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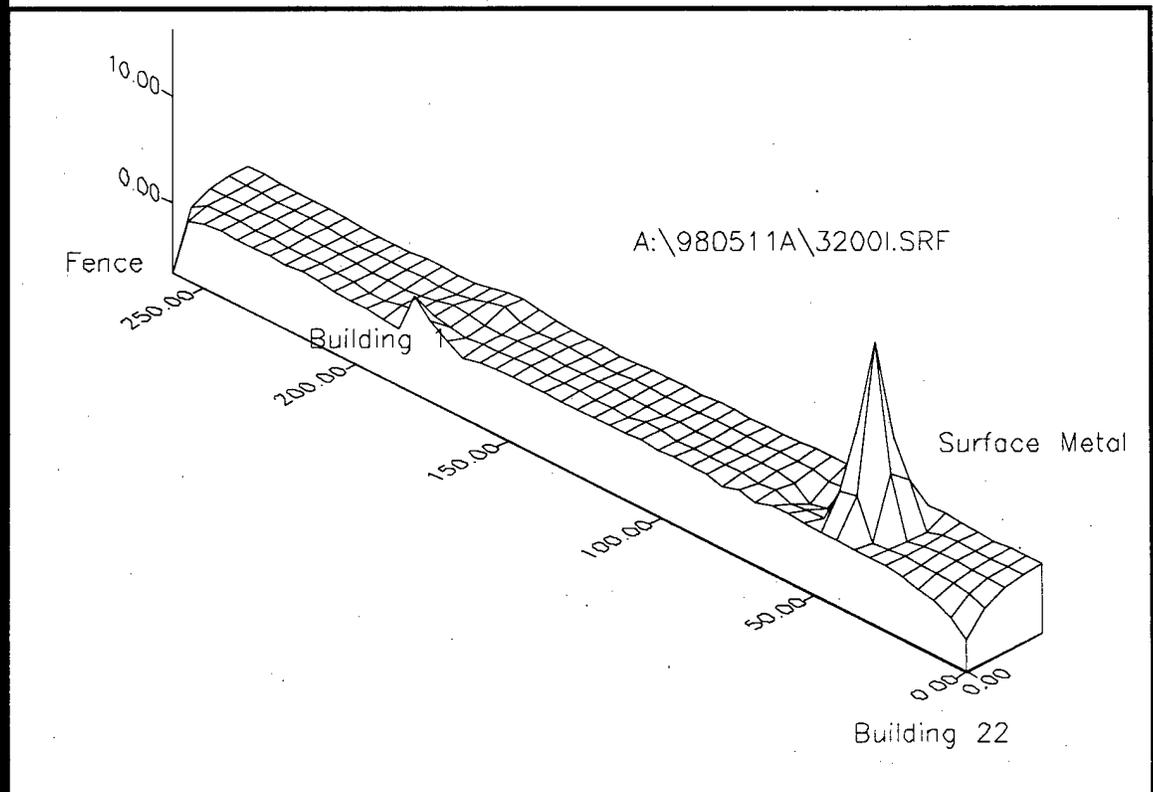
US Army Corps
of Engineers.
Engineer Research and
Development Center

Underground Storage Tank Location and Mapping of Former Landfills by Electromagnetic Surveys for the Delaware National Guard

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Foreword

This study was conducted for Headquarters, Delaware National Guard under MIPR No. W8AFAAENV98002/PO, Work Unit No. VK8, "NCRR IRP Investigation." The technical monitor was MSgt C. Ted Waters, DE-AEN-E.

The work was performed by the Energy Branch (CF-E), of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Paul H. Nielsen. Larry M. Windingland is Chief, CEERD-CF-E, and L. Michael Golish is Chief, CEERD-CF. The technical editor was William J. Wolfe, Information Technology Laboratory. The associated Technical Director was Gary W. Schanche, CEERD-CVT. The Acting Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

The Delaware Army National Guard tasked the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) to provide electromagnetic surveys to identify possible subsurface metallic features at various locations at the New Castle Rifle Range, New Castle, DE and at the Bethany Beach, Delaware National Guard Training Base.

Information gathered in the preliminary project discussions at the New Castle site indicated possible subsurface features, including:

1. An underground storage tank at a former latrine site and at a former building
2. Interfering structures along a planned county sewage system connection
3. Buried oil drums.

Possible buried items at Bethany Beach location included:

1. Underground storage tanks in the barracks area and underneath a paved area north of building 151
2. Buried 55-gal drums in the remaining search areas.

The surveys at Bethany Beach were conducted using the GEM-1, a laboratory prototype multi-frequency electromagnetic profiler,* and a rented GEM-300, a commercial multi-frequency electromagnetic profiler built by Geophysical Survey Systems, Inc. In use, the instrument induces eddy currents and measure the resultant secondary fields, giving an average conductivity value for the affected search volume. In a typical application, a survey is conducted by taking readings at points in a search area. The data is stored in the instrument. At the completion of the survey, the data is used to generate images of natural and man-made subsurface objects. The resolution of these images is related to the density of

* The GEM-1 was developed for CERL under an earlier Small Business Independent Research (SBIR) study.

data points. The minimum object size that can be discerned is related to the instrument's sensitivity. The sensitivity is limited by electrical and physical constraints. The images are generated from the data using commercial spreadsheet and mapping software. The GEM-1 operates at 800, 3200, and 9600 Hz and collects both in-phase and quadrature data. Thus, each survey can have six data plots. Some target depth information may be available by the use of multi-frequencies. Some soil and target conductivity information can be derived from the quadrature data. Most of the information of interest for this study (relatively shallow buried metal structures) appears in the 3200 Hz, in-phase data. Those data are supplied with this report. The commercial GEM-300 can operate on any of a choice of 300 frequencies, up to 16 at a time.

This report presents the results of electromagnetic surveys CERL conducted for the Delaware Army National Guard to document the presence of subsurface metallic features at the New Castle, DE Rifle Range and the Bethany Beach, DE training site.

Objective

The objective of this study was to perform electromagnetic surveys to identify possible subsurface metallic features (locate underground storage tanks and other buried metal objects) at various locations at the New Castle Rifle Range, New Castle, DE and at the Bethany Beach, Delaware National Guard Training Base.

Approach

Data surveys were taken at New Castle, DE in May 1998 and at the Bethany Beach, Delaware National Guard Training Base in June 1998. The exact dates on which data were taken can be extrapolated from the data filenames noted in the figures, which take the form Year-Month-Day (yymmdd), and are sequentially ordered by lower-case letter. For example, the first data file noted in Figure 2 (p 12) is "980507c," indicating the data was the third data set taken on 07 May 1998.

A typical survey is conducted by laying out a grid on the surface of the area to be searched. Data is taken at stations in the lines (rows). Data analysis is expedited if the survey areas are rectangular. A convenient method to identify the data lines is to lay tape measures, one along each end of the rectangle, and then to lay one or more tape measures lengthwise.

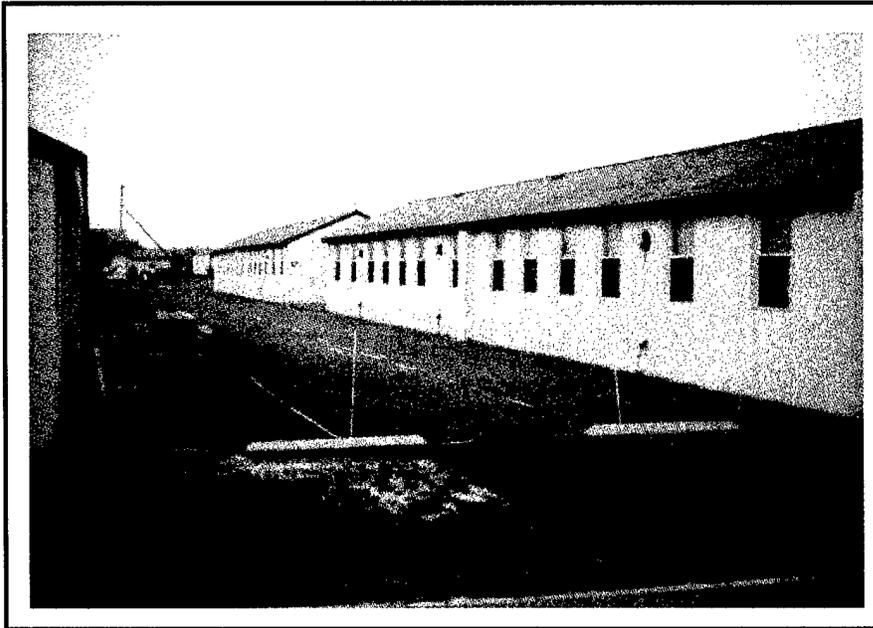


Figure 1. Tape measure placement for electromagnetic survey of area between rows of barracks, Bethany Beach, Delaware National Guard Training Base.

If a 5-ft grid is used, reasonably accurate positioning can be accomplished by placing tape measures 10 ft apart and by walking along the tape, taking a data point every 5 ft for one line of data points, then by walking in the middle between two tapes and reading the numbers on one of the two tapes for the intermediate data points. This is easy to accomplish for open, nonvegetated areas. Heavy vegetation makes it more difficult to set up the survey area and to accurately position the instrument for readings. Figure 1 shows a survey location set up between rows of barracks at Bethany Beach National Guard Training Base. The GEM-300 has a feature that allows it to take data at timed intervals. Thus a survey conducted at a walking pace can rapidly cover a relatively large area. (The operator does not need to stop at fixed locations to take data with the GEM-1.) The analysis software assumes a constant pace to locate the data points, so this technique is best suited for surveying nonobstructed areas.

The data files were downloaded from the GEM instrument to a 486 laptop computer for field processing and analysis. (CERL developed macros to expedite this processing.) The results, plotted electronically, were shown as surface and/or contour plots, scaled to accentuate such large objects as were the search objects of this study.

Mode of Technology Transfer

The results of these surveys have been delivered to the sponsors of this study, and will also be made publicly available through the World-Wide Web (WWW) at:

www.cecer.army.mil

2 Survey Areas at the New Castle Rifle Range

The surveys at New Castle Rifle Range were conducted by identifying and marking the areas to be surveyed. The easiest procedure, both for conducting surveys and for data processing, is to lay out a rectangle that includes the area to be examined. The location of the area to be surveyed must be fixed in relation to the surface of the earth so that the results can be tied to the proper location. This can be done by including a fixed point within or measurably near the survey area or by using a Global Positioning System (GPS) for location. A handheld GPS commercial receiver was used for some of the locations. However, at the time of the survey, the commercial GPS had a random offset of 15 to 100 m inserted at random times, thus its accuracy was not satisfactory for locating the search areas for this study. Most of the data for the New Castle location was taken on 5-ft centers (one area was covered with 2.5-ft centers and another on 10-ft centers).

The data points for the GEM-1 are typically located by placing fiberglass tape measures along the row of data to be taken. Usually multiple tapes are laid out prior to data gathering and when the data rows associated with these tapes are completed, the tapes are moved to the next data rows. This is repeated until the complete search area is covered. Rectangular search areas are the easiest to use with the spreadsheet (*Lotus 123* and *Procalc*) and mapping software (Golden Software's *Surfer*) used by CERL. The data files were downloaded from the GEM instrument to a 486 laptop computer for field processing and analysis. CERL has developed macros to expedite this processing whenever they can be used. The results as plotted by *Surfer* in this report are shown as surface and/or contour plots. *Surfer* automatically scales the plots according to maximum data values, thus a plot containing a large metal object may be scaled so that small items are not visible. This effect has been reduced to some extent on the contour plots by limiting the maximum and minimum values shown on the plots.

Figure 2 shows a map of part of the facility that identifies the areas surveyed in this part of the study. Note that, in this illustration, orientations are not exact and sizes were not scaled. The areas are:

1. An historic latrine with the building no longer present. This survey was conducted to identify possible underground storage tanks in the immediate area of the facility.

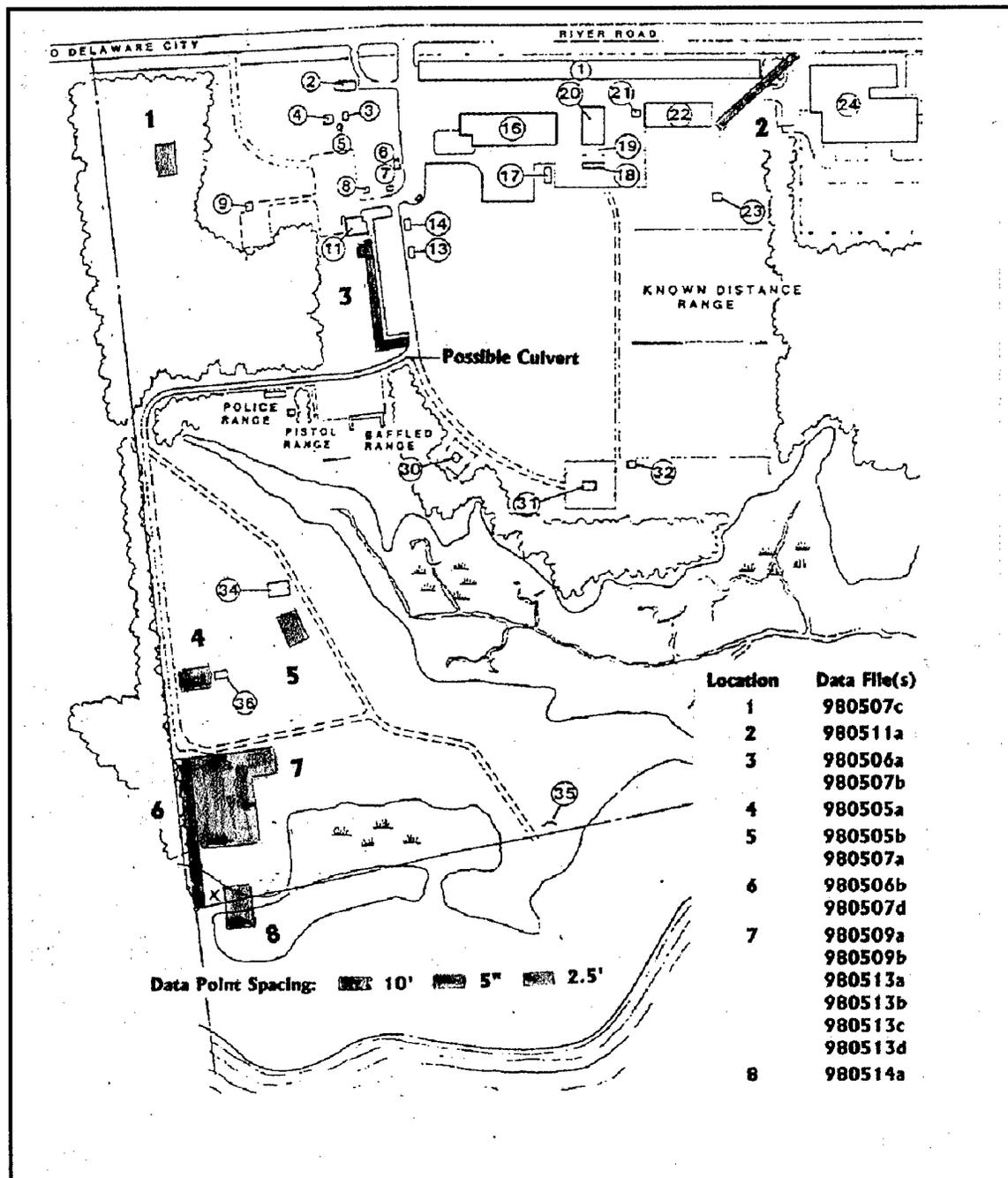


Figure 2. Locations of electromagnetic surveys conducted at the New Castle, Delaware Rifle Range, Delaware National Guard.

