United States Department of Agriculture

Natural Resources Conservation Service

**5 Radnor Corporate Center, Suite 200
Radnor, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance

Date: 6 August 1999

To: Gary Pfiefle
Acting State Conservationist
USDA-NRCS,
9173 West Barnes Drive, Suite C
Boise, Idaho 83709

Purpose:
To assist Idaho's cultural resource specialist and the Bureau of Land Management (BLM) assess several archaeological sites within the Snake River Plain.

Participants:
Tom Burnham, District Conservationist, USDA-NRCS, Jerome, ID
Carli Chesebro, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Lisa Cresswell, Archaeologist, USDI-BLM, Shoshone, ID
Patolia Dean, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Jim Doolittle, Research Soil Scientist, USDA-NRCS, Radnor, PA
Michael Falkner, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Robert Himmelreich, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Richard Holmer, Director, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Terry Livingston, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Neil Peterson, State Soil Specialist, USDA-NRCS, Boise, ID
Sharon Plagery, 1999 Archaeological Field School, Idaho State University, Pocatello, ID
Jeff Ross, Archaeologist, USDI-BLM, Twin Falls, ID
Al Spencer, Archaeologist, USDA-NRCS, Portland, OR

Activities:
All field activities were completed on 19 to 22 July 1999. On July 19, 1999, the thickness of aeolian deposits within a partially filled lava tube was assessed using both ground-penetrating radar (GPR) and electromagnetic induction (EMI). The lava tube was located in southern Lincoln County. An impromptu training session on the use of geophysical techniques for archaeological investigations was presented at this site to the Idaho State University Archaeological Field School. On July 20, EMI and GPR were used to assess the presence of unmarked gravesites located in and around the Upper Clover Creek Cemetery near Bliss, Idaho. On July 21, EMI was used to locate and map cultural features at the Pilgrim Station Historic Site. On July 22, EMI surveys were conducted on land newly acquired by the BLM at the Three Island Crossing near Glenns Ferry, Idaho.

Equipment:
The radar unit used in this study was the Subsurface Interface Radar (SIR) System-2, manufactured by Geophysical Survey Systems, Inc.[1] 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. Morey (1974), Doolittle (1987), and Daniels and others (1988) have discussed the use and operation of GPR. Antennas used were the models 5106 (200 mHz) and 5103 (400 mHz).

[1] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

The electromagnetic induction meter used in this study was the EM38 manufactured by Geonics Limited.[1] This meter is portable and requires only one person to operate. Geonics Limited (1998) has described principles of operation. No ground contact is required with this meter. This meter provides limited vertical resolution and depth information. Lateral resolution is approximately equal to the intercoil spacing.

A GEM300 multifrequency sensor, developed by Geophysical Survey systems, Inc.,[2] was also used in this study. The GEM300 sensor is a newly developed EMI sensor. The sensor weighs about 14 lbs. This sensor is configured to simultaneously measure up to 16 frequencies between 330 and 20,000 Hz with a fixed coil separation (1.3 m). Won and others (1996) have described the use and operation of this sensor.

The position of most survey grid corners was obtained with Rockwell Precision Lightweight GPS Receivers (PLGR).[2] The receiver was operated in the continuous and the mixed satellite modes. The Universal Transverse Mercator (UTM) coordinate system was used. Horizontal datum was the North American 1927. Horizontal units were expressed in meters.

To help summarize the results of this study, the SURFER for Windows program, developed by Golden Software, Inc.,[2] was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search. In each of the enclosed plots, shading and filled contour lines have been used. These options were selected to help emphasize spatial patterns. Other than showing trends and patterns in values of apparent conductivity (i.e., zones of higher or lower electrical conductivity), no significance should be attached to the shades themselves.

Conclusions:

1. Interpretations contained in this report are considered preliminary estimates of site conditions. These interpretations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

2. This study enabled participants to evaluate the suitability of data obtained with the GEM300 sensor. This sensor is easier to operate and provides more data in a short period of time than the EM38 meter. In addition, the use of this sensor in the continuous mode reduces the need for closely spaced grid lines. As a consequence, grids are easier and quicker to setup, and field time is reduced.

3. This study provided an opportunity for Tom Burnham and me to improve survey techniques for archaeological investigations. With the GEM300, survey designs were modified resulting in less time needed to setup grids. In addition, it was found that after completing an EMI survey and developing two-dimensional plots, the site should be returned to. During the return visit, the locations of detected point anomalies can be confirmed and interpretations can be improved through the process of visual correlation.

4. In general, ground-penetrating radar provided ambiguous results. Though resolution is less than with GPR, EMI can provide quick and comprehensive information on archaeological sites. Electromagnetic induction is the preferred *tool-of choice* for reconnaissance archaeological surveys on the Snake River Plain.

5. Qualitative information on the thickness of aeolian deposits within lava tubes can be derived from spatial patterns of apparent conductivity. Areas with deeper depths to basalt and thicker deposits of aeolian materials have higher conductivity than those areas with shallower depths to basalt and thinner deposits of aeolian materials. With some ground-truth auger measurements, EMI data can become more quantitative.

6. The eastern survey area at the Upper Clover Creek Cemetery contains several conspicuous anomalies. The identity of these anomalies should be verified to assure that no gravesites are located outside of the cemetery.

7. A large number of buried point reflectors were identified at the Pilgrim Station Historic Site. The alignment of several anomalies suggests the possible presence of former structures or buried cultural features that may be related to the station. Several anomalies were visually correlated with surface features.

8. The areas surveyed at Three Island Crossing have been under cultivation. Comparatively few anomalies were detected within either grid site. Grid B contained the greatest number of point anomalies.

---

[2] Trade names have been used in this report to provide specific information. Their use does not constitute endorsement.

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

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:
T. Burnham, District Conservationist, USDA-NRCS, 111 East Avenue F, Jerome, ID 83338-3132
L. Cresswell, Archaeologist, USDI-BLM, Shoshone Field Office, P.O. Box 2B, Shoshone, ID 83352
J. Culver, Acting Director, USDA-NRCS, National Soil Survey Center, Federal Building, Room 152,100 Centennial Mall North, Lincoln, NE 68508-3866
N. Peterson, State Soil Specialist, USDA-NRCS, 9173 West Barnes Drive, Suite C, Boise, Idaho 83709
J. Ross, Archaeologist, USDI-BLM, Boise District, Jarbidge Resource Area, 2620 Kimberly Road, Twin Falls, Idaho 83301
H. Smith, Director of Soils Survey Division, USDA-NRCS, Room 4250 South Building, 14th & Independence Ave. SW, Washington, DC 20250

EMI:

Background:

Electromagnetic induction is a noninvasive geophysical tool that can be used for detailed site investigations. Advantages of EMI are its portability, speed of operation, flexible observation depths, and moderate resolution of subsurface features. Results from an EMI survey are interpretable in the field. This geophysical method can, in a relatively short time, provide 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 exploratory test pits.

Electromagnetic induction measures vertical and lateral variations in magnetic and/or electrical fields associated with induced subsurface currents. Data is expressed as in-phase, quadrature phase, or apparent conductivity. The in-phase and quadrature phase responses represent the ratio of the secondary magnetic field at receiver coil to the primary magnetic field at receiver coil. 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. The magnitude of the in-phase signal is proportional to the cube of a buried metallic object's surface area and is inversely proportional to its depth raised to the sixth power (Greenhouse et al., 1998). 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 the 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). With the EM38 meter, in-phase data are expressed in parts per thousand (ppt).

Traditionally, EMI data are expressed as apparent conductivity. The EM38 meter and the GEM300 sensor automatically convert quadrature phase data into apparent conductivity data. Values of apparent conductivity are expressed in milliSiemens per meter (mS/m). Apparent conductivity is a weighted, average measurement for a column of earthen materials to a specific observation depth (Greenhouse and Slaine, 1983). Variations in apparent conductivity are caused by changes in the electrical conductivity of earthen materials. The electrical conductivity of soils is influenced by the volumetric water content, type and concentration of ions in solution, temperature and phase of the soil water, and amount and type of clays in the soil matrix (McNeill, 1980). The apparent conductivity of soils increases with increases in soluble salts, water, and clay contents (Kachanoski et al., 1988; Rhoades et al., 1976).

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

Depth of Observation:

The electrical conductivity of soils and earthen materials plays a critical role in the depth of observation that can be obtained with EMI (Greenhouse et al., 1998). The skin depth represents the maximum depth of observation for an EMI meter or sensor operating at a specific frequency and sounding a medium of known conductivity. Observation depth or skin depth is inversely proportional to frequency (Won et al., 1996). Low frequency signals have longer periods of oscillation and loose energy less rapidly than high frequency signals. As a consequence, low frequency signals travel farther through conductive mediums than high frequency signals. Greater penetration can be achieved by decreasing the frequency. At a given frequency, the depth of observation is greater in soils having low conductivity than in soils having high conductivity. However, because of other factors, such as the geometry of the meter or sensor, the depth of observation may be less than the skin depth (Greenhouse et al., 1998).

With meters developed by Geonics Limited, the depth of observation is considered to be "geometry" limited (intercoil spacing) rather than skin depth limited (McNeill, 1980). The EM38 meter operates at a frequency of 14,800 Hz. It has theoretical observation depths of about 0.75 and 1.5 meters in the horizontal and vertical dipole orientations, respectively (Geonics Limited, 1998).

With the GEM300 sensor, the depth of observation is considered "skin depth" limited rather than "geometry' limited (Won, 1980 and 1983, Won et al., 1996). The theoretical observation depth of the GEM300 is dependent upon the bulk conductivity of the profiled earthen material(s) and the operating frequency of the sensor. Mutifrequency sounding with the GEM300 allows multiple depths to be profiled with one pass of the meter.

A nomogram was developed (Won, 1980) to approximate the skin depth for a given frequency and soil conductivity. Unfortunately, independent researchers have not extensively tested this nomogram. In addition, it is believed that the nomogram is off by about one order of magnitude (Dan Delea, Geophysical Survey Systems, Inc., personal communication). 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 the northern grid site near the Clover Creek Cemetery, with the GEM300 sensor, apparent conductivity averaged 77.0, 73.0, and 71.6 mS/m at frequencies of 9,810, 12210, and 14970 Hz, respectively. Using equation [1], the estimated skin depths are about 0.58 m at 9,810 Hz, 0.53 m at 12,210 Hz, and 0.48 m at 14,790 Hz. At the eastern grid site near the Clover Creek Cemetery, apparent conductivity averaged 129.0, 126.8, and 124.8 mS/m at frequencies of 9,810, 12210, and 14970 Hz, respectively. Using equation [1], the estimated skin depths are about 0.44 m at 9,810 Hz, 0.40 m at 12,210 Hz, and 0.36 m at 14,790 Hz.

At the Pilgrim Stage Station Historic Site in Elmore County, apparent conductivity averaged 14.1, 14.8, 14.7, and 17.3 mS/m at frequencies of 9,810, 12,870, 14,790, and 18,270 Hz, respectively. The estimated skin depths are about 1.34 m at 9,810 Hz, 1.14 m at 12,870 Hz, 1.06 m at 14,790 Hz, and 0.89 m at 18,270 Hz.

