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

Subject: SOI – Geophysical Field Assistance

Date: 29 May 2001

To: Wayne M. Maresch
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Purpose:
To provide electromagnetic induction (EMI) and ground-penetrating radar (GPR) field assistance to the Tuscarora Nation's Environment Program.

Participants:
Steve Carlisle, Resource Soil Scientist, USDA-NRCS, Seneca Falls, NY
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
Neil Patterson Jr., Director, Tuscarora Environment Program, Sanborn, NY
Brian Printup, GPS/GIS Technician, Tuscarora Environment Program, Sanborn, NY
Rene Rickard, Water Quality Technician, Tuscarora Environment Program, Sanborn, NY
Ed Stein, Resource Soil Scientist, USDA-NRCS, Herkimer, NY

Activities:
All field activities were completed during the period of 21 to 24 May 2001.

Background:
The Tuscarora Environment Program is actively engaged in a program of waste reduction and management. As part of the waste management strategy, various areas of the Reservation are being assessed for cleanup. These assessments will help determine the boundaries and identify different types of wastes or debris within each site. Noninvasive geophysical surveys using EMI can play a useful role in delineating waste sites and guiding invasive sampling or monitoring surveys. The geophysical investigations discussed in this report were conducted principally at two sites: the *Army Camp* and *Teepee's Gas Station* sites

During the Korean War, the US Army established a civilian camp with barracks, offices, and other structures in an area located within the Reservation. This area is known as the "*Army Camp*" site. Following the war, all structures were demolished and most debris removed from the site. However, some concrete pads and foundations, a chimney, exposed pipes, and other remnants of these structures remain. The site is covered with a mixed vegetation of small trees, bushes and grasses. A large portion of the site has become an open dumping ground for trash. The Director, Tuscarora Environment Program, wishes to clean up this site. An EMI survey of the site was conducted in an attempt to delineate and possibly identify underground storage tanks, drums, and structures.

The second site, known as *Teepee's Gas Station*, was once a gas station. The gas station has been torn down and much of the debris has been removed from the site. However, it is not known weather the underground gas storage tanks associated with the gas station were removed. Seventeen test pits in the area have not revealed these gas storage tanks. An EMI survey was conducted on a portion of this site in an attempt to locate underground gas storage tanks.

Though not directly related to objectives of the requested geophysical assistance, a GPR survey was conducted across a small portion of a cemetery and burial site that dates back to the mid 1800's. Many of the headstones have been removed. A preliminary GPR survey was conducted to assess the feasibility of using GPR to locate unmarked graves. In addition, the study provided Ed Stein and Jim Doolittle and opportunity to evaluate the operation of NRCS New York's SIR-3 unit.

Equipment:
A GEM300 sensor, manufactured by Geophysical Survey Systems, Inc.,[1] was used in this study. This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 19,950 Hz with a fixed coil separation (1.3 m). Won and others (1996) have described the use and operation of this sensor. With the GEM300 sensor, the depth of observation is considered "skin depth limited." The skin-depth represents the maximum depth of observation. It is frequency and soil dependent: low frequency signals travel farther through conductive mediums than high frequency signal. The theoretical observation depth of the GEM300 sensor is dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequency. Multifrequency sounding with the GEM300 allows multiple depths to be profiled with one pass of the sensor.

The radar unit used at the cemetery is the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2 consists of a digital control unit (DC-2) with keypad, VGA video screen, and connector panel. A 12-volt battery powered the system. This unit is backpack portable and with an antenna requires two people to operate. A 400 MHz antenna was used in this study.

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

Field Procedures:
An irregular shaped grid with an area of about 146,500 sq ft was established at the *Army Camp* sites. Nineteen survey lines were established perpendicular to the base line. These survey lines were spaced at intervals of 30 to 60 feet along the baseline (See Figure 1, base line is Y = 50 feet). Survey flags were inserted in the ground at intervals of 50 feet along each of the nineteen survey lines and served as control points. Apparent conductivity and in-phase responses were recorded at frequencies of 9810 and 14850 Hz with the GEM300 sensor held at hip-height. The GEM300 sensor was operated in the continuous mode with observations recorded every second. The approximate locations of these observation points and the survey lines are shown in the upper left-hand plot in Figure 1. Separate surveys were required for each dipole orientation. This resulted in 1357 and 1313 observations for surveys conducted in the horizontal and vertical dipole orientations, respectively.

