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Interim Progress Report — Geophysics: Building E5375 Decommissioning, Aberdeen Proving Ground

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Interim Progress Report — Geophysics: Building E5375 Decommissioning, Aberdeen Proving Ground

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Preface

This report is one of a series on geophysical surveys around perimeters of buildings in the Canal Creek area of the Edgewood section of Aberdeen Proving Ground. The series was initiated in 1991 at Building E5032, where geophysical techniques were tested and a design for the surveys was established. The series continued in 1992, when surveys of Buildings E5190, E5282, E5375, E5440, E5476, E5481, E5485, E5487, E5489, and E5974 were completed. The surveys and reports were done sequentially, with lowest building numbers being completed first. For this reason, deeper insight into the magnetic, electrical, and radar imagery characteristics of the Canal Creek area was gained with progressively increasing building numbers. A survey at the Building 103 Dump, also completed during the spring of 1992, was not specifically designed to assist building decommissioning. This survey is included in the series because it was conducted by our geophysics team using techniques and procedures identical to those for the building decommissioning surveys.

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Abstract

Building E5375 was one of ten potentially contaminated sites in the Canal Creek area of the Edgewood section of Aberdeen Proving Ground examined by a geophysical team from Argonne National Laboratory in April and May 1992. Noninvasive geophysical surveys, including magnetics, electrical resistivity, and ground-penetrating radar (GPR), were conducted around the perimeter of the building to guide a sampling program prior to decommissioning and dismantling. Several anomalies were noted: (1) An underground storage tank located 25 ft east of Building E5375 was identified with magnetic, resistivity, and GPR profiling. (2) A three-point resistivity anomaly, 12 ft east of the northeast corner of Building E5374 (which borders Building E5375) and 5 ft south of the area surveyed with the magnetometer, may be caused by another underground storage tank. (3) A 2,500-gamma magnetic anomaly near the northeast corner of the site has no equivalent resistivity anomaly, although disruption in GPR reflectors was observed. (4) A one-point magnetic anomaly was located at the northeast corner, but its source cannot be resolved. A chaotic reflective zone to the east represents the radar signature of Building E5375 construction fill.

1 Introduction

Aberdeen Proving Ground (APG), in the state of Maryland, is currently managing a comprehensive Installation Restoration Program involving more than 360 solid-waste managing units contained within 13 study areas. The Edgewood area and two landfills in the Aberdeen area appear on the National Priority List under the Comprehensive Environmental Response, Compensation, and Liability Act. Therefore, APG has entered into an Interagency Agreement with the U.S. Environmental Protection Agency to address the listed areas.

The West Branch of the Canal Creek area (Figure 1) is one of the areas that requires a Source Definition Study because there is an ongoing release of volatile organic compounds into the creek. A report by EAI Corporation (1989) included a list of 29 potentially contaminated

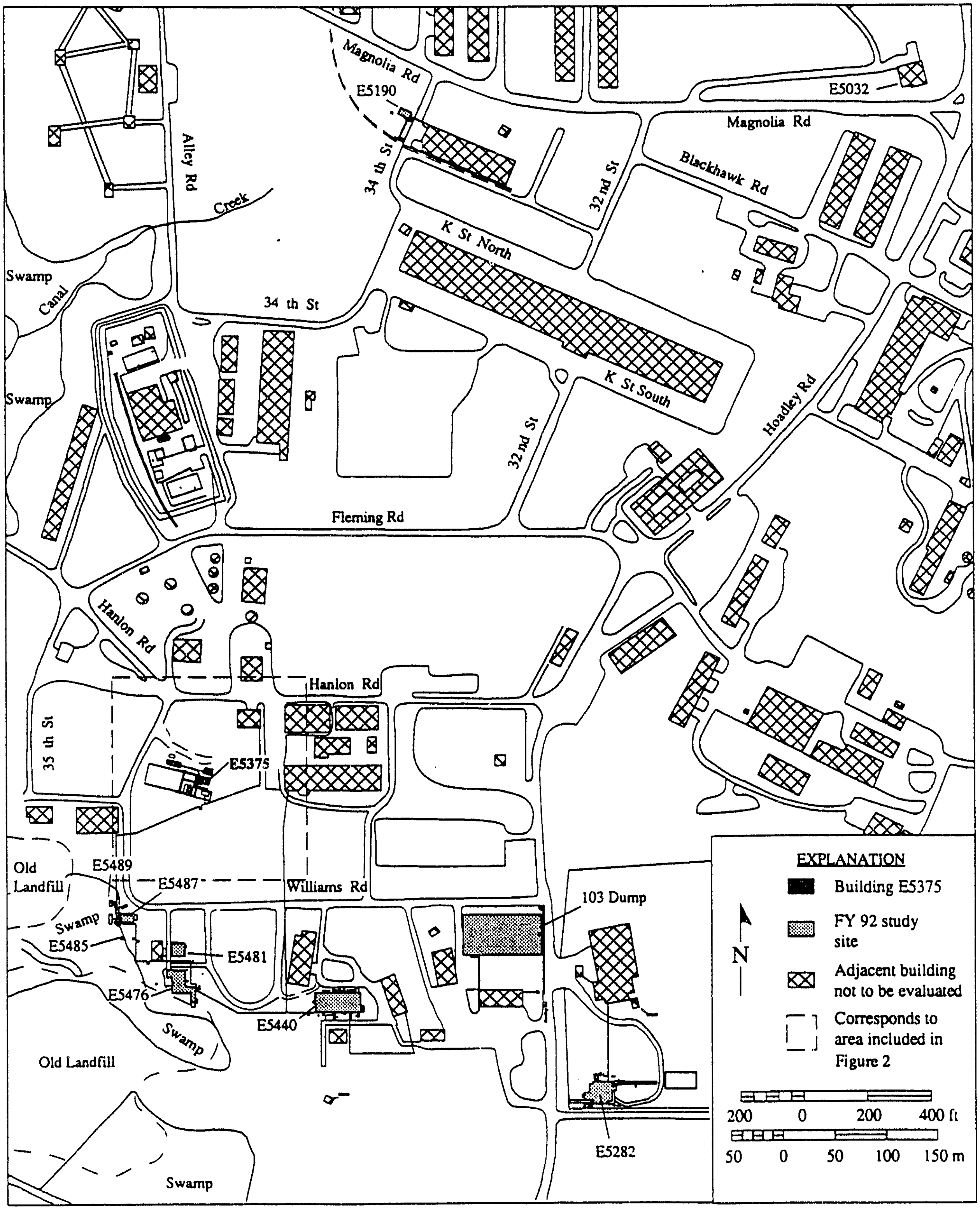

FIGURE 1 General Site Map of the Canal Creek Area, Aberdeen Proving Ground, Md.

buildings. Sixteen of the buildings contain known contaminants, nine buildings contain unknown contaminants, and four of the buildings are potentially clean. The EAI report recommended that a sampling and monitoring program be established to verify contamination levels in and around each building. Thirteen of the potentially contaminated buildings, including Building E5375 (Figure 2), located south of Hanlon Road and east and north of the west end of Williams Road, are in the West Branch of the Canal Creek area and are potential sources of volatile organic compounds. Operations have ceased and the buildings have been abandoned, but processing equipment, sumps, drains, ventilation systems, and underground storage tanks remain. These appurtenances may contain liquid, solid, or vapor contaminants of unknown nature.

Aberdeen Proving Ground is proceeding with a program to decommission the buildings, which will eliminate the actual or potential release of contaminants into the environment of the West Branch of the Canal Creek and other sites within the Edgewood area. Argonne National Laboratory has been assigned the task of developing a plan and scope of work for the proposed decommissioning. Argonne has determined that the first step in this decommissioning process, where it is technically feasible, should be a noninvasive geophysical survey around building exteriors (see Figure 3 for the boundaries of the study area for Building E5375).

1.1 History of Building E5375

According to records examined by the EAI Corporation (1989), Building E5375 was constructed in 1942 as part of the chloroacetophenone (CN) Production Plant No. 2 complex housed in Building E5380. The structure measures 23 ft × 38 ft and is built on a concrete foundation and floor. The walls consist of concrete, and the roof is corrugated transite. The building was used solely for the storage of benzene until 1950, when it was placed in a standby condition. Benzene holding tanks are still present in the building, but the procedures that were used for placing the tanks in standby status are not known. The building has not been used since 1950.

1.2 Site Reconnaissance

The geophysical survey program design for Building E5375 and the associated Benzene Tower to the north is based upon results from a similar study completed between April 8 and April 19, 1991, for Building E5032 (McGinnis and Miller 1991), which is also located in the Canal Creek area (Figure 1). The initial evaluation was further enhanced by a visit to the site in November 1991. The site is located on level terrain and is generally accessible, although surveying was restricted due to the proximity of adjacent buildings associated with the Production Plant No. 2 complex. These areas contain interconnecting steel-covered trenches, overhead pipes, and aboveground tanks. The area to the east is relatively open for surveying except for two standpipes near the southeast corner of the building.

