United States Department of Agriculture

NRCS

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Subject: MGT – Trip Report - Geophysical

August 7, 2012

To: Jay T. Mar
State Conservationist, NRCS
Tolland, Connecticut

File Code: 330-20-7

Purpose:
To determine the depth to bedrock in areas mapped as Canton and Charlton soils in the portion of Major Land Resource Area 144A located in northwestern Rhode Island.

Principal Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Jacob Isleib, Soil Scientist, USDA-NRCS, Tolland, CT
Donald Parizek, Soil Scientist, USDA-NRCS, Tolland, CT
Debbie Surabian, Acting State Soil Scientist, USDA-NRCS, Tolland, CT

Activities:
All activities were completed on July 11, 2012.

Summary:

1. Thirteen radar traverses of varying lengths were completed across two areas of Canton and Charlton fine sandy loams, very rocky, 3 to 15% slopes (CeC). These wooded, upland areas were initially mapped at a lower soil survey intensity (order 3 rather than order 2) and the MLRA 144A staff suspects that the depth to bedrock is less than described for this map unit (very deep; > 150 cm).

2. Based on a summation of 83,756 measurements of the depths to bedrock, soils are 35% (29,578) shallow, 38% (31,891) moderately deep, 18% (14,806) deep, and 9% (7,481) very deep in the traversed areas of Canton and Carlton soils. Alternatively, treating each radar traverse equally (regardless of length and number of observations), the average is 29% shallow, 42% moderately deep, 19% deep, and 10% very deep soils in the traversed areas.

3. Regardless of method use to assess the radar data, the soils in the study area are, as anticipated by the MLRA Staff, much shallower to bedrock than initially mapped. The traversed areas of Canton and Charlton fine sandy loams, very rocky, on 3 to 15% slopes, are dominantly (71 to 73%) moderately deep (50 to 100 cm) and shallow (<50 cm). With present land use and concerns for natural resources, the existing detail of mapping and soil interpretations require improvements.

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

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc:
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GPR investigation of the depth to bedrock within areas of Canton and Charlton fine sandy loams, very rocky, 3 to 15% slopes (CeC) located in Providence County, Rhode Island

Jim Doolittle

Purpose:

Most areas of Connecticut and Rhode Island were mapped at a second order for general agriculture and urban planning. Second order soil maps are prepared at scales of 1:12,000 to 1:31,680 with a minimum delineation size that can range from 0.6 to 4.0 ha. Many wooded, upland areas in these states, however, were mapped at lower intensity (order 3) with a lesser amount of field studies and a greater level of abstraction. With present land use and concerns for natural resources, the existing detail of mapping in these upland areas requires improvements.

The purpose of this ground-penetrating radar (GPR) investigation was to estimate the depth to bedrock in areas mapped as Canton and Charlton fine sandy loams, very rocky, 3 to 15% slopes (CeC) in northwest Rhode Island. Ground-penetrating radar (GPR) provides high-resolution information that can aid interpretations and the extrapolation of information obtained with traditional surveying techniques (Davis and Annan, 1989).

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. A 400 MHz antenna was used in the investigations.

The RADAN for Windows (version 6.6) software program (developed by GSSI) was used to process the radar records shown in this report.[1] Processing used included: header editing, setting 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).

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., soil horizon, bedrock) 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):

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

C is the velocity of light in a vacuum (0.3 m/ns). Typically, 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. The dielectric permittivity ranges from 1 for air, to 78 to 88 for water

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

(Cassidy, 2009). Small increments in soil moisture can result in substantial increases in the relative permittivity of soils (Daniels, 2004). Using a 100 MHz antenna, Daniels (2004) observed that the relative dielectric permittivity of most dry mineral soil materials is between 2 and 10, while for most wet mineral soil materials, it is between 10 and 30. At the time of this investigation, soils were very dry.

A small pit, excavated at the Durfee site, was used for calibration. The underlying bedrock was partially exposed at a depth of 50 cm. A radar traverse was conducted adjacent to this pit. Based on the measured depths and the two-way pulse travel times to the exposed bedrock, the velocity of propagation and the relative dielectric permittivity through the upper part of a soil profile were estimated using equations [1] and [2]. With the 400 MHz antenna, the estimated E_r was 5.15. The estimated v was 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.

