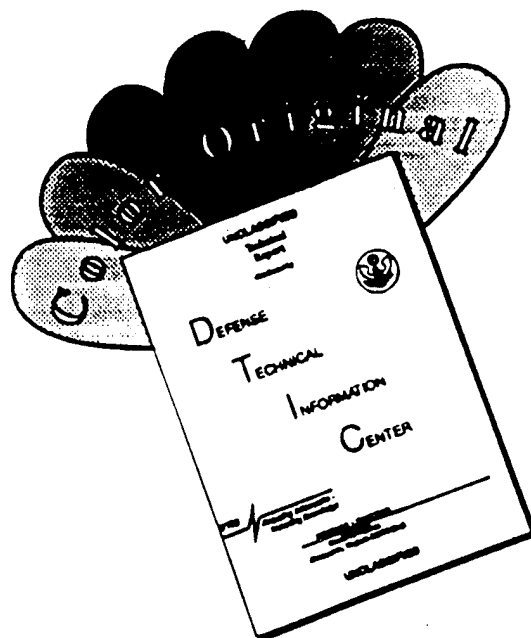


The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.



PRINTED ON RECYCLED PAPER

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

Investigation of the 26th Street Disposal Site, Edgewood Area, Aberdeen Proving Ground, Maryland

by Michael K. Sharp, Janet Simms

U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

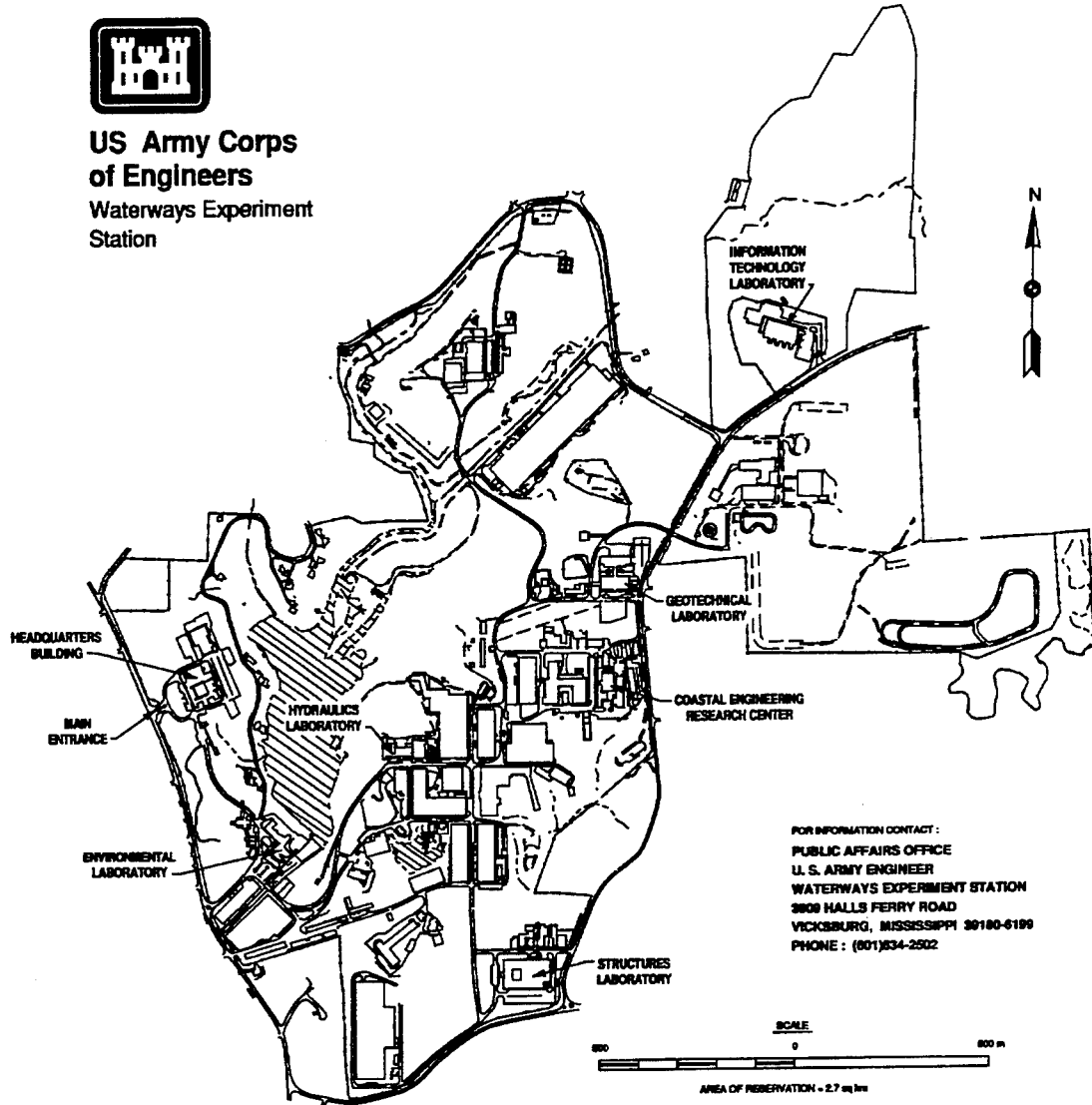
Final report

Approved for public release; distribution is unlimited

Prepared for Installation Restoration Program
Directorate of Safety, Health and Environment
Aberdeen Proving Ground, MD



**US Army Corps
of Engineers**
Waterways Experiment
Station



Waterways Experiment Station Cataloging-in-Publication Data

Sharp, Michael K.

Investigation of the 26th Street Disposal Site, Edgewood Area, Aberdeen Proving Ground, Maryland / by Michael K. Sharp, Janet Simms ; prepared for Installation Restoration Program, Directorate of Safety, Health and Environment.

54 p. : ill. ; 28 cm. — (Miscellaneous paper ; GL-95-5)

Includes bibliographic references.

1. Waste disposal sites — Maryland — Aberdeen Proving Ground. 2. Ground penetrating radar. 3. Soil surveys — Geophysical methods. I. Simms, Janet. II. United States. Army. Corps of Engineers. III. U.S. Army Engineer Waterways Experiment Station. IV. Geotechnical Laboratory (U.S. Army Engineer Waterways Experiment Station) V. Aberdeen Proving Ground (Md.). Installation Restoration Program. VI. Aberdeen Proving Ground (Md.). Directorate of Safety, Health, and Environment. VII. Title. VIII. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; GL-95-5.
TA7 W34m no.GL-95-5

Contents

Preface	iv
Conversion Factors, Non-SI to SI Units of Measurement	v
Summary	vi
1—Introduction	1
Background	1
Approach and Scope of Work	1
2—Geophysical Test Principles and Field Procedures	2
Geophysical Test Principles	2
Electrical surveys	2
Electromagnetic surveys	3
Magnetic surveys	4
GPR surveys	5
Field Procedures	6
3—Test Results and Interpretation	8
Magnetic Surveys	8
EM Surveys	9
Electrical Resistivity Surveys	10
GPR Surveys	11
Size and Depth Determinations	13
4—Conclusions	14
References	15
Figures 1 - 23	
Appendix A	

Preface

A geophysical investigation was conducted at the 26th Street Disposal Site, Edgewood Area, Aberdeen Proving Ground (APG), Maryland, by personnel of the Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), between 3 and 7 June 1994. The investigation was conducted for the Installation Restoration Program, Directorate of Safety, Health, and Environment at APG. The Technical Monitor was Mr. Jerry Burgess. Mr. Don Green was the APG Area Manager.

This report was prepared by Mr. Michael K. Sharp and Dr. Janet Simms, Earthquake Engineering and Geosciences Division (EEGD). The work was performed under the direct supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch. The work was performed under the general supervision of Drs. A. G. Franklin, Chief, EEGD, and William F. Marcuson III, Director, GL. Field work and data analysis were performed by Mr. Sharp and Dr. Simms.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval for the use of such commercial products.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
feet	0.3048	meters
gamma	1.0	nanotesla
inches	2.54	centimeters
millimho per foot	3.28	milliSiemen per meter
yards	0.9144	meters

Summary

A geophysical investigation was conducted at a disposal site along 26th Street, Edgewood Area, Aberdeen Proving Ground (APG), to delineate anomalies indicative of a fill. Electrical resistivity, magnetic, electromagnetic (EM), and ground penetrating radar (GPR) geophysical survey methods were employed to meet this objective. The area investigated included 26th Street and an area immediately west of 26th Street. The study was successful in delineating the lateral boundaries of the fill. The electrical resistivity and GPR tests were successful in determining the approximate depth and thickness of the fill.

The study provided several conclusions. First, the disposal material contains large amounts of iron (or ferrous material) as evidenced from the magnetometer survey. The magnetometer will only respond to ferrous objects. This conclusion is supported by the EM-31 in-phase and EM-61 data which indicate a material with a very high conductivity, which would also indicate metallic material. Third, an approximate fill depth can be determined from the GPR and resistivity data. The resistivity sounding through this area indicates a thickness of approximately 1 m. The radar profiles indicate thicknesses of 3 to 4 ft along a north-south axis. A conservative estimate of fill thickness is 5 ft. Fourth, the fill does not appear to extend under 26th Street.

1 Introduction

Background

The 26th Street disposal area is a solid waste management unit (SWMU) located southeast of the Chemical Agent Storage Yard (CASYS) adjacent to 26th Street (Figure 1). The unit is believed to consist of two separate areas on either side of 26th Street. The area east of 26th Street was a mask canister and charcoal burning area that was being excavated at the time of this study and, therefore, not evaluated. West of the street is a dump area for unknown materials. This study concentrated on delineating the extent of possible fill areas west of 26th Street. Some ground staining can be observed at the site.

Approach and Scope of Work

A geophysical investigation was conducted at the 26th Street site by U.S. Army Engineer Waterways Experiment Station (WES) personnel during 3-7 June 1994. The objective of the investigation was to delineate anomalies indicative of a landfill within the study area shown in Figure 2. Four geophysical methods were used in this investigation: electric, magnetic, electromagnetic (EM), and ground penetrating radar (GPR) surveys.

The success of using geophysical surveying methods for delineating targets of interest is based on there being a sufficient contrast in material properties, i.e., electrical, magnetic, chemical, etc., between the target and its surrounding materials. In this case, it is expected that there is enough contrast between the natural materials and possible fill materials. Other factors affecting the ability to detect a target using geophysical methods are the size, depth, and orientation of the target.

2 Geophysical Test Principles and Field Procedures

Geophysical Test Principles

Electrical surveys

The electrical resistivity survey method allows for the investigation of the electrical properties of subsurface materials from the ground surface. When a current is introduced into a homogeneous earth through a pair of electrodes, the current radiates out through the ground from one electrode and current paths converge on the second electrode through which current leaves the ground. In a homogeneous earth model, the potential drop will be equal for all points equidistant from the point of current entry or exit. Differences in the electrical properties of the underlying materials perturb the distribution of the equipotential surface. In the resistivity method, a known current is introduced in the ground by means of two electrodes emplaced in the ground, and a potential difference is measured at two other electrodes. Earth resistivity is calculated from the current (known) and the potential difference (measured) using Ohm's Law. The objective of the electrical resistivity surveys is the determination of the electrical resistivity or variations in resistivity of subsurface geological materials.

Two types of resistivity surveys were conducted at the site, vertical electrical sounding and resistivity profiling. In the vertical electrical sounding technique, the resistivity of the material as a function of depth is obtained below a given point on the earth's surface. In resistivity profiling, lateral variations in the resistivity of the subsurface to a near-constant depth are mapped. In conducting a sounding, four electrodes are implanted at a fixed distance with the inner electrodes spacing termed "m" and the outer electrode spacing termed "n." Current is injected into the ground through the outer electrodes and read at the inner electrodes. The outer electrodes are advanced while the inner electrodes remain constant, thereby increasing the "n" spacing. Eventually a point is reached where the inner electrode "m" spacing is increased. By steadily increasing the "m" and "n" spacing, deeper and deeper depths of investigation can be obtained. In conducting a profile, four electrodes are implanted at a uniform spacing termed "a." This spacing remains constant throughout the survey, thereby fixing the depth of investigation. Subsequent to each reading, the four electrodes are advanced a distance "a," and another reading is taken.

Electromagnetic (EM) surveys

The frequency EM technique is used to measure differences in terrain conductivity. Like electrical resistivity, conductivity is affected by differences in soil porosity, water content, chemical nature of the ground water and soil, and the physical nature of the soil. In fact, for a homogeneous earth, the true conductivity is the reciprocal of the true resistivity. Some advantages of using the EM over the electrical resistivity technique are (a) less sensitivity to localized resistivity inhomogeneities, (b) no direct contact with the ground required, thus no current injection problems, (c) smaller crew size required, and (d) rapid measurements (McNeil 1980).

The EM equipment used in this survey consists of a transmitter and receiver coil set a fixed distance apart. The transmitter coil is energized with an alternating current at an audio frequency (Khz range) to produce a time-varying magnetic field. This in turn induces small eddy currents in the ground. These currents then generate secondary magnetic fields which are sensed together with the primary field by the receiver coil. The units of conductivity are millimho per meter (mmho/m) or, in the SI system, milliSiemen per meter (mS/m). The EM data are then presented in profile plots or as isoconductivity contours, if data are obtained in a grid form. A more thorough discussion on EM theory and field procedures is given by Butler (1986), Telford et al. (1973) and Nabighian (1988).

There are two components of the induced magnetic field measured by the EM equipment. The first is the quadrature phase component, which gives the ground conductivity measurement. The second is the in-phase component, which is used primarily for calibration purposes. However, the in-phase component is significantly more sensitive to large metallic objects and hence very useful when looking for buried metal containers (Geonics 1984). When measuring the in-phase component, the true zero level is not known since the reference level is arbitrarily set by the operator. Therefore, measurements collected in this mode are relative to a reference level and have arbitrary units of parts per thousand (ppt).

Geonics models EM-31 and EM-34 ground conductivity meters were used to survey the site. The EM-31 has an intercoil spacing of 12 ft and an effective depth of exploration of about 20 ft (Geonics 1984). The EM-31 meter reading is a weighted average of the earth's conductivity as a function of depth. A thorough investigation to a depth of 15 ft is usually possible, but below that depth the effect of conductive anomalies becomes more difficult to distinguish. The EM-31, when carried at a usual height of approximately 3 ft, is most sensitive to features at a depth of about 1 ft. Half of the instrument's readings result from features shallower than about 9 ft, and the remaining half result from below that depth (Bevan 1983). The instrument can be operated in both a horizontal and vertical dipole orientation with correspondingly different effective depths of exploration. The instrument is normally operated with the dipoles vertically oriented (coils oriented horizontally and coplanar), which gives the maximum depth of penetration. The instrument can be operated in a continuous or a discrete mode. The EM-34 has separable coils connected by 10-, 20-, or 40-m cables. This allows for a greater depth of investigation depending on the coil orientation and

cable length selected. As a rule of thumb, with the coils positioned vertically (horizontal dipole), depth of investigation is 0.75 times the coil separation, and with the coils positioned horizontally (vertical dipole), depth of investigation is 1.5 times the coil separation.

A third EM device used at the site is termed the EM-61 which is a time-domain system. The EM-61 is a high-sensitivity, high-resolution time-domain metal detector which is used to detect both ferrous and nonferrous metallic objects. It consists of a powerful transmitter that generates a pulsed primary magnetic field, which induces eddy currents in nearby metallic objects. The decay of these currents is measured by two receiver coils. By making the measurement at a relatively long time after termination of the primary pulse, the response is practically independent of the electrical conductivity of the ground.

Magnetic surveys

The magnetic method of surveying is based on the ability to measure local disturbances of the earth's magnetic field. Magnetic anomalies are caused by two different types of magnetism: induced and remanent magnetization. Remanent magnetization is a permanent magnetic moment per unit volume, whereas induced magnetization is temporary magnetization that disappears if the material is removed from a magnetic field. Generally, the induced magnetization is parallel with and proportional to the inducing field (Barrows and Rocchio 1990). The remanent magnetism of a material depends on the thermal and magnetic history of the body and is independent of the field in which it is measured (Breiner 1973).

A GEM Systems GSM-19 "walking" magnetometer was used to measure the total field intensity of the local magnetic field. The magnetic unit of measurement is the nanotesla (nT) or gamma. One nanotesla is equivalent to one gamma. The local magnetic field is the vector sum of the field of the local magnetized materials (local disturbance) and the ambient (undisturbed) magnetic field.

The magnetometer was used with dual sensors thereby allowing the vertical gradient of the total magnetic field (TMF) to be measured. The gradient is taken by measuring the total field at a survey point using two sensors which are fixed a small vertical distance apart. The difference in values between the two sensors divided by their separation approximates the gradient measured at the midpoint of the sensor spacing. Two advantages of using the magnetic gradient are: (a) the regional magnetic gradient is filtered out, thus local anomalies are better defined, and (b) magnetic storm effects and diurnal magnetic variations are essentially removed, since the two readings are taken simultaneously (Breiner 1973). The magnetometers used in this survey have an absolute accuracy of approximately ± 1 gamma. For reference, the earth's magnetic field varies from approximately 60,000 gammas at the poles to 30,000 gammas at the equator (the nominal field strength at the site is approximately 53,000 gammas).

A magnetic anomaly represents a local disturbance in the earth's magnetic field which arises from a localized change in magnetization or magnetization contrast. The observed anomaly expresses the net effect of the induced and remanent magnetization and the earth's ambient magnetic field. Depth of

detection of a localized subsurface feature depends on its mass, magnetization, shape and orientation, and state of deterioration.

GPR surveys

GPR is a geophysical subsurface exploration method using high-frequency EM waves. The GPR system consists of a transmitting and a receiving antenna. The transmitting electronics generate a short-duration, high-voltage EM pulse which is radiated into the ground by the transmitting antenna. The signal is reflected by materials having contrasting electrical properties back to the receiving antenna. The magnitude of the received signal as a function of time after the transmitter has been initiated is measured. The signals are then amplified, processed, and recorded to provide a "continuous" profile of the subsurface.

The transmitted EM waves respond to changes in soil and rock conditions having sufficiently different electrical properties such as those caused by clay content, soil moisture or groundwater, water salinity, cementation, man-made objects, voids, etc. The depth of exploration is determined by the electrical properties of the soil or rock as well as by the power of the transmitting antenna. The primary disadvantage to GPR is its extremely site specific applicability; the presence of high-clay-content soils in the shallow subsurface will generally defeat the application of GPR (Olhoeft 1984). High-water contents in the shallow subsurface and shallow-water tables can also limit the applicability of GPR at some sites. A general rule is that GPR should not be applied to projects in which the mapping objective is greater than 50 ft in depth. For shallow mapping applications at sites with low-clay-content soils, GPR will generally have the best vertical and horizontal resolution of any geophysical method (Butler and Llopis 1990).

