United States Department of Agriculture

NRCS

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SUBJECT: MGT – Trip Report - Geophysical Assistance August 2, 2012

TO: Patricia S. Leavenworth
State Conservationist
NRCS, Madison, Wisconsin

File Code: 330-20-7

Purpose:
This study collected soil depth information with ground-penetrating radar (GPR) in areas that are mapped as complexes of Dunbarton soils in Southwest Wisconsin. This information will be used to support changes in soil survey legend and interpretative data.

Participants:
Jeff Deniger, Resource Soil Scientist, USDA-NRCS, Richland Center, WI
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Mike England, Soil Scientist, USDA-NRCS, Onalaska, WI
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Donna Ferren Guy, Soil Scientist, USDA-NRCS, Onalaska, WI
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Kevin Traastad, Soil Scientist, USDA-NRCS, Onalaska, WI
Heather Watson, Graduate Student, University of Wisconsin, Department of Soil Science, Madison, WI
Larry West, National Leader, Soil Survey Research and Laboratory, USDA-NRCS-NSSC, Lincoln, NE

Activities:
Field activities were completed on June 18-22, 2012.

Summary:
1. Sixty-six radar records were collected in Dane, Green, Lafayette, and Rock Counties in areas mapped as Dunbarton and similar soils. Ground-penetrating radar provided copious, georeferenced data needed to validate bedrock depths in areas of Dunbarton soils.

2. Based on 596,958 radar depth measurements, in the areas traversed by GPR, the distribution of soils according to soil depth classes is 7% shallow (< 20 inches), 90% moderately deep (20 to 40 inches), and 3% deep (40 to 60 inches). Only 151 measurements (0.003%) classified as very deep (> 60 inches). These measurements confirm depths to bedrock that were suspected by field staffs.

3. Field assistance and refresher training was provided to Mike England on the processing of radar data.

4. In areas of Dunbarton soils, compared with the 200 MHz antenna, the 400 MHz antenna surprisingly provided the best balance of exploration depth and resolution of the soil/bedrock interface. As a rule, lower frequency antennas provide greater exploration depths, but poorer resolution of subsurface features. These results are unexpected because the Dunbarton series belongs to a clayey particle-size class and a smectitic mineralogy class. These factors should result in a very poor suitability for GPR soil investigations and very restricted penetration depths.

5. Dave Evans, Natalie Irizarry Rivera, Shaunna Repking, and Heather Watson were provided training on calibration and survey procedures for the EM38 meter with global positioning system (GPS).

6. In an area mapped as Edmund and Whalen soils, apparent conductivity values recorded with the EM38 meter were exceedingly low and spatially invariable. The exceedingly dry soil moisture conditions and the relative shallow depths to electrically resistive bedrock are believed to have contributed to the low EC_a.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to be of assistance to your staff and cooperators.

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc:
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Linda A. Kruger, Secretary, Soil Survey Research & Laboratory, NSSC, MS 41, NRCS, Lincoln, NE

Technical Report on Geophysical Investigations conducted in areas of Dunbarton Soils on June 18-22, 2012

James A. Doolittle

Background:

Field office staffs in Dane, Green, and Lafayette Counties have reported higher productivity and associated greater depths to bedrock than reported in the Soil Data Mart for areas that had been mapped as Dunbarton (clayey, smectitic, mesic Lithic Hapludalfs) soils. When using the T-factor calculator, the depth to bedrock significantly affects the assigned T-factor and, therefore, soil use. When these counties were originally mapped (pre-1971), it is likely that observation depths were limited by a rubble layer, which overlies the dolomite or other limestone bedrock in areas of Dunbarton soils. The high concentration of channers in this layer is believed to have limited the depth and number of observations that were made with spade and auger. Ground-penetrating radar (GPR) can provide large, georeferenced data sets that can help overcome issues of data insufficiency and incorrectness, and validate the depth to bedrock. The purpose of this geophysical investigation is to provide improved information on the depth to bedrock in areas that are mapped as Dunbarton soils. Ground-penetrating radar data will be used to support recommendations for changes in soil survey legends and interpretative data.

Equipment:

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. (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 4.1 kg (9 lbs) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Jol (2009) and Daniels (2004) discuss the use and operation of GPR. The 200 and 400 MHz antennas were used in this study. However, after initial calibration trials, the 400 MHz antenna was selected as the most appropriate antenna, as it surprisingly provided the best balance of exploration depth and resolution of the soil/bedrock interface.

The RADAN for Windows (version 6.6) software program (GSSI) was used to process the radar records.[1] Processing included: header editing, positioning the initial pulse to time zero, color table and transformation selection, signal stacking, horizontal high pass filtration, and range gain adjustments (refer to Jol (2009) and Daniels (2004) for discussions of these techniques).

The SIR-3000 system provides a setup for the use of a GPS receiver. With this setup, each scan on radar records can be georeferenced (position/time matched). During data processing, a subprogram within RADAN is used to proportionally adjust the position of each radar scan according to the time stamp of the two nearest positions recorded with the GPS receiver. A Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack) was used to georeference data collected with the SIR-3000 system.[1]

The *Interactive 3D Module* of RADAN for Windows (version 6.6) was used to semi-automatically pick the depths to the soil/bedrock interface. The picked data were outputted to a worksheet (in an X, Y, and Z format); which included longitude, latitude, and depth to bedrock data).

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[1] Trade names are used for specific references and do not constitute endorsement.

An EM38 meter (Geonics Limited; Mississauga, Ontario) was used at one site.[1] This meter requires no ground contact and only one person to operate. These meters measure the apparent conductivity (EC_a) of the soil. Apparent conductivity is typically expressed in milliSiemens/meter (mS/m).

The EM38 meter operates at a frequency of 14,600 Hz and weighs about 1.4 kg (3.1 lbs). The meter has one transmitter and one receiver coil that are spaced 1-m apart. When placed on the soil surface, it has effective penetration depths of about 0.75 m and 1.5 m in the horizontal (HDO) and vertical (VDO) dipole orientations, respectively (Geonics Limited, 1998). A Garmin Global Positioning System Map 76 receiver was used to georeferenced the EC_a data.

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 the following equation (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 the following equation (after Daniels, 2004):

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

Where C is the velocity of propagation in a vacuum (0.3 m/ns). The velocity of pulse propagation is commonly 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 very dry.

