United States Department of Agriculture

Natural Resources Conservation Service

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SUBJECT: MGT- Trip Report, Ground-Penetrating Radar Assistance December 31, 2008

TO: Douglas Zehner File Code: 330-7
State Conservationist
USDA, NRCS
344 Merrow Road, Suite A
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Purpose:
Ground-penetrating radar (GPR) was used to interpret the thickness of recent sediments that have formed a delta into Miller's Pond in Vernon, Connecticut. In addition, GPR training was provided to Debbie Surabian.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Joe Kavan, Civil Engineer, USDA-NRCS, Tolland, CT
Benjamin Smith, Student Trainee Hydrologist, USDA-NRCS, Tolland, CT
Debbie Surabian, Soil Scientist, USDA-NRCS, Tolland, CT

Activities:
All activities were completed on December 9 and 10, 2008.

Background:
The Connecticut NRCS staff is completing a reimbursable project with the town of South Windsor, Connecticut. South Windsor town officials are concerned with sedimentation in Miller's Pond and the concrete channel that directs and drains water from Avery Brook into the pond. Because of recent sedimentation, officials feel that the functionality of the concrete channel has been seriously reduced. NRCS is completing a sediment source study to assist town officials identify the amount and probable sources of these sediment. As part of this study, the sediment in the pond and concrete channel will be quantified. A number of hand probes have been completed by NRCS geologists and engineers on a sediment delta that has formed on the upstream portions of the pond. Ground-penetrating radar assistance was requested to 1) validate previously collected hand-probe data on the thickness of recently deposited sediments and 2) provide additional data in areas where hand-probe measurements had been insufficiently gathered.

Summary:

1. Site conditions precluded a complete survey of both Miller's Pond and the sediment delta. Ice had formed on Miller's Pond, but was too thin to support a pedestrian GPR survey and too thick to permit a survey with the GPR system mounted in a raft and canoe. Only accessible areas of the sediment delta were surveyed with GPR. Fallen tree limbs, dense underbrush, and debris restricted the areas that were accessible to GPR on the sediment delta.

2. Conspicuous high amplitude, continuous subsurface reflector was identified as the base of recent alluvial sediments on radar records from the delta. An auger observation at the calibration site provided the depth and evidence of significant differences in grain-size distributions across this interface. As the underlying materials were denser, coarser textured and contained gravels; this interface was assumed to represent the base of recent alluvial sediments.

3. The radar survey was completed in less than 1/2 day. Data on the thickness of recent alluvium on the sediment delta were estimated at 46048 points along multiple traverse lines (see locations in Figure 3). Based on GPR interpretations, the average thickness of the recent sediments is about 83 cm, with an estimated range of 35 to 117 cm. One-half of the radar-interpreted thickness measurements are between 71 and 92 cm deep.

4. All data collected on the sediment delta to Miller's Pond have been forwarded to Debbie Surabian under a separate cover letter.

5. A visit to Geophysical Survey Systems, Inc. (GSSI; Salem, New Hampshire) provided personal contact for Debbie Surabian with the manufacturer of Connecticut's GPR system. Technical representatives of GSSI set up and programmed Debbie's SIR-3000 unit for the GPS option, and reviewed and discussed procedural concerns.

It is my pleasure to come to Connecticut and to be of assistance to you and your fine staff.

With kind regards,

Jim Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
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Study site:
The sediment delta to Miller's Pond is located (latitude 41.81943 N, longitude 72.51623 W) in an area of Udorthents-Urban land complex (map unit 306) off of Benedict Drive in Vernon, Connecticut. Because of thin ice, Miller's Pond could not be surveyed at this time. Much of the area surveyed with GPR was in high grasses. Areas of dense undergrowth and fallen debris could not be surveyed with GPR.

Figure 1. Debbie Surabian completes a GPR traverse along an accessible portion of the sediment delta at Miller's Pond with a 200 MHz antenna, while Benjamin Smith looks on.

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. An antenna with center frequency of 200 MHz was used in this study. The coordinates for each radar traverse were recorded with a Trimble AgGPS114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA).[1] With an antenna, the SIR-3000 requires two people to operate (see Figure 1). Daniels (2004) discusses the use and operation of GPR.

All radar records were processed with the RADAN for Windows (version 6.6) software developed by GSSI.[1] Processing was used to improve interpretations. Processing included: header editing, GPS positioning, time zero adjustments, signal stacking, migration, and range gain adjustments.