At the Three Island Crossing Site in Elmore County, for grid A, apparent conductivity averaged 44.5, 40.7, 39.1, and 37.4 mS/m at frequencies of 9,810, 12,870, 14,790, and 18,270 Hz, respectively. The estimated skin depths are about 0.76 m at 9,810 Hz, 0.69 m at 12,870 Hz, 0.66 m at 14,790 Hz, and 0.60 m at 18,270 Hz. For grid B at the Three Island Crossing Site, apparent conductivity averaged 25.8, 26.3, 27.0, and 28.9mS/m at frequencies of 9,810, 12,870, 14,790, and 18,270 Hz, respectively. The estimated skin depths are about 0.99 m at 9,810 Hz, 0.86 m at 12,870 Hz, 0.79 m at 14,790 Hz, and 0.69 m at 18,270 Hz. As these skin depths could not be verified, they represent merely estimates.

GPR:

Background:

Ground-penetrating radar is an impulse radar system designed for relatively shallow investigations. Pulses of electromagnetic energy are radiate into the ground from a transmitting antenna. Whenever a pulse contacts an interface separating layers of different dielectric properties, a portion of the energy is reflected back to the receiving antenna. By moving an antenna along the soil surface, GPR can provide a continuous profile of the subsurface.

Compared with other geophysical techniques, GPR provides the highest resolution of subsurface features. However, ground-penetrating radar does not work well in all soil environments. Soils having a high electrical conductivity rapidly dissipate the radar's energy, restrict observation depths, and create low signal to noise ratios that impair image quality and interpretability. In highly conductive soils, the use of GPR is inappropriate. Use of GPR has been most successful in areas of sandy or coarse loamy soils. Generally, observation depths range from 16 to 100 ft in sandy soils, 3 to 16 ft in loamy soils, and less than 2 ft in clayey soils.

Calibration Trials:

Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., soil horizon, stratigraphic layer) and back. To convert the two-way travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector (interface) must be known. The relationships among depth (d), two-way, pulse travel time (t), and propagation velocity (v) are described in the following equation (Morey, 1974):

$$d = vt/2 \qquad [2]$$

The velocity of propagation is principally affected by the amount and physical state (temperature dependent) of water in the profiled material(s).

The two-way travel time to a reflector can be measured on radar profiles. To convert the two-way travel time to depth, the propagation velocity of radar energy through the material must be known. The most accurate and direct method to calculate propagation velocity is to measure the depth to a physical interface (soil horizon) or target (buried metallic reflector) that appears on a radar profile. In this process the depth to a known and recognizable feature is measured and compared with the two-way travel time to this reflector on radar profiles.

Calibration trials were conducted near the entrance to the lava tube. Radar traverses were conducted with the 200 and 400 mHz antennas across a metallic reflector that was buried at a depth of about 50-cm. Based on the round-trip travel time to this reflector, the propagation velocity through the upper part of the very dry aeolian deposits was estimated to be 0.1537 m/ns with the 200 mHz antenna. This propagation velocity was used to depth scale the radar profiles and estimate the depth to a prominent subsurface interface.

Results:

Lava Tube – Lincoln County

Investigators are interested in knowing the thickness of aeolian deposits within a lava tube. The comparatively short (about 60-ft) lava tube is opened at each end. This tunnel was surveyed with both GPR and EMI. In addition, the area immediately to the east of the lava tunnel was also surveyed with the EM38 meter.

GPR:

Ground-penetrating radar provided ambiguous results. Traverses were conducted along the centerline of the lava tube with both the 200 and 400 mHz antenna. The 200 mHz antenna provided the best balance of resolution and profiling depth. Maximum depth of penetration was about 1.9 m. Radar profiles were generally of poor interpretative quality and contained high levels of background noise. They lacked high amplitude, continuous subsurface reflectors that could be unambiguously interpreted as the buried bedrock surface. Several point reflectors, assumed to be large rock fragments, were identified on the radar profile. A weak, discontinuous subsurface interface was identified and traced laterally across the radar profile. Though highly interpretative and not confirmed by ground-truth observations, the predicted depths to this weakly expressed interface are presented in Table 1. Observation points were measured in feet from the western entrance to the lava tube. In Table 1, all depths are expressed in meters.

Table 1
Predicted Depths to Subsurface Interface Observed on Radar Profiles from Lava Tube

Distance (ft)	Depth (m)
0	1.12
5	1.25
10	1.35
15	0.74
20	1.00
25	1.35
30	1.64
35	1.72
40	1.32
45	1.44
50	1.40
55	1.50
60	1.42
65	1.35

EMI:

The Lava Tube Site was located near power transmission lines. Electromagnetic fields that surround these lines appeared to interfere with EMI measurements and were a source of measurement error (rapid oscillations in the meter's readings). In addition, the EM38 meter was exceedingly difficult to null. The basalt contains ferrous minerals.

Because of these minerals, magnetic susceptibility, which can usually be ignored in EMI surveys, was believed to be present. Magnetic susceptibility affected measurements and can be an additional source of measurement error.

It was assumed that variations in the thickness of the aeolian deposits or depth to basalt could be inferred from values of apparent conductivity. The aeolian deposits have higher clay and soluble salt contents than the basalt and are therefore more conductive. Observation points with higher apparent conductivity values were assumed to have greater thickness of aeolian deposits and greater depths to basalt than those observation points with lower apparent conductivity values.

Figure 1 shows the spatial distribution of apparent conductivity within the lava tube (left plot) and the area east of the lava tube entrance (right plot). Measurements were obtained with the EM38 meter placed on the ground surface in the vertical dipole orientation. The theoretical observation depth of this meter in this orientation is about 1.5 m. In Figure 1, because of large differences in the range of apparent conductivity within and to the east of the lava tube, two separate scales have been used to show spatial patterns. Within the lava tube, values of apparent conductivity averaged 2.1 mS/m and ranged from 0.2 to 4.9 mS/m. One-half the observations had values of apparent conductivity between 1.4 and 4.9 mS/m. To the east of the lava tube entrance, values of apparent conductivity averaged 14.1 mS/m and ranged from –1.1 to 49.5 mS/m. One-half the observations had values of apparent conductivity between 4.2 and 15.0 mS/m.

A metal marker, buried near the east entrance to the lava tube, has been identified (see left plot). This artifact produced an anomalous value in the two-dimensional plot. In the absence of *ground-truth* data, depths to basalt could not be predicted. However, spatial patterns appearing in these plots suggested the locations of areas with greater or lesser depths to basalt. A conspicuous and highly anomalous area of high apparent conductivity is evident in the right-hand plot. This area is suspected to have greater clay and/or soluble salt contents and significantly deeper depths to basalt. It may represent a cavity, formed from the collapse of a lava tube, which has been filled with finer-textured materials. This feature should be more thoroughly examined.

Upper Clover Creek Cemetery – Gooding County

The Upper Clover Creek Cemetery (667450 N and 4765950 E) is located north of the town of Bliss, Idaho. The cemetery is on an east-facing slope of a small butte that overlooks Clover Creek. Historic accounts specify that the Upper Clover Creek Cemetery contains at least 28 graves. The earliest grave dates to about 1852 with most interments dating from about 1880 to 1940. In 1938, the Civilian Conservation Corps replaced many of the original markers with small cement markers. The Bureau of Land Management presently manages the land. In 1995, unknown to BLM, a resident was buried in the cemetery. This burial has prompted the BLM to consider releasing the land.

The actual number and locations of graves within the Upper Clover Creek Cemetery are uncertain. Local residences have questioned the number of burials at this site. Some markers may have been placed over unoccupied sites. It is also uncertain whether the boundary fence encloses all gravesites. This survey is an extension of an earlier survey conducted in September 1998.

Field Procedures:

Two survey grids were laid out in areas to the north and east of the cemetery. The approximate locations of the grid corners are shown in Table 2.

Table 2

Grid	Waypoint	Easting	Northing
Eastern Grid	WP001	667467	4765949
	WP002	667482	4765952
	WP003	667483	4765921
	WP004	667471	4765921
Northern Grid	WP005	667441	4766023
	WP006	667443	4766012
	WP007	667460	4766012
	WP008	667459	4766022

The dimensions of northern grid were 45 by 60 ft. The grid interval was about 5 ft. Survey flags were inserted in the ground at each grid intersection and served as observation point. This procedure produced 130 observation points.

Pulling the 200 mHz antenna along each of the 13 north-south trending grid lines completed a radar survey.

An EMI survey of the northern grid was completed with the GEM300 sensor. The sensor was held at hip height, in the vertical dipole orientation, and in the continuous mode (measurement each ½ second). Walking at a uniform pace between similarly numbered flags on the eastern- and western-most, north-south lines completed the EMI survey. This procedure produced a total of 359 observation points. In-phase, quadrature phase, and conductivity measurements were obtained at each observation point at frequencies of 9,810, 12,210, and 14,970 Hz.

A grid was hastily setup on the eastern side of the cemetery. The dimensions of eastern grid were 50 by 95 feet. Two parallel, 95-ft lines were laid out at a distance of 50 ft from each other. Along each of these lines, survey flags were inserted in the ground at an interval of 5 ft. No radar survey was conducted within the eastern grid site. Walking at a uniform pace with the GEM300 sensor between similarly numbered survey flags on each line completed the EMI survey. The GEM300 sensor was operated in the vertical dipole orientation and the continuous mode (measurement each ½ second). This procedure produced a total of 778 observation points. In-phase, quadrature phase, and conductivity measurements were obtained at each observation point at frequencies of 9,810, 12,210, and 14,970 Hz.

A third grid was laid out in the northern portion of the cemetery. However, the GEM300 sensor acted erratically in the hot (93° F) afternoon temperatures and the results of this survey were discarded.

Results:

GPR:

Radar profiles, though depth restricted, were of fair interpretative quality. In the survey of the northern grid, no conspicuous area of disturbance or grave shafts were evident on the radar profiles. Nine point anomalies were detected with GPR. The locations of these anomalies are plotted in Figure 2. These anomalies are believed to represent buried rock fragments and roots. However, some may represent buried cultural features. None of the detected anomalies are believed to represent burials. Because of poor results and interpretative ambiguity, further use of GPR was discontinued.

EMI:

Apparent conductivity data collected with the GEM300 sensor is shown in figures 2 and 3. The frequency at which data were collected is shown above each plot. The depth of observation is assumed to increase slightly as the frequency decreases.

The northern grid is shown in Figure 2. Spatial patterns are similar in each plot and for each frequency. Because of the comparatively high electrical conductivity of the soils, the maximum depth of observation was restricted (estimated range of 0.48 to 0.58 m) and similar for each frequency. In Figure 2, values of apparent conductivity increase along the southern boundary (right-hand portion of each plot) of the survey area. This increase in apparent conductivity is attributed to interference from the cemetery's barbed-wire fence. The other spatial patterns evident in these plots represent gradational changes in soil type and properties.

No significant buried cultural features were detected with the northern grid with either GPR or EMI.

