Route to Soil Scientists #33



**UNITED STATES DEPARTMENT OF AGRICULTURE** **CHESTER, PA 19013**
**NATURAL RESOURCES CONSERVATION SERVICE** **610-490-6042**

**Subject:** SOI - EM Investigations **Date:** 5 September 1995

**To:** Darwin Newton
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**Purpose:**
To provide electromagnetic induction (EM) training and field assistance to the staff of Natural Resources Conservation Service in Tennessee.

**Participants:**
Gregg Brann, District Conservationist, NRCS, Clarksville, TN
Robert Buck, Tennessee Department of Agriculture, Springfield, TN
Doug Clendenon, Soil Survey Project Leader, NRCS, Centerville, TN
James Clifton, Farm Owner, Springfield, TN
Harry Davis, Resource Soil Scientist, NRCS, Jackson, TN
Carolyn Dillard, District Conservationist, NRCS, Ashland City, TN
Jim Doolittle, Research Soil Scientist, NRCS, Chester, PA
Jim Durrett, Director of Streets, City of Clarksville, TN
Jack Frazier, Engineer, City Engineer's Office, Clarksville, TN
Mark Garretson, Soil Conservationist, NRCS, Clarksville, TN
Ken Green, Inspector, City of Clarksville, TN
Andy Hartmann, State Geologist, NRCS, Nashville, TN
Nathan Hartgrove, Soil Survey Project Leader, NRCS, Johnson City, TN
John Jenkins, Resource Soil Scientist, Clarksville, TN
Darwin Newton, State Soil Scientist, NRCS, Nashville, TN
Daryl Osborne, Inspector of Streets, City of Clarksville, TN
Randy Petersen, Inspector, City of Clarksville, TN
James Sims, State Conservation Engineer, NRCS, Nashville, TN
Philip Wilson, Soil Conservationist, NRCS, Springfield, TN

**Activities:**
Electromagnetic induction surveys were completed at the farm of James Clifton near Springfield, and within the city limits of Clarksville on 28 August 1995. During these surveys, participants were encouraged to use and become familiar with the EM31 meter.

**Equipment:**
The electromagnetic induction meter was the EM31, manufactured by GEONICS Limited. The observation depth of an EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM31 meter has a fixed intercoil spacing of 3.66 m. It operates at a frequency of 9.8 kHz. The EM31 meter has effective observation depths of about 3 and 6 m in the horizontal and

vertical dipole orientations, respectively (McNeill, 1979). Measurements of conductivity are expressed as milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER program was used to develop a two-dimensional plot of apparent conductivity values within the study sites. SURFER was developed by Golden Software, Inc. Simulated grids of the study sites were created using kriging methods with an octant search. The data was smoothed using cubic spline interpolation.

The EM data have been displayed in two-dimensional contour plot (Figures 1 to 4). In these plots, to help emphasize the spatial distribution of apparent conductivity values, colors and filled contour lines have been used. Each plot represents the spatial distribution of apparent conductivity values over a specified observation depth. Other than showing trends in values of apparent conductivity (i.e. zones of higher or lower electrical conductivity), no significance should be attached to the colors themselves.

**Discussion:**
Electromagnetic induction techniques measure the apparent conductivity of earthen materials. Apparent conductivity is a weighted average measurement for a column of earthen materials to a specified observation depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the (i) volumetric water content, (ii) type and concentration of ions in solution, (iii) temperature and phase of the soil water, and (iv) amount and type of clays in the soil matrix, (McNeill, 1980). The apparent conductivity of soils increases with increases in the exchange capacity, water content, and clay content (Kachanoski et al., 1988; Rhoades et al., 1976).

Though seldom diagnostic in themselves, lateral and vertical variations in apparent conductivity have been used to infer changes in soils and soil properties, and to detect subsurface anomalies. Interpretations of the EM data are based on the identification of spatial patterns within data sets.

