United States Department of Agriculture

NRCS

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Subject: Geol – Geophysical Training **Date:** 15 February 2011

To: Jerry M. Bernard
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1400 Independence Ave., SW, Rm 6132
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Purpose:
To provide training on the setup, calibration, and operation of the EM34-3XL meter to geologists from five states and the National Headquarters.

Participants:
Jerry Bernard, National Geologist, USDA-NRCS, Washington, DC
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Mark Hall, Geologist, USDA-NRCS, Athens, GA
Kim Kroeger, Geologist, USDA-NRCS, Raleigh, NC
Michael McCawley, Geologist, USDA-NRCS, Lincoln, NE
Jeff McClure, Geologist, USDA-NRCS, Morgantown, WV
Trent Snellings, Geologist, USDA-NRCS, Jackson, MS
Wes Tuttle, Soil Scientist (Geophysical), USDA-NRCS-NSSC, Wilkesboro, NC

Activities:
All activities were completed during the period of 7 to 9 February 2011.

Summary:

1. The USDA-NRCS's Geologic Support Unit (GSU) recently purchased an EM34-3XL meter. This is the only meter of its kind within USDA-NRCS. This meter provides nominal penetration depths ranging from about 7.5 to 60 meters (about 25 to 197 feet). It will be primarily used by the GSU for geophysical site assessments of earthen structures and substrates. Electromagnetic induction (EMI) provides a rapid and economical means to visualize subsurface trends and localized anomalous conditions that can be missed by all but the most close-spaced drilling programs.

2. In give-and-take training exercises, both participants and trainers gained knowledge and insight into the complexities of rapidly developing and leapfrogging EMI, GPS, PCs, data logging and processing software technologies. Initial difficulties in setting up and having several complementary technologies "talk to one another" were resolved by the group. The EM34-3XL meter and complementary hardware and software are properly functioning, and the system is fully operational at this time.

3. The EM34-3XL meter has Bluetooth technology and communicates directly to the Archer XF101 field PC that is a component of this system. However, a separate RS232 cable was ordered and

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will provide backup communication between the meter and PC, if the Bluetooth system should fail.

4. The Archer XF101 field PC that comes with the EM34-3XL meter has an attached Hemisphere XF101 Differential Global Positioning System (DGPS) receiver. This receiver appears to provide adequate resolution for the surveying earthen structures (see Figure 2 in attached report).

5. The EM34-3XL system is scheduled for immediate use on a watershed dam located in North Alabama. A sinkhole has formed at this site and the strategy is to use the EM34-3XL meter to assess hidden karst features and provide information useful for dam rehabilitation and repairs. Knowledge gained at this site with the EM34-3XL meter should provide additional insight into appropriate survey methodology and interpretations for other earthen structures.

6. It is imperative that the trainees recognize that the results of all geophysical site investigations are interpretive and do not substitute for direct ground-truth observations (cores). The use of geophysical methods can reduce the number of cores, direct their placement, and supplement their interpretations.

It was the pleasure of Jim Doolittle, Wes Tuttle, and the National Soil Survey Center to be of assistance to you and your staff in this training.

JONATHAN W. HEMPEL
Director
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cc:
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Report on Geophysical Training provided to NRCS Geologists on the Use and Operation of the EM34-3XL System near Verona, Virginia, on 7 to 9 February 2011.

Jim Doolittle

Background:

Electromagnetic induction is a noninvasive geophysical tool. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Electromagnetic induction can provide, in a relatively short time, a large number of spatially-referenced measurements. Maps prepared from properly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating drilling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the apparent conductivity (EC_a) of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials (Greenhouse and Slaine, 1983). In earthen materials, EC_a is principally associated with soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976). Apparent conductivity is typically expressed in milliSiemens/meter (mS/m).

Electromagnetic induction measures vertical and lateral variations in EC_a. Values of EC_a are seldom diagnostic in themselves. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations are normally used.

The effective depth of penetration and measured response of an EMI meter are influenced by coil orientation, coil separation, and frequency, as well as the conductivity of the profiled material(s). The EMI response is not uniform with depth; surface and shallow layers contribute more to the overall response than deeper layers. The orientation of the transmitter and receiver coil axes (with respect to the ground surface) affects the response from materials at different depths (McNeill, 1980). For example, in the horizontal dipole orientation (HDO), meters are more sensitive to near surface materials. In the vertical dipole orientation (VDO), meters are more sensitive to deeper materials. The greater the intercoil spacing (spacing between transmitter and receiver coils), the greater the depth of penetration, the larger the volume of earthen materials profiled, and the lower the resolution of subsurface features. Slavich (1990) reported that the actual depth of observation would vary depending on the EC_a of the profiled material(s). Greenhouse et al. (1998) noted that EMI instruments do not penetrate a fixed distance under all circumstances. The depth of penetration decreases with increasing conductivity.

