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Natural Resources Conservation Service
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Subject: Archaeology -- Geophysical Assistance **Date:** 21 May 1997

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Purpose:

The purpose of this training session was to familiarize personnel that have cultural resource responsibilities with the use of electromagnetic induction (EM). To familiarize personnel with survey techniques and interpretations, surveys were conducted at the Mellette House (Watertown), the Vanderbilt Earth Lodge City (Pollock), Ft. Pierre Chouteau (Ft. Pierre), and a prehistoric Indian Village site (Mitchell). The approximate locations of these sites in South Dakota are shown in Figure 1. At each site, surveys were designed to detect and map buried cultural features.

Participating Agencies:

Augustana College
Cheyenne River Sioux Tribe
Codington County Historical Society
Mellette House Memorial Association, Inc.
Minnehaha County Historical Society
South Dakota State Department of Environment & Natural Resources
South Dakota State Historic Preservation Office
Standing Rock Sioux Tribe
USA-Corps of Engineers
USDA-Natural Resources Conservation Service

Participants:

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Marion Travis, Volunteer, USDA-NRCS, Mobridge, SD
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Rod Voss, District Conservationist, USDA-NRCS, Kadoka, SD
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Kathy Winham, Archaeologist, Archaeology Laboratory, Augustana College, Sioux Falls, SD
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Activities:

All field activities were completed during the period of 12 to 16 May 1997.

Equipment:

The electromagnetic induction meters used in this study were the EM38 and EM31, manufactured by Geonics Limited.* Each meter is portable and requires only one person to operate. Principles of operation have been described by McNeill (1980, 1986). No ground contact is required with these meters. Each meter provides limited vertical resolution and depth information. For each meter, lateral resolution is approximately equal to the intercoil spacing. The observation depth of an EM meter is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface.

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* Trade names have been used in this report to provide specific information. Their use does not constitute endorsement by USDA-NRCS.

The EM38 meter has a fixed intercoil spacing of about 1 meter. It operates at a frequency of 13.2 kHz. The EM38 meter has effective observation depths of about 75 and 150 centimeters in the horizontal and vertical dipole orientations, respectively (McNeill, 1986). The EM31 meter has a fixed intercoil spacing of about 3.65 meters. It operates at a frequency of 9.8 kHz. The EM31 meter has effective observation depths of about 3 and 6 meters in the horizontal and vertical dipole orientations, respectively (McNeill, 1980). Values of apparent conductivity are expressed in milliSiemens per meter (mS/m).

To help summarize the results of this study, the SURFER for Windows program, developed by Golden Software, Inc.,* was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search. All grids were smoothed using a cubic spline interpolation. Shadings and filled isolines have been used in most of the enclosed plots 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.

Discussion:

Electromagnetic induction (EM) is a noninvasive geophysical tool that has been used to locate and define archaeological features (Bevan, 1983; Frohlich and Lancaster, 1986; and Dalan, 1991). Studies have demonstrated the utility of EM for locating, identifying, and determine the boundaries of various types of cultural features such as buried structures, tombs, filled fortification ditches, and earthen mounds. Advantages of EM methods include speed of operation, flexible observation depths (with commercially available systems from about 0.75 to 60 m), and moderate resolution of subsurface features. Results of EM surveys are interpretable in the field. This technique can provide in a relatively short time the large number of observations needed for site characterization and assessments. Maps prepared from correctly interpreted apparent conductivity data provide the basis for assessing site conditions and for planning further investigations.

Electromagnetic induction techniques use 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 observation depth. 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, 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 the amount of soluble salts, water, and/or clays.

Electromagnetic inductive methods measure vertical and lateral variations in the 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 the locations of buried cultural features. Interpretations of the EM data are based on the identification of spatial patterns within data sets. The size and shape of patterns revealed on two-dimensional plots provide clues as to the features causing them.

The detection of buried cultural features is affected by the electromagnetic gradient existing between artifact and soil. Detection also depends on the depth, size, shape, and orientation of the buried cultural features. The presence of scattering bodies within the soil can mask buried cultural features. The greater or more abrupt the difference in electrical properties between the buried cultural feature and the surrounding soil matrix, the more likely the artifact will be detected. Buried cultural features with electrical properties similar to the surrounding soil matrix are often difficult to discern.

The size, orientation, and depth to an artifact affect interpretations. Large objects are easier to detect than small objects. Small cultural features may be detectable at shallow depths. However, these features are generally undetectable where deeply buried. The presence of scattering bodies in the soil complicates interpretations. Strongly stratified soil horizons, stones and cobbles, tree roots, animal burrows, modern cultural features or recently disturbed soils produce unwanted noise that can mask the presence of some buried cultural features. Nearby structures, buried utility lines, and fences can interfere with a meter's electromagnetic fields. This interference is averaged into apparent conductivity measurements.

Mellette House, Watertown

The Mellette House is on the National Register of Historic Places. The house was built in 1883 by Arthur Calvin Mellette. Arthur Mellette was the last governor of the Dakota Territory and the first governor of South Dakota. The purpose of this investigation was to locate a privy and outbuildings to the home.

The home is located in areas that had been mapped as Kranzburg silty clay loam, 3 to 6 percent slopes (Ollila et al., 1966). This deep, moderately-fine textured, well drained soil formed in loess over till. An irregularly shaped 140 feet by 35 feet rectangular grid was established in an area located to the immediate north and northeast of the historic Mellette House. The grid interval was about 5 feet. At 156 equally spaced observation points, measurements were taken with an EM38 meter placed on the ground surface in the vertical dipole orientations.

Apparent conductivity averaged 12.9 mS/m and ranged from -44.0 to 160. Negative and high positive measurements often indicate the presence of metallic objects. One-half of the observations had values of apparent conductivity between 8.0 and 17 mS/m. Figure 2 is a two-dimensional plot of data collected with the EM38 meter in the vertical dipole orientation. The isoline interval is 5 mS/m. This plot simulates the spatial distribution of apparent conductivity within the upper 60 inches of the soil profile. Interference or noise from nontargeted cultural features (buried utility lines, buildings) was a significant problem at this site. The spatial patterns appearing in Figure 2 principally reflect interference from buried utility lines, metal posts and the house itself. Although the results were inconclusive and disappointing, participants became aware of "cultural noise" and the impairing affects of this form of interference especially in urban areas.

Vanderbilt Earth Lodge Site, Pollock

The remnants of several former earth lodges occur in the vicinity of Pollock, Campbell County. The site is being investigated by the Army Corps of Engineers. The site is located in the southwest quarter of Section 5, T. 128 N., R. 79 W. The site is located in areas that had been mapped as Maddock loamy fine sand, 0 to 6 percent slopes (Schumacher and Heil, 1979). Maddock is a member of the sandy, mixed, Udorthentic Haploborolls family. The site was in grassland.

A 55 by 55 meter grid was established across a portion of the site. The grid interval was 5 meters. At each of the 132 observation points, measurements were taken with an EM38 and an EM31 meter in both the horizontal and vertical dipole orientations. For each measurement, the meters were placed on the ground surface. At each observation point, the relative elevation of the surface was determined with a level and stadia rod. Elevations were not tied to a benchmark; the lowest observation point served as the 0.0 m datum. Relief was about 2.04 m.

Figure 3 shows the relative topography within the site. This plot provides an excellent overview of the site and should be of benefit to archaeologists. Two depressions, believed to be remnants of former earthen lodges, have been identified with the letter "A". Three shallow depressions are also apparent in the central portion of the site.

Figures 4 and 5 are two-dimensional plots of the data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Figures 6 and 7 are two-dimensional plots of the data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. In figures 4 to 7, two-dimensional plots of apparent conductivity have been overlaid upon three-dimensional surface net diagrams of the site. In each of these plots, the isoline interval is 2 mS/m. These figures hopefully provide a better visualization of the data and show the relationships between apparent conductivity and landscape positions.

Figures 4 and 5 represents the spatial distribution of apparent conductivity for the upper 0.75 meter and the upper 1.5 meters of the soil profile, respectively. Values of apparent conductivity increased with increasing observation depths. Apparent conductivity averaged 9.83 mS/m and 13.35 mS/m in the horizontal and vertical dipole orientations, respectively. For the shallower-sensing horizontal dipole orientation, one-half of the observations had values of apparent conductivity between 7.6 and 10.5 mS/m. For the deeper-sensing vertical dipole orientation, one-half of the observations had values of apparent conductivity between 9.8 and 15.0 mS/m. This trend is believed to reflect increased moisture and clay contents at intermediate and lower soil depths and/or the presence of shale bedrock at lower soil depths.

Figures 6 and 7 represents the spatial distribution of apparent conductivity for the upper 3 meters and the upper 6 meters of the soil profile, respectively. For these depth intervals, values of apparent conductivity increased with increasing observation depths. Apparent conductivity averaged 22.24 mS/m and 29.75 mS/m in the horizontal and vertical dipole orientations, respectively. For the shallower-sensing horizontal dipole orientation, one-half of the observations had values of apparent conductivity between 17.6 and 25.6 mS/m. For the deeper-sensing vertical dipole orientation, one-half of the observations had values of apparent conductivity between 25.0 and 33.0 mS/m. This trend is believed to reflect the occurrence of shale bedrock (Pierre formation) at lower soil depths.

