United States Department of Agriculture **Chester, PA 19013**
Soil Conservation Service **610-490-6042**

Subject: Geophysical Workshop **Date:** 17 October 1994

To: Dean Fisher
State Conservationist
USDA - Soil Conservation Service
Federal Building
200 Fourth Street SW
Huron, South Dakota 57350-2475

Purpose:
To conduct a training workshop on the uses of electromagnetic induction (EM) techniques for engineering and soil investigations.

Participants:
Pete Anderson, Ag. Engineer, SCS, Brookings, SD
Wayne Bachman, Asst. State Soil Scientist, SCS, Huron, SD
Kim Benthin, Ag. Waste Team Tech., SDACD, Brookings, SD
Kailash Bhatt, SDDENR, Pierre, SD
Scott Bickler, SDDENR, Sioux Falls, SD
Roy Boschee, Area Engineer, SCS, Brookings, SD
David Bronson, CET, SCS, Watertown, SD
Rick Carnduff, SDDENR, Pierre, SD
Kevin Christensen, SDDENR, Rapid City, SD
Jay Cofer, Office Manager, SDDENR, Vermillion, SD
Jim Doolittle, Professor, SDSU, Brookings, SD
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Tony Hagen, Technician, Lake Pelican Water Project District, Watertown, SD
Patricia Hammond, Hydrogeologist, SD Geological Survey, Vermillion, SD
Richard Hammond, Geologist, SD Geological Survey, Vermillion, SD
Curt Hanssen, Director, BSLP, Sisseton, SD
Arlan Jerke, SCT, SCS, Aberdeen, SD
Joe Jipp, SCT, SCS, Watertown, SD
Jim Kearney, Eng. Geologist, MNTC, SCS, Lincoln, NE
Kim Kempton, Soil Scientist, SCS, Webster, SD
Gary Kirschman, SCT, SCS, Madison, SD
Carlene Larson, SCT, SCS, Webster, SD
Ken Madison, Nat. Resource Scientist, SDDENR, Watertown, SD
Doug Malo, Professor, SDSU, Brookings, SD
Kalumbu Malekani, Graduate Student, SDSU, Brookings, SD
Mokgwakgwe Mashatola, Graduate Student, SDSU, Brookings, SD
Danny Merchen, SCT, SCS, Parker, SD
Jim Millar, Soil Scientist, SCS, Redfield, SD
Craig Olson, SCT, SCS, Brookings, SD
Eugene Preston, Soil Scientist, SCS, Sioux Falls, SD
Stacy Quail, Technician, Lake Pelican Water Project District, Watertown, SD
Ken Read, Ag. Waste Team Project Leader, SCS, Brookings, SD
Carol Reed, Geologist, SCS, Bismarck, ND
Diane Rickerl, Professor, SDSU, Brookings, SD
Steven Scholtes, SDDENR, Pierre, SD
Layne Schulz, Geologist, SD Geological Survey, Vermillion, SD
Loren Schultz, Soil Scientist, SCS, Aberdeen, SD
Cris Skonard, SDDENR, Sioux Falls, SD

Cindy Steele, Env. Engineer, SCS, Huron, SD
Cheryl Stohr, SCT, SCS, Clear Lake, SD
Mark Vomacka, SDDENR, Pierre, SD
Mary Lou Woolf, District Conservationist, SCS, Redfield, SD
Steve Winter, Soil Scientist, SCS, Redfield, SD

Activities:
Workshop adhered to the schedule outlined in Rodney Baumberger's letter of 2 September 1994. Field demonstration sites were located near Sisseton, Watertown, Redfield, and Sioux Falls, South Dakota.

Equipment:
The electromagnetic induction meters used were the EM38, EM31, and EM34-3 manufactured by Geonics Limited+. For each meter, the depth of observation is dependent upon intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. The EM38 meter integrates values of apparent conductivity over the upper 0.75 m in the horizontal dipole orientation, and over the upper 1.5 m in the vertical dipole orientation. The EM31 meter integrates values of apparent conductivity over the upper 2.75 m in the horizontal dipole orientation, and over the upper 6.0 m in the vertical dipole orientation.

The EM34-3 meter has intercoil spacings of 10, 20, or 40 m. A 10-m intercoil spacing was used in the investigations reported in this paper. With a 10-m intercoil spacing, the EM34-3 meter has observation depths of about 7.5 m and 15 m in the horizontal and vertical dipole orientations, respectively.

Discussion:

Agricultural Waste Facilities:

The purpose of this survey was to familiarize participants with the operations of the various meters, and to demonstrate the use of EM techniques to chart the extent of seepage and surface runoff from animal-waste holding facilities.

Site 1 - Roberts County
The survey area was located in an area of Heimdal-Svea loams, 0 to 2 percent slopes. Heimdal is a member of the coarse-loamy, mixed Udic Haploborolls and Svea is a member of the fine-loamy, mixed Pachic Udic Haploborolls families.

An irregularly shaped, rectangular grid was established in an open field on the eastern side of the Serocki waste-holding facility. The survey area covered about 2.0 acres with maximum dimensions of 500 and 250 feet. The grid interval was 50 feet. Survey flags were inserted in the ground at each 50 foot grid intersection. At each of the 44

+ Trade names have been used to provide specific information. Their mention does not constitute endorsement.

grid intersections, measurements were obtained with an EM31 meter in both the horizontal and vertical dipole orientations.

Figures 1 and 2 are two-dimensional plots of the data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. The interval is 5 mS/m. In each simulation, noticeable zones of relatively high apparent conductivity values (> 85 mS/m) appear to emanate from the east and northeast portions of the waste-holding facility. Within each zone, values of apparent conductivities decrease both horizontally (in an outward and downslope direction) and vertically (with increasing soil depth (horizontal > vertical dipole measurements)). The zones of higher conductivity values are restricted to a radius of about 50 to 100 feet from the facility. These patterns suggest the possible concentration of animal wastes in the upper part of soil profiles and its likely dissemination from the waste-holding facility. However, these patterns could also reflect the concentration of animal wastes in the soil from previous land use or management practices, or variations in soil type, till, or earthen materials related to the construction of the facility.

Several anomalous areas having high apparent conductivity values are evident in the southeast and northeast portions of the survey areas. These areas do not appear to be connected or associated with the animal waste-holding facility. They may represent differences in soils, till, or previous land uses.

Several fingers of low conductivity values extend from eastern (lower) border of the survey area toward the waste-holding facility. These fingers may delineate the locations of underlying lenses of coarser-textured materials within the till.

Site 2 - Roberts County

The selected site (Fischer) was located in an area of Forman-Buse loams, 9 to 15 percent slopes, and Buse-Forman loams, 21 to 40 percent slopes. Buse is a member of the fine-loamy, mixed Udorthentic Haploborolls and Forman is a member of the fine-loamy, mixed Udic Argiborolls families. However, as a large portion of the survey area was located on the embankment, most earthen materials profiled were borrowed.

The investigated waste-management system (Fischer) was designed to control lot runoff and collect waste from a 75 beef-cow operation. The pond does not hold water. In an attempt to detect seepage, a 350 by 60 foot, rectangular grid was established across a portion of the pond's embankment. The grid intervals were 20 and 50 feet. The survey area covered about a 0.5 acre area.

Survey flags were inserted in the ground at 20 by 50 foot intervals. At each of the 32 grid intersections, measurements were obtained with an EM31 meter in both the horizontal and vertical dipole orientations. A transit was used to establish grid lines and determine the surface elevation of each grid intersection. Elevations were not tied to a benchmark; the lowest recorded surface point was chosen as the 0.0 foot datum.

Figure 3 is a topographic map of the survey area. The contour interval is 2 feet. Relief along the embankment face was about 24 feet. The pond was located to the immediate south of the survey area. The borrow materials were located in the central portion of the survey area. Two prominent bends in the contour lines occur near the interface separating the borrow and natural materials.

Figures 4 and 5 are two-dimensional plots of the data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. The interval is 5 mS/m. In both plot, a fairly noticeable zone of relatively high apparent conductivity values appears in the north-central portion of the survey area along the base of the embankment. As water was observed on the soil surface within this zone, the higher apparent conductivity values were believed to reflect increased moisture contents of the borrowed materials.

In both figures, on the top of the embankment adjacent to the pond (south border of survey area), apparent conductivity increase in the eastern portion of the borrow materials. This pattern could indicate differences in the composition of the borrowed materials or seepage. In addition, values were conspicuously higher in measurements obtained in the vertical dipole orientation suggesting the possibility of either deep seepage or higher clay contents in this portion of the embankment.

A comparison of the patterns in figures 4 and 5 suggests a lateral flow of seepage near the base of the embankment. With the EM31 meter in the deeper-sensing (6 m) vertical dipole orientation, the zone of higher conductivities appears further up-slope (see Figure 5) than in measurements obtained in the shallower-sensing (2.75 m) horizontal dipole orientation. This zone appears to have been displaced further down the embankment in the data collected with the EM31 meter in the horizontal dipole orientation. If this zone does in fact represents seepage, it was detected at deeper depths within the borrow materials on higher-lying sections of the embankment and at shallower depths along the base of the embankment.

Site 3 - Codington County

The waste-management system was designed to control runoff and collect waste from a dairy operation. The pond appears to hold water but a nearby wells have become contaminated. An irregularly shaped, 950 by 500 foot, rectangular grid was established around the east, south, and west sides of the waste-holding structure. The grid intervals was 50 feet. The survey area covered about a 4.2 acre area. Farm buildings, fence lines, and hay bales obstructed survey operations and limited the size of the survey area. In addition, crews operating different meters (EM38, EM31, and EM34-3) surveyed different portions of the grid.

Survey flags were inserted in the ground at 50 foot intervals. At each incorporated grid intersections, measurements were obtained with the EM38 (60), EM31 (82) and EM34-3 (76) meters in both the horizontal and vertical dipole orientations. A transit was used to establish grid lines and determine the surface elevation at 69 grid intersections. Elevations were not tied to a benchmark; the lowest recorded surface point was chosen as the 0.0 foot datum.

Figure 6 is a topographic map of the survey area. The contour interval is 1 foot. Within the survey area, relief was about 12 feet. The surface slopes towards the southeast. A drainage channel was located to the southeast and east of the survey area.

Figures 7 and 8 are two-dimensional plots of the data collected with the EM38 meter in the horizontal and vertical dipole orientations, respectively. The interval is 5 mS/m. In both plot, values of apparent conductivity increase towards the south and away from the waste-holding structure. In both orientations, values of apparent conductivity were highest in the southwest portion and bordering a drainage channel in the southeast portion of the study area. Though these elevated values were associated with increase moisture contents and variations in soil types, values in excess of 70 mS/m are generally believed to indicate high concentration of soluble salts within the soil profiles.

In figures 7 and 8, a zone of higher conductivity values extends towards the waste-holding structure between grid lines 250 and 400 (near lower border of plots). As values within this zone are highest at a slight distance away from the waste-holding facility, no direct linkage is possible without other supporting information.

Figures 9 and 10 are two-dimensional plots of the data collected with the EM31 meter in the horizontal and vertical dipole orientations, respectively. The interval is 5 mS/m. In both plot, values of apparent conductivity increase towards the south and away from the waste-holding structure. In both orientations, values of apparent conductivity were highest in the south-central and in the southwest portion of the study area.

As with measurements taken with the EM38 meter (see figures 7 and 8), a zone of higher conductivity values extends towards the waste-holding structure between grid lines 250 and 400. As values within this zone are highest at a slight distance away from the waste-holding facility and increase towards the drainage channel, no direct association is possible without other information.

In Figure 9, a zone of higher conductivity values extends away from the farm structures in the extreme northeast portion of the study area. This feature represents either a near-surface phenomenon or signal interference from nearby farm buildings. Values within this zone were highest (>90 mS/m) near the structures and decrease towards the east. This zone is considered significant because of its proximity to the existing well system. Further investigations should be made in this area.

In Figure 10, a zone of higher conductivity values appears to extend away from the farm structures in the northeast portion of the study area. This feature may represent interference caused by the farm buildings or possible seepage. Values within this zone are highest (>60 mS/m) near the structures and dissipate in a plume-like fashion towards the south. This zone is considered significant because of its proximity to the existing well system. Further investigations should be made in this area.

Figures 11 and 12 are two-dimensional plots of the data collected with the EM34-3 meter in the horizontal and vertical dipole orientations, respectively. The interval is 5 mS/m. In general, compared with other plots of apparent conductivity within the study area (see figures 7 to 10), these values are lower and less variable. It is therefore presumed that the earthen materials become less conductive and more homogeneous with increasing observation depths.

In Figure 12, a conspicuous, anomalous pattern appears in the southwest portion of the study area. This pattern is believed to have been produce from "cultural noise" or signal interference from a fence-line.