Butler and Llopis (1990) have categorized EMI as a primary geophysical tool for the detection of anomalous seepage zones in earthen dams. The resolution of subsurface features with EMI, however, is inferior to that obtained with electrically resistivity and ground-penetrating radar. In addition, as with all geophysical methods, the resolution of subsurface features decreases with increasing observation depths. The detection of anomalous features within and below earthen structures with EMI depends on the size, depth, and composition (contrasting materials) of these features.

Equipment:

An EM34-3XL meter (Geonics Limited; Mississauga, Ontario) was recently purchased by NRCS Geologic Support Unit (GSU) for use in geologic and engineering applications. [1] The EM34-3XL meter requires two people to operate (Fig. 1). McNeil (1980) and Geonics Limited (1990) describe the operation of the EM34-3 meter. The EM34-3XL meter consists of receiver and transmitter coils, three reference cables (10-, 20-, and 40-m), and receiver and transmitter consoles. Compare with EM34-3

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

meters that have been previously used within USDA-NRCS, the EM34-3XL has increased transmitter power and a noticeably larger transmitter coil (see white-colored coil in Figure 1). These features are designed to improve the signal-to-noise ratio (by a factor of 10 at the 40-m intercoil spacing and by a factor of 4 at the 10- and 20-m intercoil spacings). Improved signal-to-noise ratio is advantageous when surveys are conducted in areas of high cultural and/or at times of high atmospheric noise. The frequency used by the EM34-3XL meter is dependent on the intercoil spacing: 6400 Hz for the 10-m, 1600 Hz for the 20-m, and 400 MHz for the 40-m intercoil spacings. During training exercises, a 10-m intercoil spacing was used.

Depth of penetration is dependent on frequency and coil geometry. When the coils are held in the HDO the depth of penetration is 0.75 X the intercoil spacing (7.5-m, 15-m, and 30-m for the 10-, 20-, and 40-m intercoil spacings, respectively). When the coils are held in the VDO the depth of penetration is 1.5 X intercoil spacing (15-m, 30-m, and 60-m for the 10-, 20-, and 40-m intercoil spacings, respectively). When possible, the use of HDO configuration is preferred over the VDO because the HDO configuration is relatively insensitive to misalignment of the two coils (McNeil, 1980).

Figure 1. NRCS Geologists operating the EM34-3XL meter in the horizontal dipole orientation (HDO) with a 10-m intercoil spacing. Although requiring a minimum of two people to operate, a GPS/data logger operator stationed at the mid-point between the two coils proves advantageous.

An Archer XF101 field PC with Hemisphere XF101 Differential Global Positioning System (DGPS) receiver (Juniper Systems, North Logan, Utah) is used with the EM34-3XL meter.[2] The Dat34W

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

program (Geonics Limited, Mississauga, Ontario) was used with EM34-3XL meter to display and record both GPS and EC_a data on the Archer field computer.[3]

Completed Events:
On Monday afternoon, the EM34-3XL meter was set up in a parking area near the Verona USDA Service Center. General operating theory and the components of the EM34-3XL system were described. The setup procedures for the EM34-3XL system were reviewed and discussed. The system was properly setup in the parking area. An attempt was made to connect an older RS232 cable between the Archer field computer and the receiver console, but failed (Geonics Limited was contacted and the proper cable will be forwarded to Kim Kroeger). The EM34-3XL has Bluetooth technology. Proper Bluetooth connections between several different GPS receivers and the Archer field computer could not be initially established. The problem was diagnosed to improper settings and too many competing Bluetooth signals coming from three nearby sources (other GPS receivers). Communications were finally established between the Archer XF101 field PC and the EM34-3XL meter.

On Tuesday morning, practice using the EM34-3XL meter was completed near the Waynesboro Nursery Dam, in Stuart Draft, Virginia. Several traverses were completed using a 10-m intercoil spacing and operating the meter in both dipole orientations. During this exercise, participants became familiar with field operating procedures, techniques, and sources of error.

Tuesday afternoon was spent in the Augusta County Administrative Building reviewing data download procedures and the use of the DAT34W software program (CCE certified). Raw field data collected with the Archer XF101 field PC was successfully transferred, converted and georeferenced using the DAT34W software program. Participants were given the opportunity to download data and work with the DAT34W program. Later, a PowerPoint presentation on electromagnetic induction and its uses within NRCS was provided.

On Wednesday morning, we returned to the Waynesboro Nursery Dam and completed a survey with the EM34-3XL operated in the HDO and with a 10-m intercoil spacing. Only the north-facing slope of the structure was surveyed. The results of this survey are captured in the images supplied by Kim Kroeger (Figures 2 and 3). Figure 2 shows the survey lines and referenced mid-points between the two coils. The measured EC_a for the 10-m intercoil spacing was georeferenced to these mid-points. Participants felt that surveying in only one dipole orientation at a time (rather than repositioning and realigning the two coils in two different dipole orientations at each measurement point) is easier and less susceptible to operator errors.