In figures 4 to 7, a conspicuous zone of lower apparent conductivity values extends across the site from the northwest to the southeast corners. In each plot, this zone separates areas having higher apparent conductivity located in the southwest and northeast corners of the site. These patterns are presumed to be natural as they intersect and to not appear to be affected by the remnants of the earth lodges. The patterns evident in figures 4 to 7 are believed to reflect variations in soils, soil properties and depth to bedrock. The area with low apparent conductivity values that extends across the site from the northwest to the southeast corner is believed to contain soils that are deeper to bedrock. Areas with shallower depths to shale bedrock will have higher values of apparent conductivity.

Iso-conductivity lines, shown in figures 4 to 7, bisect and do not appear to be influenced by the two major structural features identified in Figure 3 ("A"). The earthen lodges were constructed from locally derived soil materials. As these features are composed of materials identical to the surrounding soil materials, contrasts in electrically properties are unlikely. The debris materials that constitute the floors of the lodges were not sufficiently contrasting to be detected with EM techniques.

Fort Pierre Chouteau, Ft. Pierre

Fort Pierre Chouteau is on the National Register of Historic Places and is a National Landmark site. The site contains the buried remains of a fortified fur trade post. The post was operated from 1832 to 1857. The purpose of this investigation was to define a portion of the perimeter of the fort.

Fort Pierre Chouteau is being investigated by the Army Corps of Engineers. The site is located in the southwest quarter of Section 5, T. 128 N., R. 79 W. The site is located on a low terrace of the Missouri River in an area that had been mapped as Promise clay, 0 to 3 percent slopes (Borchen, 1980). Promise is a member of the very fine, montmorillonitic, mesic Vertic Haplustolls family. This deep, well drained soil formed in clayey sediments weathered from shale. The site was in grassland.

A 48 by 99 meter grid was established across a portion of the site. The grid interval was 3 meters. At each of the 578 observation points, measurements were taken with an EM38 and an EM31 meter in both the horizontal and vertical dipole orientations. For each measurement, the EM38 meter was placed on the ground surface. For each measurement, the EM31 meter was held at hip height (about 1 meter above the ground surface). At each observation point, the relative elevation of the surface was determined with a level and stadia rod. Elevations were not tied to a benchmark; the lowest observation point served as the 0.0 m datum. Relief was about 1.0 m.

Figure 8 shows the relative topography within the site. The surface slopes gradually to the East and towards the Missouri River. No conspicuous cultural features are evident or can be identified in this plot.

Figures 9 and 10 are two-dimensional plots of the data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. Figures 11 and 12 are two-dimensional plots of the data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. In each plot, point symbols have been used to identify the approximate locations of a utility pole and the base of two metal guide wires. These features interfered with some measurements.

Figures 9 and 10 represents the spatial distribution of apparent conductivity for the upper 0.75 meter and the upper 1.5 meters of the soil profile, respectively. Values of apparent conductivity increase with increasing observation depths. Apparent conductivity averaged 70.13 mS/m and 89.68 mS/m in the horizontal and vertical dipole orientations, respectively. For the shallower-sensing horizontal dipole orientation, one-half of the observations had values of apparent conductivity between 62.7 and 74.9 mS/m. For the deeper-sensing vertical dipole orientation, one-half of the observations had values of apparent conductivity between 82.8 and 95.4 mS/m. These comparatively high apparent conductivity measurements are attributed principally to the presence of soluble salts (map unit had inclusions of sodium-affected soils) and high clay content of the soils.

In figures 9 to 10, anomalously high and low values of apparent conductivity and exceedingly complex patterns of iso-conductivity lines occur in the north and northeast portions of the site. These values and patterns are believe to represent the remnants of Fort Pierre Chouteau. In each figure, segmented lines have been used to define the interpreted boundaries of the fort. Some anomalies do occur outside this boundary. Values of apparent conductivity are more moderate and spatial patterns appear less complex in other parts of the site.

Figures 11 and 12 represents the spatial distribution of apparent conductivity for the upper 3 meters and the upper 6 meters of the soil profile, respectively. For these depth intervals, values of apparent conductivity continue to increase with increasing observation depths. Apparent conductivity averaged 69.21 mS/m and 98.41 mS/m in the horizontal and vertical dipole orientations, respectively. For the shallower-sensing horizontal dipole orientation, one-half of the observations had values of apparent conductivity between 63.9 and 73.4 mS/m. For the deeper-sensing vertical dipole orientation, one-half of the observations had values of apparent conductivity between 93.2 and 102.2 mS/m. This vertical trend in apparent conductivity is believed to reflect increased concentrations of soluble salts at lower soil depths.

Measurements made with the EM31 meter appear to be more greatly influenced by the utility pole and the two guide wires than were measurements made with the EM38 meter. The EM31 meter averaged a greater volume of earthen materials into its measurements than the EM38 meter. As a consequence, compared with the EM38 meter, the EM31 meter is less sensitive to most buried cultural features within Ft. Pierre Chouteau.

Prehistoric Indian Village, Mitchell

The site is located in the northeast quarter of Section 9, T. 103 N., R. 60 W. The site is located in areas that had been mapped as Clarno-Houdek loams, 0 to 3 percent slopes (Johnson et al., 1974). Clarno is a member of the fine-loamy, mixed, mesic Typic Haplustolls family. Houdek is a member of the fine-loamy, mixed, mesic Typic Argiustolls family. These deep, well drained soils formed in glacial till on uplands.

A 30 by 27 meter grid was established across a portion of the site. The grid interval was 3 meters. At each of the 111 observation points, measurements were taken with an EM38 meter in both the horizontal and vertical dipole orientations. For each measurement, the EM38 meter was placed on the ground surface.

Figures 13 and 14 are two-dimensional plots of the data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. In each of these plots, the isoline interval is 2 mS/m. Figures 13 and 14 represents the spatial distribution of apparent conductivity for the upper 0.75 meter and the upper 1.5 meters of the soil profile, respectively. Values of apparent conductivity decrease slightly with increasing observation depths. Apparent conductivity averaged 9.16 mS/m and 8.71 mS/m in the horizontal and vertical dipole orientations, respectively. For the shallower-sensing horizontal dipole orientation, one-half of the observations had values of apparent conductivity between 7.2 and 8.8 mS/m. For the deeper-sensing vertical dipole orientation, one-half of the observations had values of apparent conductivity between 7.0 and 8.1 mS/m. The comparatively low apparent conductivity measurements were attributed to the low clay and soluble salt contents of the soils.

In Figure 13, anomalously high and low values of apparent conductivity and complex patterns of iso-conductivity lines occur in the west-central portion of the site. In Figure 14, anomalously high values of apparent conductivity and complex patterns of iso-conductivity lines occur in the west-central and northeast portions of the site. These values and patterns are unnatural in appearance and are believe to have been caused by buried cultural features. In each figure, a letter "A" has been used to define the detected anomalies. In other portions of the site, patterns are less complex and are presumed to principally reflect variations in soil properties.

Results:

1. Training was provided to over 40 individuals from 10 agencies. Electromagnetic induction surveys were completed at four historic sites in South Dakota. Participants gained exposure to survey techniques and interpretations at historic sites of local and national importance. These surveys

demonstrated some of the limitations and advantages of EM techniques. Surveys confirmed the value of integrating contemporary geophysical and computer technologies with traditional archaeological techniques. The integration of these technologies provides more comprehensive site coverage, reduces the number of unsuccessful exploratory pits, and decreases field time and costs.

2. At the Mellette House in Watertown, modern cultural features interfered with measurements and masked the presence of any outbuildings (if present). The use of EM in similarly disturbed settings with high amounts of "cultural noise" is considered inappropriate.

3. The floors of earth lodges were undetectable with EM at the Vanderbilt Earth Lodge Site near Pollock. The earth lodges were constructed from adjoining soil materials. Soils and constructed materials are electrically similar. As a consequence, these features are indistinguishable to EM. Electromagnetic induction did provide indications of the depth to shale bedrock. The use of EM to determine depths to bedrock will be beneficial to soil scientists tasked with soil survey updates.

4. Electromagnetic induction appears to have defined the location and boundaries of the Ft. Pierre Chouteau at Fort Pierre. Several structural features may have been defined as well.

5. Electromagnetic induction identified several anomalous patterns within a prehistoric Indian Village site near Mitchell.

6. Interpretations are considered preliminary estimates of site conditions. The results of geophysical site investigations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. All interpretations made in this report should be verified by ground-truth observations.

It was my pleasure to work with and to be of assistance to members of your fine staff.

