UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Northeast NTC
CHESTER, PA 19013

SUBJECT: Electromagnetic Induction (EM) survey of Animal Waste-holding Facilities; Bradford, County, Pennsylvania April 13 & 14 1992

DATE: 4 May 1992

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

Purpose:
To use electromagnetic induction (EM) techniques to monitor selected animal waste holding facilities within Bradford County, Pennsylvania.

Participants:
Bruce Benton, Geologist, SCS, Harrisburg, PA
Jim Doolittle, Soil Specialist, SCS, Chester, PA
John George, District Conservationist, SCS, Towanda, PA

Activities:
I arrived in Towanda, Pennsylvania, during the morning of 13 April 1992. Field surveys of five animal waste holding facilities were completed on 13 and 14 April 1992. I returned to Chester, Pennsylvania during the afternoon of 14 April.

Equipment:
The electromagnetic induction meter was the EM31-3 manufactured by GEONICS Limited. [1.] Measurements of conductivity are expressed as milliSiemens per meter (ms/m). Two-dimensional contour plots and three-dimensional surface nets of the EM data were prepared using SURFER software developed by Golden Software, Inc.[1.]

Discussion
Grids had been established at each site prior to the arrival of the EM equipment. Grids were established in a downslope direction of each animal waste holding facilities. Survey flags were inserted in the ground at 50 foot intervals. At each of the grid intersects, measurements were obtained with the EM31 meter in both the horizontal and vertical dipole modes.

Figures 1 through 5 are two-dimensional contour plots of apparent conductivity measurements within the grid sites. In each plot, the contour interval is 1 mS/m. Each figure consists of an upper and lower contour plot. The upper and lower plots represent computer simulations of data obtained with the EM31 in the horizontal and vertical dipole modes, respectively. The EM31 meter scans depths of 0-2.75 meters in the horizontal (h) and 0-6.0 meters in the vertical (v) dipole mode.

Bradford Site 1

This waste holding facility is about two years old. An area of higher apparent conductivities is evident near the end of the overflow pipe from the lagoon (lower left center of each plot). In addition, an area of higher conductivities is apparent in the lower plot, adjacent to the pipe and near the animal waste facility. Care was taken while conducting the survey to minimize the affect of the metallic pipe. These areas of higher conductivities are believed to be caused by (1) out-flow from the pipe outlet, and (2) direct seepage from the pipeline.

Bradford Site 2

This waste holding facility is about four years old. It supports a veal operation. No significant patterns are evident in Figure 2 to suggest seepage. The patterns evident in this figure are believed to express variations in soil and geologic material across the terrain of the study site.

Bradford Site 3

This survey was conducted in order to obtain baseline information concerning variations in apparent conductivity values across the site of a proposed animal waste holding facility. As evident in Figure 3, variations in conductivity values exist at this site. These patterns are related to variations in soil and geologic materials. The high values in the lower, extreme-left margin of the lower plot is believed to be related to a artifact (possibly a utility line) near the roadway.

Bradford Site 4

This waste holding facility is about two years old. It supports a veal operation. Because of excessive slopes and multiple fence lines, the grid at this site was highly irregular and several areas were not surveyed. In both plots, apparent conductivity values decrease rapidly away from the animal waste facility. Generally, patterns evident in Figure 4 suggest that seepage is limited and principally confined to the embankment area of the waste facility. The zone of higher conductivity values are not detectable beyond 100 feet from the edge of the facility. Seepage appears to be most noticeable along the lower left corner of the animal waste holding facility.

Bradford Site 5

This waste holding facility is about five years old. It supports a veal operation. The structure is about five years old. Seepage of contaminants appears to be restricted to the embankment area. Within the embankment, values of ECa range from 13 to 27 mS/m. The noticeable extension of a zone of higher conductivity values in the upper plot (horizontal measurements) is believed to be related to outflow from a drain pipe. The outflow pipe is situated near a drainageway.

Results:

1. Based on patterns and magnitudes of apparent ground conductivity measurements, seepage at the surveyed animal-waste holding structure appears limited and, where observable, is restricted to the embankment area. Compared with the results from similar structures in Pennsylvania and in other states, seepage appears to be very restricted. Confinement of seepage may be related to stringent site preparation measures required by the District Conservationist. Each site was compacted with a sheep-foot roller.

2. These surveys provide ground conductivity maps of the areas surrounding animal waste holding facilities. Apparent conductivities were integrated over a 3.5 m (horizontal dipole) or 6.0 m (vertical dipole orientation) profile. While some patterns suggest potential seepage of contaminants, ground truth verification is needed to confirm the nature and magnitude of these inferences. This study and other studies in Pennsylvania would be enhanced if the values and spatial patterns of apparent ground conductivity were confirmed with ground truth measurements from observation wells.

