United States Department of Agriculture

NRCS

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Subject: Soils – Geophysical **Date:** 1 February 2011

To: Janice Reid
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Purpose:
The New Jersey State Office recently purchased a ground-penetrating radar (GPR) system, with two antennas (200 and 400 MHZ) and data processing software. The purpose of this visit was to provide introductory training on the operation of the SIR-3000 ground-penetrating radar (GPR) unit and basic procedures that should be used to process radar data through the RADAN for Windows software program. In addition, at the request of the State Engineer, a sedimentation survey was completed with the GPR at Willever Lake Dam in Mansfield Township, Warren County.

Participants:
Katey Buckland, MLRA Soil Scientist, USDA-NRCS, Hammonton, NJ
Elizabeth Clarke, Biologist, USDA-NRCS, Hammonton, NJ
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Rob Tunstead, MLRA Soil Survey Office Leader, USDA-NRCS, Hammonton, NJ
Frank Wu, Agricultural Resource Specialist (SCD), USDA-NRCS, Columbia, NJ

Activities:
Activities were completed on 12, 14 and 20 January 2011. Three separate snow storms caused the delay and rescheduling of the planned activities.

Summary:

1. Training was provided on the setup and operation of the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (SIR-3000). This GPR unit was recently purchased by the New Jersey State Office. Edwin Muñiz and Rob Tunstead are the designated GPR operators. Prior to his transfer to New Jersey, Rob Tunstead had been the designated radar operator in Massachusetts. Rob is well versed and experienced with GPR.

2. Training was provided on some of the basic processing procedures contained in the RADAN for Windows program (version 6.6). These processing procedures can be used to prepare, edit, display, and print radar data. During training, proper file management and storage were stressed. Procedures covered included: color table and transformation options, header and marker editing, time zero adjustments, horizontal distance normalization, and signal stacking, migration. Participants were provided an opportunity to process a series of radar records using these procedures.

3. The RADAN for Windows program includes an *Interactive Interpretation* module. This module can be used to semi-automatically pick and scale depths to subsurface interfaces (e.g., soil horizons, stratigraphic or lithologic layers; subsurface features). The “picked” depths are automatically entered into the data files, which can be read in *Notepad* or *Excel*. Using this module, soil depth information can be quickly and accurately compiled and exported for analysis and summary.

4. Recent technological developments have allowed the integration of GPR with global positioning systems (GPS). This integration effectively geo-references each scan appearing on radar records. Although this option is presently available in New Jersey, we were not able to establish proper communication (*handshaking*) between the New Jersey’s GPR’s Signal Data Recorder (SDR) and an Archer PRO XYZ mobile mapping system. Using my GPS receivers (Trimble AG114 and ProXT) and SDR with the New Jersey’s SIR-3000, *handshaking* was established. Our initial assessment is that the settings on New Jersey’s GPS receiver are incorrect and the SDR is not properly formatted or functioning. Edmund Muniz is in contact Doug Kenny at Geophysical Survey System (Salem, NH) to resolve this problem. *Handshaking* was accomplished with New Jersey’s Garmin Map76 GPS receiver with backpack.

5. At Willever Dam Lake, the GPR performed well and provided clear and high resolution profiles of the former lake bottom. The thickness of recent bottom sediments, which have been deposited in the lake, was evident and easily interpreted on radar records. All radar records and an Excel worksheet containing the geo-referenced, interpreted sediment thicknesses have been conveyed to Edwin Muñiz for use by the State office Engineering Staff.

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

JONATHAN W. HEMPEL
Director
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Technical report on the initial ground-penetrating radar training in New Jersey (11, 13, and 20 January 2011).

Jim Doolittle

Equipment:
The soil staff in New Jersey recently purchased a TerraSIRch Subsurface Interface Radar (SIR) System-3000 (SIR-3000) unit. The radar unit is manufactured by Geophysical Survey Systems, Inc. (GSSI; Salem, NH).[1] The SIR-3000 consists of a DC-3000 digital control unit with keypad, SVGA video screen, and connector panel. The system is powered by a 10.8-volt lithium-ion rechargeable battery. The SIR-3000 weighs about 9 lbs (4.1 kg) and is backpack portable. The two antennas purchased with this unit, have center frequencies of 200 and 400 MHz. With an antenna, the SIR-3000 requires two people to operate. Daniels (2004) and Jol (2008) discuss the use and operation of GPR.

The RADAN for Windows (version 6.6) and the *Interactive 3D Module* software programs (GSSI) were also purchased with the radar unit from GSSI.[1] The RADAN software is used to process collected radar data. Recent technical developments allow the integration of GPR and GPS data (Doolittle et al., 2009). This integration effectively geo-references each scan on a radar record. Using the *Interactive 3D Module* of the RADAN for Windows (version 6.6) software program, depths to subsurface interfaces can be quickly interpreted, automatically picked and outputted to a layer file (X, Y, Z format; containing latitude, longitude, and depth). The synergism of these technologies permits the collection of large, georeferenced GPR data sets, which can be stored, manipulated, analyzed, and displayed in GIS. These collection, analysis, and display formats should greatly improve the utility of GPR in New Jersey.