<u>EM Survey at James Clifton Farm</u>
A constructed pond on the farm of James Clifton will not hold water. The pond is located in an area of karst and Sengtown (clayey, mixed, thermic Typic Paleudults) soils. The purpose of the EM investigation was to detect anomalous subsurface feature(s) which would suggest the occurrence of piping or other dissolution features.

An irregularly shaped, 200 by 225 foot grid (about 1.03 acres) was established across the pond site. Survey flags were inserted in the ground at 25 foot intervals. At each of the 75 grid intersections, measurements were obtained with an EM31 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

Within the pond site, values of apparent conductivity were relatively low and invariable. Apparent conductivity averaged 7.8 and 8.0 mS/m in the horizontal and vertical dipole orientations, respectively. Within the site, values of apparent conductivity obtained with the EM31 meter ranged from 4.9 to 13.7 mS/m and from 5.4 to 13.3 mS/m in the horizontal and vertical dipole orientations, respectively.

Figures 1 and 2 are two-dimensional plots of apparent conductivity measurements simulated from data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. Comparing the plots, values of apparent conductivity, as a rule, appear to increase slightly with increasing observation depth (responses of the EM31 in the horizontal dipole orientation were typically less than those in vertical dipole orientation). This relationship is believed to reflect increased concentrations of clay and water with increasing soil depth.

The spatial patterns appearing in figures 1 and 2 reflect variations in soil properties. In each plot, values are higher along the embankment area, and in the southern and the southeastern portions of the site. It was assumed that these portions of the site were underlain by fine-textured soil materials at shallower depths. In the northern and central portions of the site, values of apparent conductivity were lower. It was assumed that these portions of the site were underlain by coarser-textured colluvium and were deeper to fine-textured soil materials.

To verify these assumptions two auger observations were made with a powered probe (see the two point symbols in each figure). At the northern-most observation point, no layer of fine-textured soil materials were noticed to the depth of maximum observation (about 10 feet). The materials represented colluvium washed into the depression from adjacent, higher-lying slope positions. Based on the patterns in figures 1 and 2, extensive, thick deposits of coarser-textured soil materials (lower values of apparent conductivity) were presumed to surround this observation point.

The eastern-most observation point was found to be underlain by fine-textured soil materials at shallow depths. Based on the patterns in figures 1 and 2, it was presumed that thick layers of fine-textured soils materials occurred at shallow depths along the south and southeastern portions of the sites.

While no anomalous features are observable in these figures, depths to fine-textured soil materials and thickness of coarser-textured colluvium have been depicted. It is assumed that the downward movement of water will be affected by and forced to move laterally along the interface separating the coarser-textured alluvium from the fine-textured soil materials.

<u>EM Survey at Single Tree Development; Clarksville, Tennessee</u>
A 100 by 75 foot grid (about 0.17 acre) was established within a residential area in Clarksville. Survey flags were inserted in the ground at 25 foot intervals. At each of the 20 grid intersections, measurements were obtained with an EM31 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The site was located in a backyard of a residential home. It was bounded on the north and northeast by two homes and on the south by a road, chain-link fence, and overhanging power lines. In the immediate vicinity of these "cultural features," elevated EM responses were observed.

Undoubtedly, the site is underlain by buried building materials and perhaps even buried utility lines. Elevated EM responses were attributed to these "cultural features." These responses interfered with the interpretations of soil and lithologic patterns. The grid was too small and the number of observation too limited to adequately appraise the site. The obstacles noted in this survey will hamper EM studies in many urban areas.

**Results:**
Field studies provided NRCS staff personnel with an opportunity to operate the EM31 meter and to observe and appraise the use of EM techniques for site assessments. Electromagnetic induction appears to be a most appropriate geophysical technique for rapidly assessing subsurface features and conditions in areas of karst.

It was my pleasure to assist in these investigations. If I can be of further assistance please do not hesitate to request my services.

With kind regards.

James A. Doolittle
Research Soil Scientist

cc:
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**References:**

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