At each site a metal plate was buried in the soil at depths ranging from 28 to 40 cm. Based on the measured depths and the two-way pulse travel times to this known subsurface reflector (metal plate), the velocity of propagation and the relative dielectric permittivity through the upper part of a soil profile were estimated using equations [1] and [2]. Using a 400 MHz antenna, the estimated E_r varied between 5.15 and 9.49. Using a 400 MHz antenna, the estimated v ranged from 0.0974 to 0.1322 m/ns. However, both v and E_r are known to vary spatially across landscapes and with depth. This variability will have an effect on soil depth measurements.

Survey Area:

Seven study areas were selected in Dane, Green, Lafayette, and Rock Counties. Area 1 (near 43.2291 ° N. latitude, 89.7236 ° W. longitude) is located on relatively open areas within the Blackhawk Wildlife Area in Dane County. The area is principally mapped as Dunbarton silt loam on 6 to 12 % slopes, eroded (DuC2) and NewGlarus silt loam on 2 to 6 % slopes, eroded (NeB2). The deep, well drained NewGlarus soils formed in loess and clayey pedisediment and in loamy residuum weathered from the underlying dolostone. NewGlarus is a member of the fine-silty over clayey, mixed, superactive, mesic Typic Hapludalfs taxonomic family. Area 2 (around 42.8566 ° N. latitude, 89.7094 ° W. longitude) is located in a CRP field on the Hudstad Farm in Green County. The area is principally mapped as Dunbarton silt loam on 6 to 12 percent slopes, moderately eroded (DuC2) and NewGlarus silt loam on 12 to 20 % slopes, moderately eroded (NiD2).

Areas 3 and 4 are located in areas of CRP, hay lands, and pasture in Lafayette County. Area 3 (near 42.6850 ° N. latitude, 89.9456 ° W. longitude) is near the *Official Series Description* site for the Dunbarton series. The survey area is principally mapped as Dunbarton silt loam on 6 to 12 % slopes, moderately eroded (DuC2) and Sogn silt loam on 12 to 20 % slopes, moderately eroded (SoD2). The shallow and very shallow, somewhat excessively drained Sogn soils formed in residuum weathered from limestone. Sogn is a member of the loamy, mixed, superactive, mesic Lithic Haplustolls taxonomic family. Area 4 (near 42.6850 ° N. latitude, 89.9541 ° W. longitude) is located on the Vargas Farm. This area is principally mapped as Dodgeville silt loam on 2 to 6 % slopes, moderately eroded (DgB2). The moderately deep, well drained Dodgeville soils formed in loess and in the underlying clay residuum (paleosol weathered from dolomite or limestone). Dodgeville is a member of the fine-silty over clayey, mixed, superactive, mesic Typic Argiudolls taxonomic family.

Area 5 (42.5678 ° N. latitude, 89.7956 ° W. longitude) is located on the Medinger Farm in Green County. This area is principally mapped as Dunbarton silt loam on 6 to 12 (DuC2) and on 12 to 20 (DuD2) % slopes, moderately eroded; and Fayette silt loam, benches, on 2 to 6 % slopes, moderately eroded (FbB2). The very deep, well drained Fayette soils formed in loess. Fayette is a member of the fine-silty, mixed, superactive, mesic Typic Hapludalfs taxonomic family.

Area 6 (near 42.7562 ° N. latitude, 89.3674 ° W. longitude) is located in an alfalfa field on the Larson Farm in Rock County. This area is principally mapped as Edmund loam on 2 to 6 (EdB2) and on 6 to 12 to (EdC2) % slopes, eroded; and Whalen loam on 6 to 12 % slopes, eroded (WlC2). The shallow, well drained Edmund soils formed in a thin loamy mantle and in the clayey residuum weathered from the underlying bedrock. Edmund is a member of the clayey, smectitic, mesic Lithic Argiudolls taxonomic family. The moderately deep, well drained Whalan soils formed in a mantle of loamy glacial drift and clayey residuum over limestone bedrock. Whalen is a member of the fine-loamy, mixed, superactive, mesic Typic Hapludalfs taxonomic family

Area 7 (near 42.8220 ° N. latitude, 89.4290 ° W. longitude) is located in a CRP field on the Strous Farm in Green County. This area is principally mapped as Dunbarton silt loam on 2 to 6 (DuB2) and on 6 to 12 (DuC2) % slopes, moderately eroded.

Figure 1. At each site, pedestrian radar surveys were completed by pulling a 400 MHz antenna along the ground surface.

GPR Survey Procedures:

At each site, multiple, pedestrian survey lines were completed with a 400 MHz antenna (see Figure 1). Each radar traverse was stored as a separate file. Surveys were conducted by pulling the 400 MHz antenna along the ground surface. Areas of high grass were packed down and shrubs were avoided as these features jarred and lifted the antenna producing poor antenna coupling with the ground, which can result in additional background noise and inferior image quality.

Interpretation of Radar Records:

The raw radar records collected during this investigation contained significant levels of background noise and were difficult to interpret in the field. The use of advanced signal processing methods was required to reduce background noise and improve interpretations. Processing steps that were used to reduce noise included: signal stacking, horizontal high pass filtration, and range gain adjustments. These steps were sequentially applied to all radar records to improve the identification of the soil/bedrock interface.

A raw radar record that was collected in an area of Dunbarton soils is shown in Figure 2 (top record). As a preliminary step, a *time zero* adjustment was used to adjust the position of the surface pulse (see Figure 2, second from top). Stacking the radar traces was next used to remove high frequency noise, which appears as "snow" on radar records (see Figure 2, third from top). As evident in the lower record in Figure 2, a *horizontal high pass filter* is used to remove horizontal bands of low frequency noise, reduce the ringing noise of the surface pulse, and aid the identification of the soil/bedrock interface. Processing techniques such as high pass filtration reduce the amplitude of reflected radar signals that appear on radar records. As a consequence, a *range gain* function is used to selectively increase signal amplitudes (Figure 2, bottom).