With kind regards,

James A. Doolittle
Research Soil Scientist

cc:

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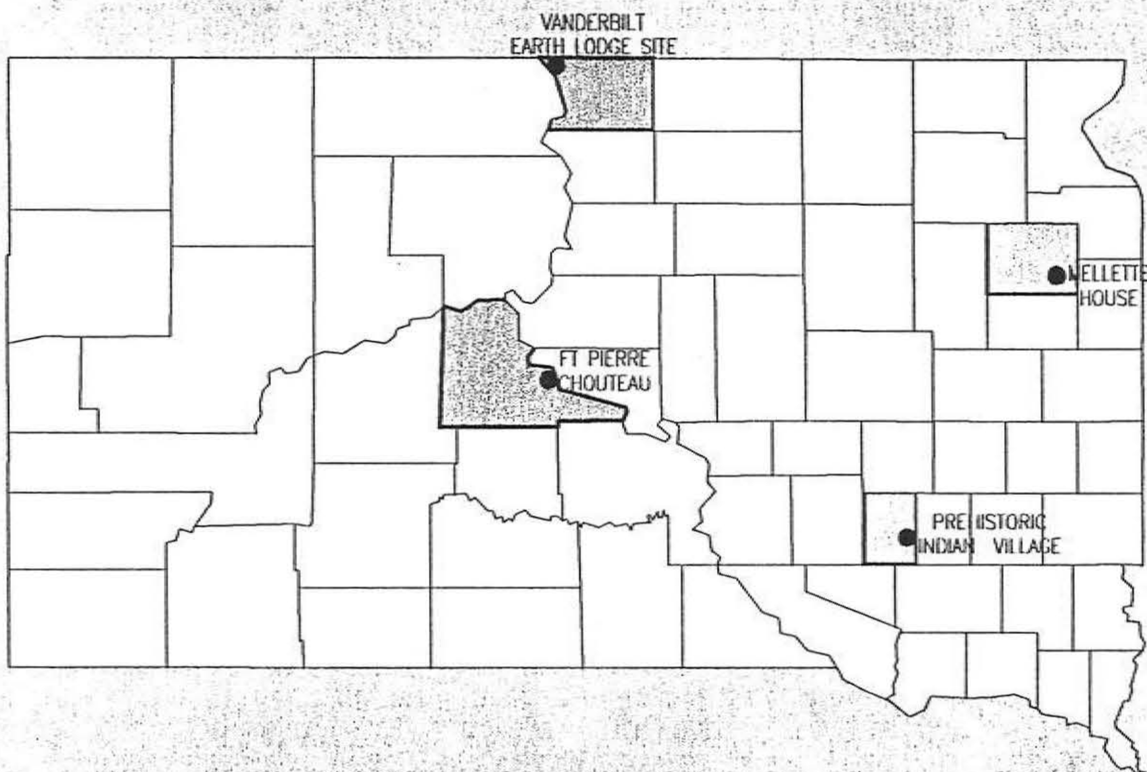
SOUTH DAKOTA

