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

Subject: SOI – Geophysical Field Assistance **Date:** 7 October 2008

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Purpose:
Ground-penetrating radar (GPR) was used to assist a research project being conducted in Leight Park, Maryland Natural Research Reserve, in Abingdon, Maryland. The research project is entitled “Using soil properties to predict nitrogen transport and transformation at the terrestrial-aquatic interface in a pedologically diverse catchment”. The focus of this research project is to better understand the role of soil texture in controlling nutrient cycling through physical and biological mechanisms. The study site is a small, steeply-sloping, forested catchment. Within this catchment a gradient in sand content runs perpendicular to and parallel with the hill slope. GPR was used in an attempt to help characterize different stratigraphic units which can influence the flow of ground water and affect nutrient cycling and transport. This project has received support from NOAA-National Estuarine Research Reserve program (NOAA Award Number: NA07NOS4200046).

Activities:
All field activities were completed on 3 October 2008.

Participants:
Mike Castellano, PhD Candidate, Crop & Soil Department, Pennsylvania State University, University Park, PA
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Steve Kinner, Technician, Crop & Soil Department, Pennsylvania State University, University Park, PA

Summary:
Ground-penetrating radar was used to characterize different stratigraphic units within the catchment. The presence and internal structure of these contrasting units will influence the flow of water and the evolution of different soils and soil properties. Knowledge gained through the interpretation of geophysical data can be used to further optimize sampling designs and improve site characterization and modeli*ng.*

Results of this brief study can be improved by measuring the relative elevation at each of the flagged reference point along the radar traverse lines. This will allow the radar data to be *surface normalization*. Surface normalization adjusts each reference mark for changes in elevation. This process can improve interpretations and the association of subsurface reflectors with soils and landscape components.

It was my pleasure to participate in this study and to work with the Mike and Steve.

With kind regards,

James A. Doolittle
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cc:
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Radar Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (SIR-3000), manufactured by Geophysical Survey Systems, Inc. (GSSI; 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. An antenna with a center frequency of 400 MHz was used in this study. Daniels (2004) discusses the use and operation of GPR.

The RADAN for Windows (version 6.6) software program (GSSI; Salem, NH) was used to process the radar records. [1] High quality radar records were collected at the site and therefore, very little post-processing was required. Processing included: header editing, setting the initial pulse to time zero, distance normalization, color table and transformation selection, and range gain adjustments (see Daniels (2004) for a discussion of these techniques).

Study Site:

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

The study site is a small, steeply sloping, forested catchment in Hanford County, Maryland (39.4521 N. Latitude, 76.2732 W. Longitude). Figure 1 is from the Web Soil Survey and shows the general location of the study site. In Figure 1, the Pulaski Highway is the major cultural feature to the immediate north and west of the site. The large body of water to the south of the site is Otter Point Creek, which opens directly into the Chesapeake Bay.

The study site is principally mapped as Evesboro loamy sands on 5 to 15 % slopes (map unit EvC). Included is a miscellaneous area of Alluvial lands (Av), and in the northern portion of the study site, small areas of Elsinboro loam on 2 to 5 % slopes, moderately eroded (EsB2); and Joppa gravelly sandy loam on 5 to 10 % slopes (JpC).

The very deep, excessively drained Evesboro soils formed in sandy marine and eolian deposits. The very deep, well drained Elsinboro soils formed in alluvium weathered from micaceous crystalline rocks on stream terraces. The very deep, somewhat excessively drained, Joppa formed in sands and gravels. The taxonomic classifications of these soils are listed in Table 1.

Figure 1. This soil map shows the general location of the study site in Hanford County, Maryland.

Table 1. Taxonomic classification of soils recognized within the study site.

Soil Series	Taxonomic Classification
Joppa	Loamy-skeletal, siliceous, semiactive, mesic Typic Hapludults
Elsinboro	Fine-loamy, mixed, semiactive, mesic Typic Hapludults
Evesboro	Mesic, coated Lamellic Quartzipsamments

Survey Procedures:
Seven GPR traverse lines of varying lengths were established along the east-facing side slopes of the catchment. Survey Flags were inserted in the ground at 3-m intervals along each traverse line. These flags provided ground control. Each line descended from a shoulder slope composed of Coastal Plain deposits onto a toe slope composed of alluvium (map unit Av). All traverses were conducted with a 400 MHz antenna in a downslope direction. As each survey flag was passed with the antenna, the operator impressed a vertical reference mark on the radar record.

