UNITED STATES DEPARTMENT OF AGRICULTURE **Northeast NTC**
SOIL CONSERVATION SERVICE **CHESTER, PA 19013**

SUBJECT: Electromagnetic Induction (EM) studies at Texas Agricultural Experiment Station, La Copita Center.

DATE: 6 November 1992

To: Richard Babcock,
State Soil Scientist
USDA-Soil Conservation Service
W. R. Poage Building
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Temple, Texas 76501-76682

Purpose:
To use electromagnetic induction (EM) techniques to continue the study of soil/vegetative relationships and soil variability within the Texas Agricultural Experiment Station, La Copita Center, near Alice, Texas.

Participants:
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Jim Stroh, Graduate Student, Texas A & M University, College Station, TX

Activities:
I arrived in Alice, Texas, during the afternoon of 14 September 1992. Field studies were conducted on 14, 15, and the morning of 16 September 1992. I returned to Chester, Pennsylvania on 16 September 1991.

Equipment:
The electromagnetic induction meters were the EM31 and the EM38 manufactured by GEONICS Limited. Measurements of conductivity were expressed in milliSiemens per meter (mS/m). Two-dimensional isopleth plots of the data were prepared using SURFER software developed by Golden Software, Inc.

Results:
Use of electromagnetic induction methods is suited to mapping the variability of some soil properties and for characterizing and differentiating soil map units at La Copita. Variations in EM response are believed to indicate differences in soil type, lithology, and temporal and spatial changes moisture contents.

Generally, EM responses increased with increasing depths profiled. The grid site selected for this investigation contained both areas of open land and mesquite groves. Differences in vegetational types were apparent. However, the selected grid site, Site 2, was in a transitional area between two soil map units: Pharr fine sandy loam, 1 to 3 percent slopes, and Runge fine sandy loam, 1 to 3 percent slopes. Both soils are similar and members of the fine-loamy, mixed, hyperthermic Typic Argiustolls family. On the bases of the soil map, this site was not similar to the previously sampled site.

Patterns of EM response were the reverse of those observed last December. However, areas of grove and grass vegetation continued to be distinguished on the bases of their EM responses. At Site 2, EM responses were lower within groves than in open areas. In the December (1991) study at Site 1, EM responses were higher within the groves than in the open areas.

Soils were noticeably wetter during this study. It was believed that the EM meters were responding more to variations in soil moisture than to variations in soil texture or calcium carbonate content. Variations in EM response may be influenced by spatial variations in the distribution of soil moisture. The groves may be intercepting significant amounts of precipitation to influence soil moisture conditions beneath their canopy. If soil conditions are in fact significantly drier beneath the groves, the lower EM response can be partially explained.

I enjoyed working in Texas and hope that the results of our field work will be of value to you and will prompt further investigations.

With kind regards.

James A. Doolittle
Soil Specialist

cc:
J. Culver, National Leader, SSQA, NSSC, SCS, Lincoln, NE
C. Holzhey, Assistant Director, Soil Survey Division, NSSC, SCS, Lincoln, NE
J Stroh, 601 Navarro,College Station, Texas 77845
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Discussion

Traverses with EM31 meter across multiple map units

Two transect lines were established across representative landscapes within La Copita Center (see Figure 1). Transects were located along farm roads. Along each transect, observations were taken at 20 meter intervals. Transect A was 1420 meters and crossed delineated areas of Clareville (fine, montmorillonitic, hyperthermic Pachic Argiustolls), Runge (fine-loamy, mixed, hyperthermic Typic Argiustolls), Czar (fine-loamy, mixed, hyperthermic Pachic Argiustolls) and Pernitas (fine-loamy, mixed, hyperthermic Typic Argiustolls) soils. Transect B was 1000 meters and crossed delineated areas of Czar (fine-loamy, mixed, hyperthermic Pachic Argiustolls) Runge (fine-loamy, mixed, hyperthermic Typic Argiustolls), Clareville (fine, montmorillonitic, hyperthermic Pachic Argiustolls), and Edroy (fine, mixed, hyperthermic Vertic Haplaquolls) soils.

An EM survey was conducted along each transect line. At twenty meter intervals, measurements were taken with the EM31 meter in both the horizontal and vertical dipole modes. The EM31 meter scans depths of 0-2.75 meters in the horizontal and 0-6.0 meters in the vertical dipole modes.

Figure 2 charts variations in apparent conductivity with depth, soil map unit, and location along each transect line. The letter "P" denotes the presence of pipelines. Variations observed in the EM data imply changes in soil type and lithology across the landscape.

With minor exceptions, apparent conductivity values increase with soil depth (see Figure 2). As noted in a previous report, this pattern, if related to the concentration and distribution of soluble salts, reflects a "normal" rather than an "inverted" conductivity profile or distribution. In areas of uniform soil materials, a "normal" conductivity profile implies a general net downward movement or increase in soluble salts with depth. Inverted conductivity distributions occur where additions or the net upward movement of salts result in near surface accumulations.

EM31 TRANSECT DATA
BASIS STATISTICS
(in mS/m)

MAP UNIT	OBS.	AVERAGE EMH	AVERAGE EMV	SD EMH	SD EMV	MINIMUM EMH	MINIMUM EMV	MAXIMUM EMH	MAXIMUM EMV
Clareville (3)	40	55	75	15.6	21.6	31	36	100	125
Czar (6, 6A)	27	44	56	28.6	37.9	15	21	130	180
Runge (47,47A)	42	36	46	9.2	11.4	22	30	60	72
Pernitas (33)	33	20	22	5.5	4.2	12	18	24	30

Some soils and map units can be differentiated by values and characteristic ranges of apparent conductivity. These values or ranges are principally determined by the clay, salt, and moisture contents of soils. In Table 1, each map unit displays a fairly unique set of statistical parameters. While the average EM response is unique for each map unit, ranges do overlap. However, considering the terrain and soil conditions traversed, similarities in ranges is considered to be a consequence of map unit inclusions.

Clareville soils have the highest clay content and the greatest averaged EM response. Czar soils have thicker, mollic epipedon than Peritas and Runge soils and a greater EM response than these soils. The transected area of Pernitas soil had large areas of exposed bedrock and was believed to be more representative of an adjoining delineation of map unit 19, Lacoste-Olmos association, gently undulating. Lacoste soils are members of the loamy, mixed, hyperthermic, shallow Petrocalcic Paleustalfs family. Olmos soils are members of the loamy-skeletal, carbonatic, hyperthermic, shallow Petrocalcic Calciustolls family. These soils are shallow to a petrocalcic horizon which should display low values of apparent conductivity.

<u>Systematic sampling of an area of Runge and Clareville soils</u>
Encouraged by the result from the study conducted in December 1991, a second grid site (Site 2) was selected to assess the relations among EM response, soil/vegetation patterns and the distribution of calcic and argillic horizons in soil profiles. A 100 by 120 meter grid was established in an area having distinct vegetation patterns. Unfortunately, the area selected for the grid contained areas of two map units: Pharr fsl (41) and Runge fsl (47), and possible, a small included area of Clareville (3) soils. Survey flags were inserted in the ground at 10 meter intervals. At each of the 120 grid intersects, measurements were obtained with the EM31 and EM38 meters in both the horizontal and vertical dipole modes.

A crude vegetation map of the survey area was constructed (Figure 3). In Figure 3, two prominent, circular area of woody vegetation are mapped in the north and northwest portions of the study site. Other portions of the grid site were mostly open and in grasses.

Figures 4 through 7 are two-dimensional contour plots of apparent conductivities within the grid site. In each plot, the contour interval is 5 mS/m. Figures 4 and 5 represent computer simulations of data obtained with the EM38 meter in the horizontal and vertical dipole modes, respectively. Figures 6 and 7 represent computer simulations of data obtained with the EM31 meter in the horizontal and vertical dipole modes, respectively.

In each figures (Figures 4 through 7), five distinct areas of higher apparent conductivity values are evident. Although some slight shifts in position are apparent, these anomalous areas occupy similar locations in each plot. These anomalous areas are more distinct and values of conductivity increase with depth. A similar relationship was observed in the 1991 study. This relationship suggested increases in the content and/or thickness of fine textured materials and/or soluble salt content with depth.

Figure 8 summarizes the results of these surveys. Generally, values of apparent conductivity are lower in the western portion of Site 2. This pattern may have been produced by differences in soils map units. The western portion of the site is in an area of Pharr fine sandy loam, 1 to 3 percent slopes (41); the eastern portion of the study site is in an area of Runge fine sandy loam, 1 to 3 percent slopes (47). Both soils are members of the fine-loamy, mixed, hyperthermic Typic Argiustolls family. Without auger observations, it is difficult to confirm the causes for these patterns

The groves were located in areas of Pharr soils. In areas of woody vegetation values of apparent conductivity are generally lower than in the more open grassland areas. This contradicts the result from the study conducted in an area of Runge soil during the 1991 survey. As soil types are different between the two sites and moisture conditions are noticeably different at the time of the two surveys, care must be exercised in making further conclusions.

A small area located within one of the groves at Site 2 was surveyed more intensively (see Subsite 2A in Figure 8). The grids dimensions were 40 by 25 meters with observations made at 5 meter intervals. The purpose of this smaller grids was to provide more intensive sampling of a grove area to illustrate patterns of short-range soil variability.

Spatial variability discerned with EM is influenced by differences in soil properties, sampling density, meter used, and interpolation methods used to construct the contour plots. Both meters were used in the survey of Subsite 2A. The meters were orientated in both the vertical and horizontal dipole modes. The interval on the two-dimensional contour plots (Figures 9 thru 12) is 5 mS/m.

Subsite 2A was located in a grove of mesquite trees. Generally, values of apparent conductivity were lower within this grove than in adjoining areas of Site 2. The more intense sampling with the meters did not reveal any unusual patterns of apparent conductivity values within the subsite. Patterns, though more intricate were similar to those collected using the 20 meter grid interval. Difference reflected disparate sampling frequency used to construct these simulations. Generally values of apparent conductivity increased with soil depth with no significant changes over relatively short distances.

