United States Department of Agriculture	**Natural Resources Conservation Service**	**5 Radnor Corporate Center, Suite 200 Radnor, PA 19087-4585**

Subject: -- Geophysical Assistance --

Date: 17 March 1999

To: Janet Oertly
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USDA-NRCS
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Purpose:
Geophysical field assistance was provided to the soil survey update at Fort Indiantown Gap, Pennsylvania.

Participating Agencies:
Pennsylvania Department of Military and Veterans Affairs
Pennsylvania State University, Department of Agronomy
USDA-NRCS

Participants:
John Chibirka, Soil Scientist, USDA-NRCS, Leesport, PA
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Activities:
All field activities were completed on 8 and 9 March 1999.

Equipment:
The Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. was used.[1] The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. A model 5103 (400 mHz) antenna was used.

The electromagnetic induction meter used in this study was the EM38 manufactured by Geonics Limited.[1] This meter is portable and requires only one person to operate. McNeill (1986) has described principles of operation. No ground contact is required with this meter. The EM38 meter operates at a frequency of 14,600 Hz. This meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing. It has theoretical observation depths of about 0.75 and 1.5 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1986). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

To help summarize the results of this study, SURFER for Windows software program developed by Golden Software Inc. [1] was used to construct two-dimensional simulations. Grids were created using kriging methods. In each of the enclosed plots, shading and filled contour lines have been used. These options were selected to help emphasize spatial patterns. Other than showing trends and patterns in values of apparent conductivity (i.e., zones of higher or lower electrical conductivity), no significance should be attached to the shades themselves.

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[1] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

Background:
Soil scientists of the USDA-NRCS are completing a detailed, digitized soil survey of the Pennsylvania Army National Guard facility at Fort Indiantown Gap (FIG). This facility contains over 15 active and inactive firing ranges. Pistol and rifle firing into earthen backstops has occurred at some ranges for over seventy years. Lead contained in the pistol and rifle shot may have become oxidized and mobilized in the soil solution. This study evaluated the potential of using ground-penetrating radar and electromagnetic induction to measure and map the concentration of lead in soils.

Field Procedures:
Radar traverses were conducted across portions of the earthen backstops and adjoining soils. Survey grids were established across portions of FIG Range #5 and #16. A 150 by 150-foot grid was laid out across FIG Range #5. A 100 by 100-foot grid was laid out across FIG Range #16. The grid interval was 25 feet. Survey flags were inserted in the ground at each grid intersection and served as observation points. At each observation point, measurements were taken with an EM38 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

Results:
Ground-penetrating radar was an inappropriate tool for measuring the concentration of lead in the backstop and adjoining soils. The radar profiles failed to clearly reveal individual shot or a concentrated layer of shot within the backstops. The rifle and pistol shot were too small to be resolved and detected with the 400 mHz antenna. Using a higher frequency (900 mHz) antenna may resolve the shot, but observation depths would be restrict in the fine-loamy soil materials that compose the backstops.

Electromagnetic induction provided some indication of lead concentrations in the backstops and surrounding soils. Anomalous areas of high (horizontal dipole orientation) and negative (vertical dipole orientation) apparent conductivity were recorded in the quadrature phase on and near the backstops.

Figures 1 and 2 show the spatial distribution of apparent conductivity within the surveyed portions of FIG Ranges 5 and 16, respectively. In both figures, the spatial distributions of apparent conductivity within the upper 0.75 and 1.5 meters of the soil profile is shown in the left-hand and right-hand plots, respectively. In each plot, the isoline interval is 10 mS/m. In addition, the locations of the backstop (berm) and targets or silhouettes have been shown. Shots are fired into the berms from positions located near the lower boundary of each plot.

In Figure 1, patterns of apparent conductivity are enigmatic and provided limited information concerning the concentration of lead in the soil materials. In the left-hand plot, many of the simulated patterns are aligned in a southwest to northeast orientation. These patterns may reflect variations in fill materials or the presence of artifacts within the upper 0.75 m of the soil profile. The location of the backstop (berm) is more obvious in the patterns for the upper 1.5 m of the soil profile. In the right-hand plot, several areas of conspicuously high positive and negative conductivity are evident in the eastern portion of the berm. This portion of the backstop is lower and contains more shot in the surface layers. The western portion of the berm was more recently added to, is higher, and contains additional earthen materials.

In the right-hand plot of Figure 1, negative values reflect the presence of buried metallic features. For earthen materials, negative conductivity is physically unattainable. Negative values often result from non-linear electromagnetic coupling in the profiled materials. Negative values represent the normalized conductivity relative to the background conductivity. Though pragmatically unattainable, the imaging of these values is useful as it provides information as to the location of anomalous features, in this case, impacted pistol and rifle shot. In Figure 1, anomalous values of apparent conductivity appear to be restricted to the berm.

