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Integrated Geophysical Investigation
MDA C & MDA H
Los Alamos National Laboratory
Los Alamos, New Mexico

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Prepared for:
Los Alamos National Laboratory ER Project

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1.0 EXECUTIVE SUMMARY

Advanced Geological Services, Inc. (AGS) performed an integrated geophysical survey for Los Alamos National Laboratory (LANL) at the MDA C (TA-50) and MDA H (TA-54) sites. The field surveys were performed during August 21 through September 9, 2001. The objectives of the surveys were to delineate existing disposal pits and shafts and to map the thickness of cover materials at each site. To achieve these objectives, an integrated geophysical investigation was performed using terrain conductivity (EM31), high-sensitivity metal detector (EM61), and digital ground-penetrating radar (GPR) techniques. In addition, the dipole-dipole electrical resistivity technique was tested at MDA C to determine its effectiveness at determining the thickness of cover materials.

The EM31 results from MDA C show east-west trending conductivity anomalies that are generally coincident with the suspected pit locations. Lateral variations within the interpreted pit locations indicate changes in fill cover and heterogeneity of buried materials. At the majority of suspected shaft locations, no consistent anomalies were observed that could be confidently attributed to the shafts. The lack of anomalies at these locations suggests either that the shafts do not exist at the locations shown or that there are insufficient contrasts in the upper 10 ft of materials.

Similar to the EM31 data, the EM61 data shows high amplitude anomalies at Pit No. 5. This suggests that the majority of the metal objects buried at the site are contained in the southern portion of Pit No. 5. Small and randomly scattered metal objects are observed throughout the remaining pit locations. The interpreted pit boundaries based on the EM61 and EM31 data show good correlation. However, there is a 40-ft discrepancy between these boundaries and the historical data.

The minimum and maximum cover thicknesses are 0.0 and 8.76 ft, respectively. The estimated volume of cover materials is approximately 61,800 cu. yd.

At MDA H, no conductivity anomalies were observed that could be confidently attributed to the suspected shafts. EM61 anomalies caused by metal objects are observed at four shaft locations. The locations of these anomalies are slightly offset from the suspected locations. The GPR data were successfully used to map the locations of 8 out of 9 shafts at the site. The thickness of cover materials was also mapped and the results indicate the cover thickness is less than 2 ft over the majority of the site. The thickness of cover material over the interpreted shaft locations range from 2 ft to 6.5 ft.

2.0 INTRODUCTION

Advanced Geological Services, Inc. (AGS) performed an integrated geophysical survey for Los Alamos National Laboratory (LANL) at the MDA C (TA-50) and MDA H (TA-54) sites. The field surveys were performed during August 21 through September 9, 2001. The objectives of the surveys were to delineate existing disposal pits and shafts and to map the thickness of cover materials at each site. To achieve these objectives, an integrated geophysical investigation was performed using terrain conductivity (EM31), high-sensitivity metal detector (EM61), and digital ground-penetrating radar (GPR) techniques. In addition, the dipole-dipole electrical resistivity technique was tested at MDA C to determine its effectiveness at determining the thickness of cover materials.

High-resolution EM31 and EM61 data were acquired to provide very detailed coverage of each site. These data were used to identify anomalies associated with disposal areas and buried metal objects. This information was used to strategically direct the subsequent GPR survey by analyzing and mapping the locations of EM anomalies such as those caused by disturbed ground and buried waste. The integrated use of these techniques produced a complementary effect, which resulted in higher confidence levels and more complete subsurface information.

3.0 BACKGROUND

3.1. MDA C SITE

MDA C at TA-50 was used to dispose uncontaminated classified materials, inorganic chemicals, hazardous chemicals, and radionuclides from 1948 to 1974. MDA C comprises 11.8 fenced acres where 7 pits and 108 shafts were excavated into the overlying soil and tuff. After each pit or shaft was filled to capacity with waste, it was backfilled to ground level with crushed tuff. In 1984, most of MDA C was covered with crushed tuff and topsoil and seeded with grass.

3.2. MDA H SITE

MDA H at TA-54 was used for the disposal of classified solid-form waste between 1960 and 1986. MDA H consists of nine 60-ft deep disposal shafts located on a 0.3-acre site. When filled to within 6 ft of the surface, 3 ft of crushed tuff backfill was placed in the shaft followed by an additional 3 ft thick concrete cap, except for shaft 9 which was covered with 6 ft of concrete. A significant mass of the material disposed in the shafts was metal shapes.

4.0 METHODOLOGY

4.1. GEODETIC POSITIONING

All geophysical instruments were integrated with a differential global positioning (DGPS) system to allow real-time navigation, provide accurate location of geophysical measurements, eliminate the need to establish a local reference grid, and allow direct integration with LANL's geographic information system (GIS). The geographic positions of all measurement points were acquired as the geophysical data were collected. The data were acquired using a Trimble Pathfinder Pro XRS system, which allowed accurate positioning with real-time accuracy better than 1 meter.

4.2. TERRAIN CONDUCTIVITY (EM31)

4.2.1. Data Collection

The terrain conductivity method uses the principle of electromagnetic induction to measure the electrical conductivity of earth/fill materials. Lateral changes in terrain conductivity can indicate the presence of disturbed ground, disposal areas, buried metallic and non-metallic waste, and impacted ground water. In addition, it is also useful in detecting linear objects such as utilities.

A Geonics EM31-MK2 was used to conduct the survey. The EM31 operates in accordance with the theory of operation at low induction numbers. An alternating current is passed through transmitter coil to induce eddy currents into the ground below the instrument. These eddy currents generate a secondary magnetic field. The quadrature-phase component of the induced secondary magnetic field is detected by a receiver coil and measured by the instrument. The measured response is linearly related to the terrain conductivity. The instrument converts the measured signal and displays it as terrain conductivity in milliseimens per meter (mS/m).

For both survey areas, EM31 data were recorded approximately at 1-ft intervals along lines spaced 10-ft apart. Geodetic coordinates were recorded at 1-second intervals using an integrated GPS system. A base station, which was free from cultural interference, was occupied at the beginning and end of each survey day to calibrate the instrument and perform system functional tests. During these tests, battery, phasing, and sensitivity checks were performed.

4.2.2. General Data Interpretation

Terrain conductivity (EM31) data are commonly used to map the lateral changes in electrical conductivity. These changes can indicate the presence of disturbed ground, buried waste, changes in soil moisture, and the occurrence of many dissolved

constituents in soil moisture and ground water. In this environment, disturbed terrain, disposal areas, dissolved constituents in soil moisture often produce elevated terrain conductivity anomalies.

The character of EM anomalies can be complex when produced by buried metal objects. Anomalies can be positive, negative, or both depending upon the location and orientation of the object with respect to the instrument orientation. If sufficient lateral resolution is achieved, shallow anomalies caused by significant metal objects are typically represented as a negative anomaly directly over the object that is surrounded by a "halo" of elevated conductivity.

4.3. HIGH-SENSITIVITY METAL DETECTOR (EM61)

4.3.1. Data Collection

Buried metal objects can be effectively located using a Geonics EM61-MK2 High-Sensitivity Metal Detector. The EM61 is a time domain electromagnetic (EM) system that can discriminate between conductive soils and metal objects. It has numerous advantages over other commonly used metal detection devices. For example, it is significantly less sensitive to cultural interference such as aboveground metal objects and overhead power lines.

The EM61 generates rapid electromagnetic pulses and measures the response of the subsurface between pulses. Secondary EM fields are generated in the ground after each pulse. These fields dissipate rapidly in earth materials but remain for a longer time in buried metal objects. The EM61 measures the prolonged metal response only after the earth response has dissipated. This response is measured and displayed in millivolts (mV).

The EM61 uses a portable time-domain transmitter and two receiver coils. The data received from the second receiver coil can be used to reduce the unwanted effects from interference and near-surface objects that can mask deeper and more significant objects.

Very high-resolution data are automatically recorded as the sensors are pulled along the ground surface. Survey wheels attached to the sensors facilitate data collection by allowing direct measurement of the distance traveled. The lateral position of each measurement is automatically recorded using a data logger. This method allows data to be recorded virtually as fast as the operator can walk. Consequently, detailed site coverage can be achieved in a cost-effective manner.

For this investigation, data were collected at less than 1-ft intervals along lines spaced 10-ft apart. Geodetic coordinates were recorded at 1-second intervals using an integrated GPS system so that each measurement point could be accurately located. A base station, which was free from cultural interference, was occupied at the beginning and end of each survey day to calibrate the instrument and perform system functional

tests. During these tests, battery, data repeatability, and sensitivity checks were performed.

4.3.2. General Data Interpretation

The EM61 anomaly maps represent the instrument's response to metal objects. Theoretically, if no metal objects are present, the instrument reading would be zero. The amplitude of any anomaly is a function of the distance (depth) to the object and the amount of metal present. Several data channels are recorded at each measurement point. The upper and lower coil channels indicate the response from each coil in millivolts (mV). The presence of buried metal would produce only positive responses from each of these coils. The differential channel, which is the difference between the upper and lower receivers, can be used to reduce the unwanted effects from small, near-surface metal objects and enhance the response from more significant objects. Buried metal objects produce a positive differential response. Objects located at or above the ground surface often produce a negative value since the response from the upper coil is higher than normal. The differential data therefore not only reduces the effects of small, near surface metal objects; it also provides an indication of the presence of cultural interference as well.