In Site 1, A 55 by 60 meter area within a grove was surveyed more intensively (see Subsite E in Figure 13). Figure 13 was simulated from the 1991 data. In Figure 13, the location of Subsite E is approximated. The grid interval was 5 meters. The purpose of this smaller grids was to provide more intensive sampling of an additional grove area in Site 1, to study temporal variations in the EM response, and to illustrate patterns of short-range soil variability. Both the EM31 and the EM38 meters were used in the survey of Subsite E. The meters were orientated in both the vertical and horizontal dipole modes. The interval on the two-dimensional contour plots (Figures 14 thru 17) is 2 mS/m.

Compared with data collected in December of 1991 (Figure 13), values of apparent conductivity collected during this survey were higher (Figures 14 thru 17). Values obtained during the present survey were 40 to 150 percent higher than values collected in 1991. The disparity among the data set decreased with increasing depth scanned by the EM meters. The elevated EM response is believed to reflect, in part, variations in soil moisture content. All sites were appreciable wetter in September 1992 than in December 1991.

The linear area of high apparent conductivity values that was evident in the 1991 data (Figure 13), is evident in Figures 15 to 17. Patterns of EM responses (Figures 15 thru 17), appear to be intricate and variable over seemingly short distances.

Figure 1

Soils of the La Copita Research Area

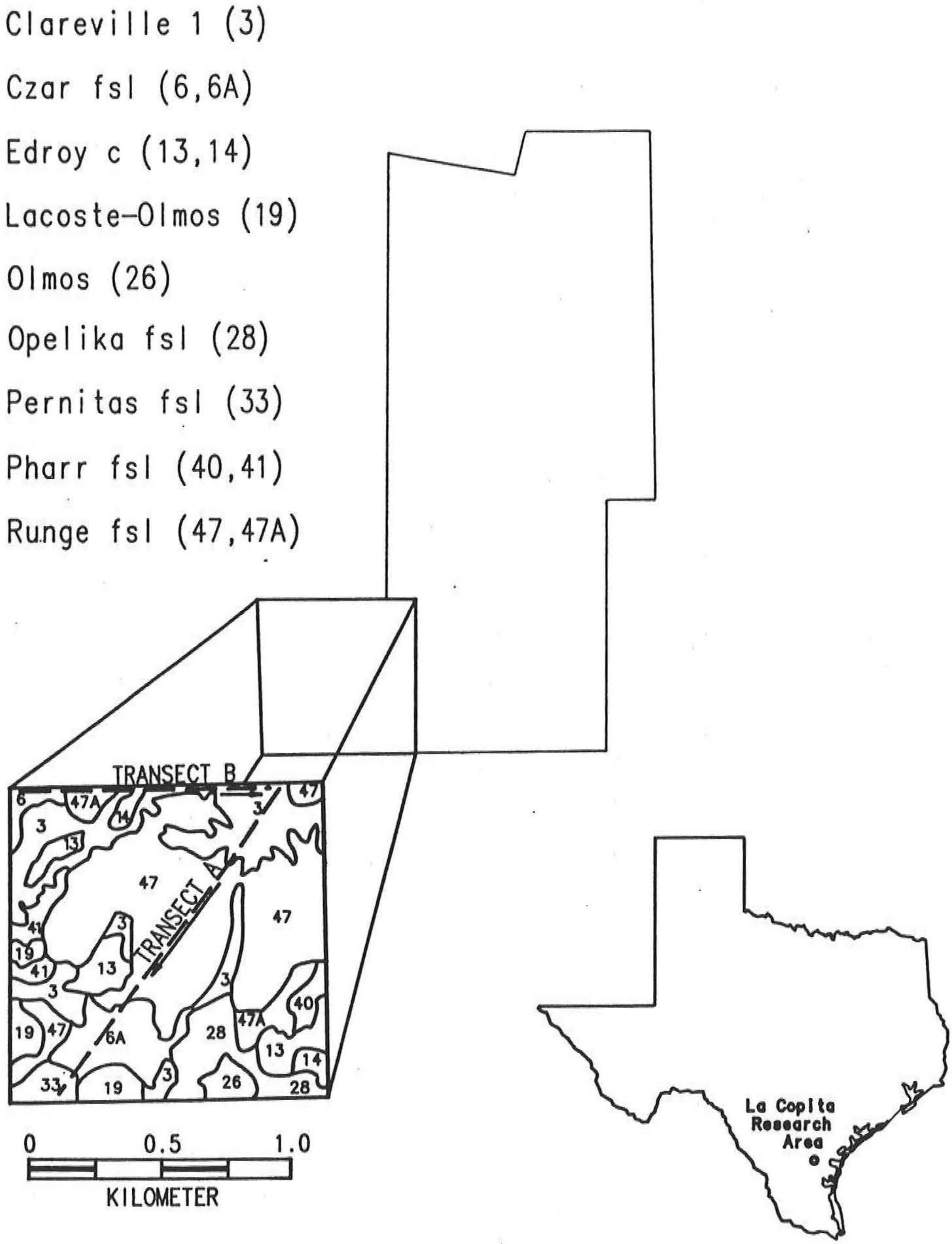
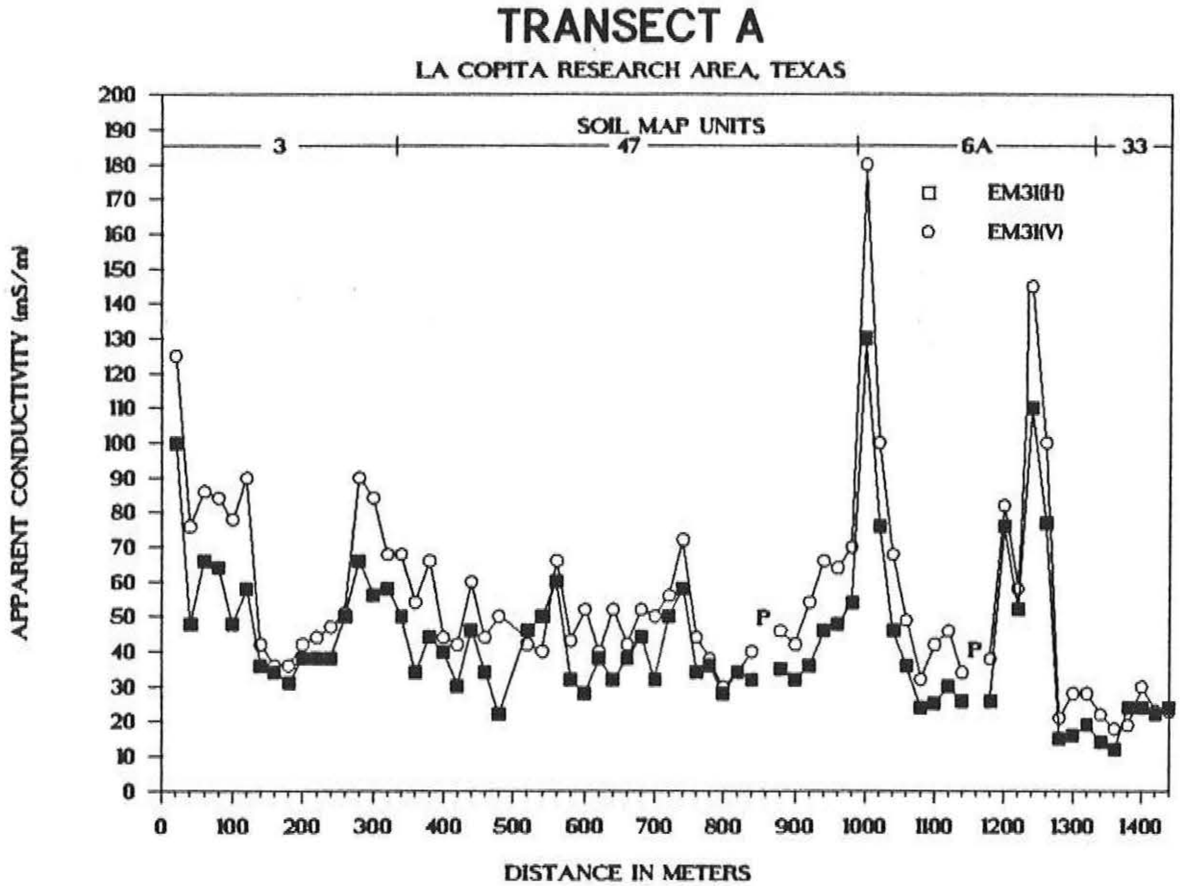


Figure 2


TRANSECT A
LA COPITA RESEARCH AREA, TEXAS
SOIL MAP UNITS
3
47
6A
33
EM31(H)
EM31(V)
P
P
APPARENT CONDUCTIVITY (mS/m)
DISTANCE IN METERS