Soils Investigation with EM techniques

Electromagnetic induction techniques can be used to map spatial variations and assess the rate and magnitude of change in soils and soil properties. Values of apparent conductivity are seldom diagnostic in themselves. However, lateral and vertical variations in these measurements can be used to infer changes in soils and soil properties. Electromagnetic responses are dependent on soil properties. Variations in electromagnetic responses are produced by changes in soil moisture, salt content, texture, and mineralogy. Each of these factors will affect the apparent conductivity of soils.

Soils and soil map units have been differentiated by their unique and characteristic ranges of EM responses. As EM measurements integrate several soil properties, responses can be correlated within a given geographic areas to a particular soil or soils.

Each soil will have a characteristic EM response. For a particular soil, the EM response will constitute a range of values which will be influenced by temporal variations in soil moisture and temperature. Furthermore, cultural and terrain features can be expected to influence these ranges. Within a given geographic area, the conductivities of some soils will overlap. Similar soils will share a similar range in EM responses. However, some soil properties and types can be inferred with EM techniques provided one is cognizant of changes in parent materials, drainage, topography, and vegetation.

Site 4 - Area of Beotia-Rondell silt loam, Spinks County

The study site consisted of about 0.9 acre of cropland in central Spinks County. Relief was about 1.4 feet. Beotia is a member of the fine-silty, mixed Pachic Udic Haploborolls family. The Rondell soil is a member of the fine-silty, mixed, Typic Calciborolls family.

A 200 by 200 foot rectangular grid was established across the study site. Survey flags were inserted in the ground at 50 foot intervals. At each of the 25 grid intersections, measurements were obtained with an EM38 and EM31 meters in both the horizontal and vertical dipole orientations.

A transit was used to establish grid lines and determine surface elevations at each grid intersection. Elevations were not tied to a

benchmark; the lowest recorded surface point was chosen as the 0.0 foot datum.

The topography of study site has been simulated in Figure 13. The contour interval is 0.25 foot. In general, the surface slopes towards the north and northeast.

Figures 14 and 15 represent two-dimensional plots of apparent conductivity values collected with an EM38 meter in the horizontal and vertical dipole orientations, respectively. In each plot, the interval is 10 mS/m. In both plots, responses appear to increase laterally towards the north and northwest. This pattern followed a general decline in surface elevations and an observed change in soil type from Beotia to Rendoll. Higher values of apparent conductivity in areas of Rendoll soil were attributed to higher concentration of calcium carbonate and other more soluble salts in the profile. However, values in excess of 100 mS/m were associated with saline soil conditions.

Figures 16 and 17 represent two-dimensional plots of apparent conductivity values collected with an EM31 meter in the horizontal and vertical dipole orientations, respectively. In each plot, the interval is 10 mS/m. Similar patterns can be observed between the data collected with both the EM38 and EM31 meters and in both orientations. Both meters can be used to map variations in soils and soil properties.

In both figures 16 and 17, EM responses appear to increase laterally towards the north and northwest. Spatial patterns were similar to those collected with the EM38 meter (Figures 14 and 15). However, EM responses measured with the EM31 meter were generally lower and less variable than response measured with the EM38 meter across the site. With the EM31 meter, at all observation sites, responses decreased with increasing depths of observation (vertical < horizontal dipole orientation). This trend implies the occurrence of more conductive materials (i.e. higher clay, soluble salts, or moisture contents) near the surface and more resistive materials at greater soil depths.

<u>Site 5 - Area of Great Bend-Beotia silt loams, till substratum, 0 to 2 percent slopes, Spinks County</u>

The study site consisted of about 0.7 acre, partly in cropland and partly idle land in south-central Spinks County. Relief was about 3.3 feet. Great Bend and Beotia soils are members of the fine-silty, mixed Udic Haploborolls and the fine-silty, mixed Pachic Udic Haploborolls family, respectively.

A 200 by 150 foot rectangular grid was established across the study site. Survey flags were inserted in the ground at 50 foot intervals. At each of the 20 grid intersections, measurements were obtained with an EM31 meter in both the horizontal and vertical dipole orientations.

A transit was used to establish grid lines and determine surface elevations at each grid intersection. Elevations were not tied to a benchmark; the lowest recorded surface point was chosen as the 0.0 foot datum.

The topography of study site has been simulated in Figure 18. The contour interval is 0.5 foot. In general, the surface slopes towards the west and the James River (immediately to the west of survey area).

Figures 19 and 20 represent two-dimensional plots of apparent conductivity values collected with an EM31 meter in the horizontal and vertical dipole orientations, respectively. In each figure, the interval is 5 mS/m. In both plots, responses appear to increase laterally towards the east. This pattern was related to changes in surface elevations, distance from the James River, and followed a predicted increase in the thickness of lacustrine deposits over till. Higher values of apparent conductivity were associated with thicker deposits of lacustrine sediments over till. Lower values of apparent conductivity were observed along the bluffs and over coarser textured (sand and gravel deposits) soil materials.

The affects of differences in management practices existing between the idle land to the west of the fence line and cultivated cropland to the east of the fence line on EM responses were not evident in the plots.

Site 6 - Area of Great Bend-Beotia silt loams, 0 to 2 percent slopes, Spinks County

In portions of Spinks County, irrigation waters have deposited excessive amounts of sodium salts on the soil surface. Through this process, some areas of Great Bend and Beotia have become sodium-affected.

Three sites having differing lengths (long, short, none) of irrigation were selected within a delineation of Great Bend and Beotia silt loam, 0 to 2 percent slopes. The purpose of this investigation was to evaluate the performance of the EM38 meter in areas of sodium-affected soils.

Results from a brief study conducted on adjoining fields of the same delineation of Great Bend and Beotia silt loam, 0 to 2 percent slopes, appeared favorable. However, additional studies are needed with a greatly expanded sample population and some chemical analysis to confirm the seeming relationship. Table 1 summarizes the results of the cursory study.

Table 1
EM Response in irrigated areas of Great Bend and Beotia soils under differing lengths of irrigation

Length of Irrigation	Number of Observations	EM38(H) Average	Standard Deviation
Long	4	45.25 mS/m	6.40
Short	5	34.60 mS/m	4.56
None	6	24.83 mS/m	2.93

The measurements obtained with an EM38 meter in the horizontal dipole orientation on the three sites were analyzed by means of an analysis of variance. The results indicate a significant difference in EM

responses collected in the horizontal dipole orientation (observation depth 0 to 75 cm) among the three sites (see Table 2).

Table 2
Analysis of Variance for EM38 (horizontal) Measurements among Three Irrigation Sites

Source of Variation	D.F.	Sum of Squares	Mean Squares	F-value	Probability
Between	2	1008.95	504.48	24.33	.0001
Within	12	248.78	20.73		

Results:

1. Results from EM surveys conducted in South Dakota have been condensed into the accompanying two-dimensional plots. Results from EM survey are interpretative and should be verified with field observations. The enclosed plots provide understanding into the subsurface conditions existing within each study area. These plots can be used to guide the selection of monitoring or sampling sites.

2. All participants had the opportunity to operate and become familiar with the various EM meters. At each study site, the performance of the various meters to chart the extent of seepage and surface runoff from animal-waste holding facilities was evaluated by the participants. General response among the participants appeared to be very favorable. Based on this response, an EM34-3 meter was loaned to South Dakota by Jim Kearney of the MNTC.

3. The results of soil investigations with EM31 and EM38 meters in Spinks County were perceived as favorable. Electromagnetic induction techniques may provide a rapid and accurate method to describe variations in soils, soil properties, and stratigraphies in South Dakota. Geophysical field assistance is available to South Dakota through the National Soil Survey Center (See part 631.04b of the National Soil Handbook (NSH)). Limited field investigation assistance or loan of EM meters can be requested through the NSSC (see NSH 631.06b).

4. I wish to applaud Cindy Steele for her excellent preparation and organization of this workshop. Cindy deserved credit for her assistance in introducing this technology to the people and various agencies represented at this workshop.

With kind regards,

James A. Doolittle

James A. Doolittle
Soil Specialist

cc:
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Steve Holzhey, Assistant Director, NSSC, MNTC, SCS, Lincoln, NE
Jim Kearney, Eng. Geologist, MNTC, SCS, Lincoln, NE
Jerome Schaar, State Soil Scientist, SCS, Huron, SD
Cindy Steele, Env. Engineer, SCS, Huron, SD

Figure 1

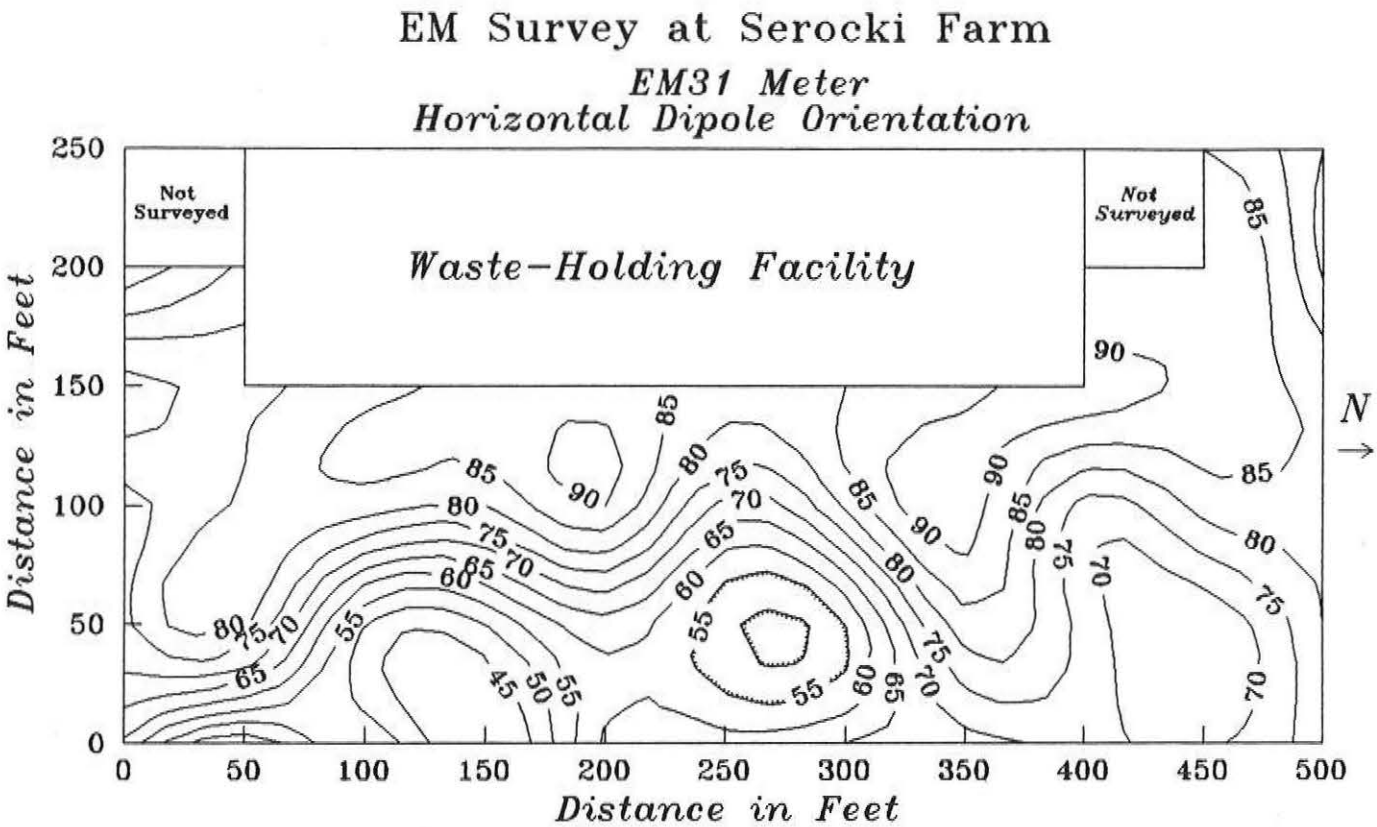

EM Survey at Serocki Farm
EM31 Meter
Horizontal Dipole Orientation
Not Surveyed
Waste-Holding Facility
Not Surveyed
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500

