Balthaser + Jule
Doolittle

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

Subject: Site Assessments with Electromagnetic Induction (EM) Techniques: Pennsylvania October 4 to 7 1993 **Date:** 14 October 1992

To: Richard N. Duncan
State Conservationist
USDA-Soil Conservation Service
Harrisburg, PA

Purpose:
To use electromagnetic induction (EM) techniques to assess and monitor selected sites within Pennsylvania.

Participants:
Tom Balthaser, District Conservationist, SCS, New Bloomfield, PA
John Benscooter, Waste Management Specialist, Susquehanna Co., PA
Bruce Benton, Geologist, SCS, Harrisburg, PA
Jim Bistline, Soil Conservation Technician, SCS, New Bloomfield, PA
Ellen Dietrich, Soil Scientist, SCS, Mill Run, PA
Jim Doolittle, Soil Specialist, SCS, Chester, PA
Jake Eckenrode, Soil Scientist, SCS, State College, PA
Robert Hotchkiss, District Conservationist, SCS, Montrose, PA
Charlie Miller, Waste Management Technician, Lackawanna Co., PA
Barry Travelpiece, Engineering Technician, SCS, Bloomsburg, PA
Paul Yankovich, District Conservationist, SCS, Bloomsburg, PA
John Zaginaylo, Area Engineer, SCS, Bloomsburg, PA

Activities:
Six sites were surveyed in Clinton, Columbia, Lackawanna, Perry, and Susquehanna counties during the week of 4 to 7 October 1993.

Equipment:
The electromagnetic induction meters were the EM31 and EM38 manufactured by GEONICS Limited. The GPS unit was the Magellen NAVPRO 5000. Two-dimensional plots of the EM data were prepared using SURFER software developed by Golden Software, Inc.

Discussion:
Grids were established at each site. Generally, grids were established in a downslope direction of each existing or proposed waste-holding area. Grid intervals varied with the size of the survey area and the time and resources available. Survey flags were inserted in the ground at each grid intersect. At each grid intersect, measurements were obtained with the EM38 and/or EM31 meters in both the horizontal and vertical dipole modes. Measurements of conductivity are expressed in milliSiemens per meter (mS/m).

For each site, computer simulations were prepared of data obtained with the EM31 and/or EM38 meters in 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 mode. The EM38 meter scans depths of 0-0.75 meters in the horizontal and 0-1.50 meters in the vertical dipole mode.

GPS/EM Survey

Area of Sequatchie loam near Lock Haven, Clinton County

The purpose of this survey was to evaluate the potential of using EM techniques and GPS to chart variations in soil type. The study site was in a nearly-level area of Sequatchie loam. Sequatchie (fine-loamy, siliceous, thermic Humic Hapludults) is a very deep, well drained soil formed in alluvium. Electromagnetic induction techniques were used to evaluate and map variations in stratigraphic layers.

The study site was located in a open, cultivated area on the flood plain of the West Branch Susquehanna River northwest of Lock Haven. The dimensions of the study site were approximately 400 feet wide and 1400 feet long (about 12.8 acres). Four traverses were made parallel with the long axis of the field. Observations were taken with the Magellen NAVPRO 5000 GPS unit and the EM31 and EM38 meters at 100 foot intervals along each of the four, equally-spaced, transect lines. The Magellen NAVPRO 5000 was used in the uncorrected, three-dimensional, autonomous mode. The Lock Haven Quadrangle (7.5 minute topographic series) was used as a reference.

Figure 1 is a plot of the recorded GPS observation sites relative to the field boundary. At the time of the survey, signal quality and position dilution of precision (PDOP) were good to exceptional. The coordinates for the field boundary were measured from the Lock Haven, Pennsylvania, 7.5 minute Topographic Quadrangle using the LAT/LONG software program. In Figure 1, the locations of these coordinates are indicated with open circles.

It is apparent from Figure 1, that the use of uncorrected, three-dimensional, autonomous GPS data for detailed site assessments is inappropriate. The locations of observation sites are scattered with little indication of the linear survey pattern. Twenty-three of the fifty observation sites were located outside the boundaries of the field. Disregarding positioning errors, figures 2 through 5 were prepared from the EM data collected at each of the observation sites. Though the placement of observation sites is incorrect, these figures characterize the area of Sequatchie loam as having low and essentially invariable EM responses.

Though inappropriate at the intensity and scale of mapping used in this exercise, the use of similarly derived GPS and EM data may be appropriate and useful in more generalized and less site-specific surveys of larger areas. These surveys could result in the production of generalized, apparent conductivity maps for broad areas. Conductivity values can be related to major soil and lithologic groupings.

EM Survey of Waste-holding Sites

Cron's Dairy Farm - Susquehanna County

The purpose of this survey was to further demonstrate the potential of using EM techniques to chart the extent of surface runoff from an animal holding area. The selected animal holding area has been in use for at least 20 years.

An irregularly shaped, rectangular grid was established in a pasture which was located immediately downslope of farm structures and the animal holding area. The survey area covered about 2.7 acres with maximum dimensions of 400 and 300 feet. The grid interval was 50 feet, except in the portion of the survey area immediately north of a fence line which bordered the pasture. Here, the grid interval was 25 feet. A county road formed the western boundary of the pasture and the study site.

Figure 6 is a topographic map of the survey area. The contour interval is 2 feet. In the southeast portion of the survey area, an intermittent stream follows the concave flexure in the contour lines. This stream extends upslope towards the holding area (see Figure 6). Contaminants from the holding area were suspected of being carried away by runoff and stream discharge into a neighbors pond.

Figures 7 through 10 are two-dimensional plots of the EM data. In each plot, a fairly broad and noticeable zone of relatively high apparent conductivity values emanates, extends, and dissipates in a downslope direction from the animal-holding area (towards lower margin of study area). Within this zone, values of apparent conductivities decrease both horizontally (in a downslope direction) and vertically (with increasing soil depth). These pattern suggest the concentrations of animal wastes in the upper part of the soils and its probable dissemination by runoff and stream discharge from the holding area. This zone is most extensive and best expressed in Figure 7, (data collected with the EM38 meter in the horizontal dipole orientation (0 to 0.75 meters)). This zone becomes more restricted with increasing observation depths. When the depth of observation is 6 meters (measurements taken with the EM31 meter in the vertical dipole orientation (Figure 10)), the zone of higher conductivity values is restricted to a radius of about 50 feet from the holding area.

Figures 7 through 10 indicate that elevated values of apparent conductivity are detectable along the stream channel at distances as great as 300 to 350 feet from the holding area.

Sheypuk's Dairy Farm - Lackawanna County

The purpose of this survey was to evaluate the potential of using EM techniques to chart the extent of surface runoff from a recently constructed, controlled microbial-composting area. The composting area was underlain with a plastic liner. A drain line was located along the downslope border of the composting area. The grid interval for this survey was 25 feet. The survey area extended from the

composting area to a wetland which formed the lower and right-hand boundaries of the survey site (see figures 11 and 12).

In figures 11 and 12, the higher values of apparent conductivity in the lower right-hand corner of the composting area may indicate the potential flow and concentration of contaminants. The drain slopes towards and outlets in this corner of the composting area.

Higher values of apparent conductivity in the lower left- and right-hand corners of Figure 11 are believed to have been produce by animal wastes. An area formerly used to pile animal wastes for short periods was located in the lower left-hand corner of figures 11 and 12. The residue from these wastes is the most probable source of the elevated EM responses observed in the horizontal dipole orientation (Figure 11) in this portion of the survey area. A stream which may have been contaminated by waste products from a dairy parlor operation is located in the lower right-hand corner of the survey area. Increased soil water and soluble salts contents may be responsible for the elevated EM responses in this portion of the survey area.

Hartelton's Dairy Farm - Columbia County

The purpose of this survey was to obtain background EM data prior to the construction of a compost storing area. The survey site was located immediately east of a county road. An irregularly-shaped rectangular grid was established across the site with maximum dimensions of 300 by 200 feet. The grid interval was 50 feet in east-west directions and 25 feet in north-south directions.

Figures 13 and 14 simulate the results of an EM38 survey conducted in the horizontal and vertical dipole orientations, respectively. The interval is 2 mS/m. Generally, values of apparent conductivity were low and invariable across the site. Piles of leaves and other organic debris are believed to be responsible for the elevated EM responses in the southeast corner of the survey area.

Amos Hoover HDP lined manure storage pond - Perry County

In September 1991, an EM survey was conducted in an area which was located down-gradient of a proposed storage pond. The results of this survey are shown in Figures 15 and 16. Data from seventy-nine observations sites were used to construct these figures. Although variable across the site, values of apparent conductivity were generally higher on lower-lying slope positions and along a drainage channel. In addition, though care was exercised in the placement of the EM31 meter, some of the variations in the EM response were attributed to the presence of metallic debris which was scattered throughout the wooded portion of the survey area.

The purpose of the 1991 survey was to provide baseline data which could be compared with data collected 2 to 3 years following the construction and use of the manure storage pond. This structure was constructed in 1992. Figures 17 and 18 are the results of the survey

conducted during this field investigation. Measurements were taken with the EM31 meter at the same observation sites used in 1991. Compared with the 1991 data, in 1993, the EM response was noticeably higher across the site. This can be attributed to wetter soil conditions in 1993. In addition, in 1993, values of apparent conductivity were conspicuously higher along the drainageway.

The location of the outlet pipe from the waste storage pond is shown in figures 17 and 18. This outlet empties into the drainage channel. Though no conclusions can be drawn from the data, values of apparent conductivity were conspicuously higher below and immediately upslope of the outlet. Saturated soil conditions, finer-textured embankment materials, and contaminants are all possible factors which can be used to explain the higher EM responses near the outlet.

In figures 19 and 20, the 1993 data is compared with the 1991 data. In 1993, the EM response was higher at all sites. In addition, the difference was greater and more variable in the shallower measurements taken with the EM31 meter in the horizontal dipole orientation. Generally, these measurements show a 2- to 5-fold increase over the 1991 data. These patterns are believed to reflect chiefly changes in soil moisture contents between 1991 (relatively dry year) and 1993 (relatively wet year). However, in both dipole orientations, the area adjacent to the outlet pipe shows the greatest change in EM response. A follow-up survey should be planned for 1995.

Results:

1. Results from a study conducted in an area of Sequatchie loam indicate that the use of uncorrected, three-dimensional, autonomous GPS data for detailed site assessments is inappropriate.

2. Results from this study support the continued use of the EM31 and EM38 meters to assess the dissemination of contaminants from animal waste holding areas by deep seepage and surface runoff.

3. Results indicate the dissemination of contaminants by surface runoff from animal waste holding structures.

4. EM surveys provide interpretative maps of variations in apparent conductivity at selected sites. Ground truth verification is needed to confirm the nature and magnitude of inferences made from these maps.

It is my pleasure to work with the members of your fine staff.

With kind regards.

