United States Department of Agriculture

NRCS

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SUBJECT: MGT – Geophysical Assistance

Date: June 4, 2012

TO: Denise C. Coleman
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NRCS, Harrisburg, Pennsylvania

File Code: 330-20-7

Purpose:
The Kravitz Tract is a historically farmed and drained area that is part of the *French Creek State Park Restoration Project*. A major goal of this restoration project is to restore 280 acres of wetlands and provide habitat for the federally endangered bog turtle. Within the Kravitz Tract, water from surrounding slopes is presently being diverted by surface drains, but older, undocumented systems of buried drainage tiles are believed to be present. The intent of the restoration project is to restore the original hydrology and a tussock-sedge habitat. The focus of the geophysical surveys is to locate undocumented subsurface drainage systems, filled areas, former stream channels, and seep areas within the Kravitz Tract.

Participants:
Matthew Azeles, Chief, Resources Management Section, PA DCNR, Bureau of State Parks, Harrisburg, PA
Eric Brown, Park Manager, PA DCNR, Bureau of State Parks, French Creek Complex, Elverson, PA
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Dennis Skyles, Park Maintenance Supervisor, PA DCNR, Bureau of State Parks, French Creek Complex, Elverson, PA

Activities:
Field activities were completed during the period of March 19-22, 2012.

Summary:

1. Electromagnetic induction data were collected on the relatively open areas of the Kravitz Tract. Although a survey was completed, the Kravitz Tract, unless cleared of most vegetation, is considered unsuitable for EMI.

2. Although there are no documents that record the presence of buried drainage tile, oral history indicates the presences of buried clay tile lines and former stacks of horseshoe-shaped drainage tile on the Kravitz Tract (Biebighauser, 2009). Several wet depressions and vertical holes were located by John Chibirka. These features may indicate where the soil has settled over a ruptured drainage tile.

3. Spatial EC_a patterns are more intricate than the soil patterns of the second-order soil map of the Kravitz Tract and do not conform to soil map unit boundaries. This is not surprising as the EMI survey was completed at a higher level of intensity. Areas of higher EC_a are associated with seep areas and wetter areas of bulrushes and sedges.

4. Areas of higher EC_a (>10 mS/m) that were recorded in the northern and eastern parts of the survey area form a seemingly anastomosing, meandering, interconnected pattern that suggests the location of former stream channels. These spatial EC_a patterns may reflect an active, buried natural drainage system.

5. Sites have been identified for detailed ground-penetrating radar surveys. These sites need to be cleared of vegetation to insure that GPR antennas have proper ground contact and to facilitate the laying out of grids and conducting GPR surveys. Once cleared, GPR surveys will be completed on these sites for the purpose of detecting buried drainage tiles.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to be of assistance in this study.

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc:
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The Use of Electromagnetic Induction (EMI) Methods to Identify Undocumented Subsurface Drainage Tile, Filled Areas, Former Stream Channels, and Seep Areas within the *Kravitz Tract* in Berks And Chester Counties, Pennsylvania, March 19 -22, 2012.

James A. Doolittle

Background:
The Kravitz Tract is a historically farmed and drained area that is part of the *French Creek State Park Restoration Project*. A major goal of this restoration project is to restore 280 acres of wetlands and provide habitat for the federally endangered bog turtle. Within the Kravitz Tract, water from surrounding slopes is presently being diverted by surface drains, but older, undocumented systems of buried drainage tiles are believed to be present. The intent of the restoration project is to restore the original hydrology and a tussock-sedge habitat. Agencies involved in this project include the Natural Lands Trust, Pennsylvania Department of Conservation & Natural Resources, Bureau of State Parks, United States Fish and Wildlife Service, and the USDA Forest Service and Natural Resources Conservation Service. The focus of the geophysical surveys is to locate undocumented subsurface drainage systems, filled areas, former stream channels, and seep areas within the Kravitz Tract. This report documents the findings of an electromagnetic induction (EMI) survey across portions of the Kravitz Tract.

Kravitz Tract:
Kravitz Tract is a 135-acre subdivision of the French Creek State Park (Figure 1). It is located along the border of Berks and Chester Counties in southeastern Pennsylvania. The entrance to the Kravitz Tract is located along Harmonyville Road about 0.7 mile west of the community of Pine Swamp. The most distinguishing cultural feature within the Kravitz Tract is a barn (see Figure 1; 40.18612 N latitude, 75.79567 W. longitude). The Kravitz Tract was operated as a private farm until it was purchased by the Pennsylvania Department of Conservation and Natural Resources in 2001. Presently, much of the former farm consists of derelict fields that are naturally revegetating into very dense stands of trees, shrubs and underbrush. .

