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Final Project Report TA-35 Los Alamos Power Reactor Experiment No. II (LAPRE II) Decommissioning Project

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FINAL PROJECT REPORT
TA-35 LOS ALAMOS POWER REACTOR EXPERIMENT NO. II (LAPRE II) DECOMMISSIONING PROJECT

by

Gilbert M. Montoya

ABSTRACT

This final report addresses the decommissioning of the LAPRE II Reactor, safety enclosure, fuel reservoir tanks, emergency fuel recovery system, primary pump pit, secondary loop, associated piping, and the post-remediation activities. Post-remedial action measurements are also included. The cost of the project, including Phase I assessment and Phase II remediation was approximately $496K. The decommissioning operation produced 533 m^3 of low-level solid radioactive waste and 5 m^3 of mixed waste.

1.0 INTRODUCTION

1.1 Los Alamos National Laboratory

Los Alamos National Laboratory (LANL, formerly Los Alamos Scientific Laboratory) was established in 1943. It has been operated by the University of California since then as a government-owned, contractor-operated (GOCO) facility for the Manhattan Engineering District of the US Army, the Atomic Energy Commission, the Energy Research and Development Administration, and now the Department of Energy. The primary mission of the Laboratory is research and development to support the nation's nuclear weapon program. Although weapons activity has always been and remains the largest single activity, the Laboratory has become a versatile and broadly based multiprogram research and development institution.

The Laboratory is located in north-central New Mexico about 60 air miles north of Albuquerque. Physical facilities include 50 sites, or technical areas, spread over 43 square miles.

1.2 Reactor Characteristics

The Los Alamos Power Reactor Experiment No. II, LAPRE II, was a test of a compact homogeneous reactor using a fuel solution composed of UO_2 (93.5% ^{235}U) dissolved in 95% H_3PO_4.[1] LAPRE II was an 800 kW water-cooled reactor. Reactor design was started early in 1955. Construction of LAPRE II began in February 1956, and the reactor operated from February 1959 to May 1959 to capitalize on the inherent advantages of this reactor type and on the most recent information on materials and chemistry then available. Much of the information used in the design of LAPRE II was obtained from research on problems encountered in the design and construction of LAPRE I.[2] Many of the design features conformed with portable power reactor specifications existing at the time. Standard items (pumps, heat exchangers, etc.) were used wherever possible. The design did not include generating equipment, but the heat dump could simulate turbine-generator operation. A schematic view of the reactor is shown in Fig. 1.

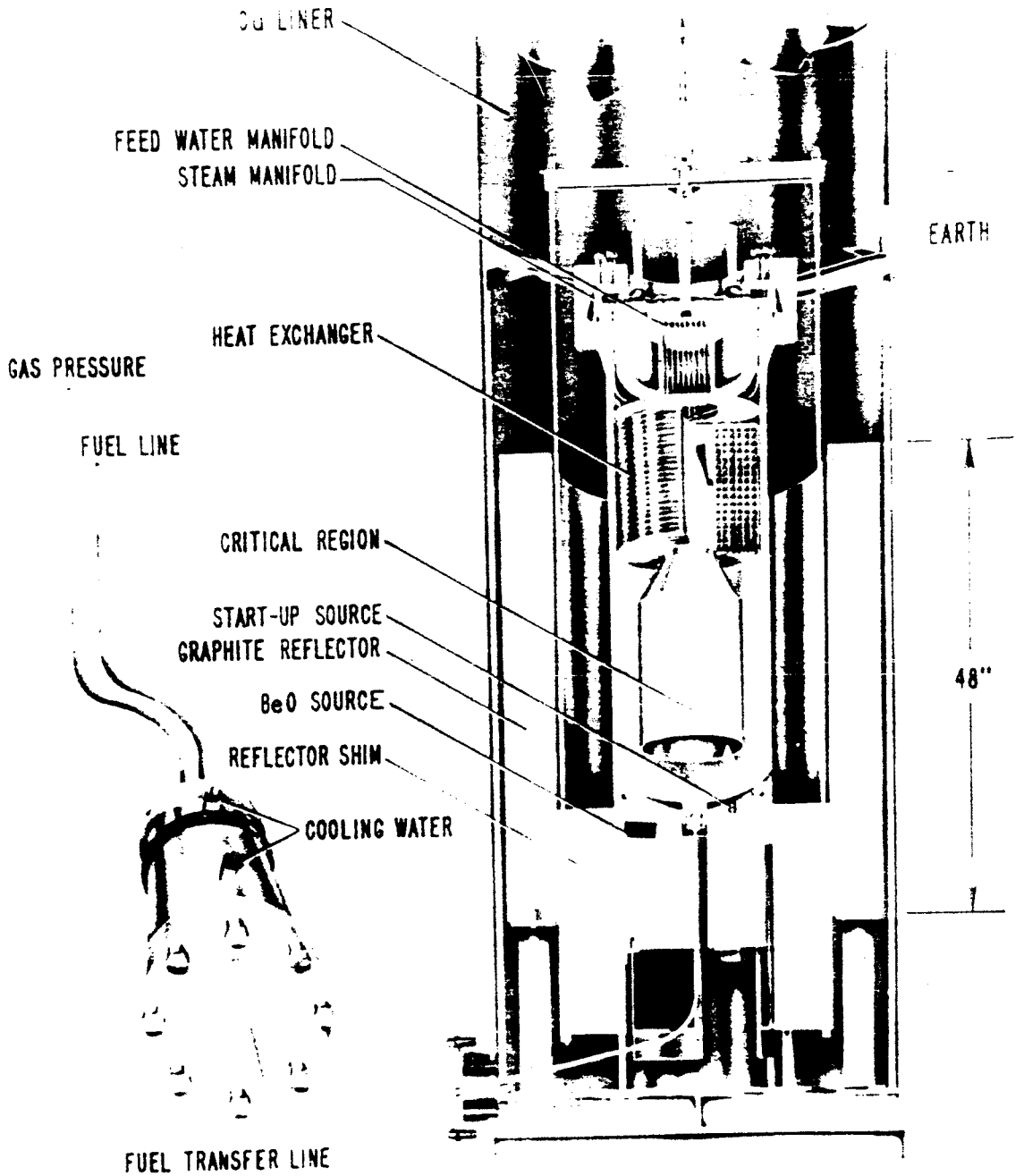

Fig. 1. Schematic view of LAPRE II.

1.3 Reactor Location

LAPRE II was located in an exclusion area on the south side of the main Laboratory building at TA-35 (Fig. 2). The location and the underground arrangement of the reactor were chosen as an economical means of obtaining the necessary personnel protection without the expense of biological shielding construction. An incidental feature was the simulation of a portable reactor installation (Fig. 3).

1.4 Purpose of the Decommissioning Project

The purpose of the TA-35 Los Alamos Power Reactor Decommissioning Project (LAPREDP) was to decommission the LAPRE II reactor at TA-35 to provide reusable land space at the site and to eliminate the hazard of accidental intrusion into a contaminated site.

1.5 Description of LAPRE II Reactor Components Removed During Decommissioning

Reactor vessel - The design of the reactor vessel is shown in Fig. 4. The vessel itself was basically a 16-in. outside diameter tube 49 in. long with an elliptical bottom. The wall thickness was 5/8 in. throughout. The reactor cover, or derby, as it was referred to, consisted of a 13-7/8 in. outside diameter cylinder 11 in. long and closed with an elliptical head. All material was Type 316 stainless steel. To protect the vessel from contact with the corrosive fuel solution, all surfaces of the vessel and derby were covered with 99.9% gold cladding machined to approximately 125 microinches.

Safety enclosure - The safety enclosure contained the reactor vessel, the shim and reflector assembly, and the concrete shielding above the reactor vessel. The enclosure also provided containment in case of a vessel rupture, a leak in fuel line, feed water line, or steam line. The safety enclosure was installed in an excavation, which was then backfilled.

Dimensions of the safety enclosure were 42-in. inside diameter, 20-ft inside length, and 5/16-in. wall thickness. The bottom end plate was 3 in. thick. It was built of mild steel, with the bottom half internally clad with 1/16 in. of copper.

Centered 8 ft above the bottom on the east side of the safety enclosure was an 8-in. flanged port that provided access for the feed water and steam lines, the thermocouple extension lines, the leak detector lines, and a pressure relief valve.

The concrete shielding was divided into two sections, or plugs, each 54 in. thick. The lower shield plug was 41 in. outside diameter and rested on a support rim 10 ft above the bottom of the vessel. The upper shield plug was removed and disposed of during postmortem activities on August 28, 1959.

Fuel reservoir tank - The fuel reservoir tank had an inside diameter of 7 in. and an inside length of 180 in., giving it a capacity of about 30 gal. It was mounted on a slope of 12%, with the lower end toward the reactor.

The fuel reservoir tank was fabricated from a low alloy steel tube with a 1/8 in. thick copper liner. Copper was selected for a liner material because it had adequate corrosion resistance at temperatures up to 100°C. The fuel reservoir tank was kept below that temperature by its external cooling jacket. However, a gold sleeve was inserted in the lower end of the tank, where hot fuel might impinge on the liner as the fuel entered from the reactor vessel.

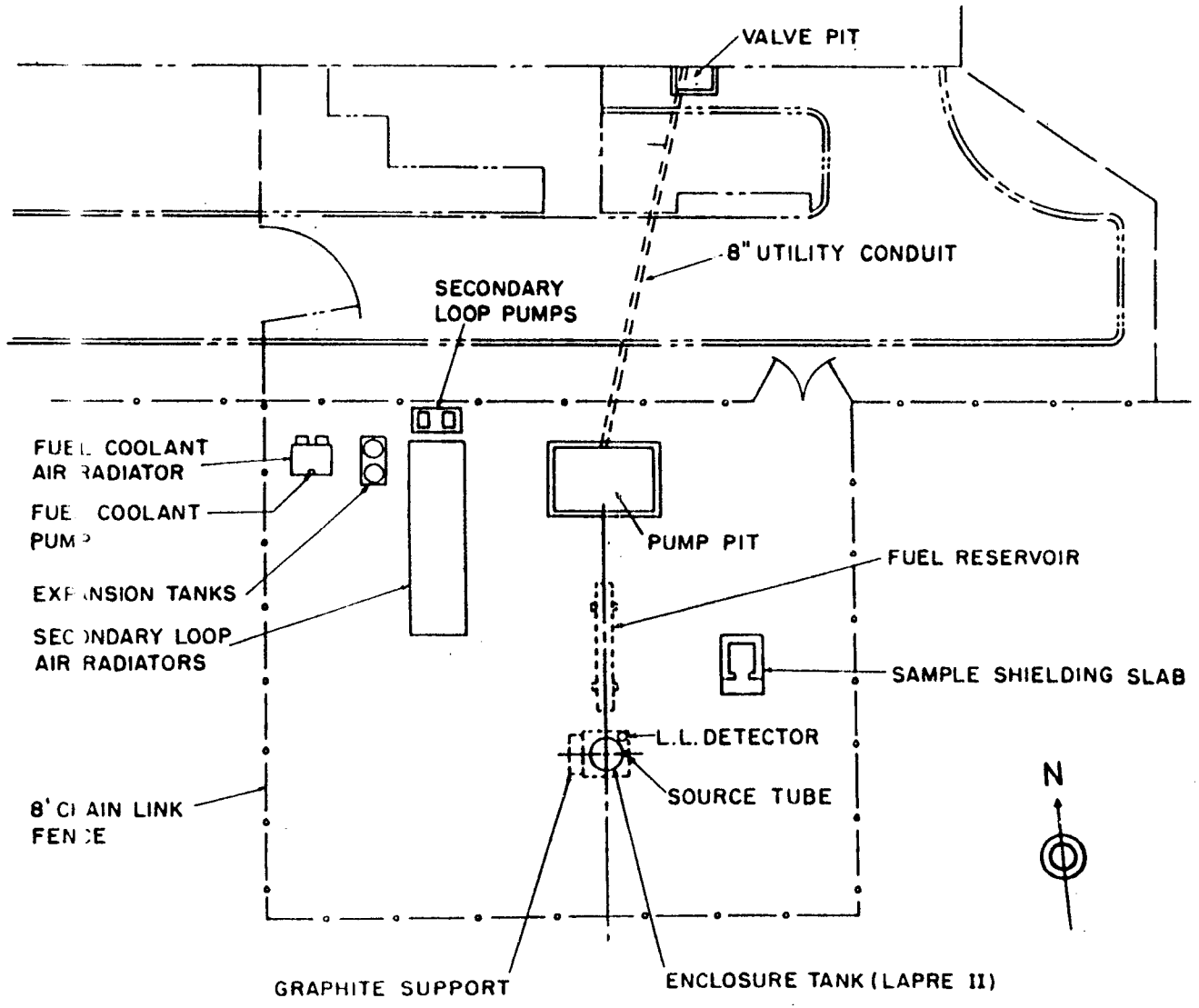

Fig. 2. Plan view of LAPRE II installation.