Figure 2

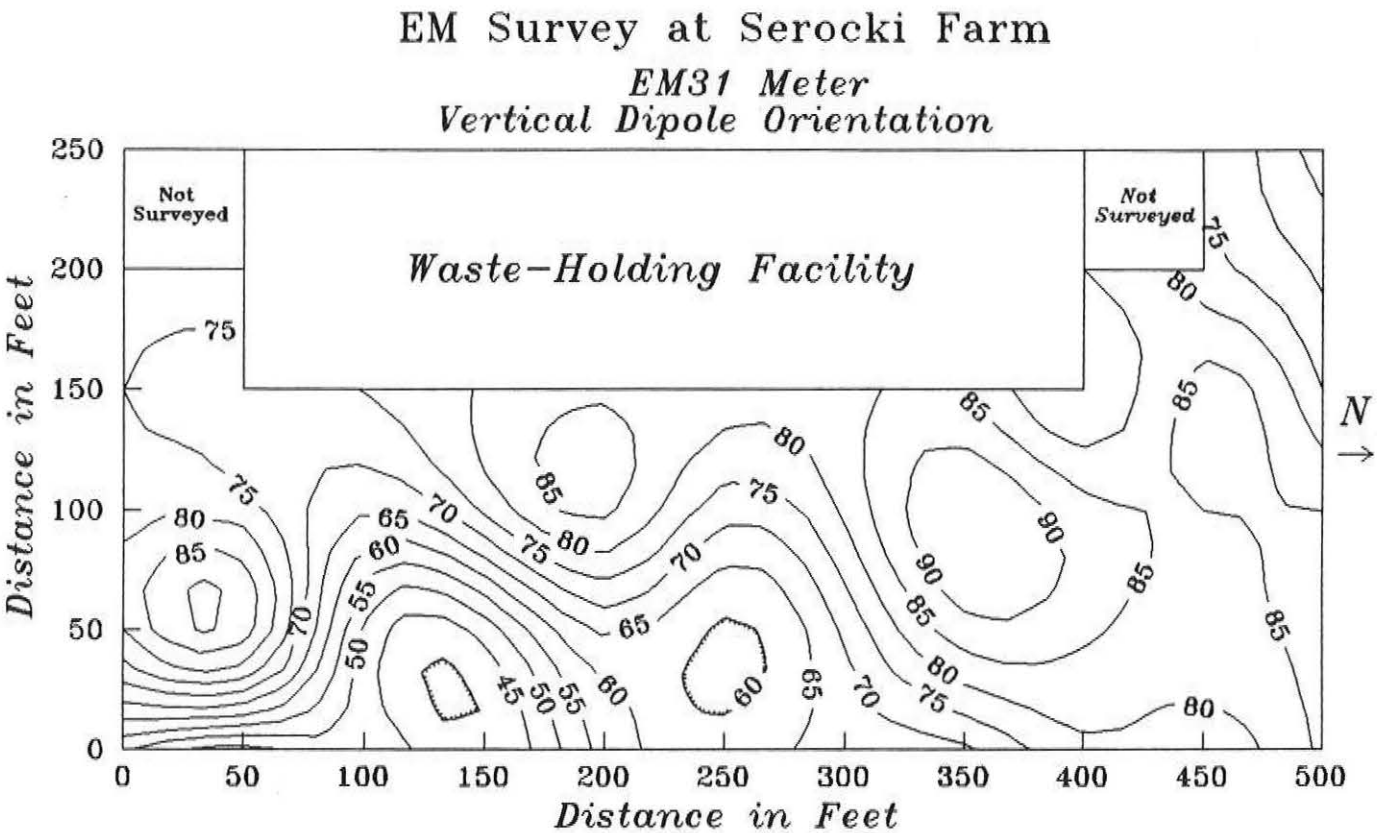

EM Survey at Serocki Farm
EM31 Meter
Vertical Dipole Orientation
Not Surveyed
Waste-Holding Facility
Not Surveyed
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500

Figure 3

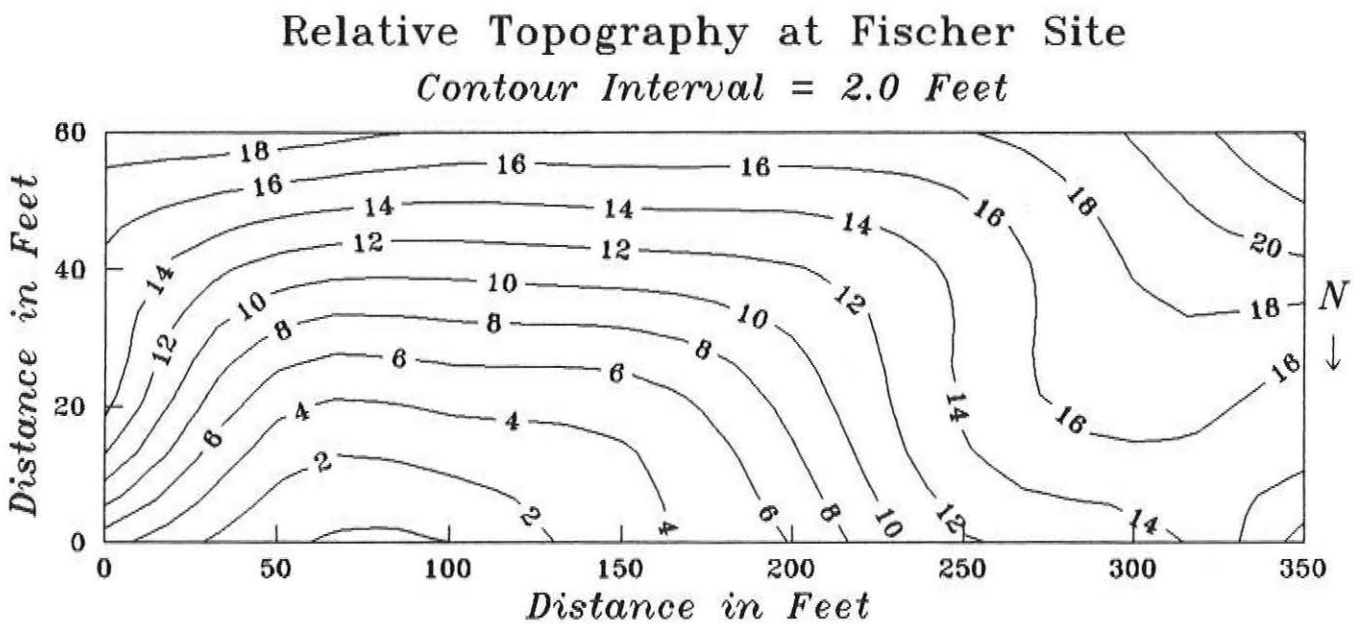
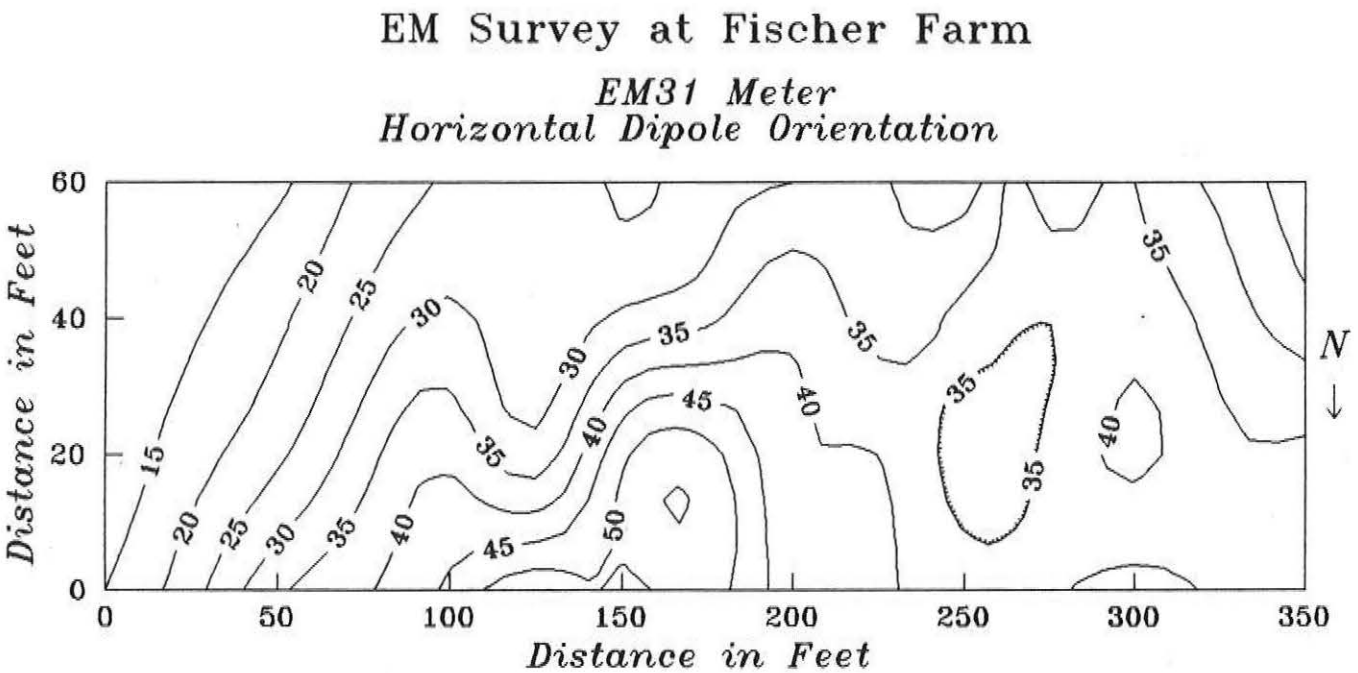

Relative Topography at Fischer Site
Contour Interval = 2.0 Feet
Distance in Feet
Distance in Feet
N
0
20
40
60
0
50
100
150
200
250
300
350
2
4
6
8
10
12
14
16
18
20

Figure 4


EM Survey at Fischer Farm
EM31 Meter
Horizontal Dipole Orientation
Distance in Feet
Distance in Feet
0
20
40
60
0
50
100
150
200
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300
350
15
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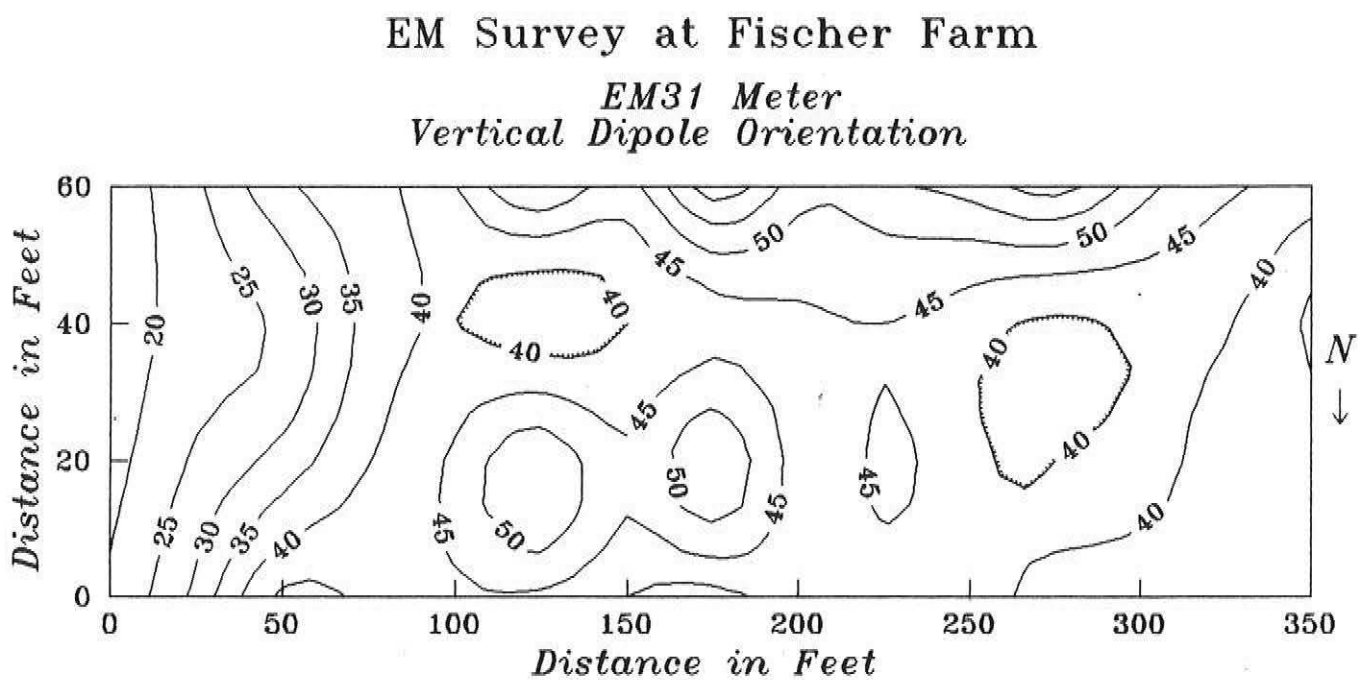
25
30
35
40
45
50
N