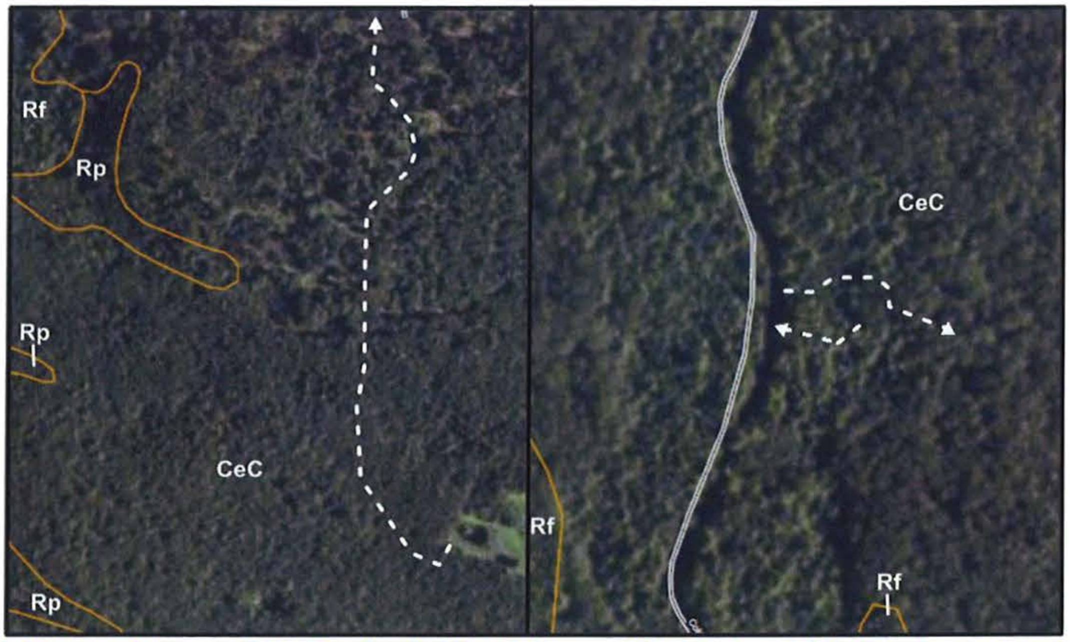

Figure 1. These soil maps of the Durfee (left) and George Washington (right) study areas are from the Web Soil Survey. On each image, the approximate locations of the GPR traverse lines are shown.

Study Sites:

Figure 1 contains soil maps of the two study sites from the Web Soil Survey.[2] The approximate locations of the traverse lines are shown on both images. Both sites are located in densely wooded areas. Both sites are mapped as Canton and Charlton fine sandy loams, very rocky, 3 to 15% slopes (CeC). The very deep, well drained Canton and Charlton soils formed in a loamy till. For Canton soils, this loamy mantle is underlain by sandy till. Charlton soils lack this underlying layer of sandy till. The taxonomic classifications of these soils are listed in Table 1.

One site is located in the Durfee Wildlife Management Area (41.9037 N. Lat., 71.7879 W. Long.) At this site, traverses were conducted along a trail that winds thru the woods and across an area known as "*Hemlock Ledges*". The other site is located within the George Washington Management Area (41.9311

[2] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed [7/24/2012].

N. Lat., 71.7847 W. Long.). Here, traverses were conducted thru the woods across a very boulder infested area.

Table 1 Soil Taxonomic Classifications

Soil Series	Taxonomic Classification
Canton	Coarse-loamy over sandy or sandy-skeletal, mixed, semiactive, mesic Typic Dystrudepts
Charlton	Coarse-loamy, mixed, active, mesic Typic Dystrudepts

Survey Procedures:
At each site, multiple, pedestrian surveys were completed with a 400 MHz antenna. Each radar traverse was stored as a separate file. Surveys were conducted by pulling the 400 MHz antenna along the ground surface.

Results:
Figure 2 is a representative radar record from an area referred to as the "*Hemlock Ledges*" within the Durfee study area. On this radar record all scales are in meters. A segmented green-colored line has been used to approximate the interpreted bedrock surface. The three vertical, segmented, white-colored lines at the top of the radar record (near the 12.5 m distance mark) were impressed by the radar operator as the antenna passed over an exposed portion of bedrock. For a map unit that is characterized by very deep (>150 cm) soils, the depth to bedrock is relatively shallow (< 100 cm) along this traverse line. The absence of radar reflections beneath the exposed bedrock is attributed to differences in impedance, greater signal attenuation, and inappropriate calibration.