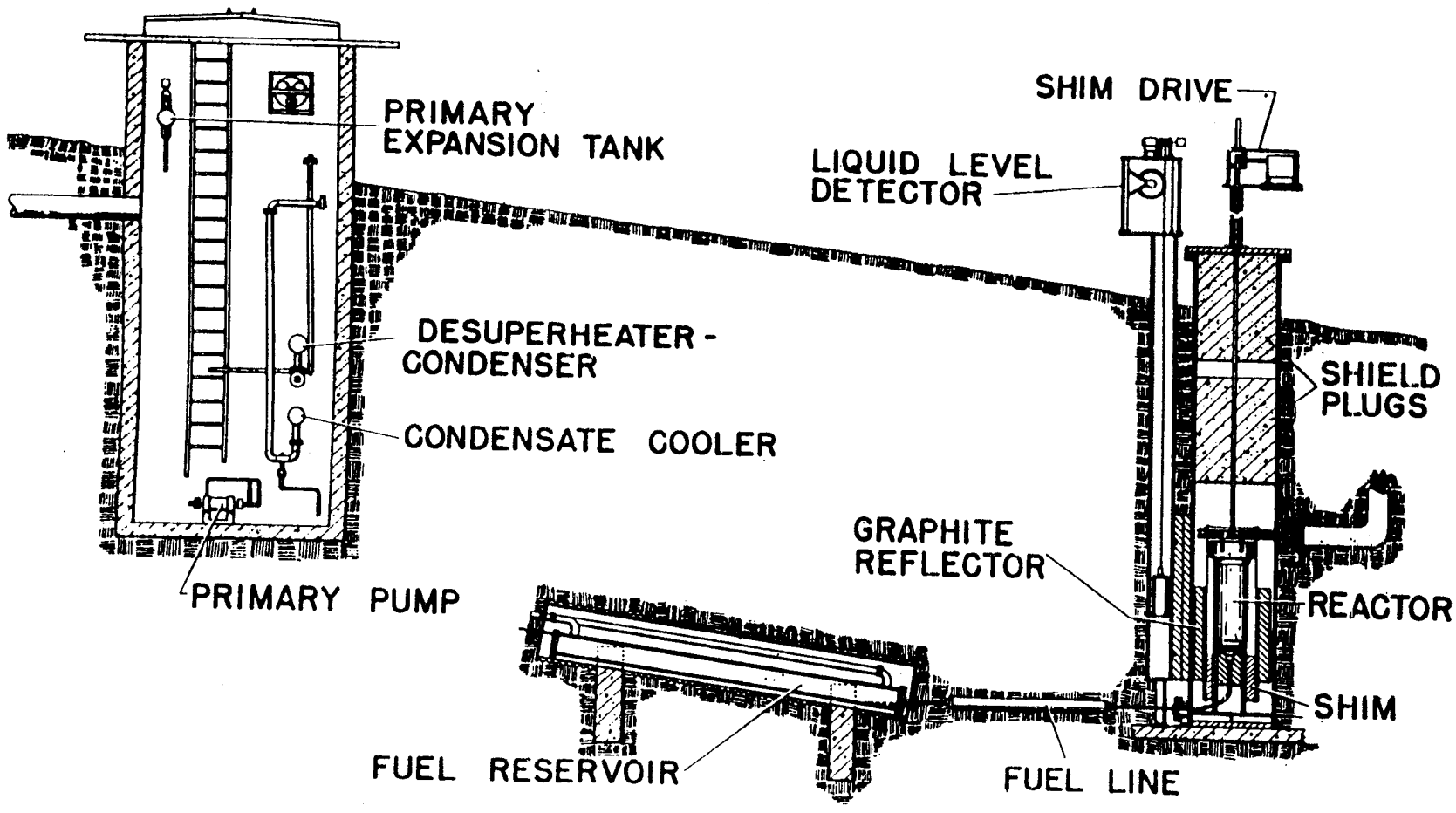

Fig. 3. Elevation of LAPRE II installation.

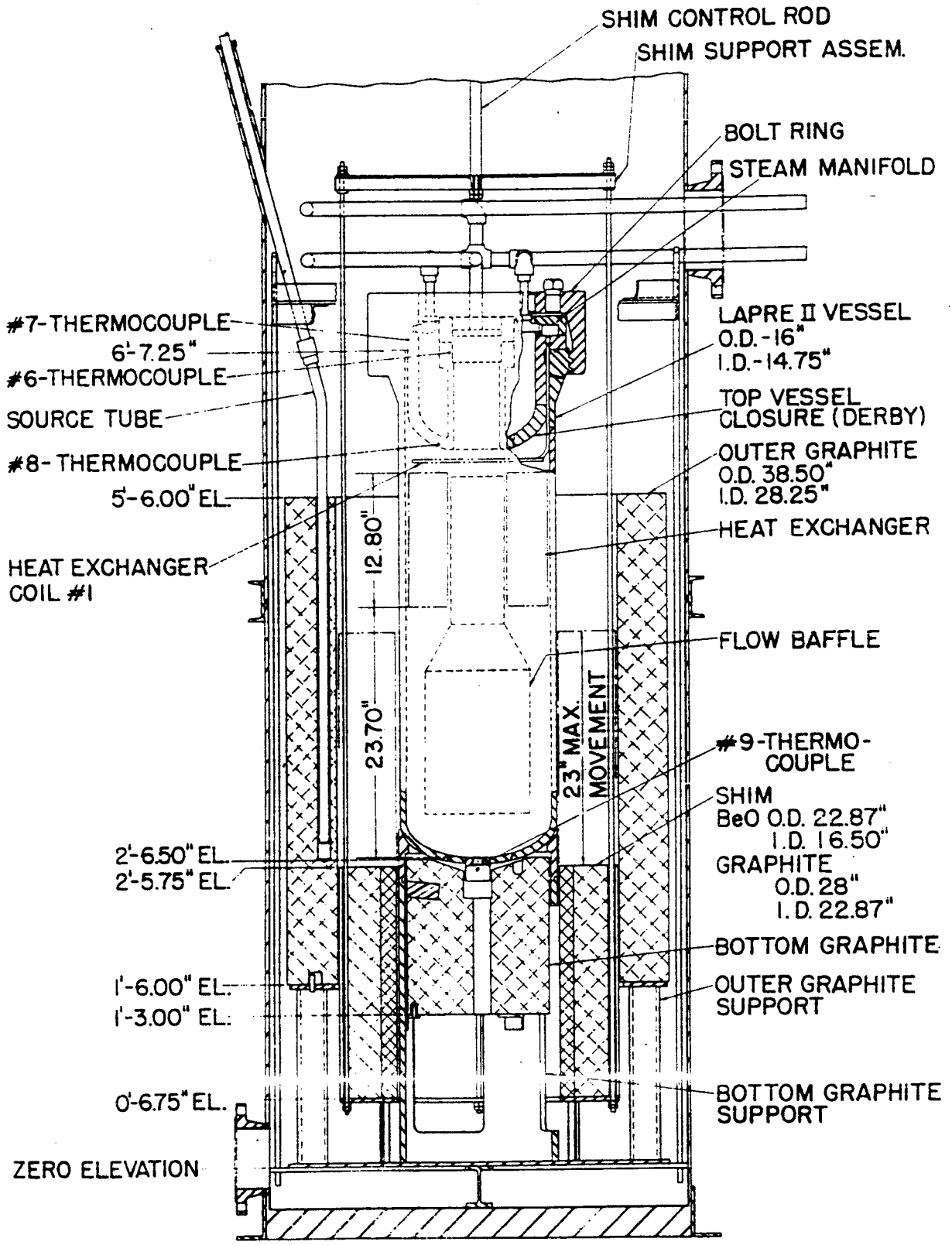

Fig. 4. Elevation of reactor assembly.

For protection against damage during backfilling, the fuel reservoir tank was housed in a 24-in. outside diameter corrugated metal pipe. The reservoir tank was mounted inside the corrugated pipe on an 8 in. x 2 in. steel channel.

Emergency fuel recovery system - The emergency fuel recovery system was installed to facilitate recovery of fuel in the event of a fuel leak in the fuel reservoir tank or in the reactor vessel. For recovery of fuel from the fuel reservoir tank, a copper tank with a 7-3/16 in. outside diameter, a 1/8 in. wall, and 16 ft long with copper ends was placed parallel to the fuel reservoir tank and 2.5 ft below its corrugated metal enclosure.

Primary pump pit - Because of the induced radioactivity in reactor outlet steam, all primary system piping and equipment were located in an underground concrete pit having plan dimensions of 8 ft 0 in. x 12 ft 0 in. and a depth of 21 ft 3 in. The main function of the primary loop was to circulate feed water to the reactor and remove steam from the reactor heat exchanger.

Secondary loop - A secondary loop arrangement was used to condense the reactor-produced steam and to dissipate the heat to atmosphere through a forced draft air radiator. The aboveground air radiators were removed during postmortem activities in 1959.

1.6 Technical Objectives

The technical objectives of the LAPRE II decommissioning project were to do the following:

- demonstrate the safe and cost-effective dismantling of a subterranean contaminated and activated nuclear-fueled reactor;
- optimize the use of a dedicated subcontractor labor crew to induce a transfer of decommissioning experience;
- provide for technology transfer by generating project performance data and documenting the decommissioning experience for use in future decommissioning projects; and
- make the site available for other use.

1.7 Project Summary

Conceptual and detailed engineering to establish the groundwork for the physical decommissioning for the project began in February 1989 and was completed in December 1991. Johnson Controls, Inc. (JCI), is the on-site subcontractor to Los Alamos National Laboratory and was therefore the subcontractor for decommissioning operations. The Waste Management Group, EM-7 (formerly HSE-7), and the Radiation Protection Group, HS-1, provided site-specific health and safety indoctrination training and specific training on all reactor-related activities. Physical decommissioning began in May 1991.

The general decommissioning approach was to complete site characterization work that provided a thorough physical, chemical, and radiological assessment of the contaminants at the TA-35 site.

In February 1989 the Geophysics Group, EES-3, performed a geophysical investigation of the LAPRE II reactor site in an attempt to locate the buried reactor and related

components. Electromagnetic induction (EMI) was used to locate metallic objects and to map changes in the electrical structure of the ground such as might result from a cut-and-fill process such as trenching. One of the problems in measuring the magnetic field at the LAPRE II site was the amount of magnetic material from the surrounding facilities. After reviewing the results of the geophysical survey, EES-13 concluded that the LAPRE II site was most likely located as indicated in the as-built drawings (ENG-C 18400-23). See also the final report by G. M. Montoya and M. T. Gerety, "Geophysical Survey of the LAPRE II Reactor Site Technical Area 35," March 1989.[3]

In May 1990, as part of the assessment phase of the LAPRE II site, the Environmental Surveillance Group, EM-8, did core drilling to determine whether the soil was contaminated. Sampling was confined to the area within the original fence around LAPRE II. For additional information, see Gilbert M. Montoya, "Los Alamos Power Reactor Experiment No. II (LAPRE II) Site Characterization Summary Report."[4]

After the site assessment, the overburden of the soil was removed to expose the remaining shield plug to the reactor. The heat exchanger was removed, then the secondary loop. The safety enclosure was excavated to allow its removal. Next, the fuel reservoir and emergency fuel recovery system were removed. The pump pit was then demolished and removed. Remedial action activities and final restoration were then completed. Physical decommissioning was completed in November 1991 and the site released for unrestricted use in January 1992 following final sampling.

1.8 Primary Participants

US Department of Energy - The LAPRE II decommissioning project was a project under the Assistant Secretary for Nuclear Energy, with program responsibilities assigned to the Division of Facility and Site Decommissioning Projects in the Office of Remedial Action and Waste Technology at the Headquarters of the Department of Energy (DOE-HQ). An on-site DOE project manager was responsible for project execution, implementation, and on-site administration. The project was subsequently transferred to EM (the Office of Environmental Restoration) in October 1989.

Decommissioning operations subcontractor (DOS) - JCI was the DOS to the Laboratory and provided all craft support in the decommissioning effort.

Other on-site organizations - Figure 5 shows organizational relationships among the project's major participants.

2.0 SITE DESCRIPTION AND RECOGNIZED HAZARDS

2.1 Description of TA-35 LAPRE II Site

Figure 6 shows the location of the TA-35 site. TA-35 is approximately 4.4 miles from TA-54, the radioactive waste management disposal site, where waste from the decommissioning project was disposed of as low-level waste.

The LAPRE II decommissioning project occurred within an existing solid waste management unit (SWMU) regulated under Section 3004(u) of the Resource, Conservation, and Recovery Act (RCRA). The site resides within Material Disposal Area X, SWMU No. 35-002, at TA-35. The EM-7 Decommissioning Program Office and the Environmental Restoration (ER) Program agreed to decontaminate and decommission the LAPRE II Reactor as an ER Program Institutional Interim Action.

