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7. Abstract

Geophysical surveys were conducted at three military landfill located on Hanford's Wahluke (North) Slope in support of an expedited response action. The purpose of the geophysical investigation was to characterize waste disposal practices and to locate areas for further environmental investigation.

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1.0 INTRODUCTION

Geophysical surveys were conducted at three sites on Hanford's Wahluke (North) Slope, Washington, from July 27 through August 4, 1992. The approximate locations of the three sites (PSN-04, H-06-H, and H-83-L) are shown in Figure 1. The purpose of the geophysical investigation was to characterize waste disposal practices at the three sites and to locate areas for further environmental investigation. To meet these objectives, magnetic and electromagnetic induction surveys were conducted in four small areas totaling 5.3 acres at site PSN-04, two areas totaling 20.9 acres at site H-06-H, and one 2.1-acre area at site H-83-L.

2.0 FIELD PROCEDURES

This section describes the field procedures used during the magnetic and electromagnetic induction surveys. Field procedures common to the geophysical surveys conducted at all of the sites are discussed first, followed by site-specific field procedures.

Magnetic equipment used during this investigation consisted of an EDA Omni Plus (a trademark of Scintrex) magnetic gradiometer (magnetometer) and an EDA Omni IV base station magnetometer (a trademark of Scintrex). Electromagnetic induction equipment consisted of a Geonics EM-31DL terrain conductivity meter (EM-31) (a trademark of Geonics Limited) coupled to an Omni digital data logger (a trademark of Omnidata International Incorporated). A description of the equipment and a theoretical discussion of the geophysical methods are presented in Appendix A.

The geophysical survey areas at each site were determined in the field based on an examination of surface characteristics such as stressed vegetation, subsidence, and surface and partially buried debris. The corners of each area were staked with 3-ft survey lath and labeled so that they could be surveyed relative to the local coordinate system.

In each survey area, a base grid was marked with surveyor's chalk/paint to provide spatial control for the geophysical survey. The base grid dimensions were equal to the selected geophysical line spacing: 10 ft for small survey areas, and 30 ft for large survey areas. Any large pieces of metallic surface debris were typically removed from the sites prior to conducting the geophysical surveys to limit the effect of such objects on the data.

Conductivity and in-phase component field strength measurements were made with the EM-31 at 5-ft intervals along perpendicular survey grid lines. EM-31 data were stored in the digital data logger and were downloaded to a laptop computer after completion of each survey or periodically throughout the day.

The intensity of the earth's total magnetic field and the vertical magnetic gradient were measured at 10-ft intervals along the grid lines closest to north-south (N-S). Magnetic data were stored in the internal

memory of the instrument. A magnetic base station was established at each site in an area free of surface metallic debris and other cultural features. A second magnetometer was placed at the base station and programmed to automatically record the intensity of the earth's magnetic field at 20-sec intervals throughout the day, thereby providing a record of the diurnal variation (drift) of the earth's total magnetic field.

Data stored in the base station and field magnetometers were downloaded to a laptop computer periodically throughout the day or after completion of the survey at a specific site. The field and base station magnetometers were connected prior to downloading, and corrections were automatically made for diurnal variation of the earth's magnetic field.

Detailed field mapping of the distribution of surface metallic objects and other surface features was conducted at each site to help differentiate magnetic and EM-31 anomalies caused by surface sources from those caused by subsurface sources. Preliminary contour maps of the geophysical data were generated daily, and anomalies were subsequently field checked to verify their source. During the field verification phase, magnetic and EM-31 anomalies were also carefully delineated and their boundaries were staked.

2.1 GEOPHYSICAL SURVEY, SITE PSN-04

Magnetic and EM-31 surveys were conducted in four small areas at site PSN-04. These areas are denoted as sites PSN-04 (North), PSN-04 (South), PSN-04 (East), and PSN-04 (West) and had dimensions of 300 ft x 300 ft, 300 ft x 200 ft, 200 ft x 200 ft, and 200 ft x 200 ft. The corners of each area were staked with 3-ft survey lath to permit the area locations to be surveyed at a later date. A 10-ft x 10-ft base grid within each site was marked with surveyor's paint to provide spatial control for the geophysical survey.

Metallic surface debris was removed from each site prior to conducting the geophysical surveys and a detailed site map was generated showing surface features such as surface debris remaining on the site, topographic depressions, mounds of soil, and areas of stressed vegetation. Site maps for PSN-04 (North), PSN-04 (South), PSN-04 (East), and PSN-04 (West) are presented in Figures 2 through 5 and include interpretations of the geophysical data.

Magnetic data were acquired at 10-ft intervals along N-S lines spaced 10 ft apart at sites PSN-04 (North) and PSN-04 (South) and along southeast-northwest (SE-NW) lines spaced 10 ft apart at sites PSN-04 (East) and PSN-04 (West). EM-31 data were acquired at 5-ft intervals along N-S and east-west (E-W) lines spaced 10 ft apart at sites PSN-04 (North) and PSN-04 (South) and along SE-NW and northeast-southwest (NE-SW) lines spaced 10 ft apart at sites PSN-04 (East) and PSN-04 (West).

2.2 GEOPHYSICAL SURVEY, SITE H-06-H

Magnetic and EM-31 surveys were conducted in two areas at site H-06-H. These areas are denoted as sites H-06-H (East) and H-06-H (West) and had dimensions of 300 ft x 300 ft and 1,950 ft x 420 ft, respectively. The corners of each area were staked with 3-ft survey lath to permit the area locations to be surveyed at a later date. To provide spatial control for the

geophysical surveys, surveyor's paint was used to mark a 10-ft x 10-ft base grid at site H-06-H (East) and a 30-ft x 30-ft base grid at site H-06-H (West).

Most metallic surface debris was removed from site H-06-H (East) prior to conducting the geophysical survey. Site maps of H-06-H (East) and (West) showing surface features such as surface debris remaining on the site, topographic depressions, mounds of soil, and areas of stressed vegetation are presented in Figures 6 and 7, respectively. The extreme size of site H-06-H (West) precluded the removal of surface debris.

At H-06-H (East), magnetic data were acquired at 10-ft intervals along approximately N-S lines spaced 10 ft apart and EM-31 data were acquired at 5-ft intervals along approximately N-S and E-W lines spaced 10 ft apart. At H-06-H (West), magnetic data were acquired at 10-ft intervals along approximately N-S lines spaced 30 ft apart and EM-31 data were acquired at 5-ft intervals along approximately N-S and E-W lines spaced 30 ft apart.

2.3 GEOPHYSICAL SURVEY, SITE H-83-L

The geophysical survey at site H-83-L was conducted in a 300-ft x 300-ft area. The corners of the survey area were staked with 3-ft survey lath to allow the area location to be surveyed at a later date. To provide spatial control for the geophysical survey, a 10-ft x 10-ft base grid was marked with surveyor's paint. Most metallic surface debris was removed from the site prior to conducting the geophysical survey. A site map showing surface features such as surface debris remaining on the site, topographic depressions, mounds of soil, and areas of stressed vegetation is presented in Figure 8.

Magnetic data were acquired at 10-ft intervals along SW-NE lines spaced 10 ft apart and EM-31 data were acquired at 5-ft intervals along SW-NE and SE-NW lines spaced 10 ft apart. A base station magnetometer was not available during this survey; therefore, the earth's total magnetic field at the base station was measured periodically with the field magnetometer and recorded in a field notebook along with the time of measurement. In-house software was later used to correct the survey data for drift (dedrift).

3.0 DATA PROCESSING AND INTERPRETATION

Color-enhanced contour maps of magnetic and EM-31 data were generated using the GEOSOFT geophysical mapping system. These maps were color-enhanced to facilitate recognition and interpretation of subtle anomalies. Prior to generating the contour maps, a number of preprocessing steps were necessary. These steps were facilitated through the use of various data processing forms and included correction of position errors in magnetic and EM-31 data files, dedrifting of magnetic data using in-house software if not done automatically in the field, and generation of data files containing line number, station number, and field reading for each data set.

3.1 GEOPHYSICAL SURVEY, SITE PSN-04

This section presents interpretations of magnetic and EM-31 data collected at the four PSN-04 sites. As previously mentioned, preliminary contour maps of the geophysical data were generated in the field and all pertinent anomalies were field checked to verify or determine their source. During the field verification phase, the anomalies were delineated using the EM-31, marked in the field with stakes, and labeled.

3.1.1 Site PSN-04 (North)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site PSN-04 (North) are presented in Figure 9. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along S-N and E-W survey lines are presented in Figures 10 and 11, respectively. Interpretation of the geophysical data for site PSN-04 (North) is summarized in Figure 2.

No anomalies indicative of significant amounts of buried metallic debris are evident on the contour maps of total magnetic field and vertical magnetic gradient (Figure 9). Two anomalies that appear to be associated with subsurface geology are evident on the contour maps of conductivity (Figures 10 and 11). A decrease in conductivity occurs over a soil mound (topographic high) and an increase in conductivity occurs in a topographic depression, indicating that a geologic unit with higher conductivity than the overlying layer occurs in the shallow subsurface. Another anomaly, labeled A-1 on the contour maps of EM-31 in-phase component (Figures 10 and 11), is indicative of a small metallic object buried at shallow depth.

3.1.2 Site PSN-04 (South)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site PSN-04 (South) are presented in Figure 12. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along S-N and E-W survey lines are presented in Figures 13 and 14, respectively. Interpretation of the geophysical data for site PSN-04 (South) is summarized in Figure 3.

Several anomalies are evident on the contour maps of magnetic and EM-31 data (Figures 12 through 14). First, an anomaly caused by a reinforced concrete pad located immediately south of the survey area (Figure 3) is apparent on the contour maps of both magnetic and EM-31 data and is appropriately labeled. Second, a northeast-trending buried pipe appears as an anomaly on contour maps of both magnetic and EM-31 conductivity data. This pipe is not apparent on contour maps of EM-31 in-phase component data. The pipe was accurately traced and marked at the site using an electromagnetic utility locator. Finally, an anomaly indicative of a buried metallic object, possibly a vault, is evident at the central portion of the pipe in the contour maps of both magnetic and EM-31 conductivity and in-phase component data and is labeled anomaly A-1.

3.1.3 Site PSN-04 (East)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site PSN-04 (East) are presented in Figure 15. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along SE-NW and NE-SW survey lines are presented in Figures 16 and 17, respectively. Interpretation of the geophysical data for site PSN-04 (East) is summarized in Figure 4.

One anomaly indicative of buried metallic debris is apparent on the contour maps of magnetic and EM-31 data (Figures 15 through 17). This anomaly, labeled A-1, appears to be caused by a trench containing metallic debris. Partially buried barbed wire and wood debris on the surface (Figure 4) indicate that the top of the debris is immediately below ground surface. With the exception of a small anomaly on the southern boundary of the site caused by a large roll of barbed wire lying on the surface, no other anomalies are apparent on the contour maps of magnetic data. In addition, no other EM-31 in-phase component anomalies are apparent on the contour maps (Figures 16 and 17). EM-31 conductivity data are highly variable across the site, most likely due to a combination of changing subsurface geology and elevation changes. In the eastern portion of the site, conductivity decreases over topographic highs and increases over depressions as a result of changes in relative distance to a fine-grained subsurface geologic layer. An increase in conductivity in the western portion of the site is associated with an increase in slope and probably reflects changing geologic materials.

3.1.4 Site PSN-04 (West)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site PSN-04 (West) are presented in Figure 18. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along SE-NW and NE-SW survey lines are presented in Figures 19 and 20, respectively. Interpretation of the geophysical data for site PSN-04 (South) is summarized in Figure 5.

Three anomalies that are probably caused by trenches containing metallic debris are evident on the contour maps of magnetic data and are labeled as anomalies A-1 through A-3 (Figure 18). Anomalies A-1 and A-2 are associated with topographic depressions exhibiting stressed vegetation (Figure 5). Soil stockpiles are located at the northeastern end of these features, indicating that the depressions may be the result of past excavation. Only very slight positive anomalies are evident over these trenches on the EM-31 in-phase component contour maps (Figures 19 and 20). EM-31 conductivity data are highly variable within the survey area, most likely due to changing subsurface geology. A linear zone of higher conductivity correlates with anomaly A-1 on the magnetic and in-phase component contour maps, and a linear zone of lower apparent conductivity correlates with anomaly A-3. The trench associated with anomaly A-2 on the contour maps of magnetic and EM-31 in-phase component data is not evident on the contour maps of conductivity. The minimal EM-31 response to the three trenches suggests that the top of metallic debris may be at depths of more than 3 ft in the trenches. Nonmetallic debris and minor amounts of metallic debris may be present at shallower depths. Although no significant magnetic or EM-31 anomalies are associated with an area of stressed vegetation observed between anomalies A-2 and A-3 (Figure 5), the

stressed vegetation may be due to disposal of nonmetallic materials near the surface or in a trench.

3.2 GEOPHYSICAL SURVEY, SITE H-06-H

This section discusses the interpretation of magnetic and EM-31 data collected at the two H-06-H sites. As previously discussed, preliminary contour maps of the geophysical data were generated in the field and all pertinent anomalies were field checked to verify or define their source. During the field verification phase, the anomalies were delineated using the EM-31, marked in the field with stakes, and labeled.

3.2.1 Site H-06-H (East)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site H-06-H (East) are presented in Figure 21. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along S-N and E-W survey lines are presented in Figures 22 and 23, respectively. Interpretation of the geophysical data for site H-06-H (East) is summarized in Figure 6.

A total of 15 anomalies indicative of buried metallic debris are evident on the contour maps of magnetic and/or EM-31 data (Figures 21 through 23). Anomalies A-1, A-2, A-3, A-4, A-5, A-7, A-8, A-10, and A-14 are caused by pits containing near-surface metallic debris. These pits were field checked with the EM-31 and staked after preliminary data processing; they range in size from about 5 ft x 5 ft to about 15 ft x 30 ft (Figure 6). Pits A-1 and A-2 are evident as relatively high-amplitude magnetic anomalies but only low-amplitude EM-31 anomalies. The low-amplitude EM-31 response over these pits may indicate metallic debris buried at depths of 3 ft or more or may be simply a function of the location of the survey lines relative to the buried metallic debris. Pits A-3, A-7, and A-8 are evident as high-amplitude magnetic and EM-31 anomalies and, therefore, most likely contain relatively near-surface metallic debris. Pits A-4, A-5, A-10, and A-14 are evident as weak magnetic and EM-31 anomalies. These anomalies are relatively small and may be indicative of only minor amounts of metallic debris or the amplitudes of these anomalies may be a function of the measurement station locations relative to the pits rather than of the pit contents.

Anomaly A-9, which is only clearly visible on the contour maps of EM-31 data collected along E-W lines, is caused by a number of partially buried liquid-bearing paint cans on the side of a small depressed area. Anomalies A-13 and A-15 are very small and appear to be caused by a single buried metallic object or possibly a very small pit (less than 5 ft x 5 ft) containing metallic debris. Anomaly A-13 is apparent on contour maps of both magnetic and EM-31 data, and A-15 is visible on the contour maps of magnetic data. Anomalies A-6, A-11, and A-12 have high amplitudes on contour maps of both magnetic and EM-31 data and are caused by large trenches containing buried metallic and nonmetallic debris. These trenches were accurately delineated with the EM-31 after preliminary field data processing had been completed and are shown in Figure 6. Trenches A-6 and A-12, both of which probably contain significant amounts of near-surface metallic debris, are about 15 ft x 60 ft and 15 ft x 40 ft, respectively. Trench A-11 is the most

predominant anomalous zone on the site. Delineating this feature with the EM-31 indicated that the trench extends approximately 175 ft north of the site and may have a total length of about 325 ft. Significant portions of the trench may contain predominantly nonmetallic debris.

Reevaluation of the geophysical data indicated that the trench may extend south to include anomalies A-10 and A-7, as indicated in Figure 6.

3.2.2 Site H-06-H (West)

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site H-06-H (West) are presented in Figures 24 and 25, respectively. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along S-N lines are presented in Figures 26 and 27, respectively. Color-enhanced contour maps of conductivity and in-phase component data collected along E-W survey lines are presented in Figures 28 and 29, respectively. Interpretation of the geophysical data for site H-06-H (West) is summarized in Figure 7.

A total of 22 anomalies possibly caused by buried metallic debris were identified during the geophysical investigation at this site. Although almost all of the anomalies are apparent on the contour maps of magnetic data (Figures 24 and 25), many are not evident on the contour maps of EM-31 data (Figures 26 through 29); however, most of the anomaly sources were located and delineated with the EM-31 during the field verification phase. The sources of many of the anomalies not evident on the EM-31 contour maps were found between survey lines. Many small pits or buried metallic objects on site may not have been located during this survey because magnetic and EM-31 data were acquired along lines spaced 30 ft apart; however, all large pits and trenches are believed to have been successfully located. Because of the relatively coarse line spacing used during this survey, many of the conclusions made as to the characteristics of the anomalies are derived from notes taken during the field verification of anomalies instead of from the characteristics of the anomalies observed on the contour maps.

To facilitate discussion, the anomalies are grouped into several categories as follows: those caused by trenches (longest dimension exceeding approximately 50 ft), those caused by large pits (dimensions exceeding about 20 ft x 20 ft), those caused by small pits (dimensions ranging from about 5 ft x 5 ft to 20 ft x 20 ft), and those caused by small buried metallic objects.

Anomalies A-2, A-5, A-7, A-16, and A-19 are caused by trenches containing metallic and nonmetallic debris. Trench A-2 generated only two small magnetic and EM-31 anomalies. However, stressed vegetation, a slight topographic depression/subsidence, and scattered glass fragments and bottles on the surface indicate that the trench encompasses an area larger than suggested by the anomalies. The trench is thought to contain predominantly nonmetallic debris, and the boundary probably coincides with the stressed vegetation and topographic depression. Trench A-5 is evident as high-amplitude magnetic and EM-31 anomalies and probably contains significant amounts of near-surface metallic debris. Metallic debris is exposed at the surface in some portions of this trench. Field verification of anomaly A-7 indicated that some areas of the trench likely contain high concentrations of metallic debris and other areas contain predominantly nonmetallic refuse.

Trench A-16 is apparent on contour maps of both magnetic and EM-31 data, indicating that it probably contains significant amounts of near-surface metallic debris. Trench A-19 generated a high-amplitude magnetic anomaly but only weak EM-31 anomalies. The trench was difficult to delineate with the EM-31; as a result, stressed vegetation and slight subsidence were used as guides in staking the trench. The metallic debris causing the magnetic anomalies may be at depths exceeding 4 ft, and the trench may contain significant amounts of nonmetallic debris.

Anomalies A-1, A-4, A-12, A-13, and A-17 are caused by large pits containing buried metallic debris. Field verification of these anomalies indicated the following: (1) minor amounts of metallic debris are exposed at the surface in pits A-1 and A-4, (2) pits A-12 and A-13 appear to contain only minor amounts of metallic debris, but may contain significant amounts of nonmetallic debris, and (3) pit A-17 contains near-surface metallic debris.

Anomalies A-6, A-8, A-10, A-11, A-15, and A-20 are caused by small pits containing metallic debris (Figure 7). Metallic debris is exposed at the surface in pits A-6 and A-8.

Field checking of magnetic and/or EM-31 anomalies A-3, A-9, A-14, A-18, A-21, and A-22 with the EM-31 indicated that they are most likely caused by small buried metallic objects. Many more small features like these may be present at the site but may not have been located because of the course line spacing used during this investigation.

3.3 Geophysical Survey, Site H-83-L

Color-enhanced contour maps of total magnetic field and vertical magnetic gradient data for site H-83-L are presented in Figure 30. Color-enhanced contour maps of conductivity and in-phase component data collected with the EM-31 along SE-NW and SW-NE survey lines are presented in Figures 31 and 32, respectively. Interpretation of the geophysical data for site H-83-L is summarized in Figure 8.

Seven anomalies labeled A-1 through A-7 are evident on contour maps of magnetic and/or EM-31 data. In general, all magnetic and EM-31 anomalies were field checked, delineated with the EM-31, and marked with stakes and flagging.

A-1 is evidenced by strong magnetic but relatively weak EM-31 anomalies (Figures 30 through 32). This anomaly coincides with two small depressions (Figure 8) and is probably caused by a trench containing metallic debris. A-2 and A-3 are indicated by strong magnetic and EM-31 anomalies. Anomaly A-2 is associated with a topographic depression and is caused by a trench containing metallic debris. No apparent surface disturbances are associated with anomaly A-3, which also appears to be caused by a trench containing metallic debris. Anomaly A-4, which is apparent only on the contour maps of EM-31 conductivity (Figures 31 and 32), is associated with a slight topographic depression. When passing through the depression, the EM-31 is closer to a subsurface geologic layer having higher conductivity than the overlying layer, resulting in a slight increase in conductivity. This anomaly was staked in the field because a large amount of surface metallic objects such as drums and metal pails were removed from the depressed area prior to conducting the geophysical survey, indicating possible contamination of near-

surface soils. Anomaly A-5 is evident on contour maps of both magnetic and EM-31 data. A piece of buried steel cable is exposed at the surface, and the anomaly likely results from a small pit containing steel cable and possibly other debris. Anomaly A-6, which is evident on contour maps of both magnetic and EM-31 data, was caused by approximately 20 1-quart containers of oil discovered under a pile of wood. Most of these containers contain liquid, and no evidence of subsurface disposal was found at this location. Anomaly A-7 is a low-amplitude anomaly that occurs only on the contour map of in-phase component for SE-NW survey lines. This anomaly is likely caused by a small object buried in the shallow surface. This anomaly was not field checked or staked.

4.0 CONCLUSIONS

Geophysical surveys using magnetic and electromagnetic methods were conducted at sites PSN-04, H-06-H, and H-83-L to characterize possible refuse disposal areas. The geophysical surveys were not intended to delineate the entire disposal areas at each site.

At site PSN-04, geophysical surveys were conducted in four small areas denoted as sites PSN-04 (North), PSN-04 (South), PSN-04 (East), and PSN-04 (West). Interpretations of the geophysical data for these sites are presented in Figures 2 through 5, respectively. Sites PSN-04 (North) and PSN-04 (South) are very near the location of the former compound and are not disposal areas. The geophysical surveys conducted over sites PSN-04 (East) and PSN-04 (West) successfully characterized portions of the disposal area used by the former compound.

Geophysical surveys were conducted in two areas at site H-06-H. The results of the geophysical surveys at sites H-06-H (East) and H-06-H (West) are summarized in Figures 6 and 7, respectively. The magnetic and EM-31 surveys successfully located numerous pits and trenches containing buried metallic debris in each of these areas.

Magnetic and EM-31 surveys were conducted in one small area at site H-83-L and successfully located several pits and trenches containing metallic debris. Figure 8 presents an interpretation of the geophysical data for site H-83-L.

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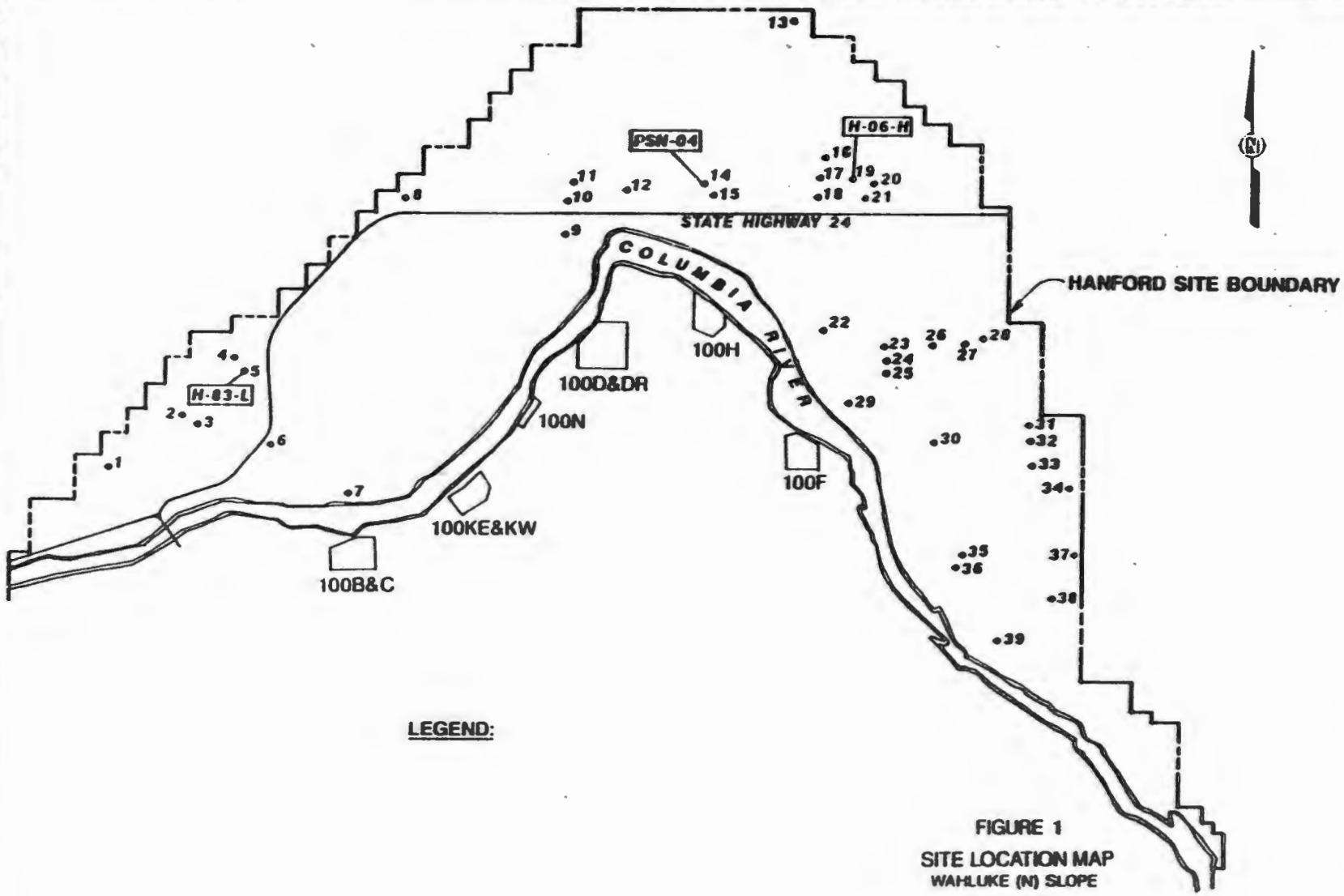
		APPROVED BY	7/10/92		



LEGEND:

FIGURE 1

SITE LOCATION MAP

WAHLUKE (N) SLOPE

PREPARED FOR

WESTINGHOUSE HANFORD CO

RICHLAND, WASHINGTON

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NOT TO SCALE

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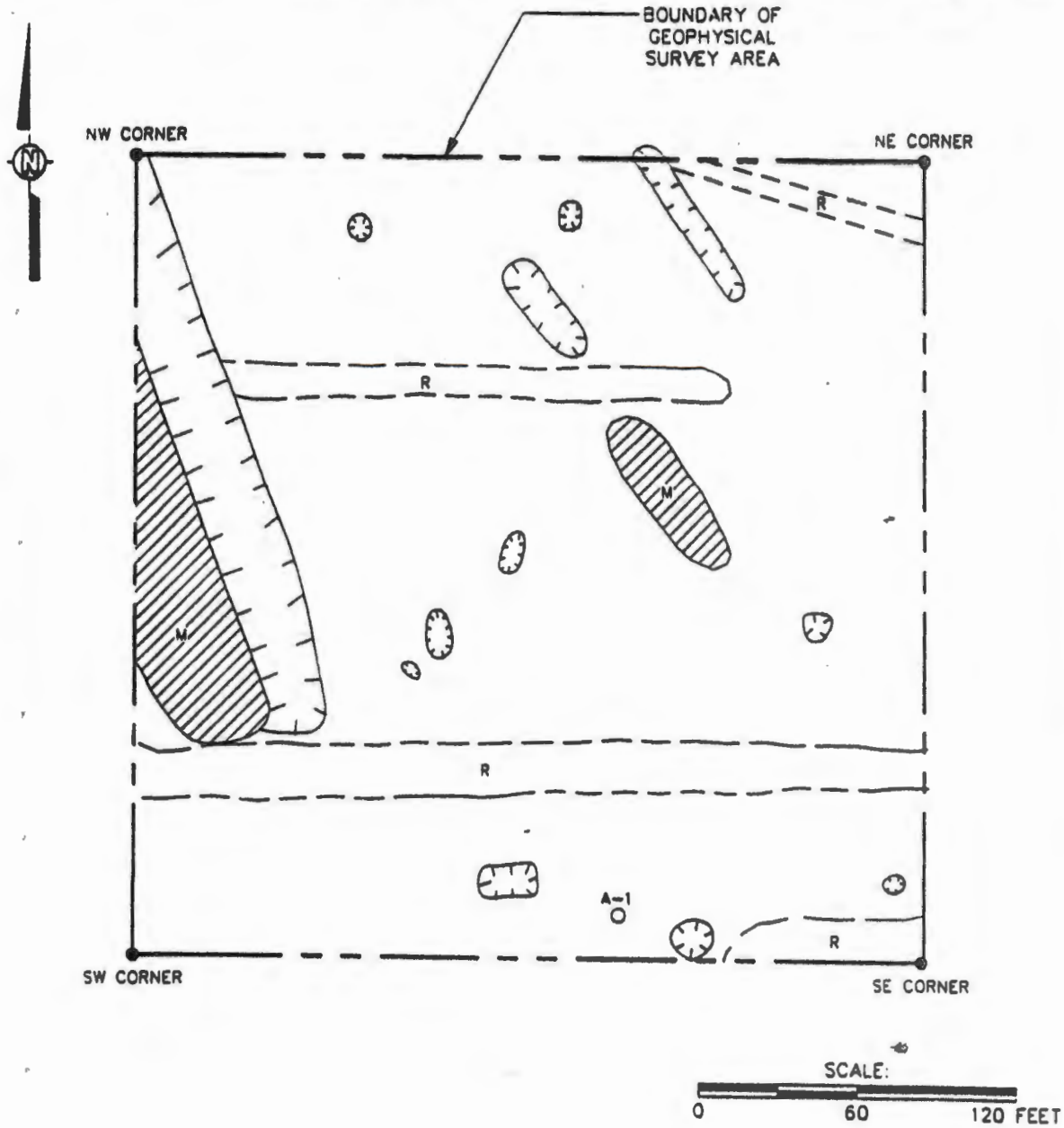

LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
(M)	MOUND/SOIL STOCKPILE
◌	SURFACE DEPRESSION
R	DIRT ROAD
A-1 ○	BURIED METALLIC OBJECT (STAKED)

FIGURE 2

SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE PSN-04 (NORTH)
WAHLUKE (N) SLOPE

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RICHLAND, WASHINGTON

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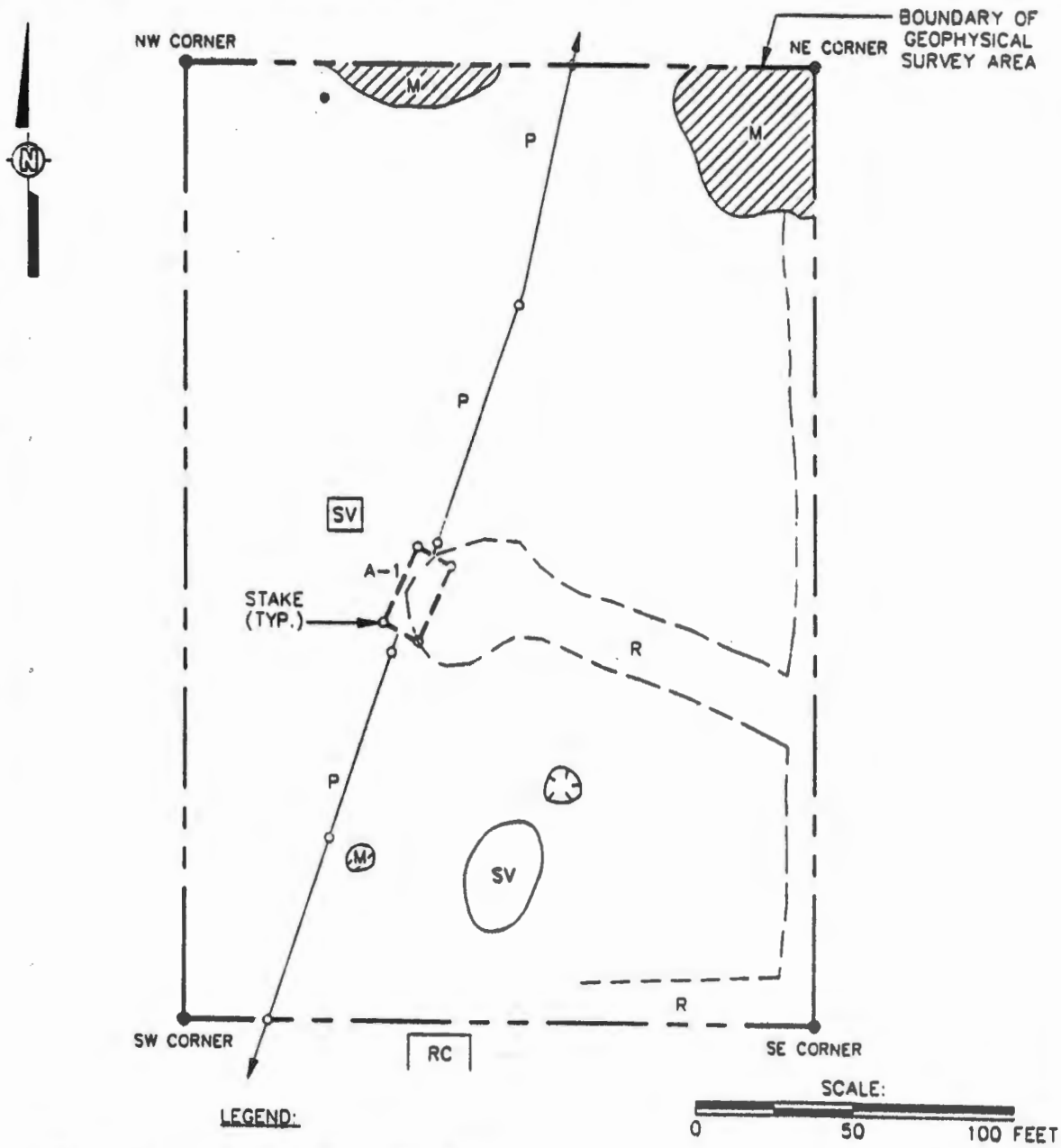
SDJF 9-9-92		199806-A2



LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
M	MOUND/SOIL STOCKPILE
	SURFACE DEPRESSION
R	DIRT ROAD
P	BURIED PIPE
RC	REINFORCED CONCRETE PAD
SV	STRESSED VEGETATION
A-1	BURIED METALLIC OBJECT (i.e., VAULT)

FIGURE 3

SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE PSN-04 (SOUTH)
WAHLUKE (N) SLOPE

PREPARED FOR

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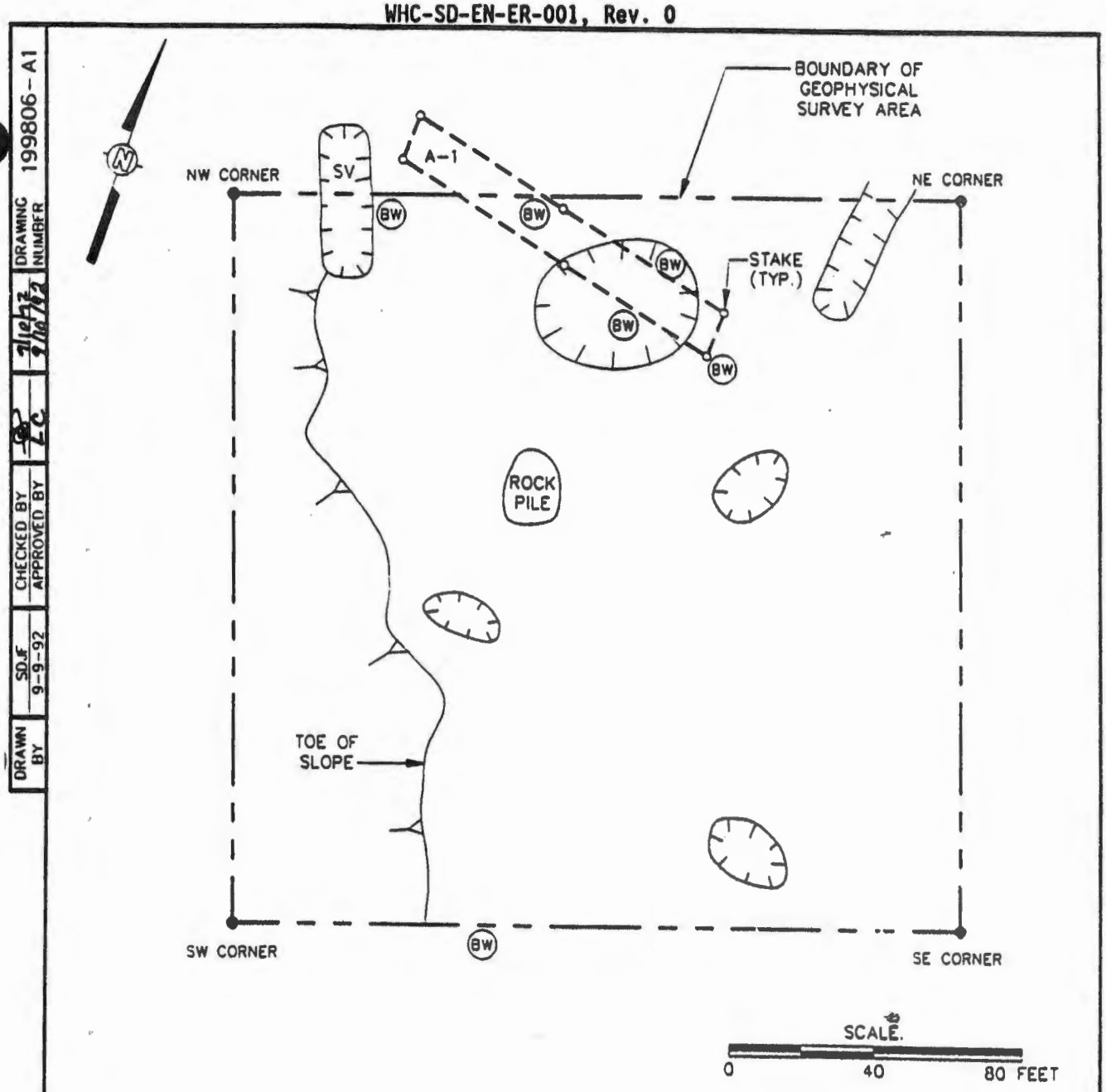
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION



LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
⊂⊃	SURFACE DEPRESSION
(BW)	BARBED WIRE
SV	STRESSED VEGETATION
[A-1]	PIT OR TRENCH CONTAINING BURIED METALLIC/NONMETALLIC DEBRIS

FIGURE 4

SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE PSN-04 (EAST)
WAHLUKE (N) SLOPE

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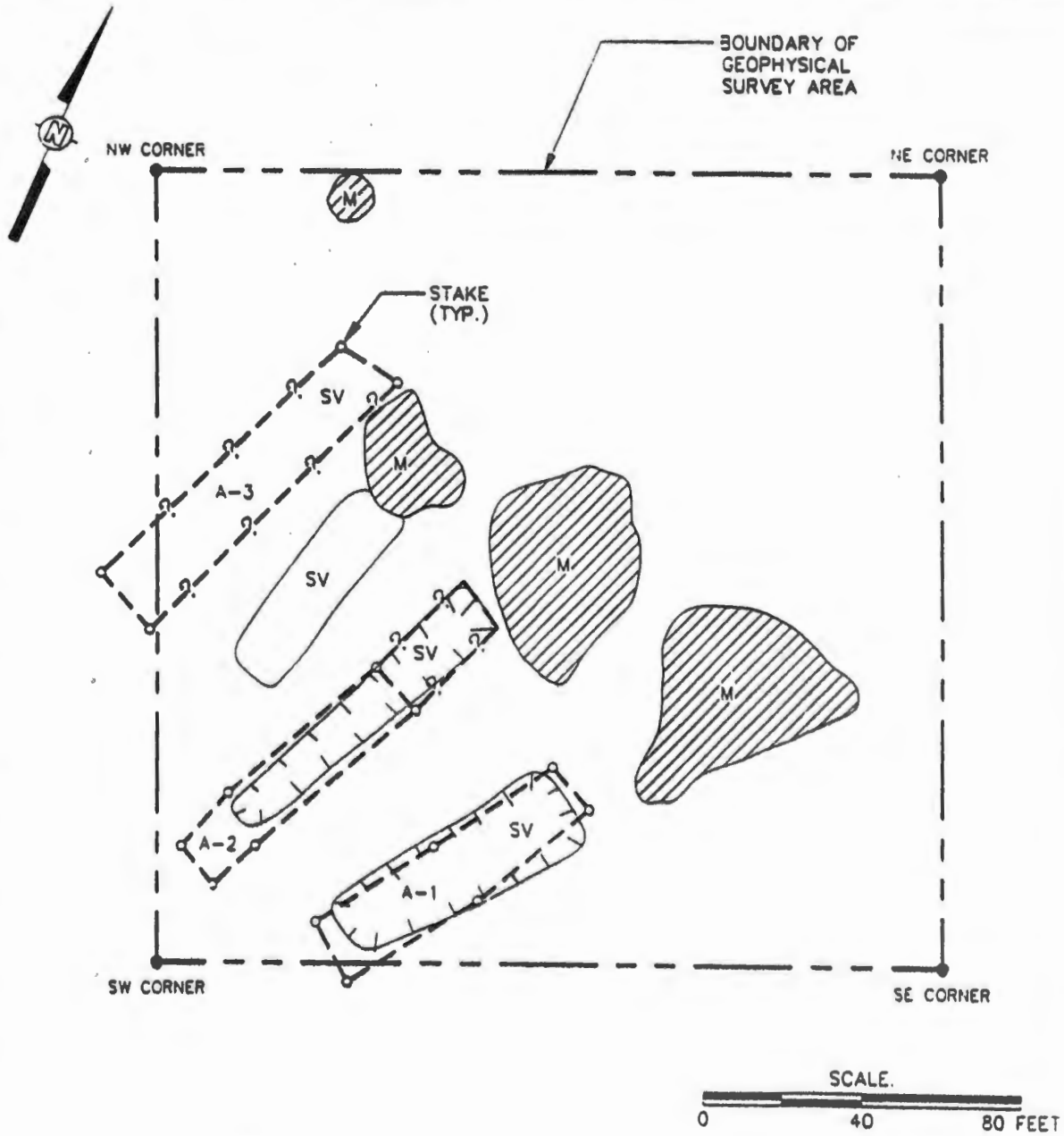
DRAWN BY	SDJF 9-9-92	CHECKED BY / APPROVED BY		9/10/92 9/10/92	DRAWING NUMBER 199806-A3



LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
(M)	MOUND/SOIL STOCKPILE
(○)	SURFACE DEPRESSION
SV	STRESSED VEGETATION
[A-1]	PIT OR TRENCH CONTAINING BURIED METALLIC/NONMETALLIC DEBRIS (QUERIED WHERE UNCERTAIN)

FIGURE 5

SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE PSN-04 (WEST)
WAHLUKE (N) SLOPE

PREPARED FOR

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RICHLAND, WASHINGTON

IT INTERNATIONAL TECHNOLOGY CORPORATION

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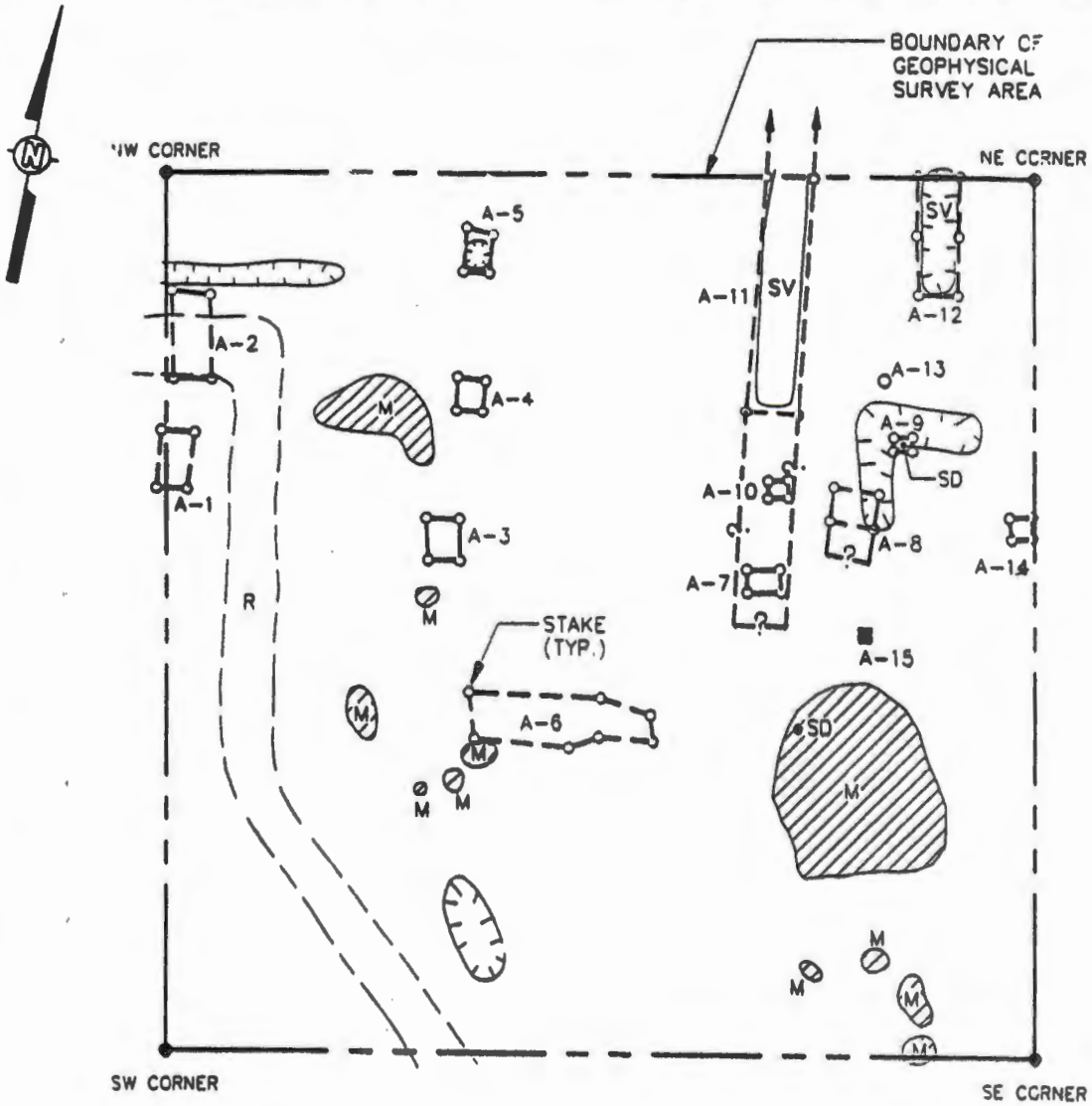
SDJF 9-9-92	LC 9/10/92	199806-A4



LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
(M)	MOUND/SOIL STOCKPILE
	SURFACE DEPRESSION
R	DIRT ROAD
SD	METALLIC SURFACE DEBRIS
SV	STRESSED VEGETATION
A-13 ○	BURIED METALLIC OBJECT (STAKED)
A-15 ■	BURIED METALLIC OBJECT (NOT STAKED)
A-1	PIT OR TRENCH CONTAINING BURIED METALLIC/NONMETALLIC DEBRIS

SCALE:
0 60 120 FEET

FIGURE 6

SITE MAP WITH GEOPHYSICAL INTERPRETATION
SITE H-06-H (EAST)
WAHLUKE (N) SLOPE

PREPARED FOR

WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

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RNER

MD

M

RC

SV

W

CD

FIGURE 7

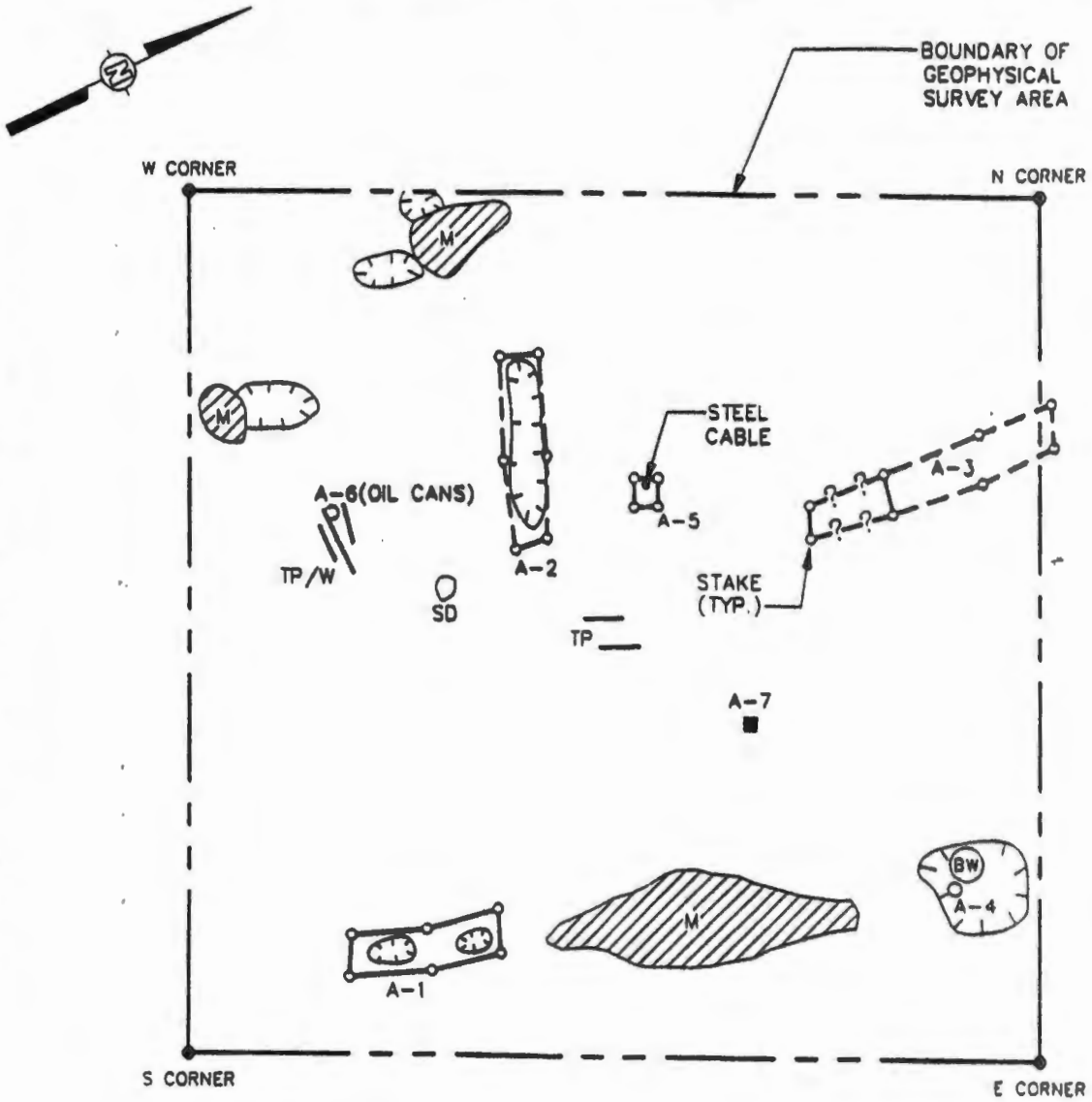
SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE H-06-H (WEST)

WAHLUKE (N) SLOPE

PREPARED FOR

WESTINGHOUSE HANFORD COMPANY
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION



LEGEND:

NW CORNER ●	STAKE MARKING CORNER OF GEOPHYSICAL SURVEY AREA
(M)	MOUND/SOIL STOCKPILE
	SURFACE DEPRESSION
(BW)	BARBED WIRE
W	WOOD DEBRIS
TP	TELEPHONE POLE
SD	METALLIC SURFACE DEBRIS
A-1 ■	BURIED METALLIC OBJECT (NOT STAKED)
A-6 ○	GEOPHYSICAL ANOMALY (STAKED)
A-1	PIT OR TRENCH CONTAINING BURIED METALLIC/ NONMETALLIC DEBRIS (QUERIED WHERE UNCERTAIN)

SCALE
0 60 120 FEET

FIGURE 8

SITE MAP WITH GEOPHYSICAL INTERPRETATION SITE H-83-L
WAHLUKE (N) SLOPE

PREPARED FOR

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RICHLAND, WASHINGTON

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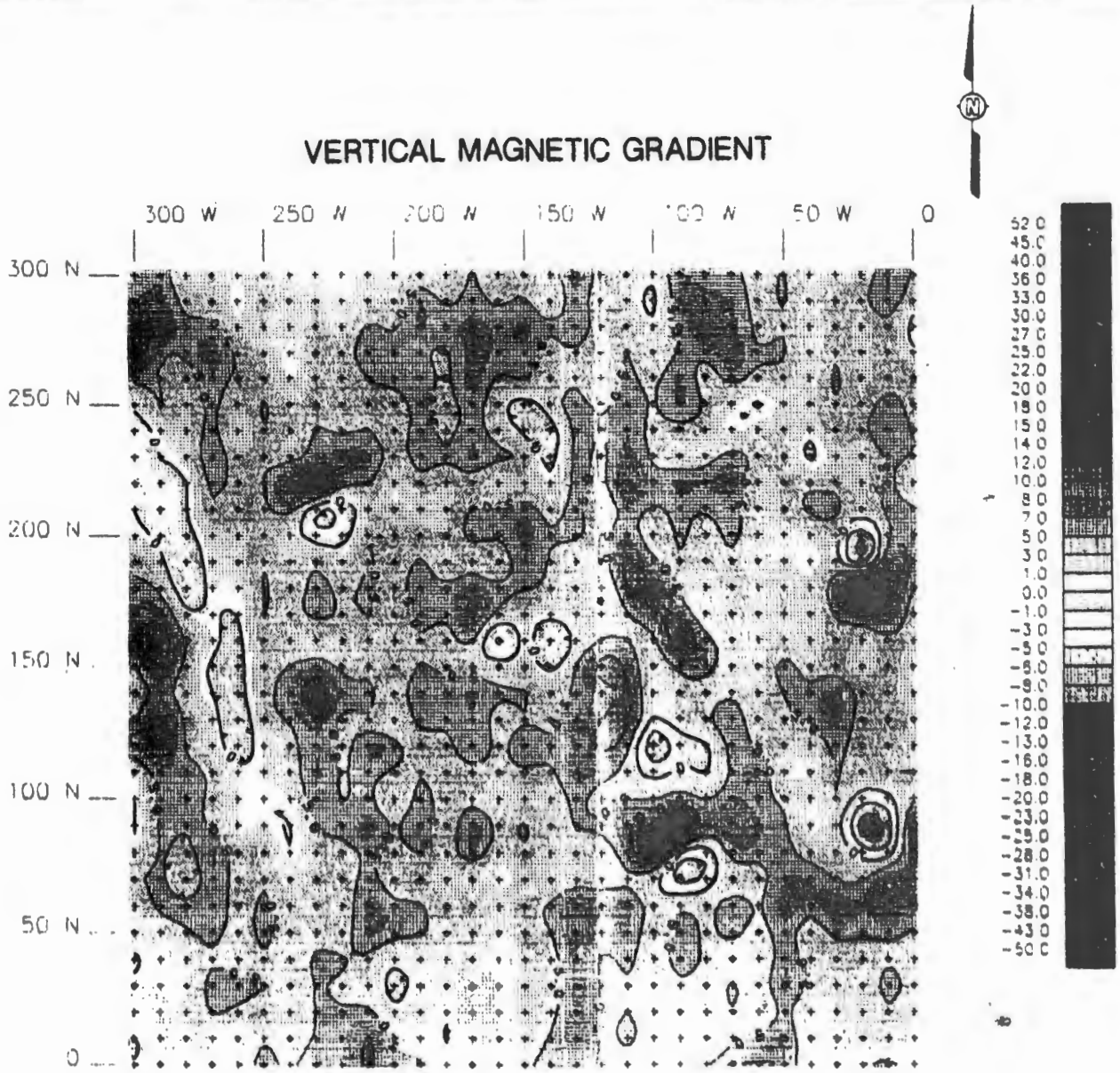
9 3 1 2 9 0 5 1 8 4 1



CONTOUR INTERVAL: 5nT/m

FIGURE 9

CONTOUR MAPS OF MAGNETIC DATA
SITE PSN-04 (NORTH)
WAHLUKE (N) SLOPE
PREPARED FOR
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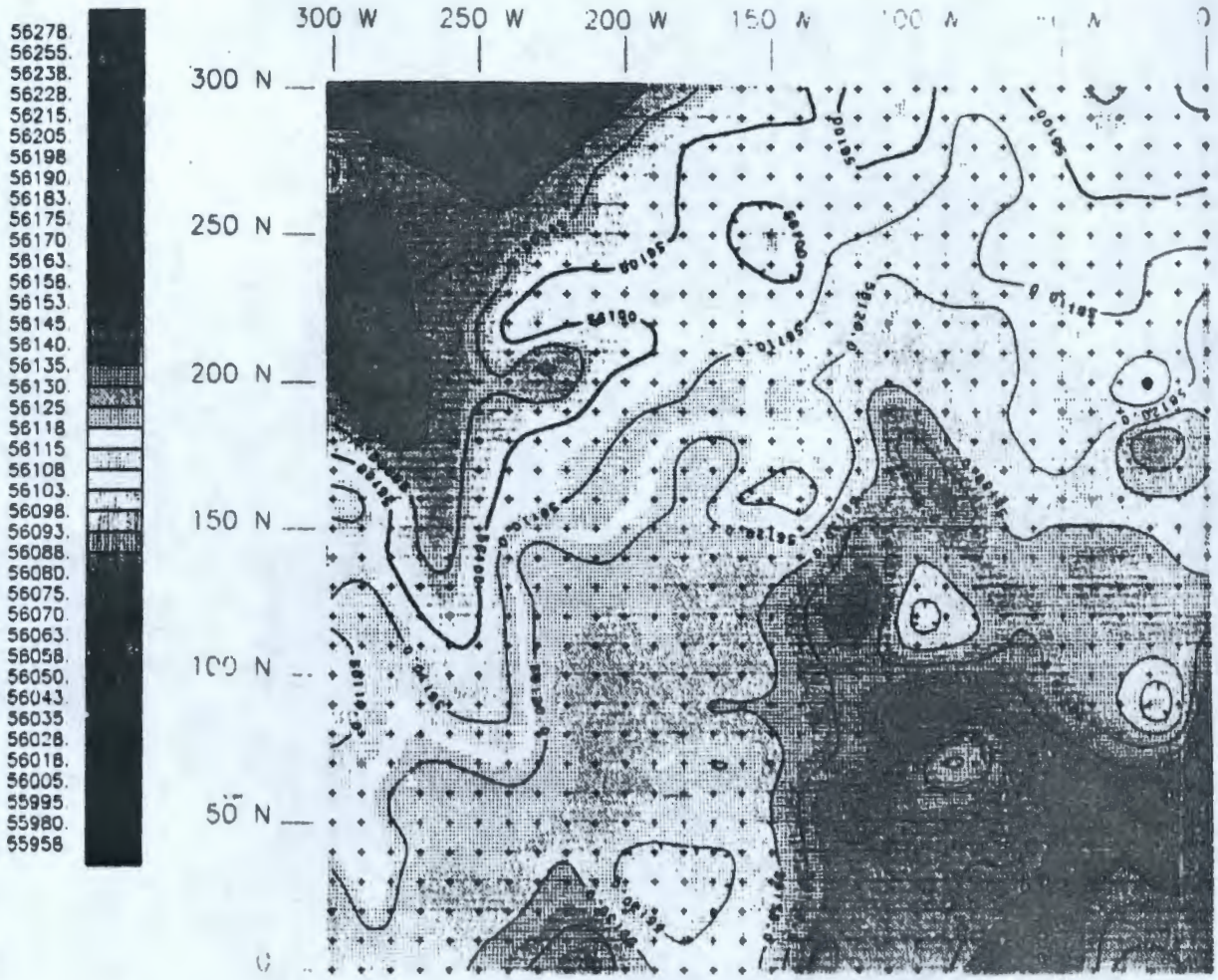
INTERNATIONAL TECHNOLOGY CORPORATION

DRAWN BY	J. WALL	CHECKED BY	JD	DRAWING NUMBER	199806-B1
	9-2-92	APPROVED BY	cjm		

TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 10 nT

LEGEND:

+ MAGNETIC SURVEY STATION

D GEOPHYSICAL ANOMALY OVER DEPRESSION

SCALE

0 30 60 120FEET

"Do Not Scale This Drawing"

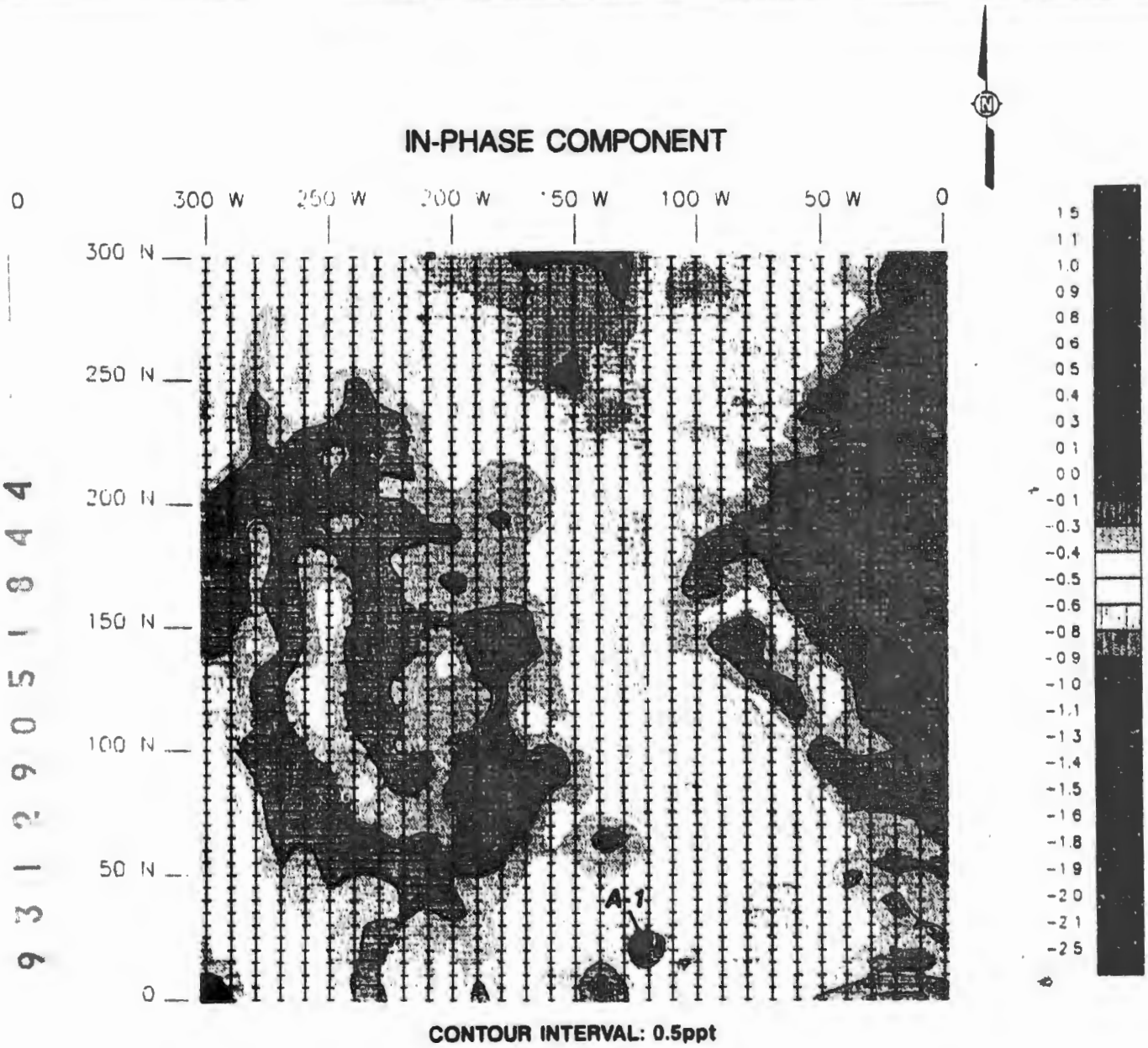


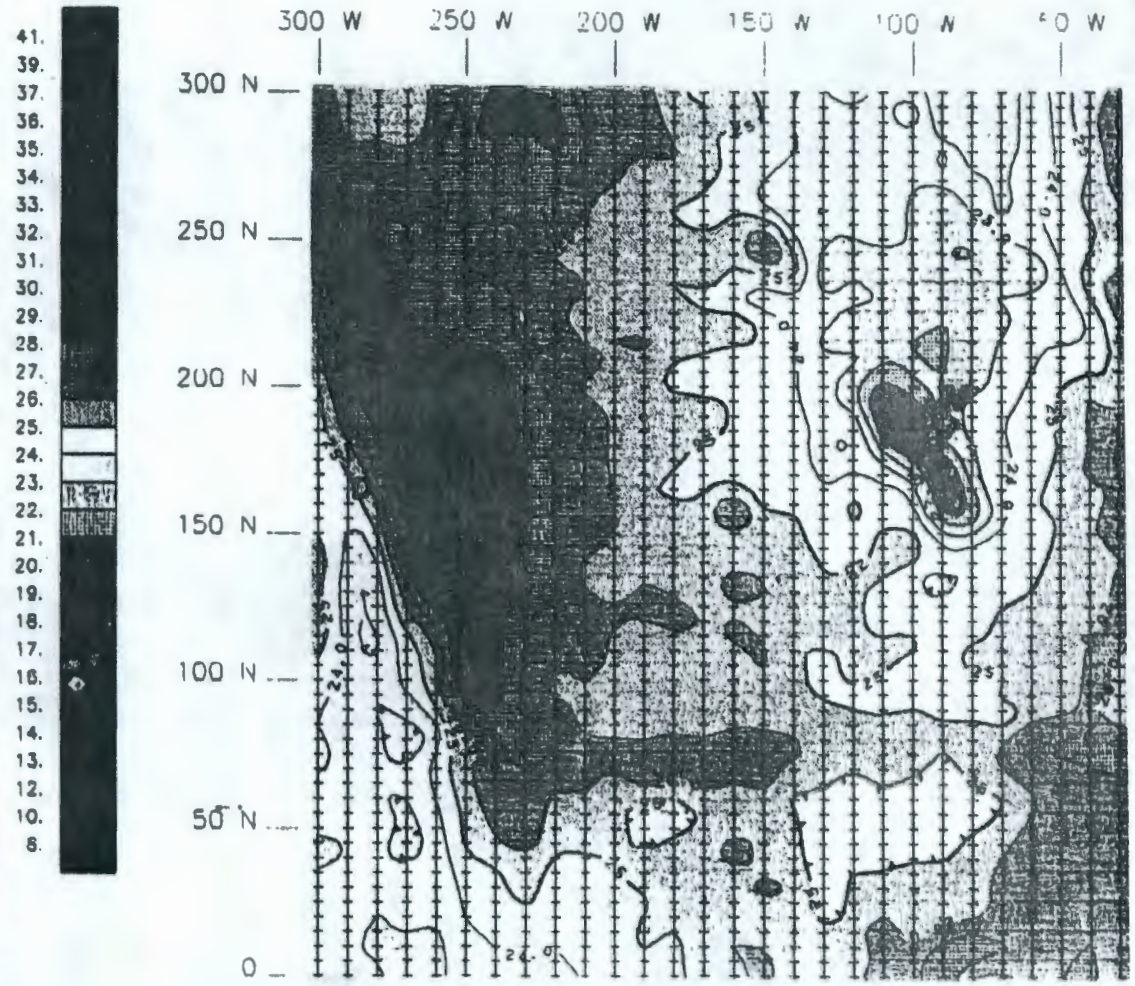
FIGURE 10

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (NORTH)
SOUTH-NORTH SURVEY LINES
WAHLUKE (N) SLOPE
PREPARED FOR
WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION

DRAWN BY	J. WALL	CHECKED BY		DRAWING NUMBER	199806-B2
	9-2-92	APPROVED BY			

CONDUCTIVITY



CONTOUR INTERVAL: 1 mS/m

LEGEND:

⊢+⊣	GEONICS EM-31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED
M	GEOPHYSICAL ANOMALY OVER SOIL I
D	GEOPHYSICAL ANOMALY OVER DEPRI

SCALE

0 30 60 120FEET

Do Not Scale This Drawing

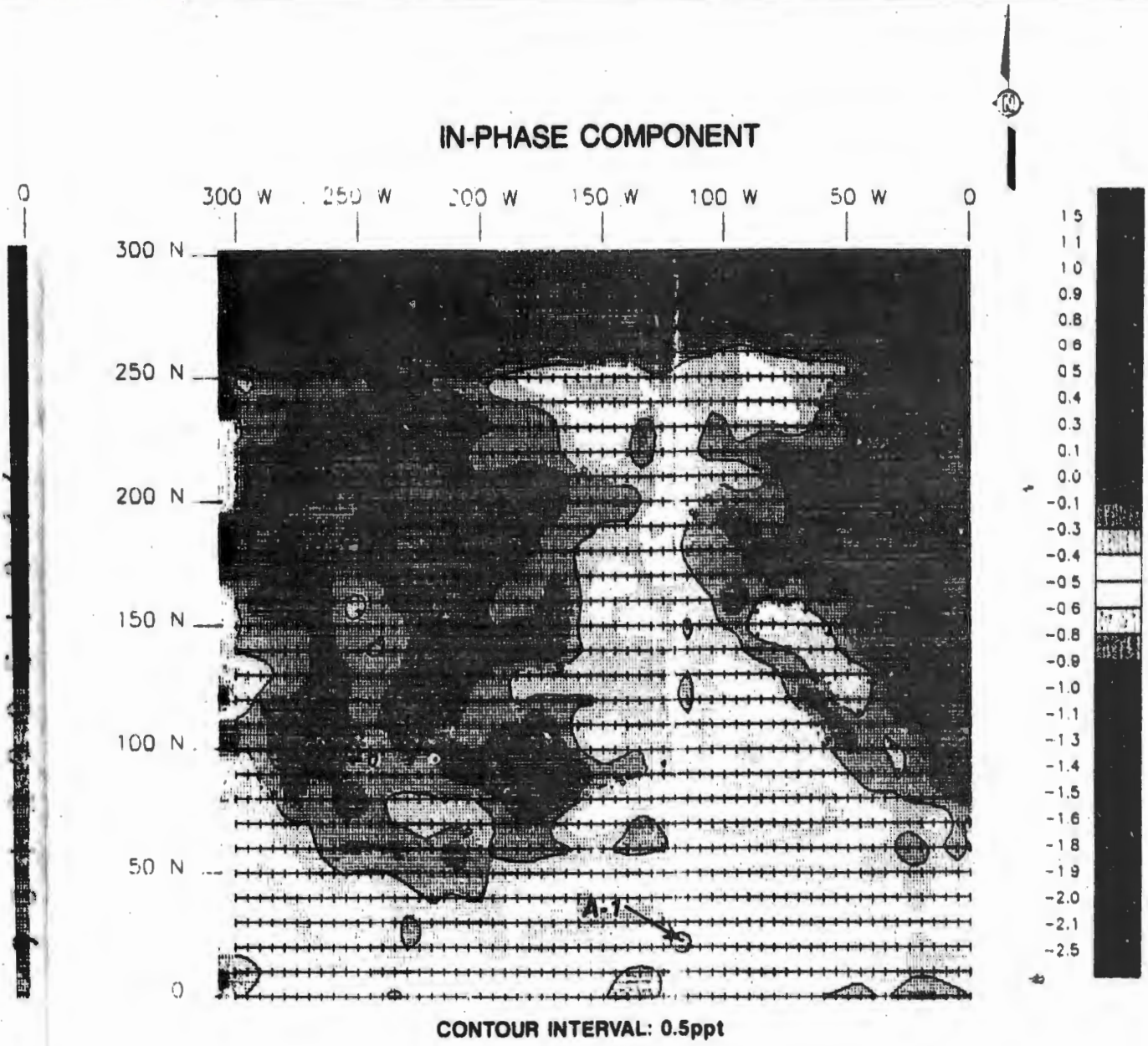


FIGURE 11

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (NORTH)
EAST-WEST SURVEY LINES
WAHLUKE (N) SLOPE

PREPARED FOR

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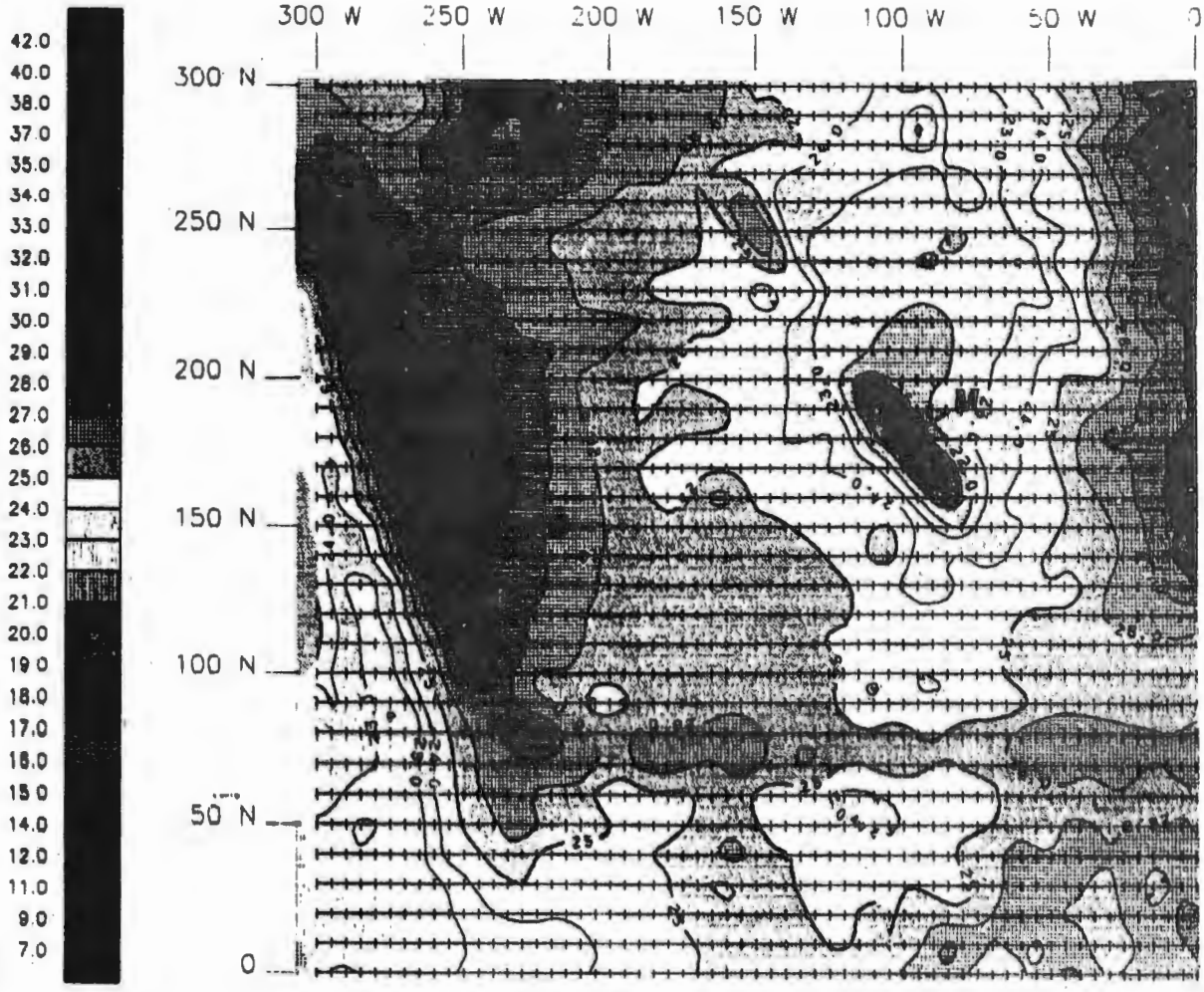
		APPROVED BY			

