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CLEANUP AND TREATMENT (CAT)

TEST: A LAND AREA DECONTAMINATION PROJECT UTILIZING A VACUUM METHOD OF SOIL REMOVAL

August 1982

MASTER

J. A. ORCUTT

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LAS VEGAS, NEVADA 89114**

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- E. H. Essington (LANL) and F. L. Miller (DRI) assisted in Phase II site selection, and prepared the Phase II "Soil Sampling Design."
- E. M. Romney (UCLA) performed a vegetation survey, de-vegetated the Phase II site, and will perform future revegetation studies.
- EG&G performed the Phase II *in situ* spectrometry surveys.
- T. P. O'Farrell (EG&G) performed a pretest (pre-Phase II) animal population survey. He will also perform a repopulation study after the Phase II test.
- J. H. Shinn (LLNL) performed a plutonium resuspension study during the Phase II test.
- T. Tamura (ORNL) performed a particle size analysis on the Phase II soil samples.
- P. B. Dunaway, DOE/NV Program Director, acted as the CAT Test Coordinator, and assisted in Phase II site selection.

CONTENTS

	Page
Figures -----	v
Tables -----	vii
Introduction -----	1
Purpose -----	1
Methods -----	2
Phase I -----	3
Phase II -----	7
Results and Discussion -----	25
Conclusions -----	39
References -----	41
Distribution -----	42

FIGURES

	Page
1 Plutonium Valley and Road Map With Notation of Check Station, Decontamination Area (ESD Hot Line), Weather Station, Phase I and Phase II Locations -----	4
2 In Phase II, Plot 1 Was Devegetated By UCLA Representatives Using a "Whizz Witch" -----	10
3 During Phase II, Plot 2 was Devegetated Leaving Only the Root Systems Intact -----	11
4 CAT Test Phase II Layout and Pretest Sampling Locations -----	12
5 EG&G IMP in the Process of Data Collection in the Contaminated Portion of Area 11 Selected for the Phase II Site -----	15
6 Phase II Land Area Decontamination Plan -----	16
7 Monitors Using the Heavy Flex Line/Solid Intake Tube Extension Vacuum Line to Vacuum Contaminated Soil During Phase II -----	17
8 Vacuuming With the Pavement Cleaning Nozzle Vacuum Line -----	19
9 CAT Test Phase II Layout and Post-Test Sampling Locations -----	22

TABLES

	Page
1 Pretest Soil Profile Sample Results -----	28
2 Pu-239 240/Am-241 Activity Ratio from Soil Profile Results -----	31
3 Pretest Surface Soil Sample Results -----	32
4 Post-Test Surface Soil Results -----	33
5 Post-Test Soil Profile Sample Results -----	34
6 EG&G IMP Measurement Survey Results -----	36
7 Pu-239,240 Concentration Related to the Initial and Final IMP Am-241 Measurements -----	37
8 Air Sample Results -----	38

INTRODUCTION

Several large land areas on the Nevada Test Site (NTS) and nearby are characterized by the presence of radioactive surface contamination. Plutonium safety shots and plutonium oxide dispersion experiments were conducted in Areas 11 and 13, respectively, during the 1950's. The experiment sites and the immediate surrounding areas are, therefore, contaminated with varying concentrations of Pu-239,240 and Am-241. The Department of Energy (DOE) proposed an investigation of a vacuum method of soil removal. The investigation was conducted by the Reynolds Electrical and Engineering Co., Inc./Environmental Sciences Department (REECo/ESD) on the NTS.

PURPOSE

The Cleanup and Treatment (CAT) test was conducted over a 3-month period in the plutonium safety shot or "Plutonium Valley" portion of Area 11. Soil in Plutonium Valley is of the Aridisol Order. The surface 0-10 cm is a gravelly loam, and is strongly alkaline (pH 8.8). The alluvial soil was formed in material weathered from tuff, basalt, and limestone. Slight to moderate wind and water erosion is evident (Reference 1).

A large truck-mounted vacuum unit, rather than conventional earthmoving equipment, was used as the primary soil collection unit. The CAT test served as an evaluation of the viability of a vacuum method of land area decontamination. Effectiveness of the vacuum method of soil removal was evaluated in relation to conventional earthmoving procedures, particularly in terms of volume reduction

of removed soil achieved over conventional techniques. Radiological safety considerations associated with use of the vacuum unit were evaluated in relation to their impact on a full-scale land decontamination program. Environmental and operational impacts of devegetation with retention of root crowns or root systems were investigated.

METHODS

A 20-year old Central Engineering Co. VAC-ALL model E5-16 vacuum truck was used as the soil collection unit for the CAT test. The VAC-ALL has a 16 cu yd (12.23 m³) capacity and an elevated tail-gate dumping capability. Prior to operation on the CAT test, the VAC-ALL was serviced by NTS mechanics and fitted with flotation tires appropriate to the Area 11 terrain. The VAC-ALL exhaust filtration system consists of a steel screen which will pass 0.12 in. (0.30 cm) diameter particles, and a dead air chamber designed to collect the sub-0.12 in. (0.30 cm) diameter particles.

The CAT test was conducted in two phases, Phase I and Phase II. Phase I tested effectiveness of water pretreatment as a dust suppressant. Phase I also tested effect of vegetation and vegetation removal, and effect of rocks and soil texture on the ease of control and operation of the VAC-ALL. Phase II utilized the most effective vacuuming techniques identified in Phase I to remove soil from a contaminated portion of Area 11. During Phase II, overall effectiveness of the vacuuming technique was evaluated in terms of cost, environmental impact, and radiological impact.