In Figure 2, patterns of apparent conductivity are less complex and interpretations are more straightforward. The most anomalous apparent conductivity values are recorded in the berm. Anomalously high positive (horizontal dipole orientation) and negative (vertical dipole orientation) apparent conductivity were recorded in the quadrature phase on and near the backstop. These anomalous patterns are believed to principally reflect the distribution and concentration of lead shot in the soil materials. Values of apparent conductivity moderate with increasing distance from the berm. At a distance of 30 to 50 feet from the backstop, deviant values are no longer apparent.

Conclusions:
1. Ground-penetrating radar was found to be an inappropriate tool for locating and quantifying the amount of lead shot in

soils at the rifle ranges. Using a higher frequency antenna (either 900mHz or 1.2 gHz) may improve interpretations and results.

2. Consistent and repeatable spatial patterns were apparent in data collected with EMI. Backstops having high concentrations of lead shot produced anomalously high positive and negative values of apparent conductivity. These anomalous values contrasted with background levels of apparent conductivity across these ranges. Simulated patterns of apparent conductivity provide limited inferential information concerning the concentration of lead in the soil materials. Electromagnetic induction may help researchers better understand the distributions of lead shot within the ranges. In addition, this technique may help researchers locate sites within the ranges that require additional soil sampling. The use of correctly interpreted EMI data provides more comprehensive coverage and reduces the total number of required soil observations.

3. Interpretations contained in this report are considered preliminary estimates of site conditions. These interpretations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

It was my pleasure to work in Pennsylvania and with members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

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EMI SURVEY
IMPACT OF LEAD IN RIFLE RANGES
FORT INDIANTOWN GAP
EM38 METER