CONDUCTIVITY



CONTOUR INTERVAL: 1 mS/m

LEGEND:

⊢+⊣	GEONICS EM-31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
M	GEOPHYSICAL ANOMALY OVER SOIL MOUND
D	GEOPHYSICAL ANOMALY OVER DEPRESSION

SCALE

0 30 60 120FEET

Do Not Scale This Drawing

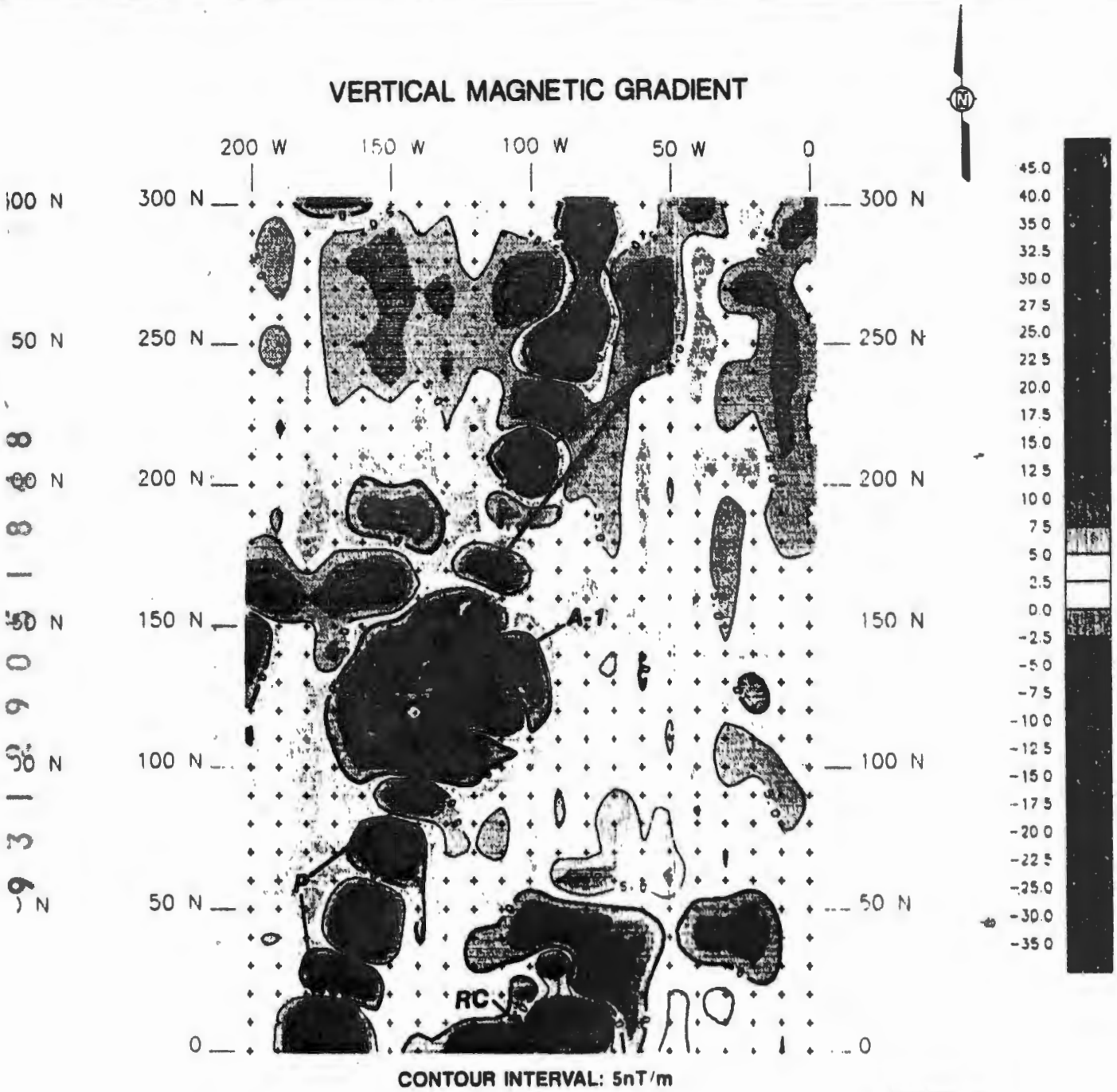


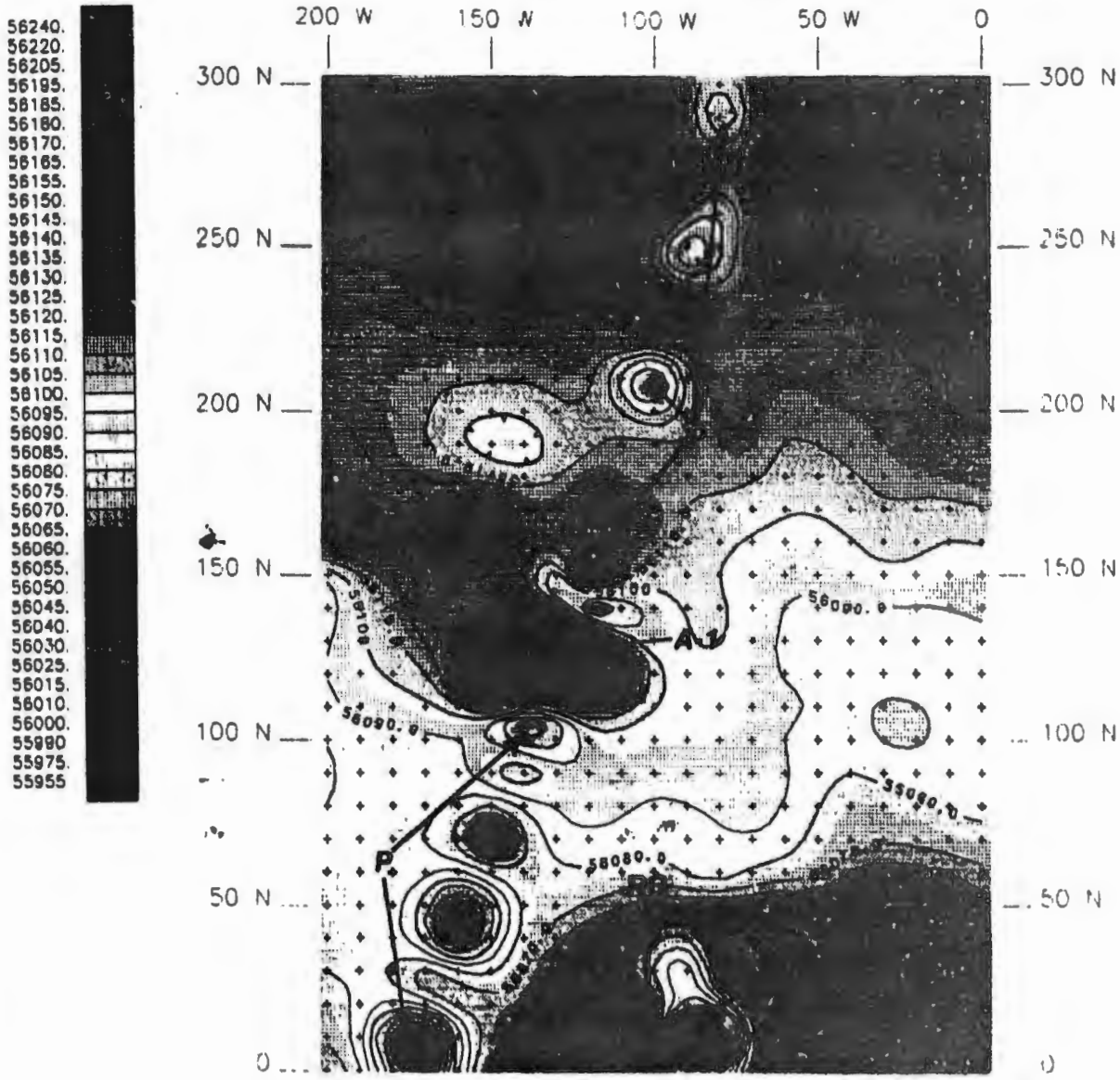
FIGURE 12

CONTOUR MAPS OF MAGNETIC DATA
SITE PSN-04 (SOUTH)
WAHLUKE (N) SLOPE
PREPARED FOR
WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION

DRAWN BY	J. WALL	CHECKED BY		7/10/92	DRAWING NUMBER	199806-B4
	9-2-92	APPROVED BY		9/10/92		

TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 10 nT

LEGEND:

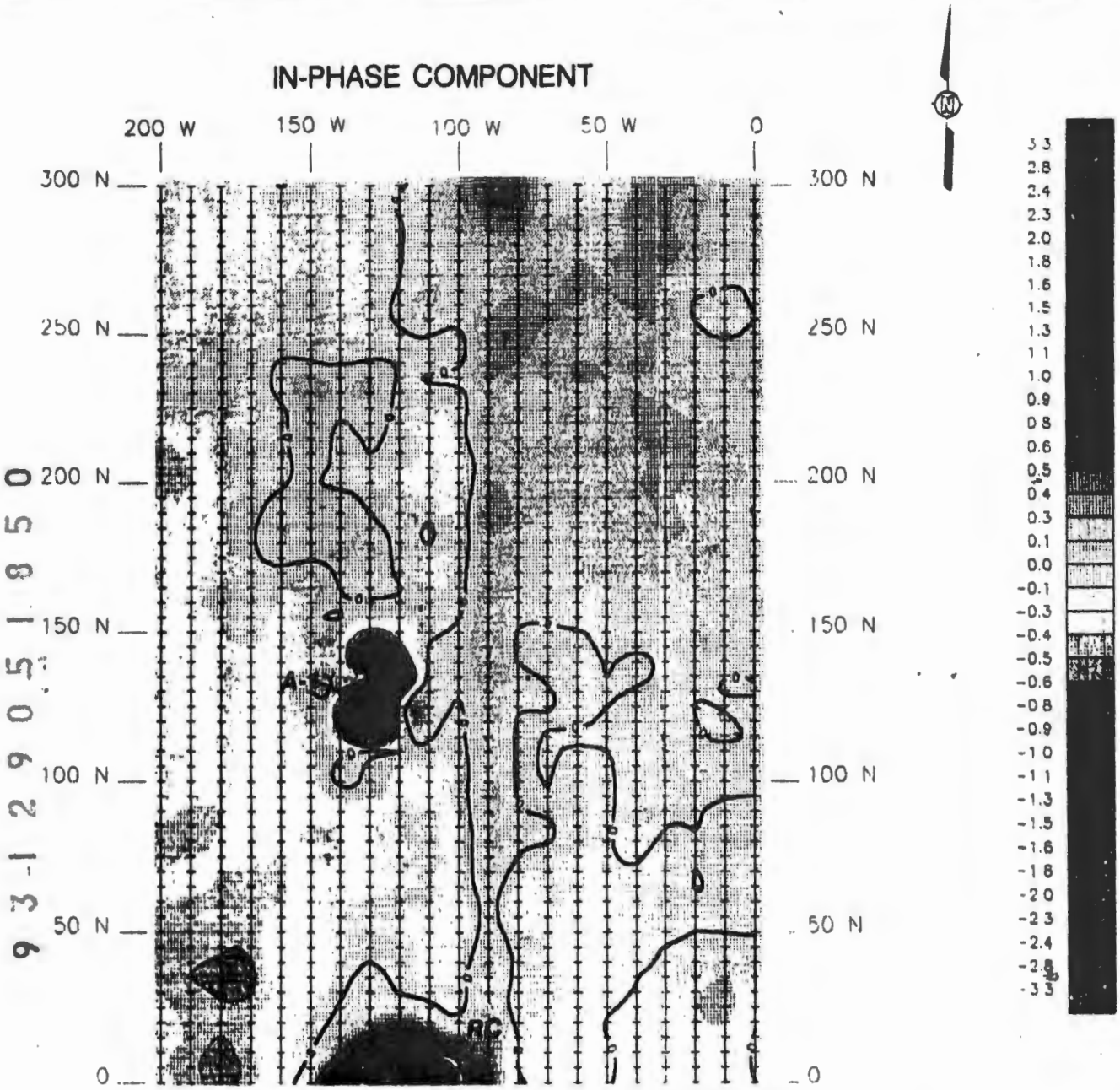
+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
P	ANOMALY CAUSED BY BURIED PIPE
RC	ANOMALY CAUSED BY REINFORCED CONCRETE PAD

SCALE

0 25 50 100FEET

067488

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 13

CONTOUR MAPS OF GEONICS EM-31 DATA

SITE PSN-04 (SOUTH)

SOUTH-NORTH SURVEY LINES

WAHLUKE (N) SLOPE

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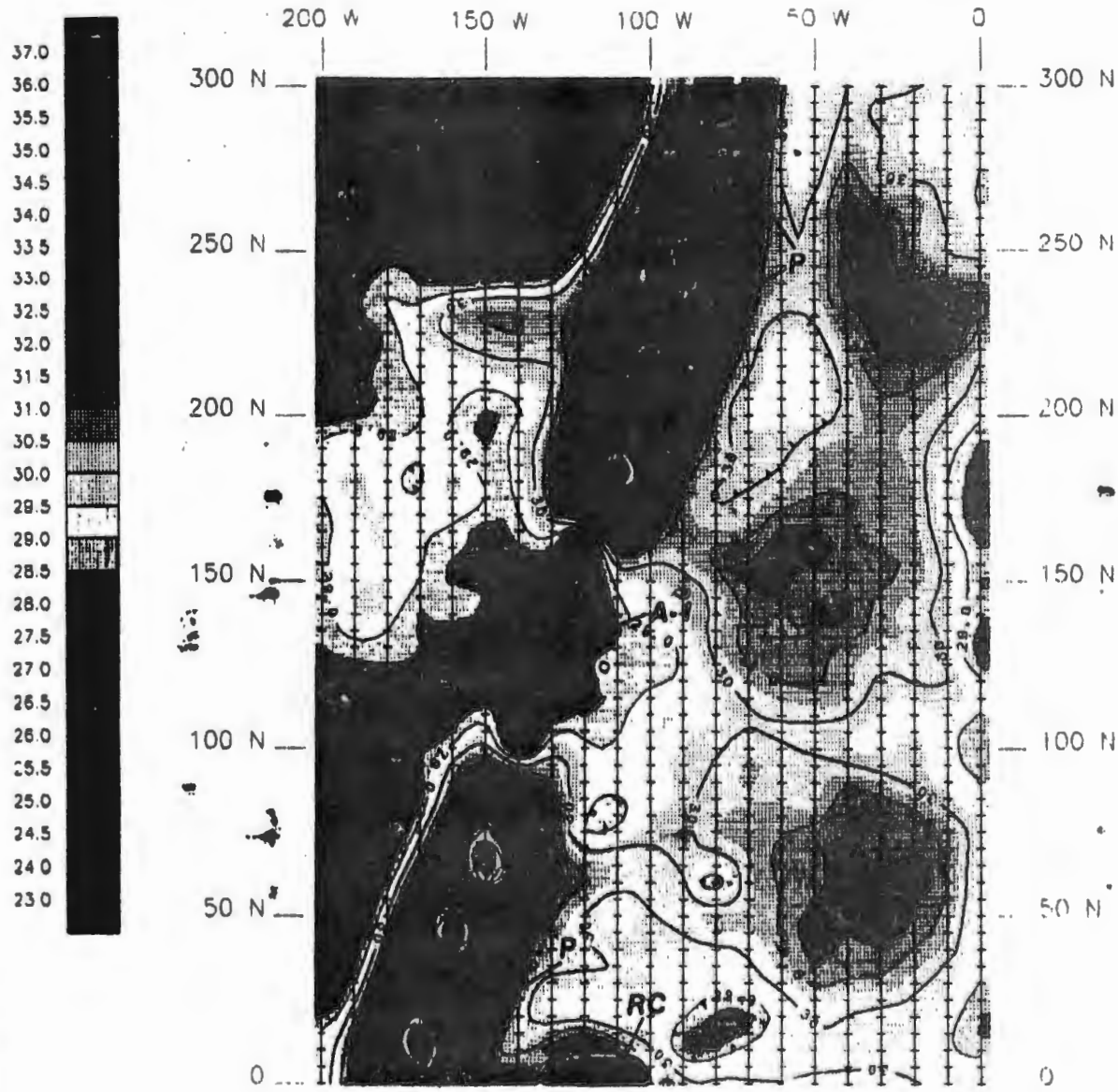
		APPROVED BY		9/10/92		

CONDUCTIVITY



CONTOUR INTERVAL: 1mS/m

LEGEND:

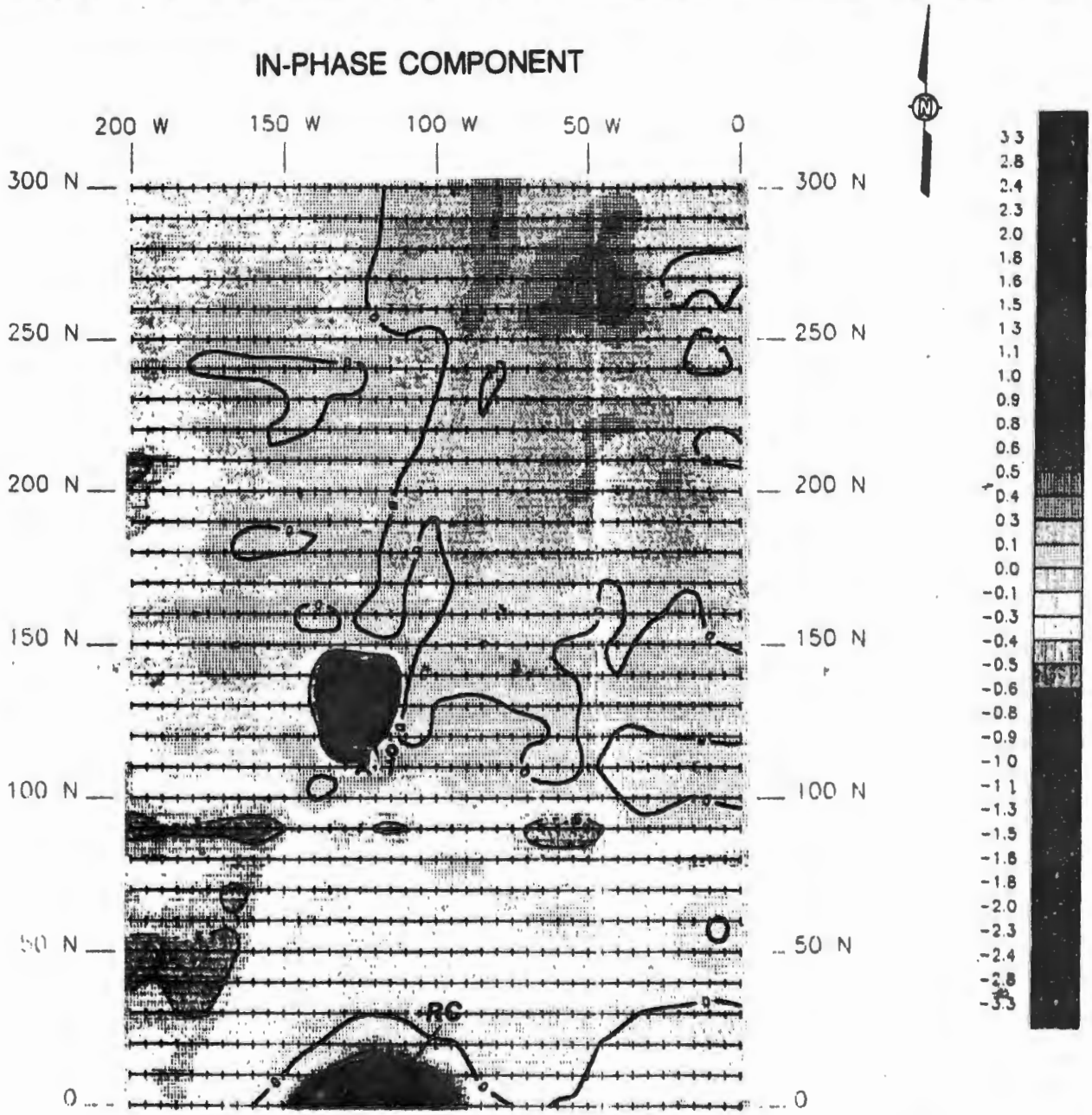
⊢+⊣	GEONICS EM-31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
P	ANOMALY CAUSED BY BURIED PIPE
RC	ANOMALY CAUSED BY REINFORCED CONCRETE PA

SCALE

0 25 50 100FEET

067400

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 14

CONTOUR MAPS OF GEONICS EM-31 DATA

SITE PSN-04 (SOUTH)

EAST-WEST SURVEY LINES

WAHLUKE (N) SLOPE

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9 3 1 2 9 0 5 1 8 5 2

TE PAD

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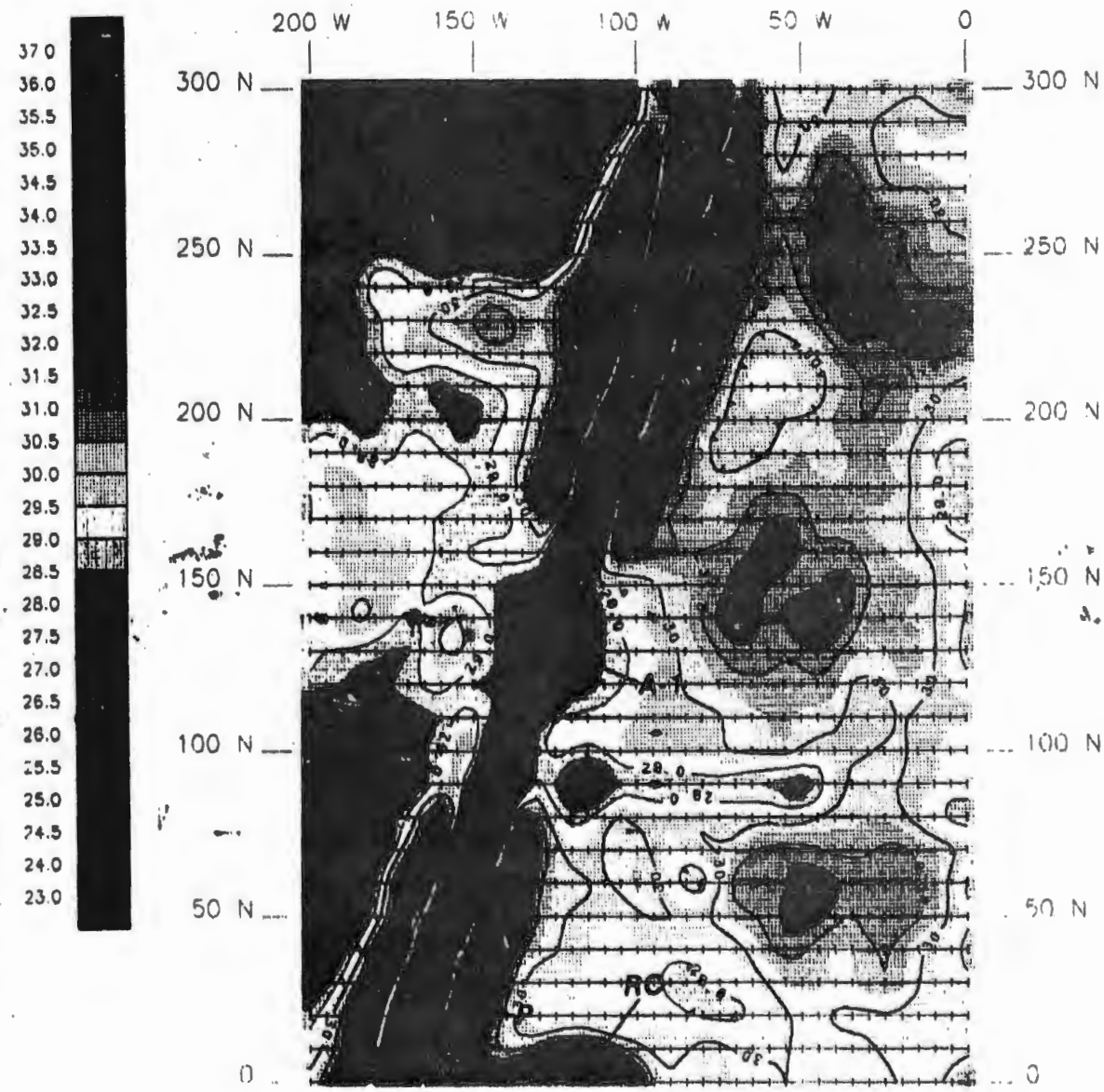
		APPROVED BY		7/10/92		

CONDUCTIVITY



CONTOUR INTERVAL: 1 mS/m

LEGEND:

⊢+⊣	GEONICS EM 31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
P	ANOMALY CAUSED BY BURIED PIPE
RC	ANOMALY CAUSED BY REINFORCED CONCRETE PAI

SCALE

0 25 50 100 FEET

057400

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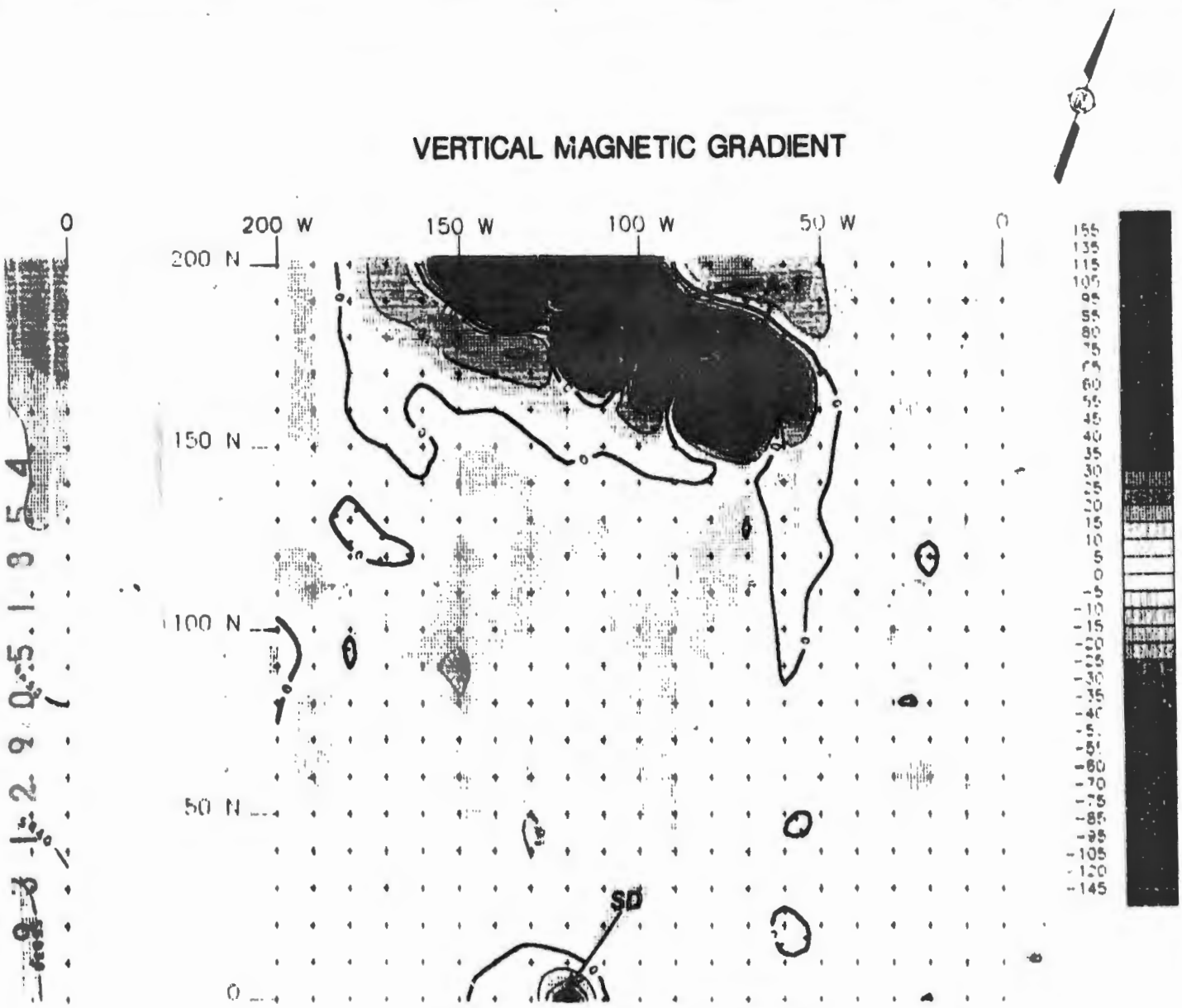
9 3 1 2 9 0 5 1 8 5 3



CONTOUR INTERVAL: 10nT/m

FIGURE 15

CONTOUR MAPS OF MAGNETIC DATA
SITE PSN-04 (EAST)
WAHLUKE (N) SLOPE
PREPARED FOR
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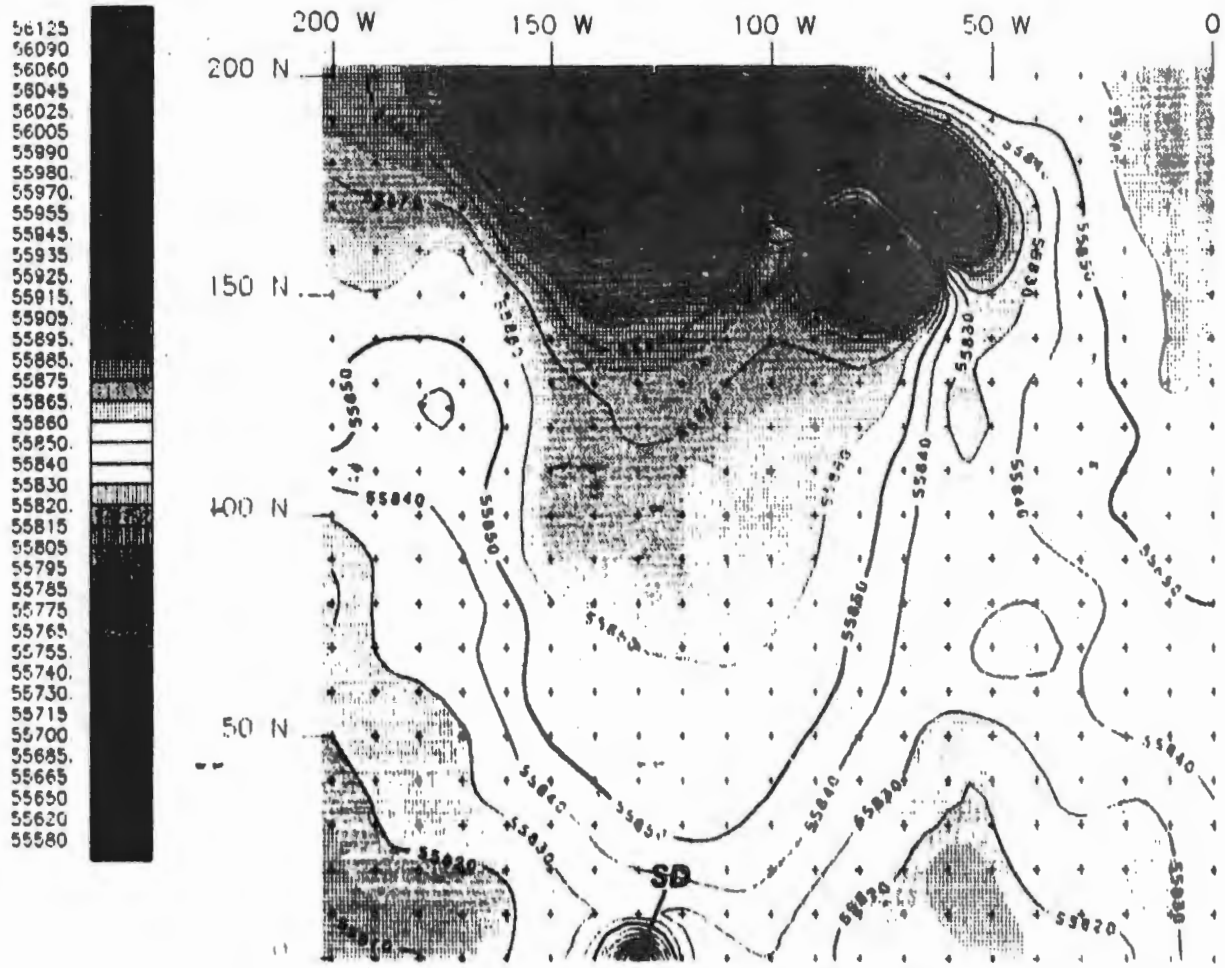
INTERNATIONAL TECHNOLOGY CORPORATION

DRAWN BY	J. WALL	CHECKED BY		DRAWING NUMBER	199806-B7
	9-2-92	APPROVED BY			

TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 10nT

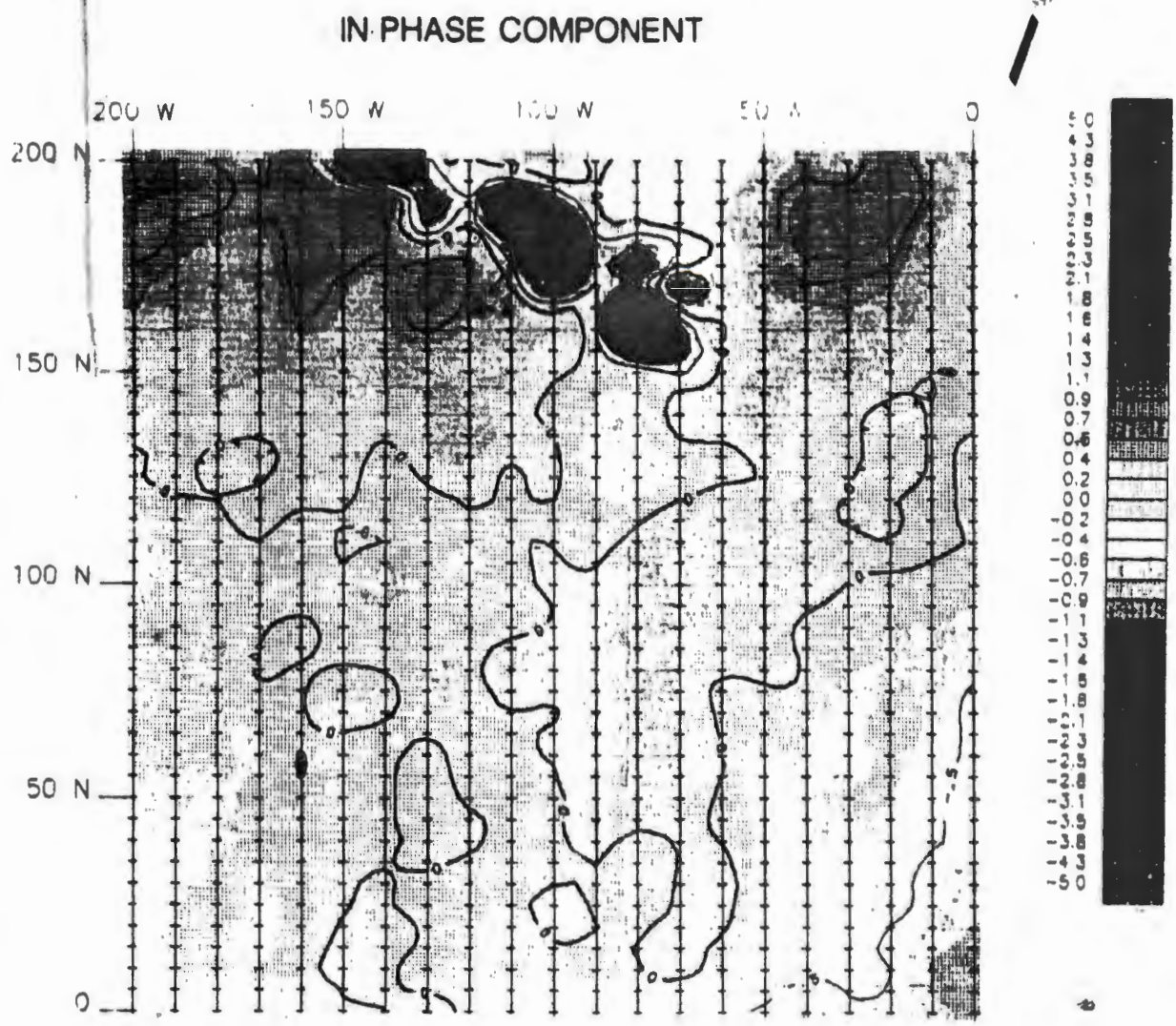
LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
SD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 20 40 80FEET