Phase I

Phase I was accomplished in an uncontaminated portion of Area 11. Phase I served to evaluate operation of the VAC-ALL over rough terrain and to familiarize the driver and operators with the equipment.

Prior to the outset of the CAT test, a REECo/ESD mobile check station was established to control access to contaminated portions of Area 11. A personnel and equipment decontamination area was selected, and a personnel decontamination unit and an equipment decontamination truck were brought to the location. The CAT test area is depicted in Figure 1.

Roads used during the test were first surveyed for Pu-239,240 and Am-241 contamination with Field Instruments for Detecting Low Energy Radiation (FIDLER). Surveys were also made to verify historical documentation of uncontaminated areas, primarily for selection of a Phase I site. The FIDLER incorporates a thin 0.063 in. (0.16 cm) sodium iodide crystal (NaI[Tl]) - photomultiplier tube detector assembly, and is appropriate for detection of plutonium and americium characteristic X-rays.

An uncontaminated area near the mobile check station was selected for the location of the Phase I site. One 39 by 335 ft (11.9 x 102.1 m) plot was delineated, and completely devegetated with shears leaving only the root crowns.

During the initial Phase I experimentation, a heavy 12 in. (30.5 cm) diameter flex line and the pavement cleaning nozzle were attached

Figure 1. Plutonium Valley and Road Map with notation of Check Station, Decontamination Area (ESD Hot Line), Weather Station, Phase I and Phase II locations.

to the right rear vacuum port of the VAC-ALL. An internal water spray dust suppression system was incorporated as a design feature in the pavement cleaning nozzle. The weight of the truck caused compaction of the dirt under the tires. Since vacuum removal of compacted soil was difficult, the vacuum line was moved from the right rear port to the left rear port. The cleaning nozzle was directed to the left side of the truck. The truck was driven over ground that had been vacuumed, thus avoiding compaction and mixing in the unvacuumed area.

The 12 in. (30.5 cm) diameter flex line and pavement cleaning nozzle were moved to the vacuum port on the left side of the truck for the second Phase I experiment. The flex line became blocked with rocks. Cross bars were installed in a metal collar just above the vacuum intake to avoid the collection of rocks greater than 3 in. (7.6 cm) in diameter. The rocks were not a source of radioactive contamination, and added unnecessary volume to the vacuumed material.

During Phase I, a lighter 8 in. (20.3 cm) diameter flex line was substituted for the 12 in. (30.5 cm) diameter line. The small diameter line often collapsed and ripped during vacuuming. A solid 12 in. (30.5 cm) diameter intake tube was substituted for a portion of the 12 in. (30.5 cm) diameter flex line to weight the line down and add some rigidity to the vacuuming geometry. Experimentation with two simultaneous vacuum lines, a 12 in. (30.5 cm) diameter line on the left side port and an 8 in. (20.3 cm) diameter line on the left rear port, was unsuccessful due to insufficient

suction at both locations. Experiments were also conducted with the solid intake tube extension substituted for the pavement cleaning nozzle.

The various vacuum configurations were evaluated in terms of soil collection efficiency, maneuverability, and soil resuspension. Two collection configurations were selected for evaluation during Phase II:

- Heavy 12 in. (30.5 cm) diameter flex line, solid intake tube extension, and pavement cleaning nozzle attached to the left rear port (the pavement nozzle was extended to the left of the truck by a tow bar attached to the left rear bumper); and
- Heavy 12 in. (30.5 cm) diameter flex line and solid intake tube extension mounted on the left side port.

Water treatment, both prior to and during vacuuming, was used for operational dust suppression and reduction of exhausted effluent. The plot surface was saturated with water 12, 4, 1 h, or immediately prior to vacuuming. Effluent exhaust and general resuspension information was collected for the various water treatment combinations. A light internal water spray, in conjunction with external surface saturation immediately prior to vacuuming, proved to optimize operational dust suppression and minimize the amount of effluent released through the exhaust port. However, the water altered the consistency of collected soil, which hardened as it dried in the truck, making dumping difficult.

Discing and/or harrowing of various sections before and following the applications of water was accomplished during Phase I. A weighted harrow proved effective in loosening the soil, and was selected for use during Phase II.

Phase II

A suitable location was selected for the Phase II CAT test area from the contaminated sites C and D overlap section of Area 11. Previous Nevada Applied Ecology Group (NAEG) documentation indicated that an area of approximately 690,000 sq ft ($64,103 \text{ m}^2$) existed which averaged 300 ± 130 pCi/g Pu-239,240 and was characterized by a 5.2 Pu-239,240 to Am-241 activity ratio (Reference 2). Within this area, two 39 by 335 ft (11.9 x 102.1 m) plots (plots 1 and 2) were laid out at a distance of 98 ft (29.8 m) apart in order to facilitate *in situ* spectrometry measurements and variations on the method of decontamination. Data collected from an LLNL weather station over a 2 yr period indicated predominantly southwesterly winds in the vicinity of Area 11 during daylight hours in the summer months. The Phase II plots were oriented from northwest to southeast in order to keep workers upwind of resuspended material during operation of the VAC-ALL. Nevada Grid Coordinates were determined for the four corners of each plot. A cursory FIDLER survey was made to verify the historical NAEG data.

The Phase II CAT test plots were staked at 33 ft (10 m) intervals on the perimeter and 3 ft (0.9 m) and 16 ft (4.9 m) from the perimeter. Plots 1 and 2 were then micro-gridded into 1080 sq ft

(100.3 m²) sections using surveyor-type small wooden hubs. A red hub was driven in the center of each section.