A Sensors and Software Inc. Pulse Echo IV GPR system with a center-frequency antenna of 100 MHz was used to conduct the GPR surveys. The pulseEKKO antennas are resistivity damped dipolar antennas. The antenna radiation patterns are the pattern of a half-wavelength dipole. When the ground conditions are suitable, the great majority of the radiated signal is transmitted into the ground (typically 90 percent). Each antenna pair is designed to have a bandwidth to center frequency ratio of one, which implies that the antennas have useable energy over the frequency range of 50 to 150 MHz. The transmitter has a peak voltage of 400 V with a rise time of 2.5 ns. The power radiated is very dependent on the soil conditions around the radiating antenna. From a specification point of view, the 400 V transmitter delivers a peak power of 3.2 kW into a 50-ohm load. The receiver electronics module digitizes the voltage at the receiver antenna connector to 16-bit resolution. The receiver electronics clip the incoming voltage at a 50-mV level. The receiver noise level is nominally around 200 μ V for a single stack. The present receiver resolution for a single bit after A/D conversion is 1.5 μ V. The received signal was displayed on a laptop computer screen during the survey to allow the operator to check data quality. The received signal was also recorded on the computer's hard disk for future processing. By recording a vertical intensity modulated scan for every foot of antenna travel, a continuous profile is developed showing reflections from subsurface strata and anomalies within the strata. A near-horizontal geologic

interface, for example, will appear as a near-horizontal line or band on the GPR record. A small localized object, such as a buried metallic object will appear as a hyperbolic-shaped event centered over the object's location.

Field Procedures

The area to be investigated was gridded with survey station markers. The grid stations on the section were marked at 20-ft intervals by implanting polyvinyl chloride (PVC) stakes into the ground. PVC stakes were used to prevent interference with the geophysical tests conducted at the sites.

Figure 3 shows the grid and locations of visible features. The features were mapped to determine if any of the interpreted geophysical anomalies corresponded to a mapped feature. If the anomaly corresponds with the location of a mapped feature, it is likely that this feature has affected the geophysical survey reading and the anomaly should be regarded cautiously. On the other hand, if the interpreted anomaly does not correspond to any of the mapped visible objects, then the anomaly may be caused by an irregularity in the subsurface. The map of surface features also aids in locating oneself in the field. Of particular interest, is the scarred area which extends through the site from north to south.

The locations of the electrical resistivity soundings and profiles are shown in Figure 4. Two soundings and two profiles were performed. One sounding was located through the ground scarred area and the other away from the scarred area in apparent natural material. The length of each line was 160 m, centered at position 120N. The profiles were perpendicular to the scarred area at two different "a" spacings of 5 and 10 m. The line spaced at 5 m extended from 0E to 220E along line 80N, and the line spaced at 10 m extended from 30E to 250E along line 80N.

The EM-31 data were collected in both the quadrature (conductivity) and in-phase mode on a 10-ft grid (i.e., measurements taken every 10 ft in the X-direction and Y-direction). Measurements were recorded on a digital data logger and transferred to a portable field computer at the conclusion of the survey. The EM-34 data were collected in the same manner (conductivity values only, the EM-34 does not record in-phase data) using the 10-m cable with the coils oriented vertically and horizontally.

The GEM Systems magnetometer allows the user to collect data continuously while walking along the survey line. The GEM magnetometer was configured to collect a reading every 1 s or approximately every 2 to 3 ft along survey lines (north-south) spaced 10 ft apart (east-west). The data were collected and stored in the internal memory of the magnetometer and transferred to a portable field computer at the conclusion of the survey.

The locations of the GPR survey lines are shown in Figure 5. The locations of the GPR lines were limited to fairly level and uncluttered areas because of the size of the antennas. A transmitter-receiver antenna separation of 3 ft was used to

conduct the survey. The survey was carried out by placing the antenna pair at one end of the line and moving the antenna pair at 1-ft increments along the line.

3 Test Results and Interpretation

In deciding what constitutes significant anomalies for a particular site, several factors must be weighed. Anomaly detection is limited by instrument accuracy and local "noise" or variations in the measurements caused by factors not associated with the anomalies of interest such as fences, power lines, steel rails, etc. (cultural noise). For the anomaly to be significant, the measurement due to the anomaly must have a response greater than that due to the interfering cultural noise. Since the anomaly amplitude, spatial extent, and wavelength are the keys to detection, the size and depth of the feature causing the anomaly are important factors in determining detectability and resolution. The intensity of the anomaly is also a function of the degree of contrast in material properties between the anomaly and the surrounding material.

The results of the TMF, magnetic gradient, EM-31 conductivity, EM-31 in-phase, EM-34 conductivity, and EM-61 data collected for the site are presented as contour maps of the measured parameter. The color coded contour maps show a two-dimensional representation of the data with hot colors (reds) indicating areas with relatively high values and cold colors (blues) showing areas with relatively low values. The electrical resistivity data are presented as profile plots.

Based upon the test method employed, noise conditions at the sites and the assumption that the target objects are relatively shallow (less than 10 ft), anomalous areas considered as significant are indicated in these figures by bold lines. No contour map is presented for the GPR data since GPR data cannot be contoured. The locations of visible features are superimposed on the plotted data. Discussed below are the major anomalies interpreted at the site.

Magnetic Surveys

The results of the TMF and magnetic gradient surveys are presented in Figures 6 and 7, respectively. The TMF shows magnetic anomalies which include the effects of magnetic drift and other factors that may or may not be present (such as magnetic storms). The magnetic drift is normally removed by occupying a base station several times during the survey to keep track of the drift which is removed from the data during processing. A gradient survey measures the difference between two total field sensors separated a small distance. The benefits of

performing a gradient survey are to reduce the effects of magnetic drift and to enhance the discrimination between neighboring magnetic anomalies. A background value for the area is selected by observing the data after contouring. Local variations from the background will appear as highs and lows due to the dipolar nature of anomalies and the orientation of the object in the ground. In the case of the gradient survey, a zero value indicates no difference between the readings of the two sensors. A gradient high will correspond to the TMF high, and a gradient low will correspond to the TMF low. The most apparent feature from both surveys is the ground scarred area. This anomalous region extends from the northern boundary to the southern boundary of the survey area. There is obviously some type of ferrous material at this location. The depth can not be determined since no clearly identifiable dipole targets exist. In addition, several smaller targets can be seen at locations 10E:170N, 50E:270N, and 70E:340N. These targets are associated with surface material. The effects of the road can be seen along line 175E from 350N to 200N. This response is attributed to the construction equipment located along the road associated with the excavation procedures. This material could not be moved until after the magnetic survey, but fortunately before the EM survey.

EM Surveys

The results of the EM-31 conductivity and in-phase surveys are presented in Figures 8 and 9, respectively. The soils at the site are mainly interbedded sands and clays. For the clays described as being reddish-brown, dark grey, silty, and lignitic, a conductivity of 15 to 20 mS/m is appropriate. For the sands described as being clayey, fine-grained, with quartz gravels, a conductivity of 20 to 30 mS/m is appropriate. In general, the site would have conductivities ranging between 20 and 25 mS/m. In the areas outside the scarred area, the values ranged around 20 mS/m as would be expected for the area. The area associated with the ground scarred section is clearly identifiable with conductivities of -12 to -32 mS/m. The anomaly is fairly consistent across the site with a wavelength of 50 ft and an amplitude of 22 ppt and 26 mS/m for the in-phase and quad-phase data, respectively. These data are less affected by the nearby surface objects (metal posts, crane, front end loader, etc.) and present a clearer picture of the extent of the material beneath the scarred area. In particular, the area beneath 26th Street does not appear to contain any of the fill material. The conductivity data across the scarred area are contoured as extremely low, even negative, values. Negative conductivities are an indication that the values are outside the linear response of the instrument. This type of signal is usually encountered over very large magnetic objects. In reality, the values would be very high positive numbers. When EM data are collected (both in-phase and quad-phase) over an area that has a conductivity or magnetic anomaly, a distinctive response is obtained. As the instrument approaches the anomaly, the values will tend to decrease from background, increase as the instrument is centered over the anomaly, then decrease again as the instrument leaves the anomaly. This effect is due to the nature of the antenna-receiver geometry. In both the in-phase and quad-phase data sets, there is an anomaly centered at 150E,225N. This anomaly is associated with the concrete poured into the drainage system extending under 26th Street. The effect seen in the data is a direct consequence of the concrete and can not be clearly identified as drainage. The cause of the anomaly centered at 195E,250N

is construction material used to excavate the east side of 26th Street. Profile lines have been extracted from the conductivity data and converted into resistivity data at locations 50N, 100N, 150N, 200N, 250N, and 300N. These profiles are shown in Appendix A. The effect of the fill is clearly seen in each plot as a resistivity low (0 to -100 ohm-m) as compared to the background (approximately 75 ohm-m). The resistivity high at a distance of 25 ft in line 200N is associated with surface debris as is the high at location 40 ft in line 150N.

The results of the EM-34 conductivity data, vertical and horizontal orientations, are presented in Figures 10 and 11, respectively. Data from the vertical survey gives a thorough investigation to a depth of 7.5 m and from the horizontal survey to a depth of 15 m. Both surveys respond to the ground scarred area, though the results appear to be somewhat "smoothed." This is due to the fact that the test is sampling a much larger volume per reading than the EM-31. Due to the smoothing effect of the data, the wavelength would not be accurate for this test.

The results of the EM-61 survey are shown in Figure 12. As with the other EM surveys, the scarred area has a clear effect on the data. The wavelength of this data is the same as the EM-31 data (50 ft) and has an amplitude of 140 mV.

Electrical Resistivity Surveys

The results of the electrical resistivity soundings are presented in Figures 13 and 14. The soundings were performed using a Schlumberger array, which gives a depth of investigation roughly equal to one-fourth the total spread. The soundings were each 160 m long which gives an effective investigation to a depth of 40 m. Figure 13 is the sounding conducted away from the scarred area (natural), and Figure 14 is the sounding in the scarred (nonnatural) area. The x-axis (AB/2) refers to the distance along the traverse in feet. There is a stark contrast between the two soundings. The 'natural' sounding shows a consistent near homogeneous layering that extends well over 15 m in depth. The interpreted depth section shows only slight changes in resistivity with depth ranging between 200 ohm-m at the surface to 80 ohm-m at depth. The 'nonnatural' sounding shows three clearly distinct layers. The first layer is interpreted to extend from the surface to 0.4 m with a resistivity of 160-180 ohm-m, the second layer to a depth of 1.2 m with a resistivity of 4 ohm-m, and the third layer has a resistivity of 70 ohm-m and extends to an undetermined depth. The fill material in the scarred area is clearly affecting the sounding data creating the very low-resistivity (4 ohm-m) second layer having a thickness of approximately 1 m.

The results of the electrical resistivity profiles are presented in Figures 15 and 16. The profiles were conducted using a Wenner array, which gives a depth of investigation roughly equal to the electrode spacing. Profiles were collected with electrode spacings of 5 and 10 m. The data shown in Figure 15 had the electrodes at a uniform spacing of 5 m, and the data shown in Figure 16 had the electrodes at a uniform spacing of 10 m. The location of the scarred area on Figure 15 is between 30 and 50 m. There is an apparent drop in the resistivity values through this section, which indicates that the material is located at a depth less than the 5 m spacing. In Figure 16 (10-m spacing), the scarred area is located between 40

and 60 m. There is a slight drop in the resistivity values through this section. However, they are not as dramatic as in the 5-m spacing line. The change in resistivity values is probably associated with the near-surface material rather than any material at depths greater than 5 m.

The values collected from a resistivity profile or sounding will both be effected by the water table. In particular, an increase in saturation will dramatically effect the resistivity values. The values will decrease as the saturation increases. To notice this effect in the profile data, different spacing lines would have to be conducted. In sounding data, the water table is generally clearly discernable as a drop in resistivity values at some appropriate depth. The sounding data collected through the scarred area shows a layer with lower resistivity values than the surrounding top or bottom layer. This layer does not appear in the sounding line collected 50 ft west. Therefore, the only conclusion is that the layer is associated with the fill material and not the water table.

GPR Surveys

The results from the GPR survey are presented in Figures 17 through 23. Each of the GPR lines were run perpendicular to the scarred area at six locations along the survey site. The radar lines were placed to aid in the determination of the depth and thickness of the fill material. The sections are investigating to a depth of approximately 10 ft. The depth is approximate since the material velocity was not determined directly. The velocity was determined based on the conductivity of the material, which relates to the soils dielectric permmitivity. This, in turn, is related to the material velocity. The velocity is needed to convert the radar time section to a depth section. The results of each radar line is presented in Table 1. Each of the lines crossed the scarred area and clearly shows a response to the area as well as information on the thickness of the fill.

The dipping reflectors that appear in lines 310N and 310Na are interesting geologic structures. The reflectors are associated with dipping layers in the subsurface. However, there is not enough information in these sections to determine if this feature is associated with a subsurface channel.

Table 1 Description of ground penetrating radar records		
Line location	Stations covered	Brief description
20N	130E-60E	Scarred area between 80E and 100E: Extends from just below the surface to a depth of 4.5 ft.
80N	60E-150E	Scarred area between 120E and 140E: Extends from the surface to a depth of 4 ft.
140N	60E-160E	Scarred area between 105E and 140E: Expression of the area is clear on the section, but thickness is not.
200N	180E-80E	Scarred area between 120E and 150E: Radar expression is difficult to distinguish, however it does exist and extends from the surface to a depth of 6 ft.
240N	80E-180E	Scarred area between 135E and 160E: Area appears as a hump in the radar section. Bottom is difficult to distinguish, possibly to a depth of 5 ft.
310N	170E-100E	Scarred area between 110E and 145E: Bottom difficult to distinguish since a dipping reflector enters the section at 145E near the bottom of the record. Possible depth to fill bottom at 5 ft.
310Na	100E-170E	Redid previous line with larger time scale to see dipping reflectors. Line was run in the opposite direction and the reflectors can be seen on the left side of the section.

Size and Depth Determination

Considering all the data collected at the site, an estimate of the size and depth (depth estimate from GPR and resistivity only) of the fill has been determined. These data are presented in Table 2. Because the data were collected by indirect methods, the values in Table 2 are approximations based on the data presented in this report.

Location	Width, ft	Depth, ft
-50N	35	
-25N	35	
0N	35	
25N	40	3
50N	45	
75N	45	3.5
100N	50	
125N	55	
150N	60	4
175N	45	
200N	40	6
225N	40	
250N	45	4.5
275N	45	
300N	45	4.5
325N	30	
350N	15	

4 Conclusions

A geophysical investigation was conducted at 26th Street, Edgewood Area, APG, to delineate anomalies indicative of a fill. Electrical resistivity, magnetic, EM, and GPR geophysical survey methods were employed to meet this objective. The investigation was carried out in the area immediately west of 26th Street and on the street. The tests were successful in delineating the lateral boundaries of the fill in a north-south, east-west direction. The electrical resistivity and GPR tests were successful in determining an approximation of the depth and thickness of the fill.

The study provided several conclusions. First, the disposal material contains large amounts of iron (or ferrous material) as evidenced from the magnetometer survey. The magnetometer will only respond to ferrous objects. This conclusion is supported by the EM-31 in-phase and EM-61 data which indicates a material with a very high conductivity, which would also indicate metallic material. Second, an approximate fill depth can be determined from the GPR and resistivity data. The resistivity sounding through this area indicates a thickness of approximately 1 m. The radar profiles indicate thicknesses of 3 to 4 ft along a north-south axis. A conservative estimate of fill thickness is 5 ft. Third, the fill does not appear to extend under 26th Street.

References

- Barrows, L. and Rocchio, J. E. (1990). "Magnetic surveying for buried metallic objects," *Ground Water Monitoring Review* 10(3), 204-211.
- Bevan, B. W. (1983). "Electromagnetics for mapping buried earth features," *Journal of Field Archaeology* 10.
- Breiner, S. (1973). "Applications manual for portable magnetometers," *Geometrics*, Sunnyvale, CA.
- Butler, D. K. (1986). "Military hydrology; report 10: Assessment and field examples of continuous wave electromagnetic surveying for ground water," Miscellaneous Paper EL-79-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Butler, D. K., and Llopis, J. L. (1990). "Assessment of anomalous seepage conditions." *Geotechnical and environmental geophysics, volume II: Environmental and groundwater*. Soc. Explor. Geoph., Tulsa, OK.
- Geonics Limited. (1984). *Operating manual for EM31-D non-contacting terrain conductivity meter*. Mississauga, Ontario, Canada.
- McNeil, J. D. (1980). "Electromagnetic terrain conductivity measurements at low induction numbers," Technical Note TN-6, Geonics Limited, Mississauga, Ontario, Canada.
- Nabighian, M. N. (1988). *Electromagnetic methods in applied geophysics*. Vol. 1, Soc. Explor. Geoph., Tulsa, OK.
- Olhoeft, G. R. (1984). "Applications and limitations of ground penetrating radar," 54th Ann. Internat. Mtg. Expanded Abstracts, Soc. Explor. Geoph., Tulsa, OK, 147-148
- Telford, W. M., Geldhart, L. P., Sheriff, R. E., and Keys, D. A. (1973). *Applied Geophysics*, Cambridge University Press, NY.

