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

Subject: -- Geophysical Assistance -- **Date:** 23 January 2003

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Purpose:
The purpose of this investigation was to evaluate the use of electromagnetic induction (EMI) to assess soils and soil properties in Southeastern Missouri.

Participants:
Dan Childress, Soil Scientist/Team Leader, USDA-NRCS, Dexter, MO
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Charles Fultz, MO Leader, USDA-NRCS, Little Rock, AR
Kevin Godsey, Soil Scientist, USDA-NRCS, Dexter, MO
John Hester, Team Leader, Eng., USDA-NRCS, Dexter, MO
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Rod Taylor, Soil Scientist, USDA-NRCS, Dexter, MO
Wes Tuttle, Soil Scientist (Geophysical) USDA-NRCS-NSSC, Wilkesboro, NC
Pat Truman, Soil Conservationists, USDA-NRCS, Dexter, MO

Activities:
All field activities were completed during the period of 3 to 4 December 2000. Field activities were abruptly curtailed because of a severe winter storm.

Equipment:
Geonics Limited manufactures the EM38, EM38DD, and EM31meters. [1] These meters are portable and require only one person to operate. No ground contact is required with these meters. McNeill (1980) and Geonics Limited (1998 and 2000) have described principles of operation for the EM31, EM38, and EM38DD meters, respectively. For each meter, lateral resolution is approximately equal to its intercoil spacing. The EM38 and EM38DD meters have a 1 m intercoil spacing and operate at a frequency of 14,600 Hz. When placed on the soil surface, these instruments have theoretical penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively (Geonics Limited, 1998 and 2000). The EM38DD meter consists of two EM38 meters bolted together and electronically coupled. One unit acts as a master unit (meter that is positioned in the vertical dipole orientation and having both transmitter and receiver activated) and one unit acts as a slave unit (meter that is positioned in the horizontal dipole orientation with only the receiver switched on). The EM31 meter 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 theoretical penetration depths of about 3.0 and 6.0 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1980). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

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

The Geonics DAS70 data acquisition system was used to record and store both EMI and GPS data.[2] The acquisition system consists of an EMI meter, Allegro field computer, and Trimble AG114 GPS receiver with backpack and frame. With this system, the meter is keypad operated and measurements can either be automatically or manually triggered.

Geophysical Survey Systems, Inc., manufactures the GEM300 multifrequency sensor.[2] Won and others (1996) describe the use and operation of this sensor. This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed coil separation of 1.3 m. With the GEM300 sensor, the penetration depth is considered "skin depth limited." The skin-depth represents the maximum depth of penetration and is frequency and soil dependent: low frequency signals travel farther through conductive mediums than high frequency signals. Theoretical penetration depths of the GEM300 sensor are dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequencies. Multifrequency sounding theoretically allows multiple depths to be profiled with one pass of the sensor. The sensor is keypad operated and measurements can either be automatically or manually triggered.

To help summarize the results of this study, the SURFER for Windows (version 8.0) developed by Golden Software, Inc., was used to construct two-dimensional simulations.[2] Grids were created using kriging methods with an octant search.

Results:

1. All participants were given the opportunity to operate, complete field surveys, and evaluate the use of these EMI devices for soil survey investigations.

2. Electromagnetic induction was used to create detailed maps showing the spatial distribution of apparent conductivity across units of management. These maps closely corresponded with soil maps or showed changes in soil properties that had developed subsequent to soil mapping. At each site, with minor exceptions, the plotted spatial patterns were reasonably similar with each device.

3. To assist EMI interpretations, computer simulations are normally used. ArcView GIS has become available to many soil scientists and field offices. Integration of EMI and ArcView GIS techniques provides a more expedient and cost-effective method for displaying EMI data, soil mapping, and multiple data sets.

4. EMI provides immediate and beneficial uses to soil scientists involved with high intensity soil mapping projects, site assessments, and precision farming initiatives. These tools represent an expedient substitute or adjunct to traditional mapping techniques. The use of these geophysical tools should be more fully understood and explored by soil scientists and conservationists within this region.

5. Geophysical interpretations are considered preliminary estimates of site conditions. The results of all geophysical investigations are interpretive and do not substitute for direct soil borings. The use of geophysical methods can reduce the number of soil observations, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

Recommendations:

A winter storm curtailed field activities before EMI surveys were completed on all scheduled sites. It is recommended that Wes Tuttle return to Missouri this fiscal year and complete the previously scheduled assignments and training. It is recommended that Wes work directly with Dennis Potter to reschedule these activities.