On June 1, 1981, field surveys were conducted by T. P. O'Farrell of EG&G to determine relative abundance of lizards on the test plots prior to disturbance. Three transects spaced 10 ft (3 m) apart were walked the length of each plot and all lizards were counted. Lizards were seen while surveyors were walking to and from survey locations but none were observed during actual surveys. The transects were resurveyed in the spring of 1982 to assess the impact of devegetation and vacuuming on the lizard population.

Small mammals were also surveyed by noting the number and location of burrow systems. Within each of the 20 test sections a 33 ft (10 m) line intercept was placed perpendicular to the long axis of the plot at each test section center point. All burrows found within 3 ft (0.9 m) of either side of the intercept were tallied and listed as either "under" or "between" shrubs. The test sections, were resurveyed in 1982 to determine whether removal of the shrubs and soil containing seed reserves used as food by desert rodents have impacted numbers of small mammals. No evidence was gathered indicating that desert kit fox were using the treatment plots for denning prior to disturbance.

The University of California at Los Angeles (UCLA) performed devegetation of the Phase II test area as part of a revegetation study and to assist cleanup. Two methods of vegetation clearing were employed on the test plots established for Phase II. Vegetation on plot 1, containing sections 1 through 10, was removed

with a gasoline-engine-powered brush saw (Hoffco "Whizz Witch") by cutting off shoots near the ground, but just above the root crowns. All cleared brush was removed and piled in windrows alongside the cleared plots. Anti-contamination coveralls, rubber boots, gloves, headcovers, and dust respirators were worn by UCLA personnel during this operation. A small amount of dust was produced below the breathing level height. Phase II devegetation procedures are illustrated in Figures 2 and 3. Vegetation from plot 2, containing sections 11 through 20, was clear-cut by hand with a grub hoe which removed the shrub crowns but left root systems intact. Two Joshua trees (*Yucca brevifolia*), a protected species, were left standing on plot 2. Progress of natural site revegetation will be monitored for several years.

Twenty surface soil sampling locations were randomly selected by use of a 33 by 329 ft (10 x 100.3 m) grid. The 20 pretest surface soil samples (10 from each plot) were collected by the standard 2 by 5 in. (5 x 12.7 cm) diameter ring method. Fifteen pretest soil profile samples (9 desert pavement, 1 wash, and 5 blowsand mound samples) were collected using the standard NAEG pit/scoop method collecting 1.0 in. (2.5 cm) increments to a depth of 10 in. (25.4 cm), thereafter collecting 2 in. (5.1 cm) increments to a depth of 20 in. (50.8 cm) or as deep as reasonably attainable. Sampling locations are noted in Figure 4.

Figure 2. In Phase II, plot 1 was devegetated by UCLA representatives using a "Whizz Witch."

Figure 3. During Phase II, plot 2 was devegetated leaving only the root systems intact.

The profile and surface soil samples were oven-dried, weighed, and sieved to pass a 10-mesh (2 mm) screen. Each resultant fraction of all pretest samples was subjected to a 10 or 100 min gamma scan on either an intrinsic germanium (IG) or a lithium-drifted germanium (Ge[Li]) detector. Five of the profile samples (4 desert pavement samples and 1 wash sample) were submitted for plutonium analysis by wet chemistry. The Pu-239,240 to Am-241 activity ratio was determined from results of the analyses of the four pavement profile samples. All analytical results are presented in the RESULTS AND DISCUSSION section (page 25) of this report.

The EG&G IMP system, a tracked vehicle with an on-board electronic counting system and an intrinsic germanium detector extended away from the body of the vehicle by a boom, was used to make *in situ* measurements of the Am-241 concentration in surface soil of the Phase II test plots. An initial or baseline *in situ* spectrometry measurement survey was conducted on plots 1 and 2 during June 23 through 26, 1981. The IMP measurement field encompassed a 848 sq ft (78.8 m^2) surface area 16 ft (4.9 m) in diameter. Because the measurement field was smaller than the actual test section, three assumptions were made regarding the distribution of radioactivity: 1) the activity was homogeneously distributed over the surface of the measurement field, 2) the measurement field was representative of the 1080 sq ft (100.3 m^2) test section, and 3) the average Pu-239,240 to Am-241 activity ratio calculated from the four pretest profile samples collected on the plots was representative of the actual activity ratio. IMP measurements, centered over the center of each test section, were made for each of the 20 test

sections. Due to possible masking of a portion of the measurement field by the support vehicle, each measurement was made in two orientations (northwest to southeast and southeast to northwest) over the center of each test section to identify any "hot spots" of activity. The IMP is shown in Figure 5 in the process of data collection.

The VAC-ALL was used to remove approximately 2 in. (5 cm) of soil from each of the test plots. The heavy flex line/solid intake tube extension configuration was used to remove soil from 1/3 of plot 1. The heavy flex line/solid intake tube extension/pavement nozzle configuration was used to remove soil from the rest of the Phase II site. Plot 1 was treated with a weighted harrow prior to vacuuming, and a 10,000 gal (37,854 l) water tanker with an internal pumping system and a high-pressure hose was used to saturate the contaminated soil just ahead of the VAC-ALL during the entire vacuuming operation. The Phase II decontamination plan is shown in Figure 6.

Four personnel were required to perform the soil removal operation when the heavy flex line/solid intake tube extension vacuum line was used. Since Plutonium Valley is a radiologically controlled area, radiation monitors performed most of the work. Radiation monitors operated the VAC-ALL, the harrow, and the water truck during Phases I and II of the CAT test. Two monitors manipulated the vacuum line (Figure 7), while a third monitor drove the VAC-ALL along the plot. The fourth monitor wetted the soil ahead of the truck.

Figure 5. EG&G IMP in the process of data collection in the contaminated portion of Area 11 selected for the Phase II site.