James A. Doolittle
Soil Specialist

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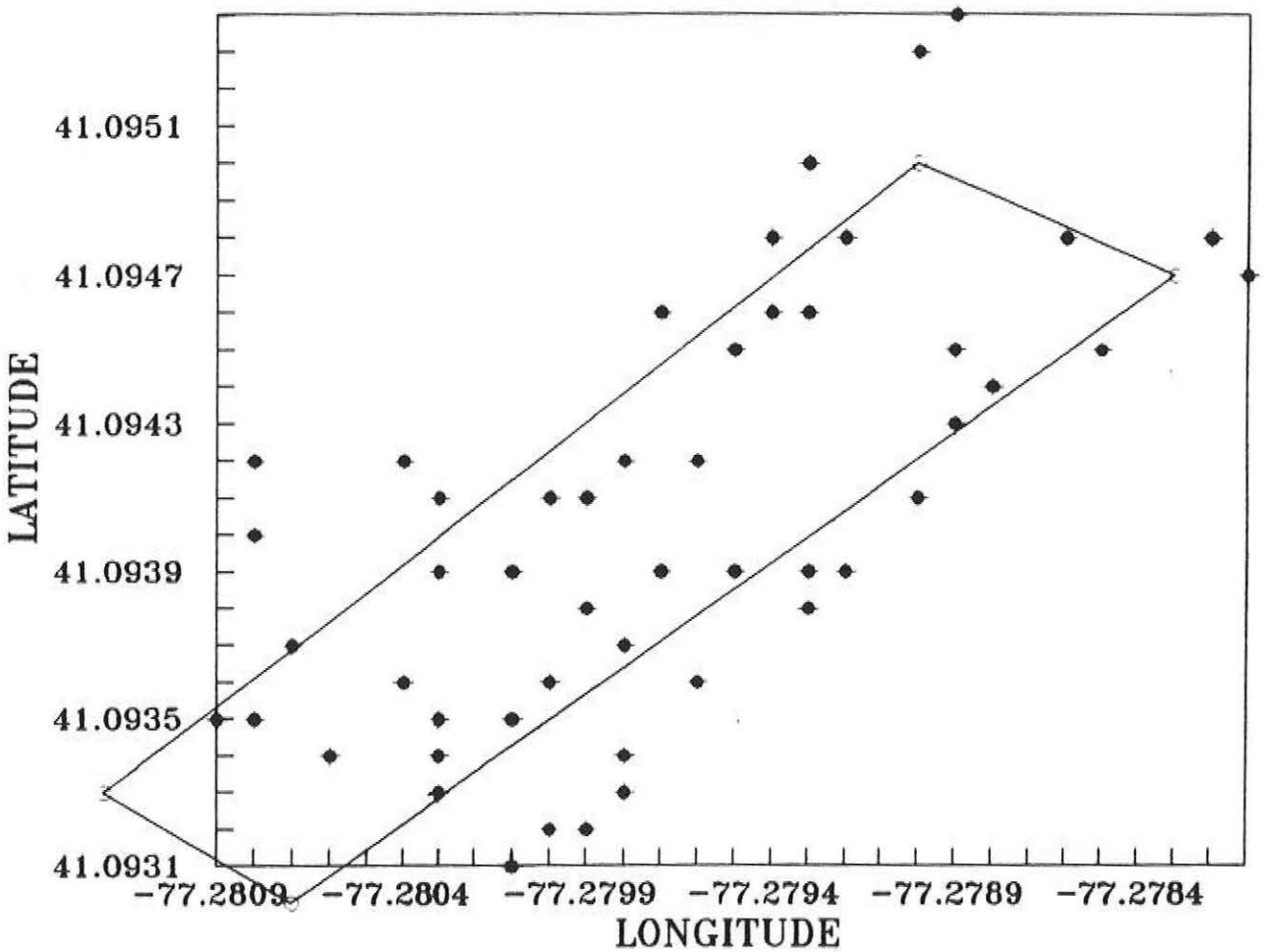
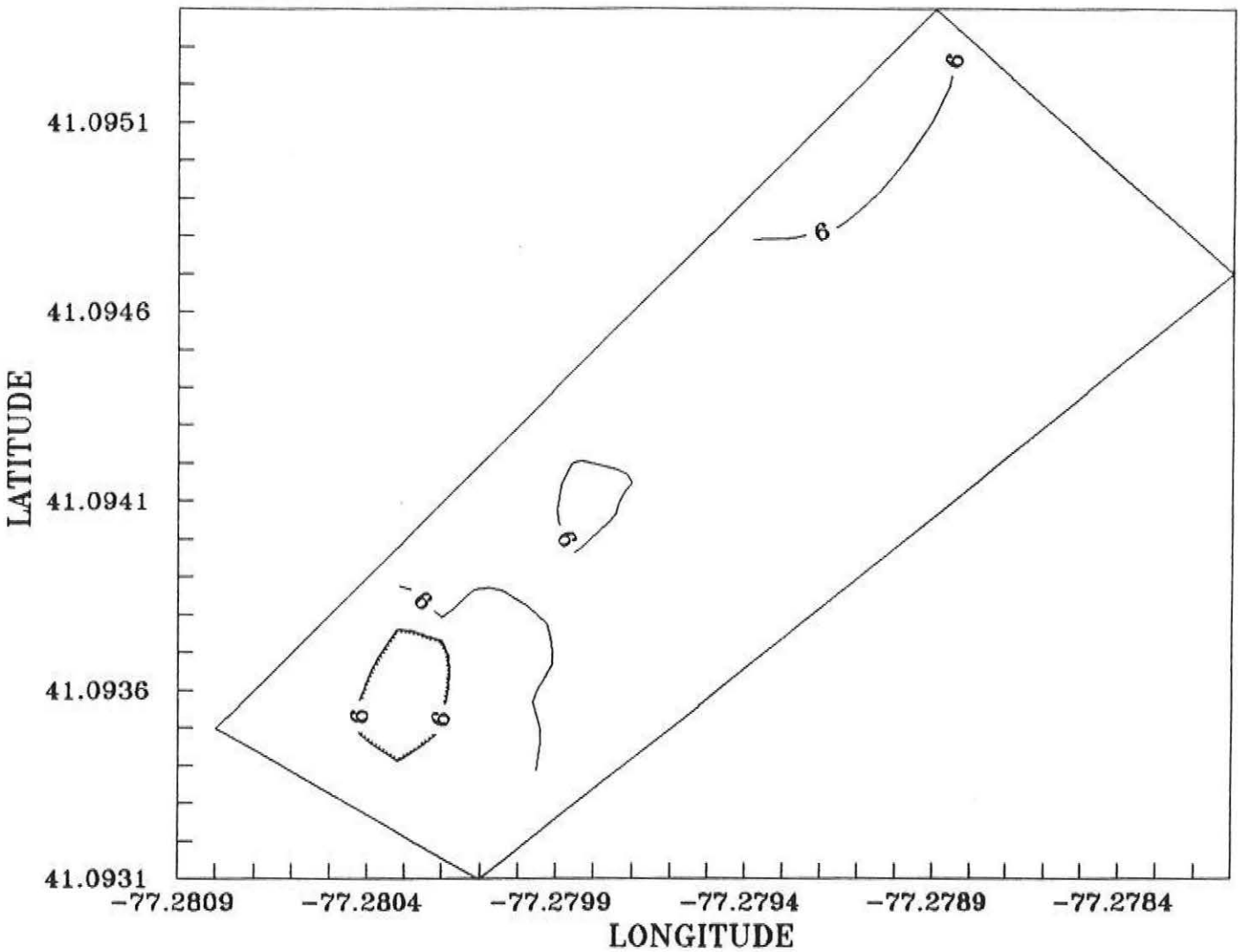
GPS SURVEY IN AN AREA OF SEQUATCHIE LOAM