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

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

With kind regards,

James A. Doolittle
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A New Generation of Soil Mapping Tools:
Alternative methods for mapping soils and soil properties are being evaluated by NRCS. The availability of computers, global positioning systems (GPS), geographical information systems (GIS), and geophysical tools are changing the way we look at and map soils. Because of their speed and ease of use, electromagnetic induction (EMI) has significant advantages over conventional soil survey techniques. The efficiency of EMI fosters the collection of larger data sets than is possible with conventional soil survey techniques. Because of the larger number of observations, maps prepared from EMI data can provide higher levels of resolution than soil maps prepared with conventional methods (Jaynes, 1995). In many areas, spatial patterns of apparent conductivity correspond well with the soil patterns shown on soil survey maps. For high intensity soil mapping, maps of apparent conductivity have been referred to as *surrogate*s for soil survey maps (Jaynes, 1995).

Electromagnetic Induction:
EMI uses electromagnetic energy to measure the apparent conductivity 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). A transmitter produces a magnetic field that induces current to flow through the subsurface. This flow of current sets up a secondary magnetic field in the soil. By comparing the difference in the magnitude and phase of these magnetic fields, the device measures the apparent conductivity of the profiled materials. No ground contact is needed with EMI.

Variations in apparent conductivity are produced by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the type and concentration of ions in solution, the amount and type of clays in the soil matrix, the volumetric water content, and the temperature and phase of the soil water (McNeill, 1980). The apparent conductivity of soils will increase with increases in soluble salt, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

Interpretations of EMI data are based on the identification of spatial patterns within data sets. Though seldom diagnostic in themselves, lateral and vertical variations in apparent conductivity have been used to infer changes in soils and soil properties. EMI integrate the bulk physical and chemical properties of a soil within a defined depth into a single value. As a consequence, measurements can be associated with changes in soil properties, soils, and soil map units (Hoekstra et al., 1992; Jaynes et al., 1993; Doolittle et al., 1996). For each soil, intrinsic physical and chemical properties, as well as temporal variations in soil water and temperature, result in a unique or characteristic range of apparent conductivity values.

Electromagnetic induction has been used to assess and map soil salinity (Cook and Walker, 1992; Corwin and Rhoades, 1990; Slavich and Petterson, 1990), sodium-affected soils (Ammons et al., 1989; Nettleton et al., 1994), depths to claypans (Doolittle et al., 1994; Sudduth and Kitchen, 1993; and Sudduth et al., 1995), and edaphic properties important to forest site productivity (McBride et al., 1990). In addition, electromagnetic induction has been used to measure soil water contents (Kachanoski et al., 1988), cation exchange capacity (McBride et al., 1990), field-scale leaching rates of solutes (Slavich and Yang, 1990; Jaynes et al., 1995) and herbicide partition coefficients (Jaynes et al., 1995). Recently, EMI has been used as a soil-mapping tool to assist precision farming (Jaynes, 1995; Jaynes et al., 1995; Sudduth et al., 1995). Doolittle and others (2002) used EMI in southeastern Missouri to assess clay content and locate sand blows in alluvial soils used for rice production.

Study Sites:
The first study site was located in the southeast quarter of Section 20, Township 24 N, Range 8 E, near the town of Batesville, Butler County. The site is located within an irrigated (center-pivot) field. This study site is in an area that has been mapped as Bosket fine sandy loam, 4 to 10 % slopes, eroded; Kobel clay; and Tuckerman-Bosket fine sandy loam, 0 to 5 % slopes (Graves, 1993). These very deep soils formed in alluvium on floodplains in the Western Lowlands of the lower Mississippi River Valley. The poorly drained and very poorly drained Kobel soil formed in clayey alluvium. Kobel is a member of the fine, smectitic, nonacid, thermic Vertic Endoaquepts family. The poorly drained Tuckerman and the well drained Bosket soils formed in loamy alluvium. Tuckerman is a member of the fine-loamy, mixed, active, thermic Typic Endoaqualfs family. Bosket is a member of the fine-loamy, mixed, active, thermic Mollic Hapludalfs family.