The eastern grid is shown in Figure 3. Four conspicuous point anomalies were detected with EMI. These anomalies are evident in the northeast portion of the survey area. The anomalies have been labeled (A, B, C, and D). Each anomaly has high negative values suggesting buried metallic objects. The largest anomaly, B, is evident on all three plots. Anomaly A is imperceptible at a frequency of 14,790 Hz (the shallow sensing, about 0.36 m), but is conspicuous at the deeper-sensing frequencies of 12,210 and 9,810 Hz. Anomaly C is apparent at frequencies of 9,810 and 12,210 Hz. Anomaly D is only apparent at a frequency of 9,810 Hz (the deepest sensing, about 0.44 m). The features that have produced these four conspicuous anomalies should be identified.

In Figure 3, each plot contains other, less conspicuous point anomalies. Compared with the area surveyed on the north side of the cemetery, the area surveyed on the east side of the cemetery contains a greater concentration of buried "cultural anomalies."

Pilgrim Stage Station Historic Site – Elmore County

The Pilgrim Stage Station Historic Site is located along Pilgrim Gulch in southeastern Elmore County. The Station was located on a terrace in an area of Buko fine sandy loam, 4 to 12 percent slopes (Noe, 1991). Buko soil is a member of the coarse-loamy over sandy or sandy-skeletal, mixed, mesic Durixerollic Camborthids family.

The station was established in the mid-1860's and served as a stopover on the Oregon Trail and later a stage stop on the Kelton Road. Historic accounts specify that highwaymen robbed the Station in 1879. In 1883, the completion of railroad lines altered the mode of shipping freight through the region and eliminated the need for the station. Today, little vestiges of the former station remain. An EMI survey of the area was conducted in an attempt to assess the number and locations of station buildings.

Field Procedures:
A 300 by 150-ft grid was established across the site. The approximate locations of the grid corners are listed in Table 3. The grid consisted of four parallel, 300-ft lines. These lines were spaced 50 ft apart. Along each of these lines, survey flags were inserted in the ground at intervals of 5 ft. An EMI survey was completed with the GEM300 sensor. The sensor was held at hip height, in the vertical dipole orientation, and operated in the continuous mode (measurement each ½ second). Walking at a uniform pace between similarly numbered flags on the four parallel lines completed the EMI survey. This procedure produced a total of 5037 observations. In-phase, quadrature phase, and apparent conductivity measurements were obtained at each observation point at frequencies of 9,810, 12,870, 14970, and 18,270 Hz.

Table 3

Pilgrim Station Historic Site
GPS Coordinates of Grid Corners

Easting	Northing
652749	4748767
652719	4748855
652678	4748838
652708	4748752

Results:
In-phase and apparent conductivity data collected with the GEM300 sensor are shown in figures 4 to 7. Each figure contains image maps of both the in-phase (upper plot) and apparent conductivity (lower plot) data collected at a specified frequency. These image maps use different colors to represent either in-phase or conductivity data. Colors are associated with percentage values (in relation to the minimum and maximum in-phase or conductivity value).

Conspicuous point anomalies are apparent in each plot. The alignment of several anomalies suggests the possible locations of former structures or buried cultural features that may be related to the station. Many of these anomalies are located on the terrace or along the slope break that separates the upland and terrace soils. In Figure 6, rectangles have been used to show associated point anomalies that appear to suggest the locations of former structures. Several anomalies were visually correlated with surface features. The magnitude of the in-phase response is lowest in areas with exposed bedrock and soils that were relatively shallow over basalt (lower right hand corner). The magnitude of the apparent conductivity response was highest on upland soils that were relatively deep over bedrock.

A benchmark was installed at the site. From this reference, the angles and distances to fourteen detected subsurface anomalies were recorded. These anomalies have been identified and labeled in Figure 6. This data can be used to locate some of the features detected with EMI for identification.

Three Island Crossing – Elmore County

The BLM has recently acquired land near the Three Island Crossing on the Snake River. This was a principal crossing of the Snake River on the Emigrant Trail. Emigrants could either choose to ford the Snake River at Three Island Crossing or continue to Boise along a longer route located on the drier south side of the river. In 1869, George Glenn constructed a ferry upriver at Two Island Crossing. By 1871, the ferry was serving both Kelton freight and emigrant traffic.

Three Island Crossing is located on the south side of the Snake River immediately downstream from Glenns Ferry, Idaho. The site is located in an area of Buko fine sandy loam, 1 to 4 percent slopes (Noe, 1991). Buko soil is a member of the coarse-loamy over sandy or sandy-skeletal, mixed, mesic Durixerollic Camborthids family.

Field Procedures:
Two, 100 by 100-ft grids were established across portions of the site. The approximate locations of the grid corners are listed in Table 4. Grid A was located east an upstream of grid B. Each grid consisted of three parallel, 100-ft lines. These lines were spaced 50 ft apart. Along each of these lines survey flags were inserted in the ground at intervals of 5 ft.

Table 4

Glenn Ferry Historic Site
GPS Coordinates of Grid Corners

Grid	Easting	Northing
A	636842	4754686
A	636872	4754687
A	636871	4754717
A	636839	4754716
B	636554	4754581
B	636584	4754582
B	636582	4754613
B	636549	4754611

Two EMI surveys were completed at Three Island Crossing with the GEM300 sensor. The sensor was held at hip height, in the vertical dipole orientation, and operated in the continuous mode (measurement each ½ second). Walking at a uniform pace between similarly numbered flags on the four parallel lines completed the EMI survey. This procedure provided 1070 and 1150 observations for grid A and grid B, respectively. In-phase, quadrature phase, and conductivity measurements were obtained at each observation point at frequencies of 9,810, 12,870, 14970, and 18,270 Hz.

In-phase and apparent conductivity data collected with the GEM300 sensor at grid A are shown in figures 8 to 11. Each figure contains image maps of both the in-phase (left-hand plot) and apparent conductivity (right-hand plot) data collected at a specified frequency. These image maps use different colors to represent either in-phase or conductivity data. Colors are associated with percentage values (in relation to the minimum and maximum in-phase or conductivity value).

In each plot of the in phase response obtained at frequencies of 12,870, 14,790, and 18,270 Hz, two conspicuous point anomalies are apparent in the eastern portion of the survey area. These features are buried at shallow depths and probably represent metallic objects. In addition, several very weakly expressed anomalies are also present in the plots of the in phase data. Few point anomalies are detectable in the plots of apparent conductivity. Compared with the plots from the Pilgrim Station, this grid contains very few point anomalies.

Linear streaks or features are evident in the in-phase and apparent conductivity data from grid A. These streaks are orientated in an east-west direction. Traverses were conducted with the GEM300 sensor orthogonal to these spatial patterns. It was tentatively assumed that these spatial patterns represent the effects of cultivation. Deep plowing may have been needed to rip up a weakly cemented pan. Jeff Ross has agreed to contact the landowner to verify this interpretation.

In-phase and apparent conductivity data collected with the GEM300 sensor at grid B are shown in figures 12 to 15. Each figure contains image maps of both the in-phase (left-hand plot) and apparent conductivity (right-hand plot) data collected at a specified frequency. These image maps use different colors to represent either in-phase or conductivity data. Colors are associated with percentage values (in relation to the minimum and maximum in-phase or conductivity value).

Several conspicuous point anomalies are apparent in the data. The largest and most conspicuous anomaly is located near the northeast corner of the grid. This feature represents a modern irrigation pipe. Other point anomalies are dispersed across the survey area. Many of these anomalies are evident in both the in-phase and conductivity plots. As these anomalies are best expressed at higher frequencies, they are suspected to represent cultural features buried at shallow depths. All are suspected to represent buried cultural features. The linear patterns evident in grid A are not as well expressed in grid B. These patterns are only evident in the plots of the in phase data and in the eastern portion of the survey area. The linear streaks are orientated in a north – south orientation.

References

Daniels, D. J., D. J. Gunton, and H. F. Scott. 1988. Introduction to subsurface radar. IEE Proceedings 135F(4): 278-320.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. pp. 11-32. In: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20. 98 p.

Geonics Limited 1998. EM38 ground conductivity meter operating manual. Geonics Ltd., Mississauga, Ontario. 33 pp.

Greenhouse, J. P., and D. D. Slaine. 1983. The use of reconnaissance electromagnetic methods to map contaminant migration. Ground Water Monitoring Review 3(2): 47-59.

Greenhouse, J. P., D. D. Slaine, and P. Gudjurgis. 1998. Application of geophysics in environmental investigations. Matrix Multimedia, Canada. CD-ROM.

Kachanoski, R. G., E. G. Gregorich, and I. J. Van Wesenbeeck. 1988. Estimating spatial variations of soil water content using noncontacting electromagnetic inductive methods. Can. J. Soil Sci. 68:715-722.

McNeill, J. D. 1980. Electromagnetic terrain conductivity measurement at low induction numbers. Technical Note TN-6. Geonics Limited, Mississauga, Ontario. 15 p.

McNeill, J. D. 1996. Why doesn't Geonics Limited build a multifrequency EM31 or EM38 meter? Technical Note TN-30. Geonics Limited, Mississauga, Ontario. 5 p.

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. pp. 212-232. In: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.

Noe, H. R. 1991. Soil Survey of Elmore County Area, Idaho, Parts of Elmore, Owyhee, and Ada Counties. USDA-Soil Conservation Service. U. S. Government Printing Office. Washington, D. C. 500 pp.

Rhoades, J. D., P. A. Raats, and R. J. Prather. 1976. Effects of liquid-phase electrical conductivity, water content, and surface conductivity on bulk soil electrical conductivity. Soil Sci. Soc. Am. J. 40:651-655.

Won, I. J. 1980. A wideband electromagnetic exploration method - Some theoretical and experimental results. Geophysics 45:928-940

Won, I. J. 1983. A sweep-frequency electromagnetic exploration method. pp. 39-64. IN: A. A. Fitch (editor) Development of Geophysical Exploration Methods. Elsevier Applied Science Publishers, Ltd. London.

Won, I. J., Dean A. Keiswetter, George R. A. Fields, and Lynn C. Sutton. 1996. GEM-2: A new multifrequency electromagnetic sensor. Journal of Environmental & Engineering Geophysics 1:129-137.

