United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard, Suite 200 Newtown Square, PA 19073**

Subject: SOI – Geophysical Field Assistance **Date:** 14 February 2008

To: Dr. Henry Lin
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Purpose:
In order to better understand the short-range variability in apparent conductivity (EC_a) in a steeply sloping, forested catchment, a detailed grid site has been established at the base of a major swale in the Shale Hills Catchment in northern Huntingdon County, Pennsylvania. During this visit, EMI surveys of this site were completed. The Hydropedology Team at Pennsylvania State University is interested in processing radar records obtained from small grid sites located in Shale Hills Catchment. A small grid site was surveyed to emphasize applicable field techniques and to facilitate training. Collected radar records were processed using basic signal-processing techniques contained in the *RADAN* (version 6.5) processing software (Geophysical Survey System, Inc., Salem, New Hampshire) and a three-dimensional (3D) pseudo-image of the site was developed. After I departed, additional training was provided by Dean Goodman, (Geophysicist, Geophysical Archaeometry Laboratory, Woodland Hills, CA) on his *GPR-SLICE*, ground-penetrating radar imaging software program.

Activities:
All field activities were completed on 6 and 7 February 2008.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Henry, Lin Assistant Professor of Hydropedology/Soil Hydrology, Crop & Soil Sciences Department, PSU, University Park, PA
Ken Takagi, Graduate Student, Department of Crop & Soil Sciences, PSU, University Park, PA
Jun Zhang, PhD Student, Department of Crop & Soil Sciences, PSU, University Park, PA

Recommendations:

1. The location of the detailed EMI grid site is at the base of a major swale, which closely adjoins the stream channel. This site is poorly situated for GPS reception and further use of GPS at this site is not recommended. To facilitate this study, the location and elevation of all flagged observation points must be measured with modern survey tools (a total station optical instrument with electronic theodolite and distance measuring device).

2. All EMI data collected in this investigation have been forwarded to Dr. Henry Lin and Ken Takagi for analysis.

3. Dean Goodman provided 3-hr of training on *GPR-SLICE*, a ground-penetrating radar imaging software program, to Jun Zhang and Dr Henry Lin. Dr Lin reported that this software has greater functionalities than *RADAN*, but

appears less straight forward and more difficult to initially understand and master.

4. As earlier planned, over the next four months, monthly EMI surveys will be conducted over the small grid site located within the Shale Hills Catchment by Ken Takagi. The purpose of these surveys is to assess the short-range (large scale) spatiotemporal variability in EC_a. Ken Takagi is instructed to collect position and elevation data for each of the observation points within this site. He will coordinate future EMI survey activities with Jim Doolittle.

5. Over the next year, bi-monthly EMI surveys of the research fields at Klepler Farm will be conducted by Jim Doolittle and Quing Zhu. The purpose of these surveys is to assess broad (small scale) spatiotemporal variability patterns in EC_a. Quing Zhu will work with Jim Doolittle in establishing the surveying dates and insuring that an ATV is available to conduct these surveys.

6. Jun Zhang will establish permanent, small, detailed grid sites within Shale Hills Catchment. These sites will be used for repeated GPR surveys, which will attempt to show spatiotemporal variations in radar imagery caused by differences in soil moisture contents, and detect preferential flow patterns and fractures in the underling Rose Hill formation.

7. I will return to Penn State on 27 February 2008 to complete EMI surveys at the Klepler Farm Research fields with Quing Zhu and the detailed grid site at Shale Hills with Ken Takagi.

It was my pleasure to participate in these studies and to work with the graduate students at Pennsylvania State University.

With kind regards,

James A. Doolittle
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cc:
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Materials and Methods:
The EM38DD meter, manufactured by Geonics limited (Mississauga, Ontario), was used in the EMI surveys of the detailed grid site and TDR monitoring sites at Shale Hills.[1] This meter requires only one person to operate. No ground contact is required with this instrument. The EM38DD meter consists of two, coupled EM38 meters. Each meter has a 1-m intercoil spacing and operates at a frequency of 14,600 Hz. This instrument weighs about 2.8 kg (6.2 lbs). Operating procedures for the EM38DD meter are described by Geonics Limited (2000). When placed on the soil surface, the EM38DD meter provides theoretical penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively.

