United States Department of Agriculture
Soil Conservation Service
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Subject: Electromagnetic Induction (EM) Survey of Animal Waste Holding Ponds in Pennsylvania
Date: November 13, 1990

To: R. N. Duncan
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SUMMARY:
The following report summarizes the measurements of apparent soil conductivity taken with an EM31 terrain meter at various animal waste holding ponds and filter strips in Pennsylvania during the week of September 10 to 14, 1990.

Electromagnetic induction (EM) methods consists of directing an electromagnetic field into the soil from an above ground transmitter to create a secondary electromagnetic field that is measured by the receiver. The use of EM techniques for ground water contamination surveys is based on the fact that electrolytic substances such as salt and leachate increase the electrical conductivity of the soil and the ground water.

The distribution of EM measurements have been summarized in the enclosed contour plots. The SURFER software program was used to construct contour plots of (i) the relative ground surface elevations, (ii) the EM vertical dipole measurements, and (iii) the EM horizontal dipole measurements.

The contour plots of apparent soil conductivity appearing in this report support contentions that some seepage and contaminant discharge is occurring from most holding ponds. However, as no ground-truth measurements were taken in the field, it is impossible to confirm the presence of seepage, the degree of contamination, or the significance of the EM data at this time. The contour plots presented in this report can be used to locate areas of high soil conductivity, assess the areal extent of suspected contaminant plumes, and aid the efficient placement of monitoring wells. Additional studies in Pennsylvania are recommended to confirm the occurrence of seepage from animal waste holding ponds, to assess the load of contaminants accumulating in the soil, to determine whether the suspected areas of contamination are enlarging, and to evaluate the potential hazards to ground water quality at these sites.

This study confirms the utility of using EM techniques to rapidly assess potential areas of ground water contaminations. The Soil

Conservation Service provides technical assistance to landowners for the construction of filter strips and animal waste holding ponds. As SCS addresses issues of water quality, the agency will assume a greater responsibility for insuring that these structures are not potential sources of ground water contamination. Some monitoring action on these structures is recommended. Additional EM studies can be used to better assess the integrity of our designs and practices. It is recommended that these studies be considered.

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DISCUSSION:

Site 1 - Lancaster County.
This animal waste holding pond is located in areas of Chester (fine-loamy, mixed, mesic Typic Hapludults), Glenelg (fine-loamy, mixed, mesic Typic Hapludults), and Newark (fine-silty, mixed, nonacid, mesic Aeric Fluvaquents) soils. The study site was located immediately downslope from the holding pond (the blanked area in Figure 1). A portion of the study site is being used as pasture for the dairy herd (upper part of Figure 1). The other portion of the study site was idle. A dirt road parallels and provided the lower boundary of the study site (0Y), The study site included a small intermittent stream (in Figure 1, the linear area with relative elevations less than 1 foot). Slopes range from 0 to 8 percent. Relief was 13.9 feet.

A 320 by 240 foot rectangular grid was established across the study site. The grid interval was 25 feet parallel to and 50 feet perpendicular to the face of the holding pond. The grid intersects provided sixty-nine observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 2 to 18 mS/m (Figure 2). A value of 4 mS/m was selected as average for the nearly level to gently sloping soils within the study site. In areas immediately adjoining the waste holding pond, measurements were 1.5 to 4.5 times higher than the selected background value (4 mS/m). A noticeable zone of higher conductivities extended 20 to 40 feet away from the embankment of the holding pond. As EM measurements decrease away and downslope from the holding pond, seepage from this structure is believed to be the source of the higher EM values.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 1 to 15 mS/m. Again, a value of 4 mS/m was selected as average for the soils within the study site. Higher readings were observed in areas of known surface discharge or runoff (in Figure 3, 0X to 40X, 320Y), and in areas being used as pasture for the dairy herd (upper part of Figure 3). Only in areas immediately adjoining the waste holding pond do soil conductivities increase with increasing soil depth (horizontal measurements were lower than vertical measurements). Horizontal measurements were noticeably higher than the vertical measurements in areas that are presently being used as pasture for the dairy herd. The accumulation of manure and other waste products are believed to be the cause of the higher conductivities in the upper 2.8 meters.

Site 2 - Lancaster County.
This animal waste holding pond is located in an area of Glenelg (fine-loamy, mixed, mesic Typic Hapludults) soils. Slopes range from 8 to 15 percent. Relief was 62.2 feet. The study site was located

immediately downslope from the holding pond. In figures 4 and 5, the animal waste holding pond is located along the upper margin of the two-dimensional contour plots between observation points 70X and 300X. The study site was in pasture (0Y to 250Y) or in idle land (250Y to 350Y). Two areas were omitted from study: (i) a pasture in the upper left corner and (ii) an area including tobacco and livestock barns in the upper right corner of these figures.

A 400 by 350 foot rectangular grid was established across the study site. Two grid were constructed across the study site. One grid with a 50 foot interval was established across the entire study site. A smaller grid with a 25 foot interval was establish perpendicular to the face of the holding pond between observation sites 70X and 300X, and 300Y and 350Y. The grid intersects provided seventy-one observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 0.5 to 28 mS/m (Figure 4). A value of 1 mS/m was selected as the average conductivity for a 6 meter profile of the moderately to strongly sloping Glenelg soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings.

In areas immediately adjoining the waste holding pond (Figure 4), the EM31 vertical measurements were 2 to 28 times higher than the selected background value (1 mS/m). This zone of noticeably higher conductivities can be seen along the upper-middle border of Figure 4. It extends about 100 feet downslope from the holding pond. As EM measurements decrease away and downslope from the holding pond, seepage from this structure is believed to be the source of the higher conductivities.

Also evident in Figure 4 is a zone of higher conductivities surrounding and running downslope from the farm building (located in blanked area in the upper right corner). This area had conductivity measurements which were 2 to 6 times higher than the background value of 1 mS/m. In this area, the higher conductivities are believed to be related to cultural noise (metal in buildings and buried debris) and surface runoff.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 0.5 to 20 mS/m (Figure 5). A slightly higher value of 3 mS/m was selected as the average conductivity for the 2.8 meter profile of the moderately to strongly sloping Glenelg soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings. With the exception of an area immediately adjoining the holding pond, the horizontal measurements were higher than vertical measurements in all portions of this study site. Surface runoff, accumulations of manure and other waste products near the surface, and cultural noise are believed to have caused the higher conductivities in the upper 2.8 meters of the soil profiles. Another explanation for the lower vertical measurements is that these deeper averaged values include the more resistive, underlying schist bedrock.

At Site 2, only in the areas immediately adjacent to the waste holding pond do soil conductivities increase with increasing soil depth. Higher vertical EM measurements in this area are believed to be the result of seepage from the holding pond.

Site 3 - Dauphin County.
This animal waste holding pond is located in an area of Duncannon (coarse-silty, mixed, mesic Ultic Hapludalfs) soils. Slopes range from 3 to 8 percent. Within the study site (see Figure 6), relief was 20.7 feet. The study site (Figure 6) included a small intermittent drainageway (running from about 150X and 250Y to 250X and 10Y). The study site was in pasture (lower left portion of Figure 6) and in cropland. The animal waste holding pond is an earthen structure with a concrete bottom.

A 250 by 250 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided fifty-two observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 3 to 26 mS/m (Figure 7). A value of 9 mS/m was selected as the average conductivity for a 6 meter profile of the gently sloping Duncannon soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings.

Along the intermittent drainageway, EM31 vertical measurements (Figure 7) were 1.6 to 2.9 times higher than the selected background value of 9 mS/m. One is quickly led to believe that wetter soil conditions existing within the drainageway are responsible for the observed inflated conductivity measurements. However, a comparison of Figures 7 and 8 reveals that the zone of highest conductivities (>2.2 times the background value) appears to emanate from the base of the embankment to the animal waste holding pond. In addition, this zone extends about 90 to 115 feet downslope from base of embankment to the holding pond. As EM values decrease away and downslope along the drainageway from the holding pond and soils were observed to become wetter along the lower reaches of the drainageway, seepage from this structure is believed to be a possible source for the inflated soil conductivity values.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 4 to 29 mS/m (Figure 8). A slightly higher value of 11 mS/m was selected as the average conductivity for the 2.8 meter profile of the gently sloping Duncannon soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from farm buildings.

In Figure 8, EM31 horizontal measurements were 1.8 to 2 times higher than the selected background value of 11 mS/m in two area (A and B) along the intermittent drainageway and in an area (C) along the embankment to the holding pond. The highest EM31 horizontal measurements were recorded in the upper reaches of the drainageway (A in Figure 8). The higher soil conductivities near A can be attributed to the deposition of dissolved salts in the waste-ladened surface runoff from nearby dairy barns. The high conductivities near B can be attributed to seepage from the animal waste holding pond. This area consist of shallow (<2.8 m) EM values of 20 to 23 mS/m. The zone of higher EM values occurs along the drainageway and slightly down-slope from the deeper zone of higher soil conductivities observed with the EM31 horizontal measurements (Figure 7).

<u>Site 4</u> - Dauphin County.
This animal waste holding pond is located in an area of Penn (fine-loamy, mixed, mesic Ultic Hapludalfs) soils. Slopes range from 3 to 8 percent. Relief was 18.7 feet (Figure 9). The study site was located immediately downslope from the holding pond. In figures 9, 10 and 11, the animal waste holding pond is located along the lower margin of the two-dimensional contour plots between observation points 30X and 220X. The study site was in pasture.

A 250 by 200 foot rectangular grid was established across the study site. The grid interval was 50 feet. The grid intersects provided twenty-nine observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 17 to 43 mS/m (Figure 10). A value of 19 mS/m was selected as the average conductivity for a 6 meter profile of the gently sloping Penn soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm structures.

In areas immediately adjoining the waste holding pond (Figure 10), the EM31 vertical measurements were 1.4 to 2.3 times higher than the selected background value (19 mS/m). A noticeable zone of higher conductivities can be seen in the lower left-hand corner of Figure 10. It extends 20 to 60 feet outwards and downslope from the embankment to the holding pond. As EM measurements decrease away and downslope from the holding pond, seepage from this structure is believed to be a factor responsible for this zone of higher conductivities.

The depressed EM values in the central portion of Figure 10 are believed to be the result of variations in soil type or possibly the depth to bedrock. No ground-truth observations were made in the field to confirm these inferences.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 13 to 36 mS/m (Figure 11). A value of 20 mS/m was selected as the average conductivity for the 2.8 meter profile of the gently sloping Penn soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm structures.

With the exception of an area immediately adjoining the holding pond, the horizontal measurements were similar to or slightly higher than vertical measurements in all portions of this study site. The accumulation of manure and other waste products near the surface are believed to be responsible for the higher conductivities in the upper 2.8 meters of the soil profiles.

At Site 4, only in the areas immediately adjacent to the waste holding pond do soil conductivities increase with increasing soil depth. Higher vertical EM measurements in this area are believed to be the result of seepage from the holding pond.

Site 5 - Dauphin County.
This two year old, concrete lined animal waste holding pond is located near Lawn, Pennsylvania. No information was available at the time of this survey as to the soil type within the study site. Slopes range from 1 to 6 percent. Relief was 12.4 feet (Figure 12). The study site surrounded the downslope side of the holding pond. The study site was in pasture.

A 250 by 125 foot rectangular grid was established across the study site. The grid interval was 50 feet. The grid intersects provided forty-five observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 16 to 250 mS/m (Figure 13). In Figure 13, the contour interval is 10 mS/m. A value of 22 mS/m was selected as the average conductivity for a 6 meter profile of the gently sloping soils within the study site. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings.

In areas immediately adjoining the waste holding pond (Figure 13), EM31 vertical measurements were 1.4 to 11.3 times higher than the selected background value (22 mS/m). This zone of noticeably higher conductivities is evident in Figure 13. It extends about 15 to 40 feet downslope from the holding pond. The exceptionally high values

(>50 mS/m) immediately adjacent to the concrete-lined holding pond are believed to be due, in part, to cultural noises associated with the pond's concrete lining and the encompassing metallic fence. In addition, seepage from this structure is believed to be responsible for the area of higher conductivities surrounding the downslope side of this holding pond. A seam in the concrete lining located near intersect 125X and 50Y is suspected of being a possible source of seepage from the holding pond.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 13 to 47 mS/m (Figure 14). In Figure 14, the contour interval is 4 mS/m. The value of 22 mS/m was also used as the average conductivity for the 2.8 meter soil profile. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings. With the exception of an area immediately adjoining the holding pond, no apparent pattern in the distribution of horizontal and vertical measurements was observed. Conductivities appear to remain constant with depth. .

At Site 5, in the areas immediately adjacent to and downslope from the waste holding pond, the apparent soil conductivity values increase noticeably with increasing soil depth. In this area, soil conductivity values were higher when measurements were averaged for a 6 m profile (EM vertical) than when averaged for a 2.8 m profile (EM horizontal). Higher EM measurements in this area are believed to have been caused by seepage from the holding pond.

Site 6 - Lebanon County.
A filter strip was selected in Lebanon County. This filter strip is located in an area of Duffield (fine-loamy, mixed, mesic Ultic Hapludalfs) soils. Slopes range from 3 to 8 percent. Relief was 7.3 feet (Figure 15). The filter strip does not appear in Figure 15 as its is located immediately upslope from the study site at approximately 100Y. The filter strip paralleled the X axis. In Figure 15, discharge from the filter strip enters the study site at grid intersect 50X, 75Y. The study site was in hayland. The blanked area in the extreme right-hand portion of Figure 15 is a paved road.

A 350 by 75 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided fifty-seven observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 8 to 33 mS/m (Figure 16). A value of 14 mS/m was selected as the average conductivity for a 6 meter profile of the gently sloping Duffield soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the filter strip and the road.

In areas adjacent to the road (Figure 16), EM31 vertical measurements were 1.1 to 2.4 times higher than the selected background value of 14 mS/m. These inflated conductivity measurements are believed to reflect the affects of road salts and surface runoff from the roadway.

In Figure 16, an area of higher conductivities appears to emanate from near the point where the filter strip discharges onto the study site (grid intersect 50X, 75Y). Apparent conductivities within this area were 1.3 to 1.6 times higher than the selected background value. This area of higher conductivities extends downslope about 55 feet from the filter strip's outlet. As EM values decrease away and downslope from the discharge outlet, seepage from the filter strip is believed to be a possible cause of these inflated soil conductivity values.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 6 to 29 mS/m (Figure 17). A value of 13 mS/m was selected as the average conductivity for the 2.8 meter profile of the gently sloping Duncannon soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the filter strip and surface runoff from the road.

In Figure 17, EM31 horizontal measurements were 1.2 to 2.2 times higher than the selected background value of 13 mS/m in areas adjacent to the roadway. These higher soil conductivities can be attributed to the deposition of dissolved salts in the surface runoff from the roadway. A slight inflation of the apparent soil conductivities can be observed in Figure 17 near the discharge outlet for the filter strip and in areas bordering the filter strip. For the Duffield soils, the EM31 vertical and horizontal measurements at most grid intersect are similar and no apparent depth relationship is evident in the data.

Site 7 - Schuylkill County.
This animal waste holding pond was constructed in 1986. Initially built as an earthen structure with a concrete bottom, it was modified to all concrete in 1990. A road parallels the western margin of this study site (0X in figures 18 and 19) and must be regarded a potential source of road salt contamination. The study site was used for pasture or was idle. No information was available at the time of this survey as to the soil type within the study site. At this site, no measurements were obtained of relative elevations.

A 200 by 175 foot rectangular grid was established across the study site (figures 18 and 19). The grid interval was 25 feet. The grid intersects provided fifty observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes.

The contour interval in Figure 18 is 4 mS/m. In the vertical mode (6 meter profile), EM measurements ranged from 12 to 60 mS/m (Figure 18). A value of 19 mS/m was selected as the average conductivity for a 6 meter profile of the soils existing within the study site. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings.

Along the periphery of the animal waste holding pond, EM31 vertical measurements (Figure 18) were 1.3 to 3.2 times higher than the selected background value of 19 mS/m. In Figure 18, zones of high soil conductivities extends 10 to 75 feet away from two edges of the holding pond. One zone appears to extend downslope from the northern border of the waste holding pond (95Y). A second zone appears to emanate from the side of the pond's embankment near point 50Y. This zone of higher conductivities is near and decreases away from the location of a floor drain (75Y). In Figure 18, no affect of road salts on soil conductivities can be seen.

In Figure 19, the contour interval is 1 mS/m. In the horizontal mode (2.8 meter profile), EM measurements ranged from 17 to 36 mS/m (Figure 19). A value of 20 mS/m was selected as the average conductivity for the 2.8 meter profile at this site. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from farm buildings.

In Figure 19, EM31 horizontal measurements were higher than the selected background value of 20 mS/m in the same two areas noted for the vertical measurements (Figure 18). The highest EM31 horizontal measurements were recorded near the location of the holding pond's floor drain (75Y). In this area, the zone of high conductivities extended about 80 feet away from the holding pond. In areas away from the holding pond, measurements taken with the EM31 in the horizontal mode were generally similar to measurements obtained in the vertical mode. The higher near surface (<2.8 m) soil conductivities in the lower right corner of Figure 19 was attributed to the deposition of dissolved salts in the waste-ladened surface runoff from nearby barns housing dairy cows.

Site 8 - Luzerne County.
This animal waste holding pond is located in an area of Meckesville (fine-loamy, mixed, mesic Typic Fragiudults) soils. Slopes range from 3 to 8 percent. This site is located on a ridgetop underlain by thinly bedded and steeply inclined layers of shale. This physical feature would facilitate the vertical migration of seepage from the holding pond. The water table is very deep below this site. The depth to the water table is beyond the range of the EM31. At this site, no measurements were obtained of relative elevations. The study site included a small gully which intermittently contains the runoff from dairy barns. The drainageway is located on 30X and runs from 250 Y to about 100Y. The study site was in cropland. The animal waste holding pond is an earthen structure with a concrete pad entrance.

A 400 by 250 foot rectangular grid was established across the study site. The grid interval was 50 feet. The grid intersects provided thirty-eight observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes.

In the vertical mode (6 meter profile), EM measurements ranged from 2 to 12 mS/m (Figure 20). A value of 4 mS/m was selected as the average conductivity for a 6 meter profile of the gently sloping Meckesville soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and runoff from farm buildings.