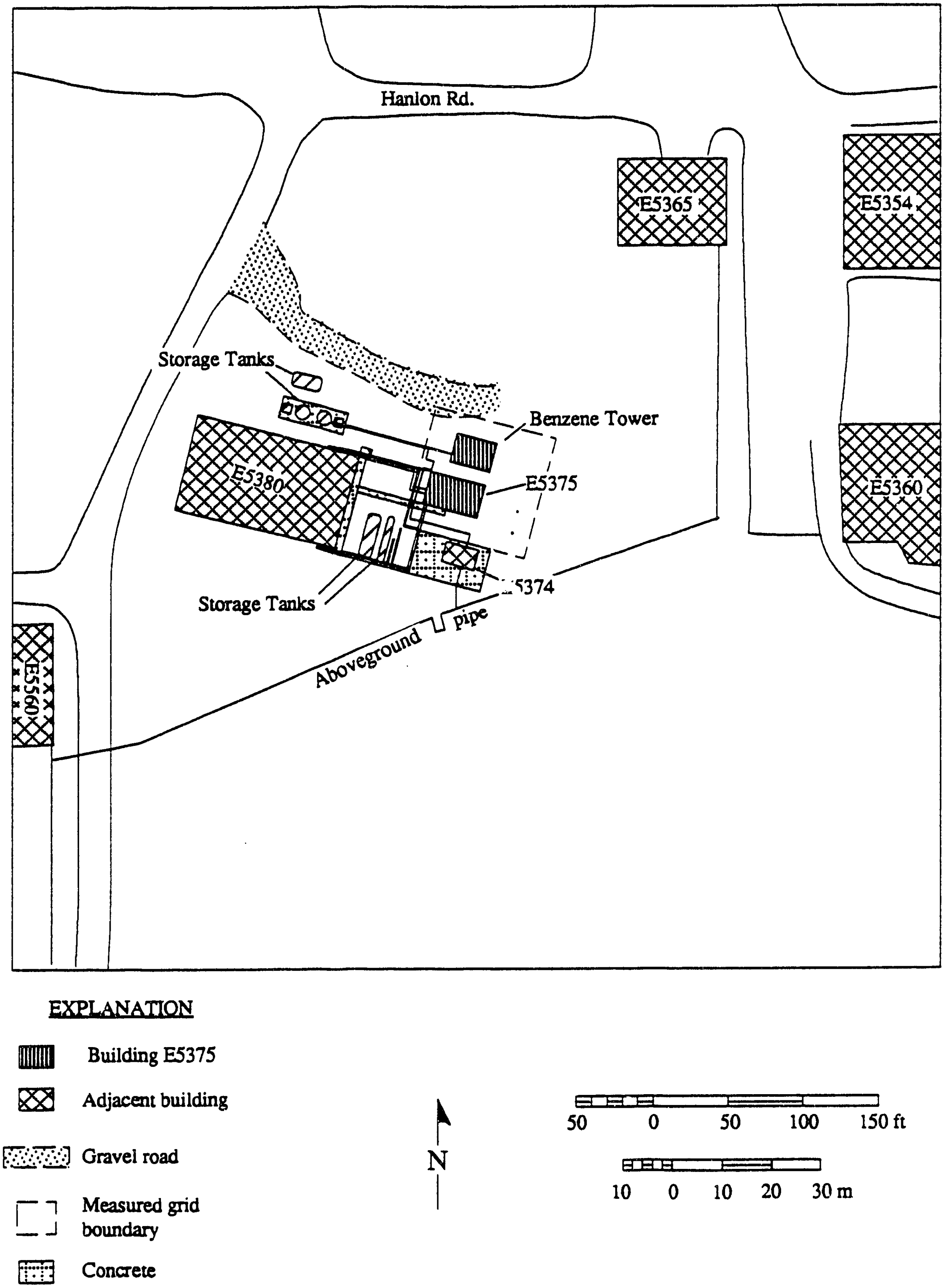

FIGURE 2 General Location Map of Building E5375 and Adjacent Benzene Tower

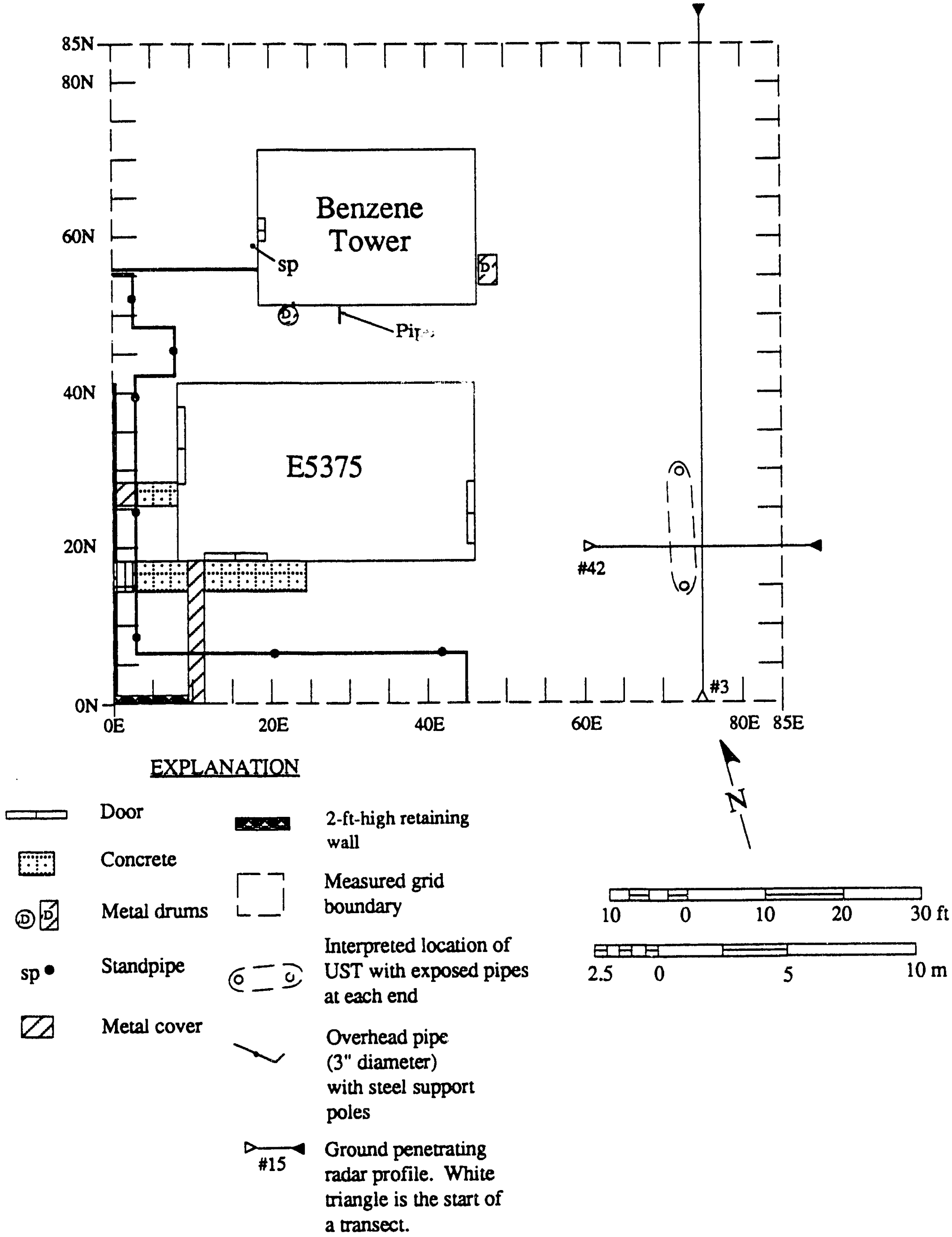

FIGURE 3 Geophysical Survey Boundaries for Building E5375 and Adjacent Benzene Tower

In addition to surface conditions at the site, subsurface characteristics were considered in planning the geophysical surveying:

1. Surficial sediments consist of estuarine silts, sands, and clays that have intermediate resistivities and are nonmagnetic. The underlying soil properties are expected to vary both horizontally and vertically in the proximity of the site, depending on naturally occurring conditions and on the presence of building excavations and operations.

2. Buildings and other attributes of the Edgewood section of Aberdeen, such as radio and radar transmissions, will contribute to interference of magnetic and electrical fields and will cause electromagnetic surveying (an easily applied, low-cost method that is frequently used to identify buried conductive objects) to be generally inapplicable (AEHA 1989).

3. Multiple sources, such as iron-rich magnetized objects, nonmagnetic objects, subsurface channels containing contaminants, and plumes of contaminants of variable resistivity, may be present in the subsurface.

Multiple working technologies were utilized in the program design to mitigate interference and to either directly detect or provide inferential data on subsurface characteristics.

1.3 Geology and Physiographic Setting

The site is contained in the topographically low and flat terrain of the Coastal Plain physiographic province. The Canal Creek area is underlain by alluvial and estuarine sands, silts, and clays. A thin veneer of sediments of the Talbot Formation of Pleistocene age overlies unconsolidated sediments of the Potomac Group of Cretaceous age (Oliveros and Gernhardt 1989). The water table is less than 10 ft from the surface, and groundwater has measurable concentrations of contaminants (USGS 1992).