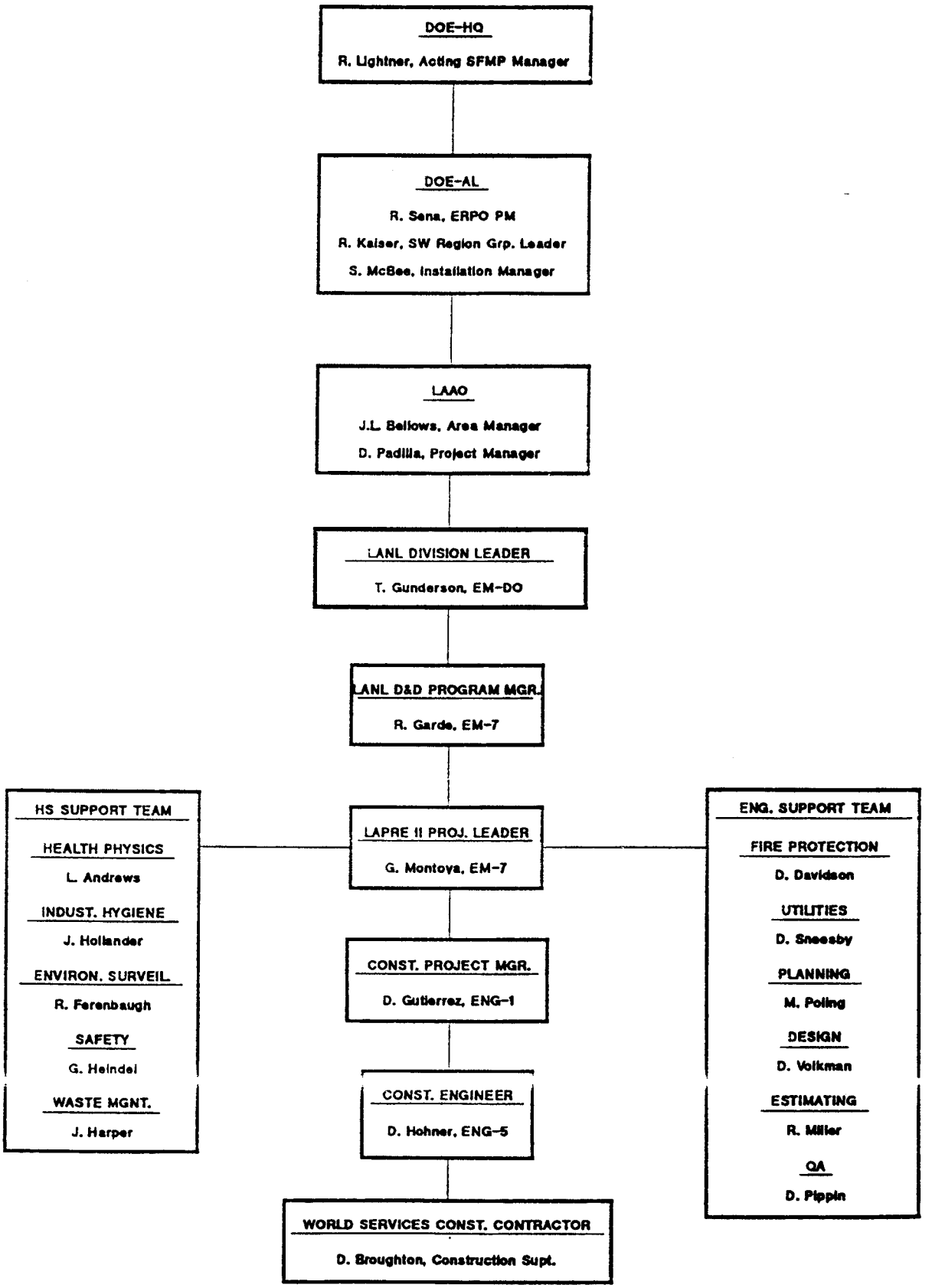

Fig. 5. Project organization chart.

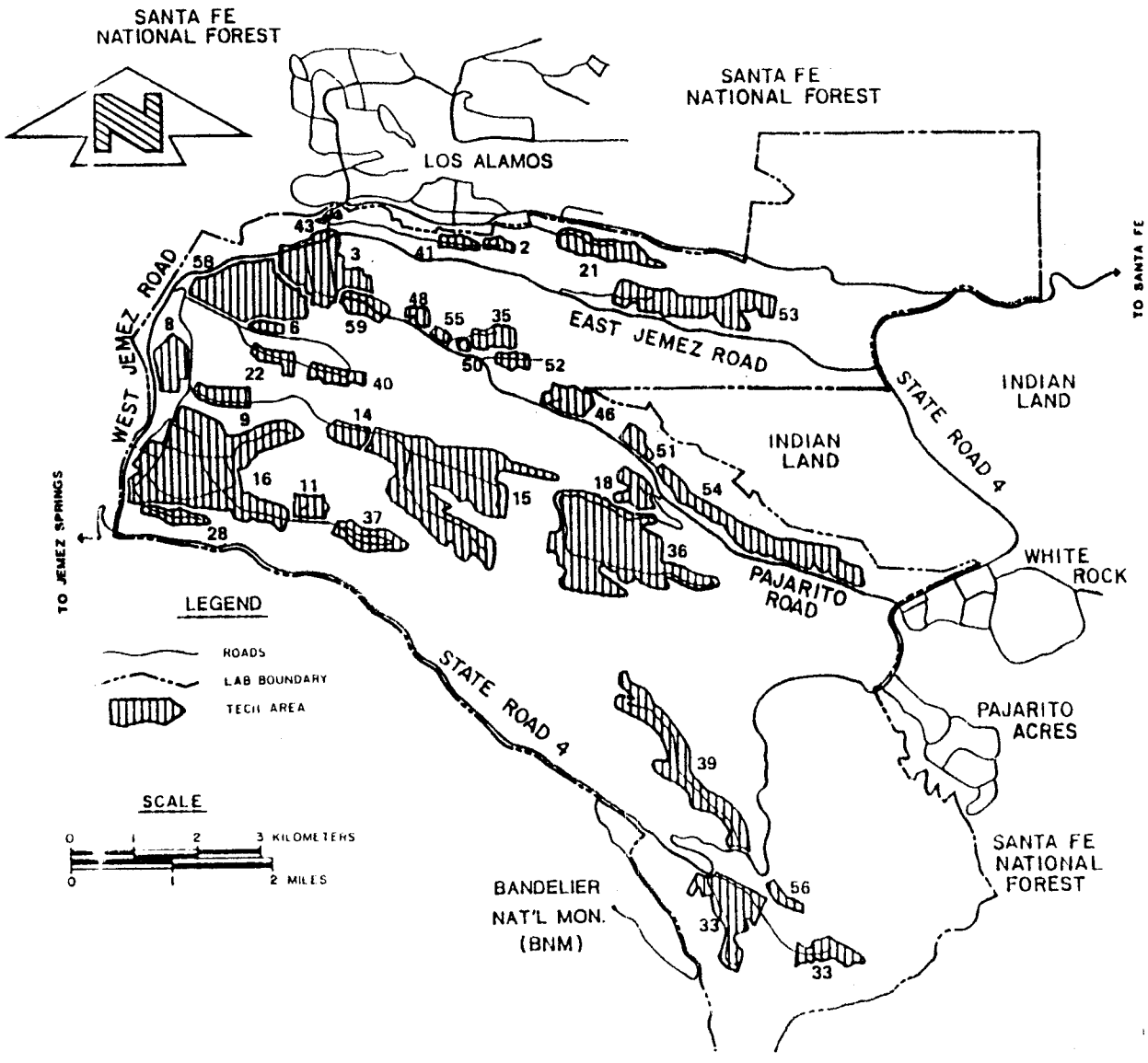

Fig. 6. Location of the LAPRE II site.

During the excavation and removal of the safety enclosure and fuel reservoir tank of the LAPRE II reactor, an additional structure (pump pit) was unearthed. Piping was also uncovered. The Decommissioning Project Management Team felt that the additional items, which were beyond the original scope of work in the Project Management Plan, should be removed. To manage such issues, a recommendation for the determination of "no further action" (NFA) is made in the RCRA Facility Investigation Work Plan. The EPA reviews the evidence for the recommendation and makes the decision for NFA or to continue characterization. For the LAPRE II reactor, removal of the pump pit was recommended to allow the entire SWMU 35-002 to become a candidate site for NFA within operable unit 1129 in the work plan for the remedial feasibility investigation. Additional funding was requested and approved to accomplish entire remediation of the site. A determination of NFA was made by the Laboratory's ER Program.

2.2 Recognized Hazards

Contamination - Contamination from fission products was distributed throughout the reactor-related systems. Neutron activation of the reactor vessel's critical region, heat exchanger, and nearby components ranged from 1 mR/h to 550 mR/h. Radiation levels on the fuel reservoir tank ranged from 1 mR/h to 5 mR/h. The 15 gallons of acid rinse solution used in 1960 to recover the fuel from the fuel reservoir tank ranged from 1 mR/h to 150 mR/h.

Industrial hazards and lead - In addition to the common industrial hazards of fall, electrical shock, crushing, rotating machinery, earth-moving equipment, and the like, another hazard at the site was lead. Lead bricks were used for radiation shielding. A waste regulated under RCRA, the lead was removed and stored under regulations of the state and the Environmental Protection Agency (EPA).

3.0 PROJECT MANAGEMENT

3.1 Project Cost and Schedule

The LAPRE II decommissioning project used DOE's Cost and Schedule Control System Criteria as the basis for complete integration of cost and schedule objectives and plans for the duration of the project. The LAPRE II decommissioning project also applied DOE Order 4700.1, Project Management System, which provided a uniform project control system for both the Laboratory and the subcontractor and allowed for a totally integrated projectwide system.[5]

Project summary schedule - The overall project summary schedule was based on an operations schedule that planned the work to begin in April 1991 and end in August 1991. The actual completion date for the operations was November 1991 because the Project Management Plan was not approved until May 1991, a larger amount of contaminated soil than anticipated was encountered, and final soil analysis took one month.

Project costs - The total estimated cost, including the assessment, planned remediation, and additional scope to remove the SWMU, was $496K. See also Section 4.3.

Figure 7 shows project costs and percent of total by elements of the WBS.

Figure 8 shows costs and percent of each dismantlement activity. Table I shows the elements of the work breakdown structure (WBS). Table II shows project costs by WBS.

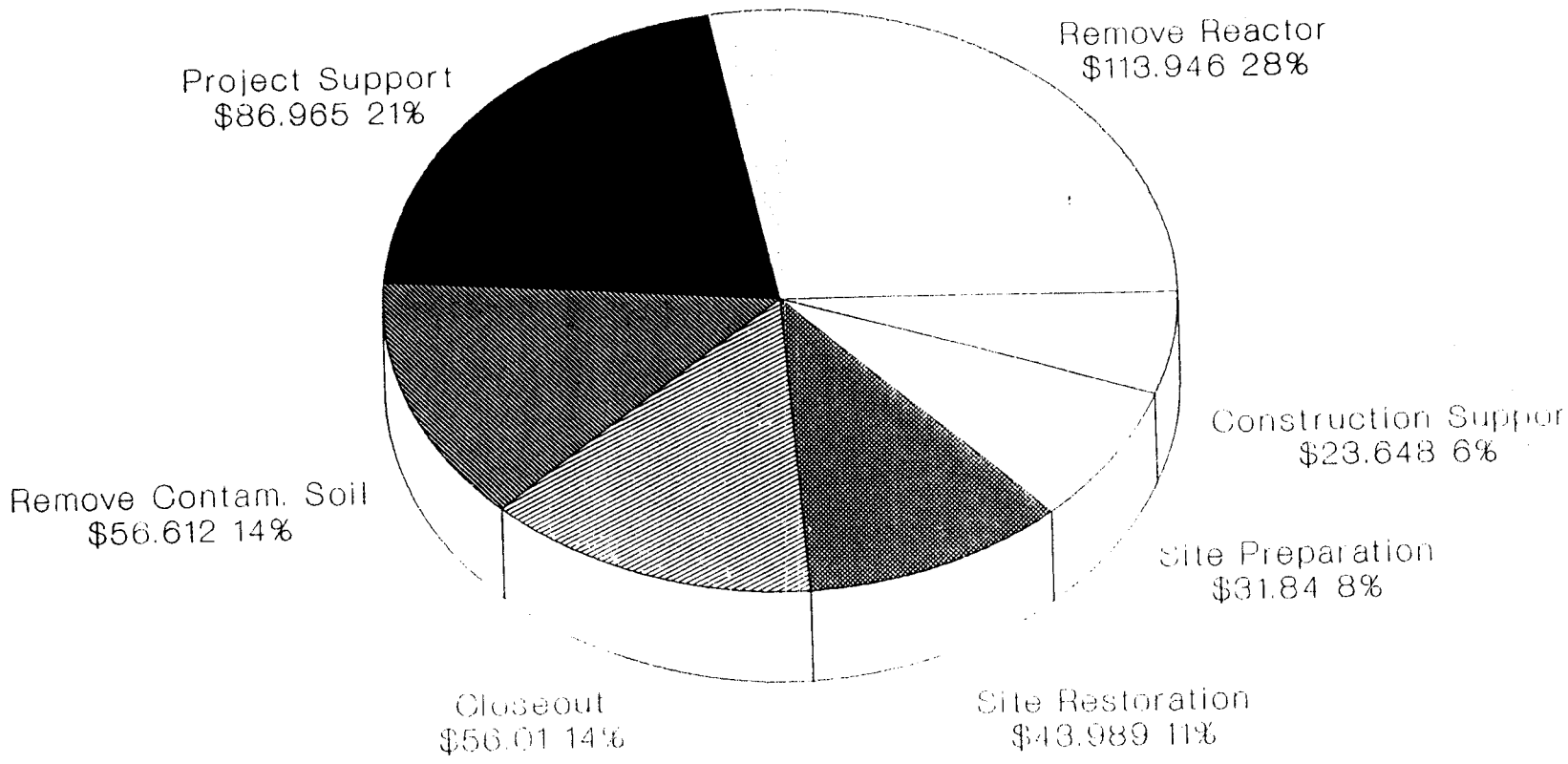

Fig. 7 Project costs and percent of total by WBS ($K).