The second study site was located in the southwest quarter of Section 7, Township 24 N., Range 10 E., near the town of Pyletown in Stoddard County. The site is in a cultivated field that has been experiencing encroachment of sodium-affected soils. The site is in an area that had been mapped as Loring silt loam, 2 to 15 % slopes; Crowley silt loam; and Falaya silt loam (Butler, 1985). The moderately well drained Loring soil formed in loess on uplands and stream terraces. Loring is shallow to moderately deep over a fragipan. Loring is a member of the fine-silty, mixed, active, thermic Oxyaquic Fragiudalfs family. The very deep, somewhat poorly drained Crowley soil formed in clayey sediments on fluviatile terraces of Pleistocene age. Crowley is a member of the fine, smectitic, hyperthermic Typic Albaqualf family. The very deep, somewhat poorly drained Falaya soil formed in alluvium on flood plains in the lower Mississippi River Valley. Falaya is a member of the coarse-silty, mixed, active, acid, thermic Aeric Fluvaquents family.

Field Procedures:
Survey procedures were simplified to expedite fieldwork. At each site, two parallel lines were laid out. Along each line, survey flags were inserted in the ground at intervals of about 30 m. These flags served as grid line end points and provided some measure of ground control. The two parallel lines enclosed a rectangular grid area. Dimensions of the grids were 240 by 240 m (about 5.76 ha) at Study Site 1 and 150 by 150 m (about 2.25 ha) at Study Site 2.

Walking at a fairly uniform pace between similarly numbered flags on the two opposing lines in a back and forth pattern across each grid area with an EMI instrument completed a survey. Each EMI instrument was operated in the continuous mode with measurements recorded at a 1-sec interval. All instruments were orientated with their long axis parallel to the direction of traverse. The EM38 and the EM38DD meters were held about 3 inches above the ground surface and operated with the DAS70 data acquisition system. Surveys were completed with the GEM300 sensor and the EM31 meter held at hip height in the vertical dipole orientation. The EM31 meter was operated with the DAS70 data acquisition system. The GEM300 sensor was not operated with a GPS receiver. For the GEM300 sensor, the locations of each measurement along each traverse line were later adjusted to provide a uniform interval between observation points.

Results:
Table 1 summarizes survey results from Study Site 1. Within this site, apparent conductivity ranged from –50.5 to 58 mS/m. Negative values are attributed to calibration errors and surface or near-surface metallic artifacts. With the EM38DD meter, apparent conductivity increased and became slightly more variable with increasing depth. In the shallower-sensing, horizontal dipole orientation (0 to 0.75 m), apparent conductivity averaged about 9.8 mS/m with a standard deviation of about 4.1 mS/m. One-half the observations had values of apparent conductivity between about 7.0 and 12.2 mS/m. In the deeper-sensing, vertical dipole orientation (0 to 1.5 m), apparent conductivity averaged 14.6 mS/m with a standard deviation of about 5.6 mS/m. One-half the observations had values of apparent conductivity between about 10.9 and 17.9 mS/m. The increased conductivity with increasing depth was attributed to greater moisture and clay contents at lower soil depths.

With the EM31 meter, apparent conductivity was only measured in the vertical dipole orientation (0 to 5 m soil depth when the meter is held at hip height). Apparent conductivity averaged about 13.9 mS/m with a standard deviation of about 4.8 mS/m. One-half the observations had values of apparent conductivity between 10.9 and 15.9 mS/m.

Table 1. Basic EMI Statistics for Study Site # 1

	EM38DD-VDO	EM38DD-HDO	EM31-VDO	EM38-VDO	9810VDO	14790VDO
Number	1358	1358	1460	1591	1528	1528
Minimum	-50.5	2.8	5.3	4.1	-4.7	-1.9
Maximum	34.5	58.0	31.1	45.8	42.5	35.8
25%-TILE	10.94	7.03	10.90	15.13	5.30	6.70
75%-TILE	17.94	12.23	15.90	24.00	13.20	14.70
Average	14.60	9.76	13.88	19.89	10.31	11.38
Standard Dev.	5.57	4.09	4.78	6.44	7.29	6.88

With the EM38 meter, apparent conductivity was only measured in the vertical dipole orientation (0 to 1.5 m). Apparent conductivity averaged about 19.9 mS/m with a standard deviation of about 6.4 mS/m. One-half the observations had values of apparent conductivity between about 15.1 and 24.0 mS/m. Data collected with the EM38 meter were higher and slightly more variable than data collected with the EM38DD meter in the vertical dipole orientation. Measurements obtained with the two meters in the vertical dipole orientation should be similar. Differences in these measurements were attributed to instrument drift and calibration, operator and survey errors.

