United States Department of Agriculture | **Natural Resources Conservation Service** | **11 Campus Boulevard Suite 200 Newtown Square, PA 19073**

Subject: **--** Geophysical Assistance -- **Date:** 17 December 2004

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Purpose:
The purpose of this investigation was to evaluate mapping and sampling protocol for high intensity soils surveys that are conducted with geophysical tools.

Participants:
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Jill Mays, Resource Specialists, City of Bloomington, Bloomington, IL
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Roger Windhorn, Resource Soil Scientist, USDA-NRCS, Champaign, IL
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Activities:
All field activities were completed during the period of 16 to 18 November 2004.

Results:

1. At the investigated sites, the response of the EM31 meter was more stable and less variable than the response of the Veris system. More variable and intricate patterns of EC_a were recorded with the Veris system. In general, both instruments created similar EC_a maps with broad spatial pattern that agreed fairly well with polygons delineated on order-two soil maps. The response of the EM31 meter provided less evidence of within-map unit variability than the Veris system. The more variable response from the Veris system enabled the distinction of within map unit components.

2. At the McLean County site, conspicuously higher EC_a measurements were recorded with the Veris system than with the EM31 meter. Although absolute values did vary with each EMI instrument, the resulting spatial patterns of EC_a are similar. Apparent conductivity varied systematically with landscape position and drainage. Patterns of EC_a approximated landforms, but did not conform to soil polygons boundaries. A high intensity soil survey of this site should provide additional insight into the factors responsible for the observed variation in $EC_{a.}$

3. At the Champaign County site, variations in EC_a within soil polygons suggests included soils and the need to subdivided polygons into smaller, more homogeneous units during order-one soil mapping. These polygons are believed to have contrasting soil properties and taxonomically distinct soils. A high-intensity soil survey of this site should result in additional, smaller soil polygons that represent purer soil consociations.

4. At the Macon County site, EC_a varied systematically with landscape position and drainage. Soil polygons and spatial patterns of EC_a are remarkably similar. The EC_a map clearly shows the soil hydro-sequence of this landscape. A high intensity survey of this site should reveal weather EC_a identifies contrasting included soils and is of value to soil mapping on this landscape.

5. Electromagnetic induction produces large amounts of data, which can be used to improve polygon line placement, polygon content descriptions, and soil interpretation. However, for maximum benefits and effective presentations, an experienced soil scientist is needed to properly interpret EMI data.

It was my pleasure to work in Illinois and with Roger and Dan. We make a good team. Special thanks are extended to Dan Withers for his preparation of the ArcView GIS images shown in this report.

With kind regards,

James A. Doolittle
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Background:
From a public perspective, electromagnetic induction (EMI) and other geophysical tools represent "high technology." As a consequence, data collected with these tools are perceived to be more accurate and reliable than data collected with conventional or traditional soil survey tools. In recent years, EMI has become an accepted tool for the refinement and improvement of soil maps prepared with traditional soil survey methods. Because EMI data are rapidly and effortlessly gathered, with apparent conductivity (EC_a) measured on a second-by-second basis, data populations are large and sampling intensities are great. As a consequence of these factors, small dissimilar areas, which may be overlooked or treated as included soils in traditional soil surveys, are often depicted on EC_a maps. Areas with different EC_a are associated with different soils and soil properties. Consequently, EC_a maps are assumed to show the within-map-unit variability that can not be depicted on order-two and -three soil survey maps.

Apparent conductivity maps show the distribution of only one soil property, EC_a. While EC_a has been associated with variations in other soil properties, the identification of the principal soil property (ies) that influences EC_a, as well as the impact of the interaction of multiple soil properties on EC_a, are seldom known and must be established thru soil sampling and analysis. Many EMI solutions are non-unique and relationships vary between sites. Initial, qualitative interpretations of EC_a provide a general impression of the hydropedologic setting. However, after a sufficient number of soil samples are collected and analyzed, a more detailed, quantitative interpretation of the data may fail to provide a single EC_a model that completely satisfies all hydropedologic parameters. As a result, EC_a maps can be misleading and inaccurate.

It is understood that traditional soil survey and geophysical methods are compatible. Synergistic use of these tools draws mutual benefits and produces more accurate and reliable products.