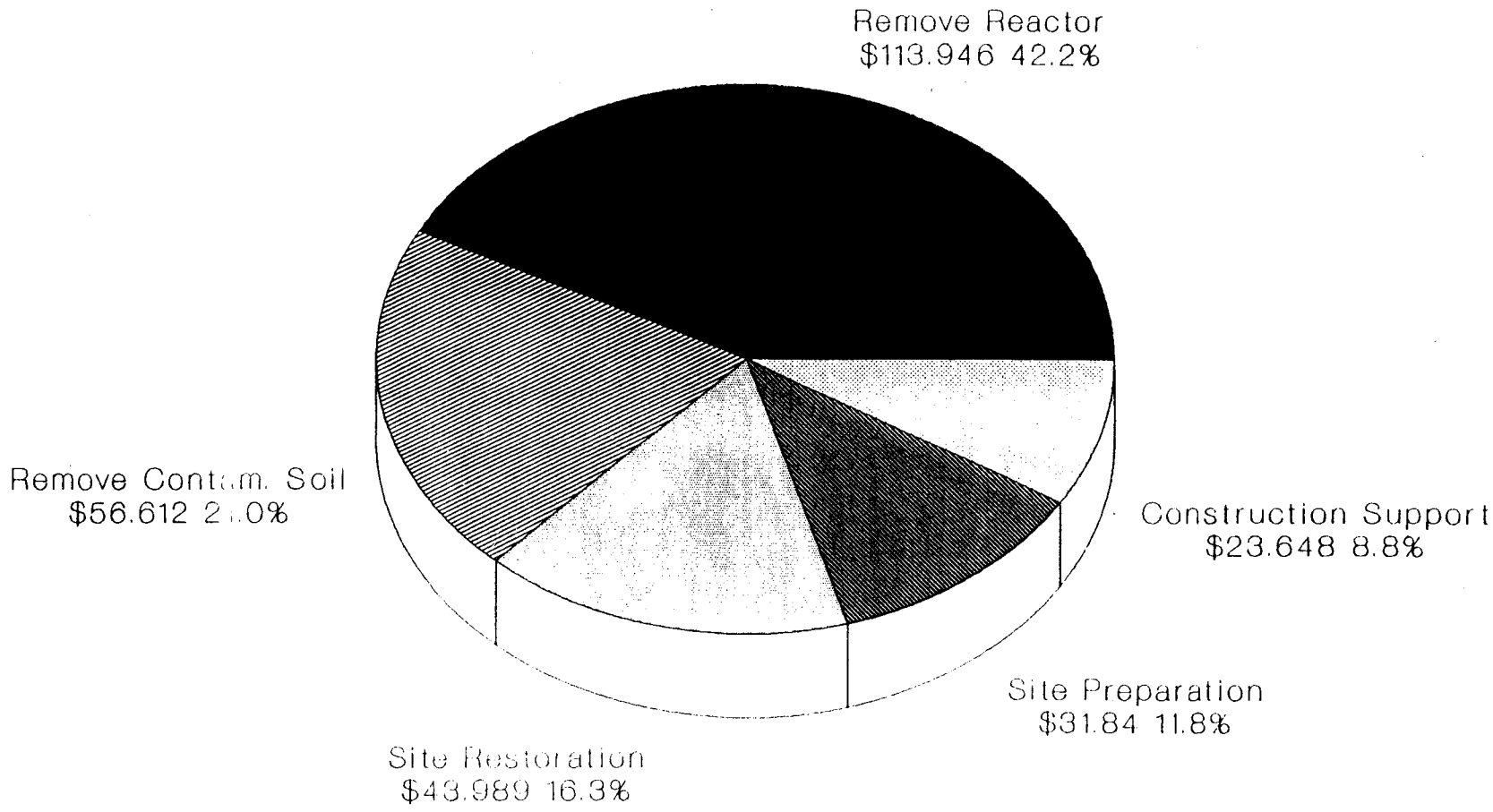

Fig. 8. Cost of major physical D&D activities ($K).

Table I. Project Work Breakdown Structure.

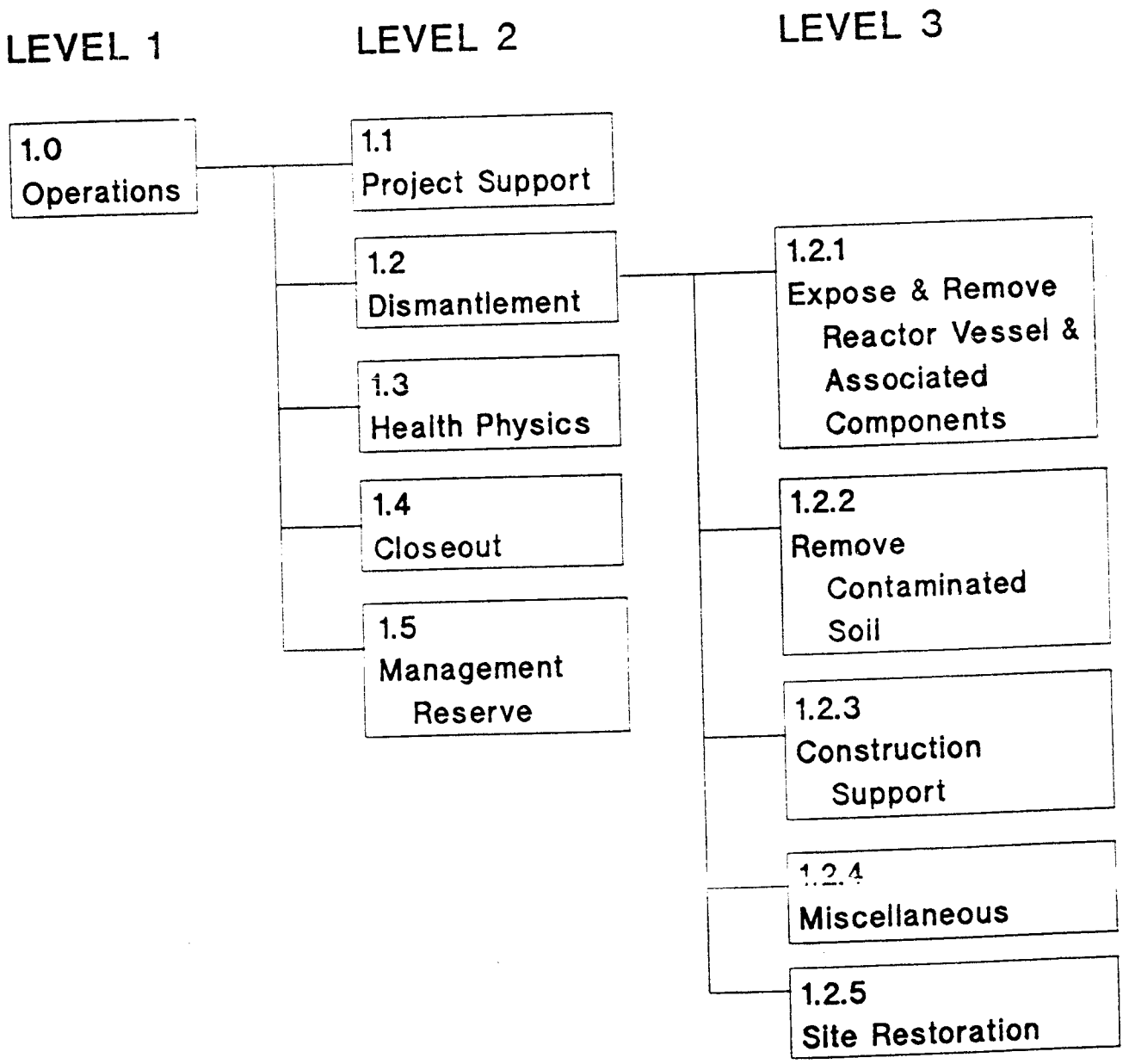

Table II. Project Costs by Work Breakdown Structure.

WBS	Activity	FY89 ($K)	FY90 ($K)	FY91-92 ($K)	TOTAL ($K)
1.1	Project support	13.00	70.00	86.965	169.965
1.2.1	Exposed and remove reactor vessel and associated components			113.946	
1.2.2	Remove contaminated soil			56.612	
1.2.3	Construction support			23.648	
1.2.4	Site preparation			31.840	
1.2.5	Site restoration			43.989	
1.3	Health physics	0.00	0.00	0.000	0.000
1.4	Closeout			56.000	
Actual cost of work performed (ACWP)		**13.00**	**70.00**	**413.000**	**496.000**

3.2 Radiological Controls

Radiological control program - Strict compliance with radiological control procedures was essential to minimize occupational radioactivity exposure to levels as low as reasonably achievable (ALARA) and to prevent spreading contamination around the site.

A trained radiation protection technician (RPT) from Radiation Protection Group, HS-1, provided continuous surveillance of all decommissioning activities associated with the LAPRE II decommissioning project.

Special requirements for radiation protection of workers were specified under the Laboratory practice of issuing a Special Work Permit (SWP) for radiation work. See also Administrative Requirements (AR) 1-3, "Standard Operating Procedures and Special Work Permits," and AR 3-1, "Personnel Radiation Exposure Control" in the *Environment, Safety, and Health Manual* (*ES&H Manual*).[6,7] After reviewing expected conditions, the project management team initiated the Radiation Work Permit (RWP), and HS-1 personnel received and approved it.

Work was monitored to ensure that the procedures were followed. The RPT surveyed and monitored the materials generated during work. Work conditions were reviewed daily. The need for changes in procedures or radiological controls was evaluated on the basis of these reviews.

The RPT used portable survey instruments to measure loose surface contamination, contact radiation levels throughout the general site, and airborne contamination concentrations. The RPT also ensured that personnel from JCI worked in a radiologically safe manner. Other routine tasks included surveying used protective clothing and source-calibrating the instruments.

All personnel working in contaminated area wore protective clothing: rubber and cotton gloves, cloth coveralls, and shoe covers. When there was a potential for high levels of contamination, a second set of protective clothing was required and supplemented with plastic or rubber apparel.

Personnel also wore full-face respirators when exposure to airborne activity was possible. The Industrial Hygiene Group, HS-5, fitted each worker with respirators. The Laboratory is required to maintain a respirator program in accordance with standards of the Occupational Safety and Health Administration (OSHA).

Personnel monitoring included monthly radiation badge dosimetry, pocket and finger ring dosimeters, bioassay analysis of urine specimens, and annual *in vivo* counting. Air in the work area was continuously sampled because of the potential for airborne contamination. Daily air samples were sent to the Health Physics Analysis Laboratory (HPAL) in HS-1 for analysis of gross alpha and gross beta-gamma activity.

Nasal smears were taken after operations involving removal of any reactor-related component and were checked for alpha and beta/gamma activity.

The LAPRE II decommissioning project was completed without a release of radioactive material from the operations area and without any worker overexposure. All personnel exposures were maintained within federal quarterly and annual limits. The ALARA principle, an operating principle that encourages keeping exposure to toxic materials and radiation to the lowest reasonable achievable level, was enforced in daily operations. Actual exposures received by D&D workers are discussed below.

No radiological impacts to the environment were caused by decommissioning work. Key factors in these achievements were the following:

- management overview,
- strict procedural controls,
- prudent deployment of RWPs,
- employee training,
- use of a dedicated subcontractor crew, and
- daily task planning.

Occupational doses - The Project Management Plan (PMP) estimated a total dose over the life of the project of 7.64 man-rem. The actual total dose was less than 1 man-rem. This successful record was the result of using principles of ALARA, good planning, and coordination.

ALARA - Project policy was to maintain personnel exposure at ALARA levels. This practice is required in DOE Order 5480.1, "Environment, Safety, and Health Program for Department of Energy Operations": Chapter XI, "Requirements for Radiation Protection," Edition 4(f).[8]

As a major management practice for ALARA, special attention was given to reviewing procedures, perfecting existing techniques, and observing work practices with an awareness of methods to reduce the potential for personnel exposure.

Preplanning of work tasks by the project leader and JCI included detailed work procedures with estimates of personnel exposures. The project leader reviewed critical operations. Observations by management personnel and the RPT ensured that procedures were followed, that radiological control practices were followed properly, and that changing conditions were properly addressed. Workers in potentially high-exposure areas received written instructions and verbal training sessions so that workers could become familiar with their predetermined tasks and crafts personnel could identify queries.

Key lessons learned in the application of ALARA at the LAPRE II decommissioning project were the following:

- to include requirements for ALARA and man-rem estimates for tasks with potential for significant exposure;
- to review all health and safety procedures carefully; and
- to monitor compliance of work with the procedures in the project management plan.