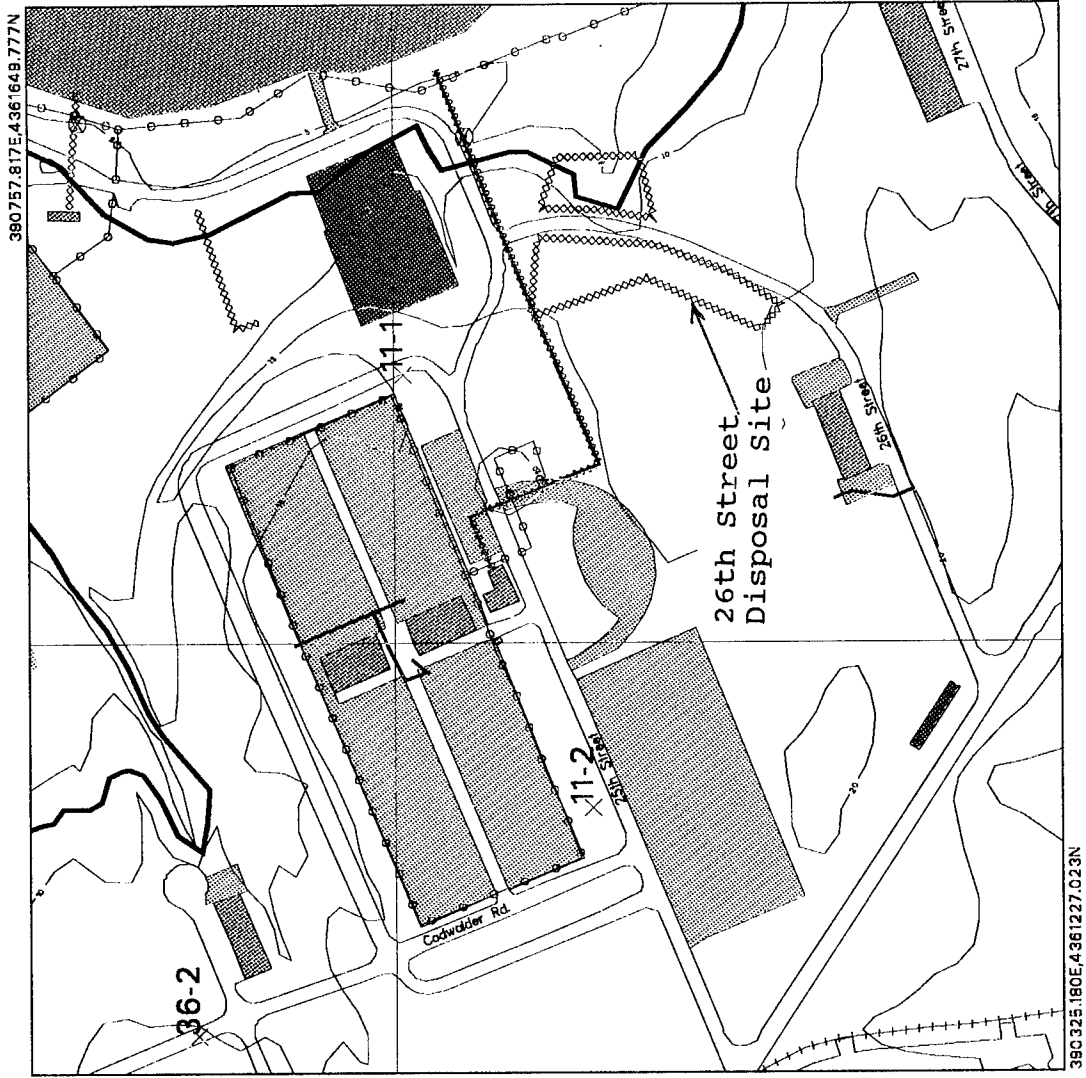


Figure 1. Vicinity map

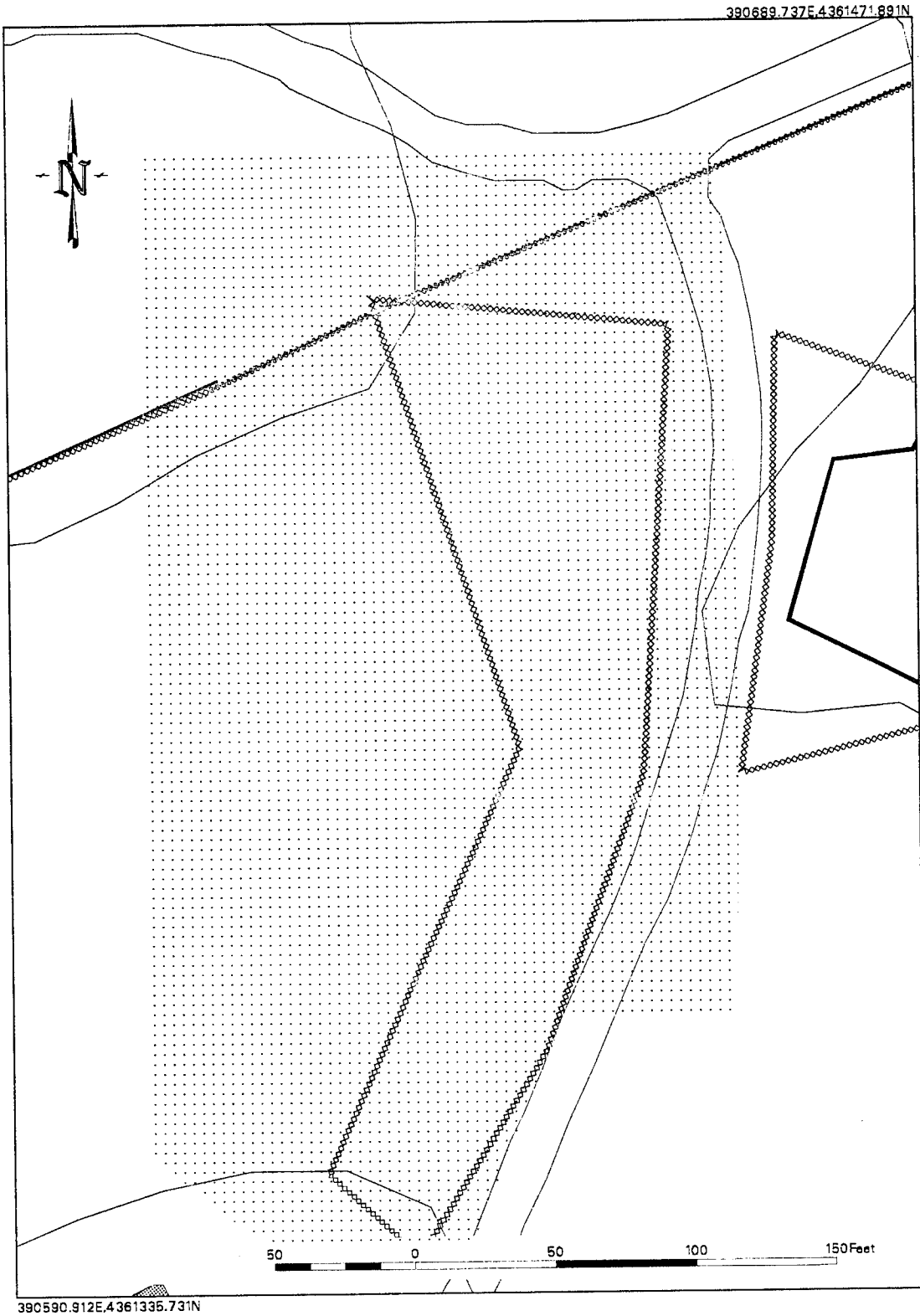


Figure 2. Location of geophysical survey area relative to disposal site

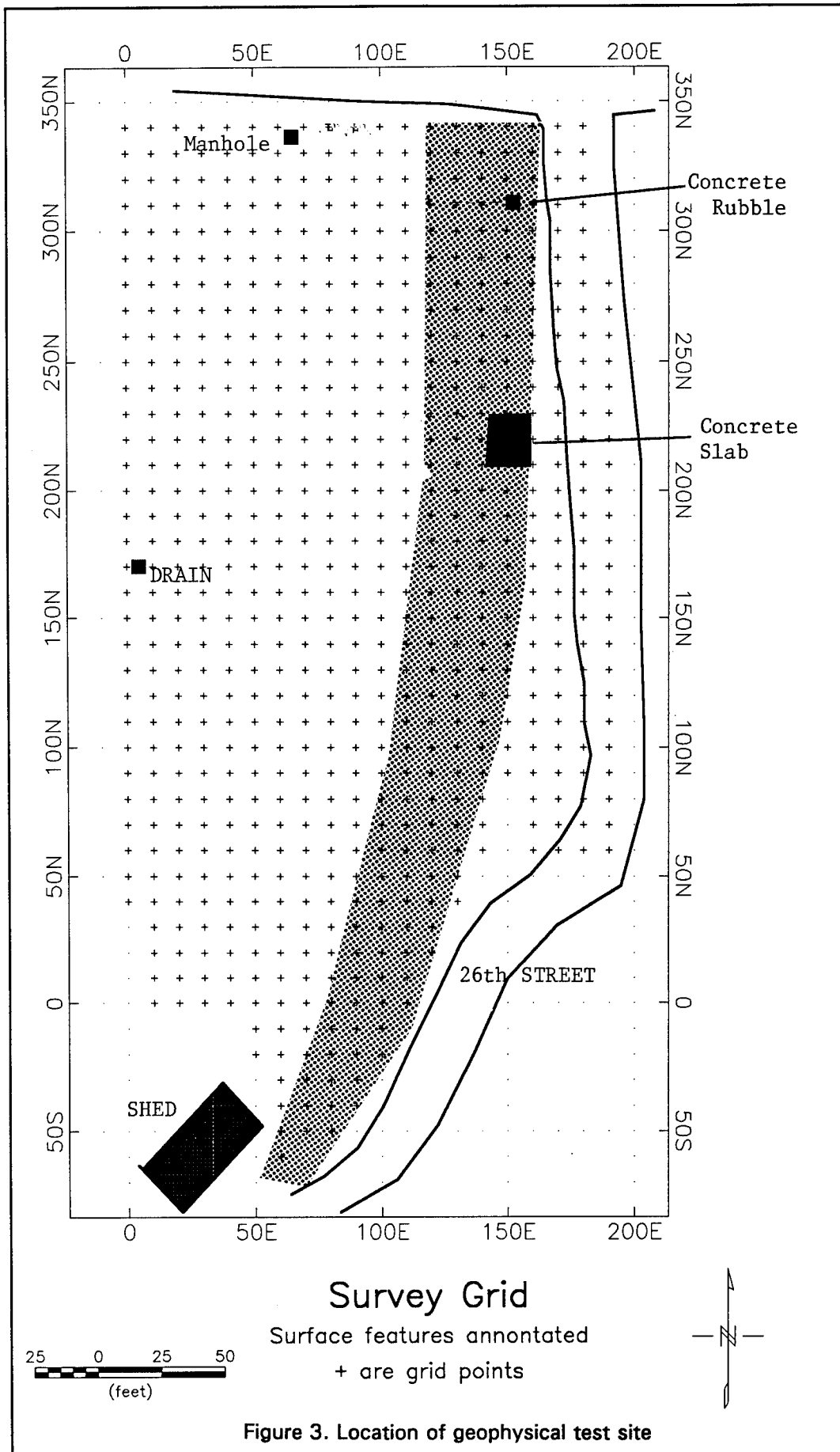
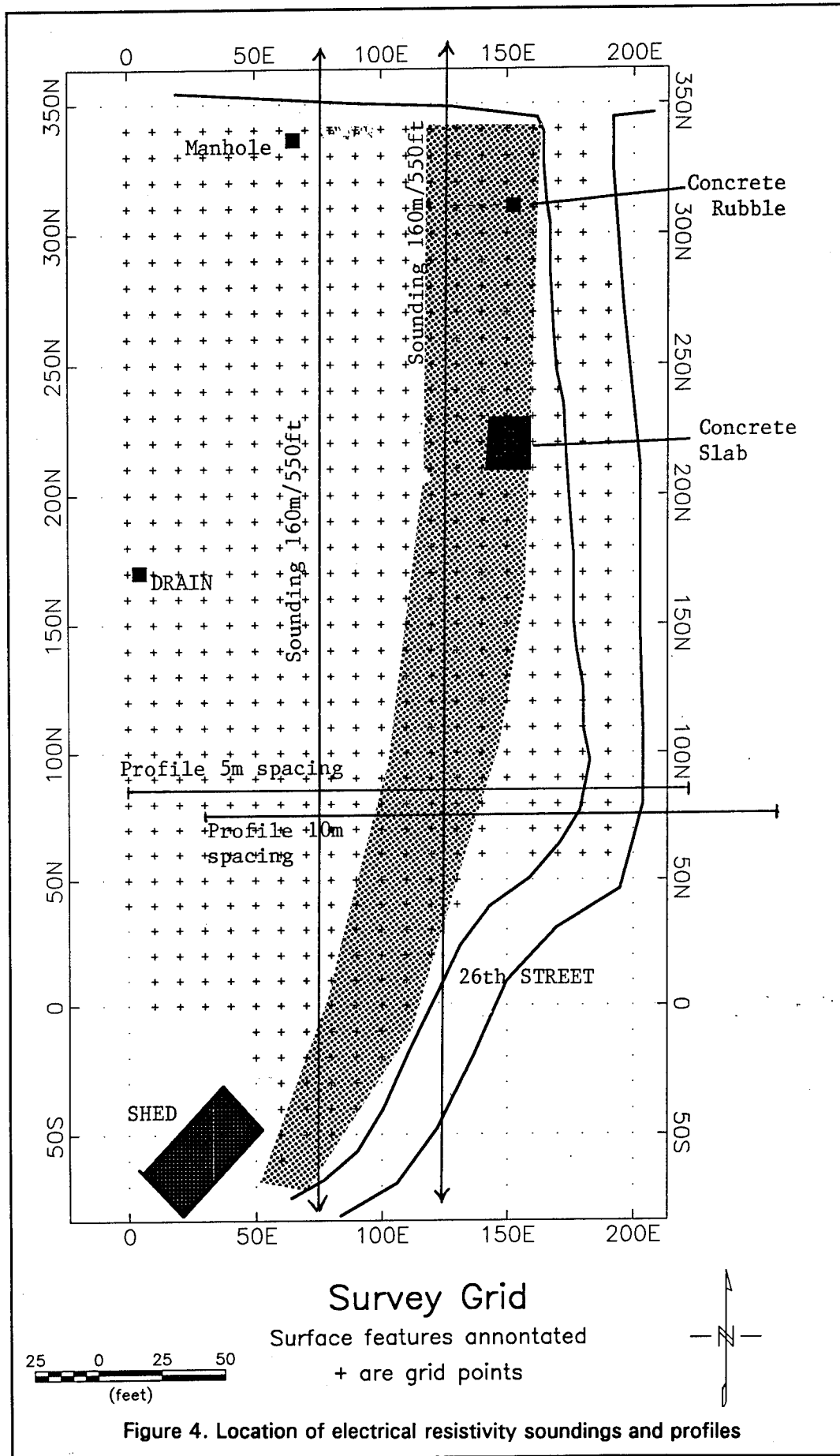
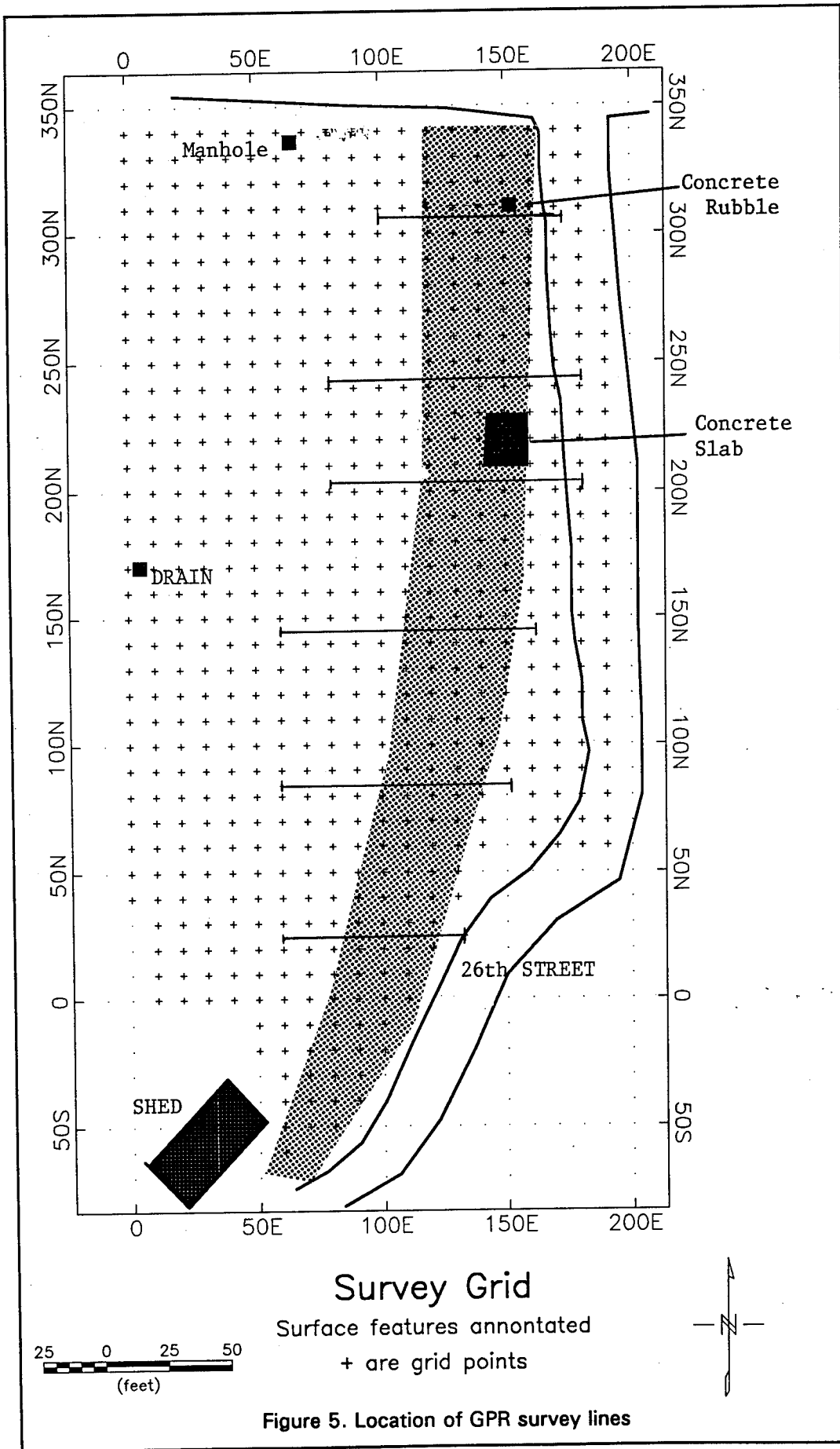