Along the intermittent drainageway, EM31 vertical measurements (Figure 20) were 1.5 to 3 times higher than the selected background value of 4 mS/m. The concentration of runoff, which is heavily laden with organic materials from the farm buildings, is believed to be responsible, in part, for these inflated conductivity measurements. In addition, a zone of slightly higher conductivities appears to emanate from the base of the embankment. This zone is 1.25 to 1.75 times higher than the selected background value of 4 mS/m and extends about 20 to 90 feet downslope from base of embankment to the holding pond. Though weakly expressed, seepage from this structure can be a possible source for these inflated soil conductivity values.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 2 to 12 mS/m (Figure 21). A slightly higher value of 3 mS/m was selected as the average conductivity for the 2.8 meter profile of the gently sloping Meckesville soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from farm buildings.

In Figure 21, EM31 horizontal measurements were 1.6 to 4 times higher than the selected background value of 3 mS/m in areas adjacent to the holding pond and along the intermittent drainageway. The highest EM31 horizontal measurements were recorded in the upper reaches of the drainageway. The higher soil conductivities along the drainageway can be attributed to the deposition of dissolved salts in the waste-ladened surface runoff from nearby dairy barns. The high conductivities along the embankment to the holding pond can be attributed to: (i) an increase clay content, (ii) a deeper depth to bedrock, or (iii) to seepage.

Site 9 - Montour County.
This animal waste holding pond is located in an area of Hagerstown (fine, mixed, mesic Typic Hapludalfs) soils. The study site was mostly in grass. At this site, no measurements were obtained of relative elevations. The animal waste holding pond is an earthen structure with a concrete floor.

A 300 by 175 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided forty-seven observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes.

In the vertical mode (6 meter profile), EM measurements ranged from 5 to 34 mS/m (Figure 22). A value of 12 mS/m was selected as the average conductivity for a 6 meter profile of the Hagerstown soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and farm buildings.

Along the downslope edge of the holding pond, EM31 vertical measurements (Figure 22) were 1.4 to 2.2 times higher than the selected background value of 10 mS/m. Seepage from the holding pond is suspected to have produced this zone of higher conductivities. In addition, along the right-hand portion of Figure 22, EM31 vertical measurements were 1.4 to 3.2 times higher than the selected background value. These higher values may have been caused by changes in soil type or runoff from farm buildings as the landowner reported discharge of milk rinse wastes in this area.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 9 to 34 mS/m (Figure 23). A value of 14 mS/m was selected as the average conductivity for the 2.8 meter profile of the Hagerstown soil. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from farm buildings.

In this area of Hagerstown soil, soil conductivities decrease with increasing soil depth as measurements taken with the EM31 meter in the horizontal position (2.8 m) are greater than those taken in the vertical position (6 m). In Figure 23, EM31 horizontal measurements were 1.2 to 2 times higher than the selected background value of 14 mS/m in areas affected by runoff from farm buildings. However, no consistent pattern of increasing or decreasing soil conductivities is evident in Figure 22. Because of the lack of definable patterns emanating from the holding pond, seepage is not suspected. In Figure 22, the higher conductivities near "A" are believed to have been caused by increased soil wetness in this area.

Site 10A - Juniata County.
This animal waste holding pond is located in an area of Kreamer (clayey, illitic, mesic Aquic Hapludults) soils. Within the study site, relief was 18.3 feet (see Figure 24). The study site is on a hillside which slopes into a small intermittent drainageway. The drainageway is located outside the study area. The study site is underlain by highly inclined beds of shale bedrock. The study site was in pasture and idle land. The animal waste holding pond is a concrete structure which was built in 1990. The holding pond is used for hog wastes.

A 275 by 125 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided fifty-nine observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 1 to 8 mS/m (Figure 28). A value of 3 mS/m was selected as the average conductivity for a 6 meter profile of the Hartleton soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond.

The apparent conductivity patterns evident in Figure 28 are believed to be a manifestation of the depth to bedrock; lower EM measurements are believed to correlate with shallow depths to bedrock. However, this inference remains highly speculative as no coring data were available for correlation with EM measurements. In addition, EM measurements increase in values downslope suggesting the occurrence of not only deeper but wetter soil conditions. Evidence supporting lateral seepage of contaminants from this holding pond is generally lacking in Figure 28. However, as the underlying shale bedrock is steeply incline, seepage may be occurring in a vertical direction to depths beyond the profiling range (6 m) of the EM31 meter.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 1 to 8 mS/m (Figure 29). A value of 4 mS/m was selected as the average conductivity for the 2.8 meter profile of the Hartleton soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond.

In Figure 29, EM31 horizontal measurements were highest atop the artificial mound containing the gravity drain pipe (180X). These higher values are believed to reflect the presence of a metallic pipe and other sources of cultural noise. Figure 29 contains no evidence which supports seepage or surface discharge from the holding pond.

Site 11 - ~~Lebanon~~ Juniata County.
A filter strip was selected in Lebanon County. This filter strip is located in an area of Edom (fine, illitic, mesic Typic Hapludalfs) and Brinkerton (fine-silty, mixed, mesic Typic Fragiaqualfs) soils. Relief was 13 feet (Figure 30). In Figure 30, a perforated distribution pipe for milkhouse waste water has been drawn at 145X. A concrete pad with a pipe discharging barnyard runoff is located in an area to the immediate right of the study site. A paved road forms the lower border (0Y) of the study site. The study site was in pasture.

A 100 by 175 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided forty observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 3 to 130 mS/m (Figure 25). A value of 7 mS/m was selected as the average conductivity for a 6 meter profile of the Kreamer soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and surface runoff from farm buildings.

In areas immediately adjacent to the holding pond, EM31 vertical measurements (Figure 25) were 1.7 to 18.6 times higher than the selected background value of 7 mS/m. One is quickly led to believe that seepage is occurring along the embankment to the holding pond. The higher readings (>60 mS/m) are believed to be, in part, the result of cultural noise (debris, metallic fence, and rebar) occurring along the periphery of the holding pond. Intermediate values of soil conductivity (10 to 60 mS/m) are believed to be the result of seepage from this structure. The affects of seepage extend about 30 to 10 feet downslope from base of embankment to the holding pond (Figure 25).

In the horizontal mode (2.8 meter profile), EM measurements ranged from 3 to 16 mS/m (Figure 26). A value of 7 mS/m was selected as the average conductivity for the 2.8 meter profile of the Kreamer soils. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from farm buildings.

In the upper left hand corner of Figure 26, EM31 horizontal measurements were 1.2 to 2.3 times higher than the selected background value of 7 mS/m. As this area is separated from the animal waste holding pond by a zone having lower soil conductivity values, these higher EM measurements are not a result of seepage or surface runoff. Rather, these high soil conductivity values are related to increases in soil moisture and clay content. These values represent a change in soil type.

<u>**Site 10B**</u> - Juniata County.
This animal waste holding pond is located in an area of Hartleton (loamy-skeletal, mixed, mesic Typic Hapludults) soils. The study site was located on an upland area and is underlain by highly inclined beds of shale. Within the study site (see Figure 27), relief was 23.9 feet. In Figure 27, an artificial mound containing a gravity outlet pipe can be seen leading away from the holding pond at 180X. The higher lying portion of the study area was idle, the lower lying portion was in hayland.. The holding pond is a concrete structure used for hogs waste.

A 300 by 150 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided seventy-four observation sites. At each grid intersect, measurements

In the vertical mode (6 meter profile), EM measurements ranged from 12 to 43 mS/m (Figure 31). A value of 19 mS/m was selected as the average conductivity for a 6 meter profile of Edom and Brinkerton soils on higher lying areas. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the filter strip and the road.

In the upper right-hand corner of Figure 31, EM31 vertical measurements were 1.1 to 2.3 times higher than the selected background value of 19 mS/m. These inflated conductivity measurements are believed to reflect the affects of surface runoff from the adjoining concrete pad and barnyard. However, as this area was formerly used as a holding area for dairy cows, the elevated soil conductivity may reflect an earlier source of contamination.

Higher soil conductivity values along the left-hand portion of Figure 31 are believed to reflect increased soil moisture in this lower-lying area. Anomalies in this portion of the study site are believed to be do to cultural noise from an adjoining concrete drainageway.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 16 to 62 mS/m (Figure 32). A value of 21 mS/m was selected as the average conductivity for the 2.8 meter profile of Edom and Brinkerton soils on higher lying areas. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the filter strip and surface runoff from the barnyard.

In the right-hand portion of Figure 32, EM31 horizontal measurements were 1.2 to 3.0 times higher than the selected background value of 21 mS/m. These higher soil conductivities can be attributed to the deposition of dissolved salts in the surface runoff from the concrete pad and the adjoining barnyard. As in Figure 31, the distribution pipe appears to have little affect on conductivity values.

<u>Site 12</u> - Bedford County.
This animal waste holding pond is located in an area of Hagerstown (fine, mixed, mesic Typic Hapludalfs) and Murrill (fine-loamy, mixed, mesic Typic Hapludults) soils. Within the study site (see Figure 33), relief was 11.8 feet. Along the right and bottom margins of Figure 33, the site is bounded by roads. The study site is drained by a small intermittent drainageway. The study site was in hayland. The animal waste holding pond is an earthen structure which was constructed in 1978.

A 200 by 275 foot rectangular grid was established across the study site. The grid interval was 25 feet. The grid intersects provided seventy-seven observation sites. At each grid intersect, measurements were taken with the EM31 in both the vertical and horizontal dipole modes. The lowest point within the study site was selected as the 0.0 datum.

In the vertical mode (6 meter profile), EM measurements ranged from 9 to 58 mS/m (Figure 34). A value of 12 mS/m was selected as the average conductivity for a 6 meter profile of the Hagerstown and Murrill soils. This value was based on an average of vertical EM31 measurements taken in areas within the study site which were believed to be removed from the influence of the holding pond and runoff from the roads.

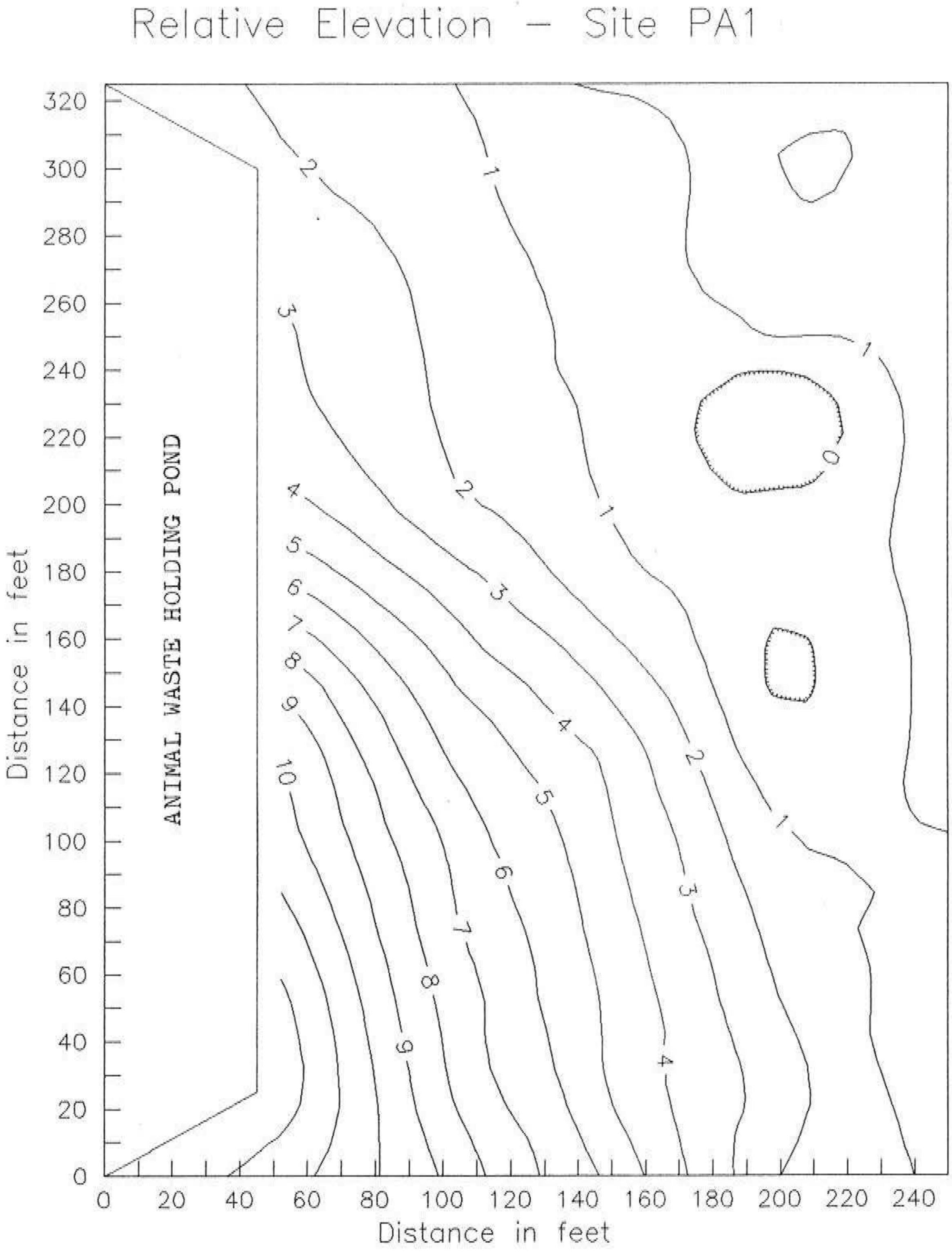
Along the embankment to the animal waste holding pond, EM31 vertical measurements (Figure 34) were 1.3 to 3.2 times higher than the selected background value of 12 mS/m. While seepage is suspected, variations in conductivity caused by differences in soil type cannot be discounted. In Figure 34, zones of higher soil conductivities extends about 0 to 60 feet downslope from the holding pond.

In Figure 34, the higher EM values near grid intersect 100X and 0Y are believed to reflect the influence of road salts.

In the horizontal mode (2.8 meter profile), EM measurements ranged from 7 to 30 mS/m (Figure 35). Compared with the vertical measurements, a slightly lower value of 9 mS/m was selected as the average conductivity for the 2.8 meter profile. This value was based on an average of horizontal EM31 measurements taken in areas within the study site which were believed to be removed from the influence of seepage from the holding pond and surface runoff from the roads.

In Figure 35, EM31 horizontal measurements were 1.6 to 3.3 times higher than the selected background value of 9 mS/m in two area (A and B) adjacent to the roadways. These higher soil conductivities can be attributed to the deposition of dissolved salts from surface runoff from the roads. No apparent zone of shallow (> 2.8 m) seepage from the holding pond is evident in Figure 35.

FIGURE 1



Relative Elevation - Site PA1
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
1
2
3
4
5
6
7
8
9
10
0