3.3 Health and Safety Oversight

In addition to radiation protection, the Health and Safety Division (HS) administered implementation of industrial safety and hygiene procedures and provided personnel

training. The Environmental Management Division (EM) ensured compliance with health, safety, and environmental requirements of DOE orders.

Safety - JCI Safety and the Safety and Risk Assessment Group, HS-3, were responsible for the safe working conditions of the workers. The safety program included review of planned work procedures, surveillance of actual work practices, training, and technical support. JCI Safety provided first-aid training, safe lifting and rigging procedures, and procedures for accident prevention and investigation. JCI Safety personnel also wrote "The TA-35 LAPRE II Reactor Decommissioning Project Health and Safety Plan."[9]

Industrial Hygiene - The Industrial Hygiene Group, HS-5, provided technical support in asbestos removal, lead removal, and respirator protection.

Environmental Protection - Environmental protection at the LAPRE II decommissioning project consisted of controlling hazardous and radiological contaminants at the site and monitoring of the site perimeter by the Environmental Surveillance Group, EM-8, to verify that there were no significant radiological effects. Objectives of environmental protection were to

- ensure that the LAPRE II decommissioning project complied with applicable regulations and that exposures were at ALARA;
- verify that any contaminants released to the environment did not pose a significant risk to the public and were representative of the concentrations expected; and
- collect and submit final verification soil samples according to the Environmental Soil Sampling Plan.[10]

3.4 Engineering

Engineering objectives for the LAPRE II decommissioning project included applying safe, cost-effective decommissioning practices to fulfill the objectives of the project. Engineering activities included establishing project work practices by developing project instructions, detailed procedures, administrative procedures, technical operations practices, engineering design activities, technical specification preparation for the task list, and input for the project schedule.

The LAPRE II decommissioning project instructions - The project management team prepared and issued project instructions during special operations. These instructions provided the subcontractor with the daily project activities not otherwise covered in detailed technical procedures, such as the project management plan and standard operating procedures (SOPs). Examples of project instructions are operational safety requirements, communication control during critical operations, and ALARA review.

Detailed procedures - The project management team developed the SOP "Removing, Packaging, and Transporting Contaminated Components Associated with the Los Alamos Power Reactor Experiment NO. II, " which covered safety and engineering requirements.[11]

JCI Health and Safety Plan - The subcontractor developed for its workers a health and safety plan specifically for the LAPRE II decommissioning project. Topics in the plan included emergency procedures, accident reporting, fire prevention and protection, traffic control, sanitation, housekeeping, environmental protection, personal protective equipment, electrical safety, and specific health and safety requirements. Details of the

plan appear in "The TA-35 LAPRE II Reactor Decommissioning Project Health and Safety Plan."[9]

3.5 Quality Assurance

The quality assurance (QA) program conformed to ANSI/ASME NQA-1, "Quality Assurance Program Requirements for Nuclear Facilities," and DOE Order AL 5700.6B, "Quality Assurance."[12,13] To ensure the requisite quality of the overall project, the QA plan for the LAPRE decommissioning project established measures, procedures, and instructions for accomplishing the decommissioning activities. The QA plan ensured that the appropriate activities established and organized the program and that the following elements were included:

- document control;
- inspection and test control;
- identification and control of items;
- control of nonconforming items and services;
- corrective actions;
- control of measuring and test equipment; and
- establishment and maintenance of quality assurance records.

Requirements and guidelines for these activities are specified in the Los Alamos Quality Assurance Manual for Engineering and Construction,[14] which complies with the requirements of DOE AL 5700.6B.

3.6 Site Security

A gate was locked overnight to ensure the security of TA-35, although a security badge was not required during normal working hours. Barricades were erected around the perimeter of the LAPRE II decommissioning project to secure open excavations during decommissioning.

4.0 DECOMMISSIONING PROJECT ACTIVITIES

4.1 Goals

The goal of the TA-35 The LAPRE II decommissioning project was to decommission the LAPRE II reactor safely and cost-effectively. The project was funded by the DOE Southwestern Area Programs Division (SAPD). The project was conducted under the requirements of the Surplus Facilities Management Program (SFMP) as stated in the SFMP Resource Manual 85-4.[15] The SFMP is a defunct program, but the requirements of the manual still provided useful guidance.

4.2 Site Preparation

Site preparation work supported the safe and expeditious dismantling and removal of the LAPRE II reactor. This work included the following:

- setting up the JCI work station;
- installing support facilities for site workers;
- establishing emergency readiness according to the TA-35 site; and
- addressing safety concerns (tripping hazards, hygiene practices, emergency alarms, etc.).

Setting up the subcontractor office - Because the LAPRE II decommissioning project was outside, a work station was constructed outside the exclusion zone of the LAPRE II decommissioning project. Personnel from JCI and Laboratory project management used the work station as an area in which to review drawings and keep important project documentation on-site.

Installing support facilities for site workers - A self-contained mobile decontamination unit accommodated the various crafts personnel involved. The unit had a change room and shower area. A dining trailer was also acquired for all crafts personnel assigned to the decommissioning project.

Safety concerns - Safety concerns in health physics and industrial safety required ongoing dialogue between project management and subcontractor personnel. A muster area was identified in case an emergency required evacuation of the site.

4.3 Scope of Work for Decommissioning

The decommissioning of the LAPRE II reactor consisted primarily of removing the concrete shield plug, reactor and heat exchanger, reactor safety enclosure, fuel reservoir tank, emergency fuel recovery system, primary pump pit, secondary loop, associated piping, and contaminated soil.

Removing the concrete shield plug - To remove the remaining concrete shield plug (54 in. thick x 41 in. outside diameter), approximately 3 ft of soil was removed to expose the plug. The plug was removed by rigging it onto eye bolts and lifting the plug with a crane (Fig. 9). The contact dose rate on the shield plug was 2 mR/h. Swipes were taken and submitted for qualitative analysis. The primary radioisotope was ^{137}Cs.

Removing the heat exchanger - The heat exchanger was removed from the enclosure so that the gold cladding could be reclaimed, because the direct contact dose rate was a manageable 30 mR/h (Fig. 10). The heat exchanger was packaged in a plastic-lined 55-gal. drum and staged as a mixed waste at TA-54, the Radioactive Solid Waste Disposal Facility.

Removing the safety enclosure - The 42 in. x 20 ft long safety enclosure that contained the reactor vessel and the shim reflector assembly was excavated on the north and east sides before rigging straps could be placed around the exterior (Fig. 11). A crane was used to lift out the steel safety enclosure. The highest exterior contact reading was 23 mR/h. The maximum interior contact reading was 550 mR/h. Permission was requested and granted from the Transportation Section of the Safety and Risk Assessment Group, HS-3, to transport the safety enclosure as a waste package of its own.

Removing the fuel reservoir tank - The fuel reservoir tank was excavated; it was located approximately 25 ft below surface grade, 6 ft north of the safety enclosure (Fig. 12). In 1960 when the fuel solution--UO_2 (93.5% ^{235}U) dissolved in H_3PO_4--was removed from the tank, approximately 15 gallons of acid rinse solution remained in the heel of the tank.

Fig. 9. Removing the concrete shield plug.

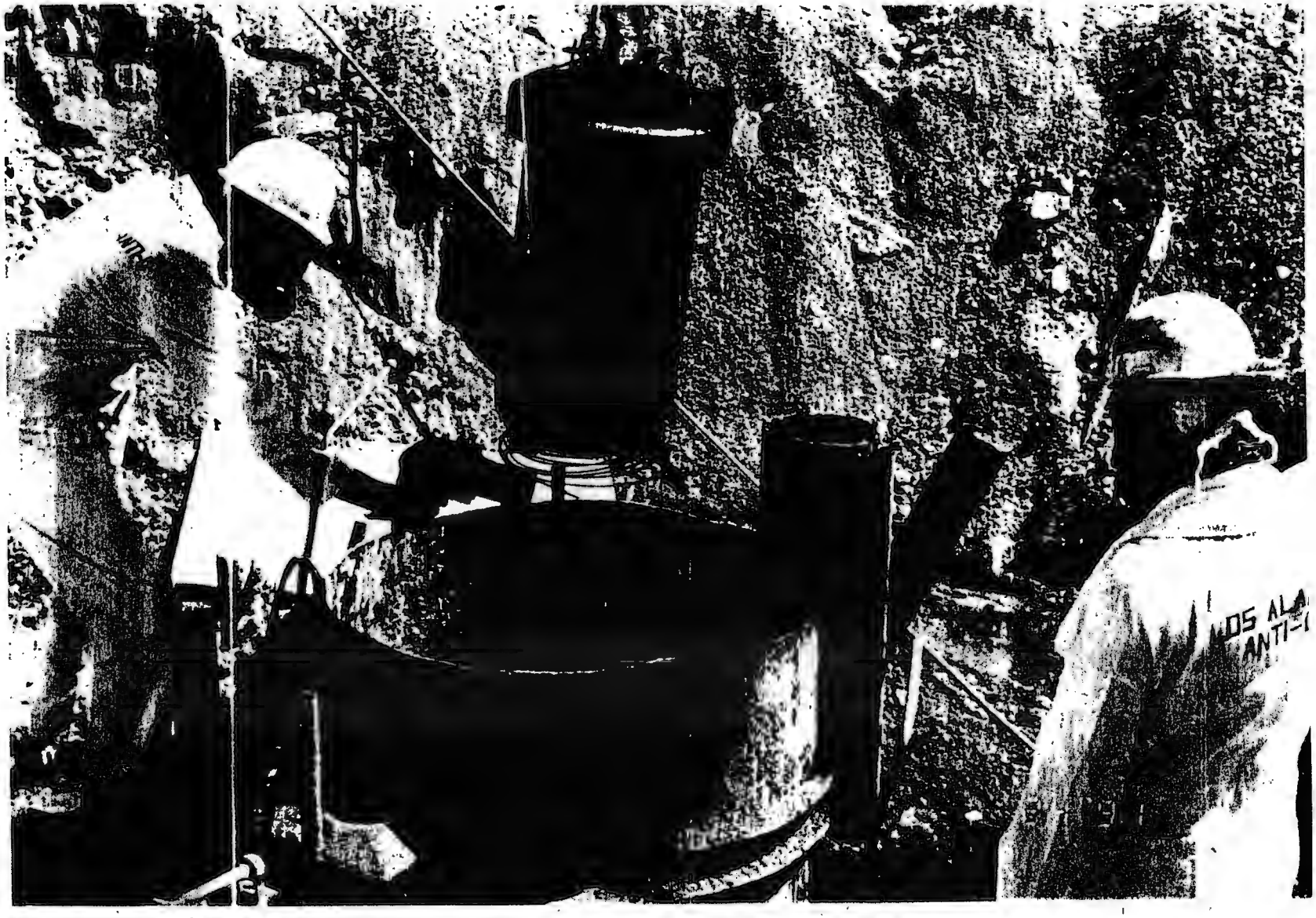

Fig. 10. Removing the heat exchanger.

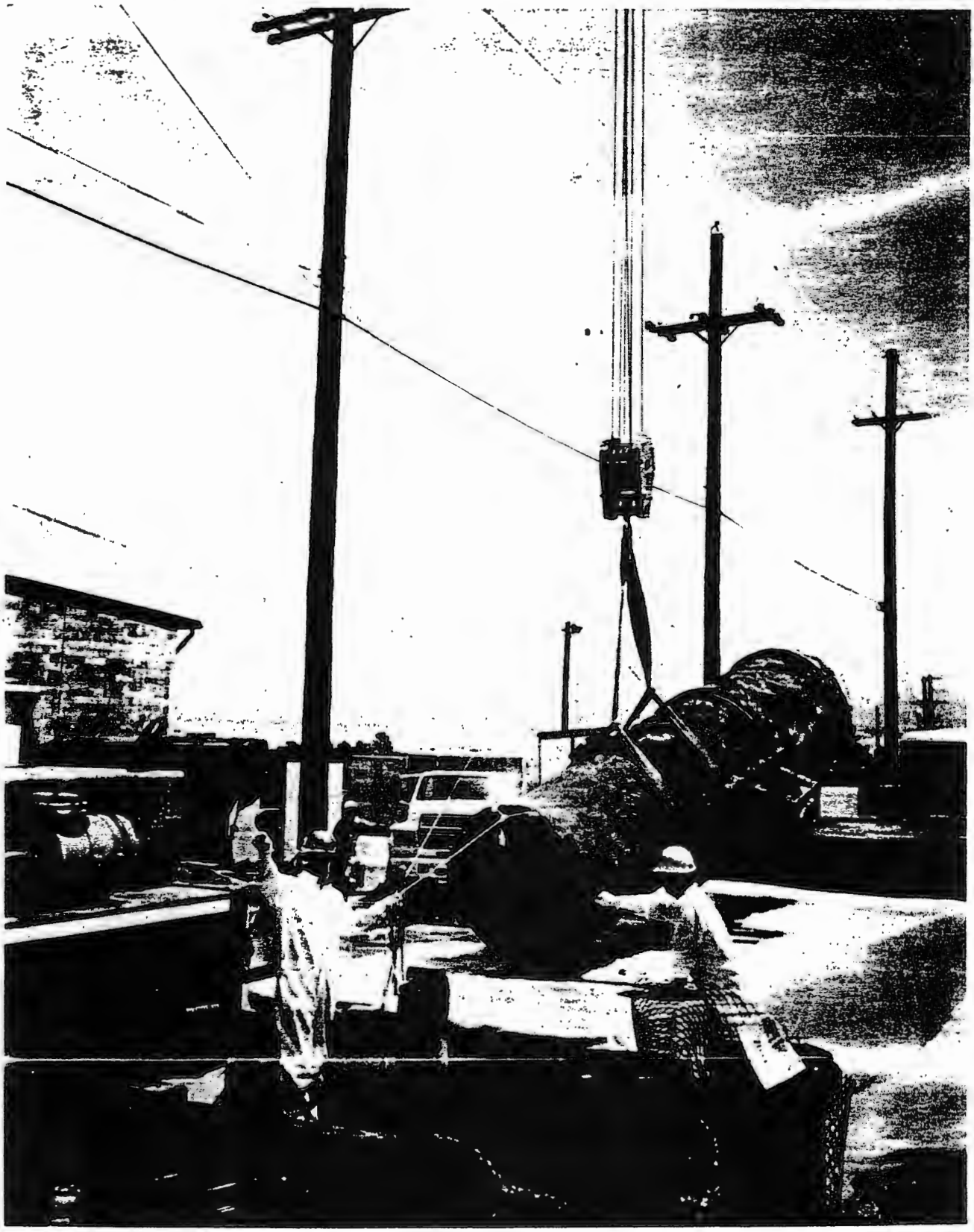

Fig. 11. Removing the reactor safety enclosure.