EMI Survey of a Lava Tube
Lincoln County, Idaho
EM38 Meter Vertical Dipole Orientation

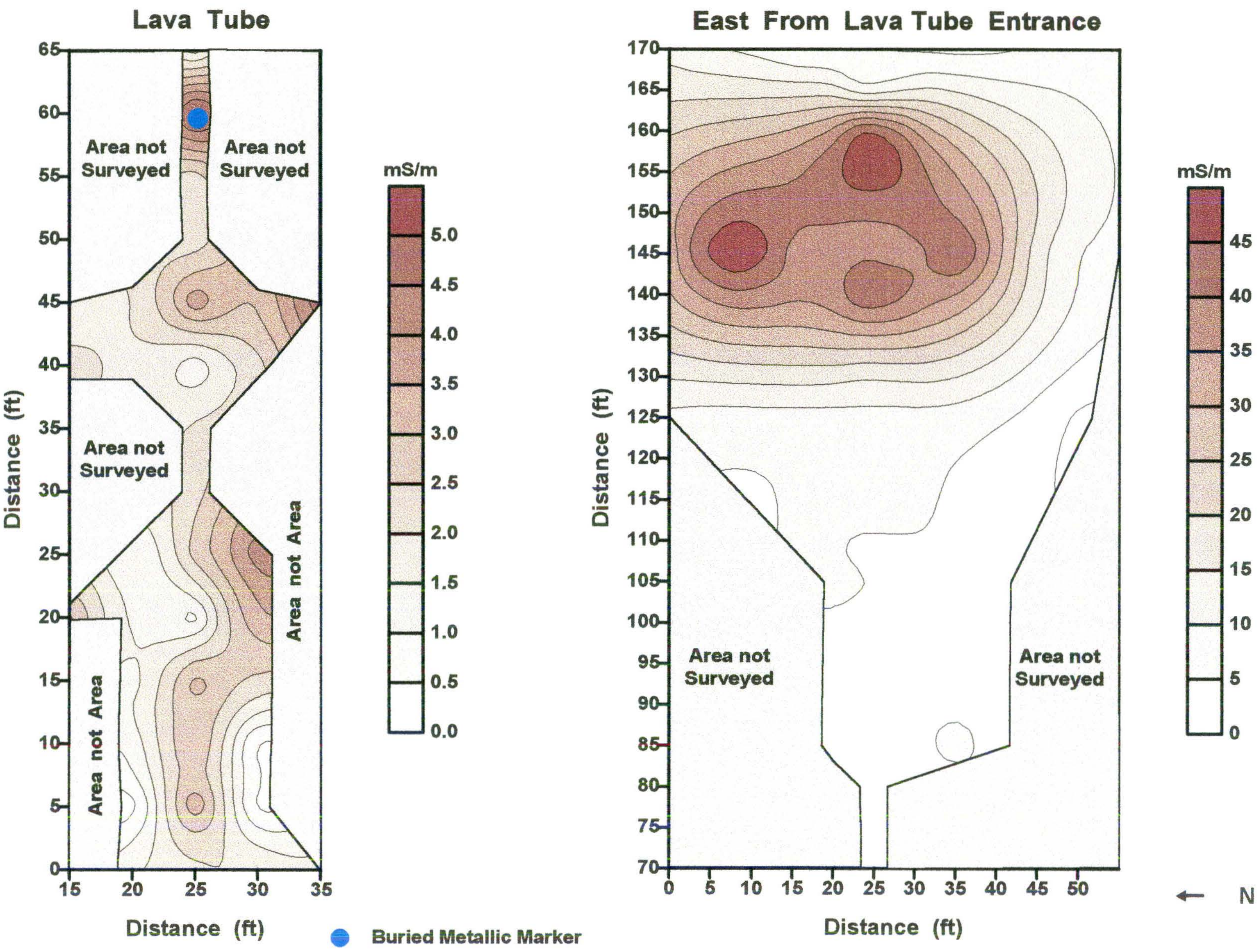


Figure 1

EMI Survey of Clover Creek Cemetery
North Side of Cemetery
Bliss, Idaho
GEM300 Sensor

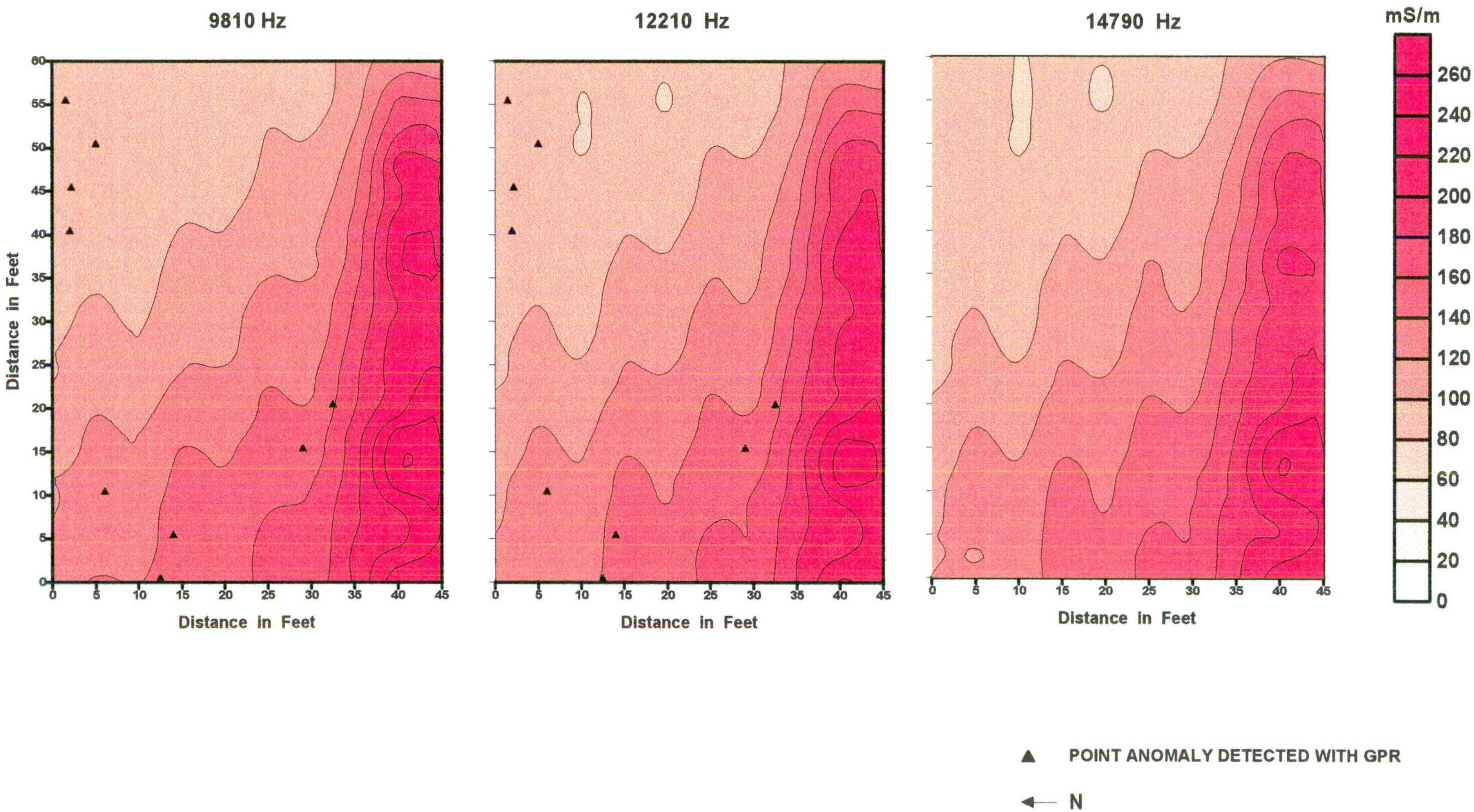


Figure 2

EMI Survey of Clover Creek Cemetery
East Side of Cemetery
Bliss, Idaho
GEM300 Sensor

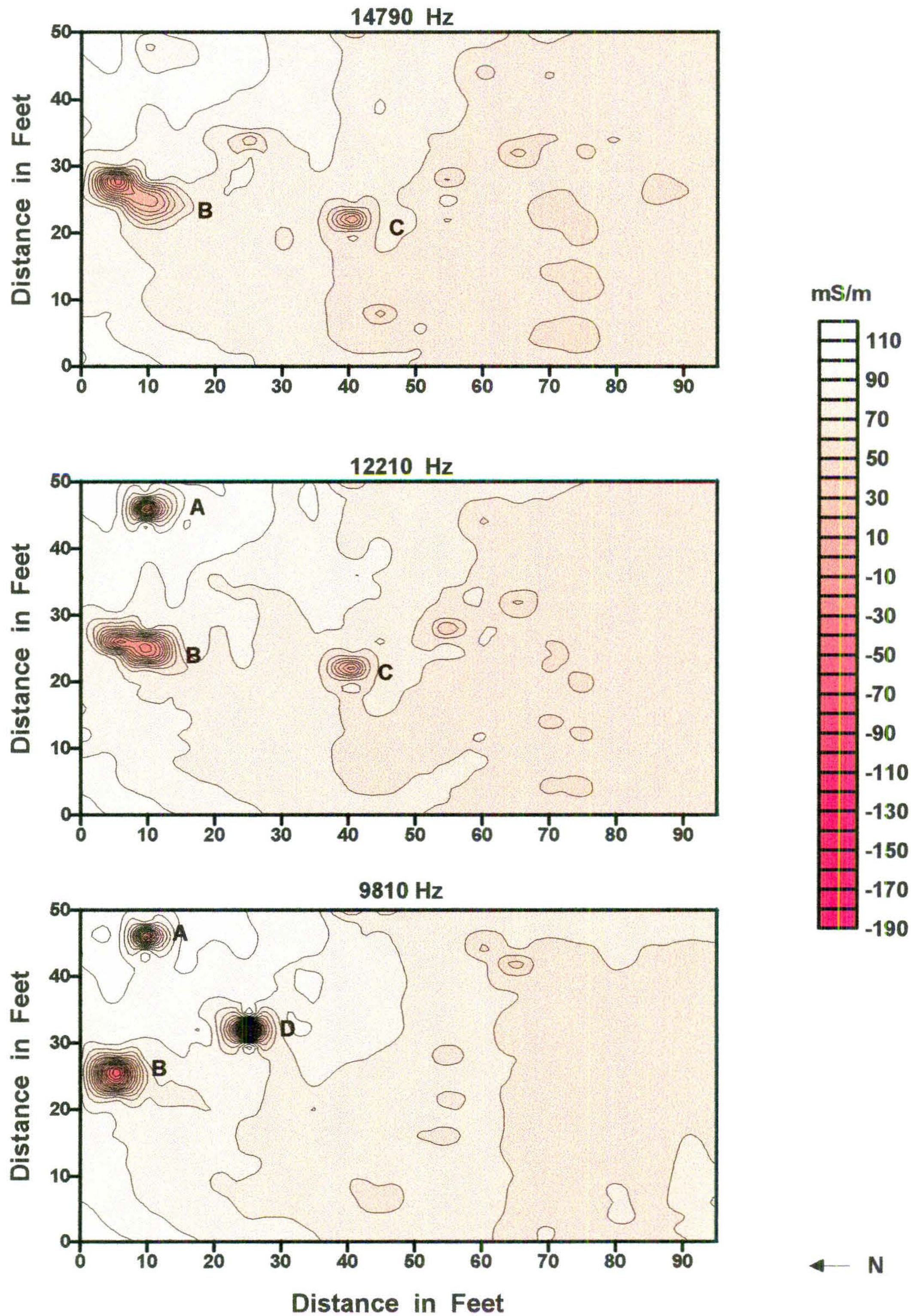


Figure 3

EMI Survey
Pilgrim Stage Station Historic Site
GEM300 Sensor
Vertical Dipole Orientation
9810 Hz