Previous studies in Illinois have indicated that high-intensity soil surveys adequately capture the variability of soils across landscapes. These studies confirmed the difficulty in obtaining repeatable soil boundaries and polygons when fields are resurveyed using traditional soil survey methods. In previous studies, EMI did help soil scientists to locate sampling points, which facilitated mapping and refined the placement of soil boundary lines and the identification of additional soil polygons. This study provide additional insight into the use of EMI with high intensity soil surveys.

Equipment:
Two geophysical tools were used in this study: the Veris 3100 soil EC mapping system (here after referred to as the Veris system) and the EM31 meter. The Veris system is a towed-array, multi-electrode resistivity unit manufactured by Veris Technologies (Salina, Kansas).[1] Operating procedures are described by Veris Technologies (1998). The Veris system converts measurements of apparent resistivity (ohm-m) into apparent conductivity (mS/m). The Veris system provides two soil depth measurements: one for the upper 0 to 30 cm (shallow) and one for the upper 0 to 90 cm (deep). The Veris system, under suitable field conditions, is pulled behind a tractor or 4WD vehicle at speeds of about 5 to 10 m/hr. A Trimble 132 GPS receiver is used to geo-reference all EC_a measurements.[1]

The EM31 meter is manufactured by Geonics Limited (Mississauga, Ontario).[1] McNeill (1980) has described the principles of operation for the EM31 meter. The EM31 meter has a 3.66-m intercoil spacing and operates at a frequency of 9,810 Hz. The EM31 meter is portable and needs only one person to operate. No ground contact is required with this meter. Lateral resolution is approximately equal to the intercoil spacing. When placed on the soil surface, the EM31 meter provides theoretical penetration depths of about 3 and 6 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1980).

The Geonics DAS70 Data Acquisition System was used with the EM31 meter to record and store both EC_a and GPS data.[1] The acquisition system consists of the EM31 meter, an Allegro field computer, and a Garmin Global Positioning System Map 76 receiver (with a CSI Radio Beacon receiver, antenna, and accessories that are fitted into a backpack). With the acquisition system, the EM31 meter is keypad operated and measurements are automatically

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

triggered.

Soil maps included in this report were scanned and digitized using Arc/Info and imported into ArcView.[2] Using ArcView, soil lines and delineations, which were mapped at smaller scales (1:20,000 or 1:15,840), were overlain at a scale of 1:7,920 on a recent aerial photograph of each site.

Study Sites:
All sites were located on loess covered till plains in east central Illinois. Each site had been mapped (order-two) as part of the progressive Illinois Soil Survey Program. The majority of soil map units are consociations. The symbols and names of all soil map units traversed during this investigation are listed in Table 1. Illinois uses a state-wide legend. The names of the map units are derived from tabular data contained in the Soil Data Mart. The map units delineated at each site are also identified in Table 1. The study sites are located in Champaign (*C*), McLean (*Mc*), and Macon (*M*) counties. The present taxonomic classifications of the soil series are listed in Table 2.

Table 1. Soil Map Units surveyed with EMI

Symbol	Map Unit Name	County
27B2	Miami silt loam, 2 to 5 percent slopes, eroded	*Mc*
68A	Sable silty clay loam, 0 to 2 percent slopes	*Mc*
134C2	Camden silt loam, 5 to 10 percent slopes, eroded	*Mc*
152A	Drummer silty clay loam, 0 to 2 percent slopes	*C, M*
154A	Flanagan silt loam, 0 to 2 percent slopes	*C, M*
171B	Catlin silt loam, 2 to 5 percent slopes	*C, M*
193B2	Mayville silt loam, 2 to 5 percent slopes, eroded	*Mc*
198A	Elburn silt loam	*M*
199B	Plano silt loam, 1 to 5 percent slopes	*M*
206	Thorp silt loam, 0 to 2 percent slopes	*C*
233B2	Birkbeck silt loam, 2 to 5 percent slopes, eroded	*Mc*
236A	Sabina silt loam, 0 to 2 percent slopes	*Mc*
622C2	Wyanet silt loam, 5 to 10 percent slopes, eroded	*C*
667B	Kaneville silt loam, 2 to 5 percent slopes	*Mc*
721A	Drummer and Elpaso silty clay loam, 0 to 2 percent slopes	*Mc*
964F	Miami and Hennepin soils, 18 to 35 percent slopes	*Mc*

<u>McLean County, Illinois:</u>
The City of Bloomington has reduced the amounts of nitrates that enter Lake Bloomington through a nutrient management program, which includes constructive wetlands. As part of this program, an intensive nutrient management monitoring project is being conducted on a site that is located in the western half of Section 18, T. 25 N., and R. 3 E. The site is located northeast of Hudson and south and west of Money Creek in McLean County. At the time of the survey, the site was in corn stubble. The site is topographically diverse with slopes ranging from 0 to 10 percent.