Figure 6. Phase II Land Area Decontamination Plan

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Figure 7. Monitors using the heavy flex line/solid intake tube extension vacuum line to vacuum contaminated soil during Phase II.

When using the pavement cleaning nozzle, one monitor operated the boom controlling the position of the nozzle while a second monitor drove the VAC-ALL. The third monitor wetted the soil ahead of the truck. The pavement cleaning nozzle configuration is pictured in Figure 8.

One modification was made to accommodate use of the pavement cleaning nozzle on the left rear port. Metal pins were installed on either side of the boom to restrict the side-to-side movement of the assembly.

Progress of Phase II was delayed two weeks for repair of the vacuum motor clutch. In addition, the project was periodically delayed for refueling, replenishment of the water supply, or change in wind direction.

Soil accumulated in the VAC-ALL during the vacuuming operation was periodically dumped in an area south of plot 1 by the road. The soil was stockpiled until the end of the Phase II operation, at which time it was removed to a Radioactive Waste Management Site (RWMS) on the NTS.

An *in situ* spectrometry measurement survey was conducted to determine the degree of decontamination achieved and to identify any remaining areas of localized contamination. The survey was conducted on July 17 through 20, 1981 by the initial IMP survey procedure.

The pavement cleaning nozzle was employed to revacuum the entire Phase II test area. The weighted harrow was again used to loosen

Figure 8. Vacuuming with the pavement cleaning nozzle vacuum line.

the plot 1 soil prior to vacuuming. Surface soil of both plots was saturated with water immediately before vacuuming.

Rocks in the path of the cleaning nozzle lifted the nozzle off the soil surface, reducing the effectiveness of the vacuum. Spikes or teeth were welded to the leading edge of the pavement cleaning nozzle. The teeth pushed the rocks out of the decontamination path, and loosened the soil ahead of the nozzle. It was also necessary to reinforce some of the VAC-ALL collection equipment welds, which did not hold up well over the rough Area 11 terrain.

The Phase II operation was delayed for two weeks in July while leaks in the vacuum unit radiator were repaired.

The IMP returned to the Phase II site August 19 and 20, 1981. One IMP measurement was made on the center of each of the 20 test sections.

As a result of the third IMP measurement survey, test sections 5 through 12 and 15 through 19 were revacuumed using the pavement cleaning nozzle. The test sections were wetted immediately prior to vacuuming. IMP measurements were made on the centers of test sections 5 through 12 and 15 through 19 on September 9, 1981. Some remaining areas of residual activity were identified as a result of this survey. These areas were revacuumed using the pavement cleaning nozzle. The final IMP measurement survey of plots 1 and 2 was conducted on September 21 and 22, 1981.

Twenty post-test surface soil samples (10 from each plot) were collected in the original pretest surface sample locations. Four

profile samples (two from each plot) were also collected. All samples were collected and treated in accordance with pretest sampling procedures. Each fraction of all post-test samples was subjected to a 100 min gamma scan on an IG or Ge(Li) detector. Post-test sampling locations are depicted in Figure 9.

The CAT test Phase II radiation safety procedures were drafted to document radiological safety procedures for the test, and specifically to prevent spreading and internal deposition of plutonium contamination under the unique circumstances of the test. Personnel involved in the operation of the VAC-ALL wore full-face respirators when working in the contaminated Phase II area. The VAC-ALL was operated only when wind directions allowed the operators to remain up-wind of the effluent.

Anti-contamination clothing (coveralls, rubber boots, gloves, and headcover) was worn by the VAC-ALL operators during Phase II. Alpha contamination surveys were conducted for all personnel and equipment leaving the area. Lung and whole-body counts were performed for personnel in the NTS whole-body counter at the end of the Phase II operation. Nasal swipes were collected and analyzed periodically during the Phase II operation.

Experiments were conducted by LLNL to determine the degree of plutonium aerosol suspension either as a result of traffic and mechanical operations or as a result of wind. In addition, the working environments of the VAC-ALL driver and operators were monitored to assess the potential for inhalation exposure even though the workers used respiratory protection.

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Meteorological measurements were also made by LLNL at two locations and summarized every 8 min during the entire course of the CAT test. These measurements were analyzed to obtain wind direction, wind speed, atmospheric stability, and atmospheric diffusivity. Concentrations of dust and plutonium aerosols, and their size distributions were measured at the 3 ft (0.9 m) height near the plots and at a location to the west, approximately up-wind. Plutonium emission rates from the plots were examined by means of a portable resuspension chamber. Resuspension chamber measurements were made over undisturbed soil isolated from traffic, and over the decontaminated plots. Vertical profiles of dust concentrations, wind speed, and a reference plutonium aerosol concentration were determined to calculate plutonium emission rates. J. H. Shinn and D. N. Homan of LLNL were responsible for collection and analysis of plutonium resuspension data. Their results are discussed in a separate report.

A Hurricane air sampler, mounted at the VAC-ALL effluent exhaust port, was used to make relative plutonium concentration ($\mu\text{Ci Pu/cc}$ air) measurements for VAC-ALL effluent under various operational conditions. Air samples were also collected at the VAC-ALL driver and vacuum operator positions. An additional air sampler was operated approximately 100 ft (30.5 m) downwind from the VAC-ALL at breathing height. The air sample results are presented in the RESULTS AND DISCUSSION section of this report.

A heat stress survey was performed by a REECO industrial hygienist on July 30, 1981. The survey was performed in the cab of the

VAC-ALL truck during Phase II of the CAT test. The survey was initiated at 0943 hours with surface winds of 10 mph (4.4 m/s) from the southwest and an air temperature of 33°C. The survey was completed at 1423 hours with surface winds of 11.4 mph (5.1 m/s) from the southwest and an air temperature of 42°C. The heat stress test results are discussed in the RESULTS AND DISCUSSION section of this report.