With the GEM300 sensor held at hip height in the vertical dipole orientation, data recorded at frequencies of 9810 and 14790 Hz were similar. The correlation coefficient for these measurements was very high (r =0.96) and significant (0.001 level). Apparent conductivity averaged about 10.3 and 11.4 mS/m at frequencies of 9810 and 14790 Hz, respectively. At a frequency of 9810 Hz, apparent conductivity ranged from –4.7 to 42.5 mS/m with a standard deviation of about 7.3 mS/m. One-half the observations had values of apparent conductivity between 5.3 and 13.2 mS/m. At a frequency of 14790 Hz, apparent conductivity ranged from –1.9 to 35.8 mS/m with a standard deviation of about 6.9 mS/m. One-half the observations had values of apparent conductivity between 6.7 and 14.7 mS/m.

With the GEM300 sensor, the depth of penetration is considered *skin depth limited*. The skin depth can be estimated with the following formula given by McNeill (1996):

$$D = 500/(s*f)^{-2} \qquad [1]$$

Where s is the ground conductivity (mS/m) and f is the frequency (kHz). At Site 1, based on equation [1], the selected frequencies and the measured, averaged conductivities, the estimated skin depths (penetration depths) would be about 49.7 m at 9,810 Hz, and 38.5 m at 14,790 Hz. While it cannot be proven that these depths were not achieved, the close similarity in the measurements obtained with the various EMI instruments, and the high and significant correlation between measurements obtained with the GEM300 sensor at different operating frequencies, makes these skin depths difficult to accept. Assuming that the GEM300 sensor operates according to the principals of low induction numbers (McNeill, 1980) and the depth of penetration is based on the intercoil spacing and dipole configuration rather than the skin depth, the penetration depth of the GEM300 sensor would be about 1 and 2 m in the horizontal and vertical dipole orientations, respectively.

Figure 1 contains plots showing the spatial distribution of apparent conductivity collected with the EM31, EM38, and EM38DD meters. Each plot in Figure 1 is identified by the meter and dipole orientation that was used to collect the data. In each plot, colors have been used to show the distribution of apparent conductivity. In each plot the isoline interval is 4 mS/m. To remove spurious measurements and lines, the *grid node editor* of Surfer 8 was used to blank or make slight changes (0.1 to 0.2 mS/m) to some of the measured EMI responses.

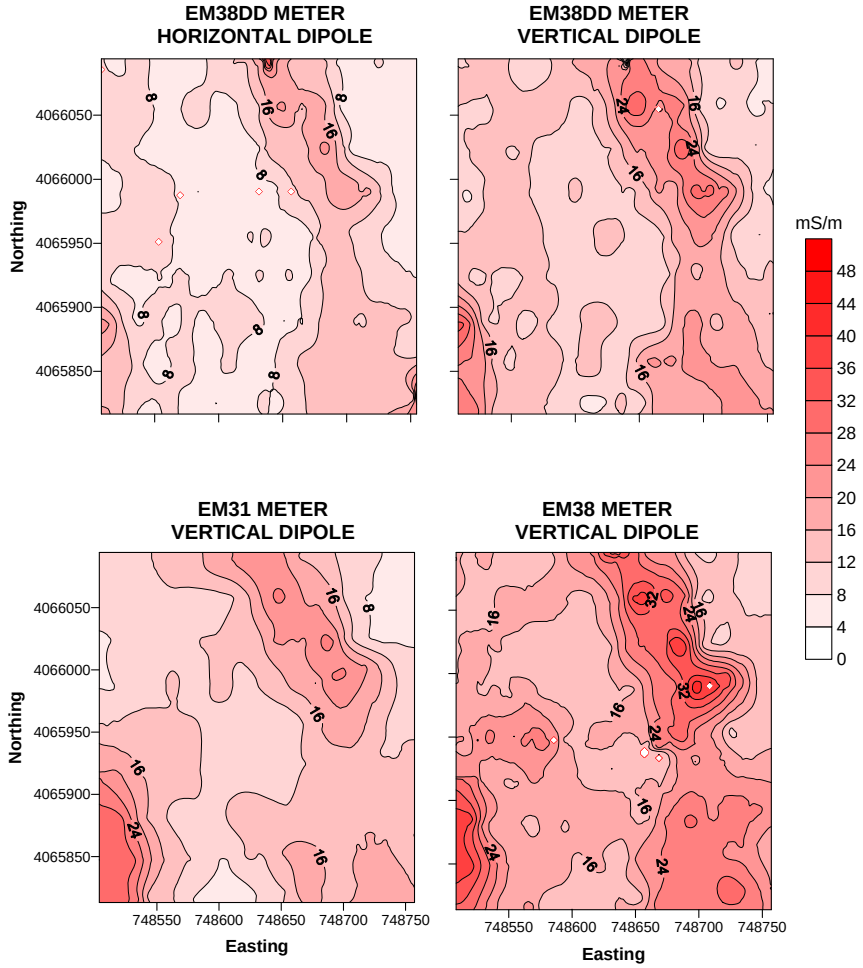

Figure 1. Plots of apparent conductivity data collected with three EMI meters at Study Site 1.