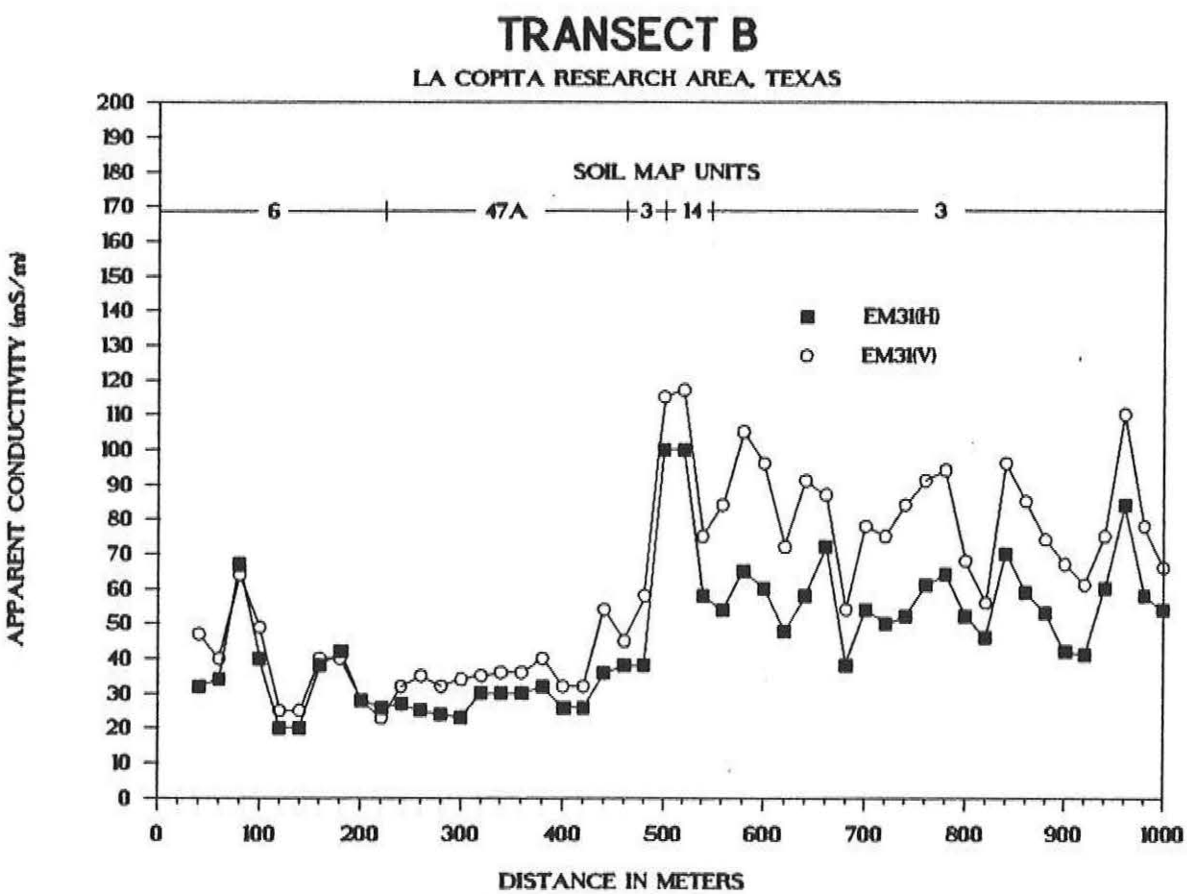
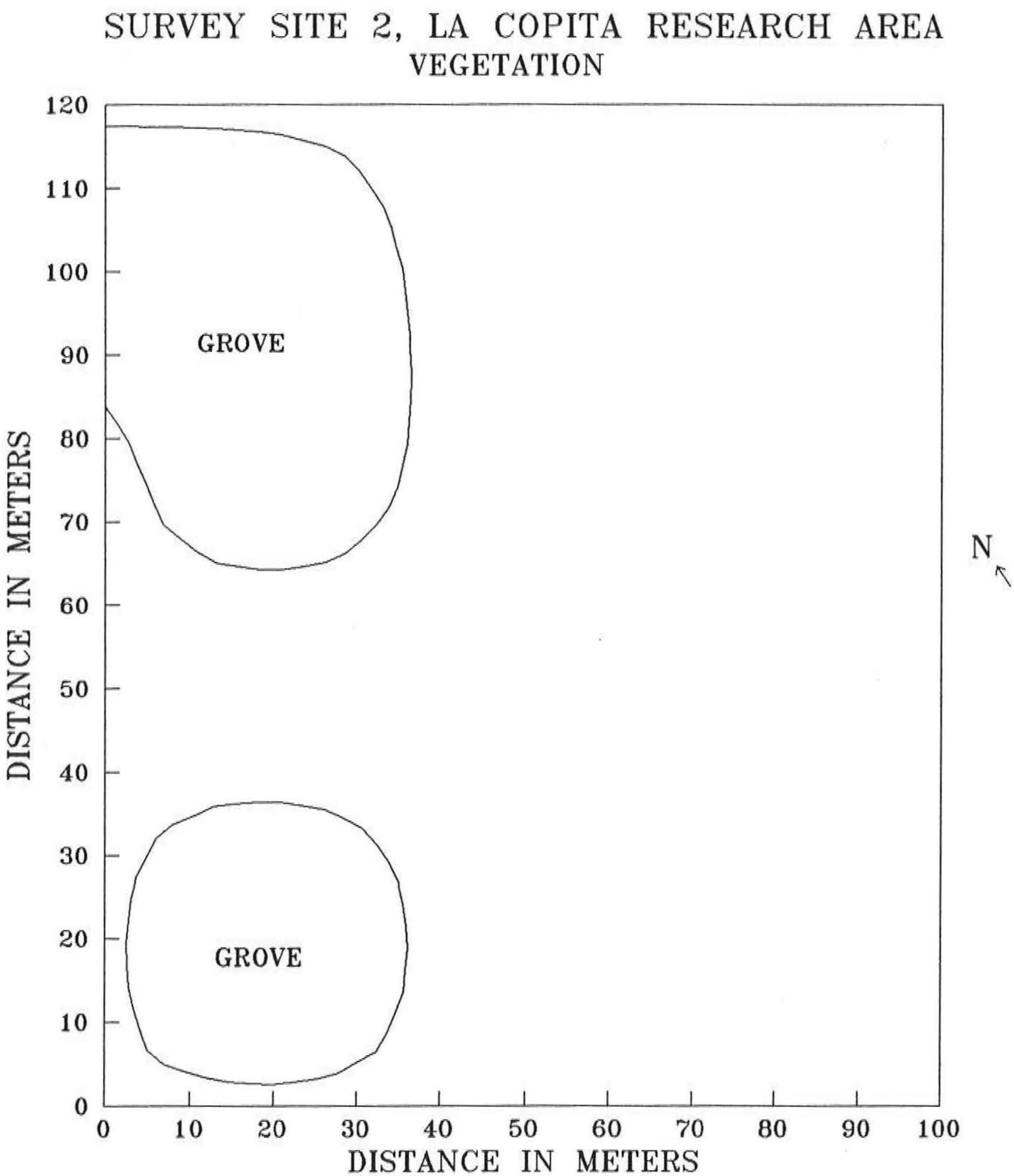

TRANSECT B
LA COPITA RESEARCH AREA, TEXAS
SOIL MAP UNITS
6
47A
3
14
3
EM31(H)
EM31(V)
APPARENT CONDUCTIVITY (mS/m)
DISTANCE IN METERS

Figure 3



SURVEY SITE 2, LA COPITA RESEARCH AREA
VEGETATION
GROVE
GROVE
DISTANCE IN METERS
DISTANCE IN METERS
0
10
20
30
40
50
60
70
80
90
100
110
120
0
10
20
30
40
50
60
70
80
90
100
N

Figure 4

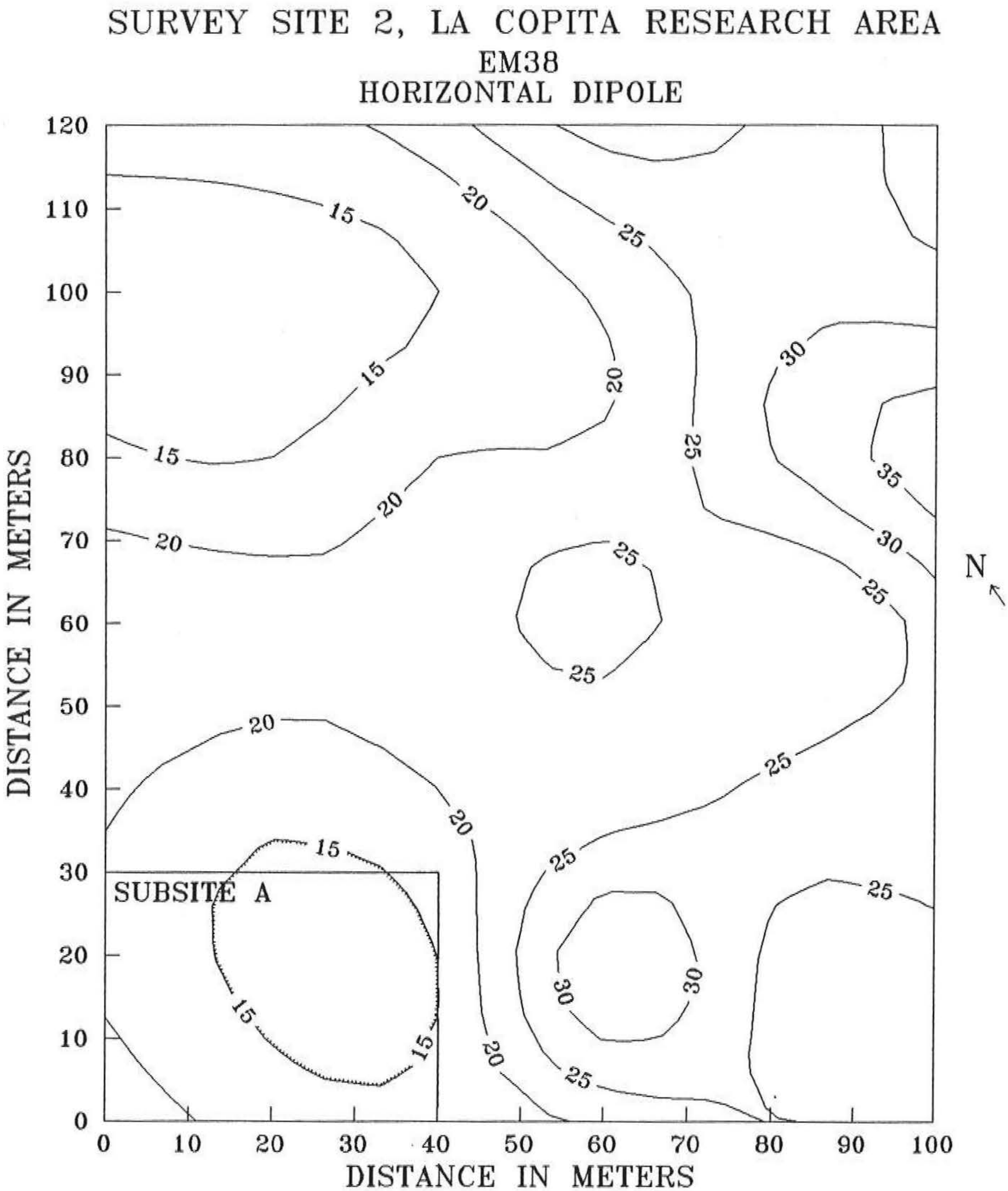

SURVEY SITE 2, LA COPITA RESEARCH AREA
EM38
HORIZONTAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
SUBSITE A
N
0
10
20
30
40
50
60
70
80
90
100
110
120
15
20
25
30
35