Lithologies at the site were determined from the sample study of a borehole (site No. 114) drilled approximately 250 ft southwest of Building E5375. The descriptive log given in Table 1 was part of a hydrogeologic study of the Canal Creek area performed by the U.S. Geological Survey (Oliveros and Gernhardt 1989). Facies represented include soils and a clayey fill material, followed by thin beds of varying stratigraphy, consisting primarily of sands to a depth of 24 ft. The greatest thickness (6.2 ft) of a single unit was a light-colored sand at a depth of 10.8 to 17.0 ft. This sand is part of the Canal Creek Aquifer (USGS 1992).

Building E5375 is located near the center of the area of study, which is bordered to the south and west by other buildings not included in the survey. Initial construction probably

TABLE 1 Lithologic Log of Borehole at Site No. 114

Description[a]	Depth (ft)	Thickness (ft)
Soil zone, brown	0.1	0.1
Fill material: with brown, [mL-cL] sand, gravel, rock fragments, sandstone, asphalt, metal	7.7	7.6
Sand, light brown-gray, [fL-mU]; with thin, black layer at top, and clayey, brown silt lense	9.0	1.3
Sand, multicolored, [fU-mU], wet; with irregular banding, and gray, clayey sand lenses	10.8	1.8
Sand, light yellow-tan, [fU-cL], clean; with sparse light gray clay lenses	17.0	6.2
No sample	19.0	2.0
Sand and gravel, purple, orange, and tan [mU-cU], silty, micaceous clay	24.0	5.0
Silt, clayey, and sand, pink and orange-mottled, micaceous; sand [fL-fU], coarsening downward	29.0	5.0

[a] Codes enclosed in brackets at selected horizons refer to color designations as specified in the Munsell Soil Color Charts (1975).

Source: Oliveros and Gernhardt (1989).

involved considerable amounts of excavation and use of fill material, so most of the shallow sediment at the site is reworked.

1.4 Surveys

The geophysical phase of the building decommissioning program at Building E5375 was carried out as planned during the period April 6 to May 8, 1992. Geophysical measurements conformed to the work plan (McGinnis et al. 1992), which called for magnetics, ground-penetrating radar (GPR), and horizontal direct-current electrical resistivity (DCER) surveys. An addition to the plan was the use of a magnetic gradiometer/metal detector to ensure detection of anomalies between survey profiles and grid stations. Seismic imaging information was not required at the site. Each technique had its own specific objectives:

- Gradiometer/metal detector sweep — to provide a rapid, 100% sweep of the site;

- Magnetometer measurements — to determine the location of such buried, iron-rich objects as tanks, pipes, debris, etc.;

- Horizontal DCER survey — to establish the regional conductive nature of the subsurface and to identify contaminant plumes to depths of approximately 10 ft; and

- Ground-penetrating radar survey — to determine the geometry of, and to find the approximate depth to, buried objects.

The following data were acquired during field operations: (1) nonpermanent ground markings of magnetic objects, (2) 331 magnetic observations, (3) 187 horizontal DCER observations, and (4) 2,390 (linear) ft of GPR profile along 48 lines. Field operations required one day for a four-person team. On-site personal computers (both notebook and desktop), interactive software, field equipment designed specifically for Aberdeen, and an all-terrain vehicle were used to expedite data acquisition and processing.

1.5 Survey Grid and Locations of Observations

Prior to geophysical surveying, wooden stakes were placed at the site corners to mark the area to be surveyed so that its sides were approximately parallel to the sides of the building. Geophysical measurements west and south of the building were restricted by the proximity to other buildings not included in the survey. Grid spacing was at 5-ft intervals. The zero coordinate was at the southwest corner of the surveyed area. Positive numbers are measured north and east of the zero coordinate, whereas negative coordinates are measured south and west. The building is not perfectly aligned north-south and east-west.

2 Instrumentation

2.1 Magnetic Gradiometer and Cable Locator

The Schonstedt MAC-51B magnetic gradiometer and cable locator is a dual-mode instrument designed for detecting shallow buried iron and steel objects and tracing underground cables and pipes. The system consists of a transmitter and a dual-function receiver designed to detect anomalous magnetic gradients.

Maps or models are not constructed from observations made with this instrument because it is not a calibrated system. The MAC-51B is an audio device used only for rapid detection of magnetic materials for further analysis with complementary instrumentation. Anomalies are identified by changes in sound amplitude and frequency and are marked on the ground surface prior to the initiation of other surveys. If anomalies detected with the MAC-51B cannot be verified with the magnetometer (see section on magnetometer), the anomaly is assumed to be insignificant.

Application of the MAC-51B in its receiver mode was the first geophysical operation following establishment of survey limits. A qualitative description of the site with 100% ground coverage is achieved using the gradiometer, whereas the results obtained with other techniques, although more quantitative, are spatially limited to single-point, survey-grid observations or to continuous readings along spaced profiles.

2.2 Magnetometer/Gradiometer

Magnetics is the best technique for identifying such buried magnetized objects as tanks, drums, and small iron-rich debris. The EDA OMNI IV magnetometer/gradiometer is a total-field, proton-precession, microprocessor-based instrument that can also measure magnetic gradients. Internal software permits down-loading directly into an on-site computer.

Total-field magnetic observations were made at 5-ft and smaller intervals along profiles, yielding a grid of data that was contoured using the SURFER V. 4.0 software by Golden, Inc. (1991), to identify potential sources of contaminants and to distinguish them from background. The SURFER software was incorporated into the field acquisition procedure, so that daily map outputs were available for observation and interpretation.

The earth's magnetic field is reasonably well-known at a given time and place, although small changes in the field occur continuously, with larger changes occurring during magnetic storms. To adjust for field changes, the instrument has internal calibration to correct observations made at cross lines and base stations. Repeat readings were used to correct data for diurnal field fluctuations.

2.3 Direct-Current Electrical Resistivity Meter

Data on the electrical properties of soils at APG may permit detection of abnormally conductive or nonconductive liquid or solid contaminants. Most of the electrical properties of sedimentary materials are a product of the chemistry of interstitial fluids. Consequently, resistivity data can be diagnostic and complement magnetic and radar measurements. Direct-current electrical resistivity measurements have been incorporated into the APG study to take the place of conductivity measurements typically made for investigations of this type using electromagnetic methods. Electromagnetic methods could not be used because of previously reported interference problems (AEHA 1989).

Resistivity equipment used on the Aberdeen project consisted of an ABEM Terrameter and Booster, model SAS 300C, that utilized a variety of electrode configurations. A modified, eight-electrode Wenner array was the configuration selected, and it was towed behind an all-terrain vehicle. Profiles were coincident with GPR and magnetic lines, and data were recorded at 5-ft intervals along the lines. Consistency of repeat observations over a test profile and over known electrical anomalies provided assurance of relative data quality and variations. Data were contoured using SURFER software as described in the magnetics section.

Electrical depth-sounding curves using a Schlumberger electrode array were also determined in the Canal Creek area to add a three-dimensional view to horizontal mapping. Each sounding curve was interpreted using the RESIX PLUS software package written by Interpex (1988). Resistivities of undisturbed soils were comparable with those observed at Building E5032, which averaged 60 Ω-m.* (See Appendix A for further information.)

2.4 Ground-Penetrating Radar System

Ground-penetrating-radar surveying was accomplished using a Geophysical Survey Systems, Inc. (GSSI), model SIR-3 radar connected to a transceiver with a cable approximately 300 ft long. Data were recorded on a digital audio tape to permit playback and computer processing. The control unit/graphic recorder was located in the transport vehicle. An IBM-compatible processing computer was located in a field office, so that the radar operator could down-load, check data-tape quality, and do preliminary processing after a day's run. Radan I computer software written by GSSI was used for processing the GPR data.

Wave-velocity characteristics of materials to be found at the Aberdeen/Edgewood area were derived from known positions of buried objects. Internal calibration was run at least twice each day to ensure that the graphic record of the range setting was consistent. Studies conducted during

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* Resistivity data acquisition and processing were done using the metric system of measurement. To convert from meters to feet, multiply values given in meters by 3.28.

the 1991 field season suggest wave velocities of 6-7 × 10^{-9} s/ft for near-surface sediment at Aberdeen; however, conditions vary with the heterogeneity of the subsurface. Typical wave velocities for different materials are shown in Table 2.

Ground-penetrating radar is probably the best method available to determine depth and geometry of objects buried near the surface. The weakness of the method is its limited depth of exploration due to wave-propagating constraints imposed by the electrical properties of soils. The maximum depth of penetration with GPR at Building E5375 was approximately 8 ft below the ground surface.

TABLE 2 Approximate Two-Way Travel Times for Various Materials

Material	Two-Way Travel Time (10^{-9} s/ft)
Air	2
Fresh water	18
Sea water	18
Sand (dry)	4.5
Sand (saturated)	11
Silt (saturated)	6
Clay (saturated)	6
Dry, sandy, coastal land	6
Marshy forested land	7
Rich agricultural land	8
Fresh-water ice	4
Granite (dry)	4.5
Limestone (dry)	5
Concrete	5
Asphalt	4-5

Source: Geophysical Survey Systems, Inc. (1987).