4.4. GROUND PENETRATING RADAR (GPR)

The GPR technique uses the transmission and reflection of radio waves to image objects beneath the ground surface. The technique responds to changes in the electrical properties of the earth or buried materials. A GPR target must possess electrical characteristics that are different from the surrounding media in order to be detected. When the transmitted wave encounters an anomalous object or layer, the wave is reflected back to the surface where it is recorded and analyzed. The waves are transmitted rapidly such that a continuous subsurface image is generated as the transmitter is pulled along the ground surface.

The GPR survey was performed using a digital SIR-2000 Subsurface Interface Radar System, manufactured by Geophysical Survey Systems, Inc. Following initial field tests to determine maximum penetration and sufficient resolution, a 200 MHz transducer was chosen to perform the survey. Data were digitally recorded, displayed, and analyzed during acquisition to allow real-time interpretation.

In-field signal velocity calculations and calibrations were performed by hyperbolic fitting on a notebook computer. This calibration was performed to verify that sufficient penetration was achieved.

4.5. DIPOLE-DIPOLE ELECTRICAL RESISTIVITY

The electrical resistivity method uses the application of electric currents to measure the ability of subsurface materials to conduct electricity. The surveys are performed by injecting an electrical current into the ground through a pair of surface electrodes. The induced current produces a potential field that is measured at the surface between a second pair of electrodes. The apparent resistivity is calculated using the electrode separation, applied current, and measured voltage.

Recent innovations in technology have automated resistivity data collection making formerly uneconomical surveys more cost effective. The system used in this investigation uses this technology and has the best accuracy and noise performance in the industry. Typical resistivity surveys require tedious placement of four electrodes along a line. The configuration of these electrodes is changed after each measurement causing significant delays between each measurement. Conversely, the instrument used during this investigation can accommodate up to 254 electrodes and automatically selects the appropriate transmitting and receiving electrodes and records each measurement.

5.0 RESULTS AND DISCUSSION

5.1. GENERAL

The initial strategy to map the cover thickness relied on the assumption that lateral changes in conductivity were attributable to changes in thickness of cover materials. This assumption would allow the "calibration" of the terrain conductivity data using the depth information obtained from the GPR and resistivity data. The goal was to obtain depth information from the GPR and resistivity data which then can be applied to the terrain conductivity data to provide a complete isopach map of the fill thickness. The approach was initially chosen to reduce project costs by maximizing coverage with the more rapid terrain conductivity survey and minimize the amount of coverage required by the slower and more expensive techniques (GPR and resistivity).

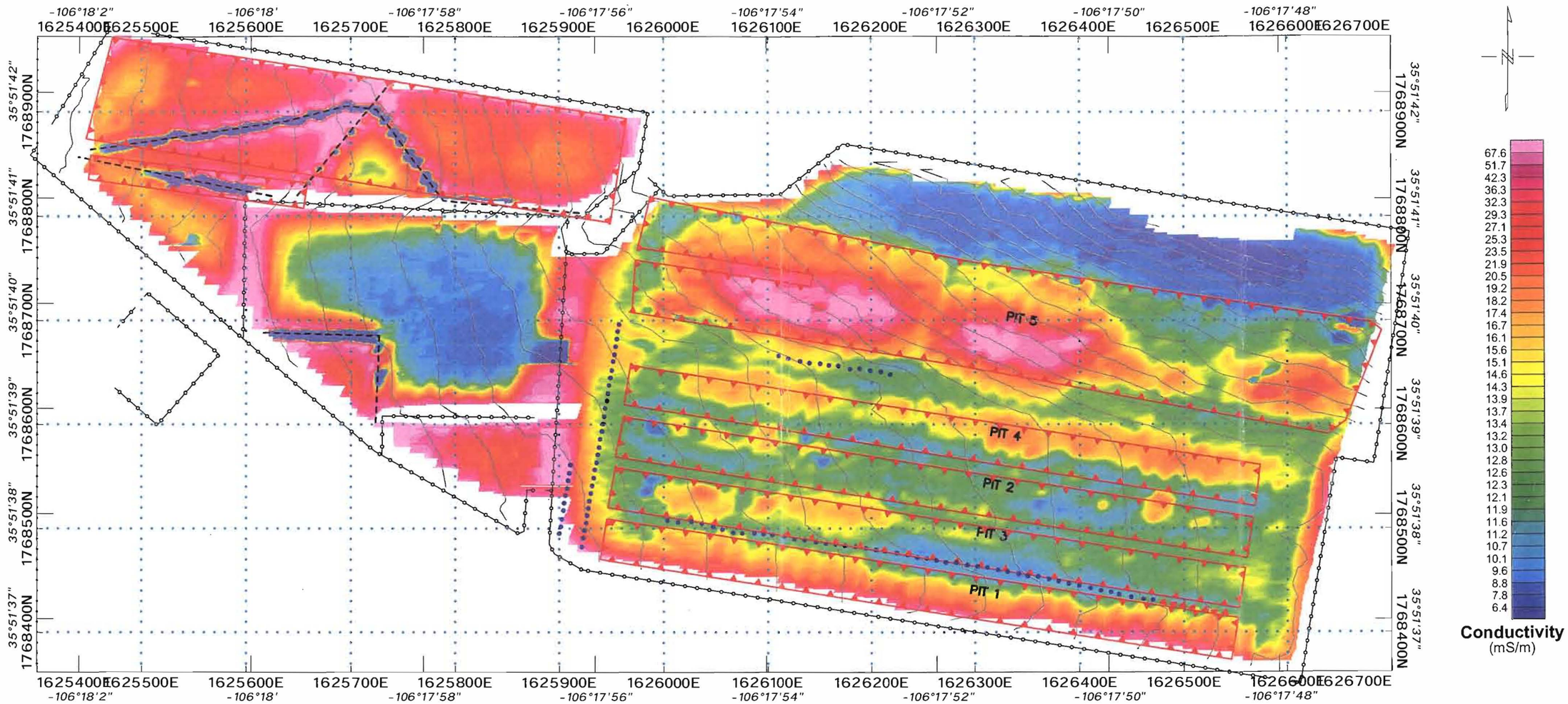
In-field testing indicated that initial assumptions regarding the lateral changes in terrain conductivity were incorrect. Furthermore, testing of the dipole-dipole resistivity technique did not provide the desired results and indicated that excessive data collection time would be required due to electrode contact problems caused by the dry cover materials (this occurred even after each of the 256 electrode locations were moistened with salt water). For these reasons, the resistivity survey was subsequently aborted.

Fortunately, the GPR testing produced very good data quality. A change in the GPR field procedure was employed to allow more rapid and accurate data collection. The instrument was reconfigured to allow direct communication with the GPS receiver. The GPS was then configured to send out a request at 5-second intervals for a GPR scan number, which was tagged with the GPS coordinates. The GPR data was later processed to interpolate the positioning information. This capability facilitated the use of an all-terrain-vehicle (ATV) for data collection. An ATV was acquired and equipped with the GPR system and antenna, as well as the GPS controller and receiver. The resulting configuration allowed the acquisition of approximately 3 miles of GPR data in one day and thickness of cover was effectively mapped at 6-inch intervals along each survey line.

5.2. MDA C AT TA-50

5.2.1. Terrain Conductivity Survey

The results of the terrain conductivity survey are presented in Figure 1. Grid coordinates for both Latitude and Longitude (in Italics) as well as New Mexico State Plane systems are shown around the grid perimeter. This map was constructed using the quadrature-phase component recorded at 22,462 measurement locations along a total line distance of 8.85 miles. The data set has minimum and maximum values of -



REVISIONS	
10/30/2003	Revised historical boundaries of pits and shafts based on LASL Engineering Drawing ENG-R4459, 1974.

Scale 1:1200

50 0 50 100 150 200 250

feet

NAD83 / New Mexico CS83 Central zone

LEGEND

- Interpreted buried utility
- Chain-link fence
- Former pit location based on historical data
- Former shaft location based on historical data
- Ground surface topography (provided by FIMAD)

Los Alamos National Laboratory ER Project

Figure 1: Terrain Conductivity Map
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

October 30, 2003

54.2 and 204.77 mS/m, respectively. The mean value and standard deviation are 21.55 and 21.46, respectively. In general, the data quality is good, with the exception of minor cultural interference caused by chain-link fences. Strong responses from buried utilities are also observed in the western portion of the survey area.

East-west trending conductivity anomalies are observed over the eastern portion of the site. The location of these conductivity highs is generally coincident with the former pit locations based on historical documents. The elevated response and anomaly character suggest the presence of disturbed ground and buried materials. For this reason and because of the good correlation with the historical data, these anomalies are interpreted as Pit Number 1 through 5.