2. A diagonal path approximating a proposed sewer line exiting the base. This survey was conducted to identify possible conflicting metallic underground structures or to document their absence.
3. An area near a former building. One underground fuel storage tank had been removed from this area.
4. The open area by ammunition storage building #36 for possible buried barrels.
5. The open area by the ammunition igloo #34 for possible buried barrels.

6. (also 7 and 8) These are all parts of one area (identified as the tower area) to be searched for buried metallic structures. The goal was to survey the whole area, but portions were too densely covered with vegetation to allow traversing of the area. Significant quantities of surface metal items were also present in some areas.

Location 1, Historic Latrine

Location 1 on Figure 2 is a former latrine site probably dating from WWI. It is located in an area of forest with considerable underbrush in the immediate area (Figure 3). The building is gone except for the concrete floor and 12 stool fixtures. Nine, approximately 6-in. diameter metallic cylindrical and 1-in. pipe structures (4-5 ft total length) and a rusted out sheet metal structure (probably the urinal) were in the immediate area. These were placed near the stools during the surveys. A 50 X 75-ft area surrounding and including the floor was surveyed on 7 May 1998, to locate possible underground storage tank and/or septic tank fixtures related to the latrine structure. The results of this survey are given in Figure 4 (3200 Hz, in-phase data). The line of the stools is centered on the horizontal 30-ft line. The other target (between 40-50 horizontal and vertical is located where the urinal sheet metal had been found and may indicate an additional near surface, relatively small metal object in that area. No obvious tank-shaped structures were found in the survey area

Location 2, Proposed Sewer Line

Location 2 is an area identified for future installation of a sewer line. It was surveyed 11 May 1998. The survey was conducted within 10 ft of Buildings 1 and 22 and the perimeter fence. The plot of the survey data (Figure 5) shows the effects of each of these. Some surface metal objects were in the area surveyed. These consisted of a small portion of metallic landing mat material and a broken box of small metal plates scattered near the portion of landing mat. No subsurface objects or structures were identified.

Location 3, Near Slab Used for Vehicle Parking

Location 3 is next to the slab for a former building adjacent to Building 11 currently used as a parking lot for military vehicles. The survey consisted of a 15-ft wide L-shaped area 360 ft long along the side of the slab, and a 15 X 35-ft area along the end. The search area was located 10 ft from the slab.



Figure 3. Location 1, former latrine site, New Castle Delaware National Guard Rifle Range.

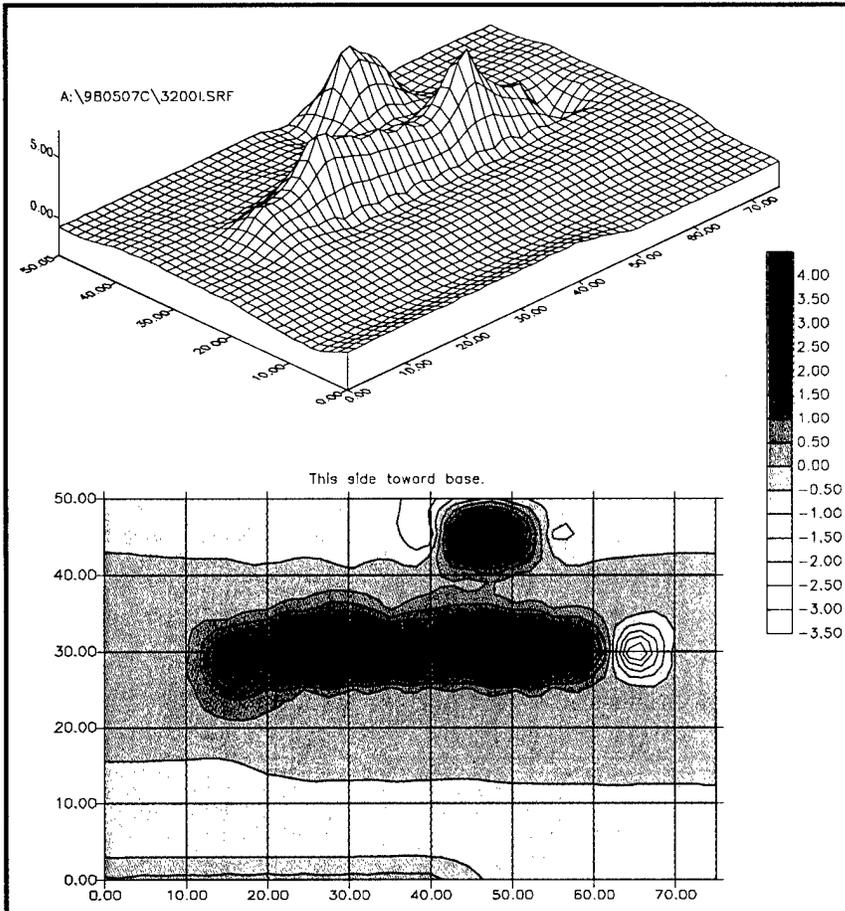


Figure 4. Electromagnetic survey results, Location 1, former latrine building site, 3200 Hz, in-phase data.

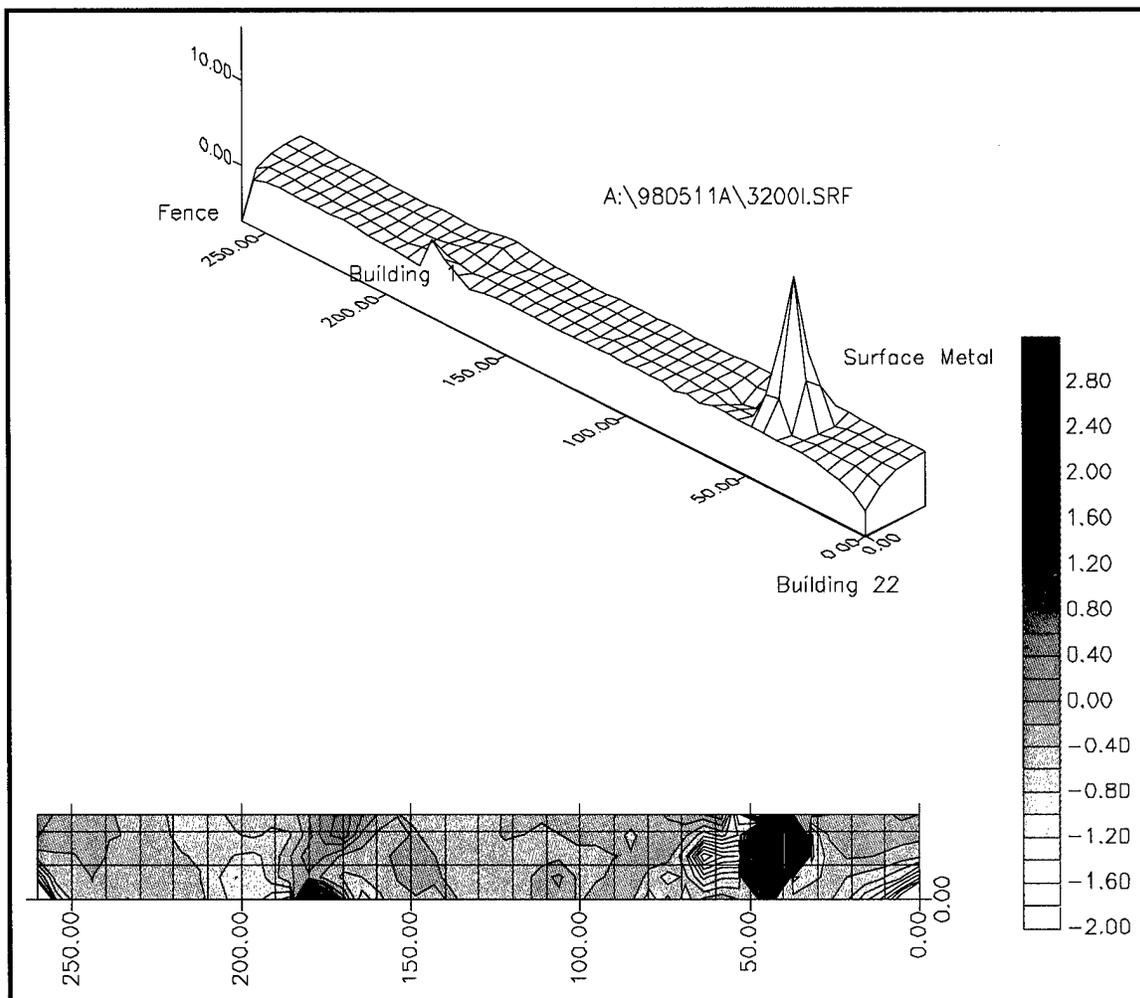


Figure 5. Electromagnetic Survey Results, Location 2, Proposed Sewer Line, 3200 Hz, in-phase data.

Figure 6 shows partial results of this survey. A buried object was found near the manhole cover close to Building 11 and a more detailed survey (with 2.5-ft data point spacing) was conducted there (see Figure 7). Note that the axis dimensions are a factor of 10 more than the actual distances due to fact that the macro used for the automated spreadsheet calculations will not accept decimal numbers. The results of this more detailed survey indicated that the underground structure extended to a point near the manhole. It was concluded that the underground object was probably the septic tank for Building 11 (Figure 8). The high reading at about 225 ft in Figure 6 coincided with a vehicle parked near the edge of the slab. An apparent covered culvert was found where the road turns to go past the target ranges. This location is identified in Figure 2.

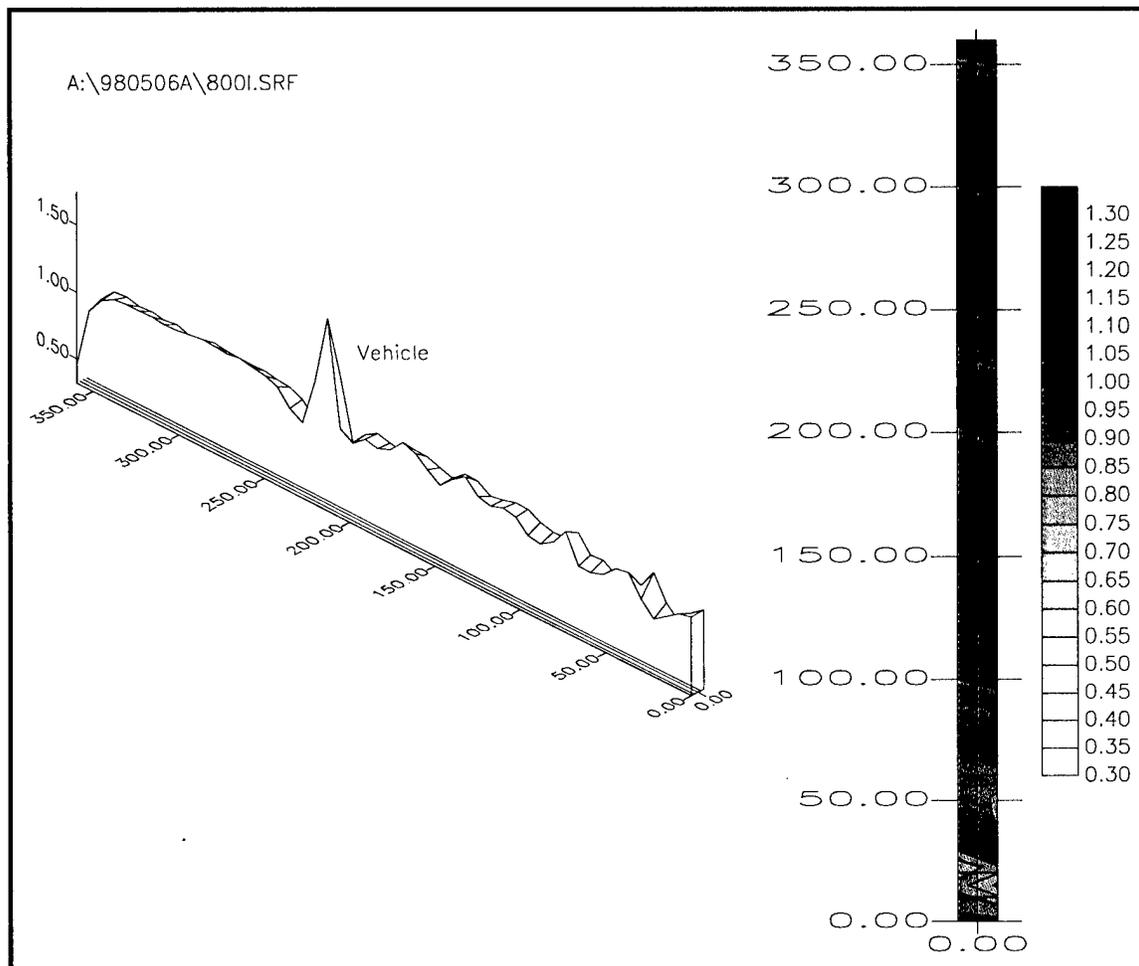


Figure 6. Electromagnetic survey location 3, 3200 Hz, in phase measurement.