An Allegro CX field computer (Juniper Systems, North Logan, UT) was used to record and store EMI and GPS data. A Garmin global-positioning system (GPS) Map76 receiver (with CSI Radio Beacon receiver and antenna) (Olathe, KS) was

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

used in this investigation.[1] The Garmin GPS receiver and antenna are mounted onto a backpack frame. During surveying, EC_a and GPS measurements were recorded in an Allegro CX field computer. The *DAT38DDW* and *Trackmaker38DD* software programs developed by Geonics Limited and Geomar Software Inc. (Mississauga, Ontario) were used to record, store, and process apparent conductivity (EC_a) and GPS data. [1]

For temporal comparisons of EMI results, EC_a data should be corrected to a standard temperature. Apparent conductivity increases with soil temperature. As the soil temperature rises, the soil water become less viscous and dissolved ions become more mobile. This results in higher EC_a values (McNeill, 1980). As it is impractical to account for temperature variations at each point and at different soil depths within the catchment, a correction factor was used that was based on a single measurement made at a depth of 50 cm (37^o F). All EC_a data were temperature corrected to a standard temperature of 75^o F.

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR-3000), manufactured by Geophysical Survey Systems, Inc. (Salem, NH). [1] The SIR-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Daniels (2004) discusses the use and operation of GPR. The 400 MHz antenna was used at the detailed grid site.

Radar records contained in this report were processed with the *RADAN* for Windows (version 6.6) software developed by GSSI. [2] Processing included: header editing, setting the initial pulse to time zero, distance normalization, surface normalization, and range gain adjustments. The Super 3D QuickDraw program developed by GSSI was used to construct a three-dimensional (3D) pseudo-image of radar records collected at the grid site.

Survey Procedures:

Pedestrian EMI surveys were completed across the detailed grid site at the Shale Hills Catchment. Two separate surveys were completed with the EM38DD meter: one with the meter operated in the continuous mode with GPS enabled; and one conducted in the manual or *station-to-station* mode with GPS disable. For the continuous survey, the meter was orientated with its long axis parallel to the direction of traverse and held about 5 cm (2 inches) above the ground surface. Horizon obstructions, satellite shading, and multipath reception negatively impacted the accuracy and reliability of GPS positioning. For the *station-to-station* survey, the meter was placed on the soil surface at each flagged observation point. EC_a was also measured at select time-domain reflectometry (TDR) monitoring sites. In this application, the EM38DD meter was also operated in the *station-to-station* mode. The meter was placed on the soil surface and two measurements (each orthogonal to the other) were obtained at each TDR monitoring site.

To collect the data required for construction of a 3D GPR pseudo-image, a survey grid was established at a selected site within Shale Hills Catchment. The grid had dimensions of 3.0 by 3.75 m. Along the two parallel Y-axis lines (3.75 m), survey flags were inserted into the ground at a spacing of 25 cm. A reference line was stretched between matching survey flags on opposing sides of the grid using a distance-graduated rope. GPR traverses were conducted along this reference line. Each radar traverse was 3-m long. The 400 MHz antenna was towed along the graduated rope on the soil surface and, as it passed each 100-cm graduation, a mark was impressed on the radar record. Following data collection along a line, the reference line was sequentially displaced 25-cm to the next pair of survey flags to repeat the process. A total of 16 traverses were required to complete the GPR survey of the grid site. In this exercise, the velocity of propagation (v) and relative dielectric permittivity (E_r) were not calculated from ground-truth observations. Soils were moist and a nominal E_r of 10 (v of 0.0942 m/ns) was used to depth scale the radar imagery.

Results:

<u>GPR:</u>

The focus of signal processing is to reduce unwanted system noise and clutter. The aim of signal processing is to enhance desired reflections from subsurface features and to improve radar interpretations. Figure 1 is 3D GPR pseudo-image of the grid site. Signal stacking (a signal averaging technique) has been used to reduce high frequency noise and display

[2] Manufacturer's names are provided for specific information; use does not constitute endorsement.

gains have been used to enhance subsurface reflections. In this pseudo-image, a 2.0 by 2.0 by 1.2 m cube has been removed. In this 3D pseudo-image a sequence of stratigraphic layers are evident within the column of colluvium. The image in Figure 1 has not been *terrain-corrected* or *surface normalized* to adjust for differences in elevation. Terrain correction is often used to improve visual presentations. Through a process known as *surface normalization*, measured elevations are assigned to each reference point and the image is corrected for changes in relief. Surface normalization helps to improve the interpretative quality of radar records and the association of subsurface reflectors with landscape components. Figure 2 has been *terrain-corrected*, but the modest relief of 79 cm within the site is hardly detectable. In this pseudo-image, a 2.0 by 2.0 by 1.0 m cube has been removed.

