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

Subject: SOI -- Geophysical Assistance **Date:** 3 September 1996

To: Lawrence E. Clark
State Conservationist
USDA-NRCS
200 North High Street
Room 522
Columbus, Ohio 43215

Purpose:
The purpose of this investigation was to evaluate the potentials of using ground-penetrating radar (GPR) and electromagnetic induction techniques to locate buried drainage tile lines in areas of fine and moderately fine textured soils.

Participants:
Jim Doolittle, Research Soil Scientist, NRCS, Radnor, PA
Angel Figueroa, District Conservationist, NRCS, Columbus, OH
Chris Hartman, Urban Conservationist, Franklin SWCD, Columbus, OH
Brady Koehler, Agriculture Resource Specialist, Franklin SWCD, Columbus, OH
Danny LeMaster, Soil Scientist, NRCS, Chillicothe, OH
Jeff Pierce, GIS Coordinator, Franklin SWCD, Columbus, OH

Activities:
All field activities were completed on 27 August 1996.

Background:
Ground-penetrating Radar:
Ground-penetrating radar is an impulse radar system designed for shallow (0 to 30 m), subsurface investigations. Compared with other geophysical techniques, GPR provides the highest resolution of subsurface features. However, results of radar surveys are site specific and interpreter dependent. Interpretations depend on the experience of the operator, complexity of soil or geologic conditions, quantity and quality of independent observation data, and the system and antennas used. In many areas, conductive soil conditions limit observation depth. Ground-penetrating radar is best suited for shallow (3 to 10 meters) investigations in electrically resistive mediums (i.e. dry, sandy soils). Use of GPR has been most successful in areas of coarse or moderately coarse textured soil materials. It has also been successfully applied in areas having highly weathered materials with low proportions of 2:1 type clays and low concentrations of soluble salts. In Franklin County, the observation depth of the radar was expected to be limited by the high clay and lime contents of the soils.

Electromagnetic Induction Methods:
Electromagnetic induction techniques use electromagnetic energy to measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity for a column of earthen materials to a specific observation depth. Variations in apparent conductivity are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of

soils is influenced by the (i) volumetric water content, (ii) type and concentration of ions in solution, (iii) temperature and phase of the soil water, and (iv) amount and type of clays in the soil matrix, (McNeill, 1980b). The apparent conductivity of soils increases with increases in the exchange capacity, water content, and clay content.

Electromagnetic induction methods measure vertical and lateral variations in the apparent conductivity. Values of apparent conductivity are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in soils or the presence of anomalous features in earthen materials. Interpretations are based on the identification of spatial patterns within data sets.

Electromagnetic induction techniques are not suitable for use in all investigations. Generally, the use of EM techniques has been most successful in areas where subsurface properties are reasonably homogeneous and the effects of one property (e.g., clay, water, or salt content) dominates over the other properties. In these areas, variations in EM response can be related to changes in the dominant property or feature (Cook and others, 1989). In order for drainage tiles to be detectable with EM techniques, they must be relatively large and electrically contrasting within the earthen materials profiled. In Franklin County, the EM meter was limited by the lack of sufficient contrast between the buried drainage tile and the surrounding soils.

MATERIALS AND METHODS:

Equipment:

The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc. This unit is backpack portable and requires two people to operate. The use and operation of GPR have been discussed by Morey (1974), Doolittle (1987), and Daniels and others (1988). The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. The 120, 300, and 500 mHz antennas were used in this investigation. The radar system was powered by a 12-VDC battery.

The electromagnetic induction meters used in this study were the EM38 and EM31, manufactured by Geonics Limited. These meters are portable and require only one person to operate. Principles of operation have been described by McNeill (1980a, 1986). No ground contact is required with these meters. Each meter provides limited vertical resolution and depth information. For each meter, lateral resolution is approximately equal to the intercoil spacing. The observation depth of an EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface.

The EM38 meter has a fixed intercoil spacing of about 40 inches. It operates at a frequency of 13.2 kHz. The EM38 meter has effective observation depths of about 30 and 60 inches in the horizontal and vertical dipole orientations, respectively (McNeill, 1986). The EM31 meter has a fixed intercoil spacing of about 12.6 feet. It operates at a frequency of 9.8 kHz. The EM31 meter has effective observation depths of about 10 and 20 feet in the horizontal and vertical dipole orientations, respectively (McNeill, 1980a). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER for Windows software, developed by Golden Software, Inc., was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search. All grids were smoothed using a cubic spline interpolation. In the enclosed plots, to help emphasize spatial patterns, filled contour lines have been used. Other than showing trends and patterns, no significance should be attached to the intensity of the filled contours themselves.

Study Areas:

Two sites were selected in Franklin County to evaluate the suitability of GPR and EM techniques for the detection of buried tiles. These sites were representative of drained soils formed in till. The first site was located about 1 mile south of Bolton Airport in southwestern Franklin County. This site was in an area that had been mapped as Crosby silt loam, 2 to 6 percent slopes (McLoda and Parkinson, 1980). Crosby soil is a member of the fine, mixed, mesic Aeric Ochraqualfs family. The second site was located about 1.25 miles south south-west of Brice in southeastern Franklin County. This site was in an area that had been mapped as Westland silty clay loam (McLoda and Parkinson, 1980). Westland soil is a member of the fine-loamy, mixed, mesic Typic Argiaquolls family.

Field Methods:

A small section of a metal pipe was buried in the ground at a depth of 20 inches (Crosby Site) and 16 inches (Westland Site). The diameter of the pipe was 5 inches. The radar was evaluated by pulling the 120, 300, or 500 mHz antenna across this buried point reflector and adjoining areas of soil. Each radar profile was evaluated for depth of observation, resolution of subsurface features, and interpretability.