An irregularly shaped 80 by 75-ft grid was established across *Teepee's Gas Station* site. The grid consisted of an 80-ft base line and two additional parallel lines. The base line spanned the distance between to metal posts that are adjacent to a drainage ditch and a road. The two parallel lines were 50 and 30 ft long and spaced 75 and 45 ft, respectively, from the base line. Along each of these lines, survey flags were inserted in the ground at intervals of 5 ft. Apparent conductivity and in-phase responses were recorded at frequencies of 9810 and 14850 Hz with the GEM300 sensor held at hip-height. Walking at a uniform pace between similarly numbered flags on the three

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

parallel lines completed an EMI survey. The GEM300 sensor was operated in the continuous mode and recorded an observation every second. The approximate locations of observation points and the survey lines are shown in the upper left-hand plot in Figure 3. The base line forms the lower boundary of each plot. Separate surveys were required for each dipole orientation. This resulted in 289 and 291 observations for surveys conducted in the horizontal and vertical dipole orientations, respectively.

EMI:

Background:

Electromagnetic induction (EMI) is a noninvasive geophysical tool that has been used to locate underground storage tanks, landfill and trench boundaries, and buried pipelines (Nyquist and Blair, 1991; Won et al., 1996; Lanz et al., 1998; Vickery and Hobbs, 1998). Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. 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 correctly interpreted EMI data provide the basis for assessing site conditions, planning further investigations, and locating sampling or monitoring sites.

Electromagnetic induction measures vertical and lateral variations in magnetic and/or electrical fields associated with induced subsurface currents. Data are expressed as in-phase, quadrature phase, or apparent conductivity. In-phase refers to the part of the signal that is in phase (has zero phase shift) with the primary or reference signal. The in-phase signal is sensitive to buried metallic objects and has been referred to as the "metal detection" mode.

Quadrature phase refers to the part of the signal that is 90 degrees out of phase with the primary signal. The quadrature phase response is linearly related to ground conductivity. Some highly conductive targets with small cross-sections, such as pipes, may show up better in the quadrature phase because of the channelization of current. With the GEM300 sensor, in-phase and quadrature phase data are expressed in parts per million (ppm).

Traditionally, EMI data are expressed as apparent conductivity. The GEM300 sensor automatically converts data recorded in the quadrature phase into apparent conductivity. Values of apparent conductivity are expressed in milliSiemens per meter (mS/m). Apparent conductivity is a weighted, average conductivity measurement for a column of earthen materials to a specific depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity 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, amount and type of clays in the soil matrix, and temperature and phase of the soil water (McNeill, 1980). The apparent conductivity of soils 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 apparent electrical conductivity. Values of apparent conductivity are seldom diagnostic in themselves, but lateral and vertical variations in these measurements can be used to infer changes in earthen materials. Interpretations are based on the identification of spatial patterns within data sets.

Results:

Army Camp Site

Figures 1 and 2 show apparent conductivity (upper plots) and in-phase (lower plots) responses collected at frequencies of 14850 and 9810 Hz, respectively. In the color plots (upper plots) of apparent conductivity, the interval is 2 mS/m. In the color plots of in-phase data, the interval is 100 ppm. The depth of observation is assumed to increase as the frequency decreases. Presumably, data collected at 14850 Hz (higher frequency) indicates shallower features than data collected at 9810 Hz (lower frequency). In each figure, data collected in the deeper-sensing vertical and the shallower sensing horizontal dipole orientations are shown in the left-hand and right-hand plots, respectively.

