United States Department of Agriculture

Natural Resources Conservation Service

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Subject: ENG -- Electromagnetic Induction (EMI) Assistance **Date:** 30 April 2004

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Purpose:
Electromagnetic induction (EMI) surveys were completed of an animal-waste holding facility and a filter strip at the Schmitz Dairy Farm in Coles Valley, Adrian Township, Monroe County. These surveys were requested to ascertain whether detectable patterns of seepage had developed.

Participants:
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
Donna Ferren Guy, Soil Scientist, USDA-NRCS, Richland Center, WI
Bob Micheel, Soil & Water Conservationist, Monroe County Land Conservation Department, Sparta, WI

Activities:
All field activities were completed on 26 April 2004.

Equipment:
An EM31meter developed by Geonics Limited was used in this investigation.[1] Principles of operation have been described by McNeill (1980a). The EM31meter is portable and requires only one person to operate. The EM31 meter operates at a frequency of 9,800 Hz and has theoretical penetration depths of about 3 and 6 m in the horizontal and vertical dipole orientations, respectively (McNeill, 1980a). The EM31 meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing. Output is calibrated to read apparent conductivity (EC_a) and is expressed in milliSiemens per meter (mS/m).

The Geonics DAS70 Data Acquisition System was used to record and store both EMI and GPS data.[1] The acquisition system consists of an EM31 meter, Allegro field computer, and Trimble AG114 GPS receiver.[1] With the acquisition system, the EM31meter is keypad operated and measurements can be automatically triggered.

To help summarize the results of this study, SURFER for Windows (version 8.0) software developed by Golden Software, Inc.,[1] was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search.

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

Survey Site:
An EMI survey was completed in the area that immediately surrounds the waste-holding facility owned and operated by Rick and Ryan Schmitz (NE ¼ of Section 33, T. 17 N, R. 2 W). The survey site is bordered to the northeast by Silver Creek. An additional survey was competed over a grass filter strip to assess the effectiveness of this installation.

The survey area is located principally in an area that had been mapped as Kickapoo fine sandy loam, 0 to 3 % slopes (Barndt and Langton, 1984). The deep, moderately well drained Kickapoo soil forms in loamy alluvium on flood plains. Kickapoo is a member of the coarse-loamy, mixed, superactive, nonacid, mesic Typic Udifluvents family. Background EC_a levels of 8 to 12 mS/m were obtained over Kickapoo soils.

The amount of open space available to conduct the EMI surveys was extremely small and restricted by farm buildings, fences, machinery and implements. These cultural features, as well as buried utility and feed lines, caused noticeable interference to the electromagnetic fields generated by the EM31 meter and produced undesired anomalous responses in both the quadrature and inphase EMI measurements. This noise interfered and masked spatial patterns related to seepage of wastes from the holding facility.

Field Procedures:
Traverses were conducted in a spiral pattern around the waste-holding facility and in closely parallel lines along the long-axis of the filter strip. For both surveys, the EM31 meter was held at hip height and in the deeper-sensing, vertical dipole orientation. At hip height and orientated in the vertical dipole orientation, the effective depth of penetration of this meter is about 5 m. The EM31 meter was operated with the DAS70 Data Acquisition system and in the continuous mode with measurements recorded at 1-sec intervals. Walking at a uniform pace, the EM31 meter recorded 786 and 104 geo-referenced measurements around the waste-holding facility and in the filter strip, respectively.

Background:
Electromagnetic induction is a noninvasive geophysical tool that is used for site assessments. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Results are interpretable in the field. This geophysical method can provide in a relatively short time the large number of observations that are needed to comprehensively cover sites. Maps prepared from properly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating sampling or monitoring sites.

Electromagnetic induction uses electromagnetic energy to measure the EC_a of earthen materials. Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in EC_a are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the volumetric water content, type and concentration of ions in solution, temperature and phase of the soil water, and amount and type of clays present in the soil (McNeill, 1980b). Apparent conductivity increases with increased soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Electromagnetic induction measures vertical and lateral variations in EC_a. Values of EC_a are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in soils and soil properties. Interpretations are based on the identification of spatial patterns within data sets. To assist interpretations, computer simulations are normally used.

Electromagnetic induction has been successfully used to investigate the migration of contaminants from waste sites (Stierman and Ruedisili, 1988; Siegrist and Hargett, 1989; Brune and Doolittle, 1990; Radcliffe et al., 1994; Drommerhausen, et al., 1995; Ranjan and Karthigesu, 1995; and Eigenberg et al., 1998). Soils affected by animal wastes have higher conductivity than soils that are unaffected by these contaminants. Electromagnetic induction has been used to infer the relative concentration, extent, and movement of contaminants from waste-holding and treatment facilities. Electromagnetic induction does not provide a direct measurement of specific ions or compounds. However, measurements of EC_a have been correlated with concentrations of chloride, ammonia, and nitrate nitrogen in the soil (Brune and Doolittle, 1990; Ranjan and Karthigesu, 1995; Eigenberg et al., 1998).