Figure 5


EM Survey at Fischer Farm
EM31 Meter
Vertical Dipole Orientation
Distance in Feet
Distance in Feet
N
0
20
40
60
0
50
100
150
200
250
300
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25
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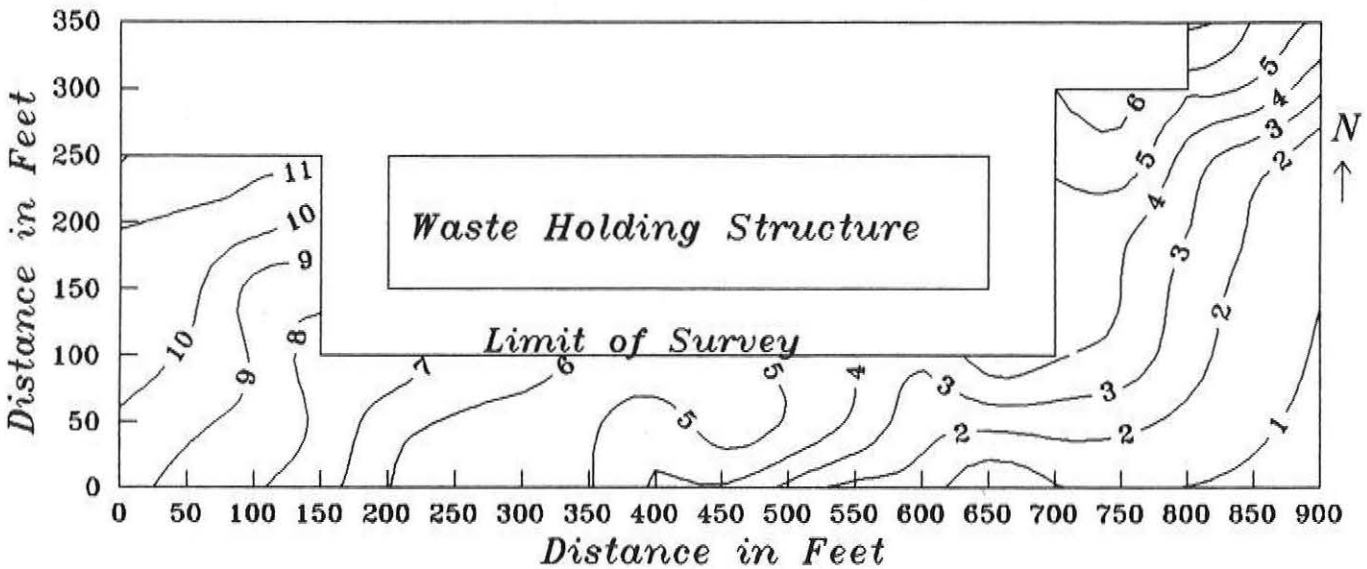
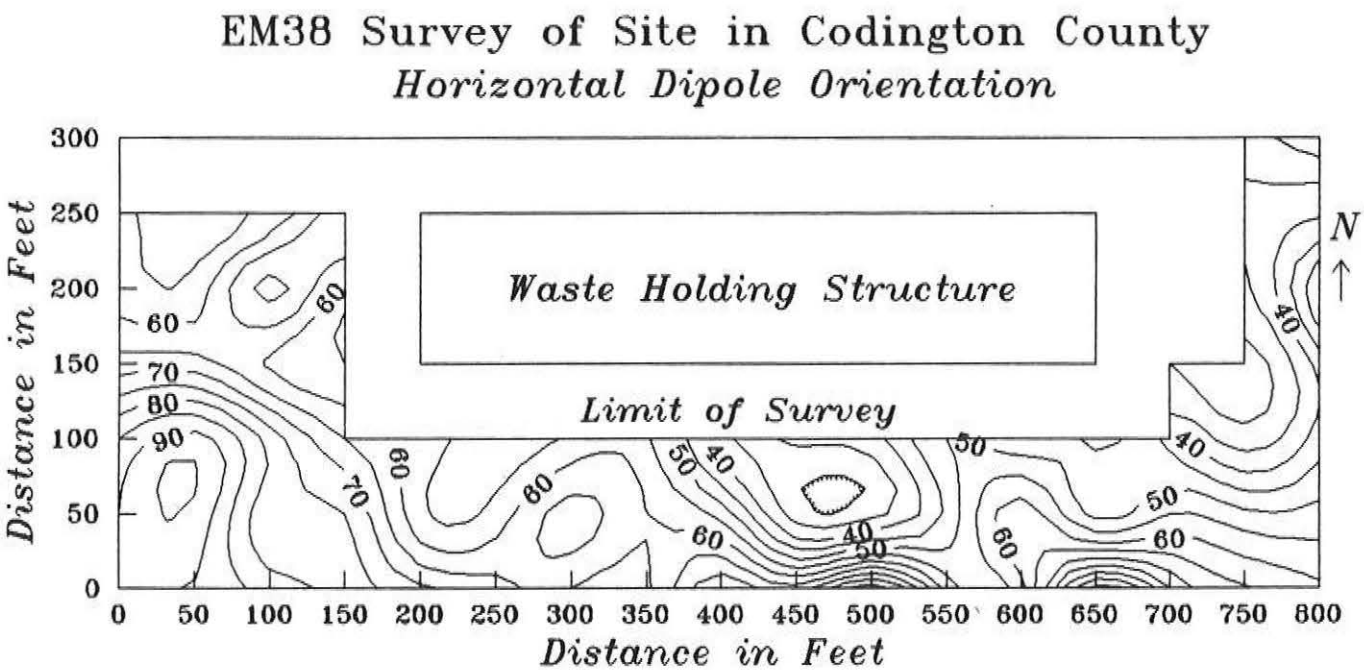
35
40
45
50

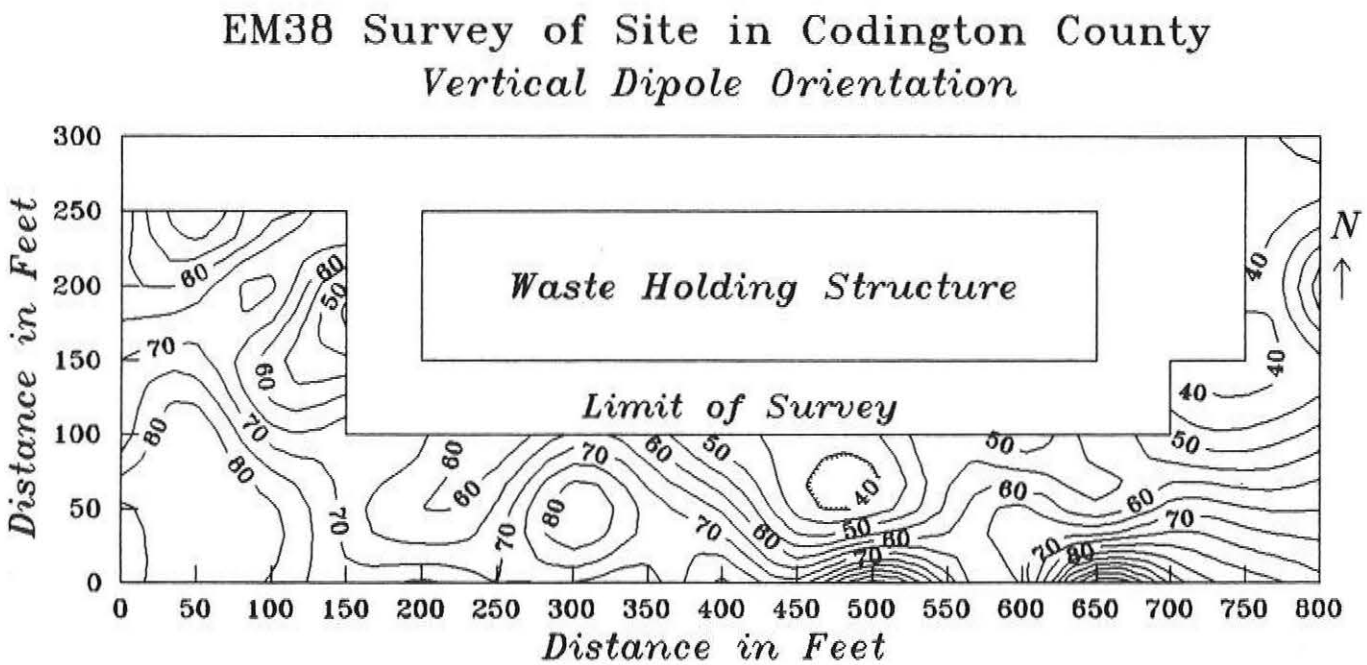
Figure 6

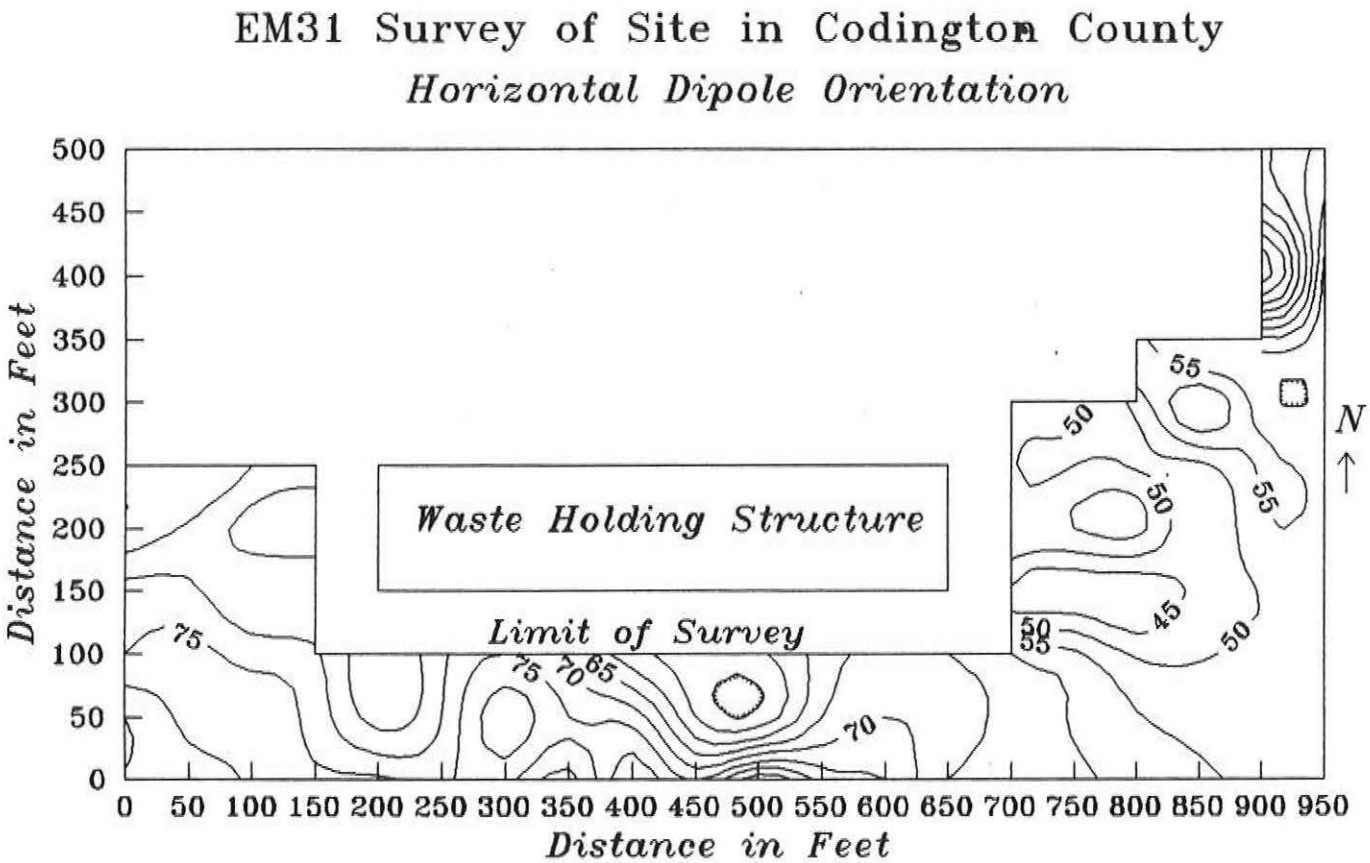
Relative Topography of the Site in Codington County

Contour Interval = 1.0 foot




EM38 Survey of Site in Codington County
Horizontal Dipole Orientation
Waste Holding Structure
Limit of Survey
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
40
50
60
70
80
90


EM38 Survey of Site in Codington County
Vertical Dipole Orientation
Waste Holding Structure
Limit of Survey
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800


EM31 Survey of Site in Codington County
Horizontal Dipole Orientation
Waste Holding Structure
Limit of Survey
Distance in Feet
Distance in Feet
N
0
50
100
150
200
250
300
350
400
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650
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70
65
55
50
45