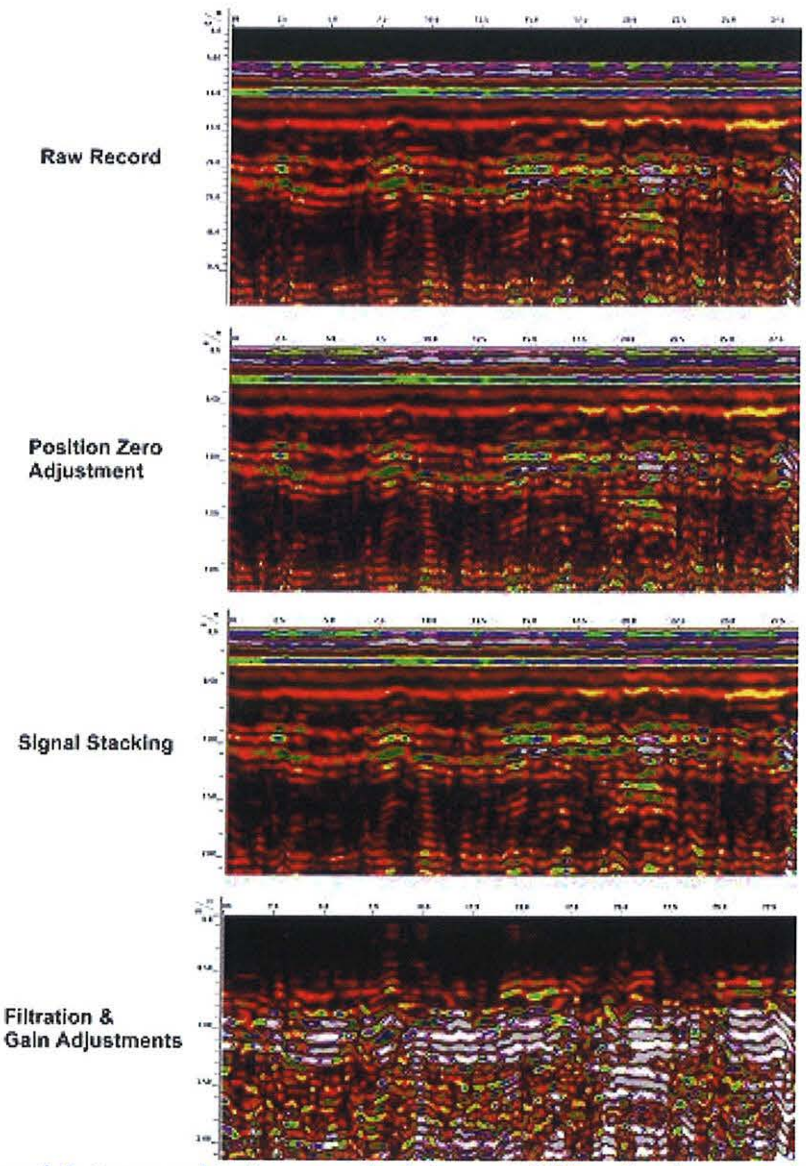

Figure 2. Sequential steps used to increase the interpretability of radar records and ease the identification of the soil/bedrock interface.

In Figure 3, the interpreted soil/bedrock interface has been identified with a green-colored segmented line. In areas of Dunbarton soils, the identification of the soil/bedrock interface is considered a relatively subjective and imprecise process. While the depth class and the approximate depth to bedrock is believed to have been adequately captured, the presence of a layer of pebbles, channers and flagstones above the bedrock surface, the irregular and pitted bedrock surface, the presence of joints (some of which extend downward for several feet) filled with residuum, and differences in degree of weathering have unquestionably added complexity to the accurate picking of the bedrock surface. On the radar record shown in Figure 3, a zone of higher amplitude (colored white and gray) reflectors is overlain by an ill-defined zone consisting of discontinuous and lower amplitude (colored red, yellow, and green) reflectors. The overlying zone is interpreted as bedrock. Because of it weaker expression on radar records, this upper stratum possibly represents a more fragmented, pitted and/or weathered members of the bedrock formation. It is also possible that the weaker expression is attributed to inappropriate gain adjustments on the SIR-3000 for the traversed soils and terrain conditions.

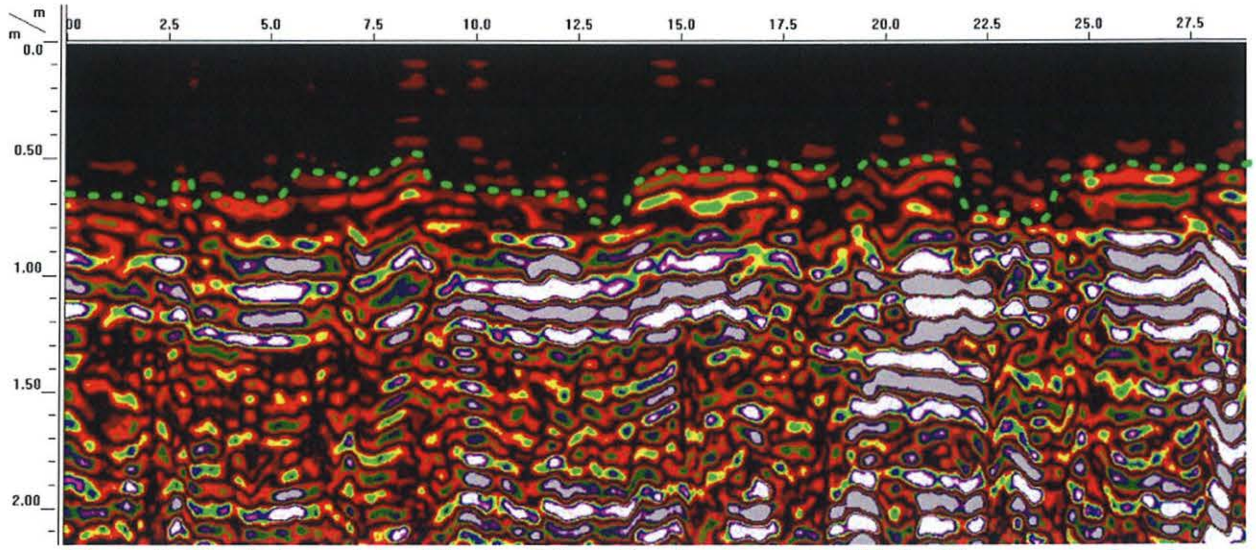

Figure 3. The interpreted soil/bedrock interface has been identified with a green-colored, segmented line on this radar record.