Calibration of GPR:
Ground-penetrating radar is a time scaled system. The system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., bedrock, soil horizon, stratigraphic layer) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships

among depth (D), two-way pulse travel time (T), and velocity of propagation (*v*) are described in equation [1] (after Daniels, 2004):

$$v = 2D/T \qquad [1]$$

The velocity of propagation is principally affected by the relative dielectric permittivity (E_r) of the profiled material(s) according to equation [2] (after Daniels, 2004):

$$E_r = (C/ v)^2 \qquad [2]$$

Where C is the velocity of propagation in a vacuum (0.298 m/ns). Velocity is expressed in meters per nanosecond (ns). In soils, the amount and physical state (temperature dependent) of water have the greatest effect on the E_r and *v*. At the time of this investigation, soils were relatively dry.

Based on the measured depth and the two-way pulse travel time to a known subsurface reflector (metal plate buried at 50 cm), the velocity of propagation and the relative dielectric permittivity through the upper part of soil profiles were estimated using equations [1] and [2]. In two areas of Evesboro soil, the estimated E_r was 4.52 and 5.94. These E_r resulted in propagation velocities of 0.1400 and 0.1222 m/ns, respectively. These velocities of propagation were averaged and a *v* of 0.1311 m/ns was used to depth scale the radar records. Using a *v* of 0.1311 m/ns, a range of 45 ns, and equation [1], the 400 MHz antenna was set to penetrate the subsurface to an estimated depth of about 295 cm.

Results:

Areas of the coarse-textured Evesboro soil are well suited to GPR. The radar records collected in this survey are displayed in Figures 2 thru 8. As the interpretive quality of these records is considered high, only minimal processing was applied. On each radar record, the direction of travel was down slope (left to right). As the elevation of each reference flag was not collected at the time of the GPR survey, the radar records could not be *surface normalized*. As a consequence, the soil surface appears horizontal and the inclination of subsurface layers is incorrect. *Surface normalization* adjusts each reference mark for changes in elevation. This process adjusts the vertical scale and allows the topography along the traverse line to be visualized. *Surface normalization* can improve interpretations and the association of subsurface reflectors with soils and landscape components. As the reference flags were left in the field, elevation data can be collected at a later date and these radar records *surfaced normalized*.

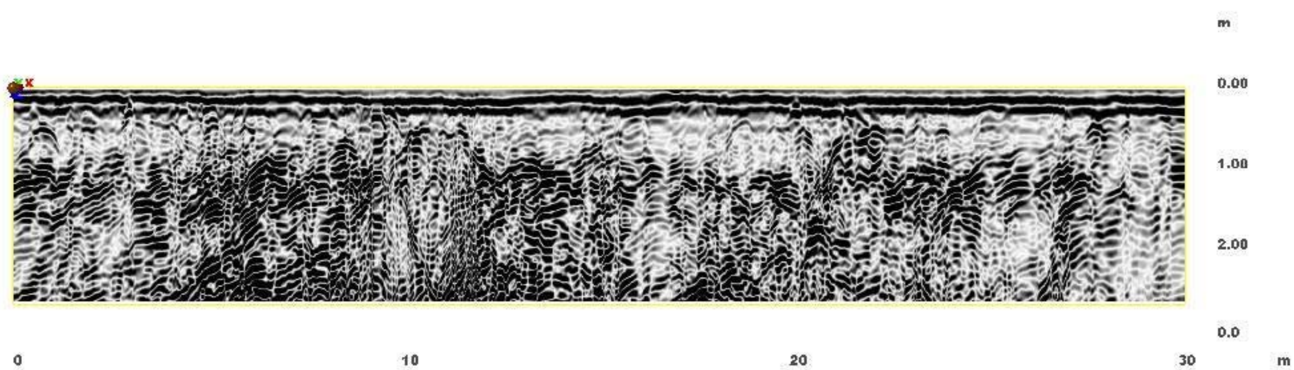

Figure 2. Radar record collected with the 400 MHz antenna along Line 1.

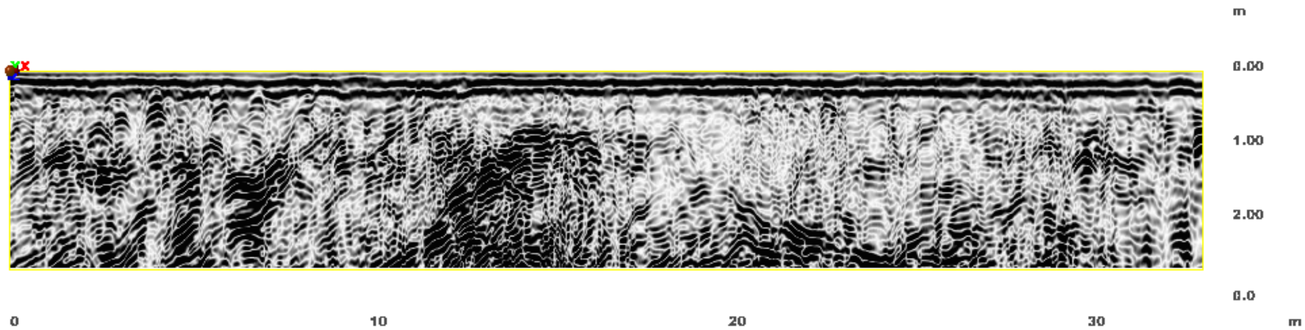

Figure 3. Radar record collected with the 400 MHz antenna along Line 2.

