United States Department of Agriculture

Natural Resources Conservation Service

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Subject: ENG -- Electromagnetic Induction (EMI) Assistance **Date:** 14 July 1998

To: Janet Oertly
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Purpose:
The purpose of this investigation was to conduct EMI surveys of a vegetative filter area and a waste-management facility in central Pennsylvania.

Participants:
Gregory Boyd, Engineering Technician, USDA-NRCS Lamar, PA
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Glen Cauffman, Farm Manager, Pennsylvania State University, State College, PA
Mike Lewis, Summer Intern, USDA-NRCS, Clarion, PA
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Activities:
Two waste facilities were surveyed; one in Northumberland County and one in Centre County. Field activities were completed in Northumberland County on 30 June 1998. Field activities were completed in Centre County on 1 July 1998.

Equipment:
The electromagnetic induction meter used was the EM31 manufactured by Geonics Limited[*] . This meter is portable and requires only one person to operate. Principles of operation have been described by McNeill (1980). No ground contact is required with this meter. The EM31 meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing. The observation depth of an EMI meter is dependent upon intercoil spacing, transmission frequency, and coil orientation (McNeill, 1980). The EM31 meter has a fixed intercoil spacing of 3.7 m. It operates at a frequency of 9.8 kHz. When placed on the ground surface, the EM31 meter has assumed observation depths of about 3 and 6 m in the horizontal and vertical dipole orientations, respectively (McNeill, 1980). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

[*] Trade names are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

To help summarize the results of this study, the SURFER for Windows program, developed by Golden Software, Inc.,* was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search. All grids were smoothed using a cubic spline interpolation. Shadings and filled isolines have been used in the enclosed plots to emphasize spatial patterns. Other than showing trends and patterns in values of apparent conductivity (i.e., zones of higher or lower electrical conductivity), no significance should be attached to the shades themselves.

Results:

Northumberland County; Site # 1

The site was located east of Sunbury. A vegetative filter area was installed in October 1997. It provides a filter for water from a feed-mixing operation. A *before-built*, electromagnetic induction survey was conducted on this site in October 1997. For the present survey, the original grid was reestablished across the site. Grid intervals were 25 and 20 feet. Survey flags were inserted in the ground at each of the twenty-four grid intersections and served as observation point. Measurements were taken with an EM31 meter placed on the ground surface in both the horizontal and vertical dipole orientations.

The topography of the survey area has been simulated in the three-dimensional contour plot shown in Figure 1. In Figure 1, the contour interval is 2 feet. Elevations were not tied to a benchmark; the lowest observation point within the site served as datum (0.0 ft). Relief is about 9.8 feet. The locations of the distribution manifold and a utility pole (used to establish the survey grid) are shown in Figure 1.

Figure 2 shows the spatial distribution of apparent conductivity as measured with the EM31 meter in the horizontal and vertical dipole orientations. In each plot, the isoline interval is 2 mS/m. Data obtained in the horizontal dipole orientation are shown in the left-hand plot. In this plot, areas of high apparent conductivity are presumed to be affected by solutes deposited on the surface from effluent. The apparent conductivity of the upper three meters (measured with the EM31 meter in the horizontal dipole orientation) averaged 1.69 mS/m with a range of 4.0 to 10.4 mS/m. One-half of the observations had an apparent conductivity between 5.2 and 6.6 mS/m.

Data obtained in the vertical dipole orientation are shown in the right-hand plot. In this plot, an anomalous area of low apparent conductivity extends down slope from the distribution manifold. At this time, no explanation is possible for this anomaly without information from exploratory coring and sampling. The apparent conductivity of the upper six meters (measured with the EM31 meter in the vertical dipole orientation) averaged 1.42 mS/m with a range of 2.2 to 9.3 mS/m. One-half of the observations had an apparent conductivity between 5.2 and 6.2 mS/m.

At the time of the October 1997 survey, soils were relatively dry. At the time of the present survey, soils were moist. The apparent conductivity of soils increases with increases in water content. Comparing the 1997 with the 1998 data, the effects of higher soil moisture contents in 1998 were not apparent in the data sets. In general, higher values of apparent conductivity occurred only at those observation points near or immediately down slope of the distribution manifold. At other observation points, measurements remained relatively constant. Higher and altered spatial patterns of apparent conductivity near the manifold pipe were attributed principally to the discharge of effluent.

Table 1 summarizes the differences in apparent conductivity measurements recorded for the two sampling periods. Values of apparent conductivity were slightly higher and more variable in 1998. This was attributed principally to discharge of effluent from the distribution manifold.

TABLE 1

* Trade names are used to provide specific information. Their mention does not constitute endorsement by USDA-NRCS.

Comparison of Apparent Conductivity Measurements
(All measurements are in mS/m)

	1997		1998	
	EM31H	**EM31V**	**EM31H**	**EM31V**
Minimum	4.0	4.5	4.0	2.2
Maximum	6.5	6.4	10.4	9.3
Average	5.4	5.5	6.4	5.8
Standard deviation	0.70	0.52	1.69	1.42

Comparative plots of the spatial distribution of apparent conductivity within the upper 3 m of the soil profile are shown in left-hand portion of Figure 3. In each plot, the isoline interval is 2 mS/m. In 1998, a conspicuous plume of higher apparent conductivity values (> 8 mS/m) appears near the distribution manifold. In general, values of apparent conductivity decrease in a down slope direction away from the distribution manifold. The pattern is plume-like and suggests overland flow and the deposition of waste products in the surface layers. This pattern is presumably associated with a decrease in the concentration of solutes with increasing distance from the distribution manifold.