FIGURE 2

EM31 Survey (V) - Site PA1

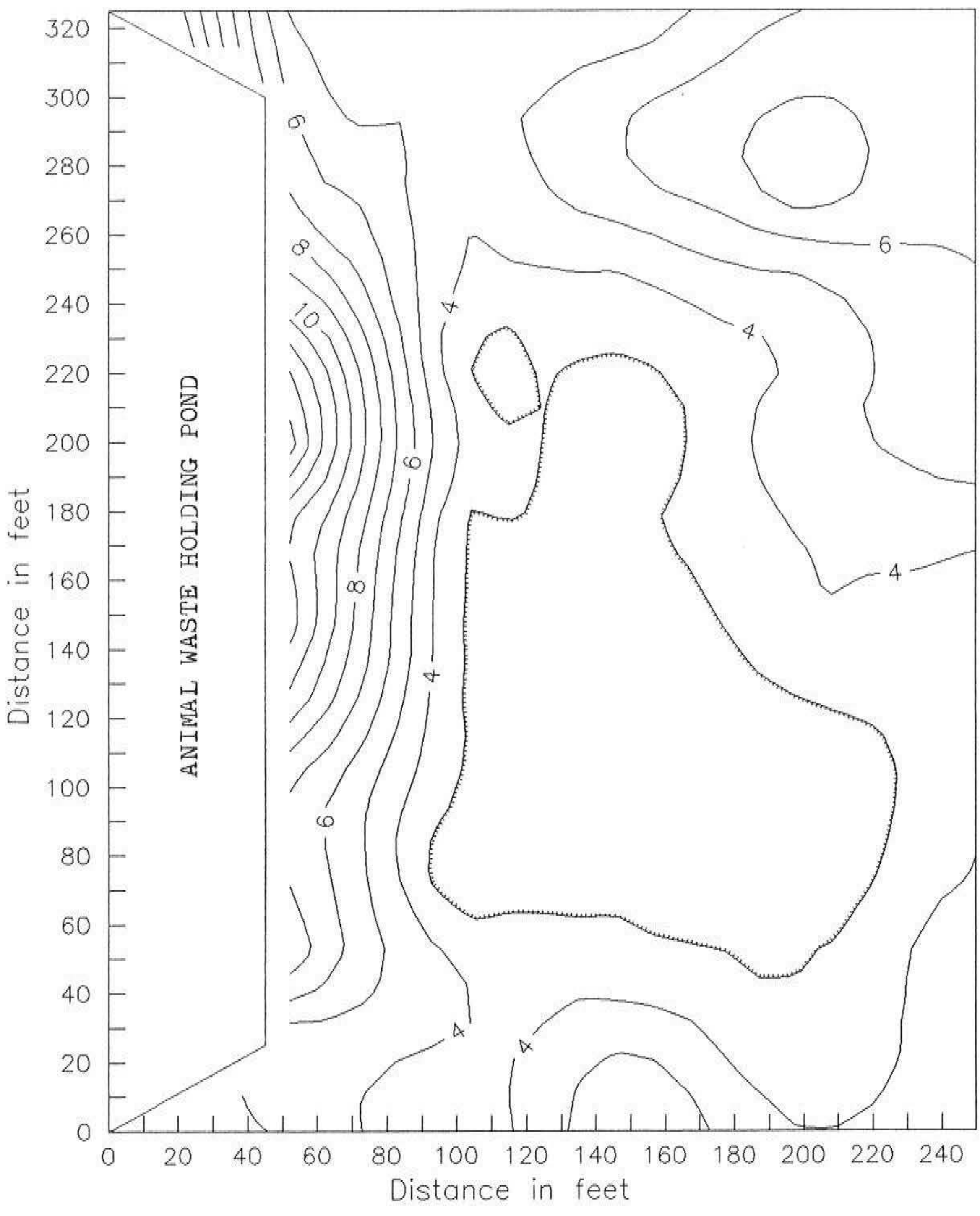
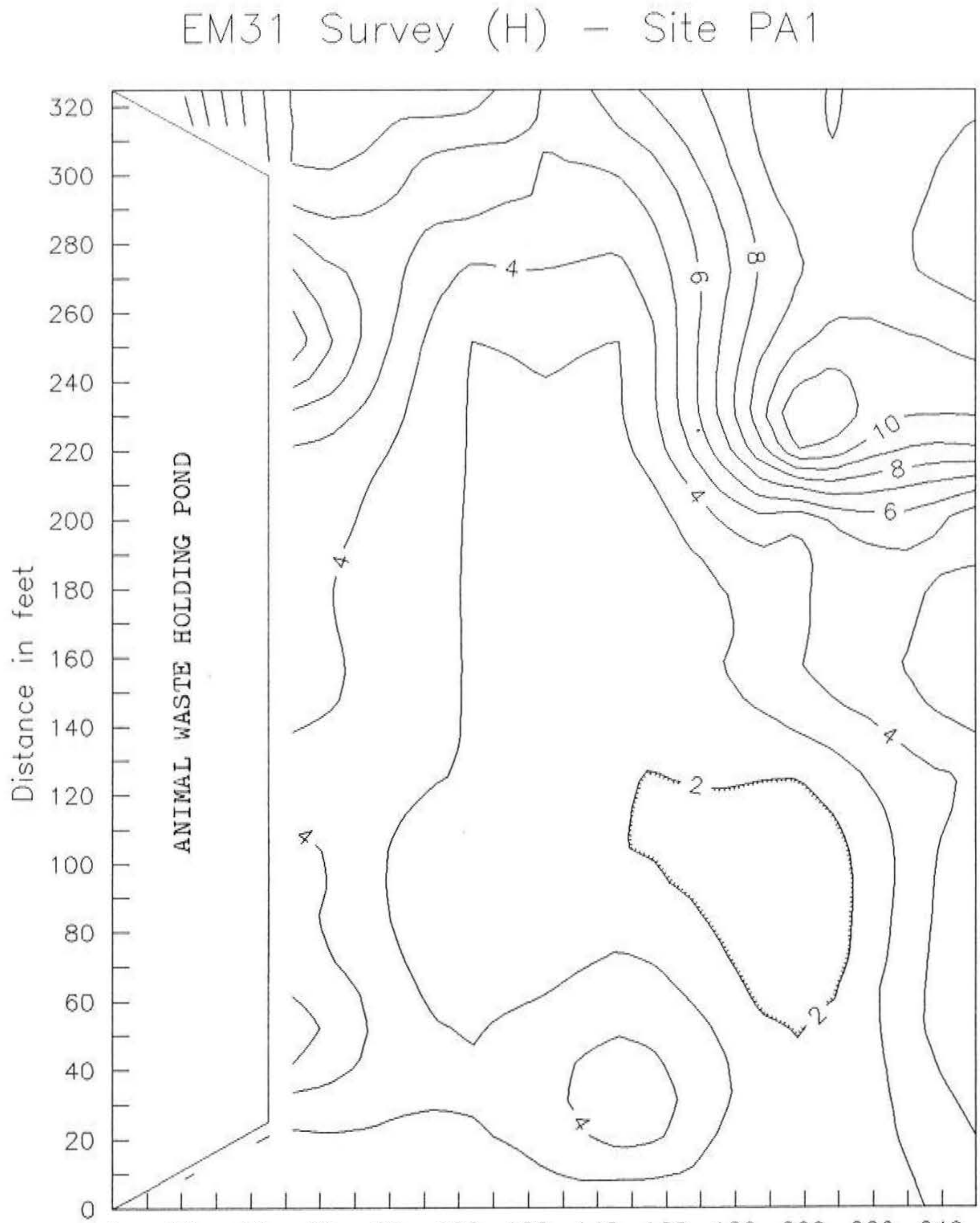


FIGURE 3



EM31 Survey (H) - Site PA1
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
4
6
8
10
2

FIGURE 4

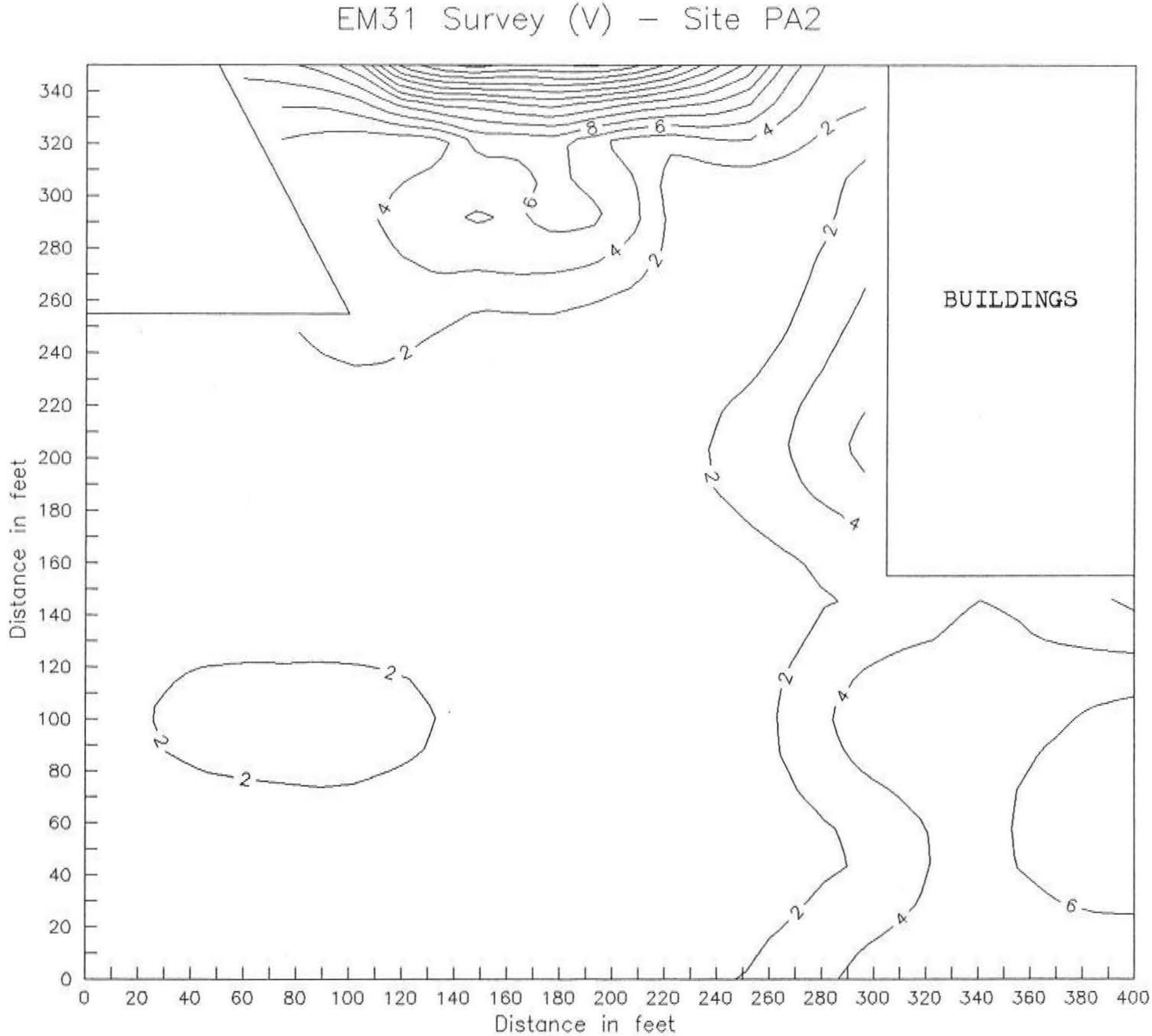
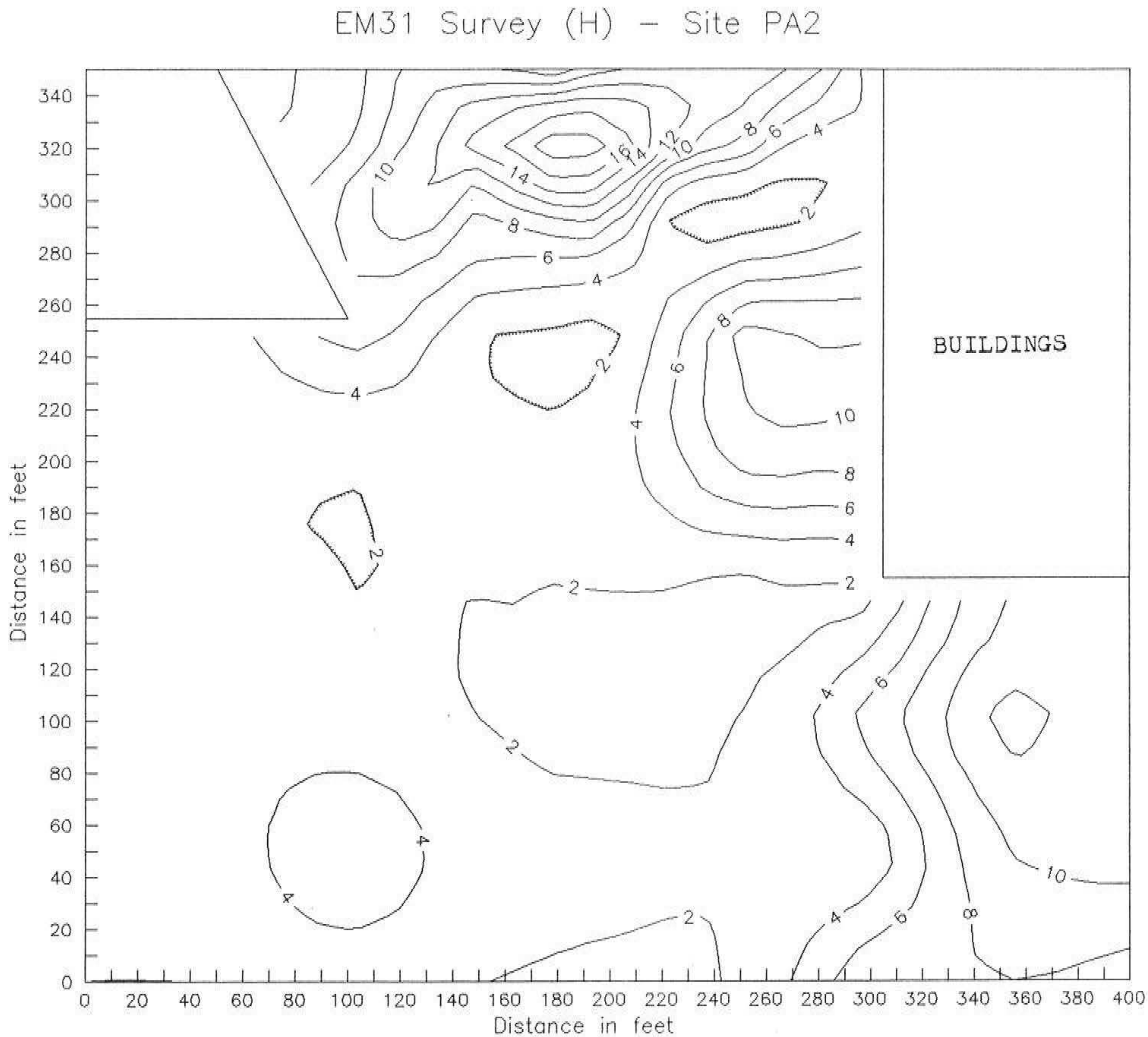
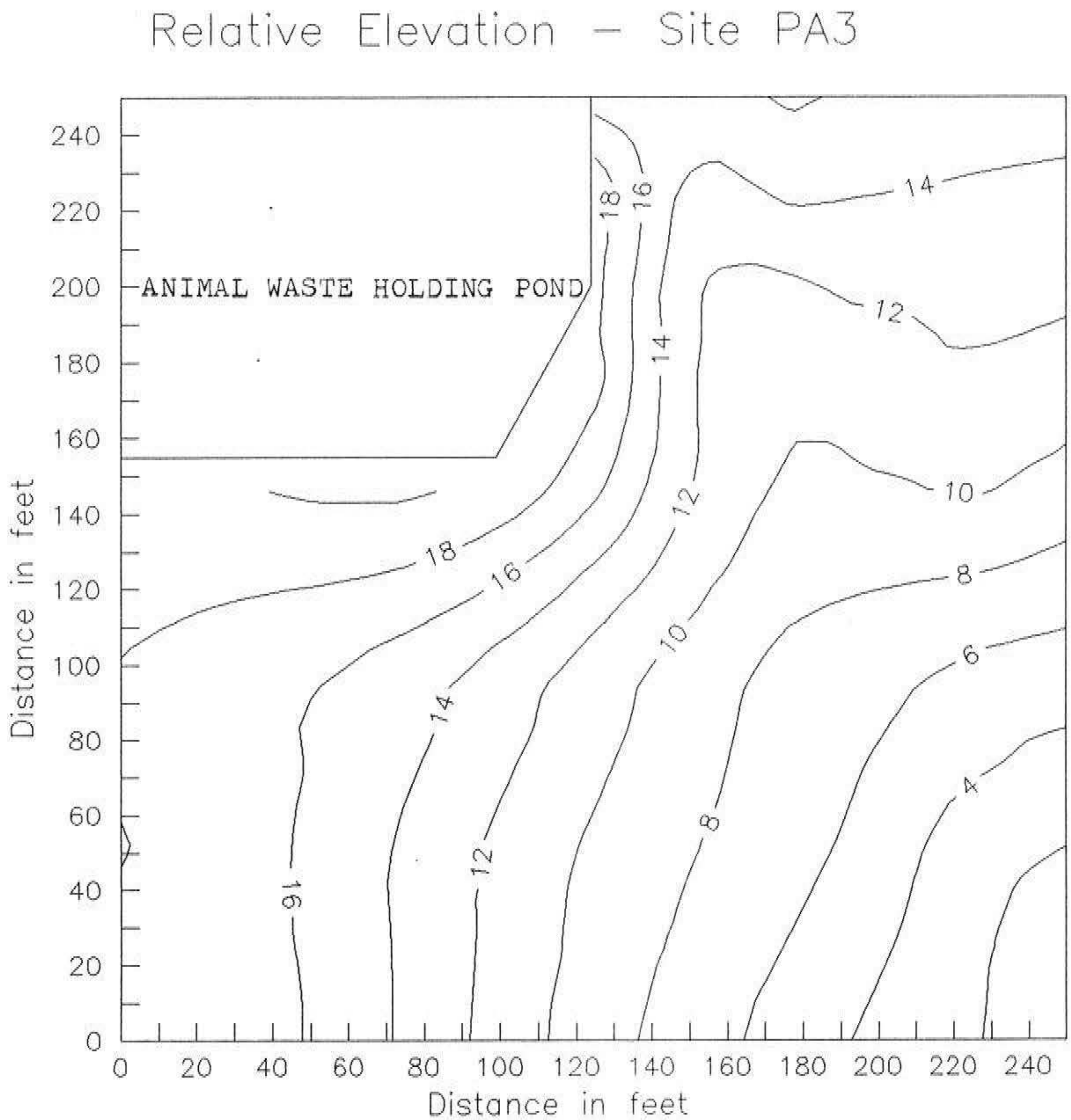

EM31 Survey (V) - Site PA2
BUILDINGS
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
2
4
6
8

FIGURE 5



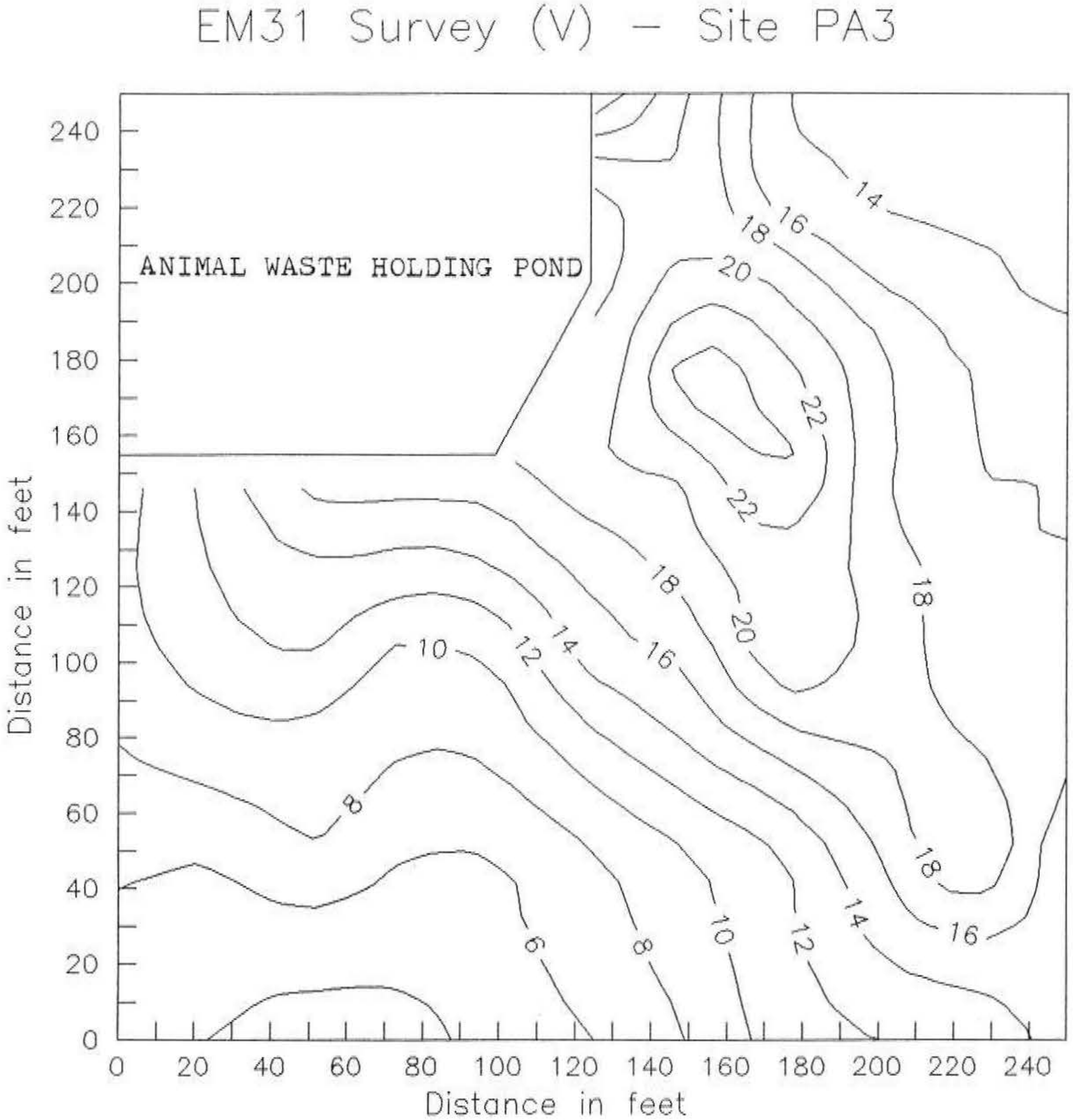
EM31 Survey (H) - Site PA2
BUILDINGS
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400