Figure 2 contains plots showing the spatial distribution of apparent conductivity collected with the GEM300 sensor in the vertical dipole orientation. In each plot, colors have been used to show the distribution of apparent conductivity. In each plot the isoline interval is 4 mS/m. To remove spurious measurements and lines, the *grid node editor* of Surfer 8 was used to blank or make slight changes (0.1 to 0.2 mS/m) to some of the measured EMI responses.

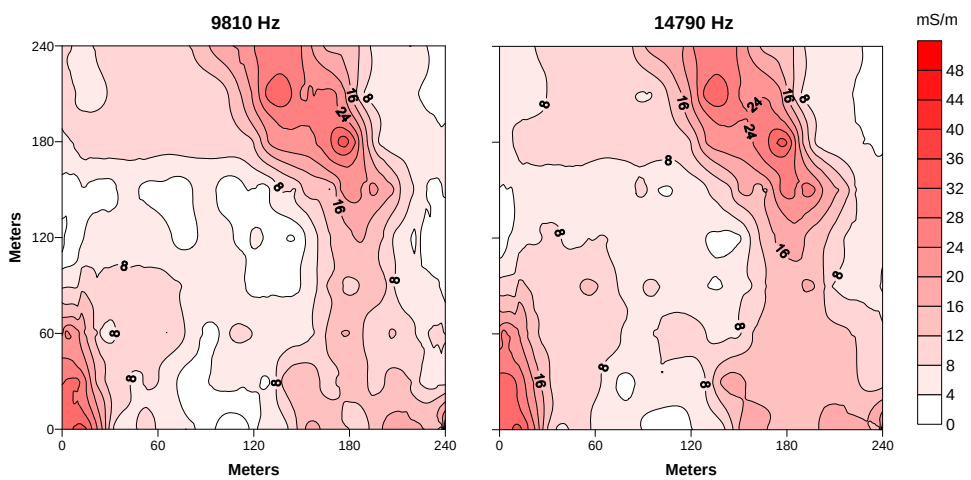

Figure 2. Plots of apparent conductivity data collected with the GEM300 sensor at Study Site 1.

Figures 1 and 2 reveal that, for data collected with the four EMI instruments, general patterns of apparent conductivity are reasonably similar. Each device has identified similar broad spatial patterns. A conspicuous ribbon of higher apparent conductivity identifies a lower-lying area of Kobel clay along a drainage channel that extends in a north-south direction across the eastern (right-hand) portion of each plot. The higher conductivity of this soil is explained by its higher clay (fine-textured control section) and moisture (poorly and very poorly drained) contents. The higher conductivity in the southwestern (lower left-hand) portion of these plots generally conforms to an area of Tuckerman-Bosket fine sandy loam, 0 to 5 % slopes. Poorly drained Tuckerman or a similar soil apparently dominates this lower-lying area. The relatively high conductivity is associated with the higher moisture content of Tuckerman soil. Other portions of survey area consists of higher-lying plane and convex surfaces that are better drained and mapped as areas of Bosket fine sandy loam, 4 to 10 % slopes.