Location 4, Near Building 36

Location 4 is the generally open area between the fence surrounding the ammo storage building #36 and the perimeter road (Figure 9). A 150 X 70-ft area was surveyed as sketched in Figure 10. No significant targets were discovered in this area. Figure 11 shows the results of this survey. The low level data value at the corner (0, 90) is due to instrument startup drift. The linear structure indicated by the data at (20, 0-120) is probably due to a small instrument instability. The variations in the data magnitudes here are relatively small when compared to other readings and do not indicate subsurface structures in this area. The drift effects could be filtered out with specialized data processing techniques if the surveys were being conducted for locating very small objects. The GPS reading at the corner labeled "Start" was 39 degrees 37.80 minutes north latitude and 75 degrees 36.52 west longitude.

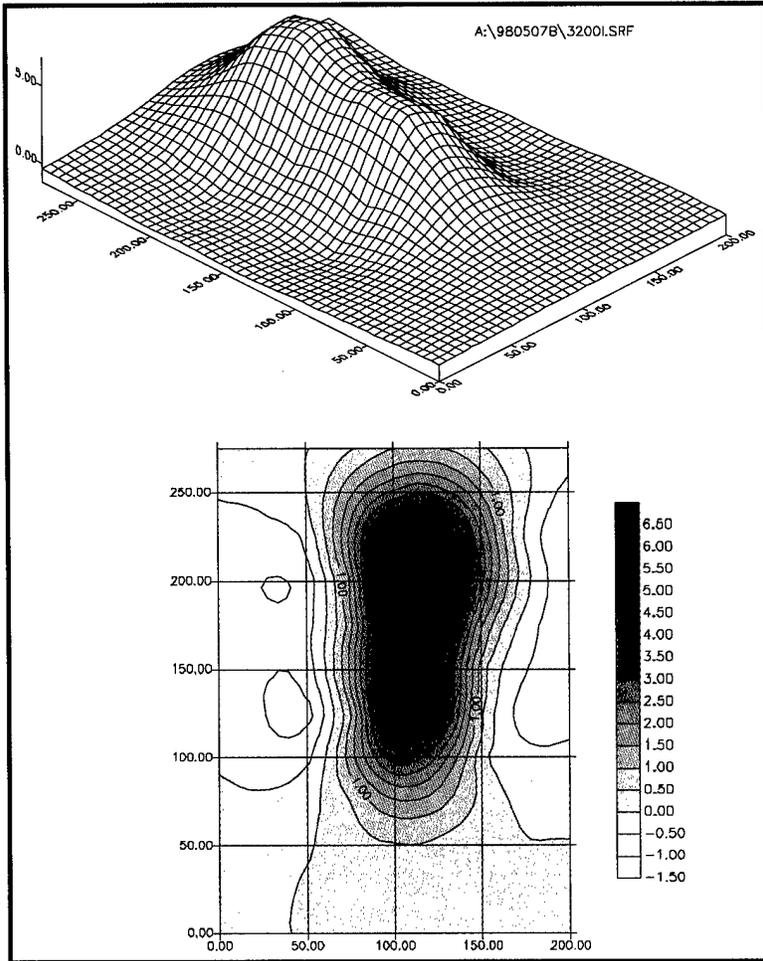


Figure 7. Suspected underground tank near building 11 (2.5-ft data point spacing).



Figure 8. Apparent location of septic tank location for Building 11.

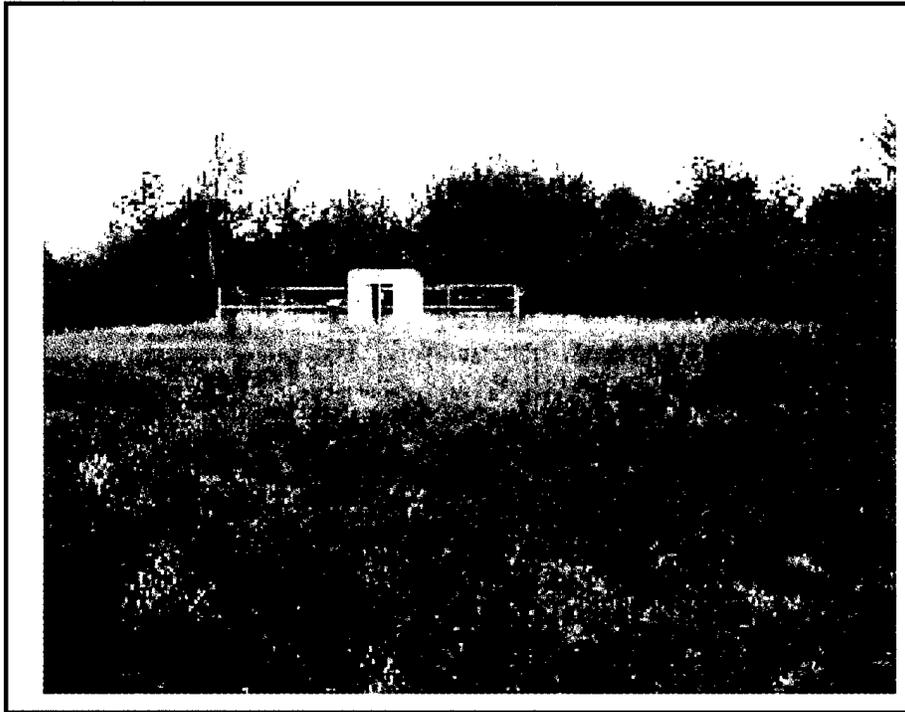


Figure 9. Location 4 survey area, New Castle Rifle Range, Delaware.

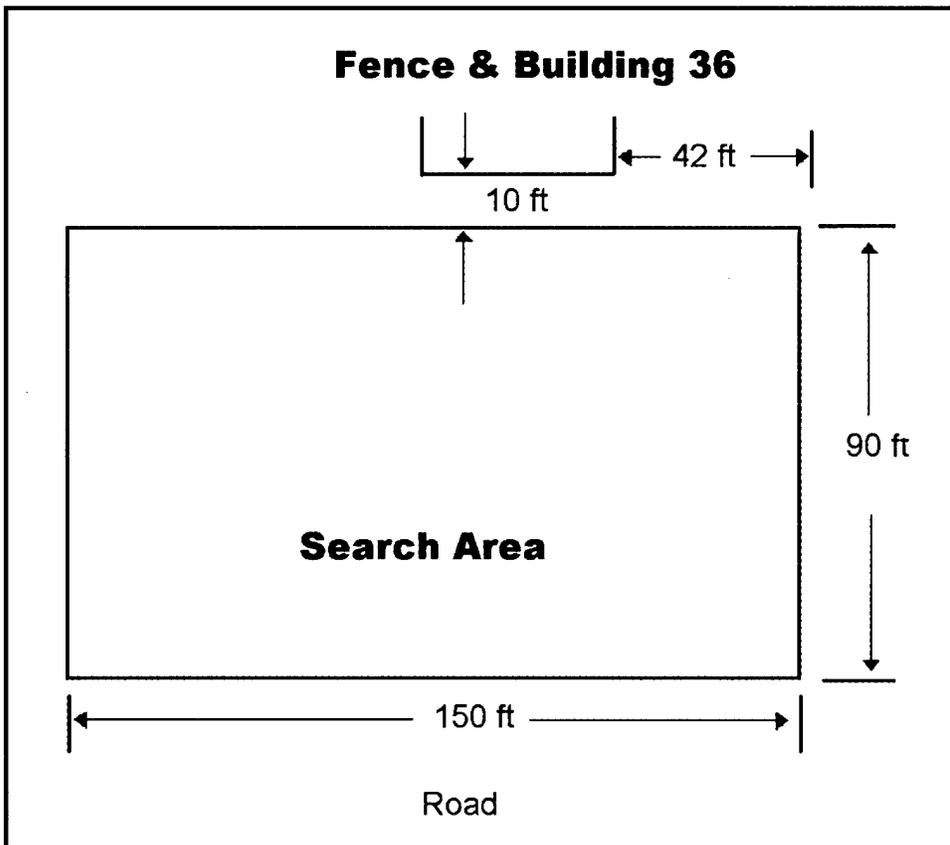


Figure 10. Orientation of location 4 search area.

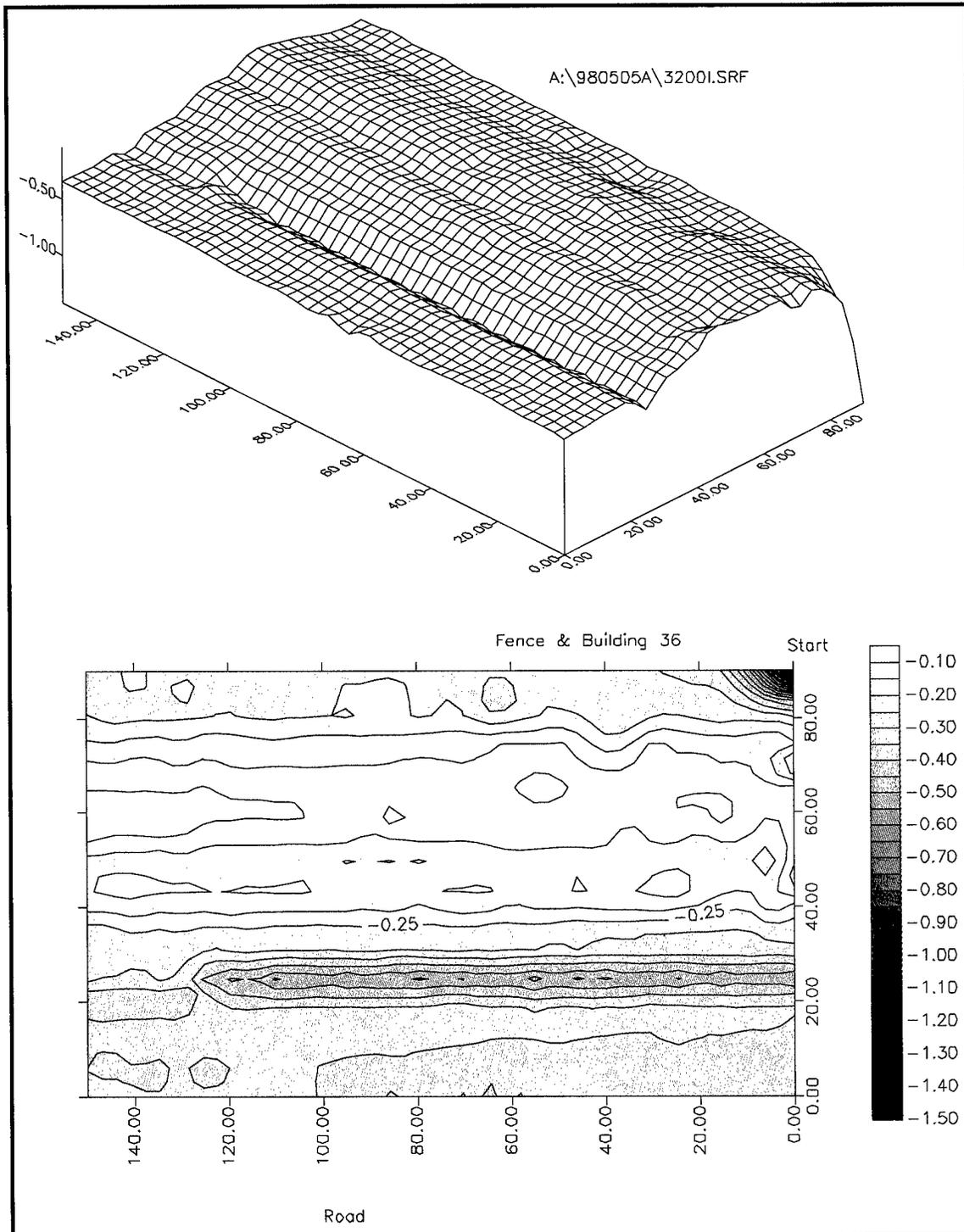


Figure 11. Electromagnetic survey results, 3200 Hz, in-phase, near Building 36, Location 4.

Location 5, Near Building 34

Location 5 is the open area next to the ammunition igloo, Building 34. The search area was 165 X 55 ft. The survey of this area was conducted on two sepa-

rate days, since the first day's data gathering was interrupted by rain. Figure 12 shows the results of this survey. No buried metallic objects were discovered in this area. The discontinuity in the data results from instrument drift resulting from taking the data on 2 separate days and could be filtered out if desired. The color scale shows the relatively small total variation in readings as compared to possible variations due to targets of significant size.

Locations 6, 7, and 8, Watchtower Area

The results of the surveys conducted in this area are plotted as Locations 6, 7a, 7b, and 8. Figure 13 shows a photograph of the test well located along the road side of survey Location 6 and Figure 14 shows a photograph of the watch tower area from the adjacent road.

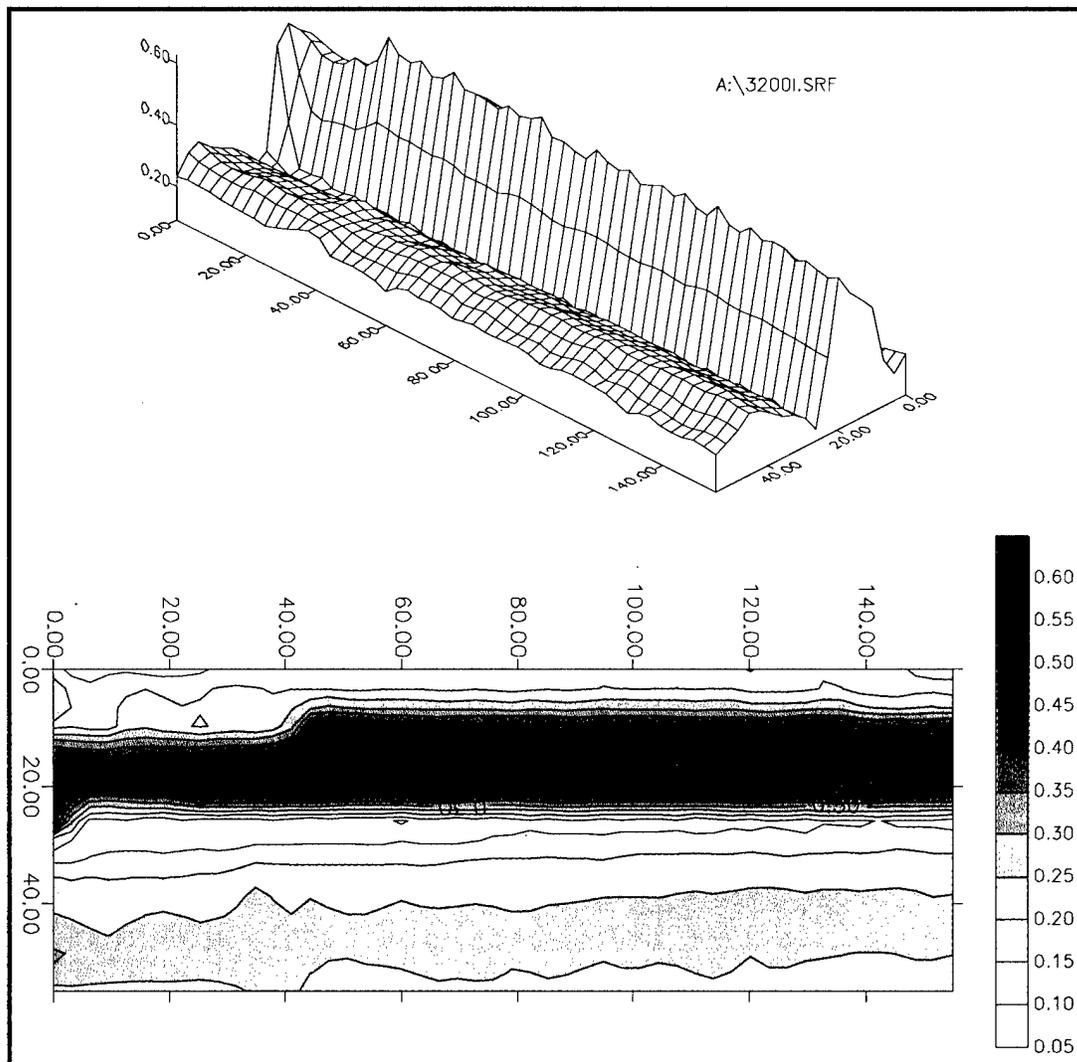


Figure 12. Electromagnetic survey results from location 5, 3200 Hz, in-phase data.



