito Plateau the alluvium consists of detritus derived from the Bandelier tuff.

Structure

The Pajarito Plateau is located along the western border of the Rio Grande structural trough. This trough is a linear structure and topographic depression formed by faulting beginning in Middle Miocene (about 20 million years ago).[169] Volcanic rocks of the plateau are faulted progressively downward to the east by numerous north-trending faults.[3] In the Los Alamos area the plateau is separated from the Sierra de los Valles by the Pajarito fault, the major fault in the area.

The Valles caldera, bounded on the east by the Sierra de los Valles, is structurally related to the Rio Grande structural trough. The Tshicoma formation and the Tshirege member[170] of the Bandelier tuff issued from this large volcanic complex. The Valles caldera is considered to be the largest recognized resurgent cauldron in the world.

Faulting in the Los Alamos area is post Bandelier time. Using the radiometric date on the Tsankawi pumice bed of 1.1 m.y. old, faulting took place less than 1.1 m.y. ago. Los Alamos is Zone 2 on earthquake probability charts.[4]

Earth tremors have been felt in the Los Alamos area recently. At 4:30 A.M. on February 17, 1971, an earth tremor of magnitude 1.80 (Richter Scale) occurred (written communication from Allan R. Sanford, New Mexico Institute Mining and Technology). The earth tremor was of such a low order of magnitude that while it was felt on Barranca Mesa it could

not be felt on South Mesa, an approximate distance of 2.1 miles (3.4 km).

There seems to be no geologic or cultural evidence to suggest intensive earthquakes have occurred for hundreds, possibly thousands, of years in this region.

"A number of pinnacles 10 to 50 feet high, eroded from soft formations and capped with boulders 2 to 5 times the diameter of the supporting pinnacle, lie in Rendija Canyon, just north of Los Alamos. These formations are unstable and it is reasonable to think that they would topple under the influence of any sizable ground tremors. We note that a 60 foot pinnacle would require 75,000 to 120,000 years to develop with the erosion rate normal in the major canyons in the area.

Remains of Indian dwellings constructed with free standing walls with little lateral support indicate the absence of strong tremors for at least 500 years. Nearby pueblos that have been occupied continuously since the late sixteenth century, buildings in Santa Fe constructed by the Spanish in the early seventeenth century, and a lack of references to earthquakes in surviving records add support to this contention".[5]

No area or regional studies of joint pattern have been done. See individual disposal sites for scattered data.

Identification of faults in the Los Alamos area is the result of other specific geological studies. No study as yet has had as its principal goal the drawing of a structural map at either a local or regional level. Four named[170] faults

in the area are: the Pajarito fault, the Los Alamos fault, the Guaje Mountain fault, and the Water Canyon fault. (See fig. 8) All four faults are north trending faults with vertical or near vertical displacements. The Pajarito fault is downthrown to the east with a maximum displacement of 400 feet[170] (121.9 m). The Los Alamos fault is downthrown to the west with a maximum displacement of 45[170] feet (13.7 m). The Guaje Mountain fault is downthrown to the west with a maximum displacement of 20 feet[170] (6.1 m). The Water Canyon fault is downthrown to the east with a maximum displacement of 30[170] feet (9.1 m).

HYDROLOGY

Climatology and Meteorology

Los Alamos has a semiarid continental mountain climate. The average annual precipitation is slightly greater than 18 inches. Seventy-five percent of this precipitation falls from May to October. Shower activity peaks in August when 1/10 inch or more of rain can be expected on one day out of four. Winter precipitation consists of snow. An average winter has 50 inches of snow with as much as 6 inches or more often falling in 24 hours.

The mean humidity value is 41 percent. The lowest humidity values average 30 percent in late spring; and the highest humidity values near 50 percent during July and August.

Prevailing winds are out of the south. They are 10 mph or less almost 80 percent of the time.

The maximum temperature reaches 90° on an average of 2 days per year with 95° the highest recorded. July is the hottest month. Freezes have been recorded in all months except July and August. An average winter includes only 18 days when mercury fails to rise above freezing. Below-zero readings can be expected only once a year (See Table 2[6]).

Water Table

The water table beneath the Pajarito Plateau is at an approximate depth of 1200[4] feet along the western margin and at an approximate depth of 600[4] feet along the eastern margin. (See Fig. 9) Water moves one foot per day eastward toward the Rio Grande where some of it is discharged through seeps and springs along the Rio Grande. The area of recharge is the intermountain basins formed by the Valles caldera.[168] Minor amounts of recharge may occur in the Sierra de los Valles.[168]

Beneath the plateau the zone of saturation (water table) lies within the Tesuque formation of the Santa Fe group. This formation consists of beds of siltstone and sandstone with lenses of clay and conglomerate. It crops out along the Rio Grande where the upper part of the formation is above the zone of saturation.

Some of the lower Tschicoma volcanic flow rocks are within the zone of saturation beneath the western part of the plateau.

The Puye formation, a conglomerate of volcanic debris from the Tschicoma formation interbedded with basalt, is above the zone of saturation along the Rio Grande. Beneath the plateau the lower part is in the zone of saturation.

Throughout the plateau the Bandelier tuff which forms the plateau surface is above the zone of saturation.

Perched Water

Perched water occurs in the interbedded basalts of the Puye formation near the eastern edge of the plateau in Pueblo, Los Alamos, and Sandia Canyons. The perched water in the basalts is probably replenished from water moving from the small bodies of perched water contained in recent alluvium in Pueblo, Los Alamos, and Sandia Canyons. Perched water is also found in small bodies in the recent alluvium of Pajarito and Mortandad Canyons. It probably occurs seasonally in upper parts of other canyons which receive seasonal runoff from the mountains and plateau.

The absence of perched water in the tuff or volcanic sediments above the main aquifer (water table) is believed by Purtymun[4] to indicate that infiltration of water from alluvium in stream channels into the underlying tuff is small due to the low permeability of the tuff.

Surface Water

The only perennial streams in the area are the Rio Grande which flows along the eastern edge of the plateau and Rito de los Frijoles which defines the southern boundary

of the area. The upper reaches of Los Alamos and Guaje Canyon have natural perennial flow. This flow is depleted by evaporation and infiltration before it crosses the western third of the plateau. In the upper and mid reaches of Pueblo and Sandia Canyons the perennial flow is due to the release of treated sewage effluent. DP Canyon and the mid-reach of Mortandad Canyon have intermittent flow due to the release of treated industrial effluents.

Surface runoff from most canyons to the Rio Grande occurs generally during periods of great precipitation(summer thunder showers). Some small canyons with small drainage areas never receive enough precipitation for storm runoff to reach the Rio Grande.

AREA A

Introduction

Area A is located in TA-21 a quarter of a mile east of the intersection of DP Road and the north perimeter road for TA-21. Specifically it is centered on coordinate E. 165+00 between coordinates N. 85+00 and N. 87+50. (See Fig. 10) It occupies most of the area between coordinates N. 85+00 and N. 87+50 and between coordinates E.167+50 and E.162+50. Surveyed corners in clockwise direction beginning with the northeast corner are: N.86+58; E.167+18; N.85+14; E.166+88; N.85+42; E.165+35; N.85+78; E.164+88; N.86+00; E.163+80; N.86+13; E.163+11; N.86+33; E.162+91; N.87+34; E.163+07 and N.87+16, E.164+04. It can also be located by township and range: SE 1/4 sec. 14, T. 19 N., R. 6E.[8] Total acreage is 1.25 (5058.6m^2).

The history of Area A consists of two stages. The first involves construction and use of pits and storage tanks between 1944 and 1949 and the second involves construction and use of a pit between April, 1969 and present (1974).

The early pits were dug in the eastern part of the area. A request for pits in Area A is dated December, 1944. From a memo[17] dated 7-5 45: "The pits at DP Site are currently being filled at such a rate that they will be filled to capacity by the early part of August. This rate is far greater than was anticipated when I requested these pits last December, and because of the construction in this area there is no room for further pits to be dug. Nor, for that matter, is it desirable to dig any more pits anywhere in the DP area because of the dust problems that would be created."

A June memo[12] states 2 pits in Area A have been dug. although on later engineering drawings there appear to be 4 pits. according to drawing ENG-C 2076 (January 24, 1945) there are only two. The north and south pits on later drawings appear as "earth storage" on ENG-C 2076 (see Fig. 11). Two pits also corresponds with the information in the June, 1944, memo.[12] Dean D. Meyer, states[171]

the pits were closed when he began work at LASL in July, 1946.

In the western part of the area are the "General's Tanks." These were built in 1945 as storage tanks. They are identified as TA-21-107 and TA-21-106. The last data on them is August, 1947.[9] (NOTE: Reference 8, p.21, states liquids were not added since 1949).

In April, 1969,[10] a large pit was dug between the older pits to the east and the storage tanks to the west. A request[16] for the expansion of this pit dated 11-9-72 from J. L. Desilets (man in charge of rehabilitation project at TA-21 begun in 1968) to C.A. Reynolds (man who was group leader of ENG-4) was met (personal communication from J. L. Desilets).

GEOLOGY AND HYDROLOGY

Area A is located on a narrow eastward-trending mesa which is a part of the Pajarito Plateau. The land surface slopes north about 100 yards and then breaks into steep bench and slope topography down to the channel of DP Canyon. The channel is approximately 100 feet below the top of the mesa.

All excavations in Area A were made in Unit 3 of the Tshirege Member of the Bandelier Tuff. Unit 3 is approximately 120 feet[10] (36.6m) thick in this local. The lower part of the unit consists of a nonwelded tuff which grades upward into the moderately welded tuff of the upper part.[10] It is unlikely any excavation cut through the upper part of Unit 3. Soil cover ranges from 2 to 5 feet (.6 to 1.5m) in thickness.[10]

"The attitude of most of the major joints are near vertical to vertical ranging from 70 to 90 degrees measured from the horizontal. Some of the joints were slightly curved, open in places and closed in others. All of the joints were filled with dark brown clay beneath the soil zone while at depth were filled or plated with dark brown or gray clay.

The orientation and distribution of the major joints in the horizontal plane of the north and south walls of the pit are shown on a rose diagram (Fig. 4).* Three point sets occur true north to N10°W, N40°E to N60°E and N80°E. Though

* See Fig. 12

all the joint sets do not intersect at 60 degrees as they would if formed in a homogeneous liquid as it cooled, the predominance of the three joints sets and near vertical attitude of the joints suggest that the joints formed as the ash flow tuff of Unit 3 cooled after emplacement."[10] ~~(See Fig. 4)~~

Surface drainage of Area A is north into DP Canyon.

Purtymun (1969)[10] estimates there is 1 150 feet (350.5m) between the top of the mesa and the top of the zone of saturation (water table) in the Puje Formation. He also, estimates the Bandelier Tuff to be 800 feet (243.8m) thick and implies there is no perched water in it.

TYPE OF WASTE

The early pits in the eastern end of Area A contain solid wastes with long life alpha contamination accompanied by slight amounts of beta and gamma.[12,13] The material buried was mainly contaminated with polonium.[171] There may be trace amounts of 239 PU in the material.[171] The estimated volume of buried material is 4000 cu. yd. ($1019.5m^3$)[171] ~~*See Fig. 12~~.

The General's Tanks contain liquid wastes. "Champion's records which were made at the time solutions were transferred into the tanks, on the basis of radioassay (total alpha) of the individual trailer tank loads, showed a total of 344 grams into the two tanks."[173] Records were kept to the nearest 0.01 grams.[173] In 1950 or 1951 a corroborative sample from each tank was taken. "... the results were in good enough agreement with the above that no corrections were thought to be necessary. So far as I* know, no records of this sampling are still in existence, but I seem to vaguely recall that the NaOH supernatant tank had about 180 grams in 50.000 gallons, and the NH_4OH tank had about 160 grams in 35,000 gallons."[173] Another reference[14] states the tanks were checked in the early 1950's and estimated to contain 160 to 1 000 grams of Pu. In 1973 an estimate of the amount of radioactivity was "an equivalent amount of about 230 grams of ^{239}Pu (about one-third of which is ^{241}Am) . . . Furthermore, only 0.7% of the

* W.B. Hoover, CNB-11

radioactivity is in solution so that any leakage would have probably stayed very close to the tanks."[9] The volume is 40 000 gallons (151,424 liters) in one tank and 9 000 (34,070 liters) in the other.[9]

The latest and largest pit contains building debris from demolition work at TA-21. The first layer of waste was buried by June 30, 1969.[10] January 4, 1971[171] the volume of debris in the pit was given as 8,500 cubic yards (2166 m^3). The pit was not used from January 1, 1972 thru June 30, 1972.[172] After it was enlarged in late 1972 or early 1973, debris from the demolition of TA-21-12 was placed in it.

MODE OF DISPOSAL

Four pits are shown in the eastern end of Area A on engineering drawing ENG-1266. An arrow pointing to them has the note: "Scaled from W.C. Kruger map 'Special Sewers "DP" Site Construction Sheet O Outside Services 4" 8-22-45." The pits are depicted as 125 feet long by 18 feet wide with rounded corners. Probably a more accurate depiction of the pits is on ENG-C 2076. On this drawing there are two pits which are rectangular. They cover 0.99 acres. There is doubt whether all 4 pits were dug. If all 4 were dug, there is still doubt whether all four were used. "At the present time the solid contaminated wastes are buried. Since the start of the project we have filled six pits. Three of these are located**between the trailer camp and the CMR Laundry,+ two on the tank area near DP East++ and one at the Alpha Site Dump*. The present dump**has been in use for one year and during that time we have filled one pit."[12] The previous quotation implies 2 pits were dug. used, and the area abandoned by June 14, 1949;- however, it does not state which two. This would correlate with the statement: "The excavated tuff was piled over two sealed disposal pits (see LASL Eng. Drawing 6250)."[10]

The "General's Tanks" TA-21-107 and TA-21-108 are two 50 000 gallon (189,280 liter) cylindrical stainless steel[14] storage tanks. The tanks are 12 feet (3.7 m) in diameter and 62 feet 10 inches (19.1 m) long. They were placed 20

*W.B. Gibson, CMB-11
**1974 designation is materials disposal Area B. +1974 designation for the CMR Laundry is materials disposal Area V.
++1974 designation is materials disposal Area A.

feet (6.1 m) apart in pits 12 feet (3.7 m) deep, 15 feet (4.6 m) wide and probably 68 feet 10 inches (21.0 m) long on 4 concrete piers. Each pier was 4 feet 10 inches (1.5 m) high with the bottom 2 feet (0.6 m) below the bottom of the pit. Each tank rested on the piers 1 foot (0.3 m) above the bottom of the pit. Sand was placed in the bottom of the pit up to the top of the piers -- a depth of 1 foot 10 inches (0.5 m). Thoroughly packed earth filled most of the rest of the pit. Directly above the tanks loose earth fill was specified, (ENG-C 2076). A concrete slab 8 inches (20.3 cm) thick, 56 feet (17.1 m) wide and 68 feet 10 inches (21.0 m) long was poured 1.5 feet (.5 m) above the tanks. Approximately 5 feet (1.5 m) of earth fill was placed above, the concrete slab. This final earth fill formed a mound 2.25 to 5.75 feet (0.7 to 1.8 m) above grade. On the north end of each tank a vent extended 15 feet (4.6 m) above the mound. On the south end of each tank the fill pipe is enclosed in a concrete (?) box with outside dimensions 2 feet 10 inches (0.9 m) high, 2 feet 10 inches (0.9 m) wide, and 4 feet 4 inches (1.3 m) long. The box extended 1 foot (0.3 m) above the mound.

The large pit in the middle of the area originally had the dimensions of ? long x 40 feet (12.2 m) wide x 22 feet (6.7 m) deep.[16] This is the pit described by Purtymun, 1969.[10] (See Figures 13; 14 and 15) "The pit was excavated in a near east-west direction leaving steep ramps on each end (Figure 1)* ~~= Fig. 5 of this report~~). The excavated tuff was piled over two sealed solid disposal pits (see LASL Eng. Drawing 6250). An access road to the bottom of the pit was cut along the south wall. Parts of the north and south walls are nearly vertical with the remainder sloping at about 1 to 5. The walls at present are stable, though several small blocks were dislodged during construction." Sometime after November 9, 1972,[16] the original pit was enlarged to include an additional 185 feet (56.4) of length. This enlargement provided approximately 6 000 cu. yd. (1529.0 m^3) of burial space for building materials

*Figure 13

from Building TA-21-12.[16] Harold Hidy, ENG-1, (personal communication) was never requested to stake or map the original pit or the enlarged pit. In March, 1974, the pit could have been two-thirds full. This pit was placed on an engineering drawing for reference in May, 1974. Building debris is being put into the pit by backing dump trucks to the edge and dumping them (personal observation).

APPEARANCE OF SITE

When the large middle pit was dug the dirt was piled to the east over the old pit area. The dirt pile was so large that the east fence had to be removed. Presently the dirt pile extends perhaps 20 feet to the east of the old fence line.

According to engineering drawing ENG-1266, (Date: 12-22-70). Area A was entirely enclosed with cyclone fence. A cyclone fence also separated the "General's Tanks" from the rest of the area. There were 2 gates, both from the south side. One led into the "General's Tanks" enclosure and the other into the rest of the area.

The fencing and gate for the "General's Tanks" remain the same. The south fence from the point where the fence enclosing the "General's Tanks" intersects it, (N.86+00, E.163+80), is greatly changed. There is a new gate immediately to the east of N.86+00, E.163+80. This gate is not useable because immediately inside it is the near vertical cut of the south wall of the open middle pit. The fence continues past the gate for maybe 50 feet. The next section of fence, including the old gate, up to point N.85+42, E.165+35 is gone. This is the area where trucks are moving in to dump. The rest of the south fence from point N.85+42, E.165+35 to point N.85+14, E.166+88 is standing but not sturdy because the dirt pile is spilling into it. As already mentioned the east fence is gone. The north fence remains intact and is the only way to estimate the boundaries of the area.

Area A is not accessible from the TA-21 north perimeter road because fencing is intact and gates are locked. It is, however, highly accessible from the TA-21 south perimeter road. To travel the south perimeter road one must pass through the main guard gate at TA-21. However, once past the gate there is nothing to prevent anyone from entering ~~the~~ Area A. The fences are down. The only signs designating it as Area A and a contaminated area are faded and posted elsewhere. No one appears to watch the area.

MONITORING

The Environmental Section H-8, monitoring points in the vicinity are not specifically designed to monitor Area A.

The "General's Tanks" were checked in the early 1950's for content.[14,173] They were again checked in 1973. "Although surveillance of these tanks has been, to say the least, minimal in the past, there has been no leakage determinable by our present information. The volume 40 000 gallons in one tank and 9 000 gallons in the other as well as chemical concentrations is comparable to the record data."[9] Continuing: "It is planned to transfer this solution to Bldg. 257 for treatment. This will take some time because we will have to rely on dilution to handle the anions which are quite high, e.g., NO_3^- at 130 000 ppm for which the MPC is 45 ppm."[9]

CONCLUSIONS

Area A has been in intermittent use since 1945. It was the second central burial ground at the Laboratory. Records on disposal have not been located except for some concerning the "General's Tanks." The only known study is one concerned with the geologic inspection of the large pit dug in 1969.

RECOMMENDATIONS

1. The faded Area A identification sign should be replaced.
2. The faded contamination warning signs should be replaced.
3. Some way of alerting people they are approaching an open pit should be found.

The fence is down on the south and east sides of the area. It is probably not practical to reestablish the cyclone fence until the pit has been filled. Since the filling of the pit is related to demolition work at TA-21, there is no way of predicting how much longer it will remain open.

4. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.

   Within a mile east or west of Area A there are four other materials disposal areas. The geology of Area A should be related to that of the other areas on the mesa.

AREA T

INTRODUCTION

Area T is the DP West absorption bed area located east of buildings TA-21-286, TA-21-288 and west of building TA-21-257 (See Fig. 16). Area T can be reached from the north perimeter road. It is less than 1/4 mile from the intersection of the north perimeter road and DP Road. The axis of the area runs southeast. Most of the area is found within coordinates N 87 + 50 and N 90 + 00 and E157 + 50 and E160 + 00. Engineering drawing ENG-C 2217, June 13, 1945, shows the absorption bed area enclosed by fence. Latest engineering drawings show no boundaries for the area, but locate points within the area. Area T was not announced as a disposal area until May 23, 1967.[33] Perhaps the following explains the lack of a good map. The job history given on a May 11, 1967 request for survey service[34] states, "location of Area T has been established and coordinates computed. Brass caps cannot be set in the area until the DP rehab has been completed, and this work isn't expected to be completed for two years, so this request should be closed. Disposal area caps can be included with the DP site brass caps when the rehab has been completed." Area T is an open area with approximate dimensions of 120' x 320' (36.6 m x 97.5 m), with an approximate acreage of .88[35] (3561.2 m^2).

Area T is one of the first disposal areas used at the Laboratory. Construction of four absorption beds for disposal of DP West

liquid waste was done in 1945. Untreated waste from the processing of plutonium at TA-21 was released to the pits from 1945 to 1952. In April 1947 plans had been drawn to connect all the tech area and DP-Site contaminated effluent lines into a central line and disposal plant. The plans had been turned over to the post engineers.[37] It is not clear whether the 1947 proposed disposal plant became the disposal treatment plant, Building TA-21-35. TA-21-35 was installed in 1952 to remove plutonium and other radionuclides.[36] The reason for installation was "because the tuff had become clogged with suspended solids,"[38] and the beds had to be abandoned. The effluents from the treatment plant were released to the absorption beds from 1952 into 1967 when a new treatment plant, TA-21-257 was built. From 1965 through 1967 absorption beds 1 and 2, also received low-level radioactive effluent from DP East (written communication Lud Emelity, H-7). When treatment plant TA-21-257 was built, there was a change in operations. Since mid-1968 effluents from the new treatment plant are mixed with cement and pumped down shafts augered between the south absorption beds and the north absorption beds.

GEOLOGY AND HYDROLOGY

"The pits* are probably excavated in Unit 3 of Tshirege Member of the Bandelier Tuff. The lower part of this unit is non-welded tuff grading up into a moderately welded tuff which underlies the pits. Joints are more numerous in the upper part of the unit

*absorption beds

due to the denser welding. Most of the joints are oriented vertical or near vertical. The total thickness of the unit is about 110'. It is underlain by moderate to dense welded tuff.

The total thickness of the Bandelier tuff underlying the mesa at Building 35* exceeds 800 ft. The tuff is in the zone of aeration; the top of the main zone of saturation is about 1150' below the surface of the mesa."[36]

With the construction of the shafts which are principally located between absorption beds ~~no.~~ 2 and 4, new geologic data was acquired. Purtymun (1969)[40] drew two cross-sections using information derived from shafts 3, 11, 19, 27, 2, 10, 18, 26, and 34. These shafts were dug with a 3-foot bucket auger and then reamed to an 8' diameter (2.4m). The shafts range in depth from 15' - 66' (4.6 - 20.1 m). Purtymun described the stratigraphy as follows: "the lower unit is a light gray moderately welded tuff with an approximate thickness of 100', it is overlain in part by reworked tuff which is deposited in a channel, or low relief cut into the lower light gray tuff unit. The upper unit forming the surface of the mesa of the disposal area is a light, brownish-gray moderately welded tuff." (See Figs. 17 and 18) The reworked tuff and pumice contain cobbles and boulders in the lower part, and ~~"The reworked tuff~~ was deposited by gaseous forces accompanying the emplacement of the upper ash flow. The cobbles and boulders occur in tabular shapes, or if in mass, show faceted sides as if deposited by sliding rather than rolling as one would expect with water-laid material. The blast caused by the

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*Building 35, TA-21-35, has been removed. It was located immediately south of the absorption beds. (See engineering drawing ENG-C-35571)

expanding gases accompanying the emplacement of the upper ash flow deposited the larger materials (cobbles and boulders) into areas of low relief in the upper surface of the lower unit. As the upper unit and reworked tuff were emplaced contemporaneously they have cooled as a single unit thus the contact between the two is gradational and not very distinct. A sharp contact is found between the reworked tuff and lower gray unit."[40]

TYPE OF WASTE

"The amount of untreated effluent released into the absorption beds during the period 1945 to 1952 ~~has been~~ was estimated as 14 000 686 gal (53 001 m^3)*. The concentration of plutonium in effluents during this period has been estimated at 60 c/m/ml (counts per minute per milliliter) with an average fluoride concentration (associated with the waste) of 160 ppm (parts per million). In addition, 10 450 gallons (39.6 m^3) of effluent, highly concentrated with ammonium citrate, was released into the beds from June 1951 to July 1952. The plutonium concentration of this waste averaged about 7 000 counts per minute per milliliter and the fluoride concentrations were about 200 ppm."[36]

From 1953 through 1967 4 294 696 gal (16 258 m^3)* of effluent went into the absorption beds. Of this amount, 1 984 626 gal (7 513 m^3)* came from DP East. (See Table 3) It is still possible to release effluents to absorption bed 4 at this time, July, 1974.

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*Written communication from Lud Emelity, H-7

As of January 1973, Wheeler[32] gives the amount of tritium in the beds as 3.6 curies and the amount of plutonium in the beds as 9.8 curies. He states all values in curies are decay corrected from the original magnitude to that as of December 31, 1972. There are 43 disposal shafts in Area T. The wastes going to the shafts are mixed with cement. "Various wastes such as the neutralized americium, "strip," alkaline fluoride and plant sludge are being mixed with cement in a pug mill operation and the slurry is being pumped to deep holes on the site. This procedure was started on May 1, 1968."[41] Also, 3-foot (.9 m)diameter bathyspheres have been placed in shafts, --3 to a layer and at various depths.[41] Besides ^{239}Pu, ^{238}Pu, ^{241}Am, and ^{235}U the shafts contain some mixed fission products which are mostly strontium and cesium.[41] Table 4 gives the equivalent ^{239}Pu in grams in each shaft. As of January 1973, Wheeler[32] gives the amount in the disposal shafts of strontium 90 - ^{90}Y as 2.3 curies, of ^{233}U as 6.9 curies, of ^{238}Pu as 12.6 curies, of ^{239}Pu as 69.4 curies, and of ^{241}Am as 1256 curies. Wheeler's values have been decay corrected from original magnitude to that as of December 31, 1972.

MODE OF DISPOSAL

The construction of the absorption beds is shown on Engineering Drawing ENG-C 2217. The four beds are numbered as follows: ~~No~~. 1 is the southwest bed; ~~No~~. 2 is the southeast bed; ~~No~~. 3 is the northwest bed; and ~~No~~. 4 is the northeast bed. Each bed is 120 ft.

(36.6 m) long, 20 ft. (6.1 m) wide, and 4 ft. (1.2 m) deep. The east and west sides of the beds were sloped so that only the center 100 ft (30.5 m) of each bed has a depth of 4 ft. (1.2 m). The north and south sides of the beds appear on ENG-C 2217 as vertical cuts. The bottom of the beds was cut level. The distance between the centers of Beds ~~No.~~ 1 and 3 and Beds ~~No.~~ 2 and 4 is 80 ft.(24.4 m).

The original surface of the site sloped to the north at 12 to 1. Therefore embankments were placed to the north of the beds and surface water interceptors were cut to the south of the beds. Probably the two embankments were built from material derived from the excavation of the beds. Each embankment had a minimum width of 10 ft (3.1 m) and a minimum height of 2 ft. (0.6 m). One embankment extended across the west end of Bed ~~No.~~ 1, the north side of Beds ~~No.~~ 1 and ~~No.~~ 2 and across the east end of Bed ~~No.~~ 2. The other embankment extended across the west end of Bed ~~No.~~ 3, the north side of Beds ~~No.~~ 3 and ~~No.~~ 4, and across the east end of Bed ~~No.~~ 4. The surface water interceptors were cut approximately 2 ft (0.6 m) deep and 3 ft (0.9 m) wide 10 ft (3.1 m) from the south sides of each pit.

The beds are sometimes referred to as covered pits. This is misleading because the beds were never roofed. They were filled with stone, gravel, sand and earth. These materials graded upward ~~in size~~. The bottom 24" (61.0 cm) was stone which ranged in size from 3" to 10" ± (7.6 to 25.4 ± cm) followed by 6" (15.2 cm) of gravel, 6" (15.2 cm) of sand and 12" (30.5 cm) earth for a total of

4 ft (1.2 m) of graded fill. "Stone in pits is to be clean and free from dirt. Grade from large at bottom to small at top to form deck for gravel. Bottoms of excavations should be trimmed and cleared of earth and loose material before filling."*

Liquid waste moved through 6"(15.2 cm) iron pipe from DP West Buildings 2, 3, 4, and 5 to a distribution box between Beds ~~No.~~ 1 and ~~No.~~ 2. The distribution box was 4' (1.2 m) long, 3' (0.9 m) wide, and 4' (1.2 m) deep with 6" (15.2 cm) walls. It was built of concrete. The interior was painted with two coats of Inertal Standard Black, or equal. The box had a 2" (5.1 cm) creosoted wood cover which was hinged to the concrete and equipped with a hasp and heavy lock. One 6" (15.2 cm) round plug 24" (61.0 cm) long was provided with the distribution box. The purpose of the plug is not known; but it may have been used to divert waste into either Bed ~~No.~~ 1 ~~and~~ or Bed ~~No.~~ 2 instead of allowing waste to flow to both. Liquid waste from Building 12** flowed through a 6" (15.2 cm) iron pipe directly into Bed ~~No.~~ 1. Overflow pipes of 6" (15.2 cm) iron connected Beds ~~No.~~ 1 and ~~No.~~ 3 and Beds ~~No.~~ 2 and ~~No.~~ 4. The overflow pipes were positioned in Beds ~~No.~~ 1 and ~~No.~~ 2 at the top of the stone layer i.e. 2 ft. (0.6 m) above the bottom and in Beds ~~No.~~ 3 and ~~No.~~ 4 at the bottom. All piping was standard weight steel pipe cut in 5 ft. (1.5 m) lengths and coated with Jennite. All joints were screwed.

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*Note on Engineering Drawing ENG-C 2217.

**Building 12 DP West has been dismantled.

"Reportably, more water* moved into pits** 1 and 3 than moved into 2 and 4, and at times some of the pits became clogged and overflowed, the overflow moving northward toward a canyon."[8]

Sixty disposal shafts were located in the site, principally between Beds ~~No.~~ 2 and ~~No.~~ 4. Forty-three of these shafts have been augered using a four foot (1.2 m) diameter bucket auger and reaming to an 8' (2.4 m) diameter. (See Fig. 19) The shafts are on 12' (3.7 m) centers. Shafts 4, 6, 7, 8, 14, 15, 16, 37, 38, 39, 40, 43, 45, 47, 49, 57 and 59 have not been augered. Shafts 6-8 and 14-16 will not be augered because of a power line. Shafts 37-40 are aligned where the overflow pipe between Beds ~~No.~~ 2 and ~~No.~~ 4 was. See Table ~~4~~ 5 for the following information on individual shafts: dates shafts were completed and filled, shaft depths, and type of rock encountered during augering. This table is composed of data from The Zia Company and Group H-7.

"The waste treatment plant at TA-21 is located near DP-West in Building DP-257 where the sludge goes from a holding tank to a pug mill where cement is added on a continuous basis. This mixture is pumped into 8 ft. x 60 ft. diameter asphalt-lined holes."[45] Irregularities in the substrate prevent all shafts from reaching a depth of 60 ft. (See Figs. 20 and 21)

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*Liquid waste

**Beds

APPEARANCE OF SITE

The shaft field of Area T is reached from the north perimeter road at TA-21. It is not necessary to pass through the main guard gate. The area is within the TA-21 fencing, but not enclosed by a fence.

There is a marked difference between walking into the shaft field of Area T and walking into the part which is not used for shafts. A fence separates the two sections. To reach the section not being used for shaft disposal one must pass through the main guard gate to TA-21. From there one goes to the H-1 Section Office to get clearance. After one has justified entering the area, he receives coveralls, "booties", and cap and a Health Physics Surveyor. Then one proceeds to the exchange badge station. The guard calls the H-1 Section Office where he receives instructions to clear one into the area. After receiving one's exchange badge one walks with his assigned Health Physics Surveyor into Area T. It is more difficult to reach this part of the area than the other. There are 3 warning signs posted as one approaches the area. However, just as in the shaft-field section, there is no fencing other than that which is a part of the TA-21 Site fencing.

The fence separating the disposal shaft section from the rest of the area cuts across the eastern ends of ~~Pits~~ Beds 1 and 3. Along the fence line there is a cave-in which could be the remains of the caisson built for an experiment described in a later section.

Earth mounds occur over Absorption Beds 2 and 4. Between Absorption Beds 2 and 4 the shaft-field is level. Occasionally one can see the cap of cold concrete on a filled shaft. Most of these caps, however, are obscured by a thin layer of dirt. There is no defined drainage across this section.