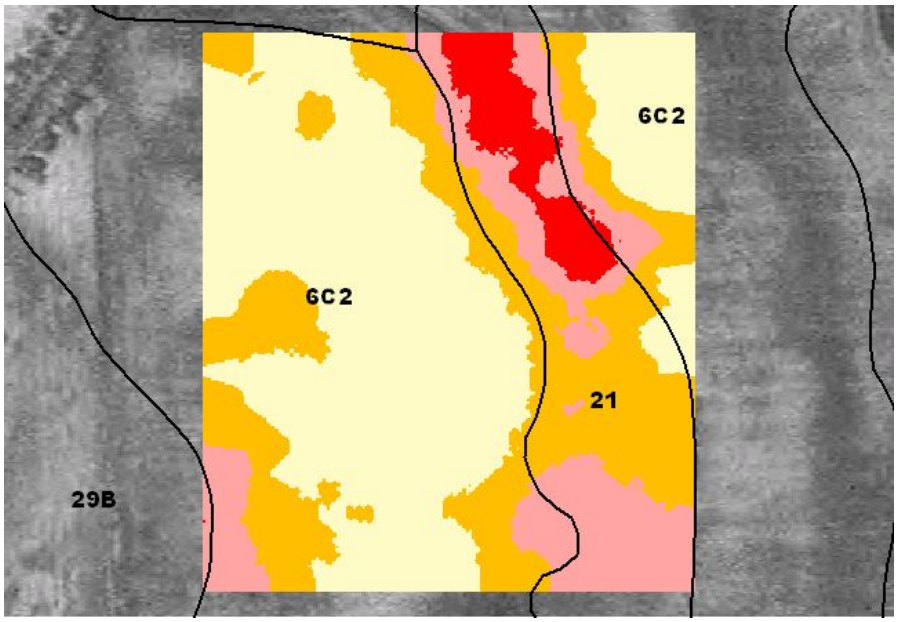

Figure 3. ArcView presentation of soil and EMI data from Study Site 1.

Figure 3 is an ArcView GIS image of the soil map and an apparent conductivity map (EM38DD meter; vertical dipole orientation) that have been overlain on an orthophoto of the study site. The map of apparent conductivity represents variations in soil properties within the upper 150 cm of the soils. As evident in Figure 3, patterns of apparent conductivity conform very well to soil map units. Based on the plot of apparent conductivity, slight adjustments in the placement of map unit boundaries may be needed. Areas of higher apparent conductivity (red, pink, and orange colors) appear to be associated with areas of Kobel clay (map unit symbol 21) and Tuckerman-Bosket fine sandy loam, 0 to 5 percent slopes (map unit symbol 29B). These map units contain soils that have comparatively higher moisture and clay contents. Areas of lower conductivity are restricted to higher lying, better drained, and more sloping areas of Bosket fine sandy loam, 4 to 10 percent slopes, eroded (map unit symbol 6C2).

Site #2

Table 2 summarizes survey results from Study Site 2. Compared with the first study site, apparent conductivity was noticeably higher and more variable at Study Site 2 with an observed range of 13.5 to 137.3 mS/m. Although mapped as areas of Loring silt loam, 2 to 15 % slopes; Crowley silt loam; and Falaya silt loam (Butler, 1985), the landowner reported the development of areas of sodium-affected soils within this field. The relatively high conductivity within this site reflects the higher soluble salt contents of these soils.

With the EM38DD meter, apparent conductivity increased and became more variable with increasing depth. In the shallower-sensing, horizontal dipole orientation (0 to 0.75 m), apparent conductivity averaged about 31.5 mS/m with a standard deviation of about 11.2 mS/m. One-half the observations had values of apparent conductivity

between about 21.2 and 39.9 mS/m. In the deeper-sensing, vertical dipole orientation (0 to 1.5 m), apparent conductivity averaged about 53.6 mS/m with a standard deviation of about 17.6 mS/m. One-half the observations had values of apparent conductivity between about 37.3 and 67.5 mS/m. The increased conductivity with increasing depth was attributed to greater soluble salt contents at lower soil depths.

Table 2
Basic EMI Statistics for Study Site # 2

	EM38DD-VDO	EM38DD-HDO	EM31-VDO	9810VDO	14790VDO
Number	679	679	1256	688	688
Minimum	24.4	13.5	26.8	42.1	41.3
Maximum	91.3	57.0	92.9	137.3	136.3
25%-TILE	37.30	21.15	43.10	62.60	62.20
75%-TILE	67.49	39.88	52.60	105.10	103.90
Average	53.63	31.48	48.39	88.51	83.86
Standard Dev.	17.57	11.25	19.78	24.21	23.87

Apparent conductivity was only measured with the EM31 meter operated in the vertical dipole orientation (0 to 5 m soil depth when the meter is held at hip height). Apparent conductivity averaged about 48.4 mS/m with a standard deviation of about 19.8 mS/m. One-half the observations had values of apparent conductivity between about 43.1 and 52.6 mS/m.

With the GEM300 sensor held at hip height in the vertical dipole orientation, data recorded at frequencies of 9810 and 14790 Hz were nearly identical. The correlation coefficient for these measurements was extremely high (r =0.99) and significant (0.001 level). Apparent conductivity averaged about 88.5 and 83.9 mS/m at frequencies of 9810 and 14790 Hz, respectively. At a frequency of 9810 Hz, apparent conductivity ranged from 42.1 to 137.3 mS/m with a standard deviation of about 24.2 mS/m. One-half the observations had values of apparent conductivity between 62.6 and 105.1 mS/m. At a frequency of 14790 Hz, apparent conductivity ranged from 41.3 to 136.3 mS/m with a standard deviation of about 23.9 mS/m. One-half the observations had values of apparent conductivity between 62.2 and 103.9 mS/m. As at the first study site, the use of multiple frequencies produced nearly identical results and provided no additional information on site conditions.