Figure 13. Test well on road end of survey location 6, New Castle Rifle Range, Delaware.



Figure 14. Watch Tower area, New Castle Rifle Range, Delaware.

Initial plans were to collect data from the total area bounded by the installation borders and the road. Since this is a relatively large area and the objects to be located are relatively large, the survey for the area was begun by laying measuring tapes every 10 ft from the road on the base side of the area to the creek by the watchtower. The first tape was placed 12 ft from the border fence. Data points were taken every 10 ft. It was determined that this technique was impractical for surveying the total area due to the amount of vegetation and the amount of surface metal found. The area labeled Location 6 was surveyed in this way. To ensure location of objects as small as a 55-gal drum, the remainder of the accessible area was surveyed on a 5-ft grid. The area to be searched was laid out in 40-ft squares with wooden stakes placed at the corners. The stakes were labeled starting with A1 near where the road turns away from the facility border fence to A13 next to the creek near the watchtower and from A1 – I1 along the road. The data plots are presented to facilitate conversion to this grid. Location 8 was near the watchtower and not directly adjacent to any of the other search areas. The grid for Location 8 was labeled from U1 – W1 to U3 – W3. These areas are shown in greater detail in Figure 15.

Location 6 is a part of the watch tower area as shown in Figures 2 and 15. This data was taken on 10-ft centers with the tape measures placed 10 ft apart and aligned parallel to (approximately 12–13 ft distant from) the facility border fence. Due to the dense brush and forest conditions, it was not possible to continue conducting the survey in this way. In addition, 10-ft point spacing may result in missing small metal objects located in the center of the 10 ft squares delineated by the data points. Thus, 5-ft data point spacing was used for the remainder of the surveys in this area. Possible subsurface metallic objects at the 50-ft marker in location 6 (Figure 16) and between 300–400 ft markers in location 6 strongly indicate typical landfill conditions. The high peak reading at about 350 ft coincided with a surface location of metallic landing mat material. Significant other surface metal was present in this area. Figure 16 shows the results of the survey of Location 6.

Location 7a is the area from B1, I1 to 25 ft past B3, I3 in the watch tower area as shown on Figures 2 and 15. The results of this survey are shown in Figure 17. Two empty barrels and an empty aboveground fuel storage tank were on the surface in or near this area. The tank was located near the G3 stake. The area near the tank appears to have a considerable amount of buried metal and may have been used as a landfill. It is recommended that the surface metal in this area be removed and the area be considered for resurveying. The item appearing at (40, 25) is a surface snow shovel. The open area from B1, E1 to B3, E3 seems to be relatively clean.

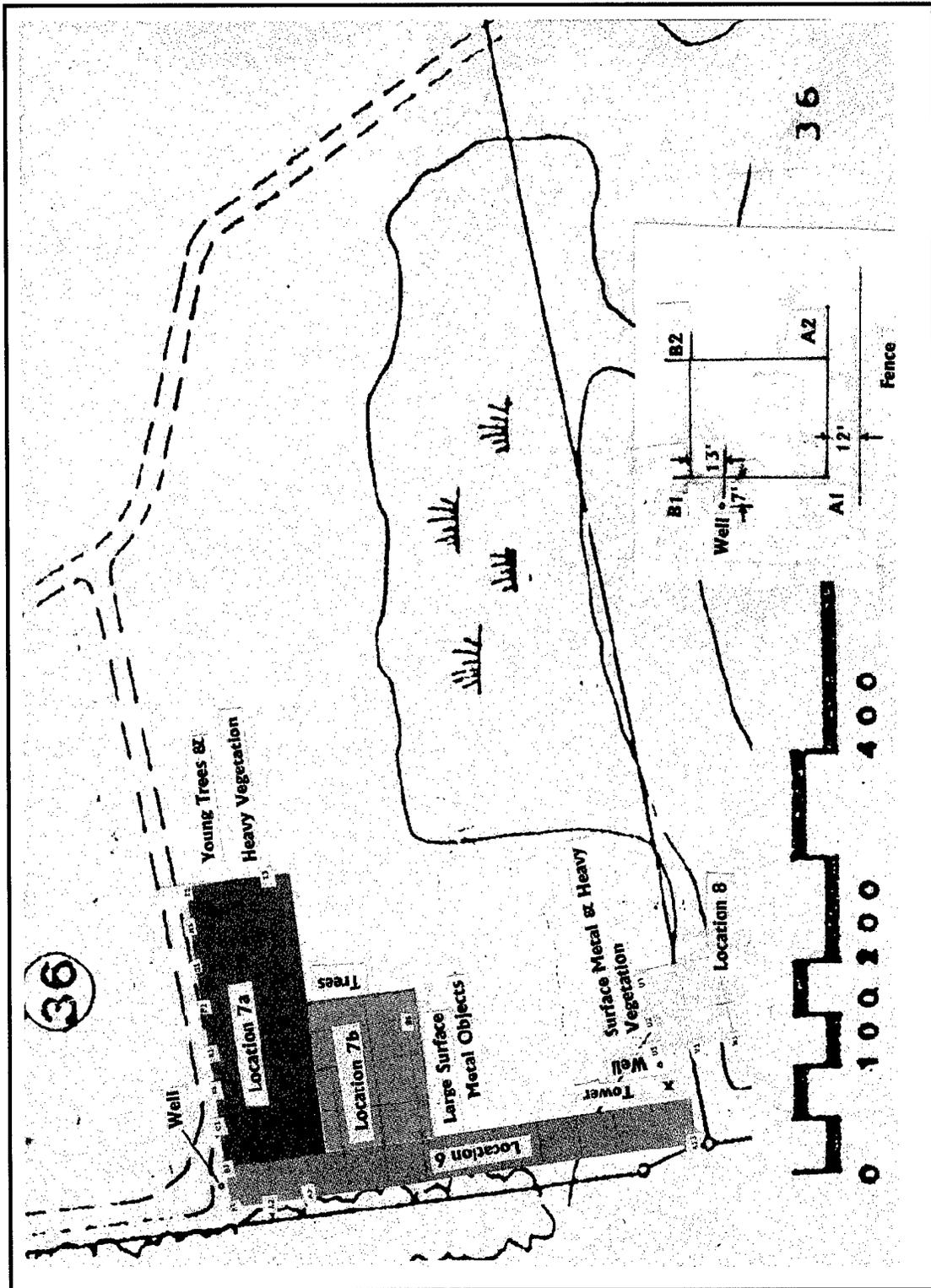


Figure 15. Detail of Watchtower survey area.

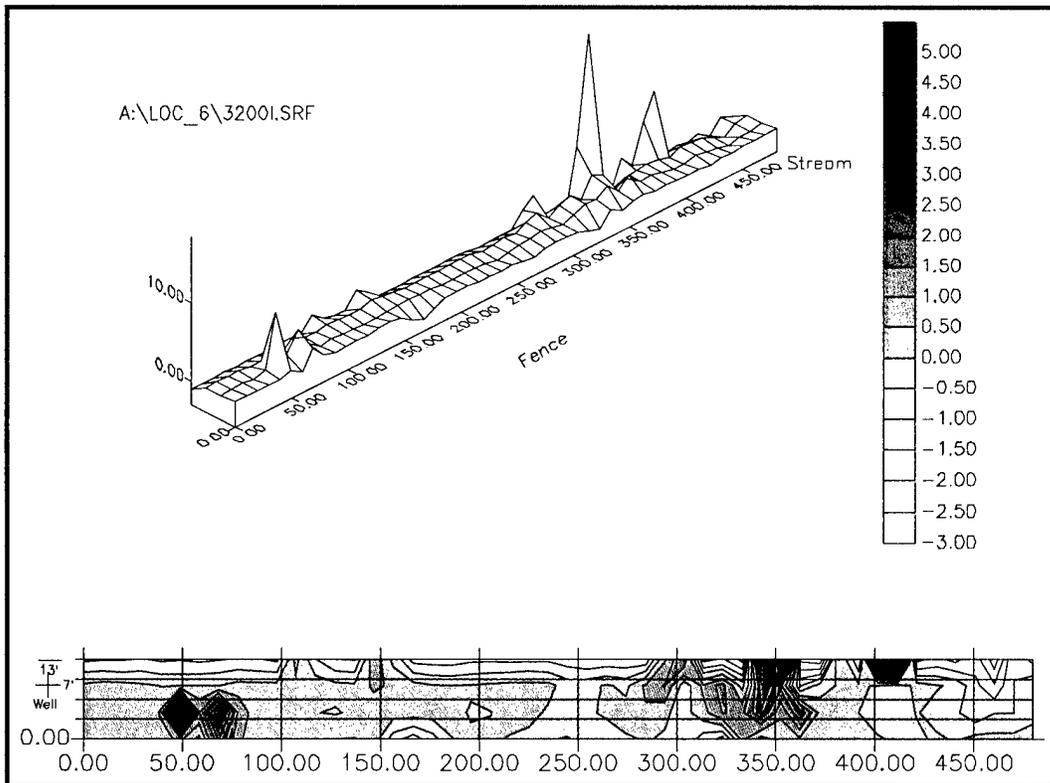


Figure 16. Electromagnetic survey results of location 6, 3200 in-phase data.

Location 7b is immediately adjacent to Location 7a, but the data rows are 145 ft in length rather than 280 ft as in Location 7a. The heavy stand of trees and brush made data gathering beyond 145 ft impossible. This area was relatively clean with the exception of a large metal door on the surface located at about (100, 30-40). The survey was not continued further in this direction because of other similar large surface metal structures and because of the dense brush beyond the surface metal. This area did not appear to have been used as landfill. The item at 45,0 did not appear on the adjacent Location 6 plot and is probably a small shallow buried metal item. The 3200 Hz, in-phase data are shown in Figure 18. Some of the surface metal in this area is shown in Figure 19.

Location 8 is situated to the upstream river side of the watchtower near the tower. Figures 2 and 15 show its approximate location and orientation. It is more or less bounded by a heavily vegetated area with considerable surface metal and other landfill type materials on one end, the creek on the other end, and the creek and wetlands on one side. Figure 20 shows the results of this survey. Several large metallic items (labeled in Figure 20) were found on the surface in this area (Figure 21). The remainder of the plot indicates possible random relatively small metal items such as would exist in a landfill area.

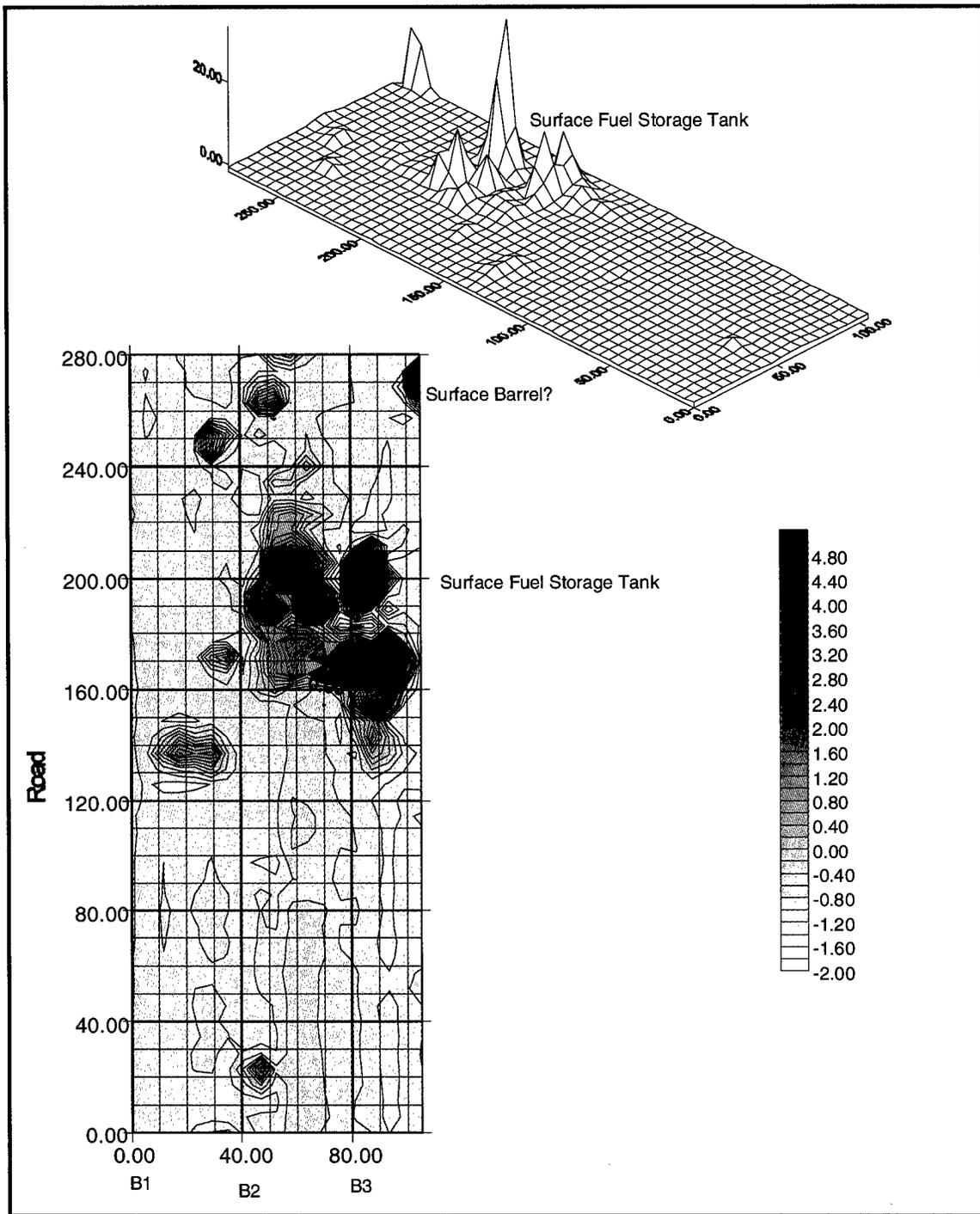


Figure 17. Electromagnetic survey results of location 7a, Watchtower area, New Castle Rifle Range, New Castle, DE, 3200 Hz, in-phase data.