The section not used for shafts has an irregular drainage pattern. The western end of Absorption Bed 1 is covered by an asphalt road. The middle section of Absorption Bed 1 is a depression. (The eastern end of Absorption Bed 1 is covered by the earth mound in the shaft-field section.) The western half of Absorption Bed 3 is a depression. The eastern half of Absorption Bed 3 is a continuation of the graded level of the shaft field. There are two drainage shoots from the asphalt road directed into this part of the area. The grass in ~~Pit~~ Bed 1 is growing well. There are some 10-~~20~~ 12 ft. (3.0-3.7 m) oaks (Quercus) between Absorption Bed 1 and Absorption Bed 2. The grass in Absorption Bed 3 is not quite so thick as that in Absorption Bed 1.

MONITORING

Some of the earliest monitoring surveys at LASL include data on Area T. In "Survey of Los Alamos and Pueblo Canyon for Radioactive Contamination and Radioassay Tests Run on Sewer-Water Samples and Water and Soil Samples Taken from Los Alamos and Pueblo Canyons," LAMS-516[181], data on fluid and soil are presented for Absorption Bed 1 and Absorption Bed 2.

Absorption Bed 1[181]

Date	Sample Type	Direct Instru. reading "Pee Wee" d/m	Po d/m/L	Pu d/m/L	Pu microg/L
July, 1946	fluid		200	6780	4.8×10^{-2}
Sept. 1946	fluid		65	97	69.2×10^{-5}
Oct.-Nov. 1946	soil	800	123	200	

Absorption Bed 2[181]

Date	Sample Type	Po d/m/L	Pu d/m/L	Pu microg./L
July, 1946	soil	80	80	5.7×10^{-4}
Sept. 1946	soil	43	122	87.1×10^{-5}

Two liter samples were taken for the fluid analysis and 50 gm samples were taken for the soil analysis. Analytical procedures are given on pages 5-7 of the report. See Figure 22 for location of Oct.-Nov. 1946 soil sample.

In April, 1947[37] in compliance with a request from Dr. L. H. Hempelmann, James F. Tribby requested W. Kingsley to collect at regular intervals, ~~fluid~~ effluent samples from the DP Site chemical sewer outlets. The first report was October 20, 1947.[47] "These water samples (a to e), in addition to being radioassayed, were submitted to the analytical group for a fluorine analysis (Samples from the same sewer were taken at 3 different times of the day.)"[47]

The result of the fluorine analysis for "DP West seepage, main drain", Area T, in mg. of fluorine per 100 mc. was 4.2. "As soon as repair work on the hood is finished, all water samples will be prepared for a spectrographic analysis and radioassay will be continued."[47] The monthly report for October 21 to November 20, 1947[48] gives a radioassay in c/m/L as 29 836 for plutonium and 5.8 for polonium. Samples collected September 26-30, 1947 were reported January 2, 1948.[49] The DP West Seepage Pit Main Drain (Area T) had the highest activity (of all sampling points) due to plutonium with 65 639 d/m/L. The January 2, 1948 report[49] also included the analytical procedures for (1) polonium in water samples and soil samples, (2) plutonium in water samples and soil samples, and (3) uranium.

According to the available records, the next monitoring work in Area T was done in 1953. At that time 5 test holes were drilled in and around the absorption beds. "Material from the test holes was analyzed to determine the relative amounts of plutonium and the ion exchange capacities of the tuft adjacent to and underlying the pits. Location of test holes are shown in Figure 1.* The exact location of the TH-3 in Pit 1** is unknown. Plutonium and ion exchange capacities of the tuft are shown in Table I.*** Hermann (1954)† concluded from the study that plutonium is readily retained by the various earth media (clay, sand, and gravel) and

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*See Figure 23 ** Bed 1

**See Table ~~5~~ 6

†Hermann, E. R., 1954, Retention of plutonium in waste seepage beds at Los Alamos: Unpublished manuscript in files of U.S. Geol. Survey at Santa Fe, N.M.; 14 p., 2 figs.

that the retention is greater in the finer materials. The horizontal migration of plutonium is very small within 20 feet of the surface, (TH-1 and TH-2, Fig. 1 and Table 1). Other observations were that the ion exchange capacities of the tuft is inadequate to account for the retention of plutonium. The retention of plutonium in the tuft is mostly due to absorption, and the effect of ion exchange is of secondary importance."[36]

A joint LASL[38] - USGS[51] study to determine distribution of plutonium previously discharged to the absorption beds was begun in October 1959 with the construction of a caisson 30' (~~1.8~~ m) deep by 6' (1.8 m) wide by 12' (3.6 m) long on the northeast corner of Absorption Bed 1.

"Horizontal holes 3 inches in diameter were drilled at 2 foot depth intervals to a depth of 12 feet so as to terminate at about the center of the seepage pit. At each 2 foot interval two holes were drilled 2 feet apart horizontally. In one hole, a 2 1/4 inch diameter plastic pipe was inserted with the far end sealed; ground tuff was inserted in the area between the pipe and the solid tuff. This hole was used for measurements of moisture. The companion hole was used for collection of liquid samples. Detail of the collection cup system is shown in Figure 5*. A porous ceramic cup was inserted to the end of the drilled hole; the hole was back filled with ground tuff. Clay was inserted and capped with a molded cement plug at the caisson face around the vaccum and the vaccum release tubes."[38] (See Fig. 25) A 7" (cm) long core sample for each 2' (m) of horizontal depth was taken when the holes

*See Figure 24

were drilled. Part of each core was assayed for gross α. (See Table 7)

In late 1960 after the first infiltration study six deep holes were drilled at the periphery of Absorption Bed 1 ranging from 76' to 99' (to m) deep. They were lined with 2 1/2" plastic pipe. The holes were augered using compressed air to remove cuttings. Samples of cuttings were taken at 5' intervals. "This core sampling procedure leaves much to be desired but results did indicate gross variations (Table V)."*[38] (See Fig. 26)

The Infiltration Study for 1960 was done in the summer. DP West raw waste flowed directly to Absorption Bed 1 for 1 month at an average rate of 8700 gallons per day. The following month tap water was applied at a rate of 6600 gallons per day. Moisture data was collected during and after these discharges. This was a preliminary study.

The 1961 Infiltration Study was similar to the 1960 one. Sixty-four hundred gallons per day of raw waste went into Absorption Bed 1 from June 30 to August 1. From August 2 thru August 26, 7100 gallons per day of tap water was applied. Sampling continued for an additional week after the application of tap water.

"Samples were collected, at each sampling depth, continuously during each day until 50 mls was obtained or until 8 hours had elapsed. Five daily samples were then composited and used as the weekly sample. (See Table 9) "The objectives of the present study were to determine if and where water moved beneath a disposal pit and to ascertain if waste products moved with the water."[50] The 1961 study was reported by both the USGS and LASL.

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*See Table 8

The USGS report[51] stated (1) "that waste water movement may have changed some of the physical properties of the tuff, such as pore and particles sizes." (2) "Some of the wastes discharged in the east end of the disposal pit may have moved laterally through the sandy material (Bed A on Sketch C and D, fig. 21)* along the sloping top of the tuff and then vertically into the tuff." (3) "The lower moisture values ~~(fig. 22A)~~ seem to coincide with areas of tuff in which the greatest amount of staining had occurred. The stained areas may indicate a different stage of weathering than that at the clay layer due to alternate wetting and drying cycles." (4) "The tuft is extensively jointed (fig. 21)* and the tendency for a liquid to move through the joints is indicated by higher gross alpha count of a 1000 per minute per dry gram at the 20' depth on figure 22-B." (5) There were "several open joints...below a depth of 25 feet. Waste water had penetrated the fineline joints to depths of at least 22 feet and subsequently altered the tuff adjacent to the joint as much as one-quarter to one-half inch. Clays developed locally and impeded drainage so that the joints retained water to the extent that the moisture content of the tuff was locally as much as 35% ~~(fig. 23, profile I)~~." (6) "Water in the low moisture range apparently moved to depths greater than 90 feet. Water in unknown quantities moves through open joints or joints enlarged by solvents in the waste." (7) "Below a depth of about 15 - 20 feet the alpha activity was low, except for local areas of high alpha activity where water carried the activity along the joints. Rapid movement of water through

*See Fig. 25

joints was substantiated during infiltration studies."

The LASL report[38] stated (1) A high concentration of potassium salts affects the movement of plutonium. (2) A low concentration of aluminum and silicon in the samples of liquid removed indicates that plutonium was not being transported on colloidal clay of such a size as to escape filtration by the tuft. (3) "...total hardness and total solids may be correlated with alpha activity." (4) "That both total solids and total hardness tend to increase with depth... suggests solution or resolution of previously deposited material." (5) "There is some indication of an inverse relationship between gross alpha content and pH. It is possible that at the lower pH values plutonium is oxidized to + 6 and although it is fairly unstable, it is not as exchangeable as Pu^{+4} and Pu^{+3}. (6) "It has been deduced from the irregularity of the curves obtained from data for holes 1, A-1, and 2, that ~~because~~ ... percolating groundwater may be perched,... or may travel rapidly along fissures as seen by a sudden decrease in percent moisture which indicates rapid drainage from the area. These two factors will exert a marked influence on the accumulation and sorption of radionuclides in the areas involved." (7) "Under field conditions, plutonium species have been shown to penetrate to at least 28 feet. That this penetration takes place along fissures is indicated by moisture data, rates of flow of liquid and by physical inspection." (8) "It is apparent that one cannot extrapolate from laboratory studies on intact core sample to conditions which prevail in the field."

Before the decision to create the shaft field at Area T, Purtymun made a reconnaissance[36] of the absorption beds in January 1967. He collected water samples from DPW-1A, DPW-3, and the caisson (See Fig. 2~~1~~3) and a sample of weathered tuff from beneath the gravel fill of Absorption Bed 1 near the caisson for radiochemical analysis. The water samples showed only background amounts of gross alpha and gross beta-gamma and no plutonium or uranium. Tritium analysis of the water samples gave approximations for DPW-1A as 462 DPM, for DPW-3 as background and for the caisson as 2000 DPM. The sample of weathered tuff had a gross alpha count of 978 c/m/g. His observations on January 1967 are as follows: "Effluents from DP-East have at times partially filled the shaft near Pit 1*, thus creating a more localized point for infiltration for liquids. Test holes DPW-1A and DPW-3 contained some effluent at the time of observation. It is supposed that the water in DPW-3 moved down the outside of the casing from water ponded in the pit."[36]

Moisture contents of the tuff were logged in holes DPW-1 and DPW-2 and DPW-5 at selected depths. "A comparison of the moisture content with previous moisture measurements (March 1961 prior to the addition of 389 thousand gallons of tap water and effluents in August 1961 during the study) is shown in Table 3.**

"The January 1967 measurements at hole DPW-1 show the effect of the 1.9 million gallons of effluent from DP-East in which the maximum concentrations of water have moved from the depth of 12 feet

**See Table 10

* Bed 1

(40 percent, August 1961) to 40 feet (41 percent, January 1967). The hole is next to the shaft.* The moisture measurements in DPW-2 and DPW-5 show a general decrease in the moisture content of the tuff from August 1961 to January 1967. The indication is that most of the effluents released into pit 1** have moved down in the area of the shaft, a focal point for collection and infiltration of effluents into the tuff."[36]

On the basis of previous studies and his reconnaissance Purtymun concluded "that the movement of the effluents in the tuft underlying the seepage pits† is mostly downward beneath the pits. The plutonium moves with the effluents and the data indicate that most of the plutonium is retained by absorption in the upper 20 feet of the tuff. Some, however, may move to greater depths through open joints."[36] This USGS reconnaissance study was one of the last done by Purtymun before he became a staff member of LASL.

The Zia Company augers the shafts in Area T. Their personnel have provided Purtymun with samples from most of the shafts. Each shaft averages about 10 samples taken from various depths. These samples are analyzed. Most of this data is unpublished.

In March 1974[182] a survey of the proposed location for the retrievable storage facility was begun. To date, July, 1974, the results have not been published. The retrievable storage facility

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*caisson

**Absorption Bed 1

†absorption beds

is to be a pit dug between Absorption Bed 1 and Absorption Bed ~~2~~ 3 west of the shaft field. The pit is to be dug within 5 feet (m) of both absorption beds and is to extend several feet west of them (person commun. from Harold Hidy, ENG-1).

March 22, 1974 a plutonium-americium surface contamination and external radiation survey[183] was done. Three monitoring stations were over Absorption Bed 1; six monitoring stations were over the proposed pit; and one monitoring station was over Absorption Bed 3. A LAFPHA/FIDLER system was used to measure the plutonium-americium surface contamination. External radiation levels were measured by a calibrated Reutor Stokes high-pressure ionization chamber dosimetry system, Model #RSS-111. The basic conclusions[183] of the survey were:

1. "There is no Pu surface contamination (less than approx. 1.2 $\mu Ci/m^2$) within the boundaries of the fenced site.*"
2. "Americium-241 was detected in Pit # 1,** but at a level of only 1.1 $\mu Ci/m^2$ assuming surface contamination."
3. "No significant levels of external radiation could be attributed to the radioactivity with the waste pits 1 and 2*** of Area T."

Seven holes were augered in April, 1974 within the boundaries of the proposed pit. The depth of the holes was 40 feet (m).

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*The "fenced site" is the part of Area T which does not include the shaft field.

**Pit # 1 = Absorption Bed 1

***Typographical error. Should read Absorption Beds 1 and 3.

Samples were collected at 2.5 ft (m) intervals from 1 ft - 10 ft (0 m) and at 5 ft.(m) intervals from 10 ft - 40 ft. (m). Samples were analyzed for moisture content, gross alpha, gross beta-gamma, tritium, and plutonium-238, 239. Complete analyses are not available at this time, July, 1974.

At the suggestion of Group H-7 holes were also augered in the shaft field. The six holes were augered in May, 1974. They were located so as to encounter a "boulder bed" which occurs at a depth of 15 - 25 ft (m) below the surface. The samples were collected at the same intervals and analyzed for the same things as those from the 7 holes augered in April. Complete analyses are not available at this time, July, 1974.

CONCLUSIONS

Area T has been in use since 1945. It is the only example of a disposal area which reflects the thinking and practices in radioactive waste disposal from the time the laboratory began until today. It is a liquid waste disposal area and not, strictly speaking, a solid waste disposal area. For its size (especially) it has received more intensive study than any other waste disposal area at the laboratory.

RECOMMENDATIONS

1. Area T should have an identification sign.
2. Contamination warning signs should be more evenly distributed around the perifery of the area. Those which are in place are faded and should be replaced.
3. Procedures involved in access to the area should be discussed.

One is supposed to put on "booties" (obtained at TA-21-257) before entering the shaft field. This precaution could be ignored by those who do not work at TA-21-257 through negligence or ignorance since there seems to be no check on those who enter this part of the area.

My visits to the shaft field have been numerous. Twice I have put on coveralls and "booties" to be lowered into a recently augered shaft. The second time I went down a shaft I was monitored by a Health Physics Surveyor. This is the only time I saw a Health Physics Surveyor in this part of the area. In the other part of the area, the part where the new retrievable storage pit is proposed, no one can enter or remain without a Health Physics Surveyor present. I think this seeming contradiction should be resolved.

4. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.

Although Area T has been an intensively studied area most of the studies did not have continuity nor did they attempt to relate (in any detail) the geology of Area T to that of the rest of the mesa on which it is located.

5. Definite boundaries for Area T, if not already established, should be.

The available information does not indicate definite boundaries have been established.

AREA B

INTRODUCTION

Area B is located on the south side of DP Road. It is east of the old trailer court area and west of TA-21. Presently, the western two-thirds of Area B is covered by a layer of asphalt and is leased to people by Los Alamos County for storage for boats and trailers. (See Fig. 27) It is between coordinates E145 + 00, N. 90 + 00, N. 95 + 00. Surveyed corners in clockwise direction, beginning with the northeast corner are N. 91 + 92, E143 + 35; N. 90 + 72, E142 + 96, N. 93 + 90, E134 + 08; N. 92 + 45, E123 + 06; N. 91 + 00, E123 + 14; N. 91 + 08, E122 + 35; N. 93 + 64, E122 + 38; and N. 95 + 09, E133 + 28. It can also be located by township and range: SE 1/4 sec. 15, T. 19 N., R. 6 E., and SW 1/4 sec. 14, T. 19 N., R. 6 E. Approximate acreage is 6.03[18].

Area B appears on engineering drawing ENG-R#4458 as one large pit. No individual pits are shown within the area. However, from old memos dated July 5, 1945 through January 31, 1952 it would appear Area B is actually a series of pits. The July 5, 1945 memo[17] is a request for the provision of a new pit for disposal of contaminated trash from CM-Division laboratories "...suggest that a trench 15 ft wide and 300 ft long be bulldozed out as deep as practical before hard rock is encountered, starting just east of the now covered CM disposal pits located SE of the coal storage yard, and running parallel to and about 40 or 50 ft. north of the DP power lines. This

trench should have a parking bumper along its north edge with a gravelled 20 ft. clearing for truck access, and of course a fence surrounding the whole area.

Such a trench in the suggested location would, in my opinion, be a realistic solution to the contaminated trash disposal problem, and would have the further advantage that it could be progressively filled and covered from the west end toward the east, and if necessary be extended for several hundred yards should the need arise."[17]

By July 12, 1945[20] the pit had been located, staked out, and a work order issued for completion by August 1, 1945. On July 30, 1945[21], there was a request to extend the completion date for the new pit. The request asked, "...that work on the new pit be continued until a 12' depth is reached, or until September first whichever is sooner."[21] A penciled note on this memo[21] says "completed 8th of August."

A January 10, 1947 memo[24] states: "The present contaminated materials disposal ditch is judged by the CMR Division maintenance engineer, J.B. Graham, to be adequate for approximately three months from date. Past experience also indicates the necessity of starting the preparation of a new ditch of that size not less than a month before actual usage. It is therefore felt necessary to start digging about March 1.

The present site is probably too small for expansion unless the south fence is moved closer to the canyon edge, or the east fence moved farther in that direction. Either of these moves would be a somewhat temporary expedient, and we suggest the assignment of a larger

area permitting reasonable expansion. Perhaps east of the DP-East site."[24]

There are several notes on this memo.[24] A typed note from Henry R. Hoyt, Assistant Associate Director, on January 13, 1947 sent this memo[24] to the Maintenance Group with the statement "For necessary action." A penciled note dated February 5, 1947 says, "Graham will issue job order to enlarge ditch until some decision has been reached by the Director." At the top of the January 10, 1947 memo is another penciled notation indicating that someone could not decide whether the memo was discussing Area A or Area B. Area B is the area discussed because the south fence of Area A would not have been near the canyon edge, nor would the east fence of Area A. This memo is the first record of discussion to find a new location for the central burial ground; however, it was the May 3, 1948 fire in Area B which initiated construction of Area C.

The question of how many pits and where they are located in Area B cannot be answered by available information. Area B is probably the first Materials Waste Disposal Area at LASL. "Letters in the CMR-12 files indicate that sometime in 1944 a pit located in the fenced area* between the Trailer Court and the CMR Laundry was in use. When this pit was filled two more were dug in the area now known as the General's Tank Area.** When these were filled (1945) three more pits were dug in the area* between the Trailer Court and

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*Area B

**Area A

CMR Laundry. Space in this area was exhausted in 1948 and new pits were started at the present location*** on Pajarito Road."[22] The "pit located in the fenced are"[22] could well be "the now covered CM disposal pits located southeast of the coal storage yard."[17] Three pits, constructed and filled after July 5, 1945, are referred to in Dean D. Meyer's memos of June 14, 1949,[12] January 31, 1952[22], and January 4, 1971.[19] In a June 12, 1964 memo[27] on Review of Preliminary Drawings: "Materials Disposal Areas" comment 6 states: "There is a covered shallow trench in Area B (ENG-R-3641) which was used for disposal of hazardous materials. The trench was three feet in depth, two feet wide and about 40 feet long. It lies parallel to the south fence line E140 + 00 and below line N.92 + 50. It extends about half the distance to E142 + 50". This "shallow trench"[27] lies in the extreme eastern end of Area B and therefore cannot be "the now covered CM disposal pits located southeast of the coal storage yard"[17] which would have had to have been located in the extreme western end of Area B in order to have had 300 ft. (91.4 m) long pits located to the east of them. It would seem there are a minimum of 5 pits located in Area B.

GEOLOGY AND HYDROLOGY

Area B is located on the same narrow eastward trending mesa as Areas A and T. The south side of Area B is approximately 100 ft from a canyon tributary to Los Alamos Canyon. The Area B pits are probably cut in the Unit 3 of the Tshirege Member of the Bandelier

***Area C.

tuff. Purtymun[26] estimates the thickness of the Bandelier tuff beneath the disposal pits to exceed 800 ft. (243.8 m). He states the tuff is in the zone of aeration and estimates the zone of saturation (water table) to be at a depth of approximately 1200 ft (365.8 m) below the surface of the mesa.

TYPE OF WASTE

Solid waste placed in Area B was logged in LA notebooks #1743 (January 6, 1947 thru November 23, 1948) and #2587 (November 24, 1948 thru April 28, 1950).[23] Long-life alpha contamination predominates but is accompanied by slight amounts of beta and gamma.[13] "The contamination on materials in these pits consists of all types of radioactive materials used at Los Alamos. Some of the known types of activity are: plutonium polonium, uranium, americium, curium, RaLa, actinium and waste products from the Water Boiler. No attempt has been made to keep the various materials separated."[22]

"The total volume of the pits, after deducting the three foot of cover material, is 28 000 cubic yards. These pits actually contain very little Plutonium. At the time they were in use, Pu was scarce and only that which was present as contamination was buried. I* would estimate that the entire pit area contains no more than 100 grams of ^{239}Pu."[19]

Approximately 90% of the contaminated waste consisted of paper, rags, rubber gloves, glassware and small metal apparatus placed in cardboard boxes by the waste originator and sealed with masking tape.[12] "The rest of the material consists of metal such as airducts and

*Dean D. Meyer

large metal apparatus. This type of material is placed in wood boxes or is wrapped with paper."[12] There is also reference to large quantities of wood from temporary storage cabinets used by the Quantity Control Department, several "live" storage batteries,[25] and contaminated or toxic chemicals.[22] Area B was the first central burial ground for LASL.

MODE OF DISPOSAL

For reasons already stated the depiction on Engineering Drawing, ENG-R 4458, of Area B as one continuous pit is wrong. Dean D. Meyer through the years[12,22,19] consistently refers to three pits in Area B which one might assume to be of the type, 15 ft (4.6 m) wide, 300 ft (91.4 m) long and 12 ft (3.7 m) deep. James G. Stearns[27] states there is a trench 2 ft (.6 m) wide, 40 ft (12.2 m) long, and 3 ft (.9 m) deep. There is no mention of the size of the "CM disposal pits."[17]

Frequently, in the literature[26] and in conversation, Area B is referred to as a single pit with an approximate depth of 20 ft (6.1 m). Area B does not appear to be a single pit. Whether some of the pits in the area have a depth of 20 ft. (6.1 m) is open to speculation. It could well be the 20 ft (6.1 m) is based on the average depth of most pits excavated in Areas C and G.

When Area B was in use, waste was handled in the following manner. "The waste disposal program requires three men. Two of these work on the contaminated truck and are furnished by the Zia

Company. The third man is a CMR-12 monitor. This monitor supervises the handling of material. Before loading he checks the boxes for external contamination and keeps records of any accountable property that is buried.

The equipment used consists of a truck and a sedan. The material in the pits is covered once a week. This requires the use of a bulldozer and operator one day a week."[12]

APPEARANCE OF SITE

Area B, west of a 1050' (320 m) radius from TA-21, is asphalted and used as a storage area for trailers and boats. The storage area is fenced and access is limited to those who lease space from the county. With the lease comes a key which must be returned with termination of the lease. Because it is in the lessee's own interest not to duplicate a key or lose it, the storage area can, in a way, be considered a controlled area. There seems to be fairly good control of the keys because there have been very few reports of vandalism or theft in the area. The gate shown on engineering drawing ENG-R #4458 is the gate into the storage area.

Before the storage area was paved with asphalt its surface was described as irregular, with drainage to the south, and grasses and oak shrubs growing in the fill material.[26] Available records do not indicate when the decision to create a storage area was made, or in creating it how much compaction and leveling of the surface was done. The storage area appears on Engineering Drawing ENG-C 26147 dated November 27, 1963. The asphalt paving is on the order of 10 years old. In a November 10, 1971 memo[28], there is a report

of an asphalt cave-in 5 ft (1.5 m) in diameter and 18 inches (45.7 cm) deep. Other cave-ins have been observed. In October 1973 everybody who leased space in the county storage area was asked to move their vehicles so that the surface could be redone. The cave-ins were patched, tar was run into the cracks, and the surface sealed.

At a distance of 1050 ft (320 m) from TA-21, a fence was erected across Area B. From this fence east toward TA-21, Area B is grassy with some brush and one good-sized pine tree. There appears to be no access to this portion of Area B.

The gate shown on Engineering Drawing, ENG-R 4458, on the western fence line does exist. When the decision was made to use most of Area B as a storage area, apparently, a decision was also made to run the south fence straight into the west fence. This cuts off the hook on the western end of Area B. The western gate gives access to this small portion of Area B.

When most of Area B became a storage area, the original fence was left intact. It is an 8' (2.4 m) cyclone fence topped with barbed wire. It shows evidence it once carried electric current. Contamination warning signs are posted on the fence surrounding the portions not in use for storage. There is no sign on any portion of the fence which designates the area as Area B.

STUDIES IN MONITORING

A fire broke out in Area B at approximately 10:20 a.m., May 3, 1948.[25] When the Fire Department arrived, they "...found sixty

percent of the open portion of the dump ablaze and flames shooting approximately fifty feet into the air. The fireman had little trouble in subduing the blaze, but persistent efforts to put it out were of little avail because of the loaded condition of the dump area in which the blaze was confined. Dense, low-hanging smoke prevailed in large volume.

At approximately 10:35 a.m., James Tribby was notified of the fire, in the absence of other Health Group personnel, and with representatives of the Safety Department went immediately to the scene of the blaze and took charge with Herbert Drager. Because of the dense smoke which scattered throughout the area, due to the condition of shifting winds, all areas east and west of the dump, from the food warehouses to the DP Laundry, were evacuated of personnel. Respiratory protection was provided for all persons at the scene, and it was necessary to close the DP road to traffic."[25]

"At 11:15 a.m. May 3, 1948, our monitoring section* drove to the D.P. contaminated dump section to assist the CMR group in surveying the extent of contamination, if any.

General air count proved negative with a Pee Wee alpha survey meter. Jim Tribby however stated that there would almost have to be a fatal concentration of contaminated particles in the smoke or air before the activity could be detected. I believe this points out a need for some sort of a portable emergency alpha air count survey meter which draws in air by force and gives a reading instantly. (If such a gadget can be made.)

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*Monitoring Section, H-2

We later helped check personnel in and around the area including firemen and security guards. The grounds and vehicles in the area were also checked. All proved negative excepting one security car windshield which had about 50 c/m and one spot on the west fence had 200 c/m. The security car is believed contaminated from former contamination trouble or from accompanying a "hot" run. The fence is believed contaminated from dust blown from the dump because it was localized in one spot only.

The smoke drifted west and close to the ground near the food storage plant corner of Trinity and D.P. road. The east wall was checked. No activity found.

It is believed there could not have been an air count present due to the absence of any deposit on local objects."[184]

"By 12:15 p.m., the fire had been extinguished except for two very small, isolated points and there was not longer any hazard from smoke. Fire Department personnel were dismissed at 1:15 p.m., but a stand-by crew of two men and one piece of apparatus were left until 5:30 p.m. to watch for rekindling of the fire.

Investigation has failed to disclose any obvious cause for the blaze, and it is presumed that it started by spontaneous combustion. The area in which the blaze occurred had not had any trash dumped into it for about three days, and much of the trash in the fire area had been in the dump for three weeks. The trash included large quantities of wood from temporary storage cabinets used by the Quantity Control Department, several "live" storage batteries, large quantities of miscellaneous scrap metals, discarded contaminated clothing and boxed laboratory waste. The conditions were ideally suited for spontaneous combustion.

During the fire, there was some evidence that chemicals had been disposed of in the dump in an unauthorized manner in cardboard containers used for the regular disposal of common laboratory waste. Several cartons of waste gave off minor explosions, and upon one occastion a cloud of pink smoke arose from the debris in the dump. Whether this was due to the heat of the fire, the action of the water or chemical reaction is not known. The condition certainly did not help in keeping the fire under control.

This most recent dump fire should serve as an object lesson in many respects. It should point to the hazards of having the dump located in areas near or in line with living and working areas where toxic smokes and vapors can create an emergency condition. Even though we are presently short of dump space, it is poor policy to leave the dump uncovered for extended periods of time. If it is not practical to cover the trash with a light layer of dirt as a temporary measure before covering over any portion completely, it is suggested that the dump be wet down with large quantities of water at least twice a week until such a time as more adequate precautions can be taken."[25]

A result of the fire, there were no doubt many other changes besides the relocation of the central burial ground.

The following is from a February, 1963 U.S.G.S. report[8]: "The highest concentration of gross alpha in soil samples collected in June 1955 a short distance downgradient in the canyon south of the pit* was 48 disintegrations per minute per dry gram." There is no map showing the precise location of the sampling point.

*Area B

The USGS was asked to do a study of Area B in 1966 because "Expansion of laboratory facilities and increased growth of the community of Los Alamos has caused a re-evaluation of present land use to determine if the land is being utilized in the best possible way. It was proposed by the Los Alamos Scientific Laboratory and the U.S. Atomic Energy Commission that a portion of the filled-in contaminated waste pit, outside the radius of 1050 ft from TA-21 (an area approved for commercial property), be leveled, filled where necessary, and sealed with asphalt, and used for a storage area for trailers and boats.

It is thought that a seal of asphalt will prevent any contamination from reaching the surface of the storage area."[26] Thirteen test holes 25-50 ft deep were drilled around the perimeter of Area B (See Fig. 28). Moisture content of the soil and tuff penetrated by the test holes was determined by neutron scattering moisture probe. Samples of the drill cuttings were analyzed for gross alpha and gross beta-gamma, plutonium and uranium. The results of the study were reported in 1966 in Ref. 26 and Ref. 29. (See Table 11) The study concluded[26] "Distribution of moisture in five test holes indicated some lateral movement of water, probably from the contaminated waste pit. The amount of water moving through the tuff was well below the estimated effective porosity of the tuff. Radiochemical analyses of the soil and tuff from the test holes showed no indication of radioactive contamination. A much larger amount of water than occurs from precipitation would be required to move radioactive contaminants from the waste pit into the adjacent soil and tuff. An asphalt covering on the pit with adequate drainage would

prevent any movement of radioactive contaminants from the waste pit."[26]

"A beta gamma survey of the material waste pit* at TA-21 was conducted on September 16, 1966. Dose rate measurements were taken at a distance of twenty inches from the surface of the black topping with an Eberline Mod. E-112-B Geiger Counter. No appreciable reading above the normal background of 0.07 mr/hr was detected."[30] The accompanying map showed the survey was down the center of the storage area portion of Area B.

The November 10, 1971 asphalt was surveyed with alpha counter Ludlem Model 139 and beta-gamma counter model E-112-B. "No alpha contamination was detected, and the beta count was background."[28]

Before the recent resurfacing of the storage area in October 1973 samples of vegetation growing through cracks in the asphalt were collected by D. McCurdy, H-8 for analysis to determine whether any contamination is being drawn out of the soil by plants. At a later date more samples were collected by W. Hanson, H-8. To date, July, 1974, there is no information on these samples.

CONCLUSIONS

Area B is the first burial ground at the Laboratory. It is not one large pit as depicted on engineering drawings, but a series of pits which were in use from 1944 until 1948. Early records on disposal have not been located. Records in LA notebooks #1743 (January 6, 1947 thru November 23, 1948) and #2587 (November 24, 1948 thru April 28, 1950) were not available for examination. Available information does not indicate any of the pits were inspected geological

*Area B

RECOMMENDATIONS

1. Area B should have an identification sign.
2. Contamination warning signs are faded and should be replaced.
3. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.

   The geology of Area B should be tied in to the geology of Area T and Area A to the east on the same mesa.
4. Vegetative mapping should be done.

   Since Area B has been abandoned a little more than 25 years, there is the opportunity for studies which could indicate what LASL should expect in current burial grounds some years in the future.

AREA C

INTRODUCTION

Area C is located on Pajarito Road (See Fig. 29). To the north of it is TA-50, to the west is Pecos Drive, and to the south is Pajarito Road. It is defined by the following coordinates beginning with the northeast point and moving in a clockwise direction: N.28+93, E.101+05; N.26+70, E.100+79; N.26+74, E.100+43; N.24+55, E.100+18; N.25+36, E.93+23; N.27+37, E.89+31; N.28+64, E.87+52; and N.30+36, E.88+52. Its location can also be given using township and range as on the mesa in the E 1/2 sec. 22, T.19 N., R.6 E.[8] The approximate acerage for Area C is 11.80.[33]

Seven days after the May 3, 1948 fire in Area B, a memo[86] stated "On May 6, 1948 we forwarded an X priority #153078 to the Zia company signed by Mr. Dittmar for the construction of a new contaminated dump. The work of digging the ditch commenced Friday morning, May 7th, and was continued through Saturday, May 8th. Work is being resumed this morning, Sunday work having been skipped.