Comparative plots of the spatial distribution of apparent conductivity within the upper 6 m of the soil profile are shown in right-hand portion of Figure 3. In each plot, the isoline interval is 2 mS/m. The patterns evident in these plots are presumed to reflect variations in soil and geologic strata, and the effects of surface deposition and seepage of effluent from the distribution manifold. In the 1998 plot, anomalously low values of apparent conductivity (< 4 mS/m) appear to emanate from the distribution manifold.

Proposed Waste-Composting Site; Pennsylvania State University, Centre County

The proposed site is located in a pasture and in area of Hagerstown silty clay loam, 3 to 8 percent slopes (Braker, 1981). Hagerstown soils are members of the fine, mixed, mesic Typic Hapludalfs family. These deep, well-drained soils formed in limestone residuum on uplands. Depth to limestone bedrock ranges from 40 to 72 inches.

A survey grid was established across the site. Except for the western most grid line (north-south trending), the grid interval was 100 feet. Survey flags were inserted in the ground at each of the thirty-four grid intersections and served as observation point. Measurements were taken with an EM31 meter operated at waist height. Measurements were taken in both the horizontal and vertical dipole orientations at each observation point. At each observation point, the relative elevation of the surface was determined with a level and stadia rod. Elevations were not tied to a benchmark; the lowest observation point within the site served as datum (88.3 feet).

The topography of the survey area has been simulated in the three-dimensional contour plot shown in Figure 4. In Figure 4, the contour interval is 2 feet. Relief is about 15.3 feet.

Apparent conductivity data was invariable and nondescript at this site. Table 2 summarizes the apparent conductivity measurements. Values of apparent conductivity were slightly higher and more variable in the deeper-sensing vertical dipole orientation. Difference in apparent conductivity can be attributed to variations in the depth to bedrock, lithology, karstification, and moisture content.

TABLE 2

Apparent Conductivity Measurements
(All measurements are in mS/m)

	EM31H	EM31V
Minimum	2.8	2.2
Maximum	6.4	8.6
Average	4.8	5.5
Standard deviation	1.00	1.37

Figure 5 shows the spatial distribution of apparent conductivity as measured with the EM31 meter in the horizontal and vertical dipole orientations. In each plot, the isoline interval is 2 mS/m. Data obtained in the horizontal dipole orientation are shown in the left-hand plot. In this plot, areas of low apparent conductivity are assumed to have shallower depths to limestone bedrock. The apparent conductivity of the upper two meters (measured with the EM31 meter held at waist height and in the horizontal dipole orientation) averaged 4.8 mS/m with a range of 2.8 to 6.4 mS/m. One-half of the observations had an apparent conductivity between 4 and 5.6 mS/m.

Data obtained in the vertical dipole orientation are shown in the right-hand plot of Figure 5. In this plot, areas of high apparent conductivity are assumed to have greater moisture contents and karstification. The apparent conductivity of the upper five meters (measured with the EM31 meter held at waist height and in the vertical dipole orientation) averaged 5.5 mS/m with a range of 2.2 to 8.6 mS/m. One-half of the observations had an apparent conductivity between 4.7 and 6.4 mS/m.

Figure 6 contains representations of the distribution of apparent conductivity measured with the EM31 meter in the horizontal and vertical dipole orientations. In this figure, two-dimensional plots of apparent conductivity have been overlaid upon three-dimensional surface net diagrams of the site. In each of these plots, the isoline interval is 2 mS/m. These figures hopefully provide a better opportunity to visualize the relationship of apparent conductivity with the landscape.

Conclusions:

1. Simulations prepared from correctly interpreted EMI data provide the basis for assessing site conditions and for designing sampling and monitoring schemes. Spatial patterns associated with the concentration of ions and compounds from waste-management facilities can be mapped with EMI. Electromagnetic induction surveys provide an indication of the extent of conditions that may pose a risk to the environment. In addition, these surveys provide a mechanism for monitoring relative changes in apparent conductivity and for locating sampling and monitoring sites.

2. At the site in Northumberland County, data collect in October 1997 were invariable and nondescript. Data collect in June 1998 were more variable and suggest the likely deposition of waste products in the surface layers. Plume-like patterns are discernible surrounding the distribution manifold. These patterns are most conspicuous in the data collected in the shallower-sensing horizontal dipole orientation and suggest surface deposition of contaminants. The plume-like pattern is presently detectable 75 feet down-slope of the distribution manifold.

3. The survey at Pennsylvania State University provided a *before-built* picture of the proposed waste-composting site. Several interpretations were hypothesized for the spatial patterns appearing in simulated plots of the site. However, as no ground-truth observations were made, these interpretations are speculative.

It was my pleasure to work in Pennsylvania and with members of your fine staff.

With kind regards,

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References

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