Results:

Blackhawk Wildlife Area, Dane County:

Within the wildlife area, two separate areas were surveyed with GPR (see Figure 4). In the northeastern survey area, based on 80,425 radar measurements collected along 8 traverse lines (radar files 40 to 47), soils are 3 % shallow, 95 % moderately deep, and 2 % deep. In the southwestern survey area, based on 83,111 radar measurements collected along 7 traverse lines (radar files 48 to 54), soils are 7 % shallow, 81 % moderately deep, and 12 % deep. Figure 4 is a *Google Earth* image showing the distribution of soils by depth classes along radar traverse lines completed in the Blackhawk Wildlife Area. Colors have been used to identify the different soil depth classes. Though not identified in the legend, a small area of very deep soils (colored green) is evident in the southwest survey area.

Tables 1 and 2 provide data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed respectively in the northeast and southwest survey areas within the Blackhawk Wildlife Area.

Table 1. Basic Statistic for GPR Traverses conducted in the northeast survey area within the Blackhawk Wildlife Preserve.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 40	1515	7742	0		**File 40**	0.16	0.84	0.00
File 41	56	10516	0		**File 41**	0.01	0.99	0.00
File 42	36	10504	0		**File 42**	0.00	1.00	0.00
File 43	174	6536	0		**File 43**	0.03	0.97	0.00
File 44	54	11651	13		**File 44**	0.00	0.99	0.00
File 45	0	7022	40		**File 45**	0.00	0.99	0.01
File 46	67	9422	0		**File 46**	0.01	0.99	0.00
File 47	3	13284	1790		**File 47**	0.00	0.88	0.12

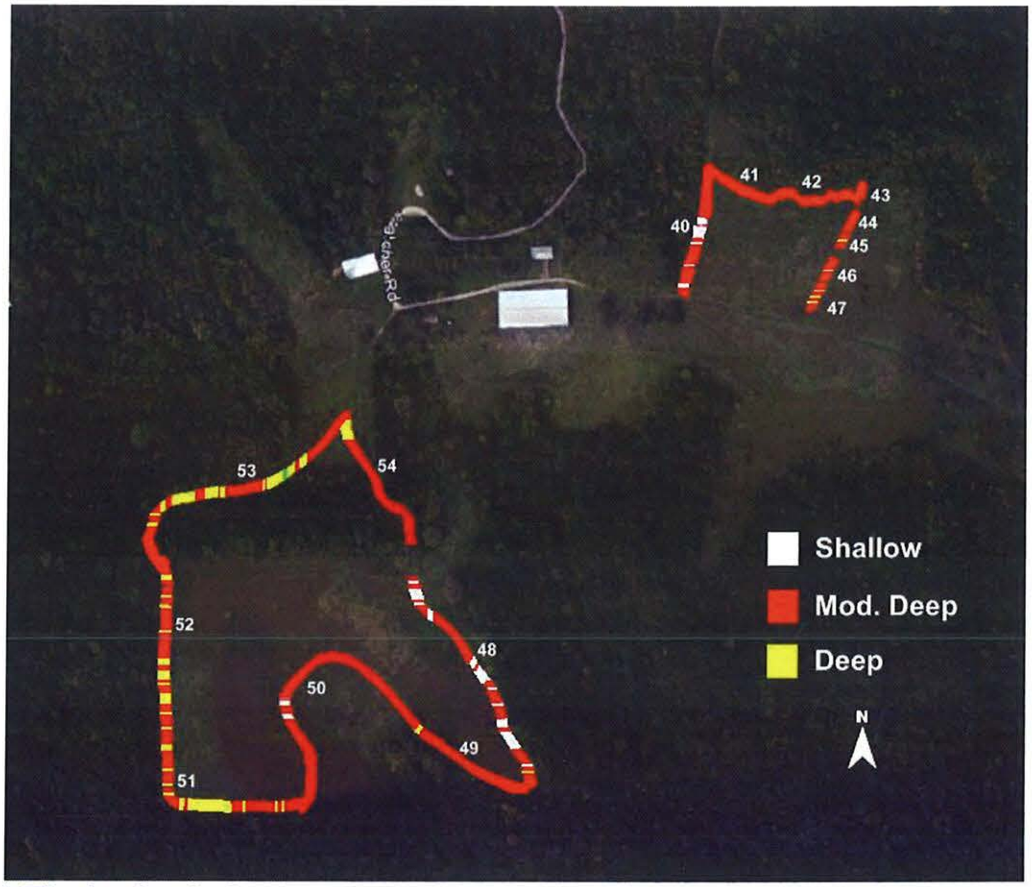

Figure 4. The depth to bedrock at the Blackhawk Wildlife Area as interpreted from radar data is shown on this Google Earth image (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

Table 2. Basic Statistic for GPR Traverses conducted in the southwest survey area within the Blackhawk Wildlife Preserve.

	Shallow	Mod Deep	Deep	V. Deep			Shallow	Mod Deep	Deep	V. Deep
File 48	5993	9241	0	0		**File 48**	0.39	0.61	0.00	0.00
File 49	66	10828	83	0		**File 49**	0.01	0.99	0.01	0.00
File 50	1011	15031	30	0		**File 50**	0.06	0.94	0.00	0.00
File 51	0	11324	4132	4		**File 51**	0.00	0.73	0.27	0.00
File 52	0	3930	676	0		**File 52**	0.00	0.85	0.15	0.00
File 53	30	9460	4032	147		**File 53**	0.00	0.69	0.29	0.01
File 54	0	6298	799	0		**File 54**	0.00	0.89	0.11	0.00

Hudstad Farm, Green County:

Within the surveyed area on the Hudstad Farm, based on 84,764 radar measurements collected along 10 traverse lines, soils are 23 % shallow, 74 % moderately deep, and 3 % deep. Figure 5 is a *Google Earth* image showing the distribution of soils by depth classes along radar traverse lines completed on the Hudstad Farm. Colors have been used to identify the interpreted depth classes.