Results:

Animal waste-holding facility:

Values of EC_a were variable around the waste-holding facility. Apparent conductivity averaged 17.2 mS/m with a range of 9.1 to 33.6 mS/m. One-half the observations had values of EC_a between 13.6 and 20.3 mS/m. For Kickapoo soils, an EC_a of less than 12.0 mS/m is considered typical. Values in excess of 12 mS/m are assumed to be the result of either soil contamination or electromagnetic field interference from the plethora of cultural features that are congested within the study area.

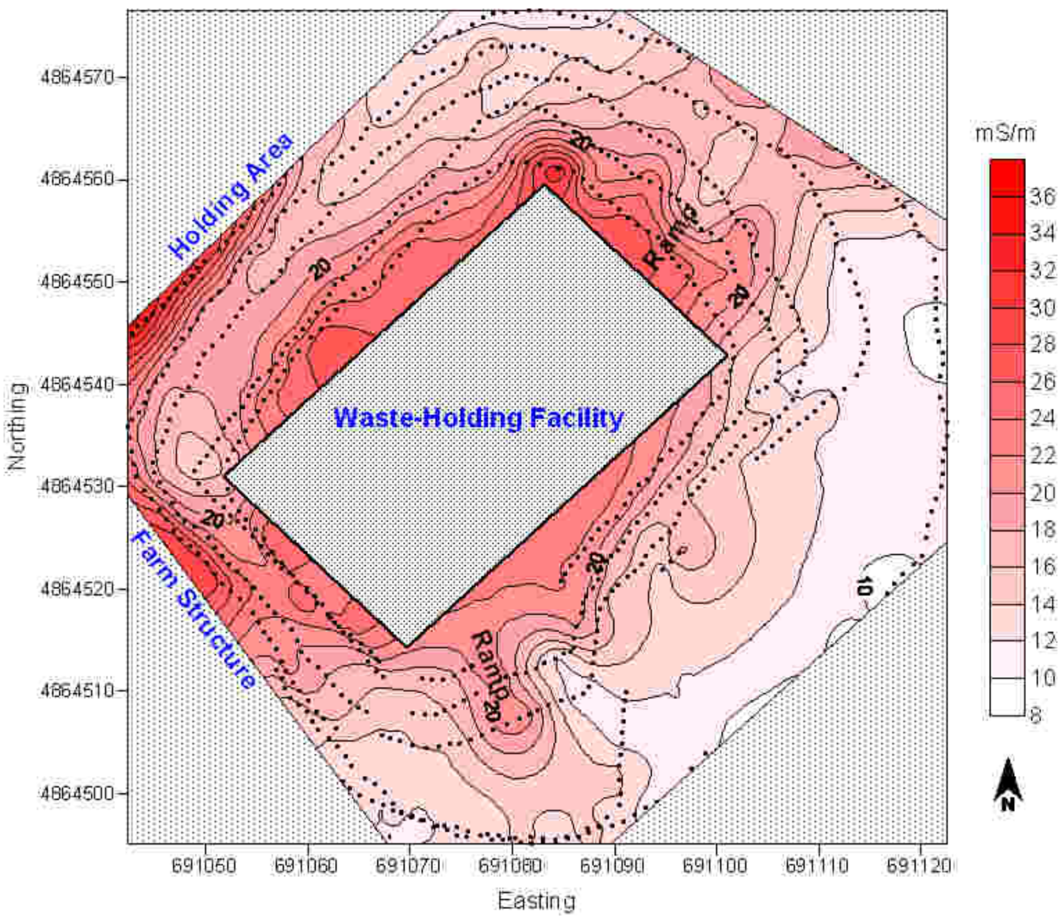

Figure 1. Spatial distribution of EC_a in an area of Kickapoo soils that surrounds the Schmitz's waste-holding facility.

Figures 1 is a two-dimension plot of EC_a obtained within the EM31 meter held at hip-height in the vertical dipole orientations. In the plot shown in Figure 1, the isoline interval is 2 mS/m. The locations of the 756 observation points are shown by point symbols. Gaps in the pattern of observation points reflect the stoppage of recordings. Recordings were stopped as the meter approached large farm machinery and implements that would cause interference. Line spacings are wider and recording gaps are more noticeable in the southeast portion of the survey area where machinery was parked and concentrated.