3 Geophysical Measurements and Surveys

3.1 Magnetometer Measurements

Total magnetic field observations were made at 331 stations for use in construction of the magnetic map shown in Figure 4. Station spacing was normally 5 ft; however, where the presurvey scan identified anomalous zones, stations were read at intervals as small as 1 ft. Peaks and troughs of positive and negative anomalies were truncated to permit a clearly displayed visual representation of the magnetic field. Thus, anomaly interiors are depicted as "white-outs".

Large anomalies south and west of the building are produced by surface interference caused by pipes, metal support racks, and an aboveground tank on the southwest side of the building. The source of a tightly constrained anomaly located at the northeast corner of Building E5375 was not identified. The major, magnetic anomaly at the site is caused by an underground storage tank centered approximately 25 ft east of the southeast corner of the building. The source of a 2,500-gamma, positive anomaly, centered at 75E,72.5N is not known. It is not expressed as a resistivity anomaly, but may be associated with a zone of enhanced reflectors observed with GPR. Small, single-station anomalies, common at other buildings and believed to be caused by construction fill, are not present at this site.

3.2 Direct Current Electrical Resistivity Measurements

The results from 187 DCER survey measurements are illustrated in Figure 5. The electrode spacing was 2 m, a configuration that provides an average resistivity for materials lying between the surface and a depth of about 3 m. At Building E5375 these materials include fill; a brown, coarse-grained material; and most of the thickness of the Upper Confining Unit (Oliveros and Gernhardt 1989), which is a silty clay.

From previous work (McGinnis and Miller 1991), background resistivities for these fine-grained, organic-rich, clayey materials were found to range from 50 to 150 Ω-m. As a basis for comparison with minima observed in other areas, a value of 6 Ω-m was observed over the "bare spot", a suspected buried tank at Building E5032, and high resistivities of up to 180 Ω-m were observed in the vicinity of a suspected old railroad bed.

Electrical depth-sounding curves collected for background in the Edgewood area indicate that resistivity values normally decrease with depth, probably due to increasing saturation and salinity. Where anomalous materials are present, this generalization is not valid. An electrical depth-sounding station centered north of Williams Road near Building E5481 was about 300 ft south of the site (see Appendix A). Inversion of the curve measured at this station results in an interpreted model where the upper 4.1 m of earth has a surficial resistivity of 366 Ω-m. From 4.1 m to the maximum depth of exploration, mean resistivity values are 105 Ω-m.

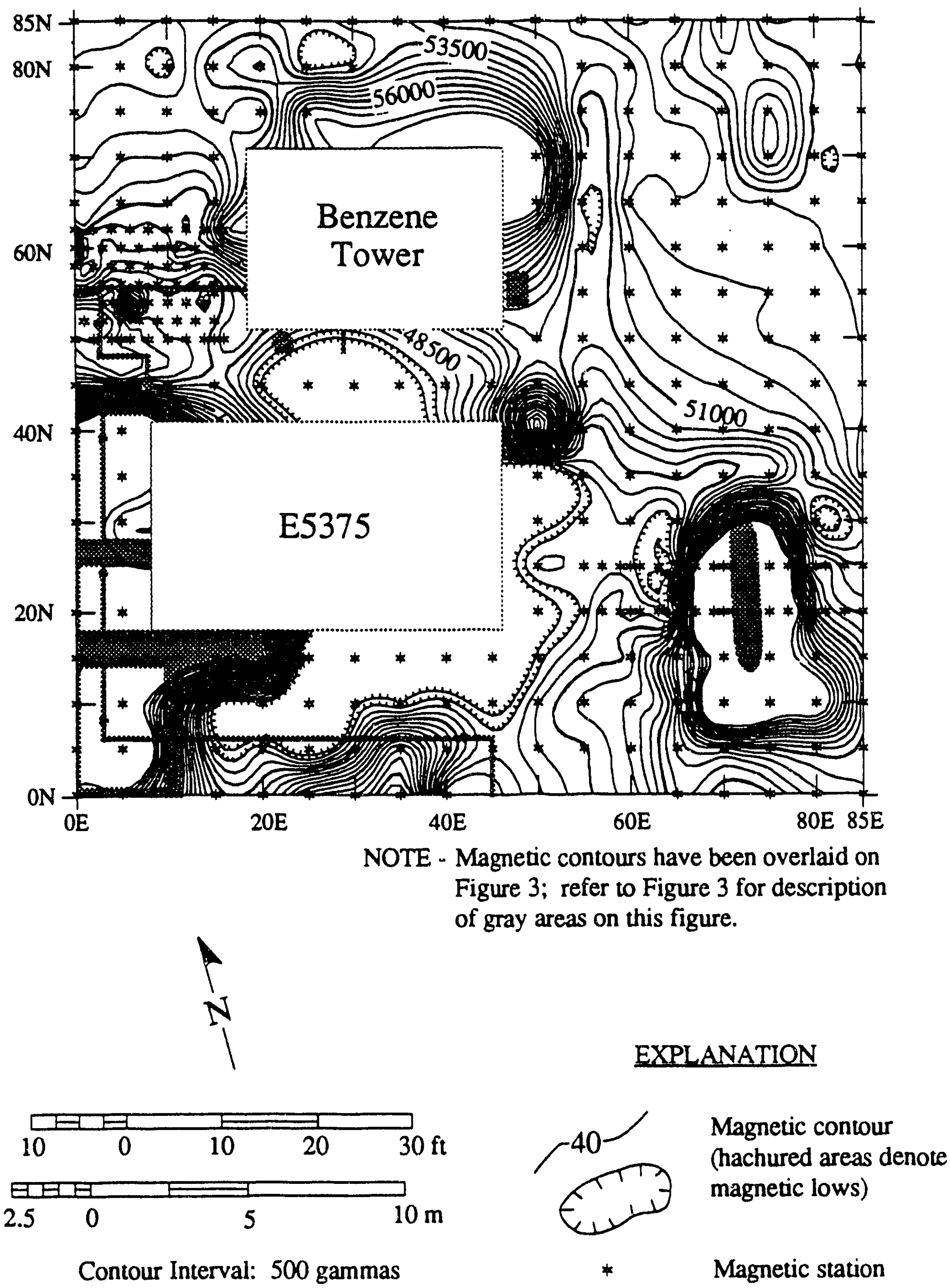
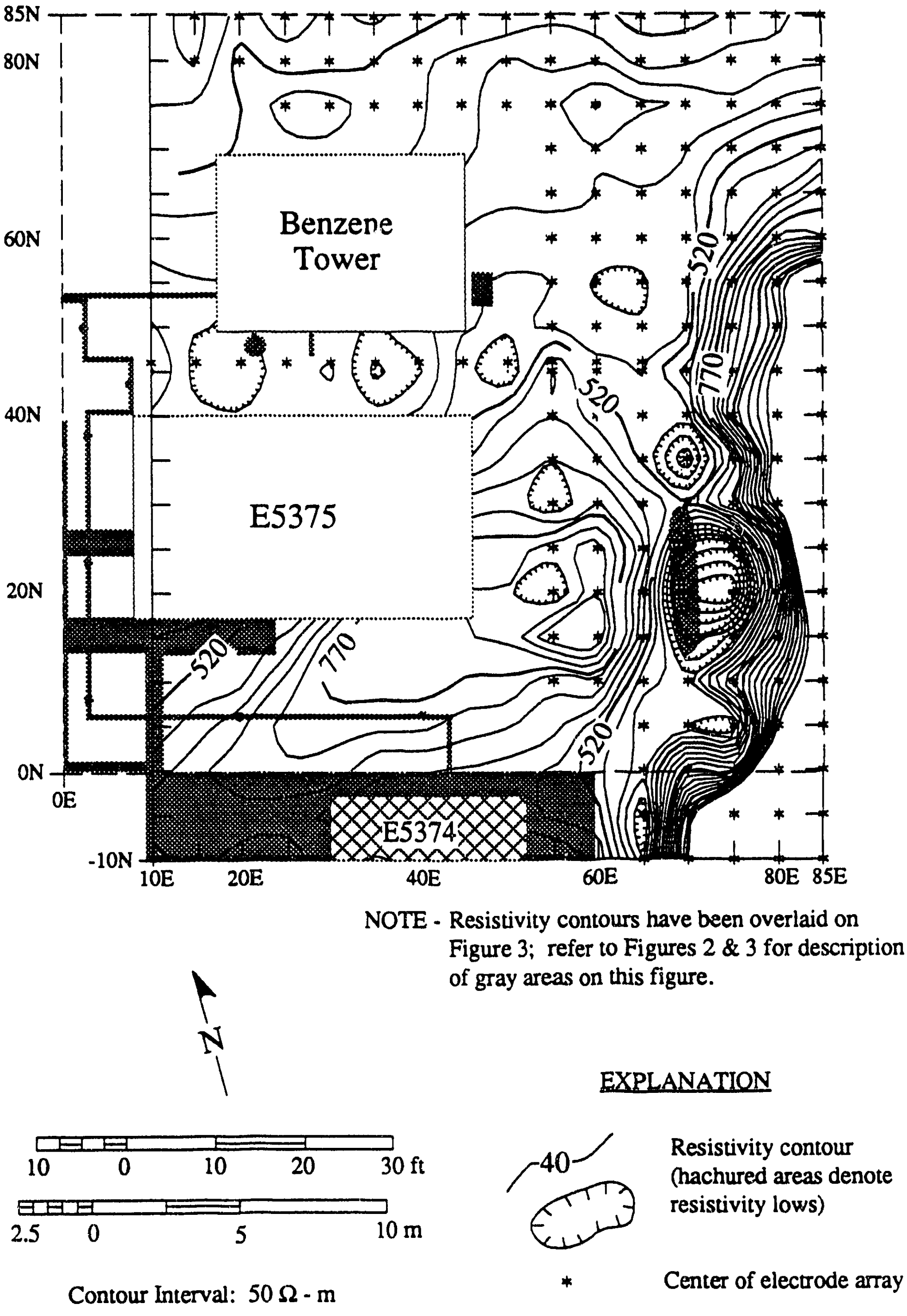