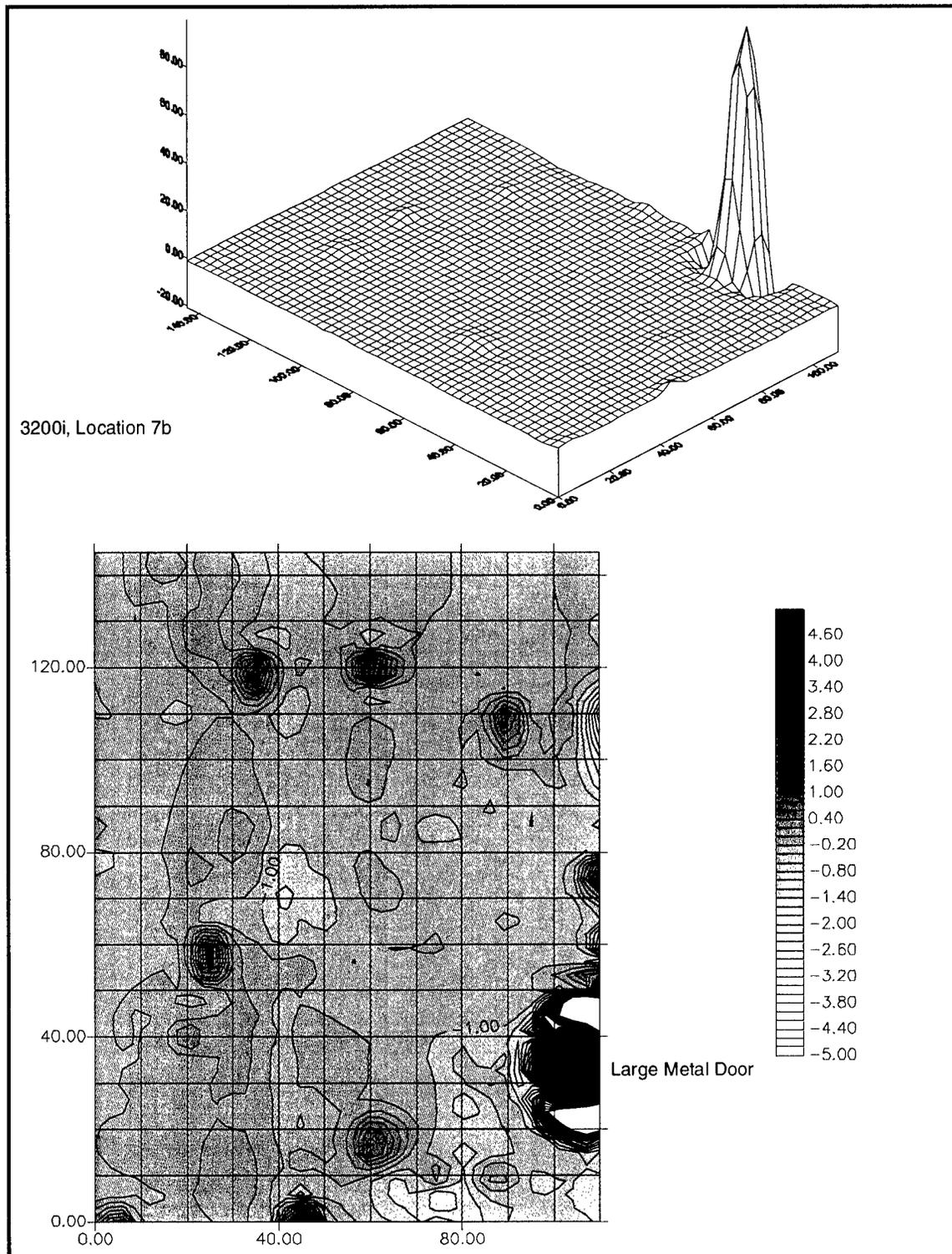


Figure 18. Location 7b, Watchtower Area, 3200 Hz, in-phase data.



Figure 19. Surface metal present on survey location 7, New Castle Rifle Range, DE.

Recommendations

The surveys at the New Castle Rifle Range were all conducted on a point-by-point basis with the GEM-1. Heavy vegetated areas (Location 1 and parts of the watchtower area) were difficult to survey due to the difficulties of traversing and of maintaining accurate data point location. Significant quantities of large surface metal were also present (Figures 20 and 21) in much of the watchtower area (Locations 6 – 8). Surface metal masks buried objects and decreases the value of the data in areas where it is present. If a more detailed electromagnetic survey of the watchtower area is necessary, it is recommended that all the surface metal be removed from the area and a survey be conducted in the winter when the vegetation may be less of an impedance. (Even in winter, considerable areas will remain inaccessible unless the vegetation is thinned. This data can be used for removal of individual buried items, however due to the grid spacing used and the dimensions of the sensor, the item may not be exactly at the location shown on the plots. If removal of individual buried items is desired, final location of the items can be done with electromagnetics (GEM-1, GEM-300, or Geonics EM-31), or possibly with a handheld magnetometer since it is likely that most such items are ferrous metal. It is also recommended that Coast Guard rebroadcast GPS location be used for placing of search areas. This signal allows accuracy to

within a few feet, while commercial GPS accuracy is limited to an order of magnitude of 100 ft.

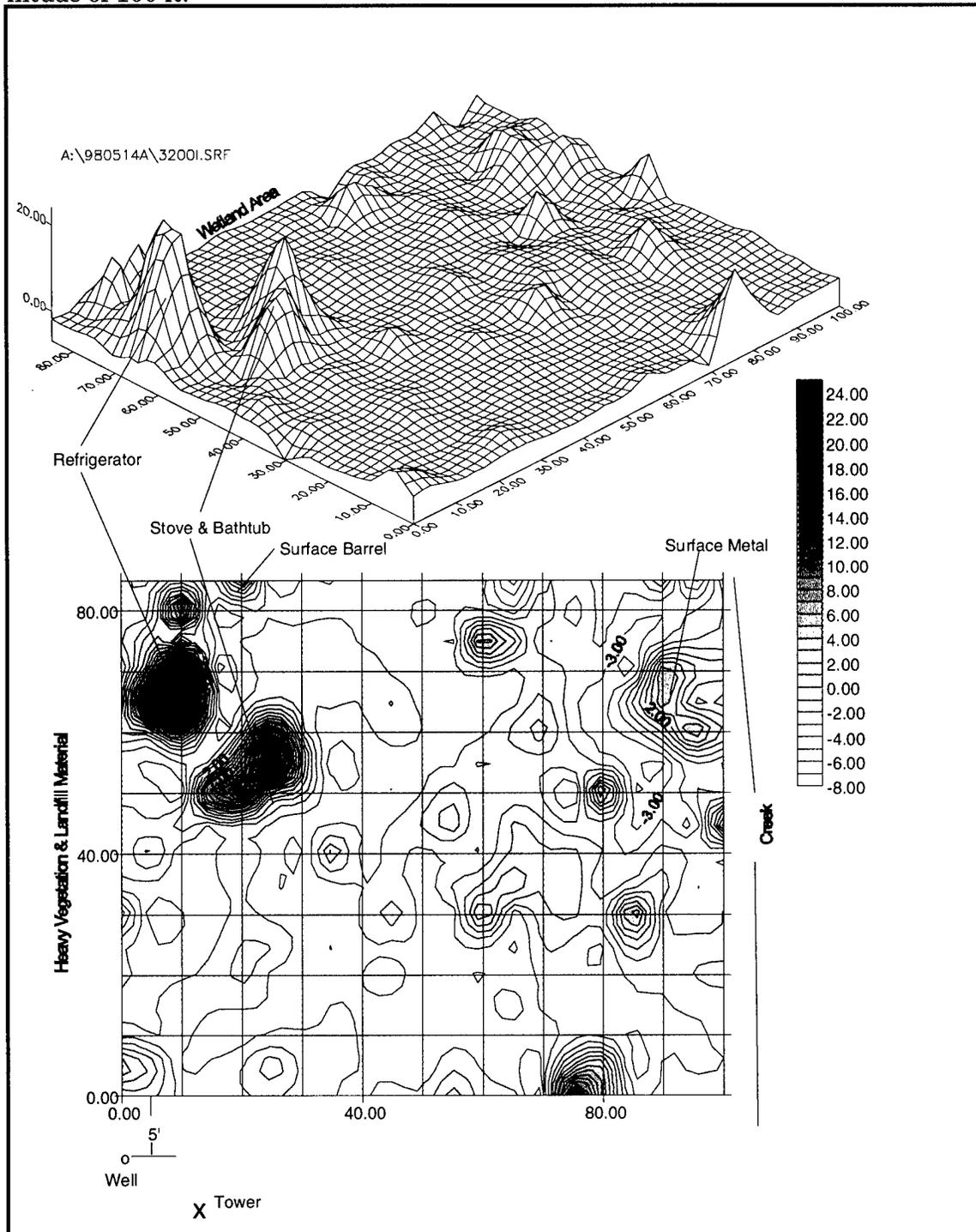


Figure 20. Electromagnetic survey results, 3200 Hz, in-phase data, location 8, Watchtower area.



Figure 21. Surface metal item and dense vegetation in the watch tower area, New Castle Rifle Range, DE.

3 Survey Areas at the Bethany Beach National Guard Training Site

Survey Locations

Figures 22 and 23 show the locations of the survey areas for this study. Figure 22 identifies the areas among the barracks, primarily between rows of buildings. The buildings in this area are cinder block (probable vintage WWII) with an insulating stucco-type finish on the outside. They are typically 20 ft wide and 40 to 100 ft long. Separation between the buildings is typically 30 ft. The buildings contain interfering metallic objects such as bunk beds and refrigerators. In addition, some air conditioners, barbecues, satellite antennas, picnic benches, and propane tanks were found in or near the areas to be surveyed. An underground tank had been discovered when additions were built onto Buildings 143 and 144. The surveys among the barracks were conducted to locate similar items or to verify that the area was clear. There is a concrete structure on the east side of Building 148 (the men's latrine), identified by a retired individual camping on the installation, as a coal bin for "bucket a day" coal stoves. According to his description, a person was assigned to each coal stove to supply it with coal for each day. Although no evidence of the coal stoves exists today, it is logical to assume that they could have been used in the barracks for heat and thus there would be no buried storage tanks for fuel oil associated with the barracks.

These surveys were conducted as shown in Figure 1, by laying a short tape measure at both the south end and north end of each search area with the ends coincident with the building corners or the end of the survey area. Two long tape measures were then placed lengthwise at the 10- and 20-ft points on the short tapes. Data was taken on a 5-ft grid using the long tapes starting at with the first line at 5 ft from the building and completing the fifth line of data at 25 ft (5 ft from the neighboring building). Data was not taken at zero or 30 ft (at the building wall surface) because high readings caused by metal objects (bunk beds, refrigerators, and air-conditioners) inside or near the buildings would tend to mask any information from subsurface objects. Some building effects are still visible at 5 ft from the buildings.

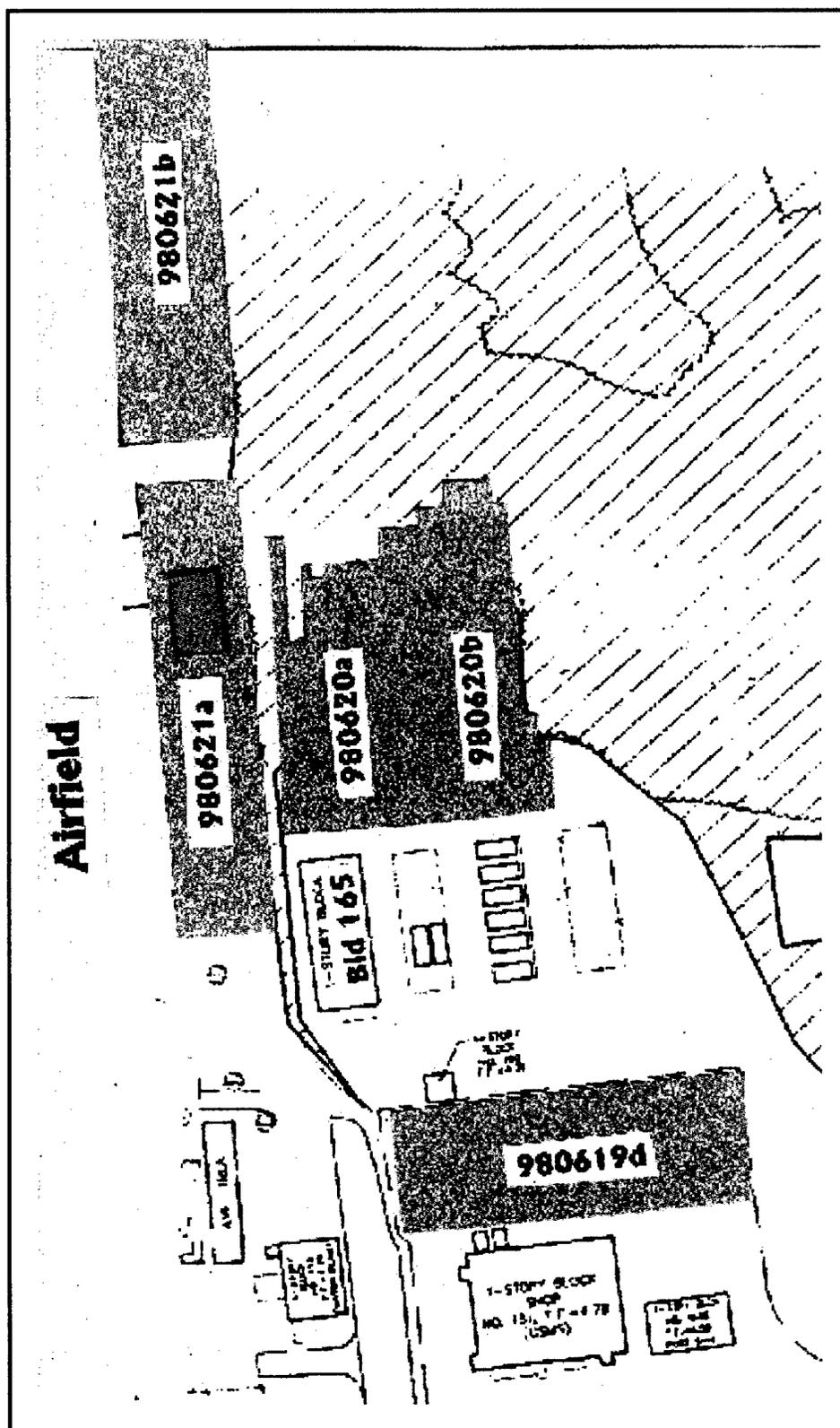


Figure 23. Electromagnetic survey locations at Bethany Beach National Guard Training Site, Bethany Beach, DE (designations in bold are data file identifiers).