Figure 3. Location of geophysical test site





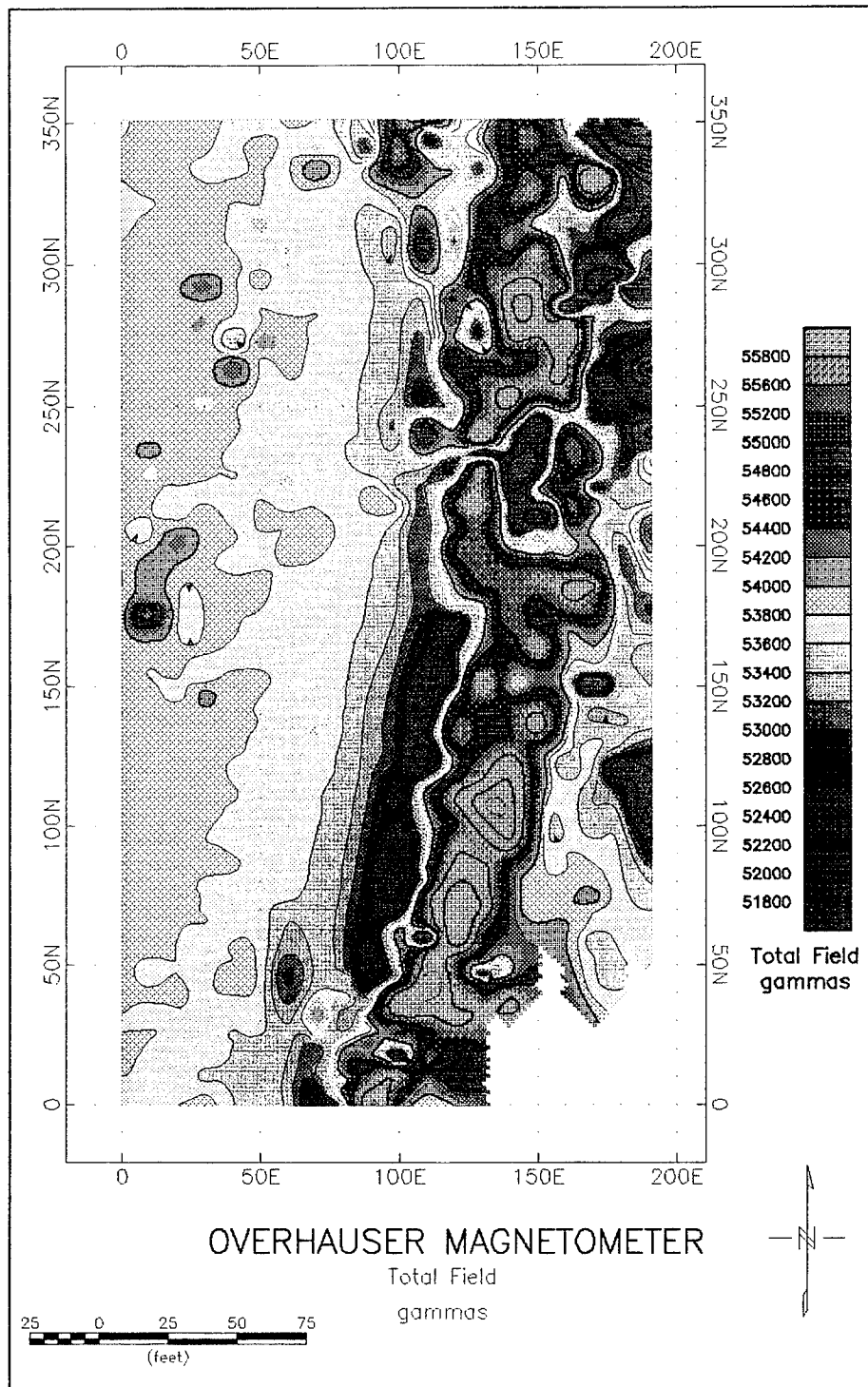


Figure 6. Total magnetic field survey results

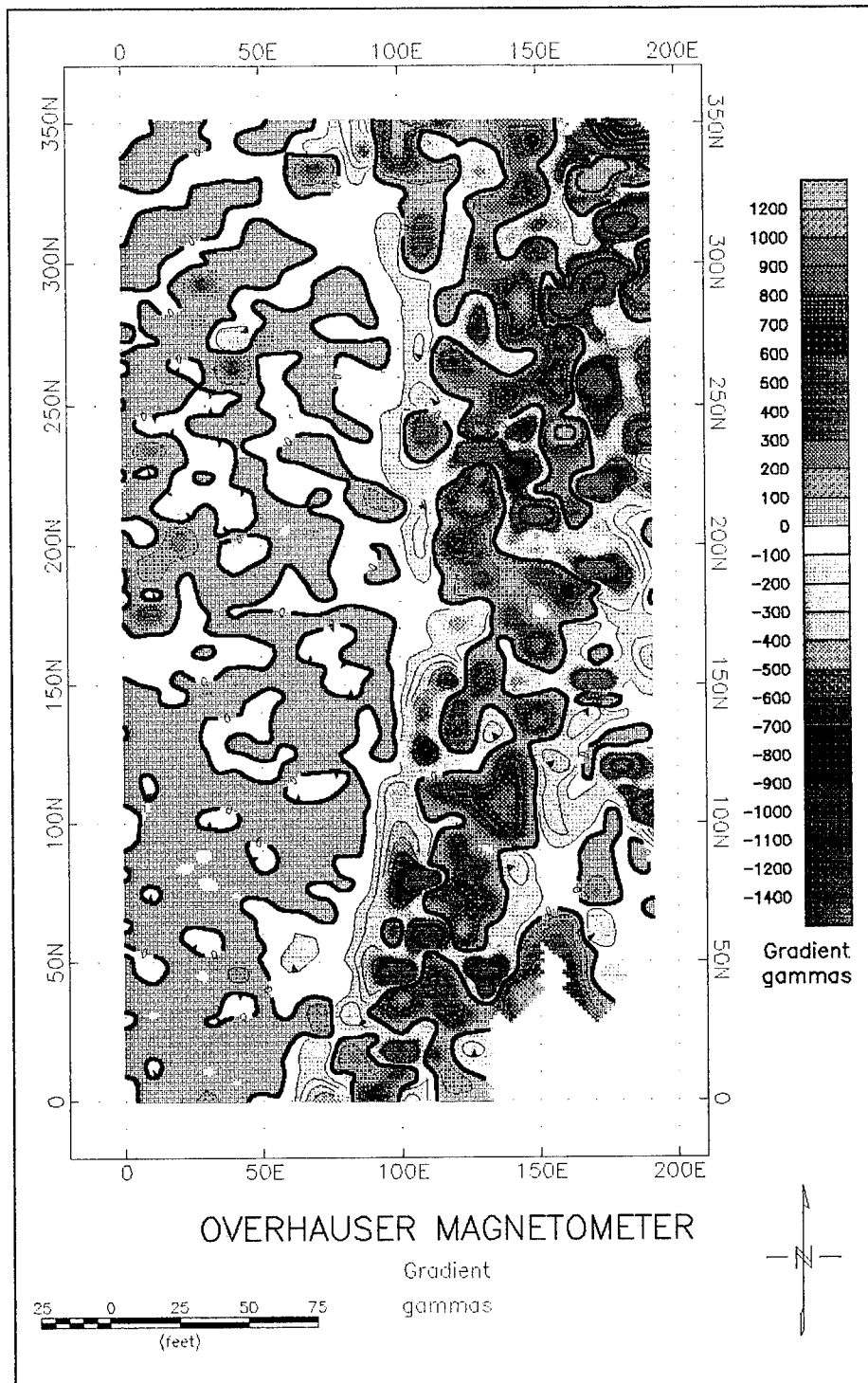


Figure 7. Magnetic gradient survey results

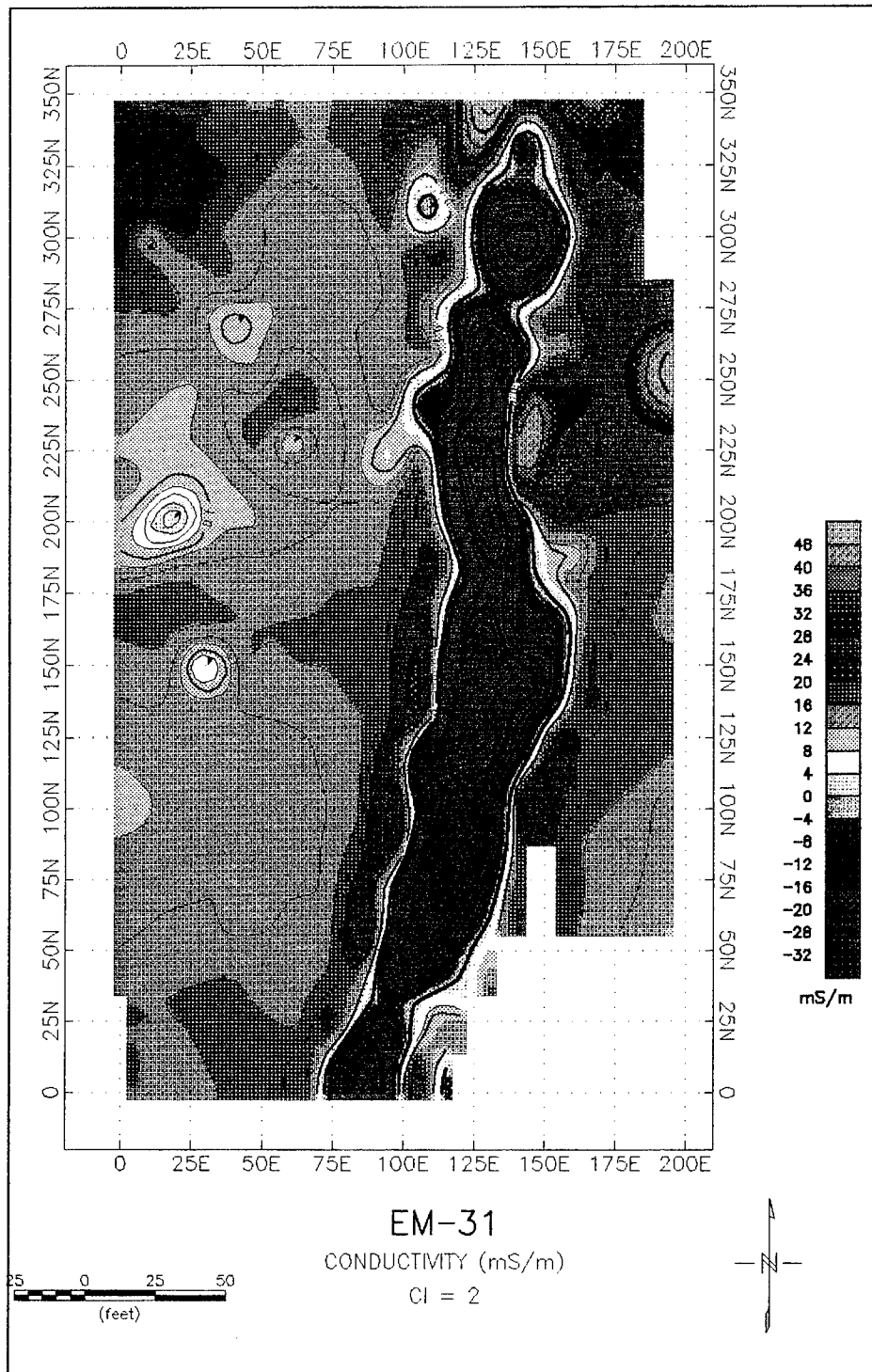


Figure 8. EM-31 conductivity survey results

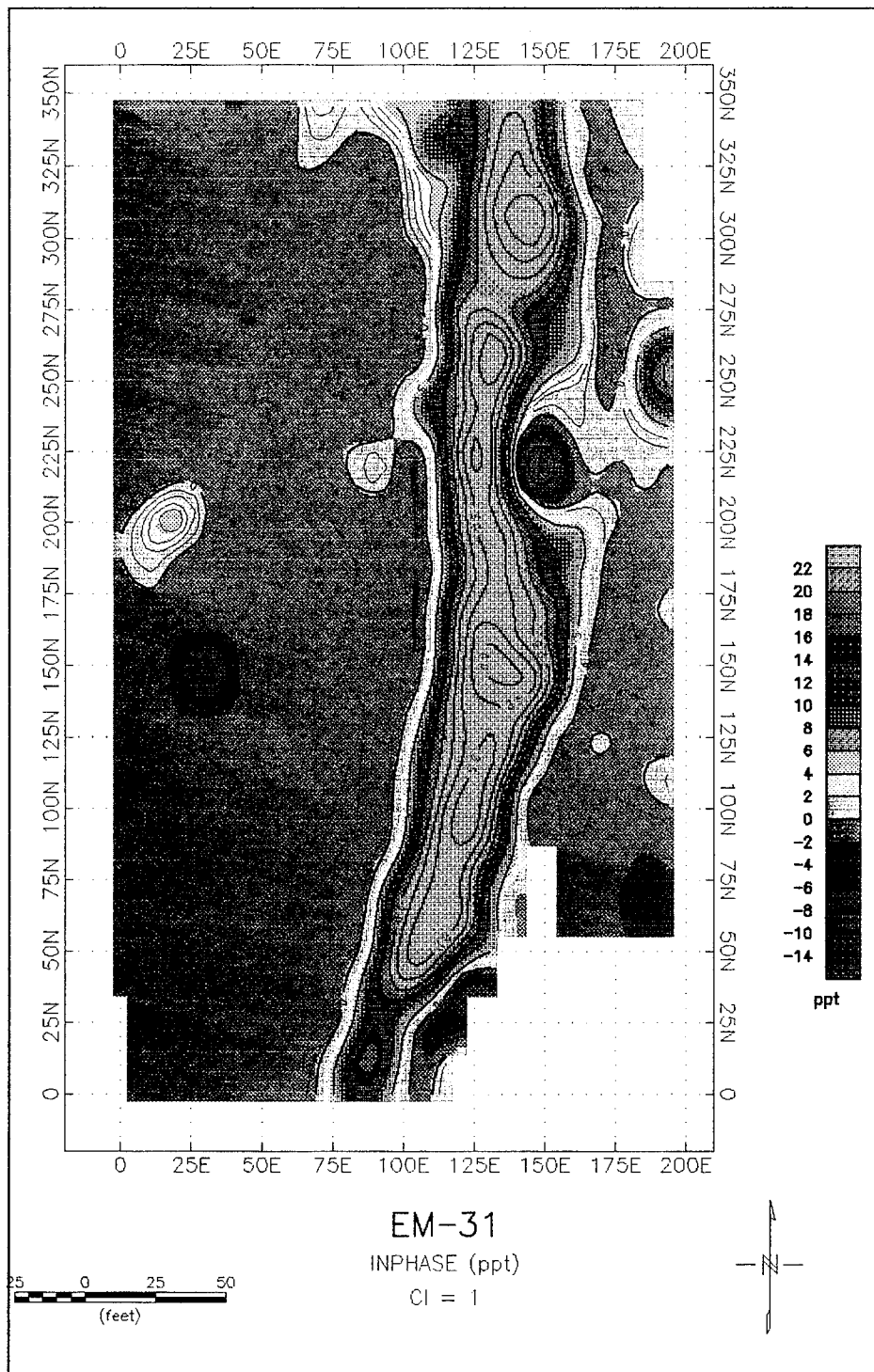


Figure 9. EM-31 in-phase survey results

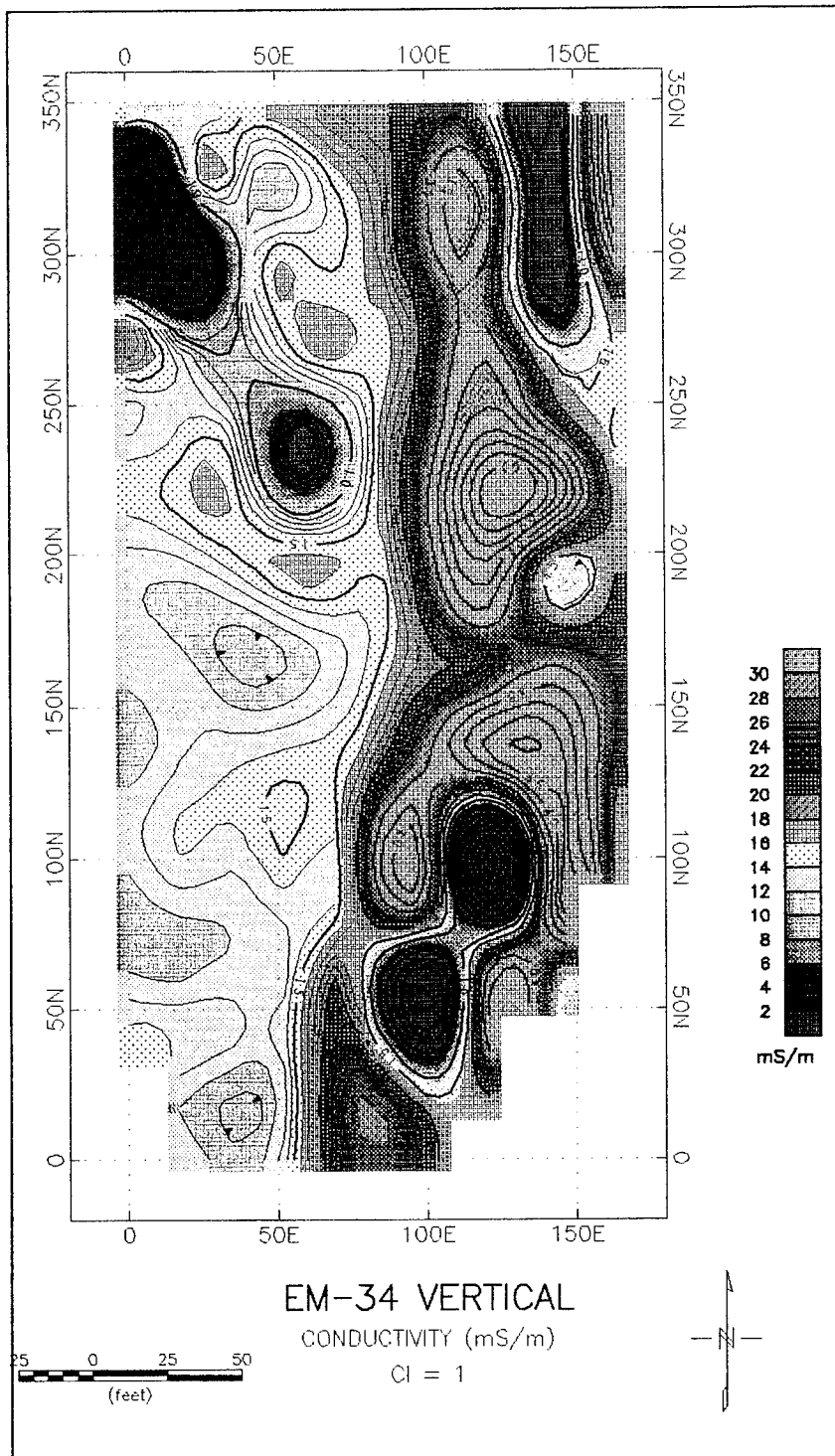


Figure 10. EM-34 vertical orientation conductivity results

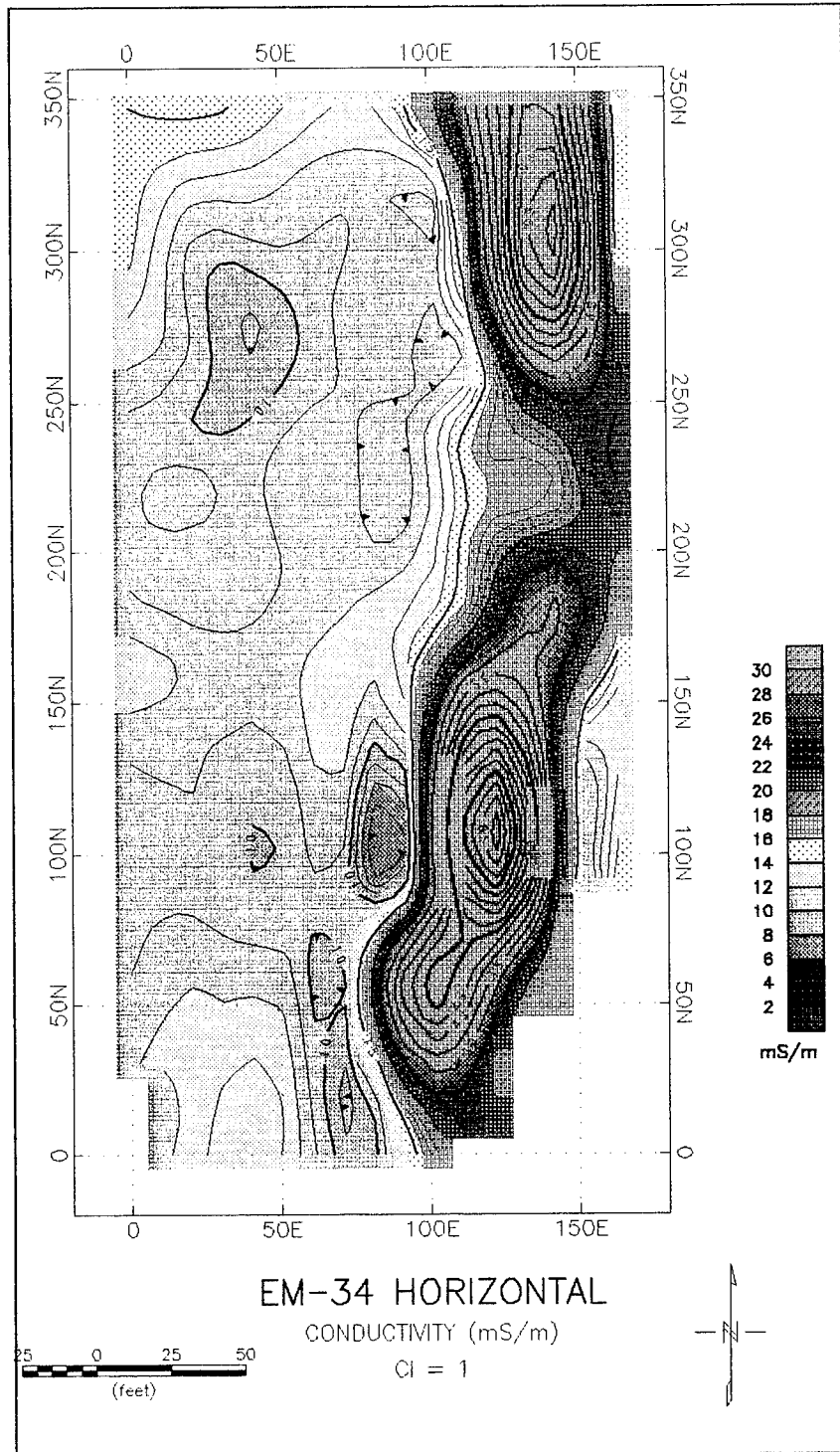


Figure 11. EM-34 horizontal orientation conductivity results

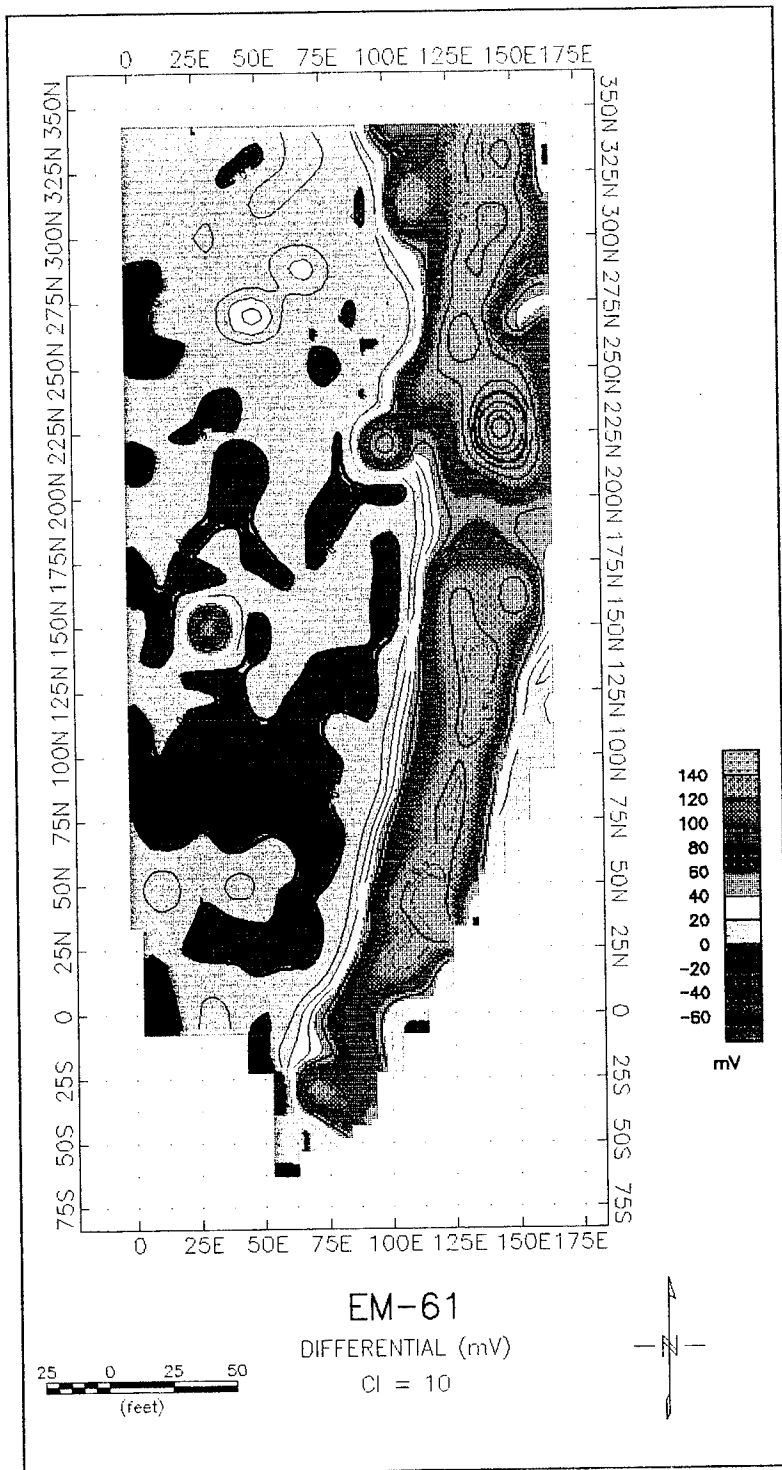


Figure 12. EM-61 survey results

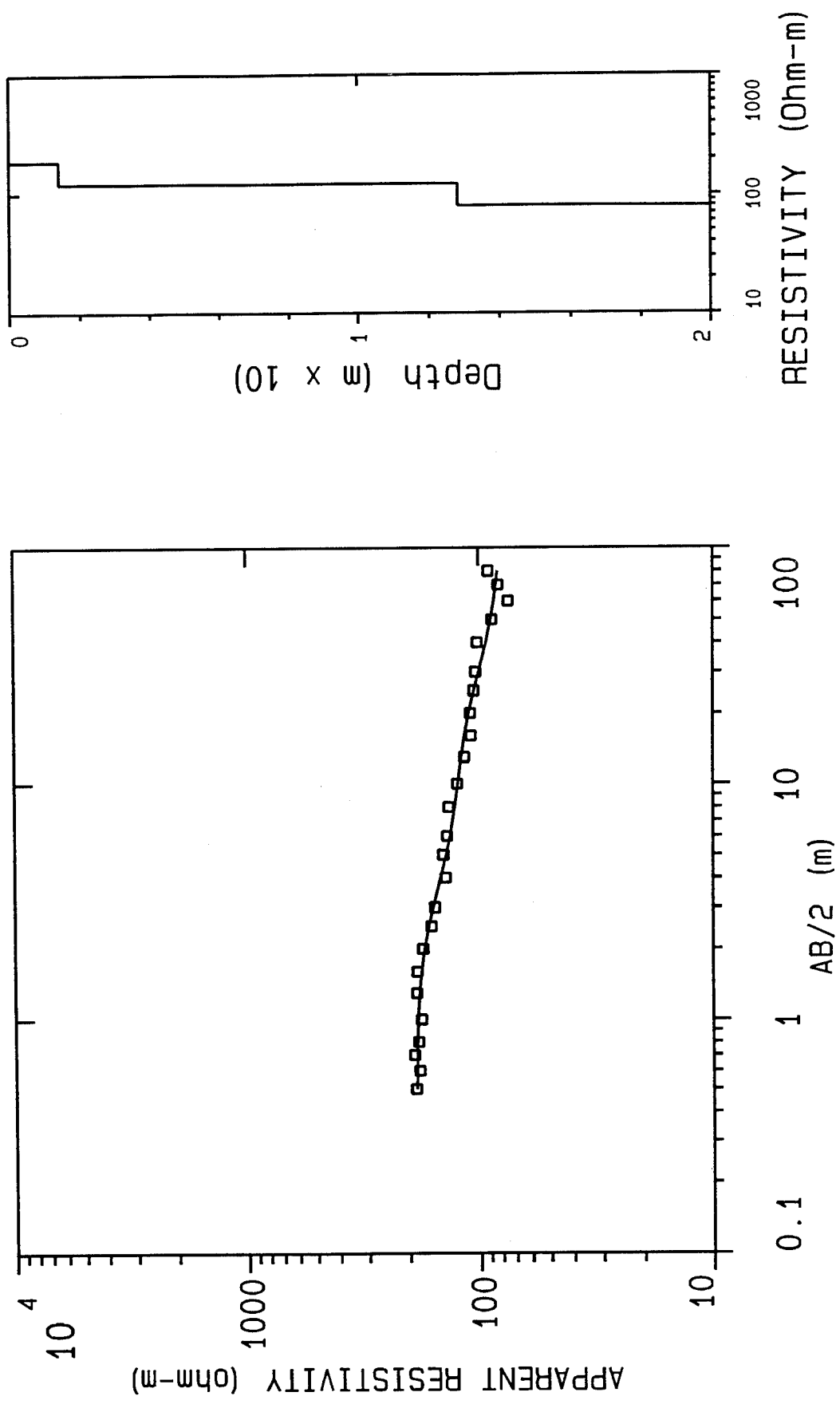


Figure 13. Electrical resistivity sounding along line 80E

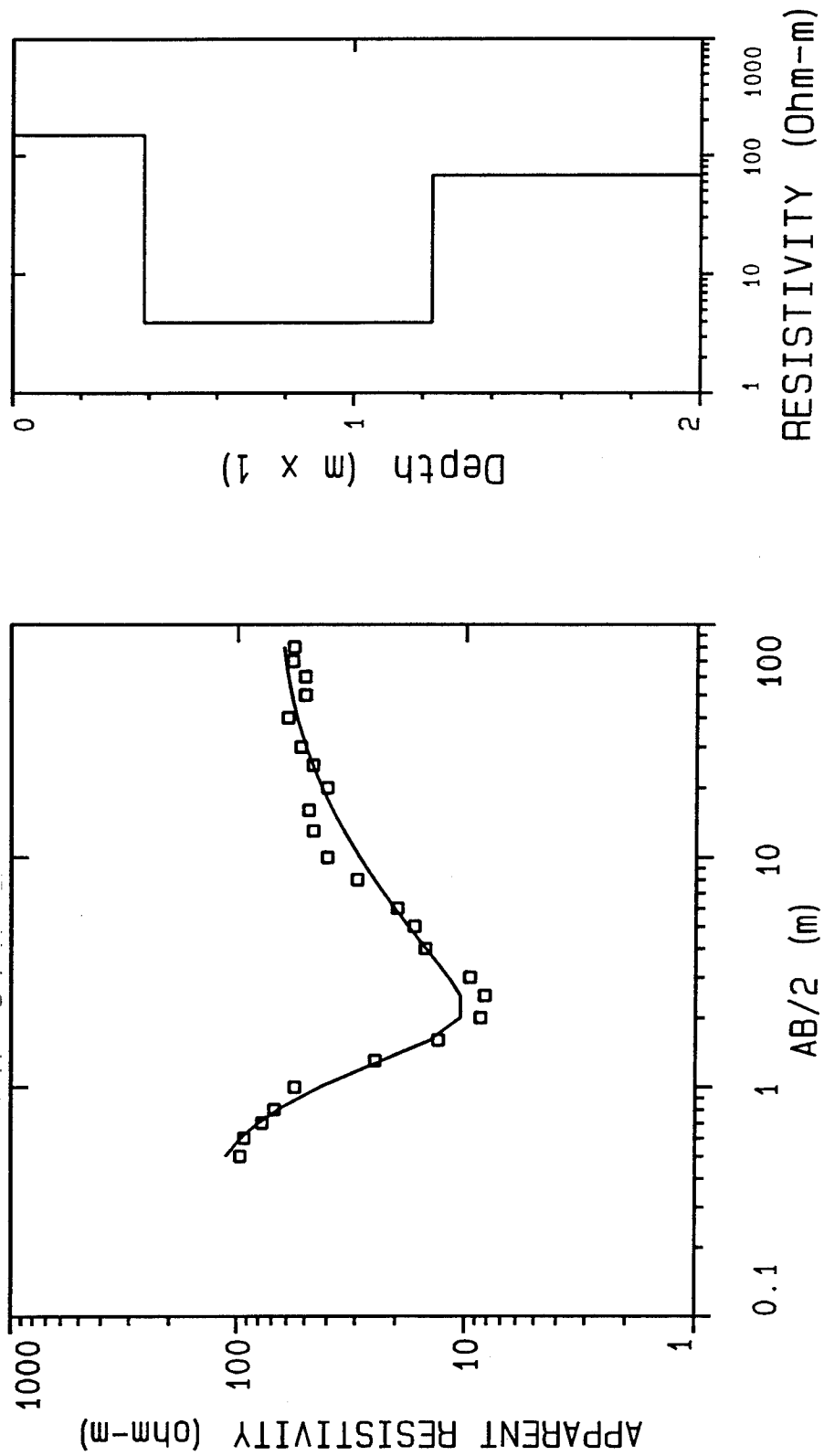


Figure 14. Electrical resistivity sounding along line 130E

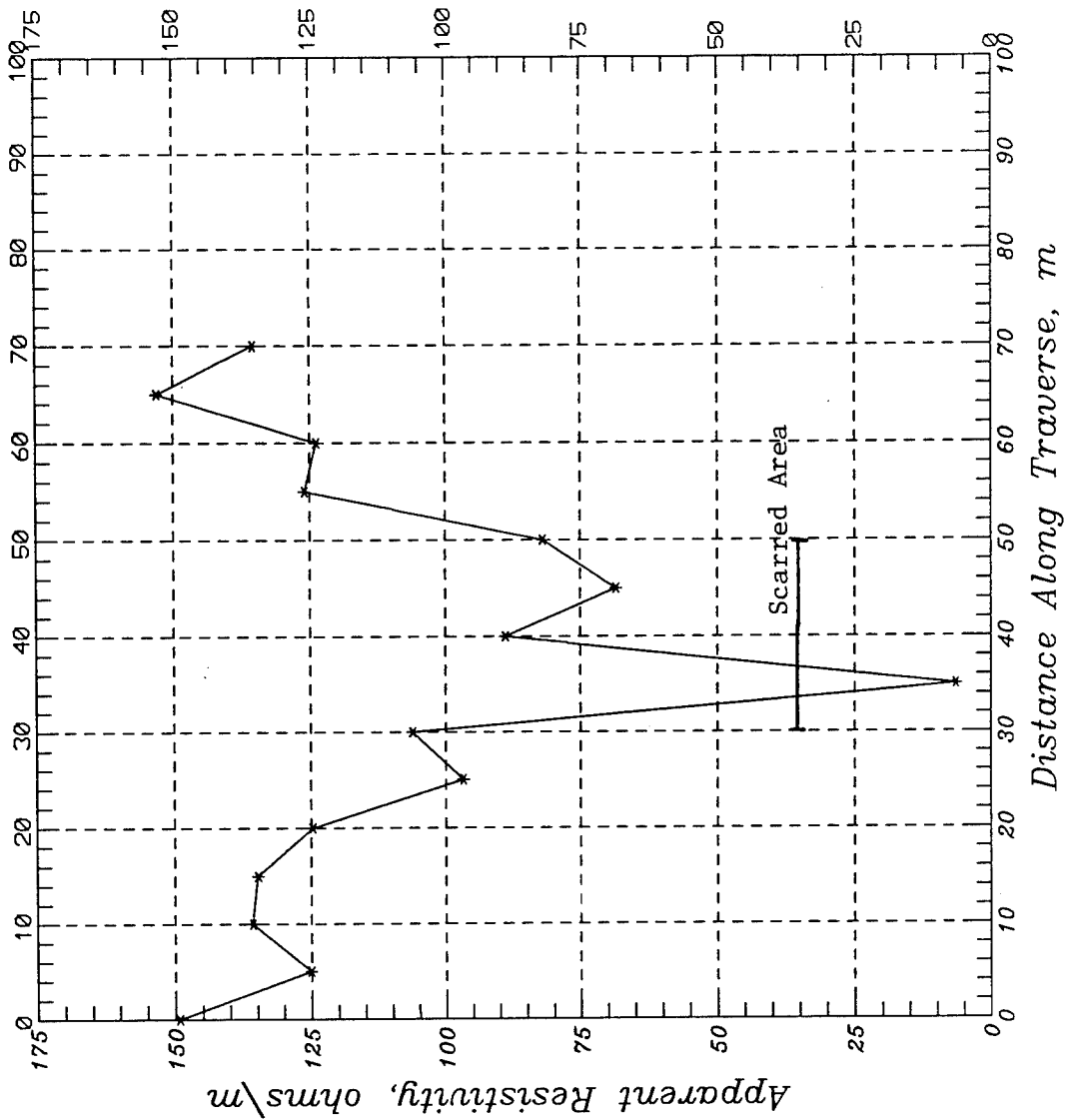


Figure 15. Electrical resistivity profile 5 m spacing along line 80N

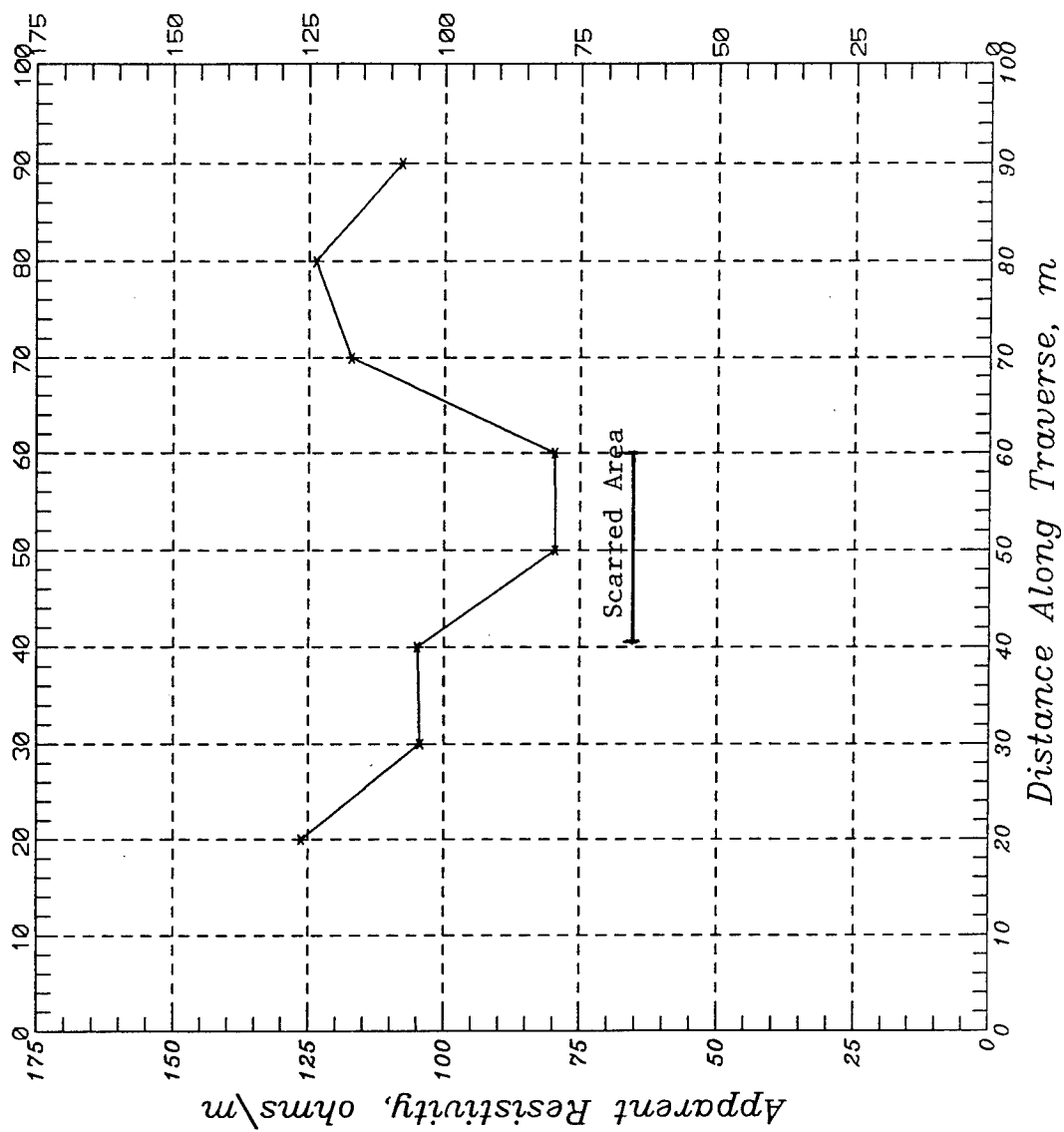
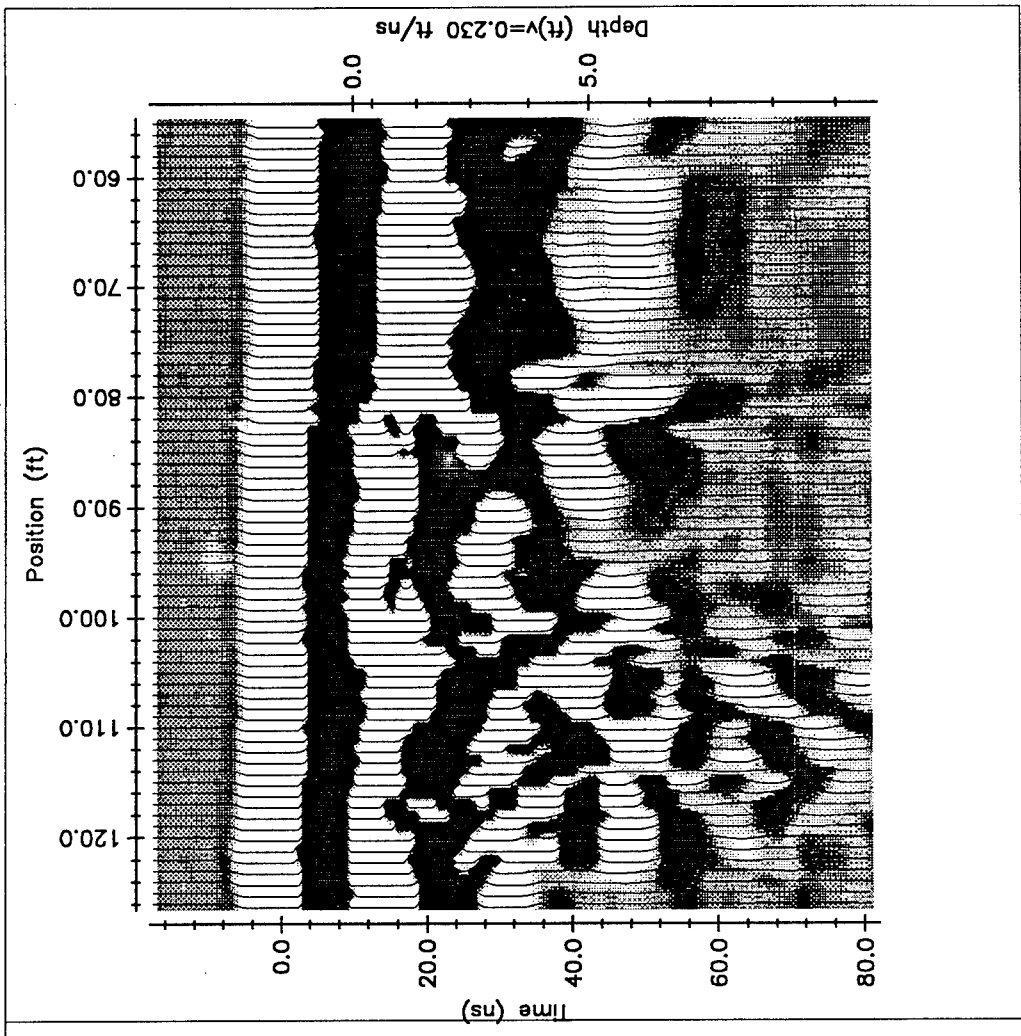


Figure 16. Electrical resistivity profile 10 m spacing along line 80N

Scarred Area



```

pulseEKKO HEADER PARAMETERS
FILE = c:\peiv\rad20n
JOB# = line 20N 126 to 60E
TITLE =
DATE = 08/06/94
NUMBER OF TRACES = 72