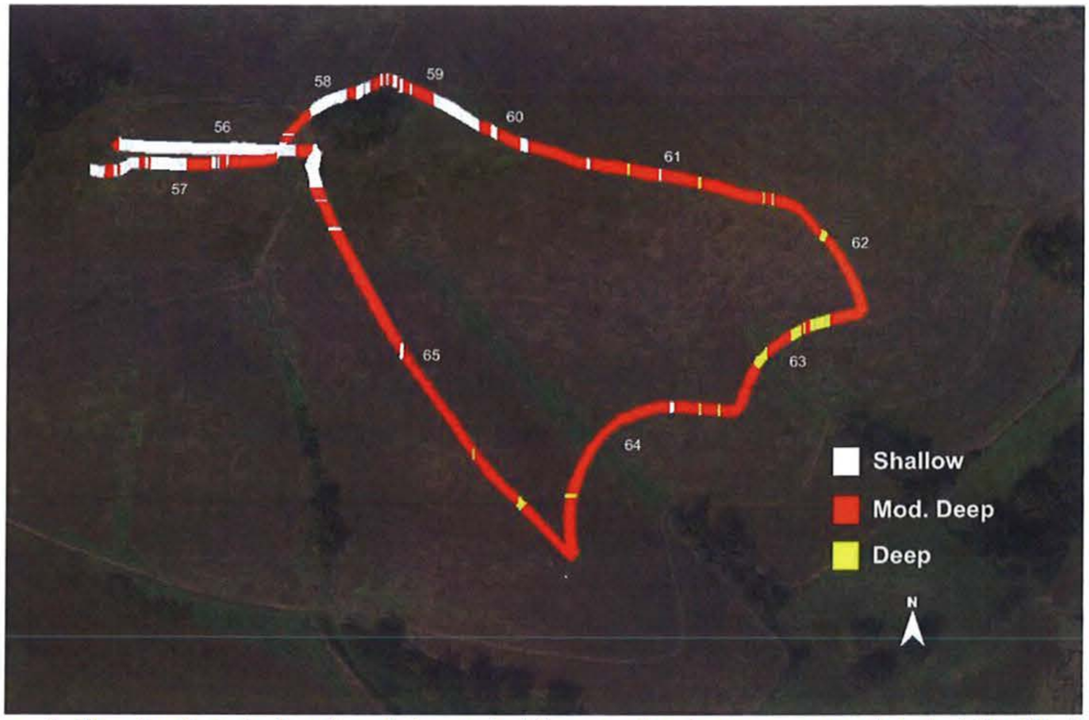

Figure 5. The depth to bedrock as interpreted from radar traverses completed at the Hudstad Farm in Green County (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

Table 3 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed within the Hudstad Farm.

Table 3. Basic Statistic for GPR Traverses conducted in the northeast survey area within the Hudstad Farm.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 56	5278	3491	0		**File 56**	0.60	0.40	0.00
File 57	2278	5954	58		**File 57**	0.27	0.72	0.01
File 58	5680	3662	0		**File 58**	0.61	0.39	0.00
File 59	427	1021	0		**File 59**	0.29	0.71	0.00
File 60	2416	7018	30		**File 60**	0.26	0.74	0.00
File 61	383	4953	249		**File 61**	0.07	0.89	0.04
File 62	60	5175	80		**File 62**	0.01	0.97	0.02
File 63	0	5920	1364		**File 63**	0.00	0.81	0.19
File 64	95	10446	127		**File 64**	0.01	0.98	0.01
File 65	2932	15482	185		**File 65**	0.16	0.83	0.01

Official Series Description (OSD) Site, Lafayette County:

Within the OSD site, based on 37,830 radar measurements collected along 5 traverse lines, soils are 3 % shallow and 97 % moderately deep. Figure 6 is a *Google Earth* image of the areas surveyed at the OSD (right) and Vargas Farm (left) areas showing the distribution of soils based on soil depth classes. Colors have been used to identify the interpreted depth classes.

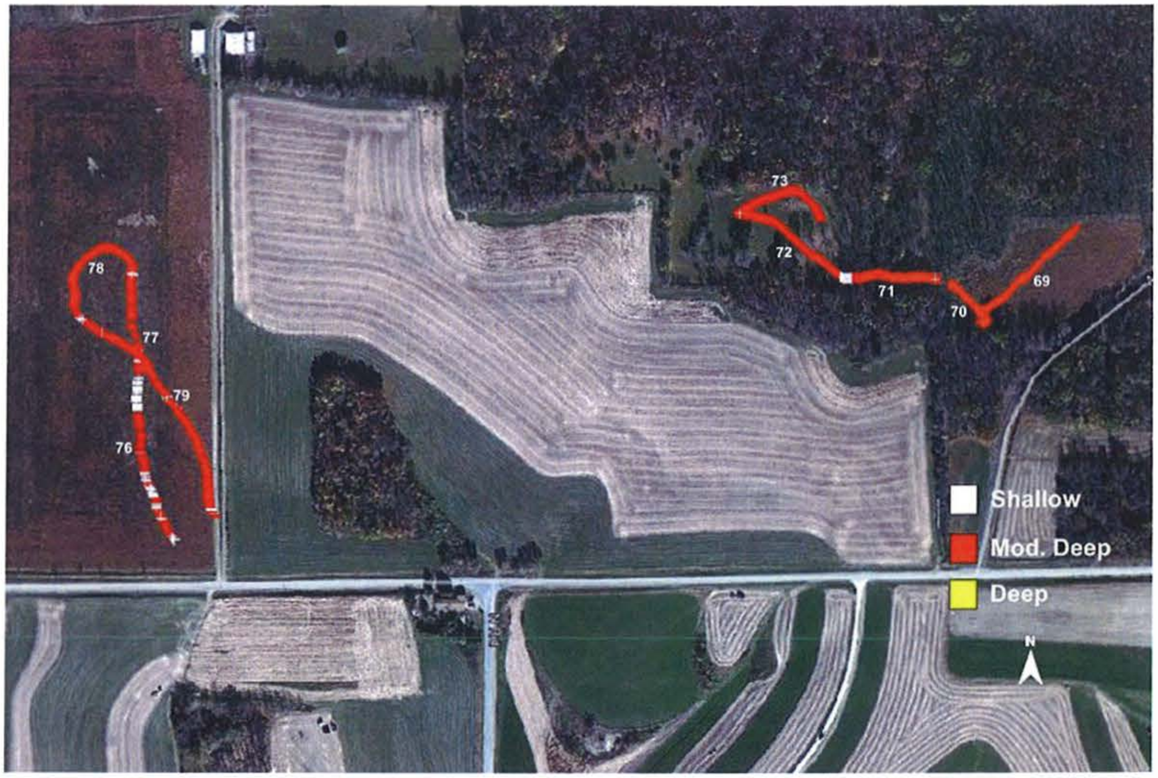

Figure 6. The depth to bedrock as interpreted from radar traverses completed at the Official Series Description Site (right) and the Vargas Farm (left) in Lafayette County (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

Table 4 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed within the OSD site.