FIGURE 4 Total Intensity Magnetic Map of Building E5375 and Adjacent Benzene Tower



NOTE - Resistivity contours have been overlaid on Figure 3; refer to Figures 2 & 3 for description of gray areas on this figure.

FIGURE 5 Apparent Resistivity Map of Building E5375 and Adjacent Benzene Tower

Apparent resistivity values in the surveyed area of Building E5375, acquired using horizontal profiling techniques, range from a minimum of 15 Ω-m over an underground storage tank (UST) 25 feet east of the building to 2,300 Ω-m near the southeast corner of the surveyed area. The high resistivities observed along the eastern border of this site are probably caused by dry, coarse-grained construction fill, although at other buildings, fill material has been associated with relatively more conductive zones. The abrupt resistivity gradient, expressed as a north-south lineament along the western margin of this anomaly, suggests that the high values are not caused by liquid contaminants. This resistivity anomaly is best interpreted as a facies boundary.

3.3 Ground-Penetrating Radar Measurements

Ground-penetrating radar measurements around the building perimeter were made at 5-ft intervals over 2,390 ft of traverse along 48 individual profiles, coincident with magnetic and resistivity profiles. The lines are numbered in sequence and are listed in Appendix B, along with the beginning and ending positions relative to the grid survey. Prior to running the production lines for the survey, replicate runs were made over the same line to determine which of the three transceivers — the 80-, 300-, or 500-MHz antenna — was best suited to study the terrain surrounding the site. The transceiver providing the best penetration and resolution of buried objects was the 300-MHz unit. Different range settings were also tested over the same transect to determine the optimum resolution and depth of penetration. A range setting of 90 ns was used for the entire survey at a scan rate of 16 scans/s, with additional data collected at 70 ns at a scan rate of 16 scans/s over the UST. Antennas were pulled by hand at approximately 3 ft/s.

Most of the profiling was done in the areas north and east of the building; some lines were run in the narrow space between Building E5375 and adjacent buildings. Perimeter profiles were designed to detect buried objects extending radially from the building. Figures 6 and 7 show the GPR profiles. The vertical scale is shown on the right side of the profile, whereas lines are marked at 10-ft intervals for the horizontal scale.

Without verification by another technique or by passing the antenna over a known buried object, characteristics of radar anomalies may only be inferred. However, where anomalies are also seen with the magnetometer or electrical resistivity meter, some interpretation of the radar anomaly is possible.

Good penetration was observed over most of the site, with resolution down to about 8 ft below the ground surface. The major findings of the GPR survey around Building E5375 are the following anomalies:

1. GPR profile No. 42 clearly shows the UST located east of Building E5375 (see Figure 6). The ends of the tank appear to coincide with aboveground vertical standpipes, and the long axis of the tank is oriented north-south. On the basis of the GPR profiles, the top of the UST is estimated to be about 1 ft below the ground surface.

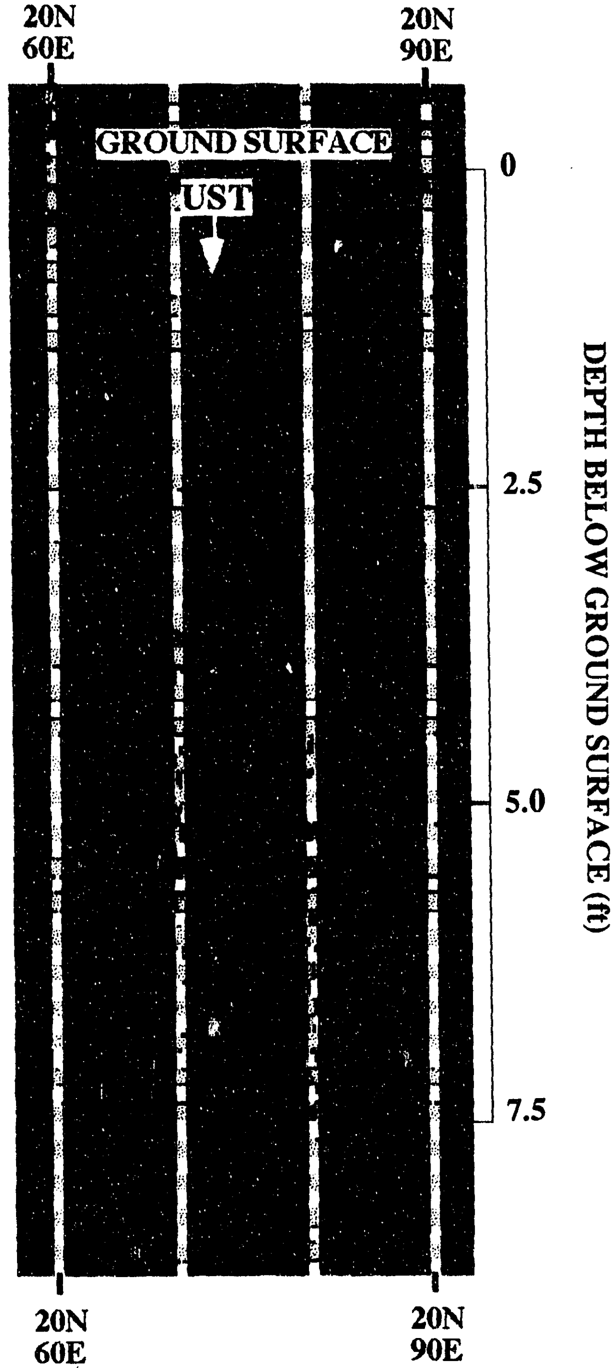


FIGURE 6 West-East Ground-Penetrating Radar Profile for the Area East of Building E5375 (The location of this profile is shown in Figure 3 as line No. 42.)