FIGURE 6

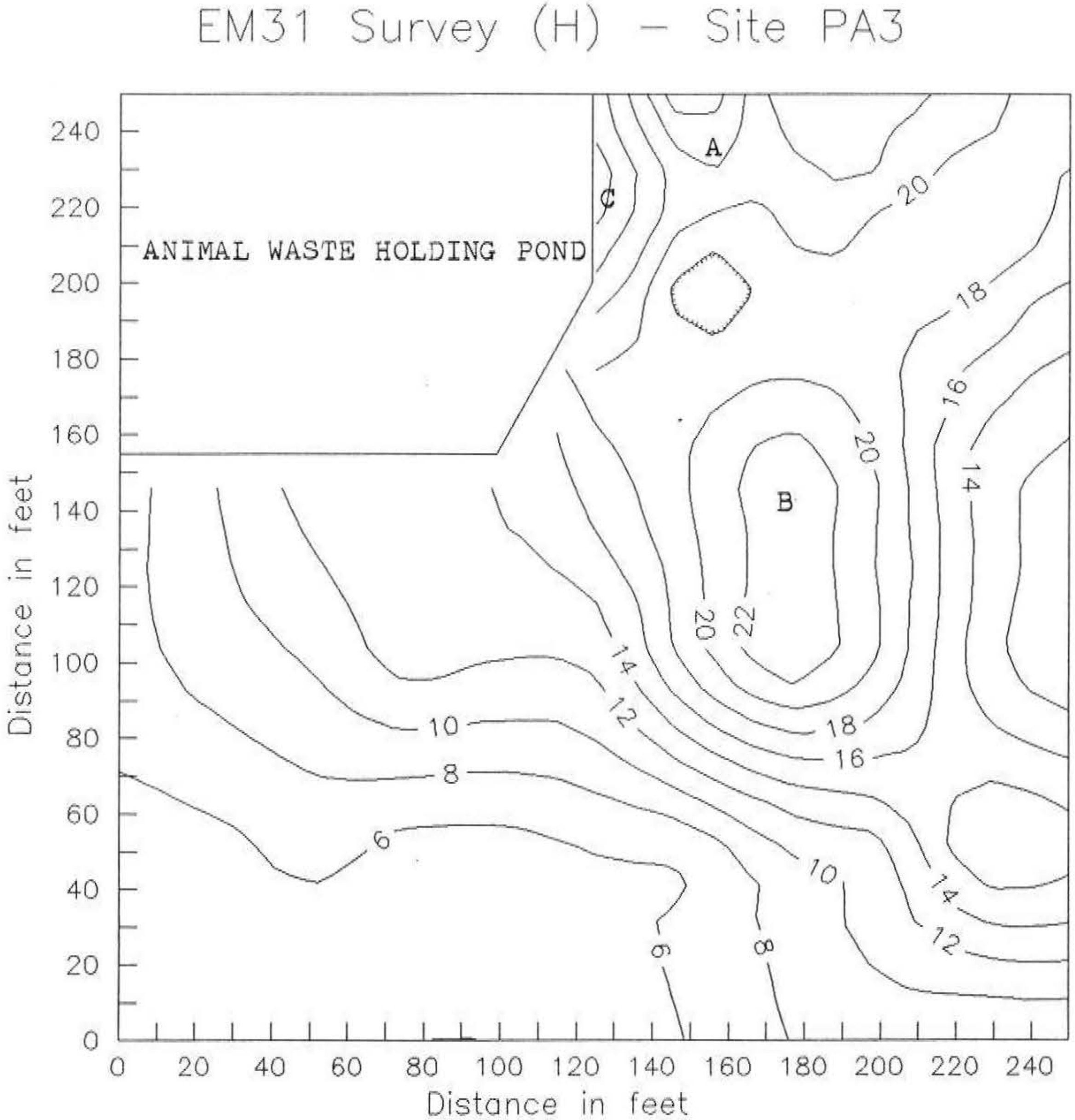


Relative Elevation — Site PA3
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
18
16
14
12
10
8
6
4

FIGURE 7



EM31 Survey (V) - Site PA3
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
6
8
10
12
14
16
18
20
22


EM31 Survey (H) - Site PA3
ANIMAL WASTE HOLDING POND
A
B
C
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
6
8
10
12
14
16
18
20
22

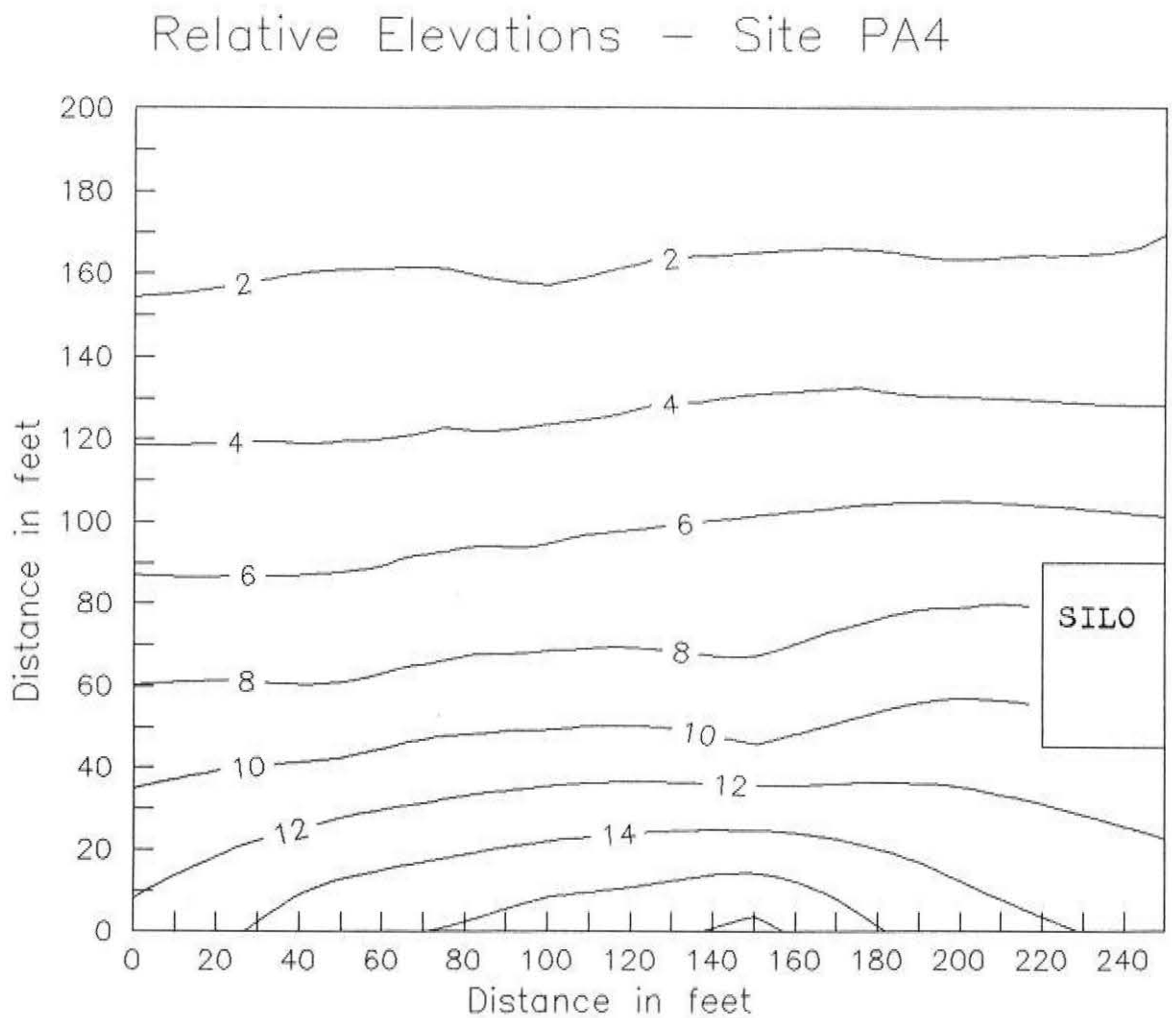

Relative Elevations – Site PA4
Distance in feet
Distance in feet
200
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
220
240
2
4
6
8
10
12
14
SILO

FIGURE 10

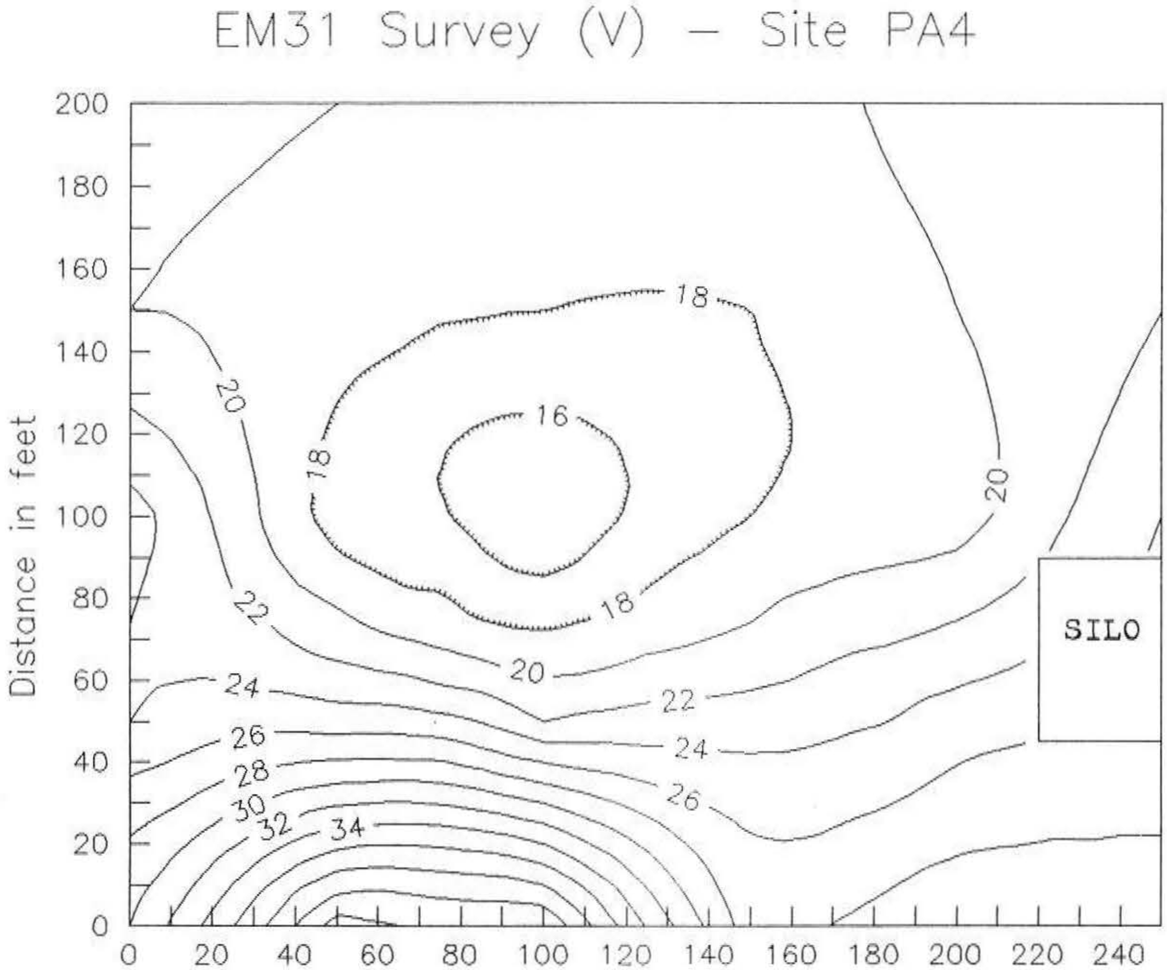
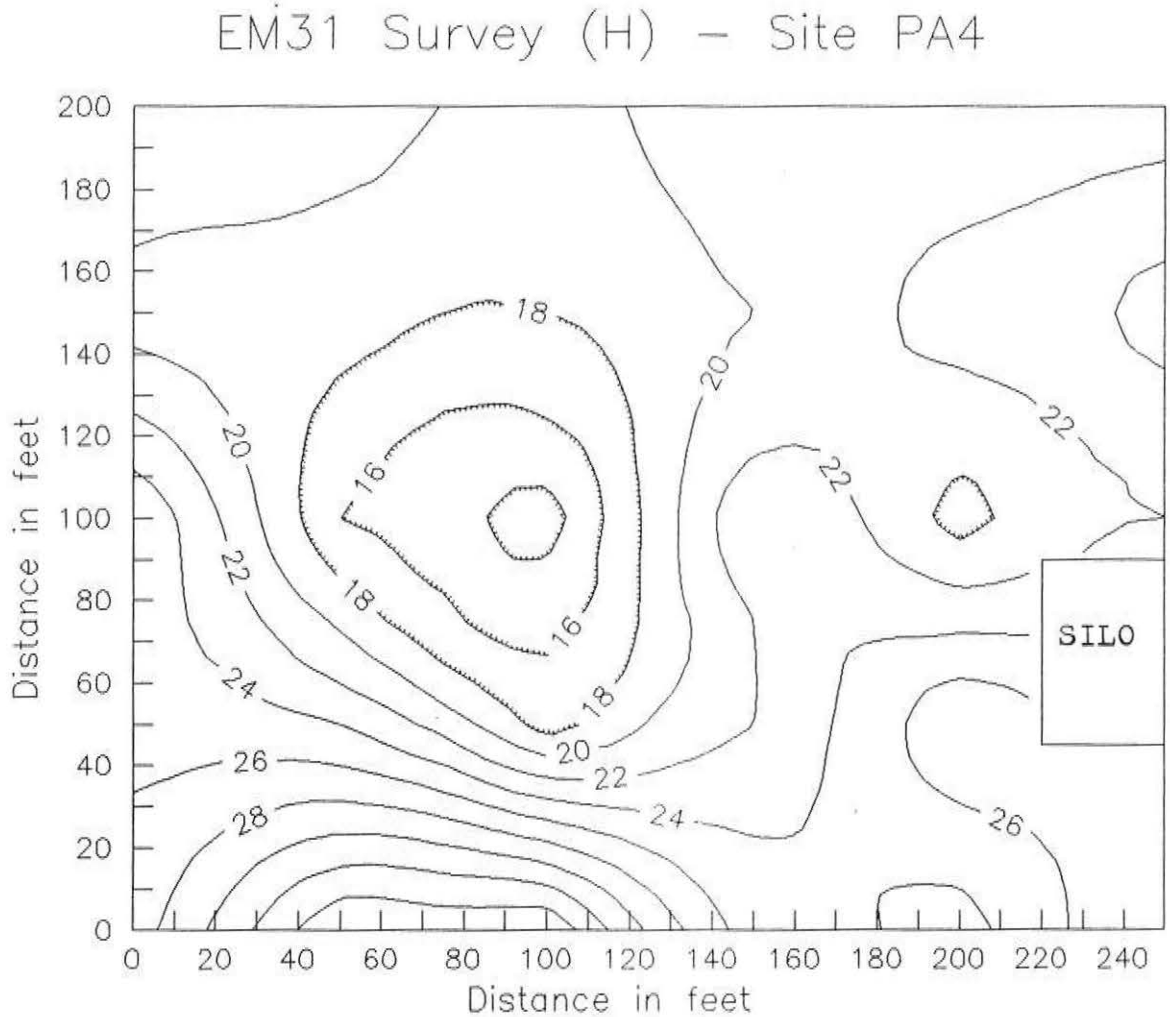

EM31 Survey (V) - Site PA4
Distance in feet
Distance in feet
SILO
200
180
160
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160 180 200 220 240
16
18
20
22
24
26
28
30
32
34