Figure 5

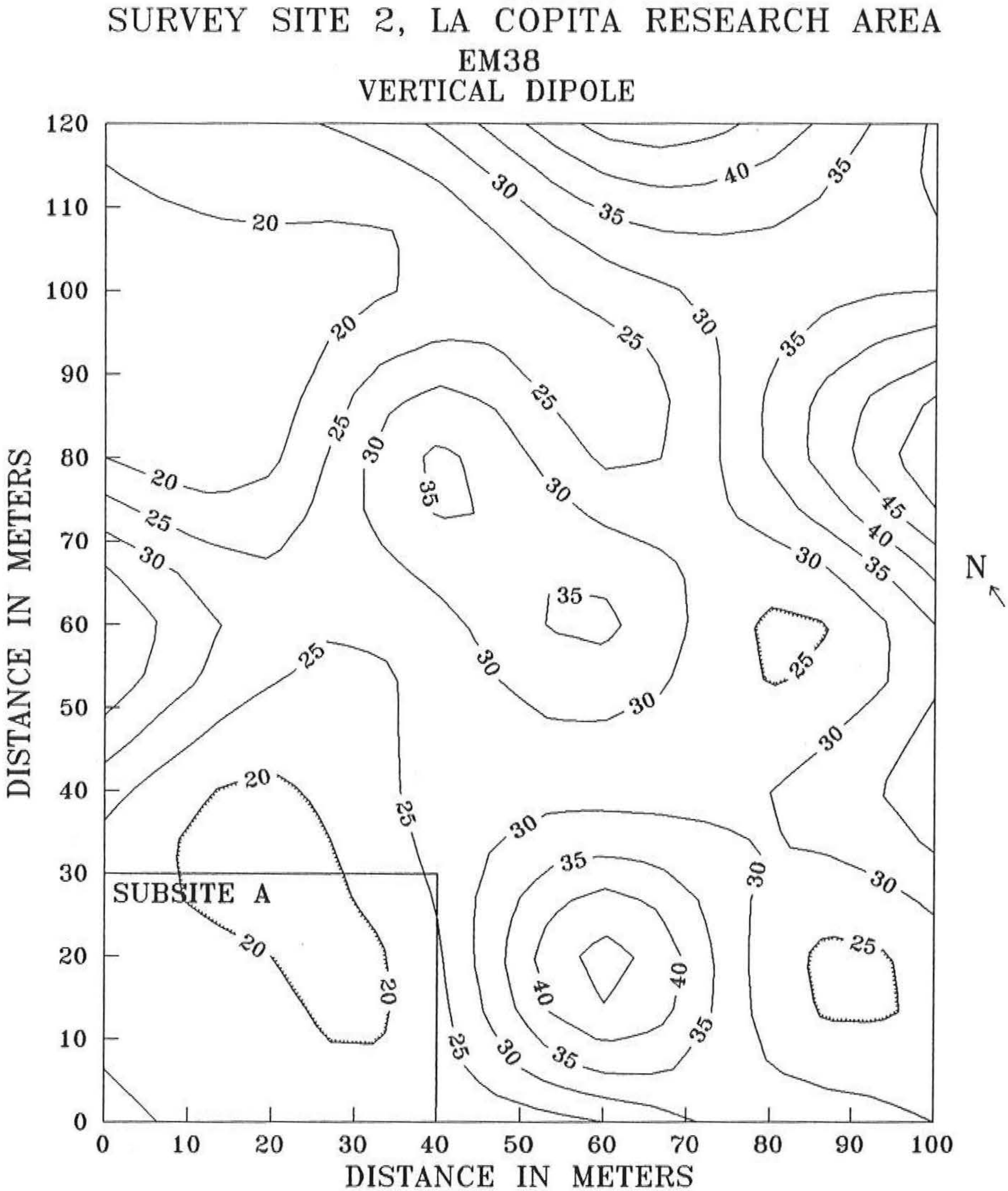
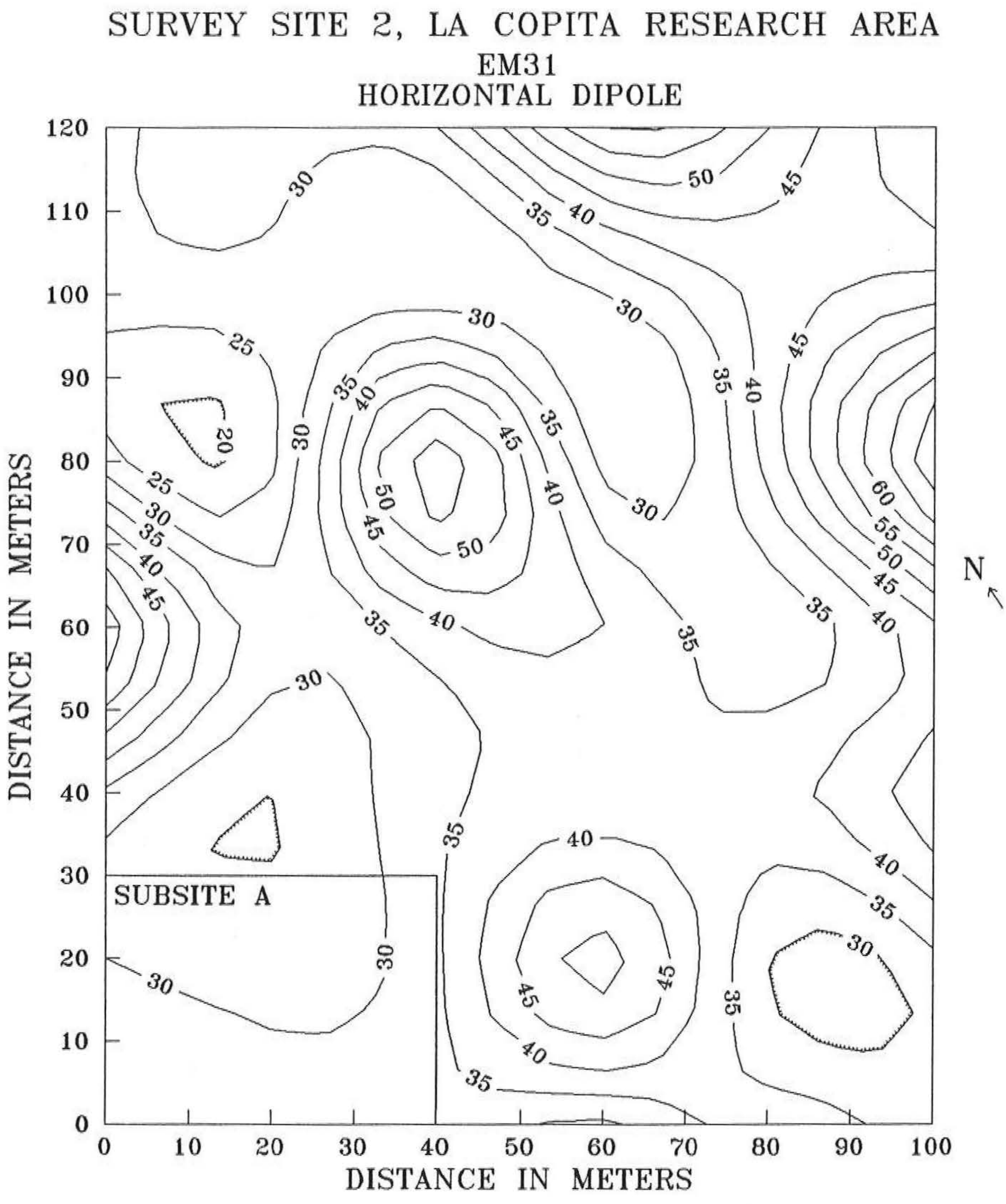
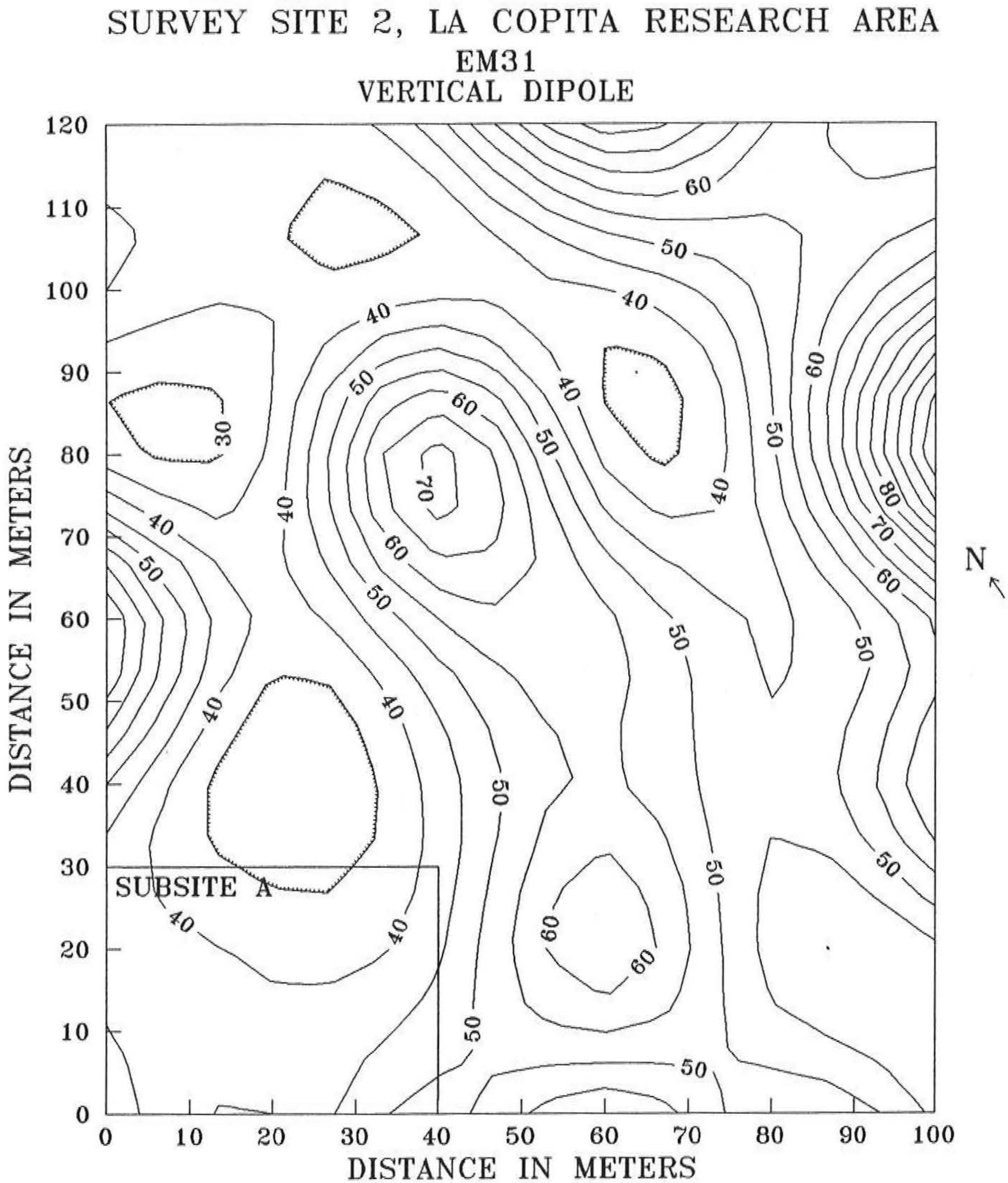