Recent technical developments allow the automatic integration of GPR and GPS data. This integration effectively geo-references each scan on the radar record. Using the *Interactive 3D Module* of the

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

RADAN processing software, depths to the base of the recent alluvial materials were interpreted and depth estimates were automatically picked and outputted to files (X, Y, Z format; containing latitude, longitude, and depth). Using this module, data were quickly compiled and exported for future plotting and visualization in GIS.

Survey Procedures:
Random, pedestrian surveys were conducted with the SIR-3000 and the 200 MHz antenna across accessible areas on the sediment delta (see traverse tracks on Figure 3). The 200 MHz antenna provided good resolution of subsurface features and adequate penetration depths. Each radar traverse was stored as a separate file. Radar records were reviewed in the field.

Calibration of GPR:

Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., soil horizon, stratigraphic layer) and back. To convert the travel time into a depth scale, 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 (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 equation (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).

At the time of the GPR survey, shallow water flowed across lower-lying portions of the sediment delta and soils were saturated. For calibration, radar traverse were conducted along two lines of flagged, hand-probe observations sites. At each of the observation sites, the measured depths to contrasting materials (denser layers of sands and gravels) were available. These measurements were associated with a prominent, continuous, subsurface interface on the radar records. Based on a correlation of the measured with the interpreted depths to this interface, the E_r (7.34) and v (0.1100 m/ns) were determined. However, these values are more typical of well drained upland soils and are inappropriate for saturated alluvial sediments. As a consequence, the site was returned to, and a more accurate assessment made. Based on the depths to two prominent subsurface reflectors (a buried plate and contrasting subsurface interface), which were identified on radar records, the estimated E_r is 49 and the v is 0.0425 m/ns. These values are considered appropriate for the saturated alluvial sediments and were used to depth-scale the radar imagery. However, as the dielectric properties of alluvial sediments are spatially variable, all measurements provided in this report should be considered as close approximations only.

Interpretation of GPR Data:
Radar records were generally of good interpretative quality. Figure 2 is a representative portion of radar record from the sediment delta on Miller's Pond. The depth scale is expressed in centimeters. The horizontal scale is expressed in meters. On this radar record, a segmented, green-colored line has been used to identify the interface that is believed to separate the more-recently deposited alluvium from the underlying, denser, coarser-textured materials. This high-amplitude reflector, though in places, more weakly expressed or partially obscured by overlying strata (see left-hand portion of Figure 2), was easily

traced across all radar records with a high degree of certainty. The weak expression of this interface in some areas is attributed to a lower contrast in the grain-size distributions of the two materials. In these areas, the distinction between these two materials was less clear and interpretations were consequentially more ambiguous (see left-hand portion of Figure 2).

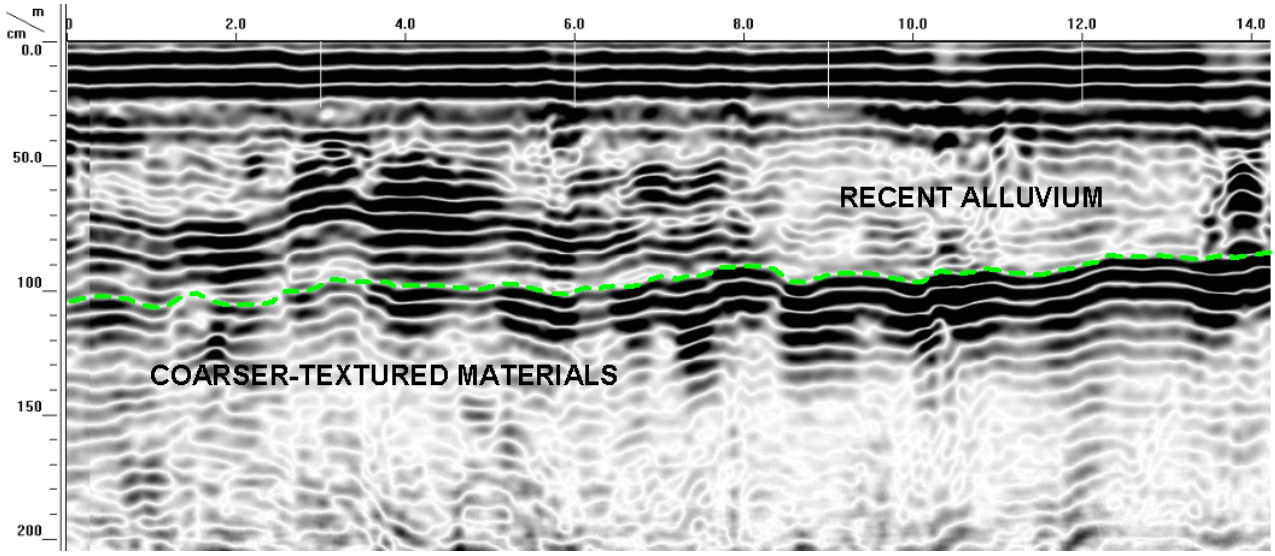

Figure 2. The interpreted contact between the more-recently deposited alluvium and the underlying, denser, coarser-textured materials has been highlighted with a green-colored line on this radar record from the sediment delta.