LOCATIONS OF STUDY SITES



MELLETTE HOUSE
WATERTOWN, SOUTH DAKOTA
EM38 METER, VERTICAL DIPOLE ORIENTATION

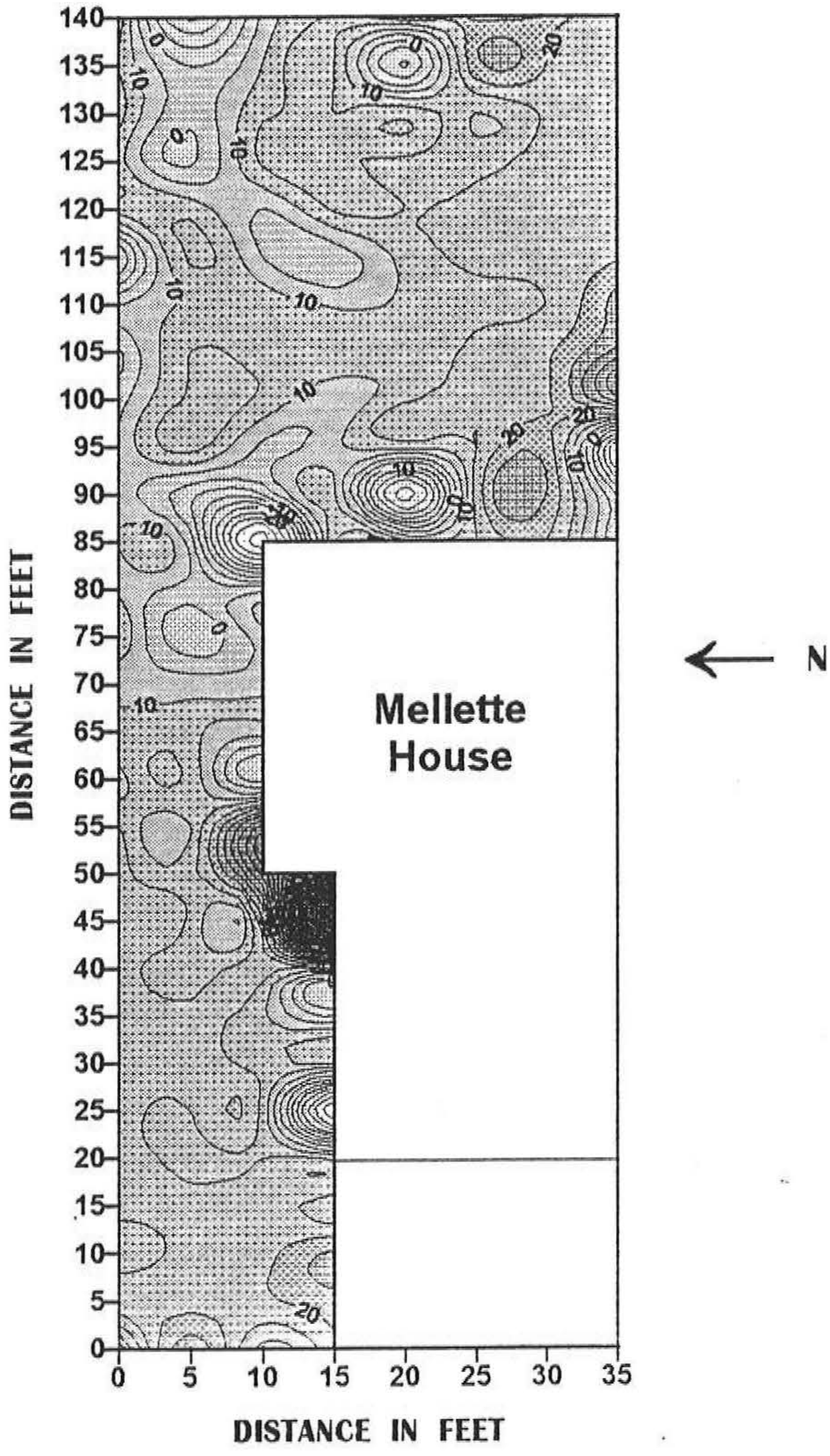


FIGURE 2

VANDERBILT EARTH LODGE SITE
POLLOCK BAY, SOUTH DAKOTA

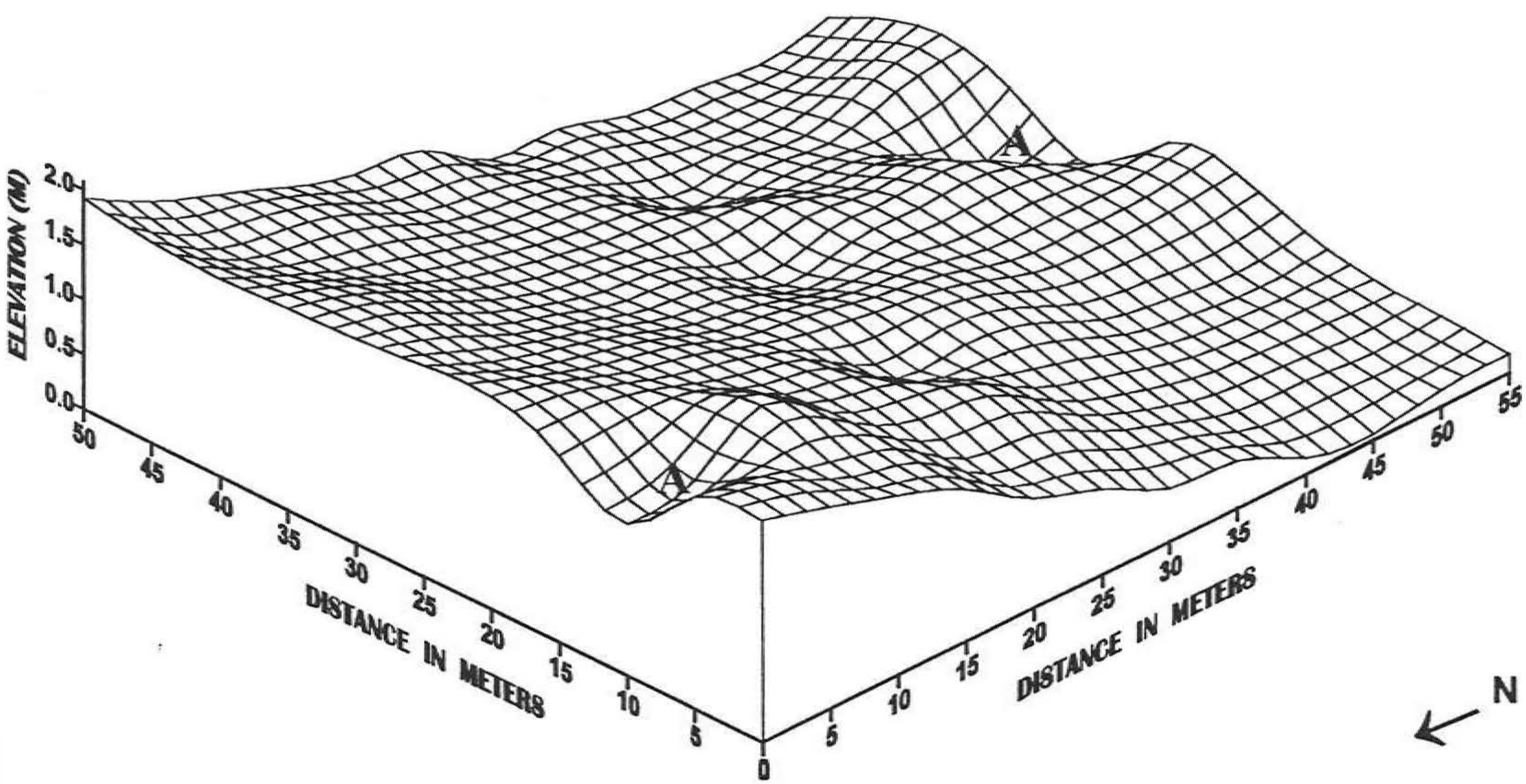


FIGURE 3

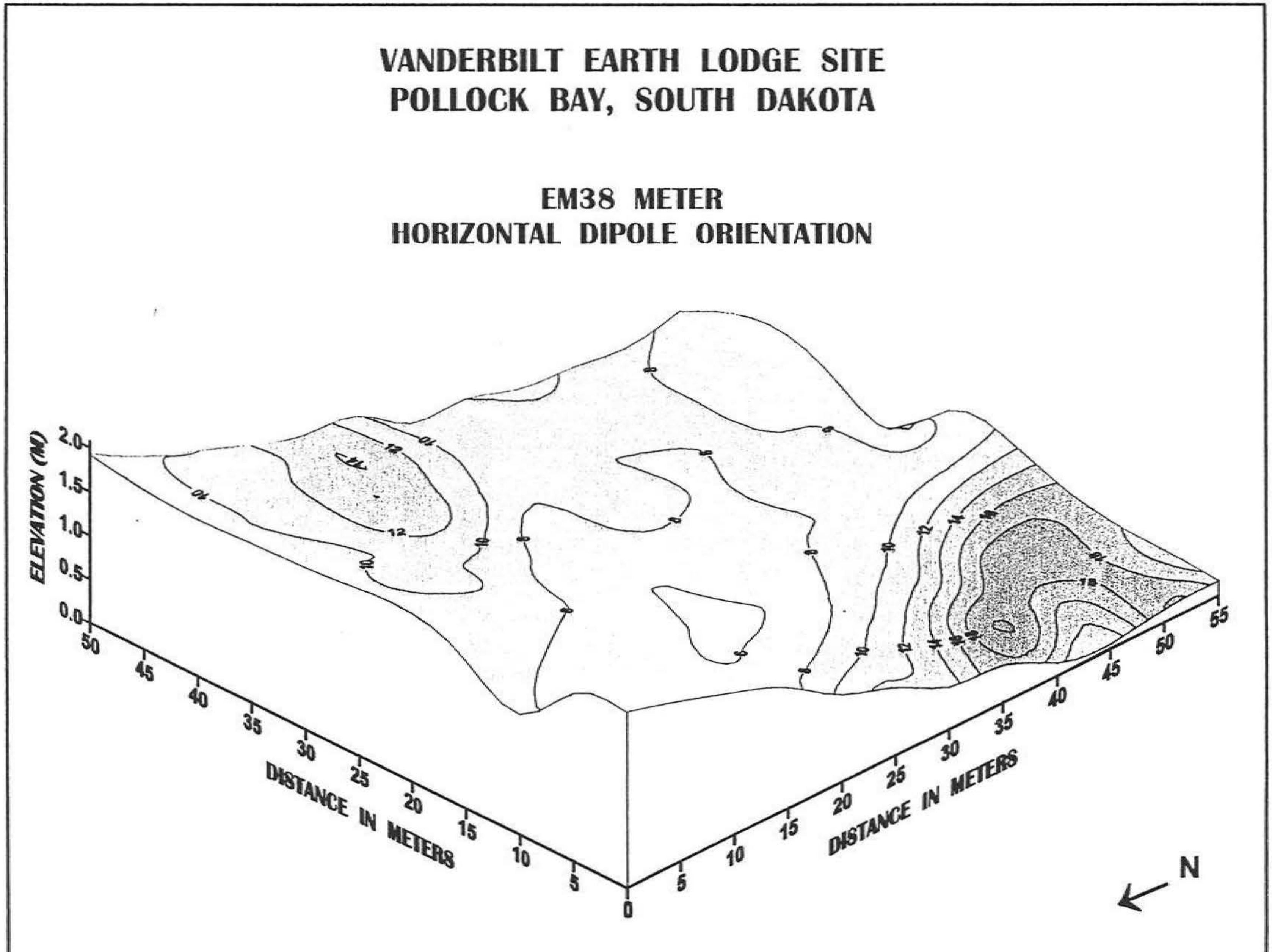

VANDERBILT EARTH LODGE SITE
POLLOCK BAY, SOUTH DAKOTA
EM38 METER
HORIZONTAL DIPOLE ORIENTATION
ELEVATION (M)
DISTANCE IN METERS
DISTANCE IN METERS
N