SURVEY SITE 2, LA COPITA RESEARCH AREA
EM38
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
SUBSITE A
N
0
10
20
30
40
50
60
70
80
90
100
110
120
20
25
30
35
40
45

Figure 6



SURVEY SITE 2, LA COPITA RESEARCH AREA
EM31
HORIZONTAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
SUBSITE A
N
0
10
20
30
40
50
60
70
80
90
100
110
120
20
25
30
35
40
45
50
55
60

Figure 7



SURVEY SITE 2, LA COPITA RESEARCH AREA
EM31
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
SUBSITE A
N

Figure 8

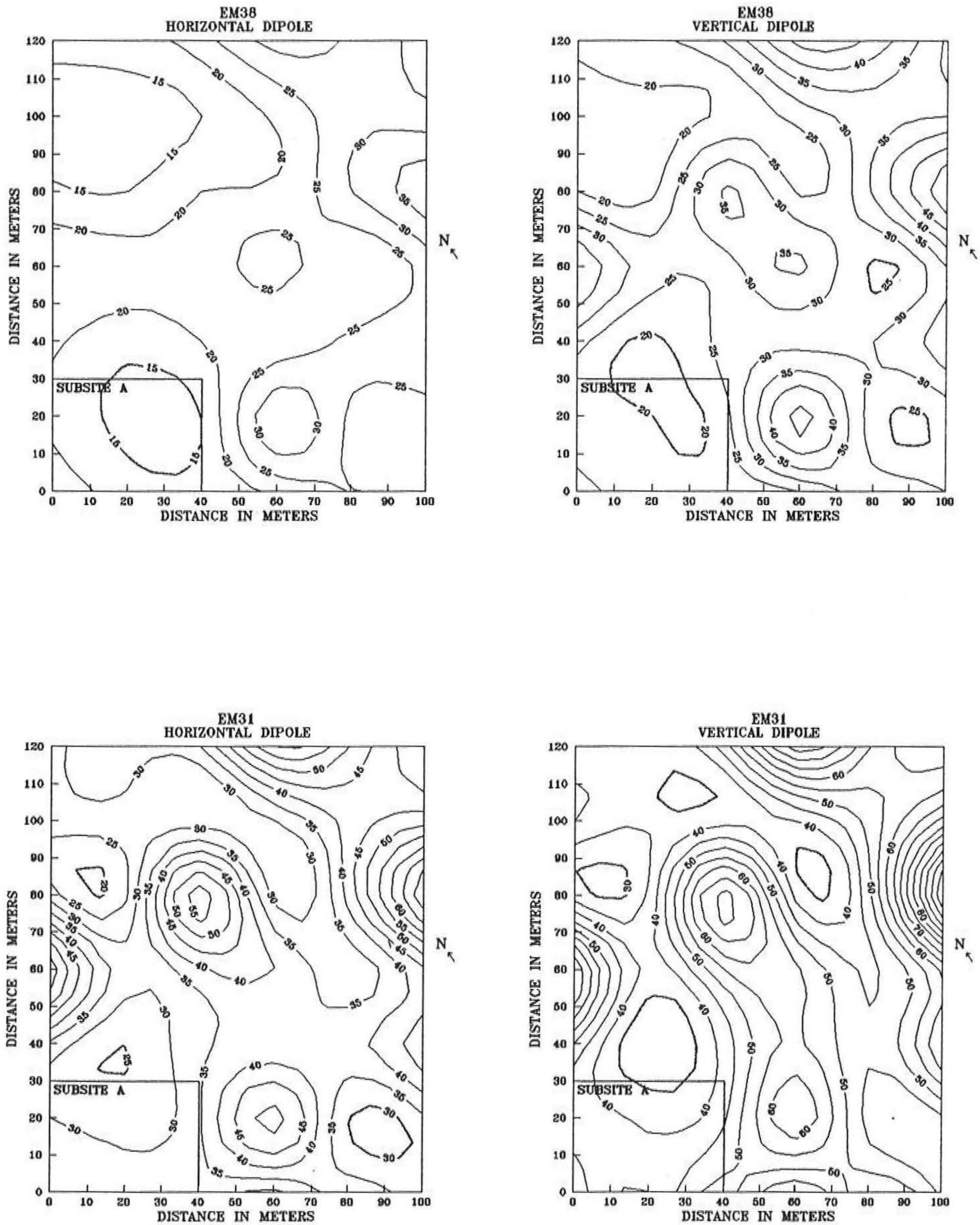

EM38
HORIZONTAL DIPOLE
EM38
VERTICAL DIPOLE
EM31
HORIZONTAL DIPOLE
EM31
VERTICAL DIPOLE