The soil survey of McLean County, Illinois, was completed in 1992 (Windhorn, 1998). This soil survey delineated nine soil map units within the study site (see Table 1). Soils on lower-lying, more poorly drained areas are Mollisols (Endoaquolls). Soils on higher-lying, better-drained areas are principally Alfisols (Hapludalfs). The present taxonomic classification of these soils is listed in Table 2. Soils predominantly belong to the fine-silty and fine particle-size and the superactive cation-exchange activity classes. At the time of the EMI surveys, soils were moist throughout. These soil properties establish moderate to high EC_a across the site. Variations in EC_a are principally attributed to differences in moisture and clay contents.

Table 2. Taxonomic Classification of soil surveyed with EMI

Series	Taxonomic Classification
Birkbeck	Fine-silty, mixed, superactive, mesic Oxyaquic Hapludalfs
Camden	Fine-silty, mixed, superactive, mesic Typic Hapludalfs
Catlin	Fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls
Drummer	Fine-silty, mixed, superactive, mesic Typic Endoaquolls
Elburn	Fine-silty, mixed, mesic Aquic Argiudolls
Elpaso	Fine-silty, mixed, superactive, mesic Typic Endoaquolls
Flanagan	Fine, smectitic, mesic Aquic Argiudolls
Hennepin	Fine-loamy, mixed, active, mesic Typic Eutrudepts
Kaneville	Fine-silty, mixed, superactive, mesic Oxyaquic Hapludalfs
Mayville	Fine-silty, mixed, superactive, mesic Oxyaquic Hapludalfs
Miami	Fine-loamy, mixed, active, mesic Oxyaquic Hapludalfs
Plano	Fine-silty, mixed, mesic Typic Argiudolls
Sabina	Fine, smectitic, mesic Aquic Hapludalfs
Sable[2]	Fine-silty, mixed, superactive, mesic Typic Endoaquolls
Thorp	Fine-silty, mixed, superactive, mesic Argiaquic Argialbolls
Wyanet	Fine-loamy, mixed, active, mesic Mollic Hapludalfs

Champaign County, Illinois:
The site is located on the University of Illinois in the northwest quarter of Section 29, T. 19 N., and R. 9 E. At the time of the survey, the site was in alfalfa. This topographically diverse (slopes ranging from 0 to 5 percent) site is located along the edge of a recessional moraine.

The soil survey of Champaign County, Illinois, was completed in 1998 (Endres, 2003). This soil survey recognized five soil map units within the site (see Table 1). The present taxonomic classification of these soil series is listed in Table 2. Soils are Alfisols and Mollisols. Alfisols (Hapludalfs) are on higher-lying, more sloping, convex surfaces of the moraine and on level till plain areas. Argialbolls dominate lower linear and concave side slopes of moraines and swales. Endoaquolls occupy lower-lying concave slopes and depressions. Most soils have argillic horizons and belong to the fine-silty particle-size and the superactive cation-exchange activity classes. At the time of the EMI surveys, soils were moist throughout. As at the McLean County site, these soil properties establish moderate to high EC_a across the site. Variations in EC_a are principally attributed to differences in moisture and clay contents.

Macon County, Illinois:
The study site is located northeast of Decatur, Illinois, in the southwest quarter of Section 29, T. 17 N., and R. 3 E. The study site consists of two fields, one in soybean stubble (surveyed with EM31 meter only) and one in corn stubble (surveyed with Veris system only). This site is located on a relatively featureless, loess covered till plain. Slopes are level and range from 0 to 2 percent.