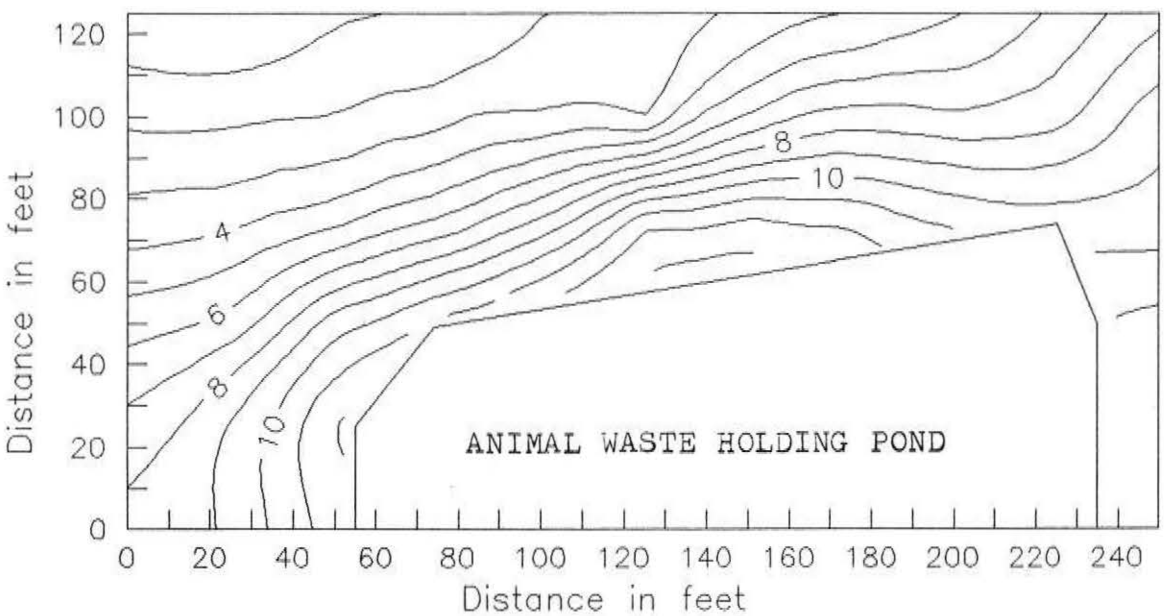
FIGURE 11



EM31 Survey (H) - Site PA4
Distance in feet
Distance in feet
SILO
0
20
40
60
80
100
120
140
160
180
200
220
240
16
18
20
22
24
26
28

FIGURE 12

Relative Elevation — Site PA5



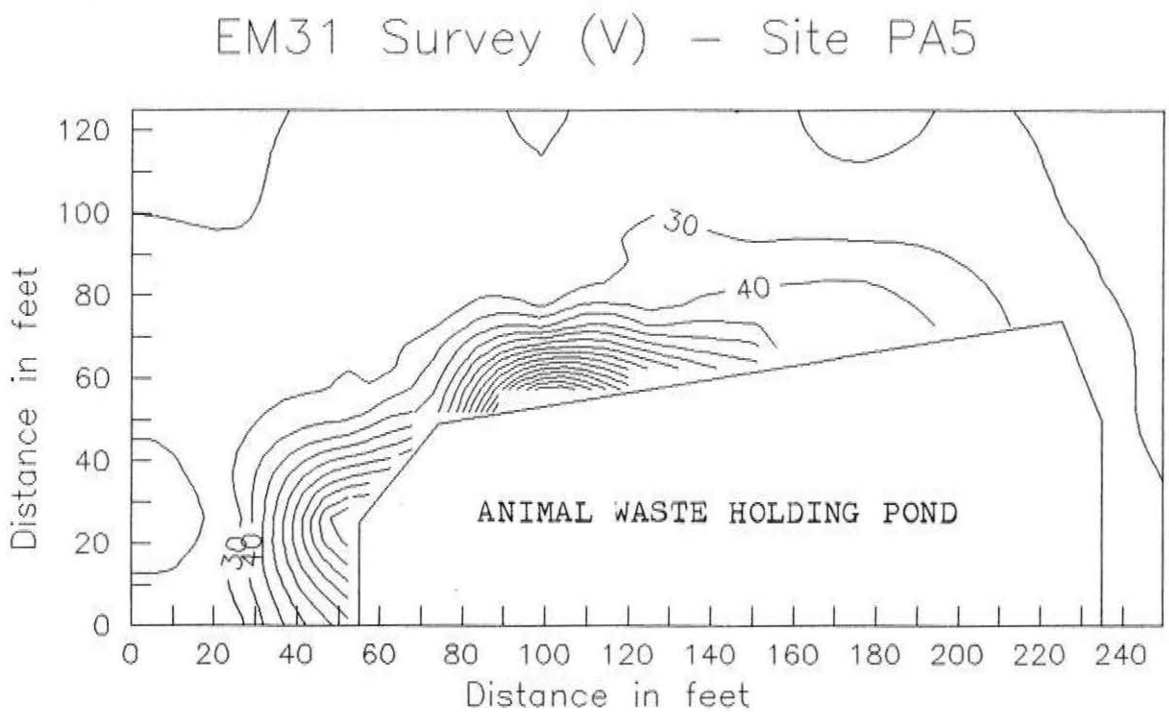
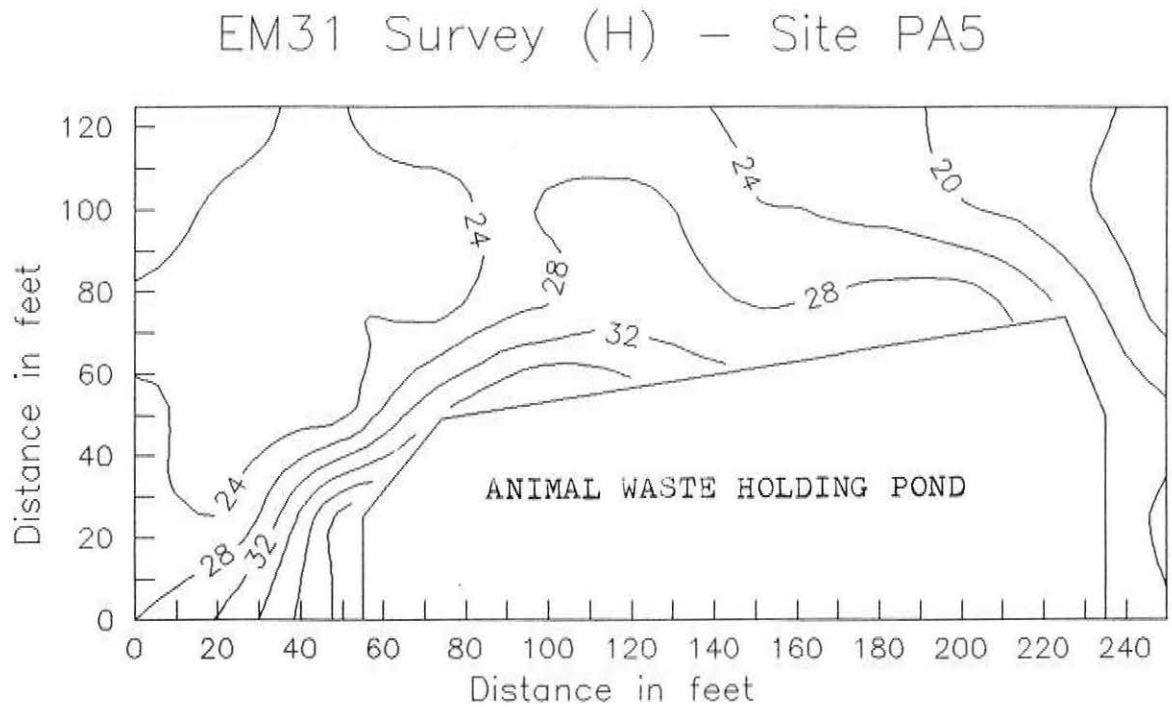

EM31 Survey (V) – Site PA5
Distance in feet
Distance in feet
ANIMAL WASTE HOLDING POND
30
40
30
40
0
20
40
60
80
100
120
0
20
40
60
80
100
120
140
160
180
200
220
240

FIGURE 14


EM31 Survey (H) - Site PA5
Distance in feet
0
20
40
60
80
100
120
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance in feet
24
28
32
24
28
32
24
20
28
ANIMAL WASTE HOLDING POND

Relative Elevation – Site PA6

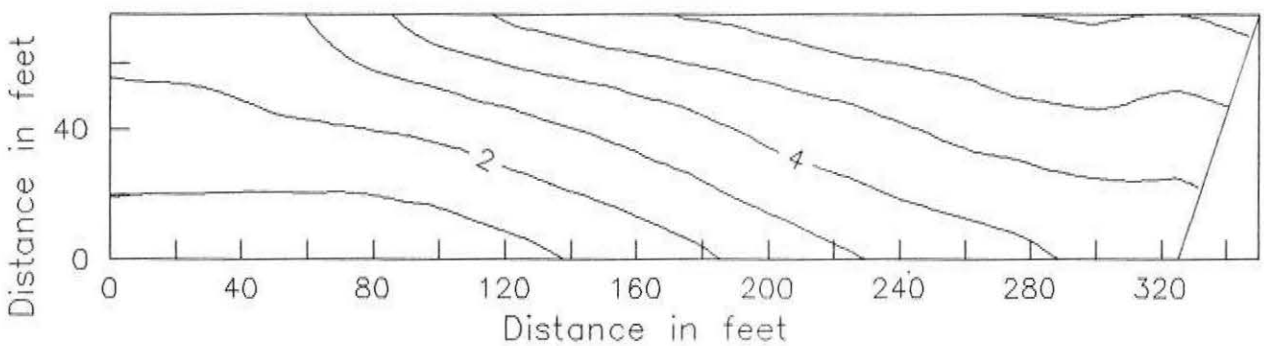


FIGURE 16

EM31 Survey (V) - Site PA6

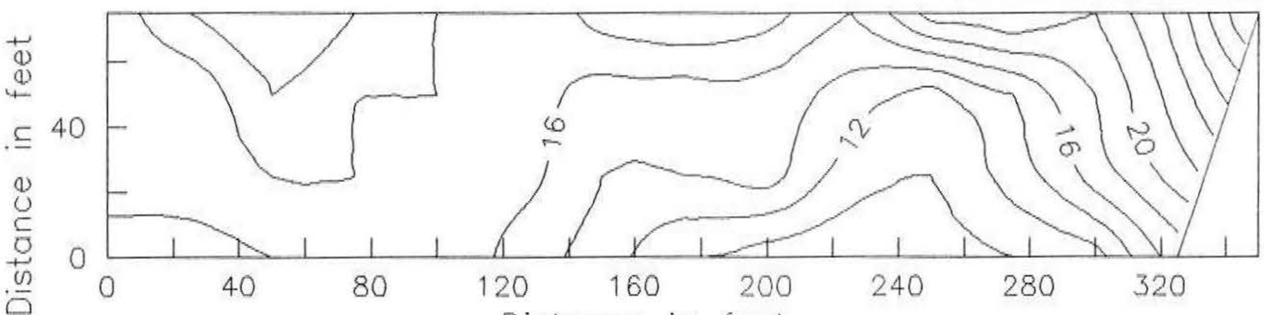


FIGURE 17

EM31 Survey (H) - Site PA6

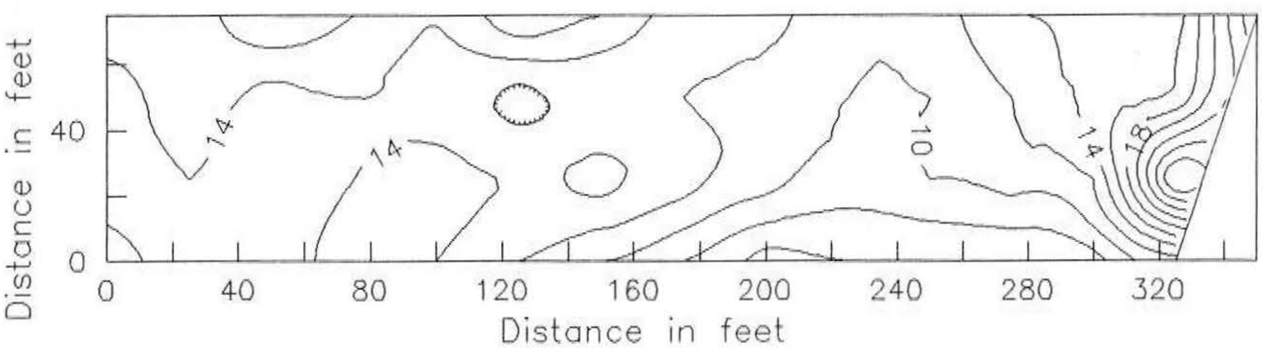


FIGURE 18

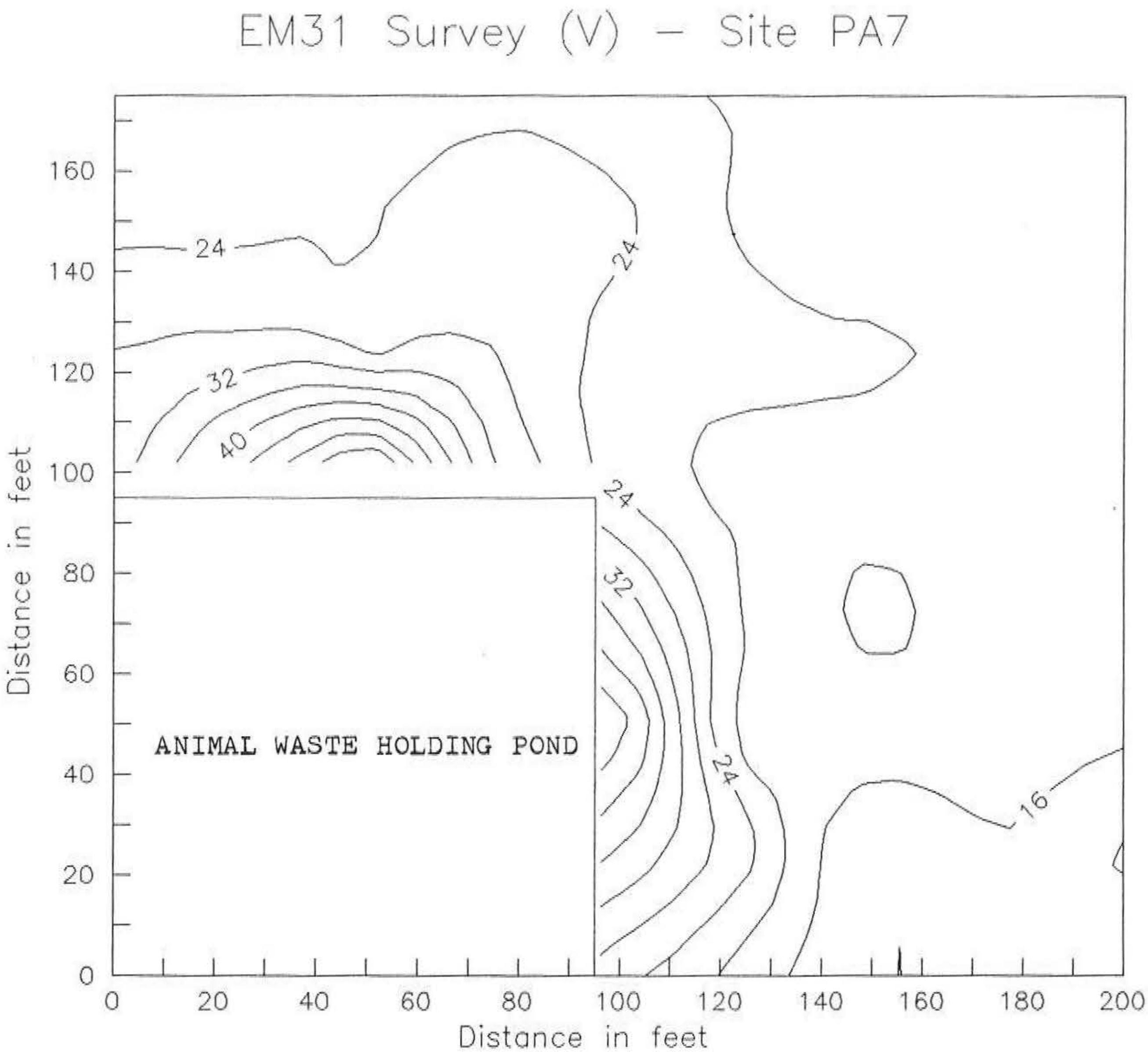
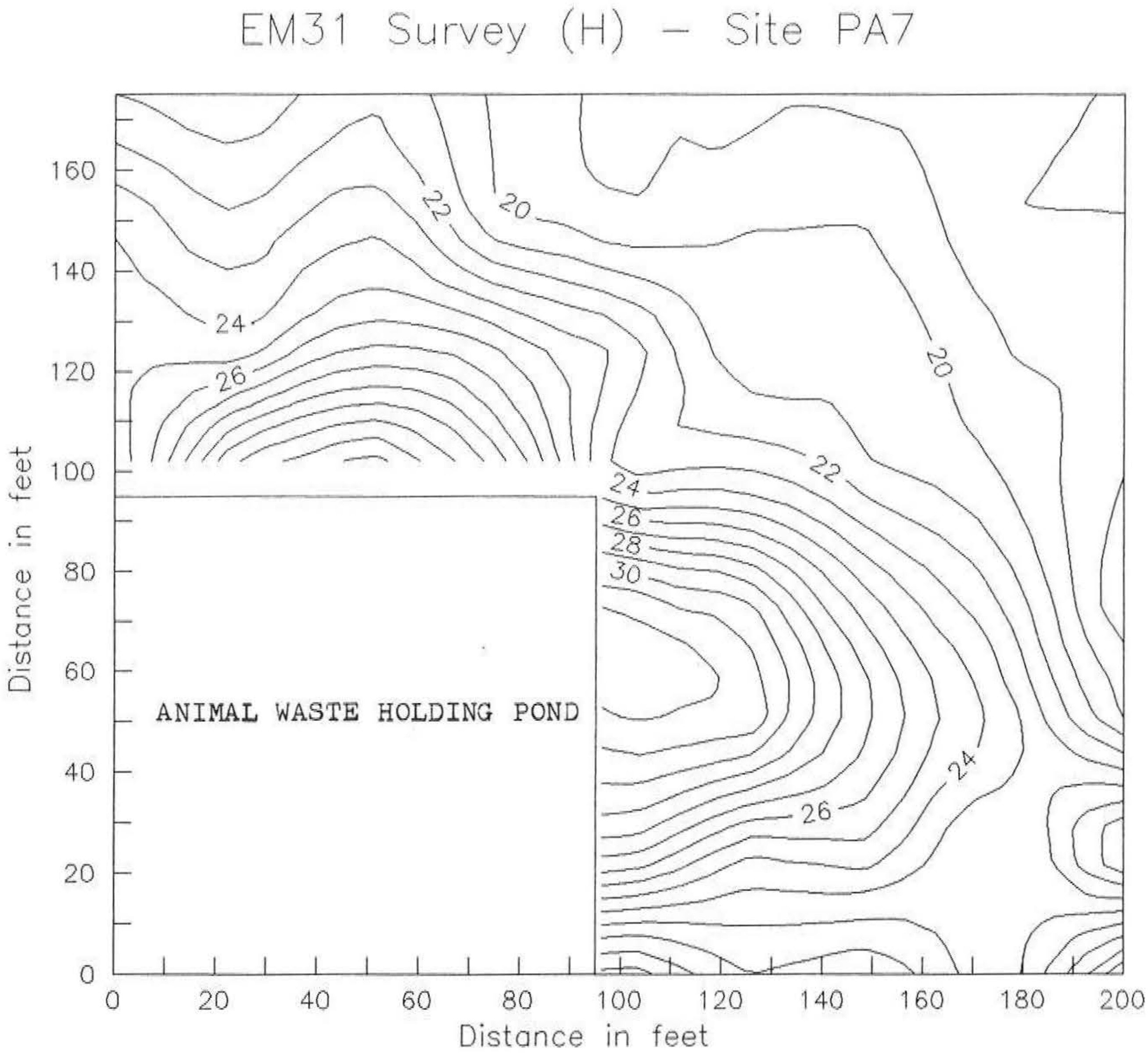