SUBSITE A
N
DISTANCE IN METERS

Figure 9

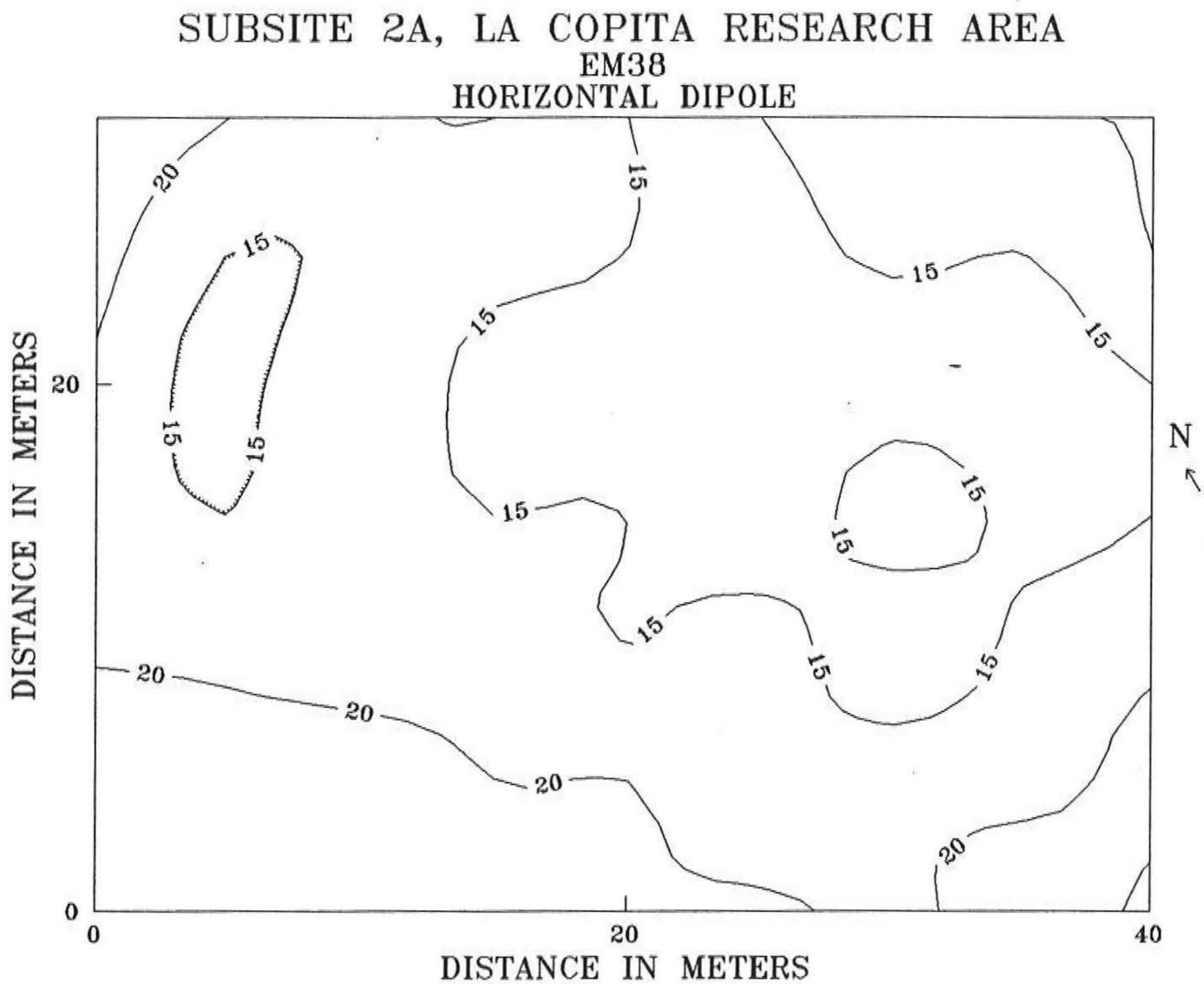
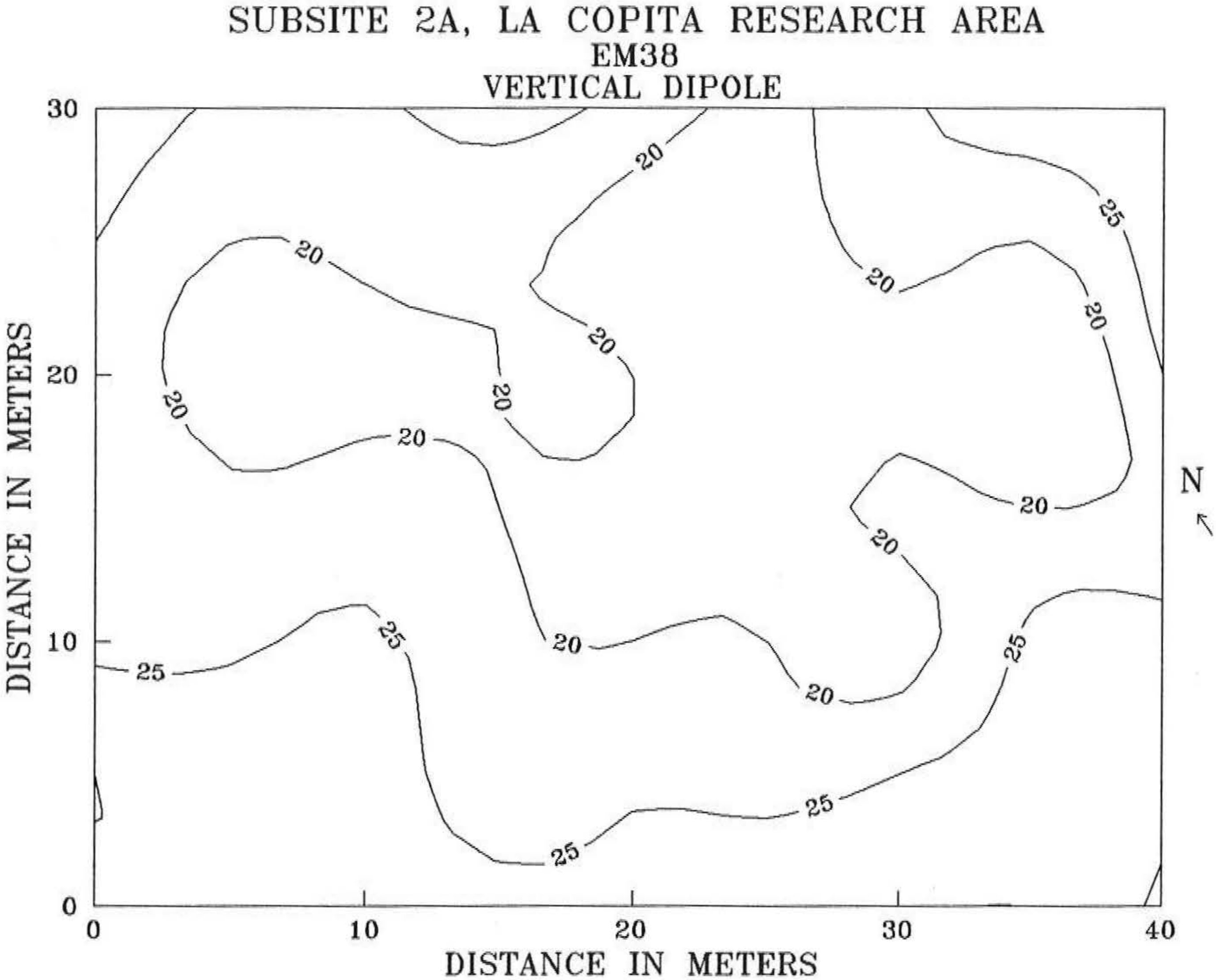
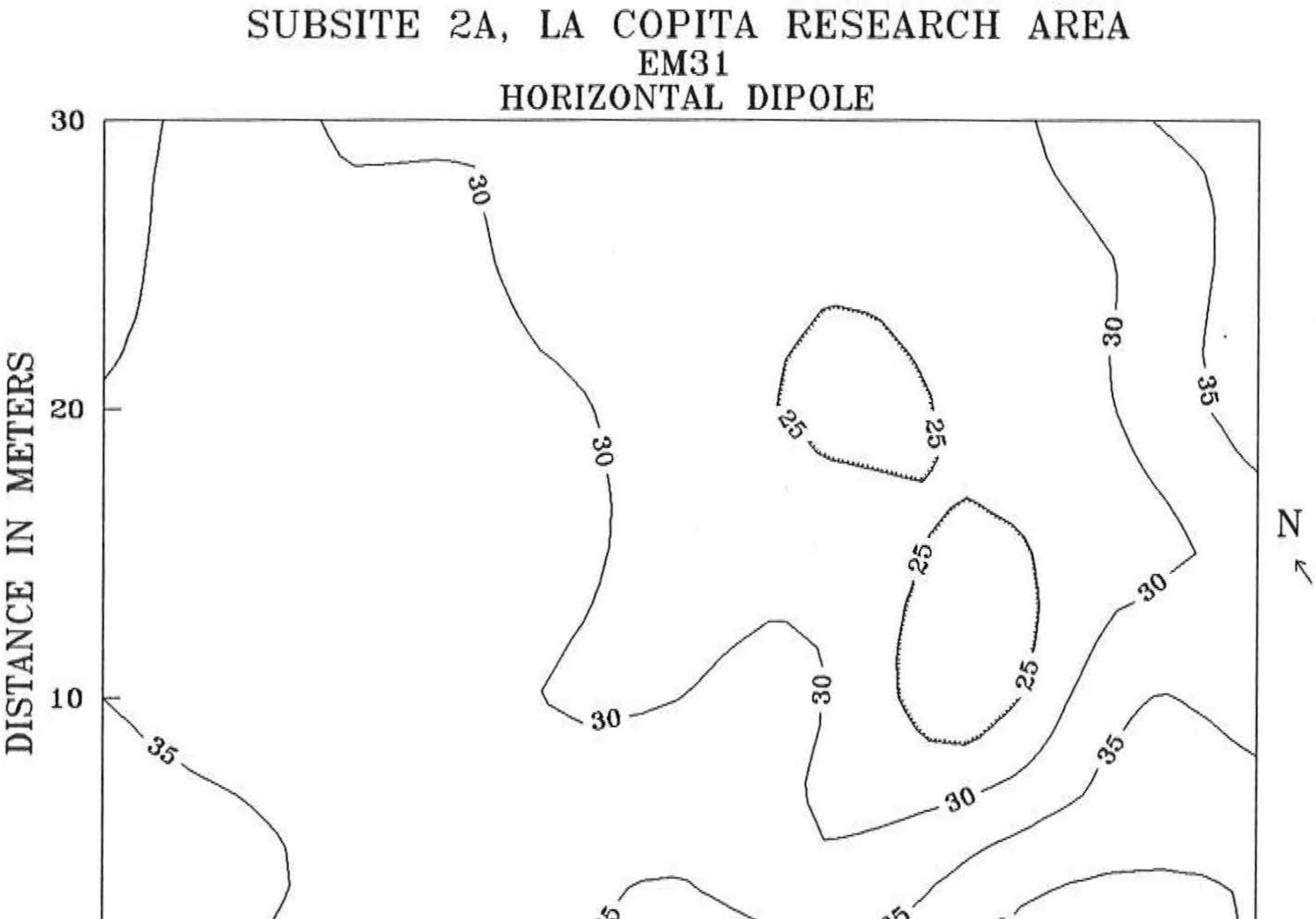

SUBSITE 2A, LA COPITA RESEARCH AREA
EM38
HORIZONTAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
0
20
40
0
20
N
15
20

Figure 10



SUBSITE 2A, LA COPITA RESEARCH AREA
EM38
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
0
10
20
30
40
0
10
20
30
20
25
N

Figure 11



SUBSITE 2A, LA COPITA RESEARCH AREA
EM31
HORIZONTAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
0
10
20
30
40
0
10
20
30
25
25
25
25
30
30
30
30
30
30
30
35
35
35
35
35
40
N