The soil survey of Macon County, Illinois, was completed in 1984 (Doll, 1990). This soil survey recognized five soil map units within the site (see Table 1). The present taxonomic classification of these soil series is listed in Table 2. Soils are Mollisols. Argiudolls dominate the slightly higher-lying, better-drained, convex surfaces. Endoaquolls dominate the slightly lower-lying, poorly drained, concave swales and linear surfaces. Most soils belong to the fine-silty particle-size class. All soils belong to the superactive cation-exchange activity class. At the time of the EMI surveys, soils were moist throughout. As at the other sites, these soil properties establish moderate to high EC_a across the site. Variations in EC_a are principally attributed to differences in moisture and clay contents.

Field Procedures:

[2] (An asterisk next to the soil's name indicates a taxadjunct to the series).

The Veris system was towed behind a 4WD vehicle. Measurements were continuously recorded and geo-referenced with a GPS receiver. An observation (two EC_a measurements (shallow and deep) with coordinates) was recorded every second. The Veris system was driven along parallel row spaced about 10 m apart and around the perimeter of the fields at speeds between 12 and 17 mph. These relatively fast speeds were necessary to pull the Veris system and to overcome the resistance of the moist soils. At these speeds, the discs occasionally lost contact with the soil resulting in erroneous measurements.

The EM1 meter was operated in the vertical dipole orientation and in the continuous mode with measurements recorded at 1-sec intervals. The EM31 was held at hip height with its long axis parallel to the direction of traverse. Traverse lines were essentially parallel, but were more widely and irregularly spaced then those completed with the Veris system. As a consequence, sample sizes were noticeably smaller with the EM31 meter than with the Veris system.

Results:

McLean County:

Table 3 summarizes the results of the EMI surveys that were conducted with the EM31 meter and the Veris 3100 system at McLean County site. For the EM31 meter, EC_a ranged from 16.6 to 50.4 mS/m. Apparent conductivity averaged 33.9 mS/m with a standard deviation of 4.2 mS/m. One-half the observations had an EC_a between 31.3 and 36.3 mS/m.

With the Veris system, initial EC_a measurements averaged 75.1 mS/m with a range of 0.8 to 765.1 mS/m for the shallow (0 to 30 cm) profiling depth. Apparent conductivity averaged 55.4 mS/m with a range of 0.3 to 104.2 mS/m for the deep (0 to 90 cm) profiling depth. The high ranges and averaged EC_a values measured with the Veris system were obviously in error as the system was known to be malfunctioning. To reduce the error, all values in excess of 70 mS/m were removed from the data set (based on assumed potential range in EC_a in these soils). This needed, but arbitrary procedure reduced the number of observations from 5155 to 3503. Based on the revised data set, for the shallow profiling depth, EC_a ranged from 0.8 to 67.3 mS/m. Apparent conductivity averaged 22.4 mS/m with a standard deviation of 7.2 mS/m. One-half of the measurements had an EC_a between 17.7 and 26.8 mS/m. Also based on the revised data set, for the deep profiling depth, EC_a ranged from 0.3 to 70.0 mS/m. Apparent conductivity averaged 51.7 mS/m with a standard deviation of 13.3 mS/m. One-half of the measurements had an EC_a between 45.1 and 61.6 mS/m.

Table 3. Basic EMI Statistics for EMI surveys at the McLean County site. Other than the number of observations, all values are in mS/m.

	EM31	Veris	
	Meter	**Shallow**	**Deep**
Number	2890	3503	3503
Minimum	16.6	0.8	0.3
Maximum	50.4	67.3	70.0
25%-tile	31.3	17.7	45.1
75%-tile	36.3	26.8	61.6
Standard Deviation	4.2	7.2	13.3