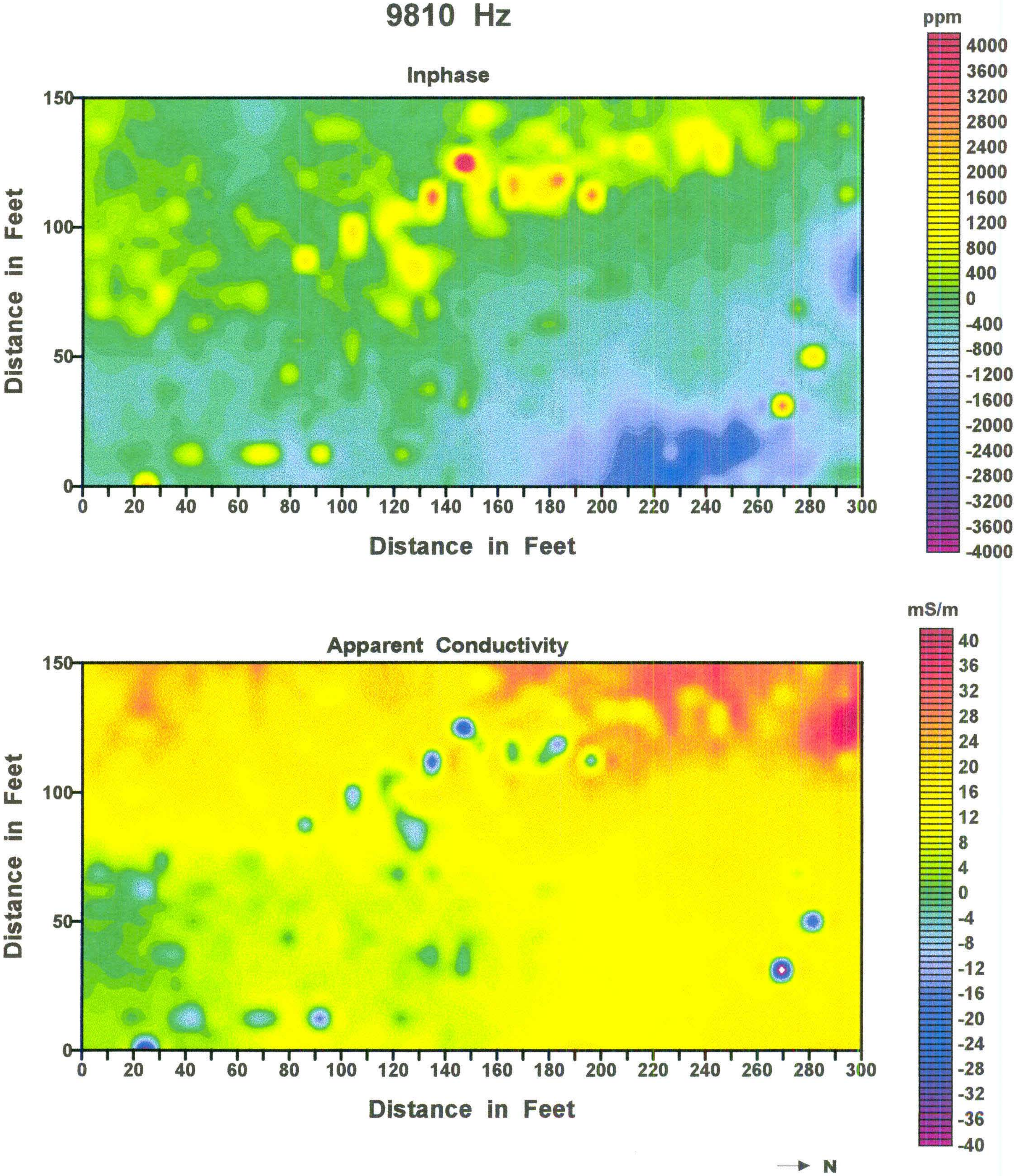


Figure 4

EMI Survey
Pilgrim Stage Station Historic Site
GEM300 Sensor
Vertical Dipole Orientation
12870 Hz

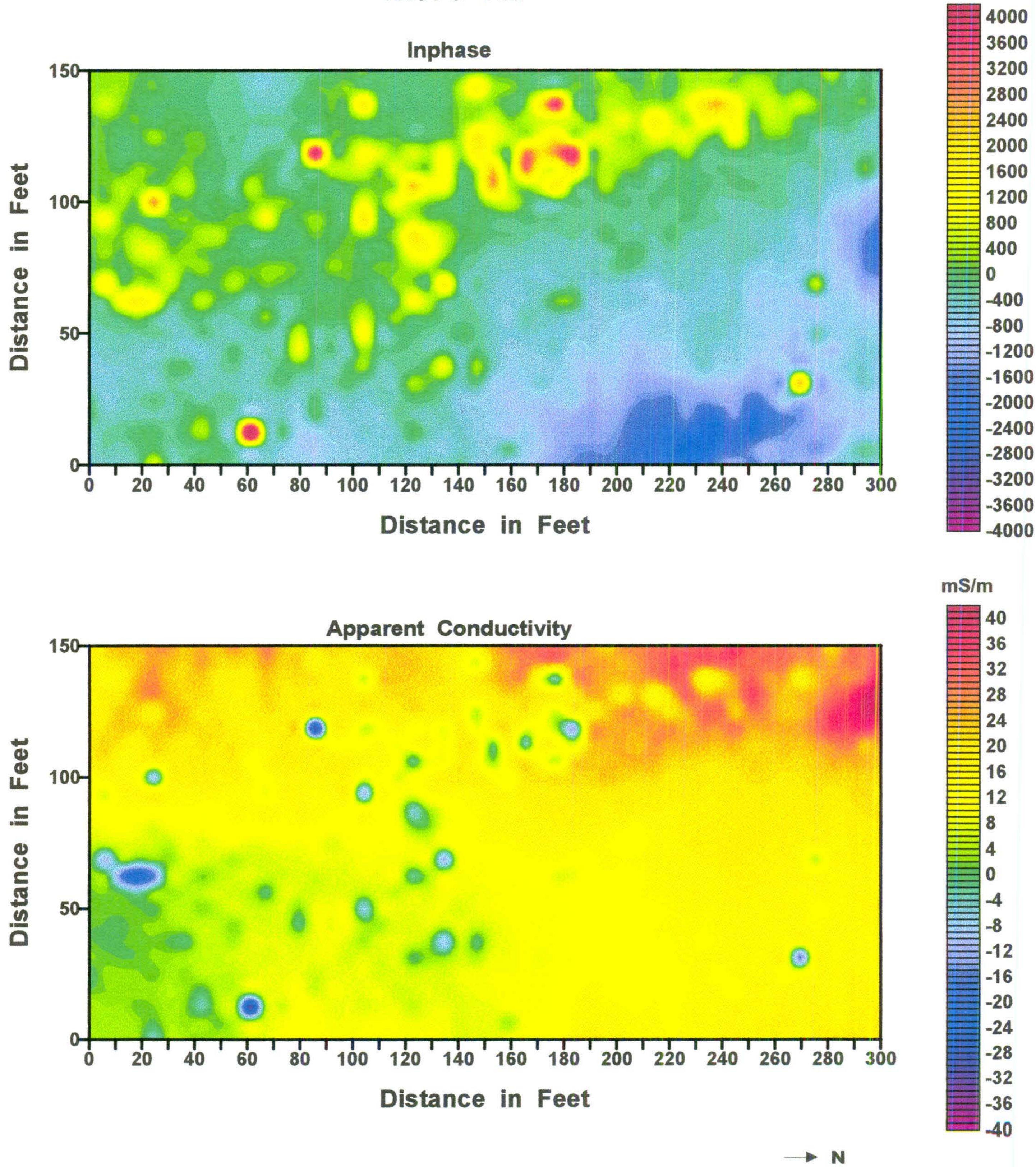


Figure 5

EMI Survey
Pilgrim Stage Station Historic Site
GEM300 Sensor
Vertical Dipole Orientation
14790 Hz

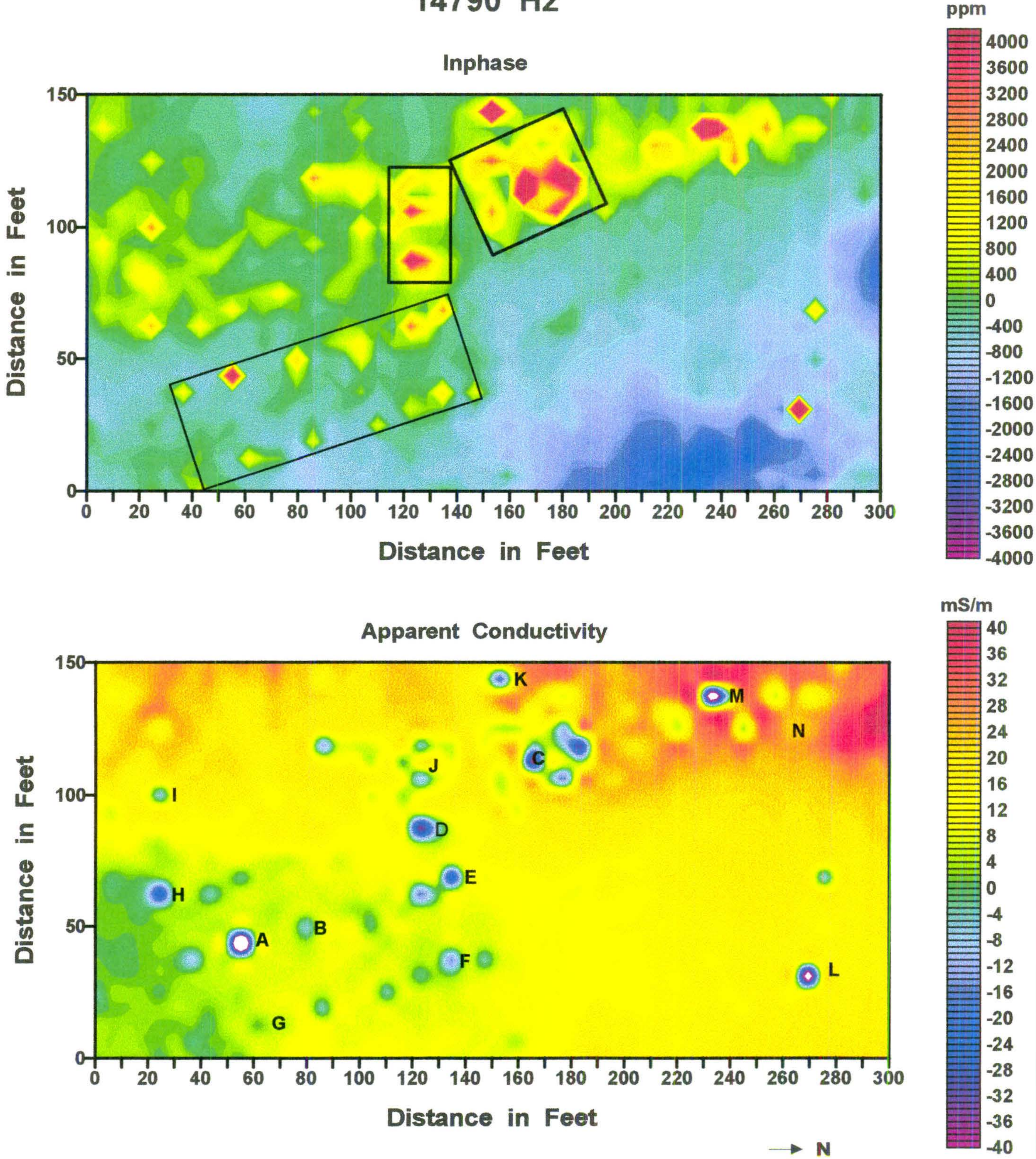


Figure 6

EMI Survey
Pilgrim Stage Station Historic Site
GEM300 Sensor
Vertical Dipole Orientation
18270 Hz