In Figure 1, a restricted but conspicuous area of higher EC_a is evident in the area that immediately surrounds the edges of the animal waste-holding facility. Measurements recorded in these areas were made very near a perimeter metal fence, which caused some interference. A pile of metallic debris caused the conspicuously high plume-like EC_a pattern that appears to emanate from the northern corner of the structure. A farm structure framed with metallic siding and roofing caused interference that caused the comparatively high EMI responses along a portion of the southwest border of the survey area. The survey area was border to the northwest by an animal holding area. Along portions of the northwest border, the meter came too near a metal fence and gate that enclosed the holding area. Proximity to these features produced unwanted interference and comparatively high EC_a.

In general, EC_a decreased outward from the waste-holding facility and reached comparatively low levels at the base of the embankment. With the exception of the southeast portion of the survey area, values of EC_a are noticeably higher than the observed background levels (< 12 mS/m) for Kickapoo soil. Higher values are attributed to limited seepage, previous land management history, and interference caused by the large number of cultural features concentrated within the survey area.

<u>Filter strip:</u>
Values of EC_a were variable within the filter strip. The spatial pattern of ECa followed a predictable pattern with the highest values recorded near the effluent outlet and the lowest values at the most distal portions of the filter strip. At the far end of the filter strip normal background levels for Kickapoo soils were measured. Within the filter strip, ECa averaged 20.7 mS/m with a range of 7 to 43.4 mS/m. One-half the observations had values of EC_a between 14.3 and 26 mS/m.

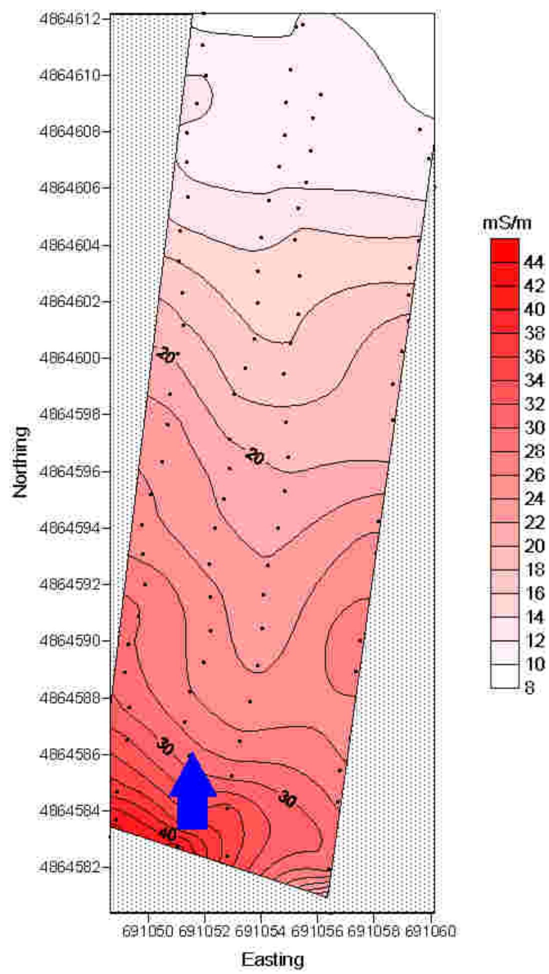

Figure 2. Plot shows the spatial distribution of EC_a within Schmitz's filter strip. The dark blue arrow is located at the point that effluent enters the filter strip and indicates the direction of flow

Figures 2 is a two-dimension plot of EC_a obtained within the EM31 meter held at hip-height in the vertical dipole orientations. In this plot, the isoline interval is 2 mS/m. The locations of the 104 observation points are shown by point symbols. The spatial pattern of ECa reflects a properly functioning grassed filter strip: high values are recorded at the source of effluent discharge; EC_a values decrease in a down slope direction away from the discharge point; and background EC_a levels resume before the distal end of the filter strip.

Conclusions:

1. Geophysical interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations are interpretive and do not substitute for direct ground-truth observations (soil sampling). The use of geophysical methods can reduce the number of coring observations, direct their placement, and supplement their interpretations. Interpretations contained in this report should be verified by ground-truth observations.

2. Based on interpretation of spatial patterns of apparent conductivity obtained from this EMI survey, no strong evidence supporting extensive seepage exists. The anomalously high values of EC_a adjoining the animal waste-holding facility are partially attributed to signal interference from nearby metallic objects. Potential seepage from the waste facility may be masked by the interference from nearby structures and fences. The survey of the animal waste-holding facility identifies a limitation of EMI surveys that are conducted in areas that surround farm structure and other cultural features.

3. Results of the EMI survey of the grassed filter strip confirm a properly functioning grassed filter strip.

4. If the results of this investigation spark interest in the use of EMI for surface and groundwater contamination assessments in Wisconsin, the National Soil Survey Center can provide additional field assistance, training, and the loan of an EM31 meter.

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

With kind regards,

James A. Doolittle
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