Figure 10

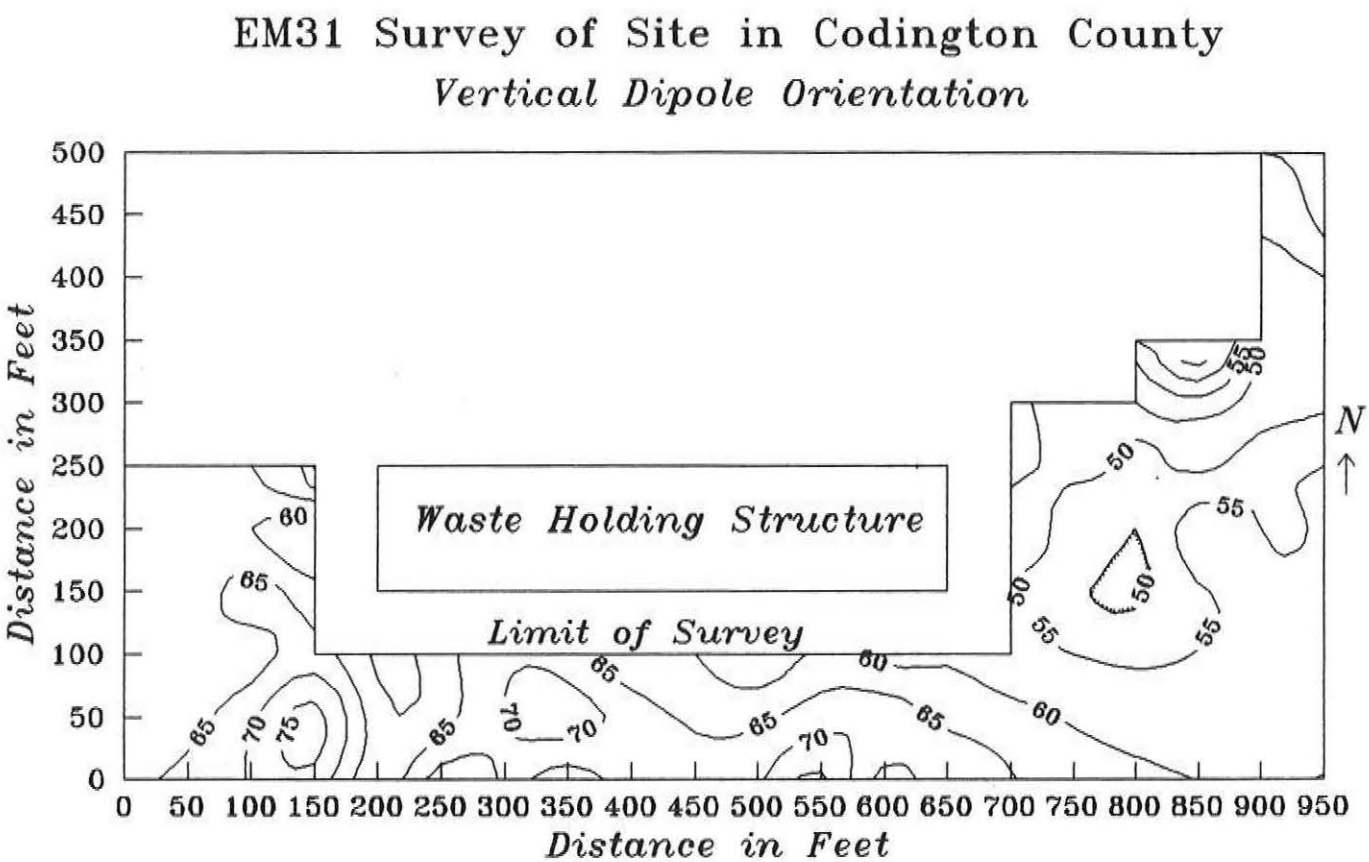

EM31 Survey of Site in Codington County
Vertical Dipole Orientation
Waste Holding Structure
Limit of Survey
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950
50
55
60
65
70
75

Figure 11

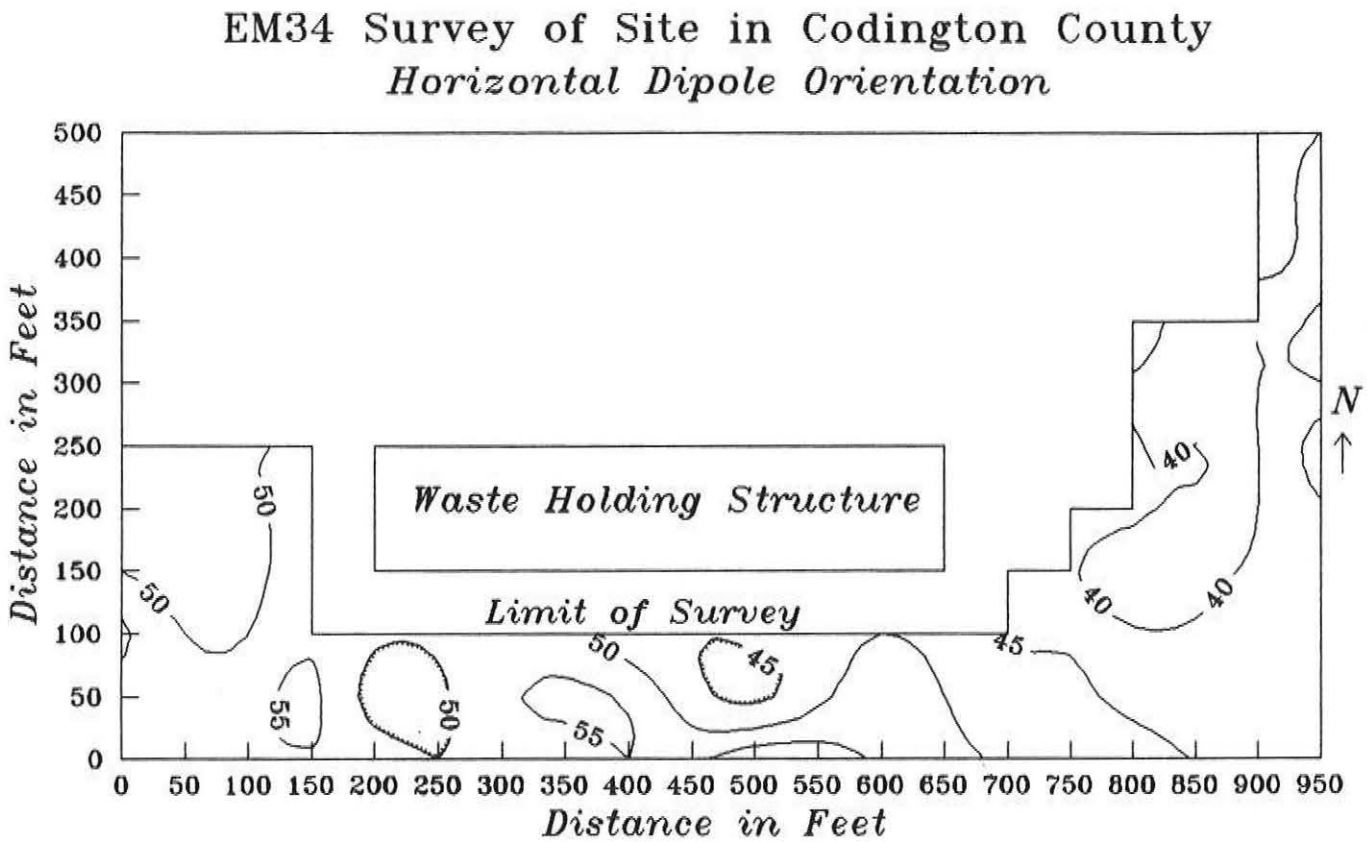

EM34 Survey of Site in Codington County
Horizontal Dipole Orientation
Waste Holding Structure
Limit of Survey
N
Distance in Feet
Distance in Feet
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
55
50
45
40

Figure 12

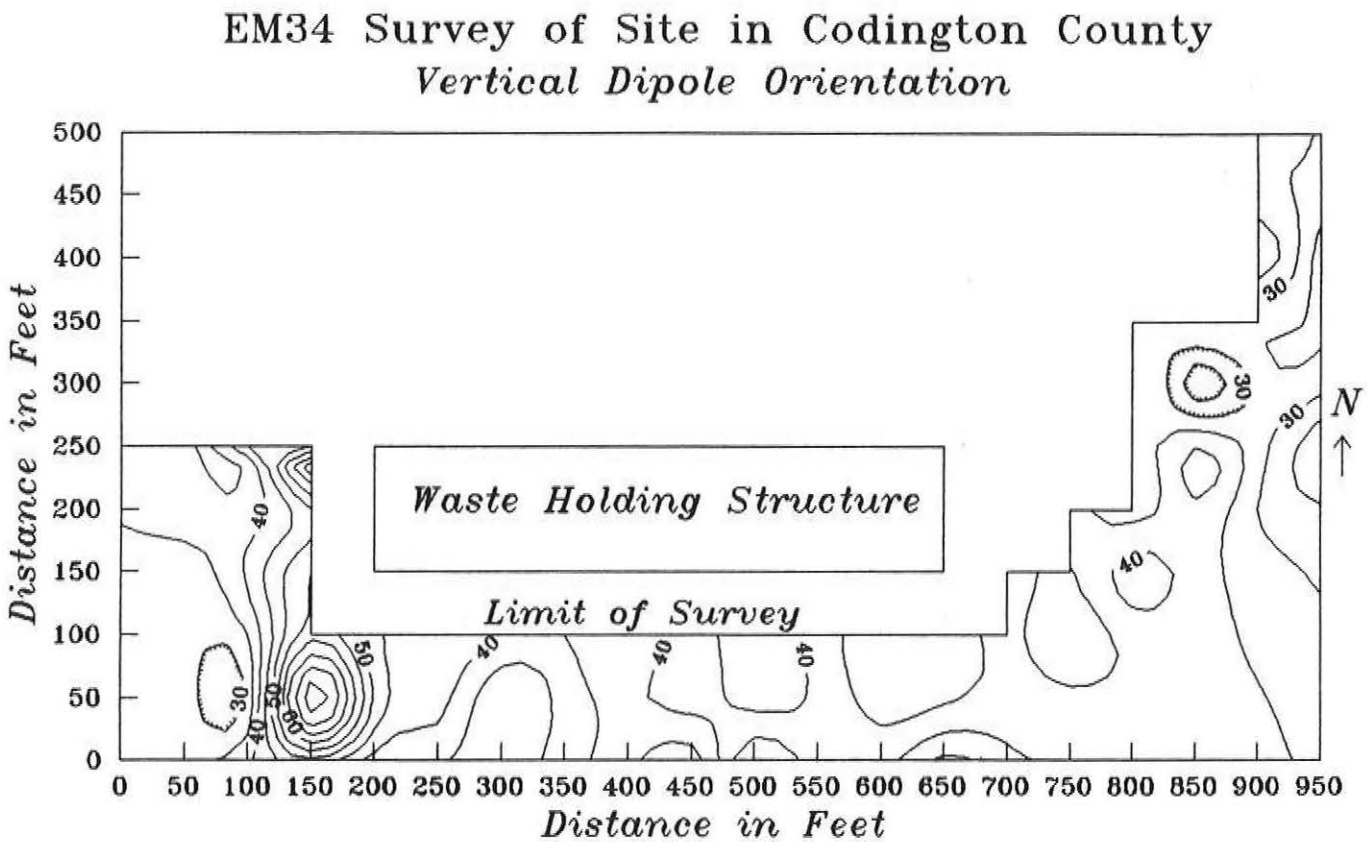

EM34 Survey of Site in Codington County
Vertical Dipole Orientation
Waste Holding Structure
Limit of Survey
Distance in Feet
Distance in Feet
N
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
900
950
30
40
50
60

Figure 13

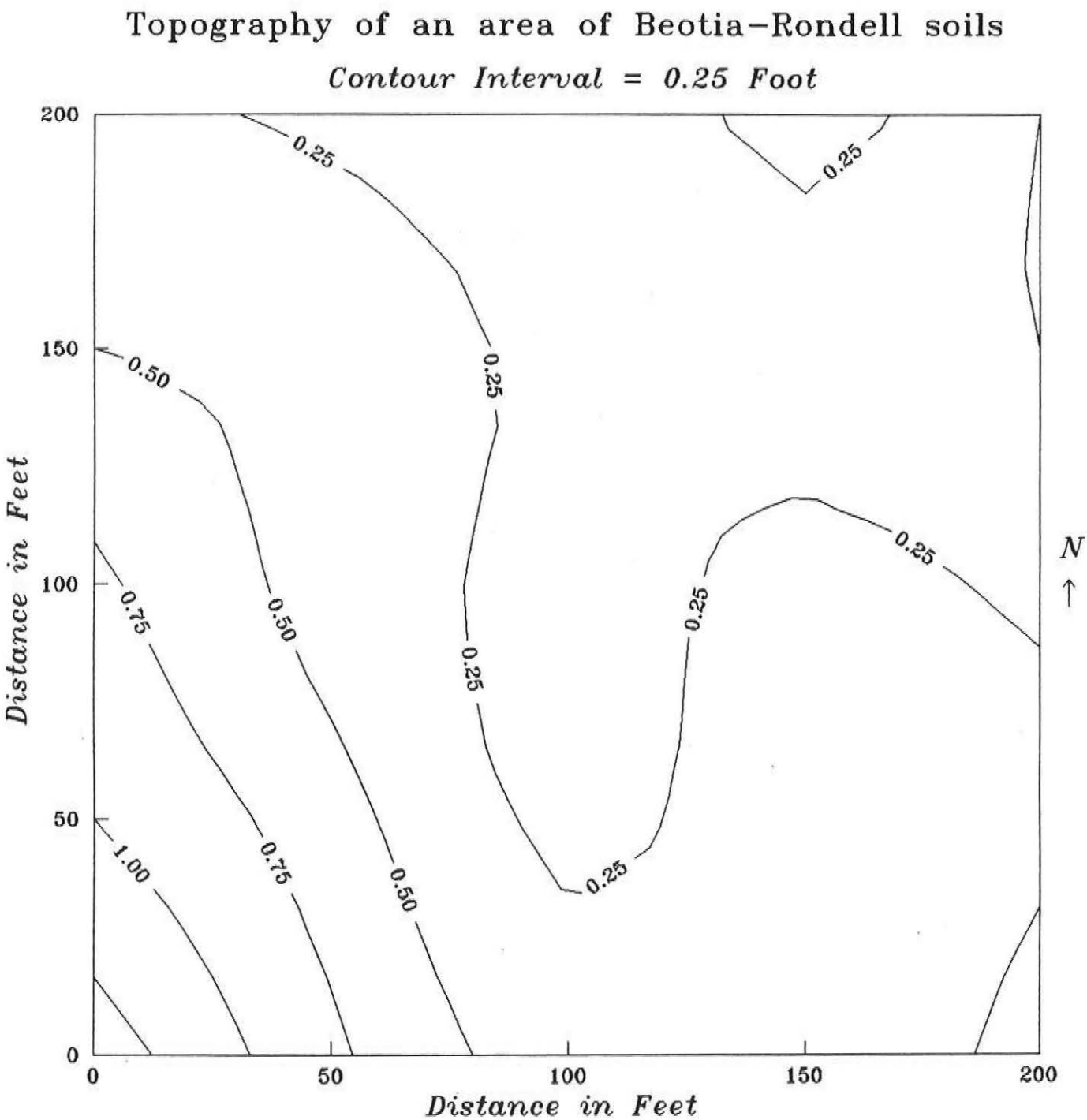

Topography of an area of Beotia-Rondell soils
Contour Interval = 0.25 Foot
0.25
0.50
0.75
1.00
N
Distance in Feet
Distance in Feet
0
50
100
150
200