The EMI survey was restricted to relatively open areas of the Tract that are shown in Figure 1. Soil delineations recognized on the soil map of the survey area (Figure 2) include: Bowmansville-Knauers silt loam (Bo); Croton silt loam, 0 to 3 % slopes (CwA & CyA); and Readington silt loam, 0 to 3 % slopes (ReA). The very deep, poorly and somewhat poorly drained Bowmansville soils formed in alluvial deposits on floodplains. The deep, poorly drained Croton soils formed in medium-textured materials over mainly sandstone, siltstone, or shale on uplands. Croton soils have a fragipan that ranges in depth from about 38 to 64 cm. Excess water is perched above the fragipan in late winter and early spring. Depth to bedrock ranges from about 100 to 152 cm. The very deep, poorly drained Knauers soils formed in alluvial deposits on backwater areas of floodplains. Knauers soils have sandy strata within a depth of 100 cm. Depth to bedrock is greater than 182 cm. The deep and very deep, moderately well drained Readington soils formed in medium-textured residuum weathered from noncalcareous shale, siltstone, and fine-grained sandstone. Depth to bedrock ranges from about 100 to 130 cm. Readington soils have a fragipan that ranges in depth from about 50 to 90 cm. Excess water is perched above the fragipan in late winter and early spring. The taxonomic classification of the identified soils is listed in Table 1. The poorly drained Croton and Knauers soils are considered hydric soils.

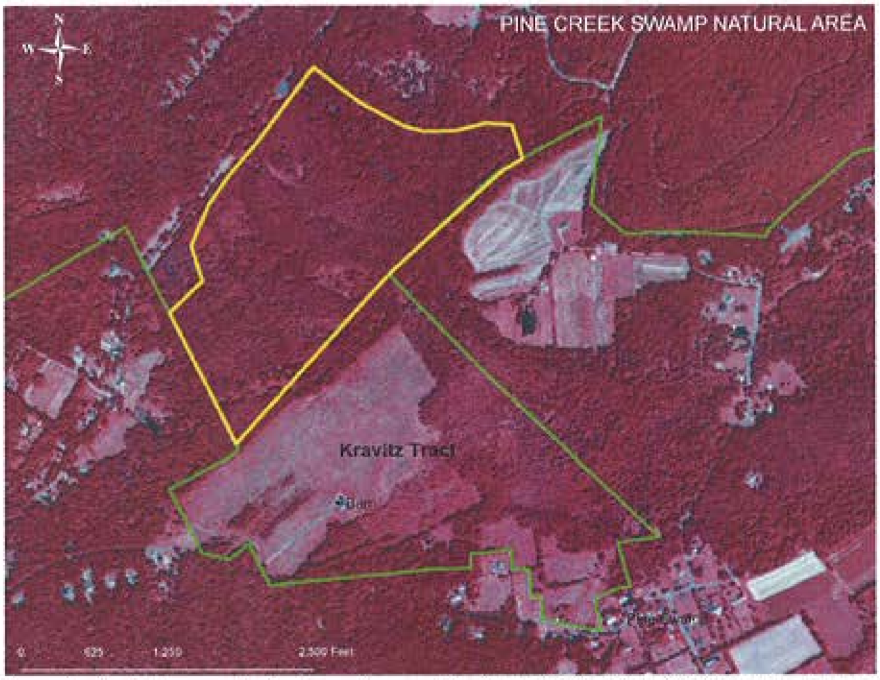

Figure 1. In this aerial photograph, the location and extent of the Kravitz Tract is shown in relationship to the Pine Creek Swamp Natural Area (outlined in yellow) and the community of Pine Swamp.