Soil stockpiled during the Phase II operation was loaded into 15 cu yd (11.5 m³) capacity dump trucks and transported to NTS RWMS U3axbl for disposal. A front-end loader was used to load the material into each of three trucks for removal. The operator of the front-end loader was dressed out in anti-contamination clothing (coveralls, rubber boots, gloves, and headcover) and a dust respirator during the operation. The soil was wetted prior to loading and again after loading to insure containment during transport. An air sample was collected downwind at the operator's breathing level during loading.

All equipment was surveyed and decontaminated prior to removal from the CAT test controlled area. A truck-mounted 1500 gal (5678 l) water tank and pressure pump system, as well as a steam generator with a hose delivery system, were used for equipment decontamination. All items were decontaminated to DOE-NTS release limits in Area 11.

RESULTS AND DISCUSSION

Phase I

Phase I was conducted in a non-radiological portion of Area 11, and served to familiarize personnel with the VAC-ALL. Experiments were conducted on the Phase I plot with a number of vacuum soil collection procedures, discing and harrowing techniques, and dust suppression techniques. The Phase I experiments are described in the METHODS, Phase I section of this report. Air samples were collected at the VAC-ALL exhaust port and 100 ft (30.5 m) downwind from the vacuuming operation. Mass loading was determined for each air sample filter.

Air filter mass loading varied from 7.8 ng/cm³ of exhausted effluent for a pre-moistened surface/internal VAC-ALL water spray to 150 ng/cm³ of exhausted effluent for a dry surface. These data were used to evaluate the relative activity resuspension characteristics of each experimental collection technique employed during Phase I. The pavement cleaning nozzle (with internal water spray) technique raised less dust than other experimental collection methods. Wetting the soil with water just prior to vacuuming also proved to reduce dust suspension.

Phase II

Soil was removed from the Phase II test area to an average depth of 2.5 in. (6.4 cm). An estimated 685 cu ft (19.4 m³) of contaminated soil was transported to U3axbl RWMS for disposal. Due

to bulking of the material during vacuum removal and stockpiling, a 20% bulking factor was used to estimate the actual volume of material removed from the Phase II site. Approximately 5720 cu ft (161.9 m^3) of soil was removed from the 26,400 sq ft (2452.6 m^2) Phase II test area.

Fifteen "pretest" soil profile samples were collected in the Phase II test area prior to initiation of the Phase II decontamination operation. Five mound profiles were collected, and analyzed for Am-241. Four desert pavement profiles and one dry wash profile were collected, and analyzed for Am-241 and Pu-239, 240. These data are presented in Table 1. Plutonium was observed in each soil increment of all four desert pavement profiles analyzed for Pu-239,240. The majority of activity was associated with the surface increment, 0.0-1.0 in. (0.0-2.5 cm), of each profile. Analytical results for the 0.0-2.5 cm (0.0-1.0 in.) increments of profiles F through I were used to establish a representative Pu-239,240 to Am-241 activity ratio for the Phase II site. The ratio was 5.69 (Table 2).

Two washes ran diagonally across plots 1 and 2. A profile sample was collected from the most pronounced portion of the wash (profile J). As noted in Table 1, an average of 94% of the total profile Pu-239,240 activity was observed in the first 2.5 cm (0.0-1.0 in.) of the four non-wash profiles. Only 70% of the total profile activity was present in the first 2.5 cm (0.0-1.0 in.) of the wash profile. As a result, more effort was required to successfully decontaminate the washes than other portions of the Phase II site.

Twenty pretest surface soil samples 0.0-2.0 in. (0.0-5.0 cm) were collected from within the 26,400 sq ft (2452.6 m²) Phase II test area. The Am-241 concentrations and inferred Pu-239,240 concentrations in these samples are presented in Table 3. The pretest surface samples were taken to confirm or verify the *in situ* measurements made during the initial IMP survey.

Blow sand mounds were observed around root crowns or stems of much of the vegetation in the Phase II area. Five blow sand mound soil profile samples (K through O in Table 1) were collected to determine depth distribution of Am-241 in these mounds. From 31.2% to 88.0% of the total profile Am-241 activity was observed in the surface 0.0-1.0 in. (0.0-2.5 cm) increment of these samples. More extensive decontamination work was required to successfully remove contaminated material from around vegetation root crowns as opposed to other portions of the plots. Presumably, wind-blown sand accumulated on the mounds for decades and buried radioactivity deposited earlier on mound surfaces.

Twenty post-test surface soil samples were collected in the pretest surface sample locations. The Am-241 analysis results are presented in Table 4. The post-test profile Am-241 analysis results are presented in Table 5 and indicate minimal to undetectable Am-241 activity to a depth of 3 in. (7.6 cm). Soil sample results for a given general area are more variable than *in situ* results because of the "hot particle" problem with soil samples and the fact that *in situ* technique integrates over relatively large areas.