Figure 14

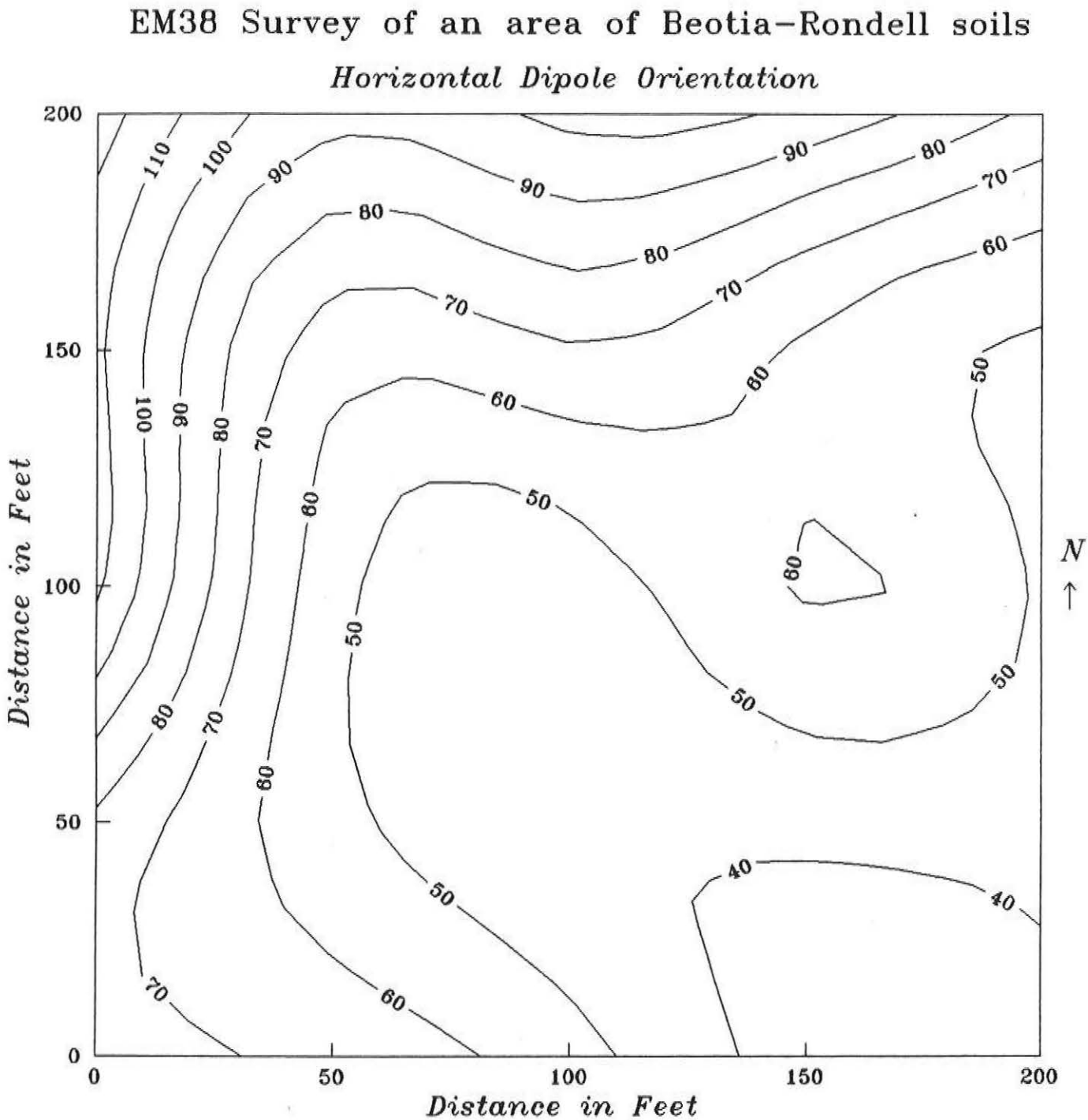

EM38 Survey of an area of Beotia-Rondell soils
Horizontal Dipole Orientation
Distance in Feet
Distance in Feet
N
0
50
100
150
200
110
100
90
80
70
60
50
40

Figure 15

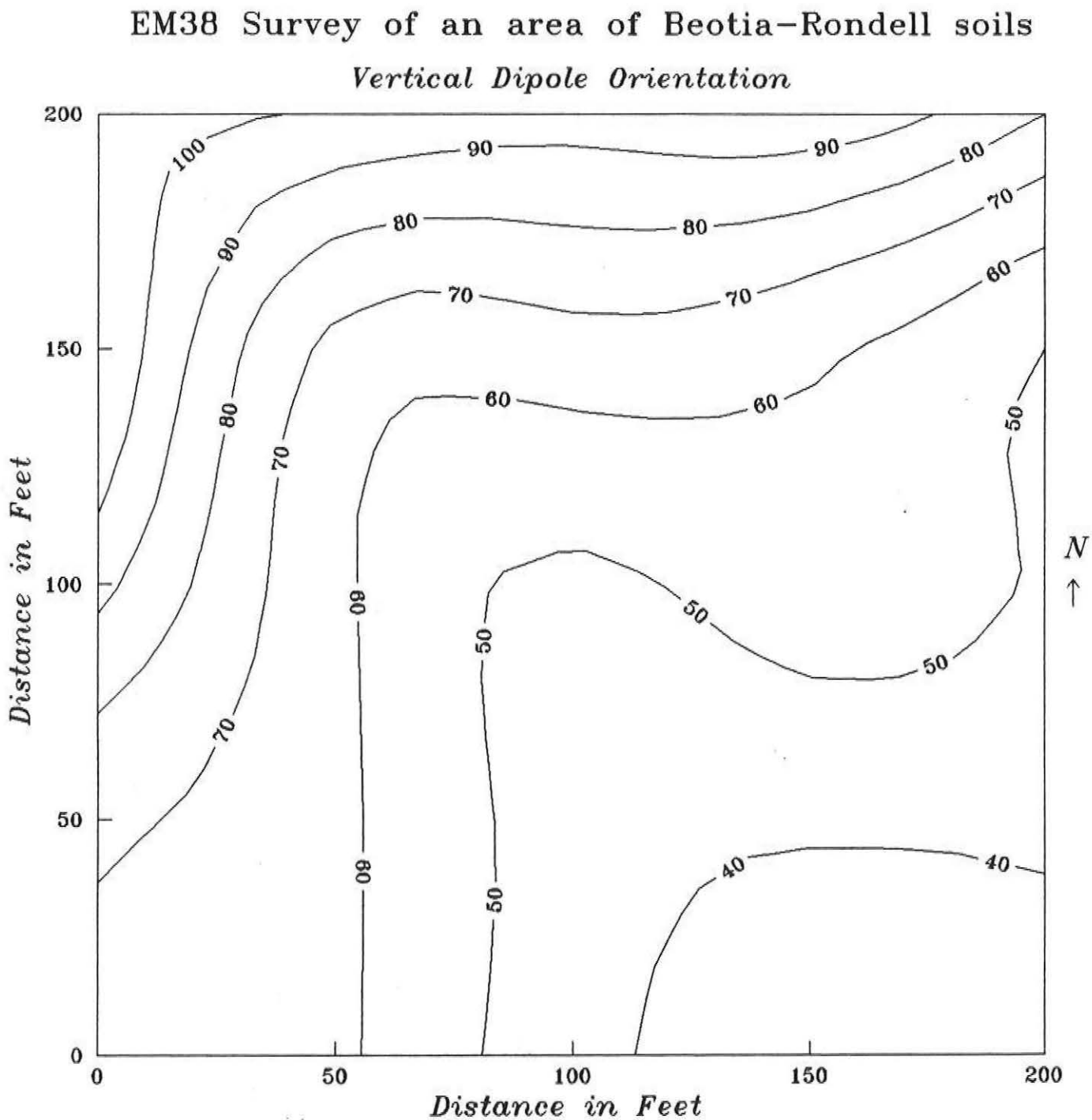

EM38 Survey of an area of Beotia-Rondell soils
Vertical Dipole Orientation
Distance in Feet
Distance in Feet
N
0
50
100
150
200
100
90
80
70
60
50
40

Figure 16

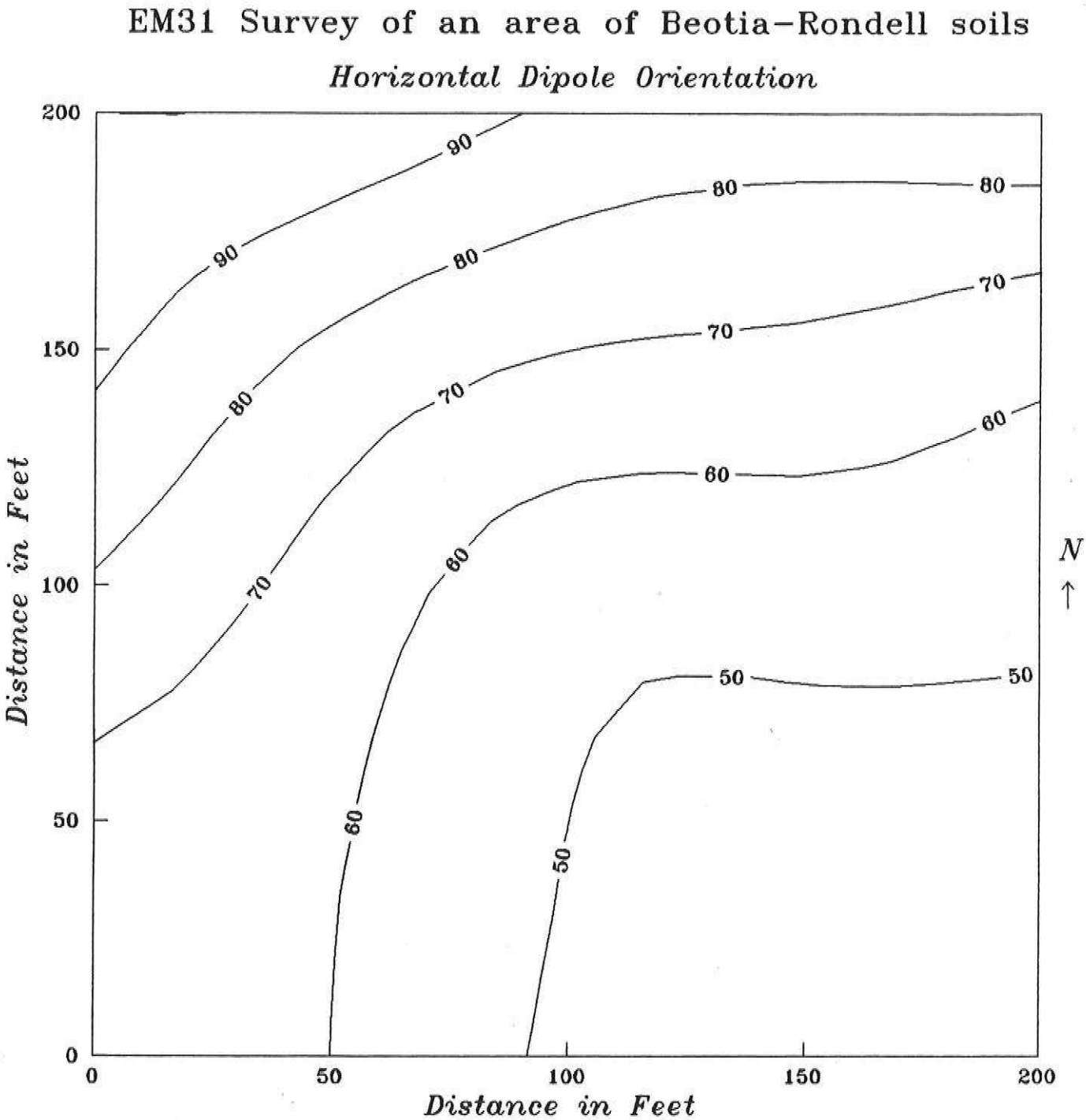

EM31 Survey of an area of Beotia-Rondell soils
Horizontal Dipole Orientation
Distance in Feet
Distance in Feet
N
0
50
100
150
200
0
50
100
150
200
90
90
80
80
80
80
70
70
70
70
60
60
60
60
50
50
50