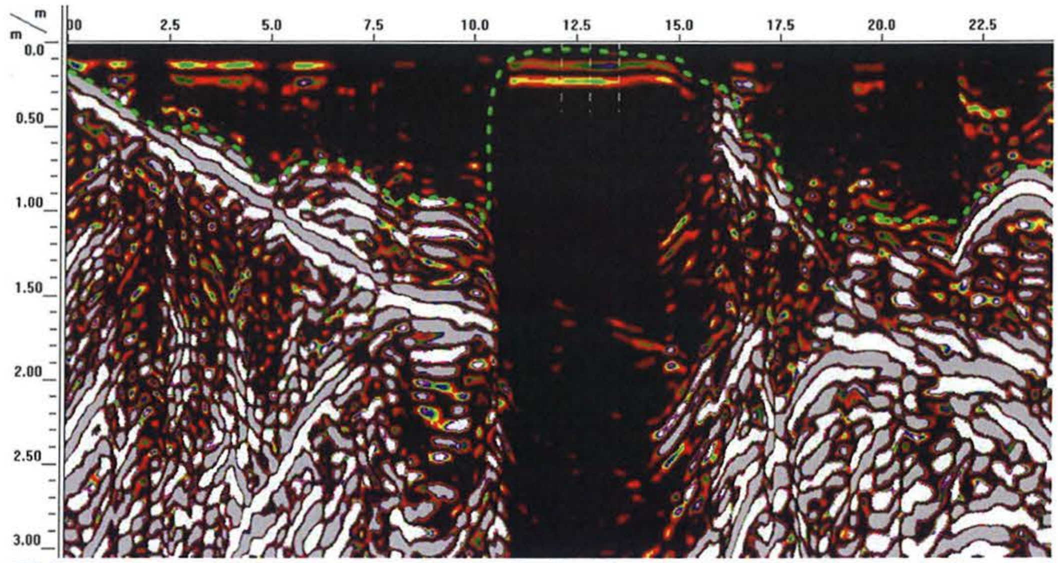

Figure 2. This representative radar record from the Durfee site clearly indicates shallower than mapped and highly irregular bedrock depths in an area of Canton and Charlton soils.

Table 2 and 3 respectively list the number and frequency of observations based on soil depth classes along the traverse lines in the two study areas. Radar traverse files 1 to 10 are from the Durfee study area. Radar traverses 16 to 18 are from the George Washington study area. According to Table 2, based on a summation of 83,756 measurements of the depths to bedrock, soils are 35% (29,578) shallow, 38% (31,891) moderately deep, 18% (14,806) deep, and 9% (7,481) very deep in the traversed areas.

According to Table 3, treating each traverse equally (regardless of length and number of observations), soils are 29% shallow, 42% moderately deep, 19% deep, and 10% very deep in the traversed areas. Regardless of method used to assess the radar data, the soils are, as anticipated by the MLRA Staff, much shallower to bedrock than initially mapped. The traversed areas of Canton and Charlton fine sandy loams, very rocky, on 3 to 15% slopes, are dominantly (71 to 73%) moderately deep (50 to 100 cm) and shallow (< 50 cm) to bedrock. Areas of very deep soils make up less than 10% of the soils in the traversed area.

Table 2. Number of measurements falling into each soil depth class for the radar traverses conducted in the two study areas.

	Shallow	*Mod Deep*	*Deep*	*V. Deep*	*Total*
File 1	223	1169	0	0	1392
File 2	262	1451	2005	2713	6431
File 3	495	4320	2623	1141	8579
File 4	401	915	312	161	1789
File 5	372	1855	2672	1222	6121
File 6	5980	4704	637	193	11514
File 7	9480	4343	109	0	13932
File 8	5915	1916	506	0	8337
File 9	1506	2911	869	9	5295
File 10	2615	1531	0	0	4146
File 16	1043	3325	680	0	5048
File 17	1286	2933	1947	45	6211
File 18	0	518	2446	1997	4961
Total	29578	31891	14806	7481	83756

Table 3. Frequency distribution according to soil depth classes for the radar traverses conducted in the two study areas.

	Shallow	*Mod Deep*	*Deep*	*V. Deep*
File 1	0.16	0.84	0.00	0.00
File 2	0.04	0.23	0.31	0.42
File 3	0.06	0.50	0.31	0.13
File 4	0.22	0.51	0.17	0.09
File 5	0.06	0.30	0.44	0.20
File 6	0.52	0.41	0.06	0.02
File 7	0.68	0.31	0.01	0.00
File 8	0.71	0.23	0.06	0.00
File 9	0.28	0.55	0.16	0.00
File 10	0.63	0.37	0.00	0.00
File 16	0.21	0.66	0.13	0.00
File 17	0.21	0.47	0.31	0.01
File 18	0.00	0.10	0.49	0.40
Average	0.29	0.42	0.19	0.10

References:

Cassidy, N.J. 2009. Electrical and magnetic properties of rocks, soils, and fluids. In *Ground Penetrating Radar: Theory and Applications*, ed. H. M. Jol, 41-72 pp. Elsevier Science, Amsterdam, The Netherlands.

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

Davis, J.L., and A.P. Annan. 1989. Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. Geophysical Prospecting, 37: 531-551.

Jol, H., 2009. *Ground Penetrating Radar: Theory and Applications*. Elsevier Science, Amsterdam, The Netherlands.