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 16

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (EAST)
SOUTHEAST-NORTHWEST SURVEY LINES
WAHLUKE (N) SLOPE

PREPARED FOR

WESTINGHOUSE HANFORD CO
RICHLAND, WASHINGTON

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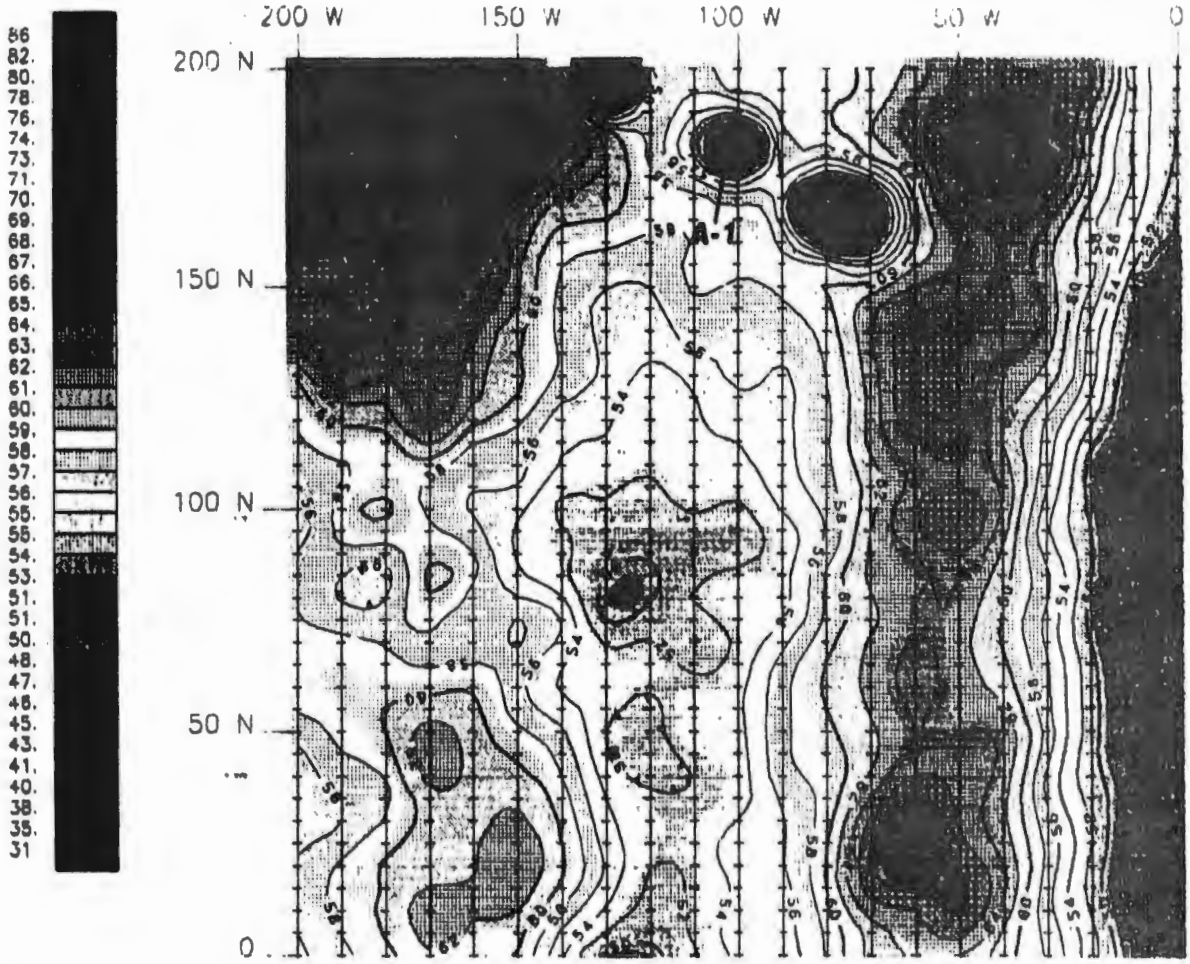
IN TEXT

9 3 1 2 9 0 5 1 8 5 6

DRAWN BY	J. WALL 9-2-92	CHECKED BY		9/10/92	DRAWING NUMBER	199806-B8
		APPROVED BY		9/10/92		

CONDUCTIVITY



CONTOUR INTERVAL: 2mS/m

LEGEND:

+ + + + GEONICS EM 31 SURVEY LINE

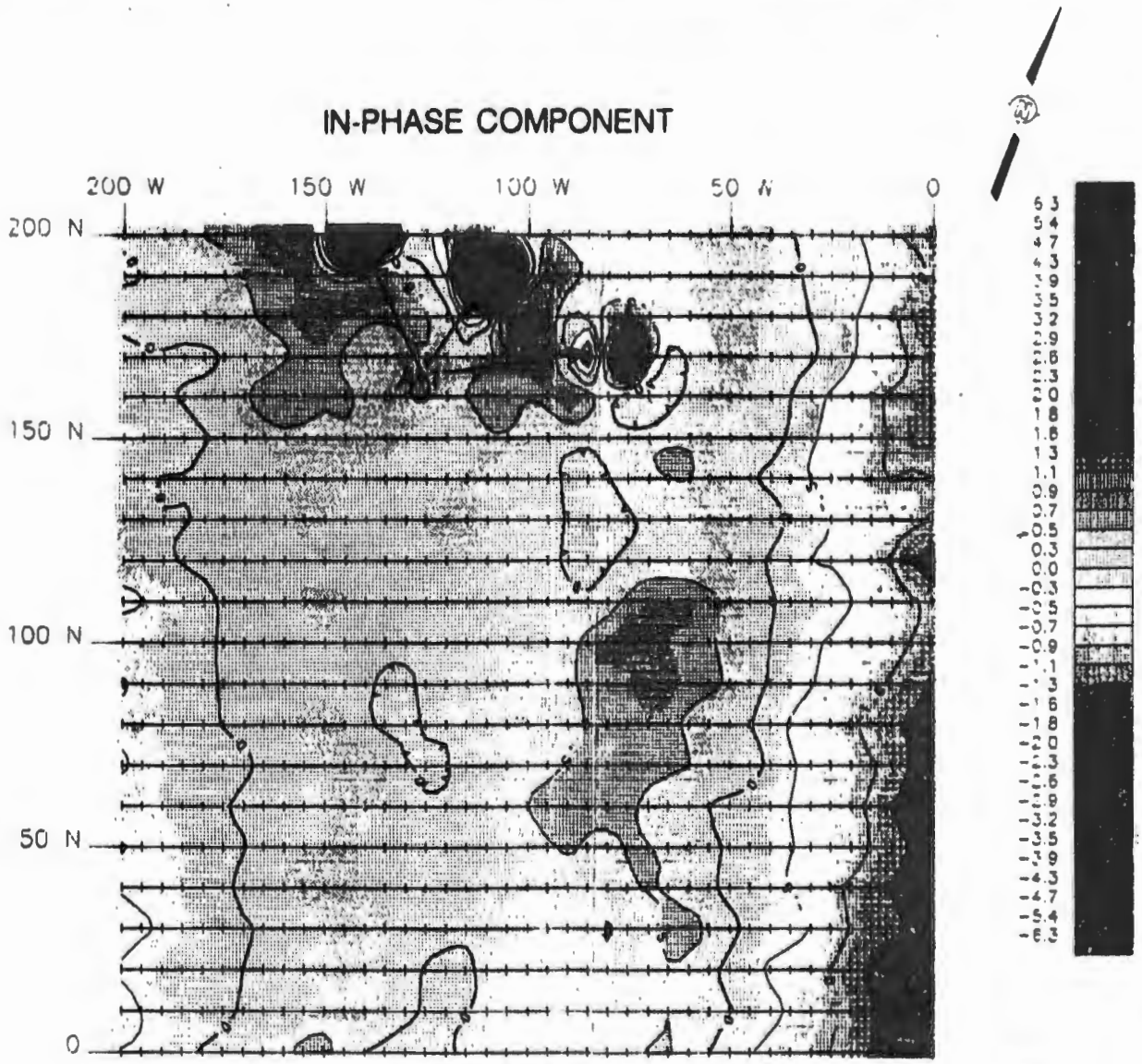
A-1 GEOPHYSICAL ANOMALY DISCUSSED IN

SCALE

0 20 40 80FEET

067488

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 17

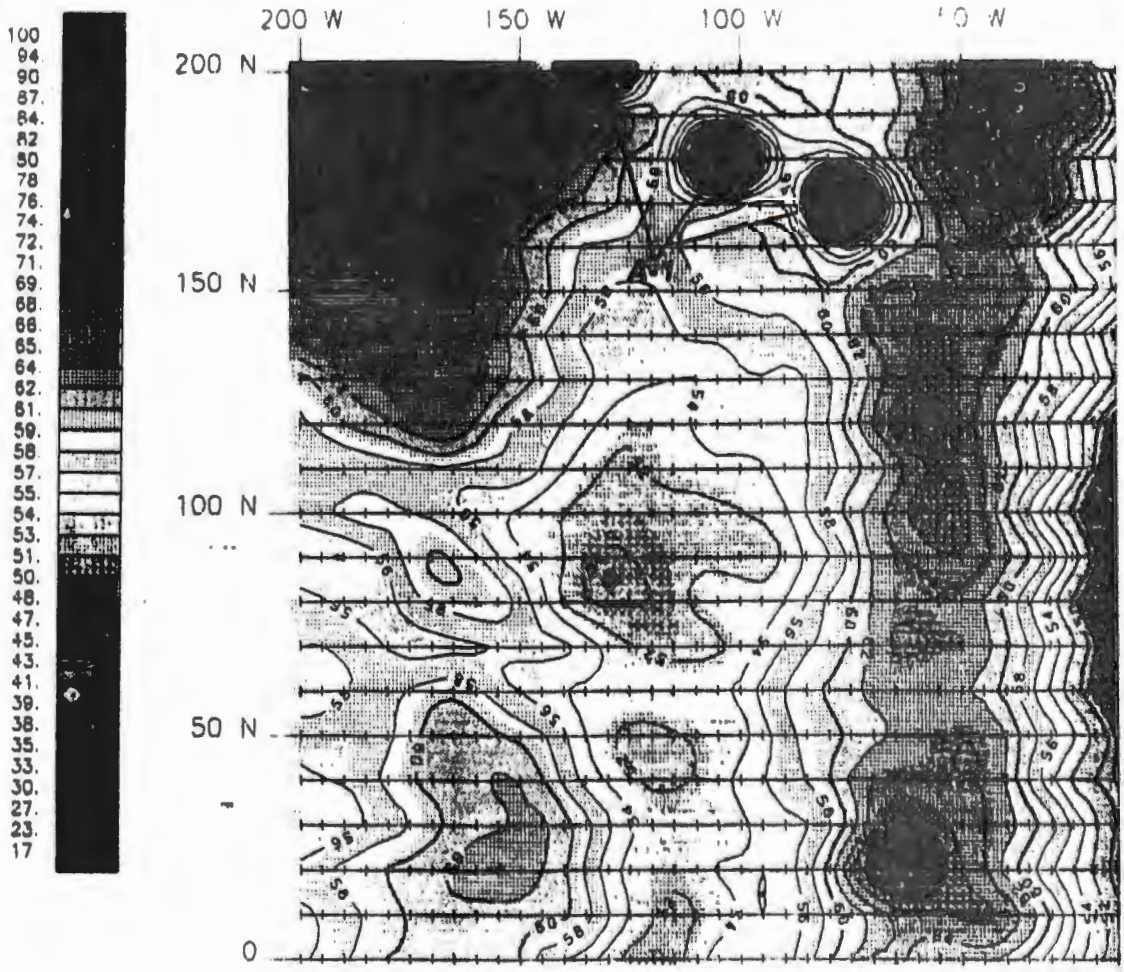
CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (EAST)
NORTHEAST-SOUTHWEST SURVEY LINES
WAHLUKE (N) SLOPE
PREPARED FOR
WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION

TEXT

DRAWN BY	J. WALL	CHECKED BY		DRAWING NUMBER
	9-2-92	APPROVED BY	9/10/92	199806-B9

CONDUCTIVITY



CONTOUR INTERVAL: 2 mS/m

LEGEND:

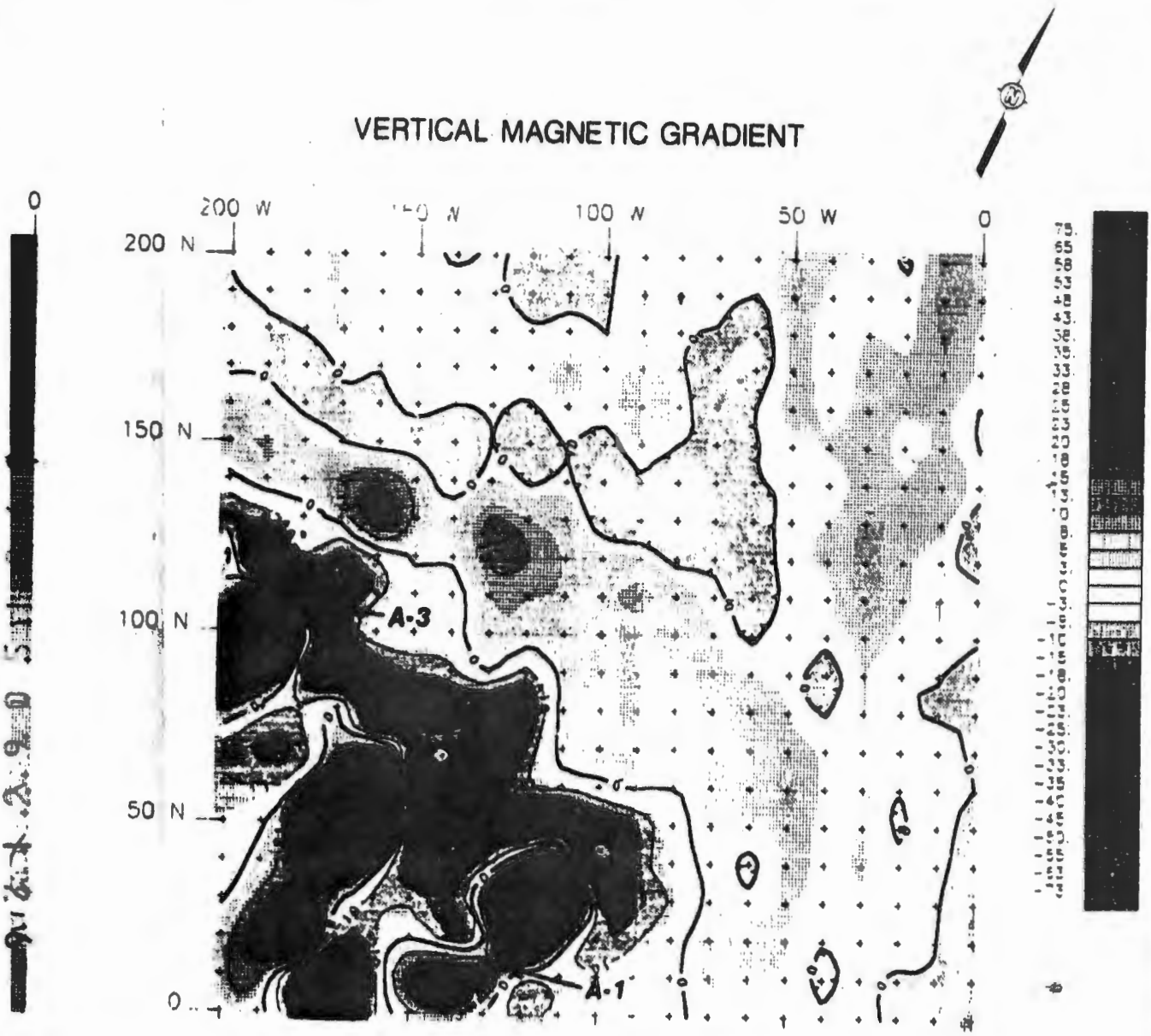
GEONICS EM 31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DIS

SCALE

0 20 40 80FEET

Do Not Scale This Drawing



CONTOUR INTERVAL: 10nT/m

FIGURE 18

CONTOUR MAPS OF MAGNETIC DATA
SITE PSN-04 (WEST)
WAHLUKE (N) SLOPE
PREPARED FOR
WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

IN TEXT

INTERNATIONAL TECHNOLOGY CORPORATION

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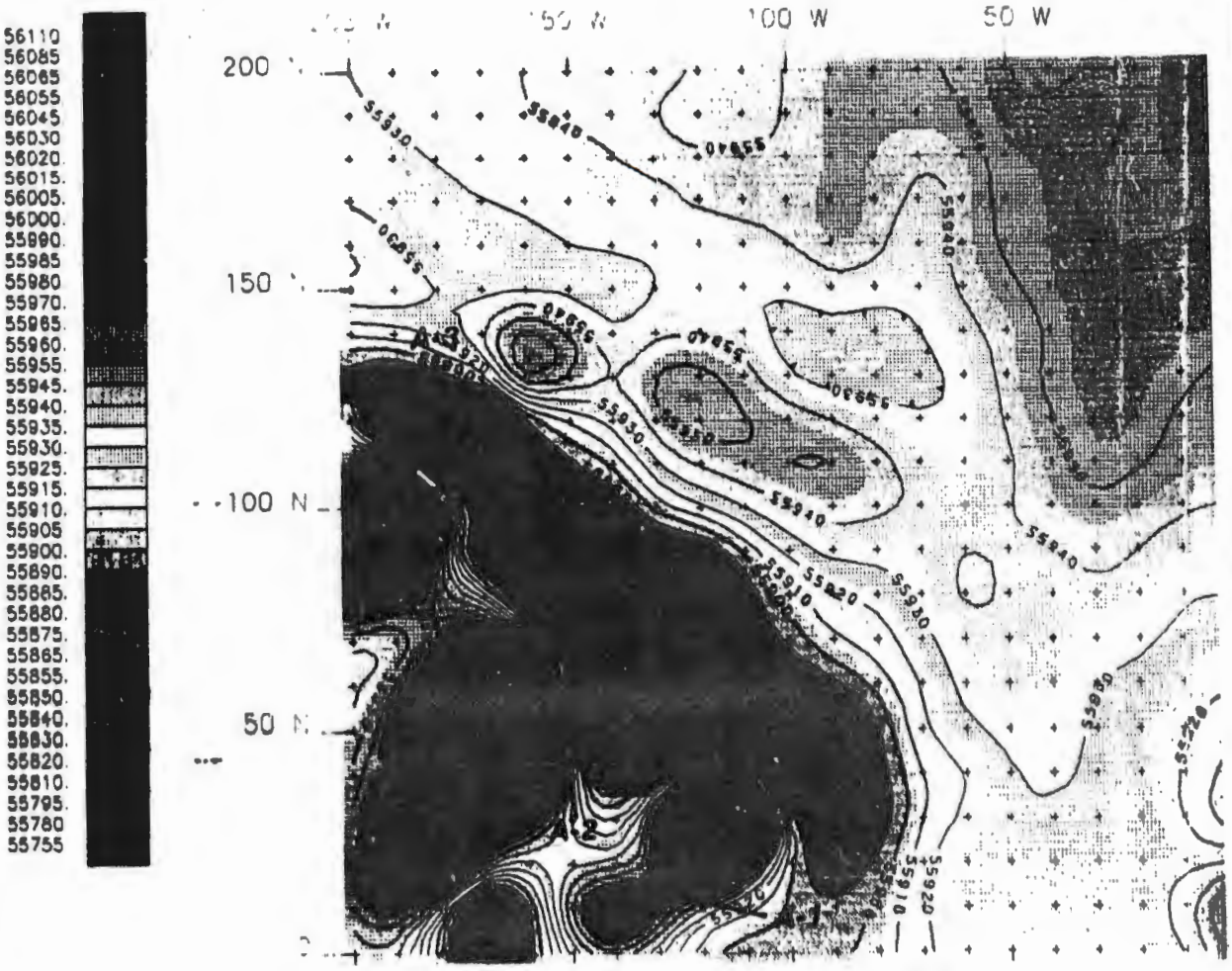
	9-2-92	APPROVED BY			

TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 10nT

LEGEND:

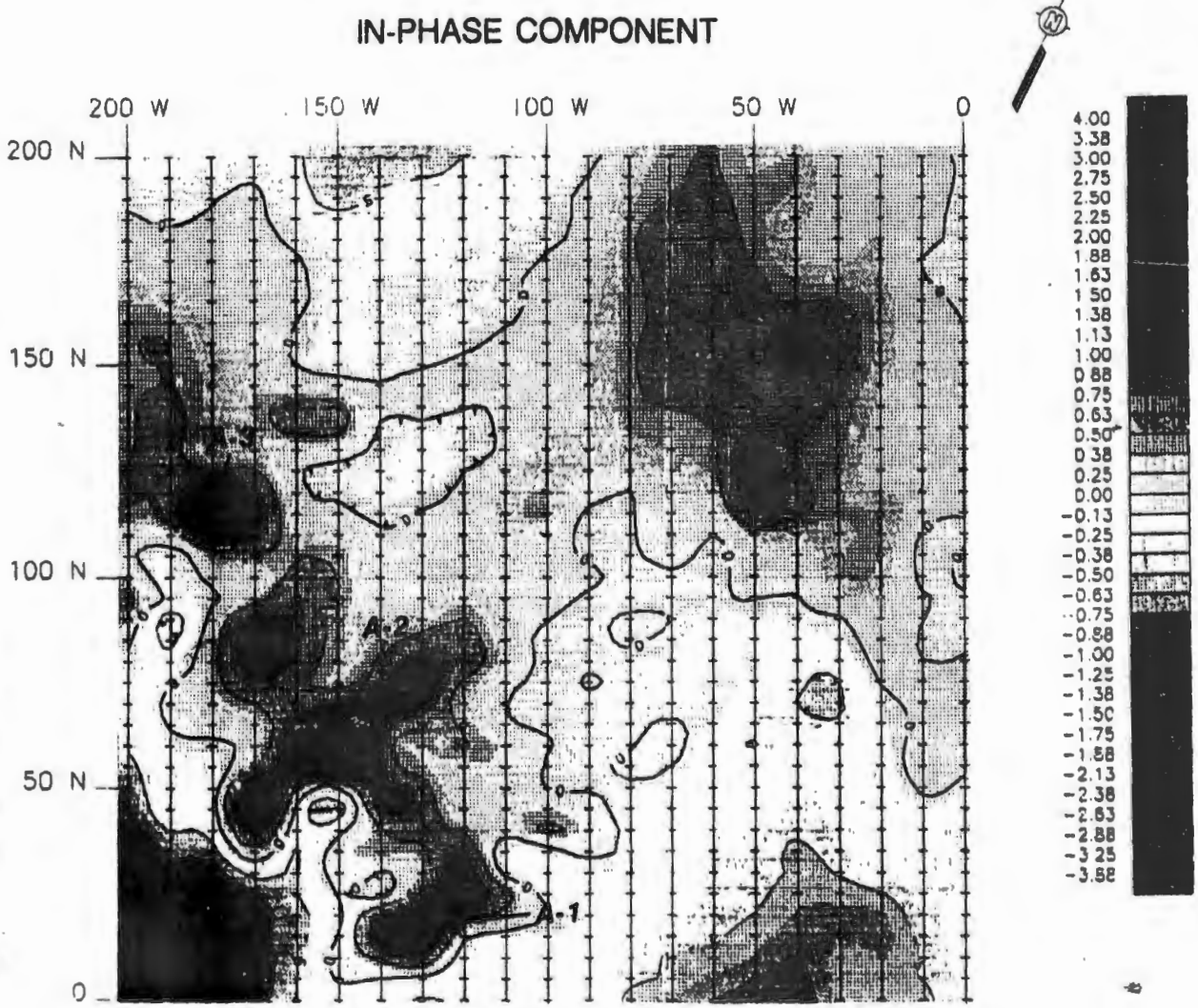
+ MAGNETIC SURVEY STATION

A-1 GEOPHYSICAL ANOMALY DISCUSSED

SCALE

0 20 40 80FEET

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 19

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (WEST)
SOUTHEAST-NORTHWEST SURVEY LINES
WAHLUKE (N) SLOPE

PREPARED FOR

WESTINGHOUSE HANFORD CO.
RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION

D IN TEXT

9 3 1 2 9 0 5 1 8 6 2

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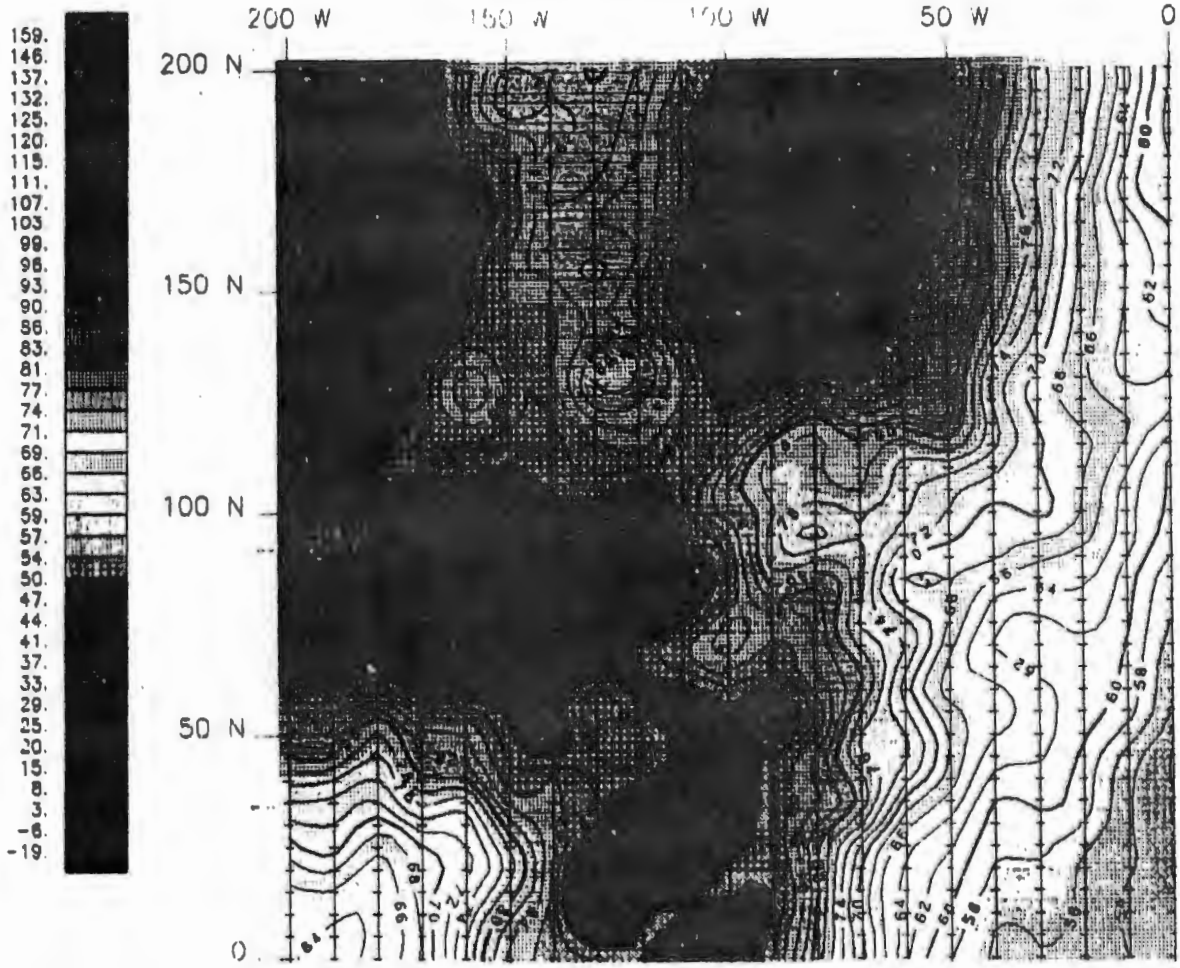


CONTOUR INTERVAL: 2 mS/m

LEGEND:

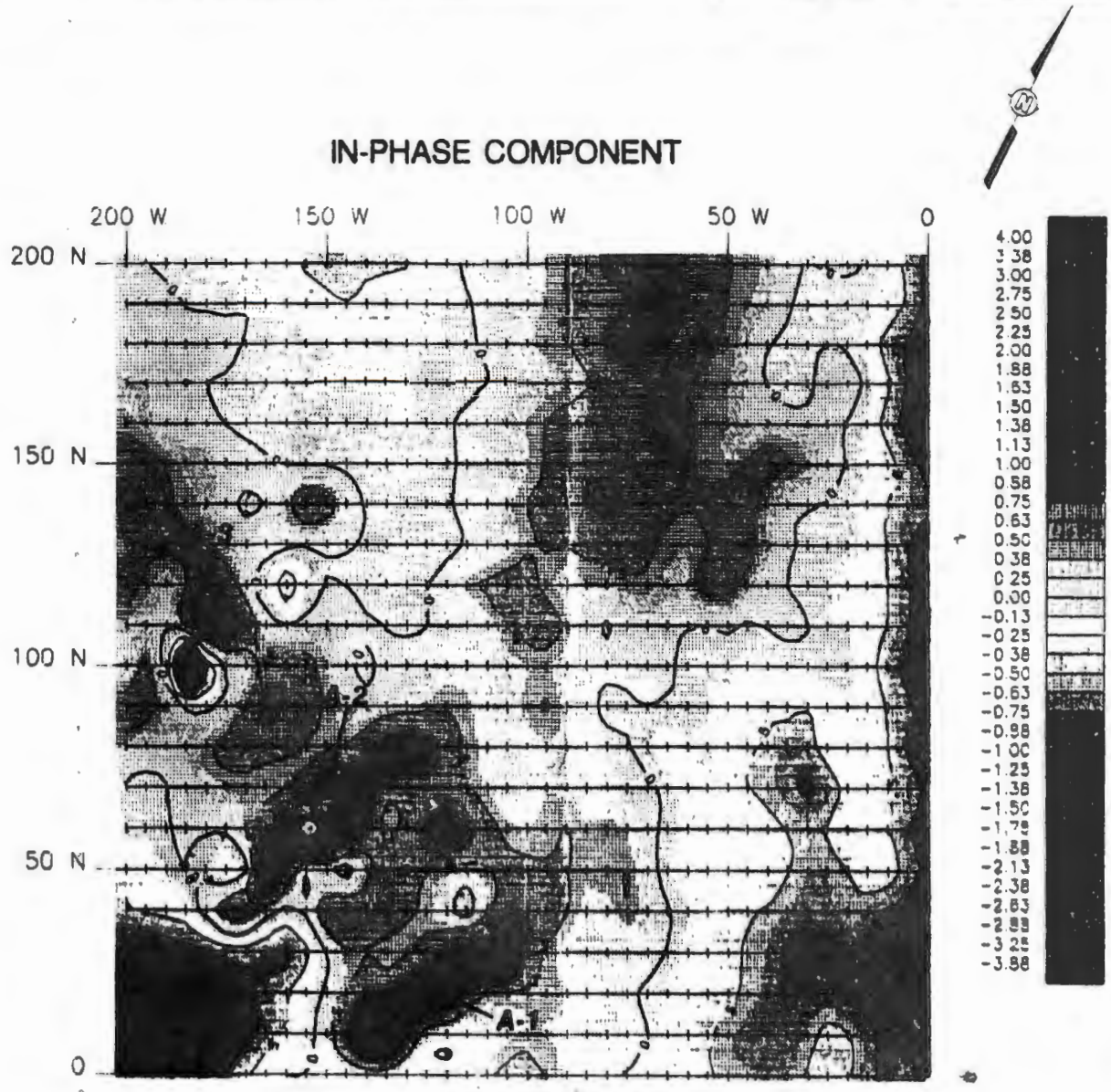
GEONICS EM-31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED

SCALE

0 20 40 80FEET

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 20

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE PSN-04 (WEST)
NORTHEAST-SOUTHWEST SURVEY LINES
WAHLUKE (N) SLOPE
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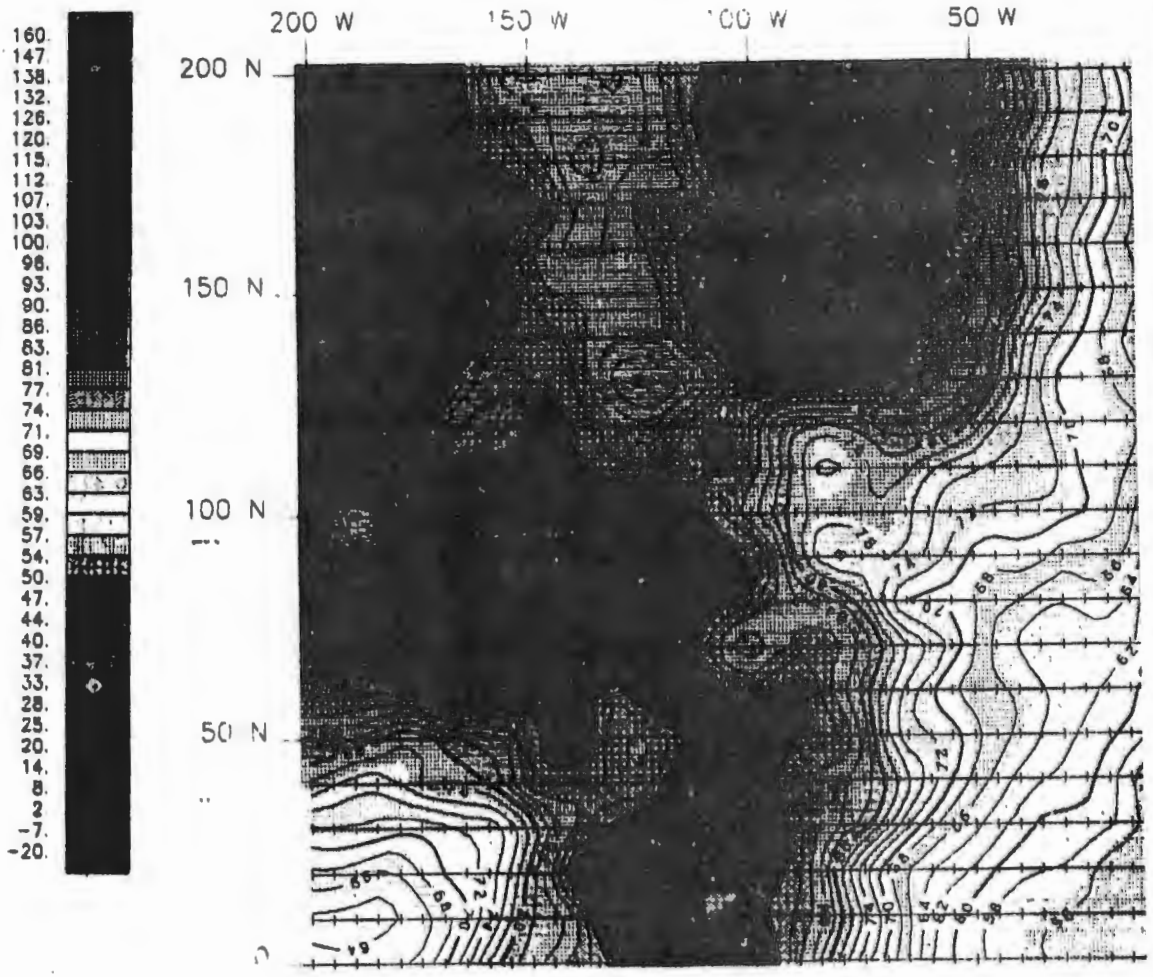

CONTOUR INTERVAL: 2mS/m

LEGEND:

