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

Subject: SOI – Geophysical Assistance **Date:** 13 April 2004

To: Edgar White
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Purpose:
Geophysical methods were used to aid investigations of a solution feature in Clinton County and an archaeological site in Centre County, Pennsylvania.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Jake Eckenrode, Resource Soil Scientist, USDA-NRCS, Lamar, PA
Ralph Homan, landowner, Centre Hall, PA
Rich Kerstetter, Reporter, Centre Daily Times, State College, PA
Yuri Plowden, Soil Scientist, USDA-NRCS, University Park, PA

Activities:
All field activities were completed on 31 March 2004.

Results:

1. Ground-penetrating radar (GPR) and electromagnetic induction (EMI) methods did not detect the presence of a larger subsurface solution feather at the Steven's Farm in Clinton County. Based on geophysical interpretations, the visible solution cavity does not appear to be connected with any larger and distinguishable subsurface feature.

2. At Old Fort, based on detailed GPR grid mapping at two suspected sites, no subsurface reflections were identified that could unambiguously be interpreted as remnants of Potter's Fort or as other buried cultural features.

As always, it is my pleasure to work in Pennsylvania and with members of your fine staff.

With kind regards,

James A. Doolittle
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cc:

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Equipment:
Geonics Limited manufacturers the EM31meter.[1] This meter is portable and requires only one person to operate. No ground contact is required with this meter. Lateral resolution is approximately equal to the intercoil spacing. McNeill (1980) has described the principles of operation for the EM31 meter. The EM31 meter has a 3.7 m intercoil spacing and operates at a frequency of 9,810 Hz. When placed on the ground surface, the EM31 meter has effective penetration depths of about 3.0 and 6.0 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1980). The Geonics DAS70 Data Acquisition System was used to record and store both EM31 and GPS data.[1] The acquisition system consists of an EM31meter, Allegro field computer, and Trimble AG114 GPS receiver. [1] With the logging system, the EM31 meter is keypad operated and measurements are automatically triggered.

To help summarize the results of the EMI survey, the SURFER for Windows, version 8.0, developed by Golden Software, Inc., was used to construct a two-dimensional simulation.[1] The grid was created using kriging methods with an octant search.

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR System-3000), manufactured by Geophysical Survey Systems, Inc.[1] The SIR System-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 System-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. With an antenna, this system requires two people to operate. A 400 MHz antenna was used in the studies described in this report. The use and operation of GPR are discussed by Morey (1974), Doolittle (1987), and Daniels (1996).

The RADAN for Windows (version 5.0) software program developed by Geophysical Survey Systems, Inc, was used to process the radar records. [1] Processing included setting the initial pulse to time zero, color table and transformation selection, marker editing, distance normalization, and range gain adjustments. In addition all radar records were migrated to remove hyperbola diffractions and to correct the geometry of steeply dipping layers. Radar records from the Potter's Fort site were processed into a three-dimensional image using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc. [1] Once processed, arbitrary cross sections and time slices were viewed and selected images attached to this report.

Solution Feature, Clinton County:
A small, solution feature had open up in a cultivated field owned by John Stevens on Dumm Road near Clintonville. Ground-penetrating radar (GPR) and electromagnetic induction (EMI) surveys were completed on a portion of the field in an attempt to determine the subsurface extent of a visible solution feature and to determine whether additional, larger subsurface solution features exist and pose a potential hazard. The field is located in an area that had been mapped as Huntington fine sandy loam (Steputis, 1966), but the map unit has been re-correlated as Barbour fine sandy loam. The very deep, well drained Barbour soil formed in recent alluvial deposits on flood plains. Barbour is a member of the coarse-loamy over sandy or sandy skeletal, mixed, active, mesic Fluventic Dystrudepts family.

<u>GPR Survey:</u>
Two traverse lines (24 and 30 m in length) were established near the solution feature. The lines were orthogonal to each other. Along each line reference flags were inserted in the ground at 3 m intervals. The relative locations of these lines and the solution feature are shown in Figure 2. Pulling the 200 MHz antenna along each line completed the GPR survey. Along each line, as the antenna was towed passed a reference point, a vertical mark was impressed on the radar record.

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

Based on a hyperbola-matching program in RADAN Windows NT, the velocity of propagation was observed to decrease with increasing depth, but averaged about 0.08 m/ns through the upper part of the soil profile. Using this velocity, a scanning time of 130 nanoseconds provided a maximum penetration depth of about 5.3 m.

Figure 1 is a portion of the radar record taken from the northeast to southwest trending traverse line. In this radar record, north is to the left and south is to the right. The depth scale is in meters. The white vertical marks at the top of the radar record represent reference points that are spaced about 3 m apart. The vertical scale is exaggerated on this radar record. In Figure 1, the approximate location of the solution cavity has been identified with a green-colored oval.

The 200 MHz antenna did not detect any major subsurface manifestation of the solution feature. The solution feature is small and limited in extent. No subsurface reflections are apparent on the radar records that would suggest the presence of a large, subsurface solution feature. If present, additional subsurface solution features appear to be restricted and too small to be detected with GPR. The numerous point reflectors evident on the record (see Figure 1) are believed to represent coarse fragments that typify the Barbour soil. A series of high-amplitude, step-liked, parallel reflectors appear to descend from a depth of about 1 m (left-hand portion of radar record) to a depth of about 3-m (right-hand portion of radar record). The identity of these interfaces is unknown; however their appearance does suggest a ledge-like feature. If rock, no major solution feature is evident within or beneath these interfaces. Multiple, medium-amplitude, disjointed or segmented horizontal planar reflectors are evident both above and below the high-amplitude, step-liked features. These wavy to near-horizontal, medium-amplitude, planar reflectors are believed to represent contrasting layers within the alluvium or strata in the underlying bedrock (?). As no deep corings were completed at the time of this investigation, these interpretations remain unconfirmed and tentative.

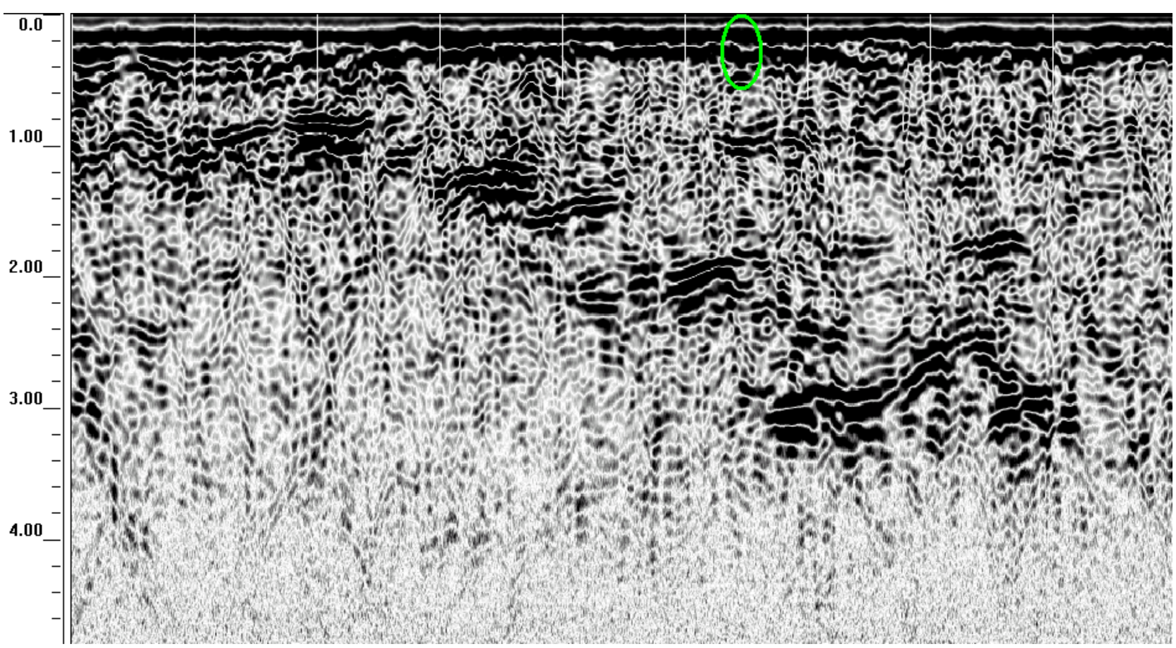

Figure 1. Radar record of traverse line that was completed at the sinkhole site with the 200 MHz antenna.

EMI Survey:

An EMI survey was competed over a larger portion of field that contained the solution feature than the area that was traversed with GPR (see Figure 2). The EM31 meter held at hip height and operated in the vertical dipole orientation with its long axis parallel to the direction of traverse. The EM31 meter was operated in the continuous mode and the DAS 70 Acquisition System recorded a geo-referenced apparent conductivity (EC_a) measurement at 1-sec intervals. Walking at a fairly brisk and uniform pace, in a random back and forth pattern across the field, 532 geo-referenced EC_a measurements were recorded.

Apparent conductivity was exceedingly low and invariable across the surveyed portion of the field. Apparent conductivity averaged 5.6 mS/m (milliSiemens per meter), with a range of 3.0 to 7.8 mS/m. The results from the EMI survey are nondescript and provide no direct and conclusive evidence supporting the presence of any major subsurface solution feature at the site. Solution features, if present, are too small and do not contrast sufficiently with the encompassing soil matrix to be detected with EMI. The underlying sandy or sandy skeletal deposits of Barbour soil are very resistive and provide a generally unfavorable medium for detecting voids. The spatial patterns evident in Figure 2 are believed to principally reflect variations in the clay content of Barbour soils.

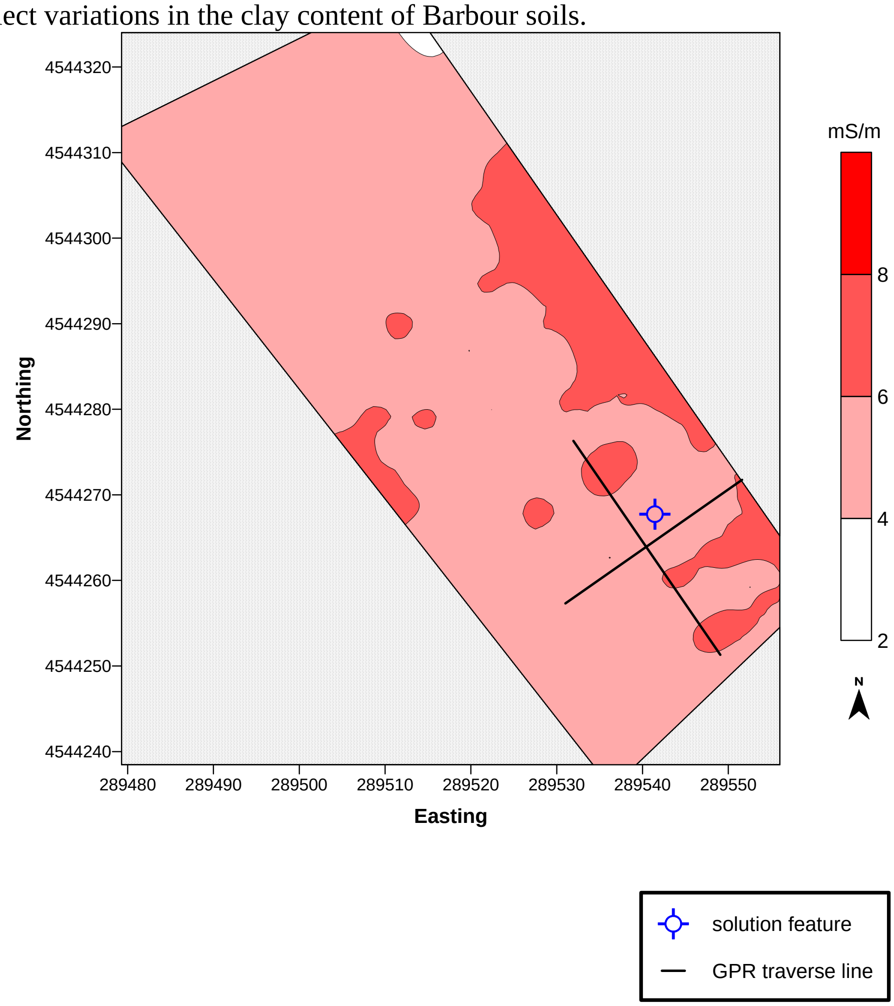

Figure 2. Plot of ECa data collected at the John Steven's Farm with the EM31 meter in the vertical dipole orientation.

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Site of Potter's Fort, Centre County:
A colonial era log fort was located near the intersection of Pennsylvania highways 45 and 144 in Centre County. This intersect is known as Old Fort and is located just to the southeast of Centre Hall. A

historical marker near the site commemorates the fort, which was known as Potter’s Fort. The fort was a wooden structure.

Two areas were selected by local historians and archaeologists as probable locations for the fort. Both sites were located in pasture. The higher-lying site is located in an area that had been mapped as Opequon-Hagerstown complex, 3 to 8 percent slopes (Braker, 1981). The lower-lying site is located near a spring in an area that had been mapped as Lindside soils (Braker, 1981). The well-drained, shallow Opequon and very deep Hagerstown soils formed in residuum weathered from limestone on uplands. The Opequon series is a member of the clayey, mixed, active, mesic Lithic Hapludalfs family. The Hagerstown series is a member of the fine, mixed, semiactive, mesic Typic Hapludalfs family. The very deep, moderately well drained Lindside soil formed in alluvium. The Lindside series is a member of the fine-silty, mixed, active, mesic Fluvaquentic Eutrudepts family.

A favorable feature of GPR for archaeological investigations is its ability to detect disturbances and the intrusion of foreign materials in soils. Results vary with soil conditions. In some soils, rates of signal attenuation are so severe that GPR cannot profile to the required depths. At Old Fort soils are shallow to very deep to limestone bedrock, which is relatively transparent to GPR. The relatively high clay content of the soils is especially attenuating to radar signals. In general, soils with high clay contents provide generally unfavorable environments for the use of GPR. However, in this area of Hagerstown, Lindside, and Opequon soils, profiling depths and resolution of subsurface features were found to be adequate for this investigation. To improve resolution of subsurface features, a higher frequency 400 MHz antenna was used in this investigation.

Two grids were laid out at the suspected sites of Potter's Fort. The upslope grid had dimensions of 10 by 10 m. The downslope grid had dimensions of 7 by 6 meters. The upslope grid consisted of 21, 10-m survey lines. The downslope grid consisted of 13, 7-m survey lines. Along each survey line, reference points were spaced at 1-m intervals. Pulling the 400 MHz antenna, in a back and forth manner, along equally spaced (50-cm) survey lines completed the GPR survey of each grid. Along each survey line, as the antenna was towed passed a reference point, a vertical mark was impressed on the radar record.

On radar records, the depth, shape, size, and location of subsurface features can be used to identify buried cultural features. In the past, reflections were identified and correlated on two-dimensional radar records. Often, in soils with complex stratigraphy or high amounts of background noise, cultural features that produced low or moderate amplitude reflections are obscured and difficult to detect on individual radar records. The use of three-dimensional (3-D) imaging techniques have helped to augment interpretations, reduce uncertainties, and aid identification of buried cultural features.

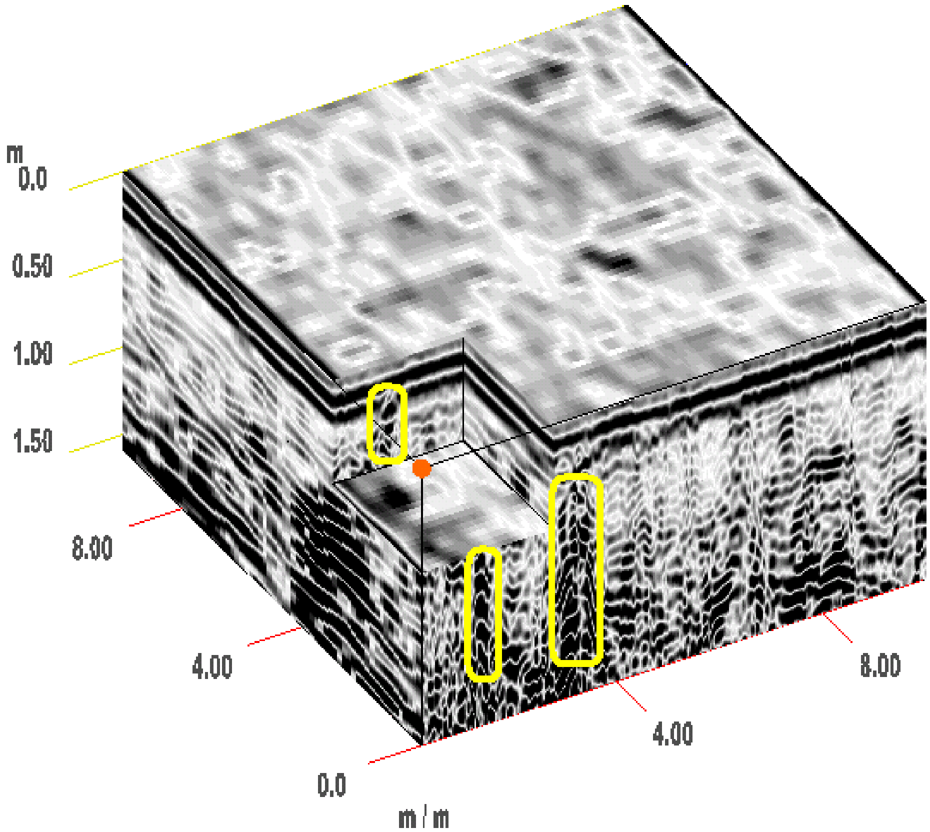

Figure 3. Three dimensional block diagram of the upslope grid site at Old Fort.

Figure 3 is a 3-D image of the upslope grid area at Old Fort. This image was derived from the computer analysis of a series of closely spaced, two-dimensional radar records. In this 3-D image, all scales are in meters. The origin is located in the southeast corner of the grid. North is to the right and is aligned with the x axis. A small slice has been taken out of a portion of this cube to a depth of about 60 cm. Several high-amplitude point reflectors have been identified in the lower left-hand corner of the 3D image (from the higher lying, southeast corner of the survey area). These reflectors have been enclosed with yellow-colored rectangular boxes. Several of these features appear to form linear features in the slice. Linear subsurface features often represent buried cultural features. In this example, a buried wall is suspected. However, these features could also represent limestone pinnacles or the strike of bedding planes. No features were identified at this site that could unambiguously be interpreted as remnants of the fort.

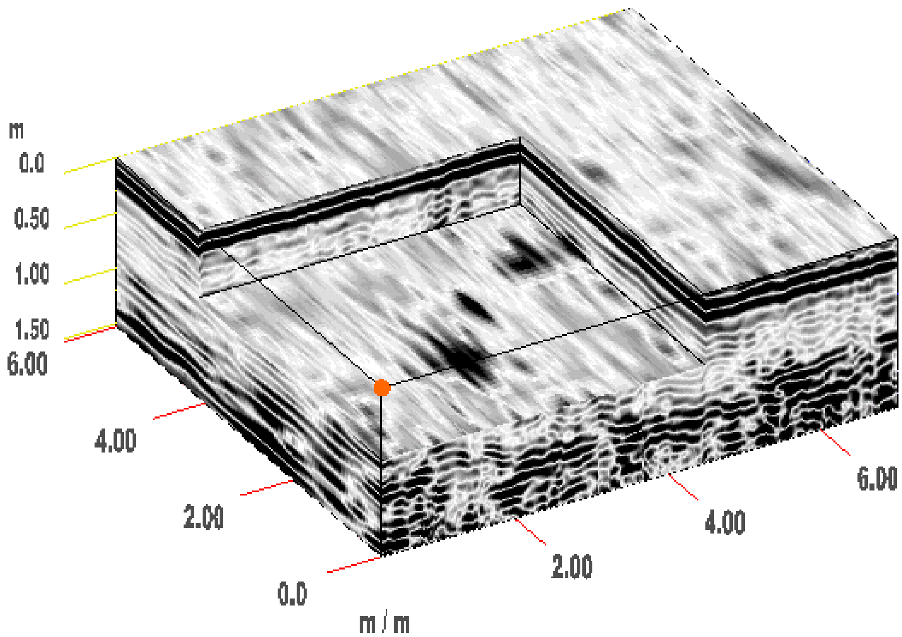

Figure 4. Three dimensional block diagram of the downslope grid site at Old Fort.

Figure 4 is a 3-D image of the downslope grid area at Old Fort. This grid was located just to the south of a spring and is in a somewhat poorly drained included soil area within the mapped Lindside polygon. All scales are in meters. The origin is located in the northeast corner of the grid. North is toward the viewer and is aligned with the y axis. A fairly large slice has been taken out of this cube to a depth of about 60 cm. Several high-amplitude planar reflectors are apparent in the time slice. These features appear to form linear features in the slice. However, as no cores were taken, interpretations remain unconfirmed and tentative. Once again, no features were identified at this site that could unambiguously be interpreted as remnants of the fort.

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