FIGURE 4

VANDERBILT EARTH LODGE SITE
POLLOCK BAY, SOUTH DAKOTA

EM38 METER
VERTICAL DIPOLE ORIENTATION

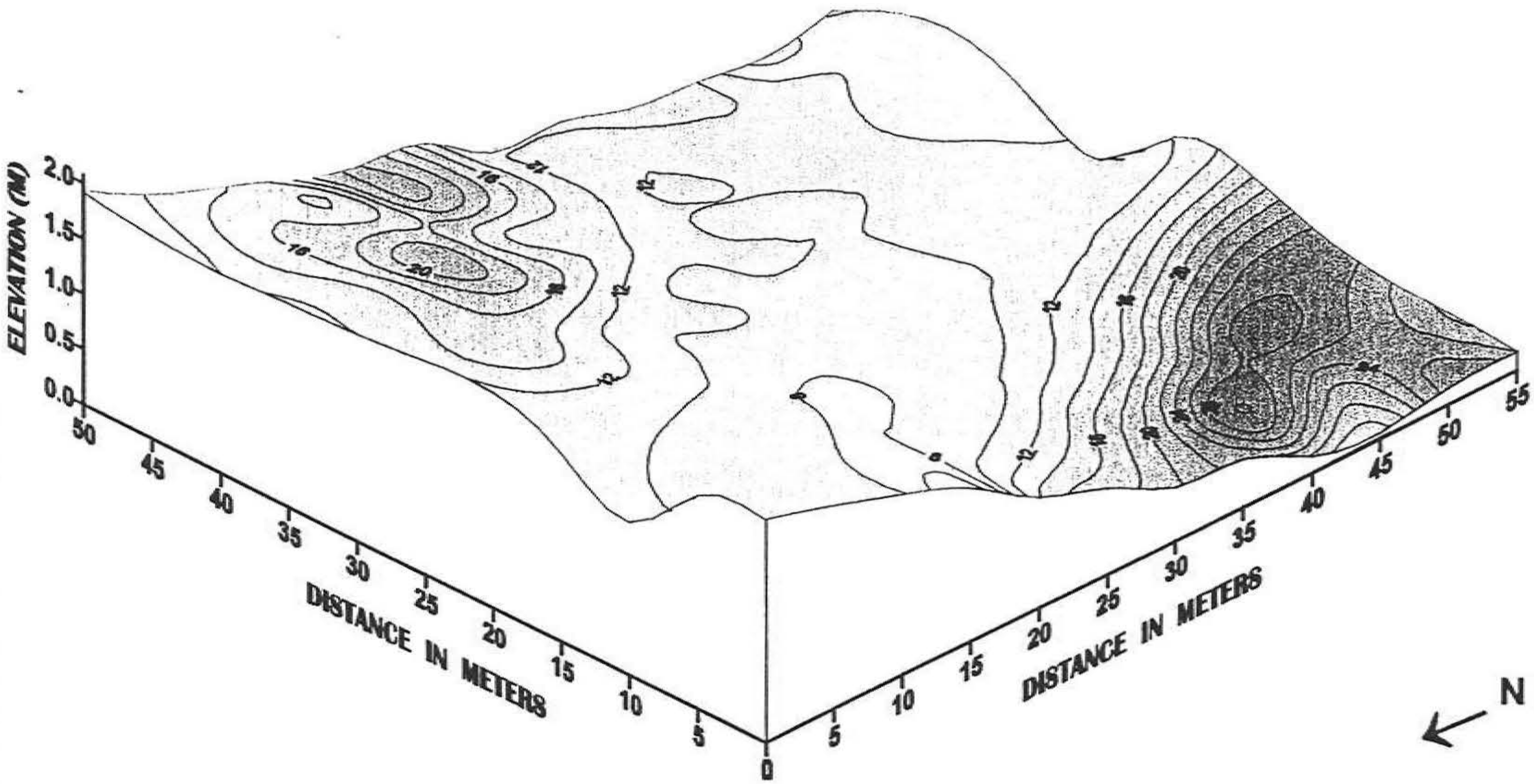


FIGURE 5

VANDERBILT EARTH LODGE SITE
POLLOCK BAY, SOUTH DAKOTA

EM31 METER
HORIZONTAL DIPOLE ORIENTATION

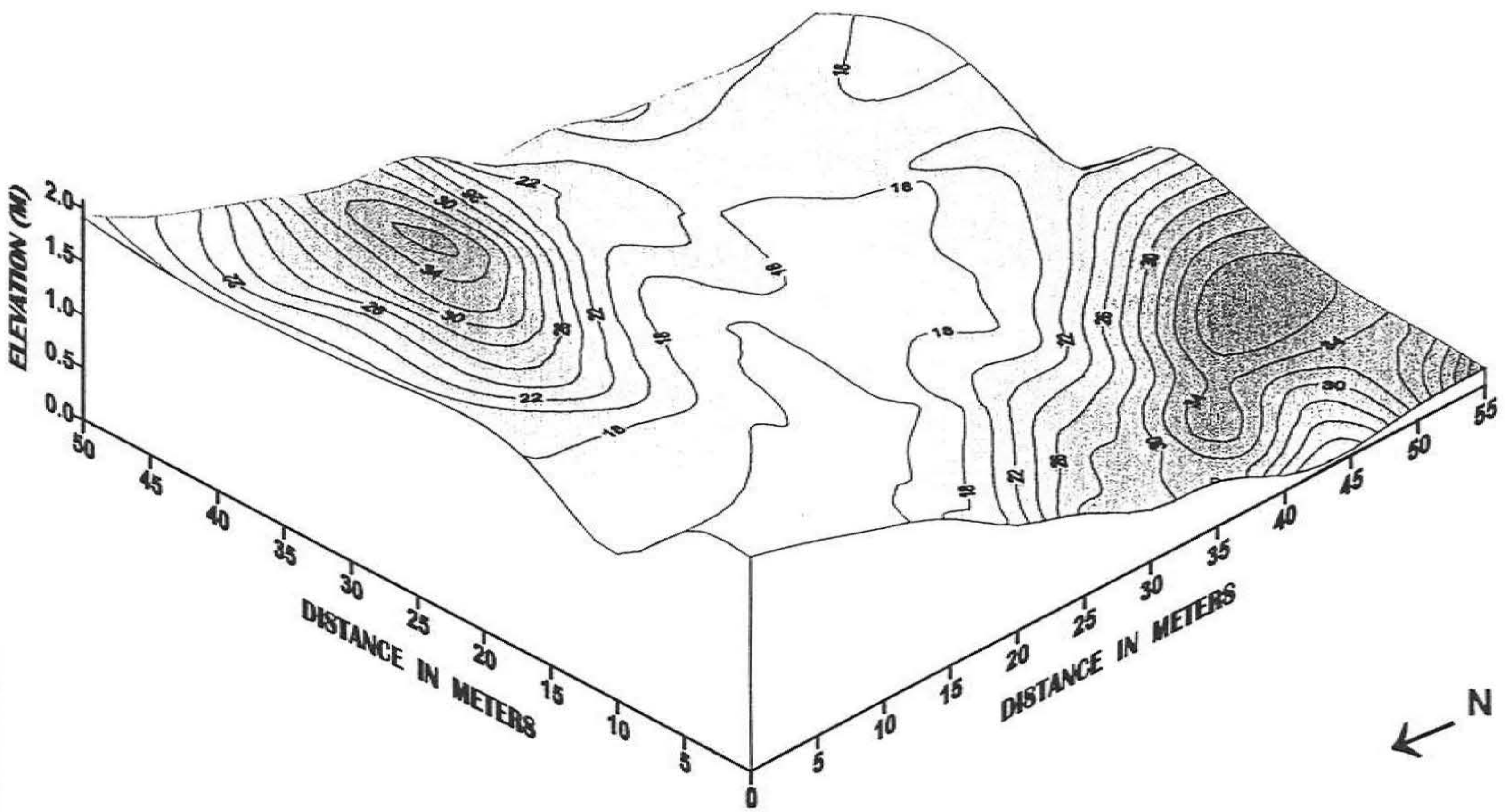


FIGURE 6

VANDERBILT EARTH LODGE SITE