GEONICS EM 31 SURVE

A-1 GEOPHYSICAL ANOMAL

SCALE

0 20 40 80FEET

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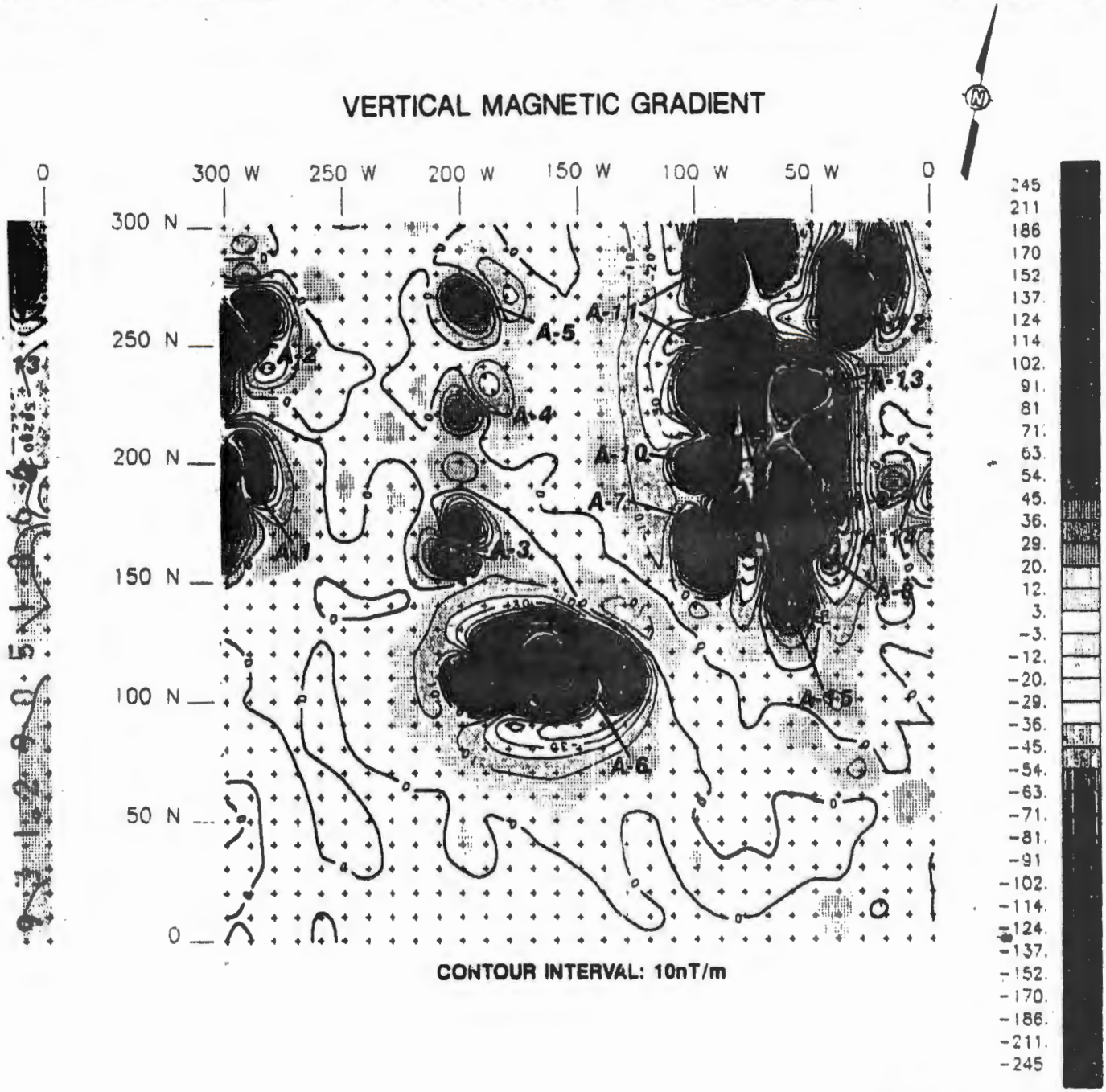

CONTOUR INTERVAL: 10nT/m

FIGURE 21

CONTOUR MAPS OF MAGNETIC DATA
SITE H-06-H (EAST)
WAHLUKE (N) SLOPE
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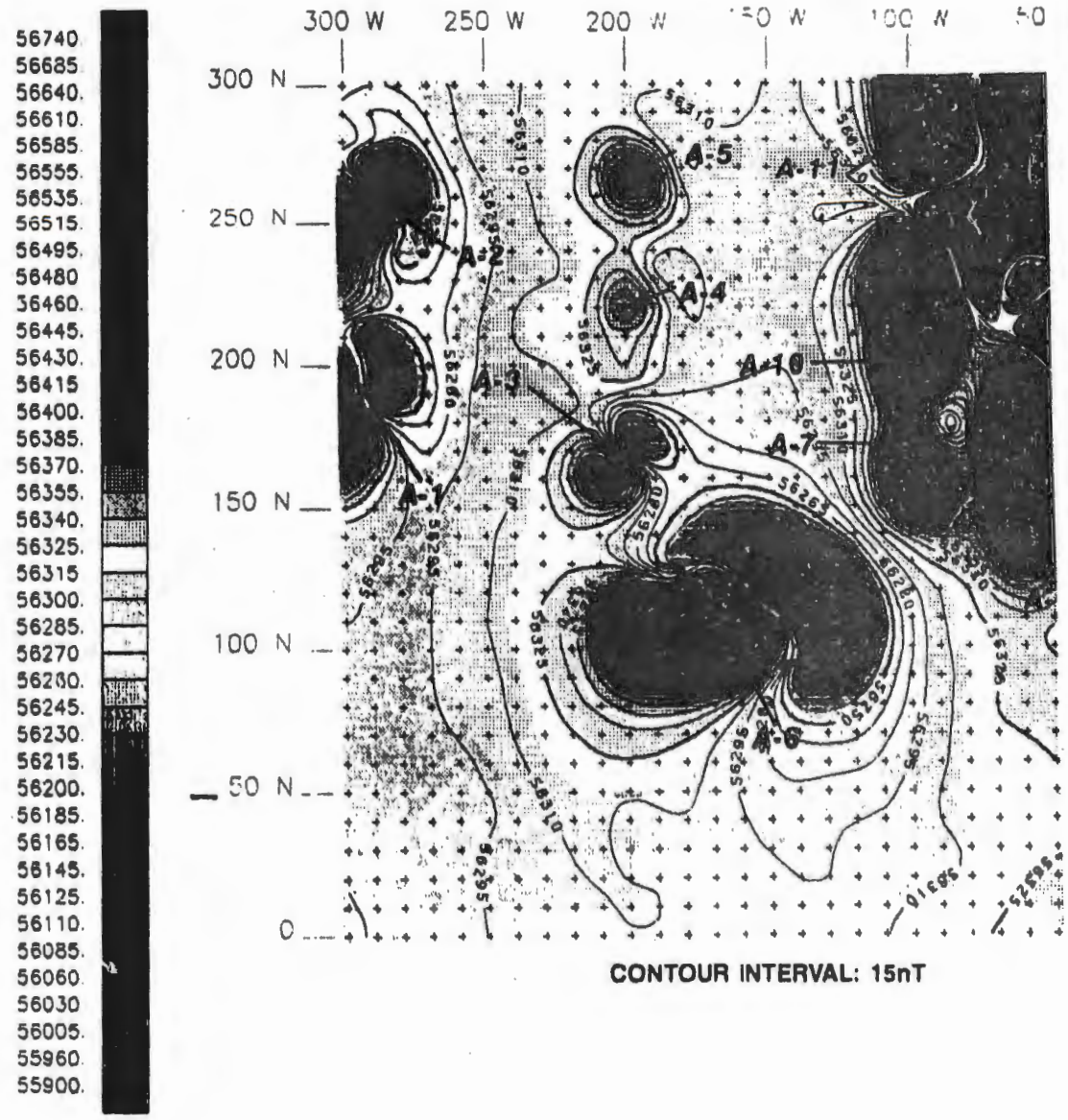
TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 15nT

LEGEND:

+ MAGNETIC SURVEY STATION

A-1 GEOPHYSICAL ANOMALY DISCUS

SCALE

0 30 60 120FEET

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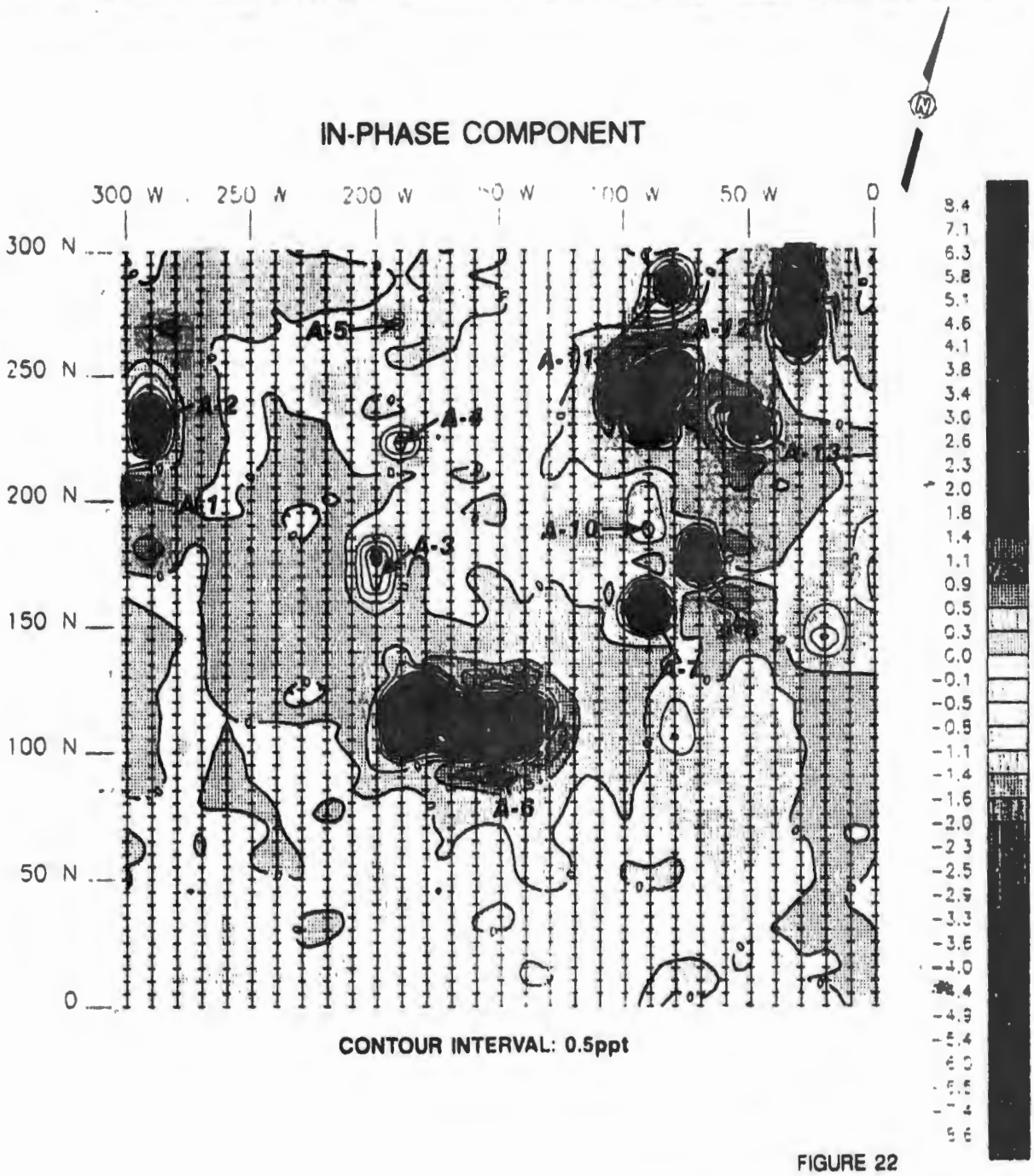

FIGURE 22

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE H-06-H (EAST)
SOUTH-NORTH SURVEY LINES
WAHLUKE (N) SLOPE
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9 3 1 2 9 0 5 1 8 6 8

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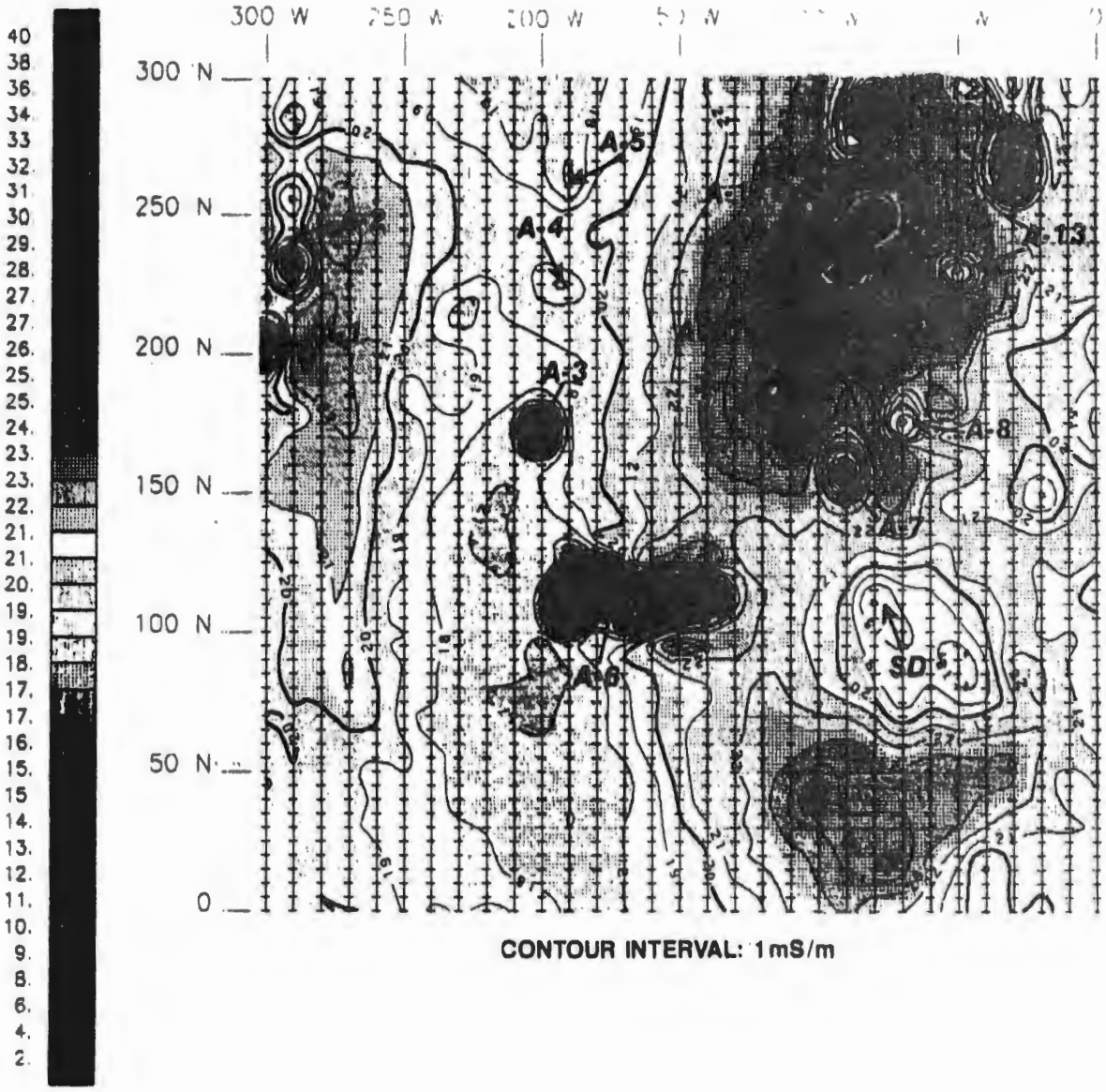

CONTOUR INTERVAL: 1 mS/m

LEGEND:

⊢⊣	GEONICS EM 31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
SD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 30 60 120FEET

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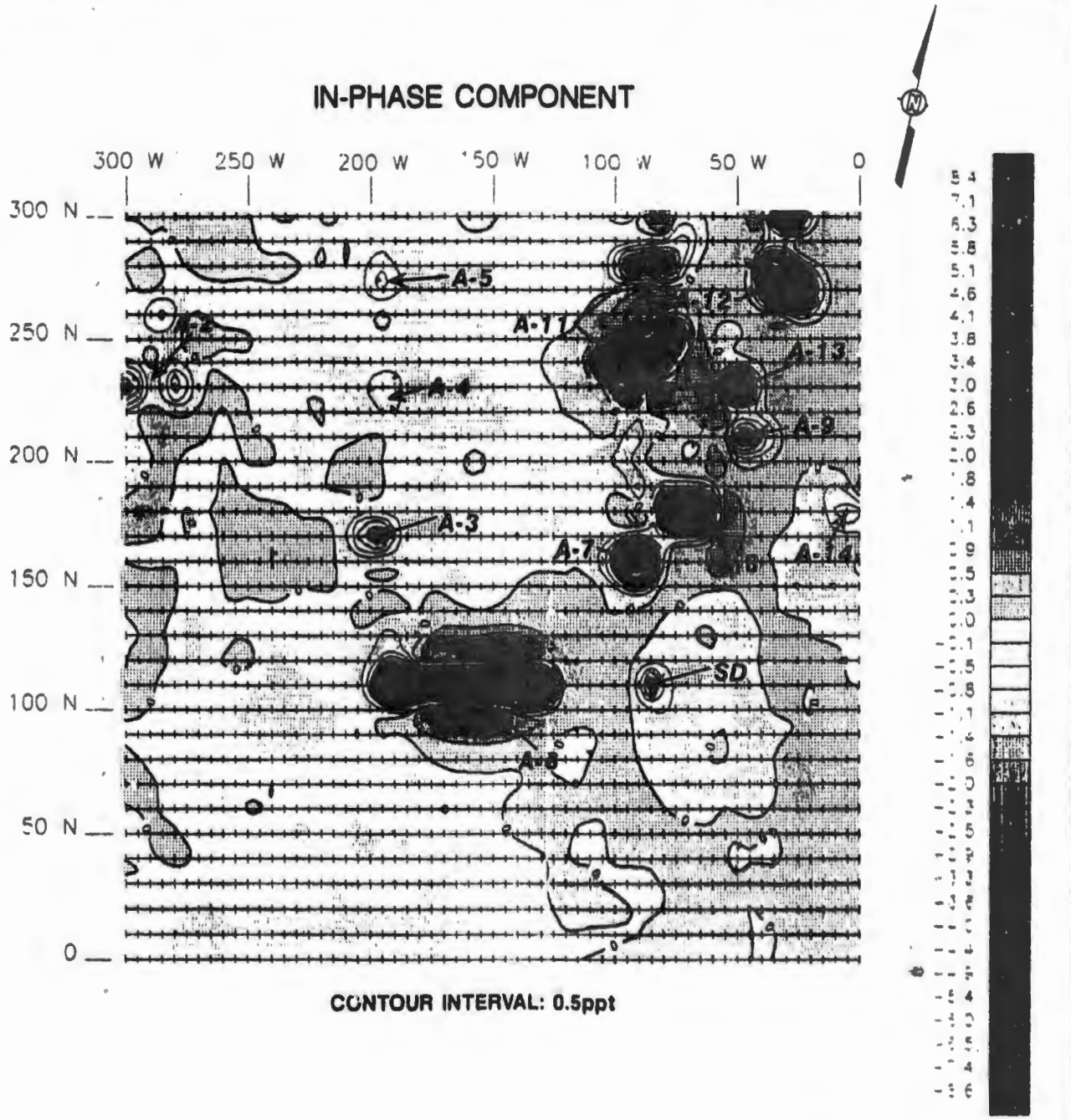

FIGURE 23
CONTOUR MAPS OF GEONICS EM-31 DATA
SITE H-06-H (EAST)
EAST-WEST SURVEY LINES
WAHLUKE (N) SLOPE
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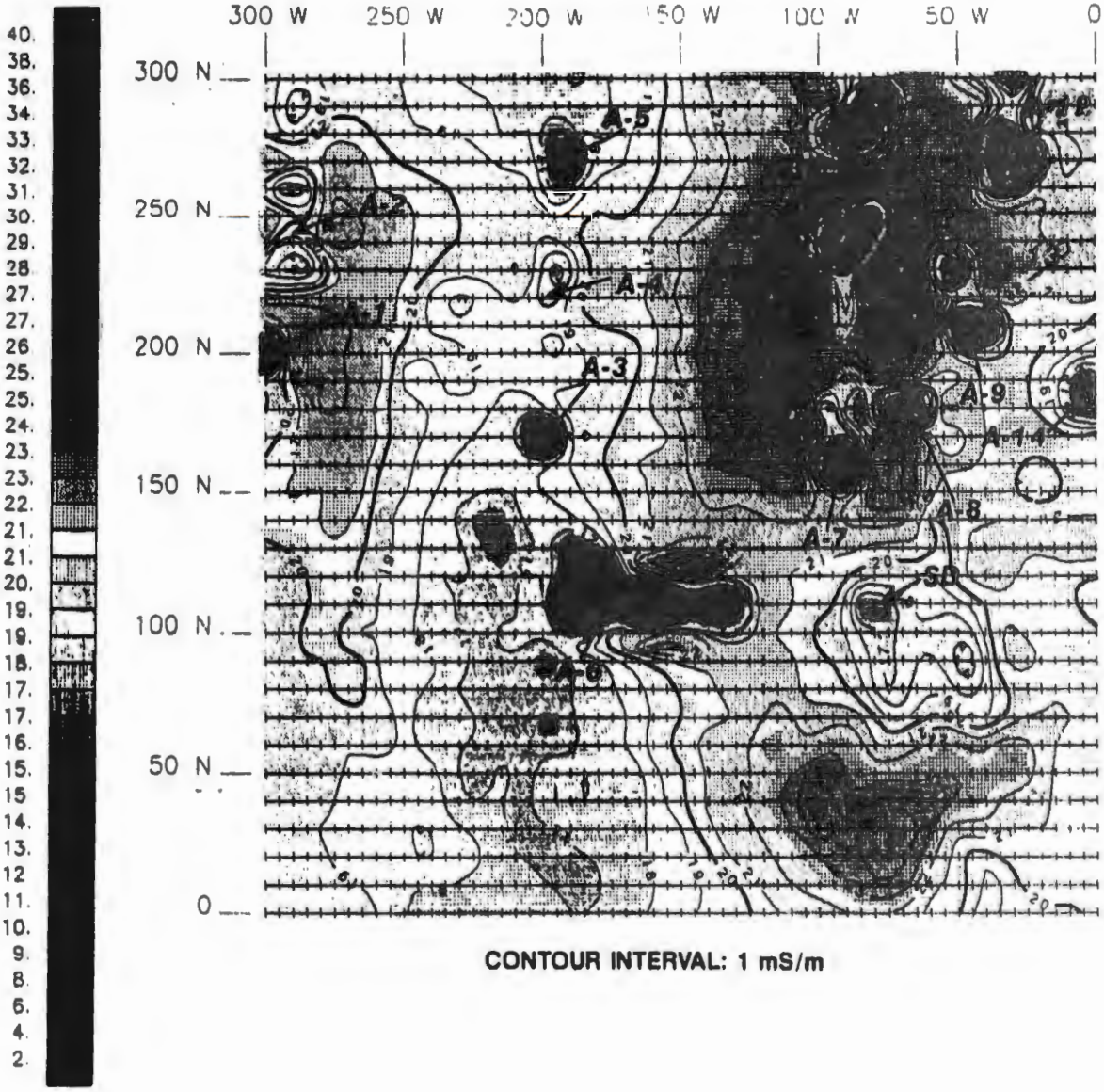

CONTOUR INTERVAL: 1 mS/m

LEGEND:

⊢+⊣	GEONICS EM 31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN T
SD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 30 60 120FEET

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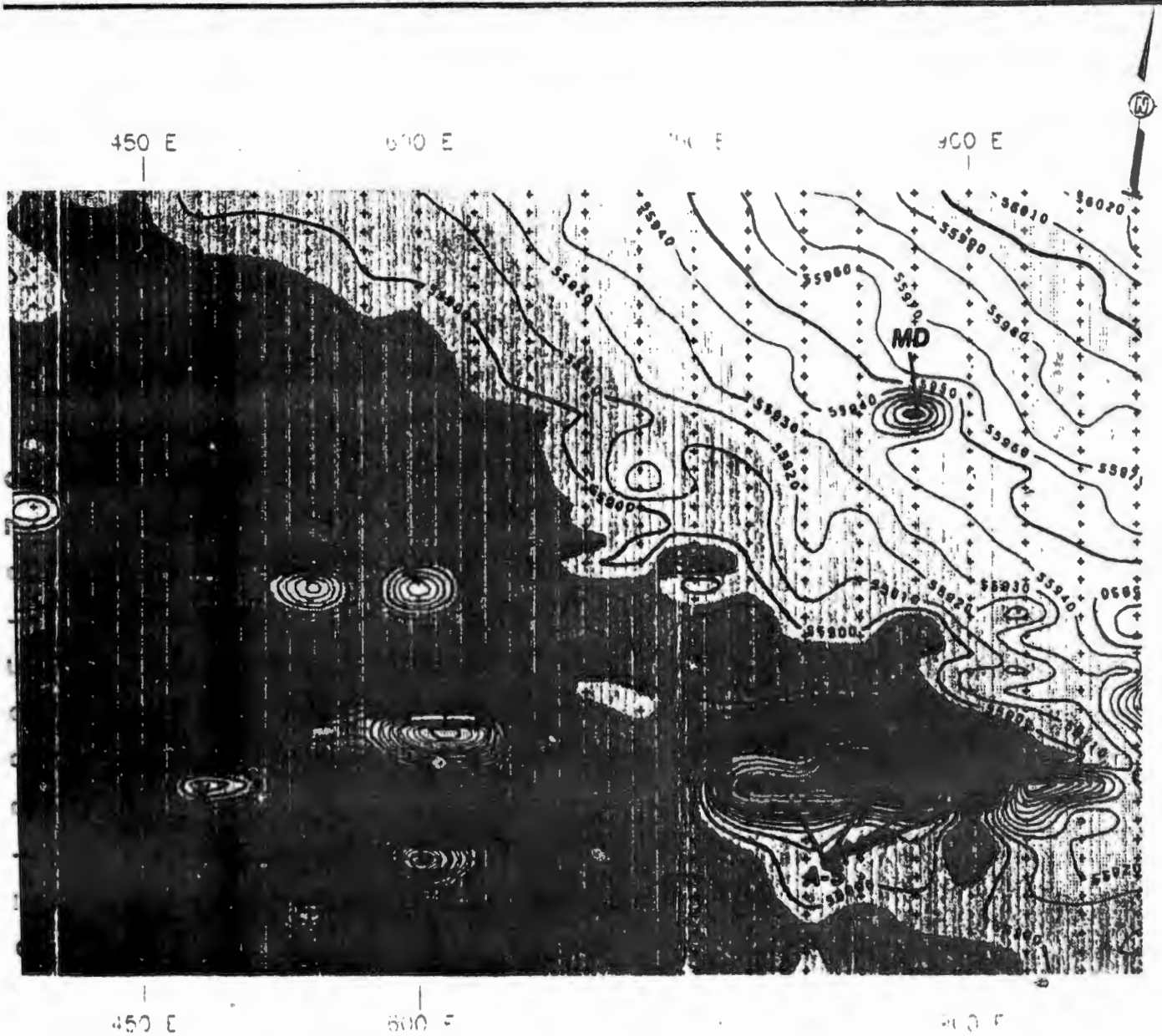

CONTOUR INTERVAL: 10 nT/m

FIGURE 24A

CONTOUR MAP OF TOTAL MAGNETIC FIELD
SITE H-06-H (WEST)
SHEET 1 OF 2
WAHLUKE (N) SLOPE
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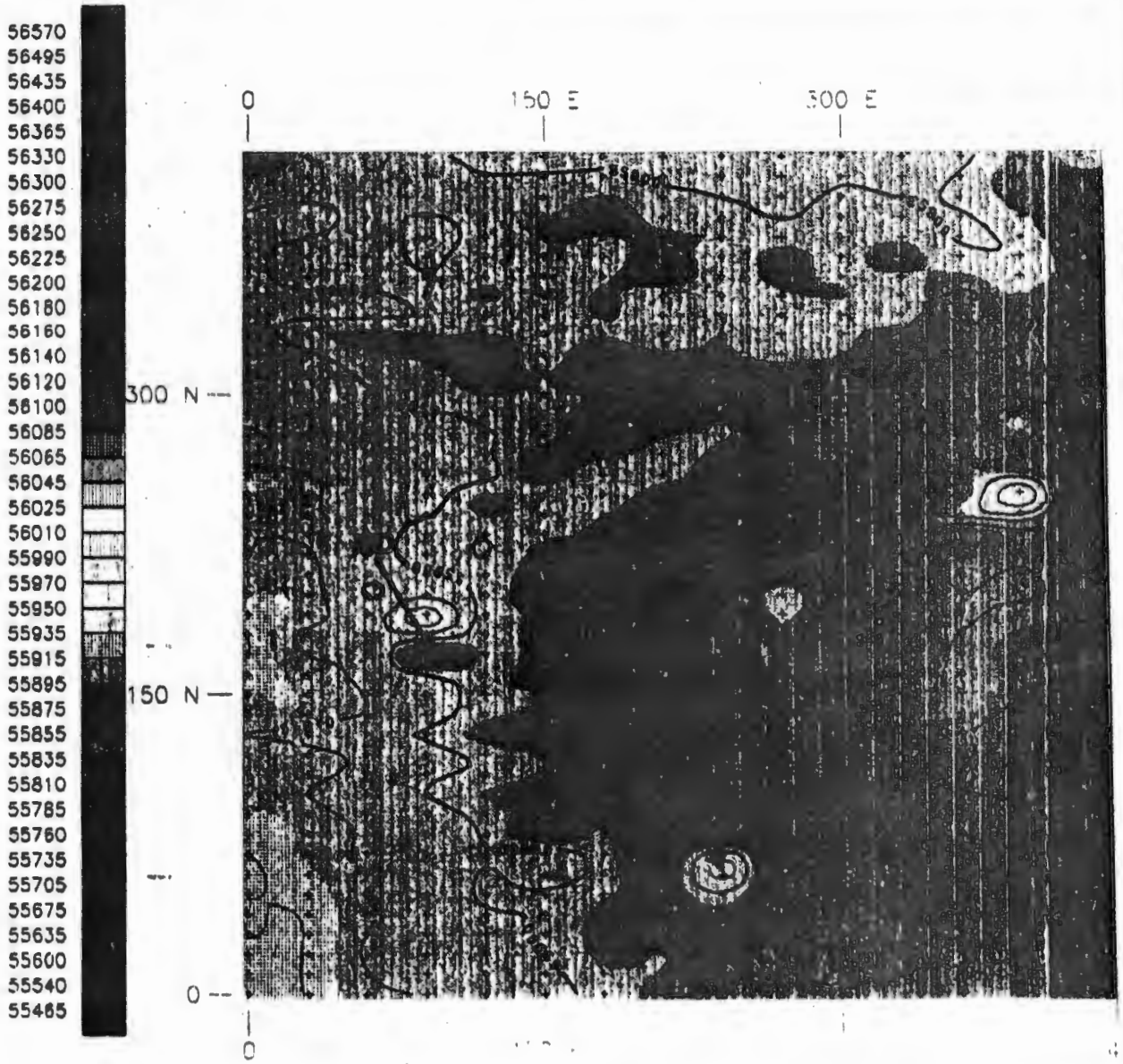

CONTOUR

LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
MD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 40 80 160FEET

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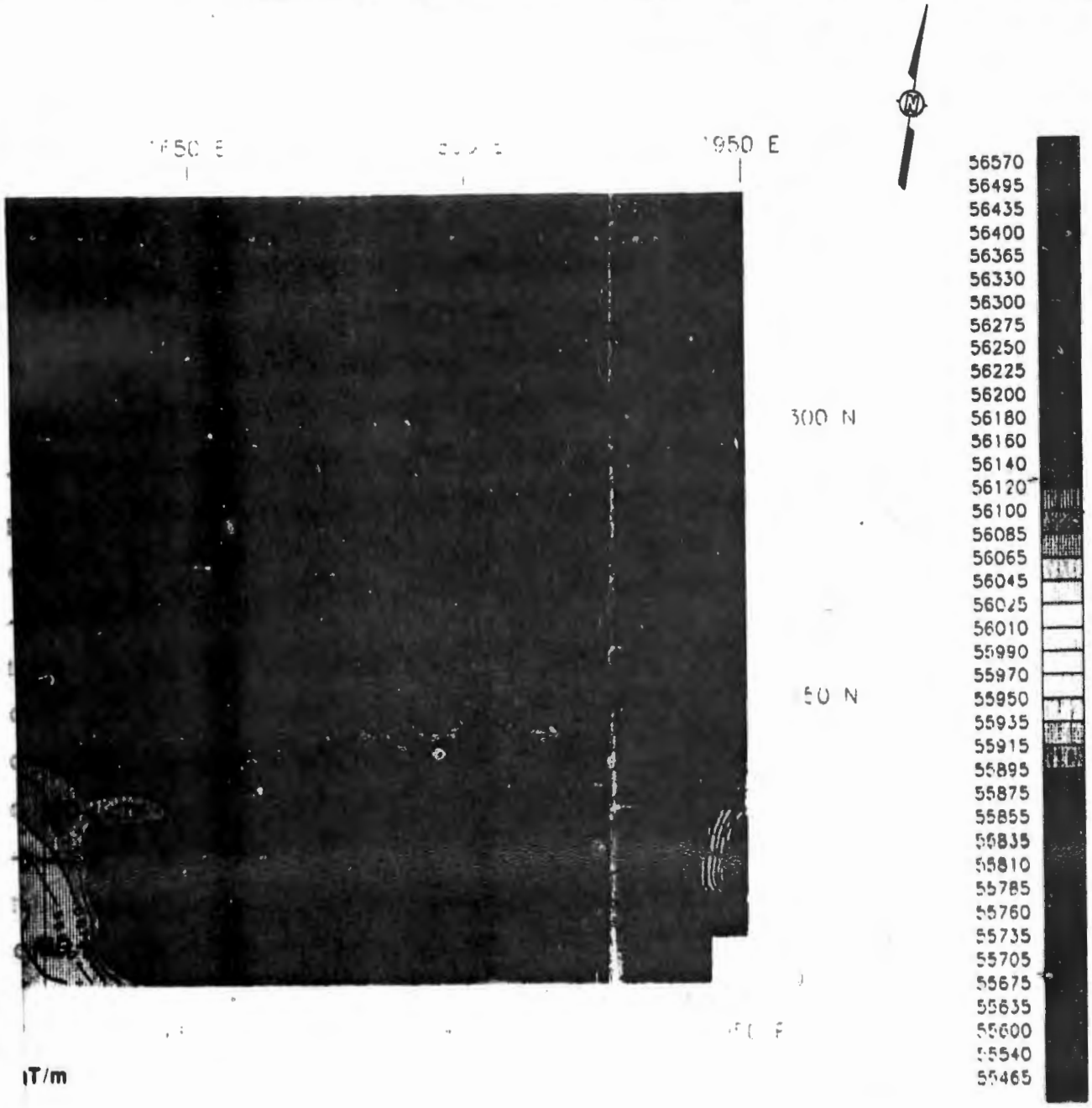

nT/m

FIGURE 24B

CONTOUR MAP OF TOTAL MAGNETIC FIELD

SITE H-06-H (WEST)

SHEET 2 OF 2

WAHLUKE (N) SLOPE

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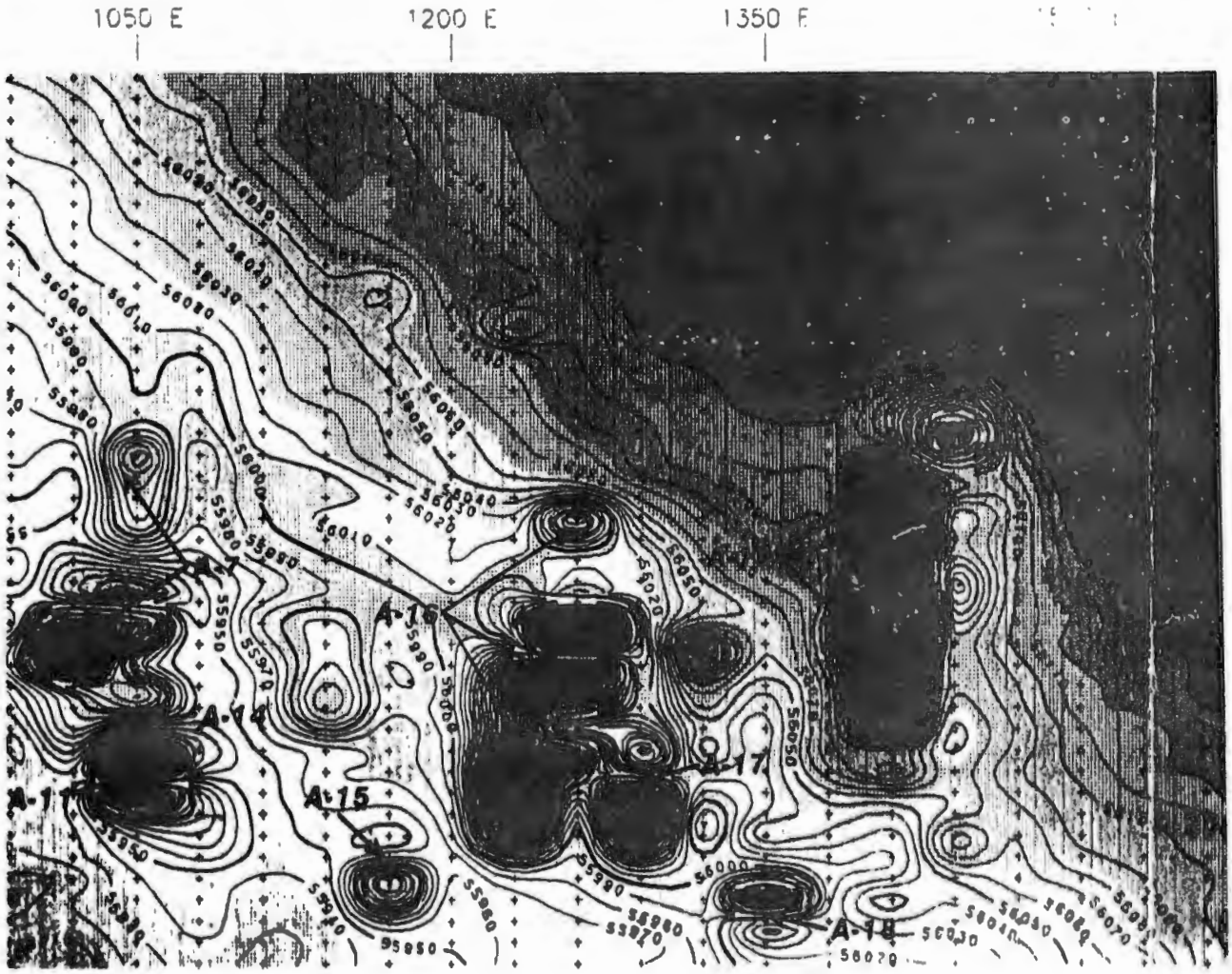