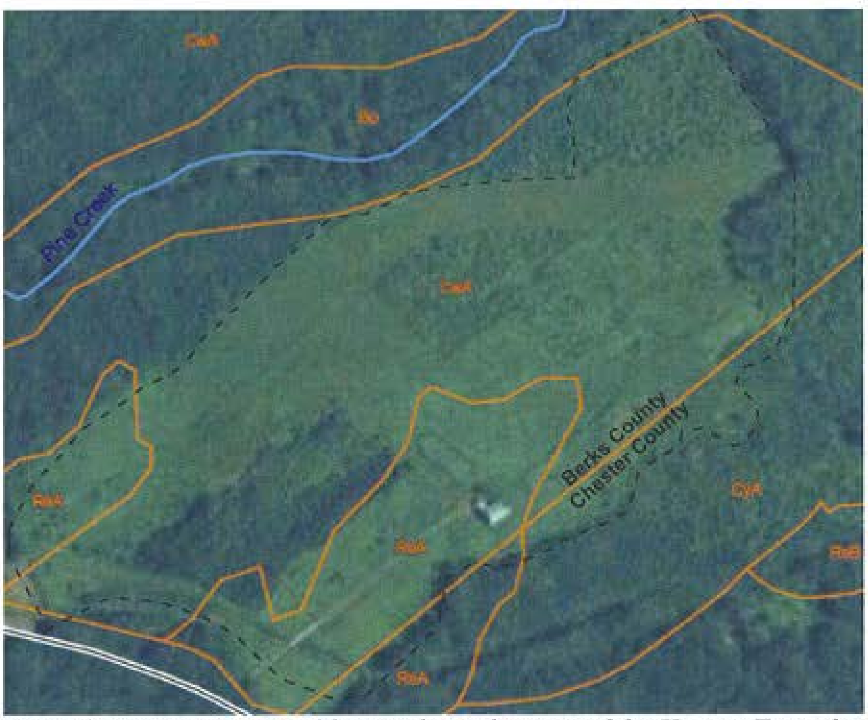

Figure 2. On this soils map, a segmented line outlines the area of the Kravitz Tract that was surveyed with EMI. Soil map is from the Web Soil Survey. [1]

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[1] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ accessed [March 26, 2012].

Table 1. Taxonomic classification of the soils indentified within the Kravitz Tract

Series	Taxonomic Classification
Bowmansville	Fine-loamy, mixed, active, nonacid, mesic Fluventic Endoaquepts
Croton	Fine-silty, mixed, active, mesic Typic Fragiaqualfs
Knauers	Fine-loamy over sandy or sandy-skeletal, mixed, active, nonacid, mesic Typic Fluvaquents
Readington	Fine-loamy, mixed, active, mesic Oxyaquic Fragiudalfs

EMI:

Electromagnetic induction uses electromagnetic energy to measure and map spatial and temporal variations in the apparent electrical conductivity (EC_a). Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific exploration depth (Greenhouse and Slaine, 1983). Apparent conductivity is a measure of the soils ability to conduct an electrical current. In soils, EC_a is primarily controlled by, and increases with soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976). As such, EC_a can be used as a measure of a number of soil physical and chemical properties. Stafford (2000) noted that EC_a is often a good substitute for a spatially varying soil property that is not easily sensed or mapped such as clay or moisture content. However, a weakness of this interpretative process is *equivalence*: variations in more than one soil properties can produce the same or similar EMI response. In many landscapes, concurrent variations in soil depth, texture and moisture contents can take place without a noticeable change in EMI response. In some landscapes an increase in soil moisture, which causes an increase in EC_a, can be offset by a decrease in clay content or soil depth (over more resistive materials such as sands or most bedrock), which decreases EC_a. Equivalent or non-uniqueness responses create ambiguities in relating EC_a to a specific soil property.

The depth of exploration and measured response are influenced by the EMI meter's coil orientation, coil separation, and frequency, as well as the conductivity of the profiled material(s). The EMI response is not uniform with depth; surface and shallow layers contribute more to the overall response than deeper layers. The orientation of the transmitter and receiver coil axis (with respect to the ground surface) affects the response from materials at different depths (McNeill, 1980). For example, in the shallower-sensing horizontal dipole orientation (HDO), meters are more sensitive to near surface materials. In the deeper-sensing vertical dipole orientation (VDO), meters are more sensitive to deeper materials. Slavich (1990) and de Jong et al. (1979) noted that the depth of exploration varies depending on the EC_a of the profiled material(s). Greenhouse et al. (1998) commented that the electrical conductivity of soils play a critical role in the depth of exploration. Furthermore, these authors noted that EMI instruments do not penetrate a fixed distance under all circumstances.