GPR Basics:
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, bedrock, 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 (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:

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

Where C is the velocity of propagation in a vacuum (0.298 m/ns). Velocity is typically 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.

Based on the measured depth and the two-way pulse travel time to known, subsurface reflectors, and equation [1], the velocity of propagation and the relative dielectric permittivity through the soil profile can be estimated. At Willever Dam, based of a confirmed depth to original bottom sediment (1.22 m) and equations [1] and [2], the estimated v and Er were 0.047 m/ns and 40.2, respectively.

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

Background:
Willever Dam (74.9560 W. Long., 40.79288 N. Lat) was constructed in the 1940s across Pohatcong Creek in Oxford, New Jersey. The dam has outlived its designed lifetime. It has been decided that the structure, which is in need of immediate rehabilitation, will be torn down and the former lake bed will be restored to its natural habitat with funds available though the USDA-NRCS's Wildlife Habitat Incentive Program (WHIP). The Wildlife Habitat Incentive Program is a voluntary program designed to develop and improve habitats that supports fish and wildlife populations. Through WHIP, the USDA-NRCS provides technical and financial assistance (up to 75 percent of the cost to install conservation practices for permanent priority fish and wildlife habitats) to landowners for the development of upland, wetland, aquatic, and other types of wildlife habitat. Restoration of the former lake bed includes the reestablishment of the Pohatcong Creek channel. This will require dredging the lake bottom sediments. A GPR investigation was conducted to estimate the thickness of accumulated sediments on the former lake bed.

The former lakebed is mapped as Cokesbury loam, dark surface, 0 to 8 percent slopes, very stony (CoadBb)[2]. The deep or very deep, poorly drained Cokesbury (fine-loamy, mixed, active, mesic Typic Fragiaquults) soils formed in till on upland depressions.

GPR Survey Procedures:
Multiple traverses were completed from side to side across the western portion of the former lake bed with a 200 MHz antenna (Figure 1). The 200 MHz antenna provided good resolution of subsurface features and satisfactory penetration depths. A Trimble AgGPS 114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA) was used to geo-reference the radar data. Each radar traverse was stored as a separate file.

Figure 1. Edwin Muñiz and Rob Tunstead complete a radar traverse across the snow-covered Willever Lake in Oxford, New Jersey.

[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 [1/23/2011].

Results:
Ground-penetrating radar provided clear, easy to interpret images of the recent sediments and the depth to the original bottom materials. Figure 2 is a representative radar record from the site. In Figure 2, the depth scale is in meters. The Universal Transverse Mercator (UTM) coordinate system is used in this image. Willever Lake has been drained. A thin, localized body of water is evident immediately below the surface pulse above the letter "*A*". A segmented, green-colored line has been used on this radar record to indicate the base of recent sediments and the contact with the original bottom materials. The sediments are largely, saturated organic-ooze. However, interfaces within the recent sediments suggest layers of coarser textured sediments, which were presumably deposited during flood events. One such layer is evident near *B*.