CONTOUR INTERVAL: 10 nT

LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
F	ANOMALY CAUSED BY METALLIC FENCE
MD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 40 80 160FEET

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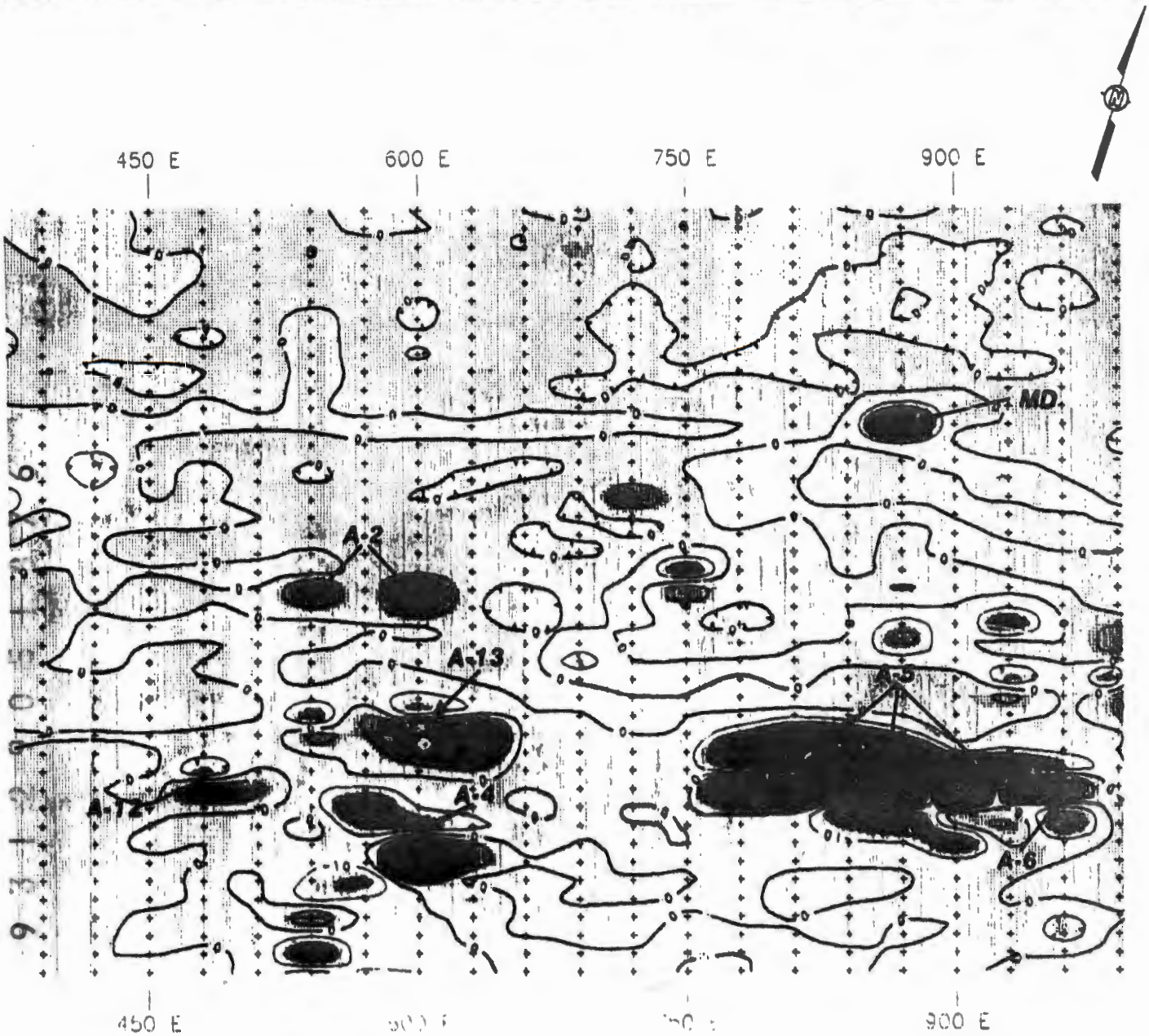

CONTOUR INTERVAL: 10 nT/m

FIGURE 25A

CONTOUR MAP OF
VERTICAL MAGNETIC GRADIENT
SITE H-06-H (WEST)
SHEET 1 OF 2
WAHLUKE (N) SLOPE
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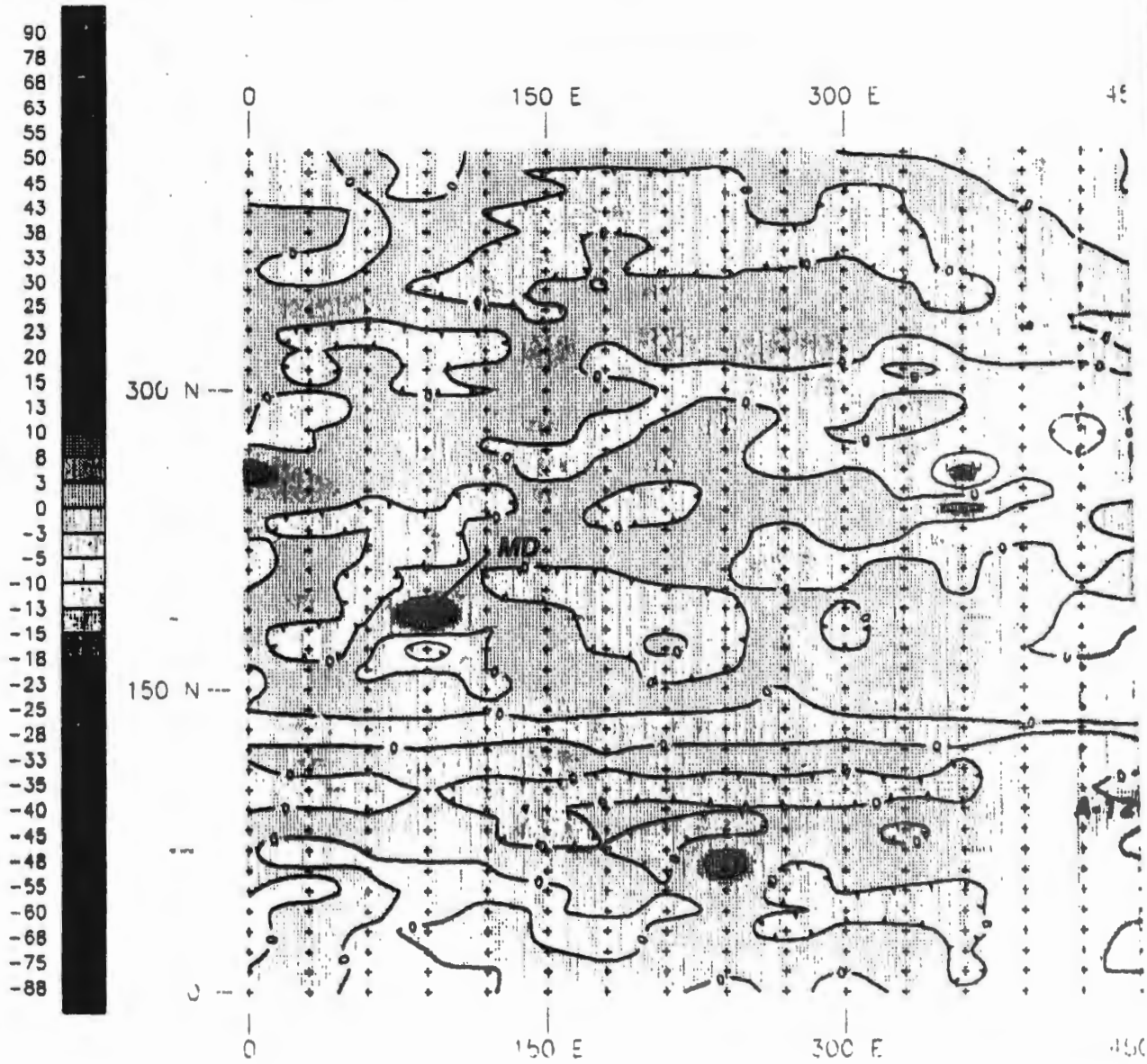

CONTOU

LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
MD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 40 80 160FEET

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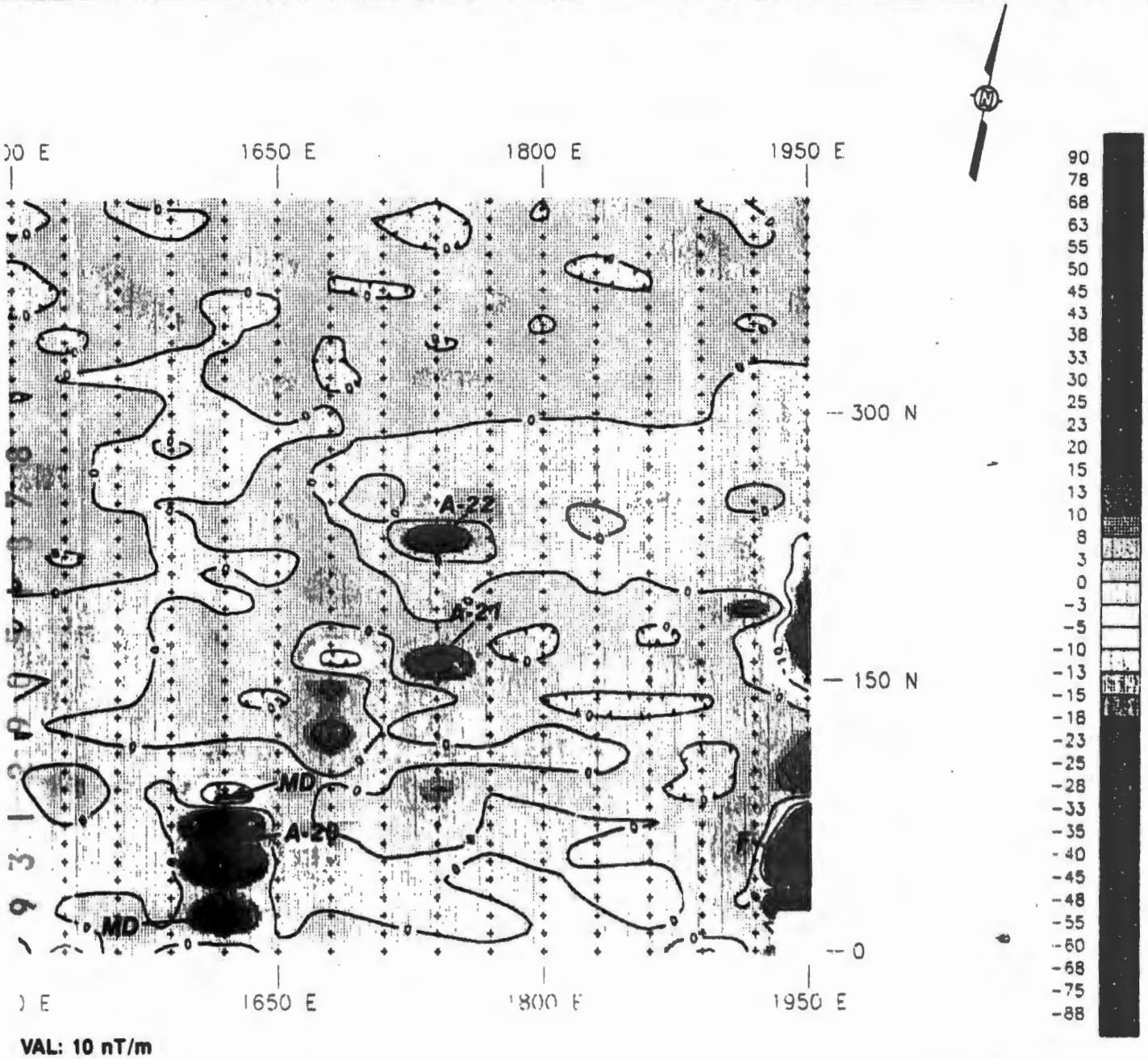

VAL: 10 nT/m

FIGURE 25B
CONTOUR MAP OF
VERTICAL MAGNETIC GRADIENT
SITE H-06-H (WEST)
SHEET 2 OF 2
WAHLUKE (N) SLOPE
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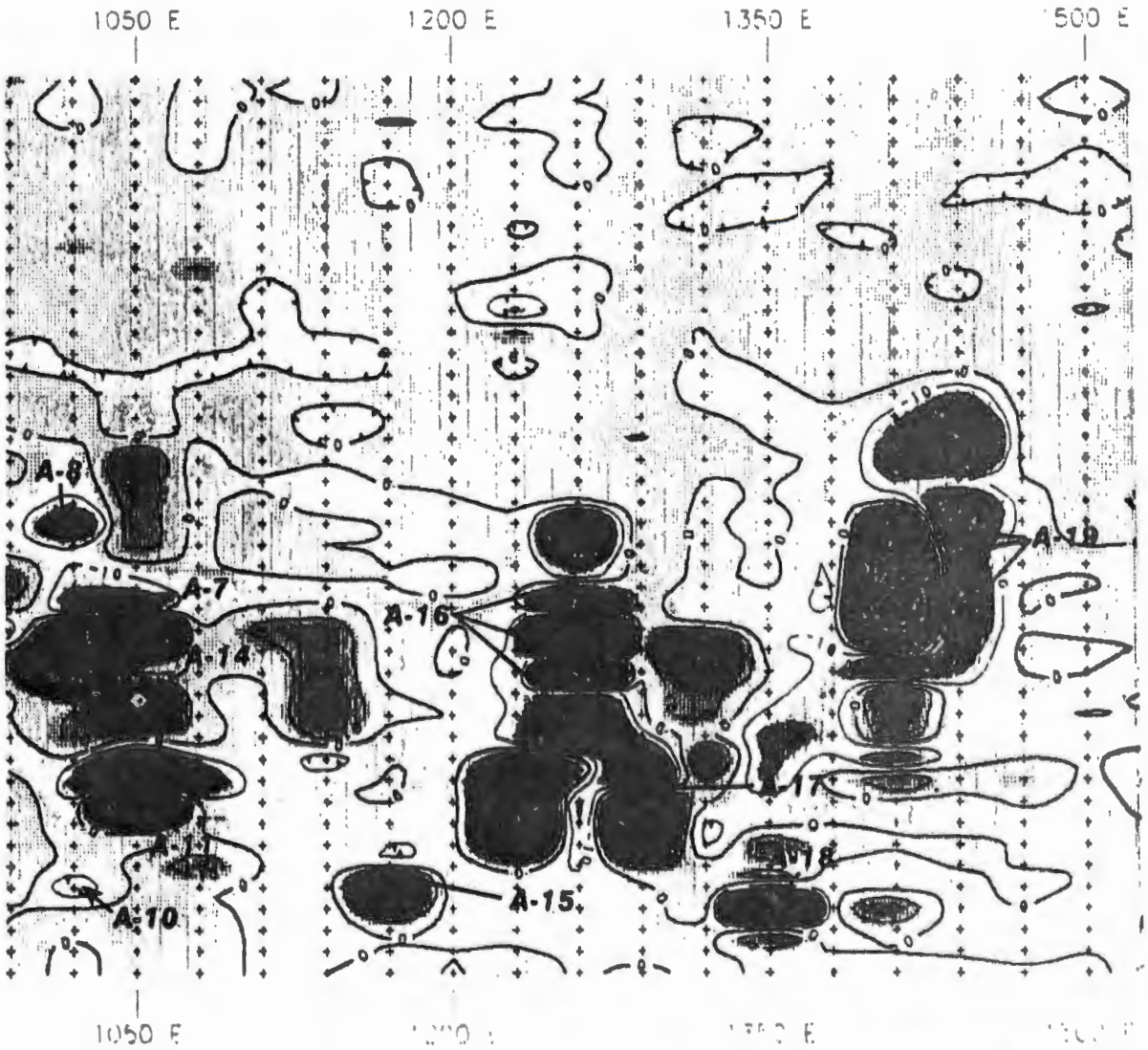

CONTOUR INTERVAL

LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
F	ANOMALY CAUSED BY METALLIC FENCE
MD	ANOMALY CAUSED BY METALLIC SURFACE DEBRI

SCALE

0 40 80 160FEET

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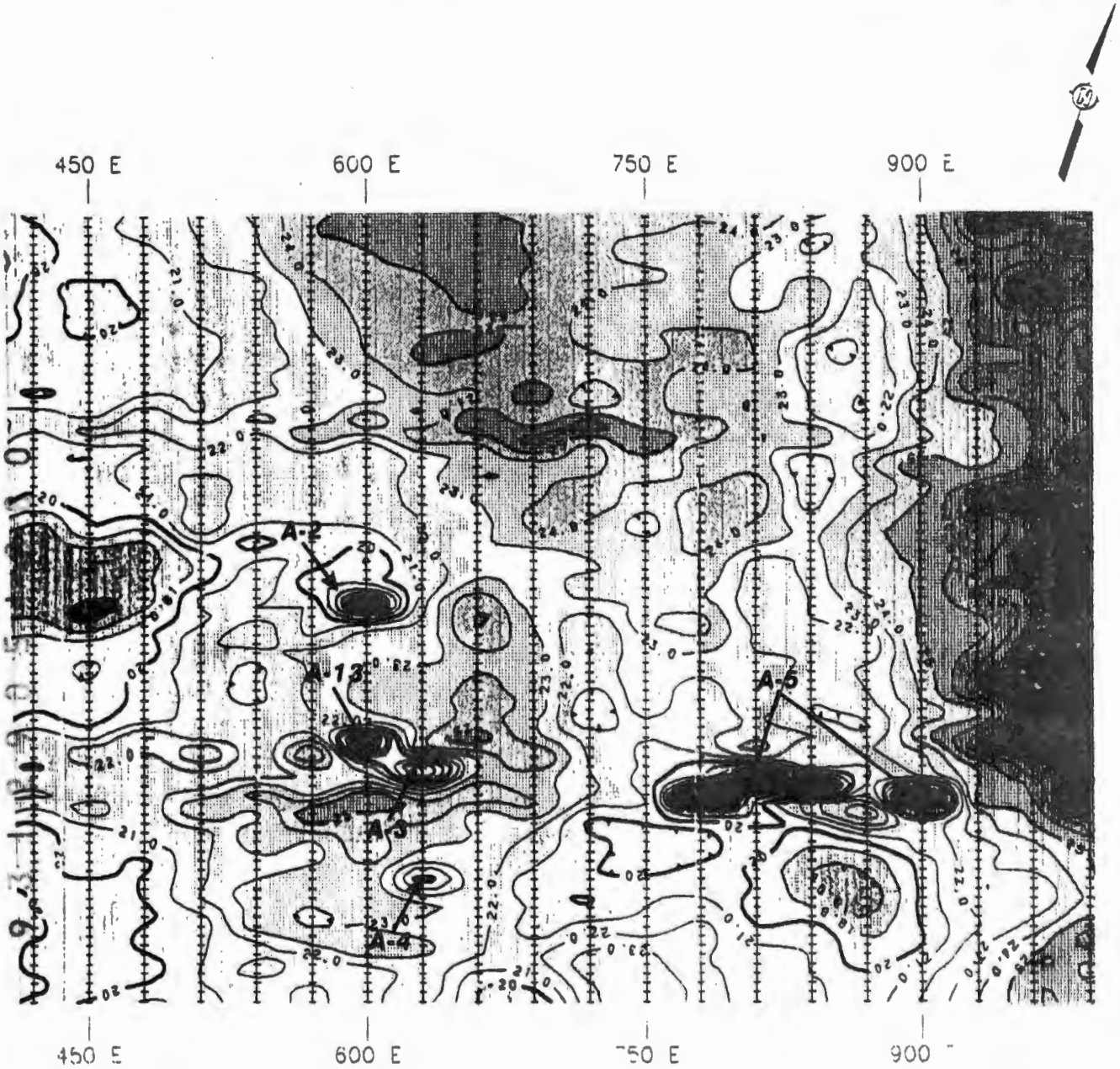

CONTOUR INTERVAL: 1 mS/m

ISSED IN TEXT

FIGURE 26A

CONTOUR MAP OF CONDUCTIVITY
SITE H-06-H (WEST)
SOUTH-NORTH SURVEY LINES
SHEET 1 OF 2
WAHLUKE (N) SLOPE
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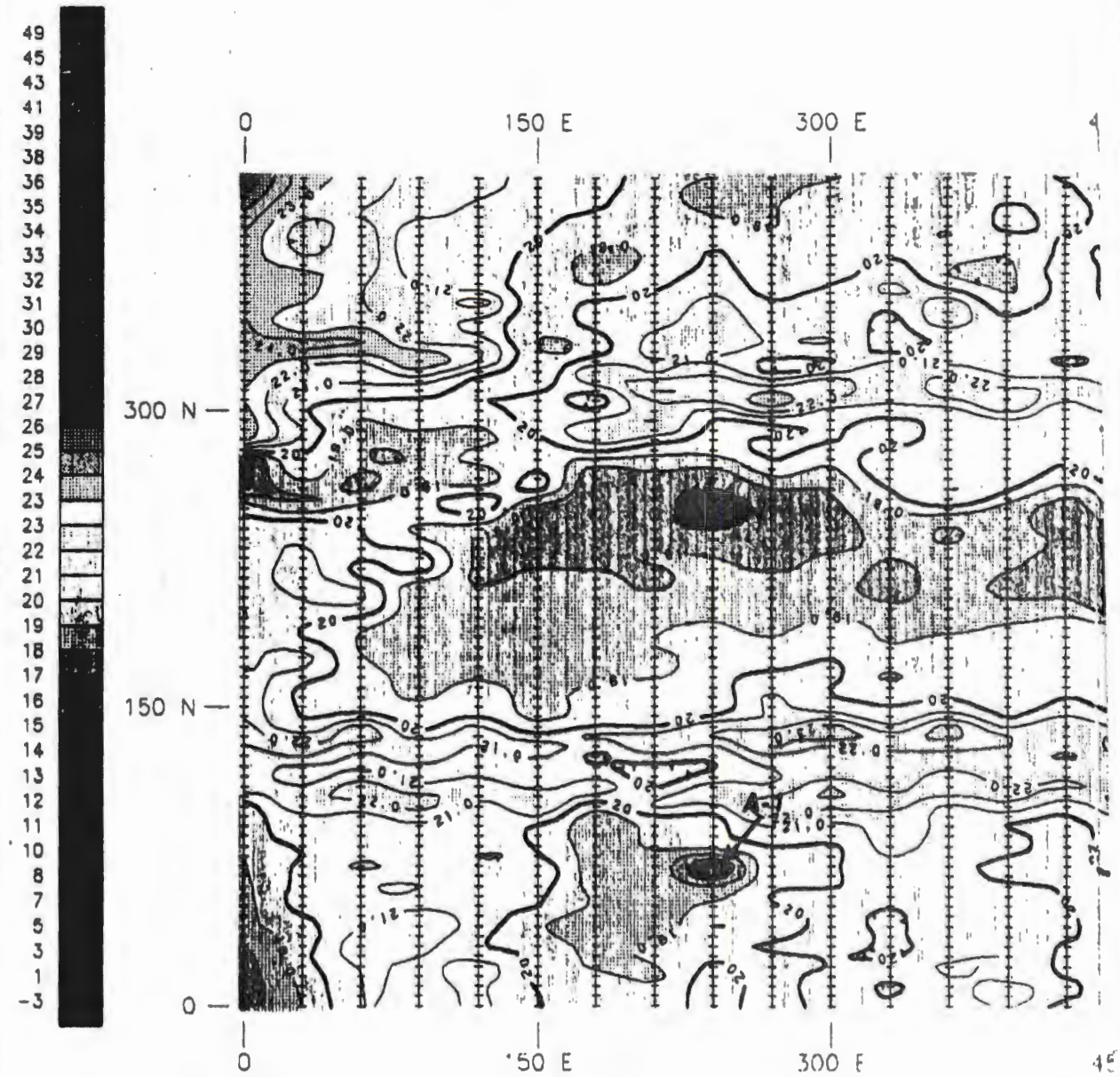

CONTOL

LEGEND:

GEONICS EM-31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED

SCALE

0 80 160FEET

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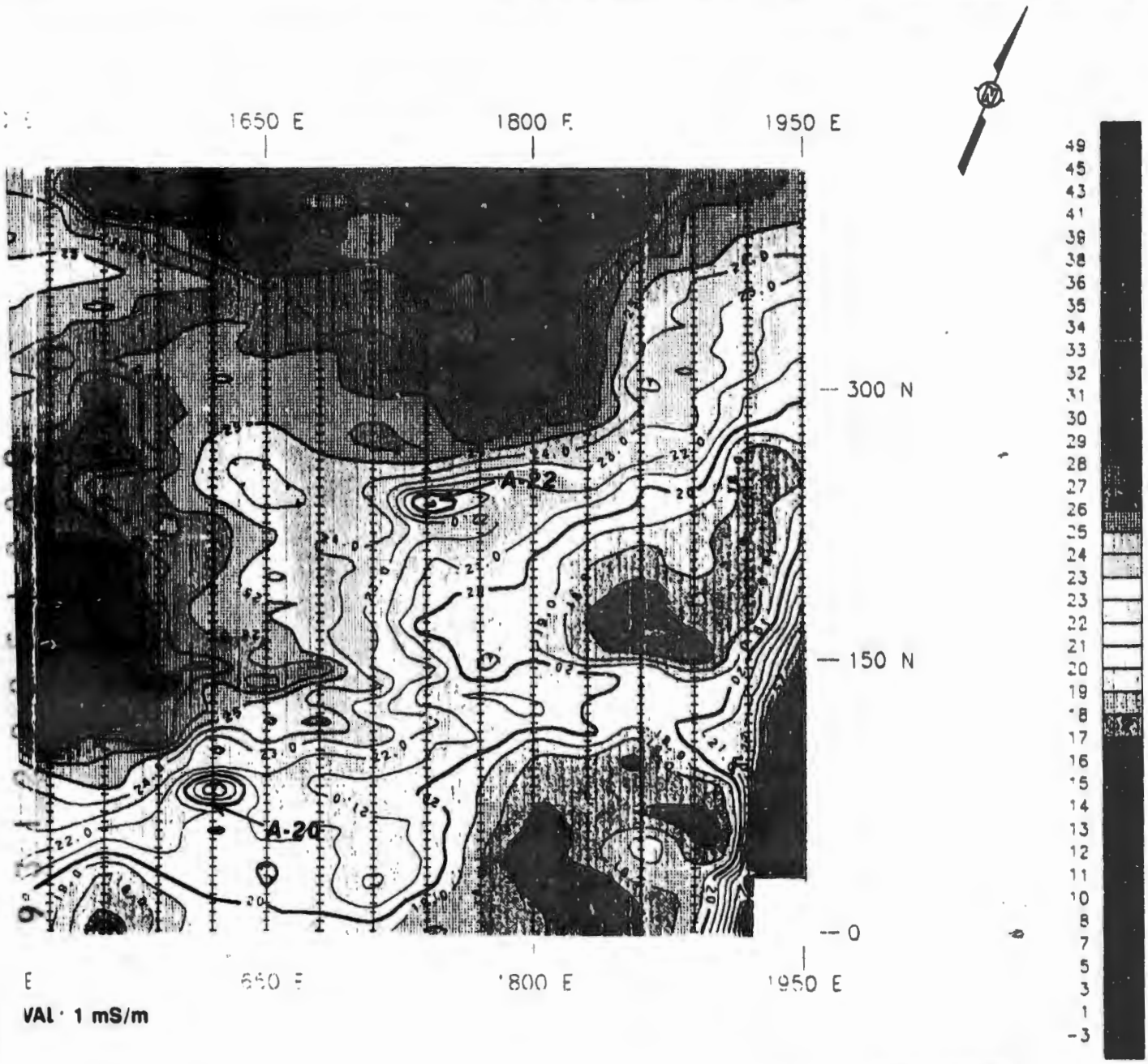

VAL · 1 mS/m

FIGURE 26B
CONTOUR MAP OF CONDUCTIVITY
SITE H-06-H (WEST)
SOUTH-NORTH SURVEY LINES
SHEET 2 OF 2
WAHLUKE (N) SLOPE
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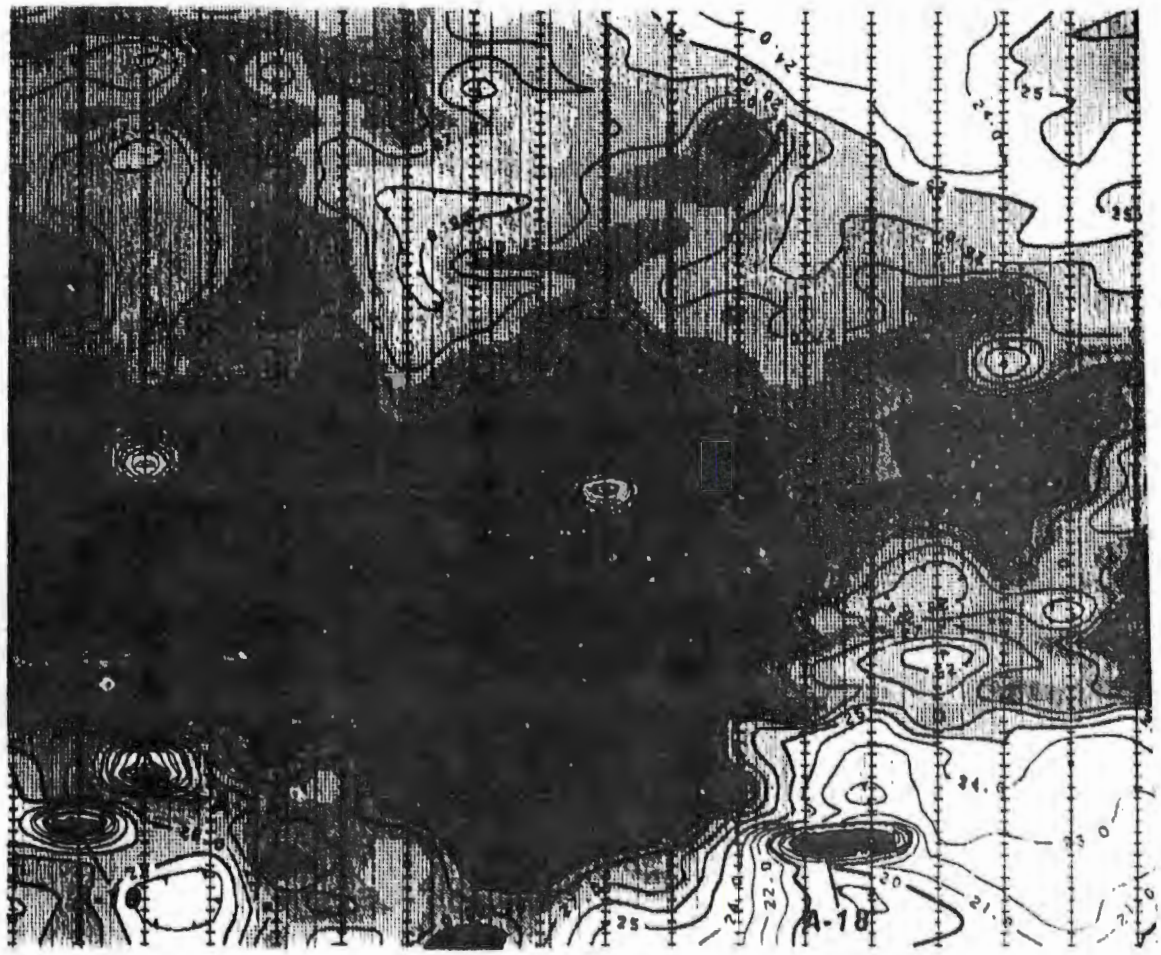

CONTOUR INTE

LEGEND:

-+-+-+-	GEONICS EM 31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN
F	ANOMALY CAUSED BY METALLIC FENC

SCALE

0 80 160 FEET

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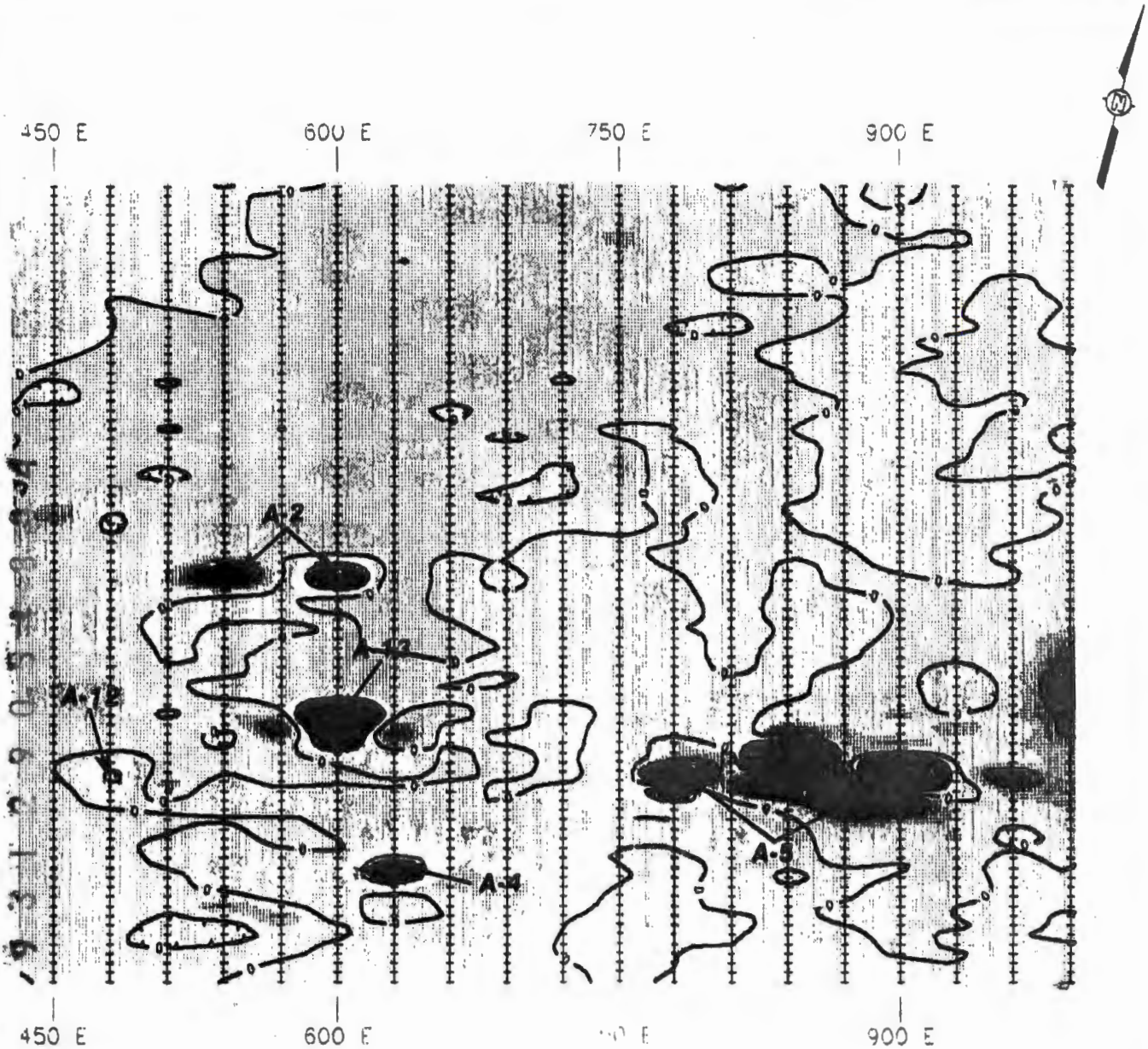

INTERVAL: 0.5ppt

FIGURE 27A

CONTOUR MAP OF IN-PHASE COMPONENT

SITE H-06-H (WEST)