The location for this new contaminated dump has been agreed to by authorized Safety and Health personnel and by CMR Division. Since it is located near the junction of the Alpha Site Road and the Pajarito Road, we are for record purposes considering it as part of the Alpha Site installation." Reportedly, the location of Area C was the first envolvement of the U.S.G.S. in disposal site approval (personal commun. from Dean Meyer).

Pit 1 was put in use ~~sometime between May and November, 1948.~~ June 10, 1948.* [23] June 14, 1949,[12] it was reported "the present dump** has been in use for one year and during that time we have filled one pit. We are now using the last pit and it should last until June 1950."[12] The "last pit" referred to in the previous quote could be Pit 2, Pit 3 or Pit 4. Pits 2 and 3 show use dates from April 1950 through April 1953.[23] Pit 4 shows a use date from April 1950 through February 1955.[23] Pit 5 shows a use date from April 1953[23] through November or December, 1964.[72,73] Pit 6 shows a use date from February 1956 through August 1959.[56] The chemical pit was probably dug in the first part of 1960:[87] and closed out in the summer of 1964. in the second quarter of 1957 Area C had been located and Pit 1 had been dug.[53] Twelve shafts were dug in Area C from February 28, 1958 through October 29, 1959. (Written commun. from John Enders, H-8). The first shafts were for the use of the CMB-DO-GS better known as the CMB dogs. These first twelve shafts are numbered 56 through 67.***By the third quarter of 1959 an additional 55 shafts were ordered dug.[56] These shafts are numbered 1-55. Twenty new shafts numbered 68-87 were dug the last half of 1962.[65] During the first quarter of 1964 an additional 20 shafts numbered 88-107 were dug.[70] In an April 23, 1965 memo[74] the statement appears: "It is understood that when these new shafts are all filled no new wells will be drilled in this Area." Table 12 shows the use dates for the 107 shafts in Area C.

The history of Area C extends from May 7, 1948, the date the first pit was started, through April 8, 1974*, the date the last shaft was filled and plugged with concrete. It is sometimes felt the last routine radioactive contaminated waste placed in Area C, December 1958[54] marks the closing of Area C and the opening of Area G. Neither idea is true. Area G pits had received non-routine radioactive waste before that date and Area C pits continued to receive non-routine radioactive

*Written commun. from John Enders, H-8. ** Area C

***The shafts were renumbered by S.E. Russo, Eng.-3 on November 20, 1962. (Written commun. from John Enders, H-8)

*Written commun. from John Enders, H-8.

contaminated waste until ~~PH~~6 was filled August 1959[56] and ~~PH~~5 was filled November or December 1964.[72,73] Since quarterly and annual reports on solid radioactive waste disposal fail to mention Area C after 1968, it can be assumed the area was not in regular use past 1968. The plugging of the last shaft, #89, in Area C April 8, 1974 would seem to indicate the formal closing of the area.

GEOLOGY AND HYDROLOGY

The mesa at Area C slopes gently eastward. Canyons approximately 1000 feet (304.8m) north and south of the area are 100-150 feet (30.5-45.7m) deep.[8] Ten-Site Canyon heads immediately northeast of the area about 150 feet (45.7m) north of Pit 5. The soil covering is approximately 3 to 5 feet (.9 to 1.5m) thick[8] above the Tshirege member[91] of the Bandelier tuff. There are two prominent nearly vertical joint sets which intersect at approximately 60°.[91] Most major joints are filled with sediments or altered material to a depth of approximately 10 feet (3.0m)[91] and spaced 10 feet (3.0m) apart.[8] All of the pits[91] and probably all of the shafts are dug in the Tshirege member.

"The soil cover on the surface of the mesa prevents most of the water on the surface from infiltrating underlying tuff. Where the soil has been removed or disturbed, water might infiltrate the underlying tuff and open joints in the tuff. Beneath the soil there is about 850 feet of the Bandelier tuff which consists of a series of ash fall and ash flows of a friable to welded rhyolite tuff. This tuff is underlain by about 575 feet of volcanic debris of the Puye Conglomerate. The main zone of saturation occurs in the Puye at a depth of about 1300 feet. Perched water may occur above the main zone of saturation, although none was encountered in test well 8 located 1.5 miles northeast of Area C."[92]

TYPE OF WASTE

Records of solid radioactive waste going into Area C can be found in LA notebooks #2587, 3478, 4644, 6030, 7277, 8453,

9293, 9593, and 12442.[23] These notebooks are used to log information on type, date, location, and volume of waste placed in the disposal area. "...records prior to 1954 are incomplete."[8]

The following values[32] are decayed corrected from original magnitude to that as of December 31, 1972. In the disposal pits of Area C there are 25 Ci of uranium which includes isotopes 234, 235, 236 and 238, 22 Ci of plutonium-239 and 149 Ci of americium-241. In the shafts of Area C there are 1400 Ci of tritium, 40 Ci sodium-22, 20 Ci of cobalt-60, 31 Ci of strontium-90-yttrium-90, 1 Ci of radium-226, 5 Ci uranium-233, .05 Ci of uranium-235, 50 Ci of fission products, and 250 Ci of induced activity. Total number of curies for the pits is 196 and total number of curies for the shafts is 1797.05.

An earlier report[134] listed the following figures for Area C: D-38 — 34,445 lbs.; ^{238}U — 0gms; ^{235}U — 13,853 gms; ^{239}Pu — 2,063 gms; ^{233}U — 1,467 gms: and ^{3}H — 10 gms (for Areas C & G which was based on estimated curies and 9,600 Ci ≅ 1 gm ^{3}H).

During the pit history of Area C hazardous chemicals and non-contaminated classified materials were buried with radioactive contaminated materials. Routine radioactive contaminated trash for the period consisted of cardboard boxes 13 in. x 13 in. x 24 in. (33cmx33cmx61cm), and 5 mil plastic bags, 13in.x24in. (33cmx61cm) and 40in.x24in. (256cmx61cm) of material generated in the Chem Labs; and 55 gal. (.20m^{3}) barrels of sludge from the waste treatment plants at Building 35 DP West, and at TA-45. Non-routine contaminated waste included debris from the demolition of Bayo Site and TA-1, classified materials, and TU chips from the shops.

It seems appropriate to comment on the establishment of the Hazardous Chemical Area in Area C. As pit use was phasing out in Area C and beginning in Area G, the idea of separate disposal for hazardous non-radioactive chemicals (which were responsible through the years for most of the fires in the disposal area) was accepted. There is no indication[54],

Pit 6, Area C was dedicated, at any time during its history, to the exclusive disposal of hazardous non-radioactive chemicals. A memo[87] dated November 12, 1959 suggests it was ~~prepared~~ proposed to use part of Pit 6 for the "permanent chemical disposal area;" but another memo[56] dated November 2, 1959 states covering of Pit 6 to ground level began September 24th and finished Oct. 2nd. Apparently the Chemical Pit, south of Pit 6, was dug in early 1960.[87]

"A brief review of the use of this pit shows that a variety of chemicals, pyrophoric metals, hydrides and powders, sealed vessels containing sodium-potassium alloy or compressed gases, and equipment not suitable for salvage, public dump or the contaminated dump have been placed in the pit. No high explosives have ever been disposed of in this pit. Normal uranium powders and hydrides have been disposed of in this pit. Inadvertently some plutonium contaminated objects were placed in the pit but have long since been covered. Because of the uranium disposed it should be assumed that the pit is mildly alpha contaminated."[90]

The hazardous Chemical Disposal Area was fenced off from the rest of Area C and the fence remains in place today, July 1974.

When the Hazardous Chemical Disposal Area was closed out in Area C it moved to Area L, Mesita del Buey.

Another disposal practice, disposing of non-radioactive classified waste with contaminated waste, was under discussion about the same time as separate disposal for non-radioactive hazardous chemicals.

"It was rather disappointing to learn during the course of our inquiries on this matter that, despite the general agreement some two years ago*, burial in contaminated pits would essentially be a last resort method of disposing of classified waste, nevertheless, a substantial part of the capacity of the existing pit** in Area C has been taken up with materials which are not contaminated, not of obvious security interest, and which it would seem could be disposed of by some other method. For example, I*** am informed that

*1957
**Probably Pit 6
***Philip F. Belcher, Assistant Director for Classification and Security

something more than seventy yards has been taken up by Security Branch, LAAO, for the dumping ~~*1957 **probably Pit 6~~ of technical area badges. It would seem to me that badges can be chopped up and disposed of in some other manner. I will concede that it perhaps is a tedious job, but in view of the fact that we have only a limited amount of real estate for disposal of classified waste it does not seem to me proper to dispose of badges by burial simply because it is easiest.

By the same token it appears that there have been large quantities of safety film from various Laboratory operations placed in the contaminated pits at Area C. Again, it would seem that there must be alternate methods of disposing of safety film which would not involve using up the limited space available in contaminated waste disposal dumps."[185]

Eventually, Area H, Mesita del Buey, was designated as the non-radioactive classified waste disposal area.

Originally the shafts in Area C were dug for the disposal of beta gamma active waste by the CMB-DO-GS at Ten Site. Shafts were to be used by many other groups for disposal and storage. See Appendix I for a listing of the contents of the 107 shafts in Area C.

MODE OF DISPOSAL

Pits #1-4 are located in the southwest quarter of the area. See Figure 29. These Pits are 610' (185.9m) long by 40' (12.2m) wide. On Engineering Drawing ENG-R1264 it is stated these are scaled dimensions. Apparently the Engineering Department was neither asked to stake these pits before dug nor asked to survey these pits while open since they seem to have no record of it. Pit #5, located to the north of Pits 1-4, is 110 feet (33.5m) wide by 705' (214.9m) long and has a maximum depth of approximately 18' (5.5m). Pit 6, in the northwest quarter of Area C, is 100 feet (30.5m) wide by 505 feet (153.9m) long with a maximum depth of approximately 23 feet (7.0m). The chemical pit is 25' (7.6m) wide by approximately 180 feet (54.9m) long and may be 12 feet[87] (3.7m) deep. Numbers on

the 107 disposal shafts in Area C do not reflect their use date or excavation date.

The first shafts #56-67 are located between Pit #4 and Pit #5; they are numbered from west to east. The next shafts, #1-55, are between Pit #1 and Pit #3; they are numbered from east to west. They were followed by Shafts #68-107 which run north-south immediately past the western ends of Pit #1-4. Shafts #98-107 parallel shafts #68-97; they are numbered from south to north. Shafts #68 and #98 are 20 feet (6.1m) from the southwest fence of Area C.

The shafts are located on 7 ~~feet~~ 6 inches (2.3m) centers. Like the pits they vary in size and depth. Shafts #56-67 are 2 feet (.6m) in diam by 10 feet (3.0m) deep.[54] Shafts #1-55 are 2 feet (.6m) in diam by 15 feet (4.6m) deep.[56] Shafts #68-107 include both 3 feet (.9m) diam 12 in (30.5cm) thick concrete-lined (.3m) shafts as well as 2 feet (.3m) diam shafts. Ten of the last 20 shafts are concrete lined. In this series of shafts, #68-107, the depth ~~may vary~~ varies from 20 feet (6.1m) to ~~60~~ 25 feet (~~18.3m~~).[8]

A strontium-90 disposal shaft, no number, is located a few feet from the corner of the south fence designated by coordinates N.25+36, E.93+23.

The fence which runs north - northeast across the western half of Area C was erected to end confusion over which part of Area C was used for radioactive contaminated waste disposal and which part was used for hazardous chemical disposal. (Personal communication from John Enders) At the time the fence was erected it was common practice for hazardous chemicals to be placed in the chemical disposal pit and then burned. Frequently John Enders received telephone calls informing him the contaminated dump was on fire. Therefore, the fence was erected to end the confusion of what was on fire.

"A meeting was held on December 28, 1950, concerning the contaminated dump. It was decided at that time that H-1 Monitoring would be responsible for Rad-Safety of all persons

entering the dump commencing January 5, 1951.

Our responsibilities are as follows:

1. Furnish full protective clothing including respirator to George Yates, Zia Co., who covers the trash every Friday. Yates has to be monitored after each job and nose swipes taken. He is scheduled for routine Health Pass test. By copy of this memo I'm* requesting that Glenn Vogt write monthly work orders to cover the bulldozer work. The maintenance man of D-Bldg. formerly took care of this detail.
2. H-1 Monitoring will be notified, upon arrival of highly active beta-gamma contaminates requiring a knowledge of tolerance times. We will also be notified upon arrival of hot filters from D.P. Site. This advance information will assist us in case of fire for which we are responsible.
3. Film badges and pocket chambers should be issued in cases of high beta-gamma activity.

CMR - Safety and CMR-12 will continue to dump chemicals in the proper place and contaminated items in another. Dean Meyer has stated that if at any time we feel that things are not dumped where we think they should, to contact him."[186]

John Enders, February 5, 1957, memo - COVERING CONTAMINATED TRASH AT CONTAMINATED DUMP,[110] reflects some changes. "It is my understanding that the dump** was formerly covered once per week. This was done at a time when trash was piled into the Dump and covering once per week was a means of reducing the danger of fire.

At present, it seems that the Dump is covered whenever: (a) requested by Eng-4, (b) when there is a slack period for Zia Roads Section. After talking to Mr. Anglin and Mr. Raper of the Zia Roads Section, I find that they point out that

*Carl Buckland

**Dump refers to a single pit.

the more frequent the covering, more fill dirt is used.

At present, the trash is placed into the Dump in single layers of boxes, etc., which cover about one half of the width of the Dump. The fire hazard is reduced because the fire department's efforts to extinguish a fire in a single layer should be successful.

Therefore, I am suggesting that the routine dump covering operation should be done only after a single layer of trash is placed into the Dump - the width of the layer to be about one-half the width of the Dump."[110]

In 1956[52] collection of "trash" from laboratories was done in the following way. Zia janitors removed "trash" from "lab hot waste cans" and put the "trash" into cardboard boxes. The boxes were then sealed and set outside the building for pickup by truck. June 27, 1957,[53] Dempster Dumpster boxes were delivered to Wings 2 and 4 of the CMR Building. "It is planned to put boxed contaminated trash in these boxes and deliver the filled boxes to the Dump."[53] (See Figure 31) By the end of 1957[95] Dempster Dumpster boxes were also placed at TA-2 (Omega Site) and TA-35 (Ten Site). At the start of the third quarter of 1958[98] Dempster Dumpster boxes were put into service at nearly all Laboratory Sites where radioactive trash was picked up. All Dempster Dumpster boxes were painted on the interior and the doors marked "For Radioactive Trash Only." "A yellow band was painted around the top of the box with black wording designating the site location of the box."[97]

During the third quarter of 1957[94] a trial use of 5 mil thick plastic bags began. The bags were not placed[21] into card board boxes before being taken to the burial ground. Waste during this time was not covered weekly. To demonstrate differences in weathering a cardboard box and a plastic bag containing laboratory waste were marked with the date and left exposed in the burial pit for approximately 3 months. Figure 30 shows the difference in weathering. The cardboard box had weathered considerably and had broken open. The plastic

bag was still intact.

The following excerpt is from the Annual Report For 1958 on Disposal Of Contaminated Solid Waste.[54] "At the CMR-Bldg. and at Sigma Bldg. loose office and change room trash is now being packaged in plastic bags. Seven six bushel capacity trash dollies have been purchased for this operation. 5 mil (thickness) 40" x 24" plastic bags are used as liners for the trash dollies. When these bags are filled they are sealed with masking tape and placed into the Dempster Dumpster containers. It is estimated that one plastic bag will hold more trash than four or five 13" x 13" x 24" cardboard boxes. The time spent by Zia Janitors in preparing the bags, filling and sealing them is about one-half that needed to do the same operation using cardboard boxes. It has been observed that these bags are more easily emptied at the disposal pit from the Dempster Dumpster containers than are the cardboard boxes which have a tendency to hang up inside the containers. At the disposal pit the bags also withstand the effects of weathering much better than the cardboard boxes.

Prior to putting the trash dollies into use, the plastic bags used in the labs for holding contaminated trash were 2 mil thick. The bags were removed, sealed, and placed into cardboard boxes. After the trash dolly system was started, these bags are also being placed into the trash dolly and because of this it was felt that an additional safety factor would be needed so 5 mil thick bags were issued as liners for the trash cans in the laboratories."[54]

The 1959 Annual Report[57] states: "Cardboard boxes located in the utility corridors of the CMR Bldg. laboratory wings are being replaced with metal cans provided with a plastic bag liner. The changeover was made in order to provide a more fireproof container for solid radioactive waste."[57]

Trucks were still in use to haul 55 gal. ($.2m^3$) sludge drums from the waste treatment plants at TA-45 and TA-21 to Area C at the end of 1958.[54] (See Figure 32) In March. 1959,

Dempster Dumpster trucks using skip-type containers began to haul the sludge drums to the burial ground.[57] Trucks continued to be used to haul non-routine contaminated waste to the disposal area.

Early shaft disposal was described in the Annual Report For 1958 on Disposal of Contaminated Solid Waste.[54]

"At infrequent intervals, CMB-DO-GS group at Ten site has beta-gamma active waste material that must be buried. In the past the material was taken to the Disposal Pit where a hole was dug into the ground and the material thrown into the hole and covered with dirt. In February, 1958, an order was submitted to have a dozen holes drilled measuring 2 feet in diameter and about 10 feet deep. The holes were located between Pits 4 and 5, Area C. These holes are now being used for disposal of the gamma active waste from Ten Site. Space* is available at this location for at least 30 to 50 more holes for future disposal.

The technique used by CMB-DO-GS for handling this waste is briefly as follows: (1) the material to be thrown away is evaporated to dryness in a hot cell at Ten Site and then placed inside a Dural container. This container is then sealed and placed inside a steel container which is in turn sealed. (2) The steel container is then removed from the hot cell and placed into a lead transfer case which is thick enough to handle up to 40 curies of material. (3) The transfer case is positioned on the back of a 1½ ton truck and fastened securely with a chain. (4) The truck is then driven to the disposal area and positioned above one of the holes. (5) A tripod with a long boom arm attached is used to transfer the material from the transport case to the hole. The steel container is pulled up out of the case by means of a string to which is attached a rope that runs through a pulley on the end of the boom. When the container is over the hole, the string is cut and a few shovels of dirt are shoveled on top of the container so as to reduce the gamma radiation at ground

*More shafts were not drilled because it was not possible to drive any further east along the border between Pits 4 and 5. (Written commun. from John Enders, H-8.)

level to less than 1 mr/hr."[54]

A modification of the procedure was reported in the Annual Report For 1959 On Disposal of Solid Radioactive Waste.[57] This year 10-Site personnel modified the equipment used for containing and shielding their waste material during transit to the disposal area. This modification included an improved container and a tuballoy cask that is provided with a trap door in the bottom that permits dropping the waste material (sealed in the canister) from the cask directly into the disposal well through a hole in the truck bed. This design improvement has permitted handling of wastes that range up to 400 curies of activity with very little personnel exposure. CMB 11 (DP-West) has plans to use this equipment when possible for their waste disposal from the hot cells."[57]

Permanent markers, metal stakes with numbered tags, were placed by each shaft in 1959.[57] Deliveries to any shaft were logged.[57] In 1961[62] "metal covers were fabricated and installed over the "active" disposal wells and wood covers were obtained for use on unused wells. At each corner of the wooden covers metal stakes have been located so as to prevent movement of the covers."

In 1967 John Enders proposed that H-1 seal the disposal shafts.[111]

"Often it is highly desirable for radiation safety and/or security reasons (or both) to seal items placed in the shafts immediately with concrete. It is now standard practice to seal filled disposal shafts with concrete.

The current procedure of obtaining Ready-Mix cement for the above operations is to (1) write a memo to Eng-4, through H-1 Group office, requesting the work to be done, (2) Eng-4, upon receiving the memo, may or may not issue a work order, apparently depending on whether Eng-4 thinks the request is necessary or not. There have been instances where the H-1 Group office has had to repeat the request and by the time the Ready-Mix finally arrives there has been a time lag of (in some cases) several months.

The simple logistics of the operation are also involved in that the Ready-Mix truck, Eng-4 representative, H-1 representative all need to be at the Area at the same time -- and this has also been difficult at times. In the event of an "emergency delivery" it would be almost impossible to schedule delivery of Ready-Mix to the disposal shaft."[111]

Enders proposal to purchase a small cement mixer, some cement and one wheelbarrow so that H-1 could do the job themselves was accepted. (Written commun. from John Enders, H-8)

"While burial of contaminated waste was the method of disposal, it was recognized that other ideas should be investigated. Dr. Jette decided that sea burial should be considered. A number of large steel containers was fabricated with gasketed lids and sea cocks. These were used for a period of time; however, when they were filled, the cost of transportation and fabrication of more boxes was so high that the idea was dropped and the full boxes were placed in pits in Area C."[108]

In 1961[62] six Standard Operating Procedures were prepared on waste disposal operations. Three additional S.O.P. were written to cover non-routine disposal operations.

APPEARANCE OF SITE

Area C is fenced with 8 feet (2.4m) cyclone fence, topped by barbed wire. An identification sign and contamination signs are hung on the fence. There are four gates. Two are off of Pajarito Road and lead into the eastern two-thirds of the area; one is located at the eastern end of Pit 5 along the east fence; one is off of Pecos Drive and leads into the western one third of the area once dedicated to hazardous chemical disposal and the present site of the meteorological tower. There are depressions in the Area where settling has taken place. Grass and clover are thick across the Area.

STUDIES AND MONITORING

There are reports of three fires at Area C. The first took place at 8:35 AM, November 7, 1950.[187] "An air sample was taken with the hand air sampler. Its negative results were reported to headquarters. There was no detectable beta

or gamma in the pit or at its edge so two firemen, in full protective clothing and respirators, entered the area with hoses from the tanktruck which had just arrived. While steam was rising from the fire, a second air sample was taken in the steam and smoke cloud. It too was found to be negative. The fire was brought under control using two tank trucks full of water."[187] Individuals were monitored and had nose swipes taken. The second fire occurred at 4:25 PM, March 24, 1953.[188] The burial ground had been checked at approximately 3:00 PM, when the crew left after the last delivery. Charles Blackwell and James Oakes were sent to investigate smoke coming from the burial ground. "Upon arriving at the dump we discovered a fire that had burned itself out with the exception of several barrels of paraffin which were boiling and burning to a small extent.... Two 5-gallon cans of foam were used to completely blanket the fire, and it was completely out by 5:25 PM. The wind was from the west and brisk, so that smoke was carried east and traveled a path between Ten-Site and Beta Site... The dry box from the Omega Fast Reactor, which had been placed in the dump on March 23, 1953, had been completely burned, leaving only the steel frame. The dump had last been covered on March 20, 1953, so that the results of only 2-days hauling was exposed to the fire. No one could determine the cause of the fire, but it was generally believed to have been caused by chemicals being accidentally placed in the boxes with some of the trash. A survey was made around the dump on the morning of March 25, 1953, to check for possible contamination from the smoke. The area east of the pit and parts of the canyon from Beta Site to Ten Site was checked, but no trace of contamination could be found. Any contamination that may have gotten into the air was well diluted and carried away rather than being deposited in the vicinity."[188]

The third fire took place November 28, 1958, in Pit #6.[189] Two boxes found burning during a covering operation. It is suspected a volatile, flammable chemical was involved, as

near the boxes. I* found a flask that possible had been used to hold acetone."[189]

The U.S.G.S. did an infiltration study north of Pecos Drive* near Area C. Two[51] infiltration pits, Pit A and Pit B, 2 feet (.6m) in diameter by 1 foot (.3m) deep were constructed during September, 1956.[190]

The 1958 study, which seems to have been conducted September through October, used Pit A. Pit A had 3 access tubes spaced 2 feet (.6m) apart with access tube #2 centered in the pit.[51] "Cores for natural moisture-content determination were collected at the site on Oct. 10, 1958."[51] Water supply was intermittent during the 1958 study.[51] It is difficult to determine precisely how the 1958 study was conducted from Abrahams (1963)[51] report of it. Data are shown in Figure 33.

The 1959-1960 study, September 21, 1959,-September 2, 1960,[190] used Pit B.[51] "The high moisture content beneath the pit before infiltration started was due in part to heavy rains in August, 1959 and the relatively poor drainage in the sandy surface soil."[51] (See Figure 34) "The soil is similar to that on Frijoles Mesa; it is about 6 feet thick and is underlain by welded tuff. The area is moderately well drained. A test-hole 20 feet deep was drilled in the center of the infiltration pit and a 2-inch plastic pipe was installed so that it projected about 1 foot above the pit. Soil and tuff were packed around the casing to prevent seepage down alongside the casing. Moisture measurements were made prior to application of water. Water was introduced into the pit and a constant head maintained at three-quarters of a foot for 99 days.

The wetted front (figure 339.3)* moved to a depth of about 4½ feet during the first 2 days of infiltration and to a depth of about 6½ feet during the next 97 days, but water did not move through the transition zone into the tuff, except in the lower moisture range. The moisture content decreased with depth from a maximum of about 38 percent in B zone of the soil to less than 4 percent within a foot of the surface of

*John Enders
*Personal commun. from W. D. Purtymun
*See Figure 34

the tuff.

Water apparently was perched on the C zone of the soil and the moisture content within the B zone approached saturation. After the first several days of infiltration, most movement of water probably was lateral, as indicated by measurements in a series of holes around another infiltration pit* nearby. Some water undoubtedly was lost by evaporation and transpiration.

Although the quantity of water used during the study was equivalent to almost 50 years of precipitation on the Pajarito Plateau, the moisture content in the A and B zones had returned to nearly normal after 8 months of drainage; the moisture content in the C zone and top 2 feet of tuff was slightly higher than before the experiment, and the moisture content of tuff between 8 and 20 feet was unchanged. However, conditions during this study cannot be considered normal because the clogging or silting of pores probably was greatly accelerated when this volume of water moved into the soil within a period of 99 days without the normal seasonal distribution which involves alternate percolation and drainage."[190]

The 1960-1961 study, September 2, 1960, through October 2, 1961, used Pit B. No water infiltrated the pit other than precipitation. "The May 19, 1961, measurements were high because of snowmelt, and the October 2, 1961, measurements were low because of low precipitation."[51] (See Figure 34)

"The fact that water did not penetrate the dense transition zone between the soil and tuff during the study or in the following year* indicates that the soil cover will impede vertical movement into the underlying tuff. Capillary rise, evaporation, and transpiration were perhaps the principal reasons that the water did not penetrate the underlying tuff, rather than the low permeability of the transition zone."[51]

In 1962[92] Abrahams and Purtymun considered the question of 60 feet (18.3m) deep shafts at Area C. "There is no serious objection to the burial of radioactive waste in holes

*Pit A

*"The Study" is the 1959-1960 study. "The following year" is the 1960-1961 study.

60 feet deep at Area C, although several precautions should be taken. They are; (1) Solid wastes should be packaged for normal underground burial; (2) Liquids and sludges should be contained so no leakage occurs; (3) The soil zone on the mesa should be disturbed as little as possible near present and future waste disposal areas. After the holes are filled, the surface should be sealed with 2 to 3 feet of packed clayey soil; (4) Adequate erosion and drainage maintenance should be provided; (5) The holes should be drilled at least 100 feet from the edge of the mesa at Area C. The principal concern is to prevent water from carrying the radioactive materials to the underlying bodies of ground water."[92]

A fluid dynamic study was reported in progress by John, Enyart, and Purtymun, 1966.[29] The study was conducted across Ten Site Canyon from Area C. The study area was approximately 450 feet (137.2m) north of the east end of Pit 5, Area C. Eight holes were augered to study the behavior of gas injected into the rock; and twelve holes were augered to study the behavior of liquid injected into the rock. (See Figure 35 and Tables 13 and 14)

April 28, 1971[109] W. D. Purtymun, H-8, reported the results of test drilling and penetration tests in the west end of Area C. The purpose of the tests was to help establish the location for the meteorological tower. (See Figures 36; 37; 38 and 39) All cuttings were monitored by Robert Sandoval, H-1. "No radioactive contamination was detected."[109] "Tests at the 120 SW guy indicated that the location is underlain by a disposal pit, probably the chemical pit. No holes were drilled of the 240 N guy, 120 N guy or the 120 SE guy."[109] ~~I understand that Wayne Hanson,~~ Ecology Section, H-8 has some data on uptake of tritium by Clover in Area C.

CONCLUSIONS

As of April 8, 1974, Area C can be considered an inactive burial ground. Its history of use covers 26 years. Area C is

the first burial ground for which detailed records were kept. Available information does not indicate any geologic mapping of the site or any geological inspection of the pits.

RECOMMENDATIONS

1. The Area C identification sign and contaminations warning signs are faded and should be replaced.
2. a. Minimum:

   Depressions over pits should be filled to ground level.

   b. Maximum:

   Fill dirt should be mounded over pits.

   Request for fill dirt for Area C is at least 8 years old.[79]

   Recommendation 2 was made 11 years ago by the U.S.G.S. "The fill probably should be compacted and mounded to minimize erosion and ponding of water on its surface."[8]
3. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.
4. Vegetation covering Area C should be studied.

   No attempt to revegetate Area C was made; nevertheless, it developed a good cover in less than 10 years.

AREA D

INTRODUCTION

Area D is located at TA-33. (See Fig. 40) It is on a point formed by Ancho Canyon and White Rock Canyon of the Rio Grande. It is located between coordinates S. 287+50 and S. 282+50 and E. 310+00 and E. 305+00. The location by township and range is SW 1/4 20, T. 18 N., R. 7 E.[8] It is 1.8 miles (2.9 km) east of the guard station at TA-33.

Two underground chambers have been designated as Area D. Eng-3 memo[33] dated, May 23, 1967, states Area D is two open areas 20 by 30 feet (6.1 by 9.1 m). Underground chamber 1 is HP-4; underground chamber 2 is HP-6. An experiment had been detonated in chamber 1 before July 22, 1948.[191] Excavation of chamber 2 began August 25, 1948, and was completed September 5, 1948.[192] The experiment in chamber 2 was detonated at 9:00 P.M., December 23, 1948.[193]

GEOLOGY AND HYDROLOGY

Area D is located on the top of a mesa formed by Ancho Canyon and White Rock Canyon of the Rio Grande. The surface appears flat and is underlain by the Tshirege member of the Bandelier tuff. The soil cover is thin. The site is approximately 1000 feet (304.8 m) above the Rio Grande and about 800 feet (243.8 m) above the bottom of Ancho Canyon.

TYPE OF WASTE

According to a 1963 USGS report[8] these underground chambers were contaminated with explosives containing uranium-238. Charles D. Blackwell, H-1, (personal communication) says the chambers were contaminated by polonium and perhaps a trace amount of uranium. The general site may be contaminated by a trace amount of ^{60}Co from a fired projectile.*

MODE OF DISPOSAL

The Chamber 2 shaft was 6 feet x 8 feet (1.8 m x 2.4 m) with a depth of 46 feet (14.0 m).[194] It was completely shored with 2 in x 12 in (5.1 cm x 30.5 cm) timbers except for the corners which had 8 in x 8 in (20.3 cm x 20.3 cm)

*(Personal commun. from Dean Meyer)

timbers.[194] The octagon shaped chamber, 14 feet (4.3m) wide with a 12 ft. (3.7m) ceiling, extended southeast from the bottom of the shaft.[194] It was concrete reinforced with steel.[194] The door of the chamber "was made of steel plate and wood filled. The edges of the door were wedge-shaped, so that the more pressure applied on the door from within, the tighter the door would be closed. The door was secured by a steel latch 3/8" thick and 3" - 4" wide, operated by a handle on the outside of the door."[194] Chamber 1 was probably very similar in construction to Chamber 2.

No equipment in Chamber 2, except half of the hemisphere which had a count of approximately 1,000,000 c/m, was brought to the surface because of the high level of contamination.[194] "A table was placed in the center of the room* to support 600 lbs. of TNT. The TNT was so arranged that the center of the explosives would be six feet from the floor... Dwayne Vier supplied approximately 600 mc of Po in a vial which was placed in with the charge. The door was closed and equipment that was in the shaft only was brought to the surface and monitored.... On April 15, 1952, the shaft was refilled and a tank truck filled with water was on hand to wet down the sand as the shaft was being filled."[194] The shot was fired at approximately 11:15 A.M. on April 15, 1952.[194] "As the explosion came, a mass of dirt and debris reached an altitude of approximately 75 feet above the mesa. The dust was quickly carried away by the wind but the mesa was covered with coarse dirt and pieces of burned wood and some metal fragments... A crater over the shaft was formed to a depth of approximately 10 feet. The steel pipes, containing the cables were pulled loose from the wall and pushed over in the pit. The concrete block; where cables terminated, was turned over."[194]

There are no records which indicate Chamber 1 was disturbed after its experiment. Charles D. Blackwell, H-1, (personal communication at Area D, TA-33) identified Chamber 1 as the chamber which was excavated after the experiment, refilled, and closed with an explosive

*Chamber

charge; and Chamber 2, as the chamber which was left undisturbed. Chamber 2 may have been misidentified on later engineering drawings.