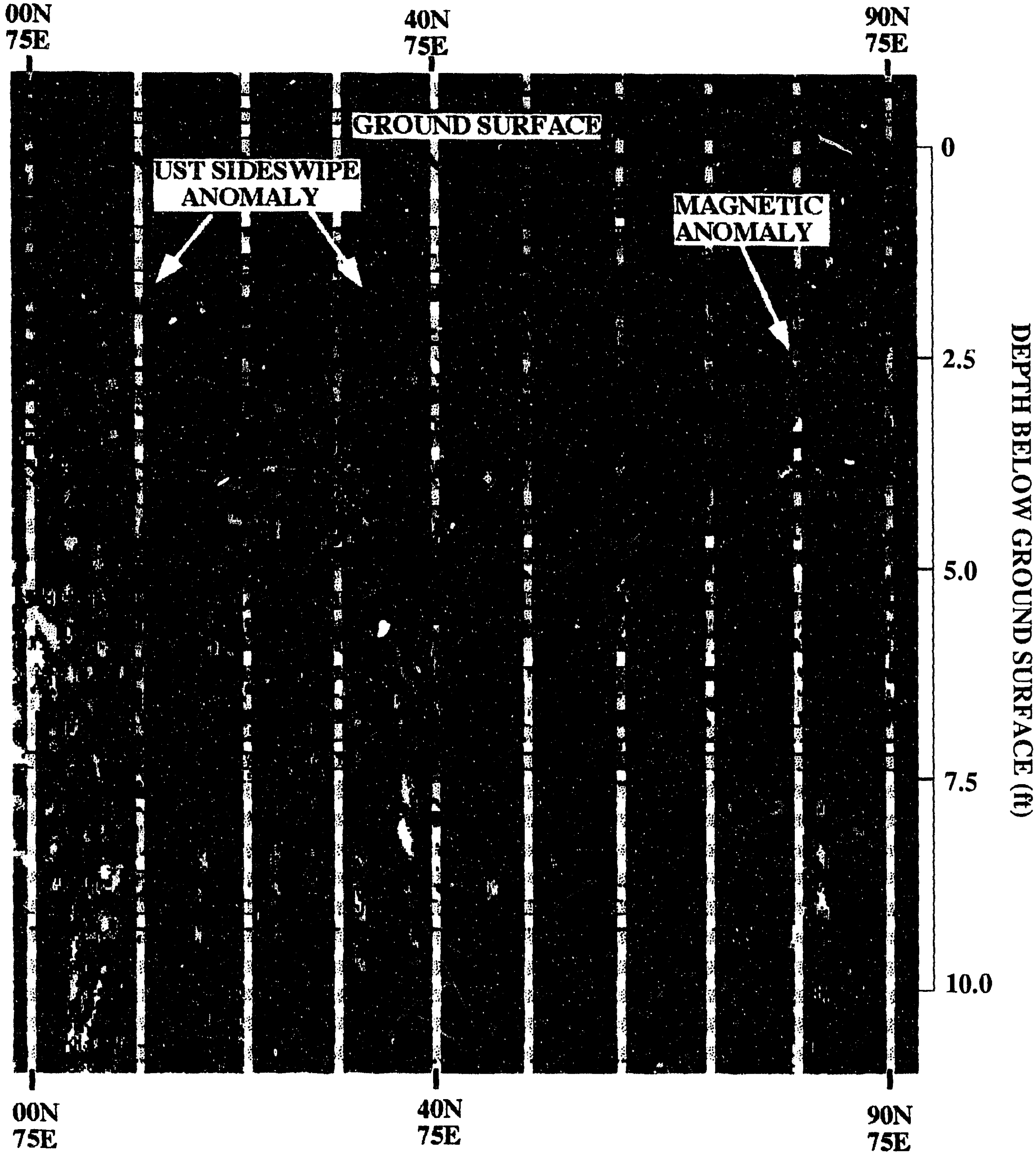


FIGURE 7 South-North Ground-Penetrating Radar Profile for the Area East of Building E5375 (The location of this profile is shown in Figure 3 as line No. 3.)

2. A south-north profile along 75E (see Figure 7) shows both the GPR sideswipe anomaly of the UST and the magnetic anomaly in the northeast corner of the study area. The depth of the UST cannot be determined with this profile because the transceiver passed 5 ft east of the tank. The magnetic anomaly in the northeast corner appears to be quite small (less than 1.5 ft in diameter) and is buried approximately 2.5 ft below the ground surface.

4 Discussion

A map of the magnetics results superimposed over the DCER results is shown in Figure 8. Both magnetics and resistivity show a prominent anomaly over the UST southeast of the building. A truncation followed by a continuation of the resistivity anomaly to the south of the UST may represent a second UST; however, the anomaly is a consequence of a low resistivity value at only three stations.

The clearly defined magnetic anomaly in the northeast corner of the surveyed area is not observed on the resistivity map, although it is associated with anomalous reflectors on the north-south GPR profile shown in Figure 7. The location of the profile relative to the UST results in a sideswipe signature on the GPR line.

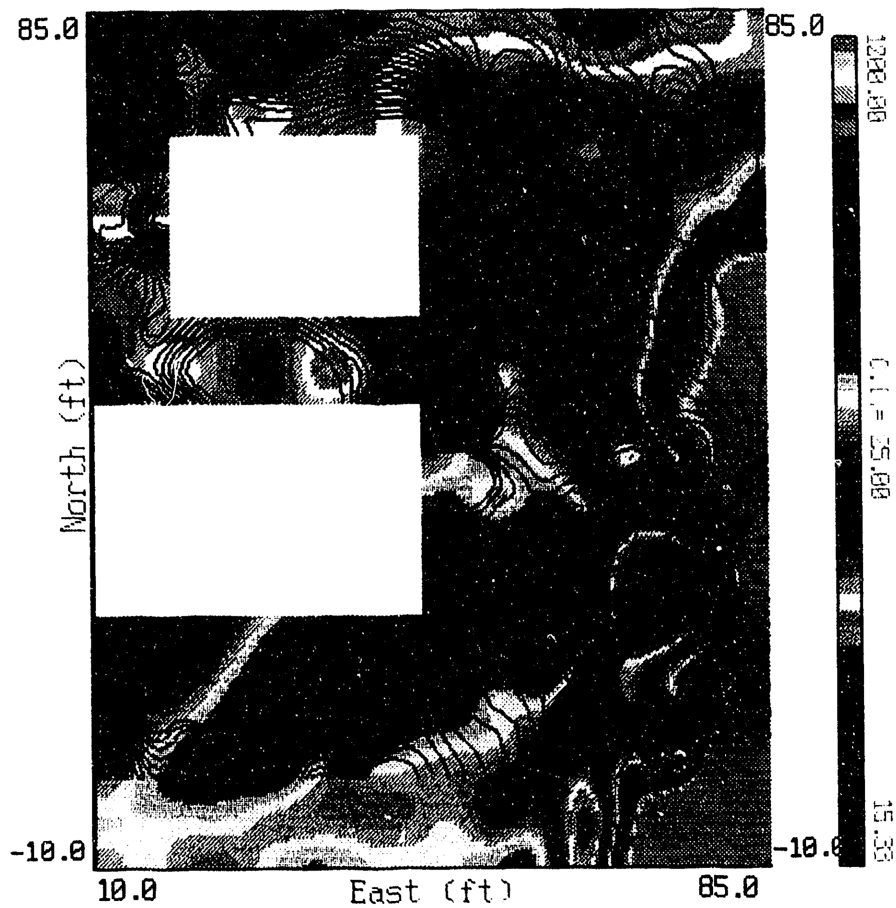


FIGURE 8 Magnetics/Resistivity Overlay Map of Building E5375 and Adjacent Benzene Tower

A second magnetic anomaly, located off the northeast corner of Building E5375, does not have a resistivity signature because a resistivity station was not occupied at this position.

The extremely high resistivity lineament flanking the southeast side of the mapped area, believed to be caused by high-resistivity fill, has no magnetic signature. Variability in magnetic and resistivity characteristics of fill material is generally represented on GPR profiles as a zone of chaotic reflectors. This variability precludes identification of point sources, as was possible at Building E5282, for example.

5 Conclusions

Specific conclusions drawn from the site surveys of Building E5375 are as follows:

1. A UST located 25 ft east of Building E5375 is clearly identified with magnetic, resistivity, and GPR profiling. The top of this tank is approximately 1 ft below the ground surface.

2. A three-point resistivity anomaly, 12 ft east of the northeast corner of Building E5374 (see Figure 5 for location relative to E5375) and 5 ft south of the area surveyed with the magnetometer, may be caused by a UST. Supporting data from GPR and magnetics are not available for further diagnosis of this anomaly.

3. Isolated, one-point magnetic anomalies, believed to be associated with construction fill and observed at Building E5282, are not seen in the surveys at Building E5375.

4. A 2,500-gamma magnetic anomaly near the northeast corner of the site has no equivalent resistivity anomaly. Disruption in GPR reflectors was observed, and the object appears to be less than 1.5 ft in diameter and buried approximately 2.5 ft below the ground surface. The lack of an electrical anomaly at this location may be due to the small size of the object.

5. The source of a magnetic anomaly at the northeast corner of Building E5375 cannot be resolved with available data. The ground surface at this location is undisturbed except for concrete rubble adjacent to the building, which prevented the establishment of a resistivity station.

6 References

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Appendix A:

Electrical Depth-Sounding Curves

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Electrical Depth-Sounding Curves

Four Schlumberger electrical depth-soundings near buildings in the Edgewood area provide a depth dimension to resistivities of soils, sediment, and anomalous unidentified materials. Soundings were made near Buildings E5282, E5440, E5481, and E5974. Locations of centers of stations and orientations of electrode arrays are listed in Table A.1, and the curves are shown at the end of Appendix A as Figures A.1-A.4.

Inversion of these curves using the Interpex code, RESIX PLUS (Interpex Limited 1988), indicates that resistivity of dry soils is from 200 to 300 Ω-m;* saturated sediments, about 100 Ω-m; saturated, organic-rich sediments, about 200 Ω-m; and anomalous materials range from less than 10 to 10,000 Ω-m. Maximum current electrode spacings (AB/2) ranged from 40 to 100 m, providing information to depths of about 50 m.

Normal undisturbed curves were observed at Buildings E5282 and E5481. These stations were located in topographically low areas where the water table lies within 3 m of the surface.

A reasonable interpretation of the curve at Building E5440, which was centered in an open area northeast of the building, is not feasible without more historical information about the site. Former roads, landfills, and other subsurface artifacts could explain the orders of magnitude change in resistivity values from 15 Ω-m to 10,000 Ω-m at a depth of 11 m.

TABLE A.1 Location of Centers of Stations and Orientations of Electrode Arrays for Schlumberger Electrical Depth-Soundings at APG

Station Center	Array Orientation	Maximum Electrode Spacing (m)
Northeast of Building E5282	E-W	50
Northeast of Building E5440	NW-SE	40
North of Building 5481	E-W	80
Northwest of Building E5974	NW-SE	100

* Electrical depth-soundings were measured in the unit of ohm-meter. Thus, discussion of electrical depth-soundings in this report gives depths measured in meters. To convert from meters to feet, multiply depths in meters by 3.28.