EM31 Survey (V) - Site PA7
Distance in feet
Distance in feet
ANIMAL WASTE HOLDING POND
24
32
40
24
24
32
24
16
0
20
40
60
80
100
120
140
160
180
200

FIGURE 19



EM31 Survey (H) - Site PA7
Distance in feet
Distance in feet
ANIMAL WASTE HOLDING POND
0
20
40
60
80
100
120
140
160
180
200
0
20
40
60
80
100
120
140
160
20
22
24
26
28
30

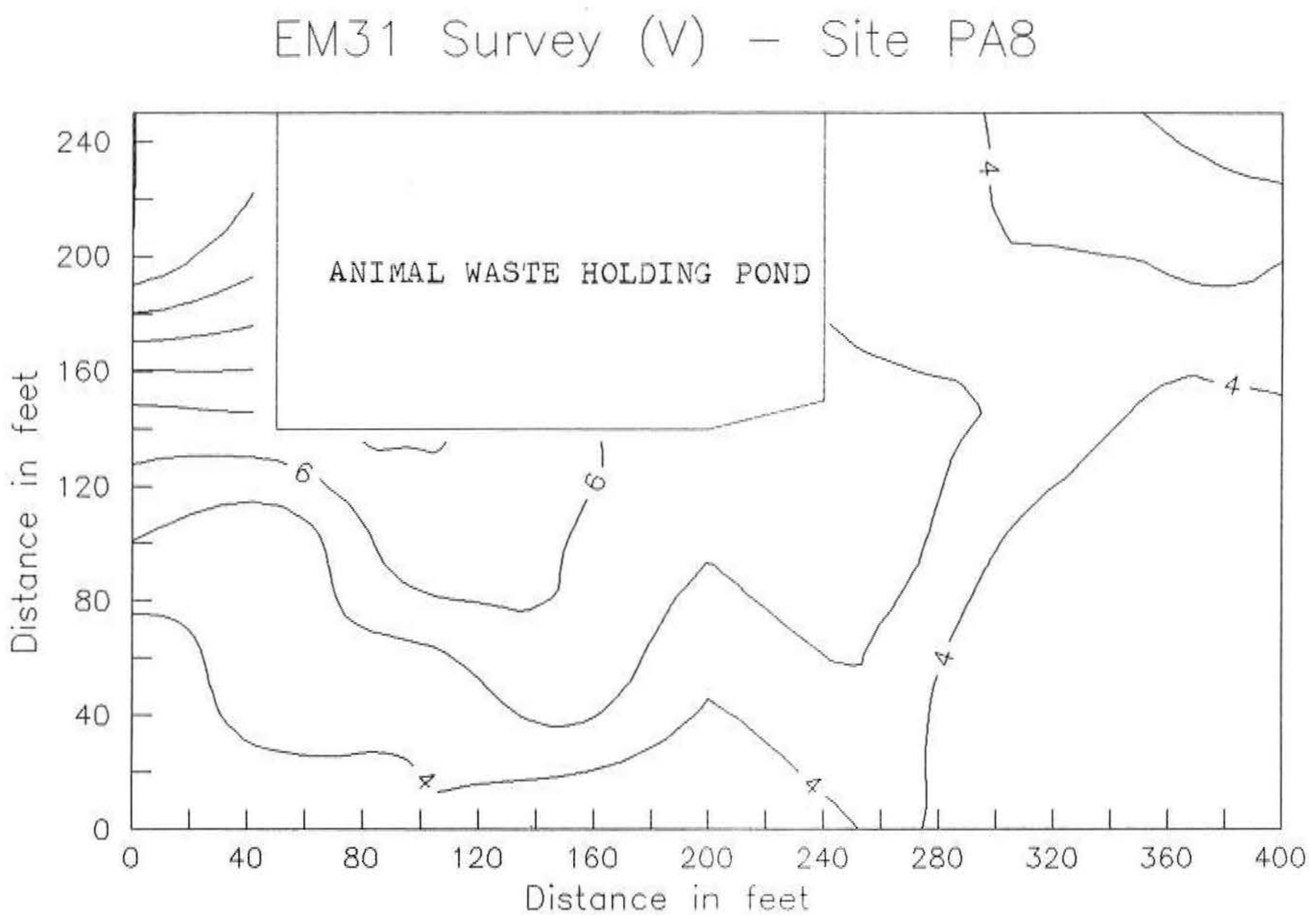
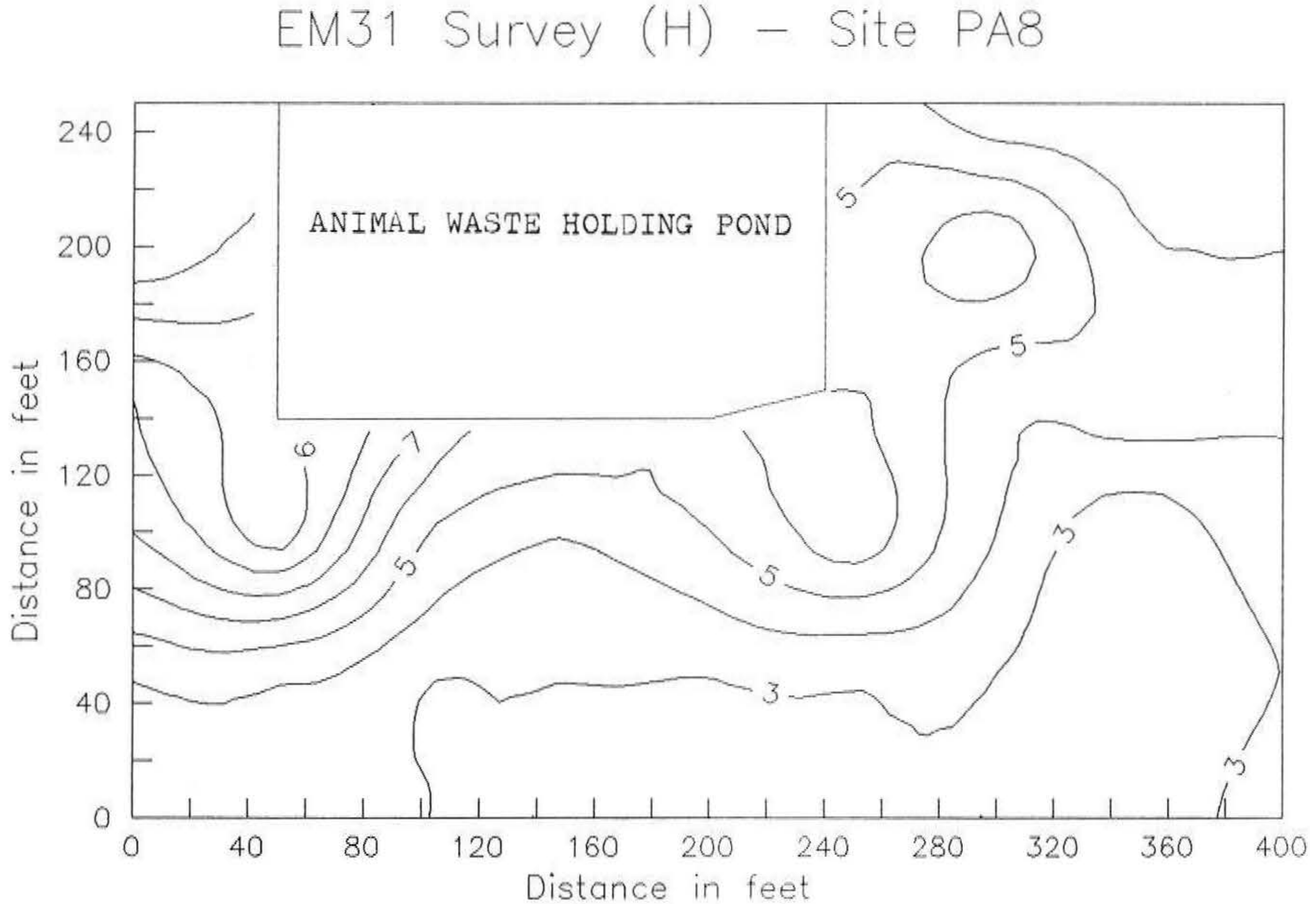
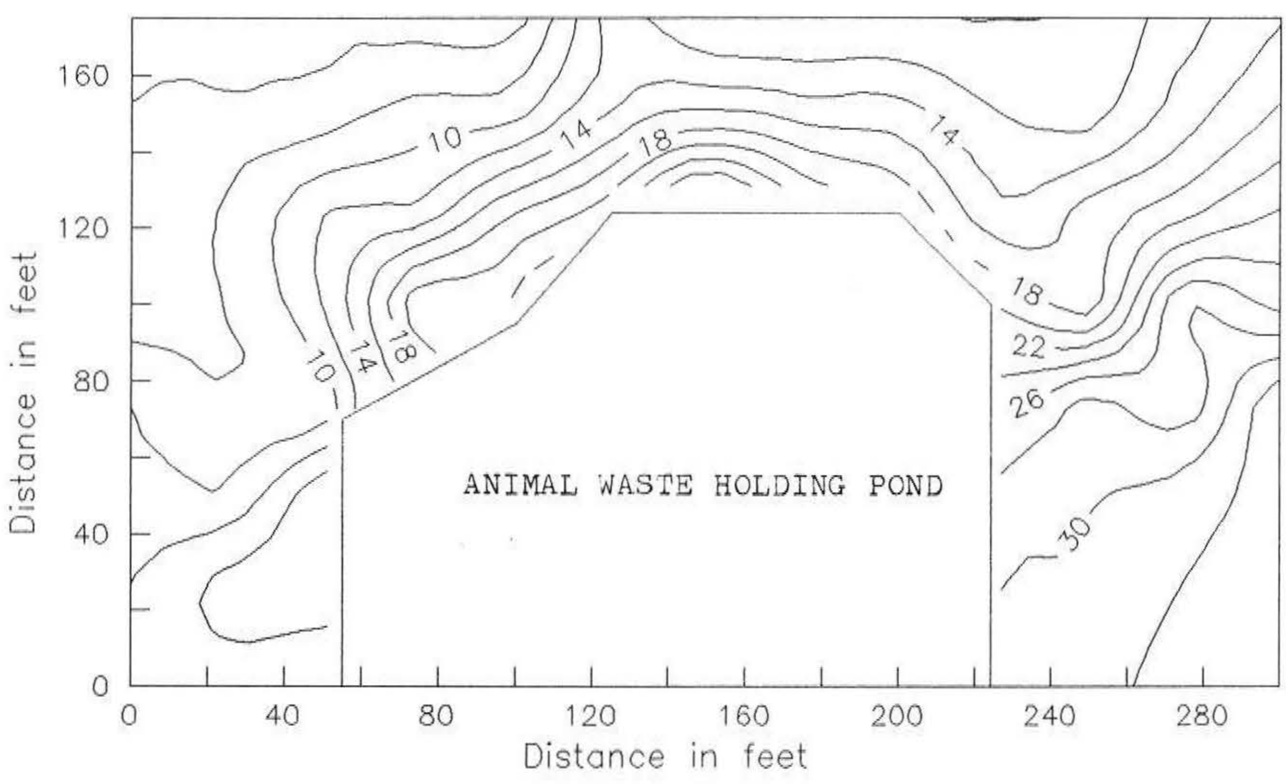

EM31 Survey (V) - Site PA8
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
6
6
4
4
4
4
4
0
40
80
120
160
200
240
280
320
360
400

FIGURE 21



EM31 Survey (H) - Site PA8
ANIMAL WASTE HOLDING POND
Distance in feet
Distance in feet
0
40
80
120
160
200
240
0
40
80
120
160
200
240
280
320
360
400
3
5
6
7

EM31 Survey (V) - Site PA9



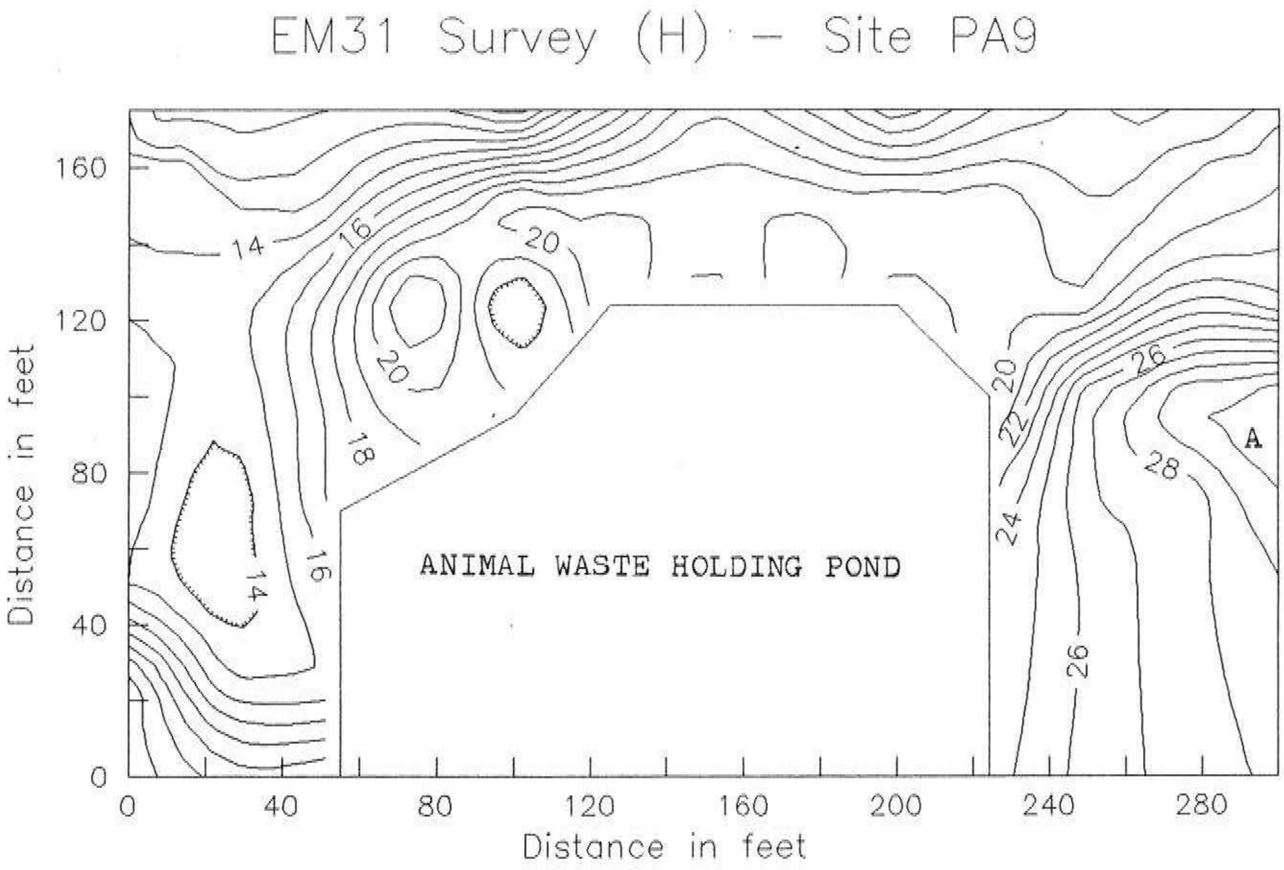

EM31 Survey (H) – Site PA9
Distance in feet
Distance in feet
ANIMAL WASTE HOLDING POND
A
0
40
80
120
160
200
240
280
14
16
18
20
22
24
26
28