EM31 Meter:
Geologists in Illinois, South Dakota, and Washington have access to EM31 meters. In addition, an EM31 meter was purchased by the Virginia State Office and was used by the State Geologist prior to his retirement. The EM31 meter is manufactured by Geonics Limited (Mississauga, Ontario). [2] The EM31 meter requires no ground contact and only one person (Fig. 4, upper) to operate. The EM31 meter weighs about 12.4 kg (27.3 lbs), 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 HDO and VDO configurations, respectively (McNeill, 1980). McNeill (1980) describes the principles of operation for the EM31 meter.

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

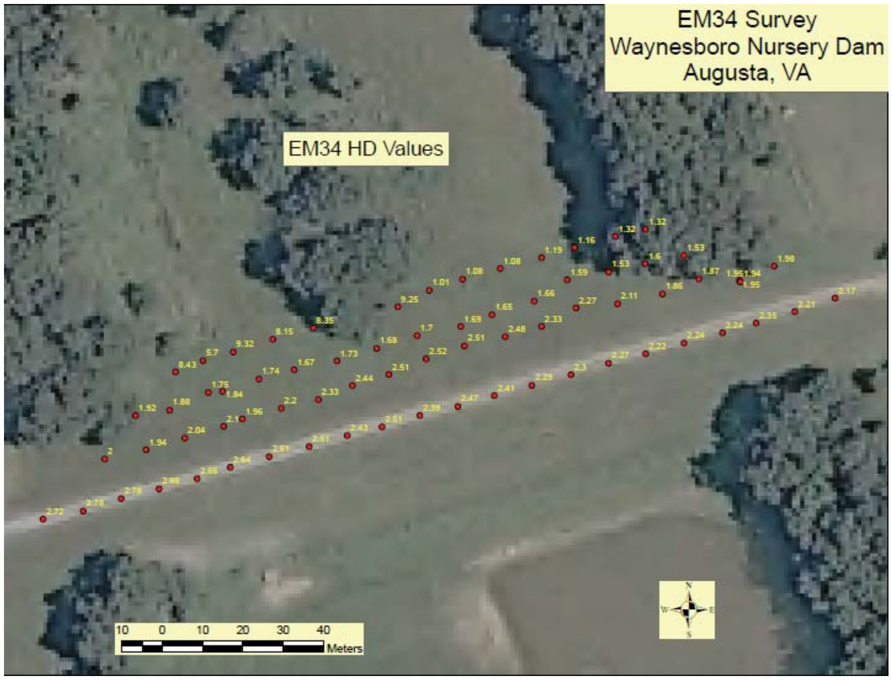

Figure 2. This image shows the location of traverse lines and measurement points (mid-points) between the two coils of the EM34-3XL meter, which was operated in the HDO with a 10-m intercoil spacing at the Waynesboro Nursery Dam in Augusta County, Virginia. Apparent conductivity measurements are expressed in mS/m.

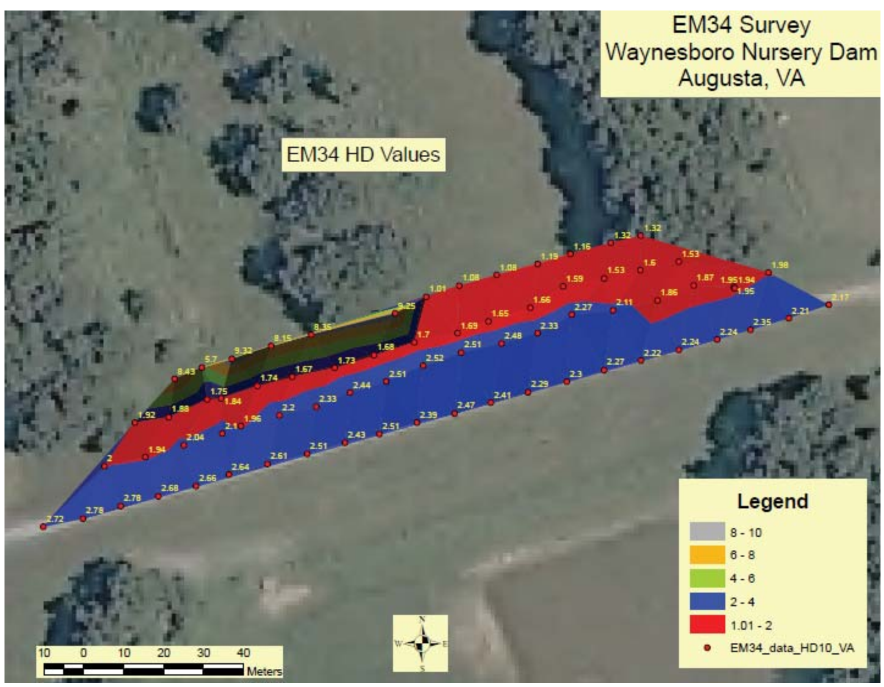

Figure 3. This contour plot shows the EC_a measured with an EM34-3XL meter operated in the HDO with a 10-m intercoil spacing at the Waynesboro Nursery Dam in Augusta County, Virginia. All EC_a measurements are expressed in mS/m. Effective penetration depth is about 7.5 m.