3. As these facilities are fairly new, it is recommended that, with the owners permission, additional survey be completed after several years to monitor potential development of contaminant plumes.

It was my pleasure to work with members of your fine staff. Their enthusiasm and concerns for monitoring the integrity of structural designs and ground water quality with EM techniques are appreciated.

With kind regards.

James A. Doolittle
Soil Specialist

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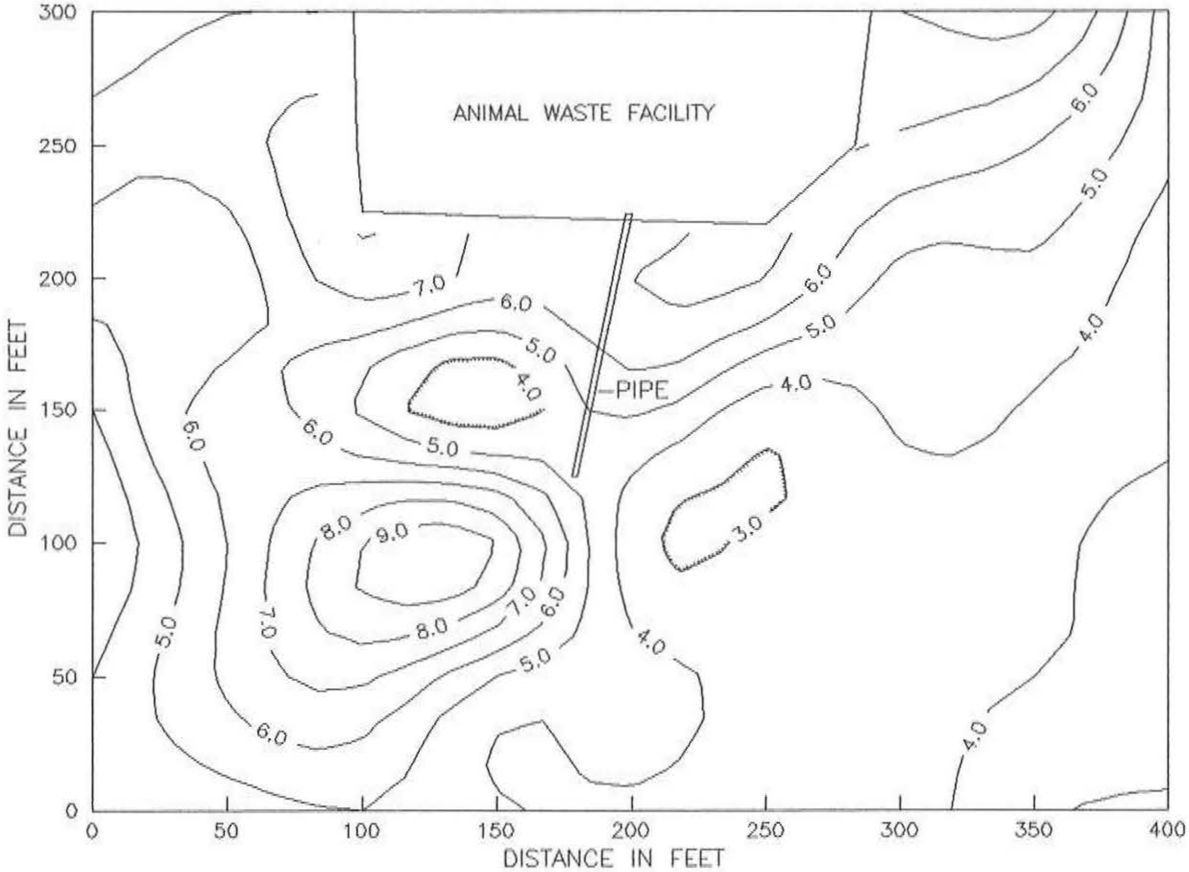
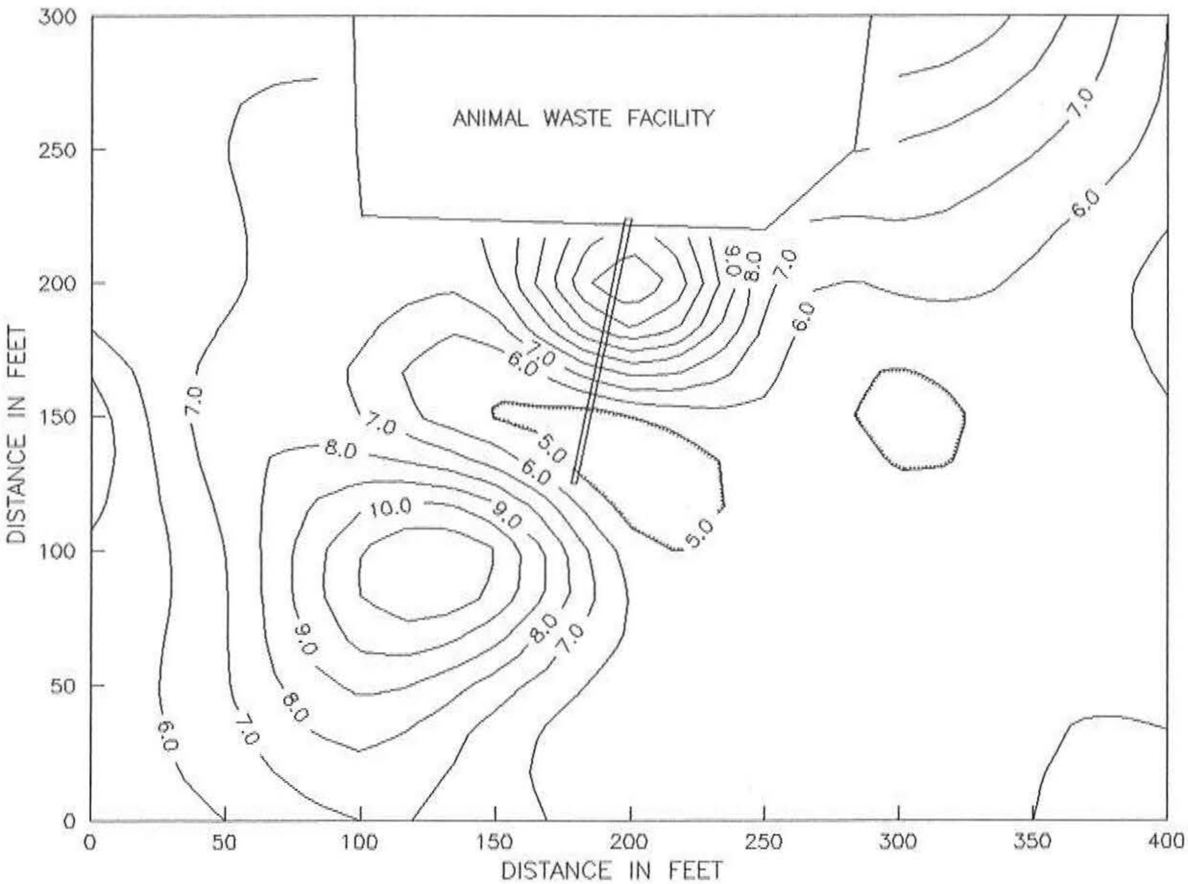
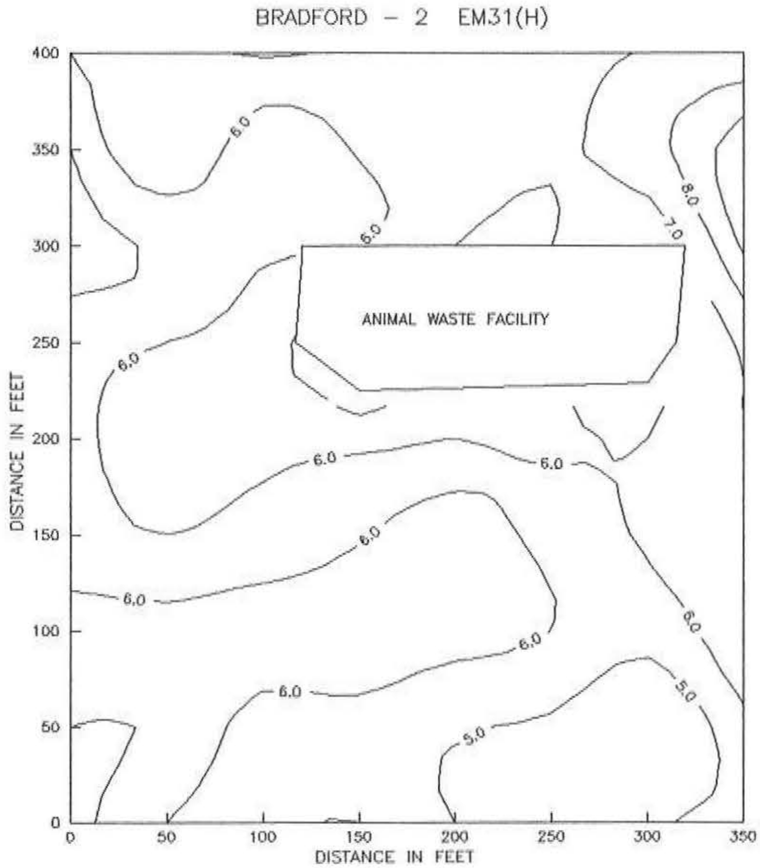
BRADFORD – 1 EM31(H)