Each plot shows a slightly different picture of the surveyed area. However, in each plot a greater number of anomalies are detected in the northern and northwestern portions of the survey area. These anomalies represent trash, debris, and structures not only buried, but on the surface of the site. With the exception of the southwest corner, the southern portion of the study area appears relatively free of anomalies. These plots provide information on the location of features within the site. The in-phase data is more sensitive to metallic objects. Anomalies apparent in both in-phase and conductivity plots are most likely metallic. The four prominent anomalies observable in the plots of apparent conductivity measured in the horizontal dipole orientation are also apparent in the in-phase plots. These anomalies are assumed to be metallic. The lower plots in each figure confirm the abundances of metallic features or features containing metals (pipes or rebar in concrete) within the northern and northeastern portions of the site. A large amount of trash has been discarded on the surface in the southwest corner of the study area. The in-phase data (see figures 1 and 2) clearly delineates this area of surface trash. In the upper plots of each figure, linear patterns of moderate apparent conductivity (yellow and orange colors) appear to connect larger, rectangular features of high conductivity (red colors). These patterns suggest the presence of underground pipe or utility lines. The areas of high conductivity (red colors) are believed to be underground structures or concrete pads.

Teepee's Gas Station

Figures 3 and 4 show apparent conductivity (upper plots) and in-phase (lower plots) responses collected at frequencies of 14850 and 9810 Hz, respectively. In the color plots (upper plots) of apparent conductivity, the interval is 2 mS/m. In the color plots of in-phase data, the interval is 100 ppm. In each figure, data collected in the deeper-sensing vertical dipole and the shallower sensing horizontal dipole orientations are shown in the left-hand and right-hand plots, respectively. Plots collected in the same dipole orientation and measuring the same response (in-phase or apparent conductivity) are remarkably similar. A buried metallic object, possibly a buried gas tank, is evident in the lower right-hand corner of each plot. This object is considered to be metallic as it is most apparent in the plots of the in-phase data (lower plots in figures 3 and 4). Plots of apparent conductivity suggest the presence of a conductive, linear area extending through this buried metallic object and extending away from the base line and the road. This anomalous area could represent a trench filled with more conducted materials. Extreme values in the lower left and right-hand corners of each plot represent interference from the metal posts that are adjacent to the drainage ditch and the road.

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 borings or well logs). 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. Simulations prepared from correctly interpreted EMI data provide the basis for assessing site conditions. Spatial patterns of apparent conductivity and in-phase data, characterize the locations of metallic objects within each site. The northern and northwestern portion of the *Army Camp* site contains the majority of the detected anomalies. However, as large amounts of surface trash and debris scattered throughout the site, it is uncertain whether surface or subsurface features cause responses. A subsurface anomaly was detected in within the area surveyed at the site of Tee Pee's Gas Station. This feature is metallic and may be a buried gas tank. On site investigations is recommended to confirm these features.

3. Results from the GPR survey of the cemetery were very promising. The 400 MHz antenna detected several subsurface anomalies that are believed to represent burials. The level of interpretive skills displayed by Ed Stein impressed me. The SIR-3 radar unit operated by Ed is in dire need of repairs. The quality of the radar imagery is seriously degraded by malfunctioning gain and paper advance controls. Ed's work would be greatly eased, his interpretations enhanced and the rate of paper consumption reduced if the unit is repaired. I

strongly recommend that the SIR-3 radar unit be returned for repairs.

It was my great pleasure to work again in New York, with members of the Tuscarora Nation, and with Ed Stein and Steve Carlisle.

With kind regards,

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EMI SURVEY OF TEE PEE'S GAS STATION
GEM300 SENSOR
9810 Hz