FIGURE 24

Relative Elevation — Site 10A

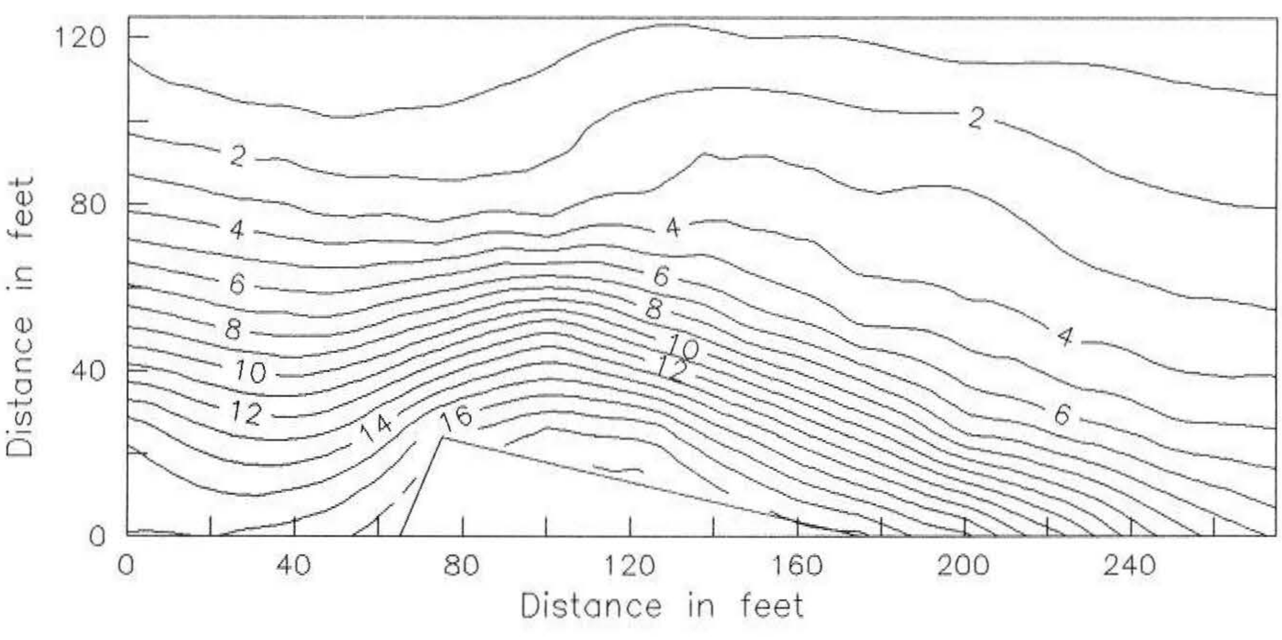
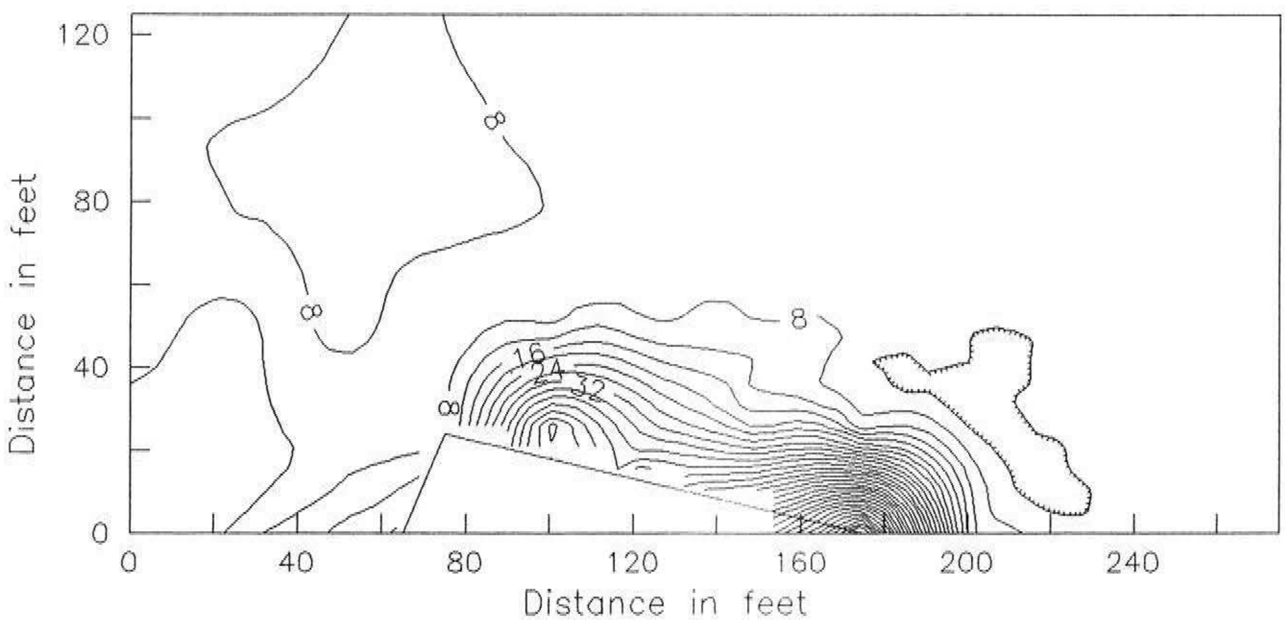


FIGURE 25

EM31 Survey (V) -Site 10A



EM31 Survey (H) -Site 10A

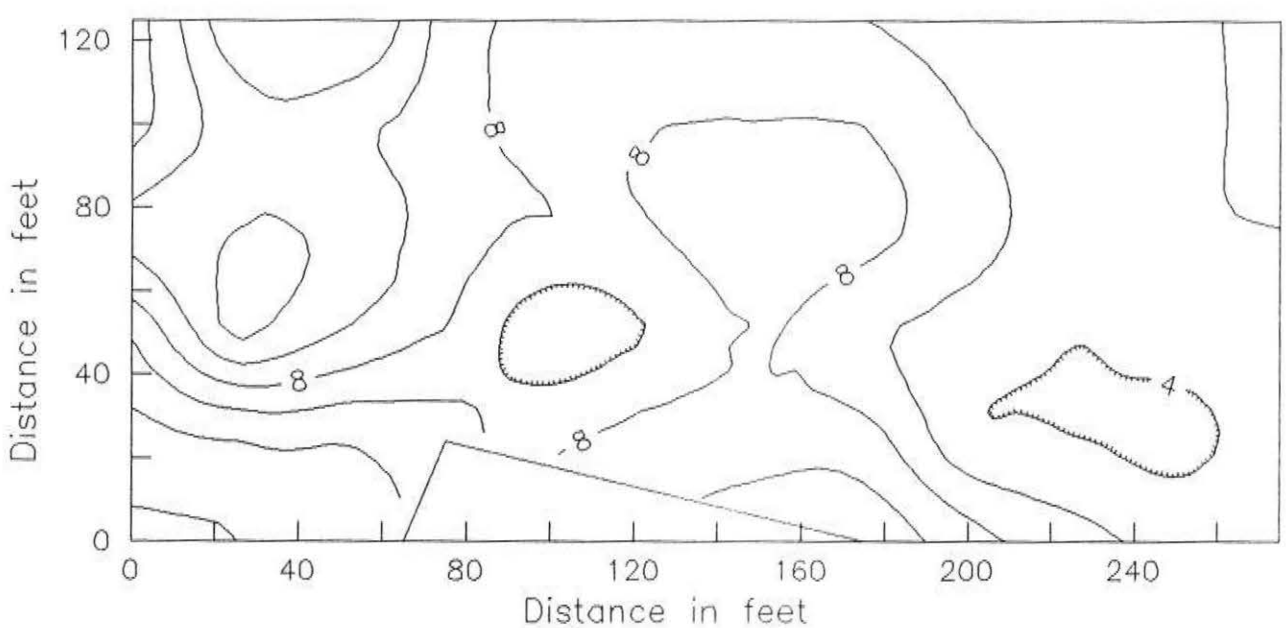


FIGURE 27

Relative Elevation – Site 10B

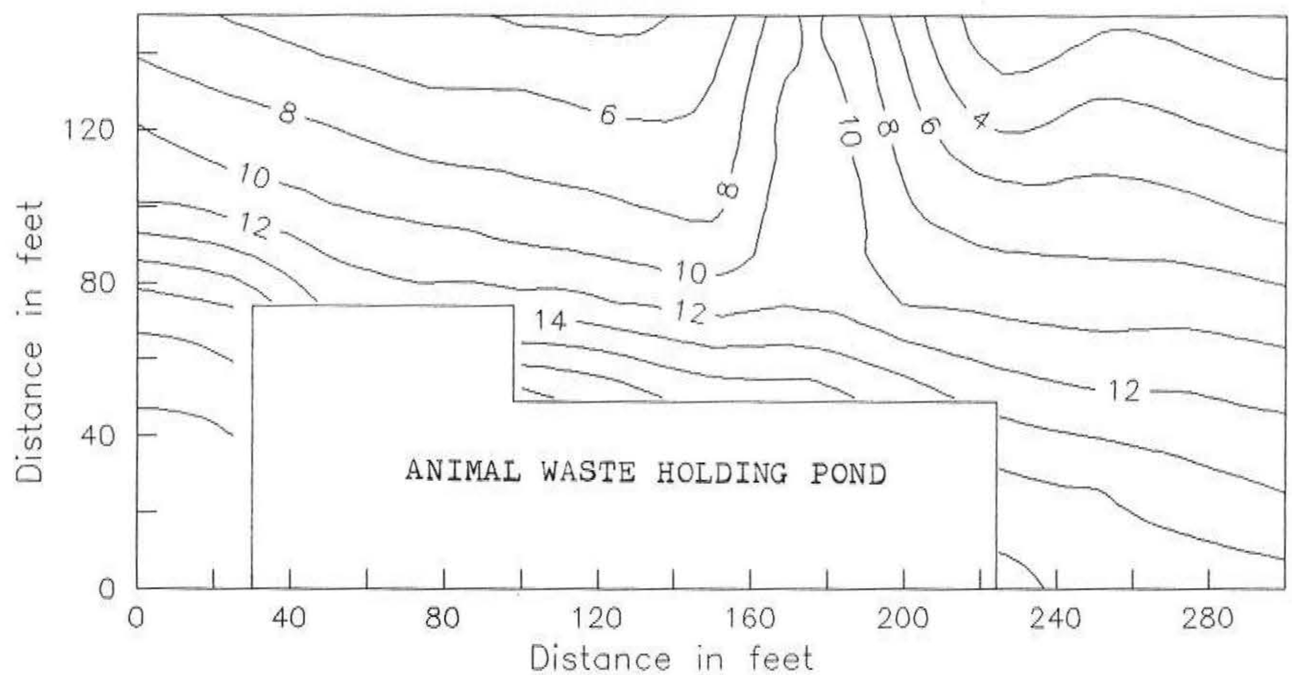
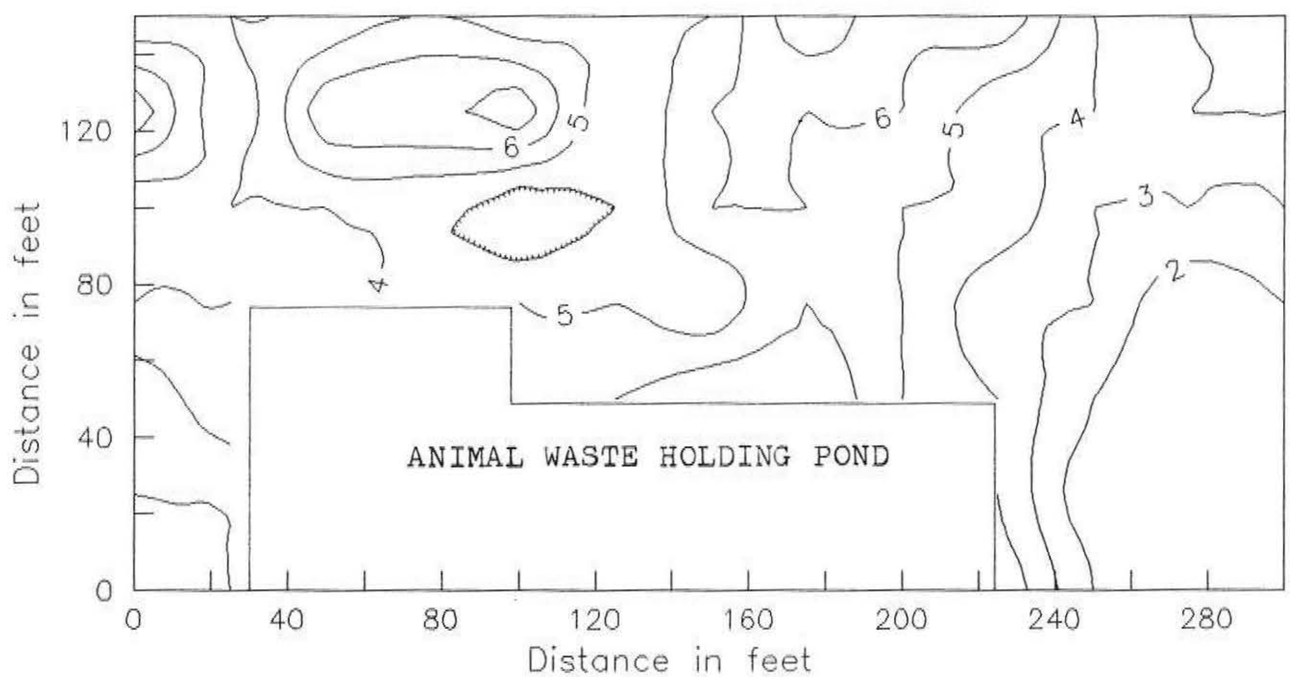