Table 4. Basic Statistic for GPR Traverses conducted near the Official Series Description Site.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 69	74	12776	0		**File 69**	0.01	0.99	0.00
File 70	5	4314	0		**File 70**	0.00	1.00	0.00
File 71	965	7905	0		**File 71**	0.11	0.89	0.00
File 72	246	5165	0		**File 72**	0.05	0.95	0.00
File 73	88	6292	0		**File 73**	0.01	0.99	0.00

Vargas Farm, Lafayette County:
Within the surveyed area of the Vargas Farm, based on 53,252 radar measurements collected along 4 traverse lines, soils are 13 % shallow and 87 % moderately deep.

Table 5 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed on the Vargas Farm.

Table 5. Basic Statistic for GPR Traverses conducted across portions of the Vargas Farm in Lafayette County.

	Shallow	Mod Deep			Shallow	Mod Deep
File 76	3749	8173		**File 76**	0.31	0.69
File 77	1172	9758		**File 77**	0.11	0.89
File 78	194	10040		**File 78**	0.02	0.98
File 79	1685	18481		**File 79**	0.08	0.92

Medinger Farm, Green County:

Within the surveyed area on the Medinger Farm, based on 83,203 radar measurements collected along 9 traverse lines, soils are 5 % shallow and 95 % moderately deep. Figure 7 is a *Google Earth* image showing the distribution of soils by depth classes along radar traverse lines completed on the Medinger Farm. Traverse 89 closely parallels the face wall of a quarry located in the wooded area to the immediate south of the line. Colors have been used to identify the interpreted depth classes.

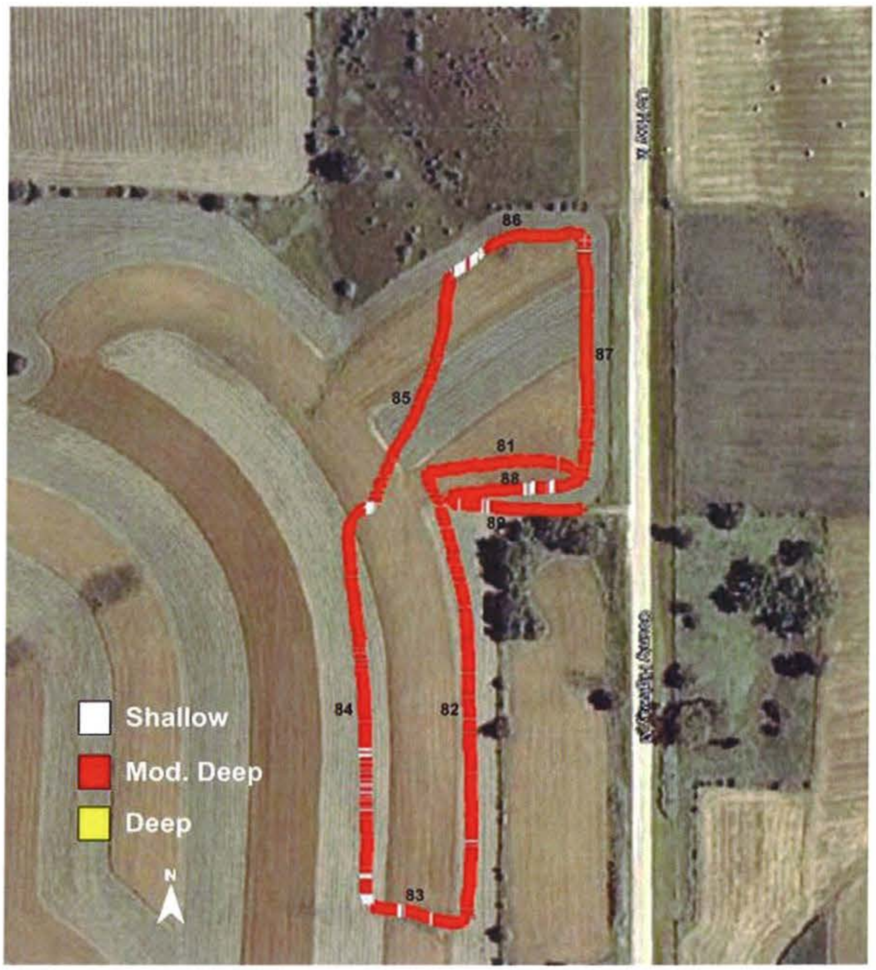

Figure 7. The depth to bedrock as interpreted from radar traverses completed at the Medinger Farm in Green County (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

Table 6 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed on Medinger Farm.

Table 6. Basic Statistic for GPR Traverses conducted across portions of the Medinger Farm in Green County.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 81	54	7317	11		**File 81**	0.01	0.99	0.00
File 82	448	17343	4		**File 82**	0.03	0.97	0.00
File 83	213	4338	0		**File 83**	0.05	0.95	0.00
File 84	1272	10253	0		**File 84**	0.11	0.89	0.00
File 85	527	15476	5		**File 85**	0.03	0.97	0.00
File 86	796	5444	0		**File 86**	0.13	0.87	0.00
File 87	182	9301	0		**File 87**	0.02	0.98	0.00
File 88	191	5081	0		**File 88**	0.04	0.96	0.00
File 89	313	4634	0		**File 89**	0.06	0.94	0.00

Larson Farm, Rock County:

Within the surveyed area on the Larson Farm, based on 120,568 radar measurements collected along 14 traverse lines, soils are 99 % moderately deep and 1 % deep to bedrock. Figure 8 is a *Google Earth* image showing the distribution of soils by depth classes along radar traverse lines completed on the Larson Farm. Colors have been used to identify the interpreted depth classes.