Figure 12

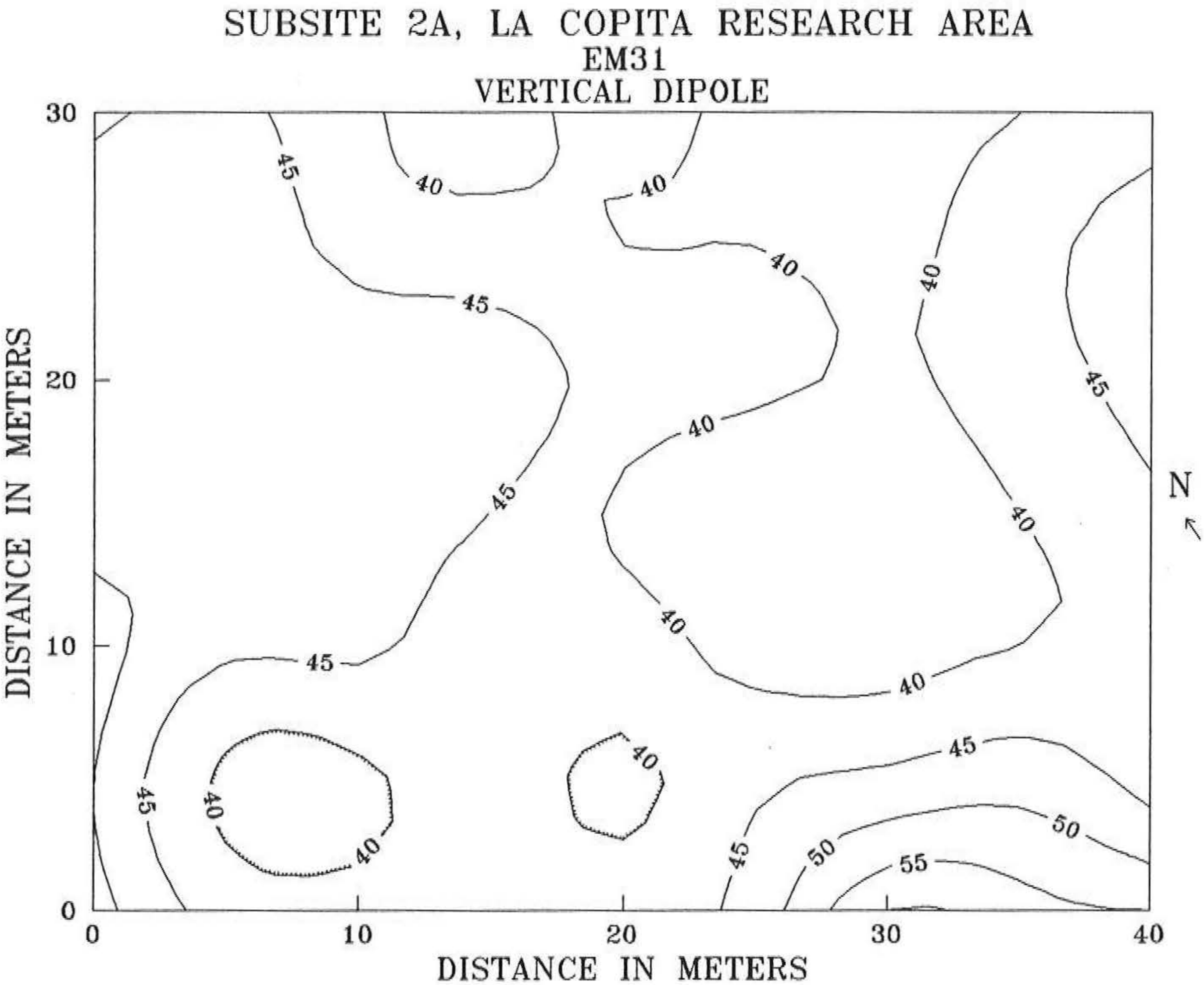

SUBSITE 2A, LA COPITA RESEARCH AREA
EM31
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
N
0
10
20
30
40
45
50
55

Figure 13

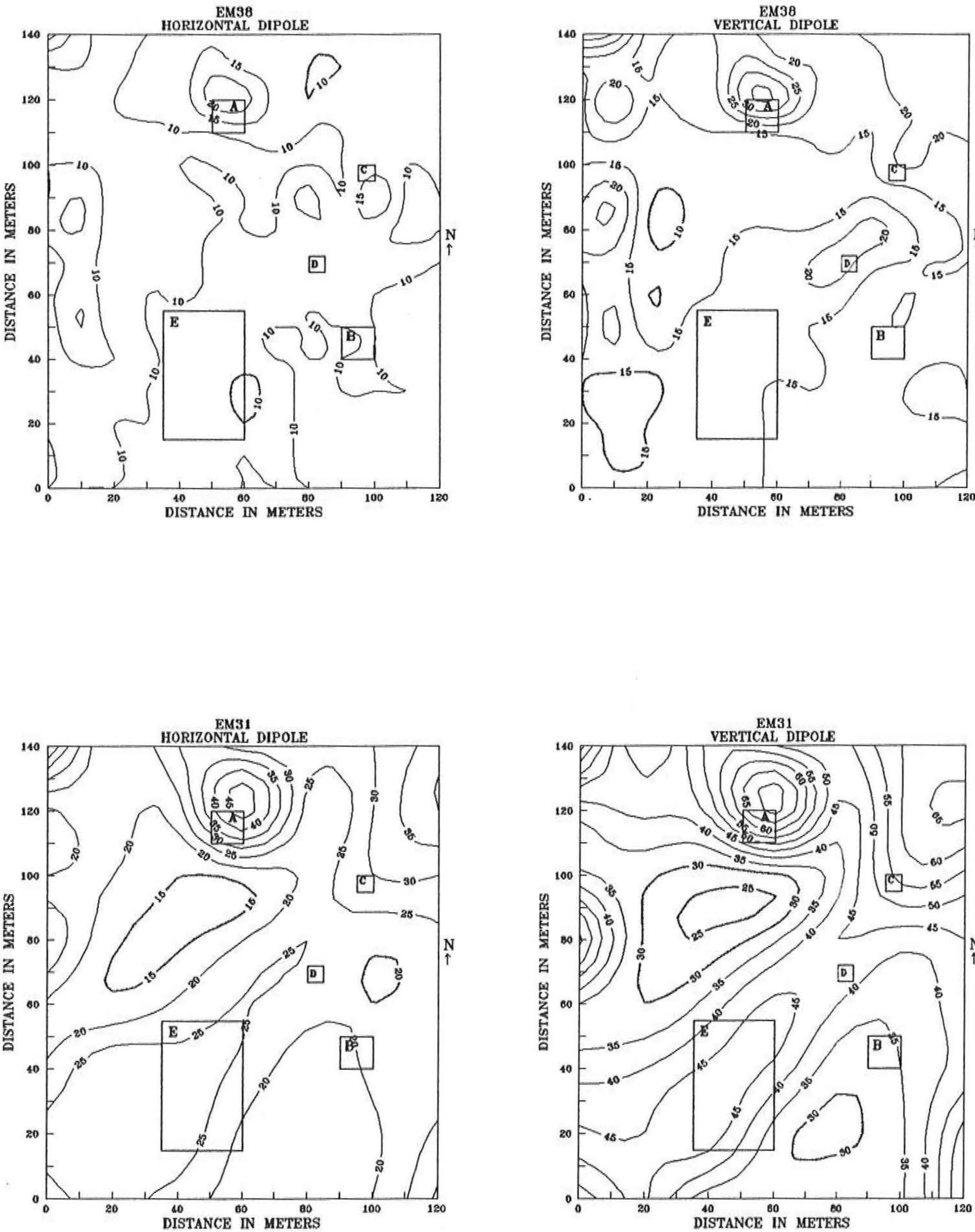
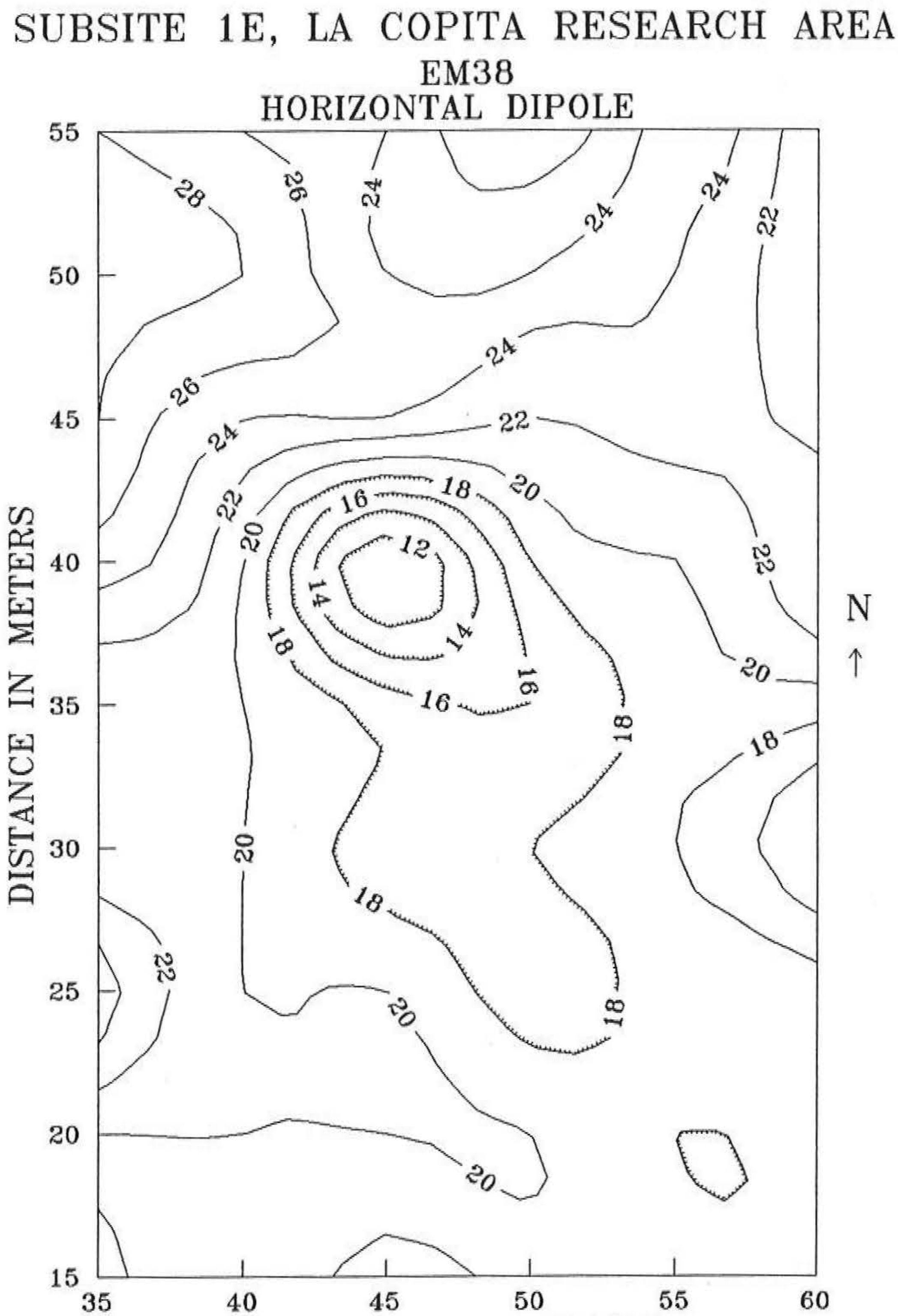