Fig. 12. Removing the fuel reservoir tank.

The liquid was removed, neutralized with lime, solidified, and disposed of as a low-level waste. Rigging straps were placed on the exterior of the reservoir, which was then lifted out, packaged in three layers of plastic, loaded onto a flatbed trailer, and transported to the radioactive solid waste disposal facility. The outside contact reading was 5 mR/h.

Removing the emergency fuel recovery system - The emergency fuel recovery system was located parallel to the fuel reservoir tank 2.5 ft below the corrugated metal enclosure. After the fuel reservoir tank was removed, the emergency fuel recovery system was located, rigged, and lifted out of the excavation for inspection to ensure that the tank was free of liquids. No liquids were present. The tank was transported to the radioactive solid waste disposal facility for burial.

Removing the primary pump pit - All primary system piping and equipment were located inside the subterranean pump pit. During the planning phase of the decommissioning effort, it was not known whether the pump pit existed or whether it was removed during postmortem of the reactor experiment in 1959. The south face of the pump pit was located during excavation of the fuel reservoir tank. Because the removal was a change of scope and because the pump pit existed in a SWMU, it was determined that removal would never be easier and that closure of a SWMU was a primary remediation factor; thus, funding was requested and approved from the ER group to remove the pump pit. A 5-ton steel headache ball was used to break up the concrete structure (Fig. 13). The highest contact reading on the interior portion of the concrete structure was 15 mR/h.

Removing the secondary loop - The secondary loop was used to extract the reactor-produced steam from the reactor. The supply and return stainless steel lines were encased in a 24-in. corrugated metal pipe (CMP). The exterior of the CMP was insulated with asbestos. The JCI asbestos abatement team removed asbestos before the secondary loop could be cut into manageable sections for disposal (Fig. 14). The subcontractor provided all site-specific training of personnel in asbestos removal. No radioactivity was detected in the piping of the secondary loop.

Site restoration - Site restoration included backfilling and contouring the site to its original condition. The Engineering Area Coordination assumed responsibility for applying asphalt at the site to modify the area to meet the needs for vehicular parking. Figure 15 shows the area after site restoration was completed.

4.4 Packaging, Transportation, and Disposal of Wastes

All radioactive solid wastes were packaged and labeled to comply with the requirements of EM-7, Waste Management, as described in the Laboratory's *Environment, Safety, and Health Manual* and in the *On-Site Transportation Manual*.[16]

Packaging - Contact-handled waste packages were limited to a maximum surface dose rate of 200 mR/h.

Transportation - All waste loads were secured and covered for shipment to the radioactive solid waste disposal site, TA-54, Area G. The HS-1 radiation protection technician (RPT) signed the Radioactive Waste Disposal Form only after approving the loading and securing of the waste load. Waste was sent to TA-54 only during hours when traffic was not expected to be heavy.

Disposal of wastes - Low-level radioactive solid waste generated by the LAPRE II decommissioning project was buried in pits at TA-54, Area G. Burial in pits consists of

Fig. 13. Removing the primary pump pit.

Fig. 14. Cutting the secondary cooling loop.

Fig. 15. Site restoration completed.

covering the waste in the pits with a meter of uncontaminated soil and revegetating the disposal area after pit closure.

All mixed waste was stored at TA-54, Area G, in accordance with applicable regulatory requirements. See also AR 10-3, "Chemical, Hazardous, and Mixed Waste," in the Laboratory's *Environment, Safety, and Health Manual.*[17]

5.0 SITE RELEASE PROGRAM

To release a successfully decommissioned facility or site from the Southwestern Area Programs Division of Decontamination and Decommissioning, it is necessary to verify and, in some cases, certify that the remediation has been completed according to the criteria for the project. For the LAPRE II decommissioning project, the derivation of cleanup guidance was provided in the "Plan for Environmental Sampling."[10]

For the site to be released without radiological restrictions, the release criteria are developed on the basis of the DOE "Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites."[18] An independent verification contractor, Oak Ridge Associated Universities (ORAU), will verify that all release criteria have been met.

5.1 Remedial Action Guidelines

Development of guidelines for residual radioactivity remaining in soils after remediation of the former LAPRE II site followed the principle of as low as reasonably achievable (ALARA). To expedite decisions on residual radioactivity at LAPRE II, two decision-making limits were used: *de minimus* limits and upper-limit concentrations guides.

De minimus limits are levels at which inconsequential health or environmental effects above background are expected. These limits were recommended by the Environmental Protection Group, EM-8, on the basis of background levels of the parameters in the area (Table III). The limits are derived from five background samples taken on Puye Mesa, southeast of the LAPRE II site in an area undisturbed by Laboratory activities. Visual inspection of the area revealed no evidence that Laboratory operations had been previously carried out in this area. The *de minimus* limits were taken as the mean plus two times the standard deviation of analysis of the background samples. This represents the 97.5 percentile of the normal distribution represented by the estimated mean and standard deviation of the samples; that is, 97.5% of background samples would be expected to fall below this limit.

The upper-limit concentration guides were derived to ensure conformance to the requirements that a member of the public receive no more than 100 mrem/y total effective dose commitment above background as a result of exposure to residual contamination (Table IV). The Environmental Protection Group, EM-8, recommended these limits. Concentration guides were derived using a methodology derived for remote SFMP sites.

The guides were derived assuming that the land was available for unrestricted use and that an inhabitant maintained a residence on the site, raised crops and livestock on site, received a proportion of food intake from foodstuffs grown on site, and used water from the main aquifer below the Pajarito Plateau. The guides were generated using the code RESRAD (residual radioactivity) developed at Argonne National Laboratory and implementing the methodology developed for remote SFMP sites (Gilbert, et al. 1989). Site-specific information included in the generation of guides included soil material bulk density, rainfall, evapotranspiration, run-off, and depth to the water table. Contamination

Table III. De Minimus Guidelines (pCi/g) for Cleanup of Residual Radioactivity.

Parameter	Mean	Standard Deviation	Guideline[a]
gross alpha	NDA[b]	NDA	Limits of detection
gross beta	NDA	NDA	Limits of detection
^{137}Cs gamma	0.85	0.22	1.3

[a]Derived as the mean of background samples plus two times the standard deviation.

[b]NDA = no detectable activity

Table IV. Soil Concentration Guidelines (pCi/g above background) Based Upon a Radiation Standard of 100 mrem/y Total Effective Dose Commitment.

Parameter	Surface	Subsurface[a]
^{60}Co	10	80
^{137}Cs	70	500
^{152}Eu	30	100
^{234}U	1000	1000
^{235}U	300	300
^{238}U	900	1000
^{90}Sr	800	900

[a]Subsurface soils are considered to be below the first 0.15 m (after DOE 1987).

was assumed to extend through 20 ft of the substrata, and subsurface contamination was assumed to extend from 6 in. to 20 ft below the surface.

Applying these guidelines involved several steps. Any above-background residual radioactivity detectable in the field after the structure was removed would be excavated. Excavation continued until these levels were reached, or until further excavation became impractical. Soil samples were obtained from soils adjacent to known contaminated areas and returned to the Laboratory for determination of gross alpha, gross beta, ^{137}Cs gamma, and other constituents as determined by reviewing known records or analyzing screening samples. The results of these analyses were then compared with *de minimus* guides calculated by RESRAD. If results were at or below *de minimus* guides, the area was considered free of residual contamination.

If the *de minimus* levels cannot be met practicably, the results are evaluated to ensure that the 100 mrem/y total effective dose limit is met. The concentration guides in Table IV are used as reference points for making this determination. These guides are based on conservative assumptions that may not be realistic. For example, residual radioactivity may occur in a location in which soil is too shallow to allow the growth of crops. Thus, the guides are applied flexibly on a case-by-case basis to account for site-specific conditions. The guides in Table IV are principally driven by the direct, external radiation and exposure pathways for dust inhalation. The surface guidelines are higher than others developed for other sites for these same radionuclides because of the small area (10 m^2) expected to contain above-background residual radioactivity. Cover attenuation of direct gamma photons and dusting explain the increase from surface to subsurface residual radioactivity.

5.2 Remedial Action

After the determination that the Los Alamos Power Reactor Experiment No. II (LAPRE II) should be decommissioned, the reactor was designated for remedial action. Because LAPRE II was known to be contaminated with radioactive materials because of program activities by the Office of Nuclear Energy (NE), the facility was accepted into the SAPD. A remediation strategy was developed and followed to manage potential radioactive and hazardous wastes generated by the project (Fig. 16).

5.3 Post-remedial Action Measurements

After decontamination and decommissioning were completed, the Environmental Protection Group, EM-8, did the final soil survey of the LAPRE II site. Table V shows the final Laboratory analysis. Appendix B is a list of EM-8 standard operating procedures (SOPs) used during soil sampling at the LAPRE II site.

Soil sample collection - After the reactor, associated structure and components, and contaminated soil were removed, a 20-ft-square grid was established on the bottom and sides of the pit, and samples were taken at each grid node. Sufficient soil for analysis (approximately 2 lb) was taken from each sampling location. The radiological samples were collected according to ER SOP 06.09, "Spade and Scoop Method for Collection of Soil Samples."[19] Samples were handled with disposable plastic sampling tools. The same procedures were followed in collecting soil for hazardous waste analysis. A record of the chain of custody for the waste site studies was used for all soil samples collected (Fig. 17).

Results of reconnaissance survey - On September 23, 1991, the Environmental Protection Group, EM-8, collected 15 composite soil samples from the site of the LAPRE II D&D project at TA-35. Eleven soil samples were collected from the sides and bottom of the pit; three samples were collected on the southeastern edge of the pit (backhoe staging area);

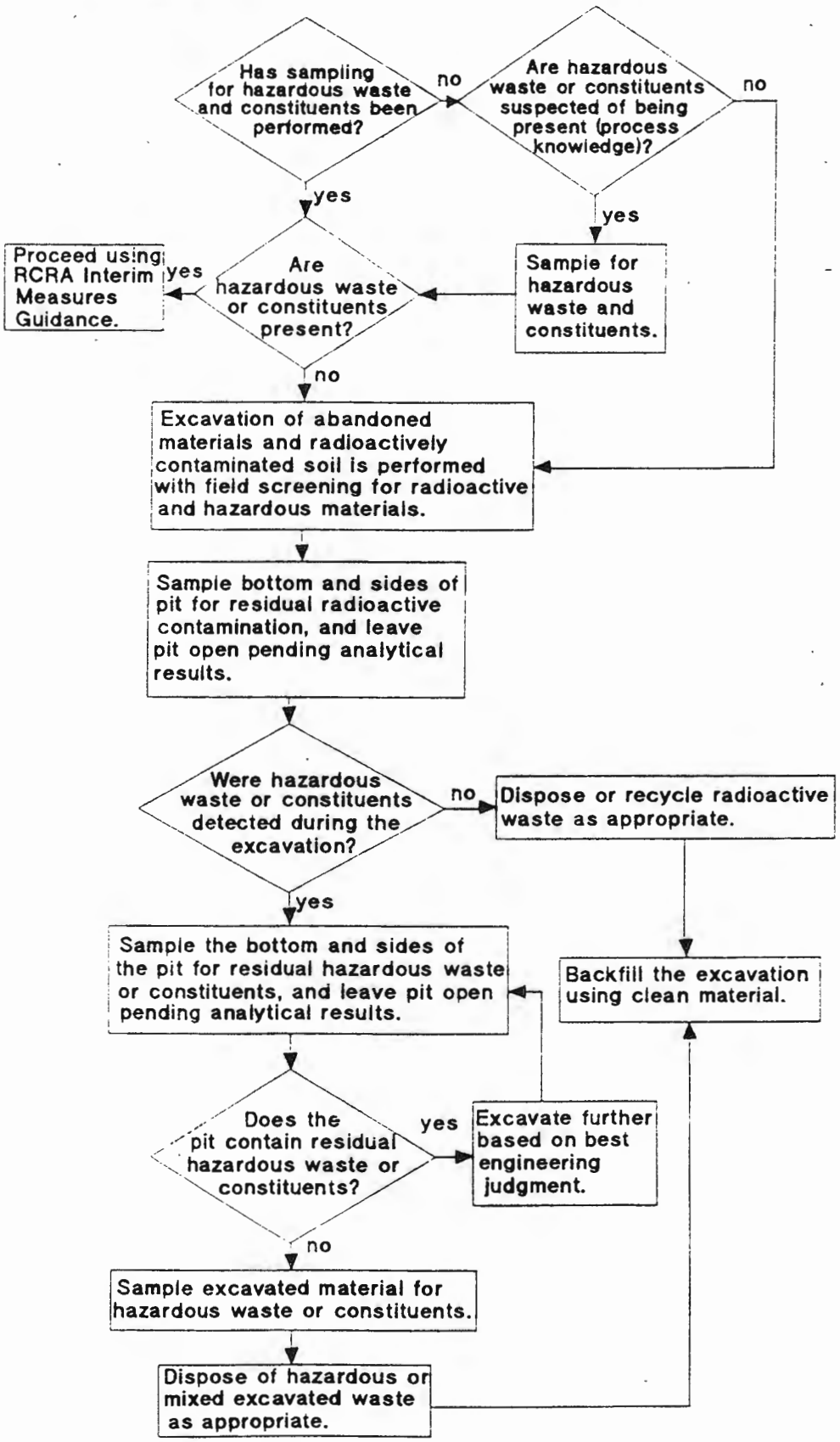

Fig. 16. LAPRE II remediation strategy.