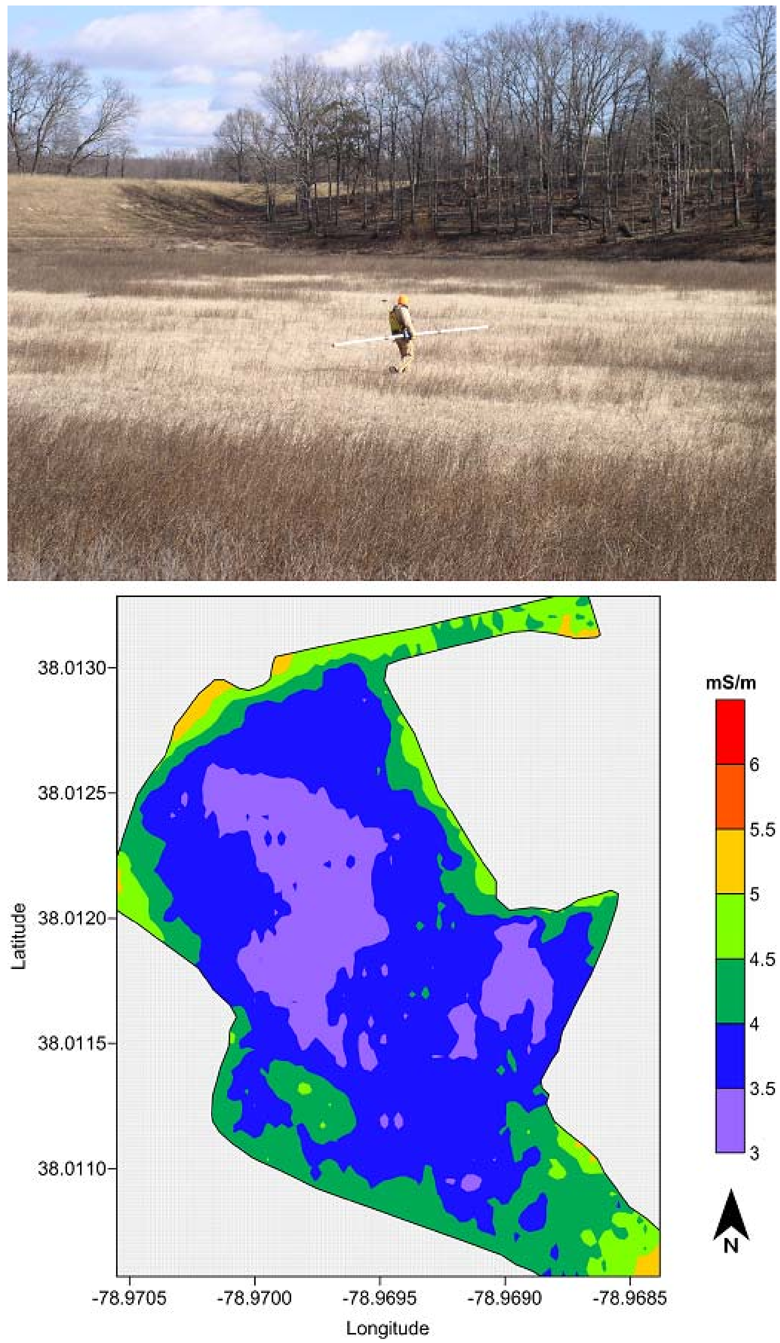

Figure 4. Wes Tuttle conduct a survey with an EM31 meter operated in the vertical dipole orientation across the open pool area behind the Waynesboro Nursery Dam. Spatial EC_a patterns across the pool area are shown in the lower plot.

During the Tuesday morning exercise, Wes Tuttle collected over 7200 geo-referenced EC_a measurements across the pool area (Figure 4, upper). The EC_a measurements were exceedingly low and invariable with an average value of 5.9 mS/m and a range of only 2.9 to 5.9 mS/m. Generally, because of calibration and operator errors, and slight fluctuations in measurements, a minimum contour interval of at least 2 to 4 mS/m should be used on images of spatial EC_a data. In the example shown in Figure 4 (lower), because of the exceeding low range in measurements (3 mS/m), an isoline interval of 0.5 mS/m was used.

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