Equipment:

An EM38-MK2 meter (Geonics Limited; Mississauga, Ontario) was used in this study.[2] Operating procedures for the EM38-MK2 meter are described by Geonics Limited (2007). The EM38-MK2 meter operates at a frequency of 14.5 kHz and weighs about 5.4 kg (11.9 lbs). The meter has one transmitter coil and two receiver coils, which are separated from the transmitter coil at distances of 1.0 and 0.5 m. This configuration provides two nominal exploration depths of 1.5 and 0.75 m when the meter is held in the vertical dipole orientation (VDO), and 0.75 and 0.40 m when the meter is held in the horizontal dipole orientation (HDO). In either dipole orientation, the EM38-MK2 meter provides measurements of

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

apparent conductivity (EC_a) over two depth intervals. Apparent conductivity is expressed in milliSiemens/meter (mS/m).

The Geonics DAS70 Data Acquisition System was used with the EM38-MK2 meter to record and store both EC_a and GPS data.[3] The acquisition system consists of the EM38-MK2 meter, an Allegro CX field computer (Juniper Systems, Logan, Utah), and a Trimble AgGPS114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA).[3] With the acquisition system, the EM38-MK2 meter is keypad operated and measurements are automatically triggered. The RTM38-MK2 program (Geomar Software, Inc., Mississauga, Ontario) was used with the EM38-MK2 meter to display and record both GPS and EC_a data on the Allegro CX field computer.[3]

To help summarize the results of the EMI surveys, SURFER for Windows (version 10.0) software (Golden Software, Inc., Golden, CO) was used to construct the simulations shown in this report.[3]

Field Methods:
The EMI survey was restricted to *relatively open* areas of the Tract that are shown in Figures 1 and 2. Forested areas were not surveyed as a result of GPS satellite shading and extremely poor accessibility

Figure 3. In the relatively open portions of the Kravitz Tract, dense stands of regrowth vegetation obstructed a thorough and systematic survey with EMI.

Pedestrian surveys were completed with the EM38-MK2 meter across the *relatively open* areas of the site. The EM38-MK2 meter was operated in the deeper-sensing, vertical dipole orientation (VDO). The instrument was operated in the continuous mode with measurements recorded at a rate of 2/sec. Where

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

possible, the long axes of the meter was orientated parallel to the direction of traverse, and held about 5 cm above the ground surface. Apparent conductivity data were recorded for both the 50 and 100 cm intercoil spacings. At the time of this survey the soil temperature was observed to be 48 ° F at a depth of 50 cm. All EC_a data were temperature corrected to a standard temperature of 75° F.

The use of the term *relatively open* is a misnomer for the Kravitz Tract. In the *relatively open* areas of the tract, dense regrowth vegetation provided a most hostile environment in which to conduct a detailed and orderly EMI survey (Figure 3). Dense stands of vines, briars, and underbrush had to be avoided. Frequently, the GPS antenna and EM38-MK2 meter became entangled with vines and tree limbs, slowing progress and fatiguing the operator. Because of the dense vegetation, it was impossible to maintain the meter at a uniform height, thus introducing some errors in the measurements. Though a survey was completed, the Kravitz Tract, in its present state, is considered unsuitable for EMI.

Results:
Table 2 provides basic statistics for the EMI data that were collected at this site. The theoretical exploration depths are 75 and 150 cm for the 50 and 100 cm intercoil spacings, respectively. In Table 2, with the exception of "Number", the unit of measure is mS/m. The number of recorded observations is 30, 650. As evident in this table, the bulk averaged EC_a increase from 6.9 mS/m for the upper 75 cm to 10.7 mS/m for the upper 150 cm of the soil profile. This general increase in EC_a with increasing depth of exploration is attributed to higher clay and/or moisture contents in the lower part of soil profiles.

Table 2. Apparent Conductivity and In-Phase Data collected with the EM38-MK2 in the Vertical Dipole Orientation at the Kravitz Tract.

	EC_a - 50 cm	EC_a - 100 cm
Number	30650	30650
Minimum	-183.6	-208.6
25%-tile	3.7	8.0
75%-tile	10.8	13.2
Maximum	242.2	94.5
Average	6.9	10.7
Std. Dev.	6.2	4.5

For measurements obtained in the deeper-sensing, 100-cm intercoil spacing, EC_a ranged from about -209 to 94 mS/m. Negative and anomalously high positive values are attributed to the presence of metallic artifact(s) scattered across the site. For the 100-cm intercoil spacing, one-half of the measurements were between about 8.0 and 13.2 mS/m. For the shallower-sensing 50-cm intercoil spacing, EC_a ranged from about -184 to 242 mS/m. However, one-half of these measurements were between about 3.7 and 10.8 mS/m. For the two exploration depths, the relatively narrow interquartile ranges suggest comparatively homogeneous soil conditions and properties across most of the survey area.