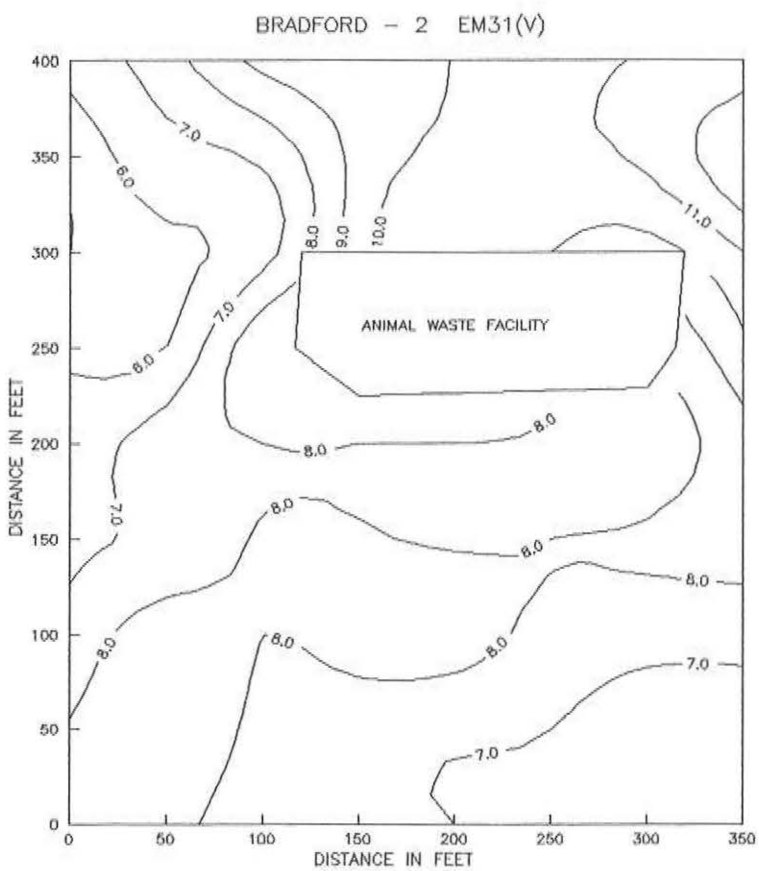


BRADFORD – 1 EM31(V)