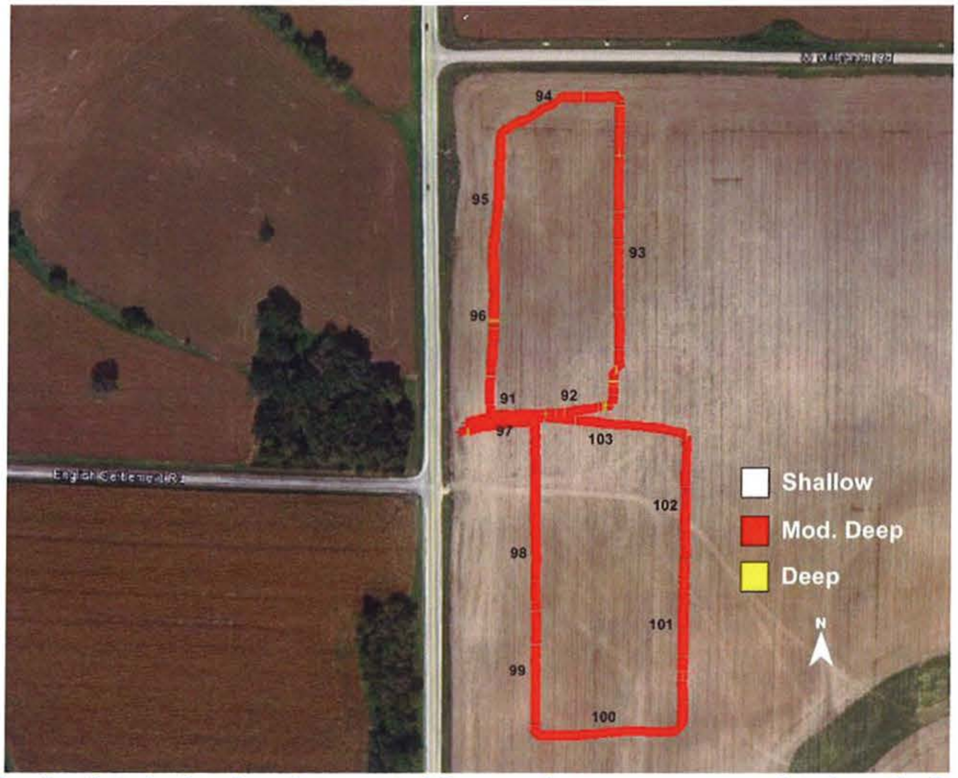

Figure 8. The depth to bedrock as interpreted from radar traverses completed on the Larson Farm in Rock County (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

Table 7 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed on the Larson Farm.

Table 7. Basic Statistic for GPR traverses conducted across portions of the Larson Farm in Rock County.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 91	16	3999	0		**File 91**	0.00	1.00	0.00
File 92	0	6807	257		**File 92**	0.00	0.96	0.04
File 93	1	22051	242		**File 93**	0.00	0.99	0.01
File 94	0	8911	24		**File 94**	0.00	1.00	0.00
File 95	0	12462	173		**File 95**	0.00	0.99	0.01
File 96	58	3826	0		**File 96**	0.01	0.99	0.00
File 97	0	3000	4		**File 97**	0.00	1.00	0.00
File 98	39	9697	0		**File 98**	0.00	1.00	0.00
File 99	70	9862	1		**File 99**	0.01	0.99	0.00
File 100	0	8969	0		**File 100**	0.00	1.00	0.00
File 101	0	10798	89		**File 101**	0.00	0.99	0.01
File 102	28	6762	32		**File 102**	0.00	0.99	0.00
File 103	0	7882	0		**File 103**	0.00	1.00	0.00
File 104	0	4246	262		**File 104**	0.00	0.94	0.06

<u>Strous Farm, Green County:</u>
Within the surveyed area on the Strous Farm, based on 53,801 radar measurements collected along 9 traverse lines, soils are 88 % moderately deep and 12 % deep to bedrock. Figure 9 is a *Google Earth* image of the areas surveyed on the Strous Farm showing the distribution of soils based on soil depth classes. Colors have been used to identify the interpreted depth classes.

Table 8 provides data on the number of observations in each soil depth class (left) and the frequency distributions (right) of measurements (by soil depth classes) for each of the radar traverses completed on Strous Farm.

Table 8. Basic Statistic for GPR traverses conducted across portions of Strous Farm in Green County.

	Shallow	Mod Deep	Deep			Shallow	Mod Deep	Deep
File 105	0	1556	3898		**File 105**	0.00	0.29	0.71
File 106	0	5527	7		**File 106**	0.00	1.00	0.00
File 107	0	3250	87		**File 107**	0.00	0.97	0.03
File 108	0	5835	244		**File 108**	0.00	0.96	0.04
File 109	0	7495	98		**File 109**	0.00	0.99	0.01
File 110	3	7526	19		**File 110**	0.00	1.00	0.00
File 111	0	6652	477		**File 111**	0.00	0.93	0.07
File 112	0	5532	84		**File 112**	0.00	0.99	0.01
File 113	0	4478	1033		**File 113**	0.00	0.81	0.19