Figures 4 and 5 are plots of the EC_a data that were respectively collected with the 50- and 100-cm intercoil spacings of the EM38-MK2 meter. The same color scales and ramps have been used in both plots. Soil boundary lines have been digitized from Web Soil Survey data[4]. A barn, access road, diversion ditch and an area planted to evergreen trees have been indentified on each simulation for general reference. The area within a stand of evergreens was not surveyed because of limited access and very poor GPS satellite reception.

[4] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Available online at http://websoilsurvey.nrcs.usda.gov/ accessed [03/22/2012].

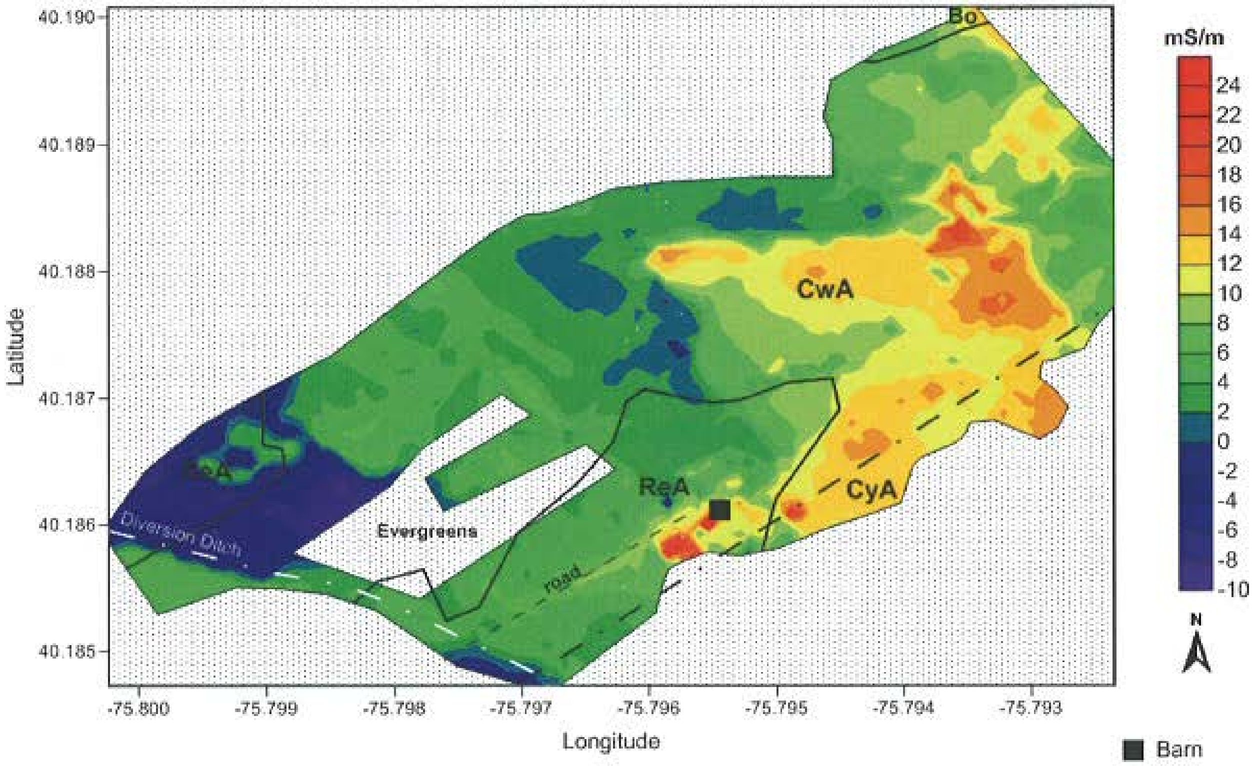

Figure 4. This simulation shows spatial EC_a patterns collected with the 50-cm intercoil spacing of the EM38-MK2 meter. The nominal depth of penetration is 0 to 75 cm.