APPEARANCE OF SITE

Area D is not fenced and does not have an identification sign or contamination warning signs. Chamber 1, identified by a structure sign HP-4, has been covered by an earth barricade since at least June 7, 1956. Chamber 2 is identified by a structure sign as HP-6. There are bench marks set around Chamber 2. The eastern one is bench mark #541, coordinates S. 283+94.0, E. 307+11.8; the southern bench mark is #540, coordinates S. 284+26.9, E. 306+85.3; the western bench mark is #543, coordinates S. 284+04.7, E. 306+45.7; and the northern bench mark is #542, coordinates S. 283+73.8, E. 306+66.0. These bench marks surround a 21 ~~feet~~ (6.4 m) square cement pad. The eastern edge of the cement pad is broken with the broken block tilted at an angle of 45°. In front of the broken section is a low pile of debris favored by vegetation. Otherwise the vegetation around the concrete pad is in no way remarkable. The Area is grassy. There is juniper on the canyon rim to the north about 100 ft. (30.5 m).

STUDIES AND MONITORING

1. Chamber 1 was surveyed July 22, 1948.[191] "As per request, enclosed area directly over the vicinity of the elevator shaft to the first experiment at T.A. 33 was monitored this A.M. Results were negative. Area south of the fence was monitored also. Results negative. Both areas are therefore considered safe for entry."[191]

2. During the excavation of Chamber 2 monitoring work was carried out. "Monitoring operations by the monitoring section of H-Division started on August 26, 1948 and continued each day for eleven days through September 5, 1948. A monitor entered the shaft each morning and afternoon of each day checking approximately at intervals of about 2.5 feet of excavation. At the same time the rock and dirt removed from the

shaft were monitored and dirt sample taken and given to Morris Milligan of the Medical Lab for Polonium analysis. This was also done each morning and afternoon. . . .

During the entire monitoring no alpha activity was detected. Morris has the results on the dirt samples. Meter used - a Pee Wee Alpha survey."[192]

3. After the detonation of the experiment, December 23, 1948, in Chamber 2, the site was inspected. "On driving to the covered-in shaft, no cracks in the ground could be found. The entire area over the shaft was checked with an Alpha survey meter. The results were negative. The area was rechecked on December 29, 1948. Results were again negative. Snow and mud hampered a complete survey on this date."[195]

4. On April 7, 1952, the re-excavation of Chamber 2 began.[194] Before heavy equipment was placed over the shaft the ground was checked for contamination and found to have negligible. On April 8th, the sand was removed from the shaft by clam shell. As the sand was removed, it was surveyed for alpha contamination. The results were negative as was the survey of the shaft as the sand was removed.

"The first contamination to be found was on the steel box on the south side of the room. It had ruptured during the shot, leaving a crack about 1/4" wide. This box housed wiring from the room and was fed from the box to the surface by ~~the~~ three steel pipes. Approximately 8000 c/m was found on the steel box about four inches above where the seam had ruptured. The rest of the steel box had very little or no count. Contamination on the steel box would not rub off but seemed to be imbedded in the pores of the metal. The sand removed from the steel door was free of contamination but contamination in the amount of 15,000 c/m could be found along the top of the door where it fitted against the concrete. The door had a felt seal and some felt was hanging loose as a result of the blast, and this felt gave a reading of approximately 30,000 c/m".[194]

The door was ~~picked~~ open with two 50-ton jacks on April 11, 1952. "Only two personnel were permitted in the pit during the operation of opening the door and these were Laboratory personnel. They were equipped with full protective clothing, including Chemox masks, and plastic hoods over the head and shoulders. As the door was opened inch by inch, the area around the door was monitored and the count began to go up very rapidly. It was very damp around the room* and drops of water and white mold could be seen on all the ledges. Everyone had been very concerned about the dust problem when the room was entered, but with so much condensation on the concrete, the Po was sticking to the surface very well."[194]

The chamber "was covered with twisted metal and all the equipment was battered and tossed about the room. The rubble was from 1' to 2' high all over the room and our meter gave a reading of 200,000 + c/m on any equipment that was checked. Henry Petrzilka shot several pictures..."[194]

A path was cleared from the door to the center of the chamber where 600 lbs. of T.N.T. were placed on a table. "By this time**, *the surface in the room was beginning to dry out because of the presence of outside air and the level of detectable contamination had risin to 250,000 c/m."[194]

"During the entire operation, the area was visited by a large number of personnel that were interested in entering the shaft and some wanted to enter the room.* Most were discouraged from entering the shaft and all but essential personnel were discouraged in various ways from entering the room*."[194]

"On April 15, 1952, the shaft was refilled and a tank truck filled with water was on hand to wet down the sand as the shaft was being filled. This was to ~~retrieve~~ relieve the dust problem in case the shaft was to be re-excavated after the shot and if no contamination could be found on the surface. Three filter queens in the area near the shaft and one placed 1000 ft. away where personnel were to be located, were run for 1 hour

*Chamber
**April 12th

15 minutes before the shot to record a background for the area and for the filter queens. The filters were changed before shot time and filters run for 1 hour 9 minutes, being stopped 30 minutes after the shot was fired. All personnel, camera crew and firing crew were stationed outside the fence over 1000 feet from firing area and all personnel were issued a respirator. The camera crew was stationed at approximately 800 feet and firing crew 600 feet from firing area. These crews were issued assault masks equipped with ultra filters. The wind, at shot time, was blowing in the direction of observers, so the shot was held up for a few minutes. It was fired at approximately 11:15 A.M., on April 15, 1952, and the wind was blowing from northeast to southwest. As the explosion came, a mass of dirt and debris reached an altitude of approximately 75 feet above the mesa. The dust was quickly carried away by the wind but the mesa was covered with coarse dirt and pieces of burned wood and some metal fragments. Monitors approached the area about 15 minutes after shot time in full protective clothing. The area was free from radioactivity contamination until we reached the fenced area, where 2000 c/m was recorded. The dirt in the area showed a count of 20,000 c/m with bits of wood going as high as 200,000 c/m. Bits of twisted metal from the room* were found in the shot area. A crater over the shaft was formed to a depth of approximately 10 feet. The steel pipes, containing the cables were pulled loose from the wall and pushed over in the pit. The concrete block, where cables terminated, was turned over. Filter queens were covered with wet dirt, some going in the intake when the dirt cloud descended after the shot. Filters were recovered and returned to Tech Area for counting."[194]

The results of the filter queen samples are listed below:

"Background Samples for 1 hour 15 minutes before shot time on Filter Queens:

#1 West side 40' from shaft	10 c/m	.0012 c/m/L
#2 East side 40' from shaft	5 c/m	.0006 c/m/L
#3 South side 40' from shaft	0 c/m	.0 c/m/L

*Chamber

#4 Personnel area 1000 ft. from shaft	0 c/m	.0 c/m/L

Filter Queen Samples for 1 hour 9 minutes. During and after shot:

#1 West side	730 c/m	.0936 c/m/L
#2 East side 40" from shaft	460 c/m	.0590 c/m/L
#3 South side 40' from shaft	95 c/m	.0122 c/m/L
#4 Personnel area 1000 ft. from shaft (1 hr. 2 minutes)	10 c/m	.0014 c/m/L"[194]

9. A polonium analysis of soil samples was reported November 15, 1952.[195] Seven samples from Area D were analyzed. Sample A - 50,000 c/m/25 gm; Sample B - No Po; Sample C - 150 c/m/25 gm; Sample D - 25 c/m/25 gm; Sample E - 5 c/m/25 gm; Sample F - 5 c/m/25 gm, Sample G - No Po. See Figure 41 for sample location. These samples may have been centered around Chamber 2.

6. "On August 24, 1953, a contamination survey was made within the fenced-in area of Underground Chamber #2 at Hot Point at TA-33. This survey was made to establish the alpha contamination level within the area and results were to be used as a guide in determining the safety precautions to be used in clearing the area of debris, removing existing mounds of dirt, and filling the open pits so that the area could be made level for building purposes.

The surface of the ground showed no detectable alpha contamination, but some of the timbers in the area gave counts ranging up to 500 c/m. Some dirt was removed around the large open pit and soil at a depth of 2 feet gave a reading of 500 c/m.

The crater of Underground Chamber #2 appears to be large enough to hold all the contaminated dirt and all mounds of dirt found to be contaminated could be pushed directly into the crater. Then a layer of dirt free from contamination could be used to leave all exposed surfaces without detectable counts. The bulldozer operator should wear protective clothing, including a respirator, while the area is being leveled. Similar

protective measures should be taken in digging the ditch to lay the large pipe which will be placed approximately one foot underground. After the area has been leveled, another survey will be made to enable us to give clearance to the entire area, and future operations may be carried out in the ordinary manner used when working within any clean area."[104]

7. On October 21, 1953[196] the area around Chamber 2 was bulldozed. A radiaction survey was then made and the results were negative. "The contamination that had been in the area has been reduced by normal decay and some will be buried under a heavy layer of dirt in the area."[196]

8. A preliminary survey of local wind conditions with primary emphasis on terrain effects under relatively light wind conditions was reported May 2, 1955.[197] Area D is now referred to as the "New Area." "This area is located in the eastern portion of TA-33 and is surrounded on the south, east and north by relatively deep and rugged canyons. In addition there are two bunkers surrounding the firing pads. In this area the wind flow is much more complicated than that in Areas 6* and 7**, and may be summarized as:

1. During the early morning hours there will be downslope winds to the north, east and west into the surrounding canyons, with considerable shifting of winds on the point itself.
2. During the morning heating period there will be west-southwest flow in the southern section; east flow in the eastern section; southeast flow in the northern section.
3. With continued heating during the day, there will be a tendency for southwest flow over the area, however, it will have marked turbulent features in the general flow area.
4. The presence of the bunkers in the area will increase the turbulent nature of the flow during all periods of the day.

Conclusion: The flow in New Area, will be marked by turbulent eddies and erratic changes in direction. No equipment could be placed in a permanent fashion, because of an observed wind direction."[197]

CONCLUSION

If Area D is considered to be just the 2 underground chambers, there

*Probably Area K
** Probably Area E

is probably little if any radioactive contamination in the Area. Chamber 2 was contaminated by polonium and it is assumed Chamber 1 was likewise. (The available records do not support the idea of other radioactive contaminants) A minimim of 22 years have passed since any experimentation. The half-life of polonium is 138 days.

~~The flow in New Area will be marked by turbulent eddies and erratic changes in direction. No confidence could be placed in a persistence forecast of an observed wind direction."~~[197]

RECOMMENDATIONS

1. Area D should have an identification sign.
2. The definition of Area D should be evaluated, with a more thorough knowledge of past activities at "Hot Point", it might be desireable to broaden the definition.
3. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring.

Even though at this time, there appears to be no need for future monitoring; a better knowledge of past activities at "Hot Point" might indicate a need.

AREA E

INTRODUCTION

Area E is located at TA-33 1.2 miles (1.9 km) south of the guard station. (See Fig. 42) It is located between coordinates S292 + 50 and S295 + 00 and E250 + 00 and E245 + 00. Specifically, the coordinates of the fenced area in clockwise direction beginning with the northeast corner are: S292 + 96, E249 + 16; S294 + 36, E249 + 15; S294 + 35, E247 + 15; and S292 + 91, E247 + 16. Area E's location by township and range is SE 1/4 sec. 24, T. 18 N., # R. 6 E. It has an approximate acreage of 0.69.[33]

The history of Area E is not well known. Underground Chamber 3, TA-33-29, may have been used.[105] Pits 1 - 4 were used. It is not clear whether Pits 5 and 6 were used. Pit 1 was inactive July 1951*; Pit 2 was reported November 7, 1962[106] as open. Pit 3 was closed September 1951*; and Pit 4 was still active when Engineering Drawing ENG-R- 3644 was drawn in the sixties. A 1963 U.S.G.S. report[8] states that the area was used between 1949 ~~to~~ and 1955.

GEOLOGY AND HYDROLOGY

Area E lies on a point formed by Chaquehui Canyon and one of its tributaries. It is on the mesa approximately 400' feet above the bottom of the canyon. The surface of the mesa slopes gently to Chaquehui Canyon approximately 20 yards to the south of Area E.[8] The soil cover is very, very thin. It supports little or no vegetation. The joint pattern is variable and joints are not prominent or persistent.[8]

*Engineering Drawing ENG-R 3644

The Tshirege member of the Bandelier tuff crops out within a few feet of the burial ground.

TYPE OF WASTE

"Area E at TA-33 has been used as a storage area and for burial of low-level radioactive contaminated equipment."[106] The Area contains several hundred kg of uranium-238.[8] Another source[108] also states the burial pits contain ^{238}U and ^{238}U alloys.

If Chamber 3, HP-29, was used, it is contaminated by the device which was fired in it. Pit 1 contains LC, LE and miscellaneous pollonium-beryllium fired targets with total curie count of 240.* Pit 2 contains Wally with a curie count of 60.* Pit 3 contains a GI can of beryllium dust immersed in kerosene.* Pit 4 contains button and miscellaneous hot material.* There is no information available on the contents of Pit 5 or Pit 6.

MODE OF DISPOSAL

Chamber 3, HP-29, is probably constructed similarly to Chamber 2, HP-6, at Area D. It has been back-filled. Underground chambers, HP-70 and HP-71, are north of the Area E fence. These chambers were not used and remain open today. Chamber 3 was either back-filled as a safety precaution or it was used.

The pits are probably shallow. The USGS reported in 1963[8] there were 4 pits each 6-7'deep. Pit 1, located along the west fence line, is approximately 19 ft(5.8 m) wide and 78 ft (23.8 m) long. Pit 2, located along the south fence line, is approximately 19 ft (5.8 m) wide and 56 ft (17.1 m) long. Pit 3, located near the southeast corner, is approximately 5 ft (1.5 m) in diameter. Pit 4, located

*Engineering Drawing ENG-R 3644

along the east fence line, is approximately 19 ft (5.8 m) wide and 125 ft (38.1 m) long. Pit 5 and Pit 6 intersect. They are located west and north of Pit 4. Pit 5 is approximately 12 ft (3.7 m) wide and 100 ft (30.5 m) long. Pit 6 is approximately 12 ft (3.7 m) wide and 75 ft (22.9 m) long.

APPEARANCE OF SITE

Area E has a barbed wire in good repair. The gate in the northwest corner is locked. Radiation signs are attached to the fence. The only clearly identifiable feature in the Area is Chamber 3 which is covered by a concrete pad. Vegetation seems to favor the edge of the concrete pad. Ten feet (3.0 m) from the pad bedrock is exposed. The west pit, Pit 1, may be partially marked by iron rods which have a welded loop at the top. Rubble against the south fence obscures the outline of Pit 2 and Pit 3. Rubble of a much coarser nature appears along the east fence. It offers some indication of the outline of Pit 4. The outlines of Pit 5 and Pit 6 are not discernable.

STUDIES AND MONITORING

February 28, 1952[198] two 50 gms soil samples were taken from Chaquehui Canyon west of Area E. They were analyzed for polonium. The approximate values for both in counts per minute (50% geometry) were 100.

The analysis soil samples (H thru M on Fig. 41) was reported November 15, 1952.[195] Samples L and M were probably taken in the same place as the February 28th samples. The analysis was for polonium. Sample L had 22 c/m/25 gm; and Sample M had 17 c/m/25 gm. Samples H thru K showed no polonium.

A fire was reported early in the morning of April 15, 1953 in Pit 4 at Area E.[199] Shortly after 8:00 a.m. H-Division, W-3 and Fire Department personnel arrived. "It was apparent that some oily rags covered with loose earth were smouldering and causing small quantities of smoke to rise. The Fire Department was then called in to flood the small smouldering portion of the pit with water. Respirators and coveralls were worn during the initial inspection and water application."[199]

On April 20, 1954[200] soil samples were collected for uranium analysis by the fluorophotometric method. "New Hot Point" on Fig.43 probably includes Area E. The results[200] were:

Field Sample No.	Vol. Sample Analyzed	Result
1	25 ml.	1975 megs/sample
2	"	850 " "
3	"	950 " "
4	"	200 " "
5	"	3750 " "
6	"	625 " "
7	"	35 " "
8	"	1050 " "
9	"	1050 " "
10	"	180 " "
11	"	57.5 " "
12	"	130 " "
13	"	152.5 " "
14	"	25 " "
15	"	22.7 " "

A preliminary survey of local wind conditions with primary emphasis on terrain effects under relatively light wind conditions was reported May 2, 1955.[197] Area E is referred to as Burial Area 7. "This area is located on the west rim of a canyon oriented generally north-south and opening to the south. The following are the successive wind conditions which should prevail in this area.

1. During the early morning hours a local north wind will prevail in the canyon, with a resulting north-northwest to northwest wind flow on the west rim of the canyon.

2. Within a few hours after sunrise the local heating will cause a reversal fo the canyon wind to a southerly wind. During the period of shifting winds in the forenoon, the flow on the west rim will shift from northwest to northeast, to south to south-southwest.

3. Continued heating throughout the day will result in increased and persistent southerly flow up the canyon and a resulting persistent south-southwest wind on the west rim of the canyon. This flow will persist until after sundown.

Conclusion: Dominant flow in Burial Area during the major part of the afternoon will be from the south-southwest. These conditions will be fairly persistent and a high degree of confidence could be placed in continuation of an observed direction of flow."[197]

In 1962[106] Dean Meyer observed: "At the time of our inspection, the area was enclosed with a three-strand barbed-wire fence, with

six signs on the fence indicating that the area is contaminated. The gate was open and the area is becoming a junk yard." Meyer suggested: "(1) The gate should be repaired and kept locked. (2) New signs should be placed on the fence, one on each side. The signs should read "contaminated area - do not enter," and should use the radiation symbol and radiation colors. (3) The open pit* on the south side of the area is full and should be covered with at least two feet of dirt. (4) The material in the area should be monitored, and if not needed it should be sent to the contaminated waste disposal area on Mesita del Buey. If the material is of value it should be sent to decontamination...and (5) The wooden building just outside the gate should be cleaned out and monitored."[106]

A 1963 U.S.G.S. report[8] stated "The fill probably should be compacted and mounded to minimize erosion and ponding of water around the pits."

CONCLUSIONS

Dean Meyer's 1962 recommendations[106] seem to have been carried out. The gate is locked. The fence is in good repair. The pits are all closed. In fact, they have been practically obliterated. Detailed records of the waste materials have not been found; therefore, knowledge of the radioactive contaminants is vague.

---

*Pit 2

RECOMMENDATIONS

1. Area E should have an identification sign.
2. Contamination warning signs are faded and should be replaced.
3. Continued effort should be made to discover the contents of the pits and whether Chamber 3 was fired.
4. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.

AREA F

INTRODUCTION

Area F is located on Two Mile Mesa Road 1.3 miles east of the intersection of Two Mile Mesa Road with West Road. (See fig.44) It is north of Two Mile Mesa Road within coordinates N.35+00 and N.30+00 and E.12+50 and E.7+50. The boundaries of area F are not strictly defined. There are two burial sites. The small one, the one closest to the road, has coordinates beginning with the northeast corner and moving in a clockwise direction of N.31+68, E.9+54; N.31+25, E.9+46; N.31+30, E.9+00; andN.31+82, E.9+13. The larger site, to the east and north, of the smaller one, coordinates beginning with the northeast corner moving in a clockwise direction of N.32+70, E.11+94; N.32+37, E.11+96; N.32+51, E.10+26; and N.32+86, E.10+28. Area F's location by township and range is described as near the center of sec. 20,T.19 #N,R.6 #E. The approximate acreage for Area F is 0.18.[33]

May 15, 1946[107] N. E. Bradbury, Director of LASL, wrote a memo to division and group leaders concerning a disposal pit at TD-site. TD-site on the memo is crossed out, and Two Mile Mesa is penciled in. Another penciled note says the pit was completed May 7, 1946. "An obsolete material pit for the disposal of classified objects and shapes has been prepared at TD-Site where such material will be made secure by burying. This pit will be open until the 1st of June. It is urged that divisions and groups "clean house" of obsolete, non-usable, but classified material by the use of this pit.

Division and group leaders desiring to use this pit will notify Security Office, Ext. 541, prior to their delivery of the obsolete classified material. The Security Office will record and locate such material in the pit."[107] It

is probable the pit referred to in Bradbury's memo is the larger of the two sites in the Area. It is not known whether the smaller site also dates 1946.

GEOLOGY AND HYDROLOGY

Two Mile Mesa is formed by tributaries of the northern branch of Pajarito Canyon. Area F is centered between the tributary canyons. It is at a distance of approximately 1500 ft. (457.2 m) from either canyon and lies about 80 feet (24.4 m) above the canyon floors. Soil cover for the smaller site is approximately 2 to 3 ft. (.6 to .9 m) thick. For the larger area it is approximately 1 to 2 ft. (.3 to .6 m) thick.[8] The surface of the smaller site is level while the surface of the larger pit slopes gently north. Excavations at both sites are in the Tshirege member of the Bandelier tuff. A 1963 USGS report[8] says there is little indication of erosion over the smaller site; however, sheet erosion is evident near the larger site and a small wash has been cut at west end of the site. "Blocky tuff with no apparent joint pattern and a northward slope of less than 5 percent crops out between the fenced area* and the south fork of Two Mile Canyon a few hundred feet north."[8]

TYPE OF WASTES

To date, July 1974, no reliable information on the waste materials has been found. The USGS reported in 1963[8] there were beta-gamma emitters buried. John Bolton, Assistant Director for Engineering, reported in 1952,[13] there was alpha contamination as well as beta-gamma. Dean Meyer, Group Leader, H-1, stated in January, 1973,[108] the burial pits contain equipment contaminated by ^{90}Sr and ^{137}Cs. Roy Reider, Group Leader H-3, in March, 1974 (personal commun.) says his sources of information indicate that the pits contain no radioactive contaminated material but do contain H E contaminated material.

MODE OF DISPOSAL

On Engineering Drawing ENG-4462 Area F is shown as two distinct sites. The smaller site is considered to have several pits within it. It

*Larger Site

approximates a square of 44 ft. (13.4 m). The larger site is rectangular, approximately 35 ft. (10.7 m) by 172 ft. (52.4 m).

APPEARANCE OF SITE

After visiting Area F, the larger site appears to be 30 ft. (9.1 m) by 385 ft. (118.3 m). (1) Area F is not identified by either an identification sign or structure signs; (2) There are no contamination warning signs posted, (3) Both ~~the~~ burial sites in the Area were once fenced with wood posts and barbed wire. A few fence post stand still. Bench marks around the burial sites can be located quite easily during those months when vegetation is not thick.

The surface of the smaller burial site is slightly irregular but shows no outlines of excavations or debris from excavations.

The appearance of the larger burial site raises questions. The larger burial site seems to be the disposal pit in Bradbury's memo.[107] If it is the same pit, was the entire pit used? If the entire pit was not used, which portions of it were used?

The two corner fence posts at the west end of the larger burial site can be found. One hundred sixty feet (48.8 m) east of these fence posts is a mound of excavated material on the southside of the pit. The earth mound is 90 ft. (27.4 m) long. The western end of the burial site is a depression. This west end, at one time fenced, is the part of the larger burial site shown on available engineering drawings. The east end of the burial site was picked on a vegetation change as well as a loss of rubble on top of the soil. The earth mound is adjacent the eastern half of the burial site where the surface is not depressed. If the earth mound is debris excavated from an approximately 400 ft. (121.9 m) long pit and was used to backfill the pit, why is it not located adjacent the western, depressed end of the pit? The fence around the western, depressed end of the pit could indicate one of two things. The western end was not used and left open; therefore, the fence was erected to keep people from falling into it. Or the western end was used and the backfill settled; therefore, the fence was erected to outline the part of the pit which was used.

The entire pit area is outlined by vegetation. There are several 10 foot (3.0 m) pine trees growing in the center of the pit and on top of the earth mound to the south of it. One particular kind of plant (not identified) seems to favor the pit; it is found only in scattered places away from the pit area.

STUDIES AND MONITORING

None known. Area F was described in the 1963 USGS report; "Geologic and hydrologic environment of radioactive waste disposal sites at Los Alamos, New Mexico."[8]

CONCLUSIONS

Not much is known about Area F. The exact size, location, and number of pits is not known. There is uncertainty as to whether Area F is a radioactive contaminated waste disposal area. No records for Area F of any studies or monitoring have been found.

RECOMMENDATIONS

1. Area F should have an identification sign.
2. Before posting contamination warning signs, an intensive search for burial records should be made. If burial records can be found, it might be discovered Area F is not a radioactively contaminated disposal area.
3. Area F should be fenced if it is discovered it contains H E or radioactive contaminated waste. Before Area F could be fenced information on size, location, and number of pits would need to be found.
4. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.
5. Vegetative mapping should be done.

Since particular kinds of vegetation seem to favor the larger burial site, it would seem wise to know why.

AREA G

INTRODUCTION

Area G is located on Mesita del Buey approximately 2 miles (3.2m) southeast of the intersection of the Access Road and Pajarito Road. (See Fig. 45) It is within coordinates E. 290+00 and E. 270+00 and E. 85+00 and E. 70+00. Its location by township and range is S 1/2 sec. 31 T. 19 N., R. 7 E.

October 19, 1956[149] Dean Meyer, Group Leader, H-1, made a request to Thomas L. Shipman, M.D., Health Division Leader, for additional waste disposal area. "The present waste disposal pit will soon be filled and the excavation of additional pits must be considered. I feel, at this time we should consider the need of such pits for the next ten years and the location be selected on our future needs.

During the last ten years we have used approximately thirty acres of real estate for our disposal program. In the next ten years our need for solid waste disposal areas is going to increase. In the next year we will have in addition to our regular daily disposal of laboratory waste several additional sources of contaminated material; these are O Building, ML Building, and M Building from TA-1. In addition, there will be portions of other structures in TA-1 and the complete acid sewer system from this area.

I believe that a reasonable request for the next ten years would be approximately forty more acres of real estate. The location of this acreage should be determined as soon as possible, since a new pit will be required by February 1, 1957."[149]

By December 14, 1956 the USGS had completed a survey of Mesita del Buey.[150] They concluded: "Although the exact location of the pits should be determined after an engineering survey of the area is conducted, there are several basic factors to be considered. First, the Tshirege member is a relatively impermeable rock and percolation from dry waste material due to seepage from precipitation would be negligible. Thus the extent and depth of this impermeable cap should describe the limits of excavation.

Second, as the thickest section of the Tshirege member occurs at the central axis of the mesa, construction for the pits might begin near the axis of the mesa and proceed toward the edge of the mesa to a minimum of 50 feet from the south cliff. By so excavating, the size and number of the joints in the rock can be observed, for the joints tend to become more open near the periphery of the mesa. It was noted in the burial pit near Ten Site*, however, that joints were filled with clay and silt.

Considering that the pits are to be established on long-term basis, it is important that future erosion possibilities be contemplated. The pits should be kept as far as practical from well defined drainage courses such as the ravines that disect the mesa, mainly along its south side. Furthermore, any natural vegetation on the mesa that feasibly can be preserved will aid in erosion control."[150]

Frederick Worman, authorized archeologist for LASL, was directed February 20, 1957[151] to request permits to remove ruins #192, 193, 194, 197-A, and 203-B as shown on the Indian Service Map. These ruins were located in the proposed route for the access road and new pit area.

Pit 1, Area G was dug in February 1957.[112] "Considerable work was involved in locating this Pit at this site. The access road (approximately 11,150 feet) was constructed after the necessary grubbing and clearing of trees and shrubs was finished. There are several Indian ruins on this Mesa. Five were excavated under the supervision of Mr. Worman, H-4. Other ruins will have to be excavated at a later date.

A fence and gate were placed around the area where Pit #1 and Pit #3 are located. The excavated dirt for Pit #1 was piled on Pit #3 site."[95]

The original acreage of Area G was 5.12. Today, July, 1974, the acreage is 36.6.[146]

During the second quarter of 1957 Pit 1 was put into use.[53] It did not, however, begin to receive routine contaminated waste until January 2, 1959.[54] September 4, 1958 a request for a new disposal pit was made. "According to our estimates, Pit 6, Area C, will be full some time in

*Area C

December, 1958. If the demolition of J-2 building is not complete by that time we will have to stop the burning of combustible material in Pit 1, Area G. It would be desirable to schedule the excavation of a new pit in Area G this fall with a completion date of some time early in December."[201] Pit 2 was started in December, 1958 and was completed in February 1959.[54] At the end of 1959 Pit 2 was in use.[57] "Due to the de-activation of the guard station on Pajarito Road, early in the year*, a fence and access gate were placed across the western part of the mesa** access road. This was done in order to prevent unauthorized access into the disposal areas."[59] April 18-19, 1961,[60] Pit 1 was retired from use and backfilled to ground level.[60] Pit 2 began receiving routine contaminated ~~was~~ waste April 20, 1961.[65] During the second quarter of 1961[61] there was the request for 2 disposal shafts near the future location of Pit #3 for bulky gamma active waste. This request was made in order to conserve space at Area C. The request does not appear to have been met. A request for the excavation of Pit 3 was made during the first quarter of 1962.[117] December 7, 1962, Pit 3 was begun.[65] It was completed in February 1963.[69] Upon completion an old Oshkosh Dump truck was placed in it. Pit 3 began to receive routine contaminated waste on June 20, 1963.[67] In July 1963, Pit 2 was backfilled to ground level.[68] ~~the third quarter of 1963~~. May 18, 1964 Pit 4 was begun, and was nearly finished on July 1, 1964.[71] A trench was cut along the south side of Pit 4 so that debris from Ta-1 could be burned.[72] Pit 4 was put into immediate use for this purpose. March 30, 1965[131] there was a request for a site layout for disposal wells in Area G southeast of Pit #4.[131] "There is enough space available for about five years usage in this area. This request is based on the assumption that we will close out Area C when the remaining disposal wells are filled."[131] A site layout of disposal wells southeast of Pit 4 does not appear to have been made. March 31, 1965[203] a request for a new disposal pit was made. "The radioactive waste disposal pit No. 3, currently in use at Area G, has

*1960
**Mesita del Buey

an estimated life expectancy of six more months. At that time we will need a new pit for disposal of laboratory wastes. We had planned on having additional space in Pit No. 4, but it now appears that the material from DP West laundry and TA-45 will fill this pit."[203] Another request for a disposal well layout was made May 5, 1965.[202] "Preliminary survey work has been completed during this quarter* for the location of Pit #5 in Area G as well as for ten more disposal wells to be located in Area G west of Pit #2."[76] During the first quarter of 1966, Pit 3 was filled, and Pit 4 began to receive routine contaminated waste.[102] In April, 1966, Pit 3 received its final dirt covering.[78] Pit #5 was dug[79] during the third quarter of 1966. Twenty disposal shafts were dug during the last quarter of 1966.[80] Pit 5 was put into use in the first quarter of 1967 as well as disposal shafts #1, 2, 3, and 11.[117] Contaminated waste was placed in the center section of Pit 5.[118] During the last quarter of 1967 Pit #4 was filled and covered to ground level.[103, 81] A request for a new disposal pit was made in the first quarter of 1968.[119] During the second quarter[82] of 1968 there was a request for an additional 10 shafts which were completed in the third quarter.[120] At that time shafts #3, 4, and 7 were full.[120] April 11, 1969 Shafts #8, and 9 were reported plugged.[141] A work order for a 6 ft. (1.8m) diameter shaft for disposal of contaminated oil was submitted in the second quarter of 1969.[122] The digging of Pit 6 was begun July 1969.[123] The perimeter fence for Area G was moved westward to include Pit 6 in October, 1969.[84] Pit #6 was in use by October 16, 1969.[84] In the fourth quarter of 1969[84] the 6 feet (1.8m) diameter shaft, Shaft #34 was dug. Pit #6 began to receive routine contaminated waste during the first quarter of 1970.[124] Shafts #12, 13, 17, 25, and 34 were in use during the first quarter of 1970.[124]

By the end of the second quarter of 1970 Shafts #12 and 13 were plugged, Shafts #24 and 25 were full, Shafts #36, 37, and 38 were in use, and shaft #35 was drilled.[125] June 11, 1970[133] a request for 10 new shafts was made. The 10 new shafts completed in June,[125] were placed in a

*Third quarter of 1965

north-south line directly east (although the request was for west[133]) of shafts #1-14. There was also a request during the second quarter of 1970[125] for a second 6 ft (1.8m) diameter shaft to receive plutonium contaminated sodium from Ten site. In the third quarter of 1970[126] the new 6 ft (1.8m) diameter shaft, Shaft #39, was augered, ten 2 ft (.6m) diameter shafts were completed, and a request for ten 3 ft (.9m) diameter shafts was made. At the end of 1970[127] Shafts #34 and 39 were in use. Five more disposal pits were requested in the first quarter of 1971.[142] These would be pits #8, 12, 16, 17, and 21. April 6, 1971[139] a request for a decontamination pit at Area G was made because: "Due to the rupture of a drum while attempting to recover a pump in Pit #6, Area G, TA-54, three Zia trucks and three dumpsters were contaminated. Attempts were made to clean these items at TA-50... Since we will not be able to complete the decontamination on the highly contaminated vehicles until such time as we can obtain this facility, we feel it is urgent that this be done immediately."[139] The decontamination pit was dug April 7-8, 1971.[142]

At the end of April[138] the Zia Company was digging Pits #8, 12, 16, 17, and 21, and completed them during the second quarter of 1971.[143] During the third quarter of 1971[144] Shafts #35, 41, 42, 43, 44, 45, 34, and 39 were in use. The perimeter fence for Area G was moved to the west to inclose Pits 8, 12, 16, 17 and 21 in this quarter.[144] Pit 8, Pit 12, and Pit 16 were in use at the end of 1971.[145] Three disposal shafts, one 6 ft (1.8m) diameter and two 3 ft (.9m) diameter, were augered during the first quarter[146] of 1972. In August 1972 Pit #6 was closed out and the final cover may have been complete in October.[147] Pit 17 received its first waste August 2, 1972, and Pit 21 received its first waste August 16, 1972.[147] Excavation of Pit 7 was complete August 3, 1973, and excavation of Pit 24 was complete September 14, 1973.[204] By January 4, 1974 (written communication from John Enders, H-8) Shafts 1 through 14, 24 through 34, 39 through 49, 58, and 72 through 75 ~~are~~ were plugged. Trench A and Trench B of the ^{238}Pu Storage Facility were begun January 7, 1974 and finished March 21-22, 1974.[207]

Construction of Pit 9 was requested February 4, 1974.[207] Pit 8 received its final cover of dirt March 27, 1974, and Pit 5 received its final covering in April, 1974.[207] Pit 17 was filled March 1, 1974 and received its final covering by the end of March.[207] Trench A was filled by the end of March, 1974.[207] March 4, 1974[215] a request to improve the access road to Area G and the internal roads of Area G was made.

GEOLOGY AND HYDROLOGY

Mesita del Buey is approximately 3 miles (4.8km) south of Los Alamos Townsite. It is a narrow southeast trending mesa, a part of the Pajarito Plateau. The mesa is as narrow as 300 ft (91.4m) and as wide as a quarter mile (402.3m). It is approximately 2 miles (3.2km) long. The surface slopes gently to the southeast from an altitude of 6,900 ft (2103.1m) to 6,600 ft (2011.7m).[206] Soil cover along the axis is 1 to 2 ft (.3 to .6m) thick[8] and thins toward Pajarito Canyon on the south and Cañada del Buey on the north. "Erosion of the soil is slow because of the small drainage area."[8] Mesita del Buey "is about 100 feet above the floor at Pajarito Canyon at its western margin and less than 80 feet at its eastern end."[158] The mesa is bounded by vertical cliffs with steep slopes at their base. The cliffs expose the Tshirege member of the Bandelier Tuff. The Tshirege member also crops out on the surface of the mesa.

At Area G the Tshirege has an average thickness of 135 ft (41.1m). Beneath the Tshirege is the Otowi member (Griggs, 1964)[164] of the Bandelier Tuff which is approximately 120 ft (36.6m)[29] thick. Beneath the Otowi is the Guaje member (Griggs, 1964)[164] of the Bandelier tuff which is approximately 11 ft (3.4m)[29] thick. The Bandelier tuff rests on the Basaltic Rocks of Chino Mesa (Griggs, 1964).[164] The basalts exceed 92 ft (28.0m)[29] in thickness. The thickness of the underlying Puye formation (Griggs, 1964)[164] is not known. In supply well PM-2, 1.67 miles (2.68km) west-northwest of Area G, (See Fig. 46) the Puye is 710 ft (216.4m) thick. PM-2 is completed in the Tesuque formation (Spiegel and Baldwin, 1963)[2] after penetrating 1,190 ft (362.7m)[29] of that formation. (See Table 15).

"The Tshirege Member has been divided into three units, determined by Baltz et al* where it outcrops in Mortandad Canyon. The Tshirege at Mesita del Buey was mapped using these units. At Mesita del Buey, as at Mortandad Canyon, Unit 1 has been subdivided into units 1a and 1b, and Unit 2 into 2a and 2b (Fig. 2).** At Mesita del Buey, Unit 3, a nonwelded to moderately welded pumiceous tuff, is absent.

Unit 1. The lower unit of the Tshirege Member consists of two layers, similar in lithology but different in color and welding. The lower layer is designated Unit 1a and the upper, Unit 1b.

Unit 1a is a light orange to light brown, pumiceous tuff breccia. It contains numerous pumice lumps as much as 6 in. long, with small quartz crystals and rock fragments of latite and rhyolite. The tuff ranges from nonwelded to moderately welded and weathers to a steep slope. In places, a vertical wall with a a talus slope at the base has formed. Unit 1a overlies the reworked sediments at the top of the Otowi Member. The upper part of the unit is exposed in Canada del Buey along the eastern edge of the mesa (Fig. 2). In the subsurface at the western part of the mesa, Unit 1a is about 30 ft thick, thinning to less than 10 ft to the east.

Unit 1b is a grayish brown tuff containing larger quartz crystals but fewer and smaller rock fragments of pumice, latite, and rhyolite. The unit moderately welded and weathers to a vertical wall or steep talus slope. It is separated from the underlying Unit 1a by a notch, caused by weathering in a vertical wall, or is recognized as a talus slope lying on the bench formed at the top of Unit 1a. Unit 1b outcrops in lower Cañada del Buey east of the mesa. Its thickness averages about 25 ft.

Unit 2. Unit 2 forms the walls and surface of Mesita del Buey. It consists of several ashflows, divided into lower Unit 2a and upper Unit 2b.

*Reference 166

** Fig. 7

Unit 2a is a light-gray pumiceous tuff that contains rock fragments of pumice, latite, and rhyolite, with some quartz crystals in a light-gray ash. The pumice fragments are devitrified and dark brown. The rock fragments in the lower part of the unit may be as long as 3 in., but they decrease in size toward the top of the unit. The western part of the unit is a moderately welded tuff that forms a vertical wall along the canyons. Eastward, the welding decreases to a nonwelded unit where it forms a talus slope. There are two ashflows or ashfalls in Unit 2a. The upper part of the unit near the western margin of the mapped area (Fig. 2)* is moderately welded tuff that becomes nonwelded as one progresses eastward. The nonwelded portion is apparently an ashfall containing numerous pumice fragments and some reworked tuff. Unit 1b is somewhat transitional into Unit 2a, and the contact is recognized by a gradual change in color and by a lithologic change. Unit 2a varies from about 85 ft thick on the west to about 30 ft thick to the east. Most of the thinning occurs in the upper ashfall.

Unit 2b is a light gray to brown, weathered rhyolite tuff with some pebble-size rock fragments of pumice, latite, and rhyolite and numerous crystals and crystal fragments of quartz and sanidine. It is a moderately welded to welded tuff that forms the upper walls and surface of the mesa. It forms ledges, benches, and vertical walls around the edge of the mesa. Unit 2b is separated from the underlying Unit 2a by an erosional contact, marked by a thin layer of silt, sand, and pumice. Unit 2b is composed of at least two ashflows that cooled as a single unit. The contact between these two flows is not evident where they outcrop, but in pits dug at Area "G" (Fig. 2)* it is recognized by increased size and number of pumice fragments with an occasional deposit of reworked tuff and pumice. Unit 2b is about 60 ft thick."[206] (See Fig. 47)

"The upper ashflows at Mesita del Buey dip 2 to 3 degrees to the southeast. The ashflows of the Bandelier Tuff thin eastward because these younger rocks lie on top of the older basalt (Fig. 3). The basalts

*Fig. 47

originated from volcanic centers to the east, and flow was north and west into the area, forming a topographic high before the tuff was laid down.

Joint Systems. The ashflows of the Bandelier Tuff are broken into a number of blocks by joints, formed by shrinkage (tension) as the ashflow cooled. The near-vertical attitude of most of these joints and the curved form of some, are indicative of formation by cooling. The joints are more numerous in welded than in nonwelded tuffs because the welded tuffs were laid down at higher temperatures.

The joints are classified as master and minor joints. Master joints are numerous and long, and may pass through one or more ashflows. A single unit may contain several ashflows emplaced at different times, but the joint pattern of the older layer may tend to govern formation of joints in the younger layer as it cools. Also, two or more ashflows may be laid down in rapid succession and cool as a single unit with joints forming in the flows at the same time.

The master joints are vertical or nearly vertical and generally dip 70 degrees from the horizontal. The vertical trend may be straight or slightly curved. The dip is deflected slightly when the joint enters a unit with different density or degree of welding.

Minor joints dip at angles less than 70 degrees. They are more numerous near the tops of ashflows and do not persist as they intersect the master joints.

A joint traced vertically through an ashflow may be closed in places and open in others. Locally the opening may be as much as 2 in. wide, but most openings are less than 1/4 in. wide. Joints terminating in the base of the soil zone or in exposed tuff on the mesa surface are filled with light-brown clay which may extend 3 to 4 ft below the surface. Below the brown clay, the joint openings are filled, or the joint faces are plated, with a light-gray clay. The light-gray clay is derived from weathering of the tuff and from minerals leached from the tuff by water and

precipitated along joint openings before development of the near-surface brown clay that seals the joint at the surface.

The master joints are tension joints formed by the contraction of the tuff as it cooled. In a cooling homogeneous molten liquid, rupture occurs as three vertical fractures intersecting at angles of 120 degrees and radiating out from numerous centers.* If the centers are evenly distributed, the fractures bound vertical hexagonal columns. A rose diagram illustrating the orientation of joints formed from a homogeneous molten liquid would show three joint sets (a number of joints with the same characteristic pattern) intersecting at angles of 60 degrees (Fig. 4).**

The heterogeneous characteristics of the tuff did not allow joint sets to form vertical hexagonal columns. A rose diagram prepared using the orientation of 1,078 master joints (492 in Area G (Fig. 2),*** 296 in Area L, and 290 in Areas J and H) showed the average of the three joint sets intersecting at angles of 30 and 90 degrees (Fig. 4).** The three joint sets, N30°W to N50°W, N60°W to N80°W, and N40°E to N60°E, comprise 40% of the joints measured for the study.

The blocks formed by the joints range from a few square feet to as much as 500 ft^2 at the surface. In the walls of the pits there is about one master joint for every 7 ft of horizontal wall."[206]

The zone of saturation (water table) lies at unknown depth beneath Area G. It is at a greater depth than 330 ft (100.6m).† The depth to water at PM-2 (elevation 6715 ft (2046.7m) was 823 ft (250.9m).[29] Water is perched seasonally in the alluvium in Pajarito Canyon.[158]

PIT 2

"In disposal Pit No. 2 the Tshirege consists of two lithologically similar ashflows that have cooled as a single unit. The flows are light-gray to light-pinkish-gray pumicious partially welded rhyolite tuff consisting chiefly of quartz and sanidine crystals in a matrix of fine-grained ash. They also contain some small rhyolite and latite rock fragments and a large amount of devitrified dark-gray pumice fragments.

**Fig. 48

†Test well T-5, approximately 1550 ft (472.4m) south-southwest of the center of Area G, was a dry hole when completed at a depth of 263 ft (80.2m).[29] (See Table 16) The difference in elevation between Pajarito Canyon, where T-5 was drilled, and the surface of the mesa at Area G is approximately 70 ft (21.3m). Therefore, 263+70≅330 ft (100.6m). Testwell T-6 approximately 1.4 miles (2.3km) west-northwest of Area G, was a dry hole at a depth of 300 ft (91.4m).

The top of a pumicious zone marks the contact between two ashflows. The pumice fragments are close together and form a soft lens in the tuff. Intersecting joints near the base of the upper flow above the pumice zone made it possible for large blocks to be dislodged easily. Several such blocks fell into the pit during construction. The soft lens became case hardened after exposure to weathering a year or more.

The exposed tuff and joints in pit No. 2 were mapped in November 1961 and March 1962 at which times the pit was partly filled with radioactive wastes (Fig. 3).* The strike (the direction of the joint in a horizontal plane) was noted to the nearest 10 degrees and the width of the joint openings and type of material filling or plating the joints also was noted.

The joint frequency averaged about one joint per seven-foot length along the walls of the pit. Three major sets of joints were noted. Twenty-seven percent of the 138 joints mapped were oriented between N. 40° E. and N. 70° E., 19 percent of the joints were oriented between true north and N. 20° W., and another 19 percent were oriented between N. 30° W. and N. 50° W. (Fig. 4).**

Joints formed by cooling and those formed by tectonic movement are difficult to differentiate in a single small area. The stresses set up in a homogeneous molten liquid as it cools to a solid would form tension joints at angles of 60 degrees (Billings, 1942, p. 123).

The heterogeneous characteristics of the tuff probably did not allow the joint sets to form at intersecting angles of 60 degrees. However, the angles between the N. 40 E. to N. 70° E. and the due North to N. 20° W. sets of joints is about 65 degrees (using an average of the two sets), which is about the angle expected between joint sets formed by cooling (Fig. 4).** Joint systems in the Tshirege Member in an area about 2 miles to the north were assumed to be formed by cooling due to their angles of intersection (Baltz and others, 1962).*** Although some of the jointing may be due to tectonic movement, no displacement along the joints was noted in pit No. 2...

*See Fig. 49

The dip (the angle of the joint measured from the horizontal) of most of the joints range from 70 degrees to 90 degrees. Joints dipping less than 70 degrees occur immediately beneath the soil and above the pumice zone. The joints are slightly curved and some joints reverse direction of attitude within the exposed surface of the tuff. The attitude of the joints which cross the pumice zone are slightly deflected due to the change in density of the pumice and tuff. A single joint may be closed in some places and open in others. Locally the amount of opening is as much as 2 inches; however, the majority of joints are open less than 1/4 inch.

Joints in the floor of the unfilled portion of the pit were not visible due to a cover of crushed tuff that resulted from construction of the pit. All joints terminating at the base of the soil zone were filled with a light-brown clay, and 3 to 4 feet below the base of the soil zone most of the joint openings are filled or the joint faces are plated with a light-gray clay. The light-gray clay is derived from weathering of the tuff and from minerals leached from the tuff by water and precipitated along the joint openings by evaporation prior to the development of the soil zone."[158]

PIT 3

Pit #3 was inspected by W. D. Purtymun, Geologist, February 6, 1963.[152] "The soil cover ranges from about 1 to 2 feet thick. The tuff below the soil zone appears to be dry. Investigations in the Los Alamos area have shown that very little water moves into the tuff where the soil cover has not been disturbed.

The lithologic character of the tuff in the pit is the same as that in the tuff in other pits in the area. The zone of soft pumice fragments at a depth of 20-25 feet in pit number 2 was not as well developed as in the new pit; the pumice fragments are smaller and wider spaced in the tuffaceous matrix.

Numerous joints in the tuff are exposed along the walls of the pit. The joints range from open to closed with clay or alteration products. Most of the joints are near vertical and beneath the soil zone are clay filled. In general the joints appear to be the same type that occur in adjacent pits.

The surface of the mesa slopes toward the east and southeast which makes the east rim the low rim of the pit. Fill from excavation of the pit is piled over the soil zone on the east side of the pit to raise the altitude of that rim...

We plan to make a detailed map* of the east and west walls of the pit when the weather permits."[152] August 3, 1964, an inspection of Pit 4 was made by W. D. Purtymun, US Geological Survey, Jack Konrad, and B. P. Williams of the LASL Engineering Department. They were also accompanied by George Dinwiddie also of the USGS.[153] "The pit was excavated on an east southeast-west-northwest axis to an approximate depth of 25 feet with a deeper slot being cut along the south wall where razed building materials could be burned. It was noted that several sections in the north and south walls had caved into the pit along fracture planes of the tuff.

Purtymun stated that he would make a study of the fracture patterns of the tuff and send a letter** outlining his conclusions and recommendations to the Engineering Department within the next two months..."[153] W. D. Purtymun made an inspection of Pit #5 on December 6, 1966.[154]

"The pit was constructed into two ash flows of the Bandelier Tuff. The contact between the flows is marked by a pumice zone which is well exposed on the north wall of the pit and along the western half of the south wall. The rim of the eastern half of the south wall has been cut and eroded below the contact. The ash flow units are of rhyolite tuff and are the same units as found in pits No. 2 and 4. Both units in this area are of fairly competent rocks that would form a stable cut in the tuff; however, the numerous joints which are near vertical and strike in random directions have caused some large slabs of the tuff to dislodge from the walls of the pit. This is caused by intersection of joints behind the cut face. John Enders has informed me that the pit will not be used until these slabs are scaled from the wall (safety measures have been taken by H-1, as the entrance of the pit roped off and posted). The joints exposed

*The map, if made, has not been located (July, 1974).
** The letter has not been located (July, 1974).

in the walls of the pit range from closed to open as much as 1 inch; however, the joints immediately below the soil zone are filled with clay or altered material. Any open joints in the floor of the pit are filled with crushed tuff due to traffic of equipment used during construction. No open joints that would require filling were noted.

The soil cover exposed in the walls of the pit ranges from about 0.5 foot to about 3 feet. Along the south wall of the pit from about sections 2+75 to 3+90 feet the upper 8 to 4 feet of the wall consists of fill material as the present pit was cut into the ramp leading into Pit No. 3 which is now filled and covered.

The land surface around the pit slopes gently to the southeast from an altitude of 6,678 feet at the northwest corner to an altitude of 6,658 feet at the southeast corner. The bottom of the inner pit is at an altitude of 6,643 which is about 50 feet above the floor of Canada del Buey and Pajarito Canyon.

On September 24 and October 9, 1969 W. D. Purtymun, H-6, made an inspection of Pit #6.[155]

The soil cover averages about one foot thick around the edges of the pit; however, in some places the soil has been stripped to the top of the tuff. The pit is completed within a single ash flow which is tentatively correlated with Unit 2 at the Meson Facility and at Mortandad Canyon. The tuff is moderately welded, light gray in color. It is fairly competent though several blocks have fallen from the north and south walls due to intersecting joints within the wall.

The majority of the joints range from vertical to about 60 degrees from horizontal. The joint frequency averages about one joint per six foot along the pit wall. Orientation of 190 joints showed three major joint sets. Twenty-four percent of the joints were oriented from N.#20°#W. to N.#50°#W.; 17 percent were oriented from N.#50°#E. to N.#70°#E.; 15 percent were oriented from N.#10°#W. to W.#10°#E.; the remaining 44 percent of the joints were of random orientation. Beneath the soil zone joints in the tuff are filled with dark brown clay derived from

weathering of the tuff. The joints in the tuff range from closed to open as much as one inch and are filled or plated with light gray clay or precipitate which in places contains some organic material from roots."[155]

On July 20, 1971, a survey was made of Pits 8, 12, 16, 17, and 21.[157] "(1) The pits inspected were 50 feet from the canyon rim (2) Maximum depths of the pits were above adjacent canyon floors (3) Generally the pits were laid out with long dimension parallel to surface topographic contours. Pit 21 the long dimension is at right angles to the contours... (4) There are numerous joints and fractures in the walls of the pits. Joint frequency is about 1 joint per 6 feet of wall in the pits. This is about the same joint frequency as found in other pits in the area. Most of the joints are vertical or near vertical ranging from 70 to 90 degrees from a horizontal plane.

Pits 8, 12, 16, and 21, cut through two ashflows in Unit 2. The contact is characterized by increase in size of pumice fragments and thin layers of reworked sediments. Pit 17 is within the lower ashflow. It was noted that in several of the pits that the thin sediments in the contact were offset several inches along near vertical joints cutting both ashflows. The offset is probably caused by compaction of the lower flows..."[157]

A survey by Margaret Anne Rogers, H-8, of Pit 7 was completed August 27, 1973. "The pit conforms (unless otherwise noted) to guidelines for pit construction as outlined in a memo from F. C. Koopman, U.S.G.S. to S. E. Russo, Eng-3 dated June 30, 1965.*

1. The pit is 50 feet from the canyon rim.
2. Maximum depth of the pit is above adjacent canyon floors.
3. The long dimension of the pit is parallel to surface topographic contours.
4. There are numerous joints and fractures in the walls of the pit. Joint frequency is about 1 joint per 6 ft. of wall in the pit. This is about the same frequency as found in other pits in the area. Most of the joints are vertical or near vertical - the lowest angle is not less than 60 degrees from a horizontal plane.

*Reference 130, APPENDIX III

Forty-two percent of the joints are root-filled. None of the joints stands open greater than 1 inch. Some joints appear to be filled with soil even to a depth of 25-30 feet.

Pit #7 is dug in Unit 2b of the Tshirege member of the Bandelier Tuff."[208]

Some of the 6 ft (1.8m) diameter shafts at Area G have been inspected by W. D. Purtymun, H-8, by means of a bosun's chair. Structural defects caused by fracturing prevented ingress of Shaft #39*. (Personal commun. from W. D. Purtymun) (See Fig. 50)

TYPE OF WASTE

Solid radioactive waste disposed of in Area G was logged in LA Notebooks #9593; 11363; 11866; S-1065; 6905; 12442; 14995; 15953; 17335; 17339; 17338; 17337; 17336; 17845, and 14909.[23] Records of waste placed in Pit 1 from January 2, 1959 through May 2, 1961 are found in LA Notebook #9593.[23] LA Notebook 11363 logs waste for Pit 2 from May 3, 1961 through January 1, 1963.[23] Pit 2 records of waste are found in LA Notebook #11363, May 3, 1961 through January 1, 1963; and in LA Notebook #11866, January 5, 1963 through June 26, 1964.[23] LA Notebook #11866 also logs waste for Pit 3 as ~~well as~~ LA Notebook S-1065, June 26, 1964 through October 20, 1965; and LA Notebook #6905, October 21, 1965 through June 30, 1967.[23] Pit 4 and Pit 5 records are found in LA Notebook #6905 and LA Notebook #14995, July 3, 1967 through May 5, 1969.[23] Pit 5 records can also be found in LA Notebook #15953, April 9, 1969 through April 19, 1972, and in LA Notebook #14909, January 13, 1972 through present.[23] LA Notebook #12442 logs waste which went into disposal shafts in Area G from January 1, 1963 to the present.[23] LA Notebook #15953 and LA Notebook #17335, April 19, 1972 through August 16, 1972, logs waste for Pit 6.[23] Records of waste in Pit 8 are found in LA Notebook #17339, October 4, 1972 to present. LA Notebook #17338 logs waste in Pit 12 from October 6, 1972 to present; LA Notebook #17337 logs waste in Pit 16 from October 15, 1971 to present; LA Notebook #17336 logs waste in Pit 17 from August 2, 1972 to present; and LA Notebook #17845 logs waste in Pit 21 from August 16, 1972 to present.[23]

*Shaft #39, on the west end of Pit 4, is called erroneously Shaft #36 on Engineering Drawing, ENG-R-4464.

December 18, 1970[134] radionuclide inventory by Wilbur Workman states: "The following report is based on all available H-1 records for radioactive waste buried at Los Alamos. From many entries in the H-1 records, the amount and type of radioactive material are listed as Classified (Secret RD). Because of entries such as these and also other similar ones, this report is an audit of H-1 records and not an investigation of complete facts. Group H-1 records from 1945 through 1960 have almost no information concerning what radioactive material or how much in gram quantities. These records were of the monitoring results of radioactive material or contaminated material. These records also included volume of waste, location of waste, date of the burial, signatures of persons involved, and from which group the material originated."[134] Area G has 50,007 lbs (2268 2.8kg) of D-38, 9034 g of U-235, 1084 g Pu-239, 0.204 g of Pu-238, O g of U-233, and less than 10 g of tritium[134].

The next radionuclide inventory was made by Merlin Wheeler, H-8, January 15, 1974.[32] He states: "The records describing the material placed in these pits generally do not contain information on the curie content of the material, but the isotopic composition is generally indicated... Americium is known to be present in the pits, occurring in association with plutonium in drums of sludge generated by liquid treatment facilities. A reliable estimate can be made of the curie content of the various isotopes using material accountability data. Other radioisotopes, such as tritium, are known to be present in the disposal pits, in unknown quanities. ... unspecified but small quantities of the following isotopes are also present in the disposal shafts. ^{24}Na, ^{32}P, ^{51}Cr, ^{57}Co, ^{59}Fe, ^{65} , ^{85}Kr, ^{91}Y, ^{105}Ag, ^{114}In, ^{131}I, ^{133}Ye, ^{147}Pm, ^{152}Eu, ^{191}Au, ^{227}Ac, ^{232}Th, ^{237} , ^{240}Pu, ^{242}Pu, ^{244}Cm, and ^{252}Cf."[32] In the inventory all values in curies are decay corrected from the original magnitude to that as of December 31, 1972.[32] In the pits at Area G there are 4000 Ci of Strontium-90-Yettrium-90; 48 Ci of Uranium which includes isotopes 234, 235, 236, and 238; 14.6 Ci of Pu-238, 326.8 Ci of Pu-239, and 2074 Ci of Americium-241.[32]

In the Area G disposal shafts there are 98,449 Ci of tritium, 46 Ci of Sodium-22, 229 Ci of Cobalt-60, 750 Ci of Strontium-90-Yettrium-90, 6 Ci of Cesium-137, 5 Ci of Uranium-233, 77 Ci of Fission Products, and 2458 Ci of induced activity.[32] The total Ci count for the shafts is 101,280; the total Ci count for the pits is 2463.4.[32]

Until 1971 no attempt to segregate waste by pit was made. Pits 1-6 received non-routine and routine radioactive contaminated waste. All these pits were initially used for non-routine waste followed by a mixture of routine and non-routine waste. Non-routine contaminated waste included debris from the demolition of TA-1 and Bayo Site, classified materials, TU chips from the shops, and pieces of heavy equipment such as dump trucks. Routine contaminated waste consisted of cardboard boxes [13 in. x 13 in. x 24 in. (33 cm x 33 cm x 61 cm)] and 5 mil plastic bags [13 in. x 24 in. (33 cm x 61 cm) and 40 in x 24 in (256 cm x 61 cm)] of material generated in the Chem Labs; and 55 gal. (.20m^3) barrels of sludge from the waste treatment plants at Building 35 DP West, TA-45 and TA-50.

In 1970 compliance with AEC-IAD-0511-21 was initiated.[127] During the third quarter of 1971[144] Pit 8 was put in use for storage of 55 gal. (.20m^3) barrels of sludge from the H-7 waste treatment plants; Pit 12 was put in use for storage of plutonium contaminated material estimated to exceed 10 nanocuries per gram; Pit 16 was put in use for crates and drums containing uranium contaminated material; Pit 17 would be put in use for low-level (<10nCi/g) TRU waste delivered by Dempster Dumpsters; and Pit 21 would be put in use for low-level uranium contaminated material delivered by Dempster Dumpster. Pit 8 contains not only sludge drums but also "nonretrievable" TRU waste.[207] Pit 7 has now (July 1974) replaced Pit 17 for low-level TRU waste. Pit 24 will replace Pit 21 for low-level uranium waste.

Sites generating transuranium waste placed in Pit #17 are: TA-3, SM-29, Wings 2, 3, 4, 5, 7, and 9; TA-3, SM-184, OHL Bldg.; TA-43,

HRL-1, HRL Bldg.; TA-48, 1, E. Side and S.W. Side; TA-48, 8, N.W. Side; TA-50, 1, S.E. Side; TA-35, Bldg. 2, 10 Site; TA-33, 86; TA-3, SM-30; TA-41, Bldg. 4, W-Site; TA-21, 2-3, S.Side; TA-21, 3-4, N. Side; TA-21, 150; TA-21, 257; and TA-21, 2, N. Side.[209]

Sites generating uranium waste placed in Pit 21 are: TA-3, SM-102; TA-3, SM-66, Docks 1, 3, 4 and 5 and W. Side; TA-3, SM-35, Press Bldg.; TA-3, SM-40; TA-21, 152-155; TA-21, 3-4, S. Side; TA-46, Bldg. 31; TA-18, Kivas 1, 2, and 3 and Bldg. 129; TA-2, Bldg. 1, Omega; TA-15, R-184; and TA-18, Bldg. 70.

See Appendix II for a listing of the contents of the 68 shafts in Area G.

MODE OF DISPOSAL

"The U.S. Geological Survey cooperated with the Atomic Energy Commission in the selection of the area* and recommended that disposal pits be no closer than 50 feet to the canyons, be no more than 50 feet deep, and that open joints in the pits be sealed with fine-grained material. The area was selected because it is relatively isolated and probably is large enough for disposal of solid wastes for 10 or more years."[8] (See Appendix III).

Engineering Drawing ENG-C 18463, (Materials Waste Pits. Standard Specifications. Mesita del Buey, TA-0) dated February 26, 1957 is undoubtedly the specifications for Pit 1. General notes on the drawing concern: "1. Location. The location of all pits will be determined and staked by Engineering Department personnel. 2. Clearing. Clearing of vegetation will be limited to those areas as staked by Engineering Department personnel. Disposal of cleared brush shall be effected by stacking and burning at the site, as agreed upon by AEC forestry authority. 3. Cross-sections. Cross-sections of the original ground of the pit area will be taken by Engineering Department Survey personnel, upon completion of the clearing, and prior to any excavation. Final cross-sections will be taken upon completion of the excavation, and prior to any burial of materials. 4. Stockpiling. The location and manner of stockpiling excavated material shall be as directed by Engineering Department personnel. 5. Pit Cover. The covering of buried materials, with regard to thickness of cover and covering schedule, shall be as directed by the H-Division custodial representative.

* Area G

6. Indian Ruins. Permission must be obtained from the Department of the Interior prior to disturbance of any Indian ruins in the area. In the event of the removal of any ruins, they will first be inspected and checked by an authorized archeologist, and disposed of under his direction. The ruins which are to remain undisturbed shall be appropriately marked with 4" by 4" wooden posts, painted white, and extending 4' above ground. The spacing and placement of the posts shall be as determined by the archeologist. Construction equipment shall refrain from crossing any ruins which are to remain in the vicinity. 7. Fencing. All temporary fencing of pits shall consist of 8' hogwire, mounted on 8" creosoted wood posts set at 10' centers, and three strands of barbed wire on wooden outriggers. Access gates shall be double 10' gates, located as directed by Engineering Department personnel. All permanent fencing of pits shall consist of 8' cyclone mesh, mounted on steel posts set at 10' centers, and 3 strands of barbed wire on steel outriggers. 8. Signs. Installation of warning signs, pit area signs, etc., shall be as directed by H-Division personnel."[210]

Eng-C 18463 shows a pit in plan view, in longitudinal cross-section, and in cross section at right angles to the axis of the pit. Pits were to be 600 ft. (182.9m) (maximum where possible) long, and a 100 ft. (30.5m) wide. One ~~toe~~ of the pit was to have a 6 to 1 slope, and the other ~~toe~~ was to have a 4 to 1 slope. The up 6 to 1 slope, covers an approximate horizontal distance of 150 ft. (45.7m); the down ramp, 4 to 1 slope, covers an approximate horizontal distance of 100 ft. (30.5m). A 25 ft. (7.6m) depth is shown for the pit with a note stating "actual depth will be determined by conditions encountered in the field."[210] The walls of the pit were to be cut "as nearly vertical as excavating equipment

will permit."[210]* A "typical road cross-section" also appears on ENG-C 18463. It is assumed this cross-section shows construction details for the access road on Mesita del Buey. The road was to be a maximum of 18 ft 0 in. (5.5m) wide. It was to have cuts on either side for drainage. From center of cut to center of cut was a distance of 16 ft. (4.9m). The crown (parabolic) of the road was 12 ft. (3.7m) wide covered by 3 inches (7.6m) of gravel.

Pits 1, 2, 3, and 4 were constructed using Materials Waste Pits Standard Specifications, Engineering drawing, ENG-C 18463. Pit 1 and pit 4 also contained fire pits. In pit 1 the fire pit was dug in the center of the floor (see fig. 51); it was redug during the third quarter of 1958. The fire pit in no. 4 was dug along the south wall.

At the end of 1959[57] chain link fence surrounded the area where Pits 1 through 5 are located. Signs were placed at 50 ft. (15.2m) intervals on the fence. These signs were identical to those on fences around other LASL disposal area. Also, numbered signs were placed on the fence posts along the west side of pit 1 for use as reference numbers when logging in waste deliveries.

June 30th, 1965 the U.S.G.S. formalized its guidelines for the construction of pits for the disposal of solid radioactive waste on Mesita del Buey (See Appendix III).