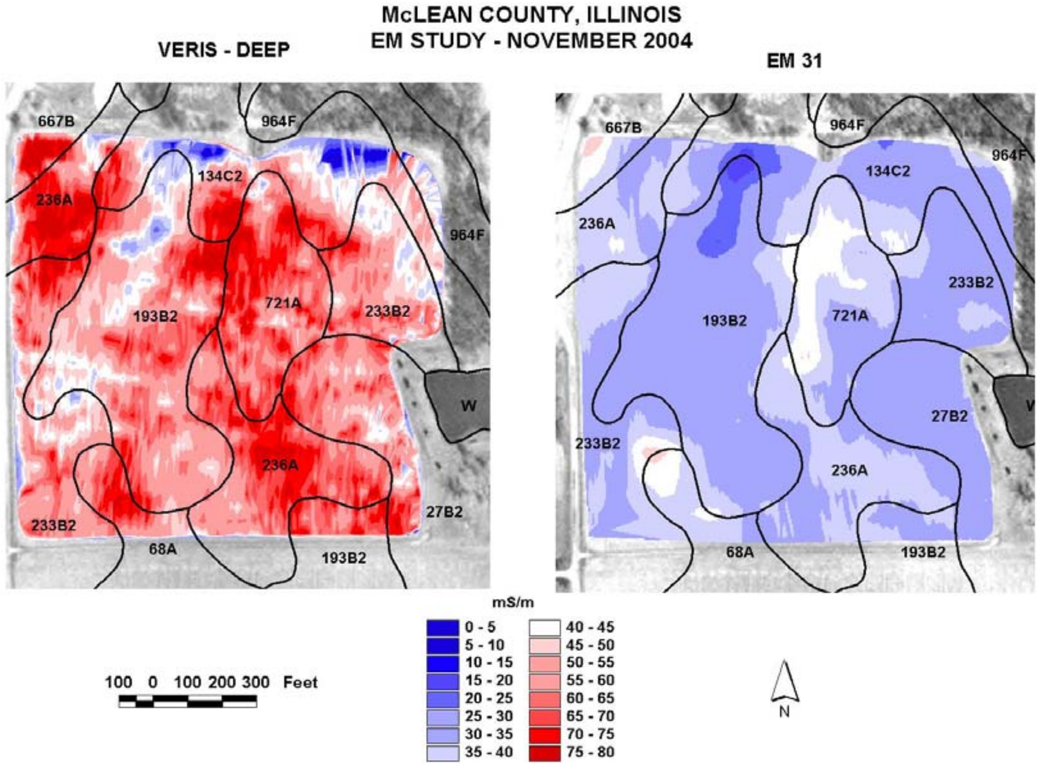

Figure 1. Relationship between EC_a *measured with the EM31 meter in the vertical dipole orientation and the Veris deep at the McLean County site.*

Figure 1 contains plots of EC_a measured with the EM31 meter and the Veris system. In both plots, the isoline interval is 5 mS/m. Absolute EC_a values varied with each instrument with conspicuously higher measurements recorded with the Veris system than with the EM31 meter. This difference can be attributed to differences in soil properties with increasing depth and differences in the effective penetration depths of each EMI instrument. In addition, the Veris system did not operate well at this site. Although absolute values did vary with each EMI instrument, the resulting spatial patterns of EC_a are surprisingly similar. Apparent conductivity varied systematically with landscape position and drainage. Higher EC_a was measured on lower-lying, more imperfectly drained units of Sable (68B), Sabina (236A), and Drummer and Elpaso (721A) soils. Lower EC_a was measured on higher-lying, better-drained, convex summits and back slopes that are dominated by Mayville (193B), Camden (M.U. 134C2), and Miami and Hennepin (M.U. 964F) soils. Patterns of EC_a approximated landforms, but did not conform to the mapped soil polygons boundaries. Soils within the study site were classified as having fine-silty and fine textural control sections. For these soils, the maximum clay contents could potentially range from 27 to 40 percent. However, it is believed that, within the study site, differences in clay content were less and observed differences in EC_a were attributed principally to differences in moisture content.

Champaign County:
Table 4 summarizes the results of the EMI surveys that were conducted with the EM31 meter and the Veris system at Champaign County site. For the EM31 meter, EC_a ranged from -32.6 to 75.4 mS/m. Apparent conductivity averaged 24.4 mS/m with a standard deviation of 5.8 mS/m. One-half the measurements had an EC_a between 20.5 and 26.6 mS/m. With the Veris system, for the shallow profiling depth, EC_a ranged from 2.3 to 38.6 mS/m. Apparent conductivity averaged 17.9 mS/m with a standard deviation of 5.0 mS/m. One-half of the shallow measurements had an EC_a between 14.8 and 19.9 mS/m. Apparent conductivity for the deep measurements ranged from 7.8 to 75.7 mS/m. Apparent conductivity averaged 30.4 mS/m with a standard deviation of 10.6 mS/m. One-half of the deep measurements had an EC_a between 23.3 and 34.5 mS/m.

Table 4
Basic EMI Statistics for EMI surveys at the Champaign County site.
Other than the number of observations, all values are in mS/m.