FIGURE 28

EM31 Survey (V) - Site 10B



EM31 Survey (H) - Site 10B

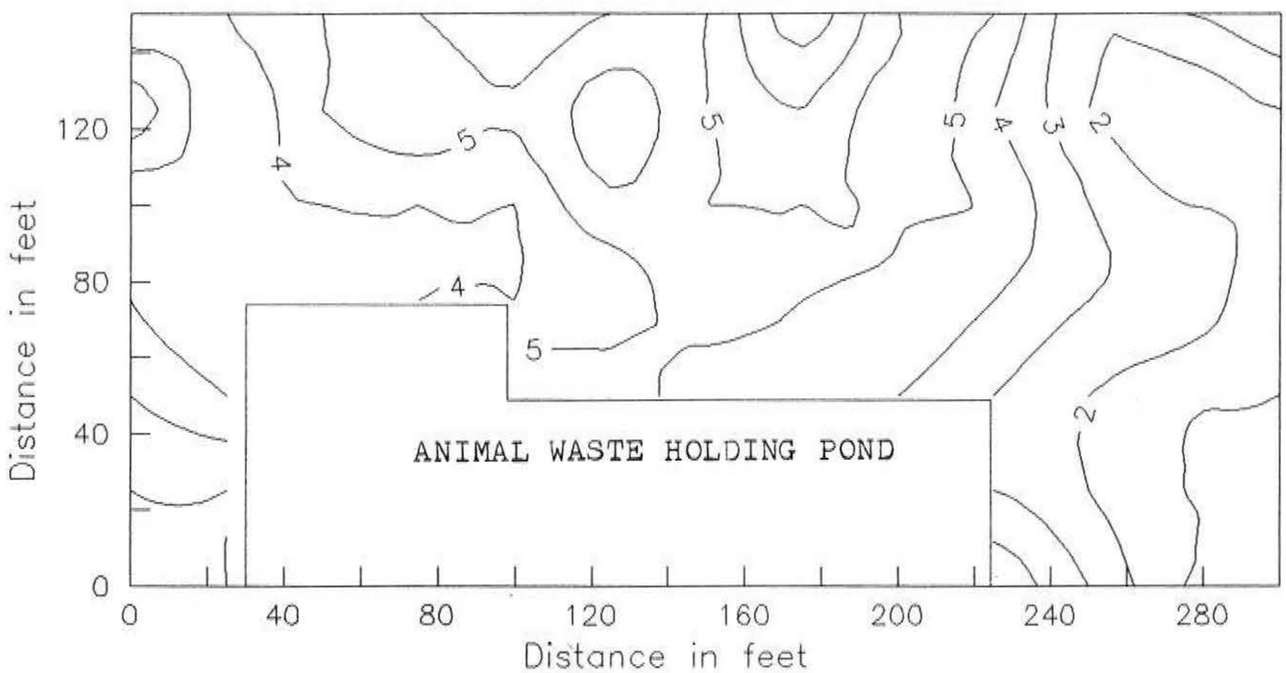


FIGURE 30

Relative Elevation - Site 11

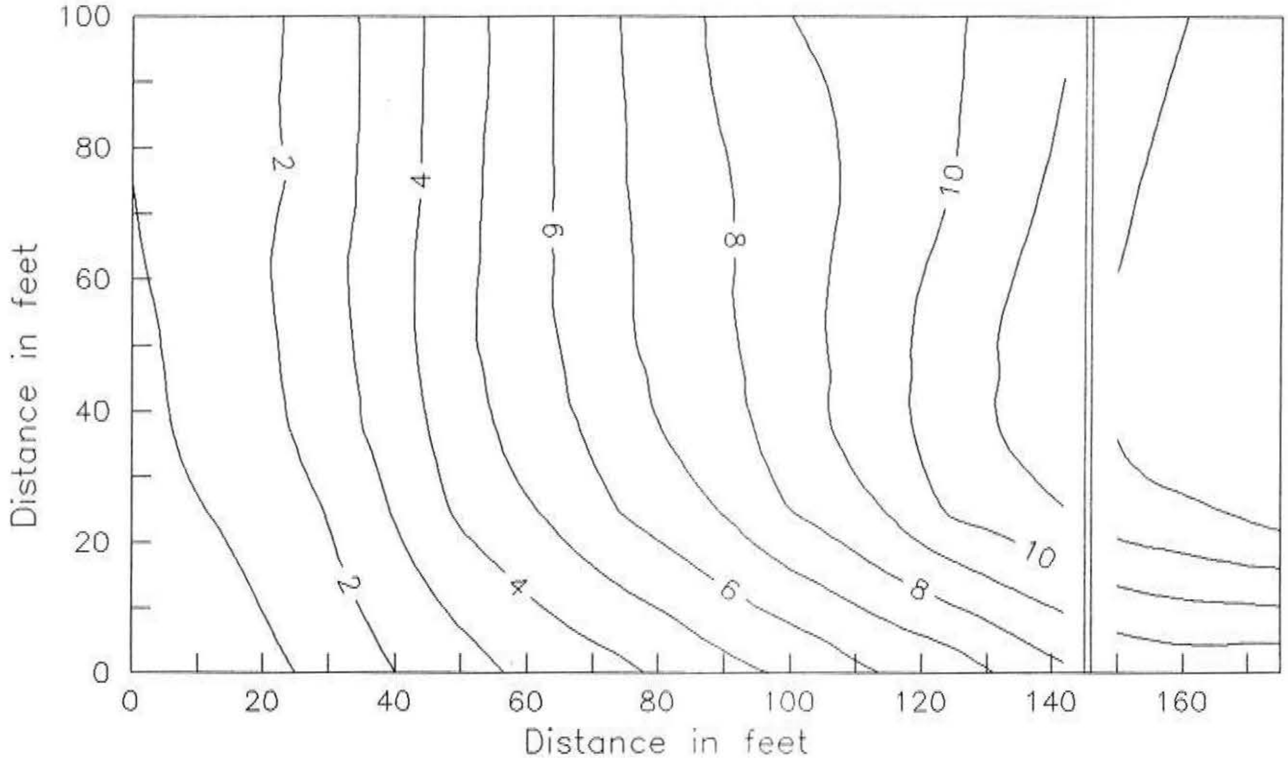
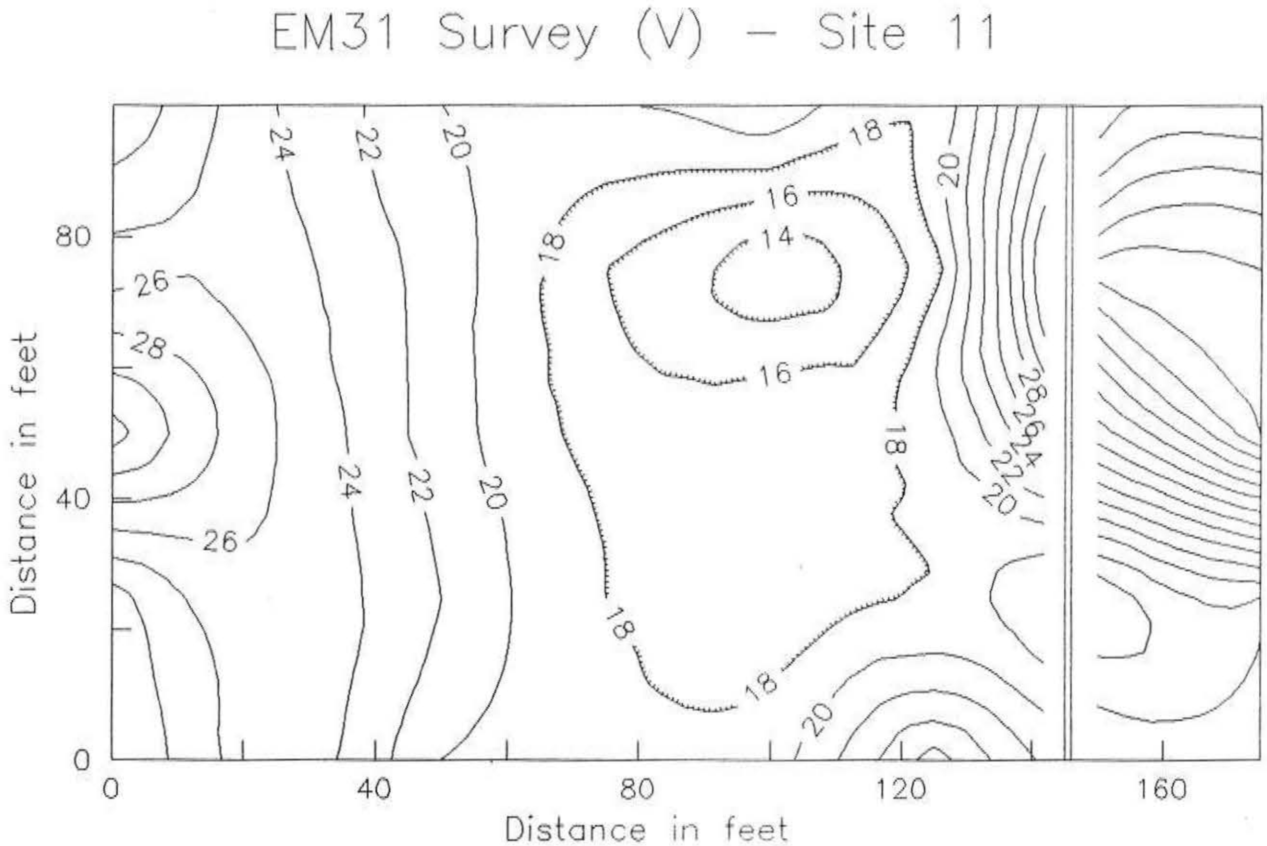
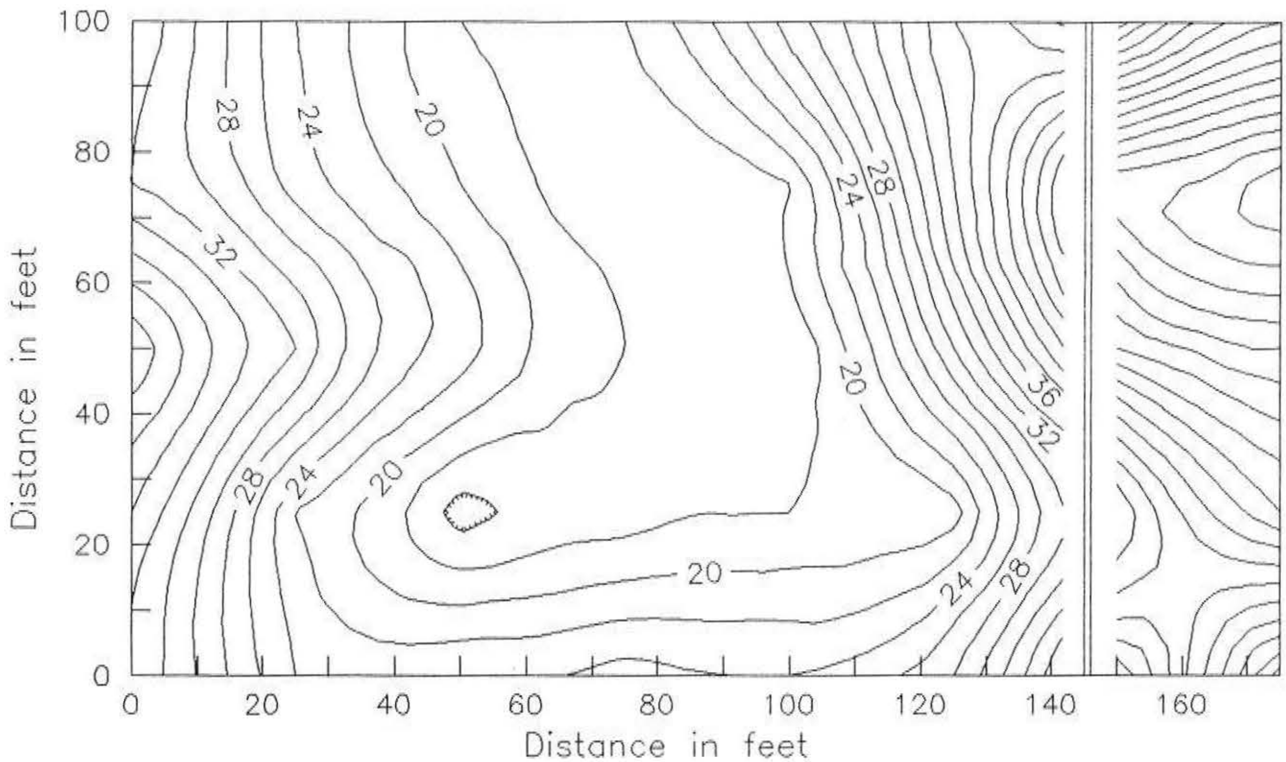


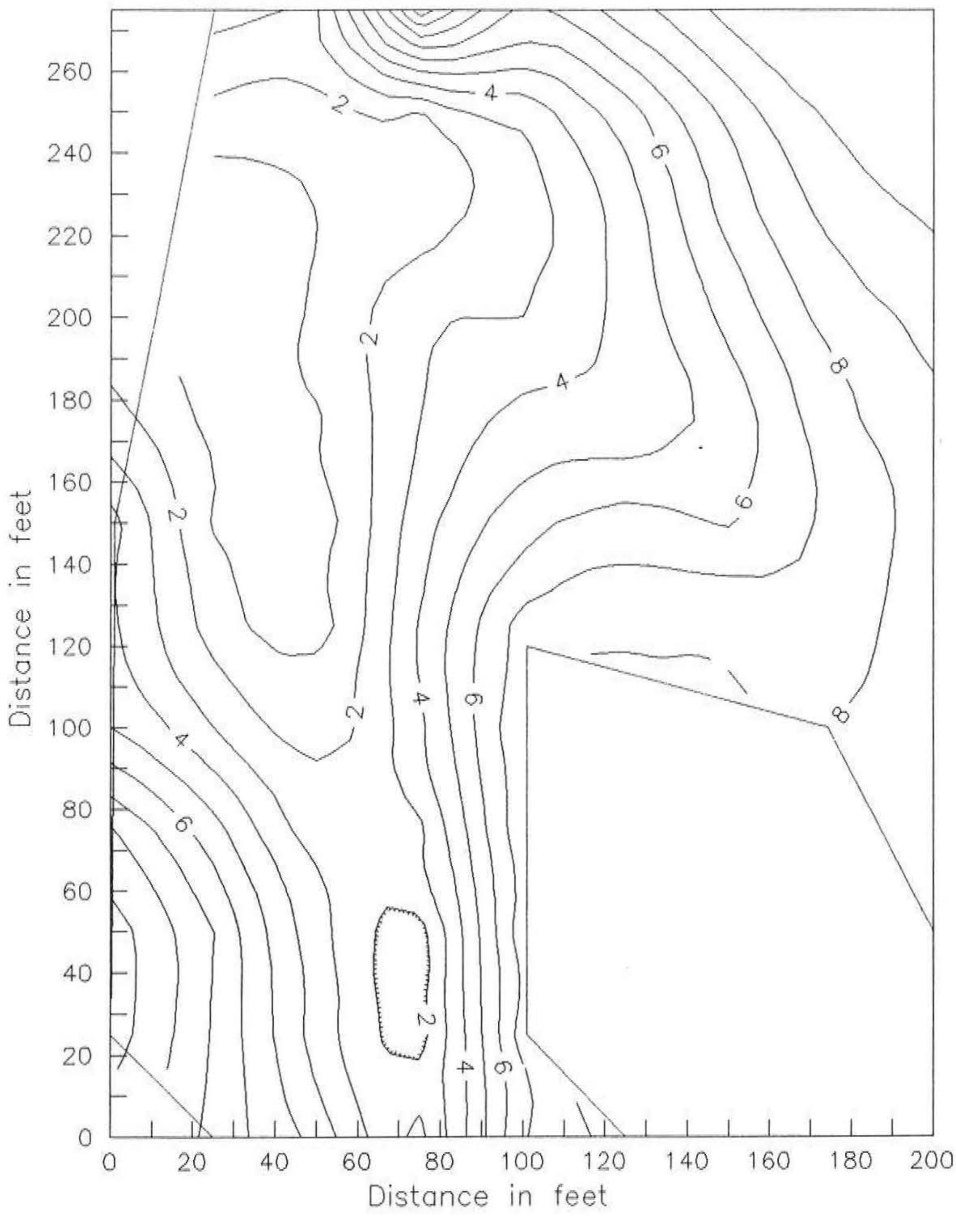
FIGURE 31

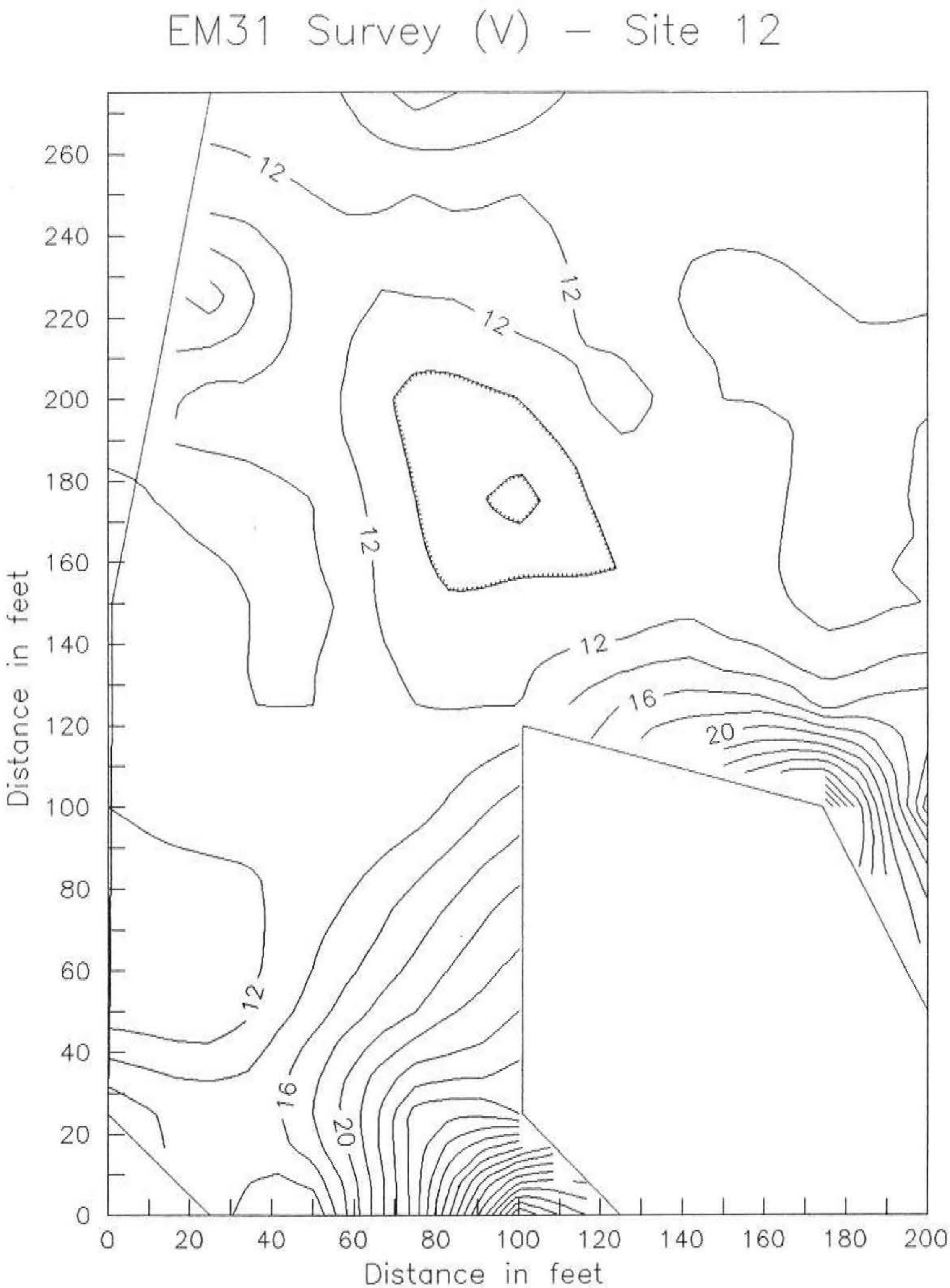

EM31 Survey (V) - Site 11
Distance in feet
Distance in feet
0
40
80
120
160
0
40
80
24
22
20
18
16
14
16
18
18
20
26
28
26
24
22
20
28
26
24
22
20
18
18
20

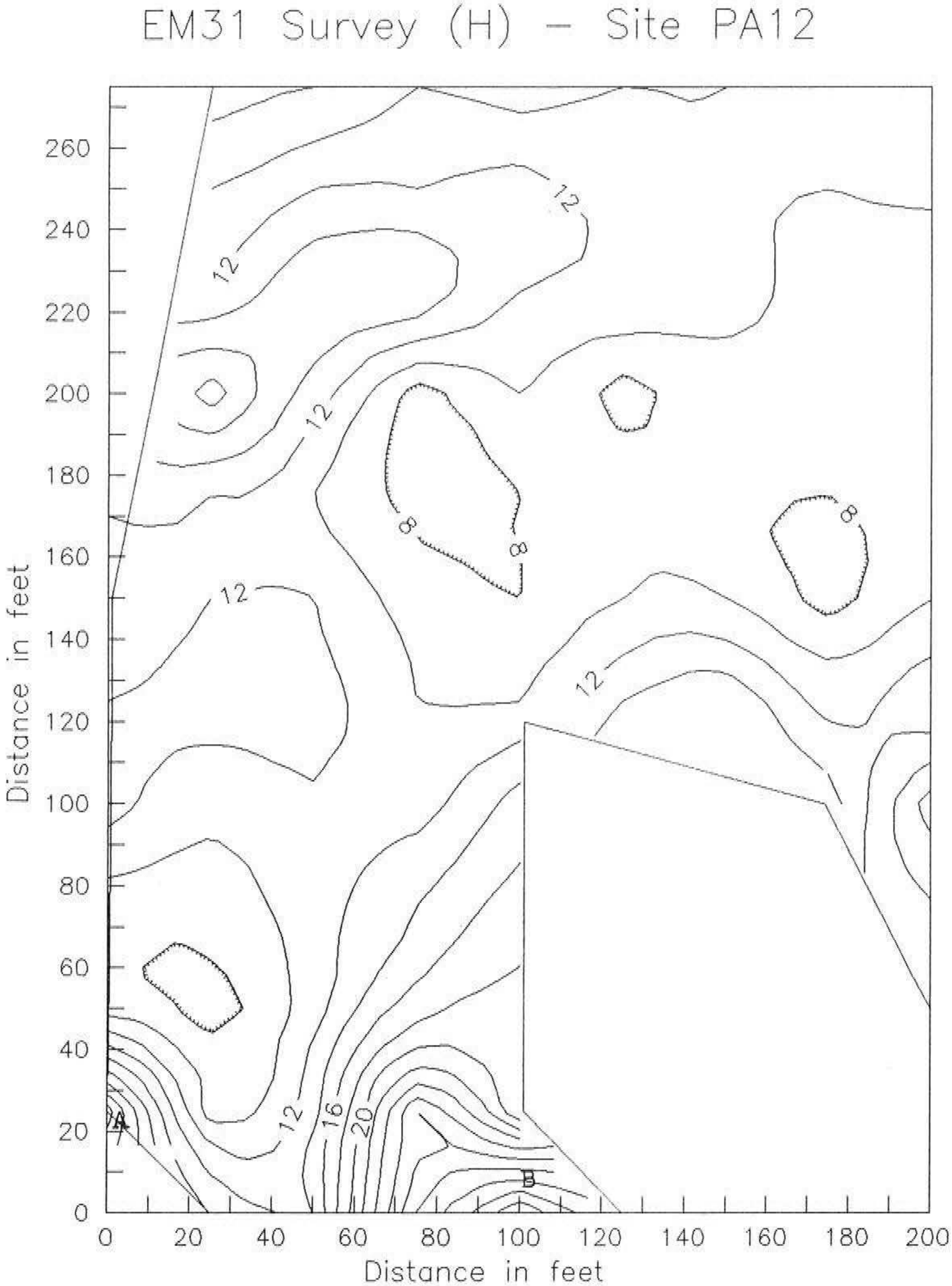
EM31 Survey (H) - Site 11



Relative Elevation — Site 12




EM31 Survey (V) - Site 12
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
12
16
20


EM31 Survey (H) - Site PA12
Distance in feet
Distance in feet
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0
20
40
60
80
100
120
140
160
180
200
12
12
12
12
12
12
16
20
8
8
8
A
B