Individual search areas are identified by the sequence in which they were completed. The designations include the date and the sequence of survey taken on that date. Thus, 980619a is the first survey (a) conducted in the year 1998 (98), month June (06), day (19). These designations are used as data file names to aid in recordkeeping. An additional area, not directly between rows of buildings (980619c) was surveyed to provide more detail when a suspected subsurface object was identified on the south end of the area 980617c.

The remaining survey areas are shown in Figure 23. An underground storage tank had been removed from underneath the paved area north of Building 151 and a survey was conducted to determine if another was present there. This area was surveyed using both instruments.

Most of the open area east of the airfield and an irregular area north of Building 165 was surveyed for possible presence of buried 55-gal drums. The areas adjacent to the airfield were surveyed with the GEM-300 and a small area on 980621a re-surveyed with the GEM-1. The irregular area north of Building 165 was surveyed by placing long tapes every 5 ft as far as possible into the heavily vegetated area. Thick stands of poison ivy and other plants limited the extent of the northern edge of this survey.

Results

The results presented in this report are contour plots of the 3200 Hz, in-phase data for the GEM-1 and the 3870 Hz, in-phase data for the GEM-300. The plots are developed from the data by the Golden Software program *Surfer*. *Surfer* automatically scales the plots according to maximum and minimum data values. In addition, contour lines tend to become overcrowded if small intervals are chosen. Thus, relatively small objects will tend not to be observable in a plot that contains wide excursions of values. For these reasons, the maximum and minimum values on these plots are limited to values shown on the scale given alongside the plot. Values higher than the chosen maximum will show as a solid red and those below the minimum chosen value will be white. The solid red area gives some indication of the size and shape of the detected object; however, the representation on the plots is probably larger than the actual object. This effect is due to the geometry and "footprint" of the sensor. The footprint is related to the zone of influence of the object. Shape information (resolution) is limited by the density of data points taken. The results of the surveys in the barracks area are presented in four different plots or blocks.

The west block (or Block 1) consists of data files 980618c between Buildings 136-137 and 133-132, and 980619b between Buildings 137-138 and 132-131. Figure 24 shows the 3200 in-phase data for these surveys in contour plots. The primary items of interest that can be identified in this data include the effects of metallic objects in the buildings along the edges of the plots. High readings caused by the presence of the propane tank area are also visible.

Figure 25 gives the results of the electromagnetic surveys of Block 2 in the barracks area. The plots are contour maps of the 3200 Hz, in-phase data. The data files for this block include 980617c between buildings 139-140 and 130-129, 980618a between buildings 140-141 and 129-128, 980618b between buildings 141-142 and 128-127, and 980619c at the south end of building 140, an area extending into the street. Items of interest in this data include the shallow buried culvert that is part of the storm water drainage system at the north end of the 980617c data and an unknown object that appears on the south end of this data.

An additional data set, 980619c (40 X 50 ft), was taken adjacent to the south end of 980617c to further define the size and shape of this object. Additional features that appear in this data include the manhole cover in the southeast corner, the diagonal electrical service (there is a matching pavement patch install diagonally across the paved street coincident with this) and an east-west feature under the south side of the road, which appears to be attached to the manhole and may be part of the drainage system. This data set was taken right up to Building 140; there appears to be some kind of relatively large metallic object (refrigerator or bed) in the southeast corner of this building. The unknown object first identified in 980617c does not appear to be attached to any of the other objects in this set of data (that is to say, it does not appear to be part of the drainage system). Two cast iron pipe studs extend up out of the foundation at the 100-ft point by Building 142. This is indicated as low readings at this point. The data does not indicate that the pipes are attached to any large metallic underground systems that extend into the surveyed area.

Figure 26 shows the 3200 Hz, in-phase data for 980617b taken between buildings 126-125. This plot shows some minor building effects and the effects of a metal pole in the center of the south edge of the data.

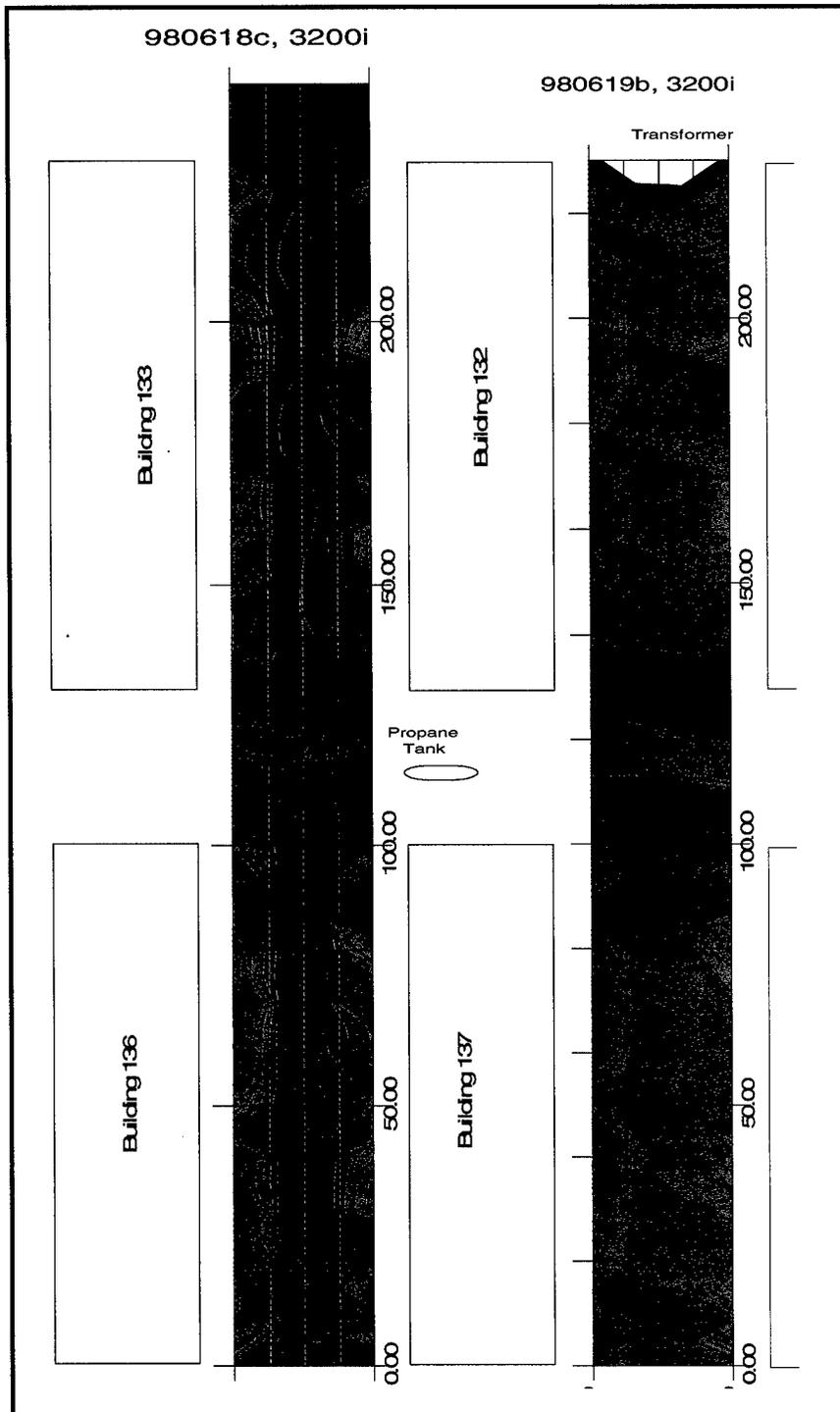


Figure 24. Electromagnetic survey data, Bethany Beach, DE, National Guard Training Site, Barracks area, Block 1.

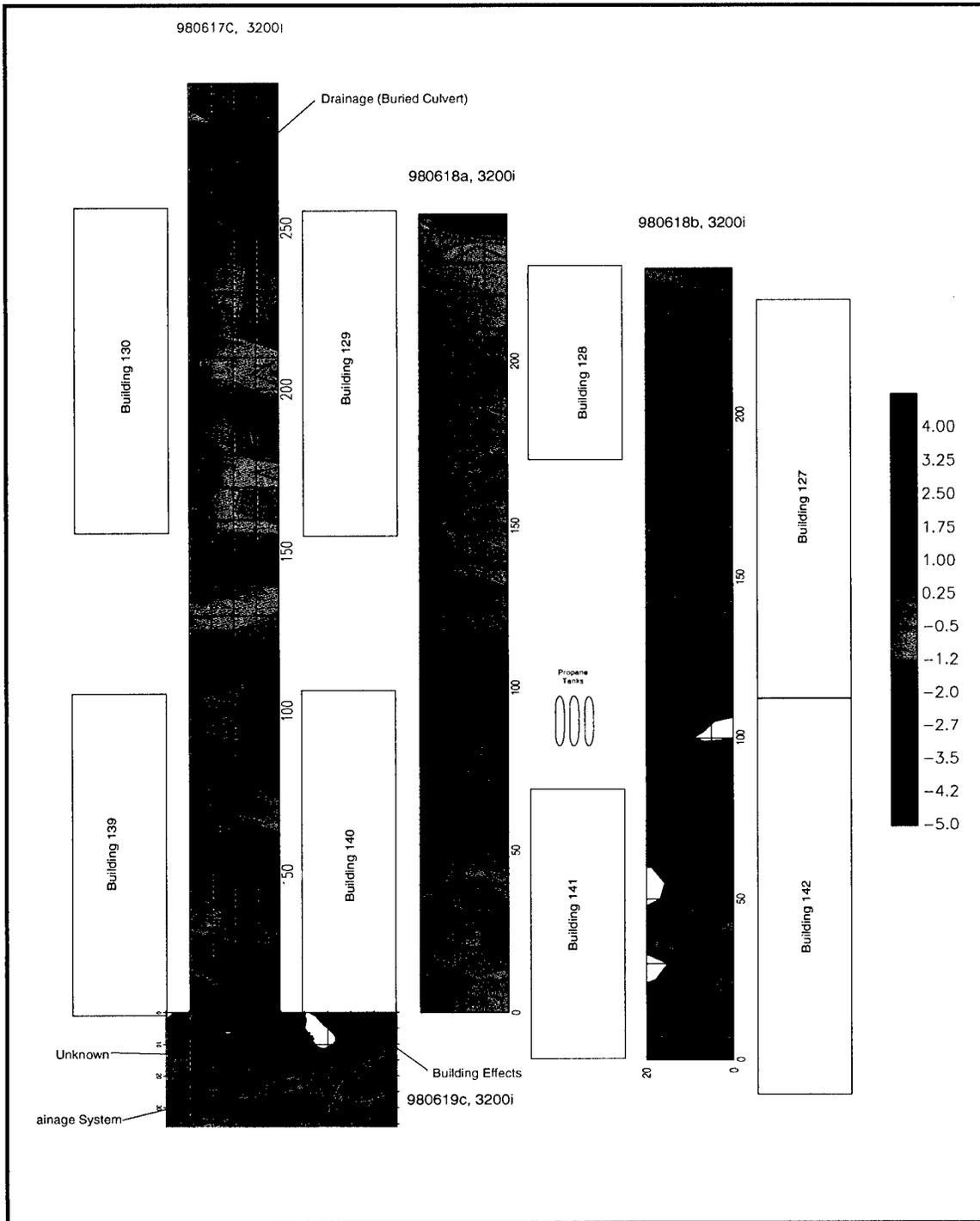


Figure 25. Electromagnetic survey data, Bethany Beach, Delaware National Guard Training Site, barracks area, Block 2.