POLLOCK BAY, SOUTH DAKOTA

EM31 METER
VERTICAL DIPOLE ORIENTATION

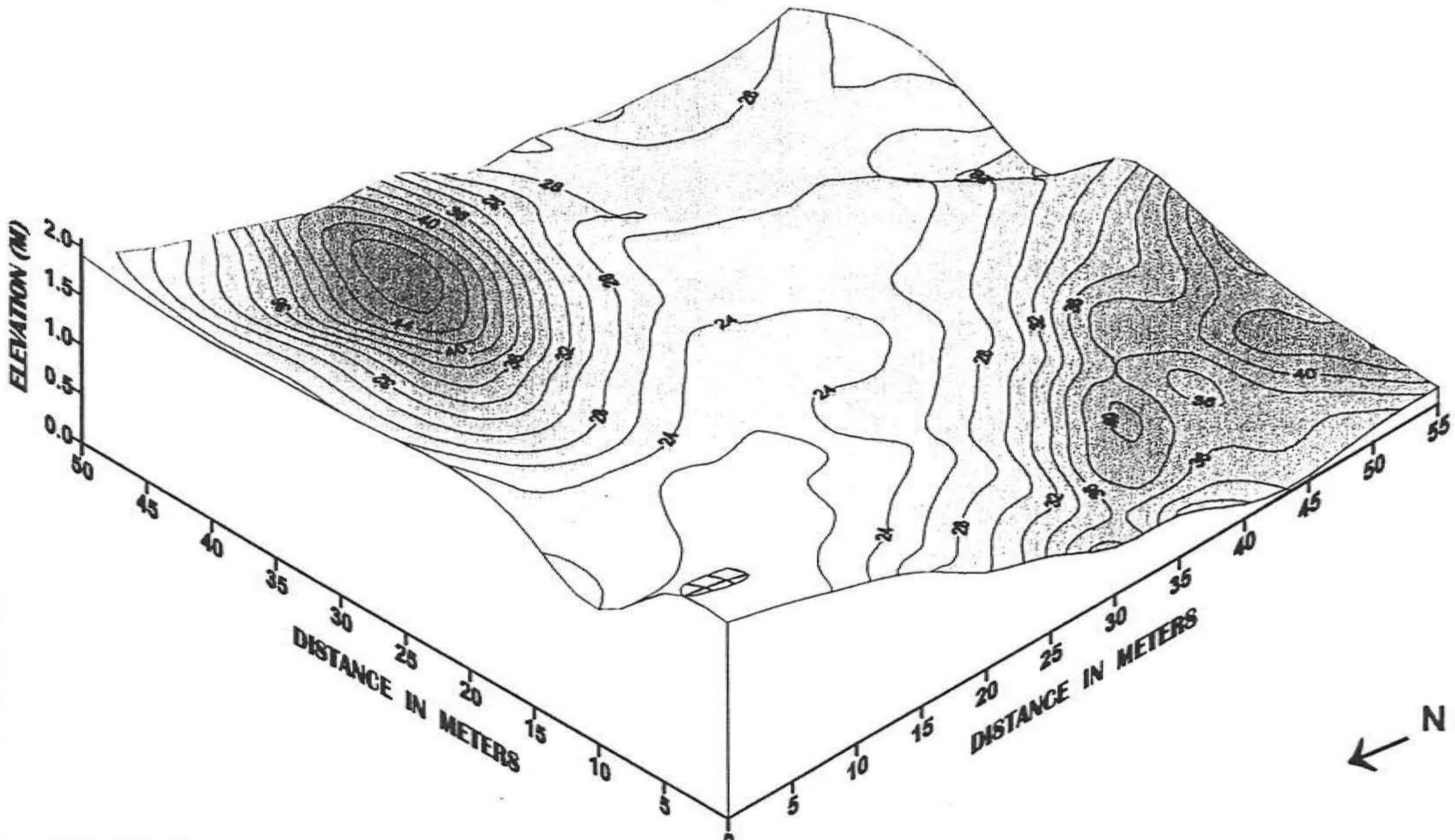


FIGURE 7

FORT PIERRE CHOUTEAU

RELATIVE TOPOGRAPHY

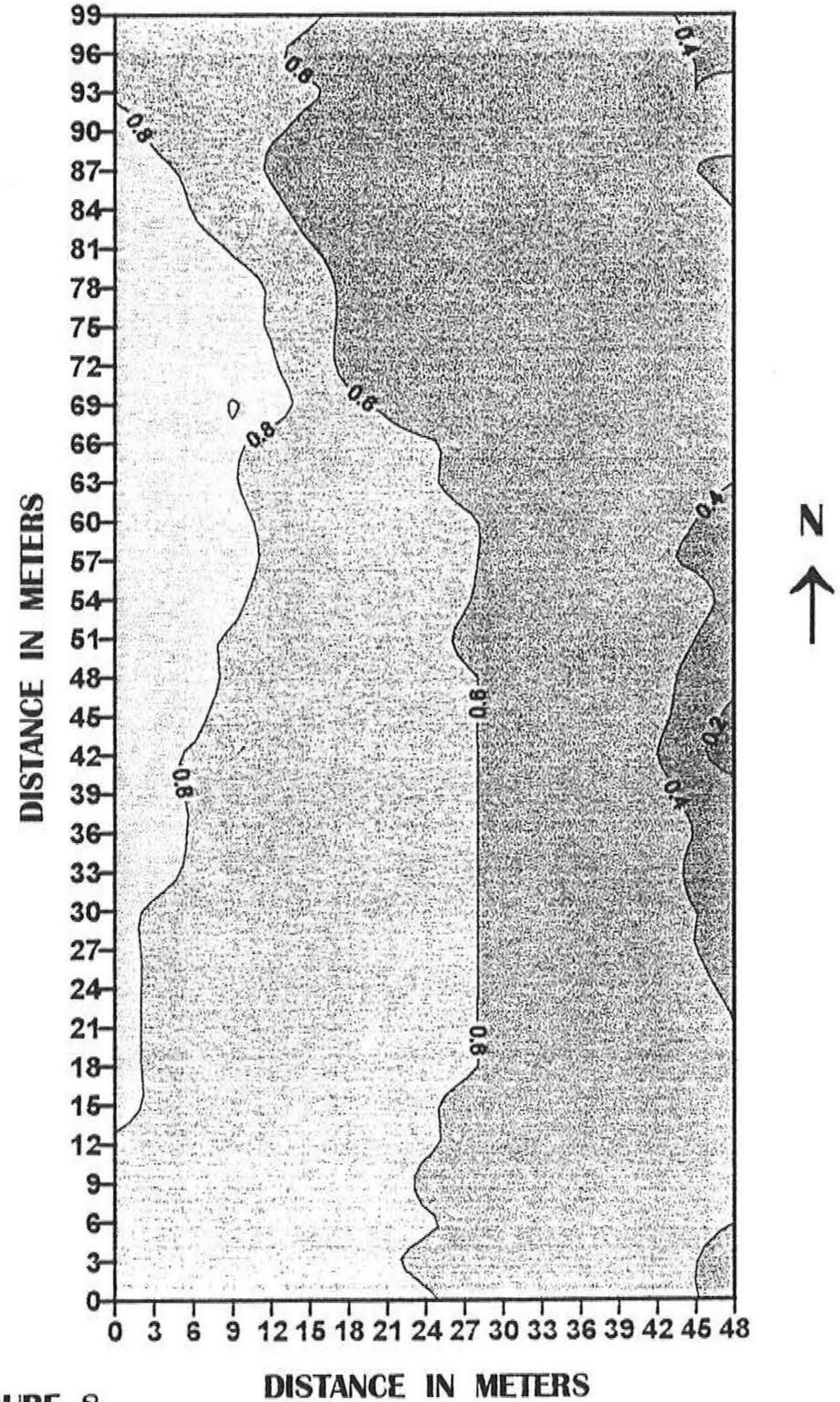


FIGURE 8

FORT PIERRE CHOUTEAU

EM38 METER
HORIZONTAL DIPOLE ORIENTATION

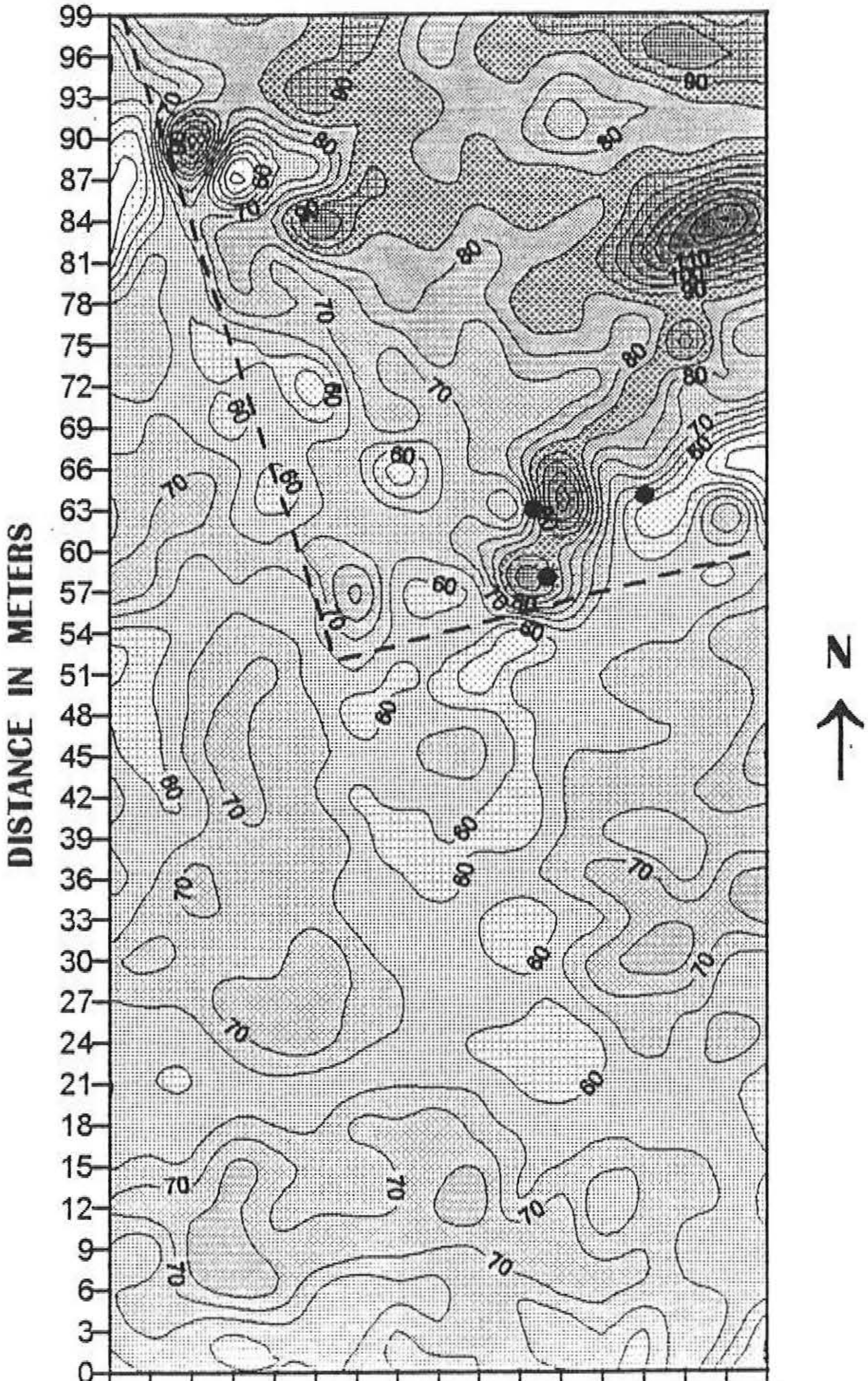