To evaluate the effectiveness of EM techniques, a grid was established across each site. The grid interval was 3 feet. At each grid intersection, a survey flag was inserted in the ground and served as an observation point. This procedure provided 49 and 24 observation points at the Crosby and Westland sites, respectively. At each observation point, measurements were taken with an EM38 meter in the vertical dipole orientation. For each measurement, the meter was placed on the ground surface.

Results:

Ground-penetrating radar:

In areas of Crosby and Westland soils, ground-penetrating radar was found to be an unsuitable tool for the detection of buried drainage tiles. At each site, the known, shallowly buried, metal pipe was imperceptible on radar profiles. Unquestionably, this target represented a better reflector of radar energy than the plastic or clay drainage tiles found in these soils.

Electromagnetic Induction:

Figures 1 and 2 are two-dimensional plots of data collected with the EM38 meter in vertical dipole orientation at the Crosby and Westland sites, respectively. In each plot, the isoline interval is 2 mS/m. Although spatial patterns and linear trends are evident in each plot, buried drainage tiles did not in themselves produced a distinct EM response.

At the Crosby site (see Figure 1), the buried drainage line was being excavated and replaced by a larger, plastic system. In Figure 1, the approximate location of the buried system has been shown. Neither the buried plastic nor tile line was detected by the EM meter. The patterns evident in this plot represent the effects of the drainage system (lower moisture content of soils near the tile). While the presence of the drainage system can be inferred from the spatial pattern appearing in this plot, the exact location of the system is poorly defined. At this scale of mapping, the horizontal resolution of the drainage system is about 3 to 6 feet.

At the Westland site (see Figure 2), low values of apparent conductivity were measured along the southern boundary of the grid. These anomalous values are believed to reflect soils with lower moisture contents and the presence of a buried drainage system. As in the case of the Crosby site, horizontal resolution was poor and the EM meter failed to identify the exact location of a drainage tile system.

Conclusions:

1. Neither ground-penetrating radar nor electromagnetic induction provided satisfactory results. At each site, ground-penetrating radar failed to detect a known metallic reflector that had been buried at shallow depths (less than 20 inches). In the areas of Crosby and Westland soils, observation depths were severely restricted. Features appearing on radar profiles were poorly expressed and lacked readily identifiable graphic signatures. It was concluded that, in these soils, many older, smaller, or partially filled drainage tile systems would be inconspicuous on radar profiles and overlooked in radar interpretations.

2. For the detection of buried drainage tiles in areas of Crosby and Westland soils, EM is considered a more appropriate tool than GPR. The EM38 meter seemed to detect the drier soil conditions existing near buried drainage systems. However, the horizontal and vertical resolution of EM was considered poor. Using the EM38 meter, subsurface drainage tile system (buried at shallow depths) can be located to within 3 feet of their actual positions. However, the use of this technique and the quality of results may require the construction of survey grids.

3. During field work, several of the participants experimented with dowsing. Some were highly successful at locating buried tiles with this technique. For the location of buried tiles, I was more impressed with the speed and accuracy of this technique than with the geophysical techniques. This statement does not represent an endorsement of dowsing, but a disapproval of GPR and EM techniques for the location of buried tile lines in areas of fine and moderately fine textured soils.

4. This field evaluation provided each participant with an opportunity to observe the operation of a ground-penetrating radar and electromagnetic induction meters. Each participant was given the opportunity to operate the EM38 meter.

It was my pleasure to work in your state, with members of your staff, and members of the Franklin County SWCD. While the tests were unfavorable, the knowledge gained should be of benefit to our customers.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
P. DeArman, Assistant State Conservationist, USDA-NRCS, 200 North High Street
Room 522, Columbus, Ohio 43215
J. Culver, Supervisory Soil Scientist, USDA-NRCS, National Soil Survey Center,
Federal Building, Room 152,100 Centennial Mall North, Lincoln,
NE 68508-3866
A. Figueroa, District Conservationist, USDA-NRCS, 1945 Frebis Avenue, Columbus, Ohio 43206
J. Gerken, Soil Scientist (Liaison) USDA-NRCS, 200 North High Street
Room 522, Columbus, Ohio 43215
S. Holzhey, Supervisory Soil Scientist, USDA-NRCS, National Soil Survey Center,
Federal Building, Room 152, 100 Centennial Mall North, Lincoln,
NE 68508-3866

References

Daniels, D. J., D. J. Gunton, and H. F. Scott. 1988. Introduction to subsurface radar. IEE Proceedings 135F(4):278-320.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. IN Soil Survey Techniques, Soil Science. Soc. Am. Special Pub. No 20. pp. 11-32.

Cook, P. G., M. W. Hughes, G. R. Walker, and G. B. Allison. 1989. The calibration of frequency-domain electromagnetic induction meters and their possible use in recharge studies. Journal of Hydrology 107:251-265.

McLoda, N. A., and R. P. Parkinson. 1980. Soil Survey of Franklin County, Ohio. USDA-Soil Conservation Service. U. S. Government Printing Office. Washington, D. C. pp. 188.

McNeill, J. D. 1980a. Electromagnetic terrain conductivity measurement at low induction numbers. Technical Note TN-6. Geonics Limited, Mississauga, Ontario. pp. 15.

McNeill, J. D. 1980b. Electrical Conductivity of soils and rocks. Technical Note TN-5. Geonics Ltd., Mississauga, Ontario. pp. 22.

McNeill, J. D. 1986. Geonics EM38 ground conductivity meter operating instructions and survey interpretation techniques. Technical Note TN-21. Geonics Ltd., Mississauga, Ontario. pp. 16.

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. pp. 212-232. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.