	EM31	Veris	
	Meter	**Shallow**	**Deep**
Number	3014	3004	3004
Minimum	-32.6	2.3	7.8
Maximum	75.4	38.6	75.7
25%-tile	20.5	14.8	23.3
75%-tile	26.6	19.9	34.5
Mean	24.4	17.9	30.4
Standard Deviation	5.8	5.0	10.6

Figure 2 contains plots of EC_a measured with the EM31 meter and the Veris system. In each plot, the isoline interval is 5 mS/m. Differences in EC_a are associated principally with changes in landform position and drainage. Higher EC_a was measured on lower-lying, somewhat poorly drained areas of Flanagan (M.U. 154A) and poorly drained Drummer (M.U. 152A) soils in the eastern (right-hand) portion of the study site. Lower and less variable EC_a was measured on lower-lying areas of Flanagan (M.U. 154A) and Thorp (M.U. 206) soils that were located on more distant from the moraine itself. Though mapped as one polygon, two areas of Flanagan soil can be distinguished based on EC_a. It is likely that more imperfectly drained conditions prevail over eastern Flanagan unit where soil conditions are believed to more closely approximate Drummer soils. This polygon will require further attention by field soil scientists conducting the high-intensity soil survey of this site.

Data collected with the Veris system appears to provide a better portrayal of the moraine's leading edge. In addition, on the more sloping areas of Catlin (M.U. 171B) and Wyanet (M. U. 622C2) soils, data collected with the Veris system revealed more variable and intricate spatial patterns of EC_a. These polygons are believed to have more variable soil properties and include taxonomically different soils. A high-intensity soil survey of these polygons may result in additional, smaller soil polygons that represent purer consociation units.

Because of the low variability of EC_a measured with the EM31meter, soils appear uniform and differences in existing soil polygons are poorly expressed across most of the site. Data collected with the Veris system provides more contrasting and intricate EC_a patterns that, to this observer, more closely approximated the landscape. Mapped soil polygons shown in the plots of Figure 2 do not appear to conform well to patterns of EC_a. Based on the results of the EMI surveys, in areas of Drummer and Flanagan soils, soil lines need to be extended upslope from their present positions.