FIGURE 9

FORT PIERRE CHOUTEAU

EM38 METER
VERTICAL DIPOLE ORIENTATION

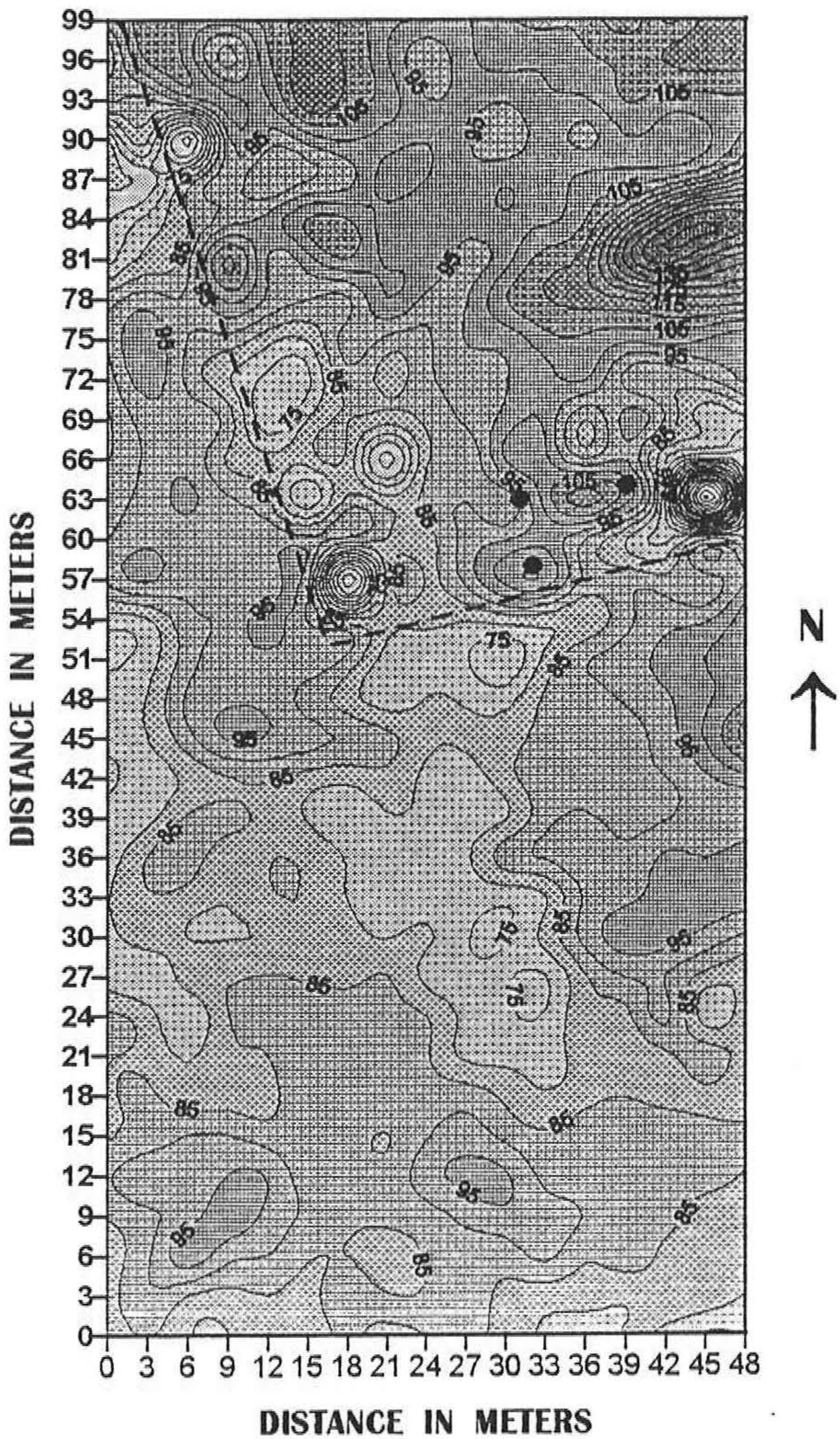


FIGURE 10

FORT PIERRE CHOUTEAU

EM31 METER
HORIZONTAL DIPOLE ORIENTATION

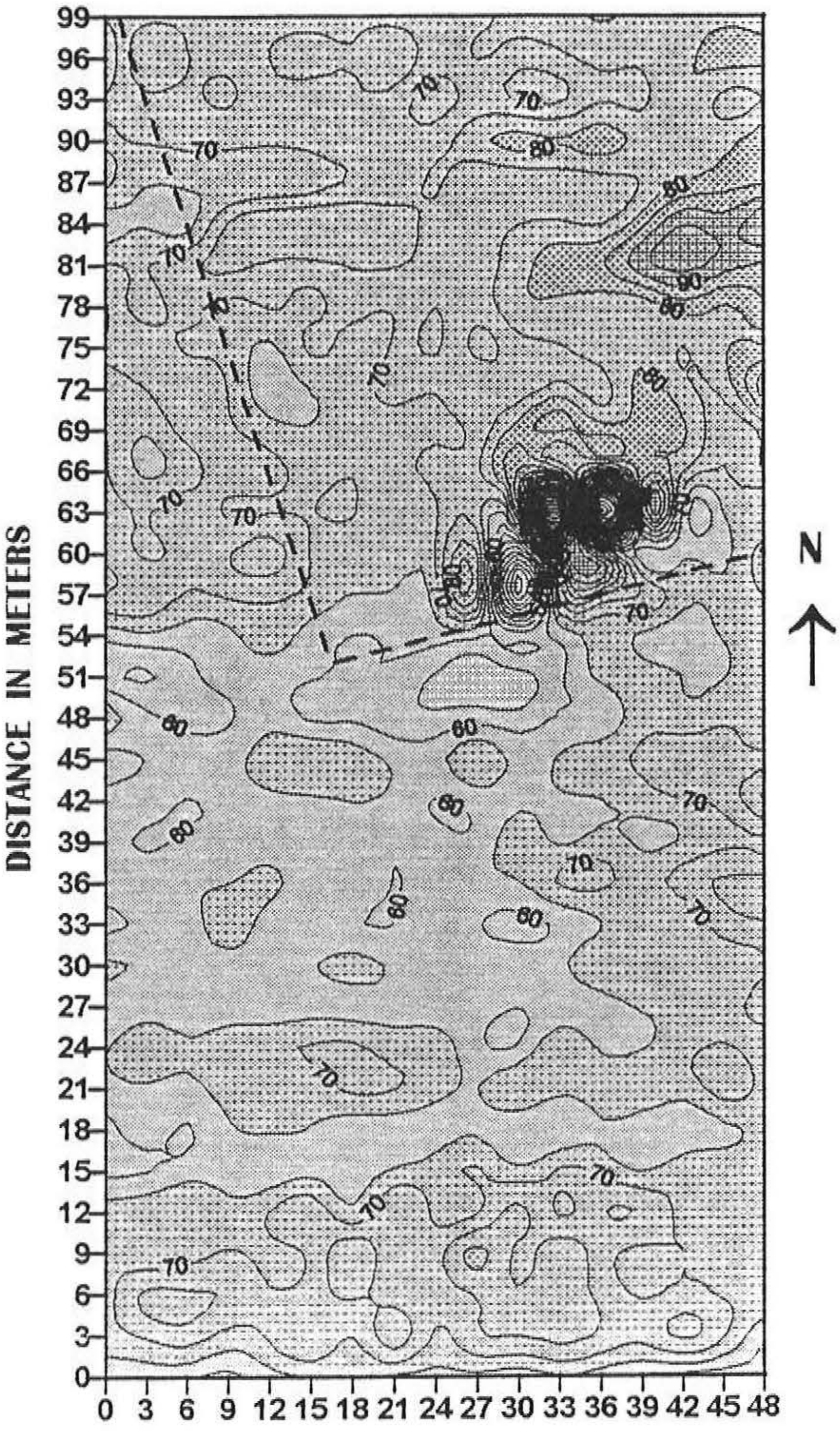


FIGURE 11

FORT PIERRE CHOUTEAU

EM31 METER
VERTICAL DIPOLE ORIENTATION

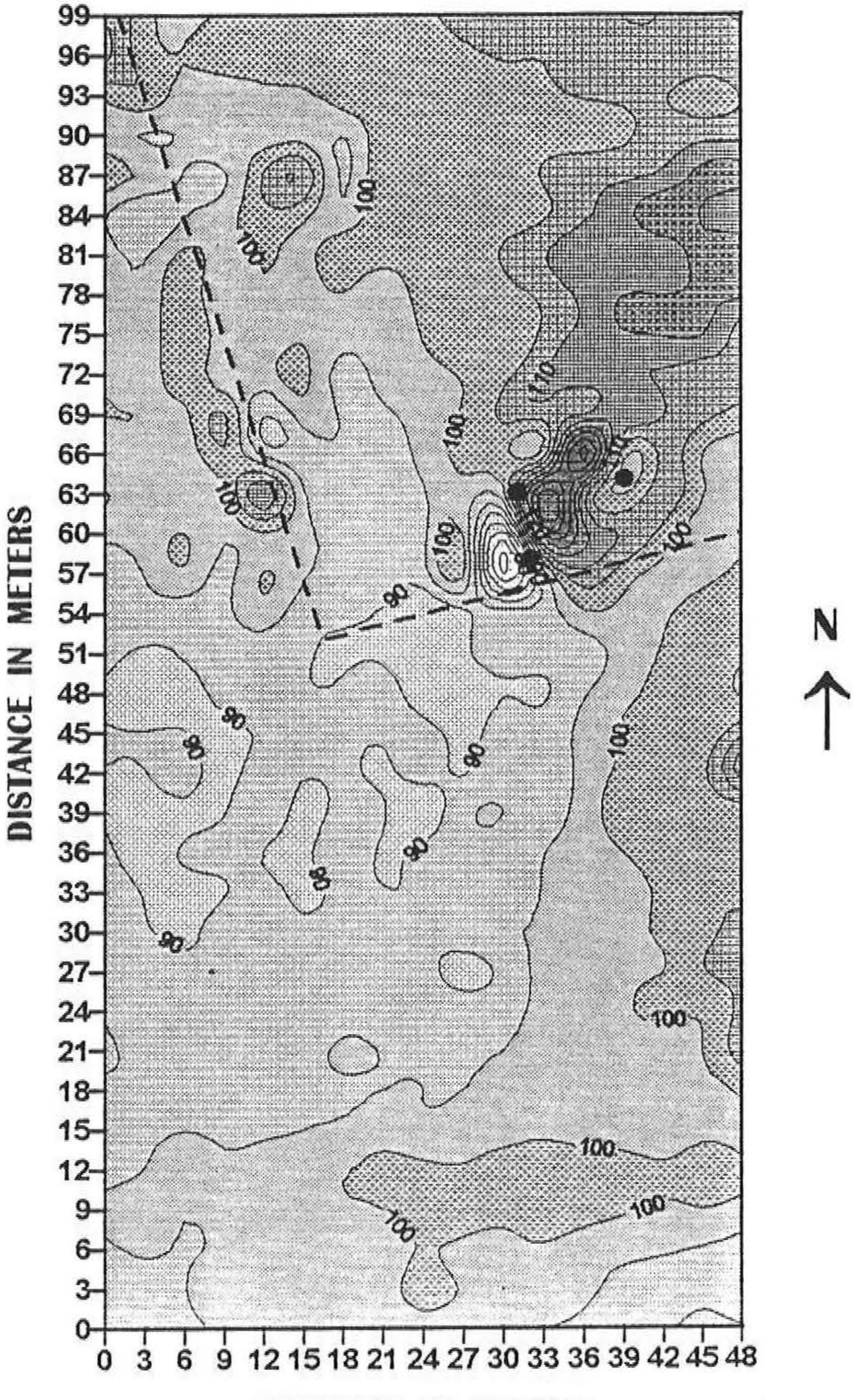