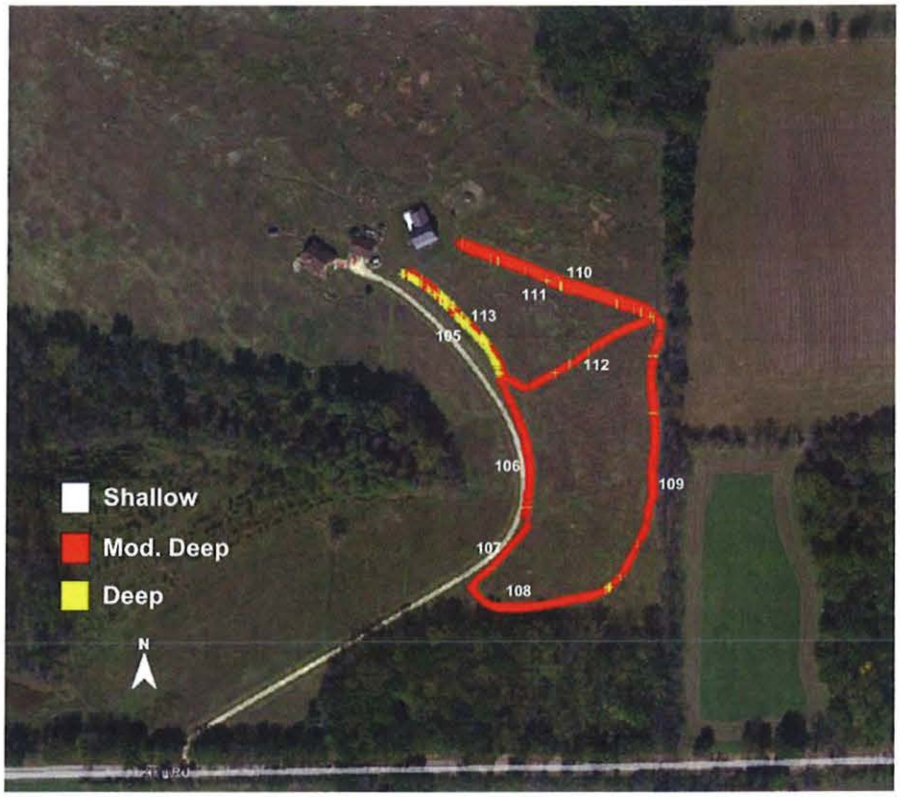

Figure 9. The depth to bedrock as interpreted from radar traverses completed on the Strous Farm in Green County (courtesy of Brian Jones of GSSI). Numbers identify separate radar traverse and files.

EMI Survey, Rock County.

The northern portion of the Larson Farm GPR survey site (see Figure 8) was surveyed with an EM38 meter. Apparent conductivity (EC_a) values recorded across this site were exceedingly low considering the mapped Edmund (clayey, smectitic, mesic Lithic Argiudolls) and Whalen (loamy, mixed, superactive, mesic Typic Hapludalfs) soils. The exceedingly dry soil moisture conditions and the relative shallow depths to electrically resistive bedrock are factors that contribute to the low EC_a. However, higher EC_a values were anticipated across the site because of the soils relatively high clay content and cation-exchange activity. Based on 5,650 measurements, the average EC_a was 5.7 mS/m with a range of 0 to 14.9 mS/m. However, half of the measurements had EC_a between only 4.25 and 7.1 mS/m.

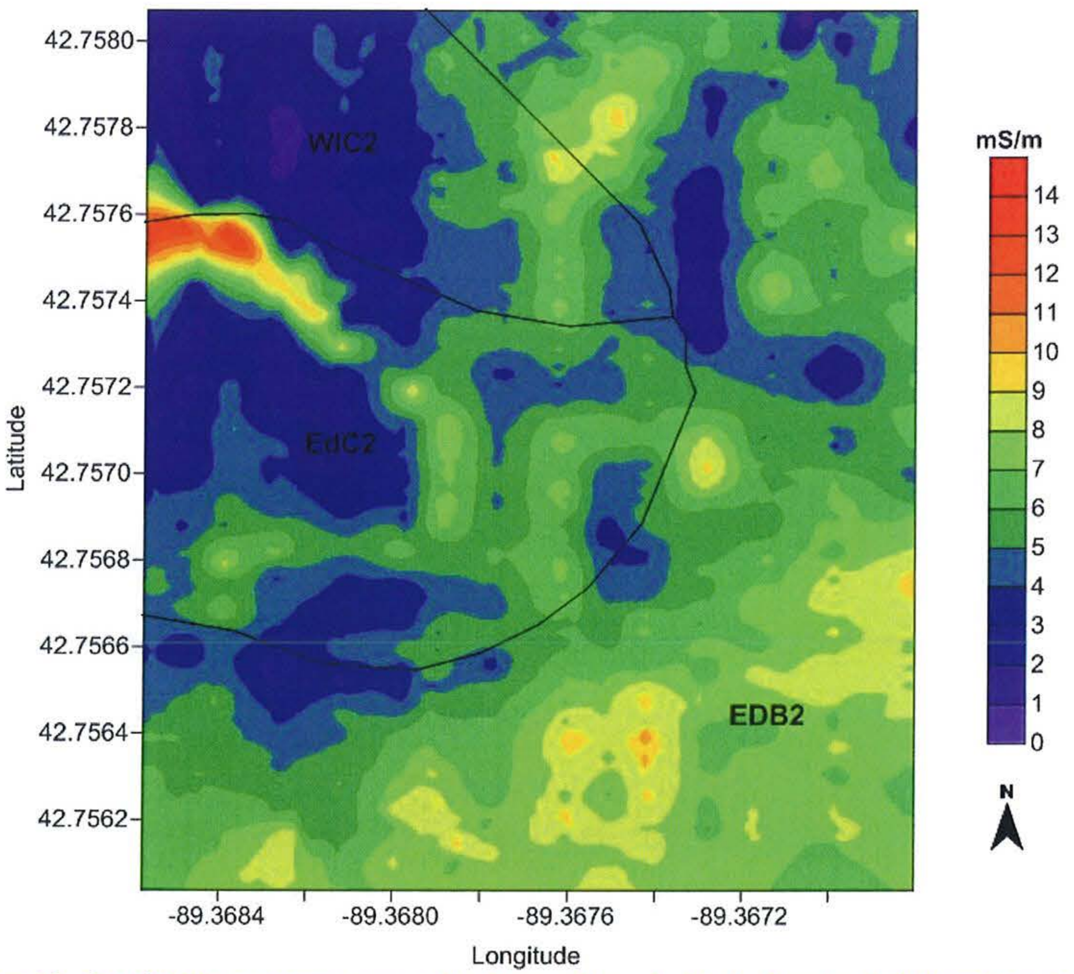

Figure 10. Spatial EC_a patterns across the Strous Farm in Rock County. Soil lines have been imported from the Web Soil Survey.

Figure 10 is a plot of the EC_a collected at this site with the EM38 meter operated in the vertical dipole orientation. When operated in the VDO, the theoretical exploration depth of this meter is 0 to 150 cm. The soil boundary lines have been digitized from Web Soil Survey data[2]. Spatial EC_a patterns appear to reflect differences in soil drainage and landscape position. Elevation declines towards the northwest corner of the site. Higher EC_a values were measured in a drainage channel which drains towards the northwest corner of the site. In general, higher EC_a were recorded on higher lying summit and upper side slopes components that dominate the southern and eastern portions of the site. Lower values of EC_a were recorded on lower-lying, lower side slopes in the northwest portion of the site. These spatial differences in EC_a may reflect differences in particle-size distributions and/or depth to bedrock.

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