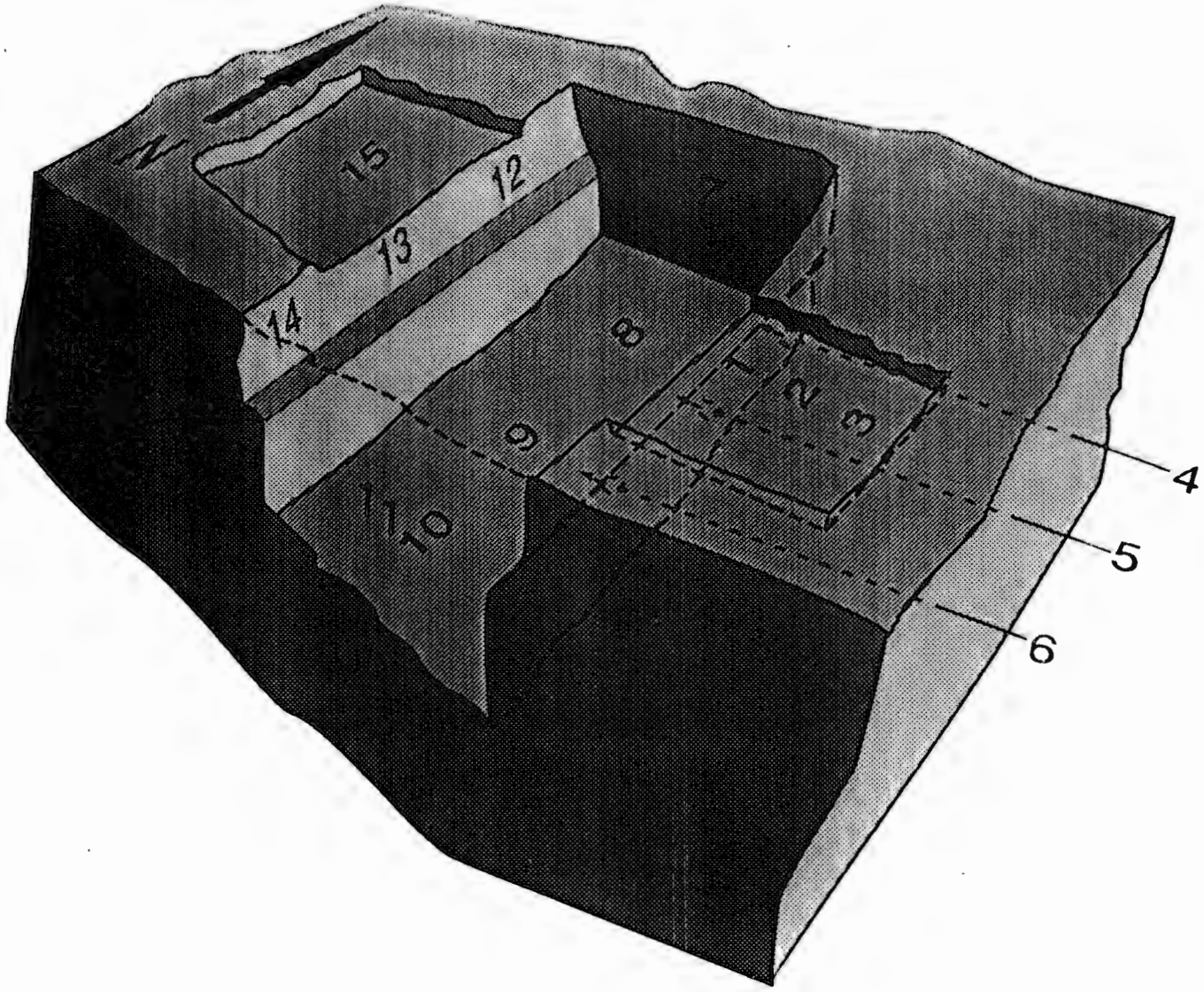

Fig. 17. LAPRE II soil sampling positions.

Table V. Analysis for Gross Alpha, Beta, and Gamma Radioactivity.

Sample Location	Total U (μg/g) (1/8/92)	^{152}Eu (pCi/g) (11/7/91)*	^{60}Co (pCi/g) (11/7/91)*	^{90}Sr (pCi/g) (10/25/91)*	^{137}Cs (pCi/g) (10/22/91)*	^{235}U, ^{238}U (ratio) (11/17/91)*
1.	2.35	0.0357	0.079	4.7	0.260	0.0084
2.	2.23	0.046	0.0899	5.2	10.1000	0.0097
3.	2.05	0.0784	0.0894	2.8	4.6800	0.0094
4.	2.43	0.0315	0.0139	0.7	2.8200	0.0079
5.	2.55	0.0056	0.0776	5.4	1.1900	0.0091
6.	1.89	0.724	0.458	6.1	6.4900	0.0117
7.	2.27	0.864	0.829	0.2	8.2500	0.0072
8.	2.25	0.712	0.529	3.6	0.0342	0.0091
9.	1.87	0.101	0.0287	1.5	0.0300	0.0077
10.	1.94	0.208	0.288	2.6	2.2500	0.0097
11.	1.8	1.09	1.929	0.4	7.7900	0.0074
12.	1.9	0.115	0.216	0.1	0.0647	0.0697
13.	1.92	0.014	0.0218	0.7	2.1500	0.0079
14.	1.88	0.138	0.142	0.3	0.2830	0.0072
15.	1.91	0.103	0.159	1.5	0.7010	0.0074
QA	1.69	0.635	0.842	4.9	5.5600	0.009

*Completion date

and another sample was collected on the northwestern edge of the pit (decontamination staging area). A composite soil sample consisted of five subsamples collected at the center and corners of a 20-ft square (Fig. 18 and Table V).

EM-8 screened soil samples for gross alpha, beta, and gamma radioactivity before they were submitted to the Health and Environmental Chemistry Group, EM-9, for analysis of ^{60}Co, ^{137}Cs, ^{152}Eu, total U (^{234}U, ^{235}U, and ^{238}U) and ^{90}Sr.

Both gross alpha and beta levels were at ≤ 25 pCi/g in all of the samples collected. Generally, gross gamma activity ranged in concentration from 0.72 to 9.51 pCi/g. Ranges were as follows.

Table VI. Ranges of Gross Gamma Activity in Soil.

Area	Range of gross gamma activity (pCi/g)
Backhoe staging area	3.12 to 6.31
Decontamination staging area	0.83
Eastern side of the pit	1.92 to 7.50
Soil activity located on the northeastern corner of the pit	1.92
Western side of the pit	0.73 to 9.51
Northern side of the pit	0.72
Southern side of the pit	5.13
Radionuclide	
^{60}Co	0 to 0.929
^{90}Sr	0.1 to 6.1
^{152}Eu	0 to 1.09
^{137}Cs	0 to 10.1

No detectable activity for alpha or beta is anything at or below 25 pCi/g.

The highest levels of ^{137}Cs were found in the backhoe staging area. Results of the total U analysis show levels at ≤ 3 μg/g.

Handling, packaging, and transport of samples were in accordance with ER SOPs 01.04 and 01.05. The samples were double-bagged in Ziploc plastic bags for transport to the Laboratory for alpha and beta counting. (Ziploc is a trademark of the Dow Chemical Company, Inc.) Samples for gamma analyses were transported in 500-ml nalgene bottles bagged in Ziploc plastic bags. All transportation of samples conformed to the requirements of the Laboratory's Safety and Risk Assessment Group, HS-3.

Sample analyses - Samples were analyzed in accordance with EM-8's SOP for its counting trailer, and the standard analytical procedures of the Health and Environmental Chemistry Group, EM-9 (see "Quality Assurance for Health and Environmental Chemistry: 1992," LA-10300-M.[20] Final verification samples were analyzed radioisotopically for ^{60}Co, ^{137}Cs, and ^{152}Eu using gamma spectroscopy, ^{234}U, ^{235}U, and ^{238}U using inductively coupled plasma mass spectrometry (ICP MS) and/or neutron activation, and ^{90}Sr by proportional counting.

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

WASTE SITE STUDIES CHAIN OF CUSTODY RECORD

Environmental Protection Group
Mail Stop K490 Los Alamos, NM

Project Name:

Sampling Team: (Print names and initial)

Date	Time	Comp.	Grab	Station Location / Sample ID	No. of Containers	α β γ / Gross Rad						Label No.	Remarks

Relinquished by:	Date / Time:	Received by:	Relinquished by:	Date / Time:	Received by:
Relinquished by:	Date / Time:	Received by:	Remarks		

Original Accompanies Shipment. Copy to Field Files.

Fig. 18. Chain of custody record.

Sampling for hazardous waste verification was done by analyzing one composite soil sample for the entire toxic compound list (TCL) in compliance with ER SOP 06.03. Results showed that no hazardous waste was present. Two methods of characterizing wastes were used: knowledge of process and chemical/physical analysis. Appendix C lists the metals, pesticides, herbicides, and organic chemicals sampled to determine whether the soil sample exceeded the stated concentrations (mg/l) as determined by the toxicity characteristic leaching procedure (TCLP). Results verified that no hazardous waste was present.

Post-remedial action status - Soil sample measurements taken after removing radioactive materials indicated that no areas of concern exist. Under the Radiological Site Assessment Program, ORAU independently assessed the remedial action done at the LAPRE II site. The assessment verifies the data supporting the adequacy of remedial action and confirming that radiological conditions at the LAPRE II site comply with the guidelines established for this project.

All remedial action was completed by January 23, 1992. The delay in completion was due to a one-month waiting period for results on soil samples. The action produced 4 55-gal. drums and 7 30-gal. drums of mixed waste, all of it contaminated lead (1.7 m^3). The action generated 533 m^3 of low-level solid waste, which was treated as outlined in ARs 10-1 and 10-3 in the Laboratory's *Environment, Safety, and Health Manual.*[21]

Quality assurance - Appropriate sample control and documentation procedures were done in the field and laboratory in accordance with ER SOP 01.05.

6.0 LESSONS LEARNED

The TA-35 LAPRE II project management team learned valuable lessons in decommissioning a subterranean contaminated and activated nuclear-fueled reactor.

Overall, the decommissioning efforts at Los Alamos have demonstrated that nuclear cleanup and waste management can be accomplished efficiently, safely, and cost effectively. The TA-35 LAPRE II reactor was decommissioned with maximum attention to the safety of workers and the public and to protection of the environment. The skills employed, technology used, and lessons learned will assist others in planning and performing similar projects.

A brief summary of lessons learned during the LAPRE II decommissioning project is as follows.

Implementation of radiological controls - The decommissioning work was planned and executed with safety, waste minimization, and productivity priorities. To perform this work safely, each task required the following:

- characterizing the site for radiological and chemical hazards;
- detailed planning, including radiological controls, to preclude spreading contamination and to minimize radiation exposure;
- preparation of contingency and emergency responses;
- thorough training, supervision, and radiological monitoring; and
- proper selection and use of protective clothing.

Radiological exposure - An aggressive ALARA campaign is employed at Los Alamos National Laboratory. Personnel exposures are routinely kept at less than 1 R/y. Detailed procedures, through training and extensive use of mock-ups, were aspects of the success of this program and the ultimate contributors to the success of the LAPRE II decommissioning project.

ACKNOWLEDGMENTS

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16. *On-site Transportation Manual.* Los Alamos National Laboratory (October 1988).

17. "Chemical, Hazardous, and Mixed Waste," Administrative Requirement 10-3 in the *Environment, Safety, and Health Manual* (June 1, 1990).

18. Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites" (Revision 2, March 1987).

19. Environmental Restoration Program, Standard Operating Procedures for Spades and Scoops, Los Alamos National Laboratory unpublished procedures (1991).

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21. "Radioactive Liquid Waste," Administrative Requirement 10-1 in the *Environment, Safety, and Health Manual*, Chapter 1 (August 1984).

Appendix A. Abbreviations and Units of Measure.

ACWP	actual cost of work performed
ALARA	as low as reasonably achievable
AR	Administrative Requirement in the *Environment, Health, and Safety Manual*
Ci	curie
cm	centimeter
CMP	corrugated metal pipe
D&D	decontamination and decommissioning
DOE	Department of Energy
DOE-HQ	Department of Energy - Headquarters
DOS	decommissioning operations subcontractor
EM	Environmental Management Division
EMI	electromagnetic induction
EPA	Environmental Protection Agency
ER	Environmental Restoration
ES&H	environment, safety, and health
FY	fiscal year
g	gram
GOCO	government-owned, contractor-operated
h	hour
HPAL	Health Physics Analysis Laboratory
HPS	health physics surveyor
HS	Health and Safety Division
JCI	Johnson Controls, Inc.
LANL	Los Alamos National Laboratory
LAPRE II	Los Alamos Power Reactor Experiment No. II
LAPREDP	Los Alamos Power Reactor Decommissioning Project
m	meter
mR	milliroentgen
mrem	millirem
NE	Office of Nuclear Energy
ORAU	Oak Ridge Associated Universities
OSHA	Occupational Safety and Health Administration
pCi	picocurie
PMP	project management plan
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
rem	radiation equivalent man
RESRAD	residual radioactive materials guidelines
RPT	radiation protection technician
RWP	Radiation Work Permit
SAPD	Southwestern Area Programs Division
SFMP	Surplus Facilities Management Program of the US Department of Energy
SOP	standard operating procedure
SWMU	solid waste management unit
SWP	Special Work Permit
TCL	Toxic Compound List
WBS	work breakdown structure
y	year

Appendix B. EM-8 Standard Operating Procedures (SOPs) used During LAPRE II Soil Sampling

SOP #	SOP Title	SOP Cross Reference
01.01.01	Records	Records
01.01.02	Training	Training and Medical Surveillance
01.02	Contain: Samp and Pres	Containers and Sampling
01.04	Samp Control and Doc	Sample Control and Documentation
01.05	QA/QC	Field Quality Assurance/Quality Control Blank Samples; Guide to Handling, Packaging, and Shipping of Samples
02.01	Protective Equip	Personal Protective Equipment
02.02	Respirators	Respirators
02.03	Pre-Brief	Pre-entry Briefings for Site Personnel
02.07	Equip. Decon.	General Equipment Decontamination
02.12	Mon. w/Photoion Detect.	Monitoring of Organic Vapors with a Photoionization Detector
02.13	Mon. w/Flame Ion Detect.	Monitoring of Organic Vapors with a Flame Ionization Detector
02.15	Alpha Surf. Contam.	Total Alpha Surface Contamination Measurements
02.16	Soil Screen for Alpha	Screening Soil Samples for Alpha Emitters
06.03	Samp. Volatile Org.	Sampling for Volatile Organics
06.08	Gas Chrom. - Orgs.	Portable Gas Chromatography Field Screening of Volatile Organic Compounds
06.09	Spade and Scoop	Spade and Scoop Method for Collection of Soil Samples
06.10	Hand Auger Samp.	Hand Auger and Thin-Wall Sampler
06.11	Steel Surf. Soil	Stainless Steel Surface Soil Sampler
06.18	Hand Auger-Sand	Hand Auger for Sand or Packed Powders and Granules
W2-01 (draft)	Berthold Low Activity Counter	Calibration, Quality Control, Detection Limit, and Use

Appendix C. Toxicity Characteristic Pesticides, Herbicides, Toxic Metals, and Organic Compounds Sampled for in Soil.

Compound	Concentration (mg/l)
Arsenic	5.0
Barium	100.0
Benzene	0.5
Cadmium	1.0
Carbon tetrachloride	0.5
Chlordane	0.03
Chlorobenzene	100.01
Chloroform	6.0
Chromium	5.0
o-Cresol	200.0
m-Cresol	200.0
p-Cresol	200.0
Cresol	200.0
2,4-D	10.0
Hexachlorobenzene	0.13
Hexachlorobutadiene	0.5
Hexacloroethane	3.0
Lead	5.0
Lindane	0.4
Mercury	0.2
Methoxychlor	10.0
Methyl ethyl ketone	200.0
Nitrobenzene	2.0
Pentachlorophenol	100.0
Pyridine	5.0
Selenium	1.0
Silver	5.0
Tetrachloroethylene	0.7
1,4-Dichlorobenzene	7.5
1,2-Dichloroethane	0.5
1,1-Dichloroethylene	0.7
2,4-Dinitrotoluene	0.13
Endrin	0.02
Heptachlor (and its hydroxide)	0.008
Toxaphene	0.5
Trichloroethylene	0.5
2,4,5-Trichlorophenol	400.0
2,4,6-Trichlorophenol	2.0
2,4,5-TP (Silvex)	1.0
Vinyl chloride	0.2

*U.S. GOVERNMENT PRINTING OFFICE: 1993-774-036/67078

Attachment C

Los Alamos
NATIONAL LABORATORY
memorandum

Earth & Environmental Sciences Division
EES-13 • Nuclear Waste Management R&D

To/MS: Marge Boettner, EM-13, M992
From/MS: Allyn Pratt, EES-13, J521 Allyn Pratt for AP
Phone/FAX: 7-4308/FAX 7-1934
Symbol: EES-13-ER-05-93-055
Date: May 10, 1993

Corrected Tables for Quarterly Report for January through March 1993

Enclosed are the two corrected tables from the above referenced report with your questions addressed. If you have further questions, please contact Felicia Aguilar at 662-1815.

Enclosures:a/s

Cy:
Jim Aldrich, EES-1, D462
Felicia Aguilar, LATA, M321
Records Processing Facility, EM-13, M707
Allyn Pratt file, J521
OU 1129 file, M321

TABLE 2 (concluded)

INC-12 ANALYTICAL DATA, TA-42

ER Bar Code	Pu238 (pCi/g)	Pu239 (pCi/g)	Pb (ppm)
AAA0990			
AAA0991	<0.03+/- 9%	<0.17+/- 13%	
AAA0992	<0.01+/- 2%	<0/002+/- 23%	
AAA0993			
AAA1691			
AAA1692			
AAA1693			
AAA1694			
AAA1695			
AAA1696			
OO26067			

TABLE 2

INC-12 ANALYTICAL DATA, TA-42

ER Bar Code	Pu238 (pCi/g)	Pu239 (pCi/g)	Pb (ppm)
AAA0951	0.036+/- 8%	1.28+/- 6.5%	17
AAA0952			
AAA0953			
AAA0954	<0.02+/- 12%	0.094+/- 15%	<5
AAA0955	<0.004+/- 1%	0.044+/- 11%	<5
AAA0956			
AAA0957	0.016+/- 25%	1.05+/- 4.8%	<5
AAA0958			
AAA0959			
AAA0960	0.0067+/-24%	0.110+/- 20%	
AAA0961	<0.002+/- 2%	0.144+/- 0.9%	
AAA0962			
AAA0963	<0.004+/- 9%	0.165/- 13%	
AAA0964	0.022+/- 19%	0.639+/- 14%	
AAA0964			
AAA0965			
AAA0966	0.009+/- 44%	<0.006+/-24%	
AAA0967	0.012+/- 30%	0.149+/- 2.9%	
AAA0968			
AAA0969	<0.003+/- 5%	0.043+/- 11%	
AAA0970	0.029+/- 18%	0.877+/- 3.0%	
AAA0971			
AAA0972			
AAA0973			
AAA0974			
AAA0975	<0.06+/- 17%	<0.406+/- 18%	
AAA0976			
AAA0977			
AAA0978	<0.01+/- 6%	<0.006+/- 45%	
AAA0979			
AAA0980			
AAA0981			
AAA0982	0.067+/- 7%	<0.002+/- 28%	
AAA0983			
AAA0984	0.010+/- 20%	0.176+/- 12%	
AAA0984			
AAA0985	<0.01+/- 3%	<0.003+/- 28%	
AAA0986			
AAA0987			
AAA0988			
AAA0989			

TABLE 1 (concluded)

EM-9 ANALYTICAL RESULTS FOR TA-42

units – pCi/g pCi/g pCi/g pCi/g ppm ppm pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g pCi/g

ER BARCODE	^{238}Pu	^{238}Pu unc	^{239}Pu	^{239}Pu unc	Pb	Pb unc	^{228}Th	^{228}Th unc	^{230}Th	^{230}Th unc	^{232}Th	^{232}Th unc	^{234}U	^{234}U unc	^{235}U	^{235}U unc	^{238}U	^{238}U unc	^{241}Am	^{241u}Am unc
AAA0984	0.132	0.07	0.29	0.111															0.749	0.171
AAA0985	0.0238	0.0424	0.0189	0.0378															0.529	0.127
AAA0986	0.332	0.144	0.0553	0.0559															0.342	0.102
AAA0987	0.465	0.471	0	0.0181															0.199	0.298
AAA0988	0.852	0.815	0.142	0.492															0.135	0.27
AAA0989	0.156	0.102	0.296	0.144															0.105	0.052
AAA0990	0.138	0.09	0.0964	0.0743															0.135	0.057
AAA0991	0.147	0.09	0.0793	0.061															0.332	0.097
AAA0992	0.0827	0.0719	0.0591	0.0535			2.59	0.81	1.52	0.55	0.91	0.395							0.933	0.194
AAA0993	0.0771	0.07	0.0	0.0024			1.83	0.69	1.1	0.44	1.46	0.53							0.309	0.09
AAA1691					10.4	NR														
AAA1692					12.5	NR														
AAA1693					15.3	NR														
AAA1694					17.1	NR														
AAA1695					12.4	NR														
AAA1696					5.3	NR														
*OO26067					<1															

unc = Uncertainty NR = Not Reported * = Quality Control Sample

TABLE 1

EM-9 ANALYTICAL RESULTS FOR TA-42

ER BARCODE	^{238}Pu	^{238}Pu unc	^{239}Pu	^{239}Pu unc	Pb	Pb unc	^{228}Th	^{228}Th unc	^{230}Th	^{230}Th unc	^{232}Th	^{232}Th unc	^{234}U	^{234}U unc	^{235}U	^{235}U unc	^{238}U	^{238}U unc	^{241}Am	^{241u}Am unc
units-	pCi/g	pCi/g	pCi/g	pCi/g	ppm	ppm	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
AAA0951	0.0739	0.0244	0.0523	0.0208	14.4	2.88													0.4910	0.0352
AAA0952					14.5	2.9														
AAA0953	0.2	0.062	0.0839	0.0395	4.3	0.86													0.0657	0.0568
AAA0954					12	2.4														
AAA0955					6.6	1.32														
AAA0956					11.7	2.34														
AAA0957	1.75	0.24	2.24	0.31	28.1	5.62													0.3320	0.1070
AAA0958					4.2	0.42														
AAA0959					3.7	0.37														
AAA0960	0.438	0.149	0.125	0.08															0.121	0.055
AAA0961	0.289	0.107	0.231	0.096															0.082	0.0477
AAA0962	0.36	0.146	0.216	0.112															0.096	0.0558
AAA0963	0.139	0.075	0.511	0.155			1.9	0.49	1.55	0.41	1.53	0.41	0.819	0.28	0.0999	0.0901	0.779	0.226	0.138	0.061
AAA0964	0.377	0.171	0.298	0.151															0.103	0.046
AAA0964	0.0973	0.0783	0.401	0.152															0.209	0.069
AAA0965																			0.157	0.075
AAA0966																			0.057	0.114
AAA0967	0.389	0.165	0.135	0.102			1.27	0.29	1.1	0.26	1.39	0.3	1	0.43	0	0.105	0.815	0.365	0.107	0.055
AAA0968	0.214	0.108	0.485	0.167															0.227	0.071
AAA0969	0.154	0.091	0.0441	0.0543															0.08	0.0455
AAA0970																			0.38	0.12
AAA0971	1.8	1.18	0.969	0.846															0.264	0.325
AAA0972	5.63	1.66	2.68	1.1															1.09	0.56
AAA0973																			0.061	0.211
AAA0974																			0.025	0.0499
AAA0975																			0.086	0.0529
AAA0976																			0.138	0.062
AAA0977																			0.071	0.0584
AAA0978																			0.039	0.0778
AAA0979																			0.041	0.034
AAA0980																			0.152	0.074
AAA0981																			0.292	0.107
AAA0982	0.0836	0.0727	0.0119	0.024															0.327	0.098
AAA0983	0.269	0.105	0.0179	0.0254															0.358	0.112
AAA0984	0.0492	0.0738	0.312	0.0159															0.463	0.116

unc = Uncertainty NR = Not Reported * = Quality Control Sample