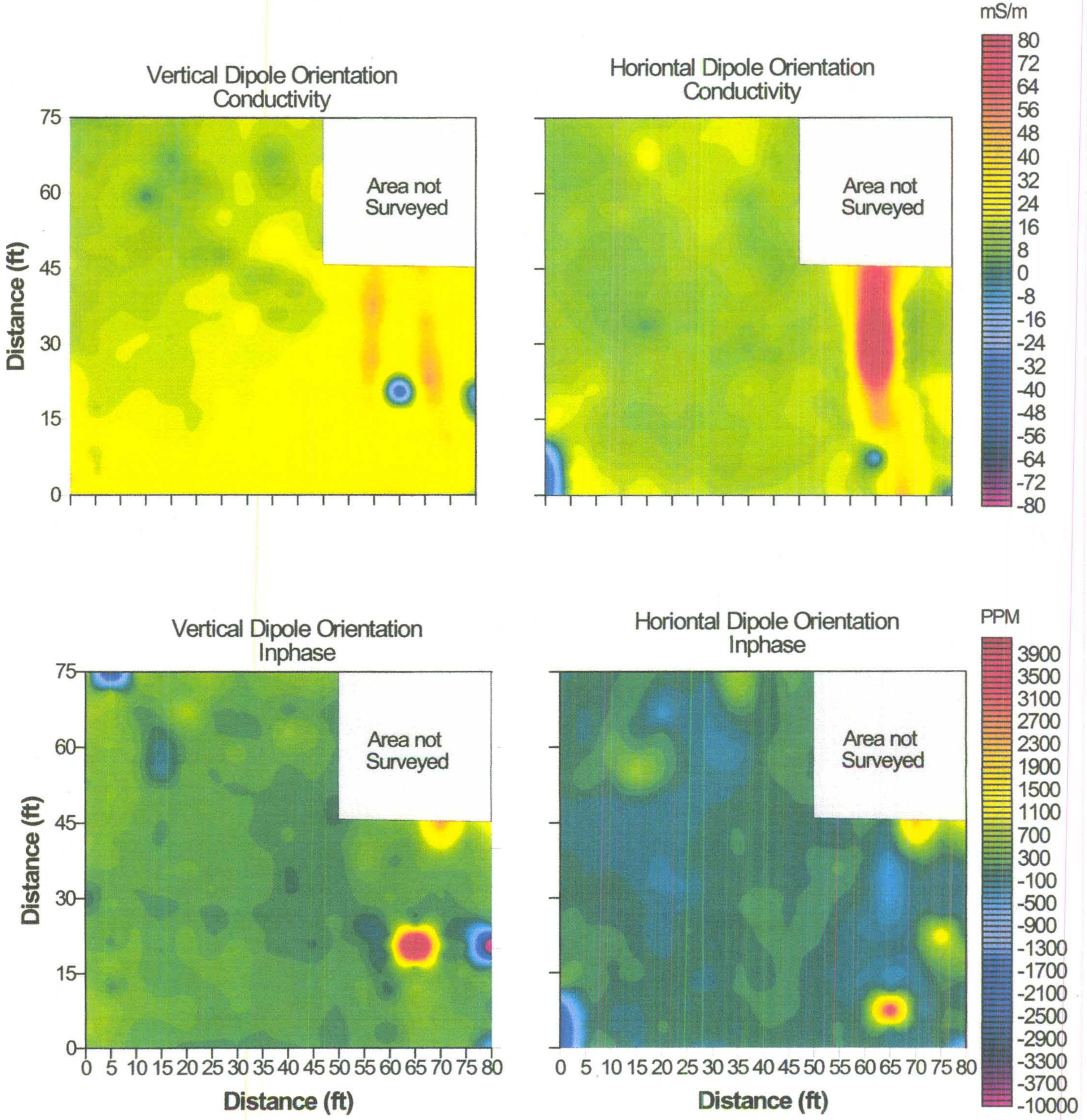

Figure 4

EMI SURVEY OF TEE PEE'S GAS STATION
GEM300 SENSOR
14850 Hz

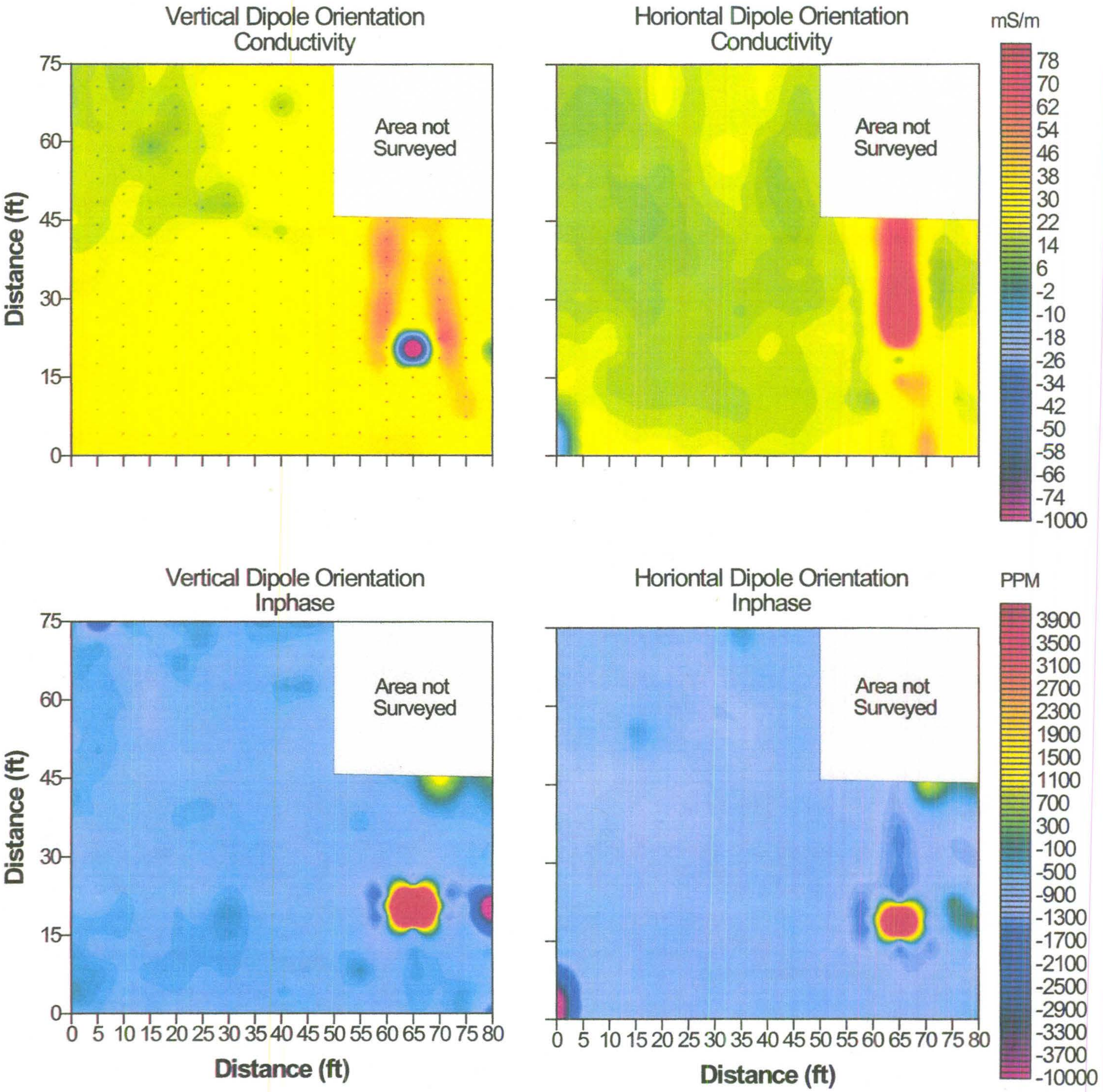

Figure 3

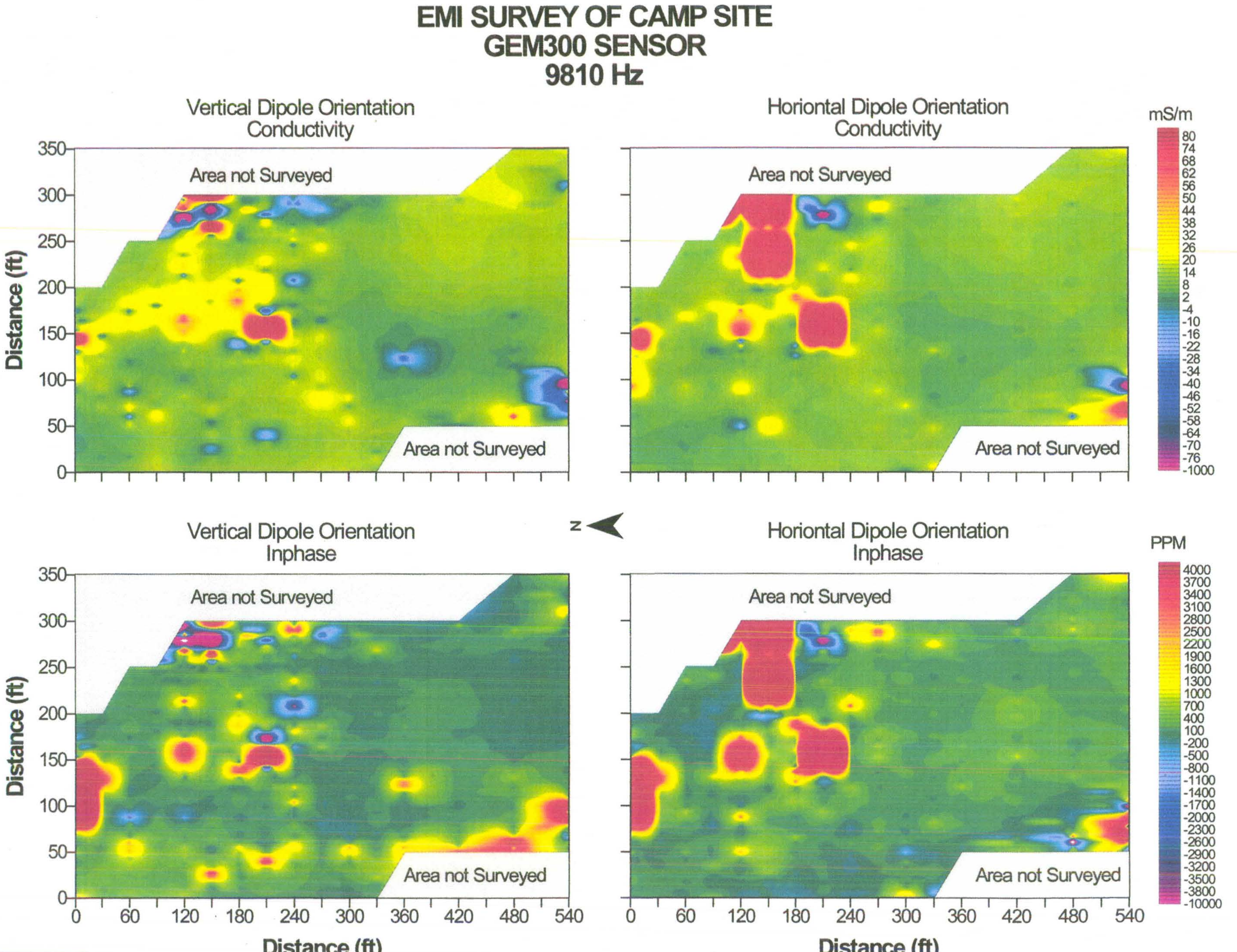
EMI SURVEY OF CAMP SITE
GEM300 SENSOR
9810 Hz
Vertical Dipole Orientation
Conductivity
Horiontal Dipole Orientation
Conductivity
Vertical Dipole Orientation
Inphase
Horiontal Dipole Orientation
Inphase
Area not Surveyed
Distance (ft)
N
mS/m
80 74 68 62 56 50 44 38 32 26 20 14 8 2 -4 -10 -16 -22 -28 -34 -40 -46 -52 -58 -64 -70 -76 -1000
PPM
4000 3700 3400 3100 2800 2500 2200 1900 1600 1300 1000 700 400 100 -200 -500 -800 -1100 -1400 -1700 -2000 -2300 -2600 -2900 -3200 -3500 -3800 -10000
0 50 100 150 200 250 300 350
0 60 120 180 240 300 360 420 480 540