<u>EMI:</u>
Ken Takagi will evaluate the EMI data collected at the detailed grid site and at selected TDR monitoring sites.

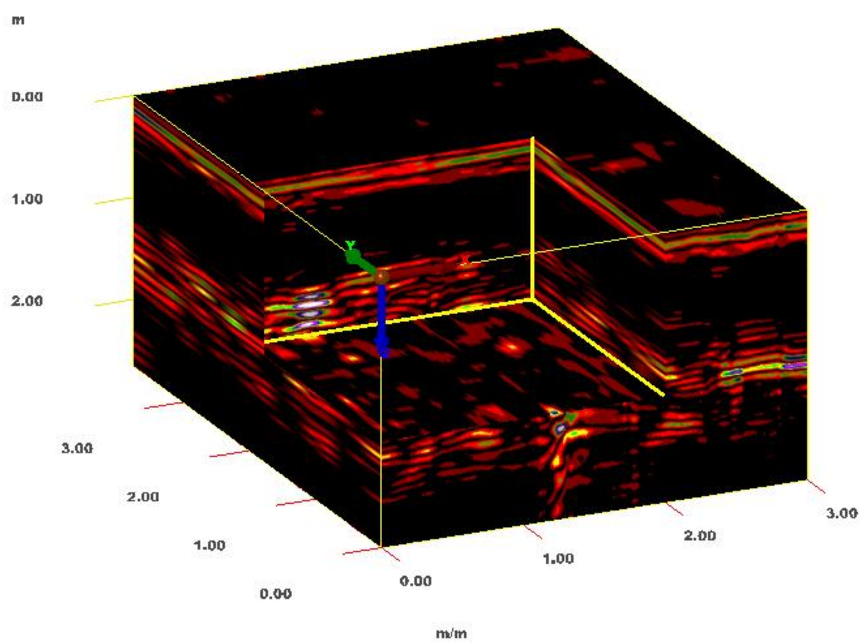

Figure 1. A 3D pseudo-image of the training grid site in Shale Hills Catchment.

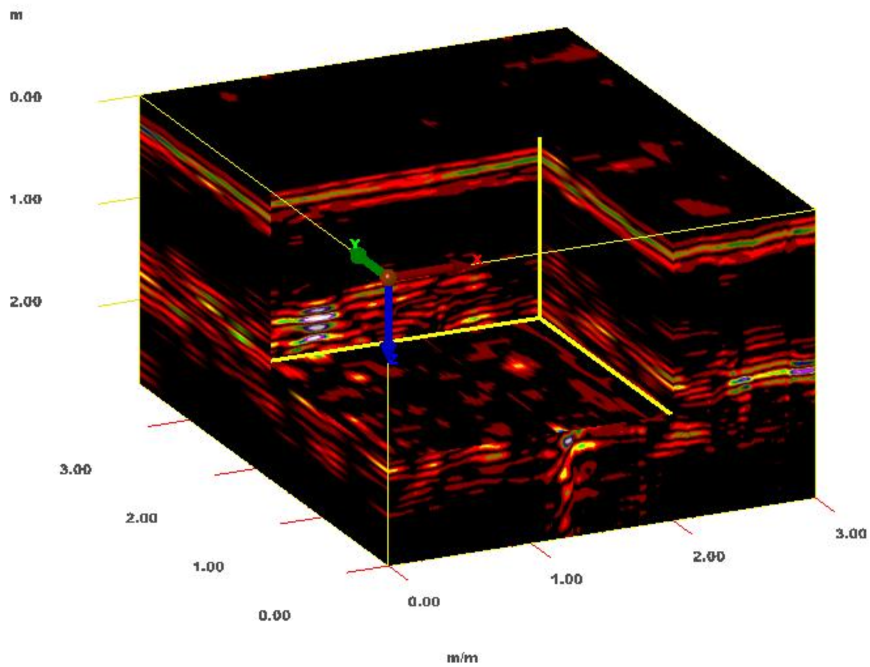

Figure 2. A *terrain-corrected* 3D pseudo-image of the training grid site in Shale Hills Catchment. Measured relief within the grid site is only 79 cm.

References:

Daniels, D. J. 2004. Ground Penetrating Radar; 2nd Edition. The Institute of Electrical Engineers, London, United Kingdom.

Geonics Limited, 2000. EM38DD ground conductivity meter: Dual dipole version operating manual. Geonics Ltd., Mississauga, Ontario.