NUMBER OF PTS/TRC = 23
TIMEZERO AT POINT = 100
TOTAL TIME WINDOW = 126.000
STARTING POSITION = 55.000
FINAL POSITION = -1.000
STEP SIZE USED = feet
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 3.000
PULSER VOLTAGE = 400
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS:
TRACE STACKING: 1
POINT STACKING: 1
TRACE DIFFERENCING: N
SELECTION TIME: -18 to 82
TRACE: 1 to 72
GAINS:
GAIN TYPE: CONSTANT
MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.0500
TRACE BOTTOM AND TOP: 1.0000 and 6.0000
MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
PAGE WIDTH: 7.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0
  
```

Figure 17. GPR survey results line 20N

pulseEKKO HEADER PARAMETERS

FILE = c:\peiv\rad80n
 JOB# = line 80N 60 to 150E
 TITLE =
 DATE = 08/06/94
 NUMBER OF TRACES = 103
 NUMBER OF PTS/TRC = 125
 TIMEZERO AT POINT = 23
 TOTAL TIME WINDOW = 100
 STARTING POSITION = 60.000
 FINAL POSITION = 162.000
 STEP SIZE USED = 1.000
 POSITION UNITS = feet
 NOMINAL FREQUENCY = 100.00
 ANTENNA SEPARATION = 3.000
 PULSER VOLTAGE = 400
 NUMBER OF STACKS = 16
 SURVEY MODE = Reflection

PROCESSING SELECTED

FILTERS:
 TRACE STACKING: 1
 POINT STACKING: 1
 TRACE DIFFERENCING: N
 SELECTION TIME: -18 to 82
 GAINS:
 TRACE: 1 to 103
 GAIN TYPE: CONSTANT
 MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS

TRACE SPACING AND WIDTH: 0.0750 and 0.0500
 TRACE BOTTOM AND TOP: 1.0000 and 6.0000
 MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
 PAGE WIDTH: 7.0000
 BORDER SIZE: 0.000
 PRINTER NAME: LAS300
 SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0

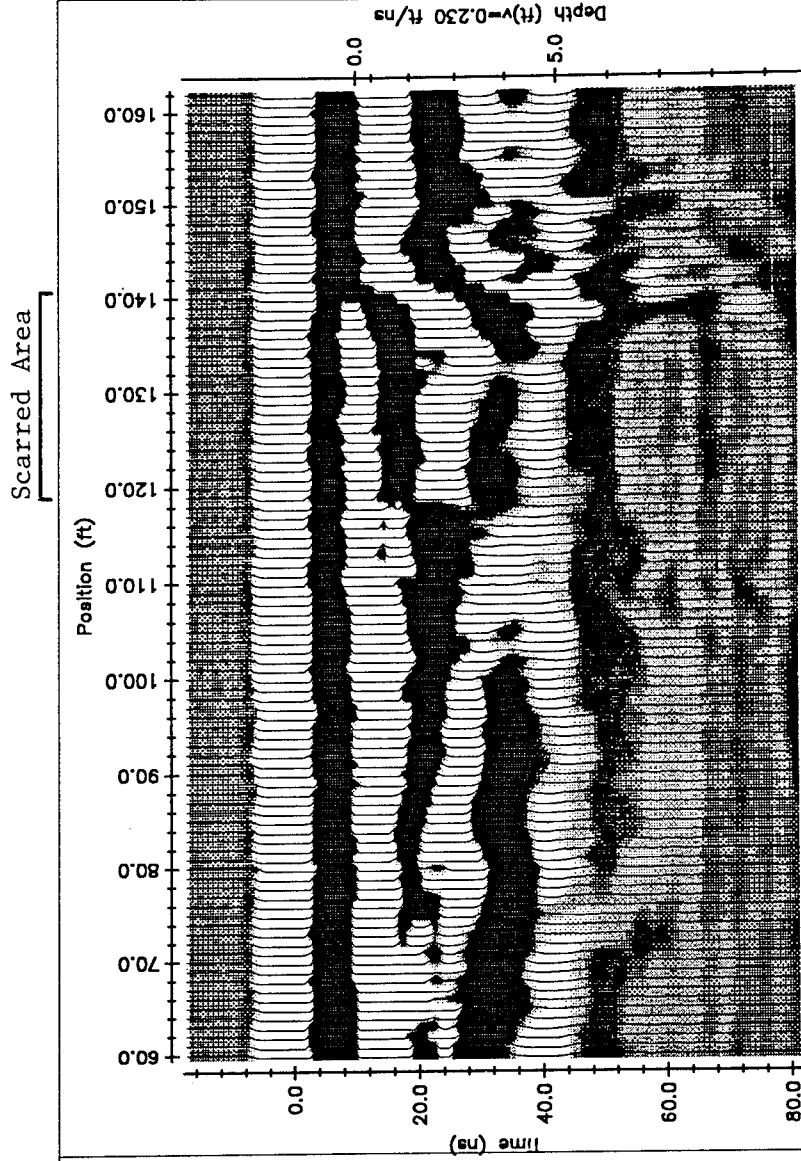
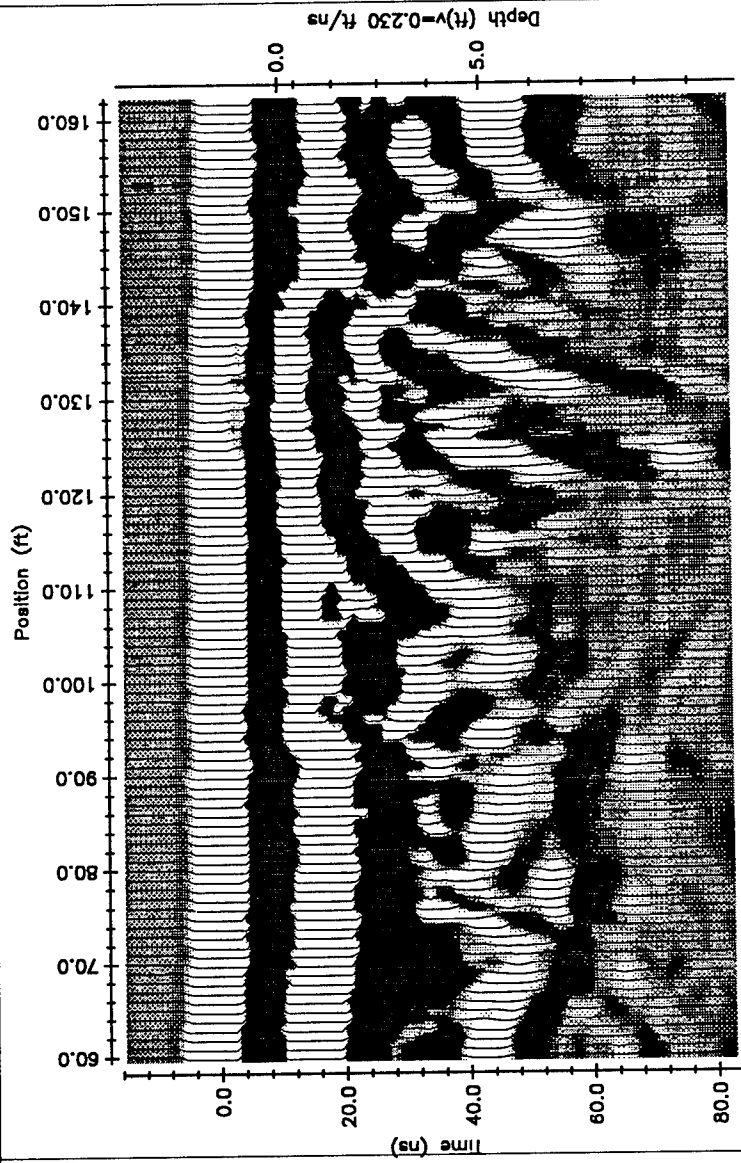


Figure 18. GPR survey results line 80N

Scarred Area



```

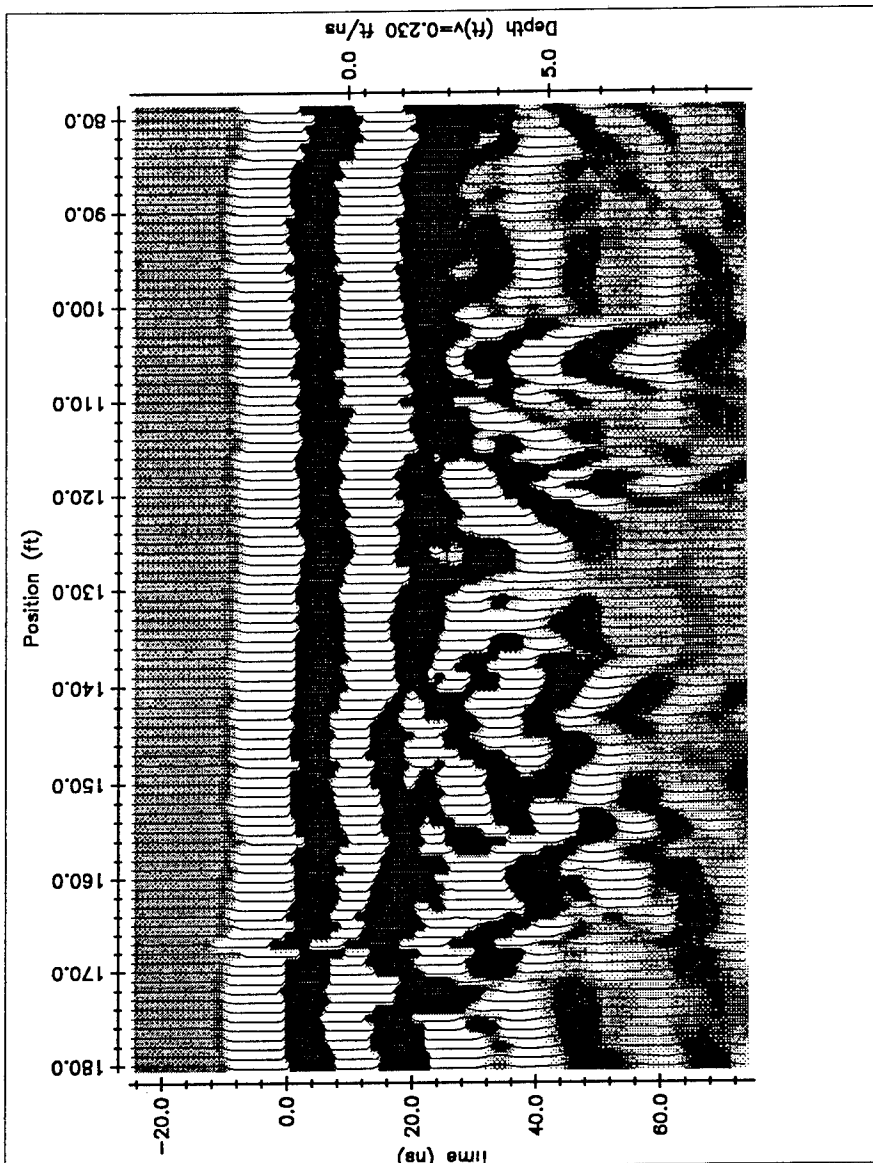
pulseEKKO HEADER PARAMETERS
FILE = c:\peiv\rad140n
JOB# = line 140N 60 to 160E
TITLE =
DATE = 08/06/94
NUMBER OF TRACES = 103
NUMBER OF PTS/TRC = 125
TIMEZERO AT POINT = 21
TOTAL TIME WINDOW = 100
STARTING POSITION = 60.000
FINAL POSITION = 162.000
STEP SIZE USED = 1.000
POSITION UNITS = feet
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 3.000
PULSER VOLTAGE = 400
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 1
          POINT STACKING: 1
          TRACE DIFFERENCING: N
SELECTION TRACE: -16 to 84
GAINS:    TRACE: 1 to 103
          GAIN TYPE: CONSTANT
          MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.0500
TRACE BOTTOM AND TOP: 1.0000 and 6.0000
MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
PAGE WIDTH: 7.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0
  