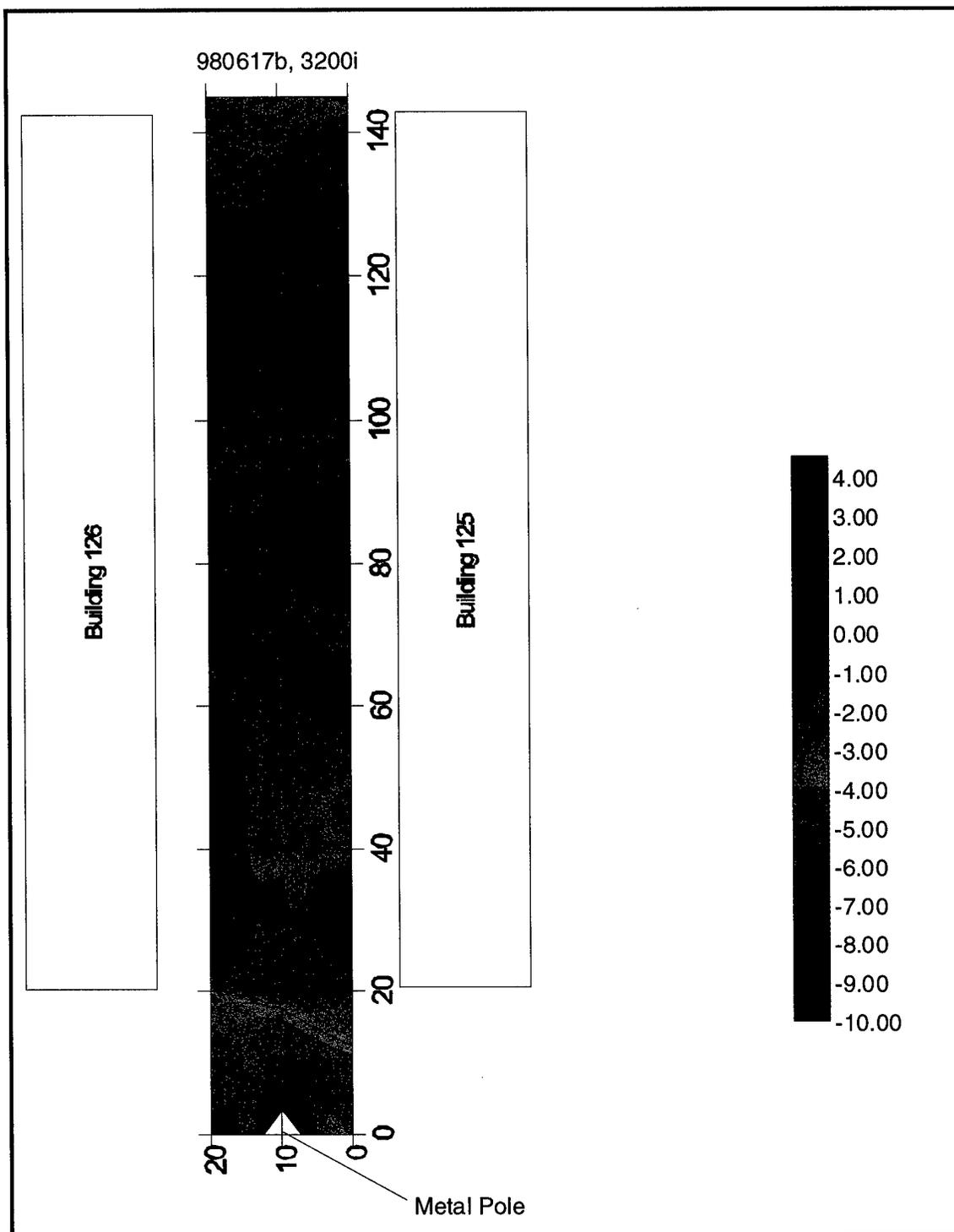


Figure 26. Electromagnetic survey data, Bethany Beach, Delaware National Guard Training Site, 980617b, 3200 Hz, in-phase data, block 3.

Figure 27 shows the 3200 Hz, in-phase data for the files 980619a between buildings 145-146 and 124-123, and 980618d between buildings 123-124. All the outstanding objects appearing on these plots are surface features including building effects, barbecues, propane tanks, air conditioners, and satellite antennas. No subsurface objects can be identified from this data.

Figure 28 shows a plot of the electromagnetic survey results of the 3200 Hz, in-phase measurements of data file 980619d, a paved area north of Building 151. An underground fuel storage had been removed from this area. This survey was conducted to determine if any other objects existed elsewhere in the area. Items visible in this plot include the small storage building just to the north of the pavement between 20 and 40 ft, the miscellaneous concrete and rock pile on the northeast corner, and the large metal containers on the south side of the search area near building 151. Some of the broken concrete on the pile contained light reinforcement. No evidence of any additional buried storage tanks or other significant metal was discovered under the paved area.

Figure 29 gives the results of the electromagnetic surveys conducted north of Building 165 on the cleared area and into the heavily vegetated area. This survey was conducted by placing tape measures on the ground with a 5-ft spacing. The tapes were carried into the vegetation a distance determined by the density of vegetation and the density of the poison ivy. Thus the lines of data are not of equal length and data point location is not as accurate as that typically expected in open areas. Some of the objects that appear on this plot are associated with broken concrete with metal reinforcement (generally heavy wire type) that was visible on the surface. Other objects were not associated with any surface articles. The spacing and configuration of the findings in this area are typical of landfills. No significant objects were found in the open (grassy) area covered in this search.

The Pennsylvania Air National Guard was using the landing strip for training during the period the surveys were being conducted and not all of the area to the east of the runway was available to be surveyed. However a strip 50 ft wide and 235 ft long south of the fuel storage area and a strip 60 ft wide and 210 ft long north of the fuel storage area were free of vehicles. These areas were surveyed with the GEM-300. Figure 30 gives the results of the north survey at 3870 Hz, in phase.

The objects of interest in this plot are effects from the National Guard trucks parked near the search area and high readings associated with the waste wood pile near the north end of the search area. No subsurface objects were observed.

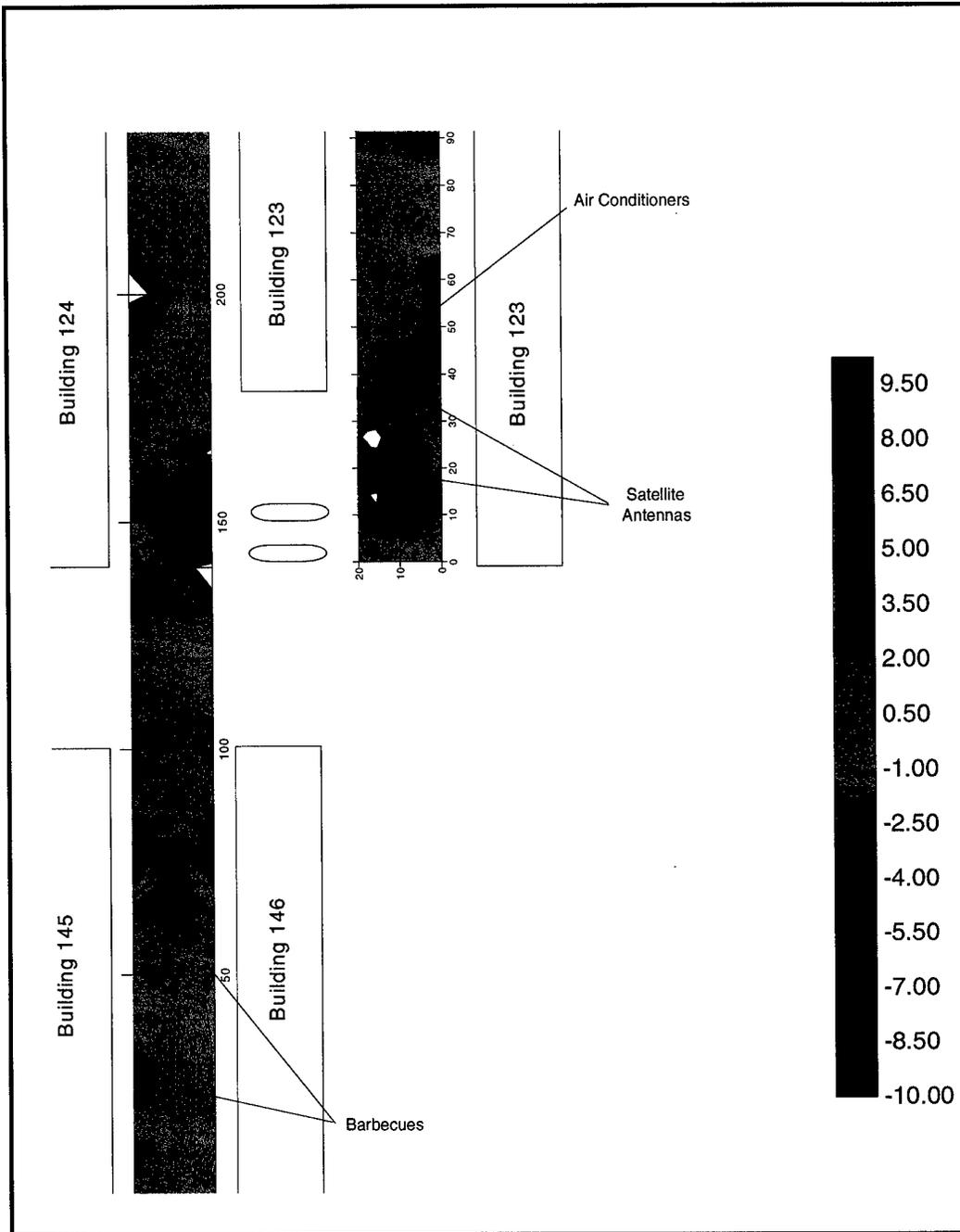


Figure 27. Electromagnetic survey data, Bethany Beach, Delaware National Guard Training Site, 3200 Hz, in-phase data, block 4.

The GEM-300 data file for the 50 X 235 ft area to the south of the fuel storage area was not saved due to technical problems and only one possible subsurface object was identified. A smaller area containing this unknown was re-surveyed with the GEM-1. Figure 31 shows the survey results. The previously identified object is probably a relatively small shallow metal object located relatively near the location shown on the plot.

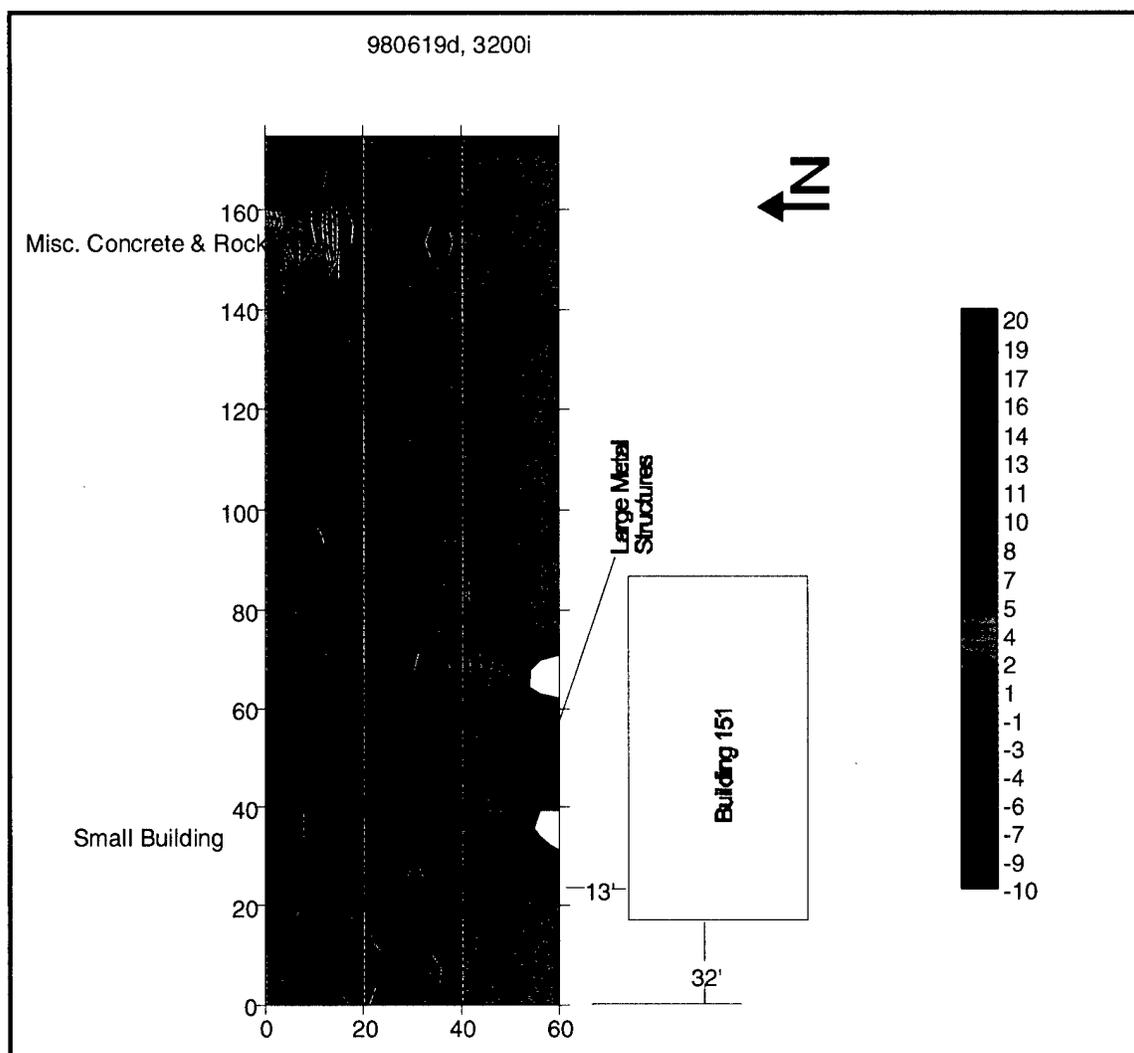


Figure 28. Electromagnetic survey data, Bethany Beach National Guard Training Site, paved area north of Building 151, 3200 Hz, in-phase data.

Discussion

One possible underground tank or similar metallic structure was found near the southwest corner of Building 140, possibly extending close to the paved street. It was apparently not connected to any other utility/drainage systems in the immediate area. Some of the high readings (objects) found in this area were associated with broken up concrete located on the surface, which contained lightweight reinforcement. Other high readings were not associated with any visible surface objects. Part of the heavily vegetated area north of Building 165 appears to have been used as a dump/landfill at one time. It was not possible to search the entire area to determine the extent of this landfill due to dense stands of poison ivy and other heavy vegetation.