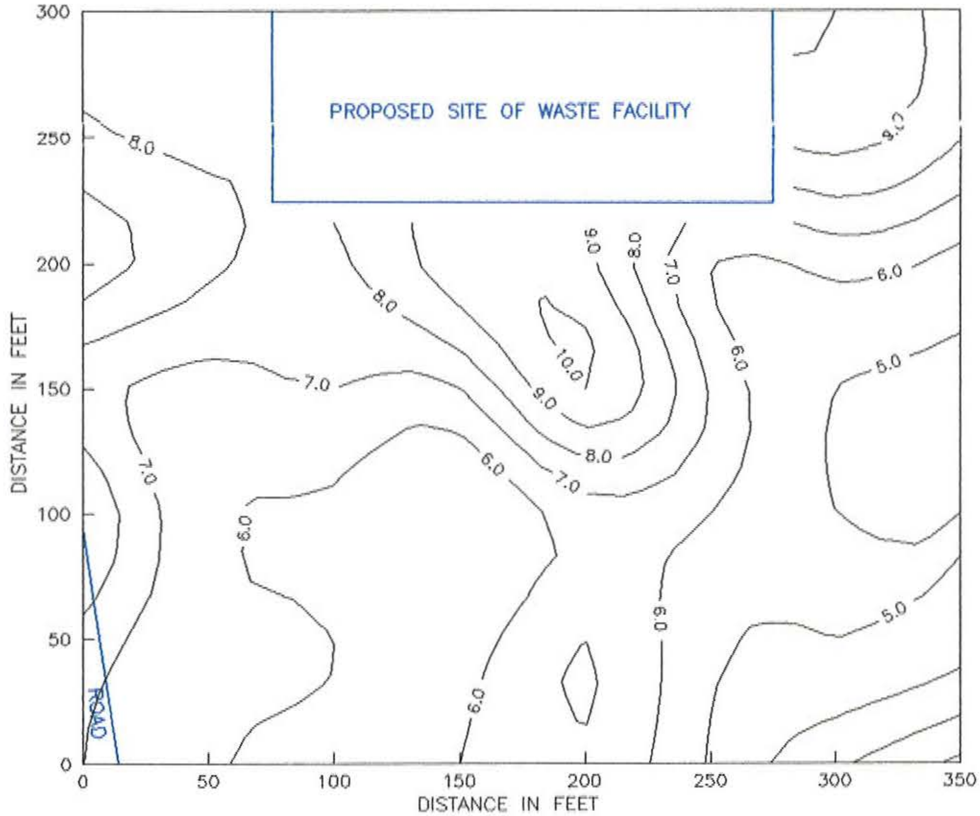


BRADFORD - 2 EM31(H)
ANIMAL WASTE FACILITY
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
400
6.0
8.0
7.0
5.0



BRADFORD - 2 EM31(V)
ANIMAL WASTE FACILITY
DISTANCE IN FEET
DISTANCE IN FEET
0
50
100
150
200
250
300
350
400
6.0
7.0
8.0
9.0
10.0
11.0

BRADFORD – 3 EM31(H)



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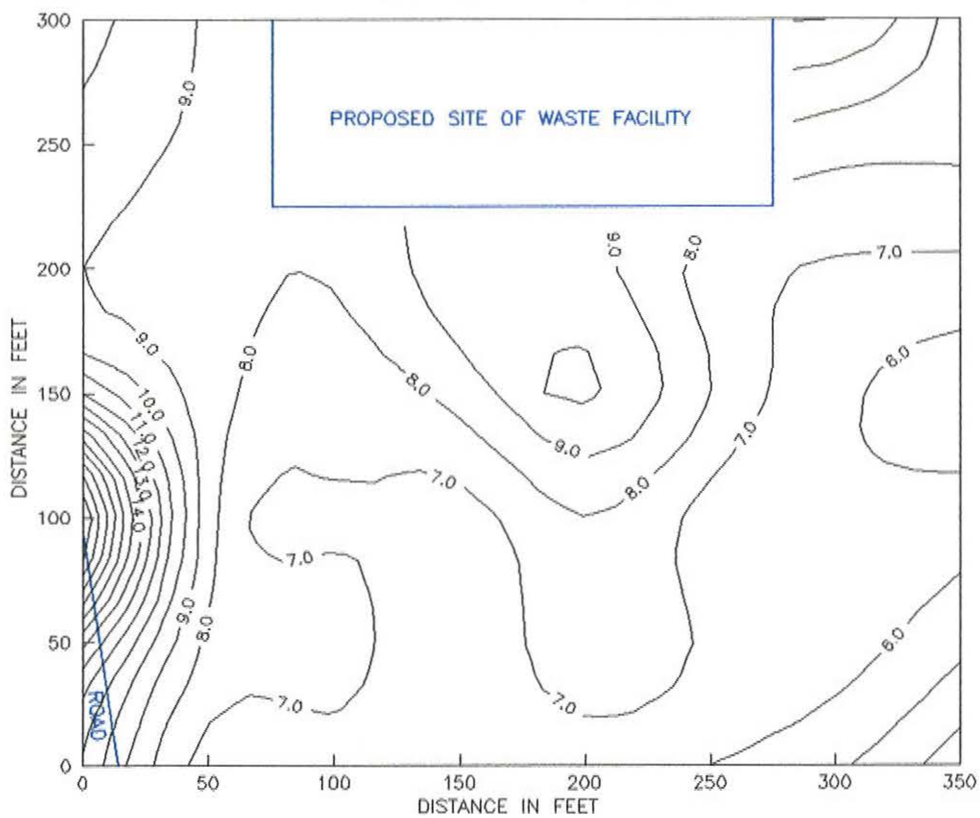