```

Figure 19. GPR survey results line 140N

Scarred Area



```

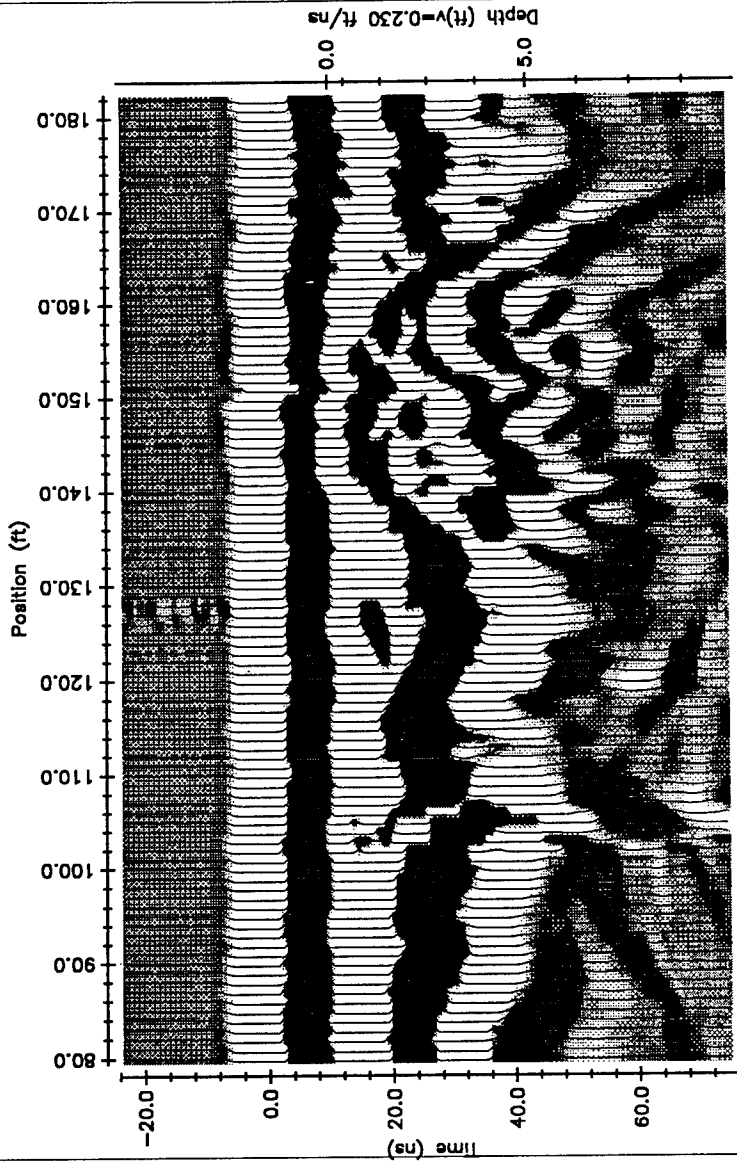
pulseEKKO HEADER PARAMETERS
FILE = c:\pei\rod\200n
JOB# = line 200N 180 to 80E
TITLE = line 200N 180 to 80E
DATE = 08/06/94
NUMBER OF TRACES = 102
NUMBER OF PTS/TRC = 125
TIMEZERO AT POINT = 32
TOTAL TIME WINDOW = 100
STARTING POSITION = 180.000
FINAL POSITION = 79.000
STEP SIZE USED = -1.000
POSITION UNITS = feet
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 3.000
PULSER VOLTAGE = 400
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS:
TRACE STACKING: 1
POINT STACKING: 1
TRACE DIFFERENCING: N
SELECTION
TIME: -25 to 75
TRACE: 1 to 102
GAINS:
GAIN TYPE: CONSTANT
MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.0500
TRACE BOTTOM AND TOP: 1.0000 and 6.0000
MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
PAGE WIDTH: 7.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0
  
```

Figure 20. GPR survey results line 200N

Scarred Area



```

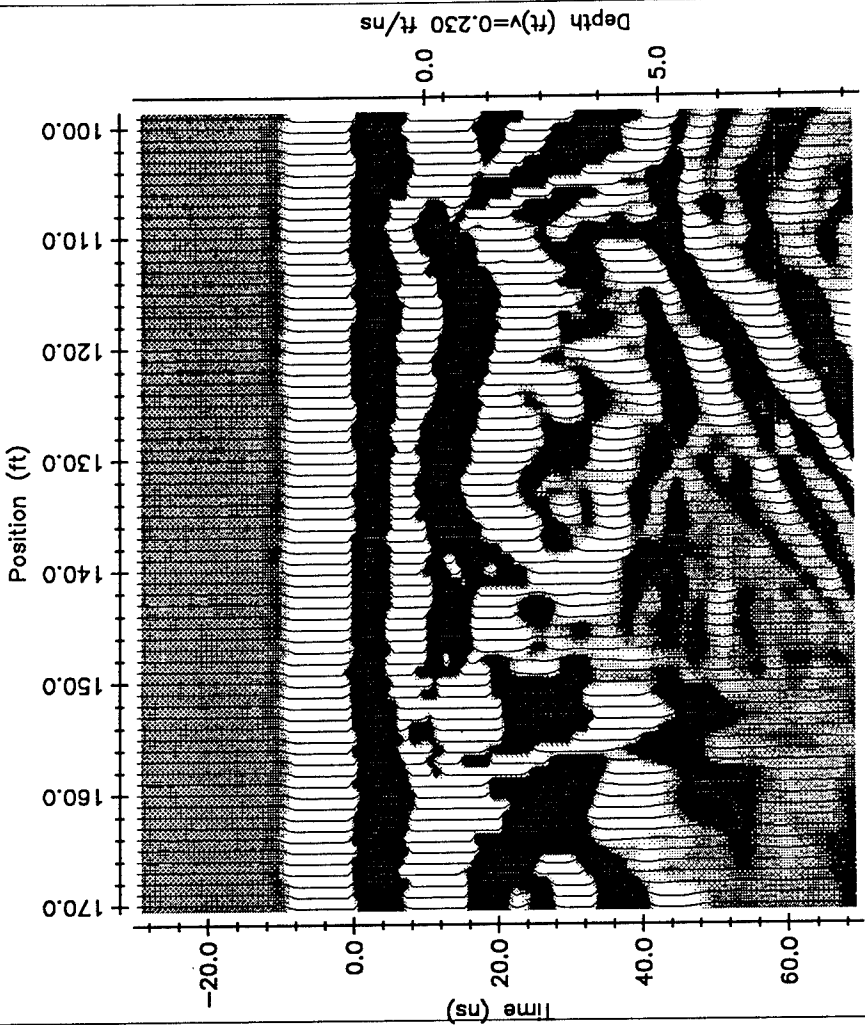
pulseEKKO HEADER PARAMETERS
FILE = c:\peiv\rad240n
JOB# = line 240N 80 to 180E
TITLE =
DATE = 08/06/94
NUMBER OF TRACES = 103
NUMBER OF PTS/TRC = 125
TIMEZERO AT POINT = 31
TOTAL TIME WINDOW = 100
STARTING POSITION = 80.000
FINAL POSITION = 182.000
STEP SIZE USED = 1.000
POSITION UNITS = feet
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 3.000
PULSER VOLTAGE = 400
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS: TRACE STACKING: 1
          POINT STACKING: 1
          TRACE DIFFERENCING: N
SELECTION TIME: -24 to 76
GAINS:    TRACE: 1 to 103
          GAIN TYPE: CONSTANT
          MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.0500
TRACE BOTTOM AND TOP: 1.0000 and 6.0000
MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
PAGE WIDTH: 7.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0
    
```

Figure 21. GPR survey results line 240N

Scarred Area



pulseEKKO HEADER PARAMETERS
 FILE = c:\peiv\rad310n
 JOB# = line 310N 170 to 100E
 TITLE =
 DATE = 08/06/94
 NUMBER OF TRACES = 72
 NUMBER OF PTS/TRC = 125
 TIMEZERO AT POINT = 38
 TOTAL TIME WINDOW = 100
 STARTING POSITION = 170.000
 FINAL POSITION = 99.000
 STEP SIZE USED = -1.000
 POSITION UNITS = feet
 NOMINAL FREQUENCY = 100.00
 ANTENNA SEPARATION = 3.000
 PULSER VOLTAGE = 400
 NUMBER OF STACKS = 16
 SURVEY MODE = Reflection

PROCESSING SELECTED
 FILTERS:
 TRACE STACKING: 1
 POINT STACKING: 1
 TRACE DIFFERENCING: N
 SELECTION TIME: -30 to 70
 TRACE: 1 to 72
 GAINS:
 GAIN TYPE: CONSTANT
 MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
 TRACE SPACING AND WIDTH: 0.0750 and 0.0500
 TRACE BOTTOM AND TOP: 1.0000 and 6.0000
 MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
 PAGE WIDTH: 7.0000
 BORDER SIZE: 0.000
 PRINTER NAME: LAS300
 SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0

Figure 22. GPR survey results line 310N

```

pulseEKKO HEADER PARAMETERS
FILE = c:\peiv\rad310an
JOB# = line 310N 100 to 170E
TITLE =
DATE = 08/06/94
NUMBER OF TRACES = 73
NUMBER OF PTS/TRC = 250
TIMEZERO AT POINT = 34
TOTAL TIME WINDOW = 200
STARTING POSITION = 100.000
FINAL POSITION = 172.000
STEP SIZE USED = 1.000
POSITION UNITS = feet
NOMINAL FREQUENCY = 100.00
ANTENNA SEPARATION = 3.000
PULSER VOLTAGE = 400
NUMBER OF STACKS = 16
SURVEY MODE = Reflection

PROCESSING SELECTED
FILTERS:
TRACE STACKING: 1
POINT STACKING: 1
TRACE DIFFERENCING: N
SELECTION
TIME: -27 to 173
TRACE: 1 to 73
GAINS:
GAIN TYPE: CONSTANT
MULTIPLIER: 0.100

PLOT LAYOUT PARAMETERS
TRACE SPACING AND WIDTH: 0.0750 and 0.0500
TRACE BOTTOM AND TOP: 1.0000 and 6.0000
MARGIN LEFT AND RIGHT: -0.7500 and 0.7500
PAGE WIDTH: 7.0000
BORDER SIZE: 0.000
PRINTER NAME: LAS300
SCALE BAR: Name:grey Type:EA Expansion:0.500 Contour:0

```

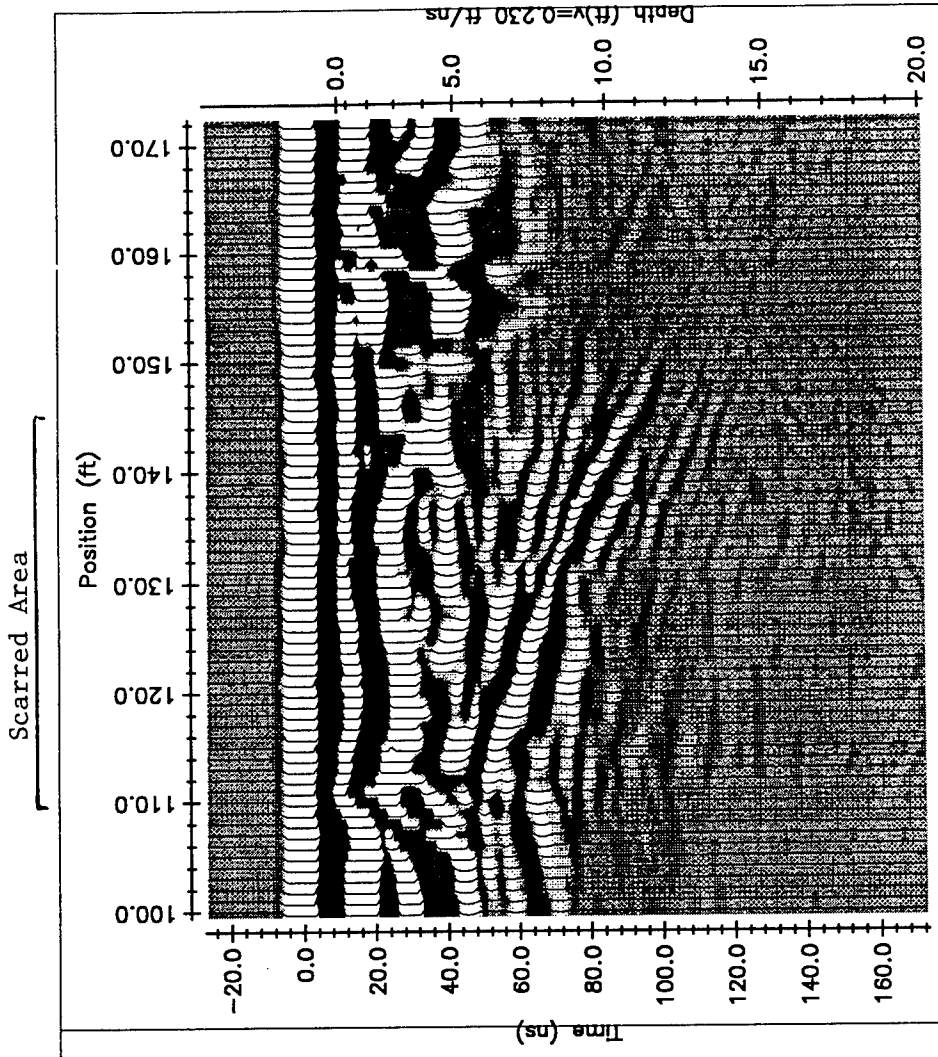
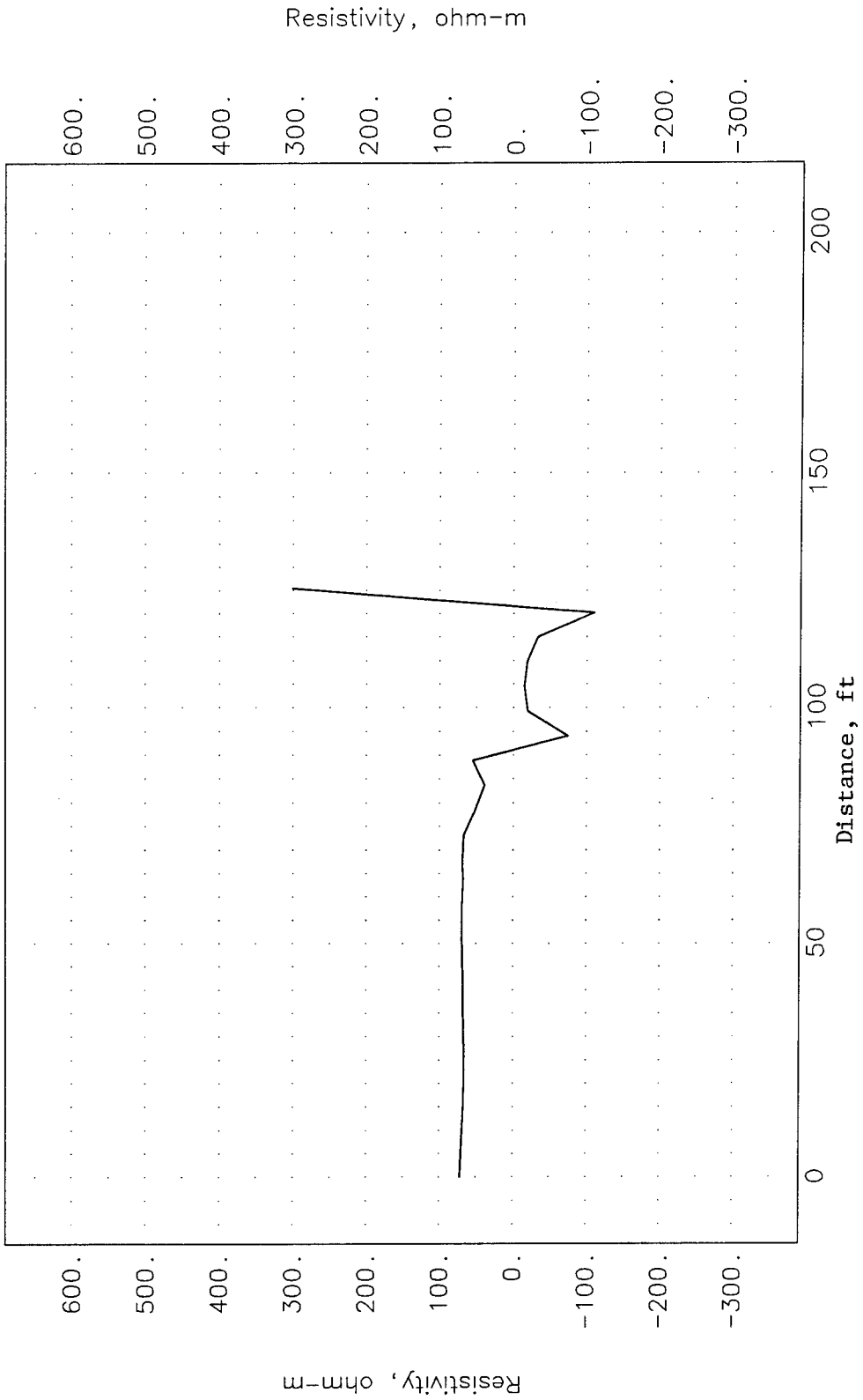


