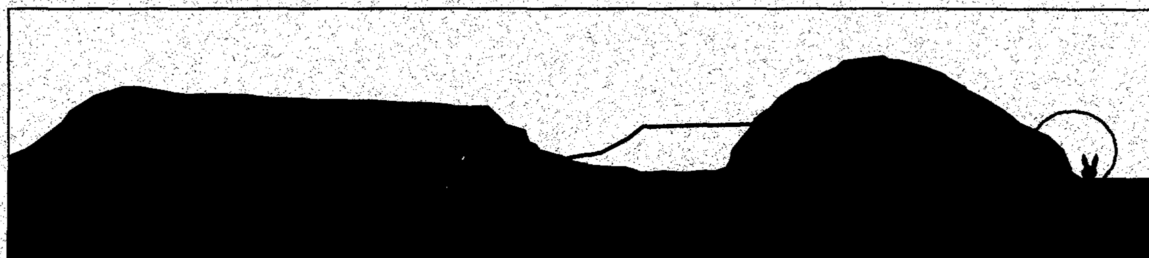
DOE/ID/12584–195
GJPO–GP–13

Technical Task Plan No. AL93–20–03



Rabbit Valley Geophysics Performance Evaluation Range

Geophysical Background and As-Built Target Characteristics

J. W. Allen

September 1994

U.S. Department of Energy
Grand Junction Projects Office

Approved for public release; distribution is unlimited.

MASTER

Work Performed Under DOE Contract No. DE–AC04–86ID12584 for the U.S. Department of Energy

RB

RUST Geotech Inc.

DOE/ID/12584-195
GJPO-GP-13

Technical Task Plan No. AL932003

Static Cell As-Builts and Background Characteristics for Rabbit Valley Geophysics Performance Evaluation Range

J. W. Allen

September 1994

U.S. Department of Energy
Grand Junction Projects Office
RUST Geotech Inc.
Grand Junction, Colorado

Contents

Figures

Figures (continued)

Tables

Executive Summary

The U.S. Department of Energy (DOE) Grand Junction Projects Office (GJPO) has provided a facility for DOE, other Government agencies, and the private sector to evaluate and document the utility of specific geophysical measurement techniques for detecting and defining cultural and environmental targets. This facility is the Rabbit Valley Geophysics Performance Evaluation Range (GPER), which includes test cells in the high-desert terrain of Rabbit Valley, 30 miles west of Grand Junction, Colorado, and test cells and calibration models at the DOE–GJPO facility in Grand Junction. The GPER provides facilities to evaluate the performance of instrumentation systems used in a variety of geophysical measurement methods. It permits objective and comprehensive quantification of the relationships among measured geophysical data, computer-modeled responses, and well-defined target and environmental parameters for individual test cells.

Geophysical surveys prior to the fiscal year (FY) 1994 construction of new test cells showed the primary test area to be relatively homogeneous and free from natural or man-made artifacts, which would generate spurious responses in performance evaluation data. Construction of nine new cell areas in Rabbit Valley was completed in June 1994 and resulted in the emplacement of approximately 150 discrete targets selected for their physical and electrical properties. These targets and their geophysical environment provide a broad range of performance evaluation parameters from "very easy to detect" to "challenging to the most advanced systems."

The Rabbit Valley GPER is user friendly; access requires no security clearance or special permission, and user support is available when requested. Data from previous surveys have been archived and are available for review and use by all users who agree to share their data. During FY 1994, users from Government agencies, private industry, and academia conducted various surveys at the Rabbit Valley site and expressed enthusiasm in their praise of the project.

I. Introduction

The U.S. Department of Energy (DOE) Office of Technology Development tasked the Grand Junction Projects Office (GJPO) to provide a facility suitable for evaluation and documentation of specific geophysical measurement techniques for detecting and defining cultural and environmental targets. Intended users of the facility are DOE Office of Waste Management and Office of Environmental Restoration programs, DOE Operations Offices, other Government agencies (U.S. Department of Defense, U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Bureau of Mines, etc.), and the private sector. This facility—the Rabbit Valley Geophysics Performance Evaluation Range (GPER)—includes test cells in the high-desert terrain of Rabbit Valley, 30 miles west of Grand Junction, Colorado, and test cells and calibration models at the DOE–GJPO facility in Grand Junction. The GPER provides facilities to evaluate the performance of instrumentation systems used in a variety of geophysical measurement methods and permits objective and comprehensive quantification of the relationships among measured geophysical data, computer modeled responses, and well-defined target and environmental parameters for individual test cells.

Use of nonintrusive investigative techniques represents a significant improvement over intrusive characterization methods, such as drilling or excavation, because there is no danger of exposing personnel to possible hazardous materials and no risk of releasing or spreading contamination through the characterization activity. Nonintrusive geophysical techniques provide the ability to infer near-surface structure and waste characteristics from measurements of physical properties associated with those targets.

The Rabbit Valley GPER provides known parameters against which the performance of nonintrusive geophysical instruments or methods can be assessed. Comparison of the responses obtained over undisturbed earth (background characteristics) with the responses observed after construction of the test cells determines the response contribution of the materials placed in the GPER cells. Quantification of this response contribution allows a direct assessment of precision and accuracy of geophysical instrumentation and furnishes performance criteria for development or adaptation of emerging geophysical methods and technologies.

II. Rabbit Valley Site Description

The Rabbit Valley site is an 80-acre tract of public land administered by the Bureau of Land Management (BLM). It is authorized for use as a geophysical test site under an Interagency Agreement between BLM and DOE–GJPO and has been approved for a Categorical Exclusion under the National Environmental Policy Act (NEPA). No aboveground structures are employed in the Rabbit Valley GPER, and all geophysical targets have been placed underground. All construction activities at the site were conducted in accordance with approved Health and Safety Plans and were conducted to minimize damage or permanent changes to the natural terrain. Interim remediation includes recontouring and scarifying the surface over test cells, with revegetation to be conducted at the most effective time of year.

The Rabbit Valley area is a multiple land-use area and is a favorite area for recreational bikers, campers, and four-wheel-drive vehicles. It is also used for grazing of cattle and sheep in the winter and spring. Signs posted at the road access points to the site request that vehicles remain on roads designated by the BLM for vehicle use, unless otherwise authorized. This restriction minimizes the possibility of damage to the terrain, to the survey grids, and to the target burial areas.

Figure 1 shows the location of the Rabbit Valley GPER in relation to Colorado and surrounding States. Figure 2 shows the route from Grand Junction to the Rabbit Valley Site via U.S. Interstate 70 to the Rabbit Valley exit, thence south and east via BLM gravel roads to the GPER. Figure 3 is a view looking across the site to the southwest from the northeast quarter-section corner, which is the reference for the site survey grids. The majority of the recently constructed static test cells are located in the flat area near the center of the photo, while several previously implanted cells are located in the right foreground of the photo.

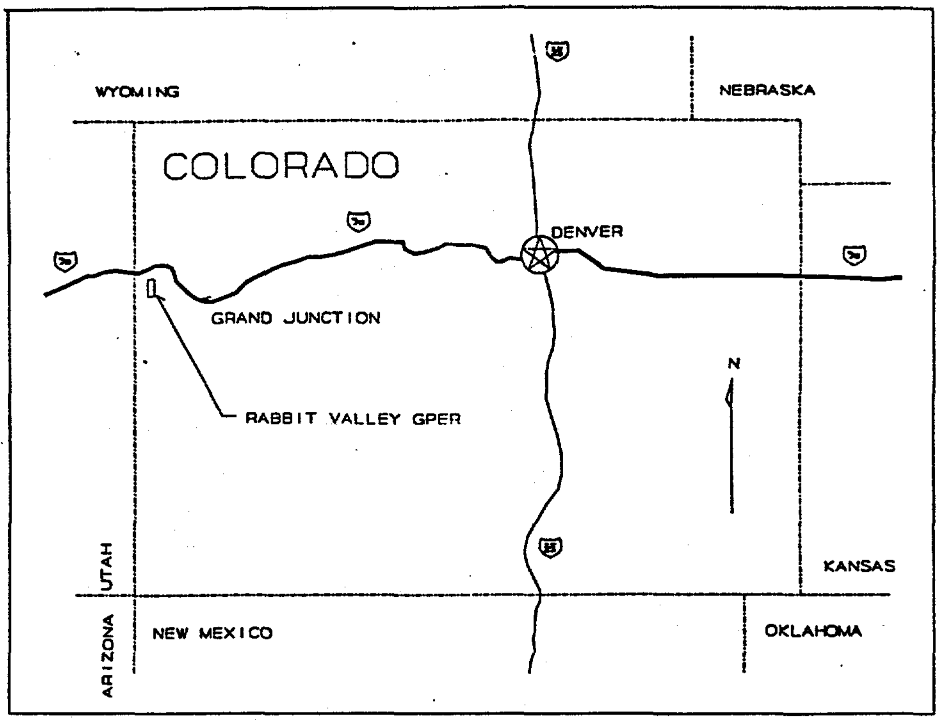


Figure 1. Location of Rabbit Valley GPER in Western Colorado

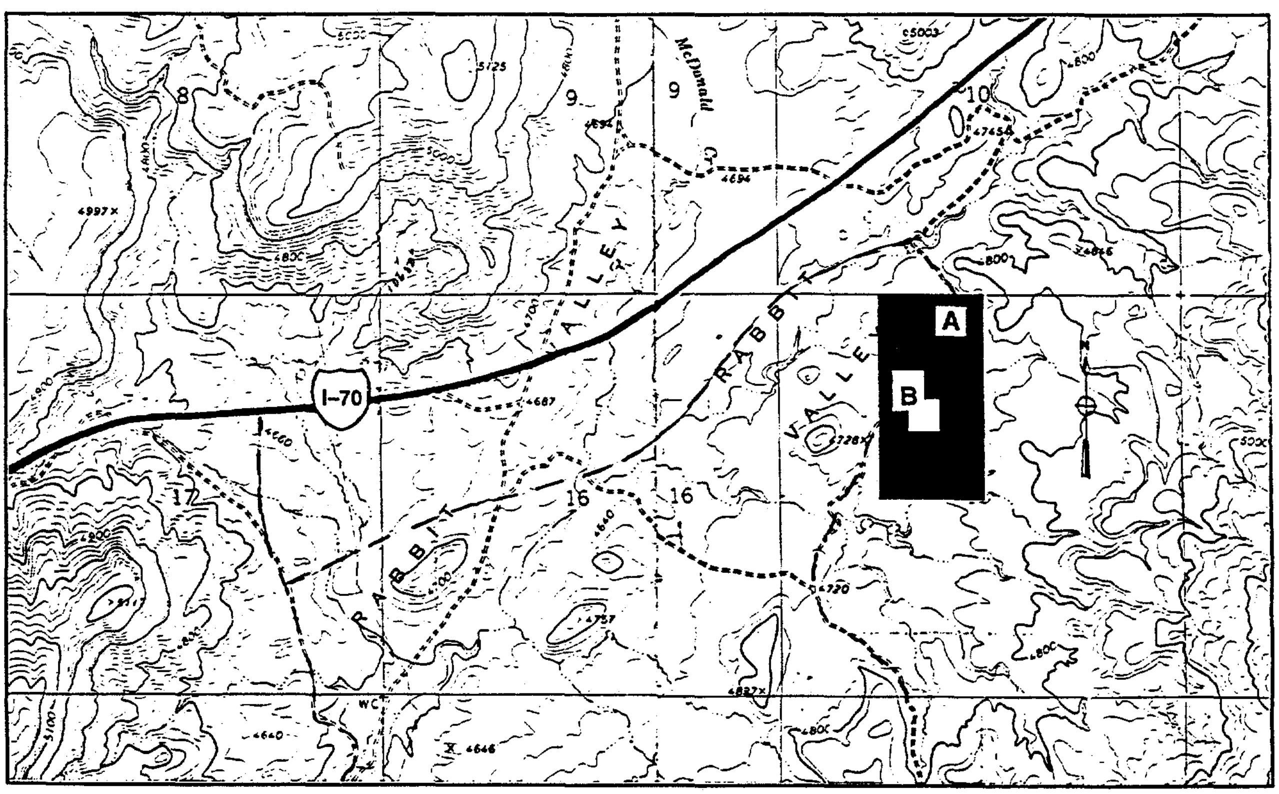


Figure 2. Area Map Showing Route to Rabbit Valley GPER

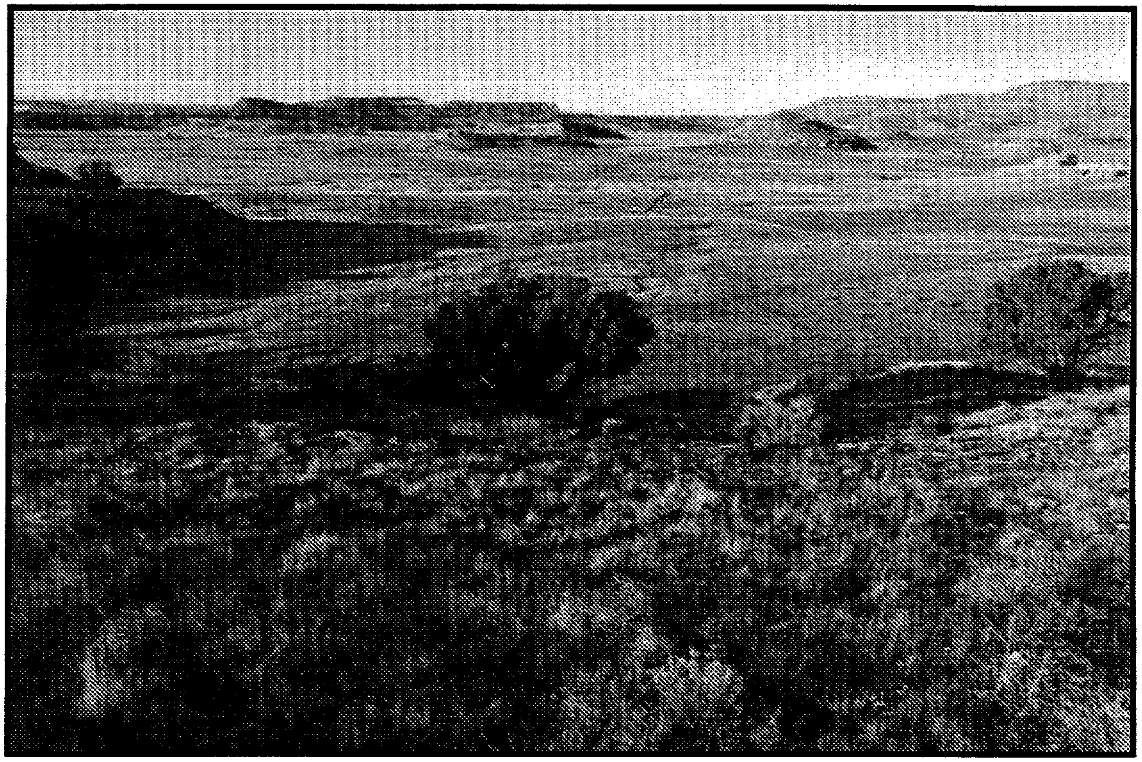


Figure 3. Rabbit Valley GPER Site

Figure 4 shows the relative layout of the static cells with grid coordinates relative to the northeast quarter-section corner. The recently constructed test cells extend over an area of approximately 20 acres to provide isolation between cells and adequate area around each cell for characterization of the background environment. Appendix A includes detailed maps showing target locations within the cells; Section V, "As-Built Specifications," presents target and cell descriptions.

III. Background Characterization

Geophysical surveys were conducted during the first quarter of fiscal year 1994 to characterize the natural background environment before construction of the test cells. Survey results showed the primary test area to be relatively homogeneous and free from natural or man-made artifacts that would generate spurious responses in performance evaluation data. Target responses over the previously implanted targets were characterized during the background surveys and during surveys conducted by several other users. Background surveys were performed with surface geophysical methods, including inductive electromagnetic (IEM) with a Geonics EM–31, magnetic/very low frequency electromagnetic (MAG/VLF–EM) with an EDA OMNI–PLUS, resistivity/induced polarization (R/IP) with an Androtex TDR–6 receiver and a Phoenix IPT–1 transmitter, time-domain electromagnetic (TDEM) with a Geonics TEM–47 system, and ground-penetrating radar (GPR) with a GSSI/SIR–8 system. An airborne magnetic/electromagnetic survey was also conducted by a subcontractor, High Sense Geophysics Ltd. The airborne equipment included a Ranger 4 EM system, a Picodas PDAS–1000 magnetometer with a Scintrex H8 cesium-vapor sensor, a global positioning system, a radar altimeter, and a video flight-path camera and recorder.

Surface surveys were conducted in two areas of the Rabbit Valley 80-acre site. The two areas were previously surveyed and gridded on 10-meter (m) station centers by RUST Geotech Inc.* land surveyors. Oak hubs were emplaced at the 10-m grid nodes. Measurement stations spaced 4 m apart

*Rust Geotech Inc. (Geotech) is the operating contractor for the GJPO

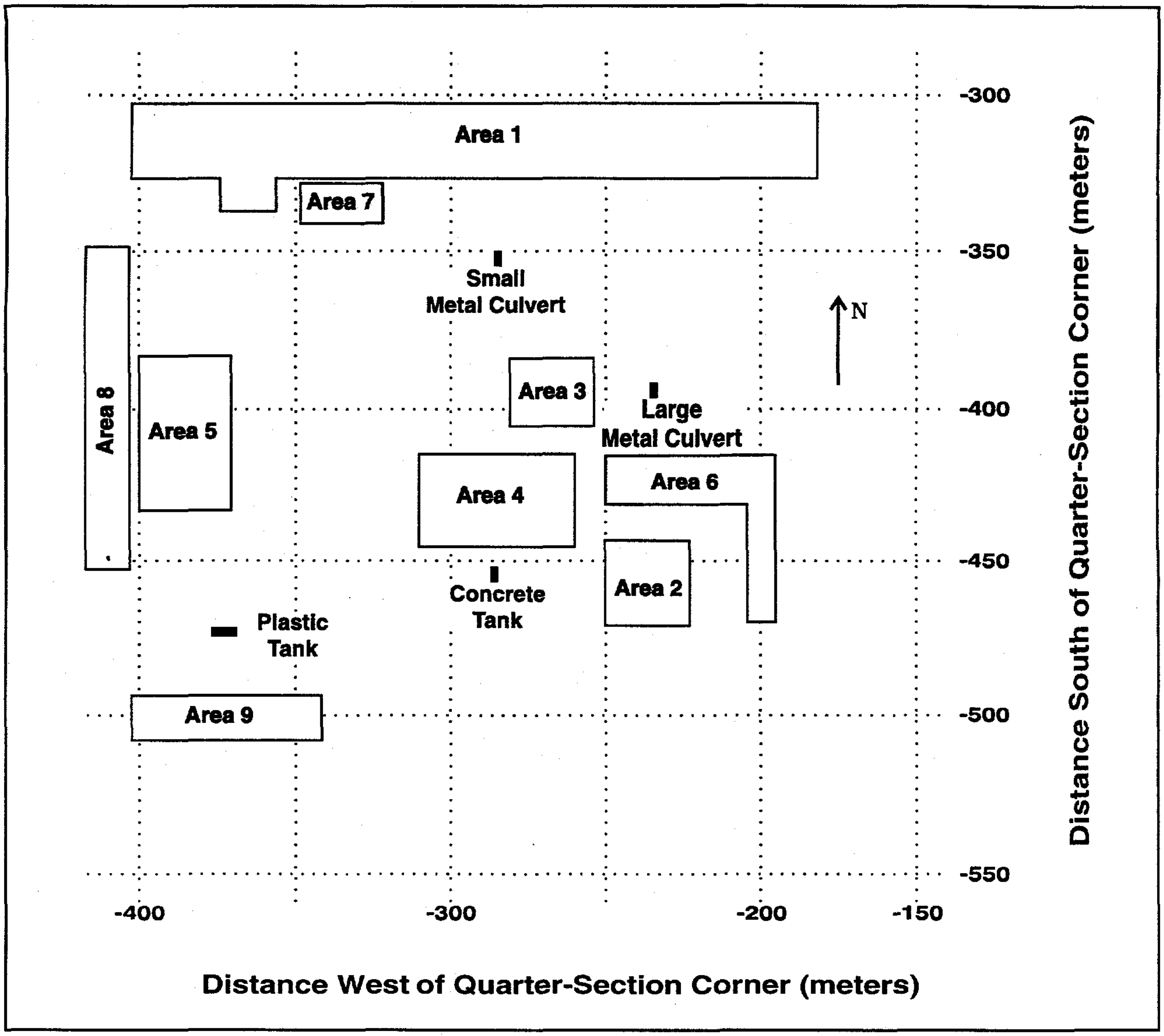


Figure 4. Rabbit Valley GPER Test Area and Target Layout

were superimposed over the surveyed grid by geophysical survey personnel, and data were collected at more than 4,800 stations for each method used.

Area A is near the northeast corner of the site and includes previously buried nonmagnetic targets (see Table 1). The portion of Area A that was surveyed extends from station 50 West, 0 North (–50, 0) to 150 West, 100 South (–150, –100). Area B is near the center of the 80-acre tract and extends from 100 West to 400 West and from 300 South to 550 South.

Area B contains both magnetic and nonmagnetic targets that were buried previously (see Table 1). The exact boundaries of the GPER are somewhat irregular because of topographical restrictions. Figure 2 shows the relative locations of the two areas surveyed. The airborne surveys covered the entire 80-acre tract using 50 east-west flight lines spaced 16 m apart. North-south tie lines were flown along the edges of the tract.

Table 2 presents a summary of the primary results of the background characterization surveys. The overall character of the data suggests a relatively homogeneous environment over the two areas of interest with only small variations in magnetic and resistive/conductive parameters. Surface and

Table 1. Rabbit Valley Previously Buried Target Information

Target Description	Location	Orientation/Depth	Primary Use
Nonreinforced concrete vault and removable wood lid covered with 0.3 m of earth Width: 1.5 m Height: 1.2 m	–180,–80	Axis vertical/0.3 m to top	GPR, R/IP, seismic, gravity, magnetic, and EM
Plastic box filled with paraffin Length: 0.8 m Width: 0.5 m Height: 0.5 m	–160,–30	Axis horizontal/0.25 m to top	GPR, R/IP, and seismic
Corrugated steel culvert Length: 1.2 m Width: 0.6 m	–285,–355	Axis horizontal, oriented north-south/2 m to top	GPR, TDEM, magnetic, seismic, R/IP, and gravity
Corrugated steel culvert Length: 3.7 m Width: 1.8 m	–235,–395	Axis horizontal, oriented north-south/2 m to top	GPR, TDEM, magnetic, seismic, R/IP, and gravity
Reinforced concrete box Length: 2.3 m Width: 2 m Height: 1.75 m	–286,–453	long axis horizontal, oriented north-south/1.35 m to top	GPR, TDEM, magnetic, seismic, and R/IP
Plastic tank: Length: 2.5 m Width: 1.25 m Height: 1 m	–374,–473	Long axis horizontal, oriented east-west/1 m to top	GPR, seismic, R/IP, and gravity

airborne survey results show good agreement after consideration of the factors that control their individual responses.

A. Surface Magnetics

Surface magnetic surveys were conducted on a 4-m grid with an EDA Instruments OMNI–PLUS proton-precession magnetometer/gradiometer with a sensor height of 2 m. Figure 5 is a map of the total

Table 2. RV GPER Site Background Characteristics

Parameter	Geophysical Survey Method				
	Airborne Magnetic/EM	Surface Magnetic	Surface R/IP	Surface TDEM	Surface IEM
Total Magnetic Field	53,456 nanoteslas (nT) ± 9 nT	53,467 ± 4 nT			
Vertical Magnetic Gradient	0 ± 0.25 nT/m	–19 ± 10 nT/m			
Near-Surface Apparent Resistivity	25 ohm-meters (Ω–m)		50 Ω–m	5 Ω–m	
Deep Apparent Resistivity	7 Ω–m		10–20 Ω–m	5 Ω–m	
Near-Surface Conductivity					40 ± 10.2 millisiemens per meter
Near-Surface In-Phase					1 ± 0.2 parts per thousand

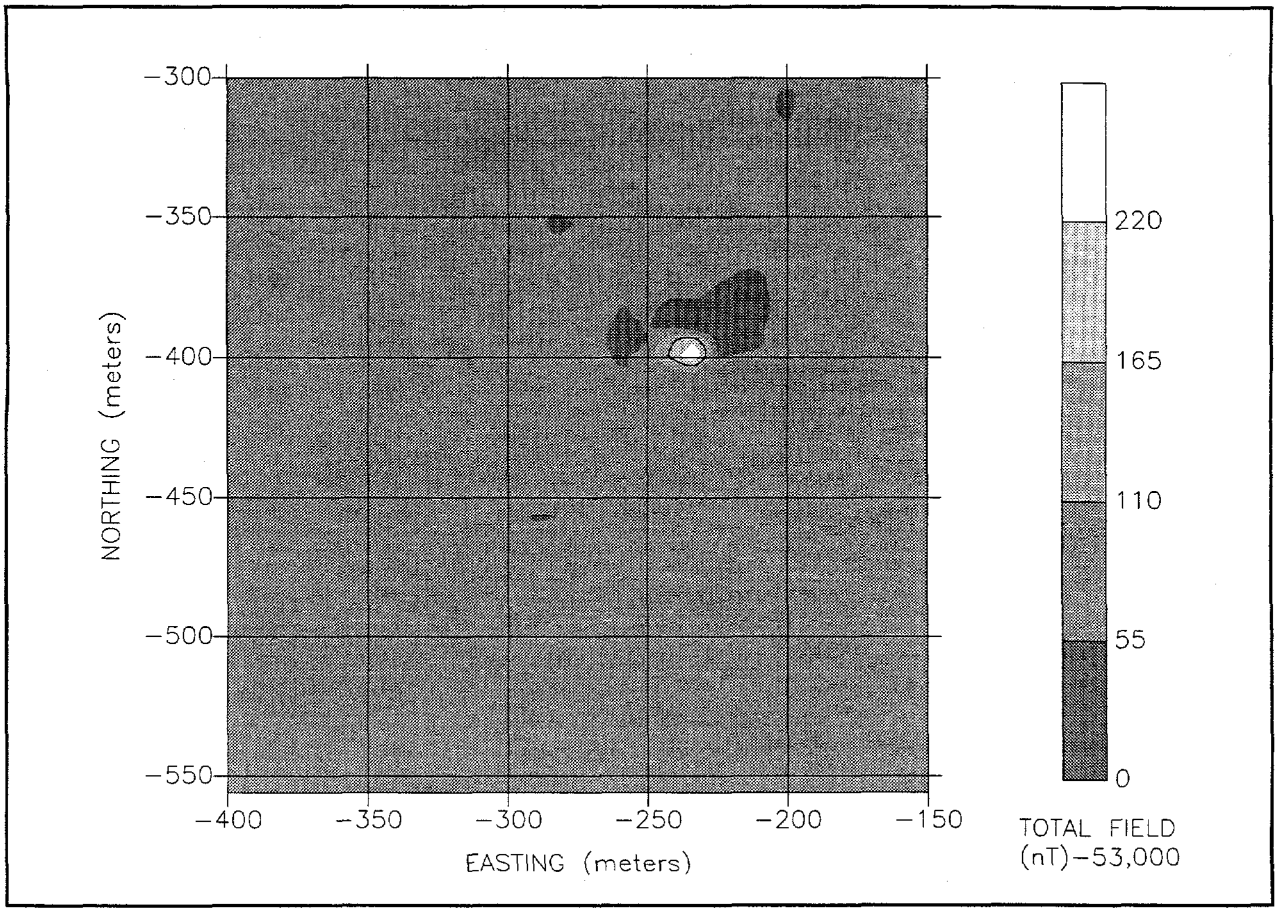


Figure 5. Total Magnetic Field at Surface

field, while Figure 6 shows the vertical gradient. The average total field was 53,477 ± 4 nanoteslas (nT) with a mean vertical gradient of –19 ± 10 nanoteslas per meter (nT/m) over the site. Total field and vertical gradient anomalies were apparent over the magnetic targets previously buried at the site.

B. Airborne Magnetics

Airborne magnetic surveys were conducted along east-west flight lines spaced 16 m apart. The surveys were conducted by a subcontractor, High-Sense Geophysics Ltd., with a Picodas PDAS–1000 magnetometer coupled to a Scintrex H8 cesium-vapor sensor. The sensor was flown in a "bird" suspended 24.4 m below a Bell Long Ranger 3 helicopter. Sensor altitude was nominally 30 m above the terrain. Survey results indicate an average total field of 53,456 ± 9 nT, as shown in Figure 7. This value is readily reconciled with the value recorded on the surface. Identifiable total field anomalies were recorded over the large steel culvert previously buried at the site. Responses from the small steel culvert and the steel-reinforced concrete tank were not as prominent.

C. Induction Electromagnetic

IEM surveys were performed on a 4-m grid with a Geonics EM–31 ground conductivity meter. Measurements were conducted using the vertical magnetic dipole (VMD) mode with the boom oriented parallel to the survey lines. Figures 8 and 9 show the conductivity and in-phase components, respectively. Near-surface conductivity ranged from 20 to 70 millisiemens per meter (mS/m), with an average value of 40 ± 0 mS/m. Conductivity values reflect some rather large lithologic features centered

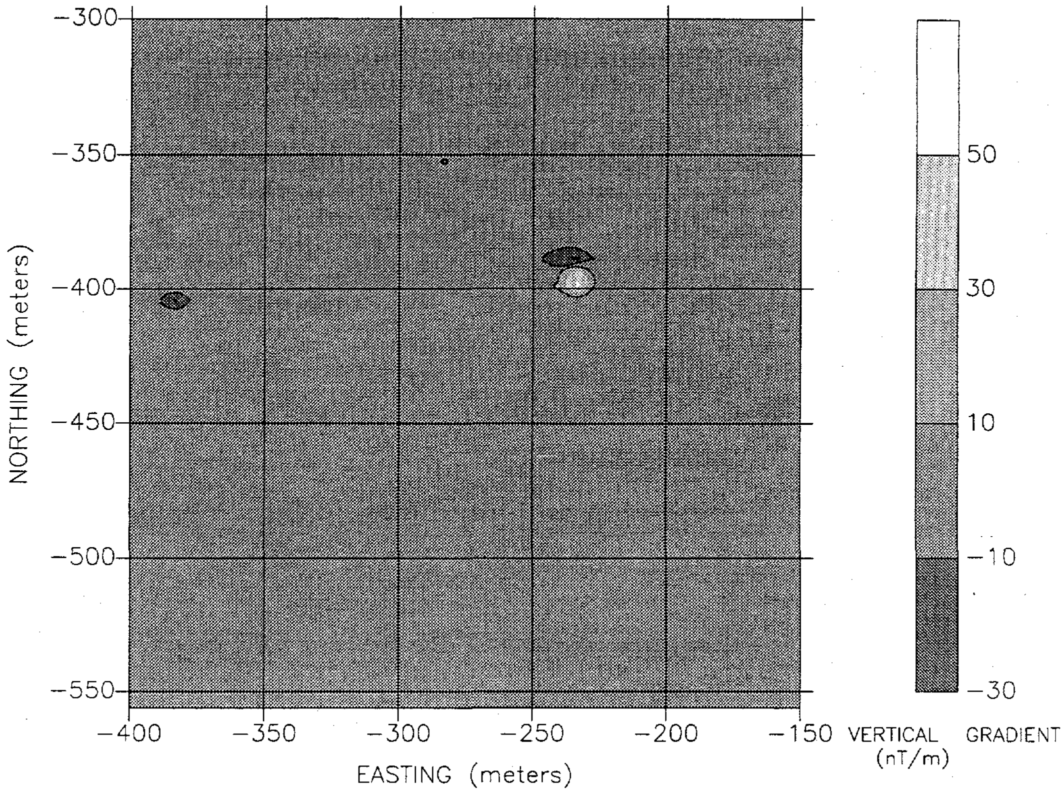


Figure 6. Vertical Gradient of Magnetic Field at Surface

around (–320, –460) and (–200, –480). The in-phase component ranged from –1.8 to +8 parts per thousand (ppt) with an average value of 0.5 ppt. Note the prominent anomalies over the large steel culvert at (–235, –395) and the steel reinforced concrete box at (–286, –453). Figure 10 is an expanded-scale contour plot of the in-phase anomaly over the large steel culvert. The smaller steel culvert did not produce a readily discernible in-phase anomaly as expected.

D. Very Low Frequency Electromagnetic

VLF–EM data were recorded on a 4-m grid with an EDA OMNI–PLUS magnetometer/VLF system concurrently with the surface magnetic surveys. Although field strengths were adequate from the three VLF transmitters recorded (Cutler, Maine, 24.0 kilohertz [kHz]; Annapolis, Maryland, 21.4 kHz; and Jim Creek, Washington, 24.8 kHz), the background data were generally uninteresting. Figure 11 is typical of the results obtained using signals from NSS, Annapolis, Maryland, at 21.4 kHz.

E. Time-Domain Electromagnetic

TDEM surveys were conducted on a 4-m grid with a Geonics TEM–47 system and a GJPO-developed rigid transmitter loop. The rigid transmitter loop provided a constant moment of 100 ampere turns meters squared (Atm^2) and was easily moved from station to station. Transmitter-antenna-to-receiver-antenna spacing was maintained at 10 m, edge-to-edge. Figures 12, 13, and 14 show apparent resistivity at early, medium, and late times, respectively.

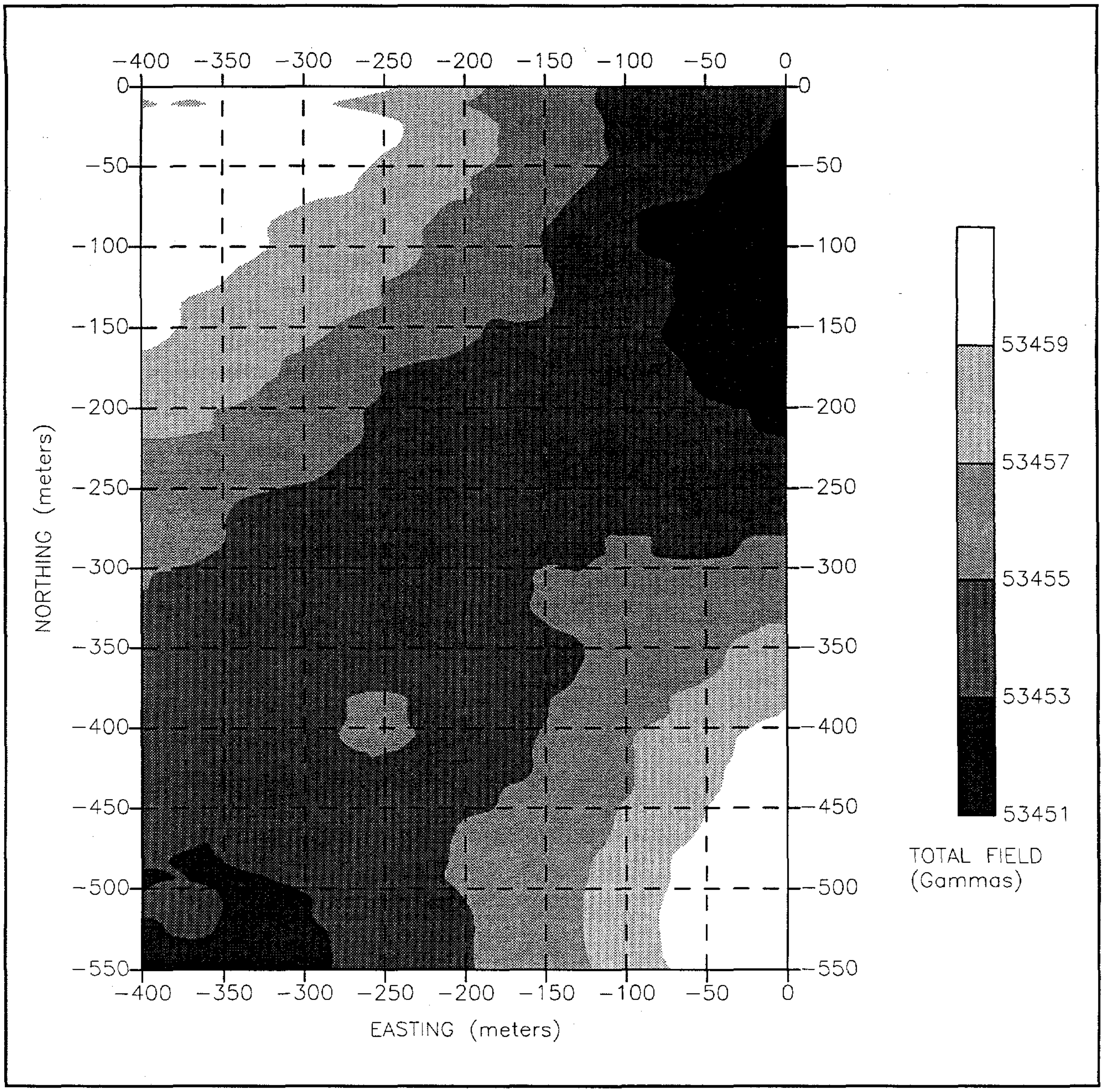


Figure 7. Total Magnetic Field at 50 Meters Above Surface

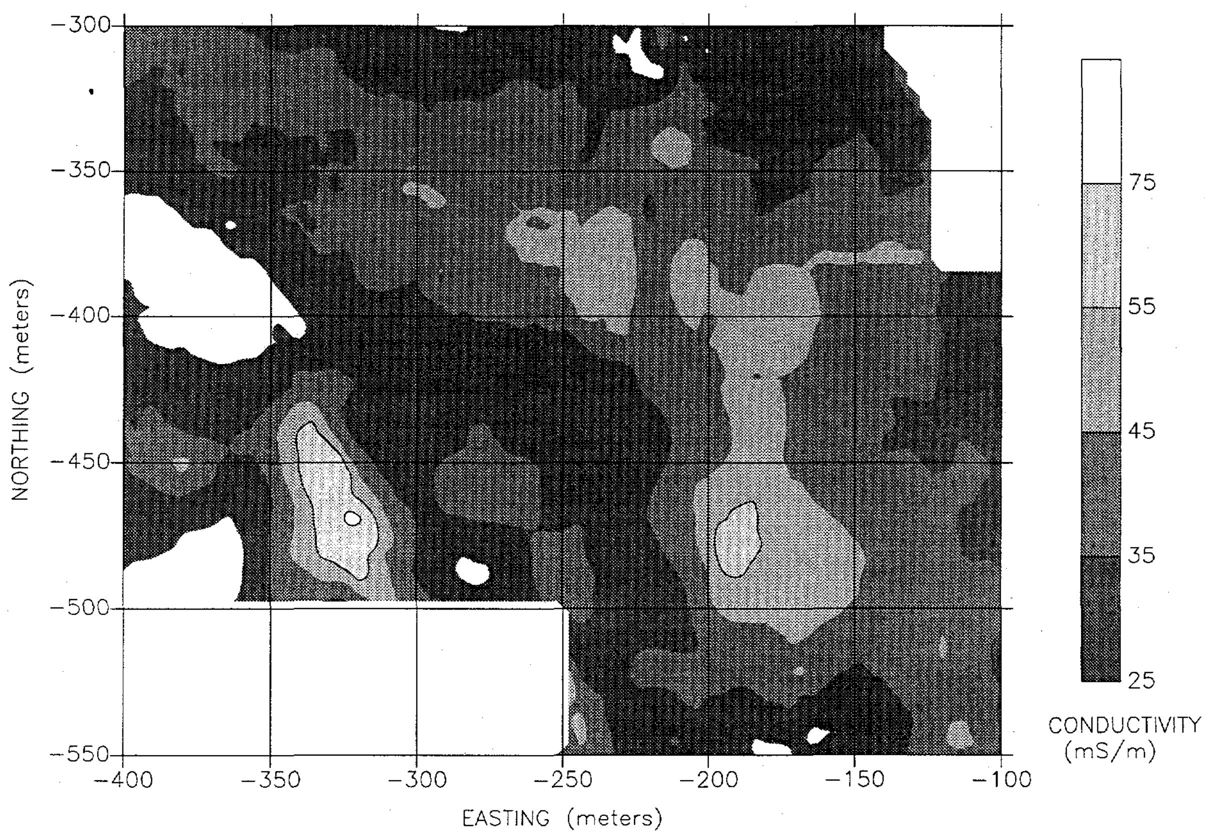


Figure 8. Conductivity From EM–31 Survey

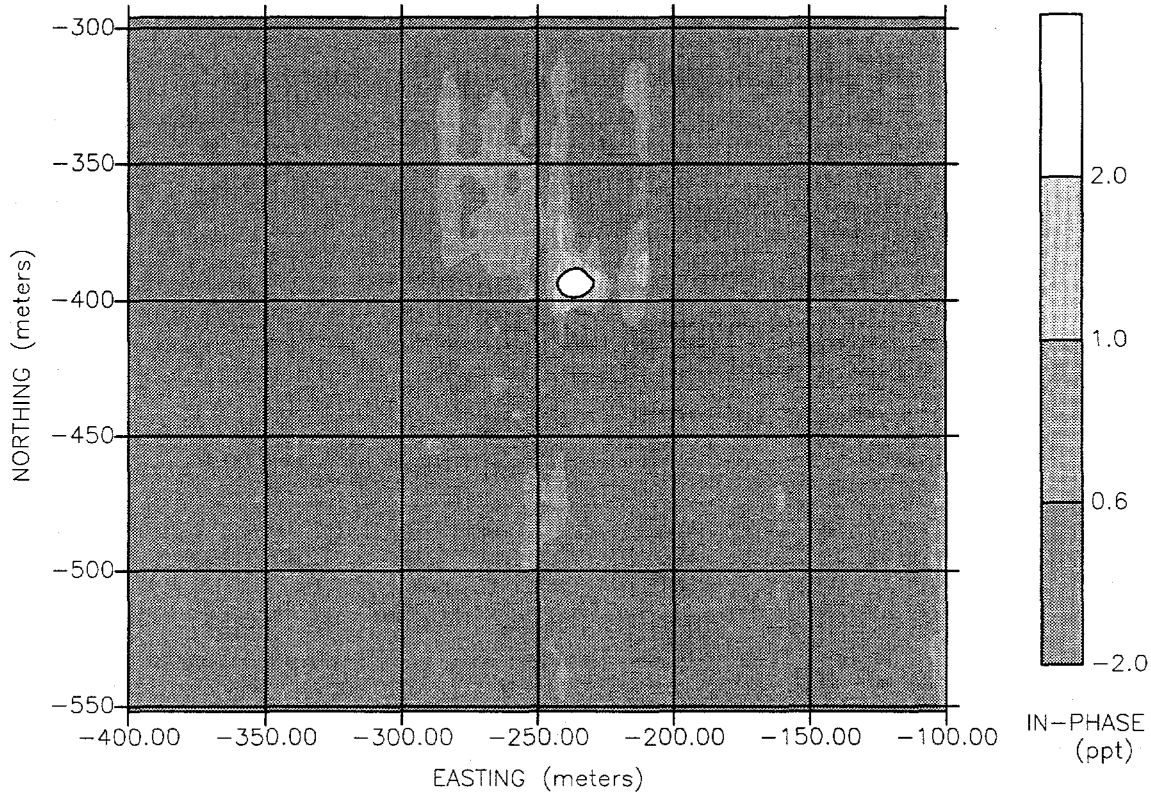


Figure 9. In-Phase From EM–31 Survey

F. Airborne Electromagnetic

Airborne electromagnetic (AEM) surveys were conducted by a subcontractor, High-Sense Geophysics Ltd., with a four-frequency EM system consisting of two coaxial coil pairs operating at 919 and 4355 hertz (Hz) and two coplanar coil pairs operating at 4165 and 35600 Hz. The coils were housed in a bird suspended 3 m below a Bell Long Ranger 3 helicopter. The system simultaneously recorded in-phase and quadrature components for the four frequencies at a rate of 10 times per second. Figures 15 and 16 show the resulting apparent resistivity for the coplanar coils operating at 4165 and 35.6 kHz, respectively.

G. Resistivity/Induced Polarization

R/IP surveys were conducted on a 4-m grid with an Androtex TDR–6 receiver and a Phoenix IPT–1 transmitter. A gradient-array configuration was employed with the survey lines running east-west with porous-pot receiver electrodes spaced 4 m apart. Transmitter electrodes were placed 300 m on either side of each 25-m survey block. Figures 17 and 18 show the apparent resistivity and the induced polarization, respectively.

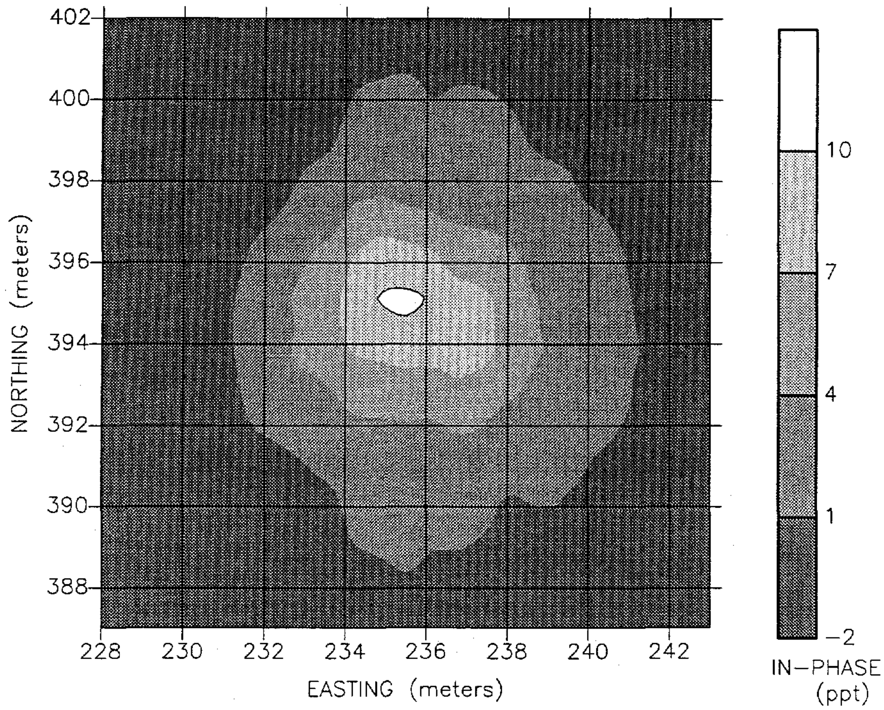


Figure 10. In-Phase Anomaly Over Large Steel Culvert

H. Ground-Penetrating Radar

GPR surveys were conducted over some of the previously buried targets and a 30-m-long east-west line (440 South) in the area where the Sand Pit (Area 4) was later constructed. A GSSI SIR–8 impulse-type radar was used in these surveys. The east-west line in Area 4 surveyed with the 80 megahertz (MHz) antenna showed only three or four small reflections (see Figure 19) in the near-surface that were attributed to lithologic variations. Penetration was estimated to be 1 m. Surveys over the concrete septic tank and the large steel culvert produced no recognizable signatures. Previous surveys over an empty concrete vault (Allen 1990) and a polyvinyl chloride (PVC) pipe cache (Allen 1992) in the northern area had produced excellent signatures at 300 and 500 MHz, respectively. Figures 21 and 22 show the results of 500-MHz surveys over the empty concrete vault and the PVC pipe cache, respectively. The results obtained by DOE Special Technologies Laboratory personnel (Koppenjan and Martinez 1994) were similar; they obtained good signatures over the empty concrete vault but were unable to "see" the steel culvert and concrete septic tank. Coleman Research Corporation obtained somewhat better results, producing good images over the empty concrete cylinder and the plastic cylinder and marginal images over the steel culvert and concrete septic tank. The higher clay content in the soils surrounding the steel culverts and the concrete septic tank may contribute to the poorer performance in this area. Soil samples collected during the earlier surveys over the empty concrete cylinder and the PVC pipe cache showed only 1.9-percent clay fraction compared to the 6 to 10 percent in the samples collected during construction.

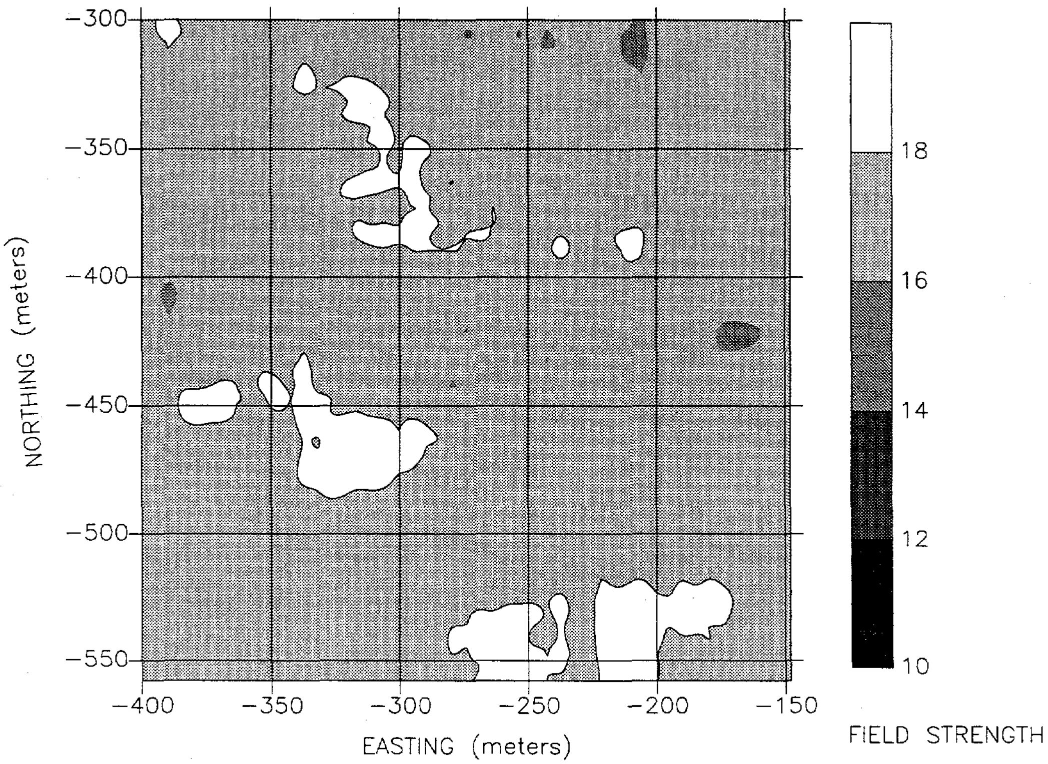


Figure 11. Field Strength of 21.4-kHz VLF–EM

IV. Range Construction and Soil Sample Analysis

Construction of the Rabbit Valley GPER test cells began in Area B on April 23, 1994, and was completed on May 12, 1994. Construction was performed by Sorter Construction Company of Grand Junction, Colorado, under a subcontract. All construction activities were conducted in accordance with the *Rabbit Valley Geophysics Performance Evaluation Range (GPER) Health and Safety Plan* (Geotech 1994b); *Minimum Drilling Health and Safety Requirements for Operation of Small Auger, Rotary, and Core Rigs* (Geotech 1994a); *Rabbit Valley Geophysics Performance Evaluation Range (GPER) Health and Safety Plan* (Sorter 1994b); *Safety Management Plan* (Sorter 1994c); and a site-specific *Health and Safety Attachment 1–12–94* (Sorter 1994a). Geotech personnel conducted a site safety briefing for all on-site participants before the start of construction. The Sorter foreman conducted daily "tailgate" safety briefings. A Geotech health and safety technician conducted daily inspections of construction activities, and a Geotech Construction health and safety engineer performed periodic inspections of Sorter's heavy equipment and tools.

A Geotech construction inspector monitored all construction activities, authorized departures from the cell specifications (i.e., depth of targets, clay layer thickness), and recorded as-built specifications for target locations, orientations, and depths. The construction inspector made photographic records (still and video) of construction activities and progress. Figures 22 through 32 show various stages in the construction, including target placement details. Figure 22 presents excavation in progress for the Clay Pit (Area 5); note the stepped vertical boundary at the left edge of the pit. Figure 23 shows the large excavator during excavation of the Sand Pit (Area 4); note the dust near the bucket of the excavator.

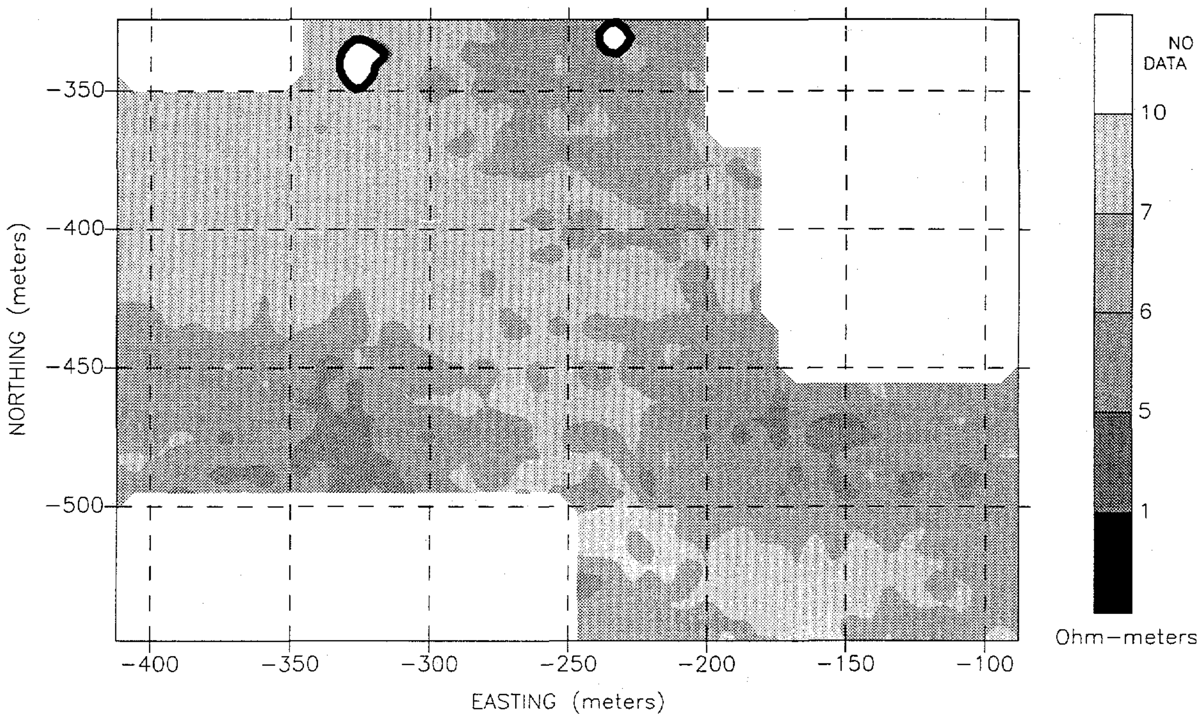


Figure 12. Apparent Early-Time Conductivity From TDEM Survey Before Construction

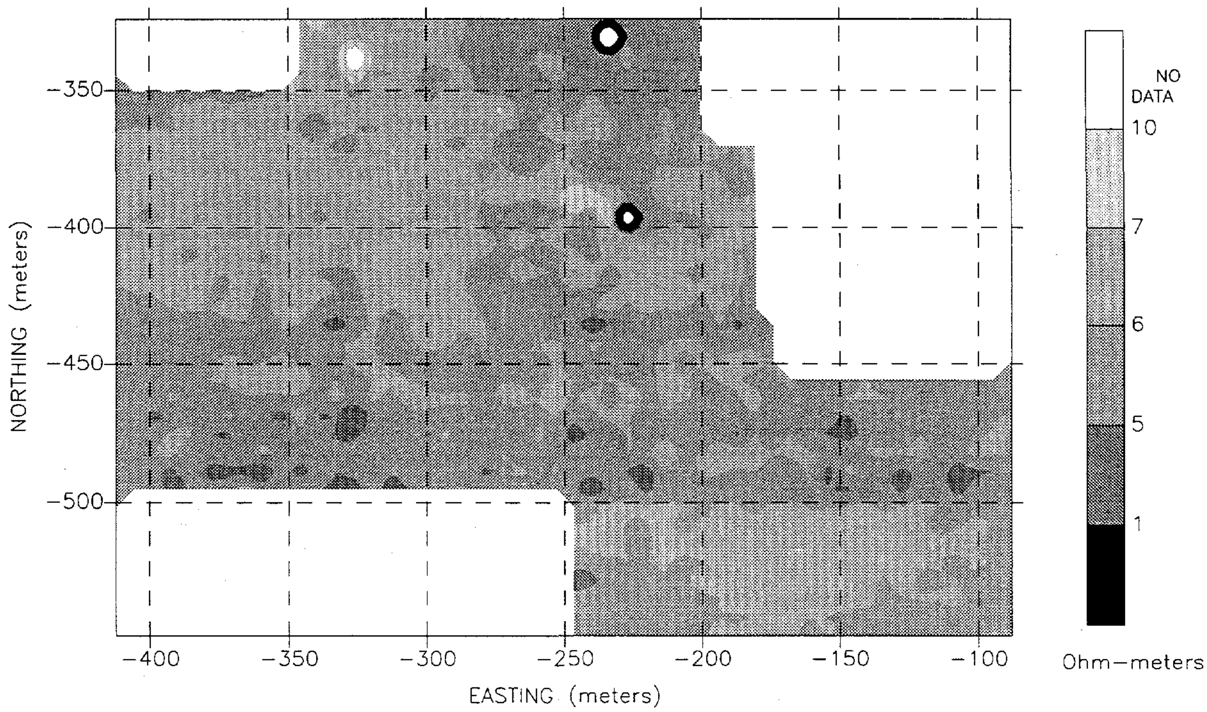


Figure 13. Apparent Medium-Time Conductivity From TDEM Survey

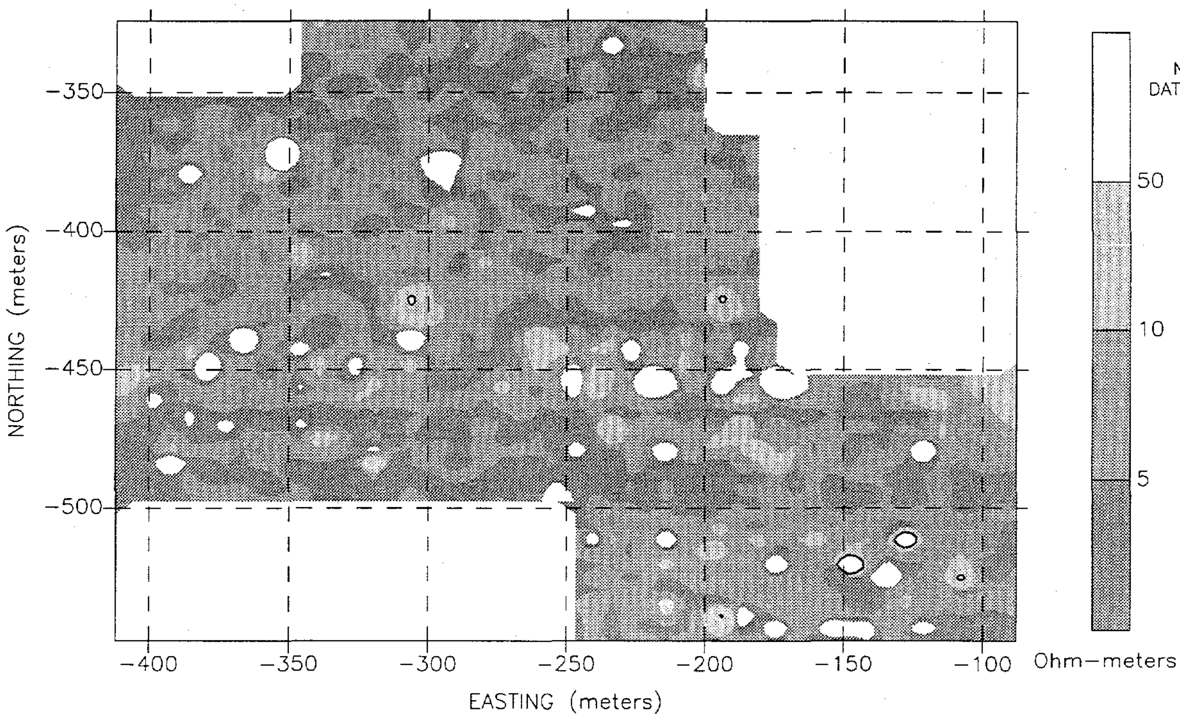


Figure 14. Apparent Late-Time Conductivity From TDEM Survey

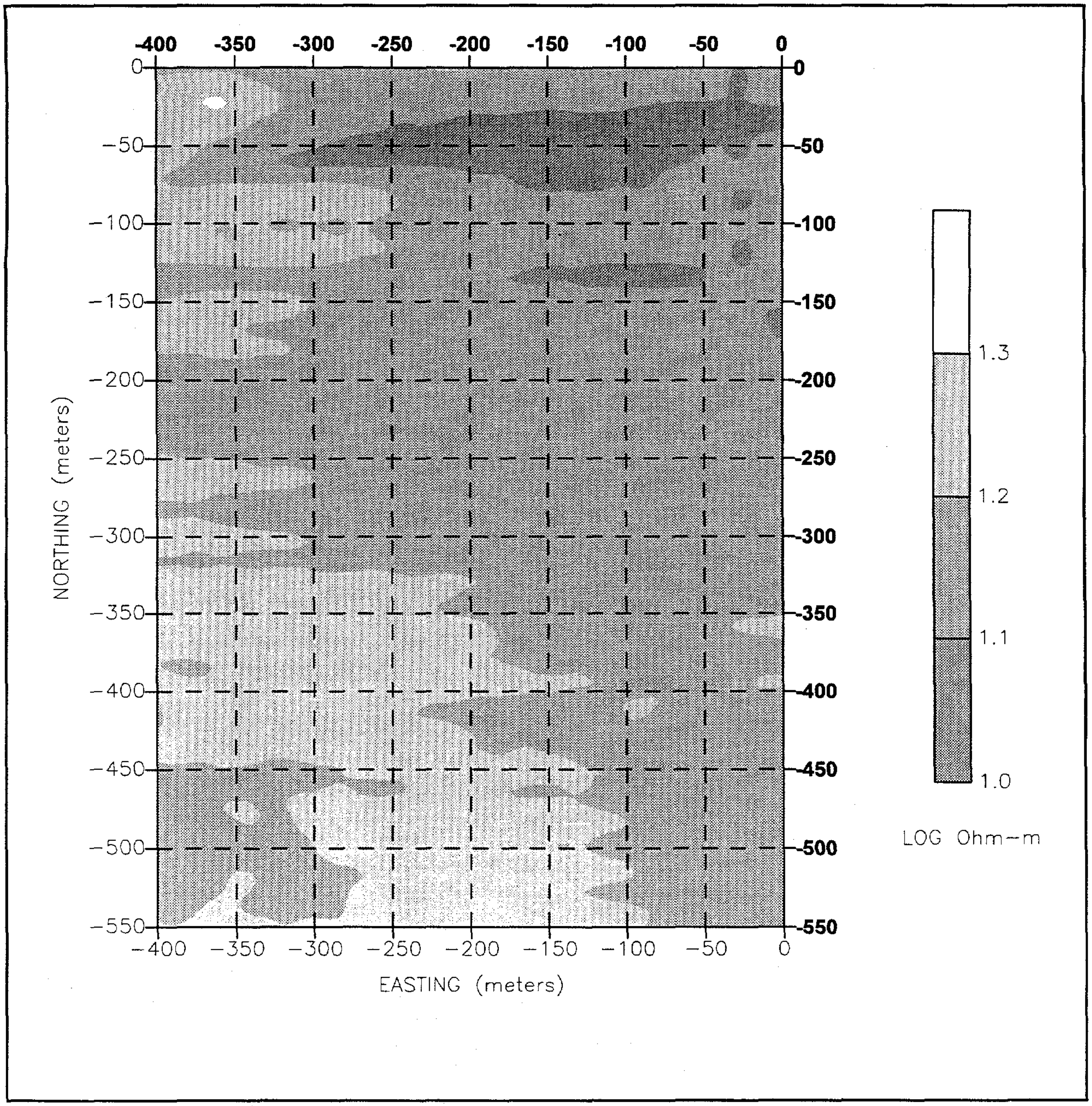


Figure 15. Apparent Resistivity at 4165 Hz From Airborne EM Survey

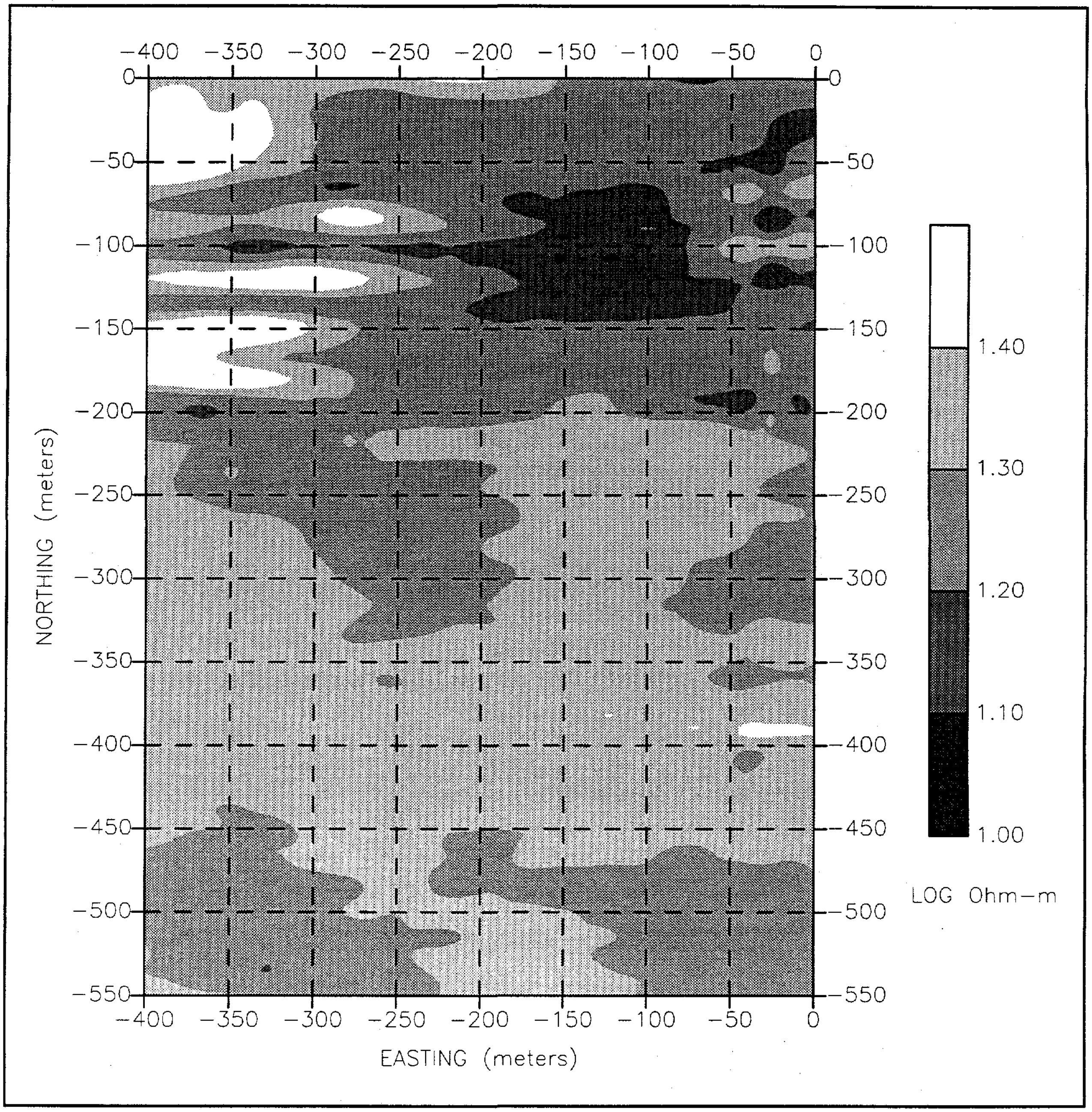


Figure 16. Apparent Resistivity at 35.6 kHz From Airborne EM Survey

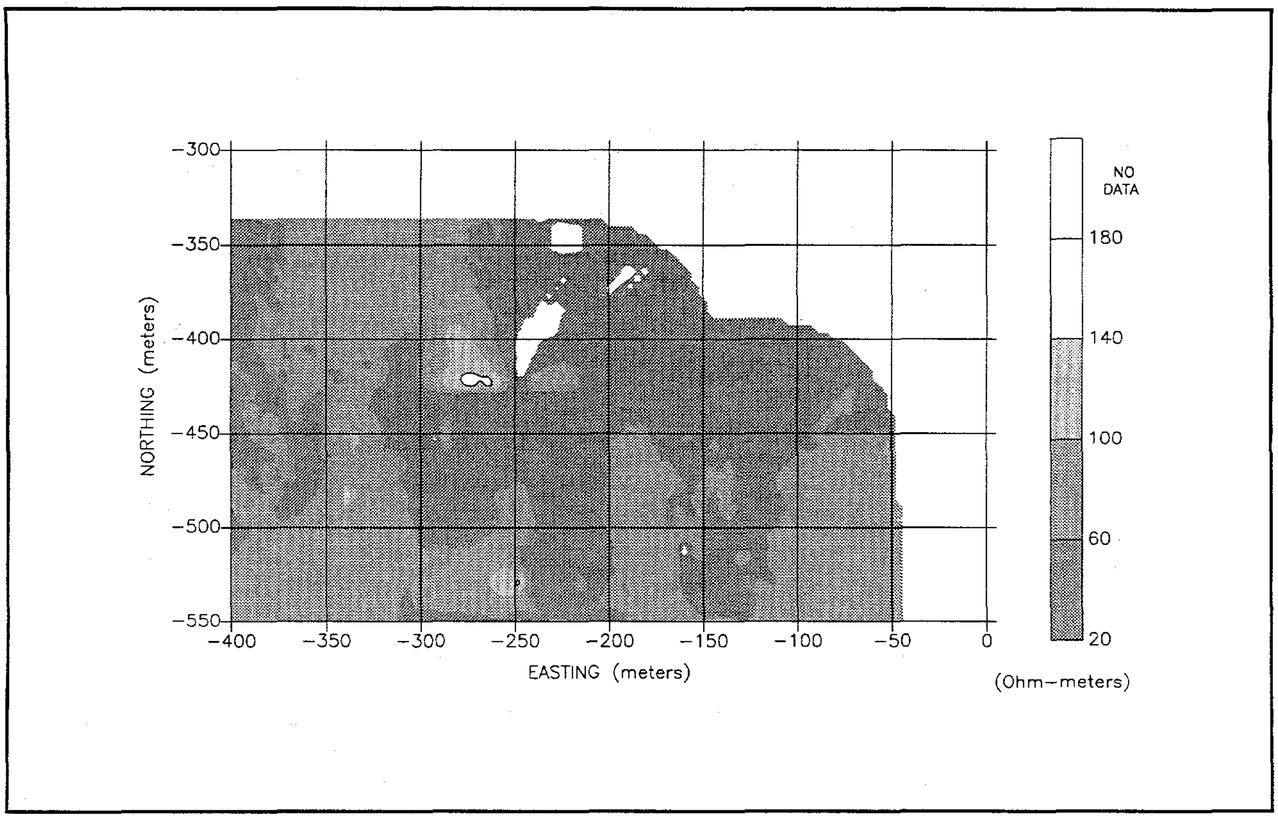


Figure 17. Apparent Resistivity From Surface R/IP Survey

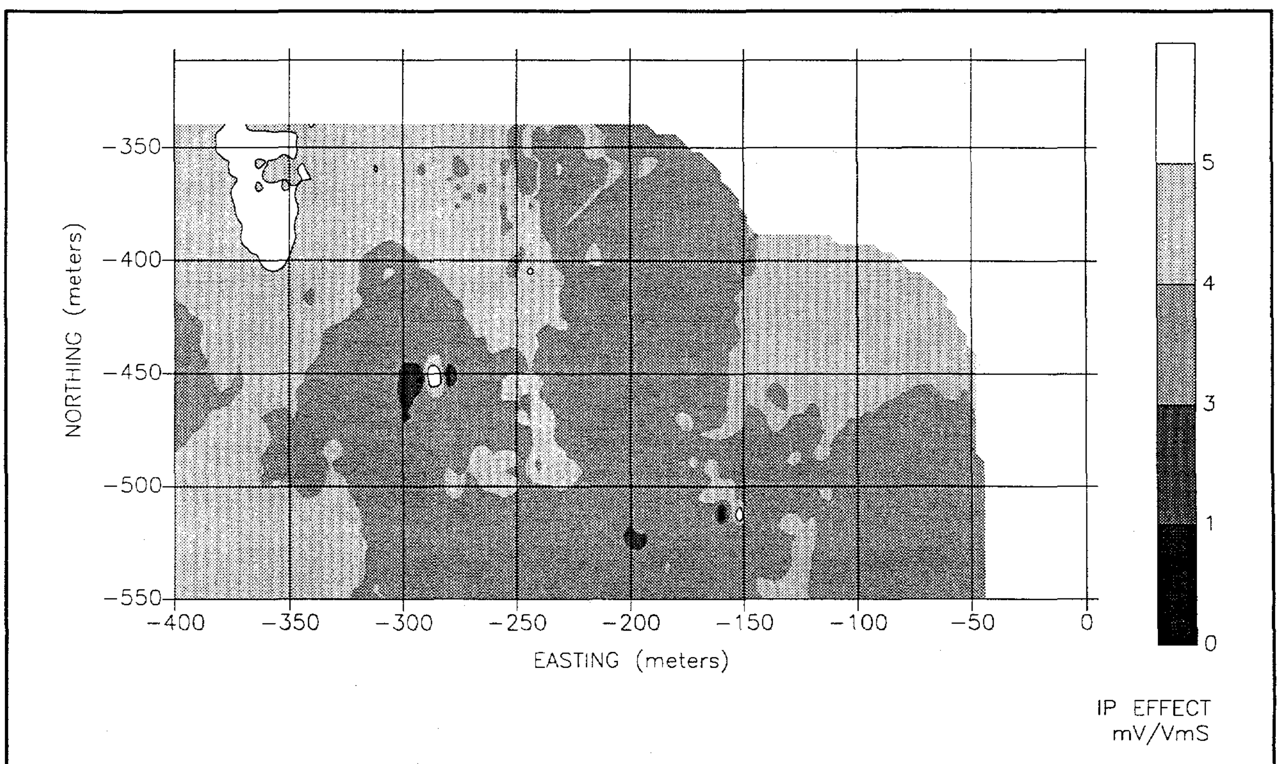


Figure 18. Induced Polarization From Surface R/IP Survey

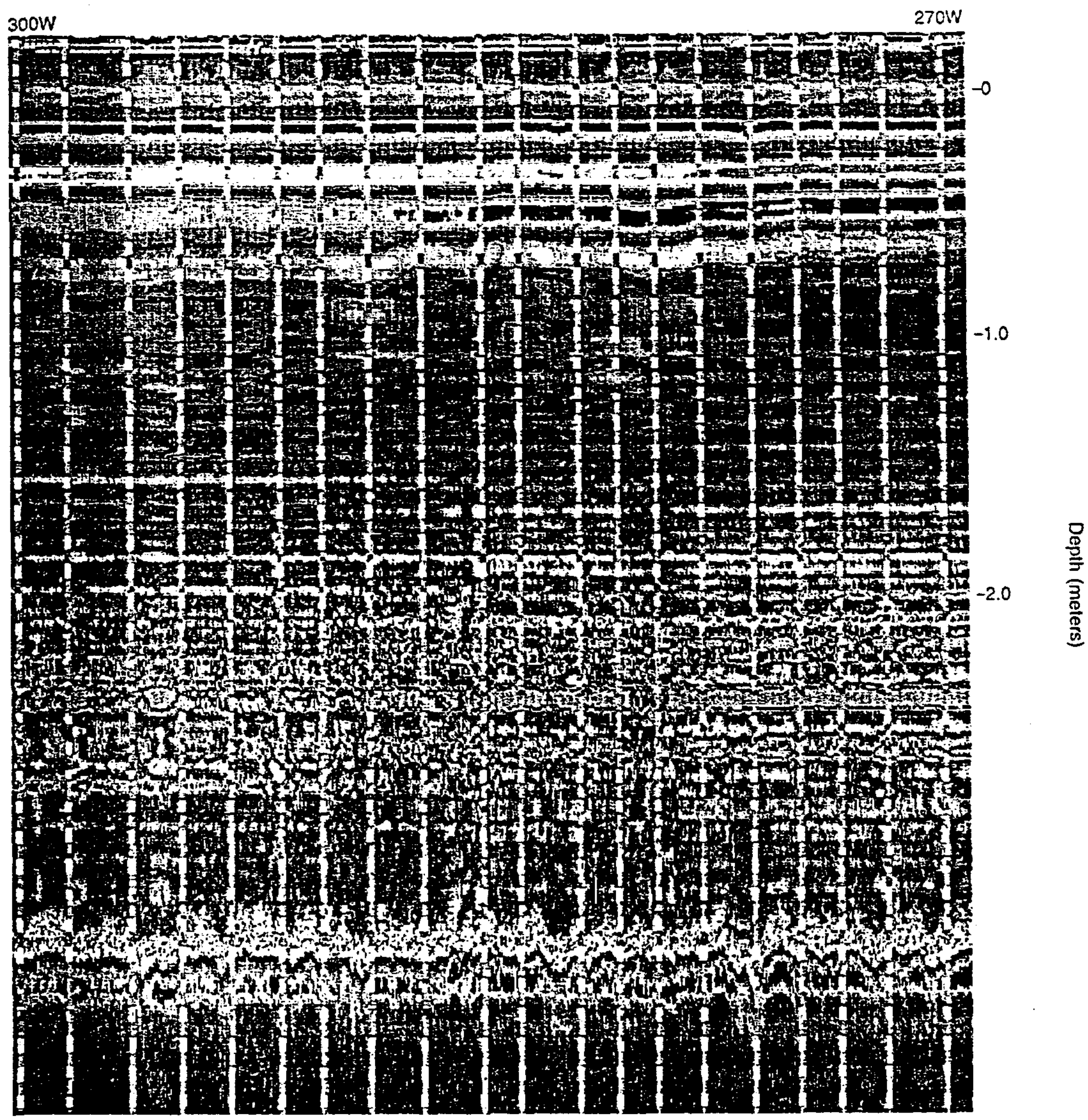


Figure 19. GPR Survey at 80 MHz Along Line 440S

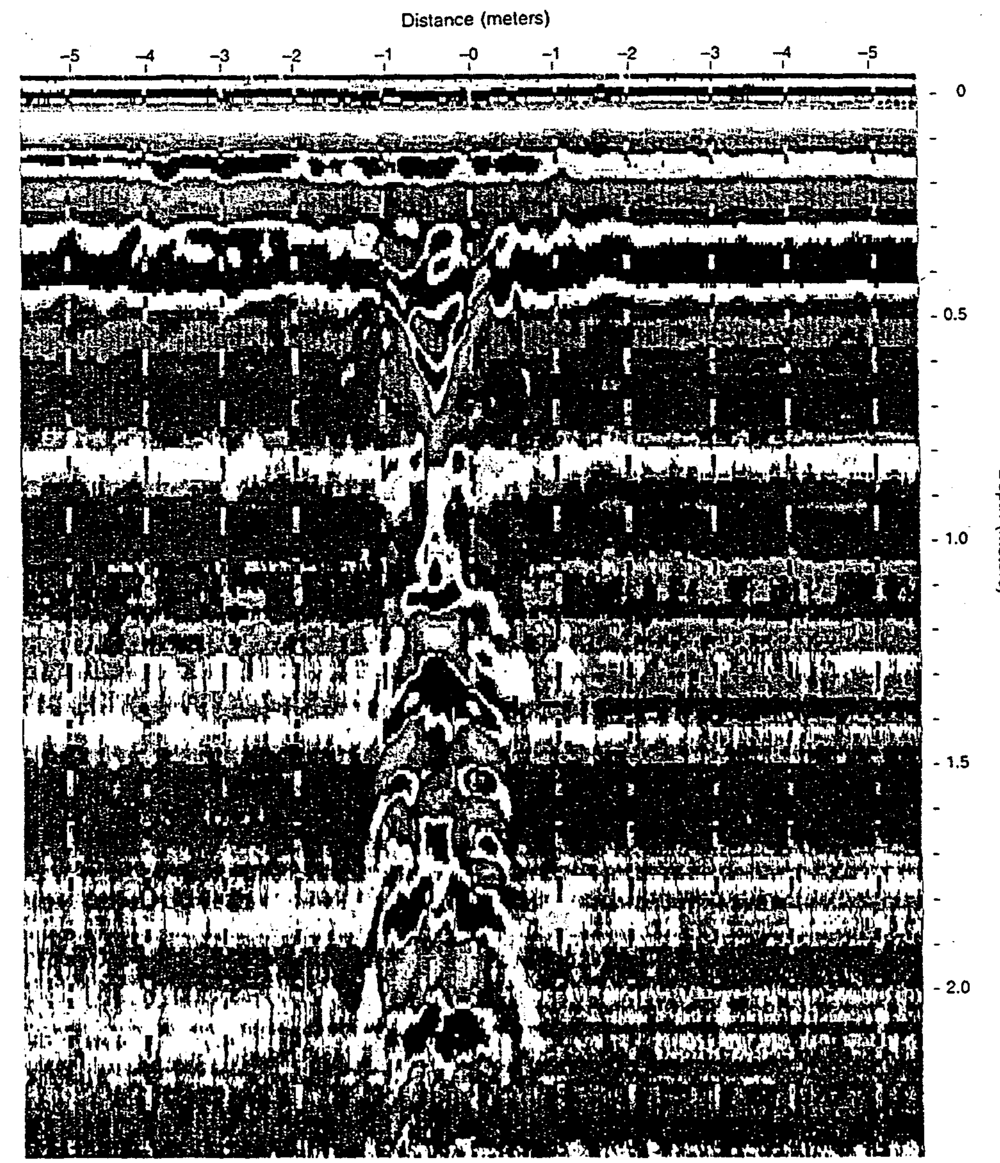


Figure 20. 500-MHz GPR Survey Over Empty Concrete Vault

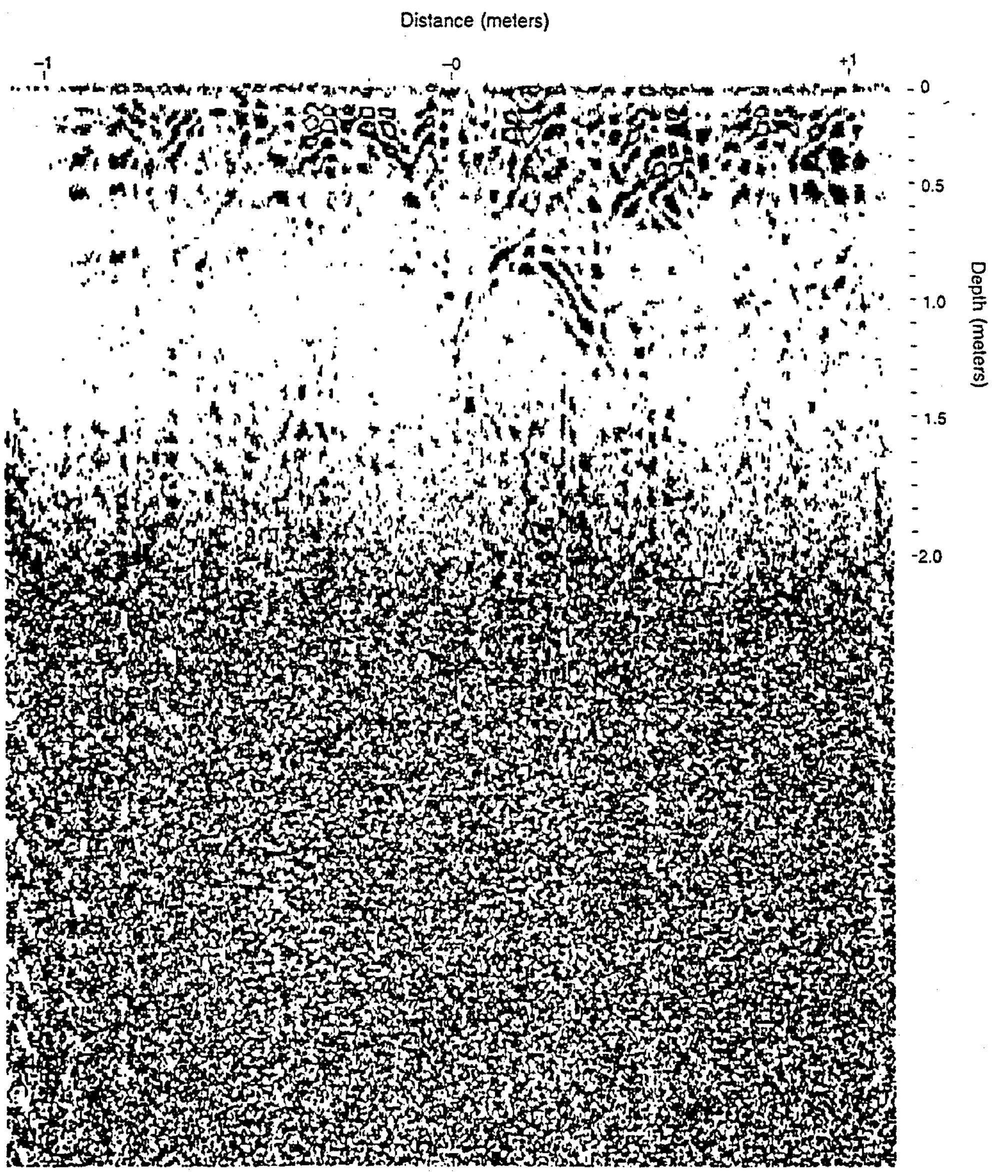


Figure 21. 500-MHz GPR Survey Over PVC Pipe Cache

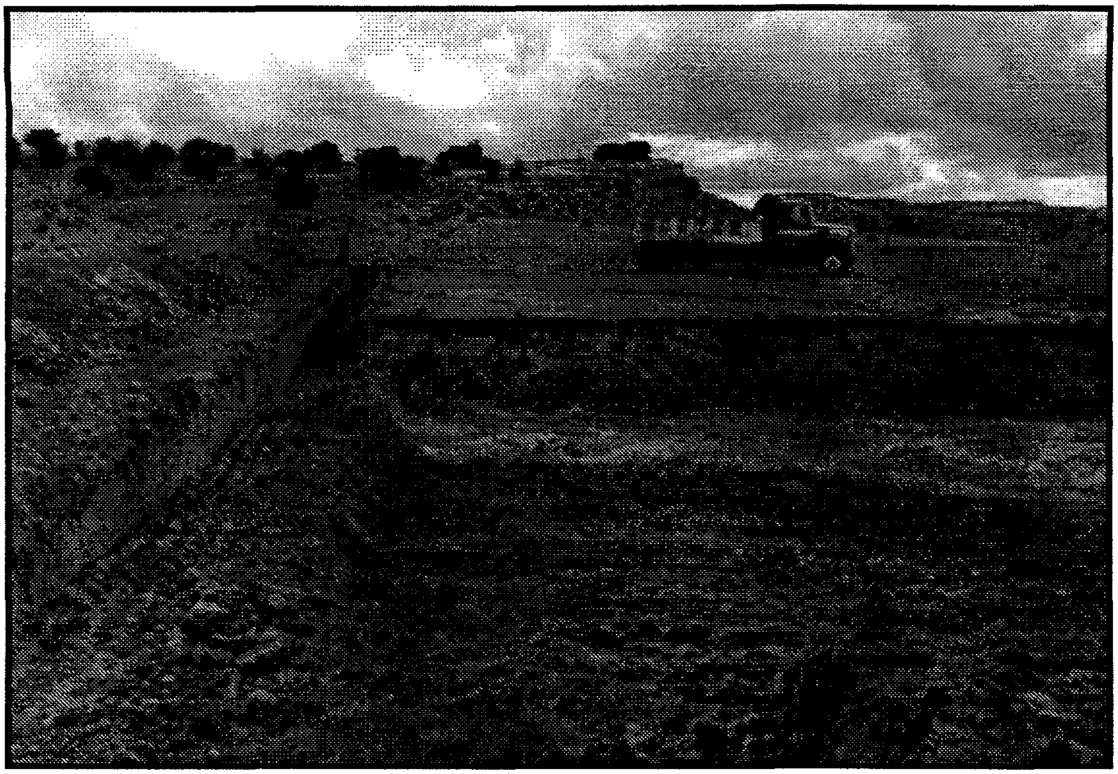


Figure 22. Construction of Clay Pit (Area 5) Showing Pit Boundary

Figure 23. Construction of Sand Pit (Area 4) Showing Excavator in Action

Figure 24. Dust Control in Action at Sand Pit

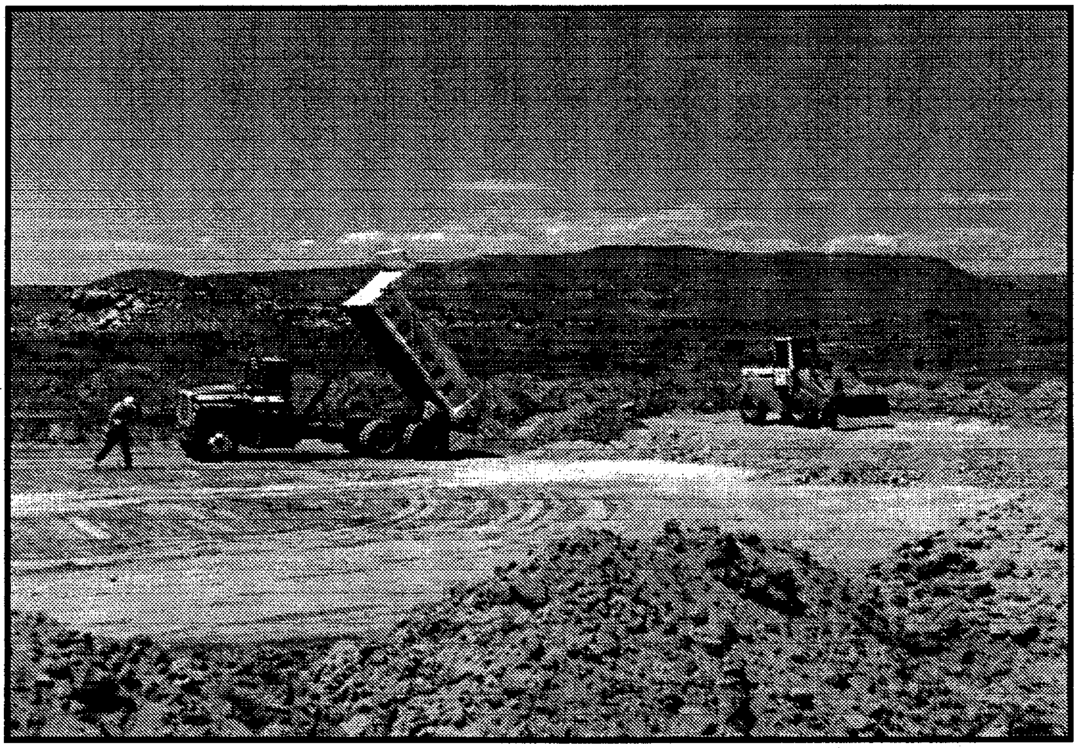


Figure 25. Placement of Clay Layer in Clay Pit

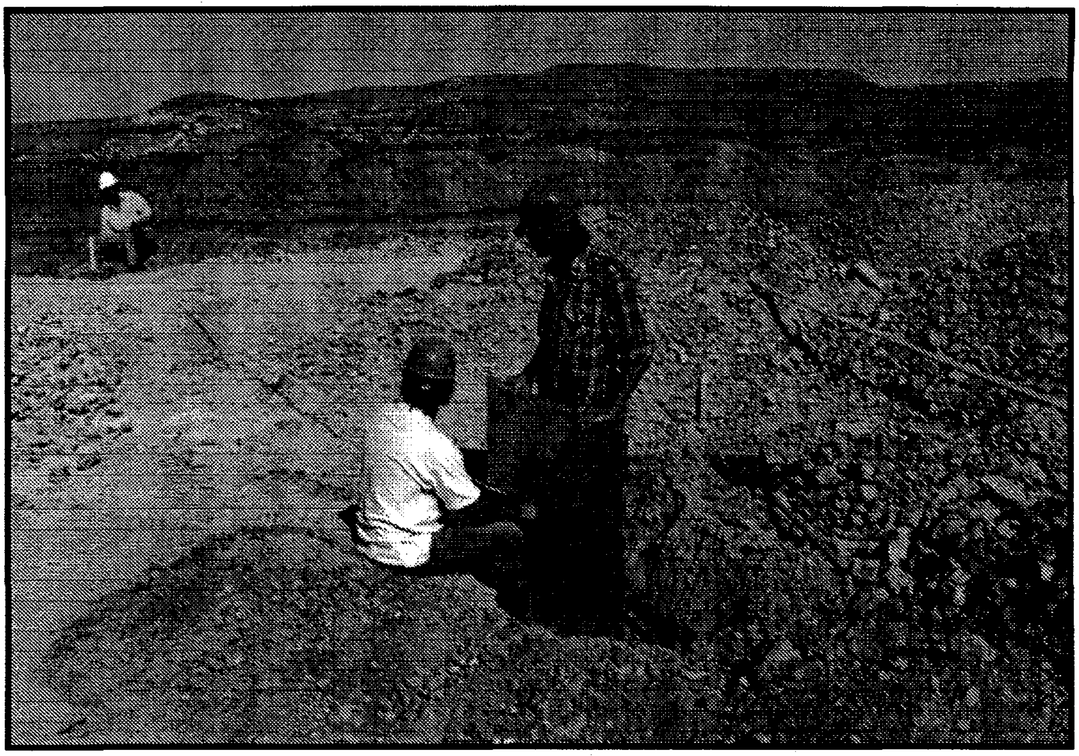


Figure 26. Placement of Metal-Sheet Target in Clay Pit

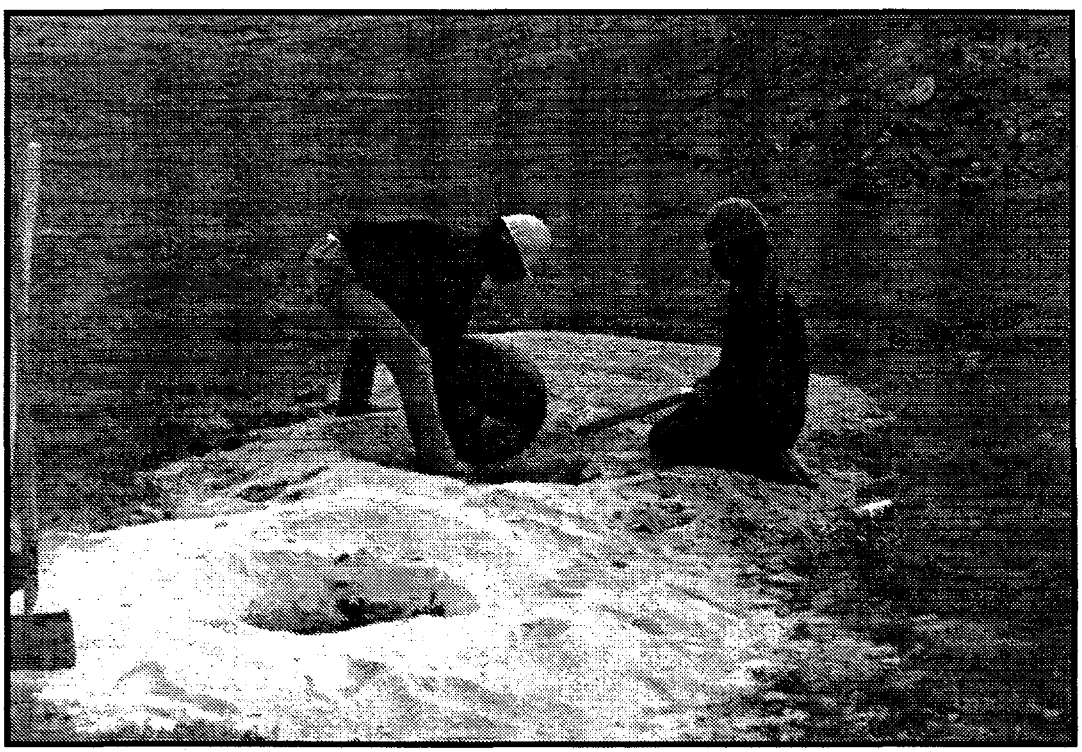


Figure 27. Emplacing 0.5-Meter Steel Sphere in Area 6

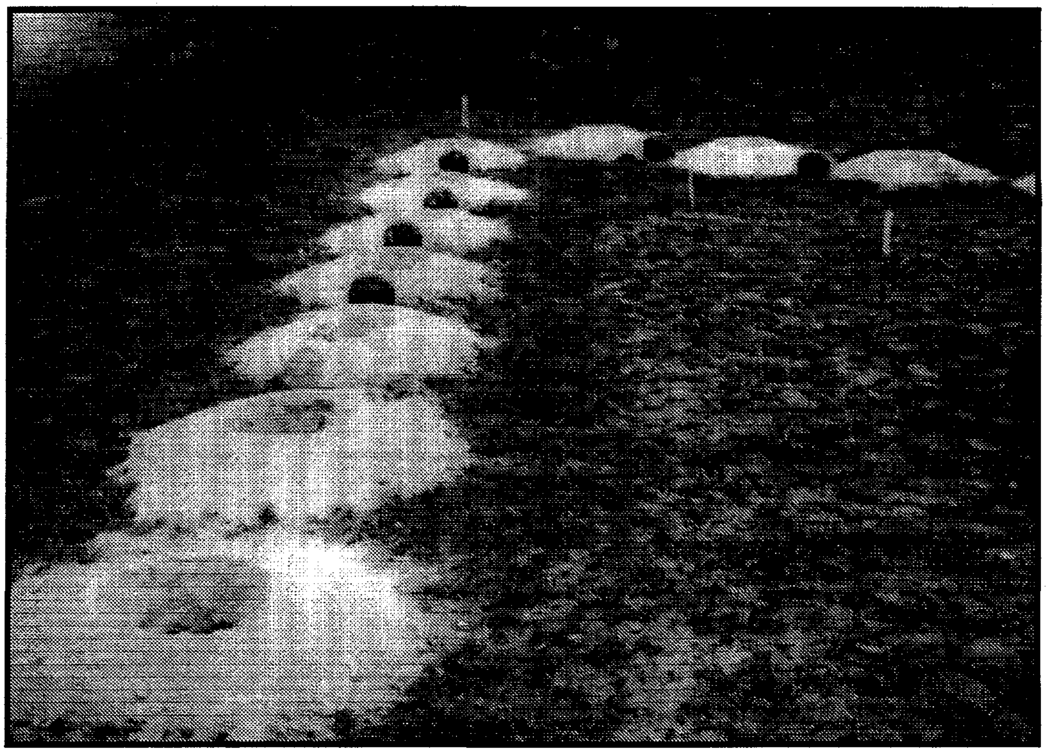


Figure 28. Plastic Spheres in Area 2 Before Burial

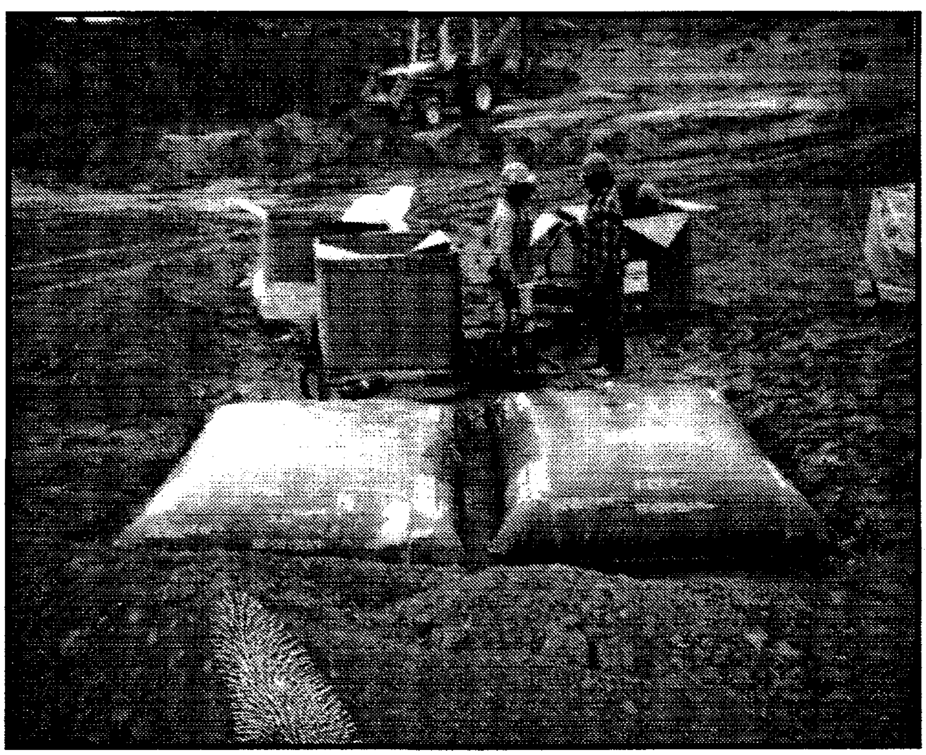


Figure 29. Filling Bladders With Soy Oil for Oil Cell

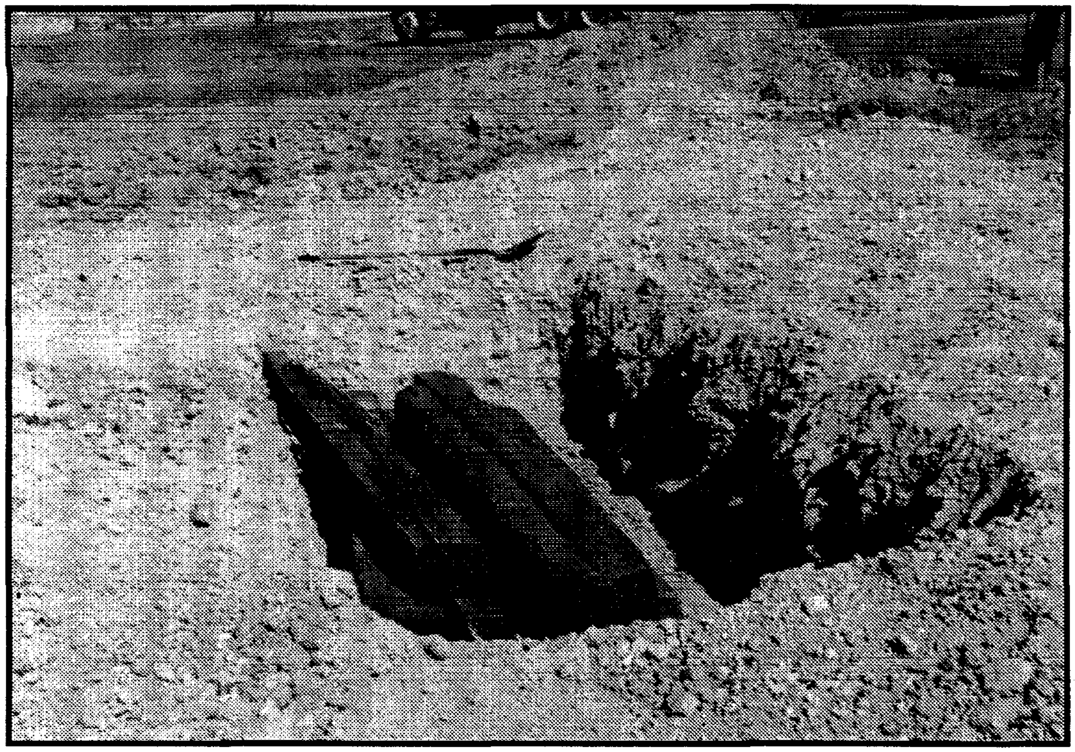


Figure 30. Wood Cell Before Burial

Figure 31. Trash Cell Before Burial

Figure 32. Recontoured Surface of Sand Pit

Dust-control measures included water spraying as shown in Figure 24. Figure 25 illustrates placement of the clay layer in the Clay Pit (Area 5), while Figure 26 illustrates placement of one of the metal sheet targets in the clay layer.

Figure 27 shows a workman emplacing a 0.5-m-diameter steel sphere in an augered borehole in Area 6, which contains steel spheres of different diameters at different depths and spacings. Figure 28 presents some of the plastic spheres awaiting emplacement in boreholes in one of the triangular patterns in Area 2. Figure 29 shows the process of filling nylon-reinforced plastic bladders with soy oil for the oil cell in the Sand Pit. Figure 30 presents the wood cell in the Clay Pit, while Figure 31 illustrates the "trash cell" in the Clay Pit. Figure 32 shows the recontoured surface of the Sand Pit after completion of construction. Note the striations on the surface follow the elevation contours to minimize erosion from rain water. Revegetation of the surface will be conducted in the fall when conditions are more favorable for seed germination.

During the construction, soil samples were collected from test areas where the intended use made it desirable to determine soil composition (e.g., mineralogy, grain-size distribution, clay fraction, clay type). Test areas sampled include the clay layer in the Clay Pit, sand in the Sand Pit, and auger cuttings from Areas 2 and 3. This soil information should aid in analysis and interpretation of GPR, EM, and R/IP surveys. The samples were analyzed in the GJPO Analytical Laboratory for loss on drying, grain size, bulk mineral, and clay mineral.

Seven soil samples were submitted to the GJPO Analytical Laboratory for analysis. Table 3 lists the sample locations, collection parameters, and major analytical results. Detailed results and procedures are in Appendix B, "Soil Sample Analysis Report."

The results of loss-on-drying (LOD) analysis indicate a low moisture content for all samples that was expected after observation of the dust rising from excavation at all depths. Grain-size analyses indicate high silt/clay content for the Clay Pit and for borings from target locations A and B in Area 6. Clay samples from the Clay Pit (NCE 923) have an appreciable smectite content. Soil samples from Area 2 showed the lowest percentage of grain size—less than 1 mm (see Appendix B), which is interpreted as the most favorable for GPR signal penetration. This area was designed specifically for analysis of GPR surveys.

Table 3. Analytical Results for Soil Samples

Sample Identification	Location	Depth (m)	Description	Mineral Abundance D = Dominant S = Subdominant M = Moderate m = Minor T = Trace	Grain Size (weight % of sample) Silt: 0.0020–0.0625 mm Clay: <0.0020 mm	Loss on Drying (weight %)
NCE 918	Area 6	1	Composite from borings at target locations C, D, E, and F	Quartz (D) Calcite (M) K-Feldspar (m) Illite (T) Kaolinite (T) Plagioclase (T)	13.68% silt 8.48% clay 22.16% total	5.6
NCE 919	Area 3	0.25–1	Composite from borings at target locations B, G, and L	Quartz (D) K-Feldspar (m) Calcite (m) Illite (T) Kaolinite (T) Plagioclase (T)	12.67% silt 5.96% clay 18.63% total	6.9
NCE 920	Area 3	1	Sample from boring at target location N	Quartz (D) Calcite (M) K-Feldspar (m) Illite (T) Kaolinite (T) Plagioclase (T)	8.24% silt 6.03% clay 14.27% total	4.4
NCE 921	Area 6	1	Composite sample from borings at target locations A and B	Quartz (D) Calcite (S) K-Feldspar (m) Plagioclase (T) Smectite (m) Illite (T)	6.81% silt 6.39% clay 13.20% total	6.9
NCE 922	Area 2	0.25–1	Composite from borings to 0.25, 0.5, and 1 m	Quartz (D) Calcite (m) K-Feldspar (T) Plagioclase (T) Illite (T) Kaolinite (T)	15.49% silt 7.25% clay 22.74% total	5.7
NCE 923	Area 5 (Clay Pit)	0. 5	Composite sample from clay layer	Quartz (D) Calcite (S) Smectite (m) Illite (T)	3.24% silt 3.37% clay 6.61% total	8.5
NCE 924	Area 4 (Sand Pit)	0–0.1	Composite sample from sandy-loam surface cover	Quartz (D) Calcite (M) K-Feldspar (T) Plagioclase (T) Illite (T) Kaolinite (T)	17.83% silt 8.45% clay 26.28% total	5.2

V. As-Built Specifications

Figure 4 shows the relative layout of test areas and targets in the Rabbit Valley GPER. Tables 4 through 11 and Figures A–1 through A–9 (Appendix A) describe specific as-built target locations, orientations, and depths.

A. Test Area 1

Test Area 1 is designed to test magnetic and electromagnetic methods with needle-like ferromagnetic bodies. Figure A–1 shows the layout of targets and Table 4 presents target details. Targets are emplaced in boreholes and shallow trenches so that the uppermost portion of each target is a known depth (centimeters [cm]) below the natural grade.

B. Test Area 2

Test Area 2 is designed for testing of high-frequency EM (GPR, etc.) and high-resolution, shallow electrical methods. It contains nonmetallic and metallic spheres in layered, nested geometric patterns. Figure A-2 (Appendix A) shows the layout of the targets; Table 5 presents details of the targets; and Figure 33 shows locations of targets in individual auger holes backfilled with the original blended and compacted soil. The triangular deployment patterns for the three layers of spheres are centered at stations 235 West and 455 South with the apex of each triangle to the north.

C. Test Area 3

Test Area 3 is designed for testing magnetic and EM methods on tabular and spherical bodies of different materials. Figure A–3 (Appendix A) shows the layout of the targets in the pit; Table 6 presents

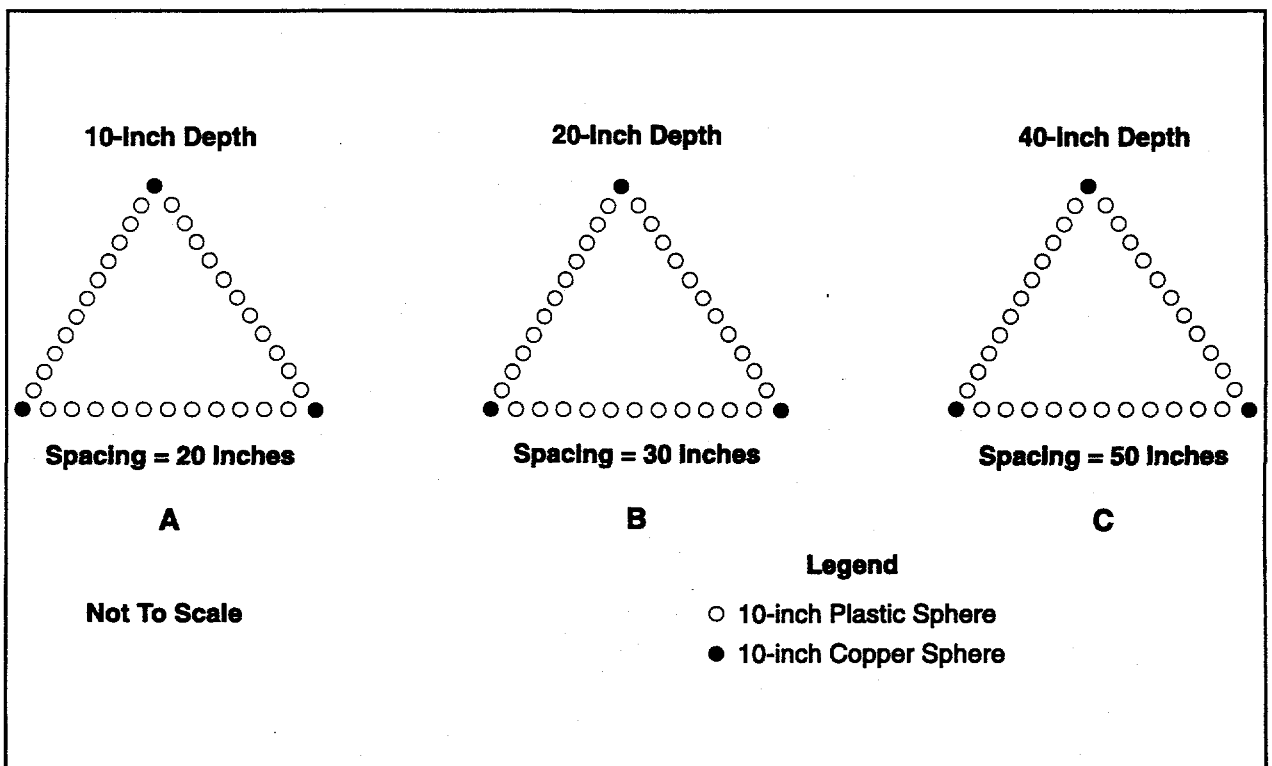


Figure 33. Deployment Pattern of Targets in Test Area 2

Table 4. Test Area 1 Target Information

Target	Description	Target Location	Orientation/Depth ± 1.3 cm
A	Steel pipe Diameter: 10.2 cm Length: 12.8 m	–395,–320	Vertical/22.9 cm to top
B	Steel pipe Diameter: 10.2 cm Length: 6.4 m	–335,–320	Horizontal, northeast-southwest/ 25.4 cm to top
C	Solid steel cylinder Diameter: 11.4 cm Length: 1.59 m	–275,–320	Dipping 67° to north/25.4 cm to top
D	Steel pipe wrapped with No. 12 AWG insulated wire at rate of 13 turns per meter: Diameter: 10.2 cm Length: 6.4 m	–365,–330	Horizontal, east-west/25.4 cm to top
E	Two-piece steel pipe welded end-to-end (length equals 12.8 m) Diameter: 10.2 cm Length: 6.4 m each pipe piece	–215,–320	Horizontal, east-west/44.5 cm to top
F	Two-piece steel pipe welded end-to-end (length equals 12.8 m) Diameter: 10.2 cm Length: 6.4 m each piece	–185,–320	Horizontal, north-south/62.2 cm to top
G	Solid steel cylinder Diameter: 11.4 cm Length: 1.59 m	–245,–320	Dipping 23° to south/25.4 cm to top
H	Six pieces of steel (piled in a pyramid) Diameter: 10.2 cm (each piece) Length: 6.4 m	–305,–320.5	East-west/27.9 cm to top of stack

Table 5. Test Area 2 Target Information

Target	Description	Spacing	Depth ± 1.3 cm
A	33 solid plastic spheres (bowling balls) Diameter: 20.3 cm, spaced 25.4 cm edge-to-edge	Diagram A in Figure 33	25.4 cm to topmost surface
B	33 solid plastic spheres (bowling balls) Diameter: 20.3 cm, spaced 50.8 cm edge-to-edge	Diagram B in Figure 33	50.8 cm to topmost surface
C	33 solid plastic spheres (bowling balls) Diameter: 20.3 cm, spaced 101.6 cm edge-to-edge	Diagram C in Figure 33	101.6 cm to topmost surface
D	3 hollow copper spheres Diameter: 25.4 cm Thickness: 1.5 millimeters (mm)	Diagram A in Figure 33	25.4 cm to topmost surface
E	3 hollow copper spheres Diameter: 25.4 cm Thickness 1.5 mm	Diagram B in Figure 33	50.8 cm to topmost surface
F	3 hollow copper spheres Diameter: 25.4 cm Thickness 1.5 mm	Diagram C in Figure 33	101.8 cm to topmost surface

Table 6. Test Area 3 Target Information

Target	Description	Target Location	Orientation/Depth ± 1.3 cm
A	Solid steel disk Diameter: 69.9 cm Thickness: 3.8 cm	–255,–390	Horizontal/25.4 cm
B	Hollow glass sphere Diameter: 25.4 cm Thickness: ≈ 2.5 millimeter (mm)	–260,–390	/25.4 cm
C	Hollow copper sphere Diameter: 25.4 cm Thickness: 1.5 mm	–265,–390	/25.4 cm
D	Hollow clay sphere Diameter: 25.4 cm Thickness: ≈ 5 mm	–270,–390	/25.4 cm
E	Hollow steel sphere Diameter: 25.4 cm Thickness: 3.3 mm	–275,–390	/25.4 cm
F	Solid steel disk Diameter: 69.9 cm Thickness: 3.8 cm	–255,–395	Horizontal/49.5 cm
G	Hollow glass sphere Diameter: 25.4 cm Thickness: ≈ 2.5 mm	–260,–395	/50.8 cm
H	Hollow copper sphere Diameter: 25.4 cm Thickness: 1.5 mm	–265,–395	/50.8 cm
I	Hollow clay sphere Diameter: 25.4 cm Thickness: ≈ 5 mm	–270,–395	/50.8 cm
J	Hollow steel sphere Diameter: 25.4 cm Thickness: 3.3 mm	–275,–395	/50.8 cm
K	Solid steel disk Diameter: 69.9 cm Thickness: 3.8 cm	–255,–400	Horizontal/99.1 cm
L	Hollow glass sphere Diameter: 25.4 cm Thickness: ≈ 2.5 mm	–260,–400	/101.6 cm
M	Hollow copper sphere Diameter: 25.4 cm Thickness: 1.5 mm	–265,–400	/101.6 cm
N	Hollow clay sphere Diameter: 25.4 cm Thickness: ≈ 5 mm	–270,–400	/91.4 cm
O	Hollow steel sphere Diameter: 25.4 cm Thickness: 3.3 mm	–275,–400	/104.1 cm

details of the targets. Spherical targets and steel disks were emplaced in auger holes and covered with the original blended and compacted soil.

D. Test Area 4 (Sand Pit)

Test Area 4 (Sand Pit) is one of two "soil swap" pits. It provides boundaries between dissimilar natural soils in addition to metal sheets and other targets. This pit is designed primarily for testing EM and electrical methods; seismic studies of the soil changes are also possible. The pit excavation is 50 m long by 30 m wide by 1.8 m deep in a clay host soil. Figure 34 shows the shape of the excavation bottom with elevation contours given relative to the surface at grid point (–260,–450). One end and one side have stepped vertical walls; the other end and other side have walls sloped at 45°. Figure 35 shows the surface of the Sand Pit after recontouring. Elevations are referenced to the same point (–260,–450). Table 7 presents coordinates, depths, and descriptions of targets; Figure A–4 (Appendix A) shows relative locations. The pit is backfilled with compacted sandy soil removed from the excavation for pit 5. Pit corner coordinates are southwest (–310,–445), and northwest (–310,–415), northeast (–260,–415), and southeast (–260,–445).

E. Test Area 5 (Clay Pit)

Test Area 5 (Clay Pit) is the other soil swap pit. It provides boundaries between two different natural soils in addition to metal sheets and other targets. This pit is designed primarily for testing EM and electrical methods; seismic studies of the soil changes are also possible. The pit excavation is 50 m long by 30 m wide by 1.8 m deep in a sandy host soil. One end and one side have stepped vertical walls, the other end and other side have walls sloped at 45°. Figure 36 presents the bottom surface elevation after excavation, while Figure 37 presents the upper surface after filling and recontouring. Table 8 presents coordinates, depths, and descriptions of targets. Figure A–5 (Appendix A) shows relative locations of the targets. The targets are covered with an 45.7-cm layer of compacted clayey soil removed from the excavation for pit 4. Pit corner coordinates are southwest (–400, –433), northwest (–400, –383), northeast (–370, –383), and southeast (–370, –433).

F. Test Area 6

Test Area 6 is designed to test magnetic and EM methods with spherical ferromagnetic bodies of different sizes emplaced at various spacings and depths. Figure A–6 (Appendix A) shows the layout of targets; Table 9 presents details of the targets. Targets were emplaced in augered boreholes and in a deep pit so that the uppermost portion of each target is the specified depth below the natural grade.

G. Test Area 7

Test Area 7 is designed to test GPR methods using nonmetallic pipes of different sizes. Figure A–7 shows the layout of the targets; Table 10 presents details of the targets. The pipes were emplaced in narrow trenches (similar to those excavated by a Ditch Witch) so that the upper surface is a specified depth below the natural grade.

H. Test Areas 8 and 9

Test Areas 8 and 9 are designed to test electrical and EM methods with underground electrical conductors. Test Area 8 contains an insulated copper wire with provision for grounding or not grounding the ends. Test Area 9 contains a bare copper wire grounded for its entire length. Figures A–8 and A–9 (Appendix A) show the layouts of Test Areas 8 and 9, respectively. Table 11 presents details of the targets.

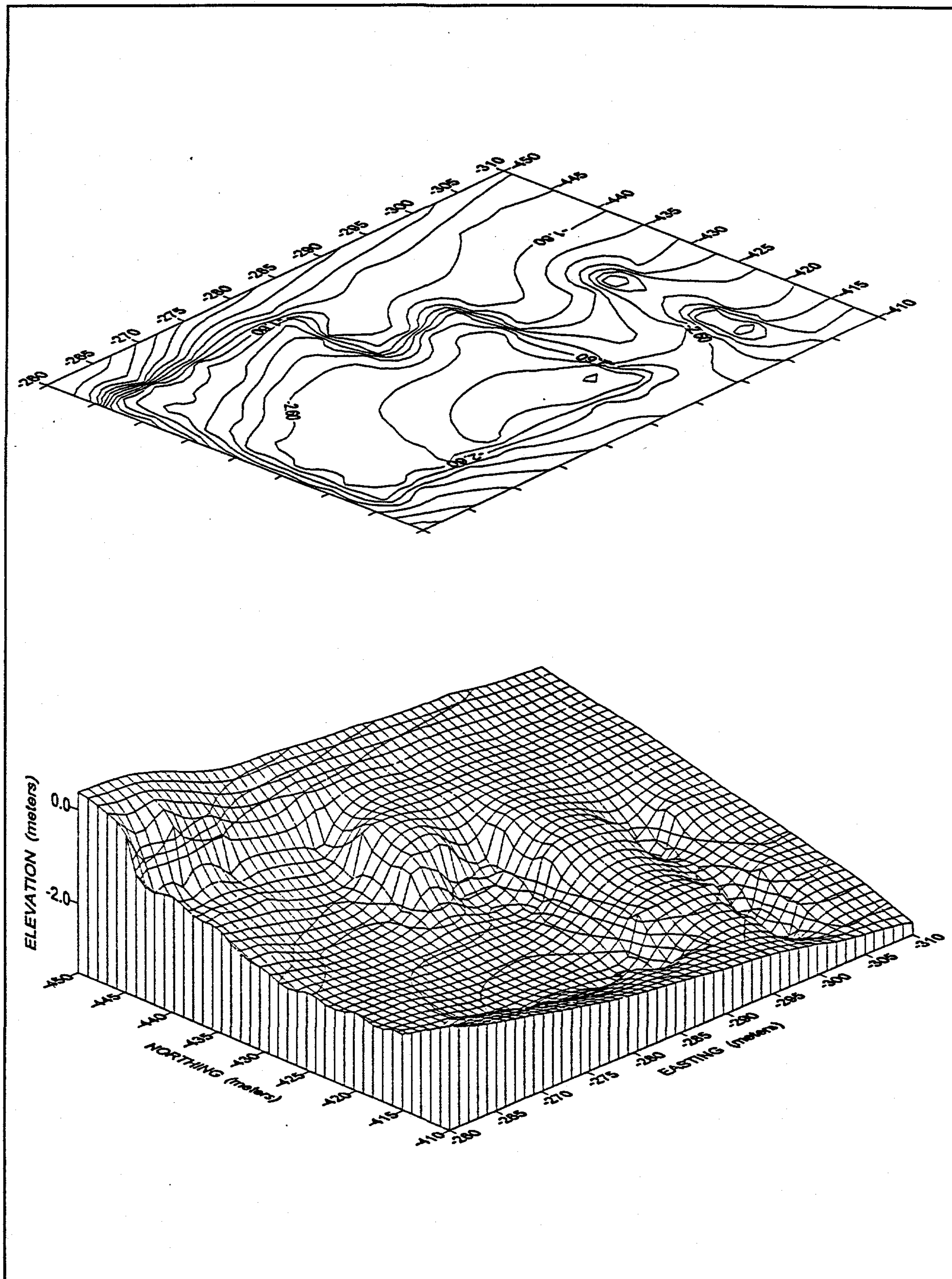


Figure 34. Bottom Surface of Sand Pit Excavation

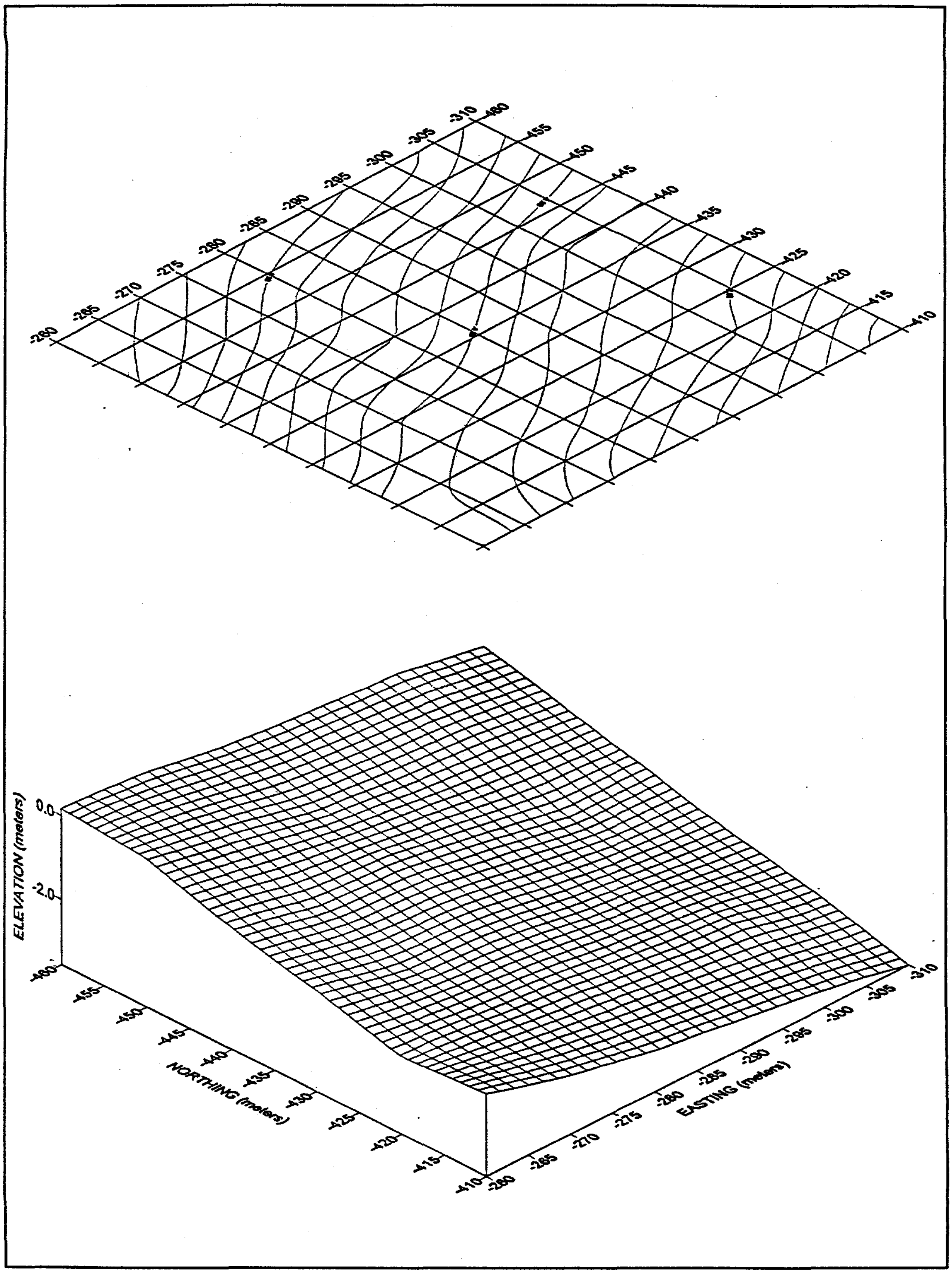


Figure 35. Upper Surface of Sand Pit After Recontouring

Table 7. Test Area 4 Target Information

Target	Description	Target Location	Orientation/Depth ± 10 cm
A	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–267,–427	Horizontal/55 cm
B	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–277,–427	Dipping 45° to north in east-west plane/ center at 78 cm
C	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–287,–427	Vertical in east-west plane/center at 88 cm
D	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–267,–437	Horizontal/64 cm
E	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–277,–437	Dipping 45° north in east-west plane/center at 81 cm
F	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–287,–437	Vertical in east-west plane/center at 98 cm
G	Steel cylinder Diameter: 9.5 cm Length: 1.19 m	–297,–437	Horizontal/50 cm axis north-south
H	Oil-filled bladder Length: 3.7 m Width: 2.6 m Height: 40.6 cm	–300,–421.5	3.7-m axis east-west/center at 64 cm

VI. Surveys by Other Users

Several other users conducted surveys at the Rabbit Valley GPER during fiscal year 1994. Personnel from the DOE Special Technologies Laboratory, Santa Barbara, California, conducted GPR surveys of the site with a stepped FM–CW GPR. They also sponsored an airborne GPR survey by Airborne Environmental Surveys of Santa Maria, California, and a vehicle-borne surface magnetic survey by Geo-Centers, Inc. of Newton Centre, Massachusettes. Personnel from Coleman Research Corporation, Orlando, Florida, collected data over five of the "old" targets at the Rabbit Valley GPER with their Earth Penetration Radar Imaging System (EPRIS), which is based on a frequency-stepped, phase-coherent radar with special data processing and imaging software. Students from Mesa State College, Grand Junction, Colorado, attended a geophysics "field camp" at the Rabbit Valley GPER and conducted surface magnetic, R/IP, IEM, and seismic surveys over the newly constructed Clay Pit area. The results of the first three (DOE-sponsored) surveys are documented in *Site Characterization at the Rabbit Valley Geophysics Performance Evaluation Range, Final Report* (February 1994), by Steven K. Koppenjan and Michael G. Martinez. Results of the Coleman tests are documented in *EPRIS Measurements Support, Final Report* (1994), prepared by the Coleman Research Corporation. Results of the Mesa State surveys have not yet been published.

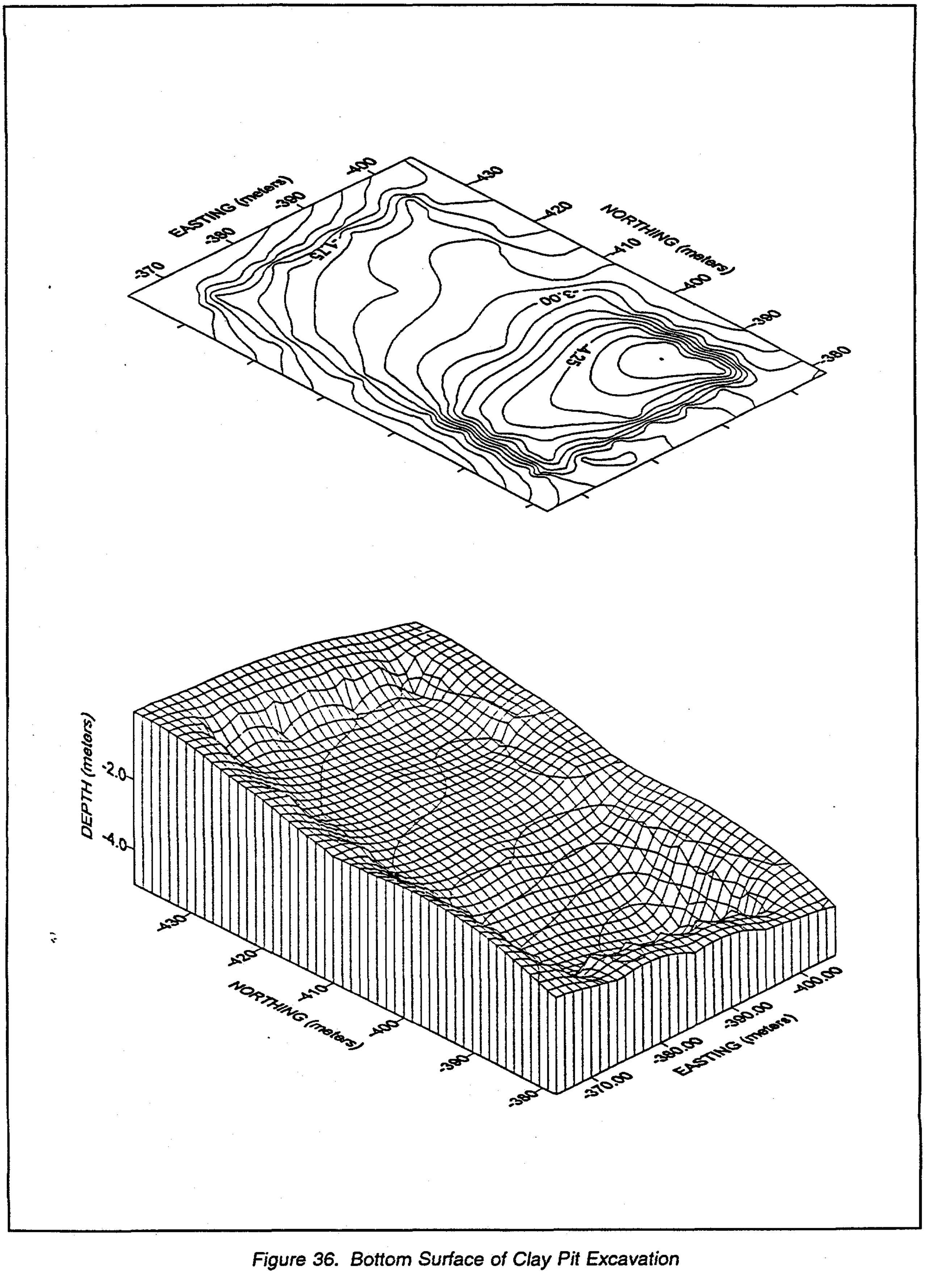


Figure 36. Bottom Surface of Clay Pit Excavation

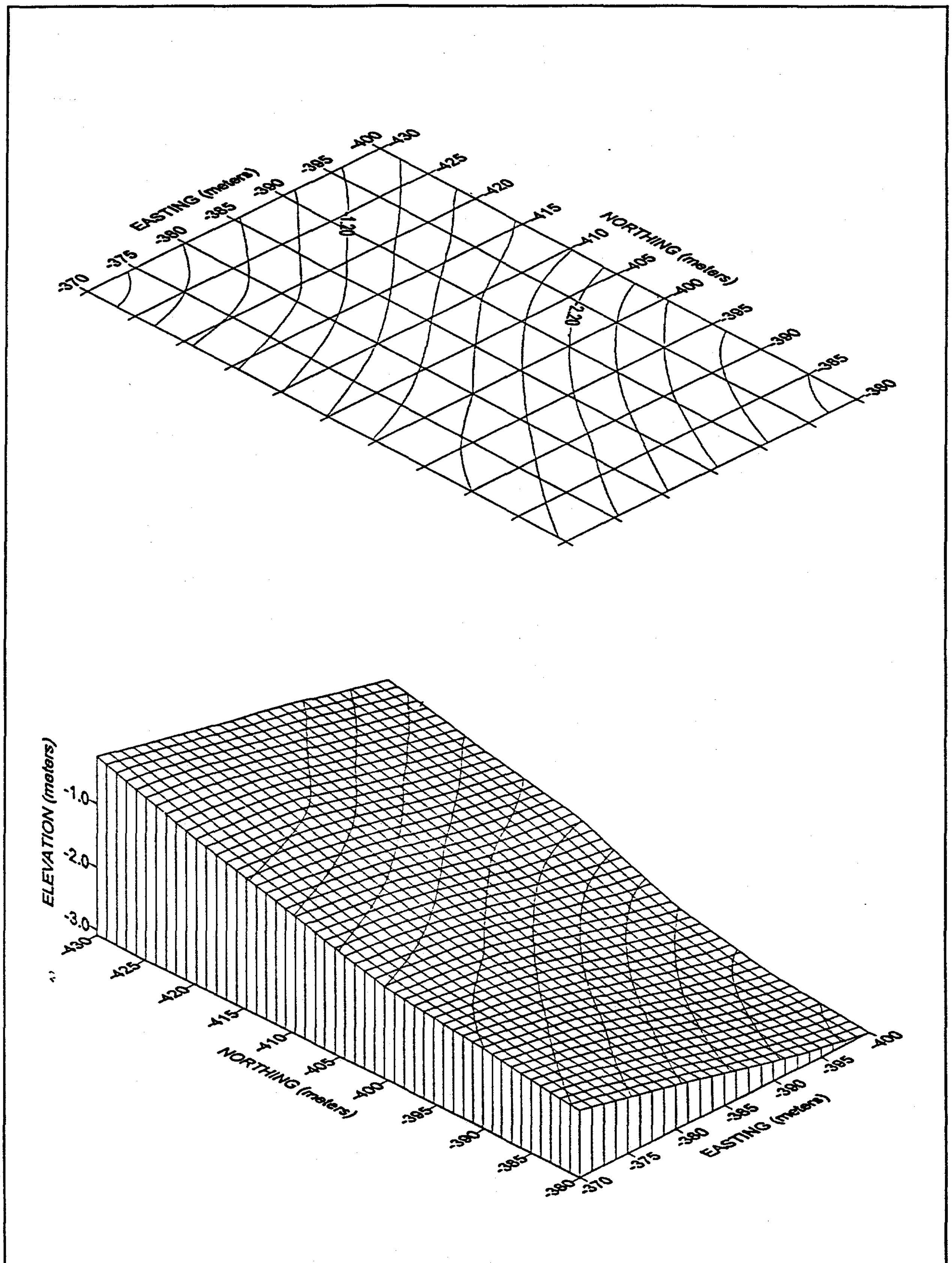


Figure 37. Upper Surface of Clay Pit After Recontouring

Table 8. Test Area 5 Target Information

Target	Description	Target Location	Orientation/Depth ± 10 cm
A	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–391,–394	Horizontal, edges north-south and east-west/73 cm
B	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–391,–407	Dipping 45° to north in east-west plane/center at 94 cm
C	Aluminum plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–391,–420	Vertical in east-west plane/center at 72 cm
D	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–381,–394	Horizontal, edges north-south and east-west/76 cm
E	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–381,–407	Dipping 45° to north in east-west plane/center at 88 cm
F	Steel plate Length: 1 m Width: 1 m Thickness: 1.3 cm	–381,–420	Vertical in east-west plane/center at 85 cm
G	Long steel cylinder Diameter: 9.6 cm Length: 1.2 m	–391,–430	Horizontal, axis east-west/94 cm
H	High stack of railroad ties Length: 2.7 m Width: 101.6 cm Height: 101.6 cm	–373,–429	2.4-m axis east-west/top 6 cm below surface
I	"Trash pit" filled with cinder blocks, wood blocks,, bricks, and metal 230-cm^3 cans randomly dispersed in 454.5 kilograms of silica sand Width: 61 cm Length: 91.4 cm Depth: 1.5 m	–397,–386	1.5 m to bottom, random placement of objects in sand fill, then fill to pit top surface

Table 9. Test Area 6 Target Information

Target	Description	Target Location	Depth ± 1.3 cm
A	Steel sphere Diameter: 50.8 cm Thickness: 3.3 millimeters (mm)	–251,–423	104.1 cm
B	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–251,–421	104.1 cm
C	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–241,–420	99.1 cm
D	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–240,–420	100.3 cm
E	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–238,–420	104.1 cm
F	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–234,–420	101.6 cm
G	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–230,–420	101 cm
H	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–220,–420	2.0 m
I	Steel sphere Diameter: 50.8 cm Thickness: 3.3 mm	–200,–420	2.5 m
J	Steel sphere Diameter: 25.4 cm Thickness: 3.3 mm	–200,–440	3.1 m
K	Steel sphere Diameter: 1.2 m Thickness: ≈ 9 mm	–200,–460	1.8 m

Table 10. Test Area 7 Target Information

Target	Description	Target Location	Depth ± 1.3 cm
A	PVC pipe Diameter: 5.1 cm Length: 3 m	–325,–330	25.4 cm
B	PVC pipe Diameter: 10.2 cm Length: 3 m	–335,–330	35.6 cm
C	PVC pipe Diameter: 20.3 cm Length: 3 m	–345,–330	50.8 cm

Table 11. Test Areas 8 and 9 Target Information

Area	Target Description	Wire End Location	Depth
8	Insulated No. 10 AWG copper wire with ends brought to surface with stakes for grounding, as desired Length of wire: 100 m	–410,–350 –410,–450	0.8 m
9	Bare No. 10 AWG copper wire Length of wire: 57 m	–400,–499 –343,–499	0.8 m

VII. References

Allen, J.W., 1990. *Ground-Penetrating Radar Studies*, prepared by UNC Geotech, Inc., for U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1992. *Ground-Penetrating Radar Detection of Buried Caches*, prepared by Chem-Nuclear Geotech, Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

Coleman Research Corporation, 1994. *EPRIS Measurements Support, Final Report*, prepared by the Coleman Research Corporation, Orlando, Florida, for the U.S. Department of the Army, Picatinny Arsenal, New Jersey, and U.S. Department of Energy Office of Technology Development.

Koppenjan, S.K., and Martinez, M.G., 1994. *Site Characterization at the Rabbit Valley Geophysics Performance Evaluation Range, Final Report*, prepared by EG&G Energy Measurements for the U.S. Department of Energy, Special Technologies Laboratory, Santa Barbara, Califormia, February.

Lesperance, L.R., to Dickerson, J.W., 1992. *Vegetation Assessment Findings and Revegetation Specifications for the Rabbit Valley Test Site*, Internal memorandum from Chem-Nuclear Geotech, Inc., Grand Junction, Colorado, May.

RUST Geotech Inc., 1992. *Rabbit Valley Geophysics Performance Evaluation Range (GPER), FY–1993 Technical Task Plan*, prepared by RUST Geotech Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1993a. *Initial Report: U.S. Department of Energy Geophysical Test Beds and Range Design Specifications for the Grand Junction Projects Office Rabbit Valley Geophysics Performance Evaluation Range*, prepared by RUST Geotech Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1993b. *Rabbit Valley Geophysics Performance Evaluation Range (GPER), FY–1994 Technical Task Plan*, prepared by RUST Geotech Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado.

____________, 1994a. *Analytical Report for Project 4RCMS2121 (Rabbit Valley GPER)*, prepared by Grand Junction Projects Office Analytical Laboratory, Grand Junction, Colorado, July.

____________, 1994b. *Minimum Drilling Health and Safety Requirements for Operation of Small Auger, Rotary, and Core Rigs*, P–GJPO–113 Rev. 3, prepared by RUST Geotech Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado, January.

____________, 1994c. *Rabbit Valley Geophysics Performance Evaluation Range (GPER) Health and Safety Plan*, prepared by RUST Geotech Inc. for the U.S. Department of Energy, Grand Junction Projects Office, Grand Junction, Colorado, March.

Sorter Construction Company, 1994a. *Health and Safety Attachment 1–12–94*, Revised April 25, 1994, Grand Junction, Colorado.

___________, 1994b. *Rabbit Valley Geophysics Performance Evaluation Range (GPER) Health and Safety Plan*, Sorter Construction Company, Grand Junction, Colorado, April.

___________, 1994c. *Safety Management Plan*, Revised April 1994, Sorter Construction Company, Grand Junction, Colorado.

VIII. Acknowledgments

The author acknowledges the contributions of many others who contributed to the successful completion of the Rabbit Valley GPER—the Geotech Geophysical Projects personnel who conceived the project, especially John Dickerson who initiated the plans; Geotech program managers; Geotech Health, Safety, and Security; Geotech Procurement; and the DOE–GJPO, DOE Albuquerque Operations Office, and DOE Headquarters for sponsoring and funding the GPER. The conscientious, hard workers of Sorter Construction Company who moved the dirt, planted the targets, and finished the construction on schedule and within budget. Thanks to Michael Cote who diligently monitored construction activities and recorded as-built data for this report.

Appendix A
Maps of Test Areas

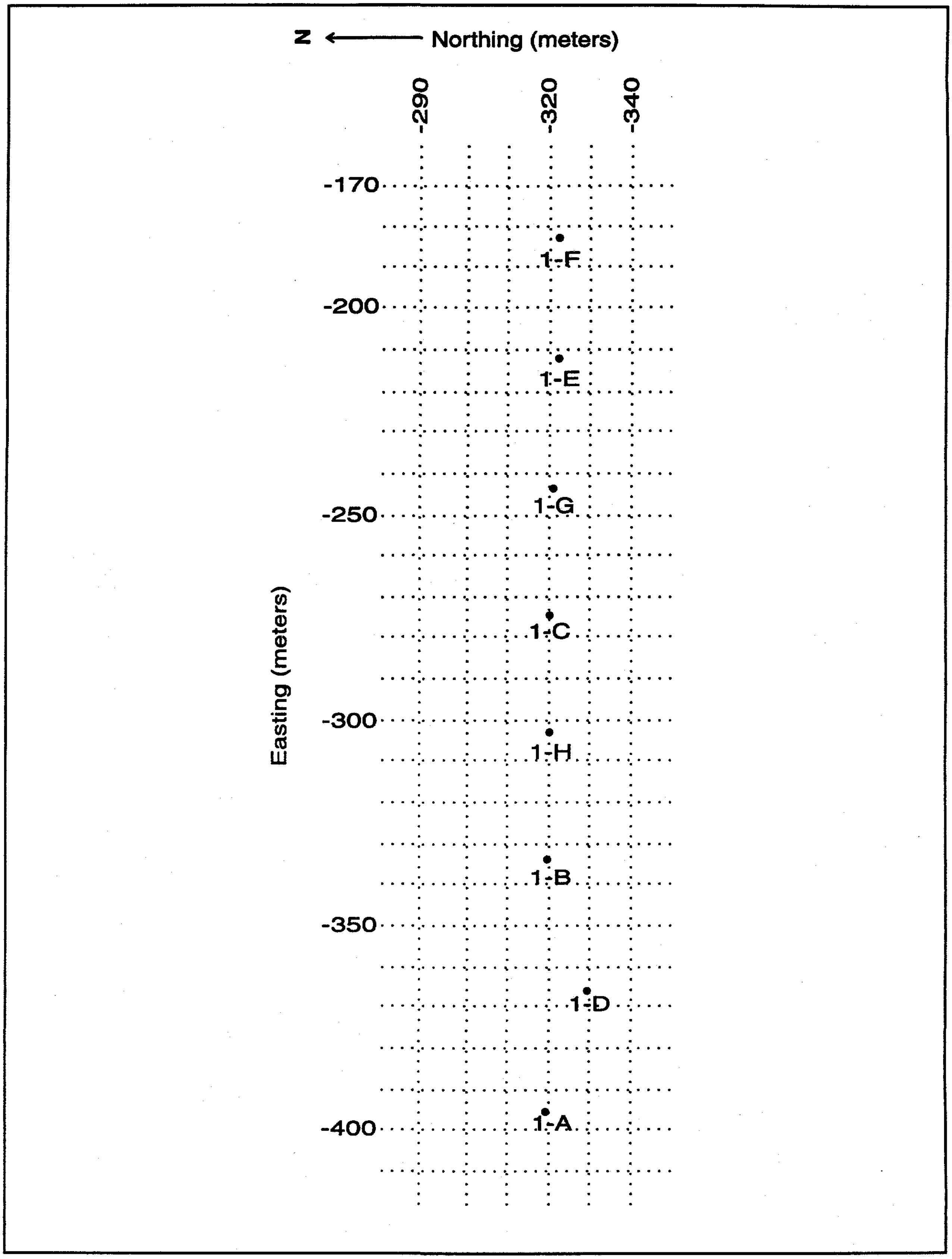


Figure A–1. Rabbit Valley GPER Area 1

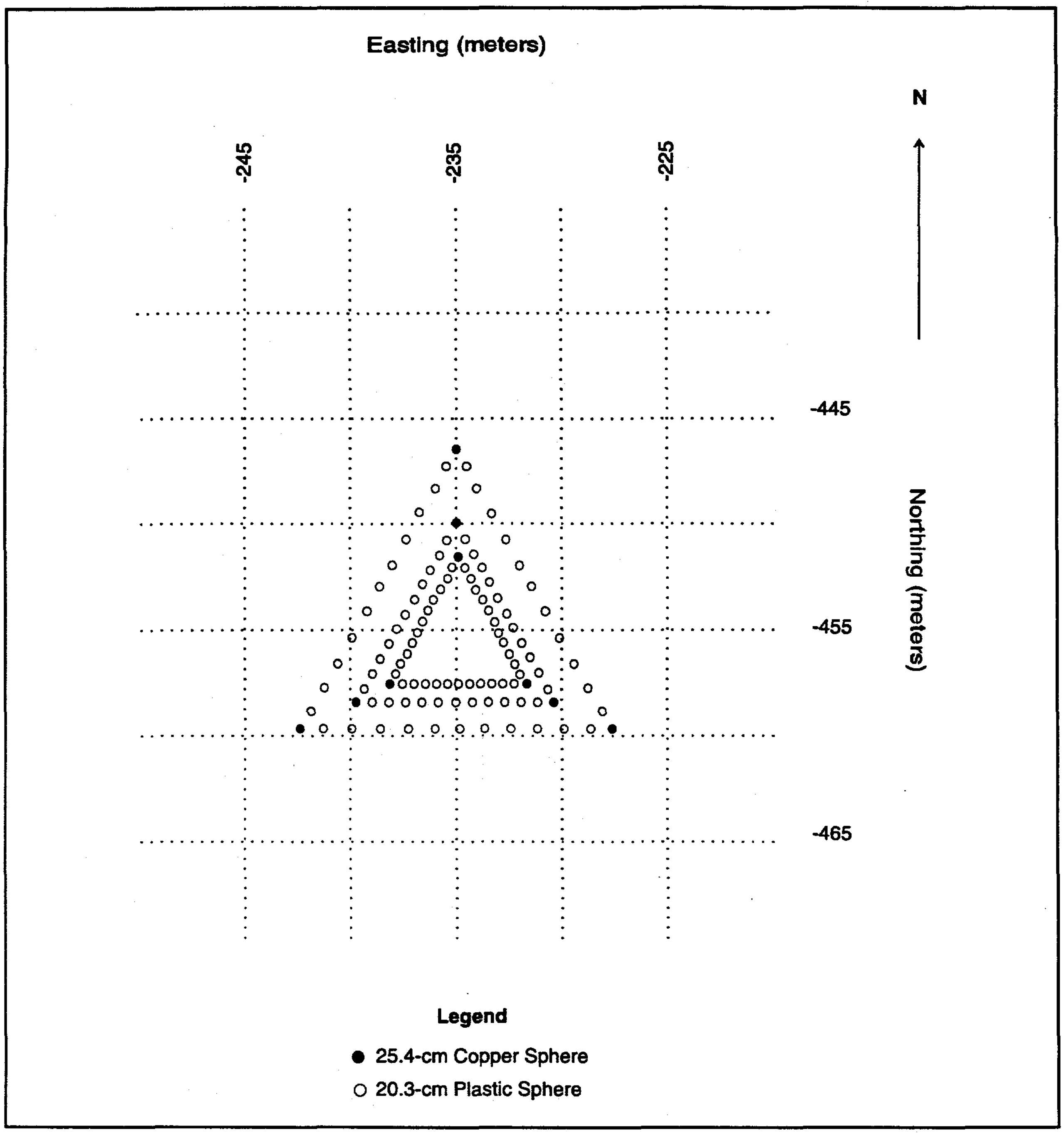


Figure A–2. Rabbit Valley GPER Area 2

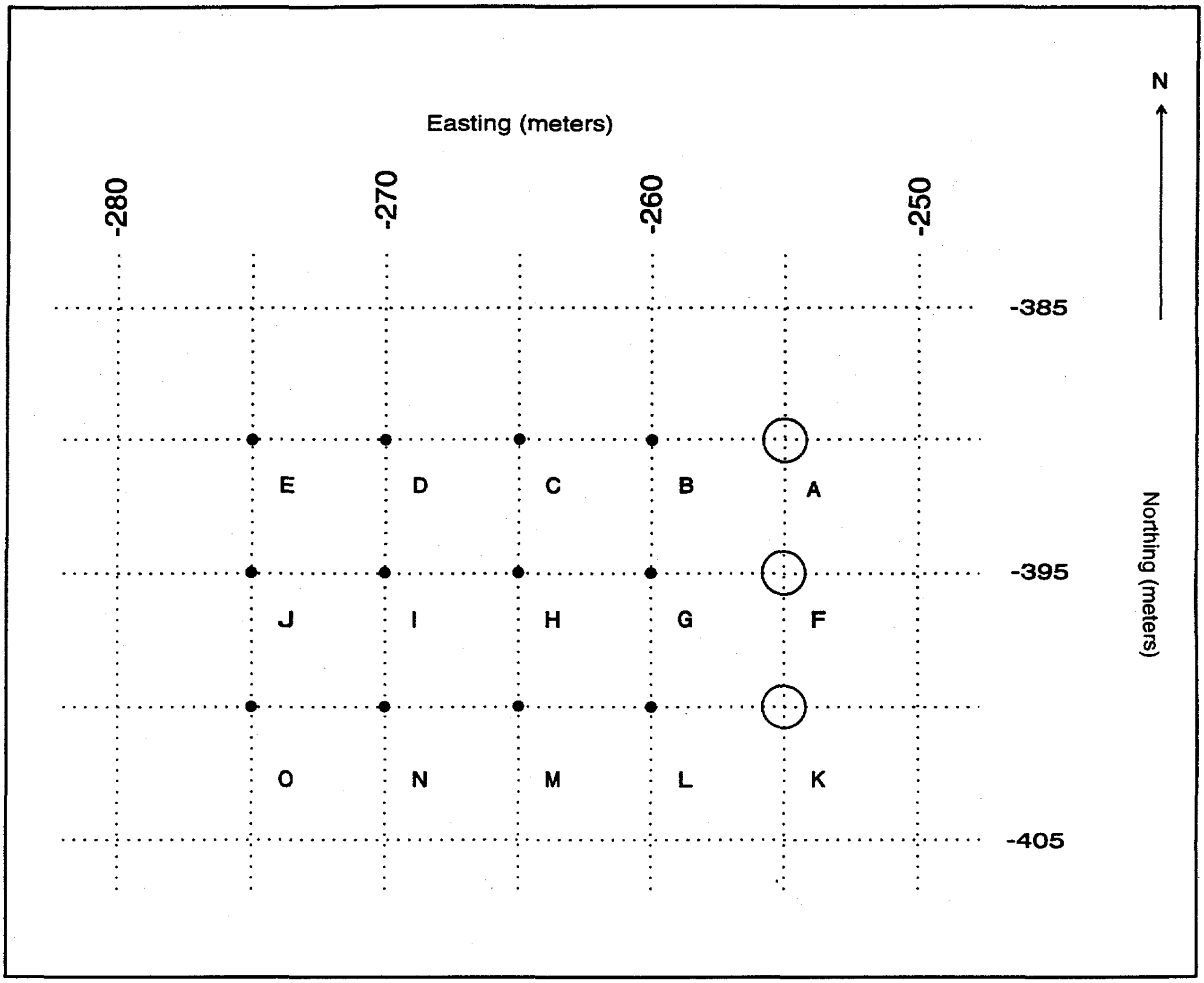


Figure A–3. Rabbit Valley GPER Area 3

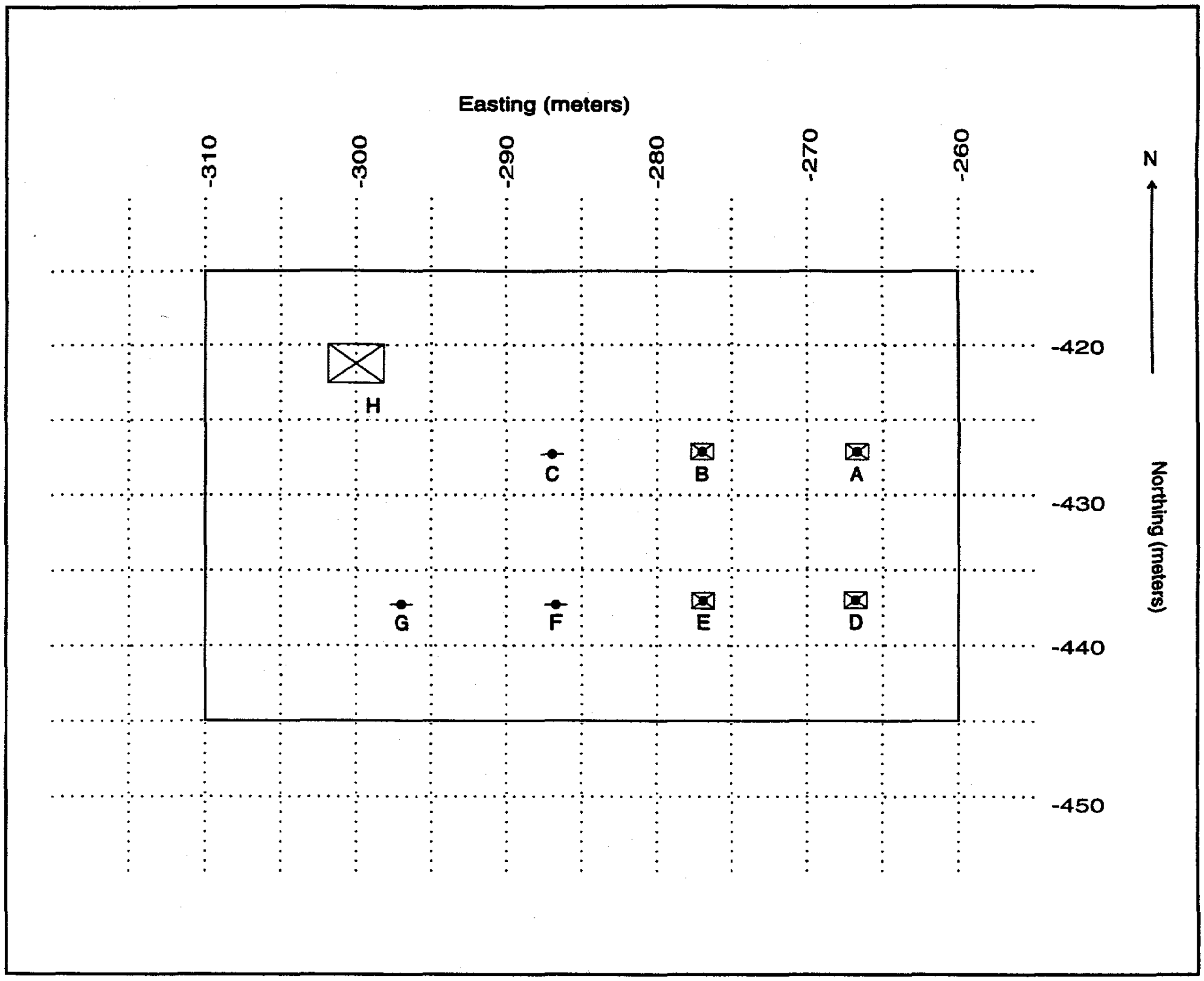


Figure A–4. Rabbit Valley GPER Area 4

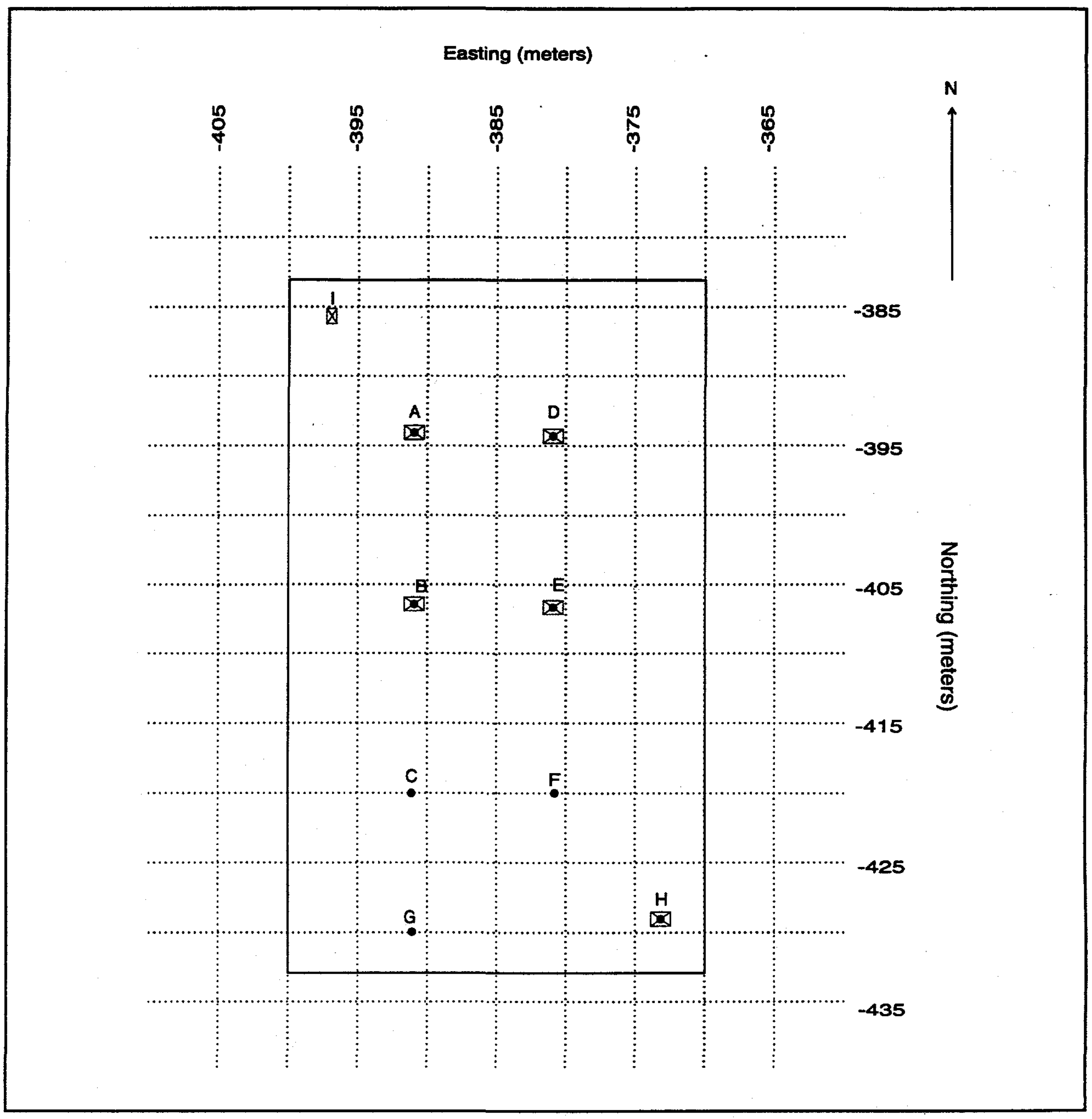


Figure A–5. Rabbit Valley GPER Area 5

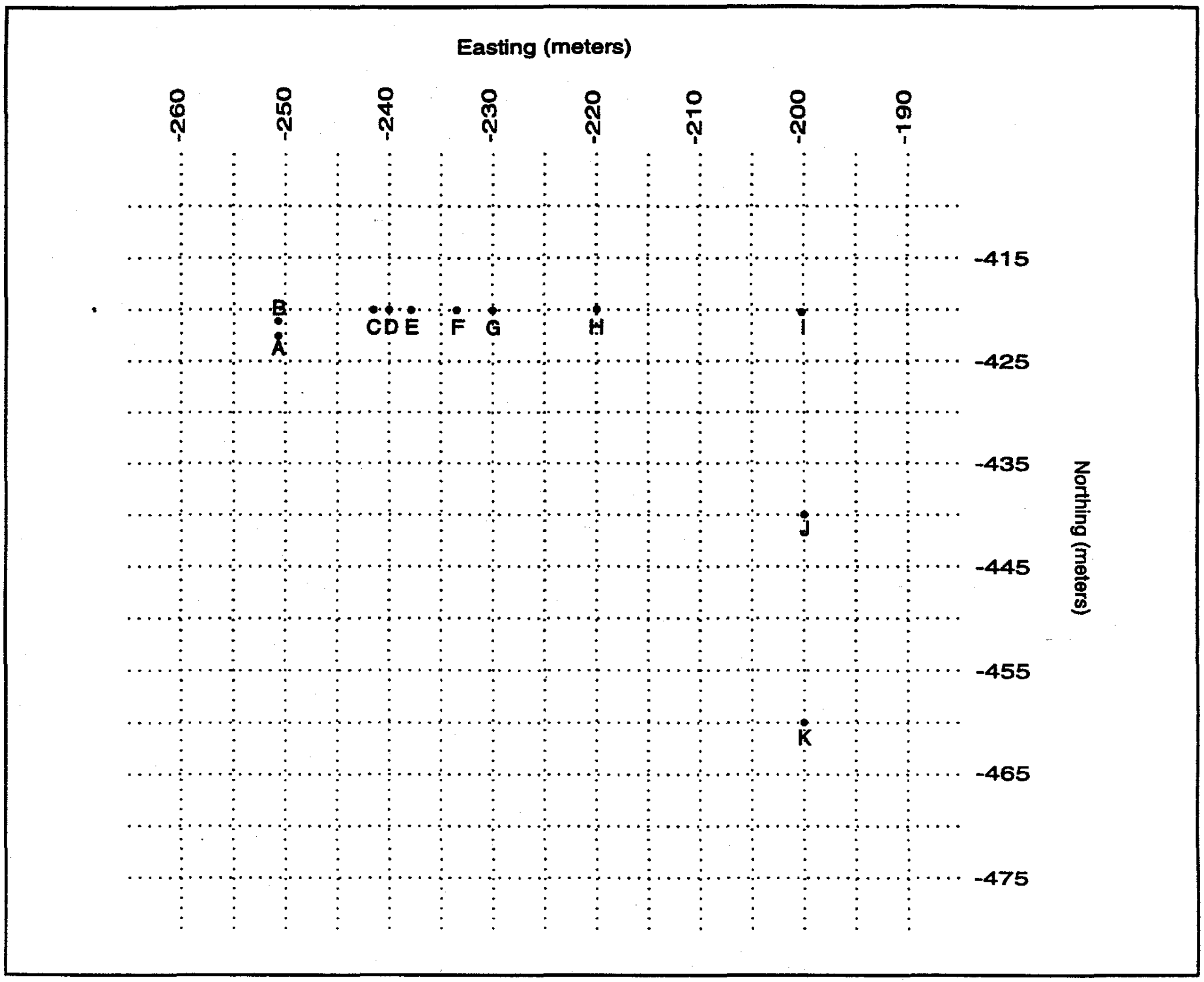


Figure A–6. Rabbit Valley GPER Area 6

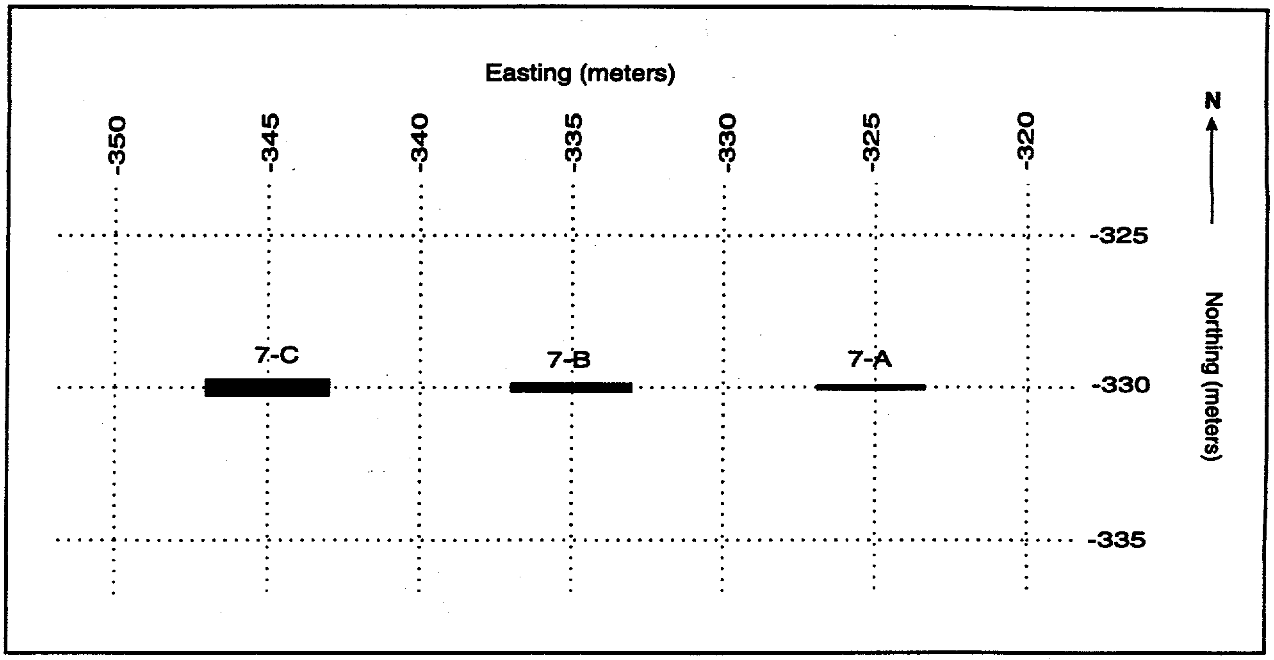


Figure A–7. Rabbit Valley GPER Area 7

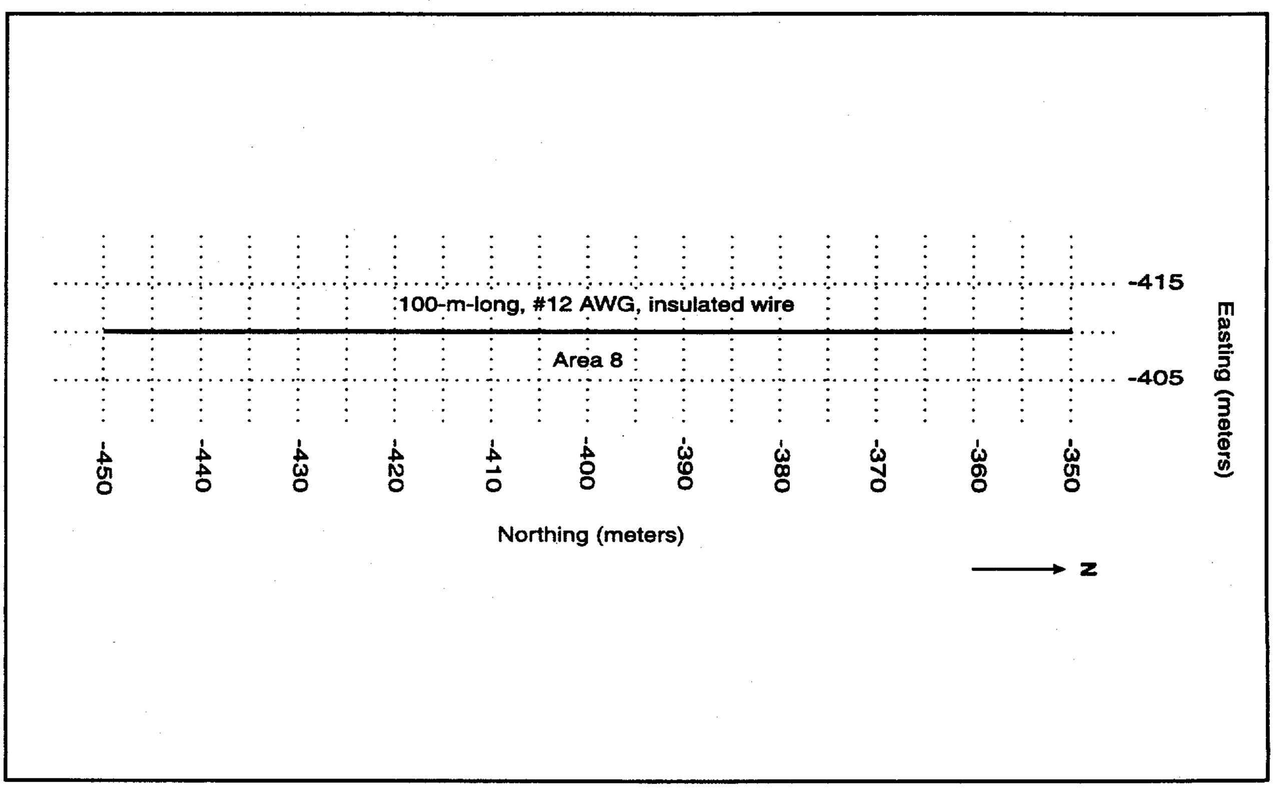


Figure A–8. Rabbit Valley GPER Area 8

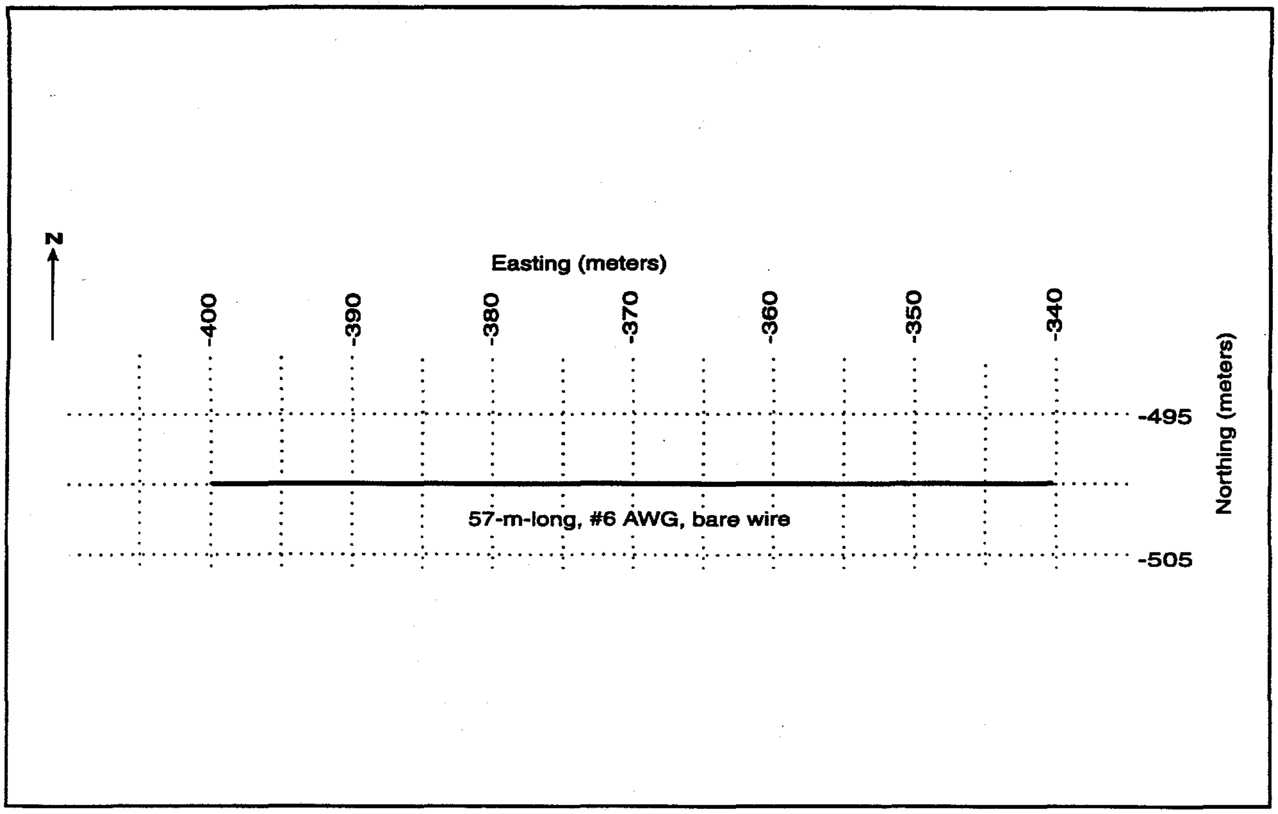


Figure A–9. Rabbit Valley GPER Area 9

Appendix B
Soil Sample Analysis Report

ANALYTICAL REPORT INDEX

Requisition: 12672 Project no.: 4RCMS2121

This report is the final data package for Requisition no. 12672 generated by the Petrology subsection of the Analytical Laboratory for a Program Development and Management research project. It is the official record and requestors are responsible for proper record-keeping in accordance with project requirements.

This report includes the following documents:

ANALYTICAL SUMMARY

This report contains the results of seven samples received under Project No. 4RCMS2121, Requisition no. 12672 on May 26, 1994.

The sample was submitted by Jim Allen for loss on drying, grain size analysis, bulk- and clay-mineral analysis using X-ray diffraction.

RELEASE OF THE DATA CONTAINED IN THIS PACKAGE HAS BEEN AUTHORIZED BY THE LABORATORY MANAGER OR THE MANAGER'S DESIGNEE.

Gerald L. Dulant For RBC 7/11/94
LABORATORY MANAGER DATE

7/5/94
PREPARED BY DATE

RESULTS

LOSS ON DRYING (LOD)

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: M2, REV 02

Lab ID	Sample Number	LOD Wt. %
219689	NCE 918	5.6
219690	NCE 919	6.9
219691	NCE 920	4.4
219692	NCE 921	6.9
219693	NCE 922	5.7
219694	NCE 923	8.5
219695	NCE 924	5.2

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

RESULTS

BULK X-RAY DIFFRACTION

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: XRD-02-83, REV 07

Sample Number	Mineral Name	Chemical Formula	PDF Card*	Abundance
NCE 918	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Moderate
	K-feldspar	$KAlSi_3O_8$	19- 932	Minor
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
	Kaolinite	$Al_2Si_2O_5(OH)_4$	14- 164	Trace
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace
NCE 919	Quartz	SiO_2	5- 490	Dominant
	K-feldspar	$KAlSi_3O_8$	19- 932	Minor
	Calcite	$CaCO_3$	5- 586	Minor
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
	Kaolinite	$Al_2Si_2O_5(OH)_4$	14- 164	Trace
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace
NCE 920	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Moderate
	K-feldspar	$KAlSi_3O_8$	19- 932	Minor
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
	Kaolinite	$Al_2Si_2O_5(OH)_4$	14- 164	Trace
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace

* Standard pattern from the Joint Committee on Powder Diffraction Standards

Explanation of Semiquantitative terms
Dominant - Predominant mineral in X-ray pattern
Subdominant - 70 to 99% of intensity of dominant phase
Moderate - 30 to 70% of intensity of dominant phase
Minor - 7 to 30% of intensity of dominant phase
Trace - <7% of intensity of dominant phase
n.d. - Not detected

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

RESULTS

BULK X-RAY DIFFRACTION

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: XRD-02-83, REV 07

Sample Number	Mineral Name	Chemical Formula	PDF Card*	Abundance
NCE 921	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Subdominant
	K-feldspar	$KAlSi_3O_8$	19- 932	Minor
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace
	Smectite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$	13- 259	Minor
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
NCE 922	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Minor
	K-feldspar	$KAlSi_3O_8$	19- 932	Trace
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
	Kaolinite	$Al_2Si_2O_5(OH)_4$	14- 164	Trace
NCE 923	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Subdominant
	Smectite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$	13- 259	Minor
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace

* Standard pattern from the Joint Committee on Powder Diffraction Standards

Explanation of Semiquantitative terms
Dominant - Predominant mineral in X-ray pattern
Subdominant - 70 to 99% of intensity of dominant phase
Moderate - 30 to 70% of intensity of dominant phase
Minor - 7 to 30% of intensity of dominant phase
Trace - <7% of intensity of dominant phase
n.d. - Not detected

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

RESULTS

BULK X-RAY DIFFRACTION

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: XRD-02-83, REV 07

Sample Number	Mineral Name	Chemical Formula	PDF Card*	Abundance
NCE 924	Quartz	SiO_2	5- 490	Dominant
	Calcite	$CaCO_3$	5- 586	Moderate
	K-feldspar	$KAlSi_3O_8$	19- 932	Trace
	Plagioclase	$(Na,Ca)Al(Al,Si)Si_2O_8$	10- 393	Trace
	Illite	$(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$	26- 911	Trace
	Kaolinite	$Al_2Si_2O_5(OH)_4$	14- 164	Trace

* Standard pattern from the Joint Committee on Powder Diffraction Standards

Explanation of Semiquantitative terms
Dominant - Predominant mineral in X-ray pattern
Subdominant - 70 to 99% of intensity of dominant phase
Moderate - 30 to 70% of intensity of dominant phase
Minor - 7 to 30% of intensity of dominant phase
Trace - <7% of intensity of dominant phase
n.d. - Not detected

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

RESULTS

CLAY MINERAL ANALYSIS

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: CMA-05-92, REV. 00

Sample NCE 918

Illite (Dominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Randomly interstratified illite/smectite (Subdominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$ / $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Chlorite (Minor)
Chemical formula: $(Mg,Fe)_5Al(Si,Al)_{10}(OH)_8$

Sample NCE 919

Illite (Dominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Randomly interstratified illite/smectite (Subdominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$ / $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Chlorite (Minor)
Chemical formula: $(Mg,Fe)_5Al(Si,Al)_{10}(OH)_8$

Explanation of Semiquantitative terms

Dominant	- Predominant mineral in X-ray pattern
Subdominant	- 70 to 99% of intensity of dominant phase
Moderate	- 30 to 70% of intensity of dominant phase
Minor	- 7 to 30% of intensity of dominant phase
Trace	- <7% of intensity of dominant phase
n.d.	- Not detected

7/5/94

Larry M. Fukui, Sr. Staff Scientist   Date

RESULTS

CLAY MINERAL ANALYSIS

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: CMA-05-92, REV. 00

Sample NCE 920

Randomly interstratified illite/smectite (Dominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$ / $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Illite (Subdominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Chlorite (Trace)
Chemical formula: $(Mg,Fe)_5Al(Si,Al)_{10}(OH)_8$

Sample NCE 921

Smectite (Dominant)
Chemical formula: $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Illite (Moderate)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Explanation of Semiquantitative terms

Dominant	- Predominant mineral in X-ray pattern
Subdominant	- 70 to 99% of intensity of dominant phase
Moderate	- 30 to 70% of intensity of dominant phase
Minor	- 7 to 30% of intensity of dominant phase
Trace	- <7% of intensity of dominant phase
n.d.	- Not detected

Larry M. Fukui — 7/5/94

Larry M. Fukui, Sr. Staff Scientist — Date

RESULTS

CLAY MINERAL ANALYSIS

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: CMA-05-92, REV. 00

<u>Sample NCE 922</u>

Randomly interstratified illite/smectite (Dominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$ / $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Illite (Subdominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Chlorite (Trace)
Chemical formula: $(Mg,Fe)_5Al(Si,Al)_{10}(OH)_8$

<u>Sample NCE 923</u>

Smectite (Dominant)
Chemical formula: $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Illite (Moderate)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

<u>Explanation of Semiquantitative terms</u>

Dominant	- Predominant mineral in X-ray pattern
Subdominant	- 70 to 99% of intensity of dominant phase
Moderate	- 30 to 70% of intensity of dominant phase
Minor	- 7 to 30% of intensity of dominant phase
Trace	- <7% of intensity of dominant phase
n.d.	- Not detected

Larry M. Fukui — 7/5/94

Larry M. Fukui, Sr. Staff Scientist   Date

RESULTS

CLAY MINERAL ANALYSIS

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: CMA-05-92, REV. 00

<u>Sample NCE 924</u>

Illite (Dominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$

Randomly interstratified illite/smectite (Subdominant)
Chemical formula: $(K,H_3O)(Al,Mg,Fe)_2(Al,Si)_4O_{10}[(OH)_2,H_2O]$ / $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}\cdot nH_2O$

Kaolinite (Moderate)
Chemical formula: $Al_2Si_2O_5(OH)_4$

Chlorite (Minor)
Chemical formula: $(Mg,Fe)_5Al(Si,Al)_{10}(OH)_8$

<u>Explanation of Semiquantitative terms</u>
Dominant - Predominant mineral in X-ray pattern
Subdominant - 70 to 99% of intensity of dominant phase
Moderate - 30 to 70% of intensity of dominant phase
Minor - 7 to 30% of intensity of dominant phase
Trace - <7% of intensity of dominant phase
n.d. - Not detected

Larry M. Fukui, Sr. Staff Scientist 7/5/94
Date

GRAIN SIZE RESULTS

SAMPLE NCE 918

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	15.77	19.44
1	35	0.50 - 1.00	6.13	7.55
2	60	0.25 - 0.50	5.96	7.35
3	120	0.125 - 0.25	14.02	17.28
4	230	0.0625 - 0.125	21.28	26.63
5	PAN	<0.0625	17.98	22.16

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-1.80	-0.40	0.70	2.90	3.90	4.30	4.75

Statistical Parameters of Grain Size

Graphic Mean (M_Z) = 2.27ϕ = 0.21 mm
Fine sand
Inclusive Graphic Standard Deviation (σ_I) = 2.17ϕ = 0.22 mm
Very poorly sorted
Inclusive Graphic Skewness (Sk_I) = -0.42
Strongly coarse skewed
Graphic Kurtosis (K_G) = 0.84
Platykurtic

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	13.68
<0.0020 (clay)	8.48
Total*	22.16

* Pan fraction in sieve analysis, above.

Larry M. Fukui, Sr. Staff Scientist 7/5/94
Date

GRAIN SIZE RESULTS

SAMPLE NCE 919

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

φ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	9.36	9.04
1	35	0.50 - 1.00	8.27	7.99
2	60	0.25 - 0.50	12.19	11.77
3	120	0.125 - 0.25	24.52	23.68
4	230	0.0625 - 0.125	29.92	28.89
5	PAN	<0.0625	19.29	18.63

Data points from graph of cumulative percent vs grain size in phi (φ)

φ @ 5%	φ @ 16%	φ @ 25	φ @ 50	φ @ 75	φ @ 84	φ @ 95
-0.70	0.90	1.80	2.90	3.75	4.10	4.70

Statistical Parameters of Grain Size

Graphic Mean (M_z) = 2.63φ = 0.16 mm
Fine sand
Inclusive Graphic Standard Deviation (σ_I) = 1.62φ = 0.32 mm
Poorly sorted
Inclusive Graphic Skewness (Sk_I) = -0.29
Coarse skewed
Graphic Kurtosis (K_G) = 1.13
Leptokurtic
JL 7/8/94

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	12.67
<0.0020 (clay)	5.96
Total*	18.63

* Pan fraction in sieve analysis, above.

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

GRAIN SIZE RESULTS

SAMPLE NCE 920

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	15.56	12.91
1	35	0.50 - 1.00	13.52	11.22
2	60	0.25 - 0.50	18.94	15.72
3	120	0.125 - 0.25	23.59	19.58
4	230	0.0625 - 0.125	31.69	26.30
5	PAN	<0.0625	17.20	14.27

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-0.80	0.30	1.00	2.65	3.55	3.90	4.60

Statistical Parameters of Grain Size

Graphic Mean (M_Z) Fine sand	=	2.28ϕ	= 0.20 mm
Inclusive Graphic Standard Deviation (σ_I) Poorly Sorted	=	1.72ϕ	= 0.30 mm
Inclusive Graphic Skewness (Sk_I) Coarse skewed	=	-0.29	
Graphic Kurtosis (K_G) Platykurtic	=	0.87	

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	8.24
<0.0020 (clay)	6.03
Total*	14.27

* Pan fraction in sieve analysis, above.

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

GRAIN SIZE RESULTS

SAMPLE NCE 921

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	43.26	54.82
1	35	0.50 - 1.00	9.21	11.67
2	60	0.25 - 0.50	4.67	5.92
3	120	0.125 - 0.25	5.17	6.55
4	230	0.0625 - 0.125	6.18	7.83
5	PAN	<0.0625	10.42	13.20

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-3.80	-3.00	-2.30	-0.40	2.30	3.70	4.60

Statistical Parameters of Grain Size

Graphic Mean (M_z) Medium sand	= 0.10ϕ	= 0.46 mm
Inclusive Graphic Standard Deviation (σ_I) Very poorly sorted	= 2.95ϕ	= 0.13 mm
Inclusive Graphic Skewness (Sk_I) Fine skewed	= 0.21	
Graphic Kurtosis (K_G) Platykurtic	= 0.75	

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	6.81
<0.0020 (clay)	6.39
Total*	13.20

* Pan fraction in sieve analysis, above.

7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

GRAIN SIZE RESULTS

SAMPLE NCE 922

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	7.67	9.02
1	35	0.50 - 1.00	5.94	6.99
2	60	0.25 - 0.50	9.63	11.33
3	120	0.125 - 0.25	19.39	22.81
4	230	0.0625 - 0.125	23.04	27.11
5	PAN	<0.0625	19.33	22.74

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-0.70	1.00	1.80	3.00	3.90	4.30	4.80

Statistical Parameters of Grain Size

Graphic Mean (M_Z) = 2.77ϕ = 0.14 mm
Fine sand
Inclusive Graphic Standard Deviation (σ_I) = 1.66ϕ = 0.31 mm
Poorly Sorted
Inclusive Graphic Skewness (Sk_I) = -0.28
Coarse Skewed
Graphic Kurtosis (K_G) = 1.07
Mesokurtic (normal distribution)

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	15.49
<0.0020 (clay)	7.25
Total*	22.74

* Pan fraction in sieve analysis, above.

Larry M. Fukui 7/5/94
Larry M. Fukui, Sr. Staff Scientist Date

GRAIN SIZE RESULTS

SAMPLE NCE 923

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	44.88	58.52
1	35	0.50 - 1.00	15.24	19.87
2	60	0.25 - 0.50	5.44	7.09
3	120	0.125 - 0.25	3.36	4.38
4	230	0.0625 - 0.125	2.70	3.52
5	PAN	<0.0625	5.07	6.61

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-1.90	-1.55	-1.20	-0.30	0.75	1.70	4.20

Statistical Parameters of Grain Size

Graphic Mean (M_z) = -0.05ϕ = 1.02 mm
Very coarse sand (hard shale grains)
Inclusive Graphic Standard Deviation (σ_I) = 1.74ϕ = 0.29 mm
Poorly sorted
Inclusive Graphic Skewness (Sk_I) = 0.35
Strongly fine skewed
Graphic Kurtosis (K_G) = 1.28
Leptokurtic

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	3.24
<0.0020 (clay)	3.37
Total*	6.61

* Pan fraction in sieve analysis, above.

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date

GRAIN SIZE RESULTS

SAMPLE NCE 924

REQUESTED BY: JIM ALLEN
PROJECT NO.: 4RCMS2121
DATE: JULY 5, 1994

REQUISITION NO.: 12672
SITE: RABBIT VALLEY
PROCEDURE: SA-02-83, REV. 05

Sieve Analysis

ϕ	Mesh	Grain Size (mm)	Weight (grams)	Weight Percent
0	18	>1.00	12.56	10.69
1	35	0.50 - 1.00	12.96	11.03
2	60	0.25 - 0.50	14.32	12.18
3	120	0.125 - 0.25	20.61	17.54
4	230	0.0625 - 0.125	26.19	22.28
5	PAN	<0.0625	30.89	26.28

Data points from graph of cumulative percent vs grain size in phi (ϕ)

ϕ @ 5%	ϕ @ 16%	ϕ @ 25	ϕ @ 50	ϕ @ 75	ϕ @ 84	ϕ @ 95
-0.60	0.45	1.30	2.90	4.05	4.40	4.80

Statistical Parameters of Grain Size

Graphic Mean (M_z) = 2.58ϕ = 0.17 mm
Fine sand
Inclusive Graphic Standard Deviation (σ_I) = 1.81ϕ = 0.28 mm
Poorly sorted
Inclusive Graphic Skewness (Sk_I) = -0.27
Coarse skewed
Graphic Kurtosis (K_G) = 0.80
Platykurtic

Pipette Analysis

Grain Size (mm)	Weight Percent
0.0020 - 0.0625 (silt)	17.83
<0.0020 (clay)	8.45
Total*	26.28

* Pan fraction in sieve analysis, above.

Larry M. Fukui 7/5/94

Larry M. Fukui, Sr. Staff Scientist Date