FIGURE 12

PREHISTORIC INDIAN VILLAGE SITE
MITCHELL, SOUTH DAKOTA

EM38 METER
HORIZONTAL DIPOLE ORIENTATION

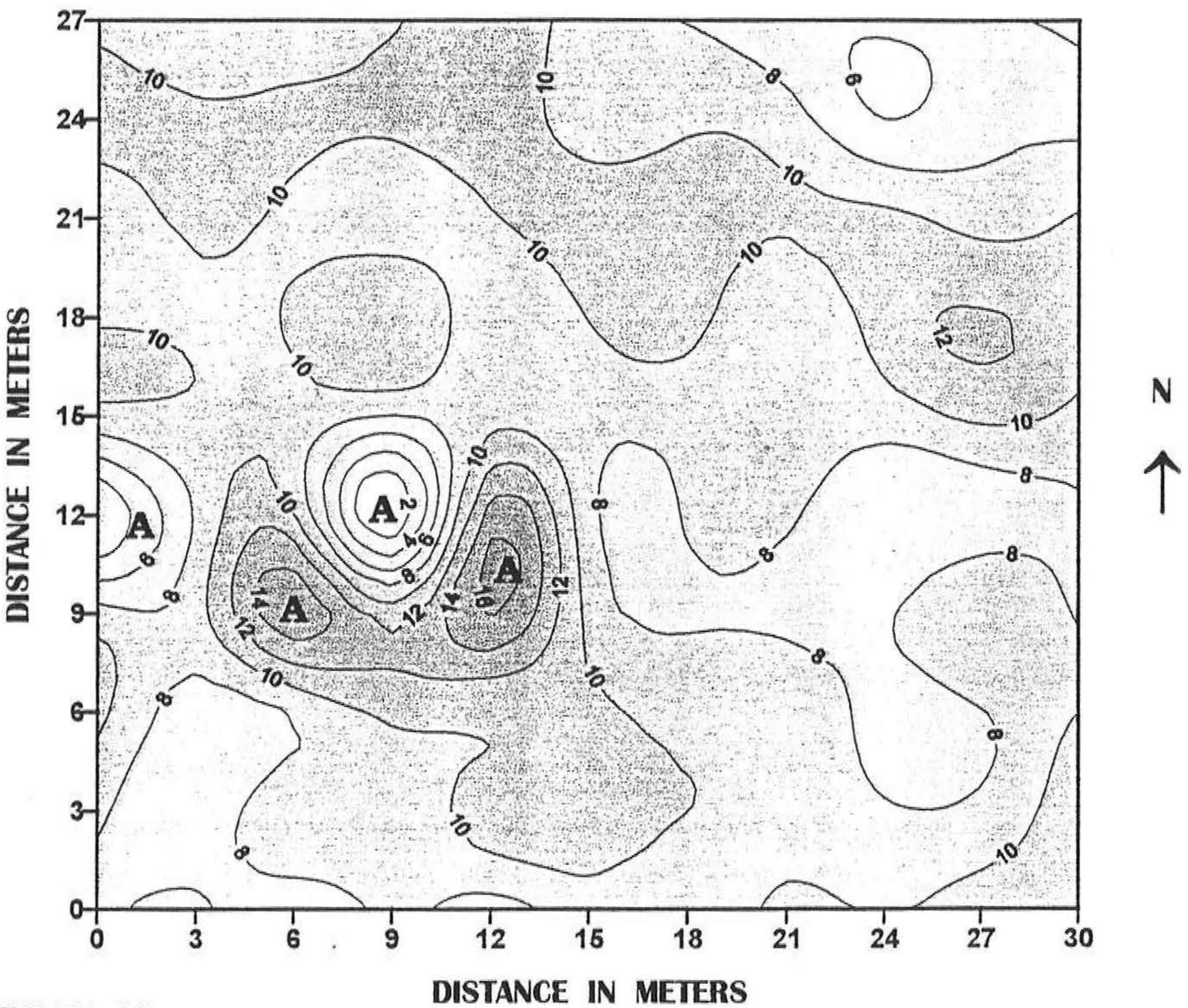


FIGURE 13

PREHISTORIC INDIAN VILLAGE SITE
MITCHELL, SOUTH DAKOTA

EM38 METER
VERTICAL DIPOLE ORIENTATION

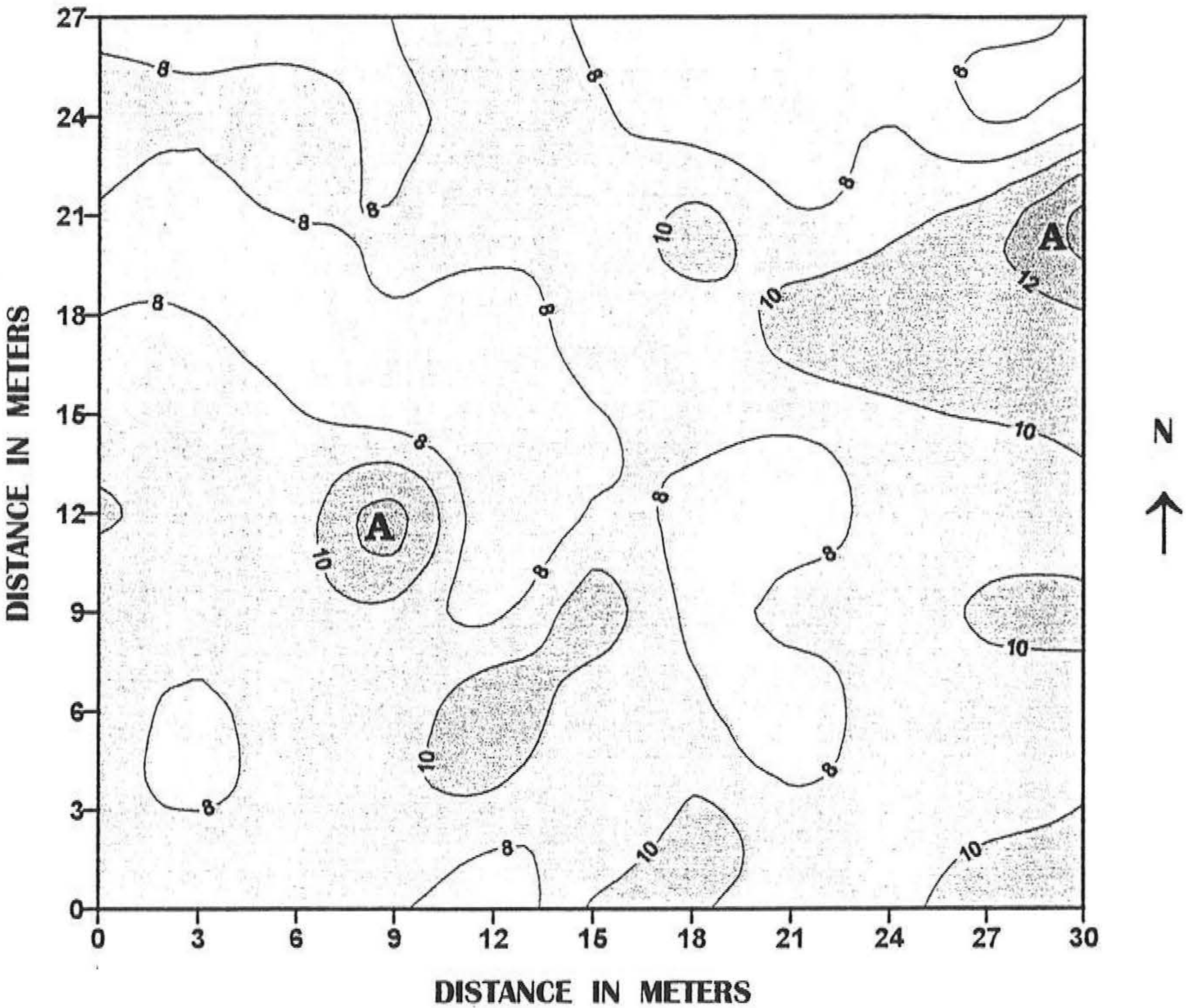


FIGURE 14