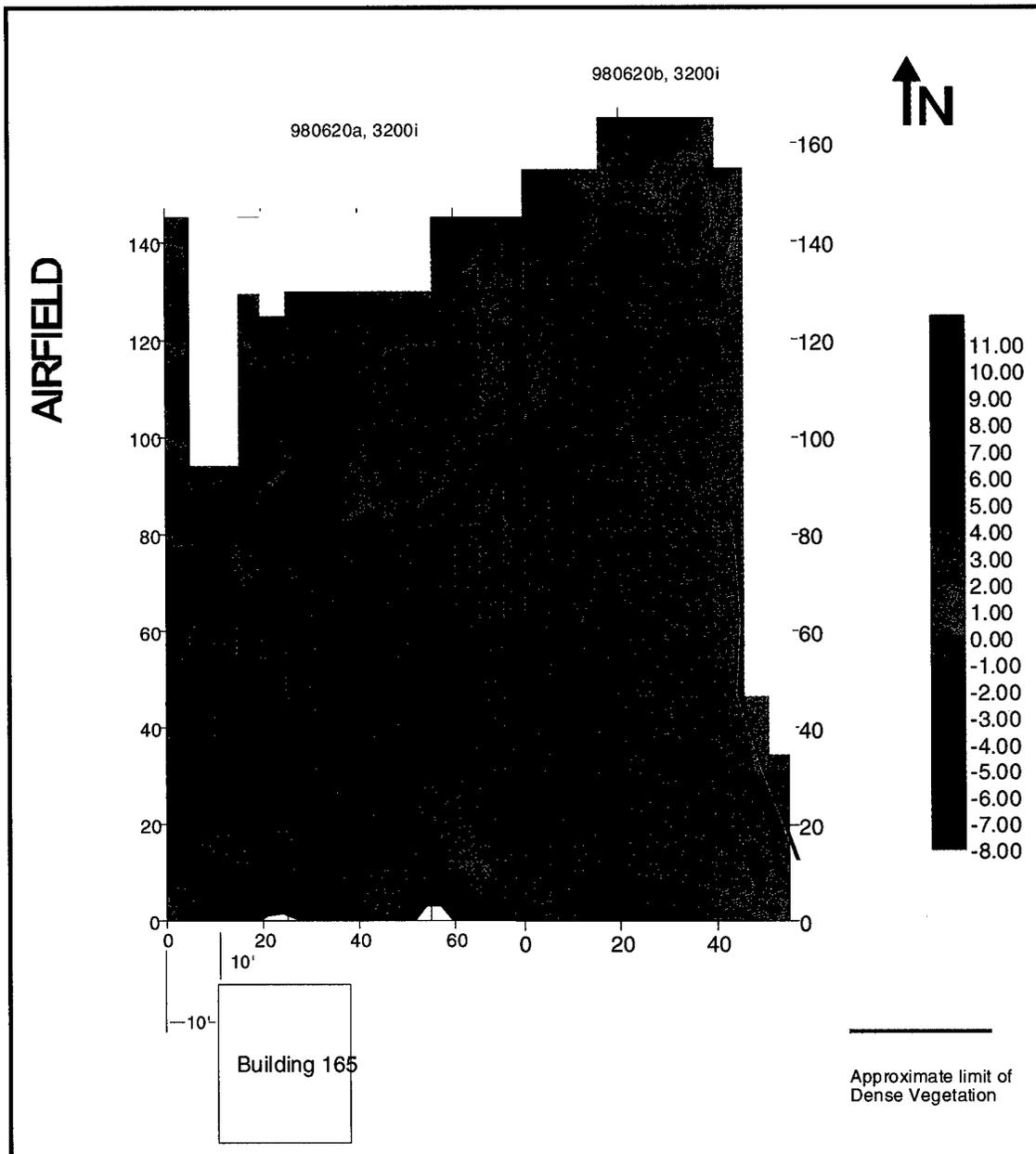


Figure 29. Electromagnetic survey data, Bethany Beach National Guard Training Site, area north of Building 165, 3200 Hz, in-phase data.

Although conducting such a survey in this area will be difficult at any time, the best season to survey this area would probably be in the winter after the leaves of the poison ivy and any other deciduous plants have fallen. The major problems related to surveying this area are setting up an accurate search grid, accurate positioning of the sensor for collecting data, and transporting the sensor through the area.

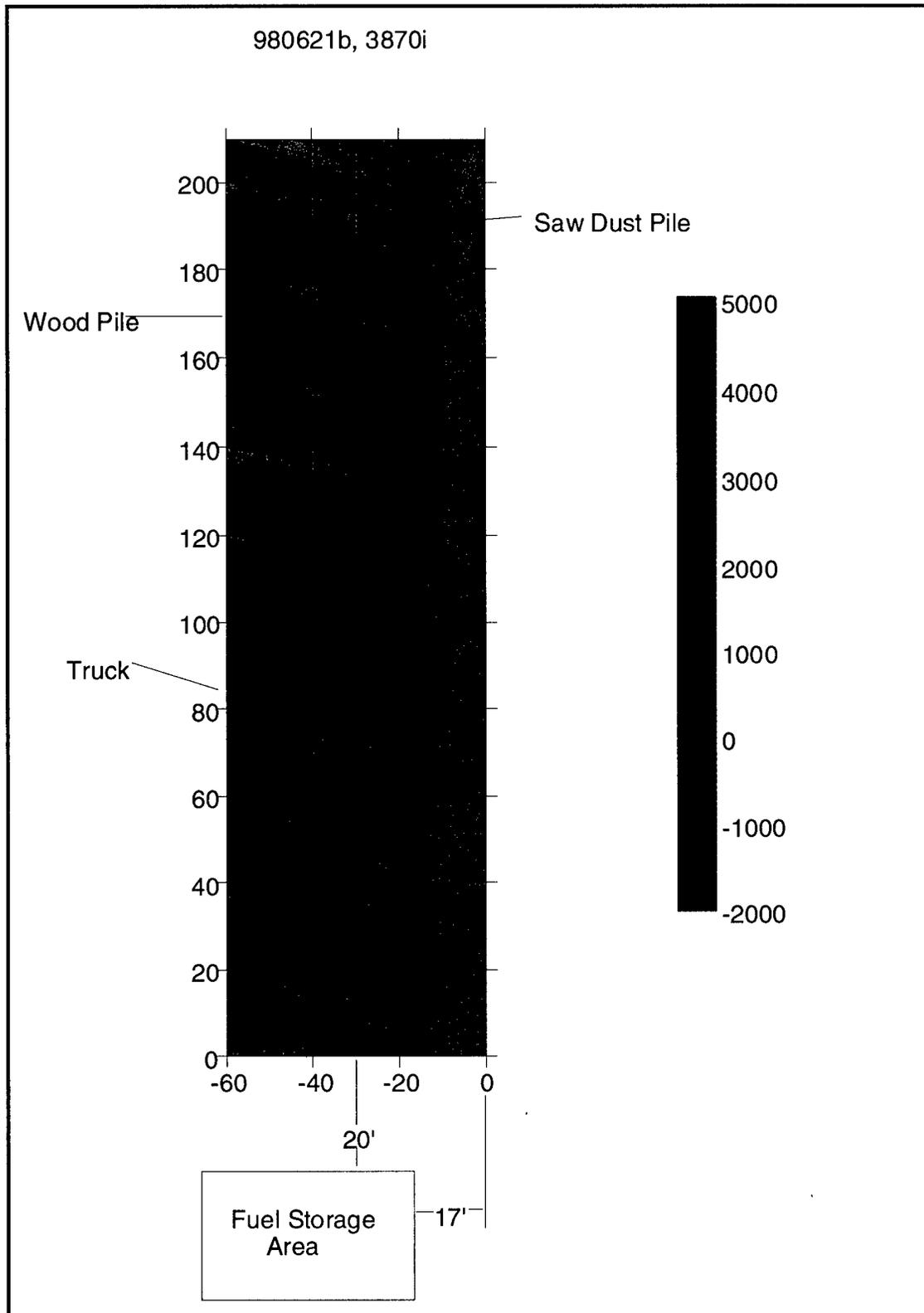


Figure 30. Electromagnetic survey data, Bethany Beach, Delaware National Guard Training Site, area near air field, 3870 Hz, in-phase data.

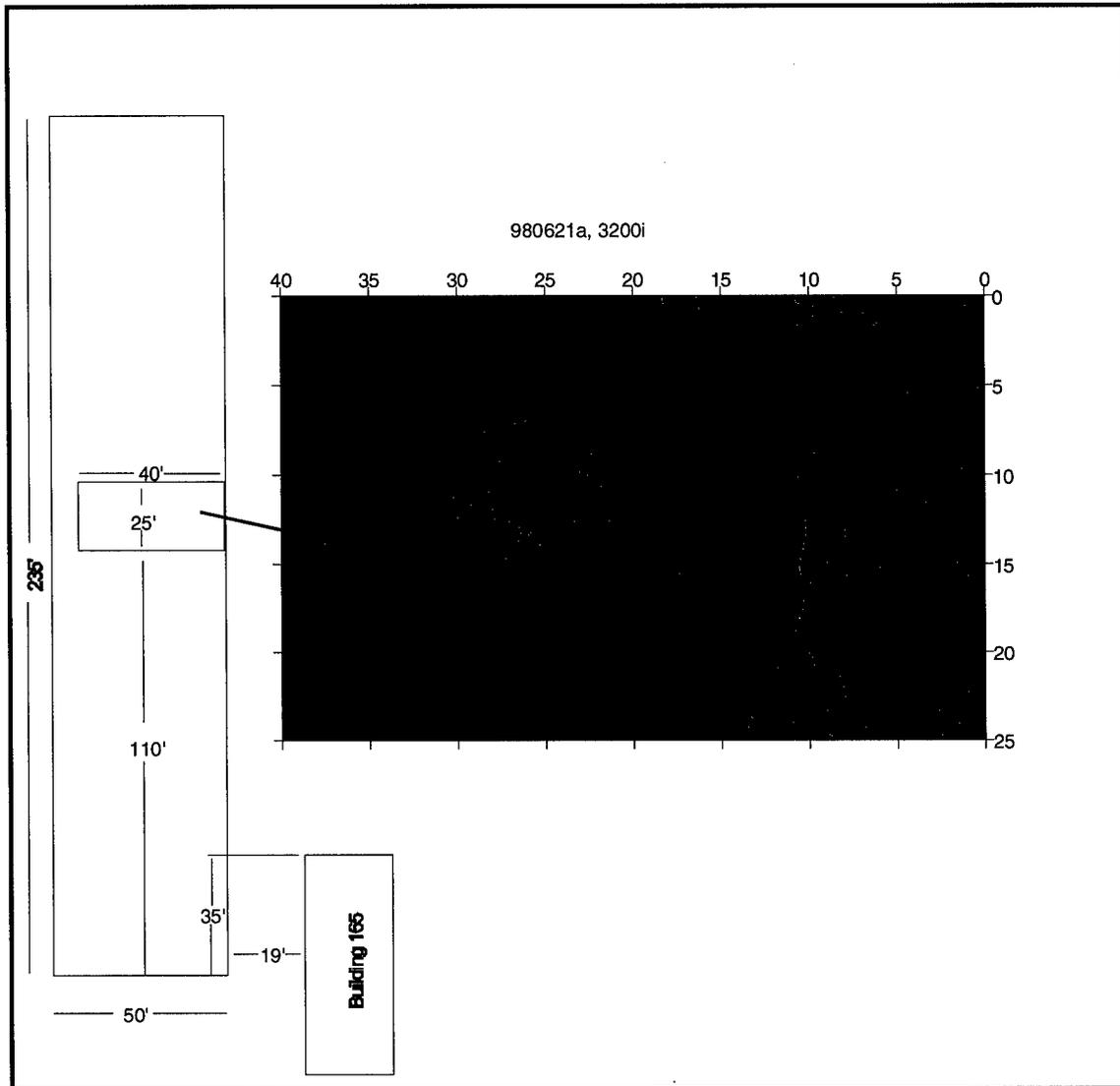


Figure 31. Electromagnetic survey data, Bethany Beach, Delaware National Guard Training Site, area near air field, 3200 Hz, in-phase data.

4 Conclusions and Recommendations

This study performed electromagnetic surveys at the New Castle Rifle Range, New Castle, DE and at the Bethany Beach, Delaware National Guard Training Base to identify possible subsurface metallic features (locate underground storage tanks and other buried metal objects) at various locations.

New Castle Rifle Range

Conclusions

1. *Location 1, Historic Latrine.* No obvious tank-shaped structures were found in the survey area.
2. *Location 2, Proposed Sewer Line.* No subsurface objects or structures were identified.
3. *Location 3, Near Slab Used for Vehicle Parking.* A buried object was found near the manhole cover close to Building 11, probably the septic tank for this Building. An apparent covered culvert was found where the road turns to go past the target ranges.
4. *Location 4, Near Building 36.* No significant targets were discovered in this area.
5. *Location 5, Near Building 34.* No buried metallic objects were discovered in this area.
6. *Locations 6, 7, and 8, Watchtower Area.* In Location 6, possible subsurface metallic objects exist at the 50-ft marker in location 6 (cf. Figure 16). The area between the 300- and 400-ft markers in location 6 strongly indicates typical landfill conditions. The high peak reading at about 350 ft coincides with a surface location of metallic landing mat material. Significant other surface metal was present in this area

Recommendation

Location 7a appears to have a considerable amount of buried metal and may have been used as a landfill. It is recommended that the surface metal in this area be removed and the area be considered for resurvey.

Bethany Beach National Guard Training Site

Conclusions

Electromagnetic surveys of Block 2 in the barracks area, including survey 980617c, 980618a, 980618b, and 980619c indicated a shallow buried culvert that is part of the storm water drainage system at the north end of the 980617c data and an unknown object that appears on the south end of this data.

An additional data set, 980619c, included a manhole cover in the southeast corner, the diagonal electrical service, and an east-west feature under the south side of the road, which appears to be attached to the manhole and may be part of the drainage system. The unknown object first identified in 980617c does not appear to be part of the drainage system. Two cast iron pipe studs extend up out of the foundation at the 100-ft point near Building 142. The data does not indicate that the pipes are attached to any large metallic underground systems that extend into the surveyed area.

In-phase data for 980617b taken between buildings 126-125 show some minor building effects and the effects of a metal pole in the center of the south edge of the data.

A survey of the paved area north of Building 151 conducted as a follow-up on the removal of an underground fuel storage tank in that area showed no evidence of any additional buried storage tanks or other significant metal under the paved area. No subsurface objects were observed.

One possible underground tank or similar metallic structure was found near the southwest corner of Building 140, possibly extending close to the paved street.

Recommendations

The major problems related to surveying this area are setting up an accurate search grid, accurate positioning of the sensor for collecting data, and transporting the sensor through the area. It is recommended that any further (or follow-up) surveys in this area be conducted in the winter after the leaves of the poison ivy and any other deciduous plants have fallen.

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14. ABSTRACT The Delaware Army National Guard tasked the U.S. Army Engineer Research and Development Center (ERDC), Construction Engineering Research Laboratory (CERL) to provide electromagnetic surveys to identify possible subsurface metallic features at various locations at the New Castle Rifle Range, New Castle, DE and at the Bethany Beach, Delaware National Guard Training Base. Surveys were conducted using multi-frequency electromagnetic profilers to induce eddy currents and measure the resultant secondary fields, giving an average conductivity value for the affected search volume. Images were generated from the data using commercial spreadsheet and mapping software. This report presents the results of the electromagnetic surveys conducted to locate subsurface metallic features at the two sites.					
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