On July 27th, 1965 a new Materials Disposal Areas Standard Pit Specifications came out, Engineering drawing ENG-C-25703. Points 1,2,3,4,6,7, and 8 of General Notes remain the same on Engineering drawing, ENG-C 25703 as on ENG-C 18463.

* It was never possible to cut vertical walls (personal commvn. from Charles Daggett, ENG-4)

"5. Pit Cover. The covering of buried materials with regard to thickness of cover and covering schedule, shall be as directed by H-Division and Group ENG-4."[211] Point 5 on ENG-C 18463 gave H-Division sole responsibility. "9. Contents. For information relative to the contents of materials disposal areas, and L.A. Notebook information, contact LASL Health Division and/or Group SP-2. 10. General. For information relative to correspondence, Indian ruin numbers, bench marks, field book information, and other survey data noted on any of these drawings, contact ENG-3 Group Office."[211]

The only difference in construction detail between ENG-C-25703 and ENG-C-18463 is the walls of the pit now show a slope of 1/4 to 1.

Pit 5 was the first pit to be constructed under the formalized U.S.G.S. guidelines and the new standard Pit Specifications. Pit 5 is 100 ft. (30.5m) wide, 600 ft. (182.9m) long with a maximum depth of 29 ft. (818m). It has an inner pit that is 50 ft. (15.2m) wide, 400 ft. (121.9m) long with a maximum depth of 5 ft. (1.5m).[154] (See Fig. 52). In some places Pit 5 is 34 ft. (10.4m) deep. Pit 6 was the last pit to be constructed with a 100 ft (30.5m) width. Pits following number 6 differ from Standard Pit Specifications, ENG-C 25703 in length, width and depth. Pits 8, 12, and 16 are 25 ft. (7.6m) wide, 300 ft. (91.4m) long and 25 ft. (7.6m) deep.[156] Pit 8 walls slope approximately 1 on 8; pit 12 walls are almost vertical; and pit 16 walls slope approximately 1 on 10.[156] Pits 17 and 21 are 50 ft. (15.2m) wide, 400 ft. (121.9m) long and 25 ft (7.6m) deep. Pit 17 walls slope approximately 1 on 6; and pit 21 walls slope approximately 1 on 12.[156]

The requested dimensions for the working area of the decontamination pit were 28 ft x 40 ft (8.5m x 12.2m) with 12 ft (3.7m)

depth.[139] Scaled dimensions from Eng-R-4463 are 30 ft x 150 ft (9.1m x 45.7m).

Pits 7 and 24 are 50 ft (15.2m) wide and 600 ft (182.9m) long. Pit 7 has a maximum depth of approximately 30 ft (9.1m); and Pit 24 has a maximum depth of approximately 25 ft (7.6m). Pit 9 is 30ft (9.1m) wide, 400 ft (182.9m) long with an average depth of 20 ft (6.2m). The south ~~toe~~ end of Pit 9 has a slope of 1 to 2.[212]

Trench A and B are 13 ft (4.0m) wide and 6 ft (1.8m) deep. Trench A is 262.5 ft* (80.9m) long; and Trench B is 218.75 ft* (66.7m) long. Two rows of 3 ft (.9m) diameter, 2 ft (.6m) deep holes[207] were augered on 4 ft (1.2m) centers in the floors of Trenchs A and B. The rows were on 3.2 ft (1.0m) centers. Into each hole was placed a concrete cask (see Fig. 53) which holds two 30 gal. (115 liter) metal drums.[207]

In Area G Pits 1 and 3 are oriented north-south; Pits 2,4,6,7 and 24 are oriented east-west; the Decontamination pit and Pits 8,9,12, and 16 are oriented northeast-southwest; and Pits 17 and 21 and Trenchs A and B are oriented northwest-southeast. See Figs. 54,55,56,57,58,59,60,61,62,63,64, and 65.

Engineering drawing, ENG-C-25700, Materials Disposal Areas FY66, Area G shafts, Mesita del Buey, TA-0 dated July 27, 1965, shows shaft layout and construction details. The following points were made under General Notes.

"1. Location. The location of all shafts will be determined and staked by the LASL Engineering Department. After shafts are bored, survey ties will be made for record purposes.

~~metal drums.~~[207]

*scaled dimension

2. Boring Sequence. Will be accordance with stakes, marked to indicate shaft number, diameter and deep as set in the field by Eng-3 personnel.

3. Stockpiling. The location and manner of stockpiling excavated material will be to the west unless otherwise specified by Eng-4.

4. Safety. The personnel safety covers must be secured in place over the shafts at all times when drilling is not in progress.

5. Boring Instructions. Shafts 1 thru 10 inclusive are to be 2 ft. diameter by 30 ft. deep.

6. Spacing. A minimum of 7'-6" from center to center is required unless otherwise specified."[214]

The drawing shows vertical cross sections of typical shafts. The unlined shaft is 2 ft. (.6m) in diameter; depth to be specified or as necessitated by field conditions. The lined shaft is 3 ft. (.9m) in diameter; depth to be specified or as necessitated by field conditions. Lined shafts are constructed[129] by centering a 12 in. (30.5 cm) diameter metal tube 1 ft. (.3m) above the bottom of the shaft. Cement is poured around the metal tube; and finished at the top of the shaft so as to promote drainage away from shaft. (See Fig. 66).

Shafts 1 through 12, 24 through 33, 40 through 49, and 72 through 81 are 2 ft. (.6m) diameter, 25 ft. (7.6m) deep unlined shafts. Shafts 13, 35 through 38, 58, and 61 through 66 are 3 ft. (.9m) in diameter, 25 ft. (7.6m) deep unlined shafts. (Written Communication from John Enders, H-8, January 10, 1974).

Shafts 34, 39, 50, 59, and 60, 6 ft. (1.8m) diameter shafts,

have steel shaft covers which are 8 ft. (2.4m) high, 6 ft. (1.8m) diameter cylinders with a lid. Construction details can be found on Engineering drawing ENG-R 3638. The shaft cover projects above ground level about 3 ft. (.9m).

In 1964, "A change in the method of placement of waste in the pits has been made, at the request of Eng-4 Group. Heretofore, waste has been placed in sections along the floor of the pit and covered when the section (about one-third of the width of the pit floor) was completed. This permitted access into and out of the pit as well as physical separation of the 55 gal. drums filled with sludge from combustible boxed material. Eng.-4 insists on filling the entire floor of the pit before covering waste material. The term "insist" is used because a work order request to cover exposed trash within Pit #3 was submitted to Eng-4 on 3/5/64 and it is the author's* opinion that Eng-4 has refused to activate an order until the pit floor is entirely covered with waste material."[70]

Classified material placed in pits is covered with 3 feet of earth when it arrives.[121] "As matters now stand this office** is to notify SP-2 when a covering job is to start so that SP-2 can arrange to deliver classified material to the Pit for immediate burial."[99]

In 1959,[99] standard operating procedure was submitted "for approval on the pick up and delivery to the disposal pit of dempster dumpster containers. Another procedure was prepared and submitted for approval on the operation of the two skip type dempster dumpster containers that are used for hauling sludge drums

* John Enders
** H-1

from TA-50 and Building 35, DP West."[99]

In 1965 "new metal cans were placed in Wing 2 of the CMR Building to hold radioactive waste. These cans are painted yellow and have the radiation symbol painted on the can. On the lid is the wording "For Radioactive Waste". As the lids to these cans open wore widely it is much easier to fill and empty. The cans are now a stock item at SM-30. It is hoped that these cans may be used to replace the red metal ones now in wide use so that the yellow painted ones will be used for holding radioactive materials."[77]

The practice of backing a truck up to the edge of a disposal pit and throwing trash off the rear was abandoned in 1959 when Pit 1 was in use. It was abandoned after Charles Blackwell, H-1, fell into the pit when the edge crumbled beneath him. (See Fig. 67) However, in 1964 when Pit 4 was in use the following appeared in a Quarterly Report:[72] "Because the pit walls began to crumble, it was decided to dump material into the trench from the top of the pit rather than risk being struck by falling rock."

A change in disposal method of sludge drums was proposed June 9, 1971.[136] "Assuming these drums may be removed later for transfer to a salt mine, it would be very desirable to stack the drums in the pit. Use of 2" x 12" planking between layers of drums has been proposed. According to Mr. Daggett, Eng-4, a 55-gal. drum can withstand the weight of 7 drums on top of it. The planking would further reduce the load of pressure.

The pit is 25' wide, 25' deep, and 400' in length. These dimensions could permit placement of about 12 drums, horizontally, across the pit. The depth of the pit would permit 8 layers of

drum (assuming no dirt cover is to be used). The total number of drums that could be stored in this manner amounts to about 9 000. H-7 Group is currently generating about 1 000 per year and at this rate the pit could last for about nine years."[136] Compare Fig. 32 (1956), Fig. 68 (1966) and Fig. 69 (1973) for the evolution in handling of sludge drums ~~at time~~ of disposal.

During the third quarter of 1972[147] an engineering study to determine feasibility and costs for providing cover for those pits used for long term storage, Pits 8, 12, and 16, indicated it would be rather expensive to provide covers. "Other types of covering material are being investigated."[147] Compliance with AEC-IAD-0511-21 was begun during the third quarter of 1970.[127]

"1. ^{238}Pu scrap from DP-West is now "stored" in metal drums in pit #5, Area G.

2. D-38 chips and turnings from the Shops Dept. are "stored" in metal drums in pit #5, Area G.

3. Tritium contaminated material is being incased in asphalt, where possible, prior to being "stored" in disposal shafts in Area G.

4. Disposal of plutonium contaminated material into disposal shafts is being segregated, where possible, from uranium contamina~~tion~~ material. This requires a larger number of shafts being "in service".

5. Sludge and/or cement paste from H-7's Treatment plants is put into 55 gal. metal drums. However, the drums are still being "stored" in disposal pits with other low level wastes."[127]

"<u>Compliance with AEC-IAD-0511-21</u>:

More complete compliance with this Directive was achieved during the last quarter of 1971 with the use of Pits #8, #12, and

#16. The material placed in these pits is considered to be retrievable.

The decision as to what material should be crated and/or packed into drums is based on estimates made by H-1 using monitoring data and information concerning the use of the equipment and other information to determine the activity/mass category.

It is of interest to note that whenever material must be crated, the disposal cost increases considerably. The current cost of a 4' x 4' x 8' plywood crate is about $75.00 and if a mobile crane is used during off-loading this brings the cost up even higher.

Other procedures that were started in 1970 and continued during 1971 include:

1. Encasement of tritium contaminated material and disposal into a 6 ft. diameter shaft.
2. Segregation, where possible, of uranium and transuranium material in disposal shafts.
3. Use of a 6 ft. diameter shaft for contaminated oil disposal.
4. Storage of D-38 and ^{238}Pu material in Pit #5.

The segregation of low-level waste into uranium and plutonium categories has not yet started. This will require additional Dempster Dumpsters for some Sites and very close supervision of the loading operations.

Low level waste is currently packaged into boxes and plastic bags. If there is a requirement to store this material, more durable packaging will be required. Also, currently, scrap material is not

usually packaged, and it, too, would require durable containers if it is to be stored for up to twenty years."[145]

During the third quarter of 1967,[81] "equipment and material was obtained which enabled H-1 to cap disposal shafts with Ready-Mix cement. The time between the filling of a shaft and capping of a shaft was greatly reduced when H-1 received the capability of capping the shafts themselves. ~~For information on current waste disposal practices see Appendix IV.~~

"The pick up and delivery of contaminated oil to Area G has posed a problem. Some of the containers are 55 gal. drums which could weigh more than 300# when full of oil. A study is now underway to decide if hoist equipment might not be used to handle these drums. Information on several designs of hoists is being received now and if such equipment is ordered, present plans call for a 6' diameter shaft to be drilled in the disposal area to receive this oil which would eliminate the fire hazard it poses when placed in the open pits."[83] The first 6 ft. (1.8m) diameter shaft, Shaft 34, was augered during the fourth quarter of 1969.[84]

"A SOP for disposal of small items contaminated with Tritium was prepared and approved in April.* Whereever possible, tritium contaminated material is to be encased in asphalt. H-7 Group now has an asphalt melter and performs the encasement. The encasement procedure was started as a result of studies made by H-7 that indicated asphalt to be a good barrier to tritium."[125] This SOP was written because of a tritium disposal to shafts November 25, 1969.[84]

For information on current waste disposal practices see Appendix IV.

* 1970

Appearance of Site: Area G is fenced with 8 ft. (2.4m) cyclone fince. ~~The gate has the~~ Area at the end of the access road for Mesita del Buey is the one gate into Area G. On this gate is the Area designation sign. There are signs posted periodically along the fence stating that Area G is a contaminated area. The signs are faded.

There is not too much vegetation within the Area. On the older pits, in the vicinity of Pits 1 and 3 and Pit 2, there is some brushy-type vegetation, but none of the pits are grassed over.

The crushed tuff cover on all filled pits is mounded; and there appears to be no erosion of that cover.

STUDIES AND MONITORING

In March 1950[29] the U.S.G.S. drilled two test wells, T-5 and T-6, for geologic and hydrologic information in the floor of Pajarito Canyon south of Mesita del Buey. Test well T-5 (SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 31, T. 19 N., R. 7 E.)[216] was approximately 1550 ft (472.4 m) south-southwest fo the center of Area G. It was a 263 ft (m) hole with a diameter of 24 in. (cm.). No water was encountered. (See Table 16). Test well T-6 (SW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 36, T. 19 N., R. 6 E.)[216] was approximately 1.4 miles (2.3 km) west-northwest of Area G. It was a 300 ft.(m) hole. No water was encountered. (See Table 17)

December 7, 1956 J. E. Weir, Jr. and John H. Abrahams, Jr. of the U.S.G.S. made a geologic investigation of Mesita del Buey at the request of the A.E.C.[150] The purpose of the investigation was to determine if Mesita del Buey was a suitable burial site for radioactive wastes.

"Mesita del Buey is capped with the welded tuff (upper) member of the Bandelier tuff, which may be subdivided into several distinct layers. The top layer of the mesa-capping is about 85 feet thick near the road junction and a maximum of about 50 feet thick near the Tshirege ruins. The layer beneath this, a pumiceous tuff, is about 30 feet thick toward the west end and thins to about 10 feet thick toward the east end of the proposed burial area. The upper few feet of the basal unit of the Tshirege member crops out in Pajarito Canyon and Cañada del Buey, and was noted to be agglomeratic and moderately pumiceous.

Information from the logs of the two test holes drilled in Pajarito Canyon show that layers of welded tuff occur in the subsurface of the basal unit. This lower unit of basically welded tuff is 60 to 100 feet thick under the area studied.

The two basal members of Bandelier tuff are more pumiceous and permeable than the Tshirege member and underlie the top member. The Puye conglomerate underlying the Bandelier tuff is encountered in drilling about 200 feet beneath the base of the Tshirege member toward the west end of the proposed burial pit area. A basalt bed occurs about 130 feet beneath the base of the Tshirege member toward the east end of the proposed burial pits. The Puye conglomerate is a water laid deposit and has a relatively high permeability but the basalt bed, which interfingers with the Puye, is impervious except for large joints and fractures. The 300-foot hole drilled into the upper part of the Puye conglomerate in Pajarito Canyon is dry and the main saturated zone of the ground water is thus more than 210 feet beneath the base of the welded tuff (Tshirege) at this point.

Although the exact location of the pits should be determined after an engineering survey of the area is conducted, there are several basic factors to be considered. First, the Tshirege member is a relatively impermeable rock and percolation from dry waste material due to seepage from precipitation would be negligible. Thus the extent and depth of this impermeable cap should describe the limits of excavation. Second, as the thickest section of the Tshirege member occurs at the central axis of the mesa, construction for the pits might begin near the axis of the mesa and proceed toward the edge of the mesa to a minimum

of 50 feet from the south cliff. By so excavating, the size and number of the joints in the rock can be observed, for the joints tend to become more open near the periphery of the mesa. It was noted in the burial pit near Ten Site, however, that joints were filled with clay and silt.

Considering that the pits are to be established on a long-term basis, it is important that future erosion possibilities be contemplated. The pits should be kept as far as practical from well defined drainage courses such as the ravines that dissect the mesa, mainly along its south side. Furthermore, any natural vegetation on the mesa that feasibly can be preserved will aid in erosion control."[150]

Some of the points in the 1956 Letter Report concerning location and construction of pits were formalized June 30, 1965 in a set of guidelines for construction, burial of wastes, and surface seal of pits. (See Appendix III) A suggestion by Dr. C. V. Theis appended to the Guidelines stated:

"It may be necessary to have periodic inspections of the sealed and finished pits to determine any unusual settling or gullying. It is thought that the times of inspection for instability and indications of adjustment of the surface to a natural condition will be shortly after the season of highest rainfall. It may be necessary to have biannual inspections."[130]

A U.S.G.S. study "to investigate movement of water and nuclides during continuous infiltration"[51] began the second quarter of 1959.[99]

"The U.S.G.S. has a water saturation experiment station located on the south edge of Pit # 2, at about the middle of the Pit. Should they start to use radioactive material in their work the west gate* would have to be locked."[99] ~~(See Fig. 70)~~

"An infiltration pit, access tubes, and a water-storage tank were installed near the edge of the vertical wall of the disposal pit (fig. 15).**

"The center of the infiltration pit was 10 feet south of the south edge of the waste disposal pit. The upper 2 feet of the infiltration pit was shored with wood planks within the soil and fill material, and the lower 1 foot was dug into the unweathered tuff. Water entered the pit through a 3/4-inch pipe connected to a value box adjacent to a 3,000-gallon storage tank.*** A float valve in the infiltration pit maintained a constant head of water of about three-fourths foot. Eight holes 40 feet deep lined with plastic tubing were installed in and near the infiltration pit (fig. 15)**.

Periodic measurements of water losses from the storage tank were made to determine the volume of water moving to the infiltration pit.

The infiltration experiment started when water was put into the pit October 8, 1959. Between December 29, 1959 and January 6, 1960 the water line froze and the pit dried up. The infiltration phase of the experiment was suspended until April 20, 1960 and then restarted. About December 9, 1960 the water line froze again and the infiltration phase of the experiment was stopped, but moisture measurements were made in access tubes for several

* Gate was located at west end of pit.

** Fig. 71 *** See Fig. 72 ~~See Fig. 73~~

months to observe drainage patterns.

Photographic evidence that water moved into the tuff from the infiltration pit was a wet patch (fig. 16)* that developed on the wall of the disposal pit 10 feet to the north. Evaporation from the wall discharged water that would have moved deeper in the tuff."[51]

The rate of infiltration of water for the 1959 study decreased from about 0.75 gph per sq. ft. (gallons per hour per square foot) to about 0.2 gph per sq. ft. For the 1960 study the rate of infiltration from about 0.68 gph per sq. ft. to about 0.1 gph per sq. ft. (See Fig. 74)

"Significant seasonal changes in the log curve of the rate of infiltration for the 1960 study occur during the months of April and September. The steeper parts of the curve show a relatively rapid decrease in the rate of infiltration with time during the months in which the average temperature is less than about 50 degrees. The flatter part of the curve shows the rate of infiltration during months in which the average temperature is above 50 degrees. In these months the rate of infiltration decreased from about 0.4 gph per sq. ft. to about 0.2 gph per sq. ft. The range of the temperature of the water in the pit, from near freezing during the winter to about 80 degrees in the summer, was enough to cause seasonal differences in the rate of infiltration into the tuff due to changes in viscosity (Horton, 1940, p. 417)**. In addition, seasonal temperature variances in the tuff beneath

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*Fig. 7~~0~~3 **Horton, R. E., 1940, An approach toward a physical interpretation of infiltration-capacity: Soil Sci. Soc. America Proc., v. 5, p. 399-417.

the infiltration pit may have been sufficient to cause some small differences in the rate of percolation.

The flatter part of the log curve of infiltration includes the time of the growing season at Los Alamos, and it is possible that evapotranspiration of tumbleweed on the soil and fill pad consumed small amount of water moving from the pit. However, when most of the plants were removed no measureable effect on the rate of infiltration took place. Several plants growing with their tap roots along the side of access tubes were kept in place. The moisture content of the upper 2 feet of material (table 7)* was reduced at access tubes 2 and 3 where the tumbleweeds were growing; the moisture content increased after the plants were removed September 1. The moisture content at all the other tubes remained high throughout the growing season.

No evidence was found that water moved through the soil and fill pad and evaported from the surface in quantities sufficient to affect the rate of infiltration in the pit. The moisture content of the upper foot of the soil ranged between 5 and 10 percent by volume, which generally is too low to transmit much water. The sandy material tends to form a barrier that reduces evaporation (Willis, 1960, p. 241).**

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*Table 7 is Table 18

**Willis, W. O., 1960, Evaporation from layered soils in the presence of a water table: Soil Sci. Soc. America Proc., v. 24 no. 4, p. 239-243.

The rate of infiltration (5 to 10 gpd per sq. ft) during the summer months was within or somewhat above the range of permeability determined from cores in the Laboratory. The field permeability (rate of percolation) in the zone of aeration cannot be directly compared to the saturated permeability (laboratory measurement) because water in the infiltration pit not only moved downward but also moved laterally as much as 8.5 feet from the edge of the infiltration pit. Thus, the rate of percolation, particularly from a small source of water located in a layered medium, is substantially less than the saturated permeability, because the water is subject to forces not involved in saturated flow.

The wetting front moving into the unsaturated tuff was sharpest in the early part of the 1959 study, but it became thicker and more diffuse as infiltration continued (fig. 18, profile I).* Energy barriers at the front retard the movement until the moisture content behind the front is raised to a maximum or optimum value (Bodman and Colman, 1944, p. 117-118).** The thickness of the zone of transmission, the area between the unwetted tuff and the maximum moisture content attained during the vertical movement, probably was a function of layering in the tuff. The average rate of movement of the part of the front containing a moisture content of 25 to 28 percent by volume was about 2 feet during the first day, about half a foot per day

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*Fig. 75

**Bodman, G. B., and Coleman, E. A., 1944, Moisture and enery conditions during downward entry of water into soils: Soil Sci. Soc. America, v.8, p.116-122.

during the next 11 days, and about a tenth of a foot per day during the next 56 days, with additional movement in the lower moisture range to a total depth of about 18 feet. The rate of movement of the front in 1960 was higher (fig. 18, profile II),* than in 1959 probably because the rock was wetted and fewer energy barriers existed to reduce the rate of movement and less water was needed to reach field capacity.

The moisture content of 25 to 28 percent apparently was the maximum attained away from the pit (fig. 18, profiles II and III)* at Site 5.** This moisture content is several percent above field capacity but is considerably less than saturation. The maximum moisture content 1 foot beneath the infiltration pit was about 40 percent, which is 6 to 7 percent less than the estimated effective porosity. The 6 to 7 percent probably represents the large pore spaces from which water drained into the underlying material, although it may also represent entrapped air. However, entrapped air should not be a problem in this study because of the large volume of porous medium involved and the probability that entrapped air beneath the infiltrating water would escape and not be surrounded or compressed (Free and Palmer, 1940, p. 395).***

The moisture content of the tuff decreased steadily above an apparent density change at about 25 feet beneath the infiltration

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*Fig. 75

***Free, G. R., and Palmer, V.J., 1941, Interrelationship of infiltration air movement, and pore-size distribution in graded silica sand: Soil Sci. Soc. America Proc., v.5, p. 390-399.

** Area G

pit to a range of 5 to 16 percent after about 9 $\frac{1}{2}$ months drainage (fig. 18, profile IV).* The moisture content below the apparent density change slowly increased during drainage and after about 2 months reached a moisture content of about 8 percent. The 8 percent saturation extended below the bottom of the access tube."[51]

For the 1960 study isohydral lines of moisture content along an east-west and a north-south section are shown in Fig. 76 for the beginning of the study, April 20, 1960, and in Fig. 77 for the end of the study, December 6, 1960. Density gradients in the tuff are reflected in the east-west sections of Figs. 76 and 77; and evaporation from the wall of Pit 2 is reflected in the north-south sections of Figs. 76 and 77.

"Water was retained in the tuff to near field capacity between the depths of 8 to 14 feet beneath the bottom of the pit approximately 3 $\frac{1}{2}$ months after the infiltration phase of the experiment was suspended in January 1960."[51] See Fig. 76. The slight bunching of the 10, 15, and 20 percent isohydral lines to the east in Figs. 76, 77, and 78 may indicate movement down dip in the tuff or density changes at access tubes 4 and 5.[51]

no ¶ "The lower moisture content at the upper part of holes 2 and 3 was due to evapotranspiration by the tumbleweeds growing there."[51]

"Moisture measurements, made on December 6 after 230 days of infiltration, (figs. 19-D and 20-E)** show a decrease in the

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*Fig. 75 **Fig. 77

moisture content of the tuff from that of previous measurements. Although the rate of evaporation from the disposal pit wall decreased steadily during the fall, because of the decreasing temperature, the rate of infiltration probably also decreased because of the greater viscosity of the water. The rate of infiltration at the near-freezing temperatures in the pit in December was probably only about half that during the middle of summer (Mavis and Wilsey, 1936, p. 17).* Water in the pit probably froze during extremely cold nights late in November and early in December before the permanent freeze, thus completely stopping infiltration for periods of several hours. The rate of percolation exceeded the rate of infiltration from the pit when the water was near freezing.

On March 1, 1961, after about three months of drainage (figs. 19-E and 20-F),** the isohydral lines assumed about the same positions and shapes as of April 20, 1960, except in the lower moisture range directly beneath the infiltration pit where a low moisture content column 3 or 4 feet in diameter formed below a depth of about 30 feet.

A total of about 11,100 gallons of water moved through the infiltration pit during the 230 days of the study, most of which infiltrated during the summer months. A water budget cannot be

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*Mavis, F. T., and Wilsey, E. F., 1936, A study of the permeability of sand: Bull.7, University of Iowa, studies in Engineering, Iowa City, Iowa.

**Fig. 78

calculated, however, because of the unknown quantities lost by evaporation."[51]

The exposed tuff and joints in Pit 2 were mapped by the U.S.G.S. in November 1961 and March 1962 when the pit was partly filled with radioactive wastes. (See Fig. 49) "The orientation of the major joint sets (intersecting at angles of 30 degrees to 90 degrees) and random orientation of the remaining joints are such that layout of a pit to avoid the intersection of joints in the walls is impossible. Pits should be laid out to make the best utilization of the area available."[158] "... The bulk of the tuff beneath the soil is quite dry. The moisture content was about 8 percent by volume in the tuff at a depth of 2 feet beneath the soil zone in a shallow hole* drilled near pit No.2. Eight feet below the soil zone the moisture content decreased to less than 4 percent and between 8 and 40 feet it was 4 percent or less.

Area G was briefly described in the 1963 USGS report, "Geologic and hydrologic environment of radioactive waste disposal sites at Los Alamos, New Mexico."[8]

W. D. Purtymun, U.S.G.S. geologist, made a brief inspection of Pit 3 February 6, 1963. He recommended:

> "Filling of the pit with waste material should be completed below the soil zone as heavy precipitation may cause erosion of the artificial east rim and expose some of the wastes or allow water to move radioactive contaminants out of the pit on to the surface of the mesa."[152] And commented:

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*May be one of the holes drilled for the 1959-1960 infiltration study.

"There should be little danger of water moving radioactive contamination from the waste material in the pit into the adjacent canyons, if the pit, when filled, is sealed with a material which would restrict infiltration of precipitation.

Little is known of the hydrologic characteristics of the crushed tuff that now is used to seal over waste disposal pits. A field study utilizing the neutron-neutron scattering moisture probes and the access tubes installed in a disposal pit that is filled and sealed is planned in the future to determine the depth of infiltration into the seal material from precipitation and the loss of moisture by evaporation."[152]

"Pit # 2, Area G, was backfilled to ground level in July.* The U.S.G.S. had installed moisture tubes in this pit and 20' extension tubes had to be put on by H-1 in order to bring the ends ~~of~~ to the ground level."[68] (See Fig. 79). "The distribution of moisture in the seal material indicated little if any water from precipitation moved to a depth greater than 4 feet before it is returned to the atmosphere by evaporation."[158]

In 1964[216] W. D. Purtymun and Edward John reviewed geologic data collected in previous Pajarito Plateau studies by the U.S.G.S. to pick a site for a new Los Alamos municipal supply well in Pajarito Canyon south of Mesita del Buey. They did no additional field studies in the preparation of their report. They recommended a site approximately 1.67 miles (2.69 km) west-northwest of Area G (NE $\frac{1}{4}$ SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 19N., R. 6 E.).[216] (See Fig. 80)

* 1963

"The depth of the pilot hole at the proposed well site should be at least 2,600 feet to determine the geologic and hydrologic conditions in this area of no deep test holes."[216]

July 1965[29] supply well PM-2 (Pajarito Mesa-2) was drilled by hydraulic rotary to a depth of 2,600 ft. (m). ~~Was~~ Water was encountered at a depth of 823 ft. (m). (See Table 15)

After inspecting Pit 4, Area G August 3, 1964, W. D. Purtymun, U.S.G.S., "was inclined to think there was a possibility that by changing the axis of future pits, to parallel the major line of fracturing, that the tendency of the banks to cave could be reduced.

Mr. Purtymun did not feel that the fissures in the rock presented any threat to the water bearing stratas below by infiltration of precipitation through the pits. It is his opinion, as stated in a report he made several months ago, that the backfill material effectively seals the pits and furthermore, the penetration of any moisture into the backfill is dispersed by evaporation into the atmosphere."[153]

In the January 1966 U.S.G.S. report, "Geology and hydrology of Area "G" Mesita del Buey, Los Alamos County, New Mexico W. D. Purtymun states:

> "Water moving through the soil to the tuff probably moves more readily into the tuff than into the joints filled with brown clay because the tuff is more permeable than the clay. Movement of water in the tuff is slow. Flatlying to near-vertical open joints probably will perch water and impede the downward movement of water in the tuff, because the water is held in

tension in the small pore spaces of the tuff.

... Large amounts of water (more than available from precipitation) would be required to move contaminants from the pits to the main groundwater body because of the large thickness of dry sediment between the land surface and the water table 850 to 900 feet below the surface of the mesa or through open joints into the adjacent canyons."[158]

In the February 1966 U.S.G.S. report,[91] "Hydrology of Waste Disposal Systems, Los Alamos, New Mexico, 1949 through 1961" there is a very brief description of Area G.

W. D. Purtymun inspected Pit 5, Area G December 6, 1966.[154] He concluded: "The disposal pit is suitable for disposal of solid or package wastes as it meets the guidelines for pit construction set forth in a conference between Eng-3, H-1, H-6, H-7 of the Los Alamos Scientific Laboratory and the U.S. Geological Survey held at Los Alamos on June 23, 1965. The guidelines are summarized in a letter to Mr. Ted Russo, Eng-3, dated June 30, 1965 from F. C. Koopman, U.S. Geological Survey."[154]

September 24 and October 9, 1969 W.D. Purtymun inspected Pit 6. He concluded: "Orientation of the joints and joint openings are about the same as in the tuff exposed in other pits in the area and should pose no problems in disposal of wastes.

The pit is suitable for the disposal of solid or package wastes as it meets the guidelines for pit construction as summarized in a letter to S.E. Russo, ENG-3, dated June 30, 1965 from F. C. Koopman, U.S. Geological Survey. For future reference we have on file a series

of photographs showing the walls of the pit."[155]

November 1970 "Geology and Hydrology of Mesita del Buey"[206] was written by W.D. Purtymun and W. R. Kennedy, H-6. The following is from the section, Soil and Tuff Moisture:

"Where the soil cover has been disturbed, as in the disposal areas, the moisture content of the tuff indicates that precipitation may have infiltrated to a depth of 10 ft. The moisture ranges from 2 to 8% by weight, decreasing with depth. Below 10 ft. the moisture content ranges from 0.5 to 2% by weight, showing that the moisture is redistributed by diffusion.

Tests of infiltration of precipitation in the tuff used to cover the waste in pits showed that moisture from a single storm may reach a depth of 6 ft, but in the weeks after the storm it is returned to the atmosphere by evaporation.

Open joints in the ashflow may allow precipitation to move into the tuff. The joints are now filled to a depth of 3 to 4 ft with clay that acts as a seal and prevents precipitation from infiltrating the tuff."[206]

From the section, Main Aquifer: "The rate of water movement computed from aquifer tests of supply wells is estimated to be 1 ft/day.* From Mesita del Buey to the Rio Grande is about 4 1/2 miles, so we estimate that any water will take over 60 years to move from beneath the mesa to the river."[206]

*C. W. Theis and C. S. Conover, "Pumping Test in the Los Alamos Canyon Well Field near Los Alamos, N.M., "U.S. Geological Survey Water Supply Paper 1619-I, 1962.

The section on Erosion Rates of Tuff states:

"Vital to the containment of wastes buried at Mesita del Buey is the rate at which the tuff encompassing the wastes erodes. Some of the wastes contain radionuclides with a very long half-life.