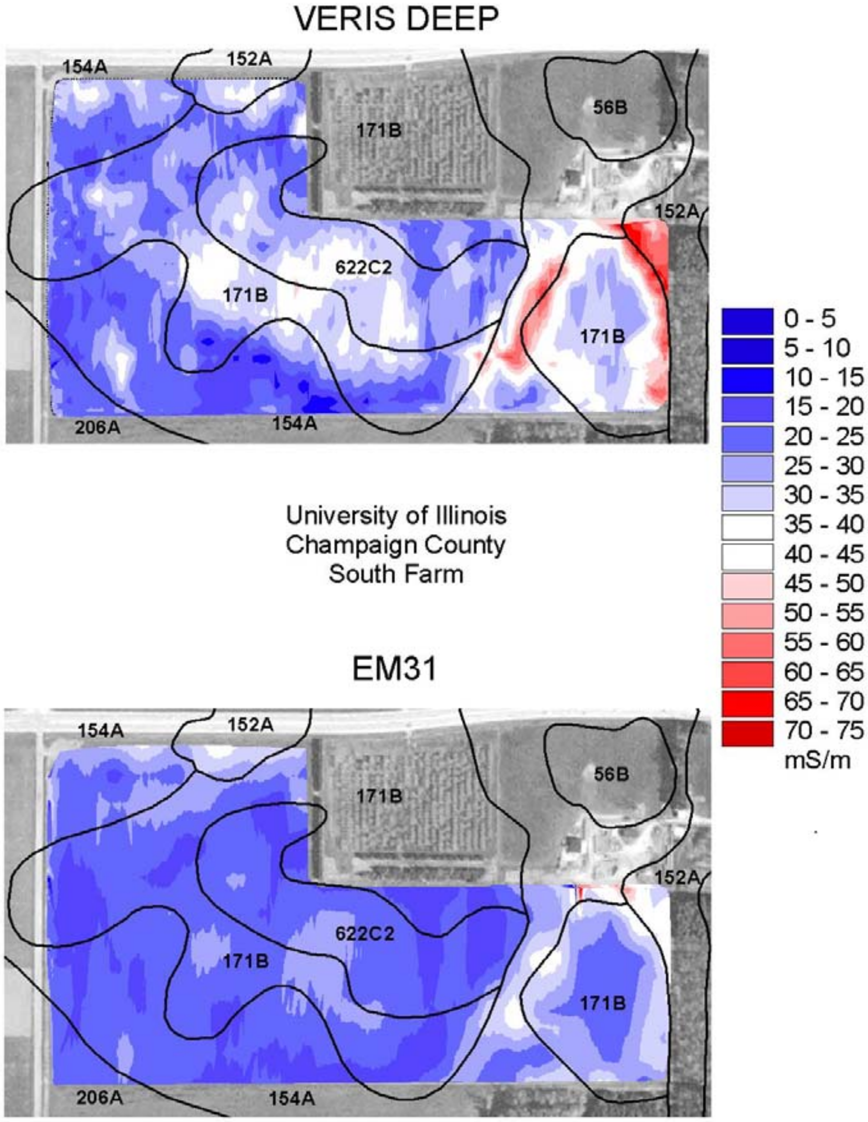

Figure 2. Relationship between EC_a *measured with the EM31 meter in the vertical dipole orientation and the Veris deep at the Champaign County site.*

Macon County:

Table 5 summarizes the results of the EMI surveys that were conducted with the EM31 meter and the Veris system at the Macon County site. With the EM31 meter, EC_a ranged from 20.6 to 76.7 mS/m. Apparent conductivity averaged 35.7 mS/m with a standard deviation of 7.2 mS/m. One-half the observations had an EC_a between 30.1 and 40.0 mS/m. With the Veris system, for the shallow profiling depth, EC_a ranged from 6.4 to 55.0 mS/m. Apparent conductivity averaged 24.0 mS/m with a standard deviation of 8.7 mS/m. One-half of the shallow measurements had an EC_a between 16.8 and 30.2 mS/m. Apparent conductivity for the deep measurements ranged from 1.7 to 86.1 mS/m. Apparent conductivity averaged 49.4 mS/m with a standard deviation of 13.7 mS/m. One-half of the deep measurements had an EC_a between 39.1 and 59.5 mS/m.

Figure 3 is a plot of EC_a measured with the EM31 meter and the Veris system. The isoline interval is 5 mS/m. As evident in this plot, absolute EC_a measurements varied with each instrument. Conspicuously higher measurements were recorded in the larger (eastern) field with the Veris system than in the smaller (western) field with the EM31 meter. Striking differences in EC_a are evident at the field boundary that separates these two fields. This difference is attributed to differences in soil properties with increasing depths and differences in resolution, effective penetration depths, and calibration of each EMI instrument. Linear, north-south trending artifacts are evident in the plot of ECa data collected with the Veris system. These lines of lower conductivity could represent buried drainage tile or the malfunctioning of the Veris systems (operated at higher than normal ground speeds across this site). Veris traverses were conducted in north-south directions across this field.

Table 5
Basic EMI Statistics for EMI surveys at the Macon County site.
Other than the number of observations, all values are in mS/m.

	EM31	Veris	
	Meter	Shallow	Deep
Number	1735	5864	5864
Minimum	20.6	6.4	1.7
Maximum	76.7	55.0	86.1
25%-tile	30.1	16.8	39.1
75%-tile	40.0	30.2	59.5
Mean	35.7	24.0	49.4
Standard Deviation	7.2	8.7	13.7