The highest conductivity anomalies in this area are observed at Pit No. 5. The high values suggest the presence of a greater amount of conductive materials (e.g., metal) or that the conductive materials are closer to the ground surface than in the other pits. The conductivity anomalies also suggest that a greater amount of buried materials is present in the southern half of the suspected pit location.

The amplitude of the anomaly over Pit No. 4 is relatively consistent throughout its length, which suggest the occurrence of laterally homogeneous materials. The west and east anomaly boundaries appear to be shifted approximately 40 ft to the east with respect to the historical boundaries shown in red. Similarly, the anomaly boundaries suggest that Pit Nos. 2 and 3 are shifted. Both of these pits exhibit lateral heterogeneity in conductivity. This fact, interpreted in conjunction with the GPR data (summarized below) suggests the buried waste occurs at greater depths in the central portion of the suspect pit locations.

The southern boundary of Pit No. 1 is masked by interference from the chain link fence located nearby. However, the eastern and western end of the anomaly is shifted in similar direction and distance as Pits No. 2, 3, and 4.

The suspected shaft locations are shown on Figure 1 as dark blue dots. At the majority of these locations, no consistent anomalies were observed that could be confidently attributed to the shafts. The lack of anomalies at these locations suggests either that the shafts do not exist at the locations shown or that there are insufficient contrasts in materials within the upper 10 ft of the shafts.

A low conductivity area exists along the northeastern area boundary is attributed to shallow bedrock and the lack of significant thickness of cover materials. This interpretation is corroborated by visual observations since exposed bedrock was noted at several locations. Similar low and laterally consistent conductivity values were also recorded in the fenced area located west of Pits No. 4 and 5.

Several linear and negative conductivity anomalies are observed in the western portion of the survey area. These anomalies are characteristic of buried utilities and are interpreted as such. The type of utility is not known but they appear to be associated

with concrete slabs that were visually observed during the survey. The area surrounding the suspected utilities exhibits elevated conductivity values and appears to be disturbed. In addition, the area appears to contain a cover material that is different from the eastern portion of the survey area.

No clear anomalies that indicate the boundaries of Pit No. 6 were observed. However, variations in cover thickness determined by GPR can be used to help delineate the pit. Similarly, no anomalies were observed that could confidently be used to locate the former Chemical Pit. A strong response from a buried utility is noted on the north edge of the suspected pit location. It is likely that this response has masked any slight variations in conductivity that would be associated with the former pit.

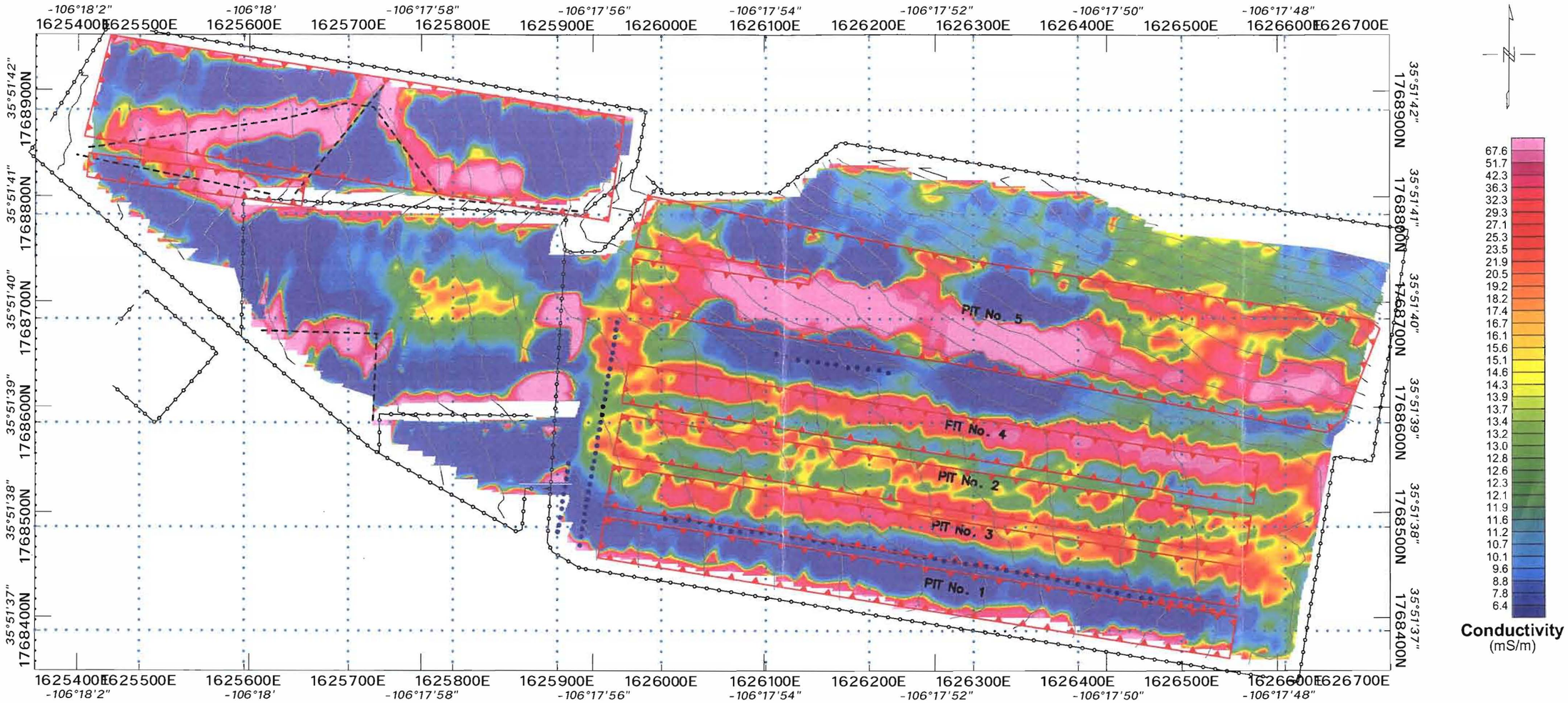
Additional data processing steps were performed to enhance the responses from the pits. Although the Chemical Pit and Pit No. 6 are still not visible, the filtered data shown in Figure 2 does enhance the locations of Pits No. 2 through 5. Both Pit No.3 and Pit No. 5 show parallel anomalies at the eastern half of their extent. This suggests the presence of separate trenches within the suspected pit locations.

5.2.2. High Sensitivity Metal Detector (EM61) Survey

The results of the EM61 survey are presented in Figure 3. To aid in interpretation, the map is annotated with a "+" symbol near the center of all significant metal objects. The data set shown in the map was processed using the differential data that was recorded at 92,026 measurement locations along a total line distance of 12.61 miles. The minimum and maximum values are -81.34 and 5011.7 mV, respectively. The mean value and standard deviation are 4.53 and 58.89, respectively. In general, the data quality is good, although small metal objects were observed throughout the survey area that created a "noisy" appearance.

Similar to the EM31 data, the EM61 data shows large high amplitude anomalies at Pit No. 5. This suggests that the majority of the metal objects buried at the site are contained in the southern portion of Pit No. 5. Small, randomly scattered metal objects are observed throughout the remaining pit locations. The locations of these objects are coincident with the pit locations observed in the EM31 data and suggest a similar 40-ft offset to the east with respect to the suspected pit locations.

The majority of the alleged shaft locations do not show significant anomalies. This suggests that either the shafts do not exist at the locations shown in historical documents or the metal shapes contained within them are greater than 10 ft below the surface. One notable exception is the group of shafts located near the site entrance at the southern boundary of the site. Significant anomalies were observed at locations coincident with the suspected shaft locations in this area. The size and general character of the anomalies are consistent with the anticipated size and shape of suspected shafts. It is possible that the remaining shafts could be located with cesium



REVISIONS	
10/30/2003	Revised historical boundaries of pits and shafts based on LASL Engineering Drawing ENG-R4459, 1974.

Scale 1:1200

50 0 50 100 150 200 250

feet

NAD83 / New Mexico CS83 Central zone

LEGEND

- Interpreted buried utility
- Chain-link fence
- Former pit location based on historical data
- Former shaft location based on historical data
- Ground surface topography (provided by FIMAD)

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Figure 2: Filtered Terrain Conductivity Map
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

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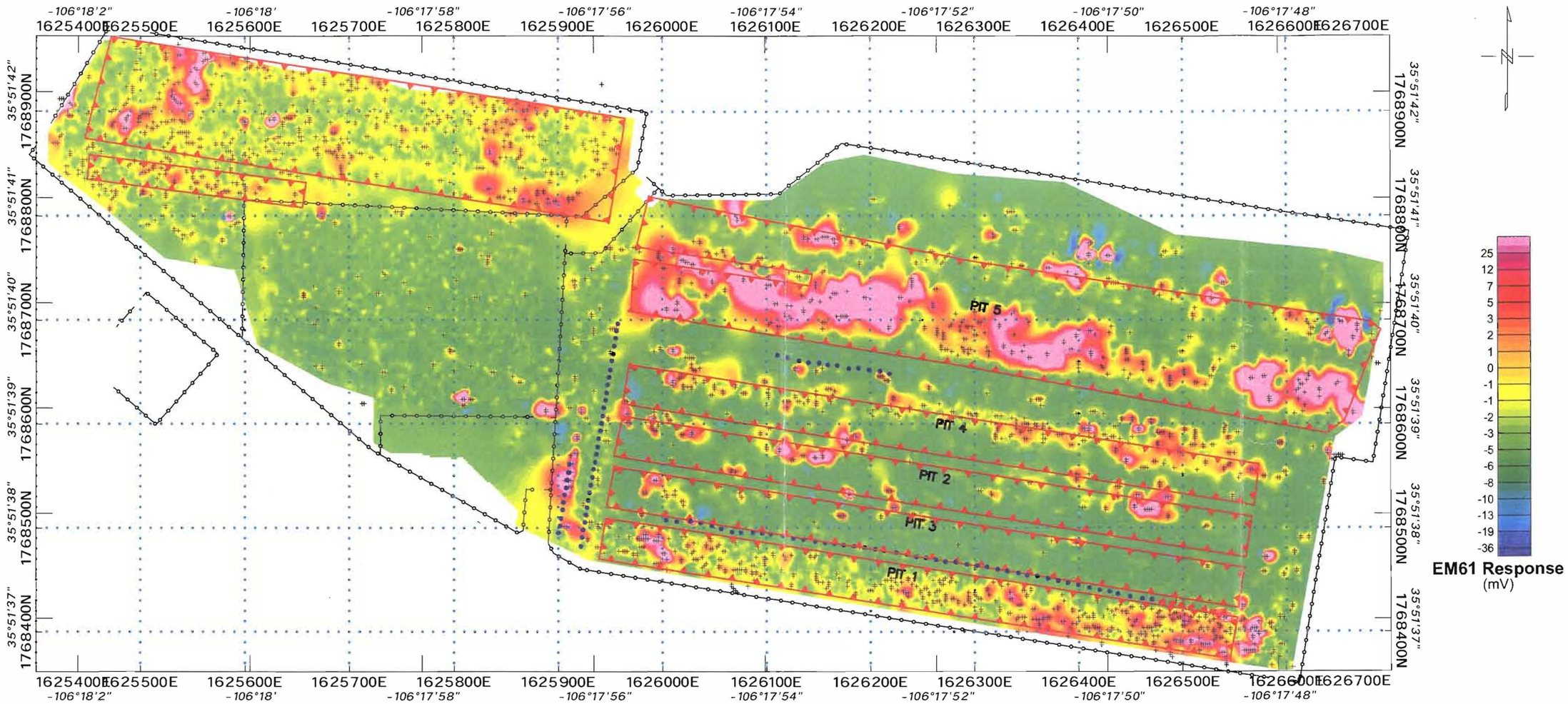


REVISIONS	
10/30/2003	Revised historical boundaries of pits and shafts based on LASL Engineering Drawing ENG-R4459, 1974.

Scale 1:1200

50 0 50 100 150 200 250

feet

NAD83 / New Mexico CS83 Central zone

LEGEND

- + Approximate location of buried metal object
- Chain-link fence
- Former pit location based on historical data
- Former shaft location based on historical data
- Ground surface topography (provided by FIMAD)

Los Alamos National Laboratory ER Project

Figure 3: EM61 Anomaly Map
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

October 30, 2003

vapor magnetometry since the technique can detect objects at greater distances. However, it is would be more sensitive to interference from the nearby fences.

5.2.3. Ground Penetrating Radar (GPR) Survey

Digital GPR data were acquired continuously along 75 lines, resulting in 3.61 miles of detailed coverage. Perpendicular "tie lines" were acquired as a quality control measure to confirm lateral correlation. In general, the data were of very good quality. Throughout the majority of the site, various interfaces and structures were observed. The base of the cover materials was observed along most lines. In addition, structures beneath this interface and objects within the pits were observed as well.

Several data processing steps were performed to enhance desired reflection events and reduce or eliminate unwanted sources of noise or airwave reflections. First, traces were sorted and interpolated using GPS coordinates that were recorded at 5-second intervals. Next, background removal filters, Butterworth bandpass filters, and mean XY filters were applied to enhance the desired signal. Finally, time-to-depth conversion was performed using a 5 inch/ms velocity. This velocity was measured using hyperbolic fitting of point source reflections.

The base of the cover materials was mapped by delineating the lateral extent of the first major reflection event on each profile. This event is interpreted as the interface between the cover materials and buried waste for the following reasons:

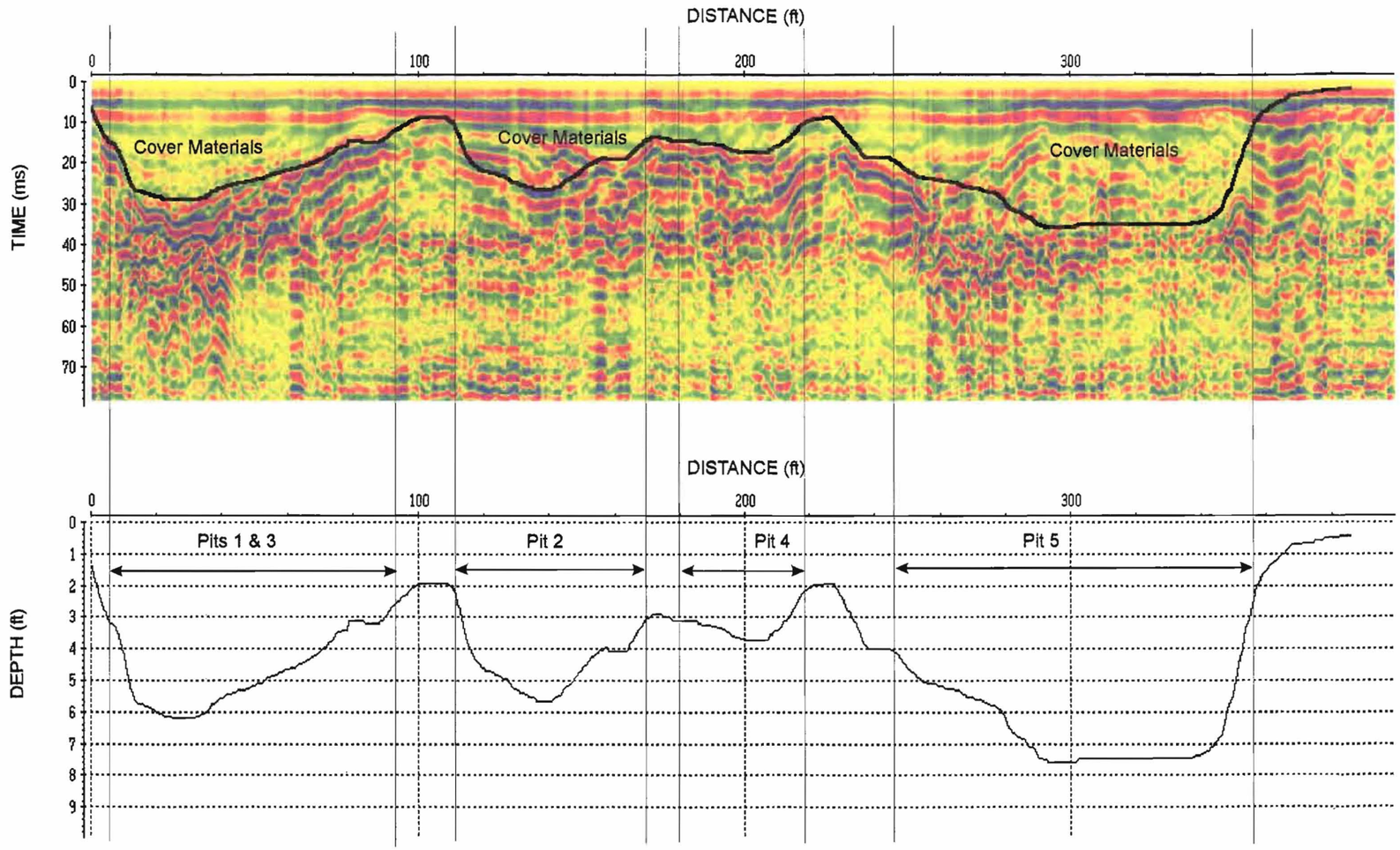
- The interface is overlain by a laterally homogeneous layer with faint chaotic reflections. Cover or fill materials often produce chaotic reflections due its physical character. This material would likely be differentiated from buried waste by weaker reflections and greater homogeneity.

- Strong reflection events are recorded at interfaces between electrically contrasting layers. The first major change in electrical properties between layers is assumed to be at the interface between cover materials and buried waste.

- The first major reflection event is laterally extensive which is assumed the case for the cover materials as well.

Figures 4 and 5 present interpreted GPR profiles from representative survey lines. The locations of all GPR survey lines are shown in Figure 6. The interpreted profiles for all lines are provided as digital images on the CD enclosed in the back of this report.

The interpreted base of the cover materials was mapped at 0.01-ft intervals along each GPR profile. The thickness of cover materials was interpreted at 6-inch intervals along each line resulting in 31,456 measurement points. The thickness values were plotted and contoured to produce the map shown in Figure 6. The cover thickness data set has minimum and maximum values of 0.0 and 8.76 ft, respectively. The mean value and



North

Los Alamos National Laboratory ER Project

Figure 4: GPR Profile of Line 9
Survey Area MDA C
Los Alamos, New Mexico

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September 31, 2001

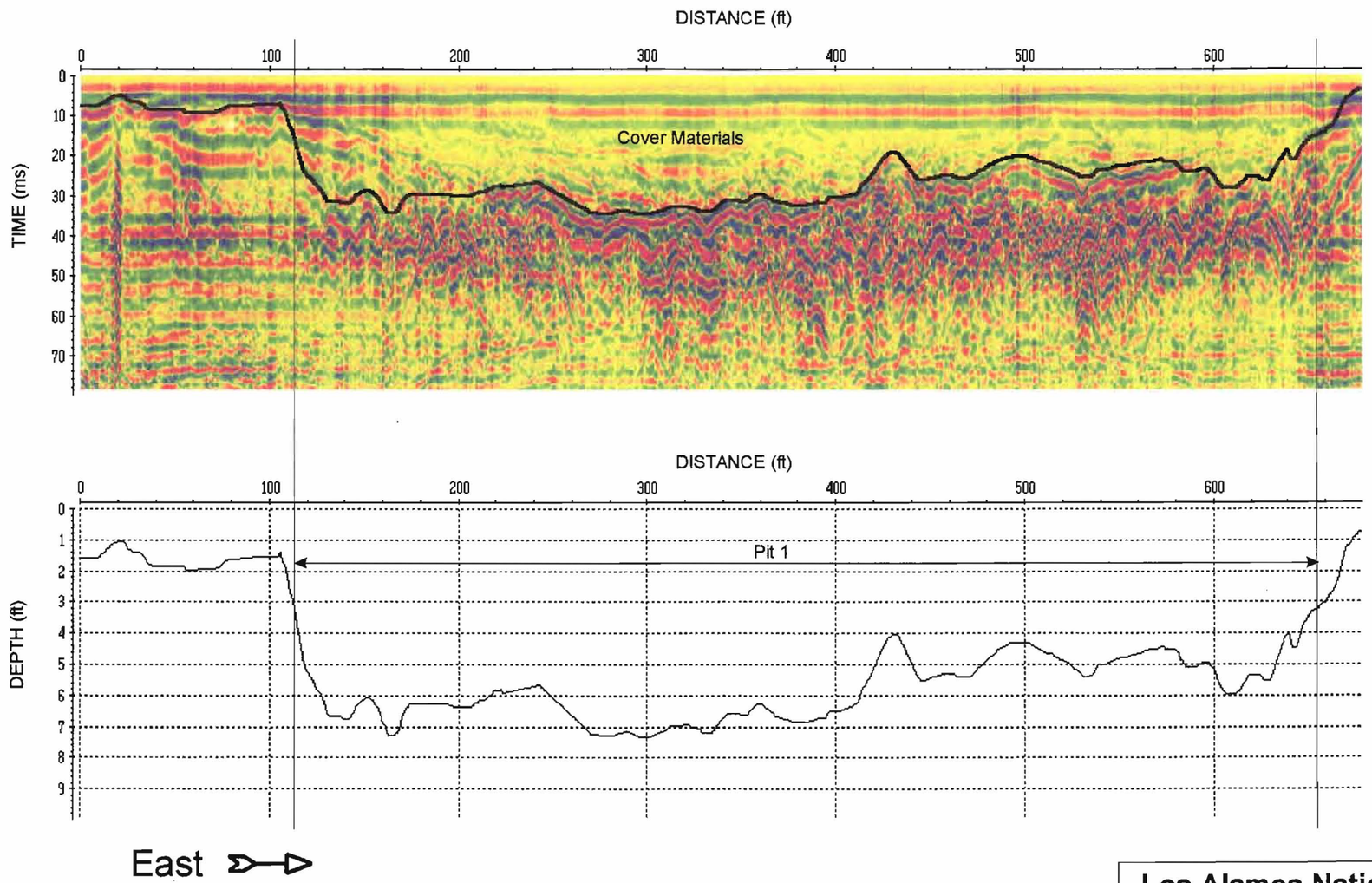

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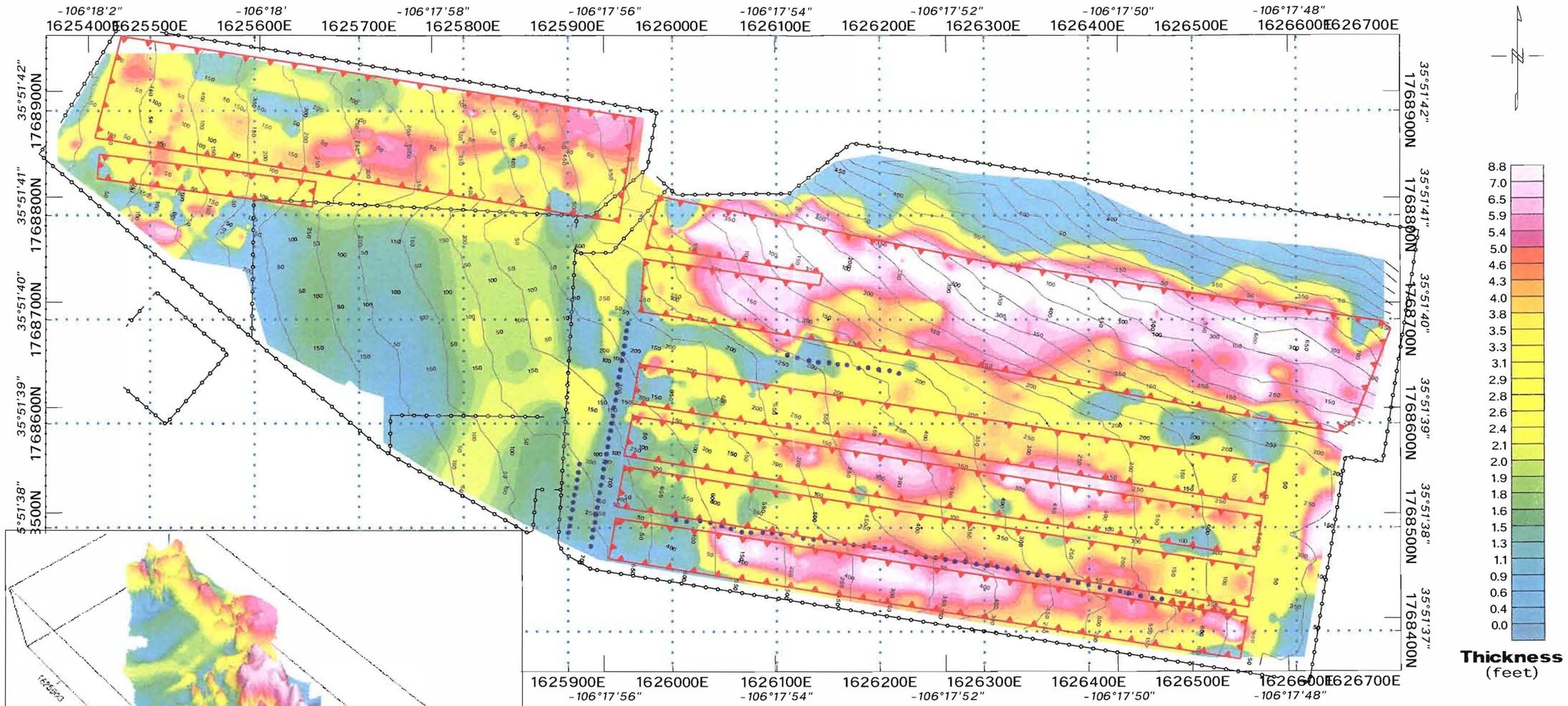
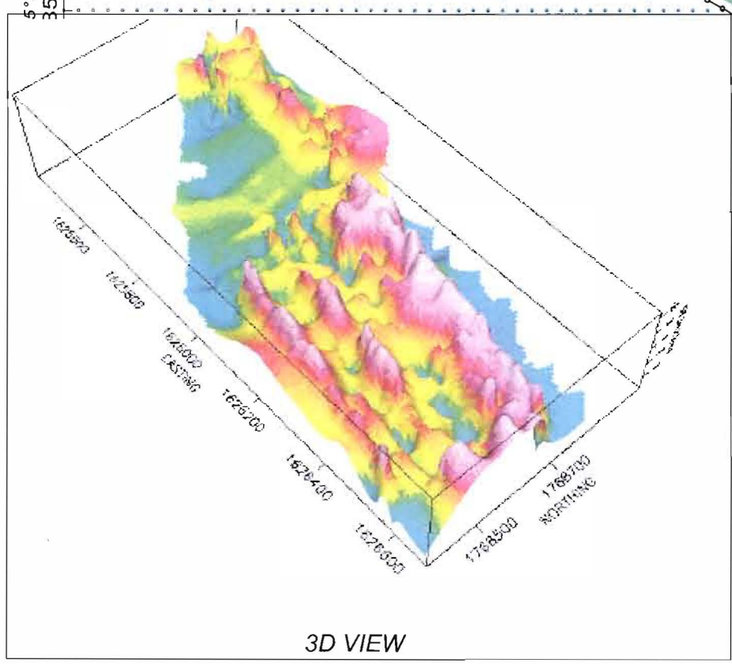
Figure 5: GPR Profile of Line 25
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

September 31, 2001





3D VIEW

Scale 1:1200

50 0 50 100 150 200 250

feet

NAD83 / New Mexico CS83 Central zone

REVISIONS	
10/30/2003	Revised historical boundaries of pits and shafts based on LASL Engineering Drawing ENG-R4459, 1974.