Figure 23. GPR survey results line 310Na

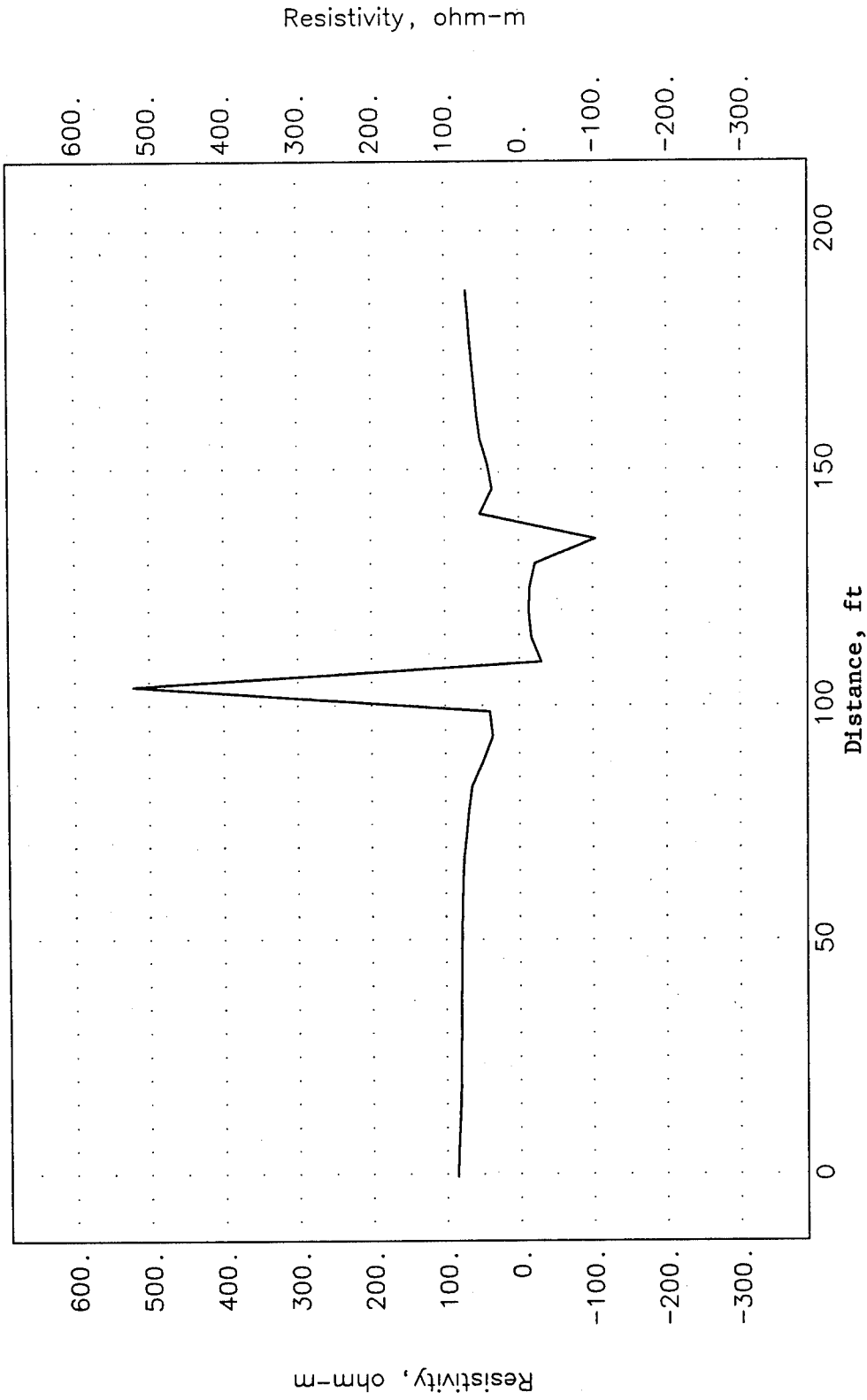
Appendix A

Line 50



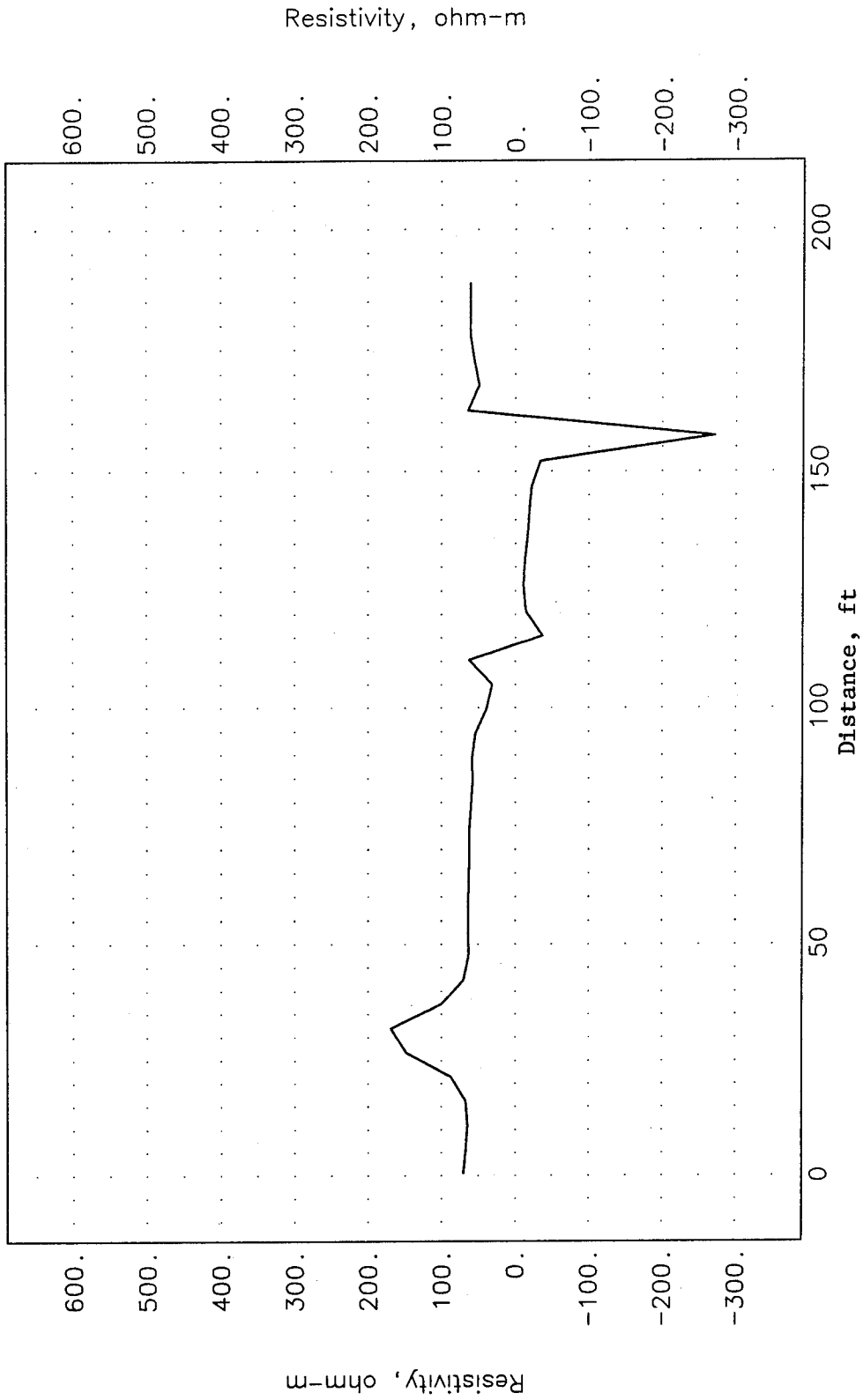
26th Street Landfill Line 50N

Line 100



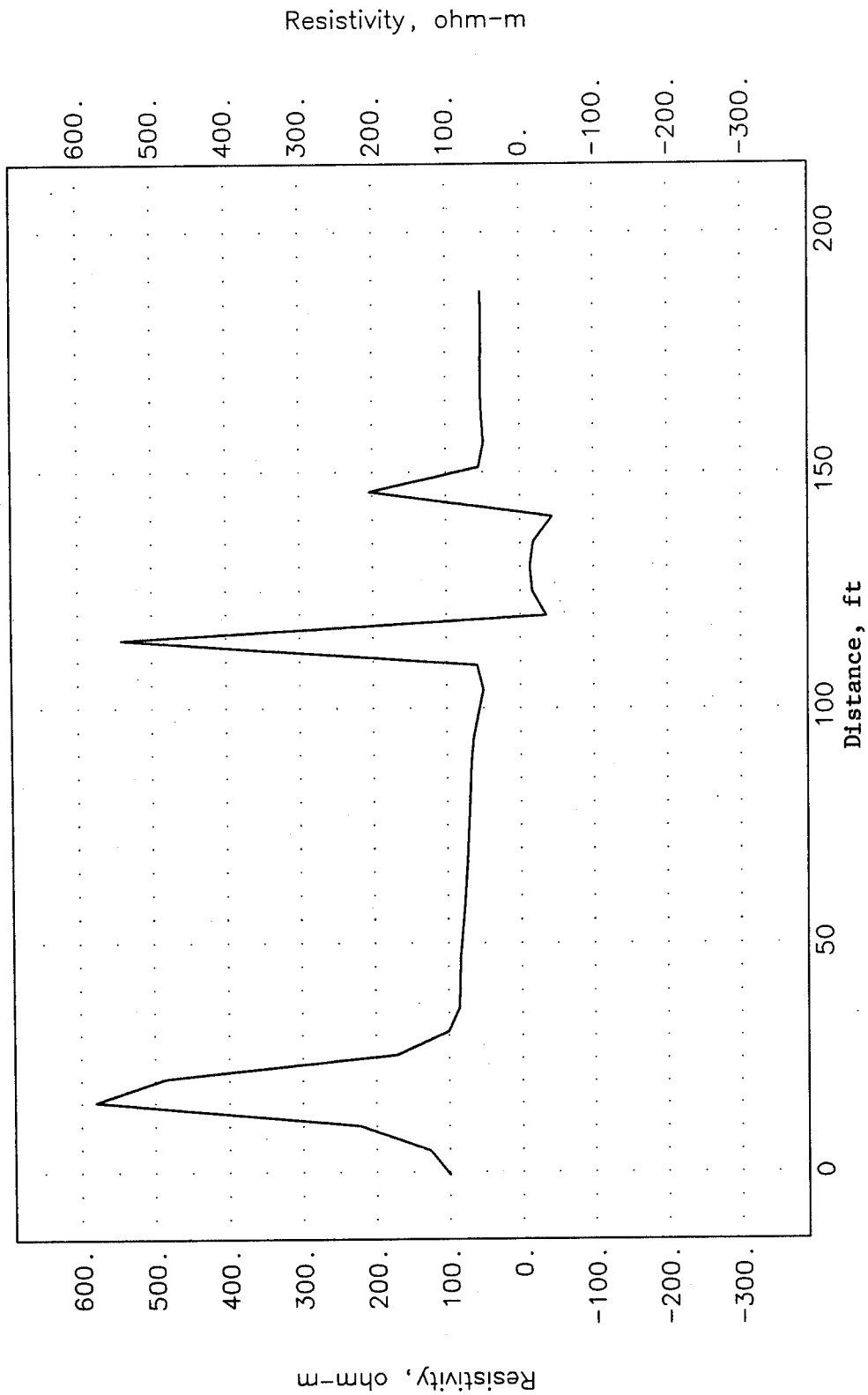
26th Street Landfill Line 100N

Line 150



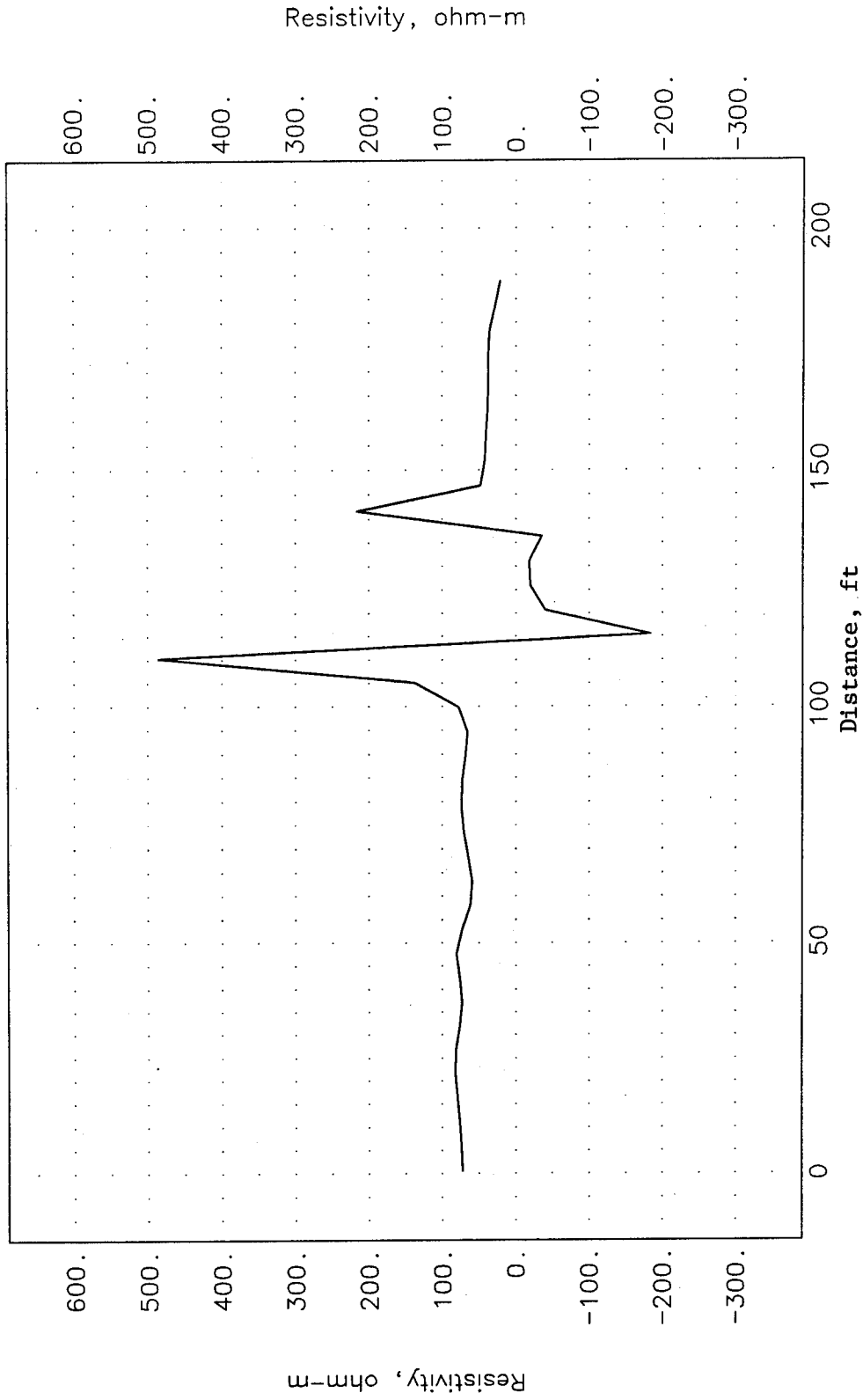
26th Street Landfill Line 150N

Line 200



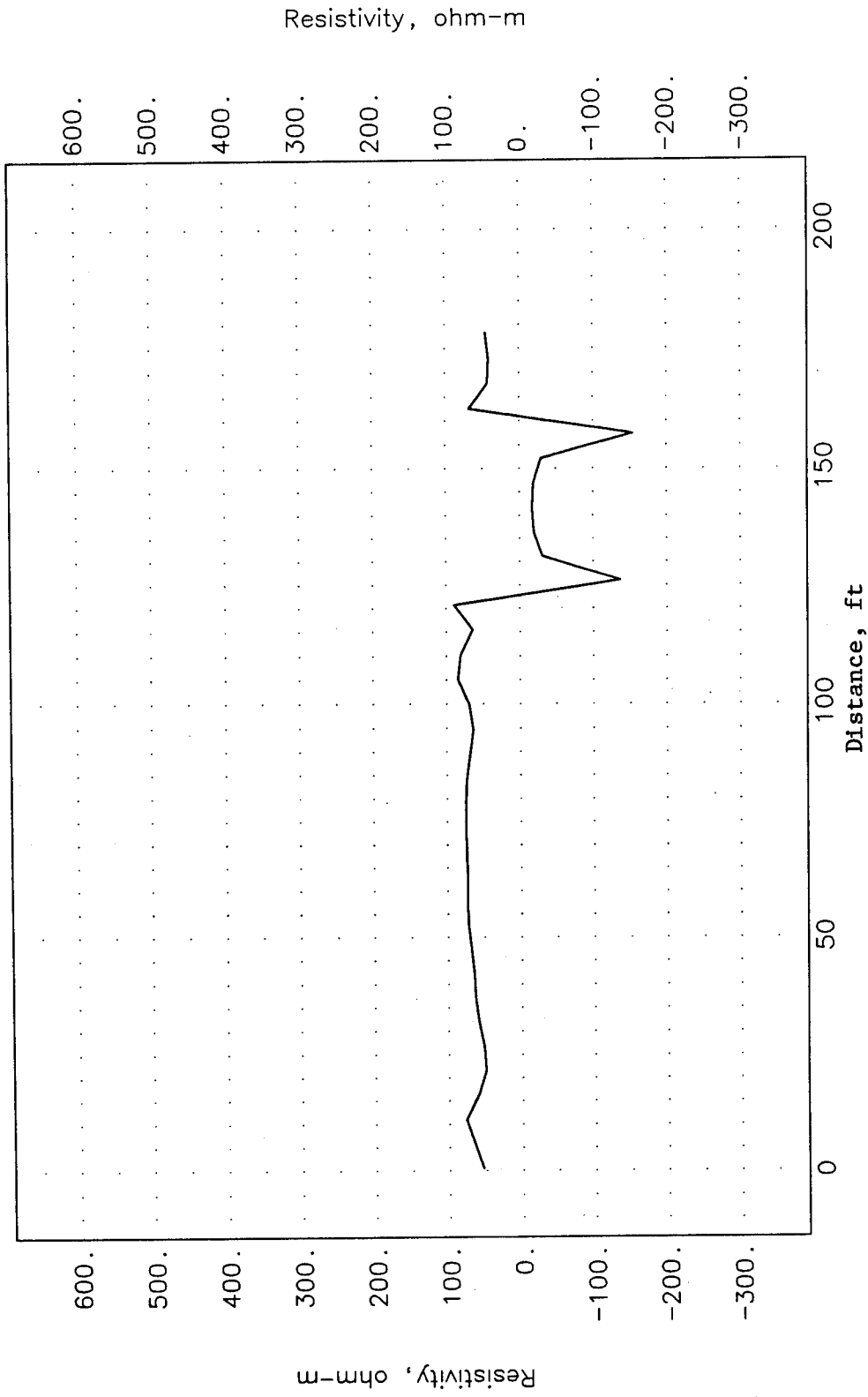
26th Street Landfill Line 200N

Line 250



26th Street Landfill Line 250N

Line 300



26th Street Landfill Line 300N

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 1995	3. REPORT TYPE AND DATES COVERED Final report	
4. TITLE AND SUBTITLE Investigation of the 26th Street Disposal Site, Edgewood Area, Aberdeen Proving Ground, Maryland			5. FUNDING NUMBERS	
6. AUTHOR(S) Michael K. Sharp, Janet E. Simms				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station 3909 Halls Ferry Road, Vicksburg, MS 39180-6199			8. PERFORMING ORGANIZATION REPORT NUMBER Miscellaneous Paper GL-95-5	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Installation Restoration Program Directorate of Safety, Health, and Environment Aberdeen Proving Ground, MD			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) <p>A geophysical investigation was conducted at 26th Street, Edgewood Area, Aberdeen Proving Ground (APG), to delineate anomalies indicative of a fill. Electrical resistivity, magnetic, electromagnetic (EM), and ground penetrating radar (GPR) geophysical survey methods were employed to meet this objective. The investigation was carried out in the area immediately west of 26th Street and on the street. The tests were successful in delineating the lateral boundaries of the fill in a north-south, east-west direction. The electrical resistivity and GPR tests were successful in determining an approximation of the depth and thickness of the fill.</p> <p>The study provided several conclusions. First, the disposal material contains large amounts of iron (or ferrous material) as evidenced from the magnetometer survey. The magnetometer will only respond to ferrous objects. This conclusion is supported by the EM-31 in-phase and EM-61 data which indicates a material with a very high conductivity, which would also indicate metallic material. Second, an approximate fill depth can be determined from the GPR and resistivity data. The resistivity sounding through this area indicates a thickness of approximately 1 m. The radar profiles indicate thicknesses of 3 to 4 ft along a north-south axis. A conservative estimate of fill thickness is 5 ft. Third, the fill does not appear to extend under 26th Street.</p>				
14. SUBJECT TERMS Disposal site Ground penetrating radar Electromagnetics Magnetics Geophysics Resistivity			15. NUMBER OF PAGES 54	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT	