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

Subject: SOI – Geophysical Field Assistance **Date:** 4 September 2003

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Purpose:
In Huntington County, ground-penetrating radar (GPR) and electromagnetic induction (EMI) were used to assist the Pennsylvania State University's Hydropedology Team map spatial variations in soils and soil properties within the Shale Hills watershed. In Potter County, GPR was used to determine the depths to bedrock and the composition (by soil depth class) of soil map units.

Participants:
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Activities:
All field activities were completed on 26 to 29 August 2003.

Results:

1. Preliminary studies at the Shale Hills watershed indicate that both ground-penetrating radar and electromagnetic induction can supply some soil information to researchers. The watershed is well instrumented and has had an order one survey completed. This small, forested watershed provides an excellent and accessible site to study spatial and temporal variations in apparent conductivity with EMI. Variations in apparent conductivity will reflect, in part, differences in soil water content and groundwater levels.

2. I wish to propose that I return to the Shale Hills Watershed every three months for a period of at least one year to complete EMI surveys, which will document spatial and temporal variations in apparent conductivity within the watershed. EMI surveys of the watershed can be completed in one day. For each survey, I will require the assistance of Brad Georgic of Pennsylvania State University. For these assignments, no assistance is required from the NRCS staff in Pennsylvania.

3. In many areas of Pennsylvania, it is exceedingly difficult to examine soil profiles and determine the depth to bedrock with conventional soil survey tools. Rock fragments limit the depth of observation and our understanding of bedrock depths within many soil map units. GPR provides a continuous record of the subsurface and can be effectively used to chart bedrock depths.

4. Fifteen transect with 254 observations were obtained with GPR in areas of Hartleton soil on B, D, and F slopes. Based on radar interpretations soils were dominantly moderately deep (75% of observations), with inclusions of deep (23%) and shallow (2%) soils. Ten transect with 150 observations were obtained with GPR in areas of Hazleton soil on B slopes. Based on radar interpretations soils were dominantly moderately deep (84% of observations), with inclusions of deep (9%) and shallow (7%) soils.

It was 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:
The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2000 consists of a digital control unit (DC-2000) with keypad, VGA video screen, and connector panel. A 12-volt battery powers the system. This unit is backpack portable and, with an antenna, requires two people to operate. The antennas used in this study have center frequencies of 200 and 400 MHz.

The RADAN NT (version 2.0) software program developed by Geophysical Survey Systems, Inc., was used to process the radar records shown in this report.[1] Processing included color transformation, marker editing, distance normalization, and range gain adjustments. Radar records collected at PSU's Shale Hills watershed were converted into bitmap images using the Radan to Bitmap Conversion Utility (version 1.4) developed by Geophysical Survey Systems, Inc.[1]

The electromagnetic induction meter used in this survey was the EM31 meter manufactured by Geonics Limited.[1] This meter is portable and requires only one person to operate. No ground contact is required with this meter. The EM31 meter has a 3.66 m intercoil spacing and operates at a frequency of 9,810 Hz. When placed on the soil 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, 1980a).

To help summarize the results of this study, SURFER for Windows (version 8.0) software developed by Golden Software,

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

Inc.,[1] was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search.

Shale Hills Watershed:

The Pennsylvania State University's Hydropedology Team is studying spatial and temporal variations in soil properties that influence soil water and flow processes at different scales within the Shale Hills watershed. The Shale Hills watershed is located near the Stone Valley Recreation center in Huntingdon County (~15 miles from State College). This forested watershed is relatively small (19.2 acres) and well defined. Figure 1 shows the relative topography for most of the watershed. This map was prepared from GPS measurements collected at 72 observation points. Based on these measurements, elevations range from 232.5 to 275.8 m within the watershed. In Figure 1, a small stream that drains the watershed is shown by a dotted line.

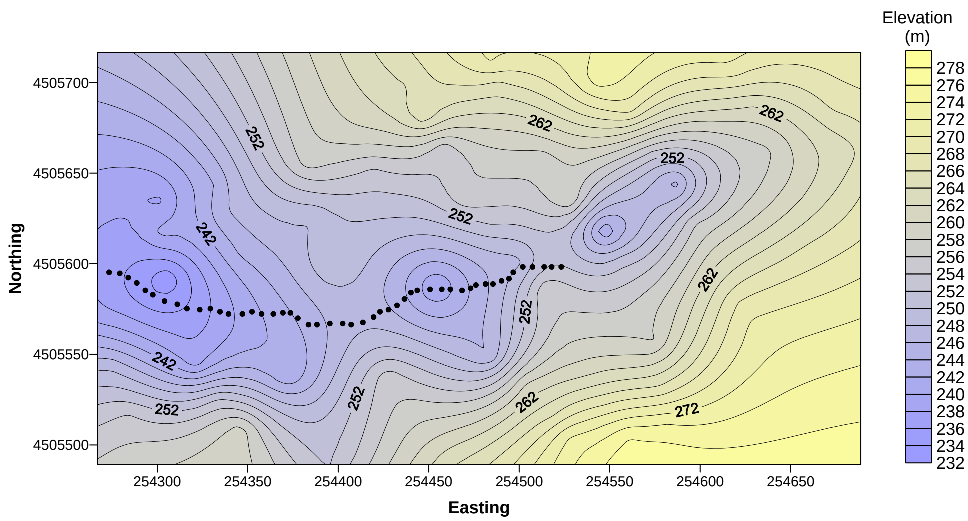

Figure 1. Relative topography of the Shale Hills Watershed (Based on GPS measurements).

The watershed had been mapped principally as Berks-Weikert association, steep, and Ernest silt loam, 3 to 8 percent slopes (Merkel, 1978). The watershed also includes small areas of Berks-Weikert shaly silt loam, 15 to 25 percent slopes, and Berks shaly silt loam, 8 to 15 percent slopes (Merkel, 1978). This year, Pennsylvania State University's Hydropedology Team developed a detailed soil map of the Shale Hills watershed. Modifications to the USDA soil map include consociations of Berks, Blairton, Ernest, and Rushtown soils in swales and along the stream channel. Weikert soil dominates the remainder of the watershed. These soils contain large amounts of rock fragments and have varying depths to thinly bedded and highly fractured bedrock. Within the watershed, the underlying bedrock is Rosehill shale.

All soils formed in materials weathered from shale. The well drained, shallow Weikert and moderately deep Berks soils are on gently sloping to very steep areas on uplands. Weikert is a member of the loamy-skeletal, mixed, active, mesic Lithic Dystrudepts family. Depths to bedrock ranges from 25 to 50 cm (10 to 20 inches). The Berks soil is a member of the loamy-skeletal, mixed, active, mesic Typic Dystrudepts family. The moderately deep, somewhat poorly and moderately well drained Blairton soil is on upland flats and drainage heads. Blairton is a member of the fine-loamy, mixed, active, mesic Aquic Hapludults family. For Berks and Blairton soils, depths to bedrock range from 50 to 100 cm (20 to 40 inches).

The very deep, moderately well drained Ernest soil is on foot slopes and colluvial fans. Ernest is a member of the fine-loamy, mixed, superactive, mesic Aquic Fragiudults family. A fragipan is within depths of about 50 to 90 cm (20 to 36 inches). The very deep, excessively drained Rushtown soil is on linear to concave swales. Rushtown is a member of the loamy-skeletal over fragmental, mixed, active, mesic Typic Dystrudepts family. For Ernest and Rushtown soils, depths to bedrock are greater than 152 cm (60 inches).

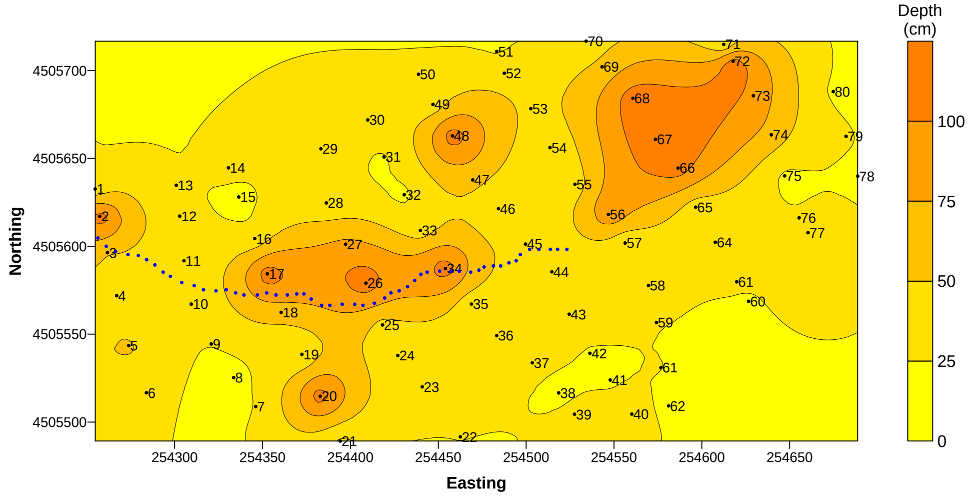

Figure 2. Simulated depths to bedrock within the Shale Hills Watershed.

Figure 2 shows the spatial distribution of bedrock depths within the Shale Hills Watershed. This map is based on 80 soil auger measurements. The locations of these observation points are shown in Figure 2. Based on 80 observations, depth to bedrock within the watershed averaged 44.2 cm with a range of 17.8 to 114.3 cm. One half of the observations had depths to bedrock between 25.4 and 45.7 cm.

Field Procedures:

Intense rain storms limited field work on both days. However, two GPR traverses were completed across a linear swale that contained areas of Rushtown, Berks, and Weikert soils. In addition, some data were collected with the EM31 meter.

Calibration of GPR:

Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from the 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 the following equation (Morey, 1974):

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

The velocity of propagation is principally affected by the dielectric permittivity (E) of the profiled material(s) according to the equation:

$$E = (C/V)^2 \qquad [2]$$

Where C is the velocity of propagation in a vacuum (0.298 m/ns). Velocity is expressed in meters per nanosecond (ns). The amount and physical state of water (temperature dependent) have the greatest effect on the dielectric permittivity and the velocity of propagation through a material.

The velocity of propagation was determined by comparing the interpreted depth to a known reflector (buried metallic reflector) on a radar record with the measured depth. Based on the measured depth and the two-way travel time to this interface, and equation [1], the velocity of propagation was estimated to be about 0.086 m/ns. The dielectric permittivity was 12. A scanning time of 50 ns was used in this investigation. Using equation [1], a scanning time of 50 ns, and a propagation velocity of 0.086 m/ns, the maximum depth of observation was about 2.15 m.

Interpretation of radar records:

Compared with the 200 MHz antenna, the smaller 400 MHz antenna provided the best balance of observation depths and resolution of subsurface features. Figure 3 is a representative radar record collected with the 400 MHz antenna across the stream and along an elongated swale area of Earnest and Rushtown soils, respectively. The direction of travel was from south (left-hand portion of record) to north (right-hand portion of record). The depth scale is in meters and based on a propagation velocity of 0.086 m/ns. Because of image compression, the equally spaced (2 m) reference points along this 50 m line are obscured.

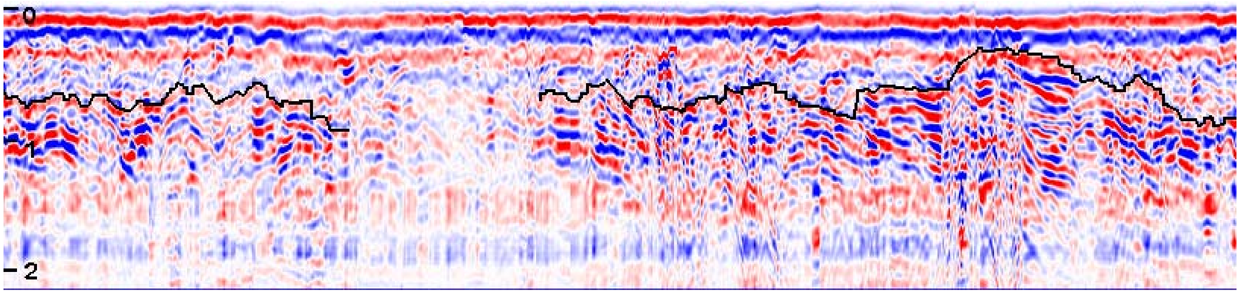

Figure 3. The interpreted depth to bedrock is shown on this radar record from the Shale Hills Watershed.

A black line on this radar record identifies the soil/bedrock interface. In Figure 3, the soil/bedrock interface varies in expression and clarity. In most areas, this interface consisted of irregular, discontinuous, high amplitude reflectors that typify a highly uneven and fractured boundary. In some areas, because of the abundance of rock fragments in the overlying soil, highly fractured bedrock surfaces, and varying degree of hardness exhibited by both rock fragments and the underlying bedrock, the soil/bedrock interface is often weakly expressed and obscured. In areas of Ernest soil located within and near the stream channel, because of higher moisture and clay contents, reflections are weaker and the soil/bedrock interface can not be trace laterally with any degree of confidence (see weaker reflections just to the left of center in Figure 3).

<u>EMI:</u>
Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are caused by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the type and concentration of ions in solution, the amount and type of clays, the volumetric water content, and the temperature and phase of the soil water (McNeill, 1980b). Apparent conductivity increases with increased soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

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 and soil properties. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations are normally used.

Figure 4 is a cross section of the watershed showing variations in apparent conductivity with landscape position. In Figure 4, the green line represents the ground surface. Relative relief (in meters) is shown on the Y-axis and is based on GPS measurements. Along this traverse line, relief is about 26.3 m. At each observation point measurements were obtained with the EM31 meter held at hip-height in the horizontal (blue line) and vertical (red line) dipole orientations. Apparent conductivity (in mS/m) is also shown on the Y-axis. Apparent conductivity is relatively low and consistent along higher-lying portions of this traverse line, but is higher and more variable on lower-lying slope positions. Measurements ranged from 3.6 to 9.8 mS/m. In general, measurements obtained with the deeper-sensing horizontal dipole orientation were higher than those obtained in the shallower-sensing horizontal dipole orientation. As seen in Figure 4 apparent conductivity increases on lower-lying slope positions and is highest for both dipole orientations along the stream bottom. The EM31 meter is believed to be responding principally to changes in soil moisture content and depth to water table.

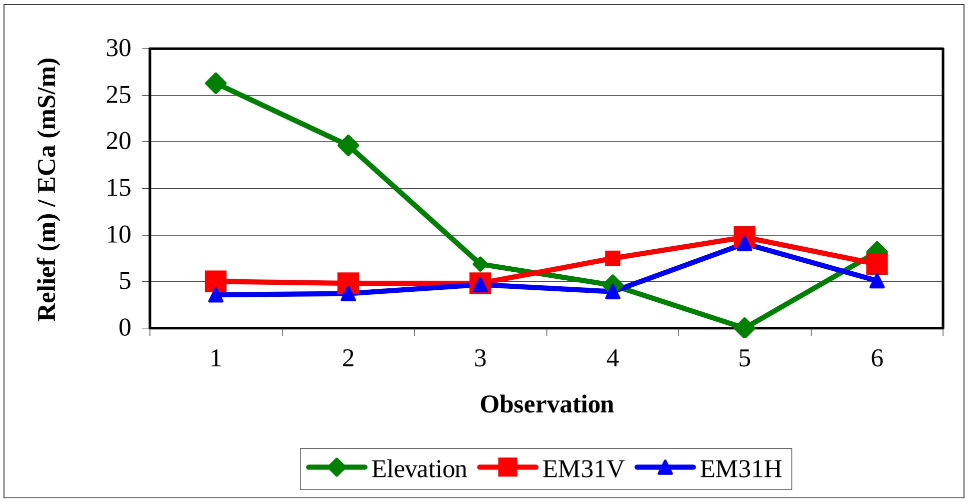

Figure 4. A cross-section of the Shale Hills Watershed showing changes in apparent conductivity measured with the EM31 meter in the horizontal (EM31H) and vertical (EM31V) dipole orientations with relative topographic positions.

Bedrock Investigations in Potter County:

<u>Background:</u>

In many upland areas of Pennsylvania, it is exceedingly difficult and impractical to determine bedrock depths with traditional soil survey tools. Numerous rock fragments restrict the penetration of shovels and augers. Soil scientists spend undue amount of time and energy attempting to determine the depth to bedrock only to be refused, in many instances, by rock fragments. In addition, uncertainties arise as to whether auger penetration was restricted by a large rock fragment or bedrock. Backhoes provide accurate and reliable soil depth information. However, backhoe pits are limited in number and widely spaced. Inferences on the depth to bedrock must be extended across the more expansive areas between a limited number of pits. As a consequence, the composition of soil map units based on soil-depth criteria is constrained by limit exposures and burdened by partial, detached, or inadequate data.

In many areas, GPR is well suited to soil-bedrock determinations. Collins and others (1989) demonstrated that GPR is more reliable and effective than the soil auger used by soil scientist to map bedrock depths. These researchers found a high (r = 0.98) and significant (0.01 level) relationship between excavated and radar interpreted bedrock depths. In their study, the average difference between actual and radar interpreted depths to bedrock was only 6 cm with 87% of the observations within 10 cm of the interpreted depths. For depths to bedrock less than 4 m, Birkhead and others (1996) observed an average error between observed and radar interpreted measurements of 4.4 %.

<u>Study Areas:</u>

Traverses were conducted in areas of Hartleton and Hazelton soils. The deep well drained Hartleton soil formed in glacial till or frost-churned materials derived from sandstone and shale on uplands. Hartleton is a member of the loamy-skeletal, mixed, active, mesic Typic Hapludult family. The deep and very deep, well drained Hazleton soil formed in residuum of acid gray, brown or red sandstone on uplands. Hazleton is a member of the loamy-skeletal, siliceous, active, mesic Typic Dystrudept family.

On the morning of 28 August, multiple radar traverses were conducted in areas of Hartleton soil on Big Nelson Run Road in Sylvania Township (NW1/4 of the Conrad 7.5 min Quadrangle). On the afternoon of 28 August, multiple radar traverses were conducted in areas of Hartleton soil in Portage Township (NW1/4 of the Wharton 7.5 min Quadrangle). These areas are underlain by the Huntley Mountain formation, which consists of sandstone with some interbeds of shale. On the morning of 29 August, multiple radar traverses were conducted in areas of Hazelton soil on Pipe Line Hollow Road in the NW1/4 of the Oleona 7.5 min Quadrangle. This area is underlain by the Pottsville formation (sandstone). Elevations were about 1750 ft.

Field Procedures:
Multiple transect were conducted in areas of map units HhB, Hartleton channery silt loam, 0 to 8 percent slopes; HhD, Hartleton channery silt loam, 8 to 25 percent slopes; HhF, Hartleton channery silt loam, 25 to 60 percent slopes; and HaB, Hazleton channery sandy loam, 0 to 8 percent slopes.

Pulling the antenna by hand completed radar surveys. Although, traverses were conducted along trails and logging roads, care was taken to select areas with a minimum of cut and fill. For all but the first transect, observation points were spaced at intervals of about 10 m. For transect 1, the interval was 5 m. At each observation point, the radar operator impressed a dashed, vertical line on the radar record. This line identified an observation point on the radar record. At each observation point, the depth to bedrock was interpreted from the radar record.

The velocity of propagation was determined by comparing the interpreted depth to a known reflector (buried metallic reflector) on the radar record with its measured depth. Based on the measured depth and the two-way travel time to this interface, and equation [1], the velocity of propagation was estimated to be about 0.095 m/ns. The dielectric permittivity was 9.8. Using equation [1], a scanning time of 50 ns, and a propagation velocity of 0.095 m/ns, the maximum depth of observation on radar records was 2.38 m.

Interpretation of radar records:
The soil/bedrock interface was identifiable on all radar records. However, in most areas, this interface consisted of irregular, discontinuous, high amplitude reflectors. Because of the abundance of similar rock-type fragments in the overlying soil, highly fractured bedrock surface, and varying degree of hardness exhibited by both rock fragments and the underlying bedrock, the soil/bedrock interface was often ambiguous and difficult to accurately trace.

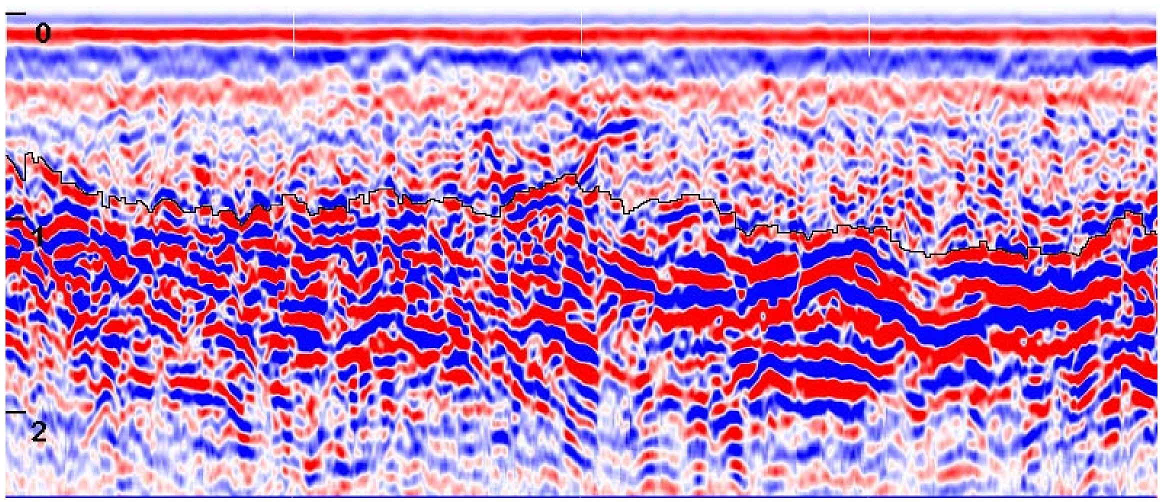

Figure 5. A radar record from an area of Hartleton channery silt loam, 8 to 25 % slopes in Potter County.

Figure 5 is a representative radar record from and area of Hazleton channery silt loam, 0 to 8 % slopes. A black line on this radar record identifies the soil/bedrock interface. The large number of rock fragments in the overlying soil, and the irregular and highly fractured bedrock surface obscures the clarity of the soil/ bedrock interface. As a consequence, the identification of the soil/bedrock interface is more ambiguous and line placement may err by as much as 25 cm.

Results:
Table 1 summarizes the frequency distribution of observations by soil depth classes (depth to bedrock) for each radar transect collected in Potter County. Depth classes are shallow (0 to .5 m), moderately deep (.5 to 1.0 m), and deep (1.0 to 1.5 m). No very deep (>1.5 m) soil was observed in the areas that were traversed with GPR.

Appendix 1 and 2 summarizes the interpreted depths to bedrock for each traverse conducted within Hartleton and Hazelton soil map units, respectively (files 11 to 35). For each radar traverse, a file number and map unit symbol is given. All depths are expressed in meters. The GPR data revealed a most unexpected finding: that all traversed areas are dominated by moderately deep soils with minor inclusions of deep and shallow soils.

Table 1. Frequency distribution of Observations along Radar Traverses according to Soil Depth Classes (all measurements are in m)

MU	Obs.	Shallow	Mod. Deep	Deep
HhB	10	0.00	0.90	0.10
HhD	15	0.00	0.73	0.27
HhD	17	0.00	0.59	0.41
HhD	16	0.00	0.81	0.19
HhF	16	0.00	0.75	0.25
HhD	17	0.00	0.82	0.18
HhD	21	0.05	0.76	0.19
HhD	14	0.00	0.71	0.29
HhD	11	0.00	0.91	0.09
HhD	19	0.05	0.68	0.26
HhD	19	0.05	0.79	0.16
HhB	24	0.00	0.54	0.46
HhD	19	0.00	0.74	0.26
HhB	20	0.05	0.95	0.00
HhB	16	0.06	0.56	0.38
HaB	15	0.07	0.73	0.20
HaB	15	0.27	0.73	0.00
HaB	15	0.07	0.87	0.07
HaB	15	0.20	0.80	0.00
HaB	15	0.00	0.80	0.20
HaB	15	0.00	1.00	0.00
HaB	15	0.00	0.67	0.33
HaB	15	0.00	0.87	0.13
HaB	15	0.07	0.93	0.00
HaB	15	0.00	1.00	0.00

References:

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Appendix 1
Hartleton soil map units, Potter County, Pennsylvania

FILE 11 HhB

OBS.	DEPTH
0	0.71
10	0.81
20	0.8
30	0.95
40	0.78
50	1.15
60	0.94
70	0.89
80	0.93
90	0.88

FILE 12 HhB

OBS.	DEPTH
0	0.83
10	0.78
20	0.96
30	1.15
40	1.01
50	0.71
60	0.82
70	1
80	1.02
90	0.97
100	0.82
110	1.05
120	0.96
130	0.84
140	0.79

FILE 13 HhD

OBS.	DEPTH
0	1.02
10	1.06
20	0.64
30	1.08
40	0.93
50	1.07
60	0.92
70	0.75
80	0.66
90	0.85
100	0.7
110	1.03
120	1.07
130	0.71
140	0.97
150	1.02
160	0.83

FILE 14 HhD

OBS.	DEPTH
0	0.9
10	0.73
20	0.9
30	1.04
40	0.98
50	0.61
60	0.9
70	0.9
80	0.75
90	1.1
100	0.75
110	1.05
120	0.85
130	0.84
140	0.69
150	0.71

FILE 15 HhF

OBS.	DEPTH
0	0.67
10	0.77
20	0.68
30	1.16
40	0.86
50	0.9
60	0.85
70	0.9
80	0.89
90	0.94
100	0.9
110	1.12
120	0.85
130	1.01
140	0.91
150	1.01

FILE 16 HhD

OBS.	DEPTH
0	0.9
10	0.98
20	0.62
30	0.68
40	1.01
50	1.18
60	0.81
70	0.67
80	1.01
90	0.84
100	0.98
110	0.61
120	0.85
130	0.93
140	0.65
150	0.75
160	0.66

FILE 17 HhD

OBS.	DEPTH
0	0.87
10	0.78
20	0.77
30	0.76
40	0.96
50	0.9
60	0.71
70	0.91
80	0.7
90	0.39
100	1.22
110	0.9
120	1.24
130	0.94
140	0.87
150	0.94
160	1.09
170	0.91
180	0.94
190	1.13
200	0.92
210	1.68

FILE 18 HhD

OBS.	DEPTH
0	0.76
10	1.01
20	0.87
30	1.05
40	0.64
50	1.05
60	0.83
70	0.78
80	1.03
90	1
100	0.98
110	0.84
120	0.61
130	0.87

FILE 19 HhD

OBS.	DEPTH
0	0.88
10	0.85
20	0.96
30	0.94
40	0.9
50	0.99
60	0.92
70	0.97
80	0.91
90	0.87
100	1.02

Appendix 1 (continued)
Hartleton soil map units, Potter County, Pennsylvania

FILE 20 HhD

OBS.	DEPTH
0	0.65
10	0.77
20	0.84
30	0.9
40	0.59
50	0.84
60	0.49
70	0.68
80	1.02
90	0.81
100	0.97
110	1.04
120	1.08
130	0.87
140	0.94
150	1.18
160	1.17
170	0.73
180	0.91

FILE 21 HhD

OBS.	DEPTH
0	1.01
10	0.6
20	0.92
30	1.17
40	0.49
50	0.81
60	0.8
70	0.98
80	0.75
90	0.8
100	0.84
110	1.05
120	0.81
130	0.65
140	0.55
150	0.83
160	0.57
170	0.74
180	0.94

FILE 22 HhB

OBS.	DEPTH
0	0.91
10	1.15
20	0.87
30	0.89
40	0.93
50	1.28
60	0.93
70	1.06
80	1.05
90	0.79
100	0.69
110	1.03
120	0.94
130	1.02
140	1.06
150	0.73
160	0.58
170	0.57
180	1.14
190	1.13
200	1.11
210	1.05
220	0.88
230	0.73

FILE 23 HhD

OBS.	DEPTH
0	0.61
10	0.62
20	0.73
30	1.08
40	1.04
50	0.97
60	0.78
70	0.58
80	0.85
90	0.82
100	0.84
110	1.03
120	1.02
130	0.71
140	0.92
150	0.8
160	0.93
170	1.02
180	1

FILE 24 HhB

OBS.	DEPTH
0	0.49
10	0.73
20	0.73
30	0.83
40	0.81
50	0.97
60	0.69
70	0.81
80	0.79
90	0.6
100	0.9
110	0.91
120	0.58
130	0.92
140	0.88
150	0.78
160	0.85
170	0.9
180	0.82
190	0.77

FILE 25 HhB

OBS.	DEPTH
0	0.87
10	0.9
20	0.77
30	0.7
40	0.49
50	0.97
60	0.96
70	1.08
80	0.92
90	0.87
100	1.14
110	1.05
120	1.01
130	1.06
140	1.24
150	0.87

Appendix 2
Hazleton soil map units, Potter County, Pennsylvania

FILE 26

OBS.	DEPTH
0	0.85
10	1.31
20	0.91
30	0.39
40	0.87
50	0.63
60	0.8
70	0.9
80	0.95
90	0.73
100	1.02
110	0.75
120	0.84
130	1.08
140	0.78

FILE 29

OBS.	DEPTH
0	0.94
10	0.57
20	0.7
30	0.63
40	0.84
50	0.96
60	0.46
70	0.46
80	0.99
90	0.63
100	0.69
110	0.79
120	0.82
130	0.95
140	0.49

FILE 32

OBS.	DEPTH
0	1.02
10	1.03
20	0.77
30	0.96
40	0.92
50	0.79
60	0.79
70	0.65
80	0.79
90	1.21
100	1.06
110	0.83
120	0.73
130	0.74
140	1.02

FILE 27

OBS.	DEPTH
0	0.65
10	0.93
20	0.91
30	0.93
40	0.86
50	0.76
60	0.76
70	0.73
80	0.41
90	0.39
100	0.68
110	0.84
120	0.41
130	0.45
140	0.59

FILE 30

OBS.	DEPTH
0	0.72
10	1.33
20	0.66
30	0.79
40	0.56
50	1.15
60	0.97
70	0.76
80	0.73
90	0.9
100	0.87
110	0.59
120	0.72
130	0.79
140	1.04

FILE 33

OBS.	DEPTH
0	0.78
10	1.11
20	0.88
30	1.01
40	0.83
50	0.91
60	0.98
70	0.74
80	0.74
90	0.88
100	0.7
110	0.76
120	0.57
130	0.92
140	0.73

FILE 28

OBS.	DEPTH
0	0.76
10	0.78
20	0.97
30	1.04
40	0.7
50	0.73
60	0.52
70	0.6
80	0.87
90	0.68
100	0.96
110	0.85
120	0.57
130	0.45
140	0.77

FILE 31

OBS.	DEPTH
0	0.51
10	0.88
20	0.83
30	0.75
40	0.65
50	0.61
60	0.86
70	0.72
80	0.74
90	0.71
100	0.69
110	0.82
120	0.85
130	0.81
140	0.81

FILE 34

OBS.	DEPTH
0	0.66
10	0.54
20	0.5
30	0.78
40	0.89
50	0.78
60	0.79
70	0.77
80	0.88
90	0.94
100	0.76
110	0.93
120	0.99
130	0.87
140	0.74

Appendix 2 (Continued)
Hazleton soil map units, Potter County, Pennsylvania

FILE 35

OBS.	DEPTH
0	0.85
10	0.81
20	0.75
30	0.8
40	0.83
50	0.66
60	0.65
70	0.87
80	0.97
90	0.83
100	0.77
110	0.93
120	0.72
130	0.66
140	0.65