The sounding curve at Building E5974 displays the most unusual surface resistivities. A 2.7-m-thick layer of extraordinarily high resistivity (3,055 Ω-m) near the surface is underlain by a layer having a higher than normal value (440 Ω-m) extending to a depth of 50 m. This is underlain by a layer having normal resistivities of near 123 Ω-m.

Earth resistivity models calculated from inversion of the sounding curves are shown in Table A.2.

TABLE A.2 Resistivity Models Calculated from Electrical Depth-Soundings

Station	Resistivity (Ω-m)	Thickness (m)	Depth (m)
E5282	108	0.4	0.4
	244	4.5	4.9
	95	unknown	unknown
E5440	269	1.2	1.2
	14	10.1	11.3
	11,525	unknown	unknown
E5481	366	4.1	4.1
	105	unknown	unknown
E5974	783	0.9	0.9
	3,055	2.7	3.6
	440	46.4	50.0
	123	unknown	unknown

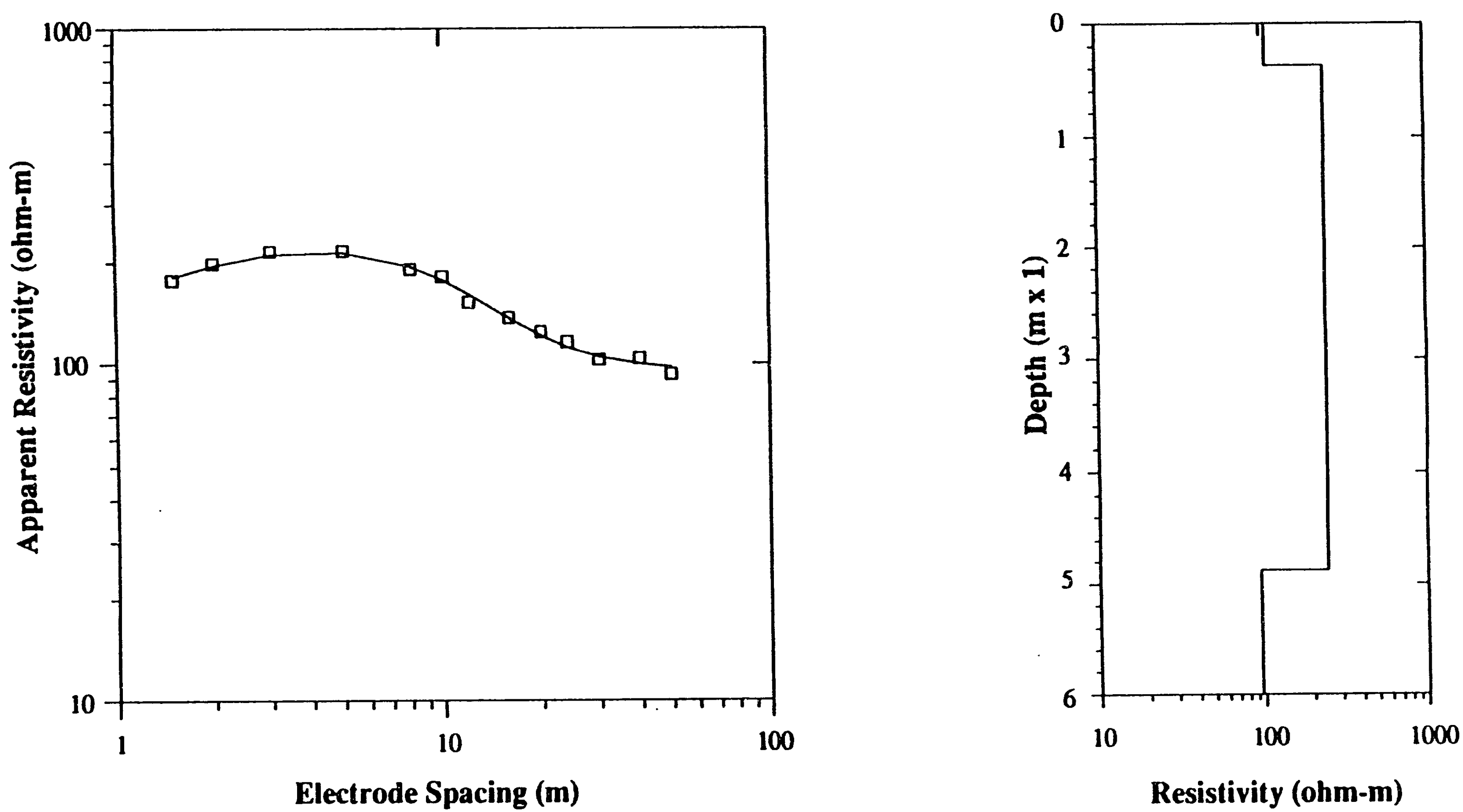

FIGURE A.1 Electrical Depth-Sounding Curve Near Building E5282

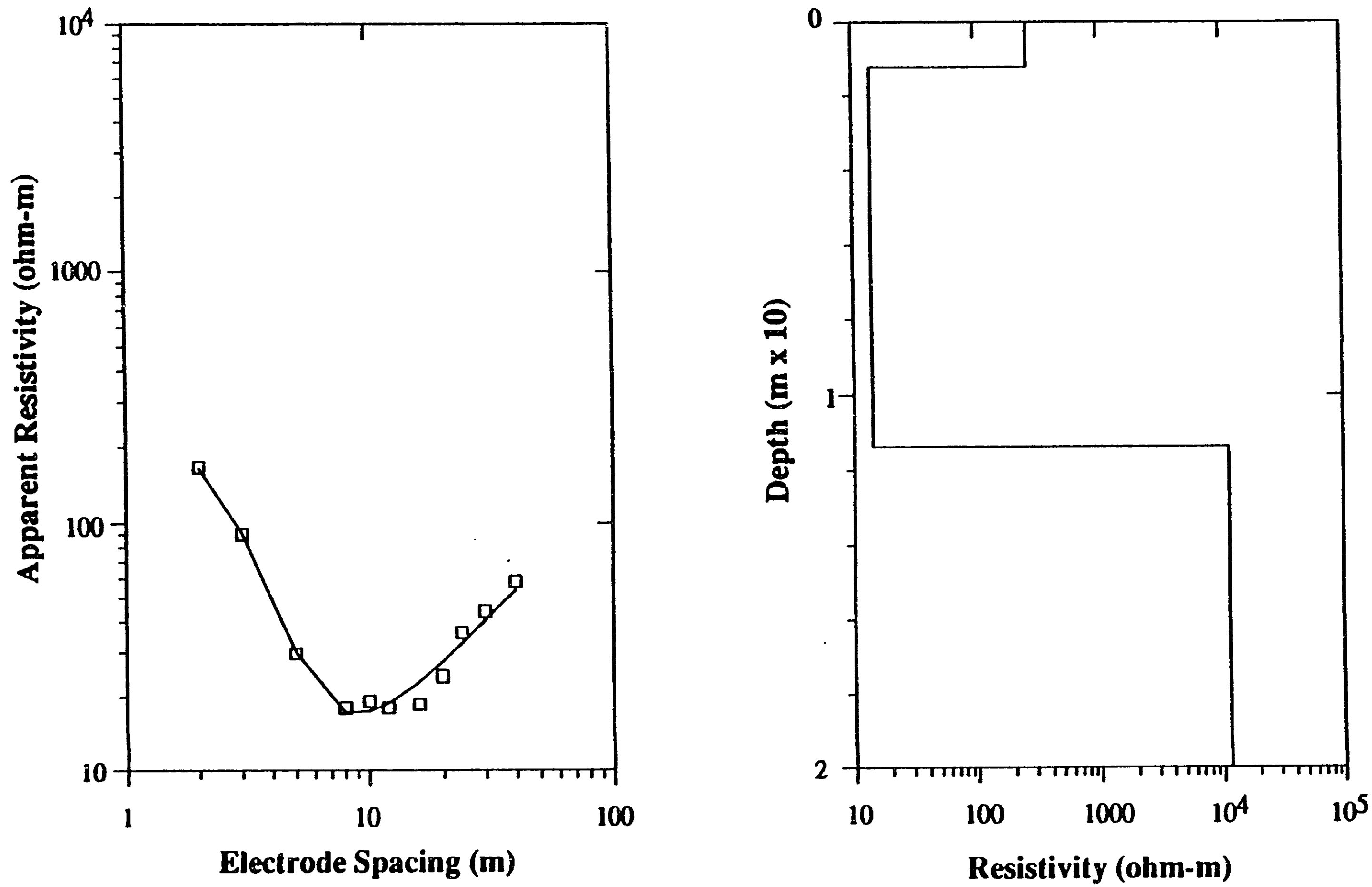

FIGURE A.2 Electrical Depth-Sounding Curve Near Building E5440

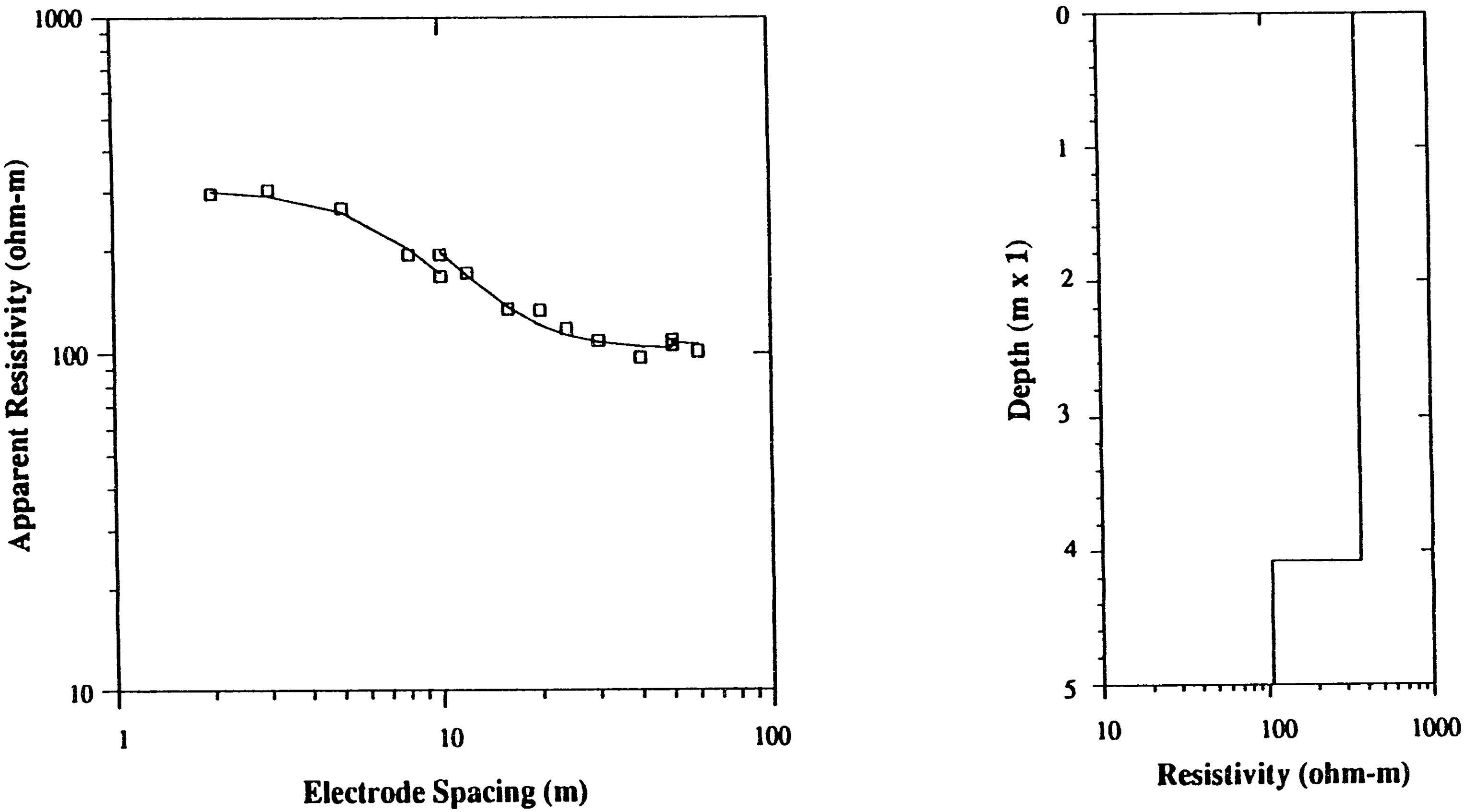

FIGURE A.3 Electrical Depth-Sounding Curve Near Building E5481

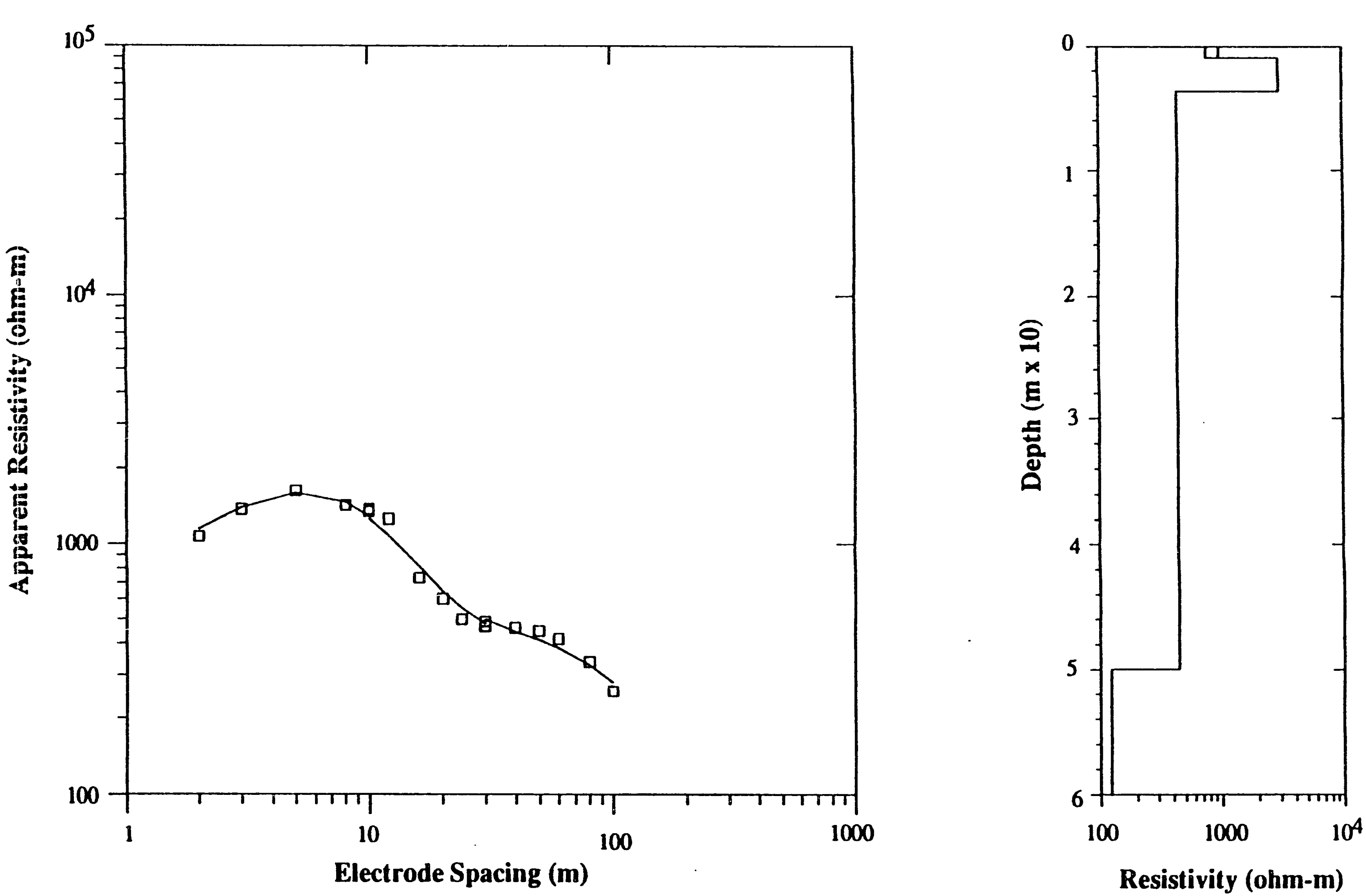

FIGURE A.4 Electrical Depth-Sounding Curve Near Building E5974