LEGEND

8> GPR survey line showing line number and direction. Major and minor ticks at 50ft and 10ft, respectively

Chain-link fence

Former pit location based on historical data

Ground surface topography (provided by FIMAD)

Los Alamos National Laboratory ER Project

Figure 6: Interpreted Thickness of Cover Materials
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

October 30, 2003

standard deviation are 3.37 and 2.02, respectively. The calculated volume of cover materials is approximately 61,800 cu. yd.

A composite interpretation map of the EM31, EM61, and GPR data sets is shown in Figure 7.

5.3. MDA H AT TA-54

5.3.1. Terrain Conductivity Survey

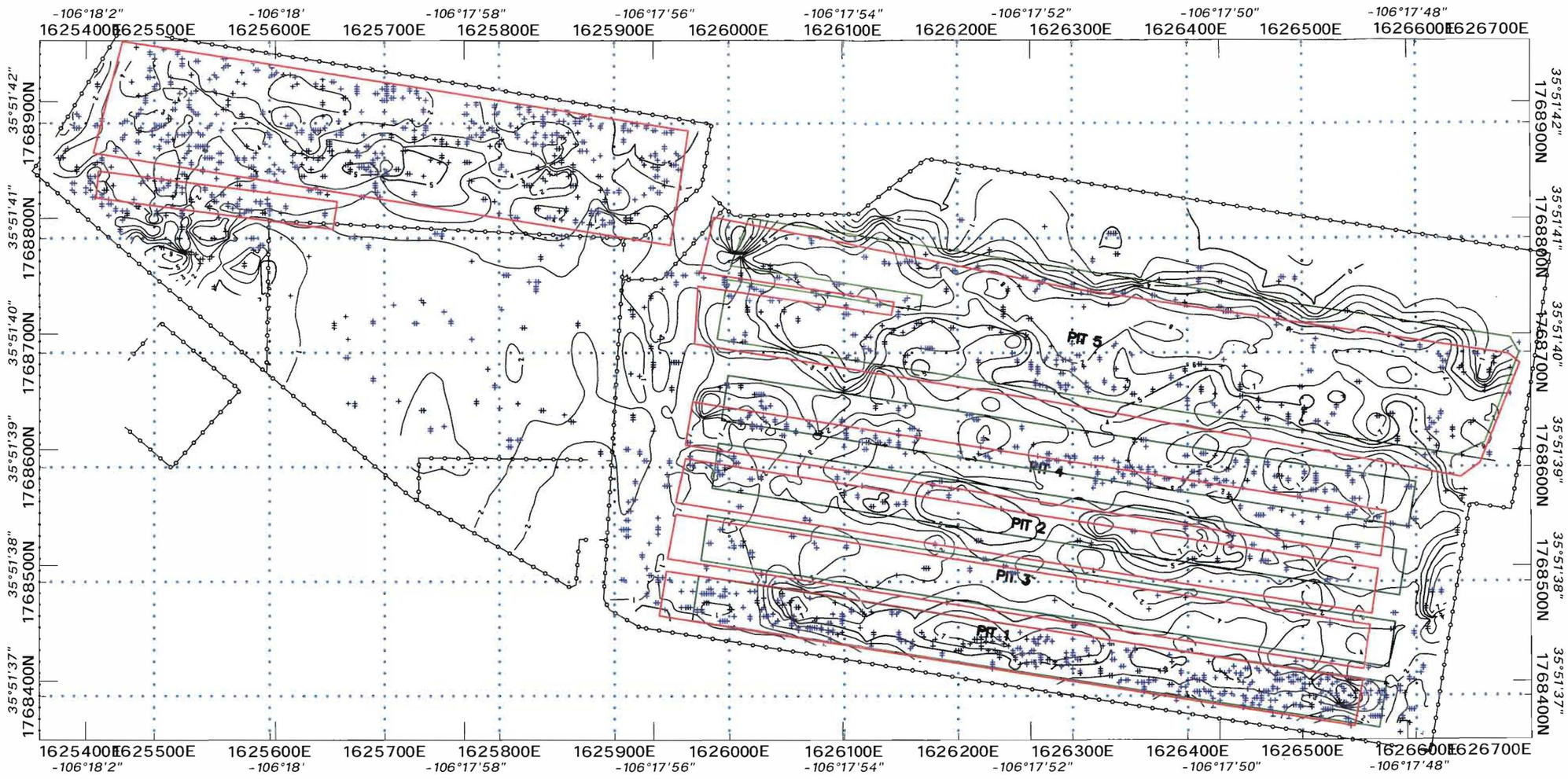
Figure 8 presents the terrain conductivity data collected at the MDA H. The elevated terrain conductivity values observed around the perimeter of the site are attributed to the chain link fence that surrounds the site. Similarly, the anomaly in the northeast corner of the site is also due to interference caused by metal frame structure. The suspected locations of the shafts, based on historical information, are shown on the map. No conductivity anomalies were observed that could be confidently attributed to these shafts.

5.3.2. High Sensitivity Metal Detector (EM61) Survey

Figure 9 presents a plan map of the EM61 data. Slight cultural interference caused by the chain link fence is observed along the southeast border as well as northwest and southwest corners of the survey area. High amplitude interference was also recorded at the northeast corner due to the presence of a metal structure. Anomalies were observed near the suspected locations of Shafts 6, 8, and 9. The anomaly shapes and locations suggest that they are caused by buried metal objects within the shafts. No significant anomalies are observed at the remaining shaft locations because no metal objects occur within the instrument's detection range (10ft). The remaining anomalies are also attributed to buried metal objects but the response indicates these objects are small and buried close to the surface.

5.3.3. Ground Penetrating Radar (GPR) Survey

The GPR results indicate the majority of the site is overlain by less that 2 ft of cover materials. Short planar anomalies were observed at the majority of the suspected shaft locations. These anomalies are associated with chaotic reflection events that suggest disturbed subsurface conditions. The anomalies are interpreted as the former shafts based on their location and character. The planar anomalies are interpreted as the interface between the cover materials and concrete cap. The planar event is visible but obscured at several shaft locations by diffractions from the shaft walls. Also obscuring the planar events are strong anomalies that occur above the interpreted concrete cap at many locations. They are associated with "multiples" or a reverberation of the impulse signal. Multiples are usually associated with anomalies caused by objects or materials that posses a high contrast in physical properties compared to the surrounding media.



REVISIONS	
10/30/2003	Revised historical boundaries of pits and shafts based on LASL Engineering Drawing ENG-R4459, 1974.

Scale 1:1200

50 0 50 100 150 200 250

feet

NAD83 / New Mexico CS83 Central zone

LEGEND

- + Approximate location of buried metal object
- Chain-link fence
- Former pit location based on historical data
- Interpreted pit location based on geophysical data
- Cover thickness contour (1 ft intervals)