SOUTH-NORTH SURVEY LINES

SHEET 1 OF 2

WAHLUKE (N) SLOPE

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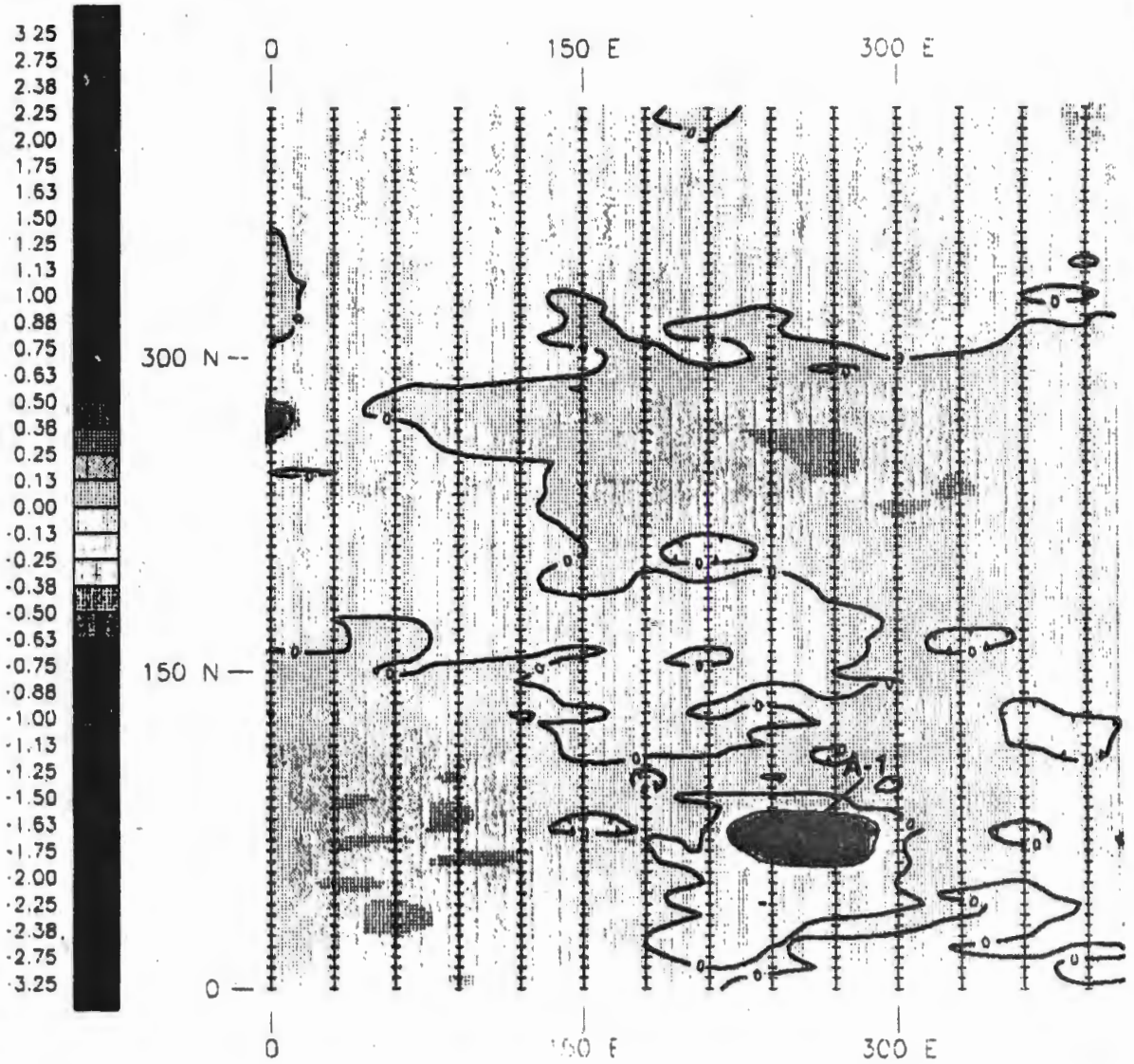

CONT

LEGEND:

GEONICS EM 31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED

SCALE

0 40 80 160FEET

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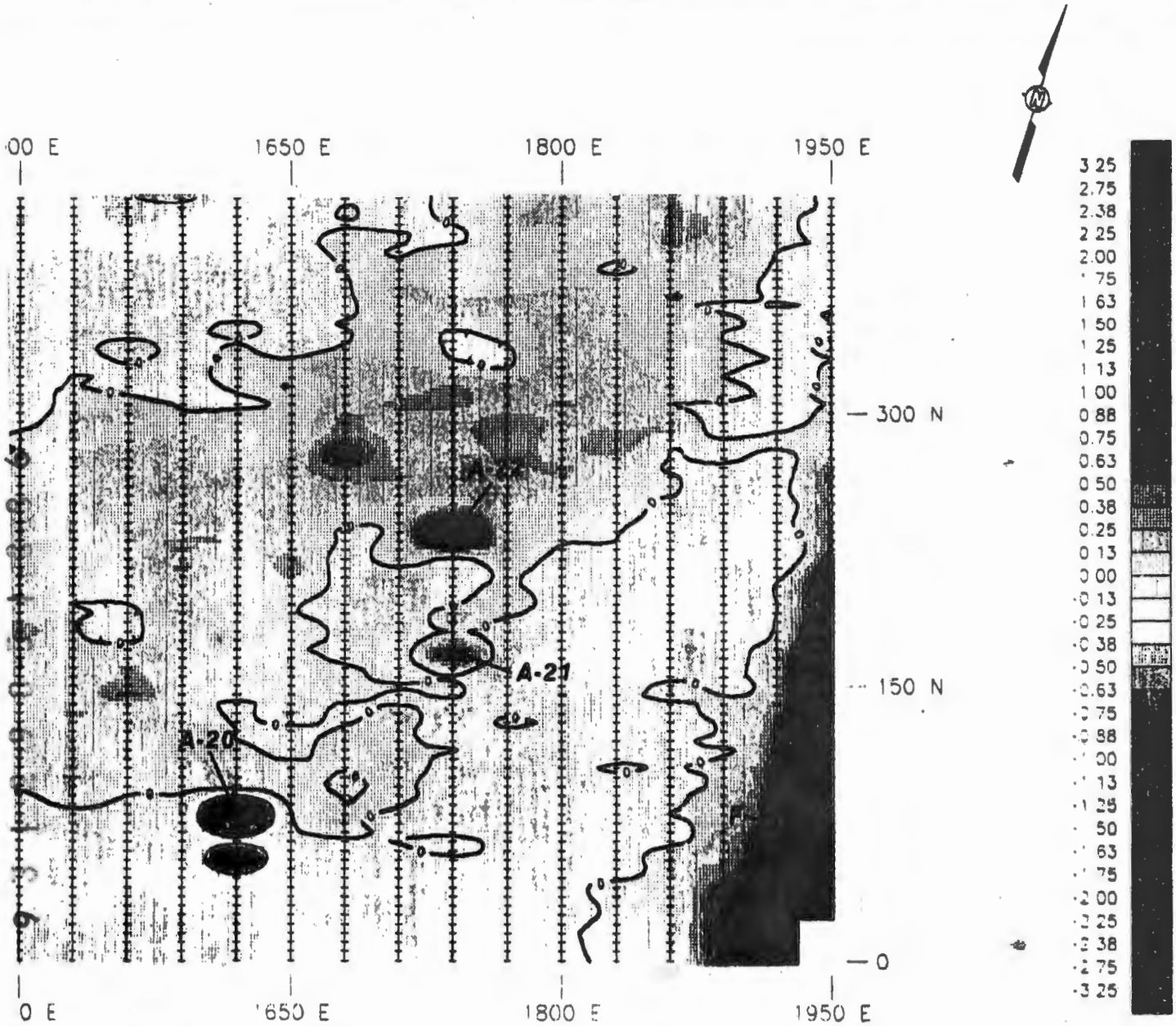

NTERVAL: 0.5ppt

FIGURE 27B

CONTOUR MAP OF IN-PHASE COMPONENT
SITE H-06-H (WEST)
SOUTH-NORTH SURVEY LINES
SHEET 2 OF 2
WAHLUKE (N) SLOPE
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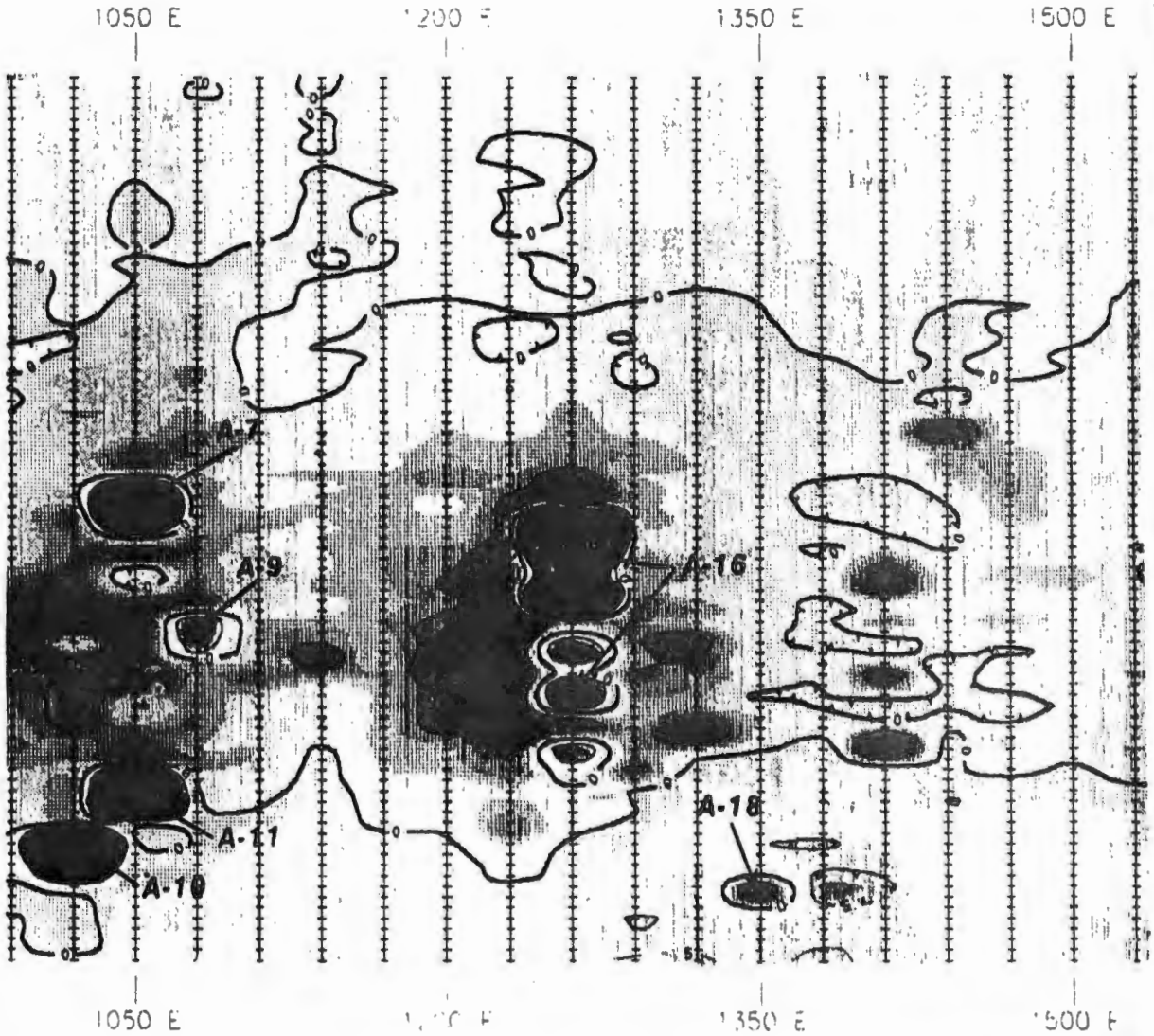

CONTOUR INTERVA

LEGEND:

⊢+⊣	GEONICS EM-31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TE
F	ANOMALY CAUSED BY METALLIC FENCE

SCALE

0 40 80 160FEET

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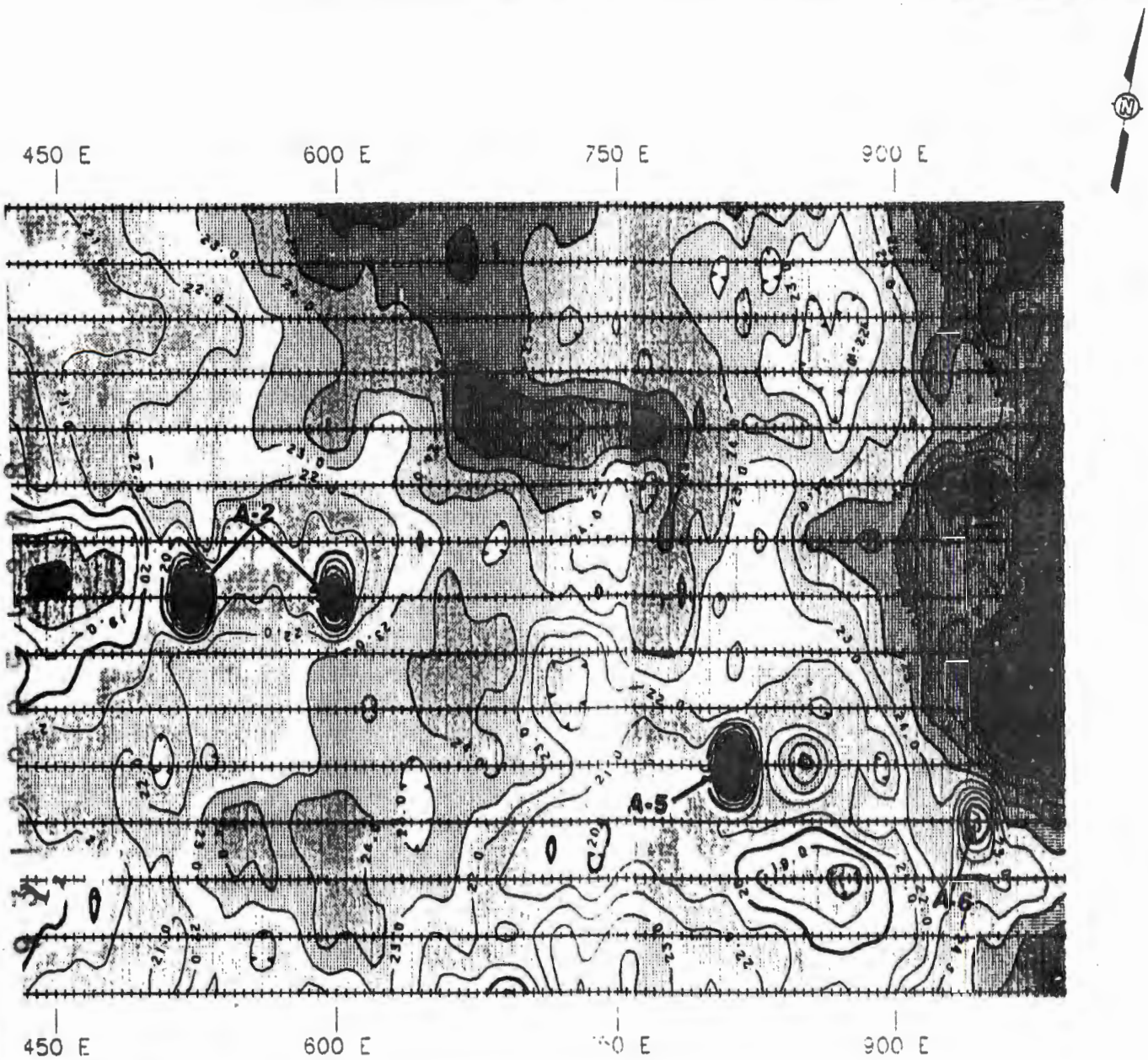

ITERVAL: 1 mS/m

FIGURE 28A

CONTOUR MAP OF CONDUCTIVITY

SITE H-06-H (WEST)

WEST-EAST SURVEY LINES

SHEET 1 OF 2

WAHLUKE (N) SLOPE

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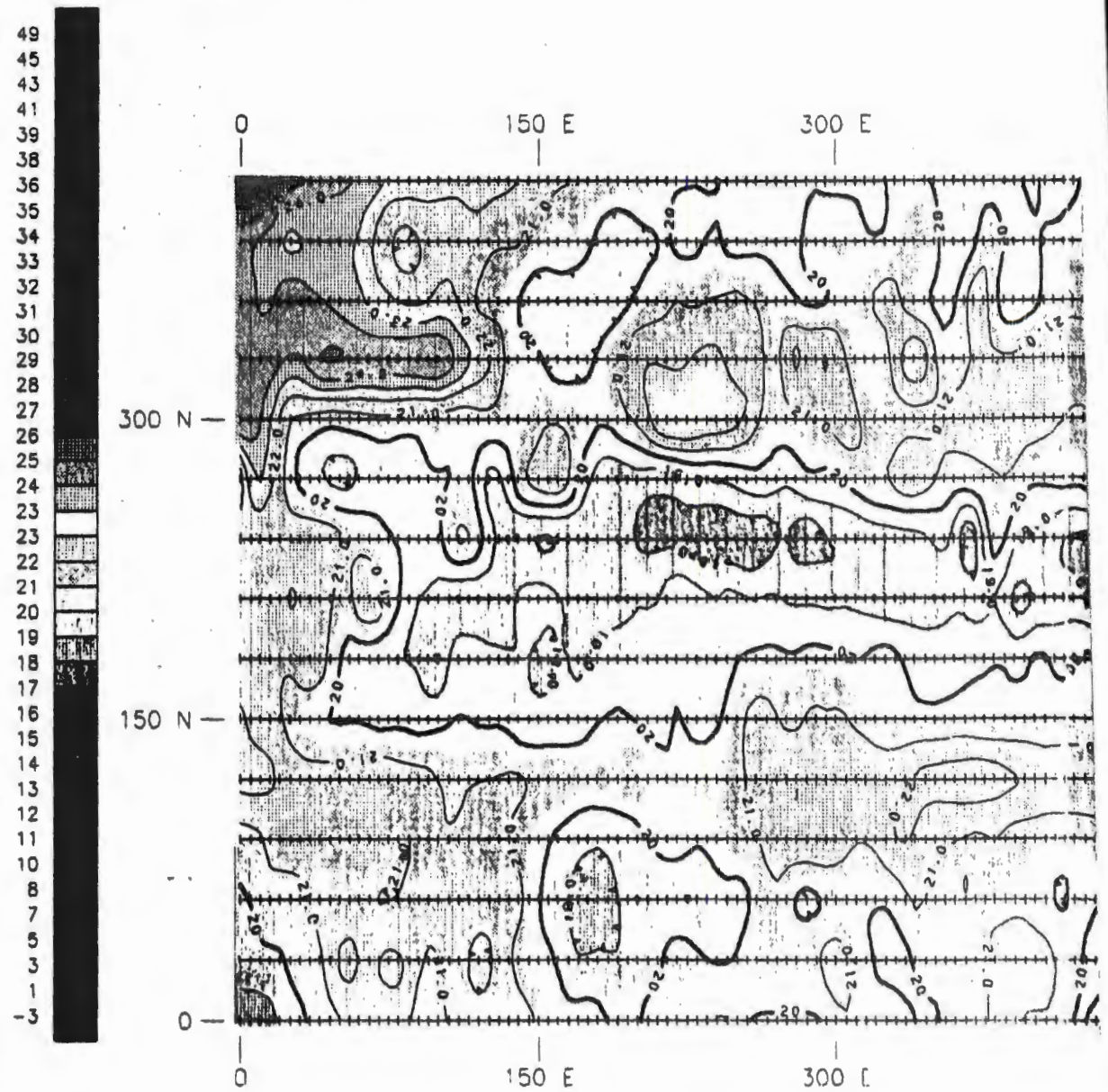

CONTOUR II

LEGEND:

GEONICS EM-31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED IN TEXT

SCALE

0 40 80 160FEET

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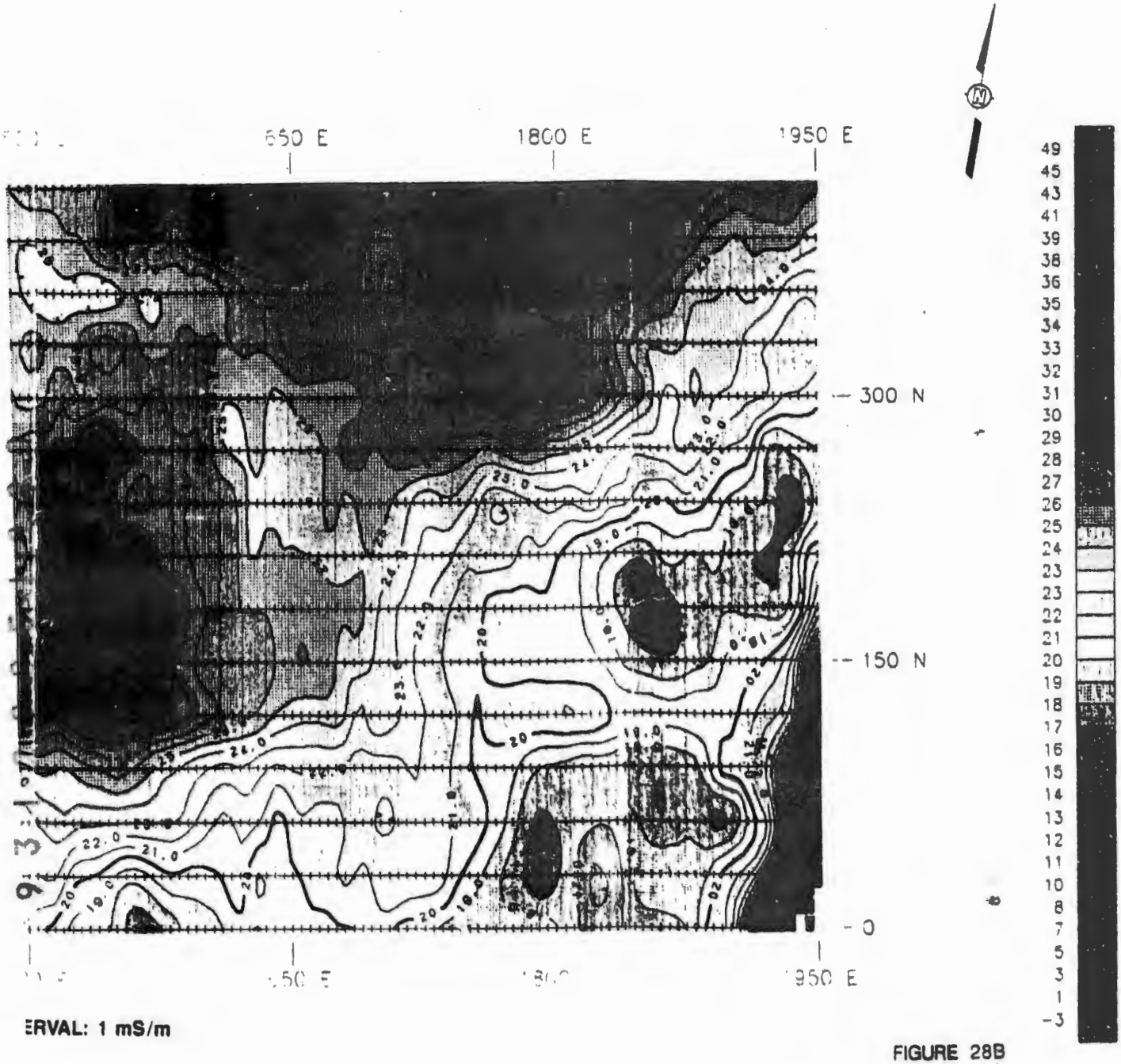

ERVAL: 1 mS/m

FIGURE 28B

CONTOUR CONTOUR MAP OF CONDUCTIVITY
SITE H-06-H (WEST)
WEST-EAST SURVEY LINES
SHEET 2 OF 2
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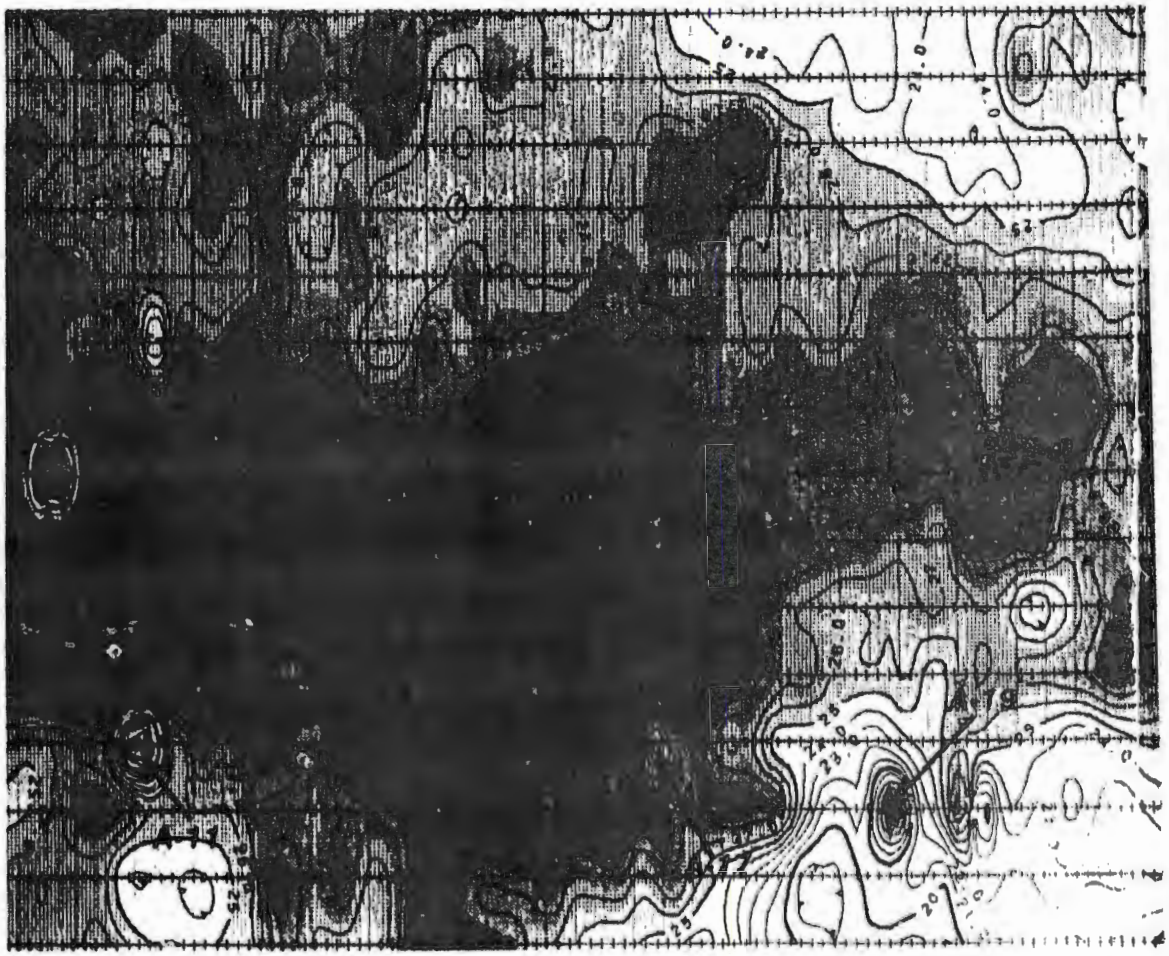

CONTOUR INTERV

LEGEND:

+-+-+-+	GEONICS EM 31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN T
F	ANOMALY CAUSED BY METALLIC FENCE

SCALE

0 10 80 160 FEET

067400

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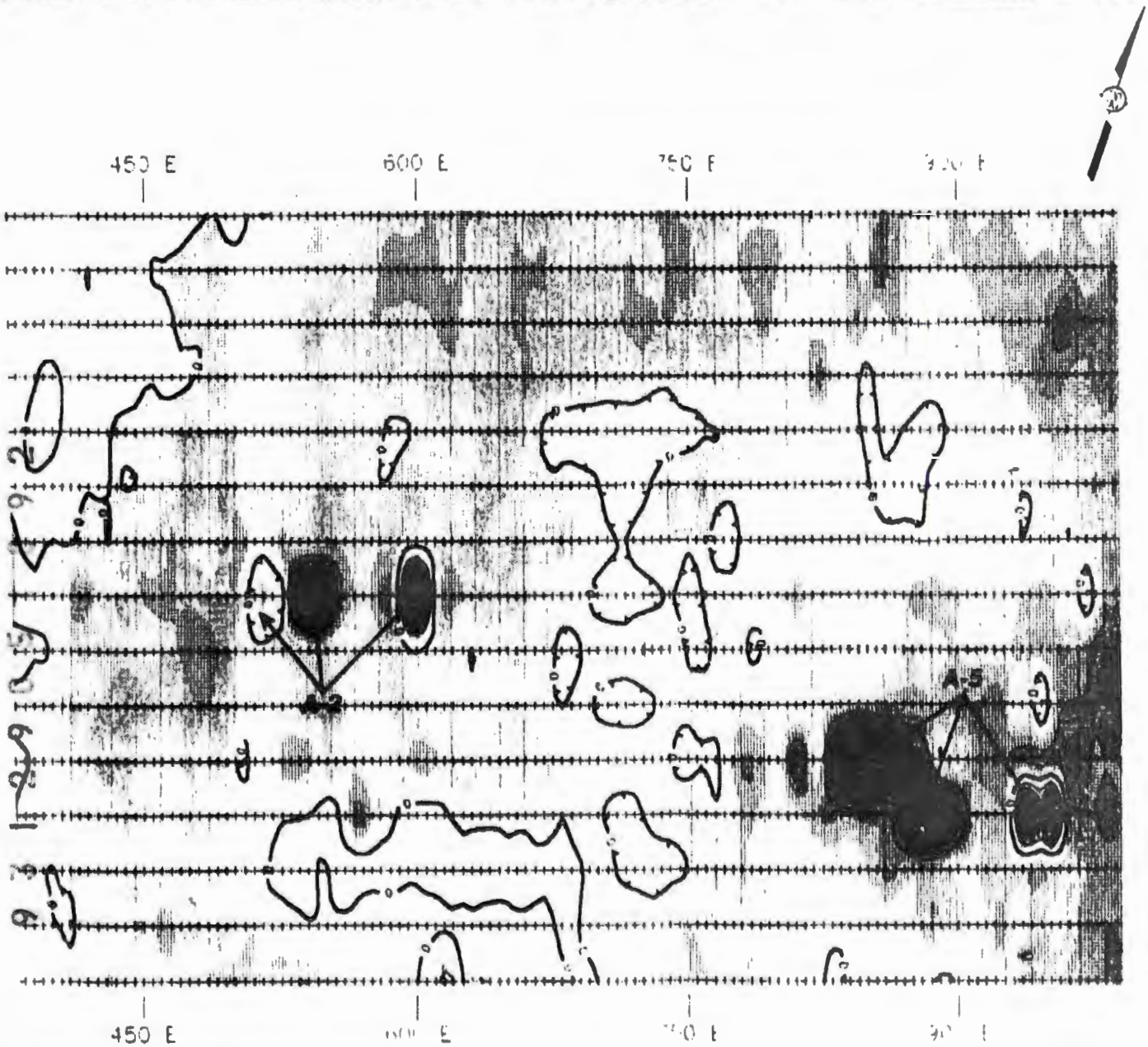

CONTOUR INTERVAL : 0.5ppt

FIGURE 29A
CONTOUR MAP OF IN-PHASE COMPONENT
SITE H-06-H (WEST)
WEST-EAST SURVEY LINES
SHEET 1 OF 2
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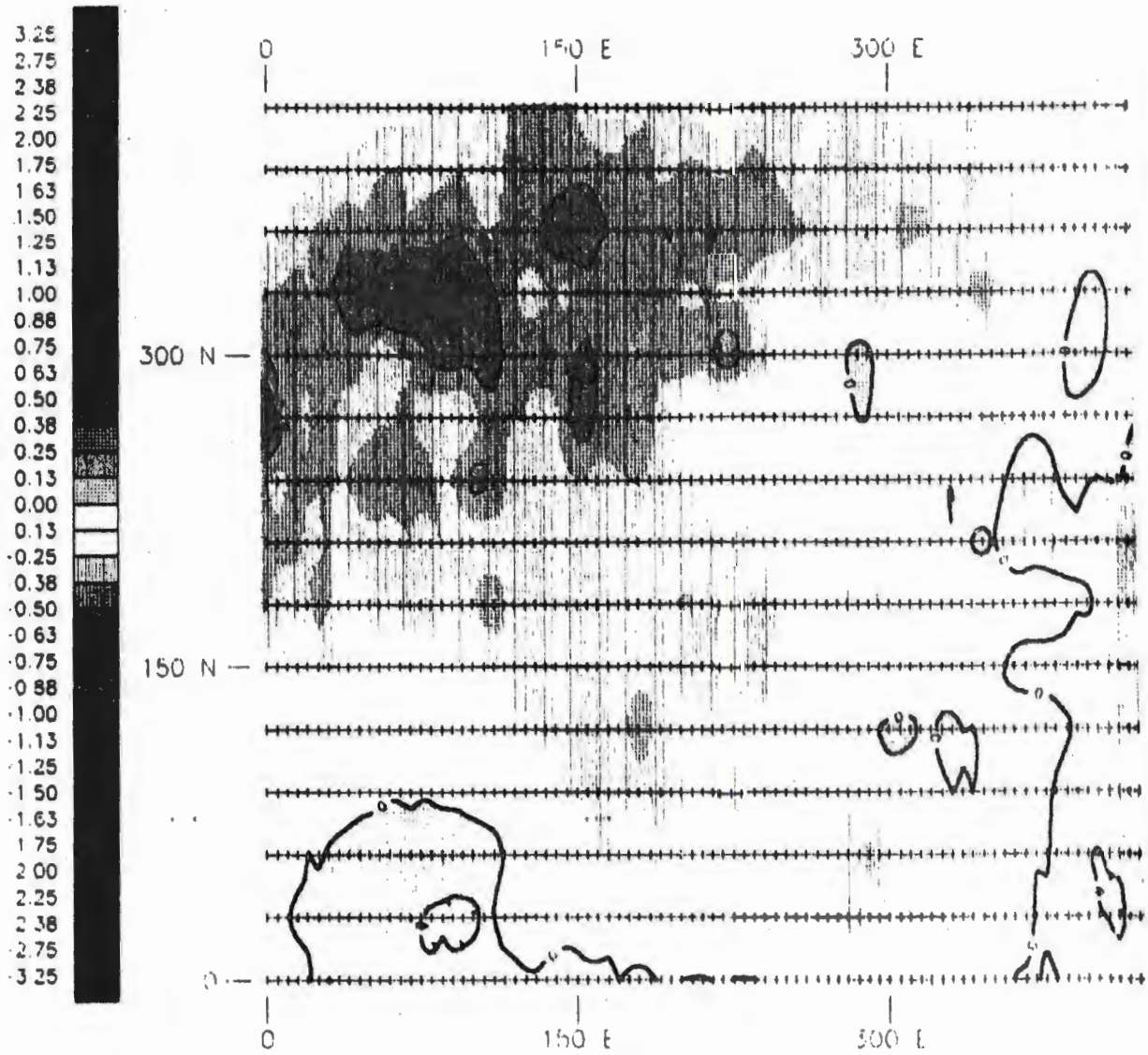

CONTOI

LEGEND:

GEONICS EM-31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED IN TEXT

SCALE

0 40 80 160FEET

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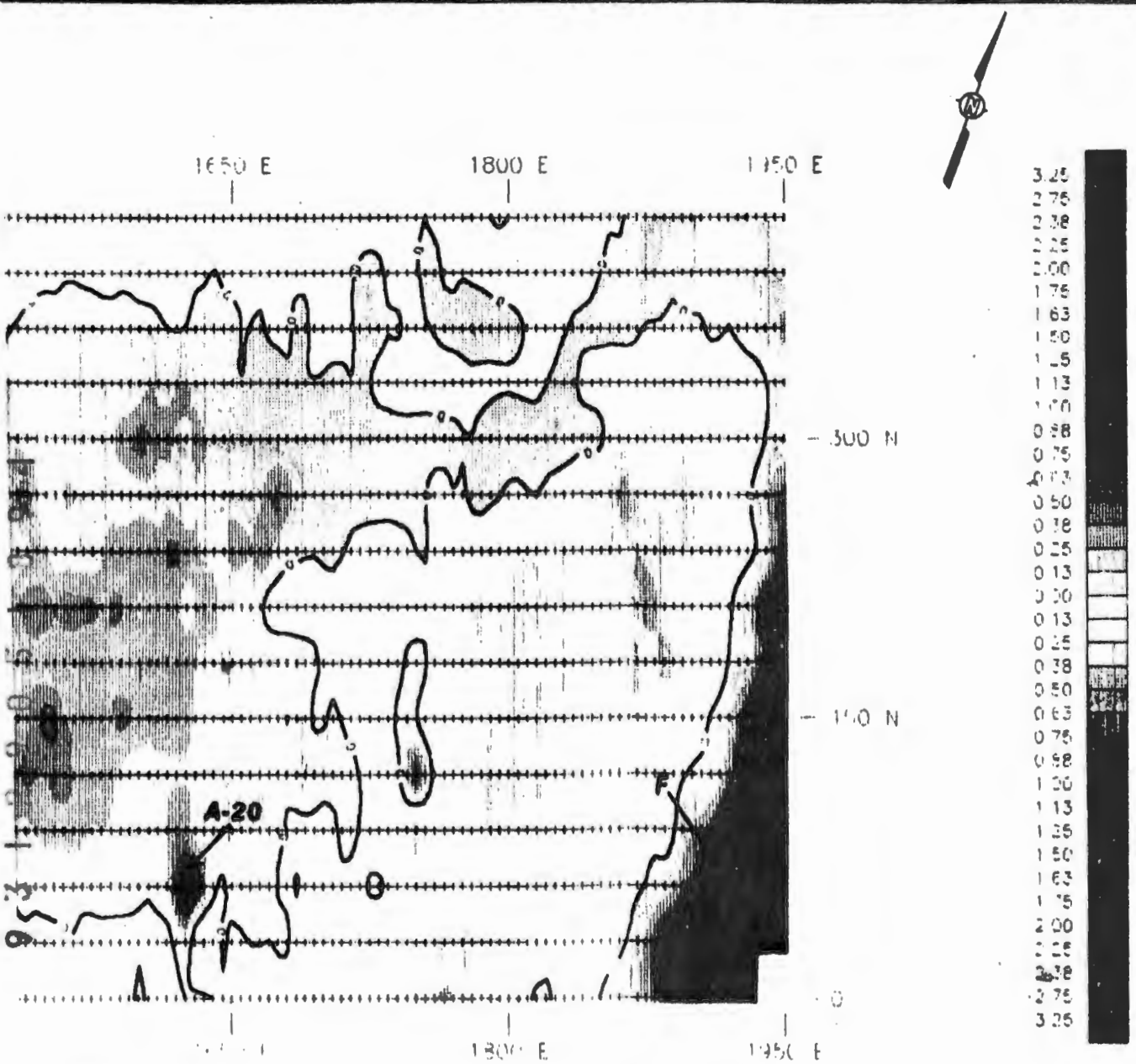

iL: 0.5ppt

FIGURE 29B

CONTOUR MAP OF IN-PHASE COMPONENT

SITE H-06-H (WEST)