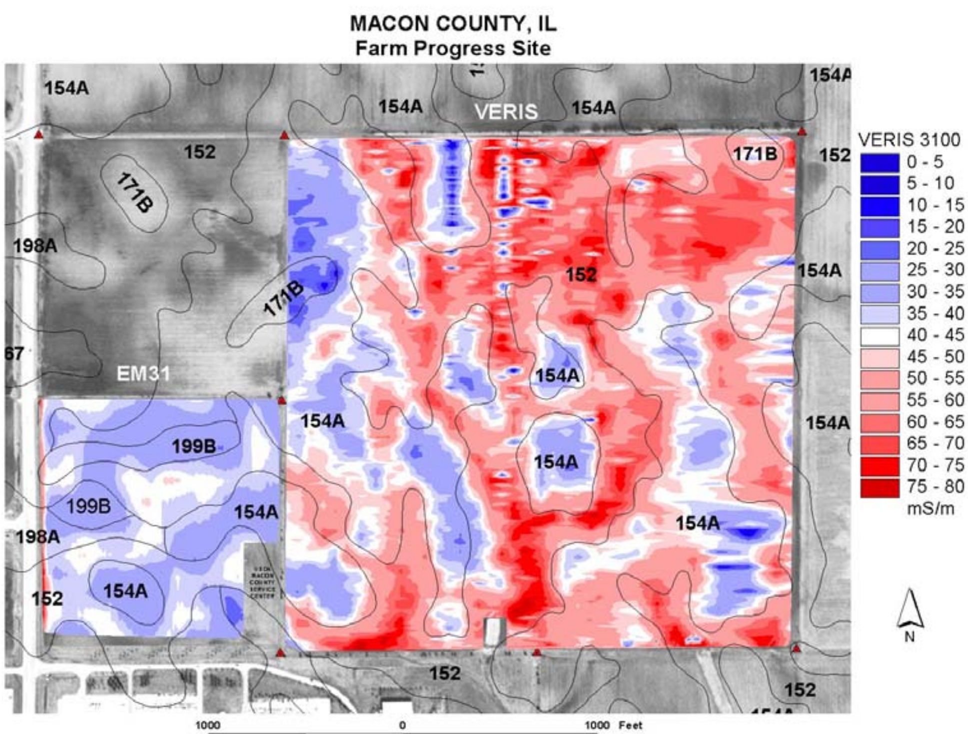

Figure 3. Patterns of ECa measured with the EM31 meter in the vertical dipole orientation (square on lower left) and Veris deep (larger square on right) at the Macon County site.

In general, EC_a measurements were not random, but varied systematically with landscape position and drainage.

Mapped soil polygons and spatial patterns of EC_a are remarkably similar. The map of EC_a suggests that only slight adjustments are needed in boundary line placements. The EC_a map clearly shows the soil hydro-sequence of this landscape. Lower EC_a was measured on slightly higher-lying, somewhat poorly drained swells of Flanagan (M.U. 154A) and Elburn (M.U. 198A) soils, and well drained Plano (M.U. 199B) soils. Higher EC_a was measured on slightly lower-lying, poorly drained swales of Drummer soils (M.U. 152A). While EC_a data collected the EM31 meter discriminate among the map units, very little variations are evident within the map units. Greater variations in EC_a are evident in the data collected with the Veris system. This variation may represent differences in clay or moisture contents and possibly, included soils within the mapped soil polygons. A high intensity survey of this site should reveal the weather these EC_a patterns identify contrasting included soils and are of value to soil mapping.

Discussion:
At all survey sites and with each EMI instrument, averaged EC_a was comparatively high (ranging from about 18 to 52 mS/m). The dominance of 2:1 expanding-lattice (smectite and vermiculite) clays with high base saturation and cation exchange capacity, and the relatively high moisture contents of the soils contributed to the relatively high EC_a. Soil maps of each site show multiple soil polygons that identify morphologically and taxonomically distinct soils. At these sites and with each instrument, a large range in EC_a was measured (absolute range was 33.8 to 84.4 mS/m). This indicates the presence of contrasting soils and soil properties. However, EC_a data sets displayed a rather low variability (standard deviation ranging from about 4 to 14 mS/m) suggesting that a majority of soils within each site are similar. Though the mapped soils can be distinguished on the basis of differences in morphology, and chemical and physical properties, these differences are often subtle, with intermediate rather than strongly contrasting properties among the soils and soil polygons. It is suspected that many of the morphological and taxonomical distinct soils on Illinois loess covered till plain have closely similar properties, which are impossible to differentiate with EMI.

Jaynes (1995) described three ways EMI could be used for soil mapping: 1) to provide a reconnaissance map to assist future sampling, 2) to refine maps of sparsely sampled soil properties that can be related to EC_a, and 3) as a direct surrogate measure of a soil property. The Illinois Soils Staff will complete an order-one soil survey on each of three sites discussed in this report. It will be invaluable to learn how the EC_a maps were used to guide sampling, refine the number of soil polygons, adjust polygon line placement, and influence the decisions of the soil scientists conducting these high intensity soil surveys.

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