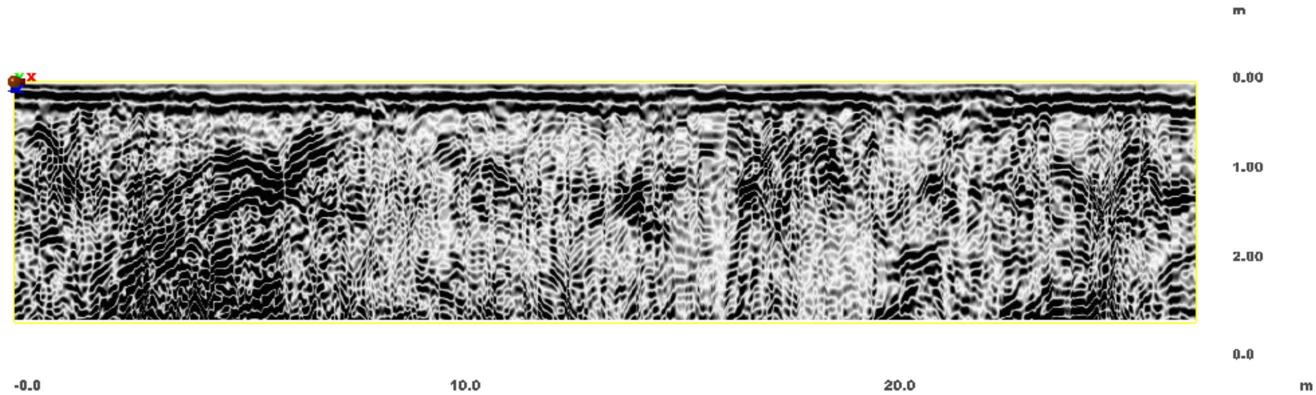

Figure 4. Radar record collected with the 400 MHz antenna along Line 3.

Most radar records from the catchment can be segmented into three distinct stratigraphic facies based on differences in type, distribution, and arrangement of subsurface reflectors. The upper slope components (left-hand portion of each radar record) are characterized by multiple, closely spaced, inclined, sub-parallel, linear reflectors. These reflectors are believed to represent sedimentary beds of contrasting grain-size distributions. This higher-lying facies is underlain by second facies on lower mid-slopes portions of the radar records. The second facies is often bounded by a broad arching pattern, and largely consists of hummocky-appearing reflectors. These reflectors are interpreted to represent more thickly-bedded materials. The lower facies (right-hand portion of each radar record) consists of a large number of point anomalies, which appear to be interconnected with or a part of short, linear layers. These segmented, linear reflections more closely parallel the soil surface than reflectors in the previous two facies. This lower-lying facies is interpreted to represent recent alluvial deposits. Isolated, larger hyperbolic patterns within the lowest-lying facies may represent parent rock or more indurated sediment.

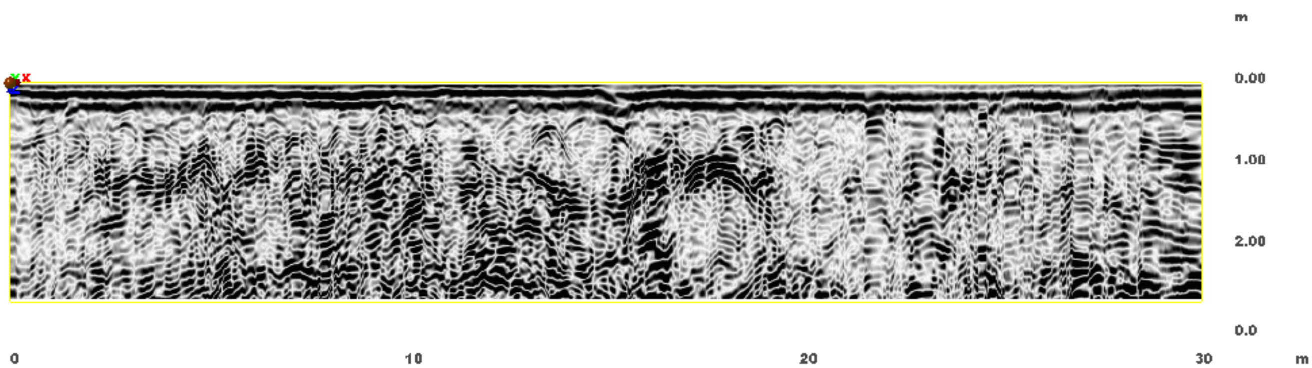

Figure 5. Radar record collected with the 400 MHz antenna along Line 4.