EM38
HORIZONTAL DIPOLE
EM38
VERTICAL DIPOLE
EM31
HORIZONTAL DIPOLE
EM31
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
N
A
B
C
D
E

Figure 14


SUBSITE 1E, LA COPITA RESEARCH AREA
EM38
HORIZONTAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
N
↑
55
50
45
40
35
30
25
20
15
35
40
45
50
55
60
28
26
24
24
24
22
24
26
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18
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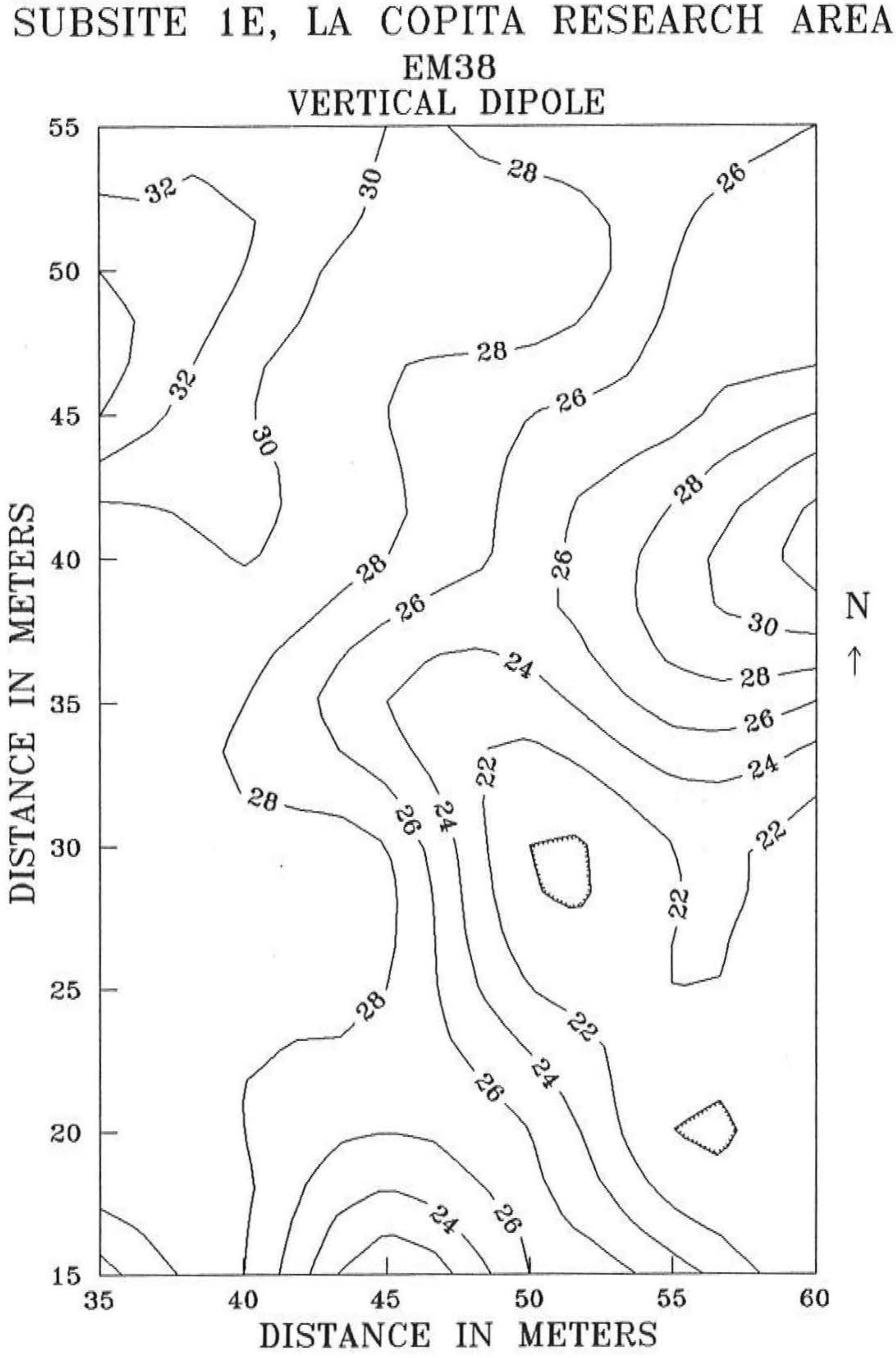
Figure 15


SUBSITE 1E, LA COPITA RESEARCH AREA
EM38
VERTICAL DIPOLE
DISTANCE IN METERS
DISTANCE IN METERS
N
35
40
45
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55
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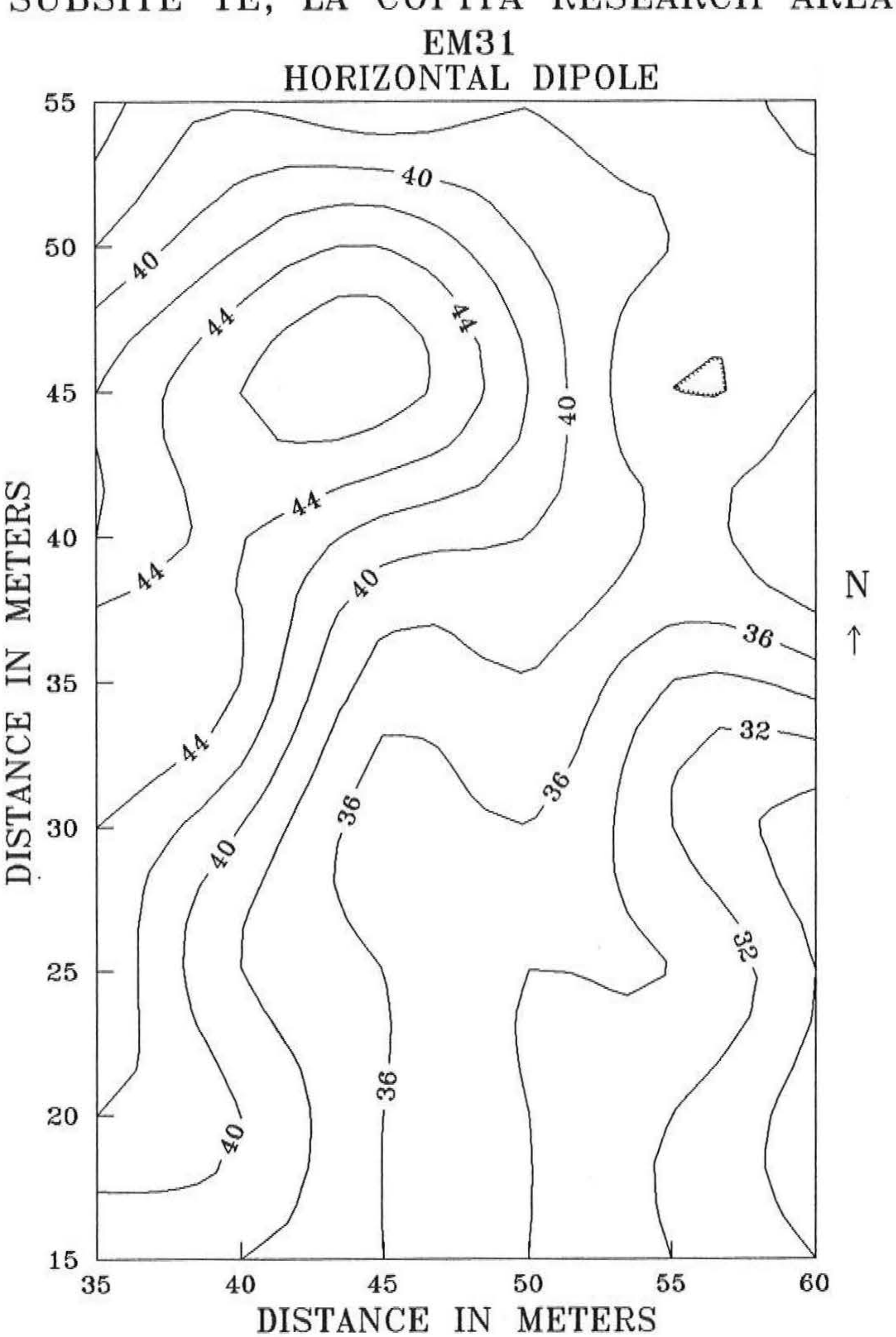
32

Figure 16



SUBSITE 1E, LA COPITA RESEARCH AREA
EM31
HORIZONTAL DIPOLE
DISTANCE IN METERS
55
50
45
40
35
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15
35
40
45
50
55
60
DISTANCE IN METERS
40
40
44
44
40
44
44
40
44
40
40
36
36
36
36
32
32
N
↑

Figure 17

SUBSITE 1E, LA COPITA RESEARCH AREA