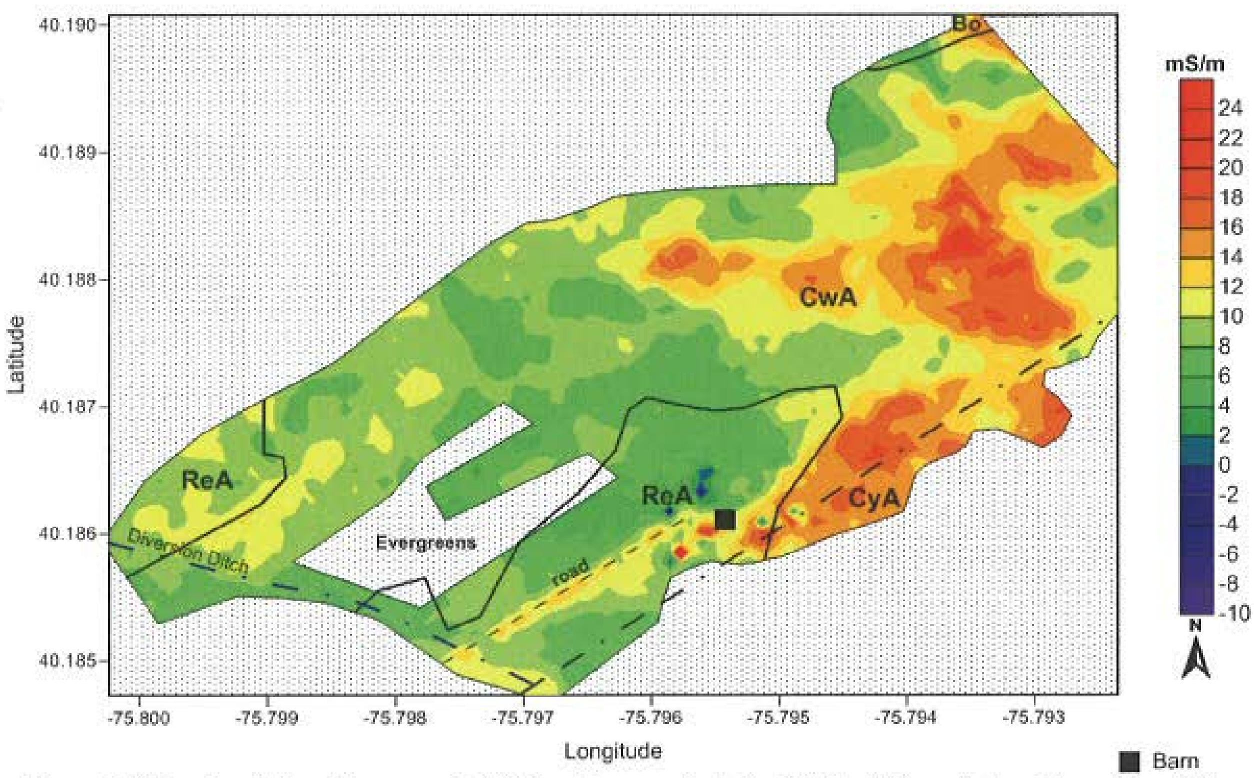

Figure 5. This simulation shows spatial EC_a patterns collected with the 100-cm intercoil spacing of the EM38-MK2 meter. The nominal depth of penetration is 0 to 150 cm.

A cursory inspection of Figures 4 and 5 reveals that spatial EC_a patterns are more intricate than the soil patterns of the second-order soil map and do not conform to soil map unit boundaries. This is not surprising as the maps were prepared at different levels of detail and using different procedures. In Figures 4 and 5, areas of higher EC_a are associated with seep areas and wetter areas of bulrushes and sedges (extreme southeastern portion of the survey area to the east of the barn). A comparison of these two figures reveals that EC_a increases with increasing soil depth (measurements recorded in the deeper-sensing 100-cm intercoil spacing (Figure 5) are higher than those recorded in the shallower-sensing 50-cm intercoil spacing (Figure 4). This relationship is mainly attributed to increased moisture contents at lower soil depths.

In Figure 5, areas of higher EC_a (>10 mS/m) that were recorded in the northern and eastern parts of the survey area form a seemingly anastomosing, meandering, interconnected pattern that suggests the location of former stream channels. These channels were plugged and filled when the surface ditches were excavated. These spatial EC_a patterns may reflect an active, buried natural drainage system.

While ditches and raised beds were observed and crossed with EMI in the field, these features provide no noticeable response in the data set. Higher values of EC_a were recorded over a gravel road that led to the barn. Higher values are attributed to soil compaction and smaller pores being filled with water rather than air in the subgrade.

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