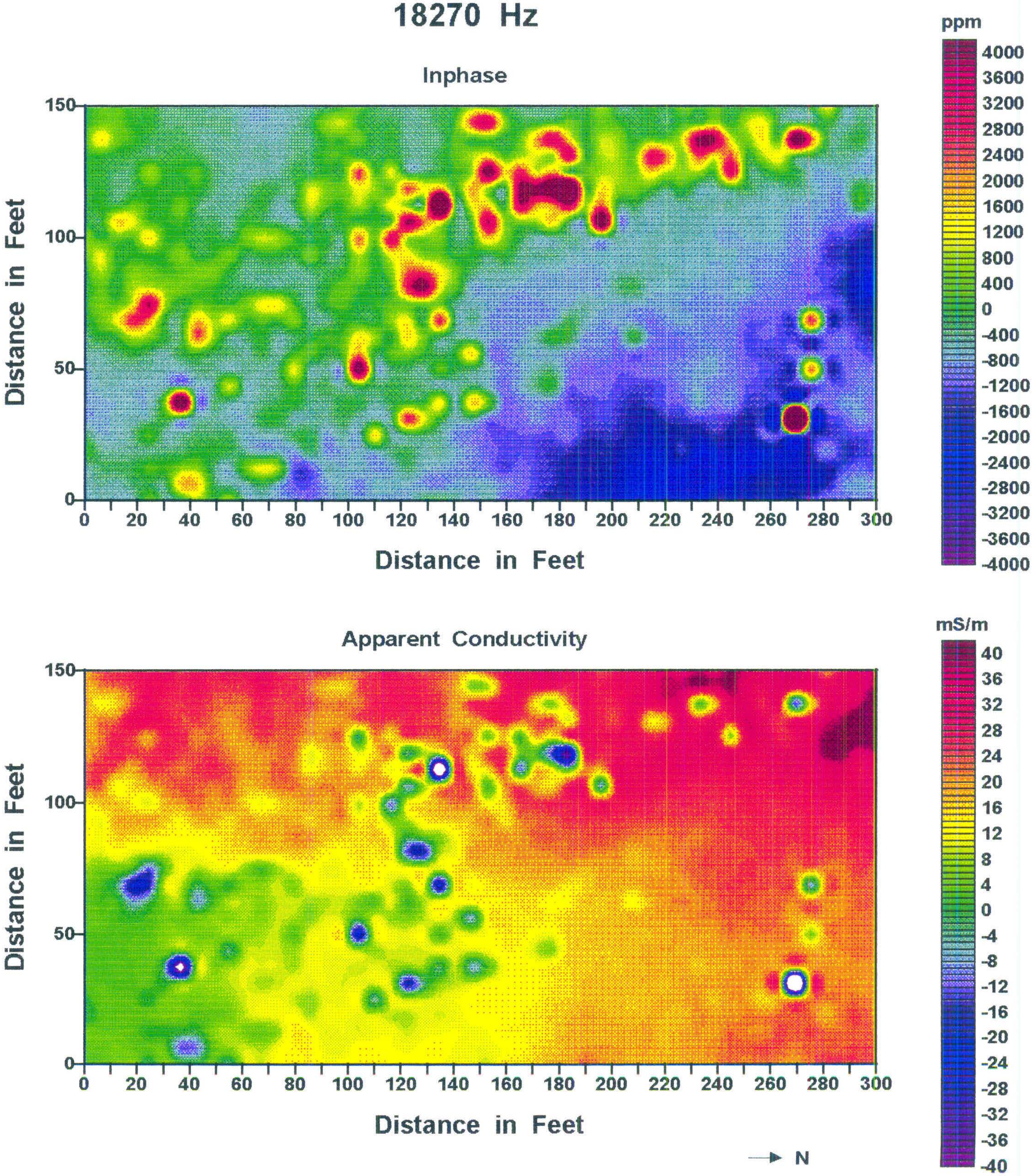


Figure 7

EMI Survey
Glenn's Ferry Historic Site
Grid A
GEM300 Sensor
Vertical Dipole Orientation
9810 Hz

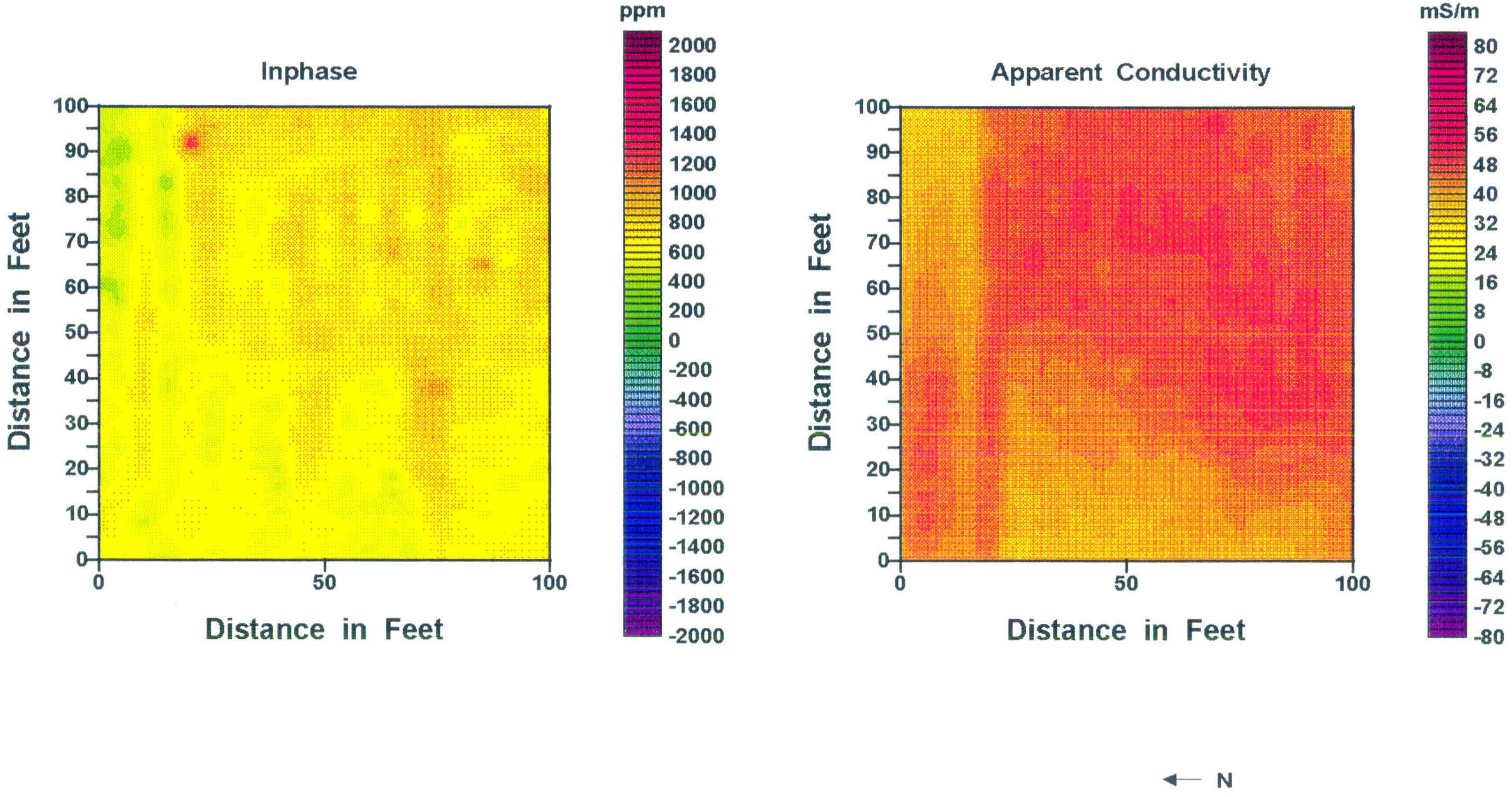
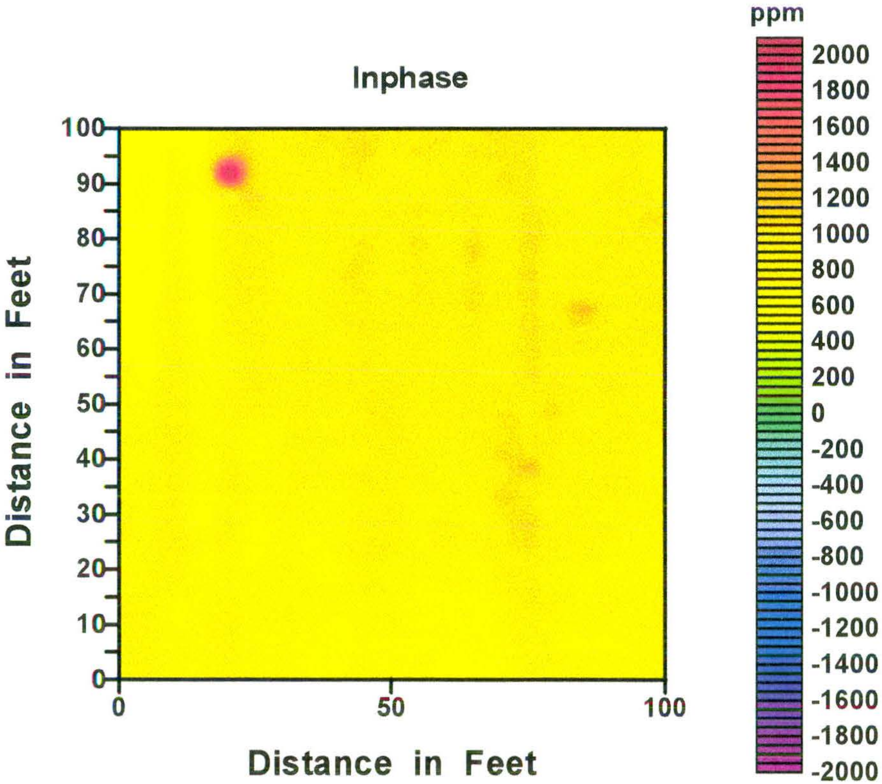


Figure 8

EMI Survey
Glenn's Ferry Station Historic Site
Grid A
GEM300 Sensor
Vertical Dipole Orientation
12870 Hz