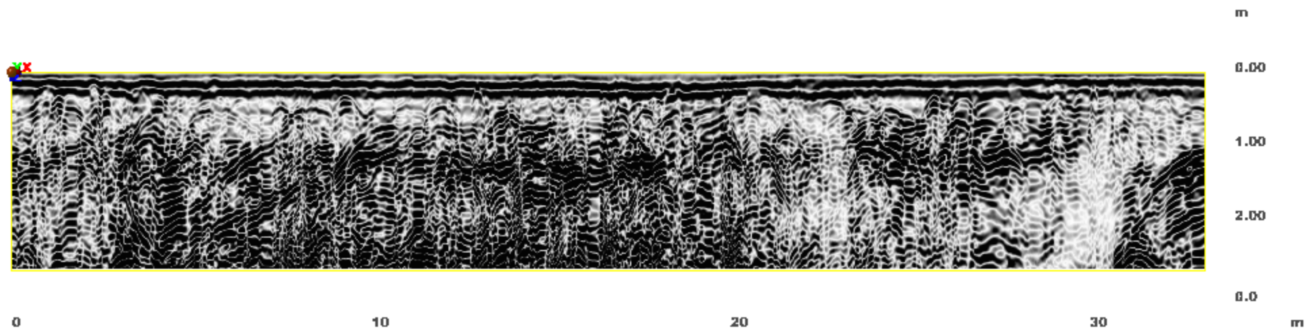

Figure 6. Radar record collected with the 400 MHz antenna along Line 5.

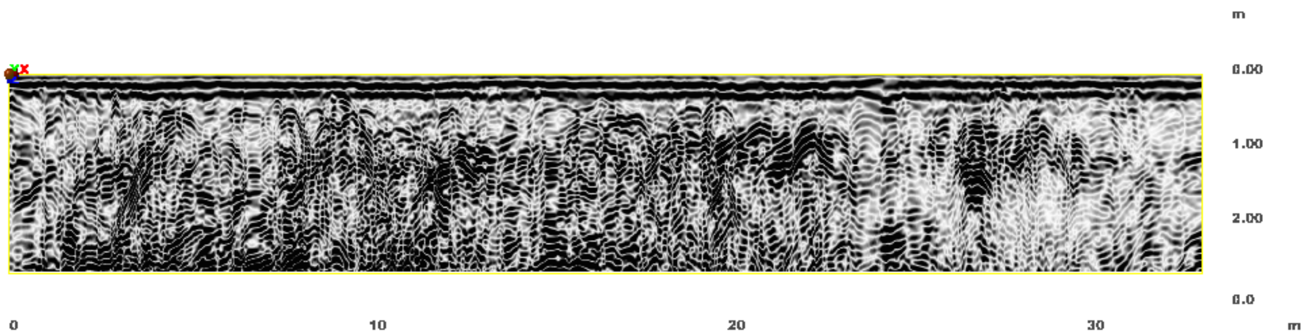

Figure 7. Radar record collected with the 400 MHz antenna along Line 6.

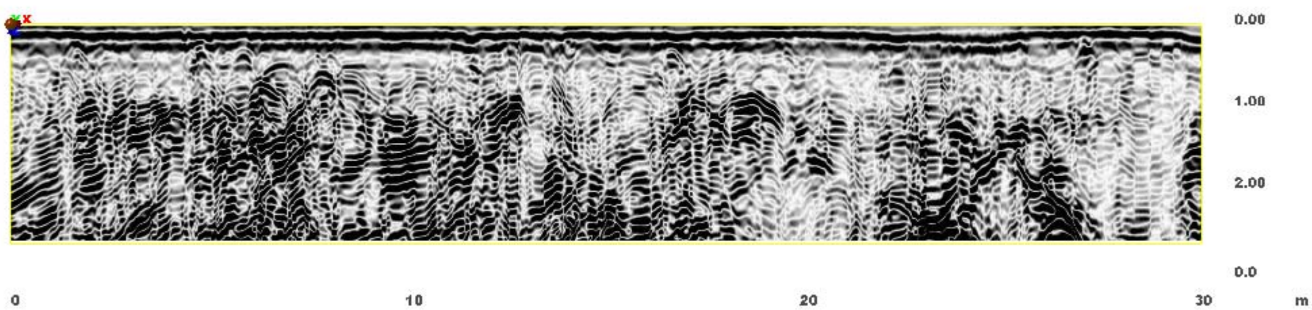

Figure 8. Radar record collected with the 400 MHz antenna along Line 7.

In this very brief study, GPR was used to profile and to characterize different stratigraphic units within this catchment. The presence of these contrasting units will influence the flow of water and the evolution of different soils and soil properties. Knowledge gained through the interpretation of geophysical data can be used to further optimize sampling designs and improve site characterization and modeli*ng.*

References:

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