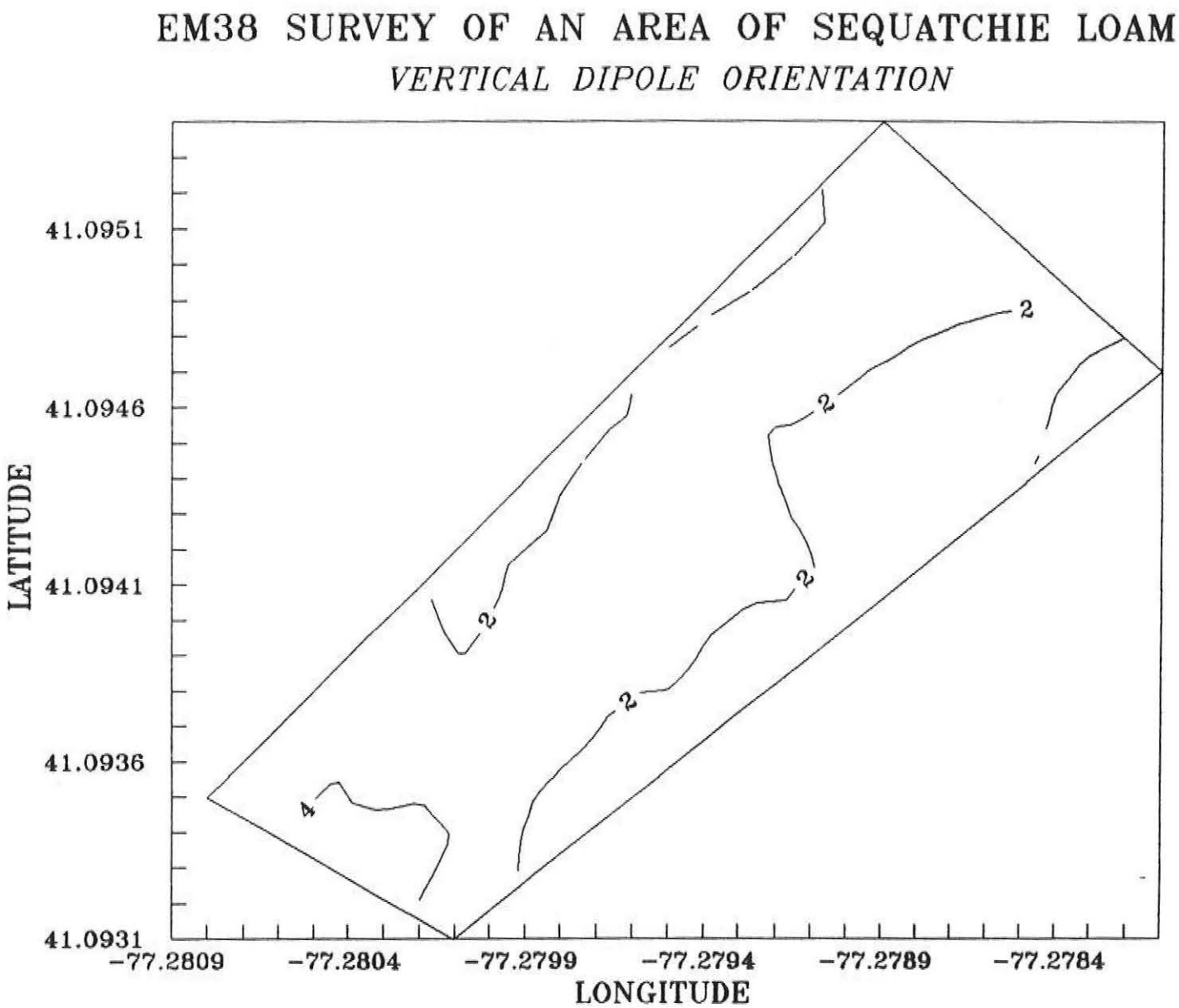
LOCATION OF OBSERVATION SITES



EM38 SURVEY OF AN AREA OF SEQUATCHIE LOAM

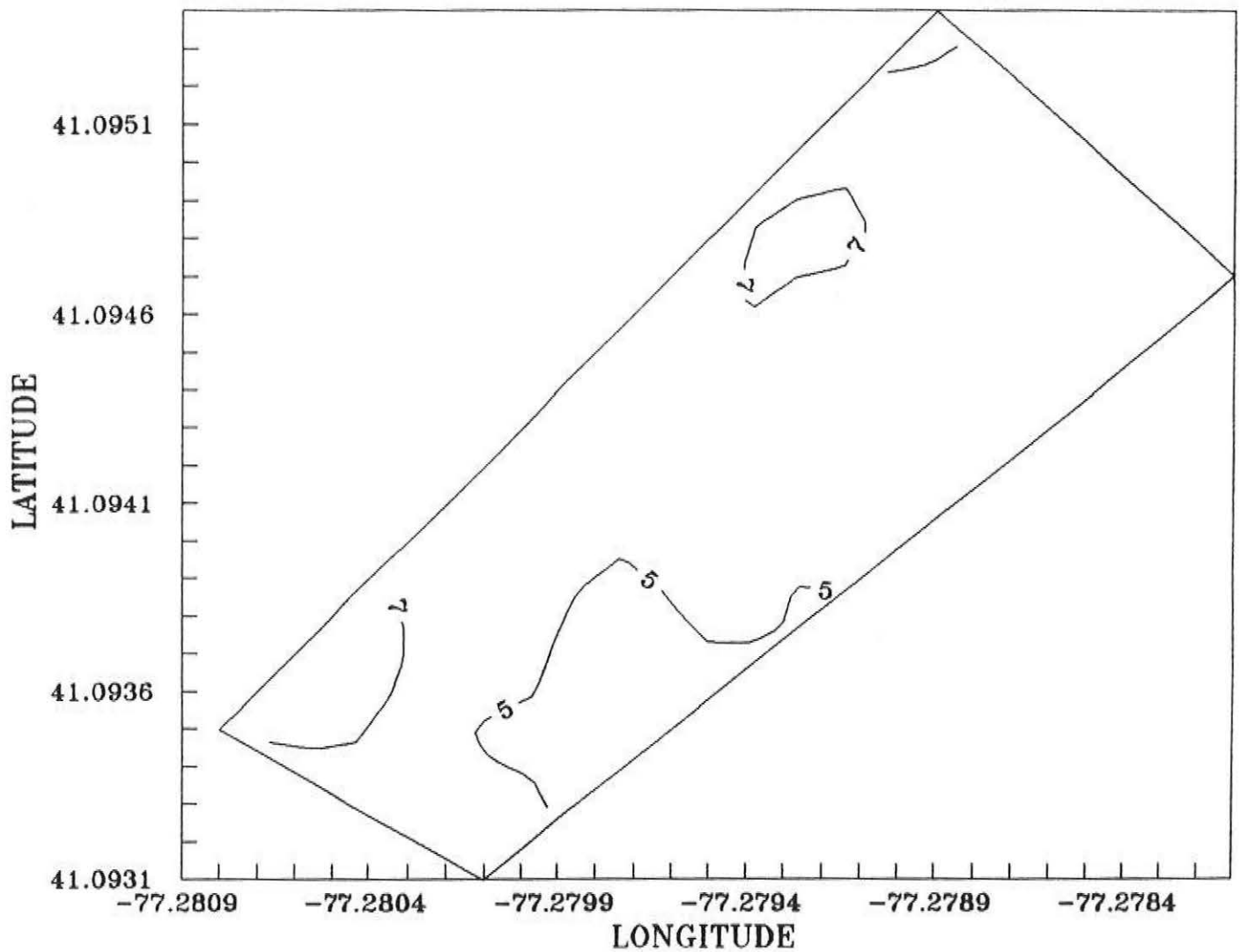
HORIZONTAL DIPOLE ORIENTATION




EM38 SURVEY OF AN AREA OF SEQUATCHIE LOAM
VERTICAL DIPOLE ORIENTATION
41.0951
41.0946
41.0941
41.0936
41.0931
LATITUDE
2
2
2
2
2
4
-77.2809
-77.2804
-77.2799
-77.2794
-77.2789
-77.2784
LONGITUDE

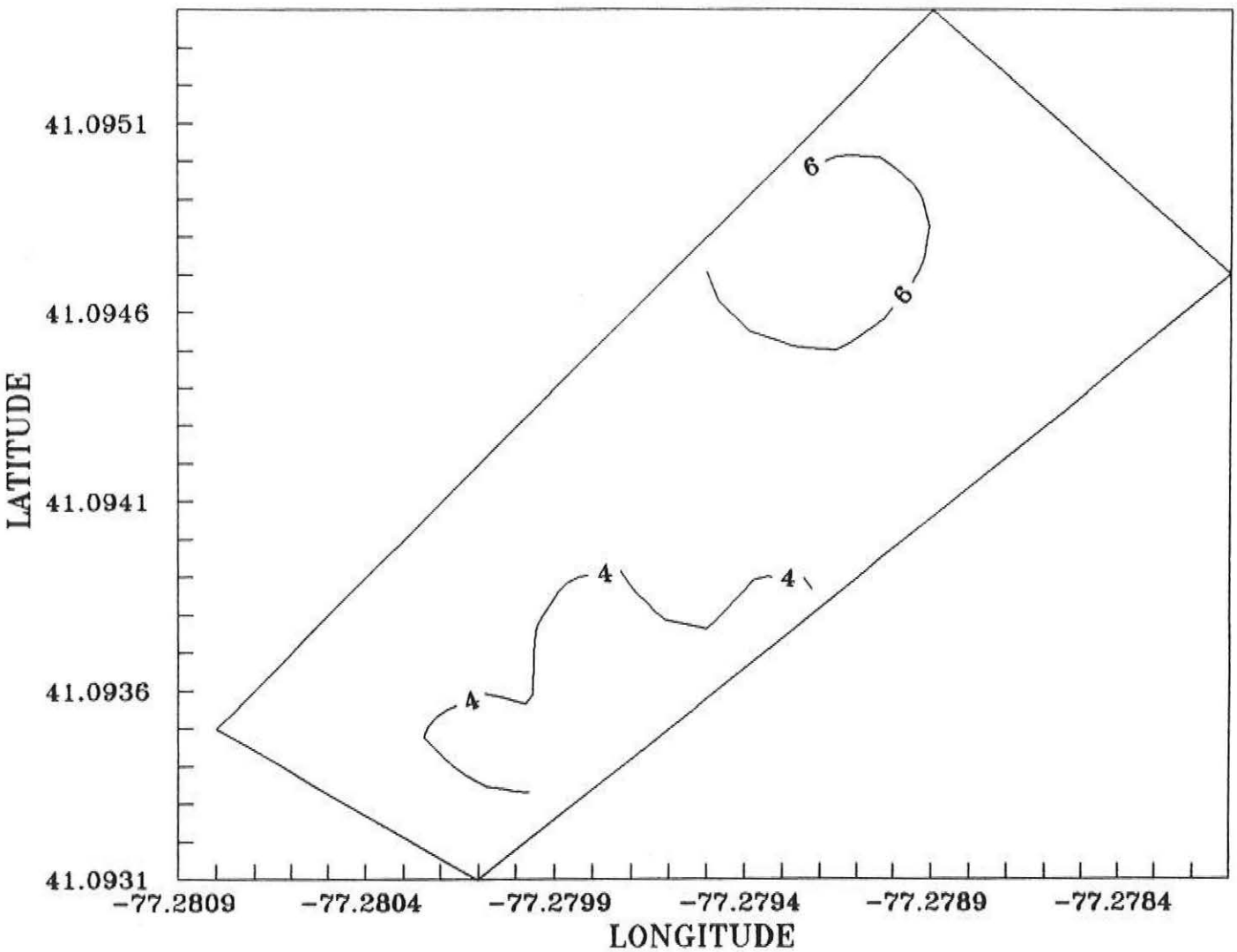
EM31 SURVEY OF AN AREA OF SEQUATCHIE LOAM

HORIZONTAL DIPOLE ORIENTATION



EM31 SURVEY OF AN AREA OF SEQUATCHIE LOAM

VERTICAL DIPOLE ORIENTATION



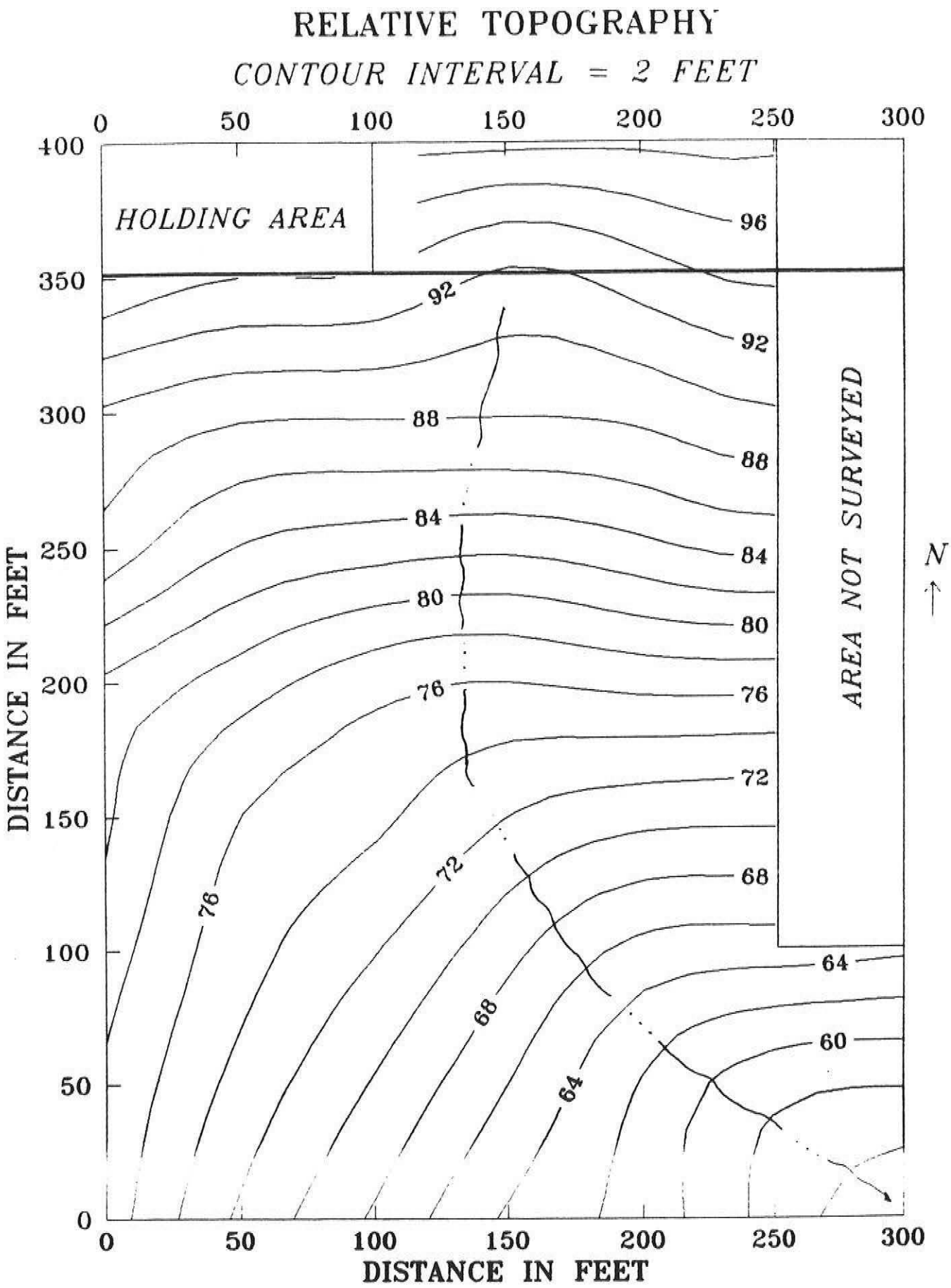
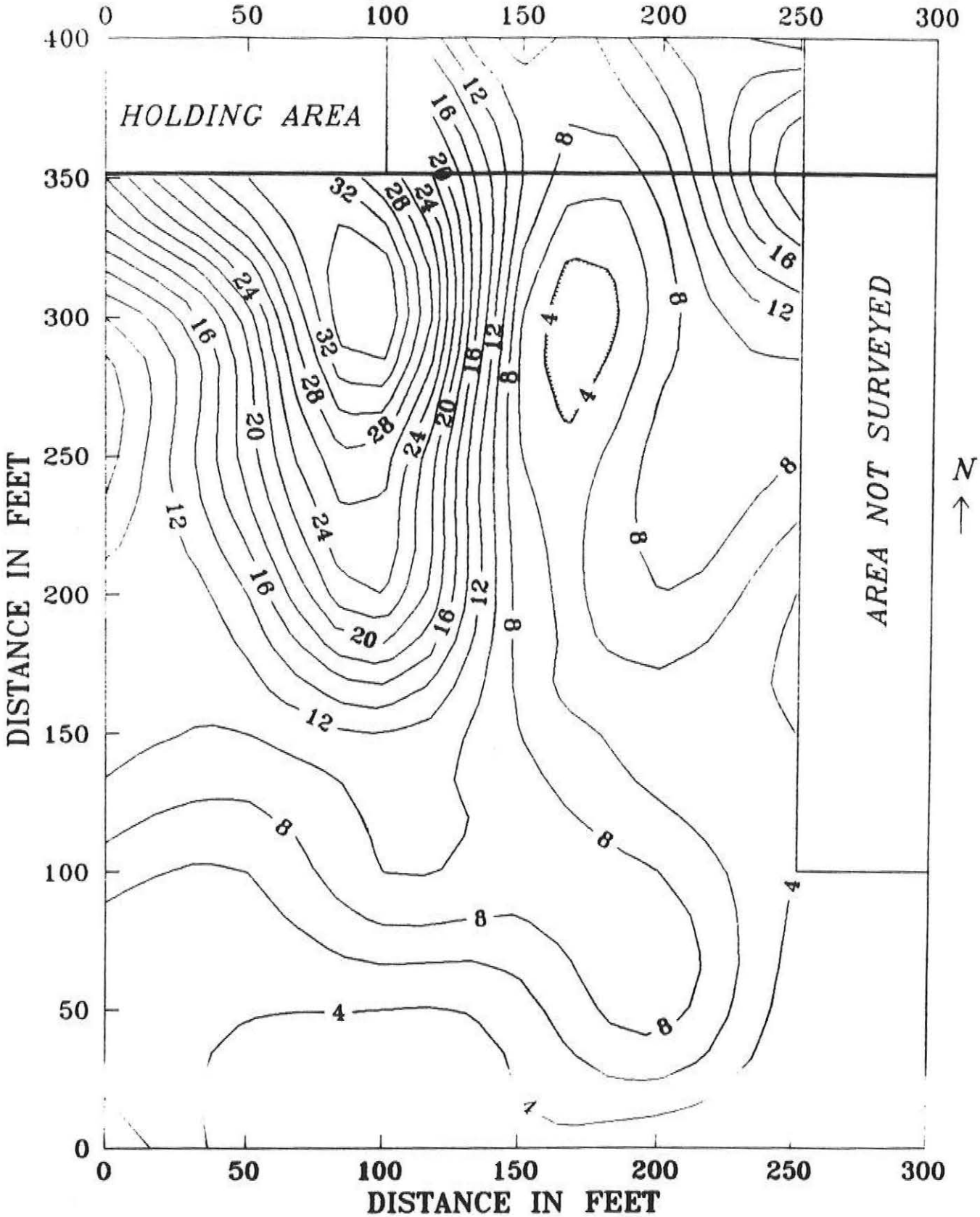
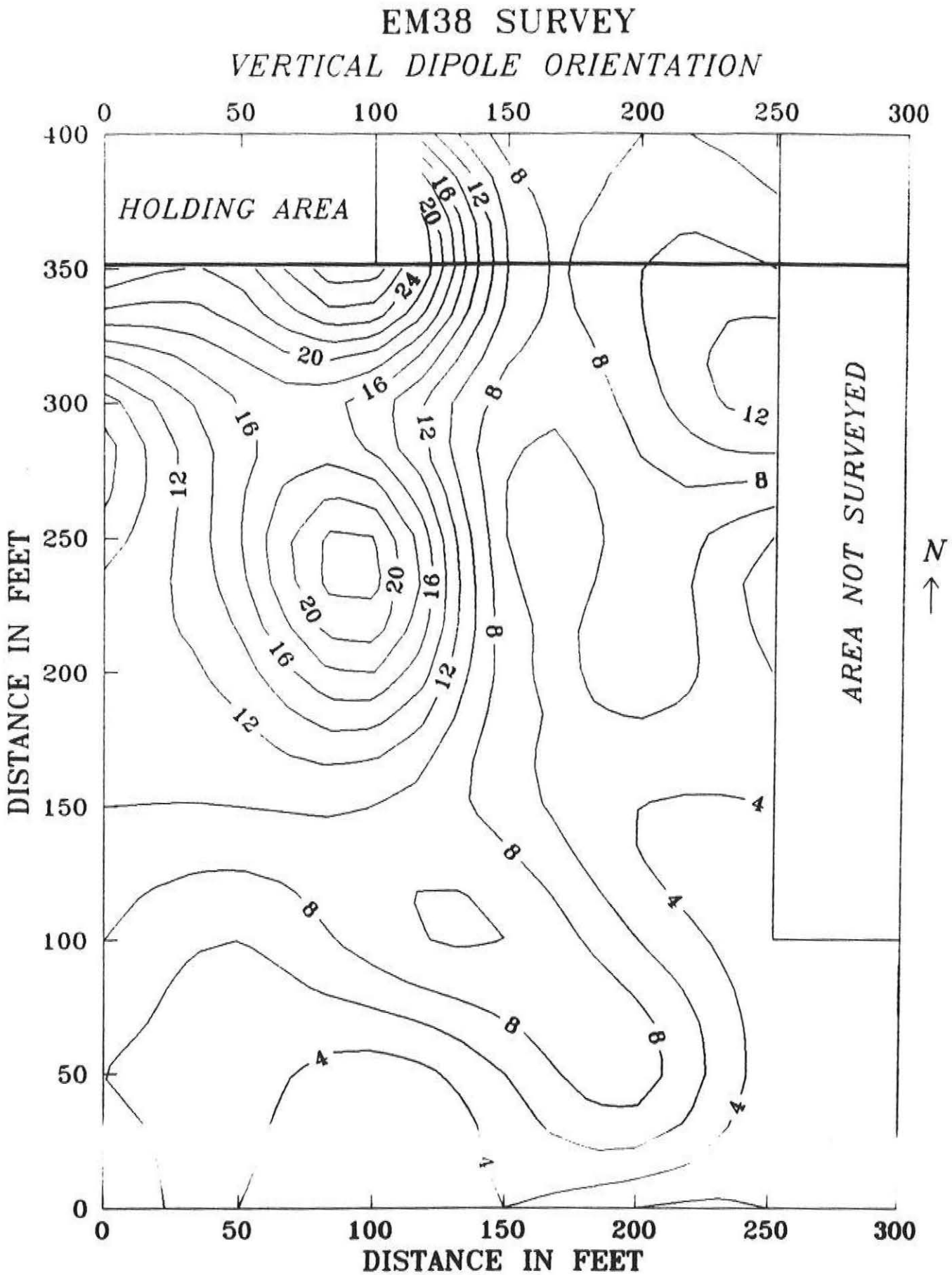

RELATIVE TOPOGRAPHY
CONTOUR INTERVAL = 2 FEET
HOLDING AREA
AREA NOT SURVEYED
N
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
400
96
92
88
84
80
76
72
68
64
60

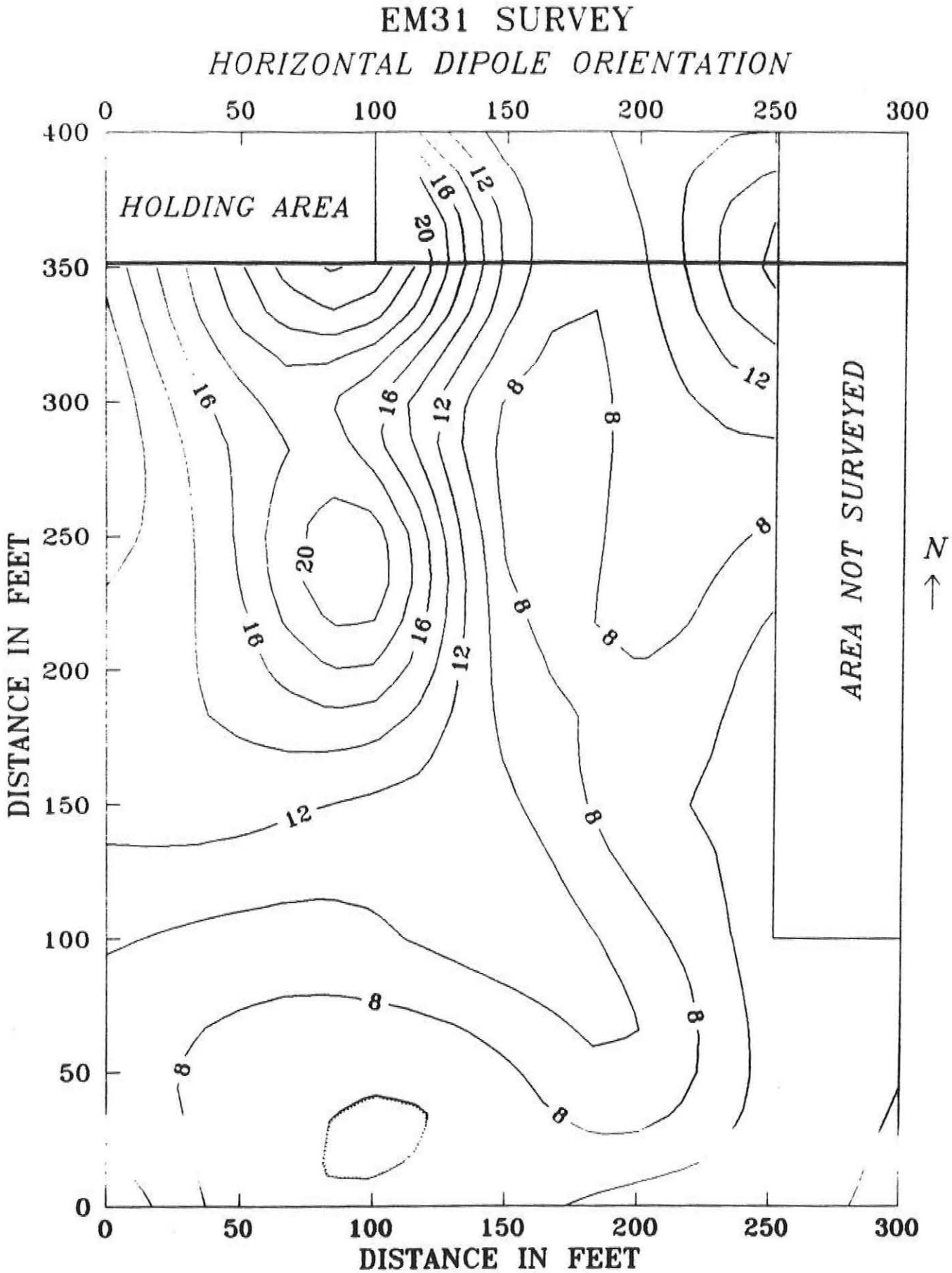
Figure 7

EM38 SURVEY

HORIZONTAL DIPOLE ORIENTATION

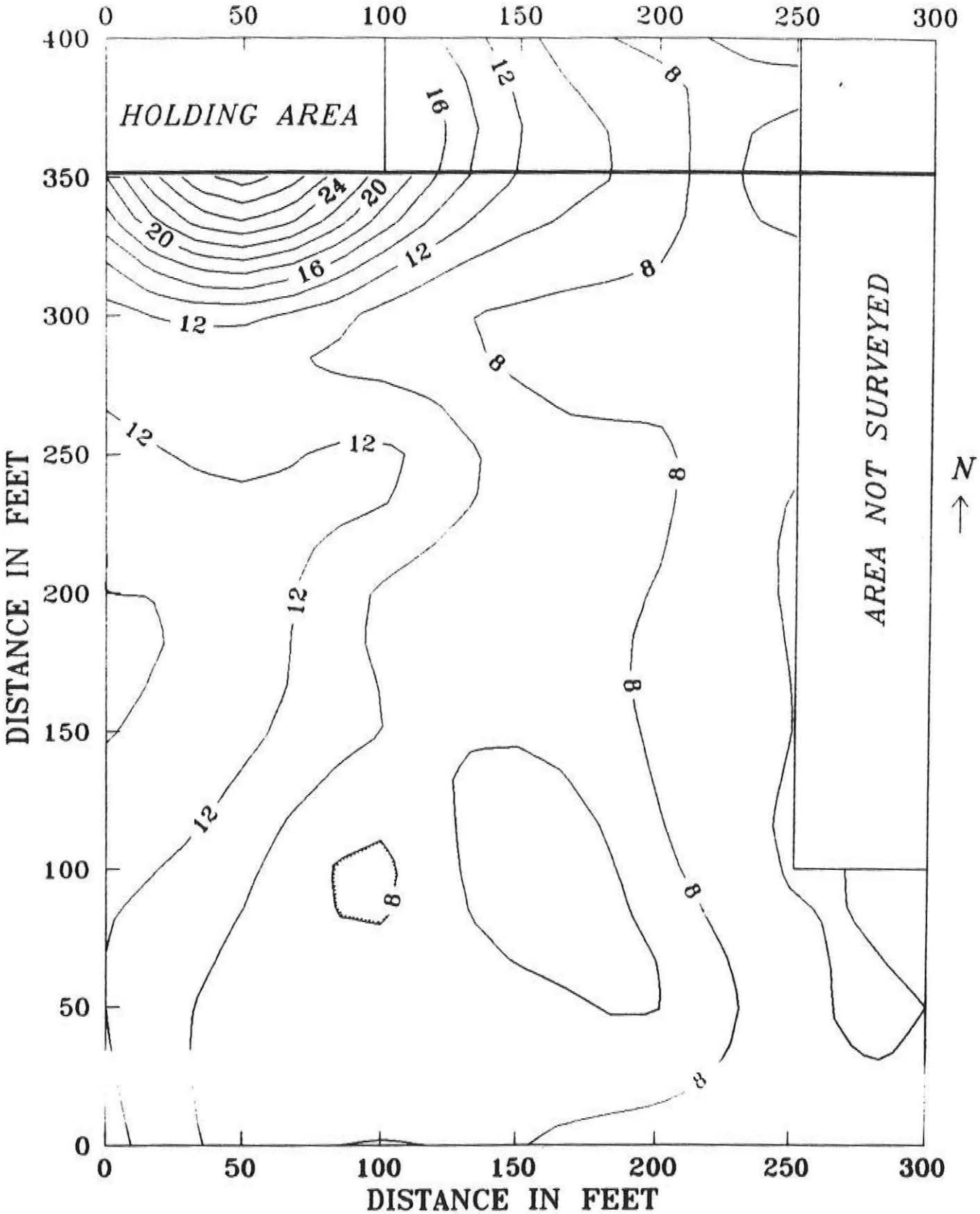


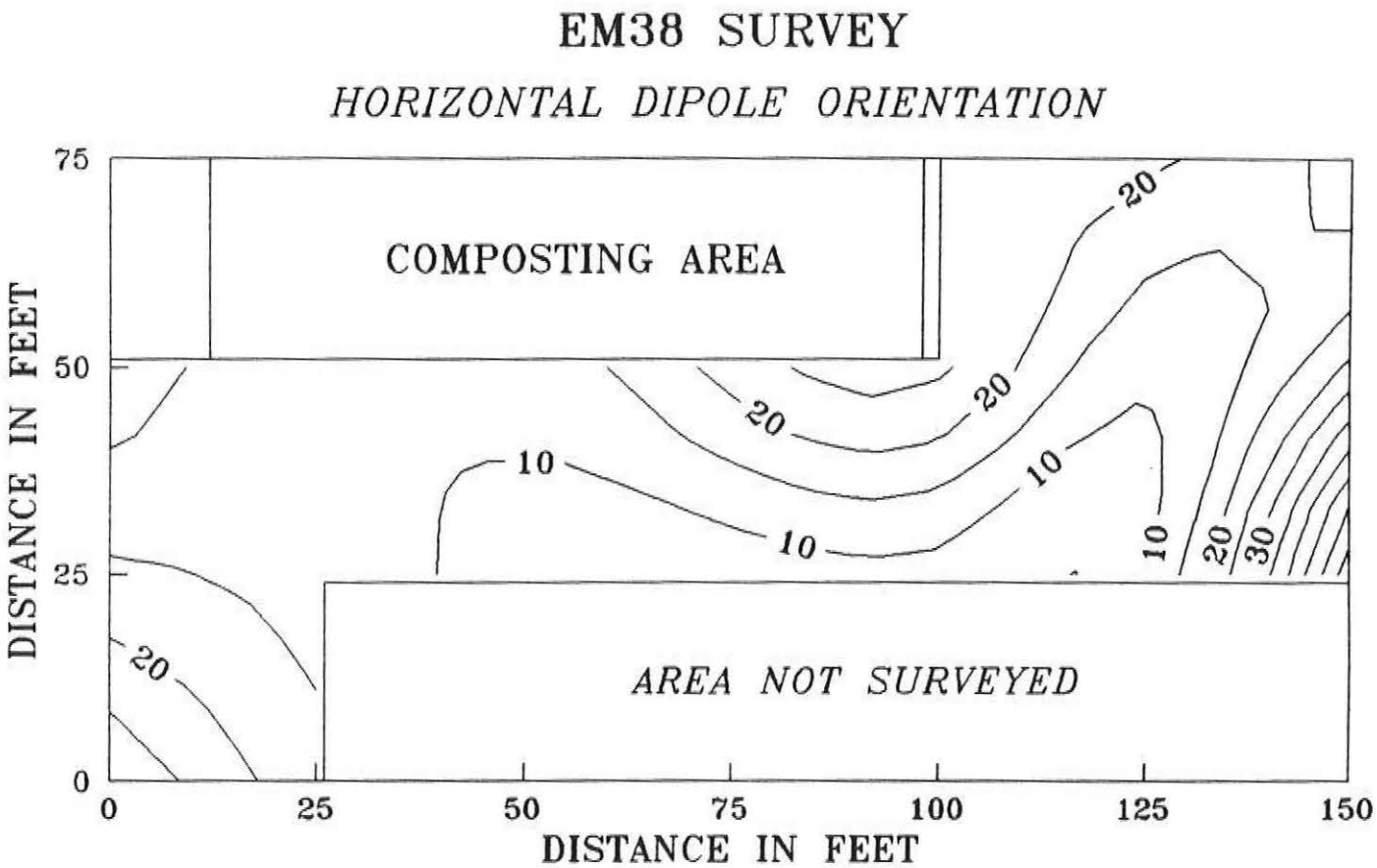

EM38 SURVEY
VERTICAL DIPOLE ORIENTATION
HOLDING AREA
AREA NOT SURVEYED
N
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
400
350
4
8
12
16
20
24

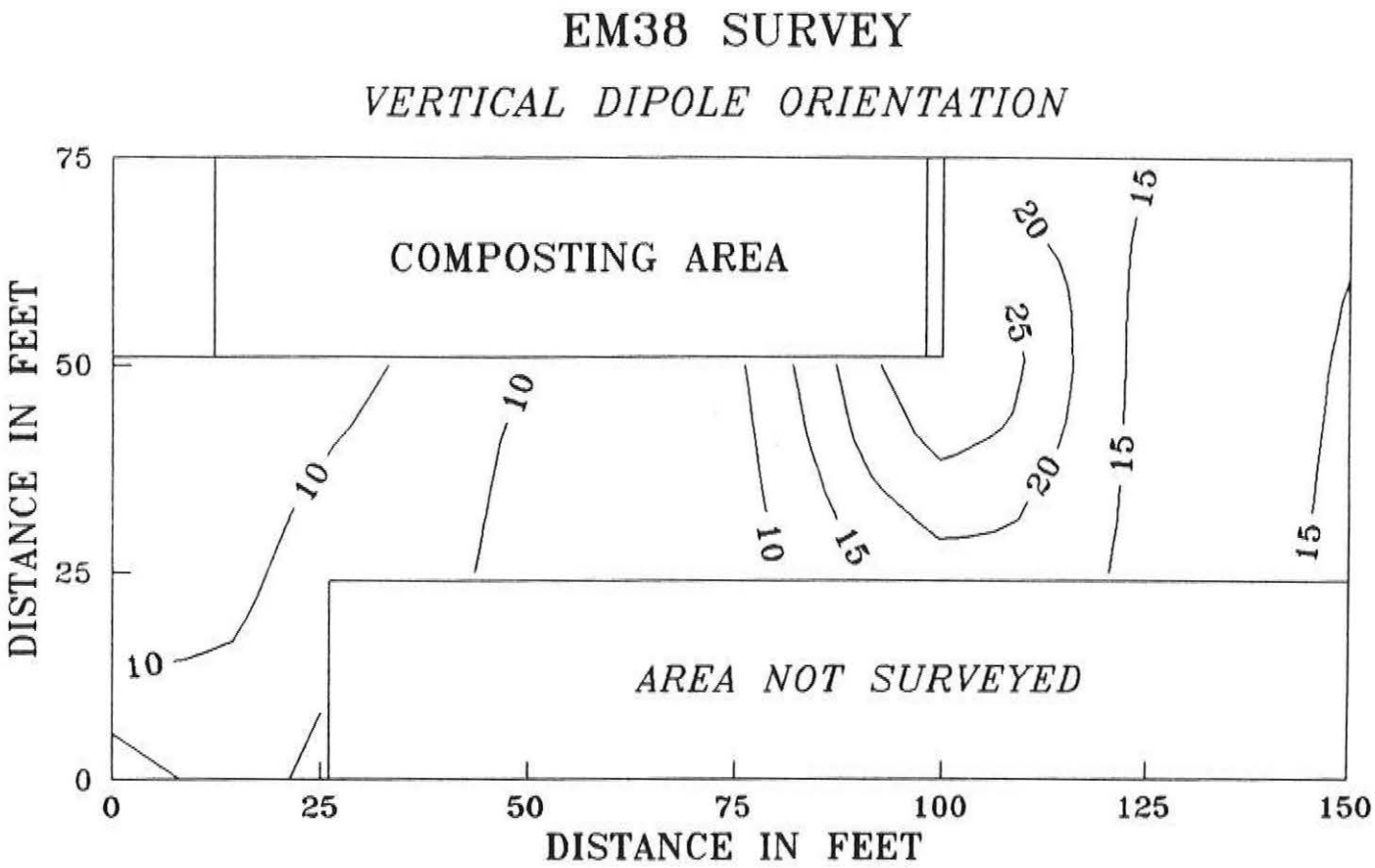

EM31 SURVEY
HORIZONTAL DIPOLE ORIENTATION
HOLDING AREA
AREA NOT SURVEYED
N
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
400
8
12
16
20

EM31 SURVEY

VERTICAL DIPOLE ORIENTATION

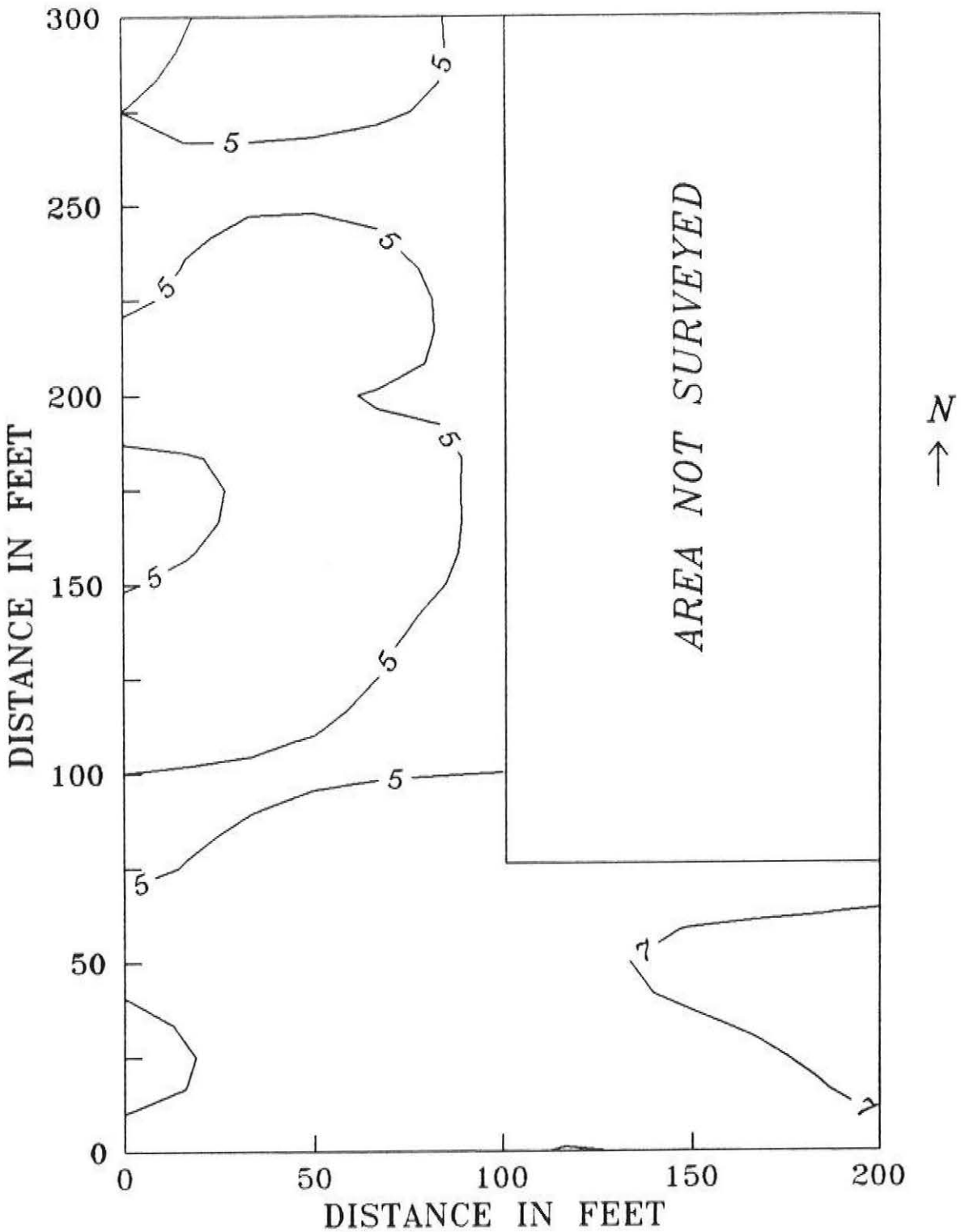



EM38 SURVEY
HORIZONTAL DIPOLE ORIENTATION
COMPOSTING AREA
AREA NOT SURVEYED
20
20
20
10
10
10
10
20
30
20
DISTANCE IN FEET
DISTANCE IN FEET
0
25
50
75
100
125
150
0
25
50
75


EM38 SURVEY
VERTICAL DIPOLE ORIENTATION
COMPOSTING AREA
AREA NOT SURVEYED
DISTANCE IN FEET
DISTANCE IN FEET
0
25
50
75
100
125
150
10
15
20
25

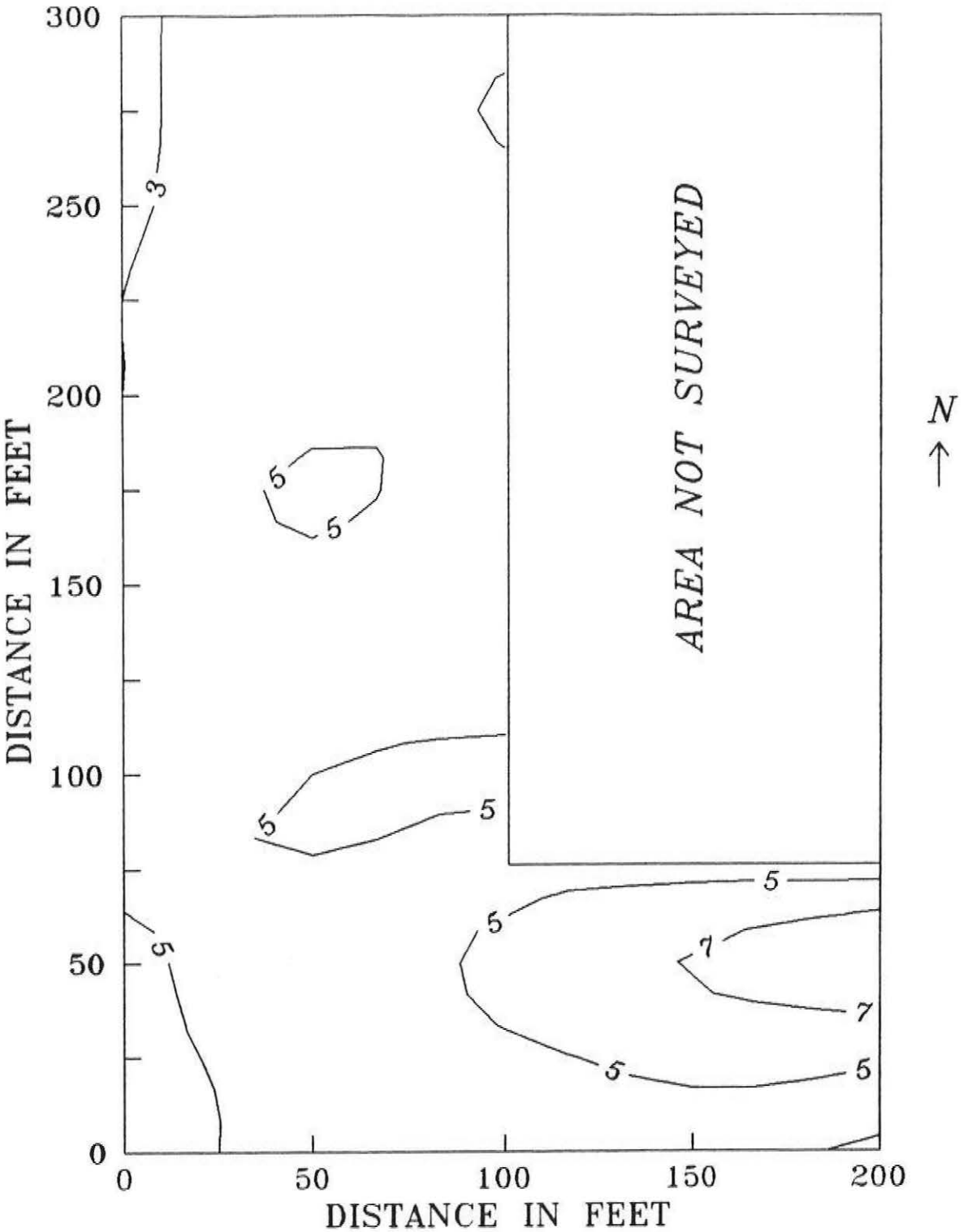
EM38 SURVEY

HORIZONTAL DIPOLE ORIENTATION



EM38 SURVEY

VERTICAL DIPOLE ORIENTATION



EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

1991 – HORIZONTAL DIPOLE ORIENTATION

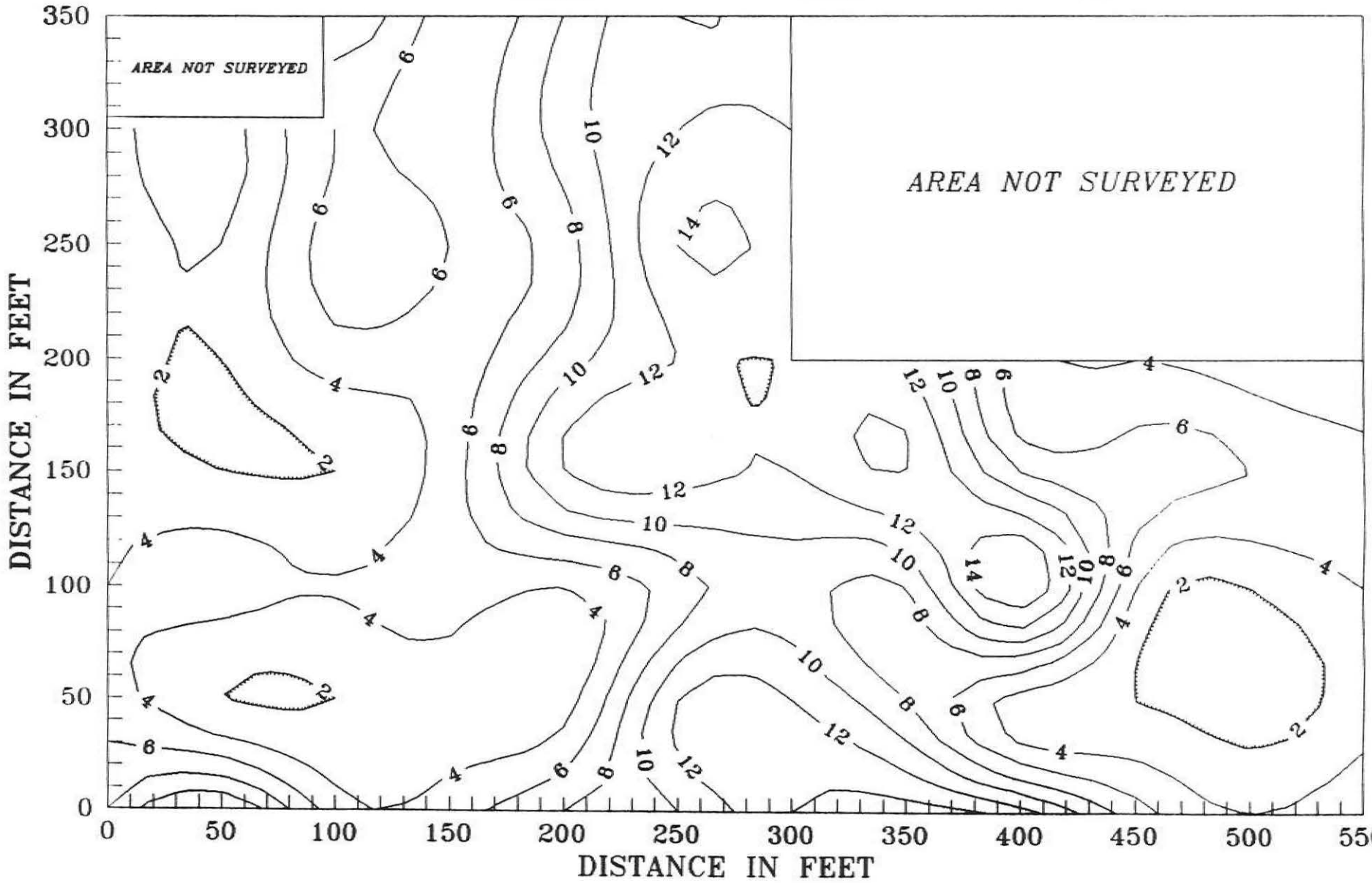


Figure 15

EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

1991 – VERTICAL DIPOLE ORIENTATION

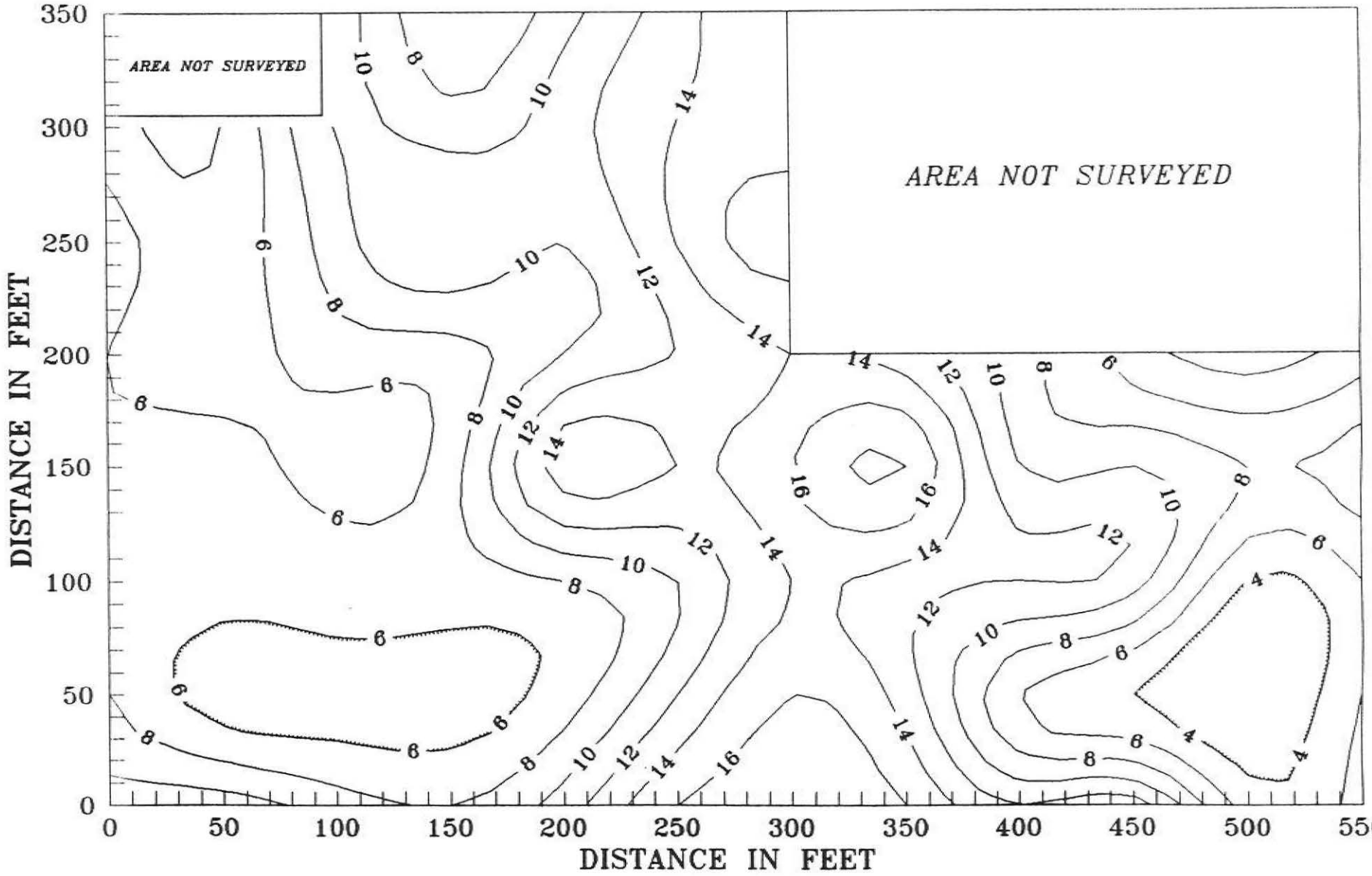


Figure 16

EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

1993 – HORIZONTAL DIPOLE ORIENTATION

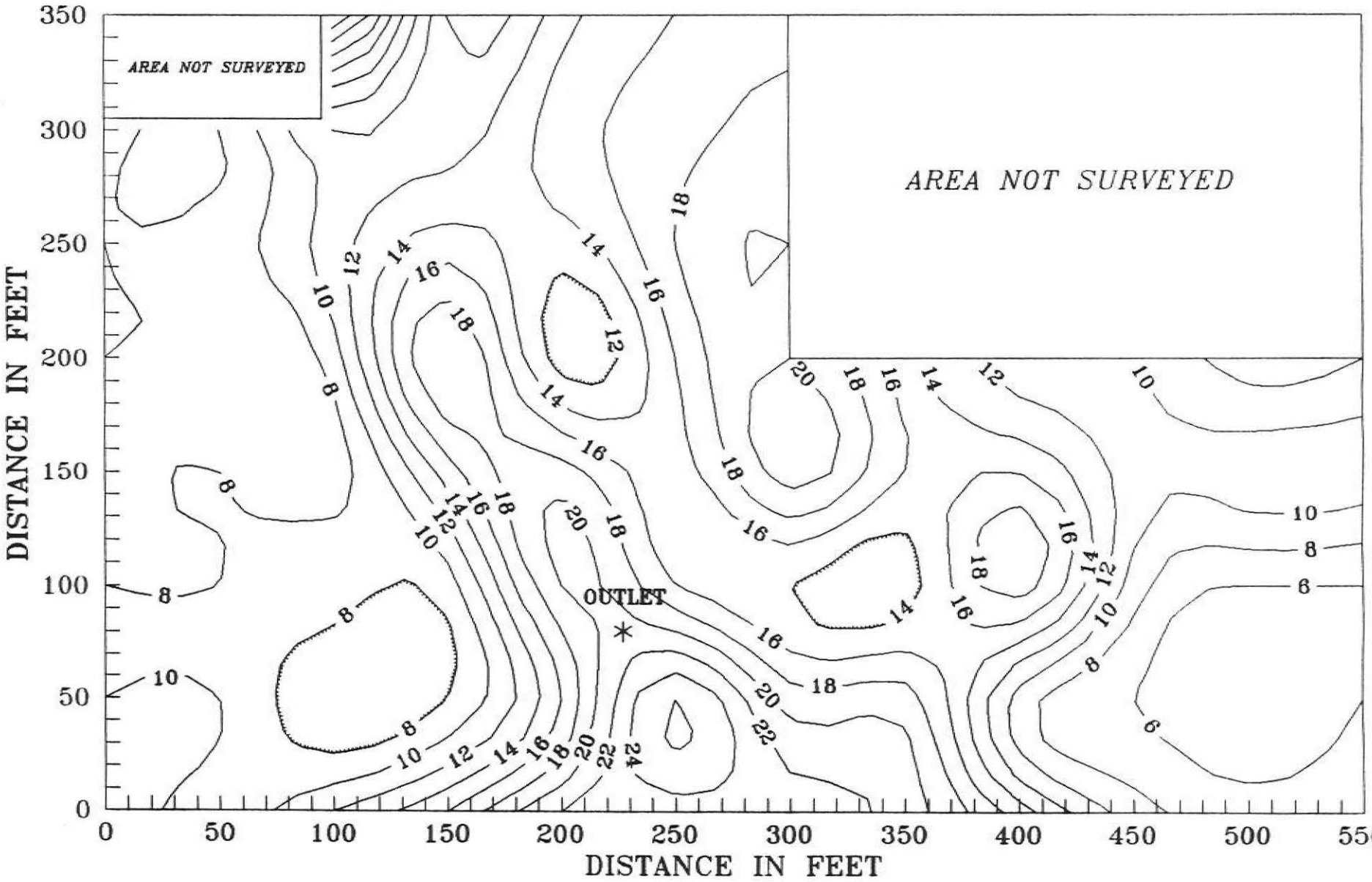


Figure 17

EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

1993 – VERTICAL DIPOLE ORIENTATION

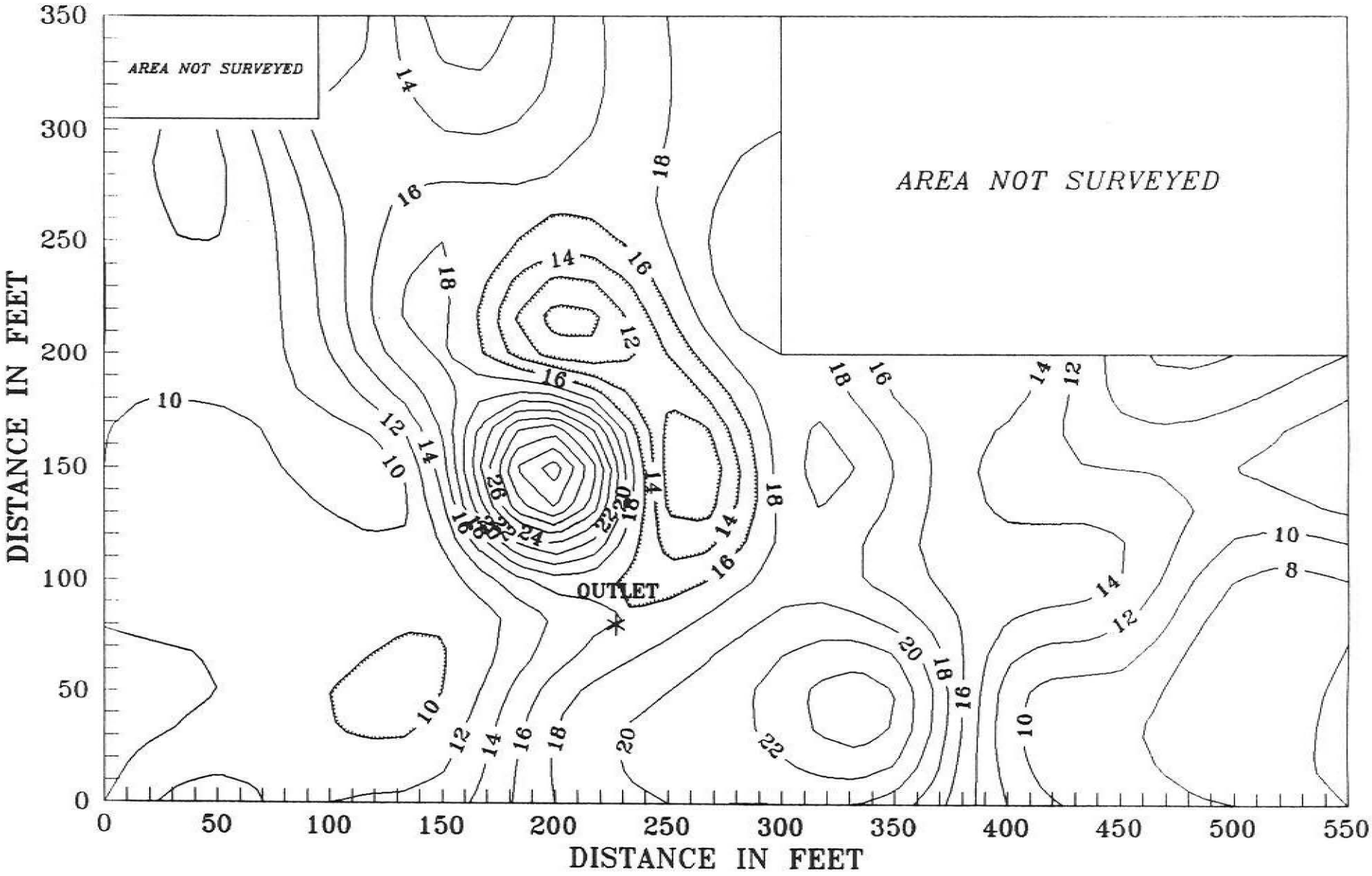


Figure 18

EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

CHANGE IN HORIZONTAL RESPONSES - 1993/1991 DATA

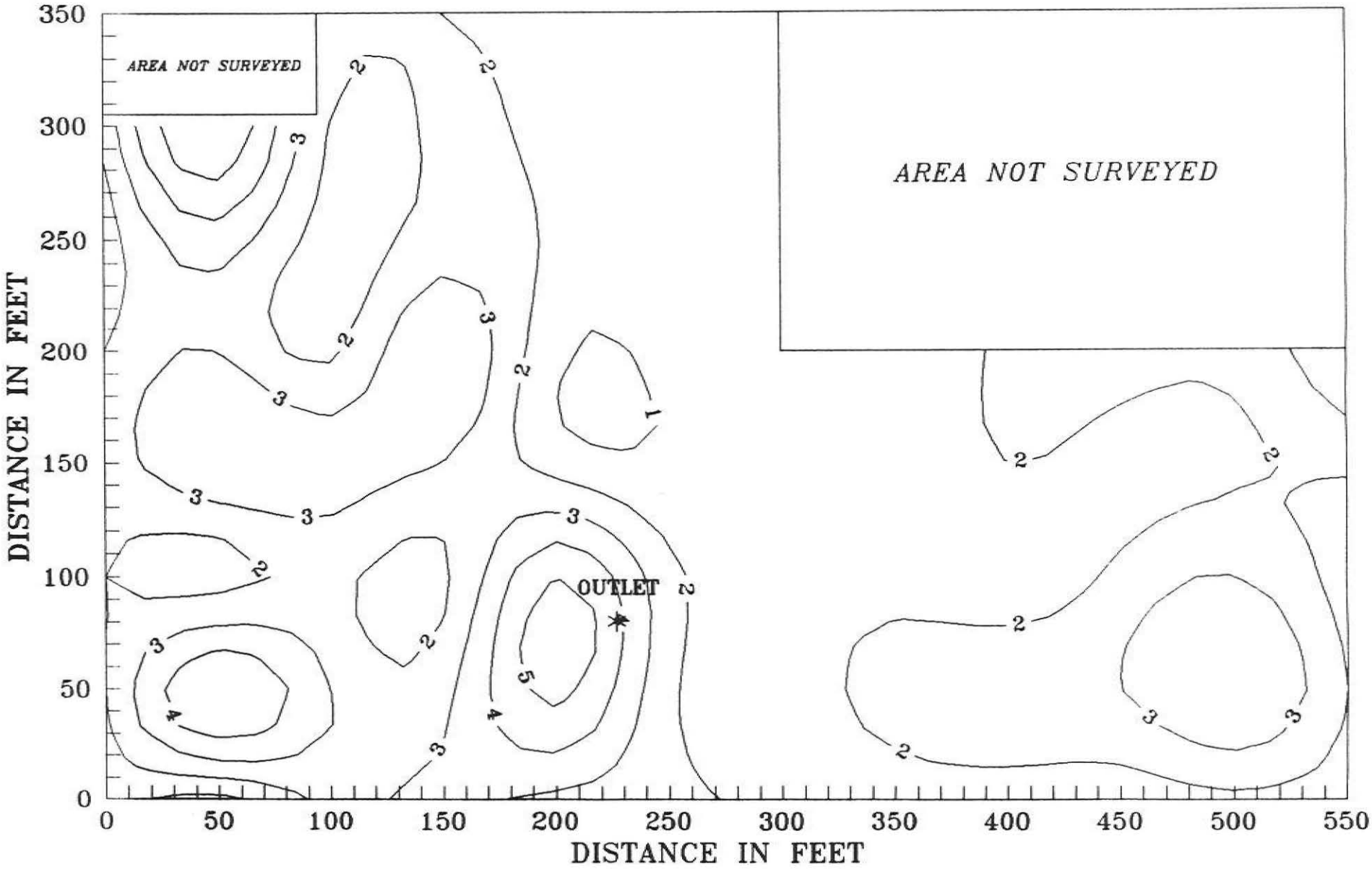


Figure 19

EM31 SURVEY OF AMOS HOOVER'S HPD LINED STORAGE AREA

CHANGE IN VERTICAL RESPONSES - 1993/1991

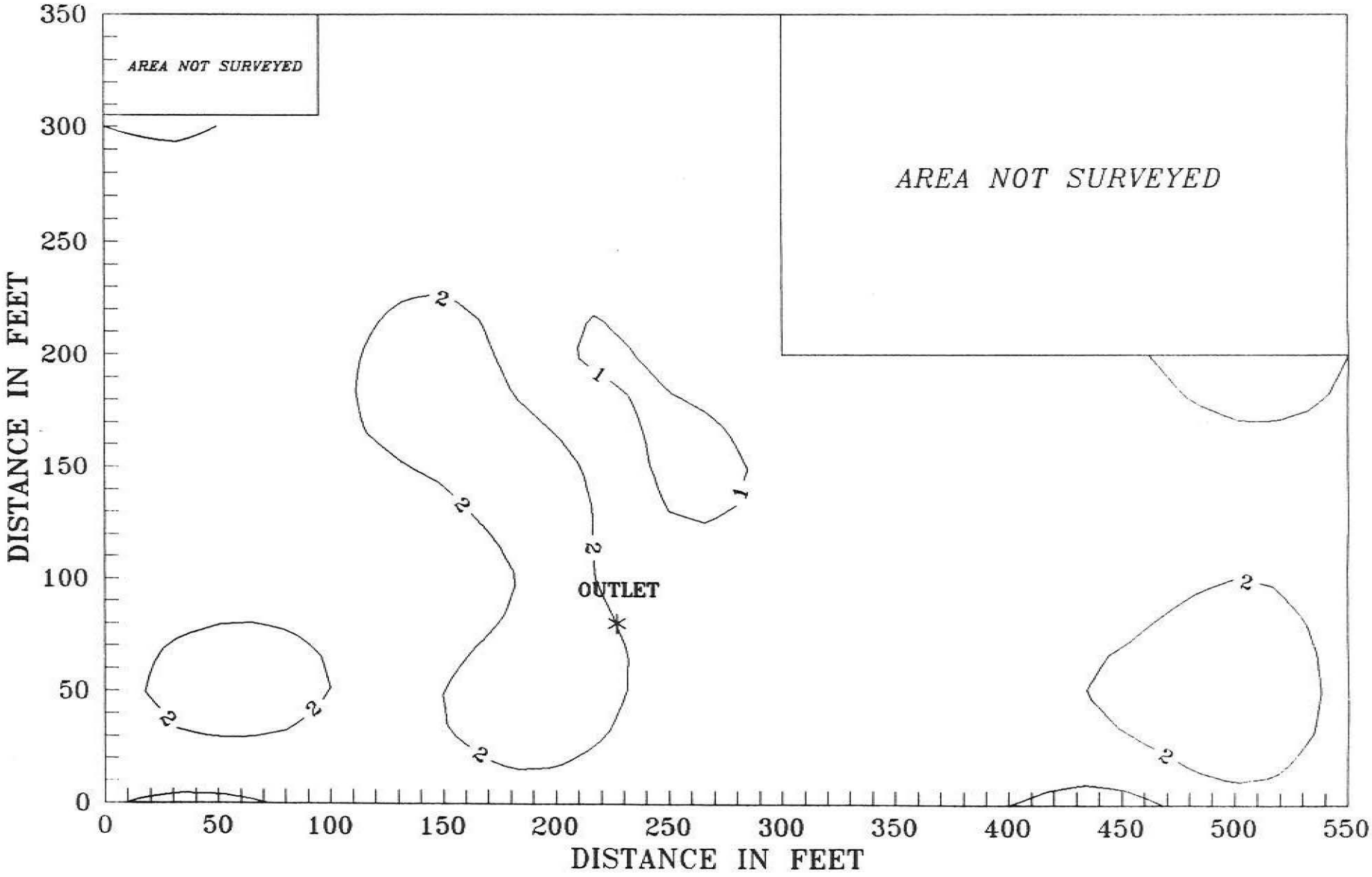


Figure 2c