Figure 17

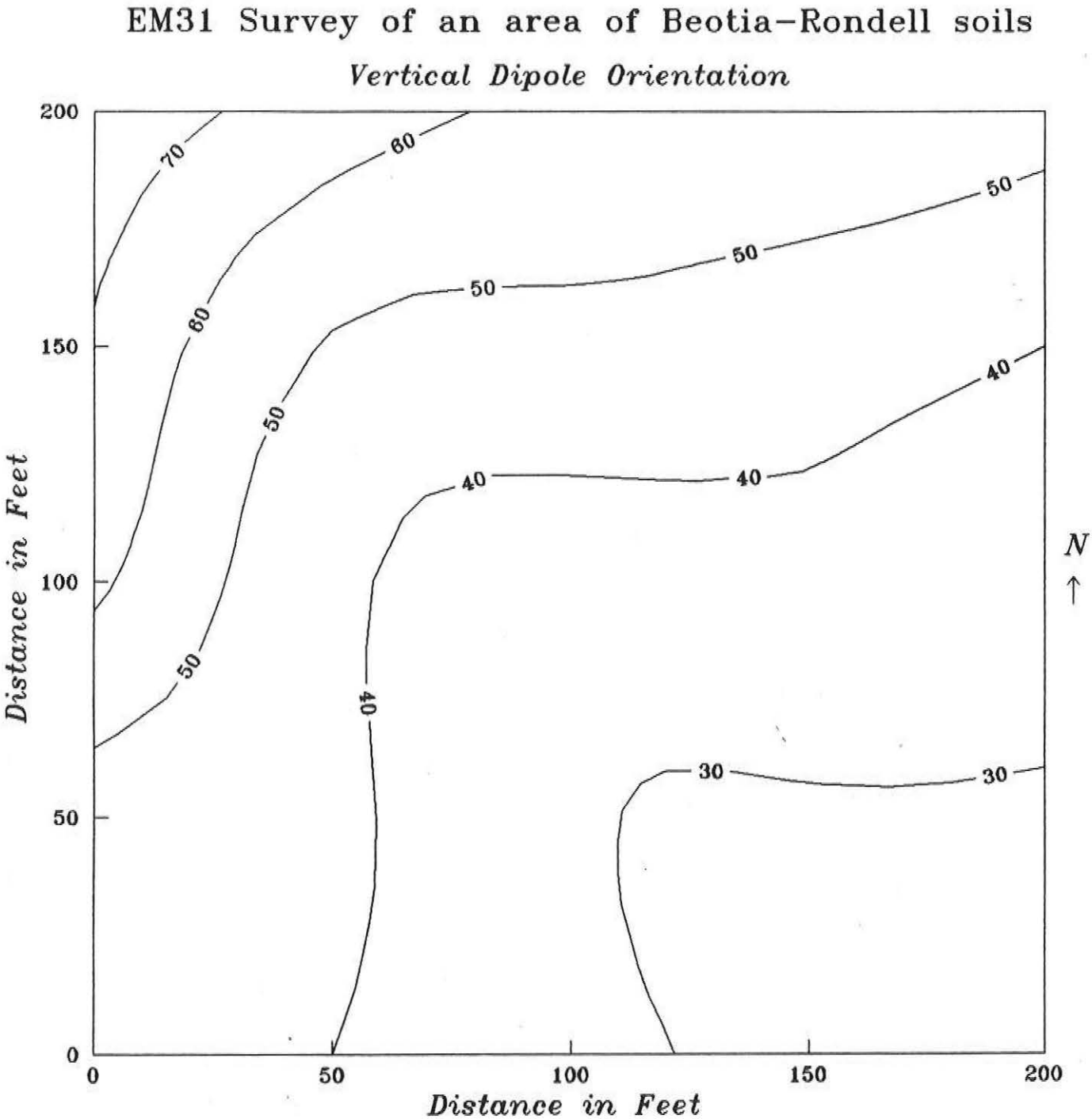

EM31 Survey of an area of Beotia-Rondell soils
Vertical Dipole Orientation
Distance in Feet
Distance in Feet
N
0
50
100
150
200
70
60
60
50
50
50
50
40
40
40
40
30
30