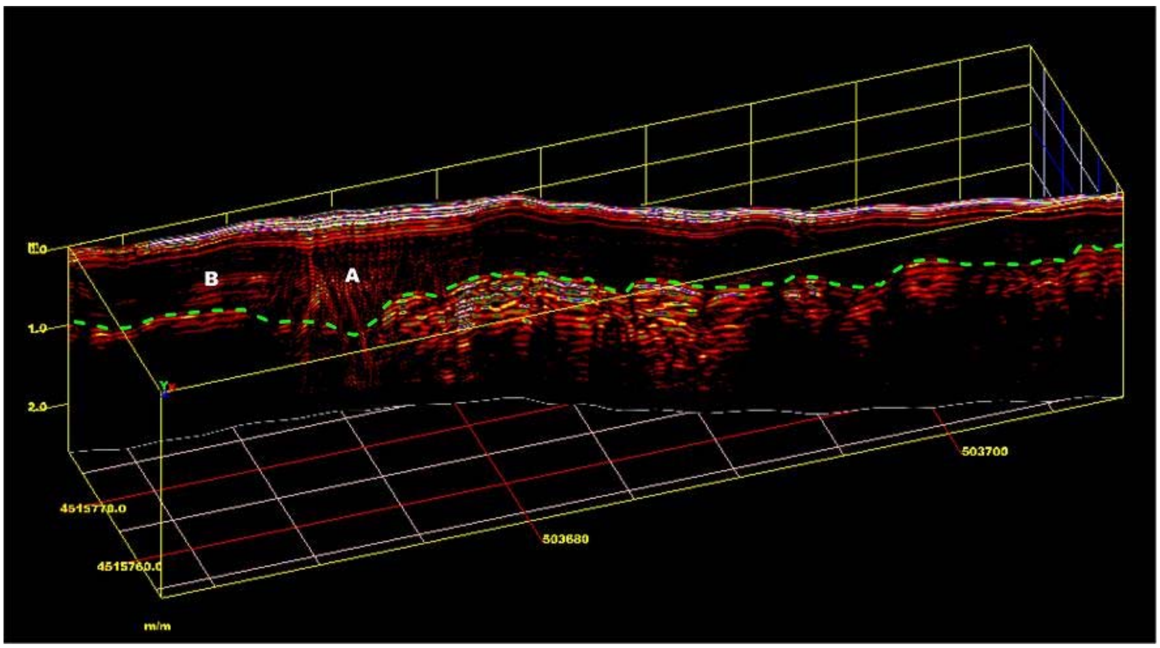

Figure 2. This three-dimensional image is from a radar record that was collected with the 200 MHz antenna at the Willever Lake Dam site.

Based on 35,499 radar measurements, the estimated average thickness of recent sediments is 1.04 m, with a range of 0.34 to 2.09 m. However, one half of these measurements were between 0.89 and 1.16 m. Table 1 summarizes the distribution of recent sediment thickness within the survey area based on 50-cm thickness intervals. For the area that was surveyed with GPR, 92 % of the interpreted measurements of recent sediments were between 0.5 and 1.5 m thick.

Table 1. Frequency distribution of sediment thickness within survey area.

Thickness of recent sediment	Frequency
0.0 to 0.5	0.01
0.5 to 1.0	0.51
1.0 to 1.5	0.41
1.5 to 2.0	0.06
> 2.0	0.01

Figure 3 contains two *Goggle Earth* images of Willever Lake. In this image, the locations of the GPR traverse lines are shown. Each traverse line is colored-coded based on the interpreted thickness (in meters) of the recent sediments.

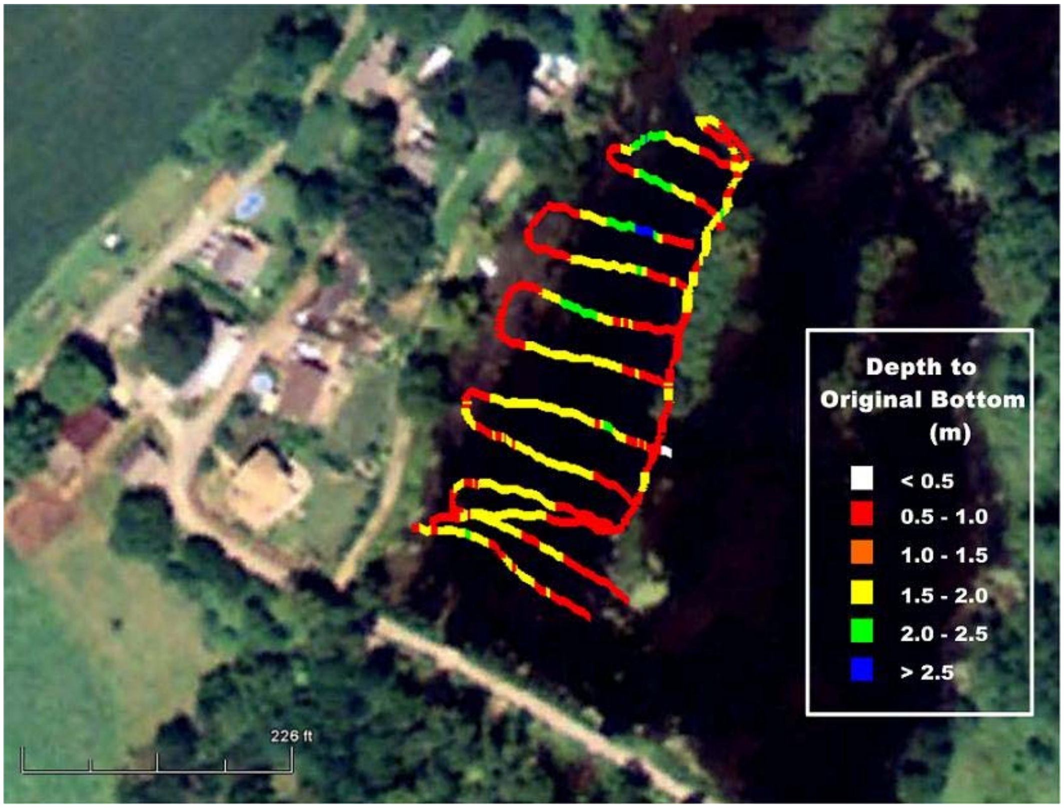

Figure 3. This Google Earth image shows the locations of GPR traverses and the interpreted thickness of bottom sediments over the surveyed portion of Lake Willever.

References:

Doolittle, J., D. Surabian, S. McVey, and D. Parizek, 2009. Three “G’s” for Soil-Bedrock Depth Interpretations. *Soil Survey Horizons* 50(1): 25-29.

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