Measurements of apparent conductivity collected with the GEM300, though comparable, were higher and more variable than those collected with the EM38DD meter. McNeill (1980) observed that the measured apparent conductivity is a function of instruments calibration, coil separation, coil orientation, and frequency. Differences in equipment calibration by the manufacturers are believed to explain the higher values of apparent conductivity recorded by the GEM300 sensor than by the EM38DD meter. In addition, differences in the depth of penetration, volume of soil material measured, and resolution of each tool will affect measurements.

Apparent conductivity values are seldom diagnostic in themselves. However, spatial patterns and the relative magnitude of apparent conductivity do provide inferential clues as to differences in soils and soil properties. With minor exceptions and regardless of device, purported penetration depths, or frequency, the plotted spatial patterns were reasonably similar with each device. Because of the magnitude of measurements, spatial patterns are presumed to principally correspond with differences in sodicity.

Figure 4 contains plots showing the spatial distribution of apparent conductivity collected with the EM38DD meter and the GEM300 sensor at Study Site 2. The EMI instrument, dipole orientation, and/or frequency that were used to collect the data are identified over each plot in Figure 4. In each plot, colors have been used to show the distribution of apparent conductivity. In each plot the isoline interval is 10 mS/m. To remove spurious measurements and lines, the *grid node editor* of Surfer 8 was used to blank or make slight changes (0.1 to 0.2 mS/m) to some of the measured EMI responses.

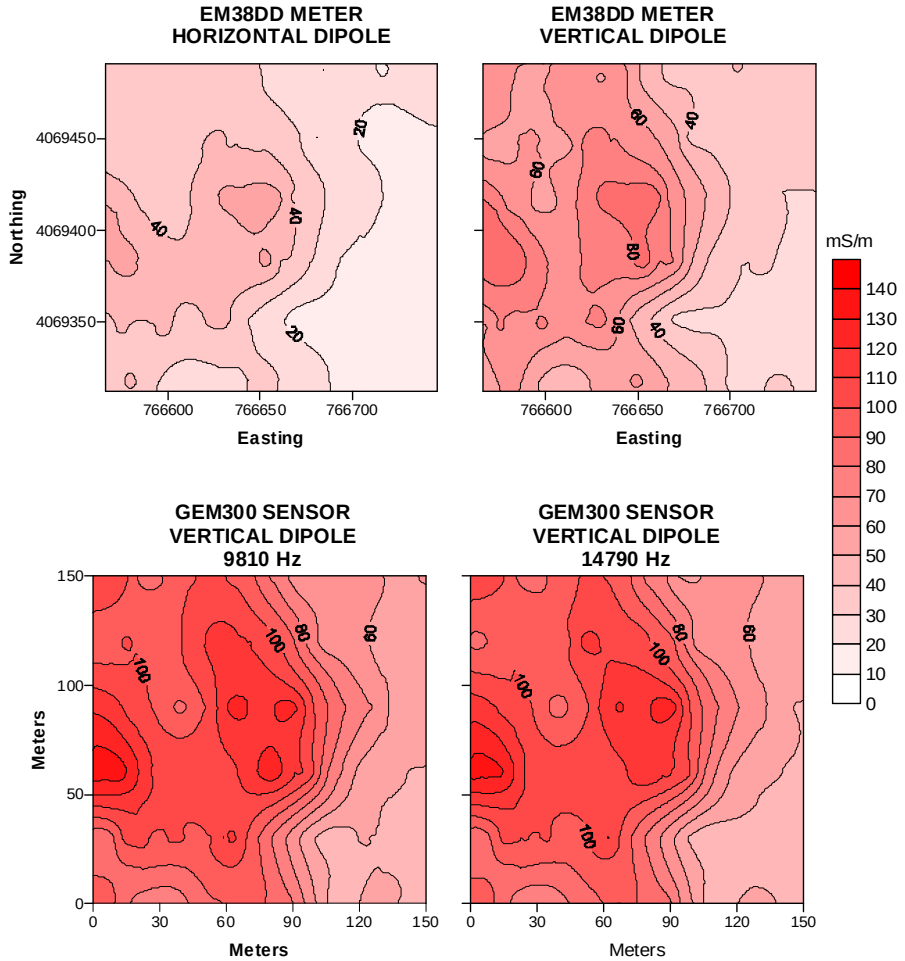

Figure 4. Plots of apparent conductivity data collected with the EM38DD meter and the GEM300 sensor at Study Site 2.