Figure 18

Topography of an area of Great Bend till substratum

Contour Interval = 0.5 Foot

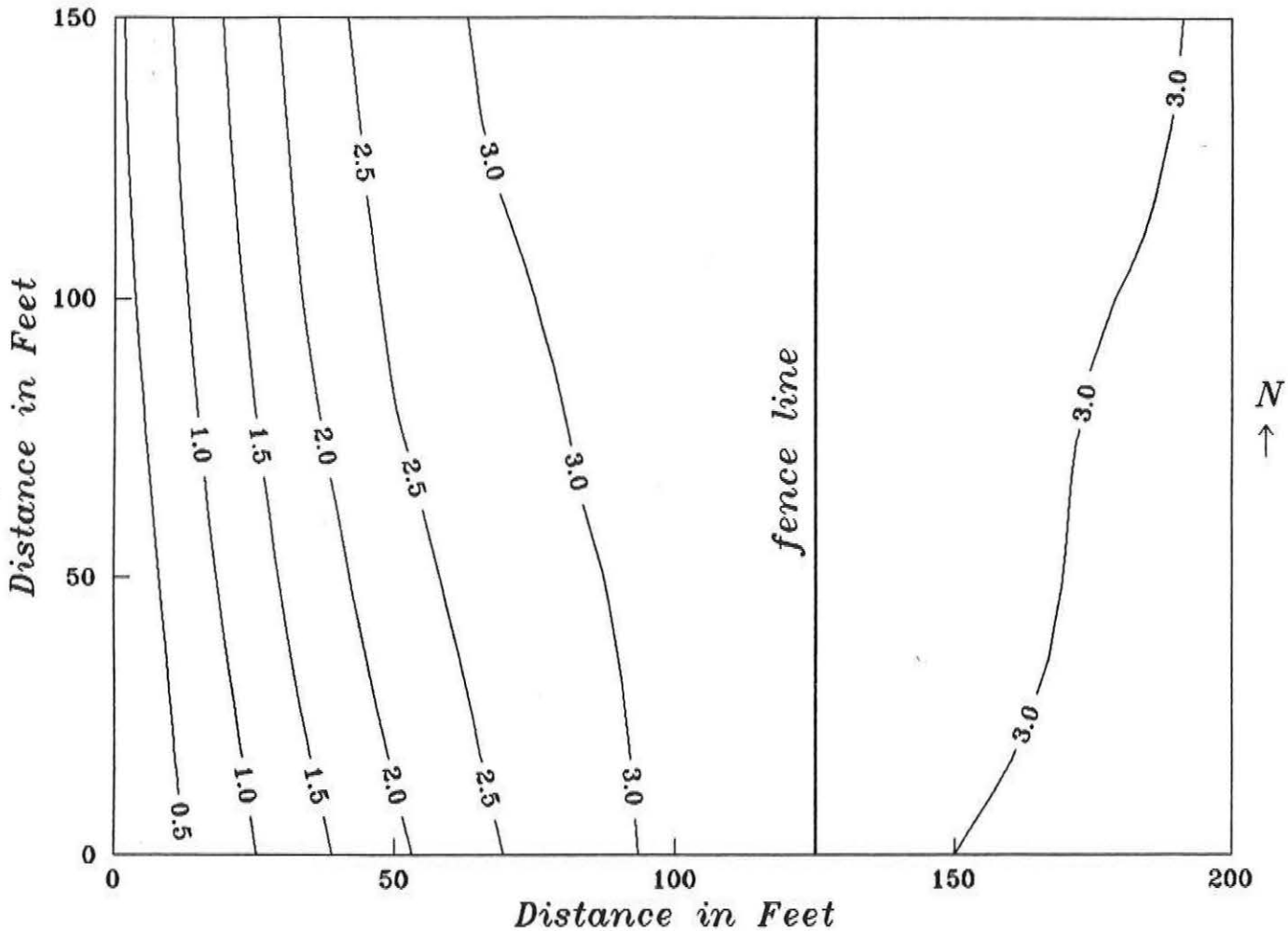


Figure 19

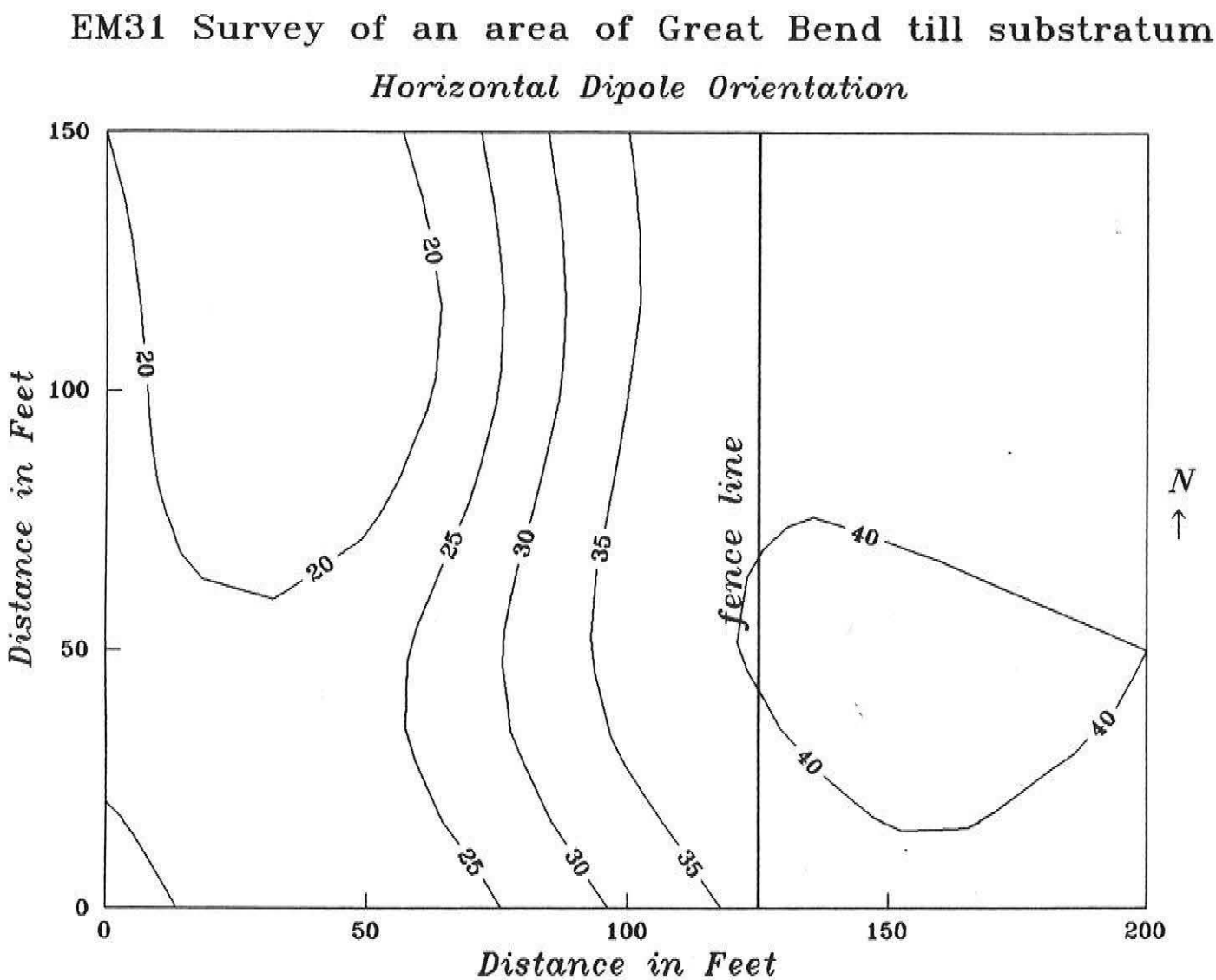
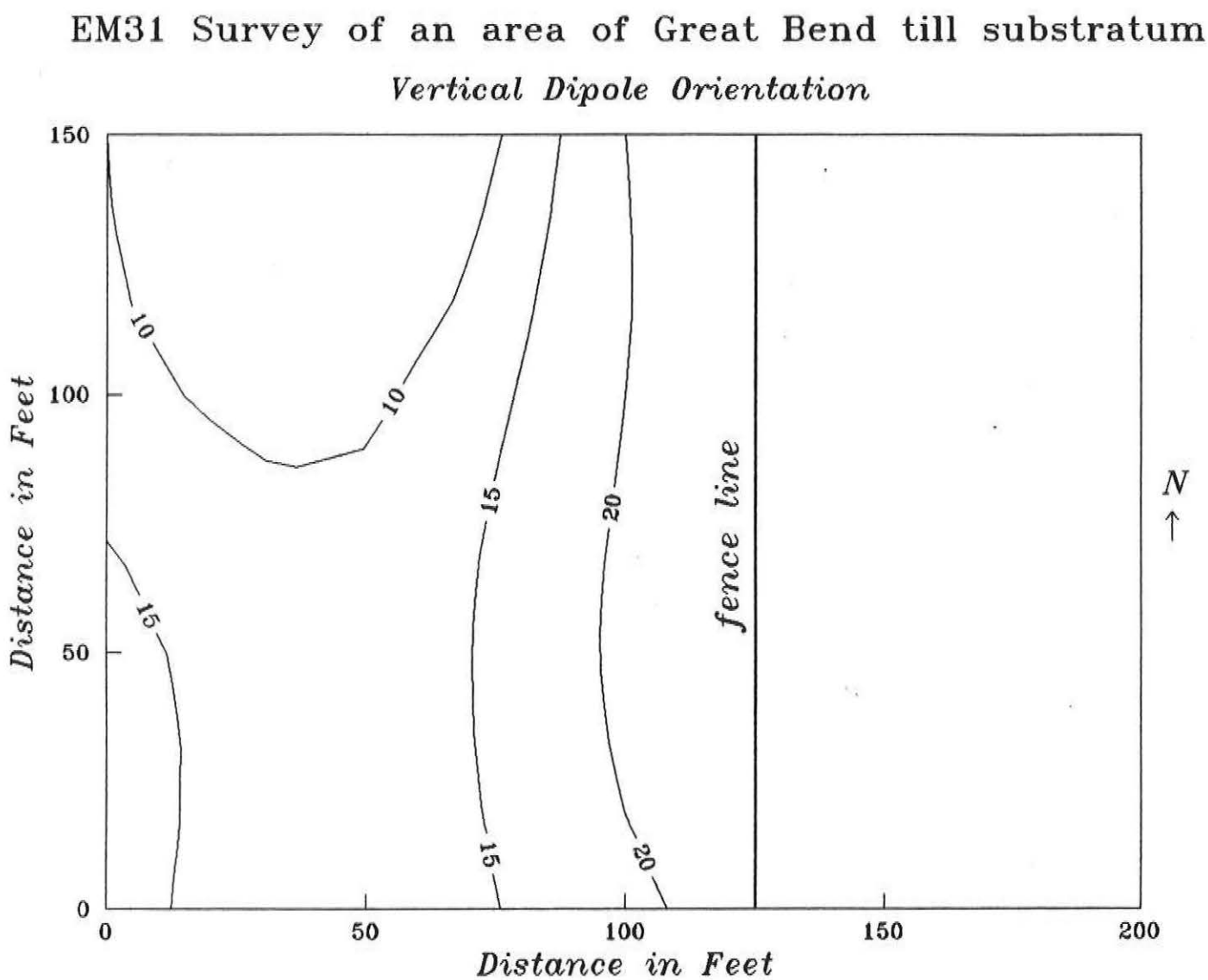

EM31 Survey of an area of Great Bend till substratum
Horizontal Dipole Orientation
150
100
50
0
Distance in Feet
0
50
100
150
200
Distance in Feet
20
20
20
25
25
30
30
35
35
40
40
40
fence line
N

Figure 20


EM31 Survey of an area of Great Bend till substratum
Vertical Dipole Orientation
150
100
50
0
Distance in Feet
0
50
100
150
200
Distance in Feet
10
10
15
15
15
20
20
fence line
N

Dismiss to a R. Parrott + file under Doolittle

United States Department of Agriculture | Natural Resource Conservation Service | 160 East 7th Street Chester, PA 19013-6092 610-490-6042

Subject: Archaeological Investigation near Oxford, Maryland, November 14 & 15, 1994

Date: November 17, 1994

File Doolittle

To: Jeri Berc
State Conservationist
USDA-NRCS
John Hanson Business Center
339 Busch's Frontage Road, Suite 301
Annapolis, Maryland 21401-5534

Purpose:
Human bones from Native American burials had been exposed along an eroding bluff near Oxford, Maryland. The site had been examined by the Maryland Historical Trust (MHT). Based on MHT findings and unless additional remains are found at this site, no further fieldwork has been planned for this site. However, concerns have been expressed for the need to halt further bank erosion. At the request of the MHT, the National Soil Survey Center (NSSC) and the NRCS staff in Maryland agreed to provide ground-penetrating radar (GPR) field assistance to help characterize the site and discern whether additional burials are present within the site.

Participants:
Tyler Bastian, Archaeologist, MHT, Crownsville, MD
James A. Doolittle, Soil Specialist, NRCS, Chester, PA
Beth Cole, Archaeologist, MHT, Crownsville, MD
Dennis Curry, Senior Archaeologist, MHT, Crownsville, MD
Richard Hughes, Chief, MHT, Crownsville, MD
Maureen Kavanagh, Archaeologist, MHT, Crownsville, MD
Susan Langley, Archaeologist, MHT, Crownsville, MD
Darrin Lowery, Contract Archaeologist, Talbot County, MD
Anne M. Lynn, State Biologist, NRCS, Annapolis, MD

Activities:
Field work was completed on 14 and 15 November, 1994.

Study Site:
The site was located in a cultivated field, in an area of Sassafras sandy loam, 2 to 5 percent slopes, moderately eroded [1] near the town

1. Reybold, William. 1970. Soil Survey of Talbot County, Maryland. USDA - Soil Conservation Service. U. S. Government Printing Office. Washington, D. C. pp. 84.

of Oxford. Sassafras is a member of the fine-loamy, siliceous, mesic Typic Hapludults family.

In the representative profile of Sassafras soils, the texture of the surface and subsurface layers are sandy loam. The upper part of the substratum is sand and loamy sand. These materials are fairly resistive and did not limit the choice of antennas or the depth of observation. However, within depths of 2.4 m and in the lower part of the scanned substratum, layers of silt loam and silty clay loam restricted the depth of observation. Within the surveyed area, these medium-textured layers occur at increasingly shallower depths with increased distances from the escarpment and in lower-lying positions of within the landscape.

Equipment:
The ground-penetrating radar unit used in this study was the Subsurface Interface Radar (SIR) System-8 manufactured by Geophysical Survey Systems, Inc. Components of the SIR System-8 used in this study were the model 4800 control unit, ADTEK SR 8004H graphic recorder, power distribution unit, transmission cable (30 m), and the models 3110 (120 mHz), 3105 (300 mHz) and 3102 (500 mHz) antennas. The system was powered by a 12-volt vehicular battery.

A range of 60 nanoseconds (ns) was used in this investigation. A metallic reflector was buried at a depth of about 18 inches and used to determine the velocity of signal propagation through Sassafras soil. Based on the scaled depth to this reflector, the estimated velocity of propagation was 0.062 m/ns, the dielectric constant was 19.9, and the maximum depth of observation was 2.4 meters. Considering the dryness of the observed soil profiles, values for the velocity of propagation and the dielectric constant are suspected of measurement errors and the depth of observation is believed to be slightly greater than estimated.

The system radiates a conical beam and scans a footprint area beneath each antenna. The footprint area is considered circular and can be approximated by the formula:

$$2 \sin^{-1} (1/e),$$

where e is the dielectric constant of the scanned materials (19.9). In this medium, the calculated beam-width for the antennas would be about 6°. The estimated beam diameter would be about 5 and 10 cm at depths of 50 and 100 cm, respectively. It is important to stress that all antennas (500, 300, and 120 mHz) will vertically profile columns of soil having similar horizontal dimensions. Often, field investigators have mistakenly believed that the physically larger 120 mHz antenna scans a larger footprint area than the smaller 300 or 500 mHz antenna.

The 300 and 500 MHz antennas provided superior resolution of subsurface features. However, subsurface horizons and features were

more easily interpreted on the radar profiles obtained with the 120 MHz antenna.

Field Procedures:
Prior to the arrival of the GPR unit, an irregularly shaped, rectangular grid had been established across the site (about 0.8 ha) by the staff of the MHT. The maximum dimensions of the grid were 120 by 70 m. The grid interval was 5 m. The grid extend inland from the bluff overlooking the Tred Avon Creek. Radar traverses were completed along each east-west trending grid line (15) with the 120 MHz antenna.

Following interpretations, additional traverses were completed along the north and south sides of grid lines 165 and 167.5 north, and along the south side of grid line 170 north. Along these lines, additional survey flags had been inserted in the ground at 1 m intervals. The 500, 300, and 120 mHz antennas were used for this part of the investigation. Following radar interpretations, five shallow, exploratory pits were excavated by MHT personnel. The purpose of these pits were to verify radar interpretations.

Interpretations:
Even under favorable site conditions (i.e. dry, coarse-textured soils) the detection of a buried cultural features with GPR can not be guaranteed. The detection of buried cultural features is affected by (i) the electromagnetic gradient existing between a cultural feature and the soil, (ii) the size, shape, and orientation of the buried cultural feature, and (iii) the presence of scattering bodies within the soil.

Unless the radar antenna passed directly over a bundle burial, it was considered unlikely that GPR would detect skeletons. Most bones are too small and not directly detectable with GPR. However, it was anticipated that GPR would discern evidence of disturbed soil conditions within grave shafts, concentrations of artifacts buried with a corpse, or chemically altered soil materials (or red ocher) which often directly surrounds a burial rather than the bones themselves. It is the abrupt truncation and obliteration of soil horizons within the grave shaft that makes most graves and some cultural features detectable with GPR. However, with the passage of time, the signs of disturbances may be erased by natural soil-forming processes or management practices.

Cultural features are difficult to distinguish in soils having numerous rock fragments, tree roots, animal burrows, or stratified and segmented soil layers. These scattering bodies produce undesired subsurface reflections which complicate radar imagery and mask the presence or identity of buried cultural features. Under such conditions, "desired" cultural features can be indistinguishable from the background clutter. The investigated area of Sassafras soils had numerous scattering bodies, many believed to be rock fragments, burrows, and segmented horizons.

In the search for buried cultural features with GPR, success is never guaranteed. Even under ideal site and soil conditions, small, buried cultural features are often missed with GPR. The usefulness of GPR for site assessment purposes depends on the amount of uncertainty or omission that is acceptable.

Results:
Radar profiles identified the locations of numerous point reflectors and a large area which was assumed to have disturbed features. Shallow pits were excavated near two, distinct, point relectors. The objects producing these distinct reflections were identified as a small, buried metallic implement and a large rock fragment.

After a cursory review of the radar profiles, an area having what appeared to be obliterated soil horizons was recognized and located in the field by the participants. Coincidentally, this area of disturbance was adjacent to the point on the escarpment where the bones had been exposed. On the radar profiles, the "disturbed area" appeared to be bounded by truncated soil horizons and was characterized by the absence of distinct subsurface images. Exploratory observations made within this area produce faint and inconclusive evidence of disturbance. Soils within the "disturbed area" appeared to be darker brown with coloration changing across an observable boundary. A few fragments of charcoal were observed within the "disturbed area." However, within the "disturbed area," no artifacts were interpreted from the radar profiles or found within the exploratory pits.

Conclusions:
Results from this survey were inconclusive and did not provide evidence supporting the presences of additional burials. Although unique and identifiable graphic signatures were noted in an area immediately adjacent to the location where exposed bones had been observed, these patterns may reflect natural processes of deposition and/or erosion rather than the effects of artificial disturbances. Without more supporting data, the location of these patterns near the burial site is considered fortuitous.

Ground-penetrating radar techniques have been used infrequently on prehistoric, Native American sites. This field study provided an opportunity to improve interpretative skills and to assess the appropriateness of GPR techniques on these sites. Further studies are needed and recommended to improve NRCS ability to assess subsurface cultural features at similar sites.

This field investigation provided an opportunity for members of NRCS and MHT to exchange information and to work together to resolve a common problem.

All graphic profiles were turned over to Dennis Curry of the MHT for further analysis.

It was a pleasure to work with Anne Lynn and the staff of the Maryland Historical Trust. I thank you for this opportunity.

With kind regards,

James A. Doolittle

O. D. Ashford, Director, NNTC, NRCS, Chester, PA
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