TABLE 1. PRETEST SOIL PROFILE SAMPLE RESULTS

Profile*	Depth (cm)	Concentration	
		Pu-239,240 (pCi/g)**	Am-241 (pCi/g)***
A	0.0 - 2.5		76.0
	2.5 - 5.0		29.9
	5.0 - 7.5		16.5
	7.5 - 10.0		3.96
	10.0 - 12.5		0.52
↓	12.5 - 15.0		1.17
	15.0 - 17.5		0.20
	0.0 - 2.5		17.8
	2.5 - 5.0		1.70
	5.0 - 7.5		1.06
B	7.5 - 10.0		<0.30
	10.0 - 12.5		0.51
	12.5 - 15.0		0.57
	15.0 - 17.5		0.53
	17.5 - 20.0		<0.073
↓	20.0 - 22.5		Missing
	22.5 - 25.0		<0.24
	25.0 - 30.0		<0.32
	0.0 - 2.5		41.3
	2.5 - 5.0		<0.38
C	5.0 - 7.5		<0.26
	7.5 - 10.0		0.84
	10.0 - 12.5		1.76
	12.5 - 15.0		0.55
	15.0 - 17.5		<0.31
D	0.0 - 2.5		33.6
	2.5 - 5.0		0.74
	5.0 - 7.5		<0.35
	7.5 - 10.0		1.11
	10.0 - 12.5		<0.19
↓	12.5 - 15.0		<0.23
	15.0 - 17.5		0.19
	0.0 - 2.5		45.3
	2.5 - 5.0		8.91
	5.0 - 7.5		3.17
E	7.5 - 10.0		<0.30

*Refer to Figure 4 for sample location.

**Pu-239,240 concentration determined by chemical isolation and alpha spectrometry.

***Am-241 concentration determined by 100 min gamma count.

The analyses from profiles A-E and H were provided by LLNL.

NOTE: The symbol "<" indicates "less than detection limits."

TABLE 1 (Continued)

Profile*	Depth (cm)	Concentration	
		Pu-239,240 (pCi/g)**	Am-241 (pCi/g)***
E	10.0 - 12.5		<0.21
	12.5 - 15.0		<0.15
↓	15.0 - 17.5		<0.20
F	0.0 - 2.5	219 ± 42.7	52.1 ± 5.26
	2.5 - 5.0	2.28 ± 0.643	<0.80
↓	5.0 - 7.5	2.27 ± 0.506	0.686 ± 0.638
	7.5 - 10.0	1.38 ± 0.396	<0.80
G	0.0 - 2.5	504 ± 96.3	75.5 ± 7.02
	2.5 - 5.0	8.06 ± 2.12	1.06 ± 0.763
↓	5.0 - 7.5	18.1 ± 4.05	0.874 ± 0.613
	7.5 - 10.0	0.849 ± 0.273	<0.80
H	0.0 - 2.5	458 ± 43.1	67.2 ± 6.45
	2.5 - 5.0	12.8 ± 3.37	4.66 ± 1.18
↓	5.0 - 7.5	16.2 ± 10.7	<0.80
	7.5 - 10.0	16.2 ± 9.90	<0.80
I	0.0 - 2.5	377 ± 33.9	74.8 ± 11.9
	2.5 - 5.0	22.5 ± 6.17	4.22 ± 2.92
↓	5.0 - 7.5	12.1 ± 2.12	<0.80
	7.5 - 10.0	2.84 ± 0.707	<0.80
J, Wash	0.0 - 2.5	273 ± 22.9	43.4 ± 4.21
	2.5 - 5.0	79.8 ± 6.22	10.9 ± 1.77
↓	5.0 - 7.5	25.8 ± 2.12	4.13 ± 1.12
	7.5 - 10.0	12.3 ± 1.22	2.59 ± 0.917
K, Mound	0.0 - 2.5		15.8
	2.5 - 5.0		0.84
	5.0 - 7.5		<0.24
	7.5 - 10.0		2.21
↓	10.0 - 12.5		<0.28
	12.5 - 15.0		1.37
	15.0 - 17.5		0.34
L, Mound	0.0 - 2.5		70.5
↓	2.5 - 5.0		7.36
	5.0 - 7.5		2.27
M, Mound	0.0 - 2.5		133.
	2.5 - 5.0		213.
	5.0 - 7.5		10.4
↓	7.5 - 10.0		8.77
	10.0 - 12.5		Missing
	12.5 - 15.0		0.49
	15.0 - 17.5		0.18

*Refer to Figure 4 for sample location.

**Pu-239,240 concentration determined by chemical isolation and alpha spectrometry.

***Am-241 concentration determined by 100 min gamma count.

The analyses from profiles A-E and H were provided by LLNL.

NOTE: The symbol "<" indicates "less than detection limits."

TABLE 1 (Continued)

<u>Profile*</u>	<u>Depth (cm)</u>	<u>Concentration</u>	
		<u>Pu-239,240 (pCi/g)**</u>	<u>Am-241 (pCi/g)***</u>
N, Mound	0.0 - 2.5		116.
	2.5 - 5.0		134.
	5.0 - 7.5		51.7
	7.5 - 10.0		21.0
	10.0 - 12.5		15.7
	12.5 - 15.0		24.8
	15.0 - 17.5		7.10
	17.5 - 20.0		1.10
	20.0 - 22.5		<0.28
	22.5 - 25.0		<0.29
O, Mound	0.0 - 2.5		53.6
	2.5 - 5.0		25.7
	5.0 - 7.5		1.9
	7.5 - 10.0		1.28
	10.0 - 12.5		0.21
	12.5 - 15.0		1.17
	15.0 - 17.5		0.51
	17.5 - 20.0		1.08
	20.0 - 22.5		1.80
	22.5 - 25.0		1.10

*Refer to Figure 4 for sample location.

**Pu-239,240 concentration determined by chemical isolation and alpha spectrometry.

***Am-241 concentration determined by 100 min gamma count.

The analyses from profiles A-E and H were provided by LLNL.

NOTE: The symbol "<" indicates "less than detection limits."