Figure 2

EMI SURVEY OF CAMP SITE
GEM300 SENSOR
14850 Hz

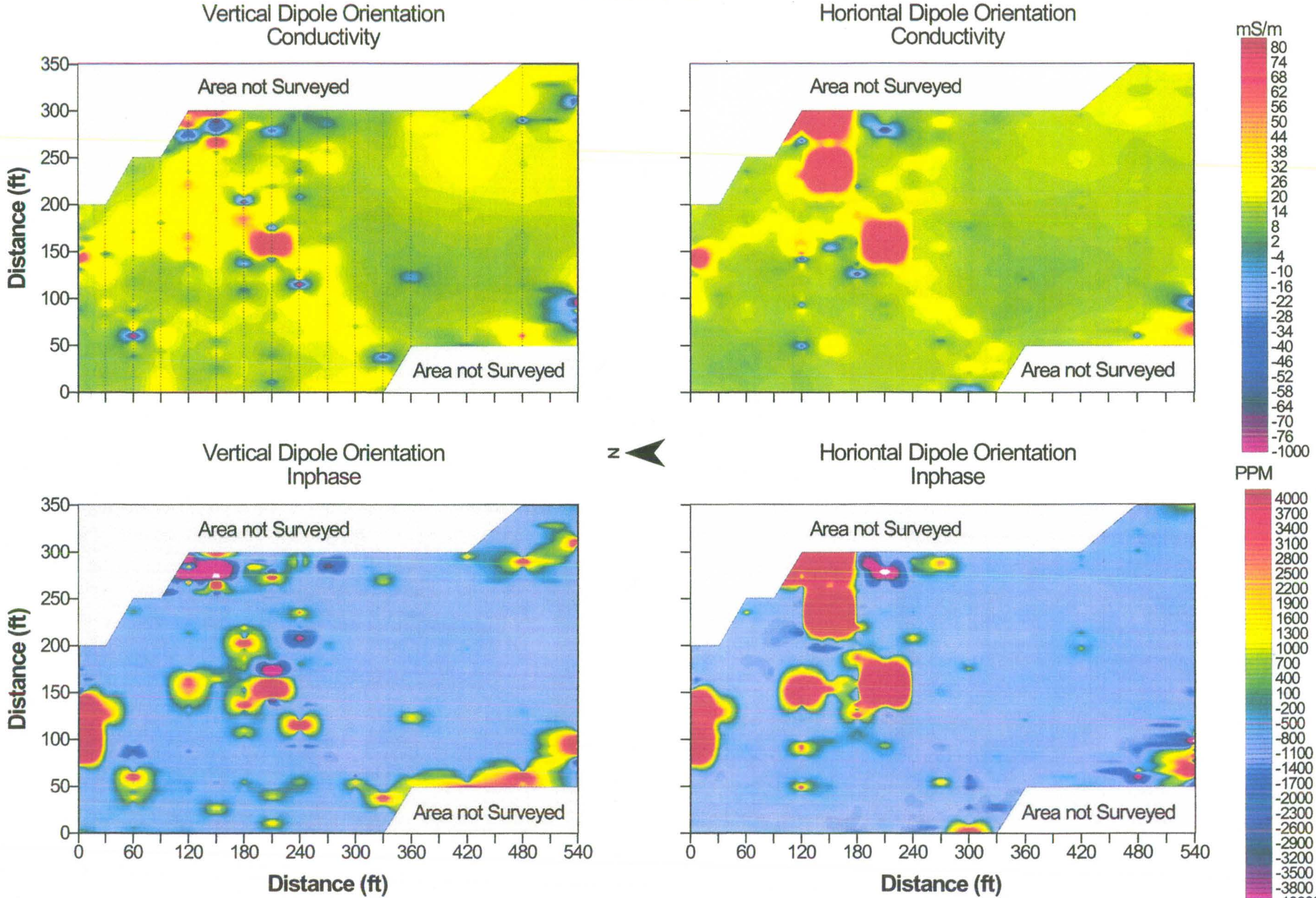

Figure 1