Estimates of the thickness of the organic enriched materials:
The radar survey was completed in less than 1/2 day. The thickness of the recent alluvial sediments was estimated at 46048 points along multiple radar traverse lines (see locations in Figure 3). Based on radar interpretations, the average thickness of the recent alluvial sediments is about 83 cm, with a range of about 35 to 117 cm. One-half of the radar-interpreted thickness measurements were between 71 and 92 cm deep. The number and frequency distribution of radar observations on the thickness of recent alluvial sediments (based on 50-cm soil depth classes) are shown in Table 1.

Table 1
The number and frequency distribution of radar observations on the thickness of recent alluvial sediments across the sediment delta of Miller's Pond.

Thickness (cm)	Observations	Frequency (%)
0 to 50	3864	0.08
50 to 100	35633	0.77
100 to 150	6551	0.15
> 150	0	0.00

Figure 3 is a Goggle Earth image of the sediment-delta area of Millers Pond. In this image, the locations of the GPR traverse lines are shown. Colors have been used to identify the interpreted thickness of recent alluvial deposits. In general, the thickness of this material appears to thicken towards the northeast and the present principal stream channel.

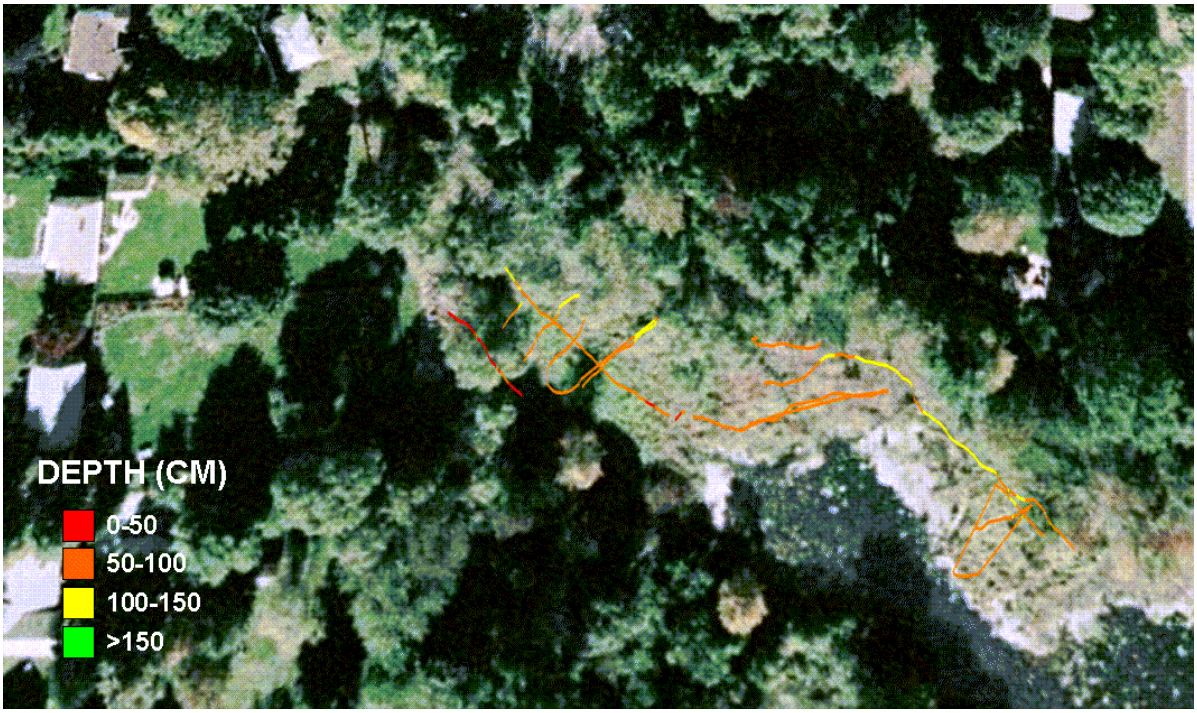

Figure 3. The thickness of recent alluvial materials on the sediment delta of Miller's Pond as interpreted from radar records. All depths are expressed in centimeters.

References:

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