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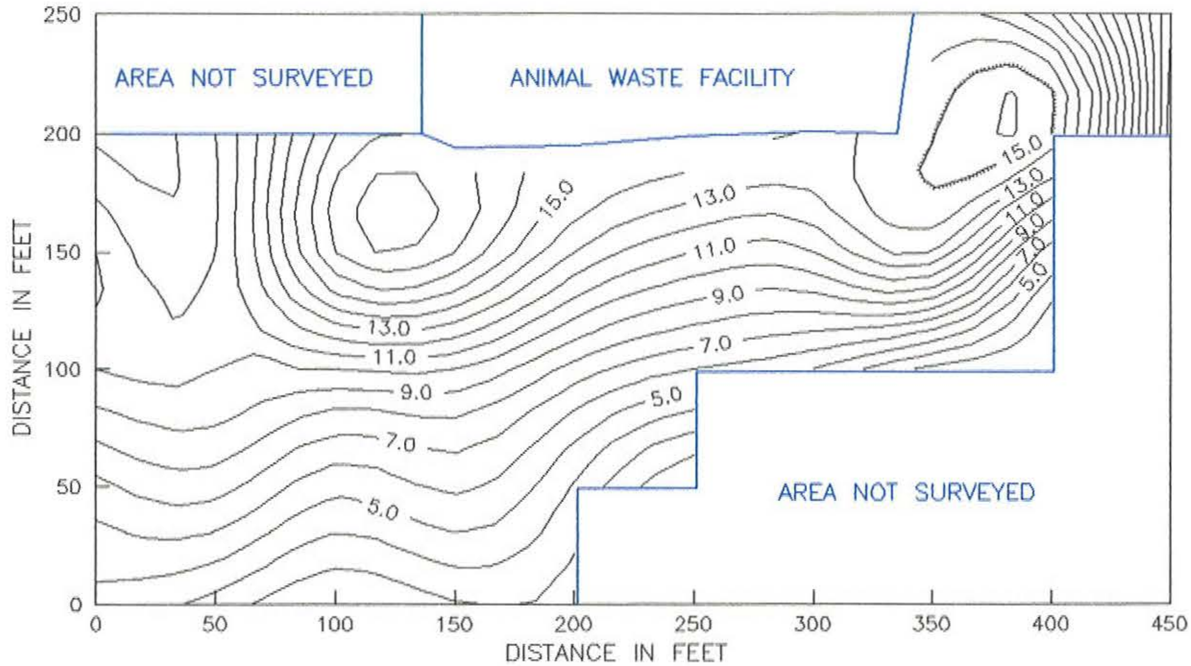