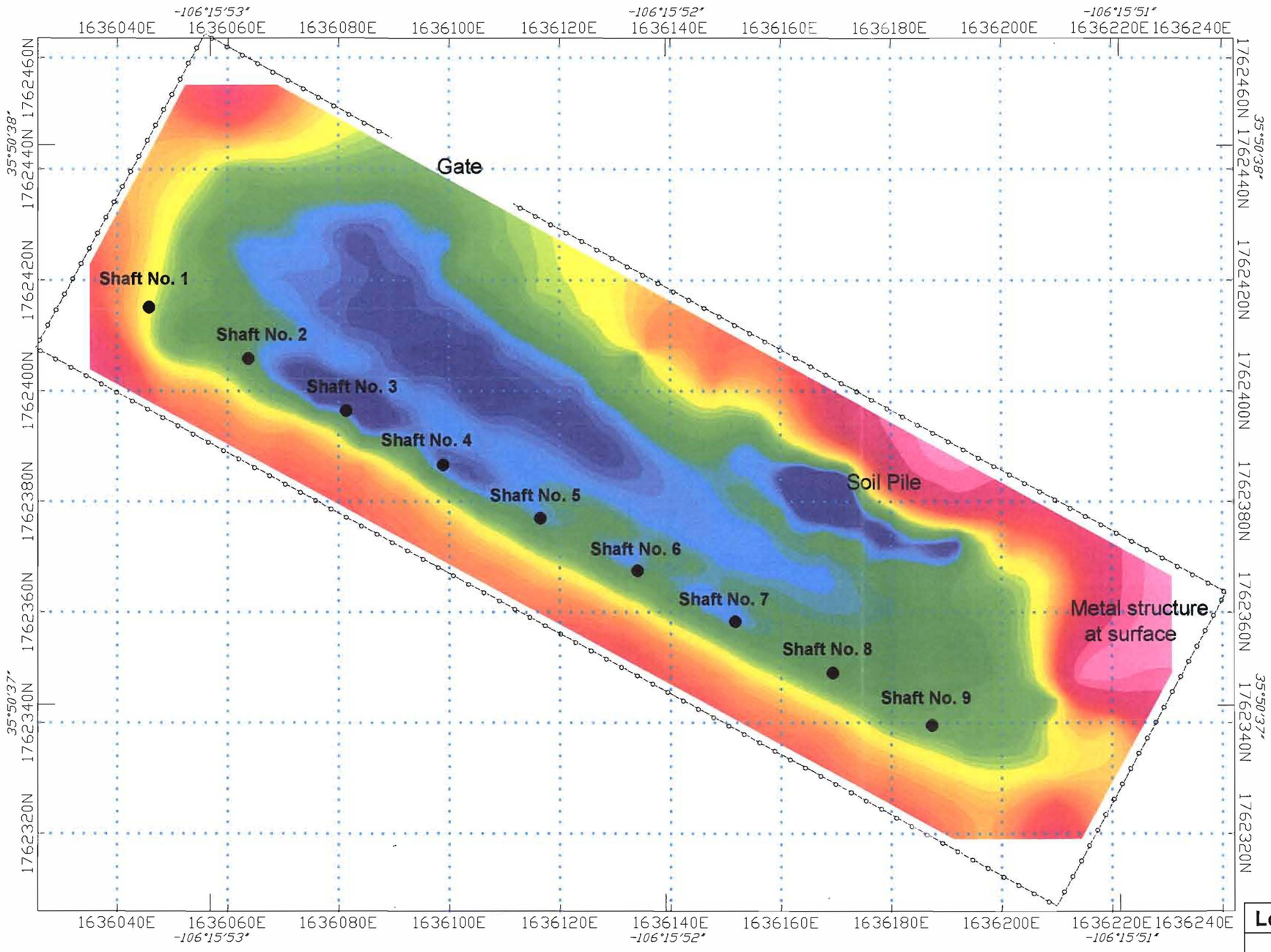
Los Alamos National Laboratory ER Project

Figure 7: Composite Geophysical Interpretation Map
Survey Area MDA C
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

October 30, 2003



N

LEGEND

Chain-link fence

Former shaft location based on historical data

Scale 1:240

10 0 10 20 30 40 50

feet

WGS 84 / New Mexico CS83 Central zone

Conductivity
(mS/m)

-2.4 9.5 10.9 12.1 13.2 14.3 16.6 20.0 24.6 31.0 39.1 49.8 59.7 68.5 77.0 83.9 89.3 99.2 139.0 217.0

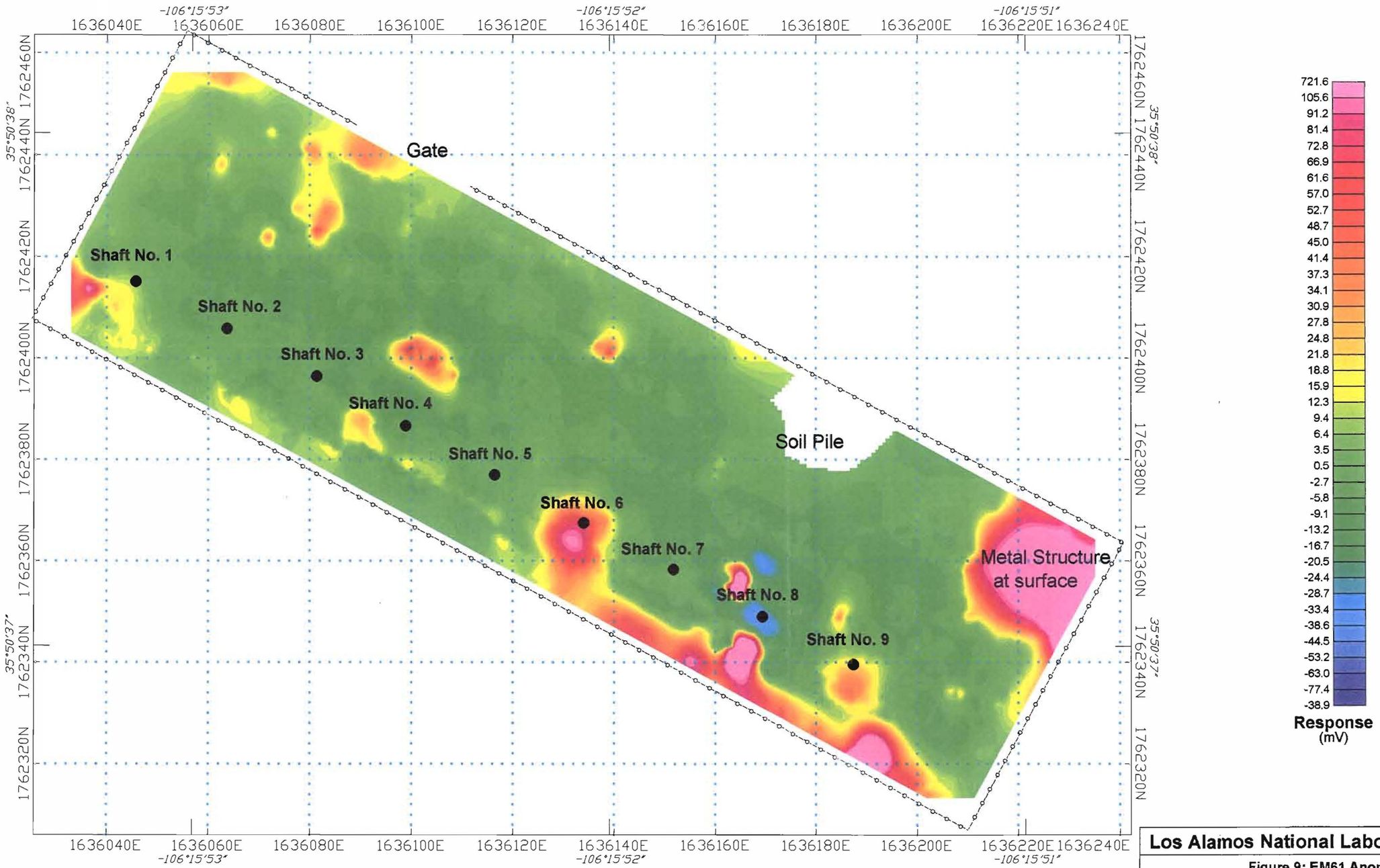
Los Alamos National Laboratory ER Project

Figure 8: Terrain Conductivity (EM31) Map
Survey Area MDA H
Los Alamos, New Mexico