WEST-EAST SURVEY LINES

SHEET 2 OF 2

WAHLUKE (N) SLOPE

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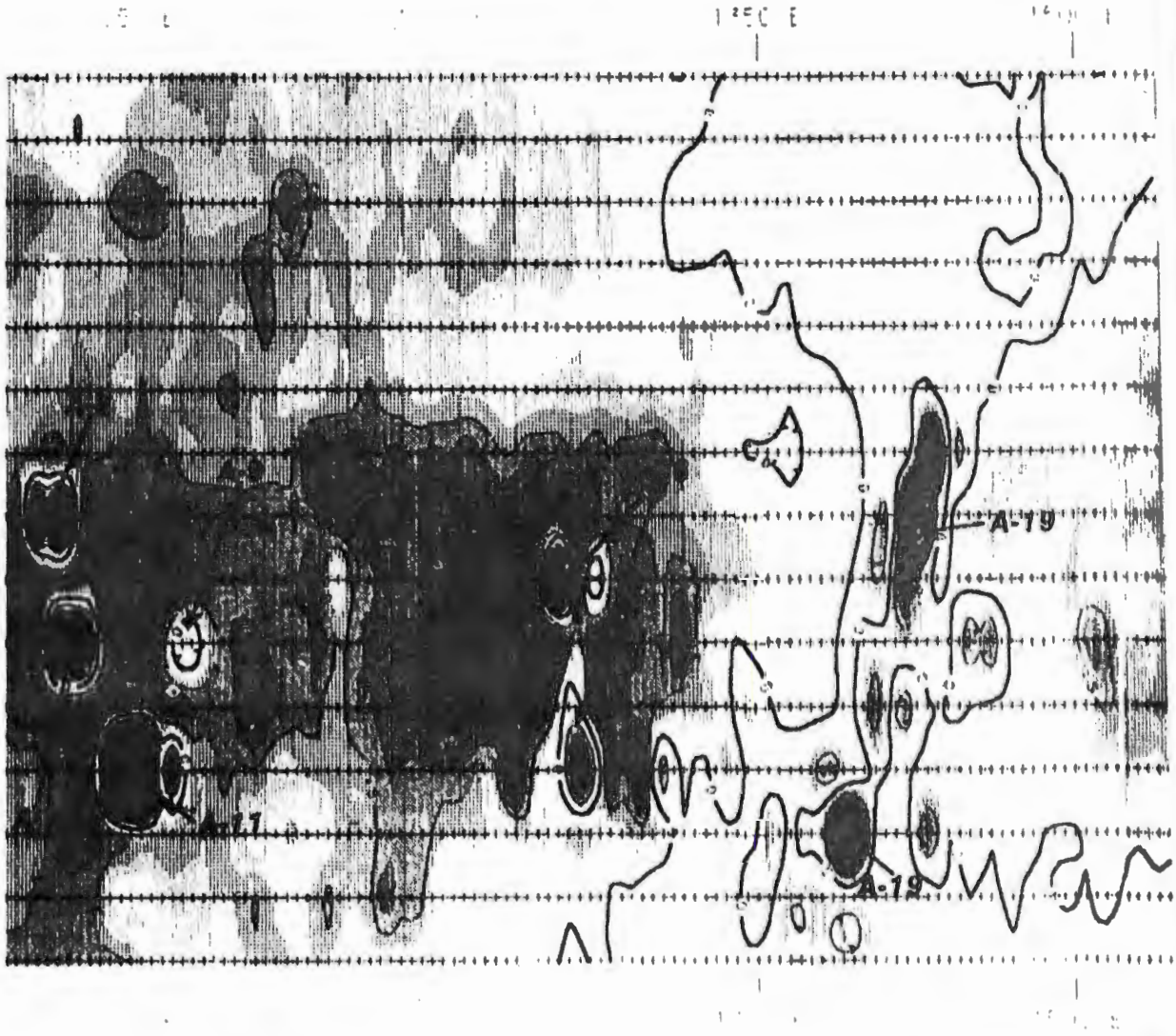
	9-2-92	APPROVED BY			



CONTOUR INTERVAL

LEGEND:

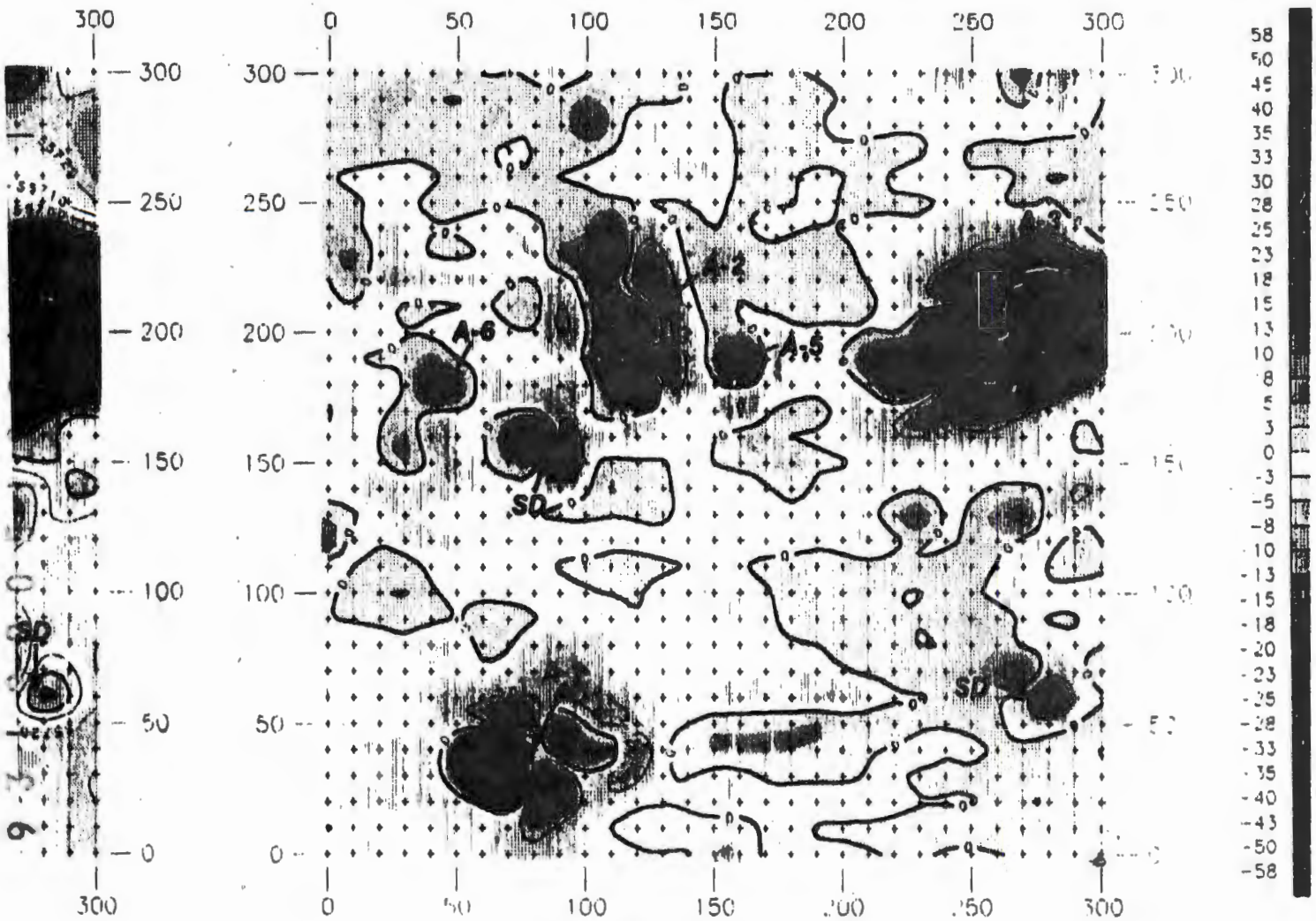
⊢+⊣	GEONICS FM-31 SURVEY LINE
A-1	GEOPHYSICAL ANOMALY DISCUSSED IN TEXT
F	ANOMALY CAUSED BY METALLIC FENCE

SCALE

0 40 80 160FEET

Do Not Scale This Drawing

VERTICAL MAGNETIC GRADIENT



CONTOUR INTERVAL: 10 nT/m

FIGURE 30

CONTOUR MAPS OF MAGNETIC DAT/
SITE H-83-L
WAHLUKE (N) SLOPE
PREPARED FOR

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RICHLAND, WASHINGTON

INTERNATIONAL TECHNOLOGY CORPORATION

) IN TEXT

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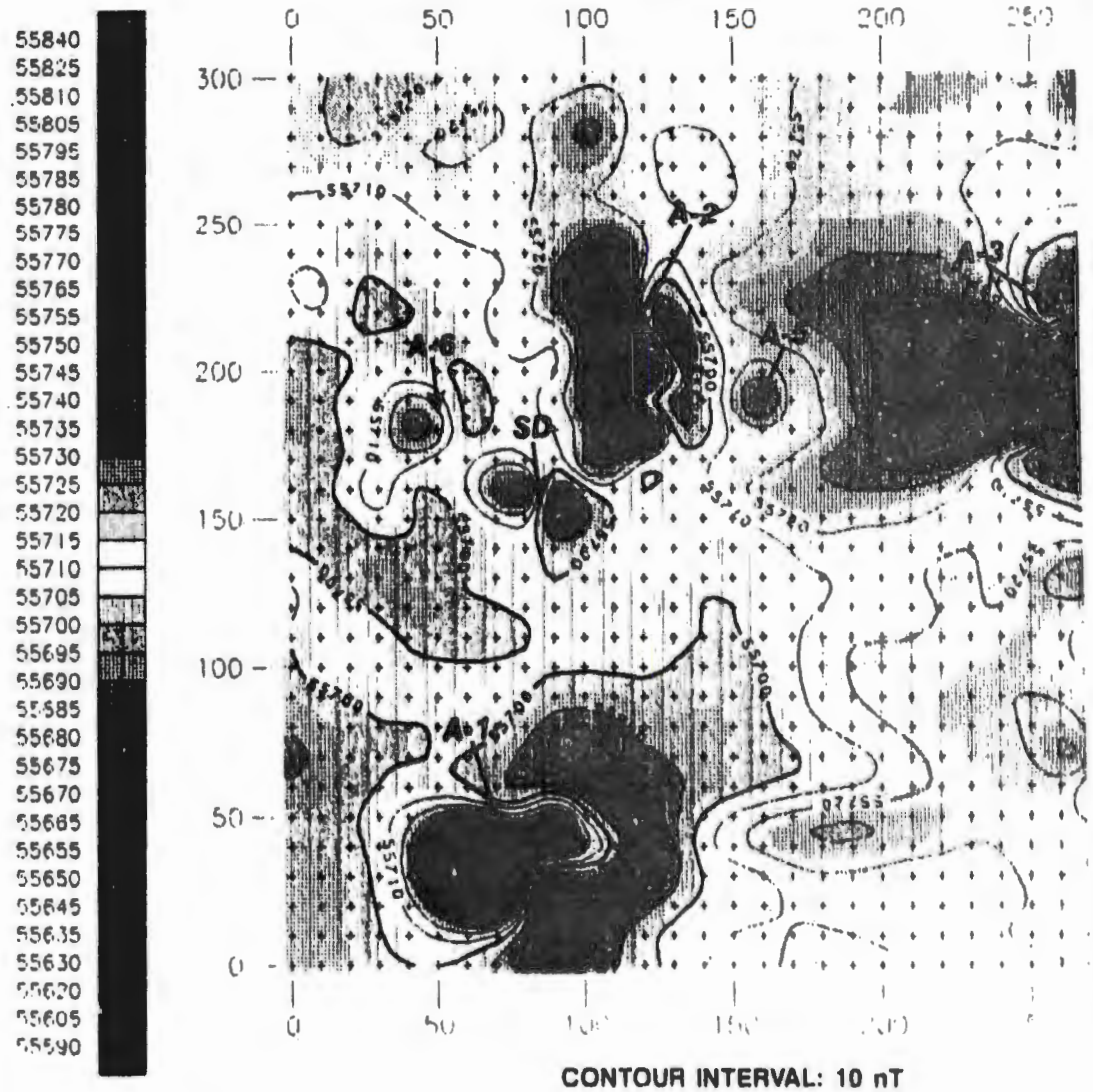
TOTAL MAGNETIC FIELD



CONTOUR INTERVAL: 10 nT

LEGEND:

+	MAGNETIC SURVEY STATION
A-1	GEOPHYSICAL ANOMALY DISCUSSE
SD	ANOMALY CAUSED BY METALLIC SURFACE DEBRIS

SCALE

0 30 60 120FEET

Do Not Scale This Drawing

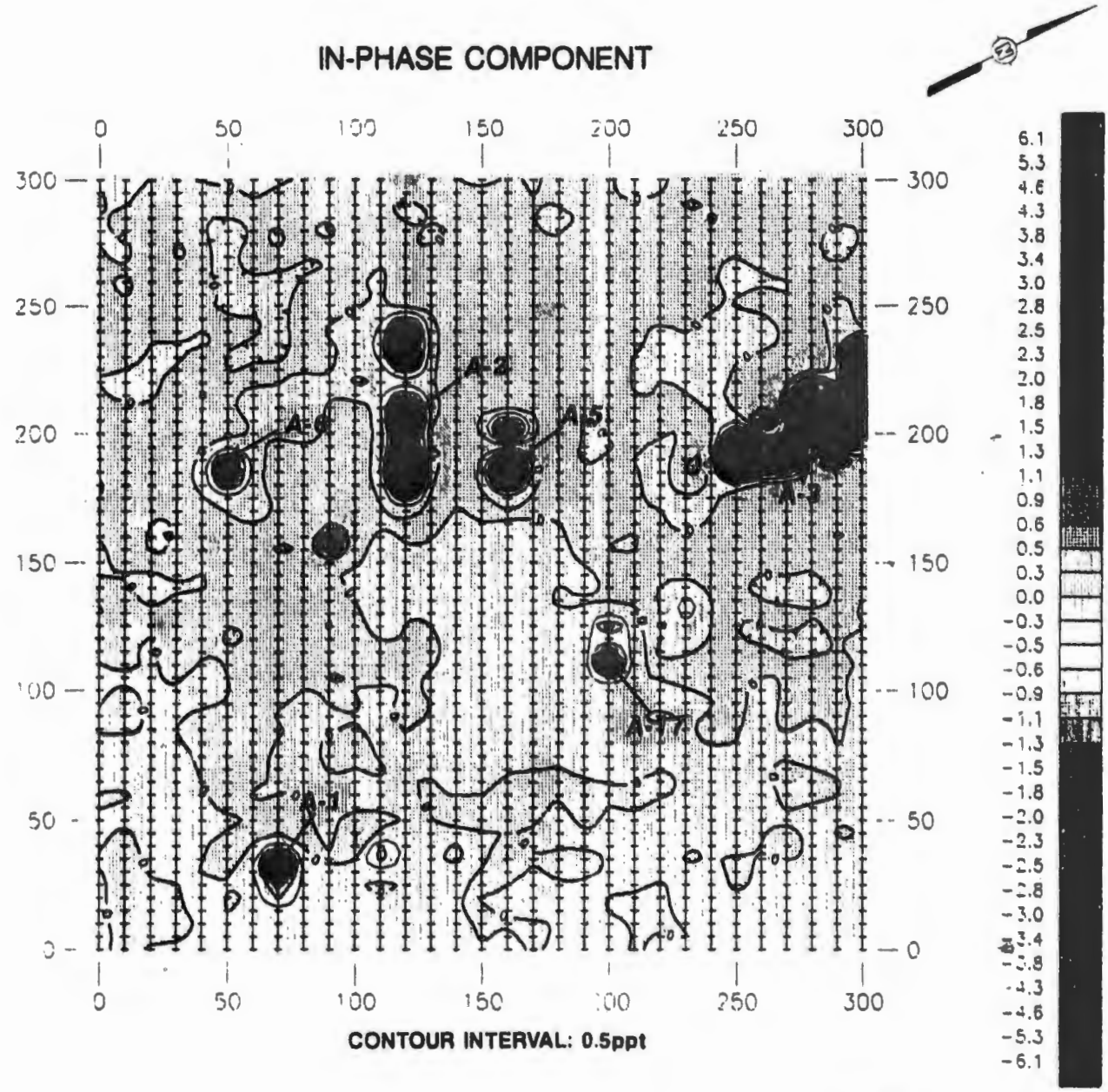


FIGURE 31

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE H-83-L
SOUTHEAST-NORTHWEST SURVEY LINES
WAHLUKE (N) SLOPE

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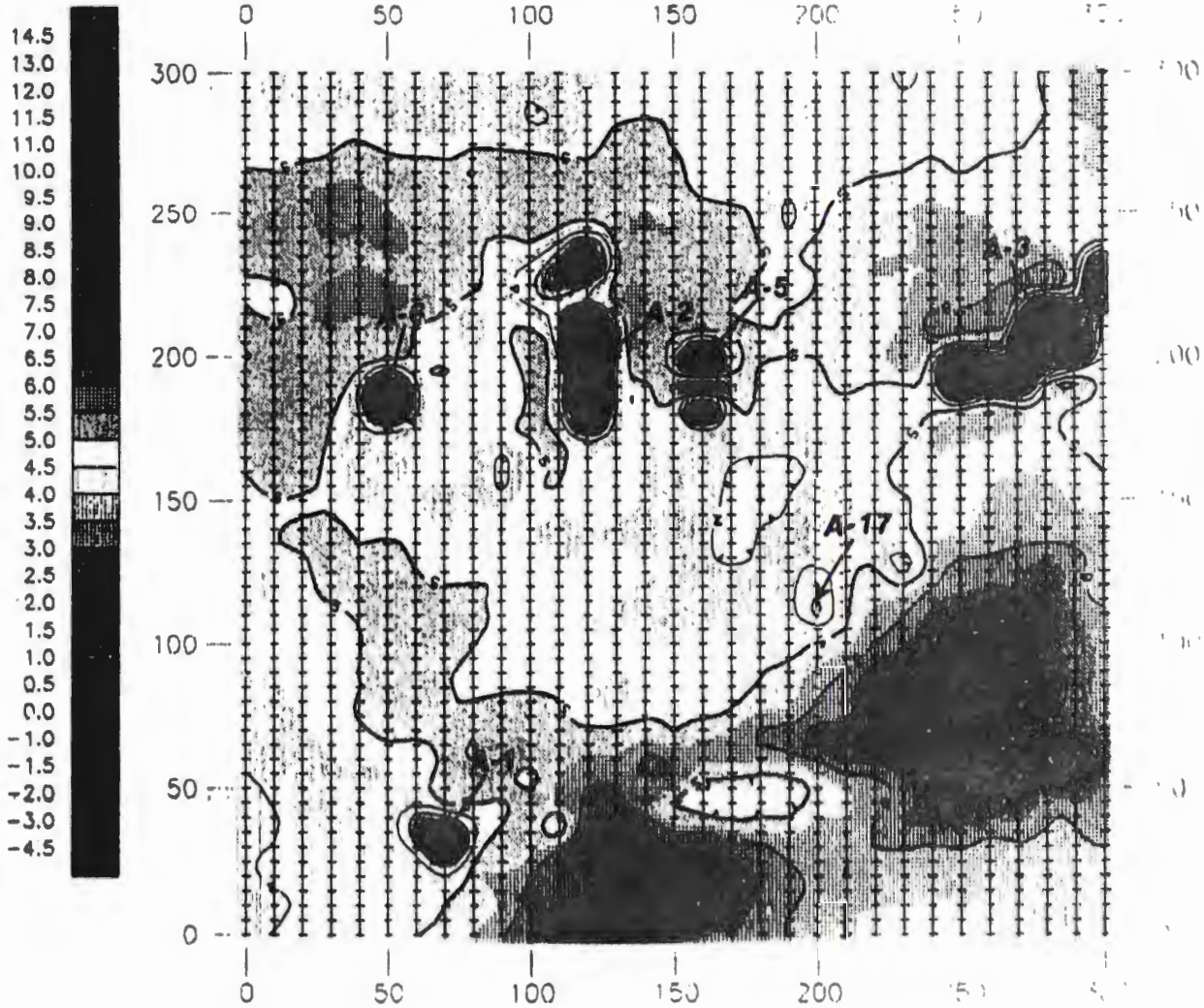
	9-2-92	APPROVED BY			

CONDUCTIVITY



CONTOUR INTERVAL: 1 mS/m

LEGEND:

GEONICS EM 31 SURVEY LINE

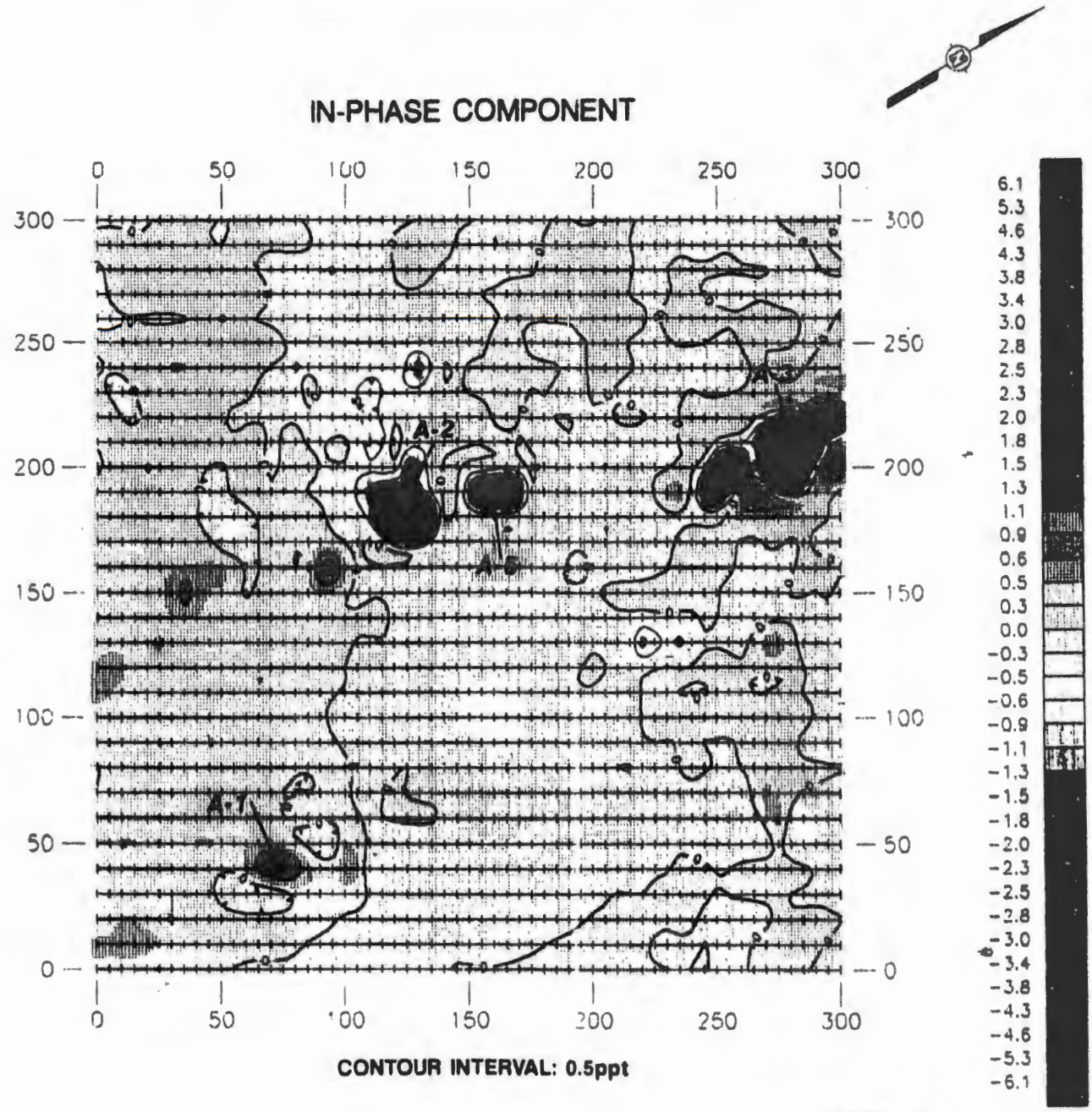
A-1 GEOPHYSICAL ANOMALY DISCUSSED IN TE

SCALE

0 30 60 120FEET

067-88

Do Not Scale This Drawing



CONTOUR INTERVAL: 0.5ppt

FIGURE 32

CONTOUR MAPS OF GEONICS EM-31 DATA
SITE H-83-L
SOUTHWEST-NORTHEAST SURVEY LINES
WAHLUKE (N) SLOPE

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9 3 1 2 9 0 5 1 9 0 0

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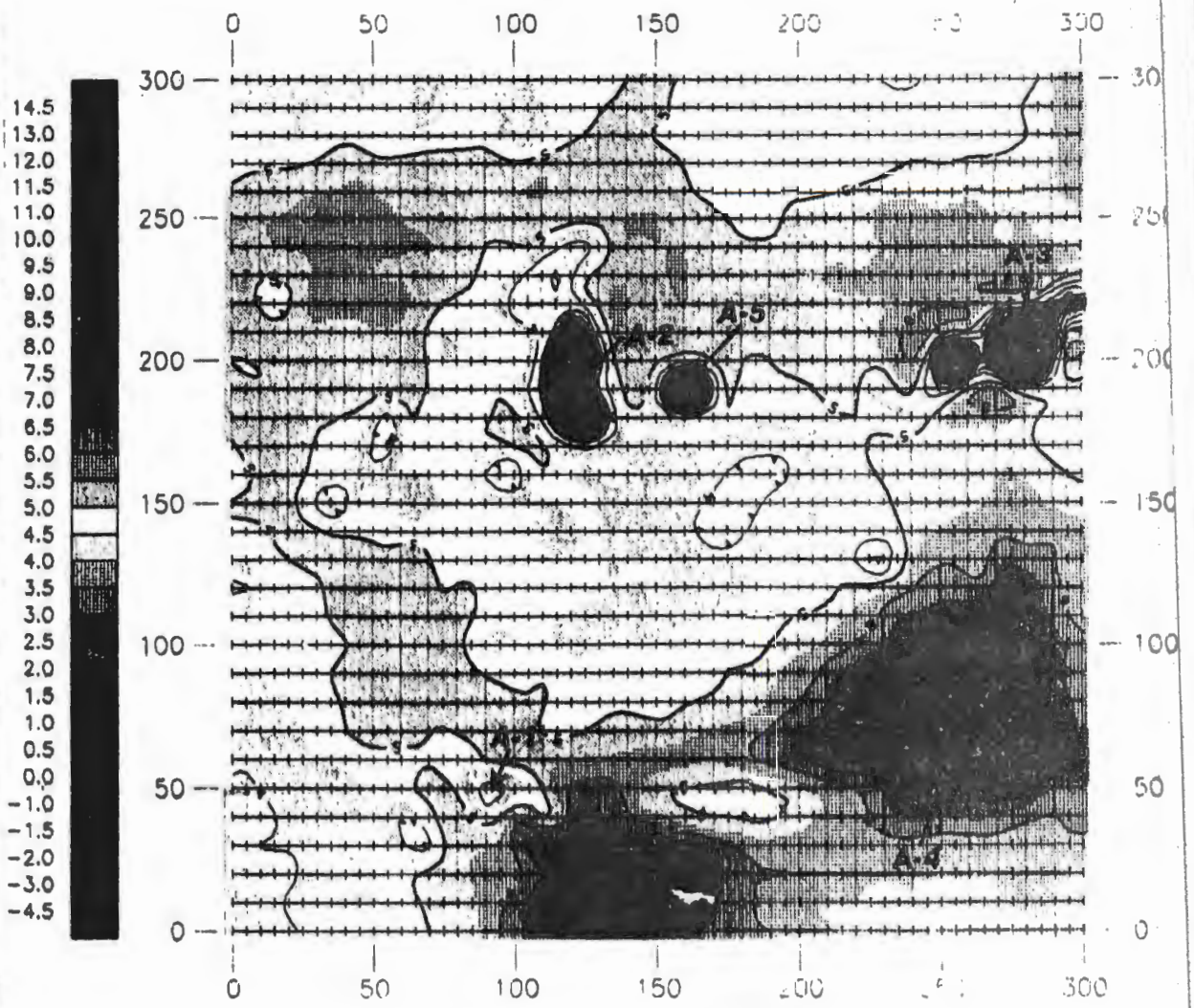
		APPROVED BY		9/13/92		

CONDUCTIVITY



CONTOUR INTERVAL: 1 mS/m

LEGEND:

GEONICS EM-31 SURVEY LINE

A-1 GEOPHYSICAL ANOMALY DISCUSSED IN TEXT

SCALE

0 30 60 120FEET

Do Not Scale This Drawing

APPENDIX A

THEORETICAL BACKGROUND

A.1 MAGNETIC METHODS

Magnetic instruments used during this investigation consist of EDA Omni IV and Omni Plus magnetic gradiometers. These instruments, which are proton precession magnetometers, measure the intensity of the earth's magnetic field in nanoteslas (nT) and the vertical gradient of the magnetic field in nanoteslas per meter (nT/m). The vertical gradient is measured by simultaneously recording the magnetic field with two sensors at different heights. To determine the vertical magnetic gradient, the upper sensor reading is subtracted from the lower sensor reading, and the result is then divided by the distance between the sensors.

During operation of the proton precession magnetometer, direct current is applied to a coil that is wrapped around a sensor bottle filled with a hydrogen-rich fluid. The current temporarily polarizes the protons in the fluid. When the current is turned off, the protons precess around the earth's magnetic field at a frequency proportional to the total magnetic field intensity (Milsom 1989). Measurement of the precession frequency, as a voltage induced in another coil, permits the calculation of the intensity of the earth's magnetic field.

The earth's magnetic field originates in currents in the earth's liquid outer core. The magnetic field varies in intensity from about 25,000 nT near the equator, where it is parallel to the earth's surface, to about 70,000 nT near the poles, where it is perpendicular to the earth's surface. In North America, the intensity of the earth's magnetic field varies from about 48,000 to 60,000 nT.

Anomalies in the earth's field are caused by induced or remanent magnetism. Remanent magnetism is magnetism caused by naturally magnetic materials. Induced magnetic anomalies result from the induction of a secondary magnetic field in a ferromagnetic material (such as pipelines, drums, tanks, or well casings) due to the earth's magnetic field. The shape and amplitude of an induced magnetic anomaly over a ferromagnetic object depends on the geometry, size, depth, and magnetic susceptibility of the object and on the magnitude and inclination of the earth's magnetic field in the study area (Dobrin 1976; Telford et al. 1976). The inclination of the earth's magnetic field varies from about 60 to 75 degrees in North America, and induced magnetic anomalies over buried objects such as drums, pipes, tanks, and buried metallic debris generally exhibit an asymmetrical, south up/north down signature (maximum amplitude on the south side and minimum on the north). Magnetic anomalies due to buried metallic objects have dimensions much greater than the dimensions of the objects themselves. As an extreme example, a magnetometer may begin to sense a buried oil well casing at a distance of more than 50 ft.

The magnetic method is not effective in areas having ferromagnetic material at the surface because the signal from the surface material obscures the signal from any buried objects. Because of the high precision required in the measurement of the frequency at which the protons precess, the presence of an alternating current electrical power source can render the signal immeasurable (Breiner 1973). Furthermore, the precession signal is sharply degraded in the presence of large magnetic gradients exceeding about 600 nT/m (Breiner 1973).

Large volumes of data can be acquired quickly with modern magnetometers, and the clear signatures from strong magnetic sources such as metallic objects make magnetometers effective in their search. The magnetic method has been effectively used to delineate old waste sites and to search for oil wells, drums, tanks, pipes, and buried metallic debris. The method is also useful for searching for magnetic ore bodies, delineating basement rock, and mapping subsurface geology characterized by volcanic or mafic rocks.

A.2 ELECTROMAGNETIC METHODS

Electromagnetic induction equipment used during this investigation consists of a Metrotech Model 810 utility locator (a trademark of Metrotech Corporation), a Radio Detection Model RD-400 utility locator (RD-400) (a trademark of Radio Detection Corporation), a Fisher TW-6 metal detector (a trademark of Fisher Corporation), and a Geonics EM-31DL terrain conductivity meter (EM-31) with an Omni digital data logger.

A.2.1. Utility Locator Methods

The Metrotech and RD-400 line tracers are specifically designed to accurately locate and delineate underground pipes and utilities. A transmitter emits a radio-frequency signal that induces a secondary EM field in nearby utilities. A receiver unit measures the signal strength of this secondary field and emits an audible response to allow the precise location and tracing of the pipe, cable, or other conductor in which the signal is induced. If the utility is accessible, the source signal can be directly applied to it, making the secondary field much larger and more readily measured. These line tracers are effective in locating long metallic objects. A Fisher TW-6 metal detector was used to find smaller metallic objects and to aid in the accurate delineation of pits during field verification. The TW-6 has a transmitter and a receiver at the ends of a short boom. The transmitter induces an EM field, generating currents in flow when good conductors are encountered in the subsurface. These currents generate secondary fields that are measured by the receiver when the conductor is crossed.

A.2.2 Electromagnetic Induction Methods

The EM-31 has a transmitter coil mounted at one end and a receiver coil at the other end of a 12-ft-long plastic boom. An audiofrequency alternating current is applied to the transmitter coil, causing the coil to radiate a primary EM field. As described by Faraday's law of induction, this time-varying magnetic field induces eddy currents in conductive materials in the subsurface. These eddy currents have an associated secondary magnetic field with a strength and phase shift (relative to the primary field) that depend on the conductivity of the medium. The receiver coil measures the resultant effect of both primary and secondary fields. By comparing the signal at the receiver to that at the transmitter, the instrument records the component of the secondary field in-phase (in-phase) and 90 degrees out-of-phase (quadrature) with the primary field.

Most geologic materials are poor conductors. The flow of current through the material takes place in the pore fluids (Keller and Frischknecht,

1966); as such, conductivity is predominantly a function of soil type, porosity, permeability, pore fluid ion content, and degree of saturation. The EM-31 is calibrated so that the out-of-phase component is converted to electrical conductivity in units of millisiemens per meter (mS/m) (McNeill 1980). The in-phase component is read in parts per thousand (ppt) of the primary EM field and is generally adjusted in the field to read zero response over background materials.

The depth of penetration for EM induction instruments depends on the transmitter/receiver separation and coil orientation (McNeill 1980). The EM-31 has an effective exploration depth of about 18 ft when operating in the vertical dipole mode (horizontal coils). In this mode, the maximum instrument response results from materials at a depth about two-fifths the coil spacing (about 2 ft below ground surface with the instrument at the normal operating height of about 3 ft), providing that no large metallic features such as tanks, drums, pipes, and reinforced concrete are present. A single buried drum typically can be located to depths of about 5 ft, whereas clusters of drums can be located to significantly greater depths if background noise is limited or negligible. The EM-31 has an effective exploration depth of about 9 ft when operating in the horizontal dipole mode (vertical coils) and is most sensitive to materials immediately beneath the ground surface.

The EM-31 generally must pass over or very near to a buried metallic object to detect it. Both the out-of-phase and in-phase components exhibit a characteristic anomaly over near-surface metallic conductors. This anomaly consists of a narrow zone having strong negative amplitude centered over the target and a broader lobe of weaker, positive amplitude on either side of the target. For long, linear conductors such as pipelines, the characteristic anomaly is as described when the axis of the coil (instrument boom) is at an angle to the conductor. However, when the instrument boom is oriented parallel to the conductor, a positive amplitude anomaly is obtained.

EM applications include mapping conductive groundwater contaminant plumes in very shallow aquifers and delineating oil brine pits; landfill boundaries; buried pipes, cables, drums, tanks; and pits and trenches containing buried metallic and nonmetallic debris.

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