TABLE 2. Pu-239,240/Am-241 ACTIVITY RATIO
FROM SOIL PROFILE RESULTS

<u>Profile*</u>	<u>Pu-239,240/Am-241**</u>
F	4.20 ± 0.922
G	6.68 ± 1.42
H	6.82 ± 0.917
I	5.04 ± 1.62

- NOTE: 1. An average of the above data is used to represent the Pu-239,240/Am-241 for the Phase II test area.
2. Pu-239,240/Am-241 = 5.69 for the purpose of this report.

*Refer to Figure 4 for sample location.

**The surface increment data for each of the four profile samples was used to determine the Pu/Am.

TABLE 3. PRETEST SURFACE SOIL SAMPLE RESULTS

<u>Sample No.*</u>	<u>Concentration</u>	
	<u>Am-241</u> <u>(pCi/g)**</u>	<u>Pu-239,240</u> <u>(pCi/g)***</u>
1	76.1	433
2	63.1	359
3	108	615
4	166	945
5	121	688
6	43.1	245
7	88.2	502
8	80.3	457
9	52.9	301
10	44.6	254
11	9.16	52.1
12	20.0	114
13	40.0	228
14	27.0	154
15	34.0	193
16	48.2	274
17	7.04	40.1
18	95.2	542
19	10.5	59.7
20	112	637

*Refer to Figure 4 for sample locations.

**Am-241 concentration determined by LLNL by 100 min gamma count.

***Pu-239,240 concentration inferred from the Pu/Am data:
Pu-239,240/Am-241 = 5.69

TABLE 4. POST-TEST SURFACE SOIL RESULTS

<u>Sample No.*</u>	<u>Concentration Am-241 (pCi/g)**</u>
1.1	9.43 ± 1.49
2.1	3.01 ± 0.993
3.1	<0.80
4.1	12.0 ± 2.41
5.1	<0.80
6.1	8.68 ± 2.12
7.1	<0.80
8.1	0.815 ± 0.573
9.1	16.5 ± 2.76
10.1	6.08 ± 1.90
11.1	<0.80
12.1	1.91 ± 1.01
13.1	7.56 ± 2.06
14.1	<0.80
15.1	3.54 ± 1.05
16.1	3.86 ± 1.08
17.1	<0.80
18.1	1.03 ± 0.827
19.1	12.6 ± 1.80
20.1	<0.80

*Refer to Figure 9 for sample locations.

**Am-241 concentration determined by 100 min gamma count.

NOTE: The symbol "<" indicates "less than detection limits."

TABLE 5. POST-TEST SOIL PROFILE SAMPLE RESULTS

<u>Profile*</u>	<u>Depth (cm)</u>	<u>Concentration Am-241 (pCi/g)**</u>
a	0.0 - 2.5	1.18 ± 0.727
↓	2.5 - 5.0	3.01 ± 0.987
	5.0 - 7.5	<0.80
b	0.0 - 2.5	1.50 ± 0.783
	2.5 - 5.0	<0.80
↓	5.0 - 7.5	<0.80
	7.5 - 10.0	<0.80
c	0.0 - 2.5	2.31 ± 0.947
	2.5 - 5.0	<0.80
↓	5.0 - 7.5	<0.80
d	0.0 - 2.5	<0.80
↓	2.5 - 5.0	<0.80

*Refer to Figure 9 for sample locations.

**Am-241 concentration determined by 100 min gamma count.

NOTE: The symbol "<" indicates "less than detection limits."

The Am-241 activity concentration measurement results for the five EG&G IMP surveys are presented in Table 6. Comparisons of initial and final IMP measurements (Table 7) were used to gauge success of the decontamination effort in the field. The pretest and post-test soil samples were collected for project documentation.

Hurricane type air samplers were used to make relative plutonium concentration ($\mu\text{Ci Pu/cc air}$) measurements at the effluent exhaust port, driver position, operator position, and 328 ft (99.9 m) downwind from the operation. A conservative estimate of plutonium air concentration was derived from the mass loading of the air filter paper during sampler operation. Ten of the air filters were submitted for quantitative plutonium analysis, and results are detailed in Table 8. Concentrations were above MPC and DAC limits only at the effluent exhaust port of the VAC-ALL and at the vacuum operator position. The data in Table 8 represent the "worst case" samples for the operation. Again, respiratory protection was worn and lung/whole-body counting data did not indicate internal deposition of radionuclides. Thus, the air sampling data represents a potential rather than an actual inhalation hazard associated with the VAC-ALL.

No alpha contamination was detected on personnel or personal clothing during Phase II. Nasal swipe results did not indicate internal deposition of alpha contamination.

The heat stress measurements discussed in the METHODS section of this report indicated an initial heat stress index of 21.1°C which

TABLE 6. EG&G IMP MEASUREMENT SURVEY RESULTS

Test Section No.	Am-241 (pCi/g)				
	Initial Survey (6/23-26/81)	2nd Survey (7/17-20/81)	3rd Survey (8/19-20/81)	4th Survey (9/9/81)	Final Survey (9/21-22/81)
1	80.2	8.0	7.9	*	*
2	101.5	10.5	10.9	*	6.2
3	107.3	31.5	8.7	*	*
4	97.3	59.6	24.1	*	1.5
5	131.5	71.8	22.2	11.8	3.3
6	103.1	49.1	19.5	11.8	9.5
7	86.9	42.2	25.2	12.7	4.4
8	86.3	37.2	15.7	10.6	4.5
9	92.3	42.7	15.8	9.0	*
10	86.2	48.0	33.1	21.3	3.6
11	46.9	20.2	9.6	4.2	*
12	41.6	22.9	12.1	4.5	*
13	44.0	8.2	8.3	*	*
14	45.0	8.6	8.3	*	*
15	47.7	21.2	21.7	6.0	*
16	40.0	19.8	8.3	5.9	*
17	40.5	29.6	28.4	15.5	3.1
18	50.9	23.7	21.2	8.0	*
19	51.4	27.7	11.9	2.3	*
20	57.3	14.5	6.2	*	*

* Successfully decontaminated test sections were not resurveyed during the 4th and final IMP measurement surveys.