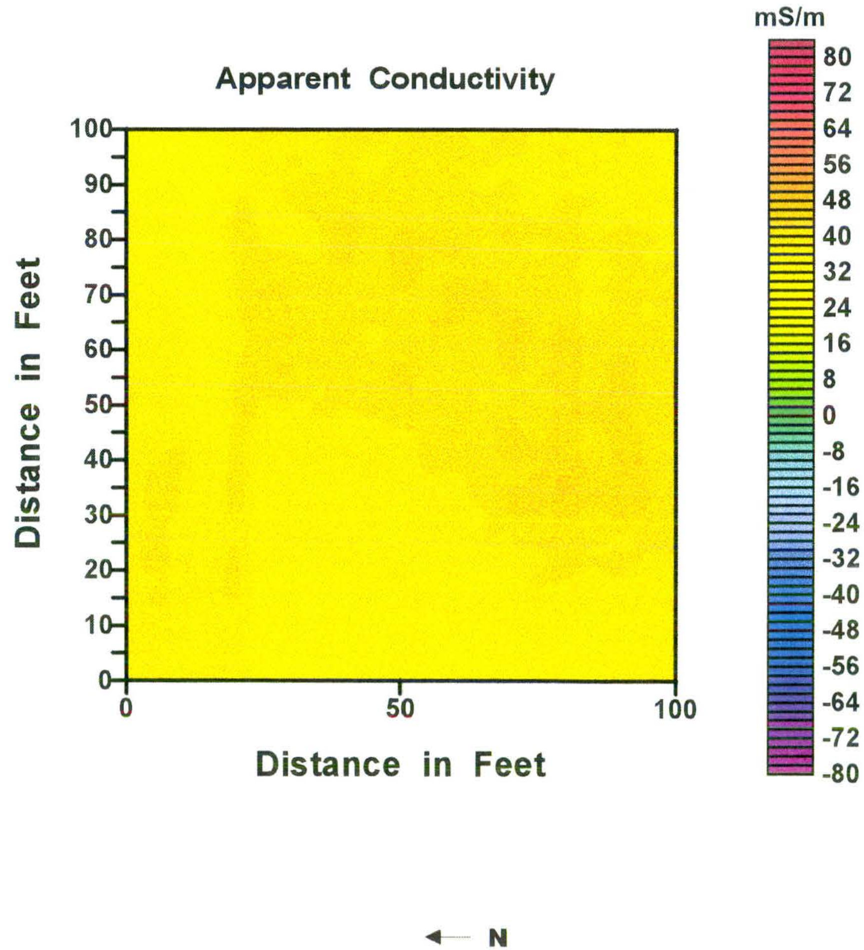


Figure 9

EMI Survey
Glenn's Ferry Historic Site
Grid A
GEM300 Sensor
Vertical Dipole Orientation
14790 Hz

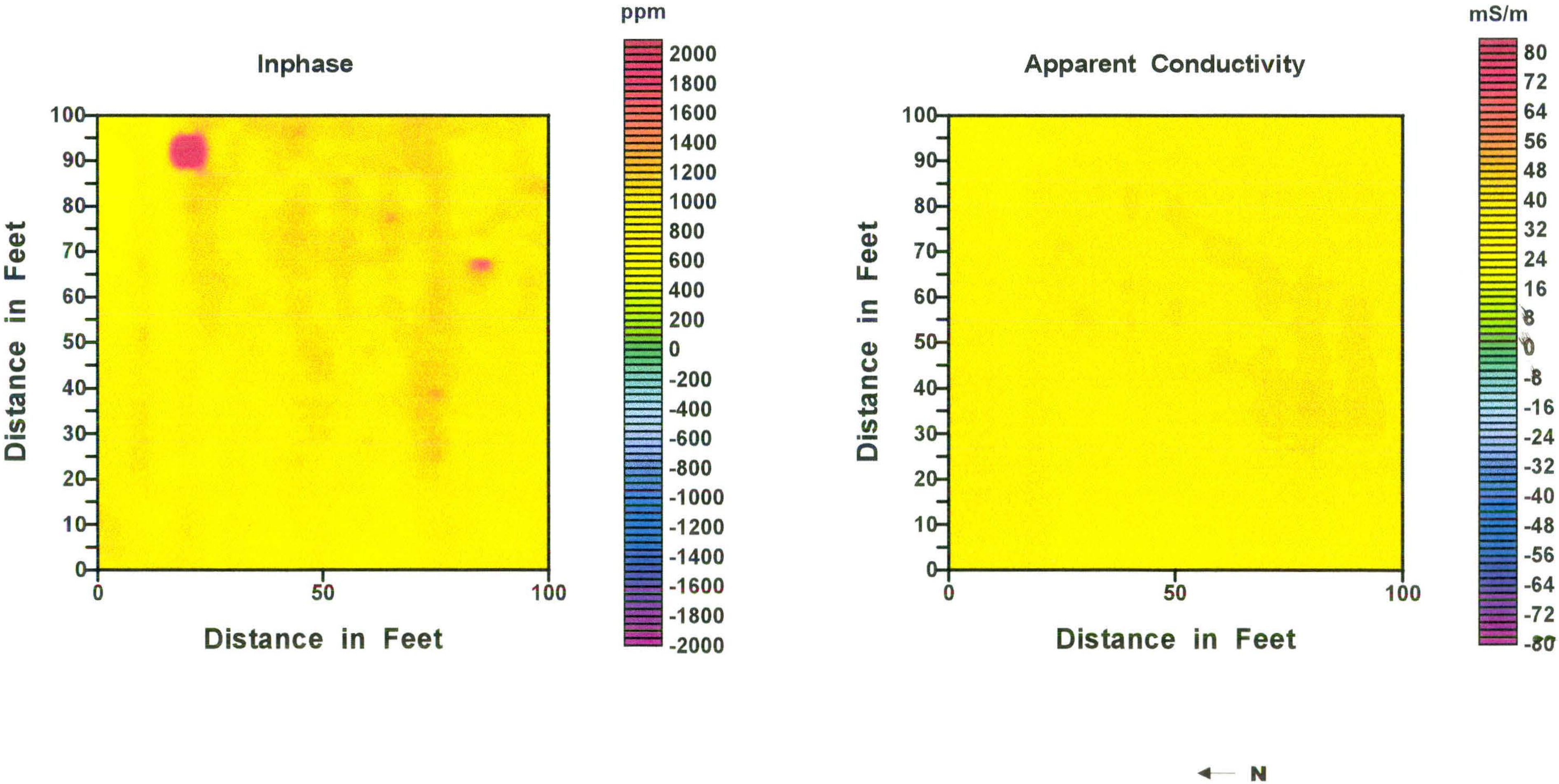


Figure 10

EMI Survey
Glenn's Ferry Station Historic Site
Grid A
GEM300 Sensor
Vertical Dipole Orientation
18270 Hz

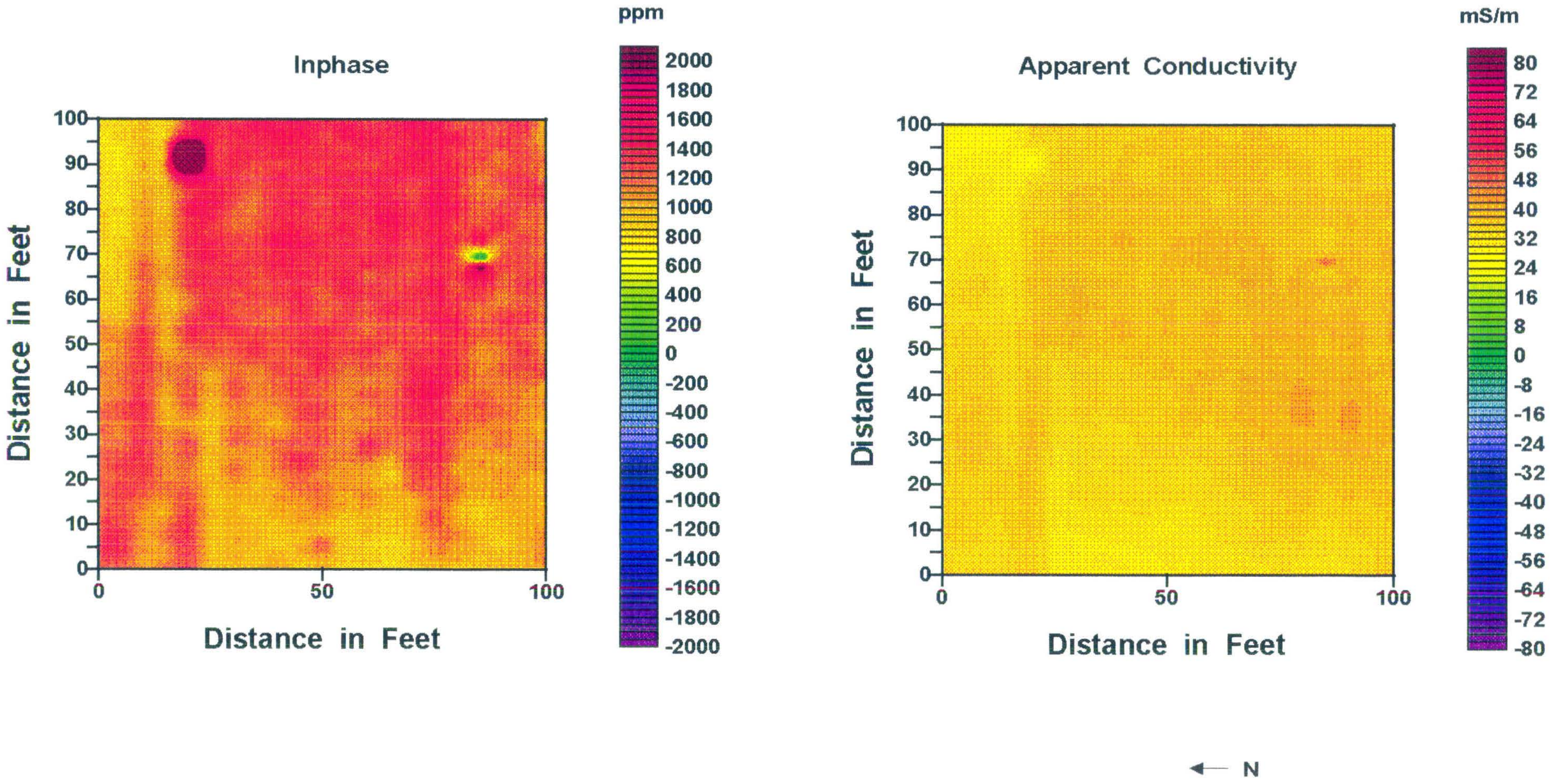


Figure 11

EMI Survey
Glenn's Ferry Historic Site
Grid B
GEM300 Sensor
Vertical Dipole Orientation
9810 Hz