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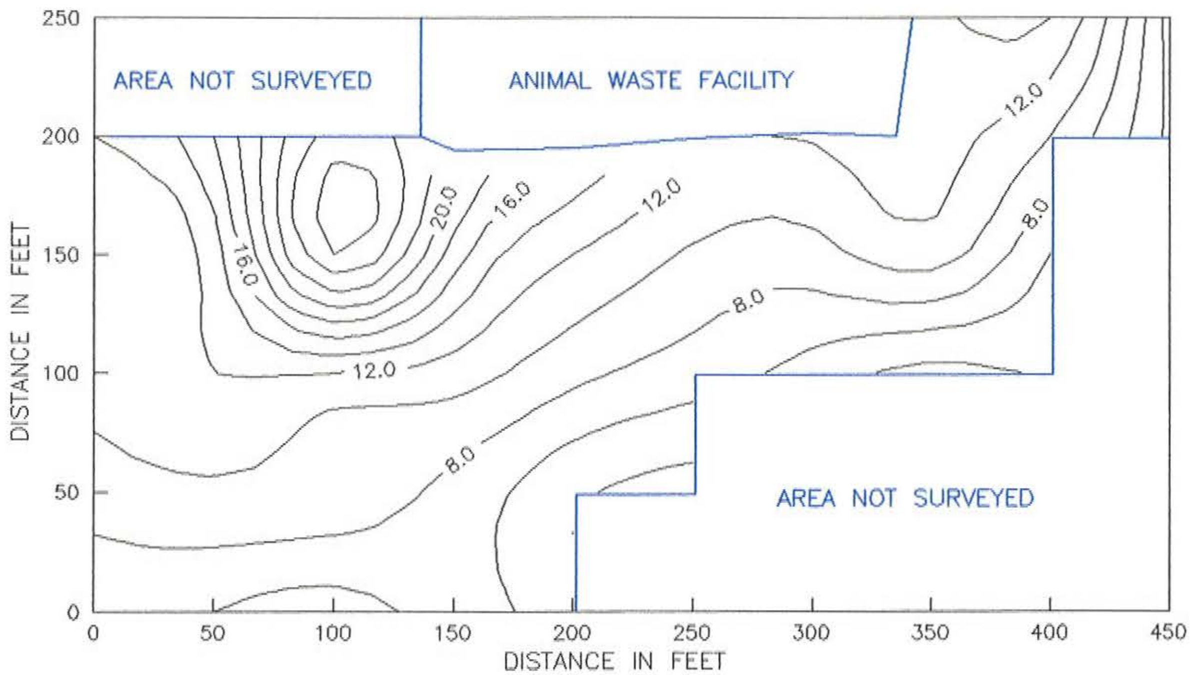
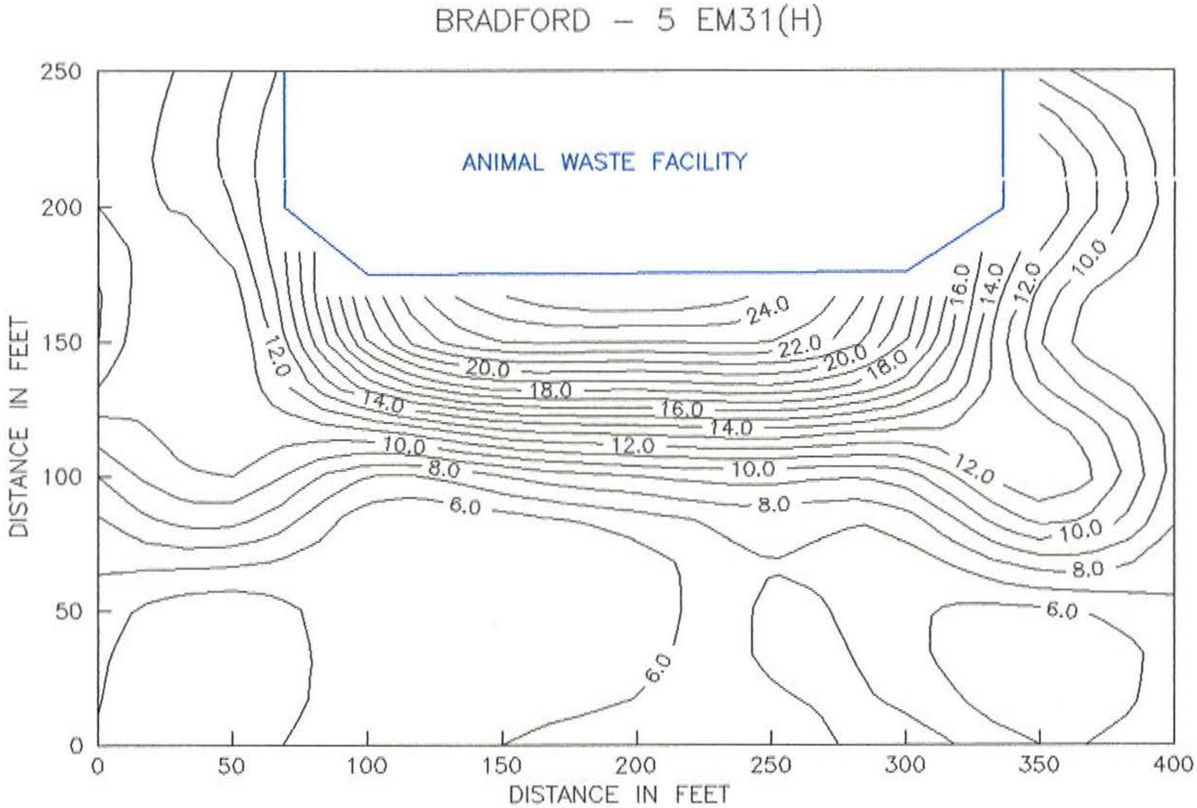
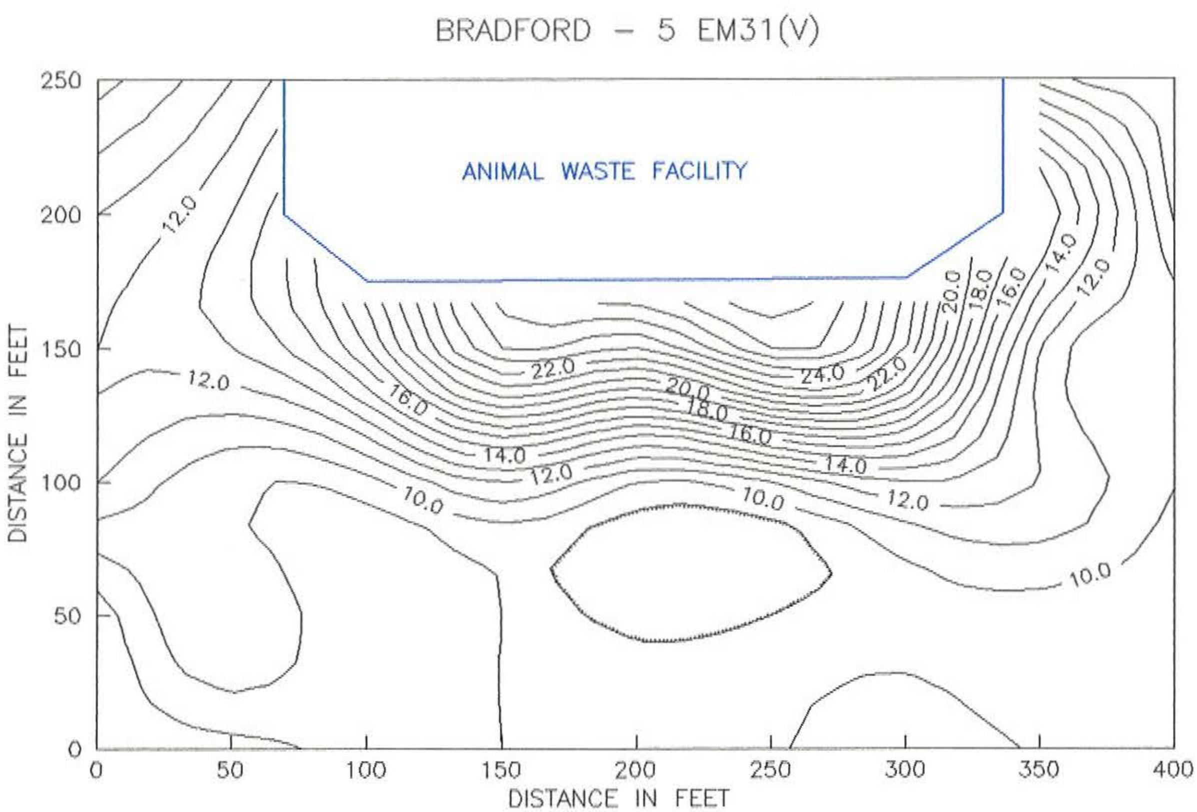