TABLE 7. Pu-239,240 CONCENTRATION RELATED TO THE INITIAL
AND FINAL IMP Am-241 MEASUREMENTS

Test Section	Initial Measurements		Final Measurements	
	Am-241 (pCi/g)	Pu-239,240 (pCi/g)*	Am-241 (pCi/g)	Pu-239,240 (pCi/g)*
1	80.2	456	7.9	45
2	101.5	577.5	6.2	35
3	107.3	610.5	8.7	50.
4	97.3	544	1.5	8.5
5	131.5	748.2	3.3	19
6	103.1	586.6	9.5	54
7	86.9	494	4.4	25
8	86.3	491	4.5	26
9	92.3	525	9.0	51
10	86.2	490.	3.6	20.
11	46.9	267	4.2	24
12	41.6	237	4.5	26
13	44.0	250.	8.3	47
14	45.0	260.	8.3	47
15	47.7	271	6.0	34
16	40.0	230.	5.9	34
17	40.5	230.	3.1	18
18	50.9	290.	8.0	46
19	51.4	292	2.3	13
20	57.3	326	6.2	35

*Pu-239,240 concentration inferred from the Pu/Am data: Pu-239,240/
Am-241 = 5.69

TABLE 8. AIR SAMPLE RESULTS

<u>Date</u>	<u>Sample Description*</u>	<u>Concentration Pu-239, 240 ($\mu\text{Ci/cc Air}$)**</u>
7-2-81	VAC-ALL Exhaust, Plot 1	$2.81 \times 10^{-11} \pm 0.244$
7-6-81	VAC-ALL Exhaust, Plot 1	$9.67 \times 10^{-11} \pm 0.909$
7-9-81	VAC-ALL Exhaust, Plot 1	$9.84 \times 10^{-11} \pm 0.787$
7-10-81	VAC-ALL Exhaust, Plot 1	$3.35 \times 10^{-10} \pm 0.285$
7-8-81	Approximately 100 m downwind from VAC-ALL, Plot 1	$1.26 \times 10^{-12} \pm 0.0718$
7-10-81	Approximately 100 m downwind from VAC-ALL, Plot 1	$5.77 \times 10^{-13} \pm 0.329$
7-30-81	Approximately 100 m downwind from VAC-ALL, Plot 2	$4.24 \times 10^{-13} \pm 0.216$
8-12-81	VAC-ALL Exhaust, Plot 2	$1.20 \times 10^{-11} \pm 0.0540$
8-12-81	Vacuum Operator Position	$4.30 \times 10^{-12} \pm 0.189$
8-12-81	Driver Position	$9.49 \times 10^{-13} \pm 0.522$

* Pavement cleaning nozzle configuration and water saturation prior to vacuuming employed during each sampling period.

**Pu-239,240 concentration determined by chemical isolation and alpha spectrometry.

increased, in a linear fashion, to 23.3°C at the end of the day. Continuous heavy work (350-500 K cal/h metabolic rate), with no work rest regimen, is allowed up to a heat stress index of 25.0°C in accordance with the permissible heat exposure Threshold Limit Value published by the American Conference of Governmental Industrial Hygienists (ACGIH).

CONCLUSIONS

During the CAT test it became obvious that the 20 yr old VAC-ALL could not be used to decontaminate areas larger than the one-quarter hectare Phase II site. Equipment malfunctions and experimental modifications accounted for about 20% of the Phase II operation. The VAC-ALL exhaust filtration system was inadequate for containment of the dry contaminated surface soil. Wetting of soil was therefore necessary. However, vacuuming of dry soil is much more efficient. State-of-the-art commercial equipment, with a positive displacement blower system and a three-stage exhaust filtration system, is available. The state-of-the-art vacuum equipment will contain particles greater than one micron in diameter. Decontamination of land areas by the vacuum method thus is feasible only with state-of-the-art equipment.

The CAT test was conducted over rock-strewn desert pavement with intersperse blow-sand mounds and washes. Ambient temperatures exceeded 105°F during the Phase II operation. The CAT test was a rigorous test of the vacuum method of soil removal, and the two 39 by 335 ft (11.9 x 102.1 m) Phase II plots were decontaminated

to less than 10 pCi/g of Am-241 contamination in surface soil. The CAT test was successful under difficult environmental conditions.

The vacuum soil removal technique facilitates removal of contaminated surface soil without disturbance of the vegetation root systems. The vacuum method also allows for selective removal of contaminated soil, and exclusion of rocks greater than 3 in. (7.6 cm) in diameter from collected material.

Where contamination is present in only the surface 0.0-1.0 in. (0.0-2.5 cm) of soil, the vacuum method of soil removal presents an advantage over conventional earthmoving techniques. Since the VAC-ALL is capable of removing less than 2 in. (5 cm) of soil per pass, the total volume of collected material can be reduced greatly in comparison with conventional earthmoving techniques.

Volume reduction due to removal depth control and selective exclusion of rock from collected material translates into operational cost reduction. Department of Transportation-approved container construction costs, transportation costs, and burial costs would decrease in proportion with the degree of volume reduction achieved.

Revegetation, repopulation by animals, and soil studies will be conducted through time for the CAT test Phase II site. It is likely that leaving root systems in place and minimizing removal of organic matter and nutrients will facilitate revegetation and

soil stabilization, thereby decreasing the environmental impact of vacuum soil removal techniques in comparison with conventional earthmoving techniques.

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