Appendix B:

Ground-Penetrating Radar Line Coordinates

Appendix B:

Ground-Penetrating Radar Line Coordinates

Line No.[a]	Start Coordinates		End Coordinates	
	North	East	North	East
1	00	85	90	85
2	00	80	90	80
3	00	75	90	75
4	00	70	90	70
5	00	65	90	65
6	00	60	90	60
7	00	55	90	55
8	85	00	85	90
9	80	00	80	90
10	75	00	75	30
11	70	00	70	18
12	65	00	65	18
13	60	00	60	18
14	55	00	55	18
15	75	50	75	90
16	70	50	70	90
17	65	55	65	90
18	60	54	60	90
19	55	50	55	90
20	50	32	50	90
21	45	00	45	90
22	40	48	40	90
23	35	50	35	85
24	30	48	30	85

Line No.[a]	Start Coordinates		End Coordinates	
	North	East	North	East
25	25	48	25	90
26	20	48	20	90
27	15	4	15	90
28	10	14	10	90
29	05	00	05	90
30	00	00	00	90
31	00	45	18	45
32	00	40	18	40
33	00	35	18	35
34	00	30	18	30
35	00	25	18	25
36	00	20	18	20
37	00	15	18	15
38	01	10	85	10
39	01	05	90	05
40	10	60	10	90
41	15	60	15	90
42	20	60	20	90
43	25	60	25	90
44	30	60	30	90
45	00	80	40	80
46	00	75	40	75
47	00	70	40	70
48	00	65	40	65

[a] GPR lines 1-39 were collected at a range setting of 90 ns at 16 scans/s. Lines 40-48 were collected at a range setting of 70 ns at 16 scans/s.

END

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