Prepared for: Los Alamos ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

September 31, 2001



Scale 1:240

10 0 10 20 30 40 50

feet

WGS 84 / New Mexico CS83 Central zone

LEGEND

Chain-link fence

Former shaft location based on historical data

Los Alamos National Laboratory ER Project

Figure 9: EM61 Anomaly Map
Survey Area MDA H
Los Alamos, New Mexico

Prepared for: Los Alamos ER

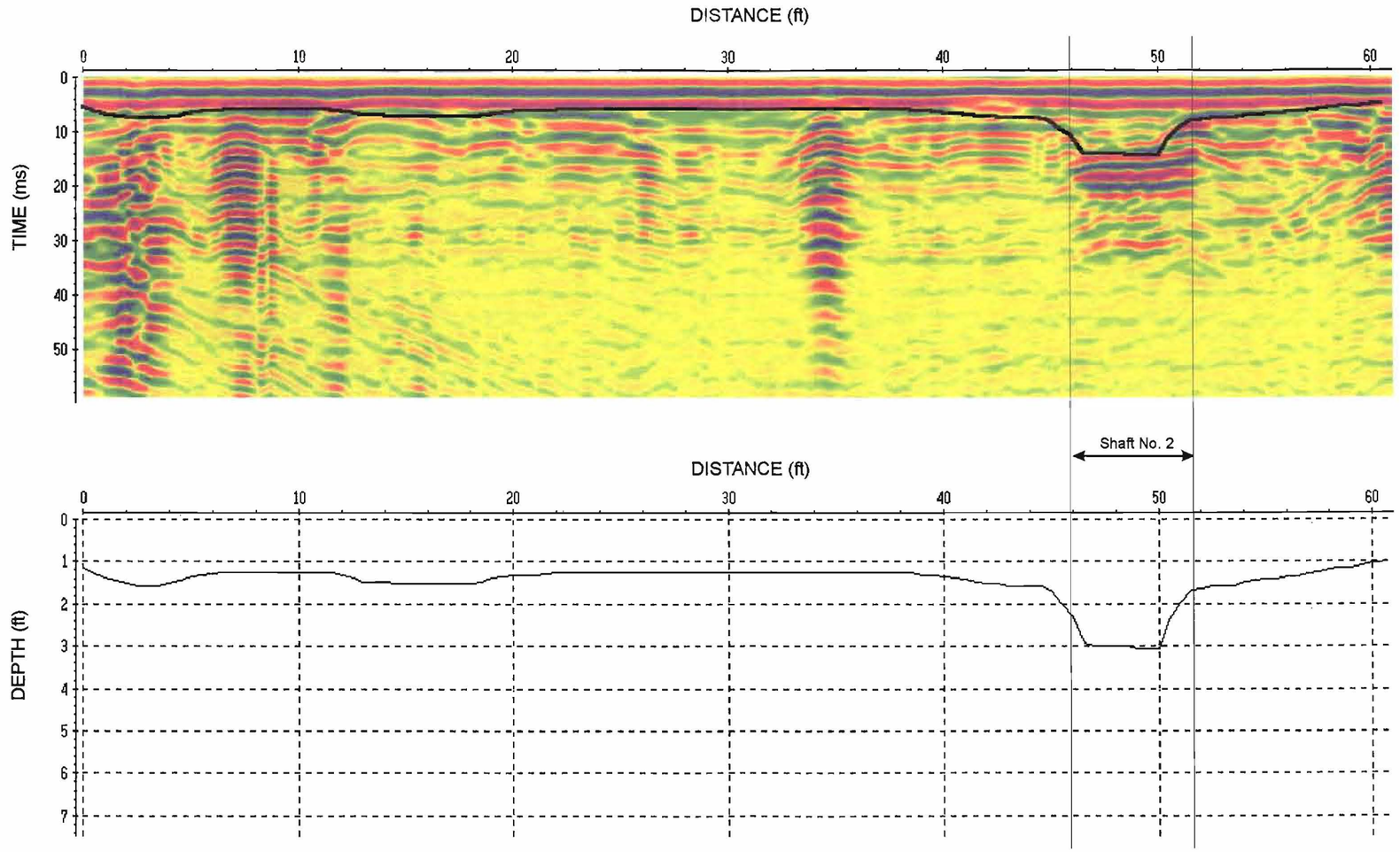
Prepared by: ADVANCED GEOLOGICAL SERVICES

September 31, 2001

These types of anomalies are also observed at locations and depths that appear to be in native soil and bedrock. These anomalies may be caused by either voids or pyroclasts within the tuff bedrock.

The interpreted GPR profiles are presented on the enclosed CD. A representative profile is shown in Figure 10. The planar reflection event observed at 12 ns and a distance of approximately 50 ft is interpreted as the concrete cover of Shaft No. 2. Strong hyperbolic events are also observed at 7 ft and 36 ft along the line. These anomalies appear to be caused by native features such as voids or pyroclasts within the volcanic bedrock.

Figure 11 presents an isopach map of the interpreted thickness of cover materials based upon the GPR data. An increase in thickness of cover materials was observed in isolated locations near 8 out of 9 shaft locations. These anomalies are interpreted as the present locations of the shafts.



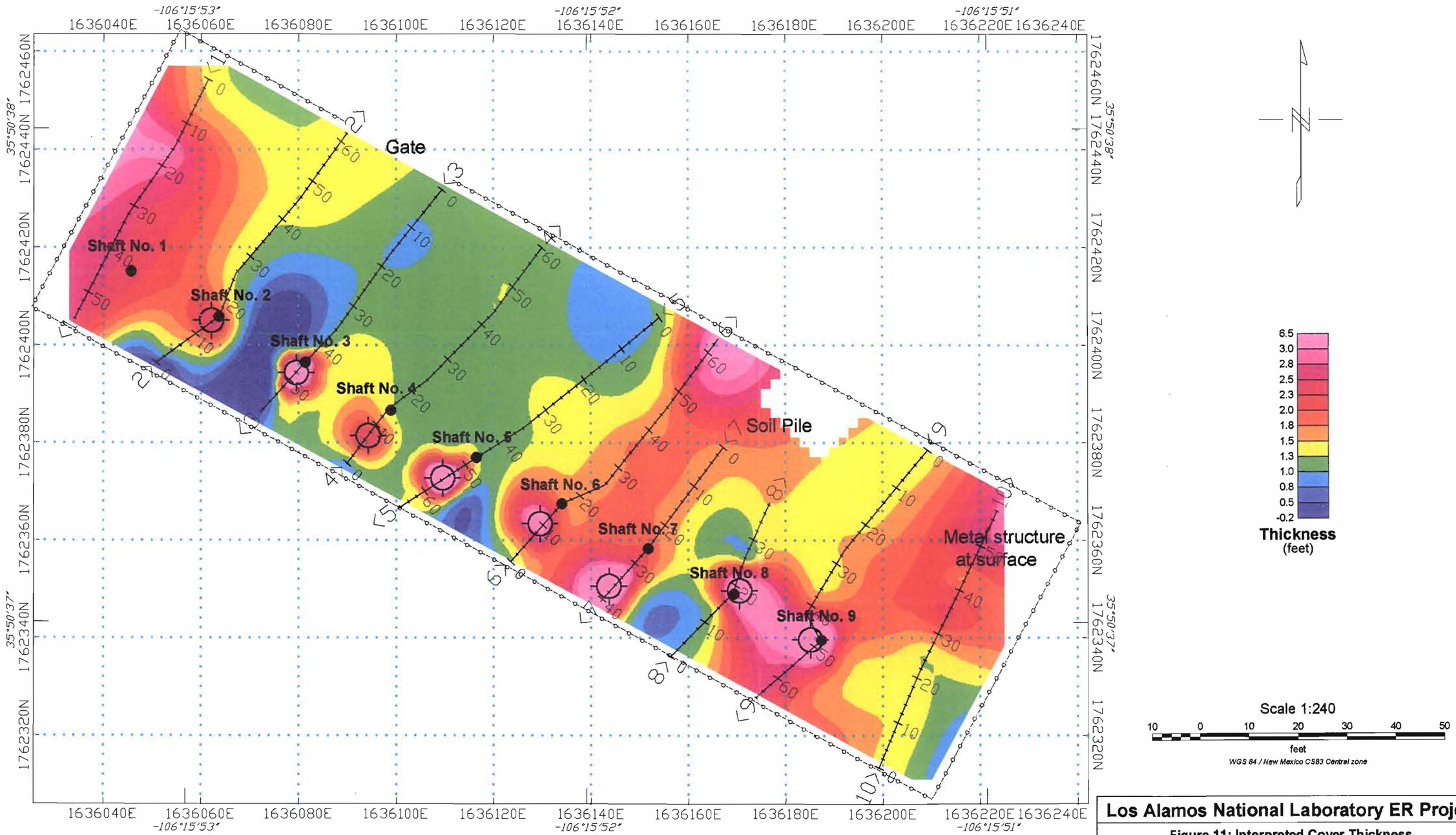
Los Alamos National Laboratory ER Project

Figure 10: GPR Profile of Line 2
Survey Area MDA H
Los Alamos, New Mexico

Prepared for: Los Alamos National Laboratory ER

Prepared by: Advanced Geological Services

September 31, 2001



LEGEND

8> GPR survey line showing line number and direction.

Chain-link fence

Former shaft location based on historical data

Interpreted shaft location

Los Alamos National Laboratory ER Project

Figure 11: Interpreted Cover Thickness
Survey Area MDA H
Los Alamos, New Mexico

Prepared for: Los Alamos ER

Prepared by: ADVANCED GEOLOGICAL SERVICES

September 31, 2001

APPENDIX A
CD CONTAINING REPORT, DATA, MAPS, AND IMAGES

1. Purpose

The data, programs, and information provided on this CD are included to allow flexible use of the geophysical data collected during the investigation at the MDA C (TA-50) and MDA H (TA-54) sites during August 21 through September 9, 2001. The data and maps produced by AGS can be viewed, printed, and exported to a variety of formats using the free Geosoft Oasis Montaj interface provided on this CD.

2 Interface Program for EM61 and EM31 data

The free interface included on this CD will allow users to view, print, and export the terrain conductivity (EM31) and EM61 maps and data sets. Specifically the interface can be used to:

- View Geosoft Database Files (.gdb), Geosoft XYZ files, Geosoft Binary Files, ASEG GDF and other data files View data profiles from *.GDB files
- Create profile maps and print them out
- View Geosoft Map and PLT files, and Autocad DXF files
- View Geosoft, ER Mapper, USGS grid files as well as a variety of PC image and grid formats (Tiff, BMP, ArcView, GeoTiff) and others Convert grids and images to a variety of supported formats
- Export data in GDB to XYZ, GBN, ASEG-GDF, USGS ODDF, USGS POST, Comma Separated Value (CSV) and other files.
- Export maps to a variety of image formats
- Print maps to windows compatible printers, plotters.

Included with the software is a PDF file that contains a tutorial that explains how to get started using the Oasis Montaj interface.

3 Report text and graphics

The report is included as a Microsoft Word 97 file. The figures have been converted to TIFF format and can be view with commonly used image viewing software such as those include with the later versions of Windows®.

4 GPR data

The GPR data were processed, interpreted, and exported using the REFLEX-Win software package. The final interpreted GPR profiles were exported as TIFF images and are included on the CD.