There is no practical method to determine the erosion rate of the tuff during the short time that the mesa has been used for waste disposal. Erosion rates can be approximated by relating the age of the tuff to its past erosion. Erosion rates based on these assumptions are conservative because the tuff probably eroded faster initially than at present. The area is more stable since the stream channels in Canada del Buey and Pajarito Canyon have cut to a temporary base level on the resistant basalt.

Radiometric dating indicates that the tuff was emplaced about 1.1 million years ago.** The thickness of Unit 3 tuff eroded from the surface of the mesa at Area G is estimated to be about 80 ft. on the basis of geologic sections on the plateau where this unit is preserved. Its erosion rate for the past 1.1 million years is about 7.2×10^{-5} ft/year. Vertical downcutting in the canyons has been estimated at 1.9×10^{-4} ft/year in Cañada del Buey and 1.6×10^{-4} ft/year in Pajarito Canyon. Wilden and Criley** estimated the vertical downcutting in major canyons to be 5 to 8×10^{-4}

**R. Wilden and E.E. Criley, "Geology of Los Alamos," in "Geologic Studies and Material Properties Investigations of Mesita de Los Alamos, "Los Alamos Scientific Laboratory report LA-3728 (1963)

ft/year. At Area G, horizontal erosion at the top of the mesa is estimated to be about 4.5×10^{-4} ft/year.

Wastes are buried in the natural confines of the tuff to a level 2 ft below the mesa surface and then covered and mounded over with 6 to 8 ft of tuff. Considering the vertical erosion of 2 ft of tuff on the mesa top at a rate of 7.2×10^{-5} ft/year, it would take 27,000 years for the mesa top to erode to the top of the wastes.

The edges of the pits are 50 ft or more from the edge of the mesa. Considering the horizontal erosion of 60 ft of tuff at a rate of 4.5×10^{-4} ft/year it would take more than 110,000 years for the tuff to erode far enough to expose the wastes in the pits."[206]

The following is from the Waste Disposal Areas section:

"The pits and most of the shafts extend into Unit 2b, and the deeper (64 ft) shafts extend through Unit 2b into the top of Unit 2a of the Tshirege Member of the Bandelier Tuff."[206]

The secton on Waste Disposal and the Geohydrologic Environment states:

"Total containment of contaminants is of paramount importance in the disposal of wastes at Mesita del Buey. Initial containment is accomplished with the burial of wastes in pits or shafts. After burial, the major means of transport of contaminants to the environment would be in the hydrologic cycle.

Transport of contamination by surface runoff on the mesa seems unlikely because the wastes are buried.

Little if any water from precipitation or surface runoff infiltrates through the seal material overlying wastes in filled pits. There is not enough water to leach the contaminants from the wastes and move them into the tuff. The bottoms of the pits are underlain by about 590 ft of tuff along the western part of the mesa and about 240 ft of tuff along the eastern edge. The hydrologic characteristics and conditions of the soil, seal material, and tuff indicate no recharge to the stream-connected aquifers or main aquifer through the surface soil, buried wastes, or underlying tuff at Mesita del Buey.

The natural moisture content of the unsaturated tuff is in the range in which moisture is redistributed by diffusion. Contaminants may be transported by diffusion if gases or volatile fluids are placed in shafts or pits. Diffusion may take place through the tuff where there are large amounts of pore space, through open joints, or along contacts between ashflows.

Vertical and horizontal erosion rates of the tuff surrounding the waste in pits or shafts indicate that under present climatic conditions the estimated life of the pits will be about 27,000 years. Routine maintenance to control erosion of the seal material will extend this life."[206]

A safety analysis[156] of Pits 8, 12, 16, 17 and 21 was made June 21, 1971. M. Dean Keller, ENG-1 remarked:

"The design slope on the pits was 1 on 6, but in many cases the actual slope was greater. A more desirable slope would have been 1 on 4.

The volcanic tuff in this area is a poorly welded Unit 2b tuff, greatly resembling the Unit 3 tuff on Mesita de Los Alamos. Fracturing is extensive and the possibility of cave-ins does exist."[156]

The July 20, 1971[157] survey of Pits 8, 12, 16, 17 and 21 was made to see if the pits conformed to the guidelines for pit construction as outlined in the memo from F. C. Koopman, USGS, to S. E. Russo, ENG-3, dated June 30, 1965.

Contrary to the guidelines the long dimension of Pit 21 is at right angles to topographic contour lines. "When the pit is filled, a greater thickness of seal material should be used to cover the wastes ~~of~~ to prevent erosion from forming gullies down the long dimension."[157]

"The only joint that will need attention is in pit 17 about 265 ft from the NW corner on the SW wall. The joint opening, strikes 75° to 80° NW and is open 2 to 5 inches, extends 4 to about 12 ft. below the rim of the pit. Joint opening is near vertical. The opening can be filled and plugged when wastes in the pit are laid up to the level."[157]

In several of the pits vertical displacement along vertical joints was observed. "This is general information and does not effect the use of the pits for disposal of wastes."[157]

"Recent rains have produced small amounts of runoff which has entered the ramp on the NW ends of pits 8 and 17. Runoff should be diverted from the pits. Pit 17 will probably experience some sheet wash runoff into the pit along the SW wall.

In the future tuff excavated from the pits should be piled up gradient from the pit to prevent runoff along the walls.

Unless noted, the pit construction meets the suggested guidelines as presented in the letter of June 30, 1965.

As per conversation with W. D. Purtymun on July 20, 1971, photographs* of the walls and bottoms of the pits should be obtained for the record prior to the disposal of any wastes in the pits."[157]

Wayne Hanson, Ecology H-8, reported his inspection of Pit 7 August 21, 1973[218] to J. Herceg and J. Mohrbacher, Solid Waste Management H-8. "...the following comments reflect my immediate impressions:

1. Several joints in the tuff are of great interest from the standpoints of
   A. Lateral movement of radioactive materials that may be released by container failure;
   B. Vertical movement of radioactive materials by soils dynamics, particularly from the standpoint of whether the joints contain clay or other materials; and
   C. The joints are prime sites of root channeling by the vegetation that occupies the site now (especially trees and shrubs) and will be part of the future picture, unless vegetation control is a management tool.

* See Figs. 58, 60, 61, 62, and 63

2. Assuming that Pit 7 is representative of the situation in Pit 8, which contains the leaking 55 gallon drums of TRU sludge awaiting a decision as to treatment, there are several studies of radioactive waste mobilization that may be undertaken if the decision is made to bury the 1,600 drums in their present condition. We would like to be kept advised of plans for disposition of the drums in Pit 8, with enough advance notice that we can properly design the studies.

3. I would appreciate whatever information exists about the various pits in G Area and in the other waste disposal areas on the following points:

   A. Date of excavation and finished depth

   B. Type and amount of radioactive materials buried

   C. Depth of fill over material

   D. Date the pit was finally covered.

This information will enable us to reconstruct plant succession in various areas and under various conditions. I realized this is a large order and much of the information may be mere estimates; however, we need the best information that exists to design future studies and to make recommendations for your immediate use.

4. Pit 7 appears to be as "ecologically acceptable" as can be expected under the circumstances of waste disposal; but it exhibits several areas of concern where we presently have great need of more information.[21]

D-62.

Observations from the August 27, 1973[208] survey by Margaret Anne Rogers, Solid Waste Management H-8, of Pit 7 are:

"There is no indication care has been taken to see no run-off from precipitation on the mesa enters the pit while it is being filled.

Since there is heavy equipment in the area something should be done to improve the surface drainage from Pit # 8. There appears to be some surface run-off into the pit from the north end causing some ponding at times underneath the barrels. To a lesser degree the same condition exists for Pit # 12."[208]

February 9, 1972 Dean D. Meyer, Group Leader, H-1, wrote: "As you may have noticed during flights on Ross Aviation between Los Alamos and Albuquerque, our waste pits at TA-54 remind one of strip mining. The visual impact on the environment has been rather drastic. Please estimate how much it would cost to level, seed and water some type of vegetation cover on the areas outlined in ink on the attached photo."[217] (See Fig. 81)

March 28, 1974[219] John Warren, Solid Waste Management Section H-8, asked that a program "to establish needed improvements in <u>erosion control</u> and <u>soil fixation</u>"[219] be started for the approximate 12 acres of Area G where Pits 1 thru 5 are located. "It is recognized that much of the early work may be experimental in nature, testing different possible concepts or techniques.

To establish an initial program plan we request that in the next few weeks, you take a close look at the designated area, and formulate possible courses of action that can be tried or tested. It would be appreciated if these proposals could be submitted to the Waste Management Section by April 26. Shortly thereafter, if necessary, a meeting of all interested parties will be called to discuss and select the initial work to be done."[219]

Wayne Hanson, H-8 replied June 4, 1974.[220]

"In response to your Memo H8-WM-151 of 28 March 1974, we have mobilized a variety of talent to address the above topic. On May 8, Mr. Dick Cooke of the US Forest Service in Santa Fe, visited the Areas G and C environs to determine what the situation looked like so that he could make knowledgable recommendations. On 28-29 May, Dr. Elmer Remmenga of Colorado State University, was brought in as a Visiting Professor to consult[redacted] on the project. As a result of these inputs, we now plan to proceed as follows:

1. Jack Nyhan has taken Area G soil samples for analysis of nutrients, as a basis for fertilizer recommendations;
2. Dick Cooke is immediately furnishing information on vendors of rangeland drills, grass seeds, and fertilizers; upon receipt of the soils analyses from Jack he will bring in the USFS rehabilitation and revegetation specialist to make firm recommendations;

3. We believe that watering facilities, such as the temporary line we discussed with Remmenga, will be highly desirable if not imperative to achieve any sort of success in the revegetation effort; perhaps you have some estimates from ENG concerning this;
4. We propose to do some very small scale flower pot experiments immediately upon which to base extrapolation to the Area G situation; and
5. We anticipate reconstructing a scheme of natural vegetation succession on disturbed LASL waste pits according to information furnished by you in Memo H8-WM-173* and data that we will be requesting in the future.

I will keep you informed as details become available."[220]

After a particularly dry August and early September ~~2~~ two heavy rains fell at Area G September 10-11, 1973.[221] Rain 1, midnight - 9:30 a.m. September 10, produced, .72 inches (cm) of precipitation at Area G; Rain 2, 6:30 p.m. September 10 - 4:00 a.m. September 11, produced 1.5 inches (cm) of precipitation at Area G.

Following Rain 1 ponding occurred in Pit 8 only. Moisture continued to run into the Pit throughout the day (September 10). This moisture seemed to be moving along the soil-tuff interface to the intersection of this interface with the north ramp of Pit 8 and then down the ramp into the pit.

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*Memo from John Enders, H-8 to Wayne Hanson, H-8, Subject: History of Pits 1-6 in Area G, Dated April 11, 1974

Following Rain 2 ponding occurred in the Decontamination Pit and Pits 7,8, 12 and 17. Water did not pond in Pits 16 and 21. Direct rain fell into the pits plus runoff down a ramp (the north ramp for the Decontamination Pit and Pits 8, 12, and 17 and the west ramp for Pit 7).(See Figs. 82 and 83) Very little water ran over and down the walls of the Pits. Mud streaks on the north wall of Pit 7 in Fig. 84 are an example showing that most water running down the walls of the pits did not reach the bottom of the pits. Depth of ponding in the pits ranged from a fraction of an inch to 9 1/2 inches (cm). Figure 85 shows the 9 1/2 inch (cm) watermark on the south wall of Pit 7 approximately 268 ft.( ) from the west end of the pit. Where water was ponded against the walls of a pit, it moved up the walls (in the tuff) by capillary action. The greatest upward movement of water by capillary action occurred in Pit 8. (See Fig. 86) Of particular interest is the movement of precipitation through the soil into intersecting joints which (in Fig. 87) channeled water to an opening on the south wall of Pit 7.

An attempt to correlate observed disappearance of moisture with estimated rates of evaporation in Pit 7 had mixed success. The formula worked out by Sumner Barr, meteorologist H-8, gave the best correlation between observation and estimation during the time water was ponded. It did demonstrate that the

disappearance ~~fo~~ the Pit 7 pond was primarily due to penetration of moisture instead of evaporation of moisture. After the disappearance of the pond (when the bottom of Pit 7 was still wet), estimated rates of evaporation dried up the pit bottom more than a week before observation showed it dry.[221]

W. D. Purtymun and Linda Trocki completed the augering of 4 holes in Pit 7 September 20, 1973.[221] For all holes samples of cuttings ~~were~~ taken at 5 ft.(m) intervals were analyzed for moisture content. Hole # 1, 146 ft (m) from the west end of the pit along the south wall, was 117 ft deep. Holes # 2 and # 3, 224 ft (m) and 353 ft (m) respectively from the west end of the pit along the north wall, and Hole # 4, 256 ft (m) from the west end of the pit along the south wall, were 50 ft. deep. Only Hole # 4 was in the area where water ponded in Pit 7. In the first 5 ft (m) Hole # 4 showed approximately 5 times the amount of moisture than in the first 5 ft (m) of Holes # 1, # 2 and # 3.

"In the open pits at Area G there seems to be a relationship between ponding and amount of precipitation and between ponding and elevation of each pit."[221] Pit 8 which was not the lowest pit held water after Rain 1. All pits except the highest pit, Pit 16, and the third highest pit, Pit 21, held water after Rain 2. "The missing ponding factor (or factors) has not yet been determined. Possibilities for the missing factor(s) are: fracture pattern, fracture fillings, powdered rock debris on pit bottom, and type of waste in pit.

At the times Rains 1 and 2 grading to prevent water from running into the open pits was not done. It has been done now. While this report does not try to determine the significance of ponding, it does seem wise to maintain grading and thus minimize a possible problem.

From looking at the Pit # 7 pond, it appears more water is absorbed than is evaporated. There is no way with present data to say how long this water is retained by the tuff---does it continue to migrate downward (or laterally) or after a certain period (of absence of new precipitation) does it migrate upward?"[221]

During the geologic inspections of Pits 7 and 24 numerous roots were found in the walls of the pits. The roots, in many cases, extended to the bottom of the pits. Most of the time they were associated with joints. Figure 88 is an example of roots following vertical joints and brecciating tuff adjacent to the joint plane. Figure 89 shows roots which grew horizontally parallel to a watermark on an exposed joint plane in the north wall of Pit 24. Figure 90 shows roots penetrating the tuff at a depth of 20 ft (m) in the south wall of Pit 24, this is a rare case where roots do not appear to be directly associated with joints in the tuff.

September 11, 1973 a root sample was taken from a wall in Pit ~~# 3~~ 7. "The sample was one of the largest pieces exposed on the pit wall.

The sample was sent to the Laboratory of Tree Ring Research, University of Arizona, Tucson. They report that insufficient

growth rings are present in the sample to permit tree-ring dating. The material is from a coniferous tree, as indicated by cell structure. No estimate of sample age was made."[222]

November 2, 1973 five samples of roots were taken from 4 joints in the north wall and 1 joint in the south wall of Pit 7 for ^{14}C dating. On November 19, one sample from the north wall of Pit 24 was substituted for one sample from the north wall of Pit 7. The sample from Pit 24 and one sample from the north wall of Pit 7 were taken beneath watermarks on exposed joint planes. (See Figs. 84 and 89 for location of these samples)

All roots samples indicated a ^{14}C age of post-1950 in the range 1956-1961. The period 1956-1961 spans the beginning of Area G through the excavation of Pit 2. The site of Pits 7 and 24 was not within the perimeter fence of Area G until 1969. At that time the vegetation was removed. It is likely there was some vegetative disturbance at the site of Pits 7 and 24 before 1969. There seems to be a good correlation between the ^{14}C dates on the roots and the known history of the area.

The ^{14}C dates on 2 of the samples also dated watermarks which are particularly common in Pit 24. The assumption is that roots grow downward seeking moisture, and spread laterally when they find it. The watermarks (See Figs. 91 and 92 for additional examples) belong, therefore to the current climatic regime and are not relics of some ancient climatic regime.

Jacques Renault, Geologist, New Mexico Bureau of Mines and Mineral Resources examined and took samples of fracture fillings in Pit 7 and 24 November 6, 1973. The following is his report:[223]

"REPORT ON THE EXAMINATION OF FRACTURE FILLINGS IN DISPOSAL PITS NO. 7 AND NO. 24, LOS ALAMOS SCIENTIFIC LABORATORIES

Introduction

The disposal pits No. 7 and No. 24* were visited on the afternoon of Nov. 11, 1973 with Ms. Margaret Ann Rogers. Samples were collected from pit No. 7 for optical and X-ray examination. Fracture numbers in this report are those used by Ms. Rogers in her fracture study of Pit No. 7.

Field Observations

Caliche filled fractures** in pits Nos. 7 and 24 extend downward about three to seven meters from the original land surface. At the surface, they are up to four centimeters wide and diminish in thickness downward. Caliche is mixed with brown clayey fillings in fractures about five meters below the land surface. Below the mixed zone, fracture fillings are predominately brown clay.***

Fractures in the pits show varying degrees of permeability with some openings† tens of centimeters wide and others tightly closed. Open fractures display horizontal structures in the brown clayey coatings which can be traced from fracture to fracture within two meters of the floor of pit No. 24.†† The clayey coatings in these fractures show small scale dessication cracks.†††

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*See Fig. 93, **See Fig. 94, ***See Fig. 95, †See Fig. 96, ††See Figs. 89 and 91, †††See Fig. 9~~5~~1

Microscopic Examination

The fracture margins near fracture No. 43 in Pit No. 7 were examined under the binocular microscope. Within a few centimeters of the fracture~~s~~ surfaces, the tuff is unaltered. Delicate rock structures extend from unaltered tuff into clayey material of the fractures without geometric disruption. Pumice fragments show decreasing alteration for a distance of less than 15 mm away from the fracture margins toward fresh rock. Alteration of pumice is to clay minerals stained with limonite.* Rounded pumice fragments are mixed with clay and caliche in fracture no. 52.**

Mineralogy

X-ray diffraction analysis of the fracture filling material indicates only montmorillonite and calcite as the important secondary crystalline phases present. The near surface caliche fillings appear to be relatively pure $CaCO_3$; whereas, the brown clay is predominantly montmorillonite with a trace of low christobalite.

Interpretation

The existence of a caliche zone of fracture filling near the ground surface which is succeeded by mixed montmorillonite-caliche and then montmorillonite filled fractures with depth is most easily explained by ground water activity. The presence of trace christobalite is the only evidence of volcanic origin for some of the components of the fracture fillings, and it is very definitely a trace constituent.

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*See Figs. 97, 98, and 99, **See Fig. 100

The dessication cracks and horizontal structures in open fractures suggest that meteoric water was standing in the fractures at some time prior to the excavation of the pits.* Montmorillonite is a swelling clay and in small fractures could be permeable to gas flow.**

Some rock material may have been transported in the fractures. The rounded pumice fragments in the fractures is evidence of this, but the rounding of the fragments cannot be said with certainty to be due to abrasion, because the pumice fragments within the rock mass are sometimes round.

The gradation of intensity of clayey alteration products at the fracture margins with the preservation of delicate rock structures there is incontrovertiable evidence that much of the development of montmorillonite has occurred in place.

The development of caliche in the near surface fractures and of montmorillonite in deeper fractures had undoubtedly diminished the initial permeability of the fracture system. Prior to excavation of the disposal pits, infiltration of meteoric water into the Bandelier tuff by way of these fractures was thus greatly inhibited. The caliche, especially, has served as a barrier to infiltration from the surface and retarded the sealing of deeper fractures by montmorillonite. Nevertheless, meteoric water has found its way into openings in fractures below the caliche zone as evidenced by water lines and dessication

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*See Figs. 89, 91, 92, 95, **See Figs. 95 and 101

cracks on fracture walls. Excavation of the pits below the caliche zone has made unweathered tuff again susceptible to infiltration by meteoric water.

Any excavation which exposes fresh tuff will enhance the tuff's acceptance of meteoric water and the effect will increase with the depth of excavation.* In the zone of montmorillonite fracture fillings, the expansion of this clay during wetting may exert sufficient stress on the fracture walls to dilate them irreversibly.

In view of the zoned character of the fracture filling mineralogy and the physical properties of the montmorillonite, it would seem that disposal pits confined to the caliche zone are less likely to contribute contaminants to the groundwater by way of infiltration then those which extend into the zone of montmorillonite fracture fillings.

Summary and Conclusions

Field relationships, microscopic observations, and X-ray mineralogy demonstrate that the fracture fillings exposed on the walls of disposal pits no. 7 and 24 are due to alteration of the Bandelier tuff by meteoric water. There are three zones of alteration: 1) an upper zone of caliche filled fractures, 2) an intermediate zone of mixed caliche and montmorillonite filled fractures, and 3) a lower zone of montmorillonite filled fractures. In recent times water has been stationary in some of the open fractures indicating that 1) water can gain access to the fractures

*See Fig. 87

and 2) some of the fractures are plugged at depth. Porosity of the caliche filled fractures appears to be less than that of the montmorillonite filled fractures. Prior to excavation of the disposal pits, surface weathering and the resulting deposition of caliche and clays in the fractures inhibited infiltration of meteoric water. Excavation of the pits has exposed unaltered tuff, and as a result, infiltration of meteoric water into the lower zone can be expected to increase. Montmorillonite is a swelling clay and is expected to plug fractures when it is wet; furthermore, it is conceivable that expansion of this clay could cause fracture walls to move apart irreversibly. The montmorillonite filled fractures will have low permeability to gasses when wet and high permeability to gasses when dry. Disposal pit depth should be confined to the caliche zone."[223]

W. D. Purtymun, H-6 reported on the migration of tritium in the Area G shaft disposal area July 7, 1970.[135]

Samples of tuff were collected during the augering of Shafts 34-38, 40-49. They were analyzed for moisture content and tritium content in moisture. Table 19 shows results of the analyses and Figure 102 shows locations and status of shafts as of June 24, 1970.

"Laboratory analyses of three samples of tuff from a depth of 25 feet indicated the following hydrologic properties

Porosity	Specific Retention	Specific Yield
	(percent by volume)	
44	17	27
37	20	17
36	18	18

The moisture content of the tuff ranged from 0.1 to 6.4% with an average of 1.2 percent by volume.

The tritium concentrations from samples collected from shaft 34 (November 1969) located about 55 feet east of existing shaft 14 ranged from 62 to 454 x 10^{-6} μCi/ml of moisture.

The concentrations in samples from shafts 35 to 38 located about 80 feet south of shaft 14 ranged from 0 to 106 x 10^{-6} μCi/ml of moisture.

High tritium concentrations (range 1,779 to 1,180,630 x 10^{-6} μCi/ml os moisture) were found in samples collected from shafts 39 through 48 which are located in a line about 6 feet east of shafts 4 through 13 that are filled with wastes.

The low moisture content of the tuff indicates that the tritium is being distributed through the pore space of the tuff as well as joints or fractures by diffusion in a water vapor. There is probably some moisture gradient (greater in the wastes themselves) which will aid in the outward movement of the tritium as the volumes of greater moisture seek equilibrium in the tuff. There appears to be little if any pattern in the distribution of the tritium, probably due in part varying concentrations buried at various depths within the shafts and in part to a possible distribution that could be joint controlled.

In talking to Jack Healy there was some question as to if the moisture distilled from the tuff for analyses was in part bound water or water of crystallation. I ran a few tests and as near as I could determine the moisture distilled from the tuff was not

in the form of bound water or water of crystallization."[135]

Shafts 1-14 were augered in the spring of 1966.[159] All except Shaft 14 received some waste contaminated with tritium.[159]

This initial report stimulated interest for the study described in LAMS Report, "Underground Movement of Tritium from Solid-Waste Storage Shafts."[159] In August 1970 14 test holes were laid out and drilled. (See Fig. 103)

"The test holes, 6 in. in diameter and 50 ft deep, were drilled with a power auger. Tuff samples representing 5 ft. intervals were collected from the auger cuttings. The holes were thoroughly cleaned before each 5 ft sample run, and the results of the tritium analyses indicated that there was little, if any, cross-contamination between samples from successive 5 ft intervals."[15] (See Table 20) "In general the tritium concentrations increased to a maximum between depths of 10 and 30 ft and then decreased with depth.

Isotritium contours were constructed at depths of 10 to 15 ft, 20 to 25 ft, 30 to 35 ft, and 40 t0 45 ft (Figs. 2 and 3).* Test holes and burial shafts were used for control points on Fig. 2 while only the test holes were used on Fig. 3. The irregularities in the isotritium contours just east of the shafts are due to the movement of the tritium through open joints which provide a much more rapid means of migration than movement through the tuff matrix. The effect of these joints is apparent only near the shafts due to the close spacing of control points used in construction of the contours. West of the shafts where control points (test holes) are located on 20 ft centers the effect of the

*See Fig. 104

joints on movement of the tritium is not apparent. The contours are elongated to the west of the shafts showing the principal movement of the tritium.

Isotritium contours were also constructed for a vertical plane extending east and west through shaft 13 (Fig. 4).* The contours show that the major movement of tritium took place along the contact between the two ashflows. The abundance of pumice fragments in the lower part of the upper ashflow and the presence of the reworked tuff between the two flows causes a greater porosity and permeability in the contact region as compared to the matrix or joints in the overlying or underlying tuff. The tritiated moisture migrating along the contact serves as a source for movement into the upper and lower ashflows.

A comparison of the isotritium contours in planview (Figs. 2 and 3)* just above and below the contact shows that migration of the tritium was not uniform along the contact but greater in a westerly direction. This is due to a thickening of the layer of reworked tuff lying along the contact which increases the rate of movement in that direction.

The tuff in the ashflows is not homogenous. It is broken by joints, and porosity varies within the tuff matrix. The contact between the two ashflows adds to the inhomogeneity. Thus the extent of the migration can only be approximated. About 4 yr after the wastes were stored in shafts 12 and 13, a 100 pCi/ml contour has moved to a distance of about 105 ft west of the shafts along the contact between the two ashflows (Fig. 4),*

*See Fig. 104

G-67

and the 100 pCi/ml contour extrapolated beneath the shafts is at a depth of about 97 ft below the surface of the mesa. There is a second contact beneath the lower ashflow (Fig. 4),* however, and this contact would slow the vertical migration of tritiated water vapors through the tuff by allowing them to move laterally along the more permeable contact. In general, the volume of tuff containing the tritiated moisture has assumed the shape of an irregular lens, shortened to the east and elongated to the west (Fig. 4).*

Little water from precipitation infiltrates through the soil into the underlying tuff.** There is not enough water to leach the tritium from the wastes and move it through the 240 ft of dry tuff and 610 ft of dry volcanic rocks and sediments to the main aquifer that lies at a depth of about 850 ft at Area G.

RELEASE OF TRITIUM TO THE ATMOSPHERE

Intake of air during periods of high atmospheric pressure and exhaust of air during periods of low pressure have been noted for burial shafts and test holes in the tuff in Area G. The soil and weathered surface tuff forms a partial barrier against the exchange of air between the underlying tuff and the atmosphere.*** Air was pumped from shaft 47 to determine if measureable amounts of tritium could be released to the atmosphere during an atmospheric low.

The air in the shafts is nearly saturated with water vapor. The measured relative humidity varied from 94 to 98% at a

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*See Fig. 104, **W. D. Purtymun, "Geology and Hydrology of Mesita del Buey," Los Alamos Scientific Laboratory Report LA-4660 (1971).

***J. L. Kunkler, "Measurement of Atmospheric Pressure and Subsurface Gas Pressure in the Unsaturated Zone of the Bandelier Tuff, Los Alamos, New Mexico," U.S. Geol. Survey Prof.Paper 650-D (1969).

temperature of about 70°F. Prior to receiving wastes, shaft 47 was sealed at the surface and air pumped out of the unlined shaft at a rate of about 2.5 cfm for 24 h. Moisture was collected in a condenser at the pump and analyzed for tritium. The tritium concentration was 577,000 pCi/ml of water, about half the concentration found in moisture from a sample of tuff collected from a depth of 25 ft(Table I).*

A number of samples of surface soil were collected west o- shaft 13 out to a distance of 120 ft (Table III).** Tritiated moisture concentrations generally decreased with distance from shafts 12 and 13. The sample collected at 80 ft consisted of tuff since there was no soil cover at that point. We therefore conclude that tritium is being released to the atmosphere as a result of evaporation of soil moisture near the shafts.

In an effort to determine whether or not vegetation has any influence on the transfer of tritiated moisture from the disposal shafts to the atmosphere, five samples of vegetation and moisture transpired from vegetation were collected in the immediate vicinity of the disposal shafts (Table IV).** These analyses indicate that there is an uptake of tritium by plants from the soil and tuff and that tritiated moisture is being transpired to the atmosphere. Measurements from two samples collected about 0.5 miles west of the shafts are included for comparison. No attempt was made to determine the amount of tritiated moisture being released to the atmosphere due to transpiration from plants and evaporation from surface soil adjacent to the shafts.

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*See Table 19

**Table 21

Dean D. Meyer, Group Leader, H-1 requested of Harry S. Jordan, Group Leader, H-8 on May 26, 1971[137] that background information on tritium be taken on the newly excavated Pits 8, 12, 16, 17 and 21. "In the past, Group H-6 has detected tritium in the soil from and around our old pits. If possible, I would like Group H-8 to sample soil from the new pits, possibly core drilling in the bottom of one or more. These samples would give us a background which we do not have for the old pits."[137]

"Nine test holes were drilled in August 1971 in and adjacent to the new disposal pits at TA-54 (See sketch on location).* Five of the test holes (8A, 12A, 16A, and 21A) were drilled to a depth of 30 feet in the floor of the pits. Four of the test holes (8A, 16B, 17B and 21B) were drilled to depths of 60 feet, three on the perimeter and one near the center of the area....

Samples of tuff were collected over a five foot interval. The moisture content of each sample was determined and moisture distilled out for tritium analyses."[224] (See Table 22)

"There was no pattern to the distribution of tritium with depth. Concentrations are low, within background data on tritium collected from a shaft at Area L (20 pCi/ml).

In undisturbed areas on the mesa moisture concentrations in the tuff will range from 3 to 8 per cent by weight in upper 10 feet of soil and tuff. The concentrations decrease with depth. Soil cover in the areas of holes 8B, 16B, 17B, and 21B was distributed by heavy equipment used in construction of the pits. The moisture content of samples in the upper 10 feet of soil and tuff from the above holes ranged from 0.6 to 5.0 per

*Figure 105

cent by weight with an average of 1.8.

The moisture contents of tuff from holes 8A, 12A, 16A, 17A, and 21A (located in bottom of pits) and below depths of 10 feet in holes 8B, 16B, 17B, and 21B ranged from < 0.1 to 1.4 per cent by weight with an average of 0.4. The moisture in the soil and tuff is in the low moisture range where movement is by diffusion.

The pits are constructed in Unit 2b of the Tshirege Member of the Bandelier Tuff....

The test holes drilled in the bottom of the pits (within the lower ashflow) are completed into the top of Units 2a. The test holes drilled on the perimeter and near the center of the area are completed through Unit 2b into the top of Unit 2a.

Radiochemical analyses of samples collected from test hole 21B were composited according to stratigraphic units (i.e. upper ashflow, reworked material, and lower ashflow of unit 2b and upper ashflow of unit 2a) and analyzed for gross alpha and beta activity as well as ^{238}Pu, ^{239}Pu, ^{137}Cs and Natural Uranium (Table 2).** The results of the analyses are within limits of background data in the Los Alamos area. The positive value of 0.005 pCi/g (picocuries per gram) of ^{239}Pu in the upper ashflow (depth 0-10 feet) is within limits established for ^{239}Pu fallout in Los Alamos, Santa Fe and Espanola areas."[224]

**Table 23

In early December 1973 W. D. Purtymun, H-8 and M. Wheeler, H-8 augered 5 test holes in the fill over Pits 1 and 2 (See Fig. 106). M. Wheeler reported the results of the study February 13, 1974.[225]

"ABSTRACT

Soil samples were collected from the fill material overlying Pit No. 1 and Pit 2, Area G, to depths of 3.8 metres. Moisture contents varied between 3 and 13% but generally showed a similar trend with depth at all sample points. Penetration of annual precipitation appears to occur to depths of two to three metres. The moisture contents were above those observed in undisturbed tuff, and below those occurring in natural soils. Further field investigations will be required to determine actual moisture movement rates.

Tritium concentrations were significantly higher than normal background. Concentration gradients indicate that tritium is diffusing towards and perhaps out of the soil surface. No atmospheric sampling data is available concerning the quantities of tritium in the air above this site.

Sampling Procedures

In early December, 1973, samples were collected of the cover material on Pits 1 and 2, Area G, TA-54. Material was collected by two methods; holes were drilled using a four-inch power auger, and samples of the material brought to the surface were collected

at regular depth intervals; a split-spoon sampler was driven into the material with an impact hammer, returned to the surface, and the samples removed from the sampler.