Areas of sodium-affected soils have slick-spots that are characterized by their small sizes, irregularly shapes, spotty occurrences, and variable expressions. In the plots of Figure 4, the irregular shape and spotty occurrence of areas of high apparent conductivity conforms to patterns of sodium-affected soils.

In west Tennessee, Ammons and others (1989) used EMI to reclassify areas of Routon (fine-silty, mixed, active, thermic Typic Epiaqualfs) soils based on the correlation between EMI response and sodium absorption ratio (SAR). Within areas of Routon soil, an EMI response (measured with the EM38 meter in the horizontal dipole orientation) of 63 mS/m correlated with a SAR of 15 and resulted in the soil being reclassified as a Natraqualfs. Nettleton and others (1994) used EMI to predict exchangeable sodium percentage and describe the composition of sodium-affected soil map units in south-central Illinois. They found that measurements obtained with the EM38 meter in the vertical dipole orientation correlated well with exchangeable sodium percentage. Soil with natric horizon had EMI responses greater than or equal to 55 mS/m. Sodium-affected soils had EMI responses between 30 and 55 mS/m. Based on these criteria, within the study site, 38 % soils would be sodium-affected and 52 % of the soils would have a natric horizons. However, soil sampling and laboratory analysis are required to ascertain the relationship that exists between apparent conductivity and exchangeable sodium percentage or SAR in these soils of southeastern Missouri.

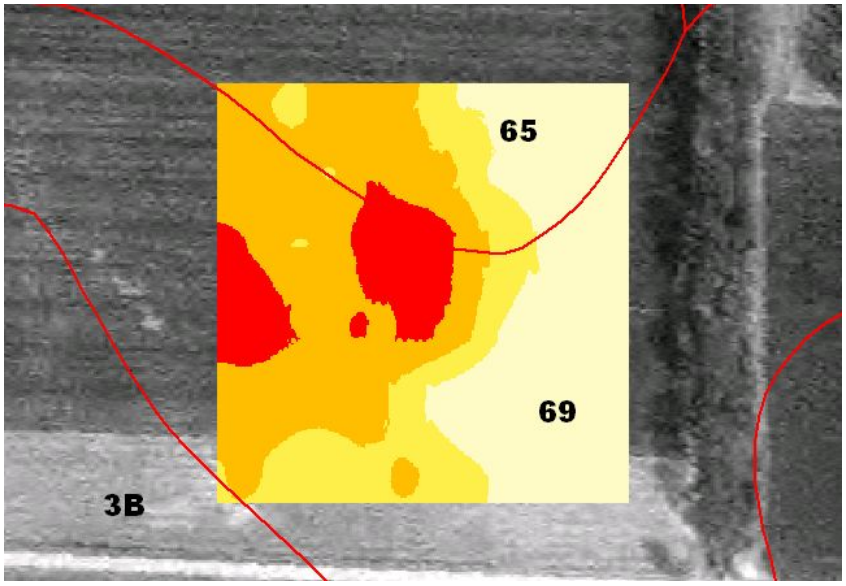

Figure 5. ArcView presentation of soil and EMI data from Study Site 2.

Figure 5 is an ArcView GIS image of the soil map and an apparent conductivity map (EM38DD meter; vertical dipole orientation) that have been overlain on an orthophoto of the study site. The map of apparent conductivity represents variations in soil properties within the upper 150 cm of the soils. As evident in Figure 5, patterns of apparent conductivity do not conform very well to soil map units and reflect the encroachment of sodicity into this unit of management since the soil map was prepared. Based on the plot of apparent conductivity, this area appears to require remapping. Areas of higher apparent conductivity (red and orange colors) cross map unit lines and do not conform to either areas of Crowley silt loam (map unit symbol 65) or Falaya silt loam (map unit symbol 69). The surface slopes towards a ridge located to the southwest and west (lower left- and left-hand portions of the figure). The isolines appear to approximate contour lines and suggest seepage and the deposition of salts from this adjoining ridge. Areas of lower conductivity are restricted to more distal and lower-lying areas of both of these map units (map unit symbols 65 and 69).

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