FTIG RANGE #5

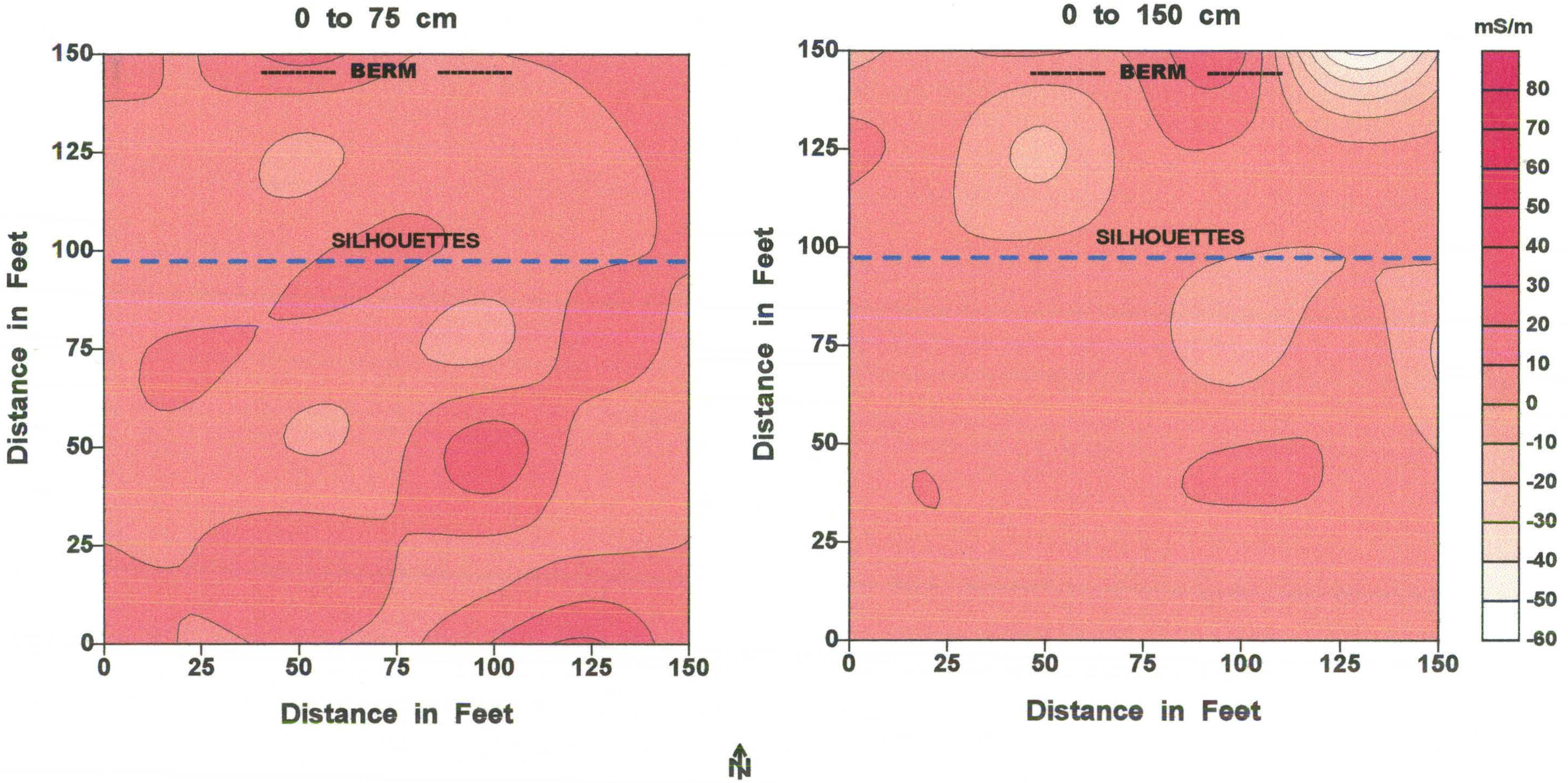

Figure 1

EMI SURVEY
IMPACT OF LEAD IN RIFLE RANGES
FORT INDIANTOWN GAP
EM38 METER

FTIG RANGE #16

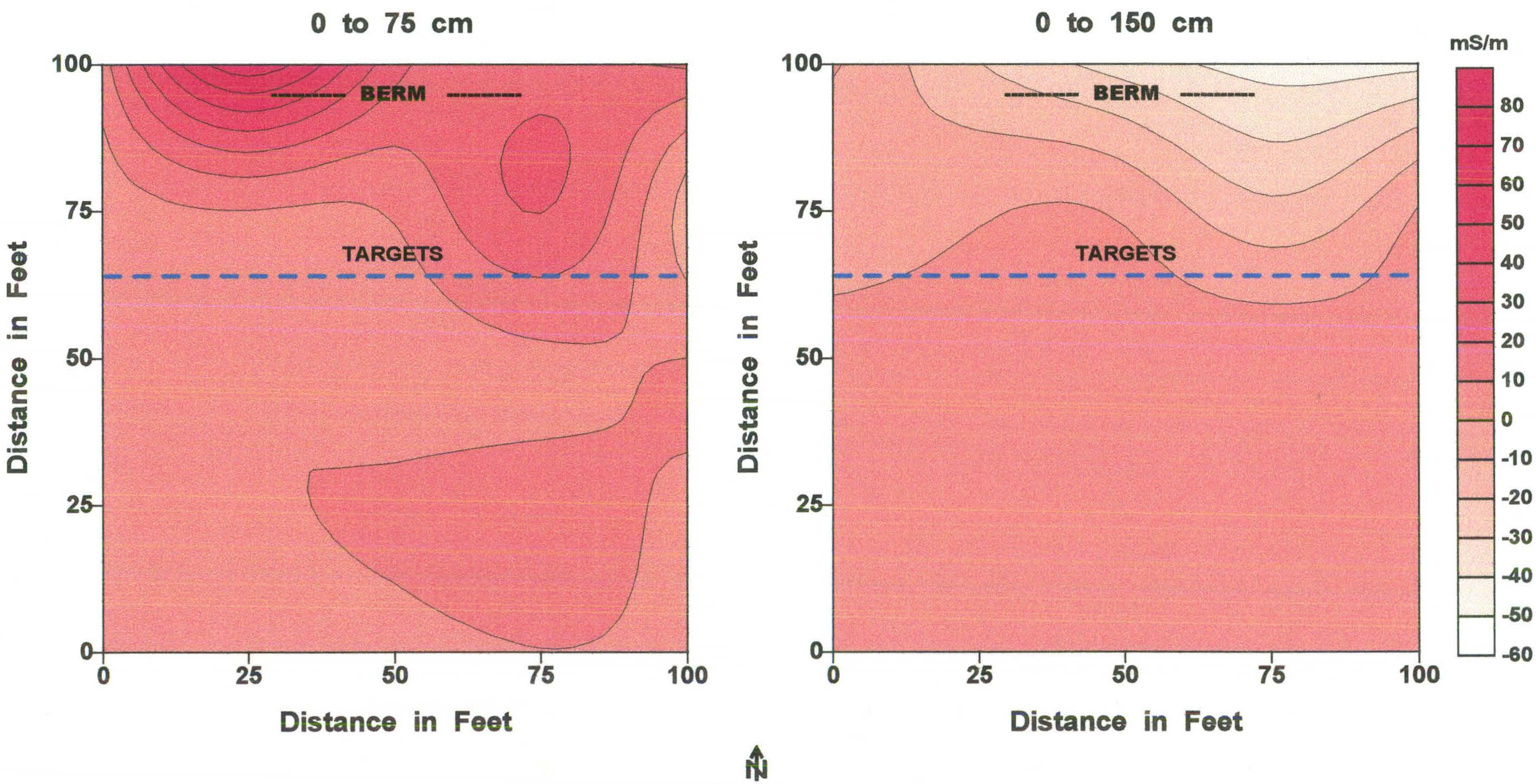

Figure 2