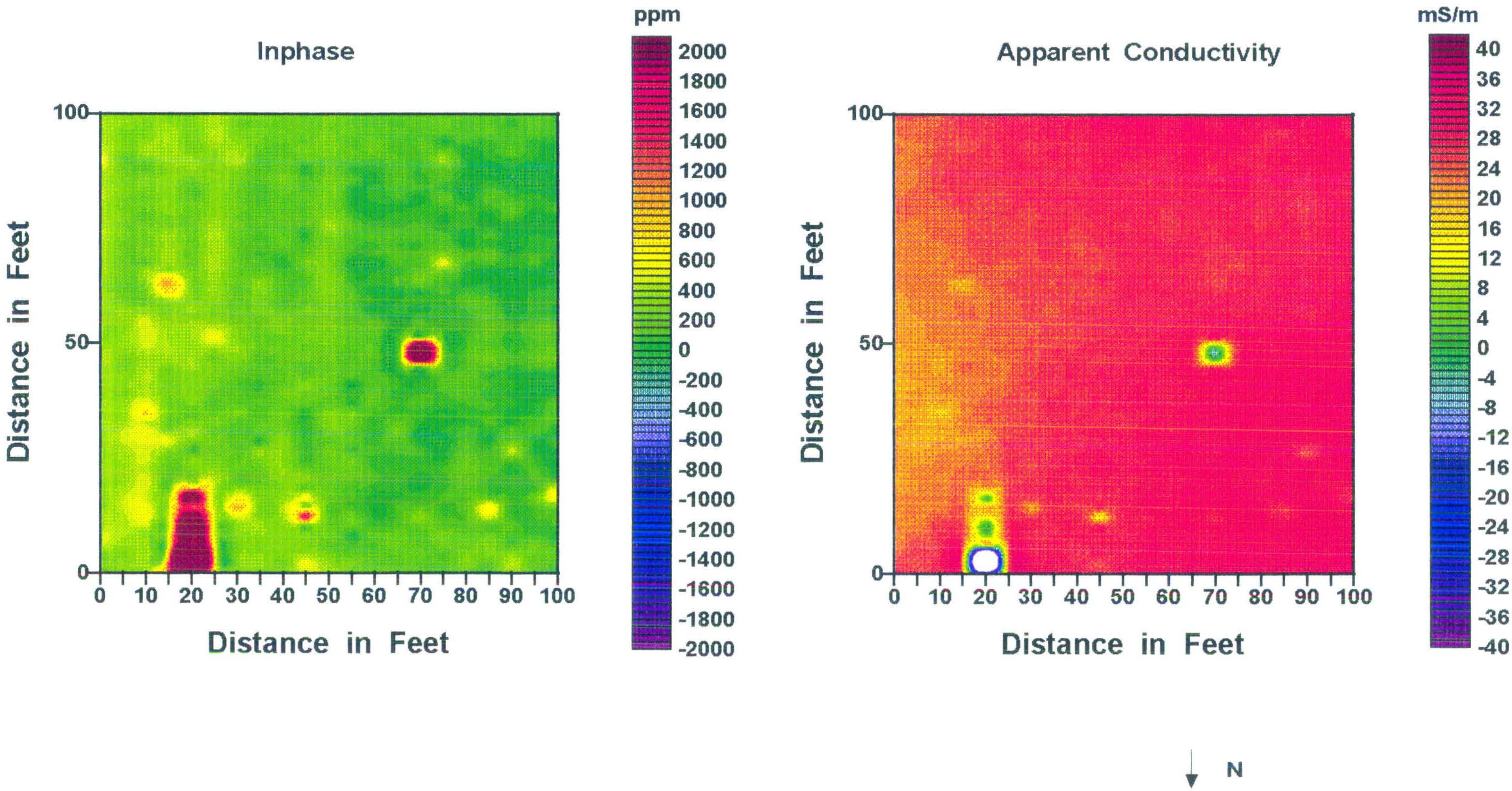


Figure 12

EMI Survey
Glenn's Ferry Historic Site
Grid B
GEM300 Sensor
Vertical Dipole Orientation
14790 Hz

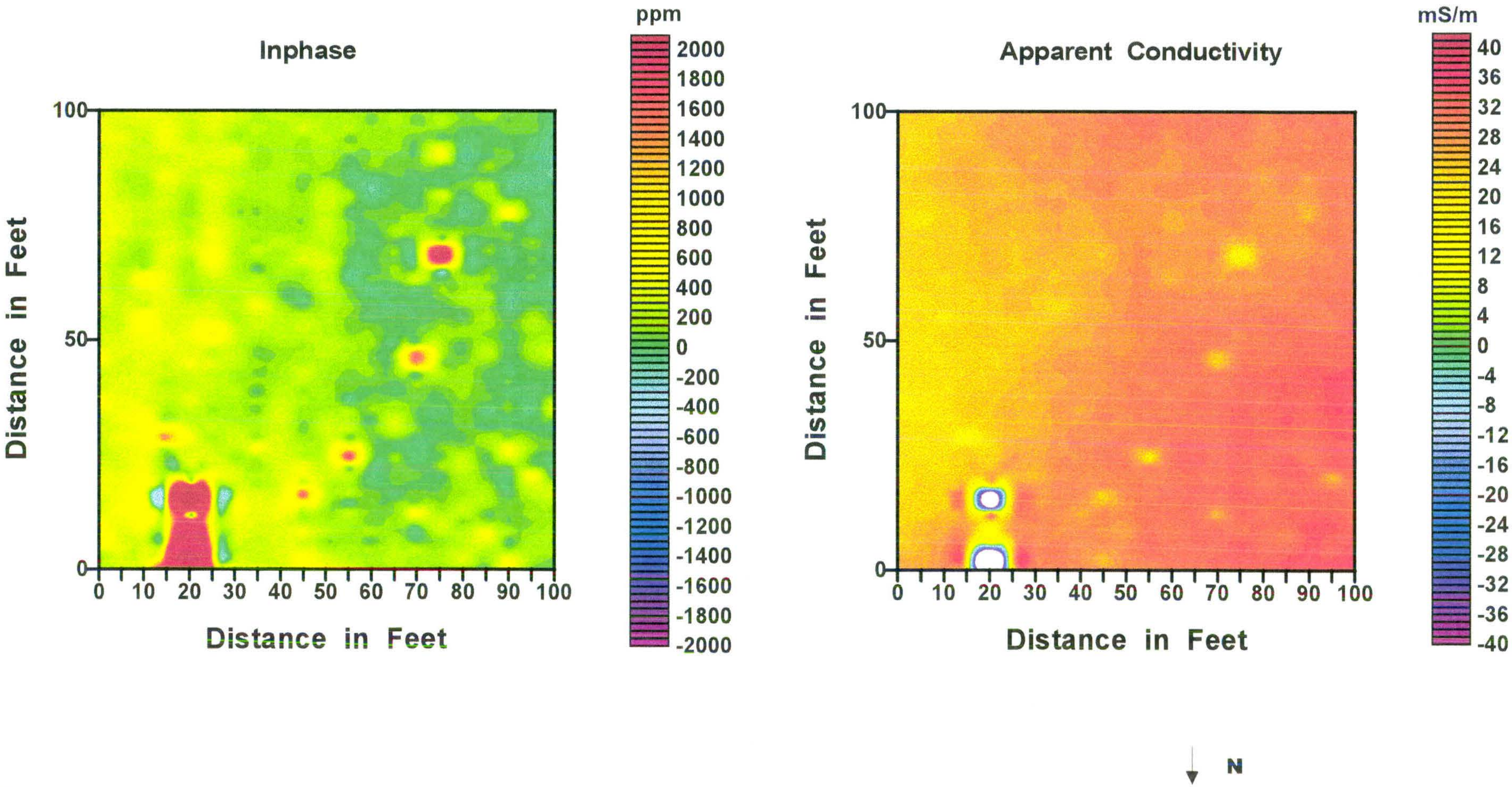


Figure 14

EMI Survey
Glenn's Ferry Historic Site
Grid B
GEM300 Sensor
Vertical Dipole Orientation
18270 Hz

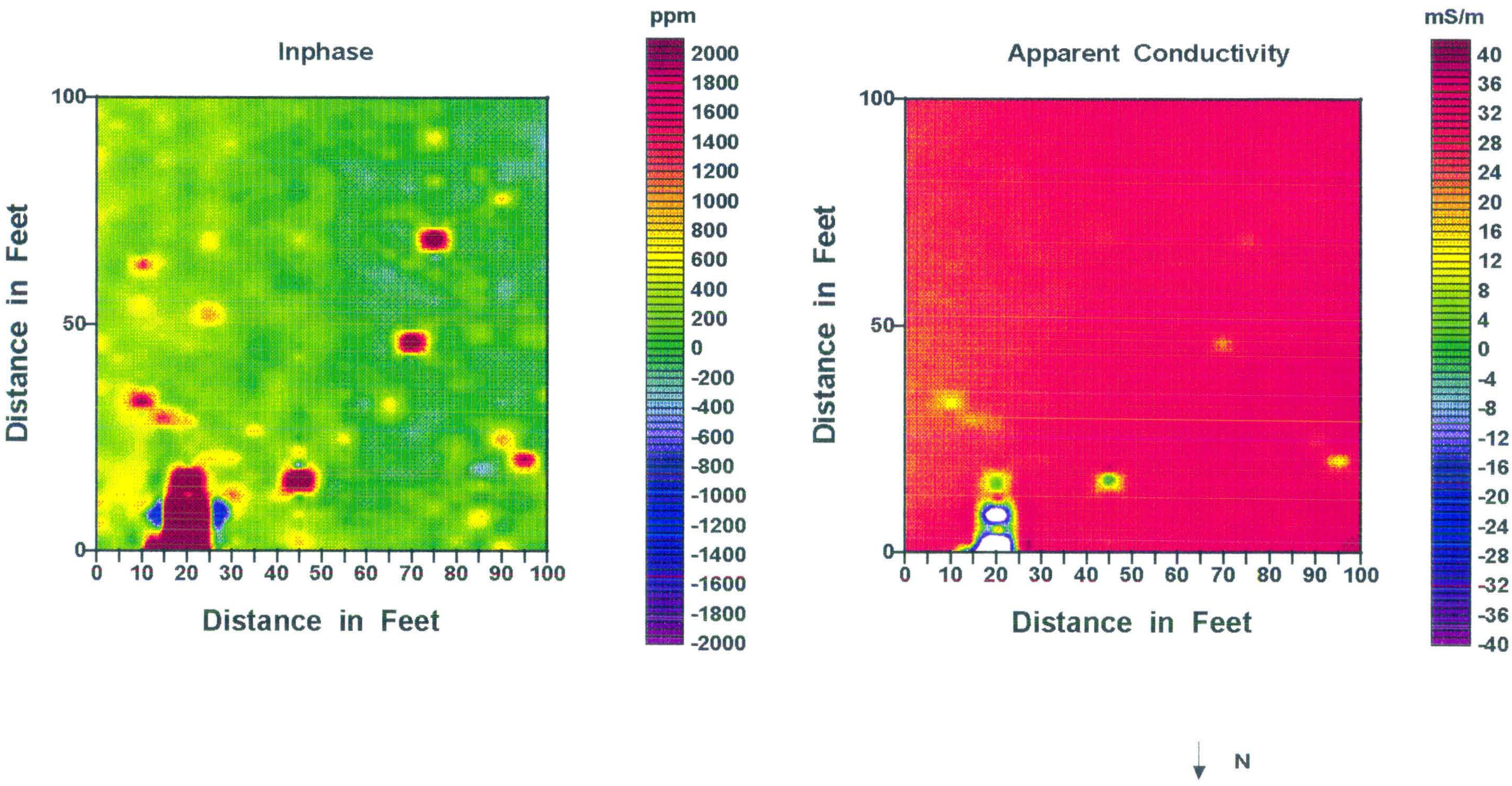


Figure 15