BRADFORD - 5 EM31(H)
ANIMAL WASTE FACILITY
DISTANCE IN FEET
DISTANCE IN FEET
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
0
50
100
150
200
250
300
350
400



BRADFORD - 5 EM31(V)
ANIMAL WASTE FACILITY
DISTANCE IN FEET
DISTANCE IN FEET
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
0
50
100
150
200
250
300
350
400

Review of Electromagnetic Induction Methods

Electromagnetic inductive (EM) is a surface-geophysical method in which electromagnetic energy is used to measure the terrain or apparent conductivity of earthen materials. This technique has been used extensively to monitor groundwater quality and potential seepage from waste sites (Brune and Doolittle, 1990; Byrnes and Stoner, 1988; De Rose, 1986; Greenhouse and Slaine, 1983; Greenhouse et al., 1987; and Siegrist and Hargett, 1989)

For surveying, the meter is placed on the ground surface or held above the surface at a specified distance. A power source within the meter generates an alternating current in the transmitter coil. The current flow produces a primary magnetic field and induces electrical currents in the soil. The induced current flow is proportional to the electrical conductivity of the intervening medium. The electrical currents create a secondary magnetic field in the soil. The secondary magnetic field is of the same frequency as the primary field but of different phase and direction. The primary and secondary fields are measured as a change in the potential induced in the receiver coil. At low transmission frequency, the ratio of the secondary to the primary magnetic field is directly proportional to the ground conductivity. Values of apparent conductivity are expressed in milliSiemen per meter (mS/m).

Electromagnetic methods measure the apparent conductivity of earthen materials. Apparent conductivity is the weighted average conductivity measurement for a column of earthen materials to a specified penetration depth (Greenhouse and Slaine; 1983). The averages are weighted according to the depth response function of the meter (Slavich and Petterson, 1990).

Variations in the meters response are produced by changes in the ionic concentration of earthen materials which reflects changes in sediment type, degree of saturation, nature of the ions in solution, and metallic objects. Factors influencing the conductivity of earthen materials include: (i) the volumetric water content, (ii) the amount and type of ions in soil water, (iii) the amount and type of clays in the soil matrix, and (iv) the soil temperature. Williams and Baker (1982), and Williams (1983) observed that, in areas of salt affected soils, 65 to 70 percent of the variation in measurements could be explained by the concentration of soluble salts. However, as water provides the electrolytic solution through which the current must pass, a threshold level of moisture is required in order to obtain meaningful results (Van der Lelij, 1983).

The depth of penetration is dependent upon the intercoil spacing, transmission frequency, and coil orientation relative to the ground surface. Table 1 list the anticipated depths of measurements for the EM31 meter. The actual depth of measurement will depend on the conductivity of the earthen material(s) scanned.

TABLE 1

Depth of Measurement

Meter	Intercoil Spacing	Depth of Measurement Horizontal	Depth of Measurement Vertical
EM31	3.7m	2.75m	6.0m

The conductivity meters provide limited vertical resolution and depth information. However, as discussed by Benson and others (1984), the absolute EM values are not necessarily diagnostic in themselves, but lateral and vertical variations in these measurements are significant. The seasonal variation in soil conductivity (produced by variations in soil moisture and temperature) can be added to the statement by Benson. Interpretations of the EM data are based on the identification of spatial patterns in the data set appearing on two-dimensional contour plots.

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