The samples were analyzed for moisture content using standard gravimetric techniques. Moisture samples were removed from the soil by heat distillation and analyzed for tritium content. Selected samples will be analyzed for plutonium, cesium, and strontium. A summary of the resultant data is summarized in Table 1.* The technique used in collecting the samples is indicated in the table. A sketch map of the location of the sample holes is presented as Fig. 1.**

The various sample holes are of varying depths, primarily reflecting thickness of cover material in the various locations. Great care was taken to cease penetration at the first indication that waste material was being encountered. A thorough monitoring of the samples and sampling equipment performed by an H-1 monitor, indicated no detectable contamination.

After the drilling was completed, the holes were backfilled a short distance, and a 2-inch plastic pipe placed in the hole. The hole was backfilled around the pipe, and the pipe was capped. These casings will be used as access tubes for a neutron moisture meter to provide further monitoring of moisture movement in the fill material.

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*Table 24

**Fig. 106

Three additional sets of holes have been drilled in tuff material underlying disposal pits which were not in full service.* Samples were collected using the power auger described above, and analyzed for moisture content. A summary of data from selected holes in Pits 7, 8, and 24 is presented in Table 2. Analysis for tritium was not performed. However, data from field investigations in 1971 indicated that background tritium concentrations in undisturbed tuff are on the order of 10-20 pico-curies/millilitre.**

Discussion

The fill material on Pit No. 1 and Pit No. 2 appears to have been undisturbed since covering was completed in April 1961 and July 1963, respectively. This lack of disturbance is indicated by the presence of mature specimens of Chrysothamus parrihowardi (rabbitbrush) in the vicinity of the sample holes. This plant species requires ten to twenty years to reach adult size.

In general, a peak in the water content was located at one to two metres depth. Below this interval moisture contents decreased with depth, and then at depths of about three metres remained somewhat constant with depth. This indicates that moisture penetration by precipitation is confined primarily to the upper 2 to 3 metres of material. Penetration below that depth may occur during years of unusually high precipitation, and from slow redistribution of near surface moisture.

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*Reference 226

**Reference 224

Moisture contents were well below field capacity values (estimated as 15-20% for this material) indicating that moisture movement is primarily caused by capillary forces. No actual movement rates can be inferred from this data without additional field measurements. The variation in moisture contents observed between the fill on Pit No. 1 and that on Pit No. 2 may be due either to variations in soil conductivity or differences in surface slopes. Further work is planned to substantiate this.

It is interesting to compare the moisture content of the fill material with that of the tuff beneath disposal Pits 7, 8, and 24. Pits 7 and 24 were constructed in the fall of 1973, and the bottoms had been exposed to precipitation for only a few months when the moisture samples were collected. The moisture contents are similar to, or lower than those recorded in other, undisturbed portions of the tuff.* Pit No. 8 was constructed in August 1971, and was thus exposed to precipitation for more than two years. Water is known to have accumulated in the bottom of the pit on at least one occasion (September, 1973).** This increased moisture input is reflected in the higher moisture contents observed beneath Pit No. 8, compared with Pits 7 and 24.

No firm comparison can be made between the moisture transmitting capacity of the fill material (crushed tuff) and the undisturbed tuff. However, the similarity of the moisture regime beneath Pit No. 8 and that in the fill material indicates that the transmission capabilities of the two materials are in the same range of values. Generally speaking, both material

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*J. H. Abrahams, Jr., J.E. Weir, Jr., and W.D. Purtymun, "Distribution of Moisture in Soil and Near-Surface Tuff on the Pajarito Plateau, Los Alamos County, New Mexico". U.S. Geological Survey, Prof. Paper 424-D, 1961, 1961.

**M. A. Rogers, Personal communication September 1973.

can be characterized as "poor conductors" of moisture. For comparison, moisture contents of undisturbed natural soils range up to 20% by weight at depths of one to two metres.*

The recorded tritium concentrations are of considerable interest. Environmental monitoring in the Los Alamos area indicates that background tritium concentrations are in the range of 10-20 pico-curies/millilitre,***,† for both soils and near surface tuff. The tritium concentrations observed in the fill on Pit No. 1 are more than three orders of magnitude higher than this. A search of disposal records for that pit did not reveal any single item that would appear to be a source of the tritium. Several entries recorded the disposal of 50-100 curie quantities of tritium, but none were in the near vicinity of the moisture samples holes. The significant concentration gradient towards the surface, indicates that tritium is diffusing towards, and perhaps out of the ground surface. Additional monitoring will be necessary to determine the actual quantities of tritium entering the atmosphere or vegetation at this site.

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*J. H. Abrahams, Jr., J. E. Weir, Jr., and W. D. Purtymun, "Distribution of Moisture in Soil and Near-Surface Tuff on the Pajarito Plateau, Los Alamos County, New Mexico". U.S. Geol.Sur. Prof. Paper 424-D, 1961.

***Reference 224

†J.E. Herceg, Environmental Monitoring in the vicinity of the Los Alamos Scientific Laboratory, Calendar Year 1972. Los Alamos document, LA-5184, March 1973.

Conclusion

Moisture sampling data indicates that precipitation is penetrating to a depth of one to two metres in the fill material. The material appears to have about the same moisture transmission capacity as undisturbed tuff, both materials being lower than natural soils in the area.

Unusually high tritium concentrations were observed in the fill on Pit No. 1, but cannot be attributed to any specific source. Tritium appears to be migrating towards the ground surface."[225]

In the fall of 1973 W. D. Purtymun and Linda Trocki also augered three 50 ft (m) deep holes in Pit 24. As in Pit 7, samples of cuttings at 5 foot (m) intervals were taken and analyzed for moisture content. (See Table 25 and 26)

"As yet I* don't have a profile showing bottom elevations of Pits 7 and 24 for correlation purposes; however, drilling breaks were indicated at 15 to 17 feet in Pit 7 and at 19 - 24 feet in Pit 24 which are about the contacts of Unit 2b and Unit 2a. A second drilling break occurred ~50 ± 5 feet in both pits. The second contact is between Unit 2a and Unit 1b and is shown by a slight increase in moisture contents in Hole 1(Pit 7), and Holes 1 and 3 (Pit 24) indicating a change in the hydrologic characteristic of the two ashflow units.

Test holes in Pits 7 and 24 were logged at 2 foot intervals with the neutron moisture sonde for background information. The

*W. D. Purtymun

moisture content of the tuff was below limits of the calibration curve which is ~ 5 percent moisture by volume. My calculations indicate that in the low range of ~ 5 to 10 percent by volume the moisture will be redistributed by diffusion. Above ~ 10 percent distribution would be by diffusion and capillary with some effect of gravity."[226] The neutron moisture probe was run down the holes several months after they were augered and before plastic pipe was cemented into the top of the holes. (See Figs. 107 and 108). When the pits are filled with wastes, the pipe will serve as access tubes for the neutron moisture probe. In the first quarter of 1974 "Zia carpenters added wood shielding planks around the pipes embedded in the floors of Pit # 7 and #24. The additional shielding* should provide better protection for these pipes during pit filling operations."[207]

Pit 8 contains a number of 55 gallon drums of sludge from H-7's waste treatment plants. While drums were being off-loaded January 5, 1973,[140] the lids from 2 drums came loose spilling sludge on the pit floor. Heavy plastic bags were placed over the 2 drums; and one cubic yard of fill was placed on top of the spilled sludge. "The original idea of shoveling the sludge back into another drum had to be shelved as the material was frozen solid to the ground.

Apparently, H-7 has been using second hand drums to hold sludge. I** would recommend that only new drums be used and

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*Additional shielding to that shown in Figs. 107 and 108

**John Enders

that H-7 inspect each drum prior to loading onto the skip-type container to assure that the lids are secured properly."[140]

The drums in Pit 8 have had other problems and consequently produced problems. Damage during transport and damage as a result of palletizing promoted corrosion in some cases. (The Pit 8 drums were made part of a corrosion study.)

After the September 10-11, 1973 rains a sample of the ponded water in Pit 8 was taken for plutonium analysis. The results were negative. Because the drums were known to be leaking, it was felt the situation offered an excellent opportunity to study migration of transuranics in the tuff and fill material. Merlin Wheeler, Keith Schiager, and Wm. D. Purtymun, H-8 made a request for monitoring in Pit 8, Area G, on January 7, 1974.[162]

"The following procedures are recommended for monitoring the movement of soil moisture and radionuclides within and out of Pit No. 8.

1. Placement of access holes for moisture measurement with neutron thermalization probe. Three 10-metre boreholes will be augered in the bottom of the pit, two on the north end and one on the south, located within a metre of the present stack of drums. Five centimetre plastic casing will be cemented into the upper one metre of the bore-holes, and extended above the surface of the filled pit.

2. Placement of access tubes for installation of soil moisture cells. Five-centimetre plastic casing will be located at four positions around the perimeter of the drum stack and extended above the surface of the filled pit. These casings will be used for locating electronic soil moisture sensing cells after the pit is filled. The cells are not expected to be on hand at the time the pit is filled. After the cells have been placed, the casings will be pulled back at least a metre, and used for moisture monitoring with a neutron probe.
3. Placement of access tubes for coring the tuff. Four to six steel pipes will be located around the perimeter of the stack, and if possible in the interior of the stack. These pipes will be set a few centimeters into the tuff to secure the bottoms and extended above the surface of the filled pit. They will permit core sampling of the tuff after the pit has been filled, and ensure that no waste containers are encountered during the sampling. Three of the pipes will be located within a metre of the moisture access tubes.
4. Placement of access tubes for sampling fill material. Four to six plastic casings will be located around the perimeter of the drum stack, with the bottoms of the casings about one metre above the bottom of the drum

stack. These casings will permit sampling of the fill material adjacent to the drums, and ensure that no waste containers are encountered during the sampling."[162]

At the end of February 1974 all access holes for moisture measurement had been augered around the drums. All access tubes for coring the tuff, all access ~~for~~ tubes for sampling the fill material and all access tubes for the installation of soil moisture cells had been placed around the drums.

January 14, 1974[161] John Warren, H-8, had proposed a plan for the disposal by burial of the leaking drums of ^{238}Pu contaminated sludge. At the end of February when the monitoring network was set up, other types of waste were placed around the drums. (See Figs. 109 and 110) Pit 8 received its final cover of dirt March 27, 1974. When the pit was back-filled with crushed tuff there was disruption of the monitoring pipe. Figure 111 shows the monitoring network as it exists.

W. D. Purtymun reported the moisture content of samples taken during the augering of holes in Pit 8 for the moisture neutron probe on February 7, 1974.[226]

"The increase in moisture content of the tuff as the result of water ponding in a pit left open over a period of years is shown in the data from the holes drilled in Pit 8 in January 1974. Pit 8 was constructed in the summer of 1971. Background data (Memo H8-M2371* attached) indicated that the moisture content of cutting from Hole 8A drilled in August 1971 ranged

*Reference 224

from 0.2 to 1.4 percent by weight. The moisture content of the tuff in cuttings from the three holes drilled in January 1974 ranged from 1.6 to 9.8 percent by weight."[226] See Table 27.

M. Wheeler described the monitoring in the ^{238}Pu Retrievable Storage complex July 10, 1974.[228]

"Four types of monitoring were included in the complex. Access tubes permit sampling of the air within the cavity formed by the metal sheeting and the tops of the casks. This will permit detection of any escaping gases, radioactive or otherwise. Soil moisture sensors were placed adjacent to selected casks, located level with the bottom of the cask. These will permit measurements of the moisture regime around the cask. The sensors can also be used for soil temperature measurements. The location of the sensors is indicated in Figure 1.* Thermocouples were placed adjacent to the casks at four locations in Trench B, as indicated in Figure 1.* They will be also used for soil temperature measurements. Three of the casks, No. 1 and 2 in Trench A, and No. 81 in Trench B were fitted with thermocouples located inside the drums of waste. These units, in conjunction with external temperature data, will provide information on generation and migration of heat produced by decay of the ^{238}Pu.

The complex has not been filled at present, and is not scheduled to be for many months. As a result, the sensors external to the casks will more likely reflect external climatic conditions than soil conditions. Consequently, a regular

*Fig. 112

recording program has not yet been initiated. Such a program will be started when the portions of the trenches containing the various sensors are completed. Instrumentation of additional drums with thermocouples is anticipated."[228]

There were two fires at Area G. The first, September 16, 1960, was in Pit 1; the second, November 21, 1964, was in Pit 3. Both fires were reported by a Security Guard. The Fire Department hosed down smoldering debris in Pit 1. "Fire had apparently started during the noon hour and had burned most of the exposed waste prior to discovery."[189]

The fire in Pit 3 was reported about 5:30 p.m.[160,73] It was located in boxed trash at the north end of the pit on the east. An area about 25 ft (m) wide and 100 ft(30.5 m) long was burned. Charles Blackwell (H-1) estimated that the wind, at the time of the fire, was about 5 mph from the west.[160] "The smoke from the fire crossed the road along the east edge of the pit and passed on down the mesa. A survey of the roadway and the perimeter fence that was in the smoke path indicated alpha activity form 1500 to 2000 c/m. An attempt to monitor the area outside the fence will be made on 11/24. The north approach to Pit # 3 was also highly contaminated (2000 to 20 000 c/m)"[160] "The smoke from the fire travelled slowly east of Pit # 3 and a monitoring survey of this area indicated radioactive contamination out as far as about 450 feet from the area fence. This is only the second time, after a fire in a contaminated

dump, that radioactive contamination has been detected outside of the area fence."[73] The fire was put out at 9:45 p.m.[160]

"An inspection of the burned area was made on 11/22/64 by Blackwell and Enders* in an effort to determine the probable cause of the fire. Some charred metal turnings were observed as well as two 5 gallon glass jars. Reactive metal turnings could have started it and the glass jars could also have focused the sun's rays onto paper and started the fire. Actually we still don't know how it was caused. Burning embers from the fire in pit # 4 also should not be ruled out as a possible source. An inspection of the Dump Run Log book shows that Dempster Dumpsters from DP West, CMR Bldg., TA-46, TA-48 and Shops Bldg. were emptied before the fire started."[160]

"Pit # 4 was completed during the summer and was used to receive scrap material from TA-1. A trench, dug along the south floor of the pit, was used for burning combustible scrap. Air samples, taken during burning operations, were all negative which would indicate that the smoke generated did not contain measurable amounts of radioactive material."[73]

Conclusions

Area G is the largest disposal area at LASL. It has been in operation since early 1957. The site was originally picked because of its isolated location and because it offered ample space for disposal activities over a period of years. Although

*Charles Blackwell and John Enders, H-1

it is not as isolated as it once was, it still has enough space for disposal needs in the foreseeable future. Detailed disposal records have been kept throughout the history of Area G. All of the pits and some of the shafts received a geologic inspection before being put in use.

Recommendations

Monitoring activities are increasing in Area G.

1. The Area G identification sign and contamination warning signs are faded and should be replaced.
2. Detailed geologic mapping should be done to establish fracture pattern and stratigraphy in order to form a basis for future monitoring work.

Although there exists a geologic map of Area G, this map is not as detailed as the one proposed. The proposed map should make it possible to be highly selective in placement of monitoring points as well as providing information which will suggest the location and use of future pits and shafts.

STUDIES AND MONITORING

Concern, expressed as action, about radioactive contamination of the Los Alamos environs by Laboratory activities dates back to early 1944, "Report on Contamination of Creek Water - II"[229] March 2, 1944[230] water analyses by the U.S. Geological Survey of water taken from 1. West end building "D" (room no. 103) 2. "U" building (room U-18) and 3. Mains at Don Gasper Avenue and Water Street, Santa Fe, New Mexico, were received by the Laboratory.

In 1945[231] and 1946[231] interest in the chemical and sanitary sewer lines and Los Alamos and Pueblo Canyons seems to have become more intense.[31, 232, 233, 46] From the "Preliminary Survey of Sewer System," June 11, 1946:

> "It is evident that most every sewer line orginating in the Tech Area or at DP site is contaminated. They are poorly planned, and even more poorly used and maintained. In several instances the septic tanks are too small and in almost every instance the septic tanks are not operating properly because of improper bacterial action.
>
> It is very desirable that water and earth samples be taken at each sewer location to determine the degree of hazard. Further, it is desirable that some type of check be made by qualified technicians to determine why the sanitary sewers are contaminated or why the acid sewer should show evidence of refuge from sanitary installations."

February 20, 1947, LAMS-516,[181] "Survey of Los Alamos and Pueblo Canyon for Radioactive Contamination and Radioassay Tests Run on Sewer-Water Samples and Water and Soil Samples Taken from Los Alamos and Pueblo Canyons" was published.

> "Chemical sewers and sanitary sewer lines draining the Tech Area, D. P. Site, CMR-12 Laundry, and surrounding residential areas flow into Pueblo and Los Alamos Canyon 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 sources of 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 prelininary 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."[181]

Similar monitoring continued at least through 1949.[234, 235, 49, 236, 237]

"The U.S. Geological Survey in cooperation with the U.S. Atomic Energy Commission and the University of California, Los Alamos Scientific Laboratory, began a program in 1949 to monitor the chemical and radiochemical concentrations in surface and ground water in the Los Alamos area. Water samples for chemical and radiochemical analyses were collected downgradient from waste disposal points, industrial-waste treatment plants, and disposal pits. (fig. 1)*."[239]

"The purpose of collecting these data is to determine if, or to what extent, low-level radioactive effluents from the operation of the Los Alamos Scientific Laboratory contaminate surface and ground-water systems downgradient from Los Alamos."[238]

There were at least eleven reports in this series describing monitoring of surface and ground water, and hydrology related to movement of water, in the Los Alamos area. The first report, "Geologic and Hydrologic Environment of Radioactive Waste Disposal Sites at Los Alamos, New Mexico"[8] was released February, 1963. "A systematic sampling program was started about 1956, and a period of intensive sample collection lasted from July, 1957 through July, 1959, after which the program was reduced and sampling was done on a less intensive and a more selective basis."[8]

Other reports in the series presented basic-data on the chemical and radiochemical analyses of water and on the hydrology of the Los Alamos area:

2. "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, 1949-55."[240]

* Figure 113

3. "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, January, 1956 through June, 1957."[241]
4. "The Hydrology and the Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July, 1957 through June, 1961."[242]
5. "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1961 through June 1962."[243]
6. "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1962 through June 1963."[244]
7. "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1963 through June 1964."[239]
8. "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1964 through June 1965."[245]
9. The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1965 through June 1966."[246]
10. "The Chemical and Radiochemical Quality of Surface and Ground Water at Los Alamos, New Mexico, July 1965 through June 1967."[238]
11. "Chemical and Radiochemical Analyses of Water in the Los Alamos Area, New Mexico, Made by the U.S. Geological Survey, 1960 through 1968."[247]

"The chemical and radiochemical quality-of-water data are presented in five parts: (1) Pajarito Plateau, test and supply wells, and surface water; (2) Mortandad Canyon, surface water and observation wells; (3) Los Alamos and DP Canyon, surface water and observation wells;

(4) White Rock Canyon, springs and streams entering Rio Grande; and

(5) Rio Chama and Rio Grande surface water.

The water samples were collected by personnel of Group H-6 of the Los Alamos Scientific Laboratory and by the U.S. Geological Survey. Radiochemical analyses were made by Group H-6; William Kennedy, Group Leader. Chemical analyses were made by Group H-7; C. W. Christenson, Group Leader."[238]

"Soil Adsorption of Radioactive Wastes at Los Alamos"[248] appeared in the December 1958 Sewage and Industrial Wastes.

"Certain of the results obtained in this study are not in complete agreement with those of Swope (~~7~~*) who found that both cesium and hardness broke through resin columns at about the same point. McHenry et al.** (~~9~~) indicate a marked effect of the presence of cesium on the breakthrough of strontium. These studies did not show a similar effect. It is possible that the discrepancies are related to the different exchange properties of the basic adsorbents under study.

Orcutt et al.*** (~~10~~) have developed excellent expressions for dispersion and exchange phenomena applicable to radionuclides as they move through soils. Whether nuclides in low concentrations that are amenable to soil disposal will follow accepted physical laws is not known. Thomas (~~11~~) † has stated that it remains to be proved that elements at concentrations of 10^{-7} M follow classical chemistry or the accepted physical laws of ion exchange. It is possible that a demonstration of the applicability of the mathematical treatment of Orcutt et al.*** (~~10~~) to solutions where concentrations of solute approach 10^{-7} M will indicate the nature of their chemistry.

It has been demonstrated that the tuff local to Los Alamos has a rather high capacity for the retention of various nuclides. This is especially notable since this particular material has an ion exchange capacity which is about as low as any to be found in nature. Cs^{137} is apparently very tightly bound to the tuff and resists leaching by any of the common agents. Pu^{239} likewise is readily retained by the tuff and from actual experience at Los Alamos, plutonium in wastes discharged into the ground appear

to remain at the point of discharge. However, from what is known about the chemistry of plutonium, it is entirely possible that this nuclide could be released at some future time by inadvertent discharge of solutions such as versene in the same area. Work on this phase is being conducted at Los Alamos.

Sr^{90} is not retained by the tuff nearly so well as cesium and plutonium and it is much more easily released. It is becoming increasingly apparent that its fixation poses a most important problem, and it remains the controlling isotope in the disposal of radioactive wastes. Disposal of this isotope to soils is to be undertaken with extreme caution and only with foreknowledge of the nature of the soil and its capacity for the ions known to be present in the waste. Because Sr^{90} can be leached by other ions, a disposal area receiving this isotope must be closely guarded so that no other wastes will be discharged which might contain concentrations of ions sufficient to dislodge the already adsorbed nuclide."[248]

Conclusions from the 1966 U.S.G.S. study, "Hydrology of Waste Disposal Systems, Los Alamos, New Mexico, 1949 through 1961"[91] state:

"Chemical and radiochemical contamination at Los Alamos is limited to the canyon disposal areas receiving treated industrial effluent. It is greatest near points of effluent discharge; even here concentrations are usually below MPC and they diminish downgradient in the canyons. Test and supply wells completed in the main zone of ground water saturation indicate no chemical or radiochemical contamination. Monitoring of ground water at the supply wells and of surface water in the Rio Grande and at springs emptying to the river confirms that no detectable contamination has reached these waters.

Chemical treatment of liquid wastes and burial of solid wastes as practiced by the Los Alamos Scientific Laboratory reduce likelihood of serious contamination. Chemical treatment is complemented by the effectiveness of local geologic and hydrologic conditions in containing chemical wastes within narrow areal and spatial limits.

Practices, conditions and their interrelationships pertinent to the conclusion that it is unlikely that significant contamination could reach the river or the supply wells are summarized as follows:

1. Liquid wastes are treated to one-tenth MPC of radioactivity before discharge into the disposal areas.
2. Storm runoff and treated sewage dilute the effluent and reduce the already low levels of radioactivity.
3. Chemistry of the liquid wastes, especially their high pH, promotes exchange of radioactive components in the effluent with ions in clay, and attachment of effluent components to clay particles.
4. Clay minerals, montmorillonite and illite are weathering products of the tuff and are in large quantity in the canyons. They effectively bind radioactive ions or molecules. Clay particles, with attached radioactive material, are dispersed down gradient and laterally in the canyon disposal areas by sudden strong flows of effluent or storm runoff. Seepage also disperses radioactive material by carrying some of it vertically and laterally to buried clays. These factors combine to decrease the likelihood of occurrence of a larger anomalous concentration.
5. Sludge produced in chemical treatment of liquid wastes is mixed with vermiculite or cement and put in barrels to prevent leakage or leaching.
6. Soil around the solids disposal pits and the compacted tuff used to cover the pits when they are filled inhibit the infiltration of water from precipitation through the waste.
7. The tuff of the plateau can retain certain nuclides by ion exchange.
8. The large volume of unsaturated volcanic rock and sediment under the plateau is a potential reservoir for storage of contaminated water.

4. "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1962" 276

9. The slow movement of ground water (about 360 feet per year) would allow an interval greater than 70 years for chemical reaction and for radioactive decay of contaminants between the time that they might enter the ground water and the time that water would reach the river or the zone from which water is being pumped."[91]

From 1958 through 1970 LASL reported measurements of air particulate radioactivity and activity in precipitation:

1. "Radioactivity in Environmental Air at Los Alamos, New Mexico for the Period November 17, 1958 through December 31, 1959."[258]

3. ~~2~~. "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico for 1961."[259]

5. ~~3~~. "Strontium-90, Cesium-137, and Radioactive Rare Earths in Environmental Rain and Air at Los Alamos, New Mexico 1958-June 1963."[261]

6. ~~4~~. "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1963."[261]

7. ~~5~~. "Strontium-90, Cesium-137, and Radioactive Rare Earths in Environmental Rain and Air at Los Alamos, New Mexico, 1963-1964."[255]

8. ~~6~~. "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1964."[249]

9. ~~7~~. "Beta-Gamma Radioactivity in Environmental Air at Los Alamos, New Mexico, for 1965."[250]

10. ~~8~~. "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1966."[251]

11. ~~9~~. "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1967."[252]

12. ~~10~~. "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1968."[253]

13. ~~11~~. "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1969."[254]

14. 12. "Beta Radioactivity in Environmental Air and Precipitation at Los Alamos, New Mexico, for 1970."[257]

In 1962, a study on "Plants As Monitors of Radioactive Contamination of the Environment of Los Alamos, New Mexico "[262] was published.

The "Los Alamos Environmental Monitoring Program,"[256] 1970, gives an outline "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."[256]

Beginning in 1970 there are a series of reports which give the data outlined above:

1. "Los Alamos Environmental Monitoring Program July through December, 1970."[263]
2. "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, January through June, 1971."[264]
3. "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory, July through December, 1971."[265]
4. "Environmental Monitoring in the Vicinity of the Los Alamos Scientific Laboratory. Calendar Year 1972."[266]
5. "Environmental Surveillance at Los Alamos during 1973."[267]

See Figure 114 for TLD and air sampler locations, Figure 115 for regional surface water, sediment and soil sampling locations; Figure 116 for water sampling locations in White Rock Canyon of the Rio Grande; and Figure 117 for water, sediment, and soil sampling locations on or near the LASL site.[267]

Sample preparation and specific analyses are described in Appendix V.

Specific studies done in recent years are:

1. "Regional Survey of Tritium in Surface and Ground Water in the Los Alamos Area, New Mexico, August 1966 through May 1969."[268]
2. "Plutonium in Stream Channel Alluvium in the Los Alamos Area, New Mexico."[269]
3. "Plutonium and Strontium in Soil in the Los Alamos, Espanola, and Santa Fe, New Mexico, Areas."[270]
4. "Plutonium and Strontium in Soil Near Technical Area 21, Los Alamos Scientific Laboratory, Los Alamos, New Mexico."[271]
5. "Los Alamos Land Areas Environmental Radiation Survey 1972."[272]

A proposed plan for environmental monitoring of waste disposal areas was made by K. J. Schiager, H-8, ~~Alternate Group~~ Environmental Section Leader, December 27, 1973.

"It is the intention of the Environmental Section to establish a routine environmental monitoring program around all waste burial or storage areas both active and inactive. Furthermore, we would like to establish a program which would generate data useful to all three sections of the Environmental Studies Group.

From the standpoint of environmental surveillance we would like to document any current release or dispersion of contaminants from the disposal areas whether by atmospheric dispersion or by hydrologic transport. In consideration of the local ecology we would like to determine whether or not the buried materials have any effect on re-vegetation programs or ecological succession over completed waste pits; this would be in contrast to the normal disruption of the areas resulting from physical disturbance and operation of heavy equipment. Finally, for the waste management studies we would like to provide data which could be used to evaluate the longer range probabilities of migration of materials from the disposal site.

For the evaluation of atmospheric dispersion from active waste pits, we plan to install high volume air samplers to be operated on limited duty cycles only during pit filling operations. It is anticipated that these air samplers could be operated from gasoline powered generators in locations where line power is not available. From these air samplers we would like to obtain data on general dust loadings of the atmosphere resulting from waste burial operations in addition to the identification of any releases of radioactive or chemical contaminants from the burial operations.

The monitoring of dispersion into the tuff or the migration of moisture through the filled pit and the surrounding tuff would be by means of sampling tubes extending from the surface to the level of the bottom of the pit or lower in an array around each pit. Merlin Wheeler has developed a plan for the installation of sampling and access tubes around Pit #8 in Area G and this plan will be completed in the very near future.* We propose that similar access tubes be installed in each active disposal pit and that with slight modifications similar access points be installed around the perimeter of inactive pits. For the inactive pits a smaller number of sampling access tubes may be adequate (probably from 4 to 8 tubes per pit). We would intend to measure soil moisture profiles through these access tubes by means of a neutron moisture gauge. We would also sample any moisture that might be found in the sampling tubes as well as collecting core samples of the tuff at the bottoms of the access tubes.

An additional effort should be undertaken by Sumner Barr and Bill Purtymun to determine the moisture balance at or near the surface of filled pits. This would include meteorlogical data on precipitation (both total amounts and precipitation rates) and on evaporation rates in order to determine the net moisture budget of the fill material in the pit. The methods for this latter effort have not yet been defined, but it is our intent to initiate this effort in the near future.

Sampling of vegetation over completed disposal pits will be undertaken to determine whether or not any of the contaminants buried in the pit have

* Ref. 274

migrated to the surface and are being absorbed by plant tissues. For this effort we will require assistance from the ecology section as to appropriate plant sampling and characterization techniques."[273]

CONCLUSIONS

The Los Alamos Scientific Laboratory has been disposing of solid radioactive wastes since 1944. Throughout the history of the laboratory, the principal means of disposal has been pits. In the sixties, shafts began to be used as well as pits.

The LASL Materials Disposal Areas examined in this report were A, T, B, C, D, E, F, and G. One of these, Area T, technically involves a liquid waste disposal operation; and cannot be strictly considered a solid waste disposal area. All the areas with the exception of Area T and Area G are inactive. Areas A, T, B, C, D, E, and F were used in the forties; Areas T, C, E, and G were used in the fifties; and Areas T, C, and G were used in the sixties and seventies.

In the late fifties waste disposal documentation improved greatly; therefore knowledge of Areas T, C, and G is much better than of Areas A, B, D, E, and F. Knowledge of Area G, which began in the late fifties, is far better than any other area.

Radioactive contamination studies and monitoring have been done at LASL since 1944. Through the years the U. S. Geological Survey has had a large part in this work. Available information indicates that the U.S.G.S. did the majority of the specific studies and a significant amount of the monitoring in the fifties and sixties. Reliance on the U.S.G.S for this work seems to have been the result of a lack of qualified LASL personnel.

RECOMMENDATIONS

1. Site Improvements

   a. Specific boundaries should be designated for Areas T, D, and F.

b. The areas which are not adequately fenced should be. This includes Areas A, T, and F. If Area D is to be considered just the 2 underground chambers, there is no need for fencing.

c. Identification signs and radioactive contamination warning signs should be replaced or posted for all areas. Replacement of contamination warning signs should be done at Areas A, T, B, C, E and G; posting of contamination warning signs should be done at Area F and possibly Area D depending on how Area D is defined. Replacement of identification signs at Areas A, C, E and G should be done; posting of identification signs at Areas T, B, D, E, and F should be done.

d. Individual pits and shafts within each area should be clearly identified. In some cases this involves replacement of weathered signs and in others it involves erecting signs where none have been. Areas affected are A, T, C, E, F and G.

e. No area or unused part of an area should be left as a landscape scar. Areas which should have restoration plans are A, T, E, F, and G.

2. Studies and Monitoring

a. The "History of LASL Near-Surface Land Burial Facilities for Solid Radioactive Wastes" should be a continuing project for the next several years and thereafter a publication which is periodically updated. With the exception of Area G it is quite possible that there are many records on the other Areas which have not been located. It is important extensive effort be made to locate them at this time before

passage of time renders the task impossible. It may turn out the only way to gain insight on some of the areas is through interviews with previous LASL employees, LASL retirees, and LASL personnel.

b. Detailed geologic mapping for each area should be done to establish fracture pattern and stratigraphy in order to have a basis for future monitoring. The mapping project should not result in 8 individual maps which cannot be easily related to each other. Detailed mapping should extend from Area to Area with special emphasis at any particular Area.

c. Vegetative mapping in the Areas should be done. In the case of Areas T, B, C, D and F, mapping can provide insight for revegetation of other Areas.

d. A comprehensive ion exchange study of the soil, fracture fillings, and tuff in the Areas should be done. "Soil Absorption of Radioactive Wastes at Los Alamos"[248] is based on too few samples to generalize on the ion exchange capacity of the soil, fracture fillings and tuff in the Los Alamos area. Because of the variability in the physical and chemical properties of the tuff which in turn creates variability in the soils and fracture fillings, more work should be done on ion exchange.

e. A program should be designed to monitor specific disposal areas. The present monitoring network is not intended to do this. The assumption, which monitoring data supports, that because LASL is fortunate in its climate and geological

setting, it has no problems and will have no problems with migration of radionuclides should be more thoroughly investigated.